EIA for Hong Kong Offshore Wind Farm in Southeastern Waters

Wind Farm Model Calibration Report

March 2009

Report no: R1370032

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Contents

Figures

Tables

1 Summary

1.1 Objectives

This report presents the model set up and calibration of a fine grid model, named as Wind Farm Model, of the proposed Hong Kong Offshore Wind Farm in Southeastern Waters.

1.2 Calibration Procedures

The development of the Wind Farm Model was based on the model setup of the Update Model, which was constructed, calibrated and verified by Delft Hydraulics under the *Update on Cumulative Water Quality and Hydrological Effect of Coastal Development and Upgrading of Assessment Tool*. The Update Model is a fully calibrated and verified model. The model grid of Wind Farm Model was refined to give a better representation of the hydrodynamic conditions in the Study Area. The areas covered by the model included the Victoria Harbour, Eastern Buffer, Junk Bay, Port Shelter and Mirs Bay Water Control Zones. Calibration of the Wind Farm Model was performed through the comparison of the hydrodynamic results predicted by the Wind Farm Model with those of the Update Model.

Representative observation points and cross-sections were selected for checking the validity of the Wind Farm Model. Velocities, current directions, salinity flux and accumulated flows obtained at the observation points and cross-sections were compared with the prediction results of the Update Model for model verification.

2 Model Setup

2.1 Hydrodynamic Regime

In the Study Area, tidal flows are strong in Victoria Harbour, where contributes the tidal zone of Pearl River Estuary. The open sea of eastern waters were affected by the Taiwan and Kuroshio Currents which tend to drift towards west in dry season and by Hainan Current which tends to drift towards east in wet season.

2.2 Hydrodynamics Physics

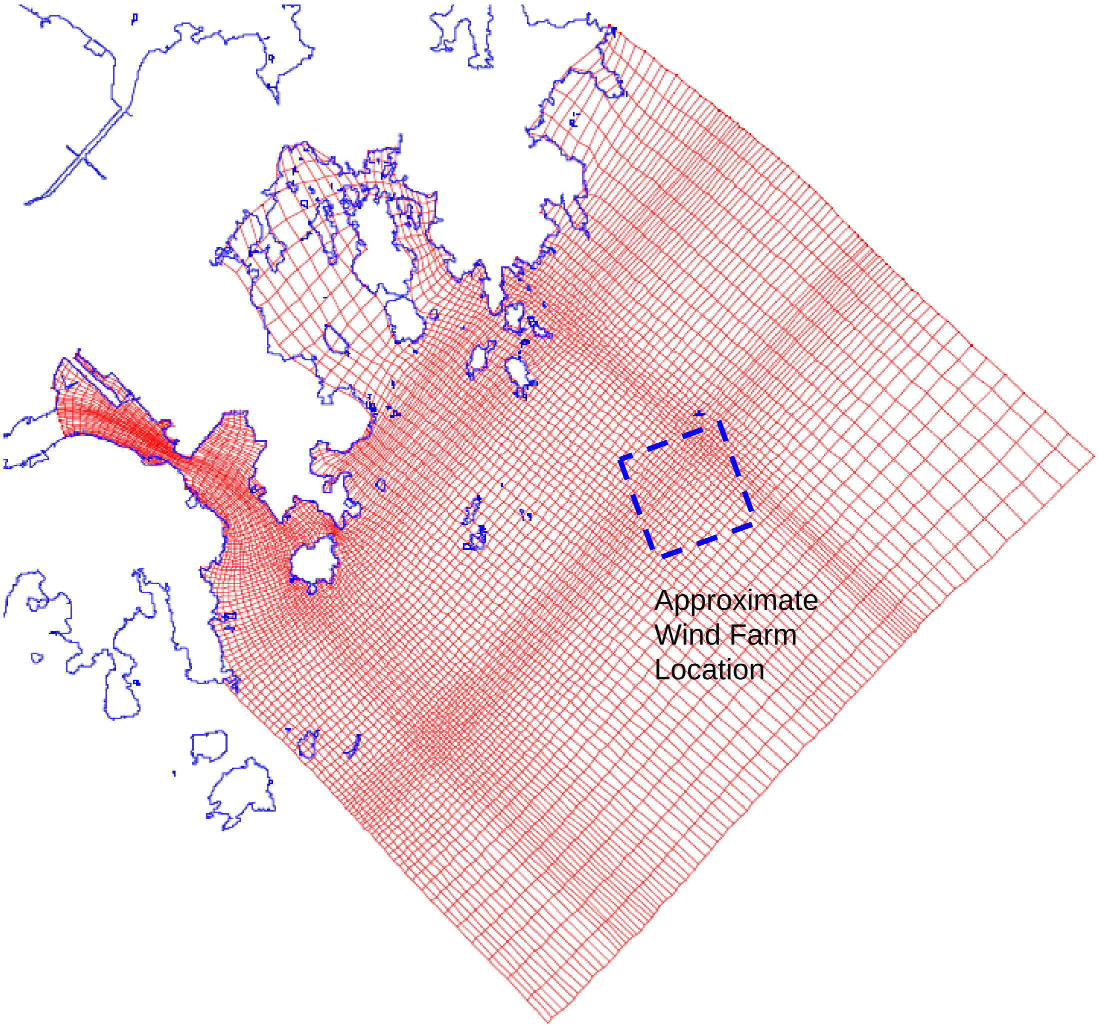
The laws of mass conservation (continuity) and momentum conservation govern the marine hydraulics. In the Study Area, vertical momentum and accelerations may be neglected when comparing with tidal effects. In a three dimensional hydraulic model for incompressible fluid, the hydrostatic equation generally applies. Under the shallow water and Boussinesq assumptions, Navier Stokes equations with consideration of Coriolis force and Reynold’s stress are applied for hydrodynamic analysis.

As an integral part of the hydrodynamic analysis and impact assessment, hydrodynamic equations are solved numerically to obtain the horizontal flow velocities and water levels. A curvilinear grid is set up to approximate the configuration of the coastline in the eastern waters, and therefore the land boundary conditions. The equations are solved iteratively using the cyclic method, which is a modified Alternating Direction Implicit (ADI) method (Leendertse, 1967, 1971 and 1973) coupling the water levels and velocities implicitly along grid lines leading to systems of equations with a small bandwidth. In order to prevent wiggles, forester filter (Forester, 1979) is used to check and remove negative values. Details of the theoretical background and numerical aspects of the hydrodynamic model are presented in the Delft3D-FLOW User Manual issued by WL | Delft Hydraulics.

2.3 Modeling Grid Layout

The Wind Farm Model consists of 92 x 113 active grid cells. The smallest grid sizes are in Junk Bay and Tung Lung Chau and are less than 60m. The sizes of the model grid increase toward the open boundaries. The largest grid cells at the open boundaries are approximately 1200m. Figure 2-1 shows the grid layout of the Wind Farm Model.

Figure 2-1 Grid Layout of the Wind Farm Model



2.4 Bathymetry Schematization

The bathymetry schematization of the Wind Farm Model was based on the depth data from the Update Model. The depth data of the Wind Farm Model were interpolated from the data of the Update Model and checked with reference to the Marine Charts 1916 and 1917.

Figure 2-2 presents graphically the bathymetry schematization of Wind Farm Model. A comparison from Update Model in Tung Lung Chau is shown in Figure 2-3. The reference level used in the Wind Farm Model was Principal Datum Hong Kong and all the depth data were relative to this datum.

Figure 2-2 Bathymetry Schematization

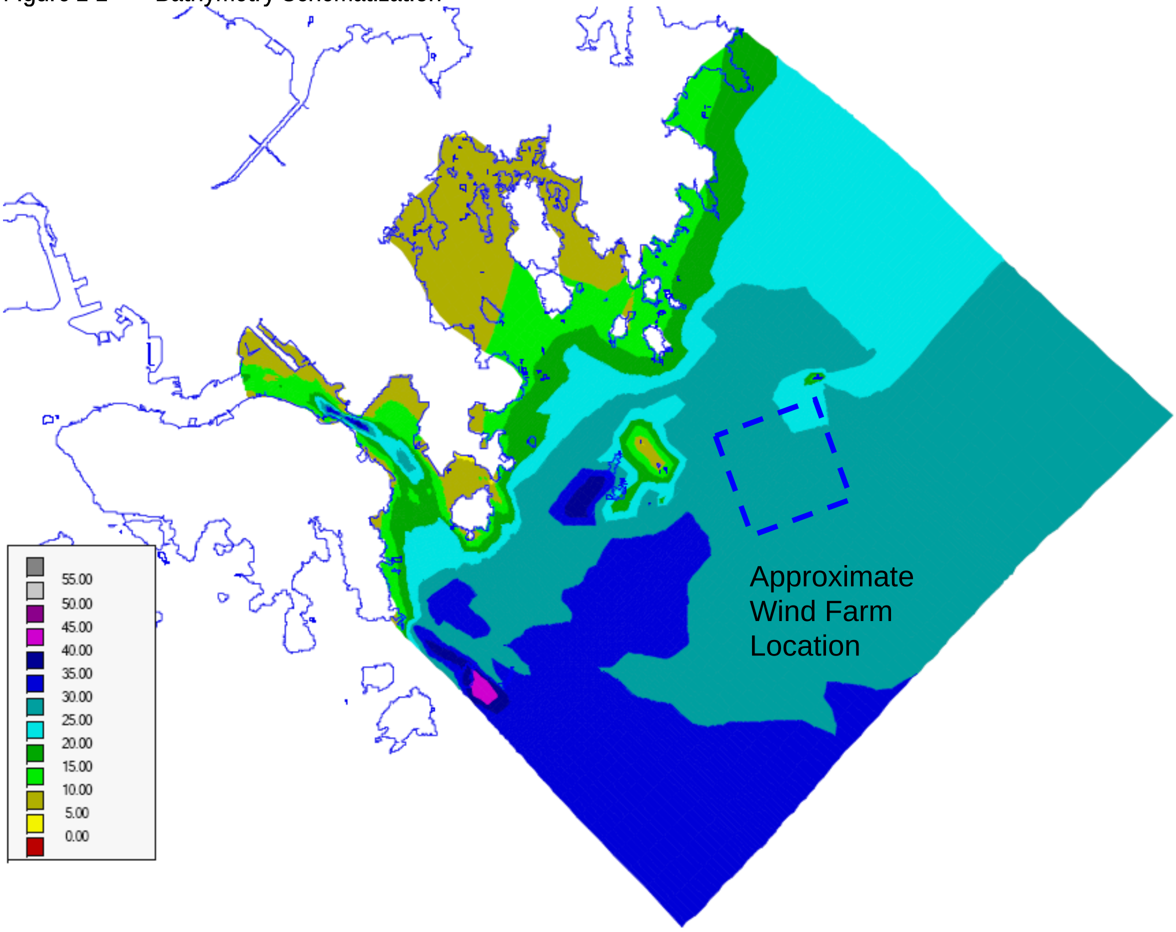
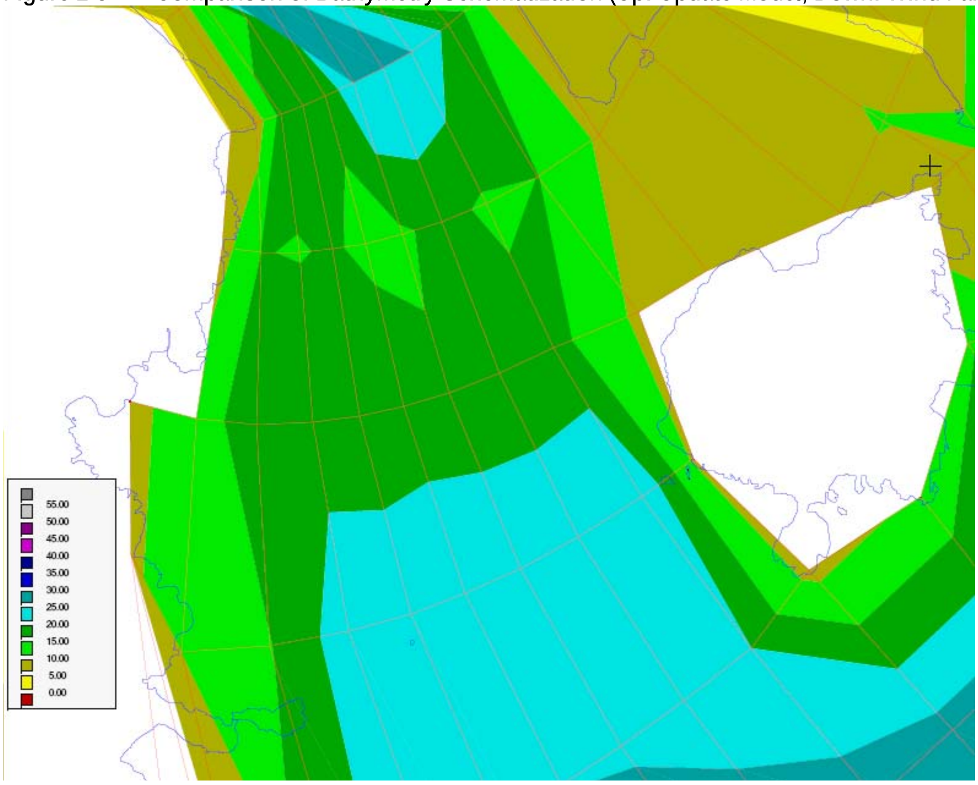
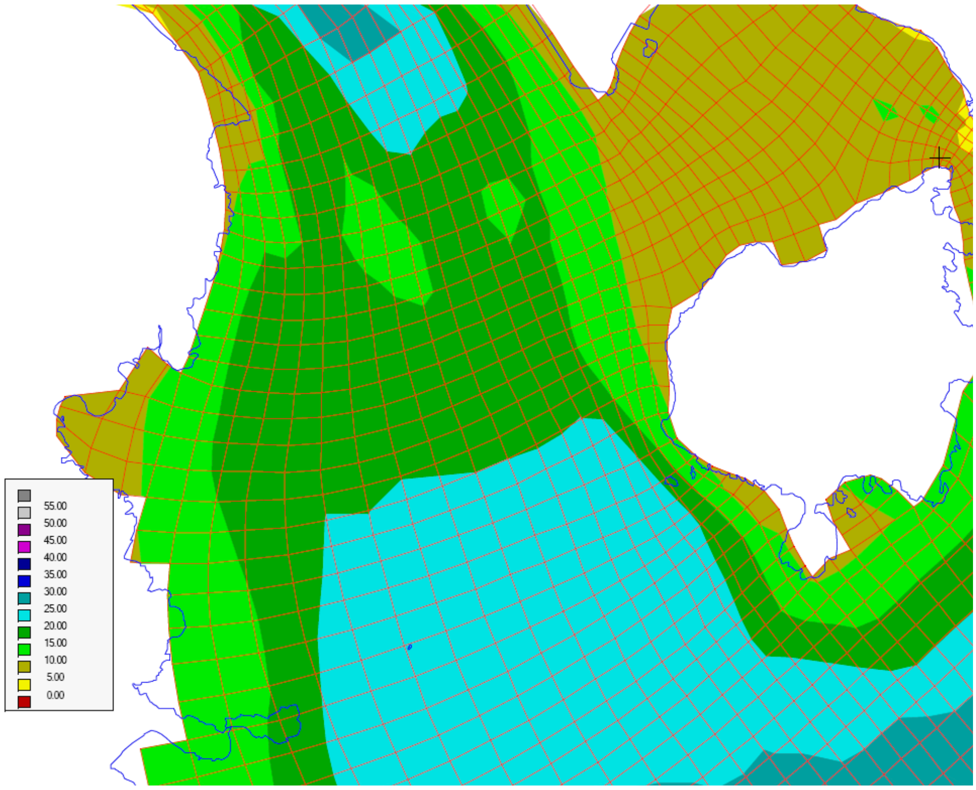


Figure 2-3 Comparison of Bathymetry Schematization (Up: Update Model, Down: Wind Farm Model)





2.5 Simulation Period

The simulation periods for the dry and wet seasons hydrodynamic modeling are listed as follows:

Dry season simulation period: 2 December to 17 December

Wet season simulation period: 26 July to 10 August

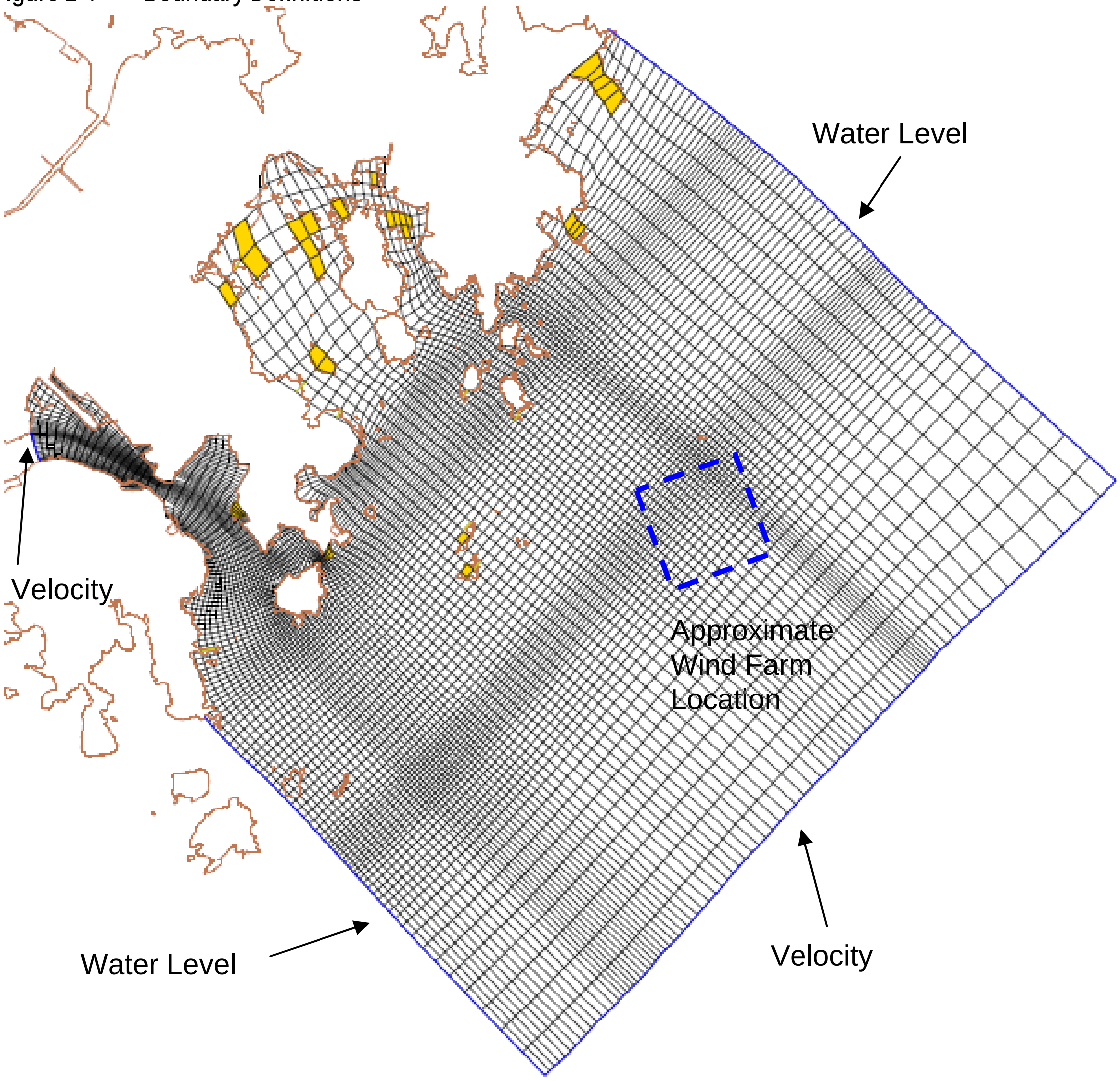
In order to determine a sufficient spin-up period, the first simulation included a first 8 days spin-up and a 15 days spring-neap cycle. The last time-step results of this first simulation were used as the restart file for the additional model run of a full spring-neap cycle. Therefore, the total spin-up time were 23 days. The computational time step for hydrodynamic computations was 1 minute.

2.6 Boundary Condition

The Update Model provided open boundary conditions to drive the Wind Farm Model through a nesting process. Water levels, salinities and velocities generated by the Update Model were transferred to the Wind Farm Model at the open boundaries.

There were four open boundaries in the Wind Farm Model. Figure 2-4 shows the definitions of these open boundaries. Two boundaries were defined as current whilst the other boundaries were defined as water level.

Figure 2-4 Boundary Definitions



2.7 Discharges

The Update Model covered the major Pearl River Estuary discharges including the discharges from Humen, Jiaomen, Hongqili, Hengmen, Muodaomen, Jitimen, Hutiaomen and Aimen. The influence on hydrodynamic regime due to the Pearl River Estuary discharges were transferred to the Wind Farm Model through the nesting process at the open boundaries as discussed above.

As the main driving force would be the tidal currents, the discharges from the storm outfalls within Junk Bay and Port Shelter would not change the hydrodynamic regime in the area. Nevertheless, constant flow rates of Eastern Drainage Channel (EDC) were input into the model for dry and wet season simulations as shown in Table 2.1. The flow values were based on the following reports:

- *Agreement No. CE3/97 Feasibility Study for Intensification and Extension of Tseung Kwan O New Town: Eastern Drainage Channel Water Quality Assessment Jan 2001*
- *Agreement No. CE87/2001(CE) Further Development of Tseung Kwan O Junk Bay Model Calibration Report: Hydrodynamics and Water Quality Oct 2004*

Table 2.1 Flow rates of Eastern Drainage Channel

	Flow Rate (m^3/s)	Discharge Location in Wind Farm Model
Dry Season	0.016	Exit of the Eastern Drainage Channel at Tseung Kwan O. The discharge is treated as a single point source distributed uniformly over all vertical layers
Wet Season	0.324	

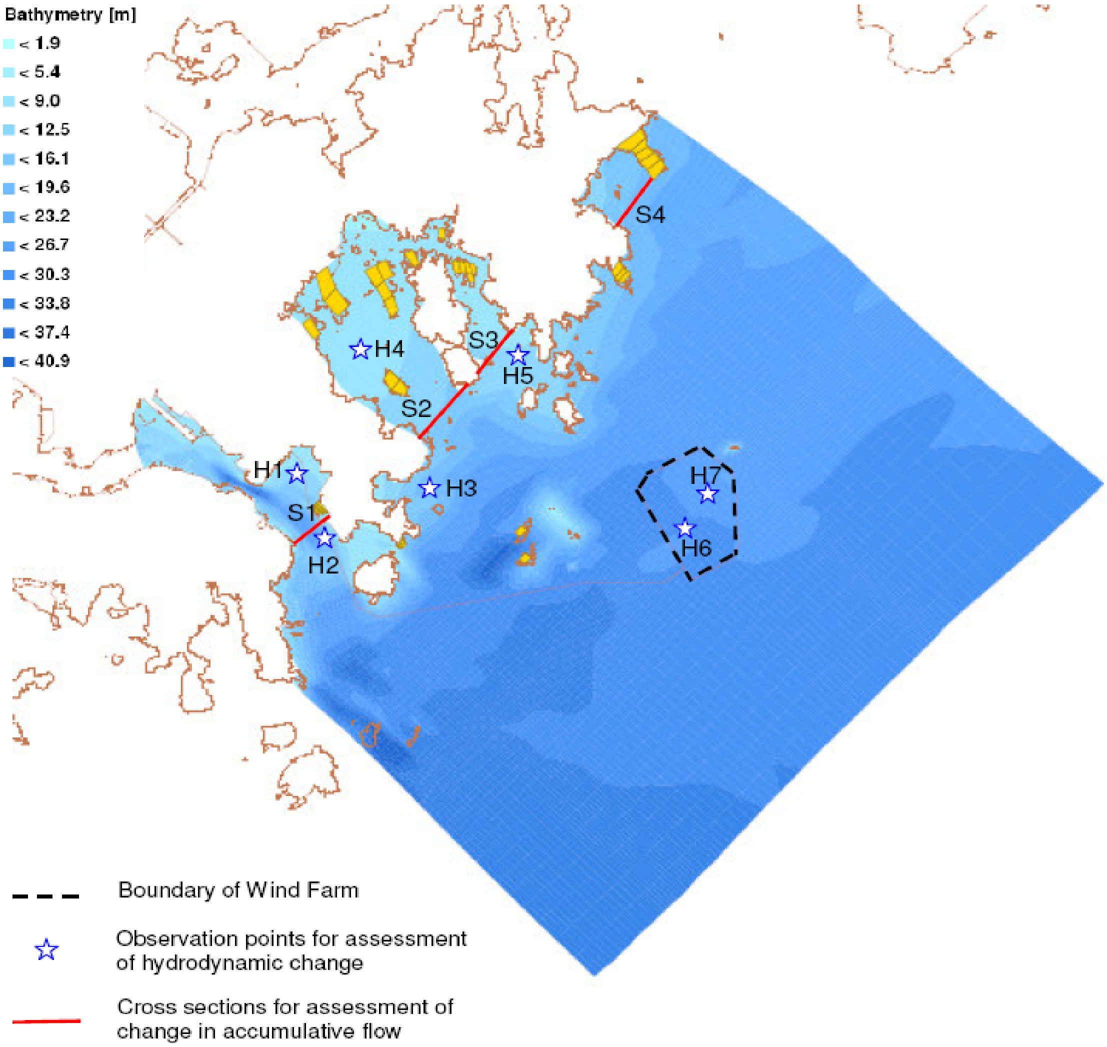
2.8 Cross Sections and Observation Points

In order to determine the changes in flushing capacity and current speeds, the semi-enclosed water bodies and major channels nearest to the project site are selected. Cross-sections are defined at the entrances / exits of the semi-enclosed water bodies and across the major channels to determine the flushing capacity, whereas observation points are defined at locations within the semi-enclosed waster bodies and at the wind farm site to determine the changes in current speeds. The locations of the selected cross sections and observation points are shown in Figure 2-5.

The four cross-sections are Tattong Channel (S1), Port Shelter (S2), Rocky Harbour (S3) and Tai Long Wan (S4). The cross section is defined as a single segment at each channel covering all grid cells between two land boundaries across the channel to examine the changes in accumulated flows.

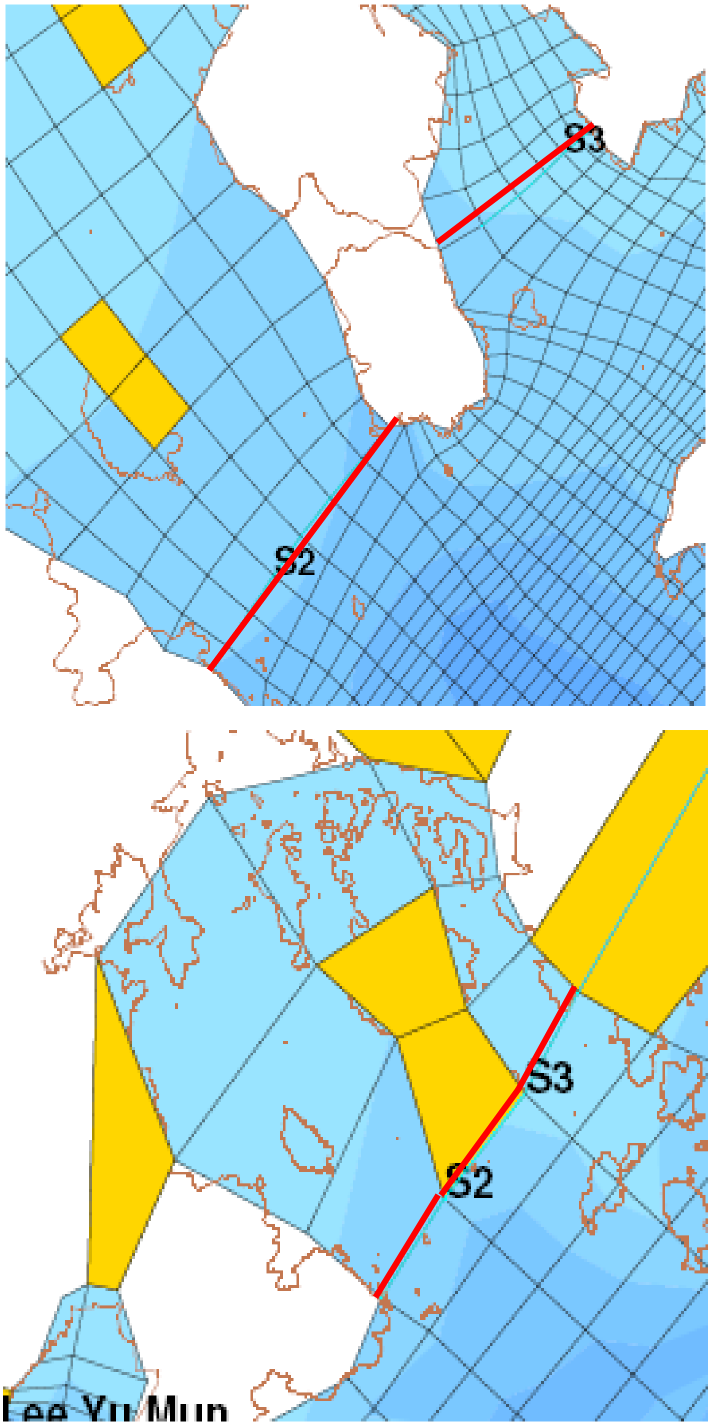
The seven observation points are at Tseung Kwan O (H1), Fat Tong Chau (H2), Clear Water Bay (H3), Shelter Island (H4), Ma Tau Wan (H5), and the proposed wind farm location (WF) (H6 and H7) for comparison of salinities, velocities and current directions with the predicted results by the Update model.

Figure 2-5 Cross Sections and Observation Points



There is a significant difference between the grid layout of the Wind Farm Model and the Update Model particularly in Port Shelter and Rocky Harbour. Figure 2-6 shows the grid layouts of these two areas in the Update Model and Wind Farm Model. It is obvious that the Update Model grids are much coarser than the Wind Farm Model grids, failing to match accurately with the land boundary. The accuracy of the Update Model prediction of accumulated flow and salinity flux through the cross sections defined in Port Shelter (S2) and Rocky Harbour (S3) are expected to be low. Therefore, no attempt is made in this report to compare the accumulated flows and salinity fluxes through the cross sections S2 and S3 predicted by the Update Model and Wind Farm Model. The calibration results for other cross sections are however presented in the following sections.

Figure 2-6 Comparison of Modelling Grid Layout (Up: Wind Farm Model; Down: Update Model)

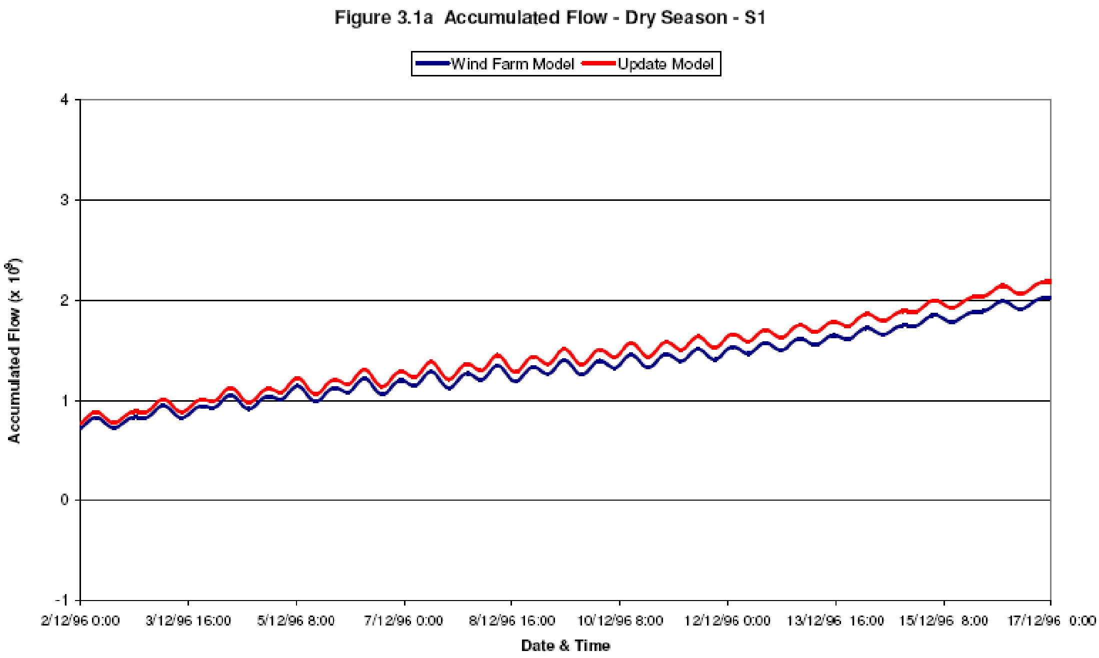


3 Calibration Results

3.1 Accumulated Flow

Figure 3-1 and Figure 3-2 show the predicted accumulated flows in Tattong Channel and Tai Long Wan for dry and wet season respectively. The predicted accumulated flows from Wind Farm Model and Update Model at these two cross sections matched reasonably well. The small differences in accumulated flows would be caused by the coarse Update Model grids as described in the section above. In contrast, the Wind Farm Model with refined grid sizes could better reflect the coastline providing more accurate results.

Figure 3-1 Accumulated Flow at S1 and S4 during Dry Season



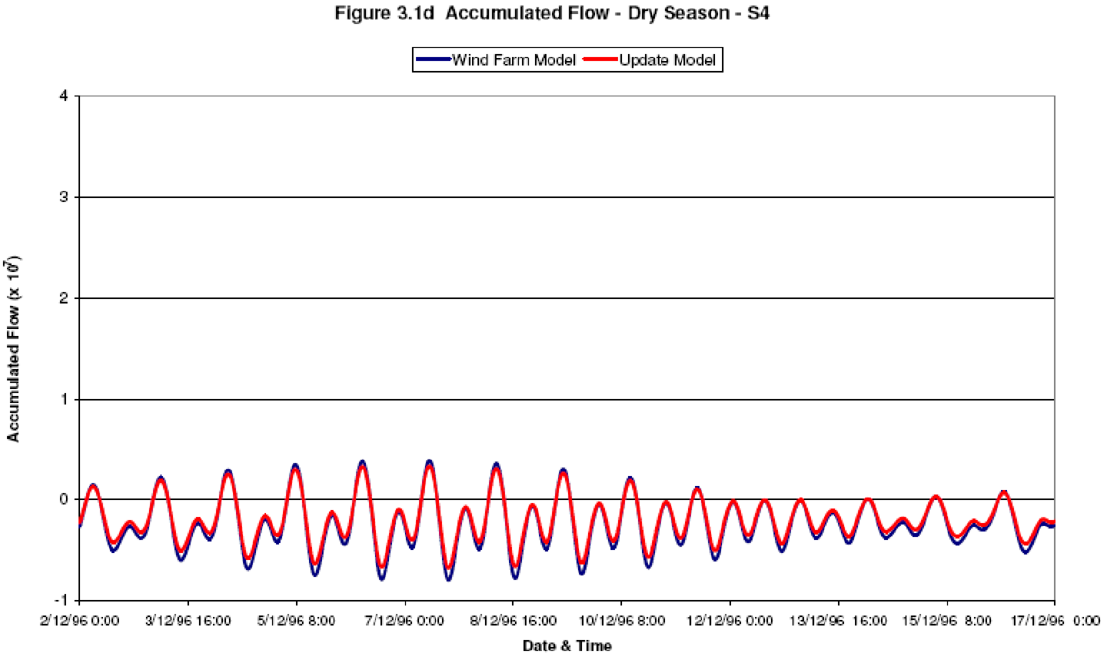


Figure 3-2 Accumulated Flow at S1 and S4 during Wet Season

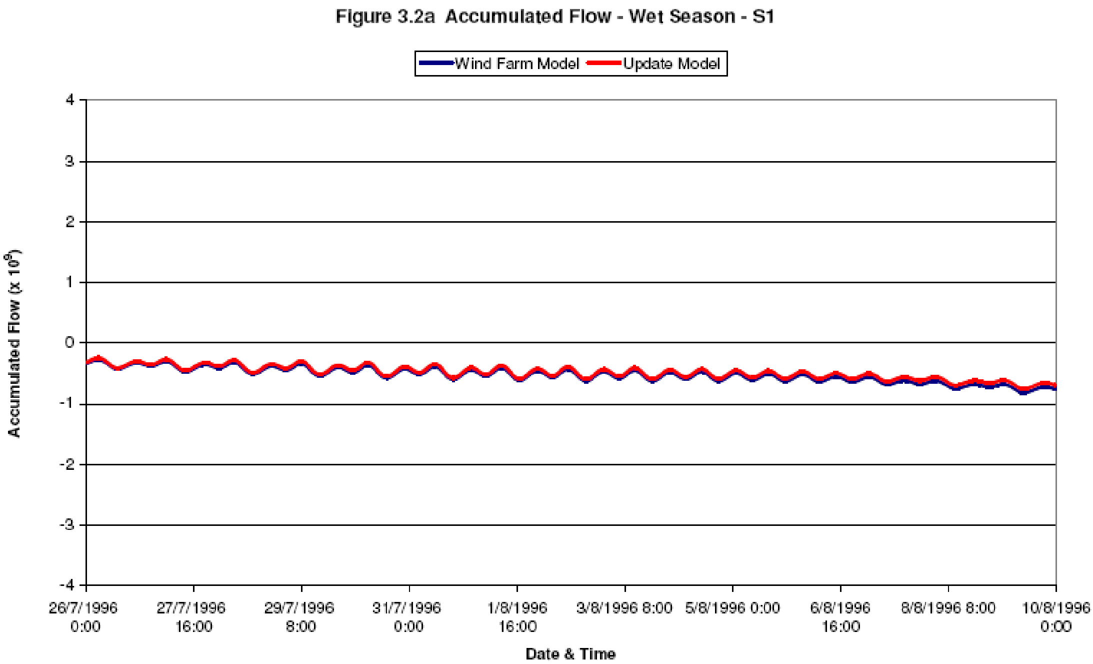
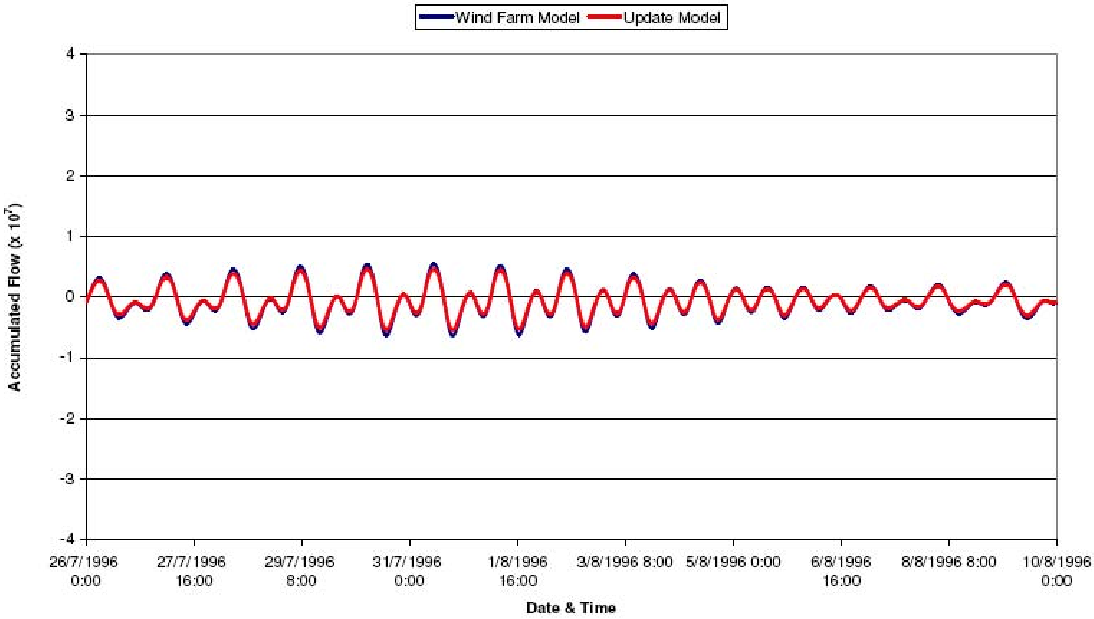


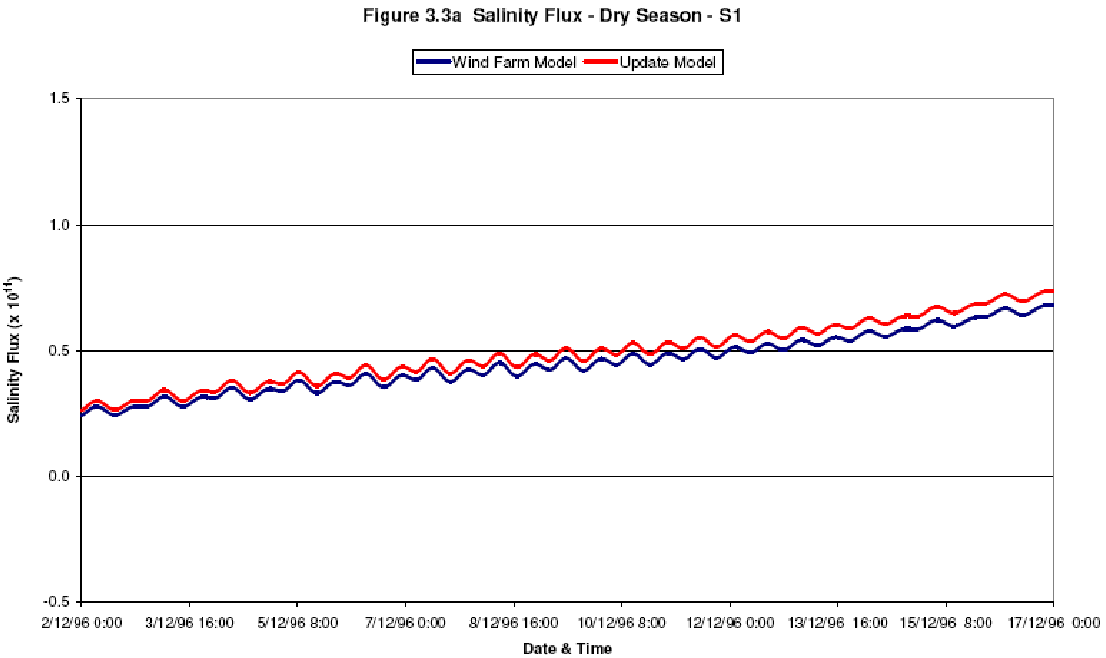
Figure 3.2d Accumulated Flow - Wet Season - S4



3.2 Salinity Flux

Figure 3-3 and Figure 3-4 show the predicted salinity fluxes at Tattong Channel and Tai Long Wan. The predicted salinity fluxes at these cross-sections are rather stable. In the dry season, the predicted salinity fluxes from Wind Farm Model and Update Model at these two cross sections matched reasonably well. Small differences were predicted in the wet season. This would be due to the fact that the Update Model grids were rather coarse and could not accurately match with the land boundary whilst the Wind Farm Model with refined grid sizes could better reflect the coastline providing more accurate results.

Figure 3-3 Salinity Flux at S1 and S4 during Dry Season



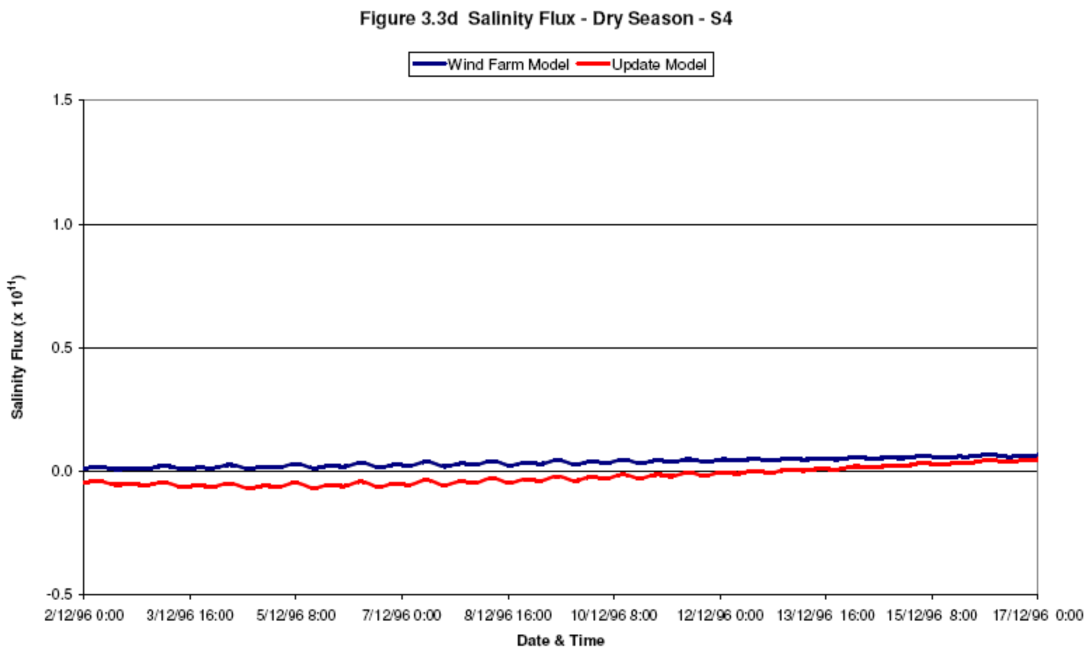
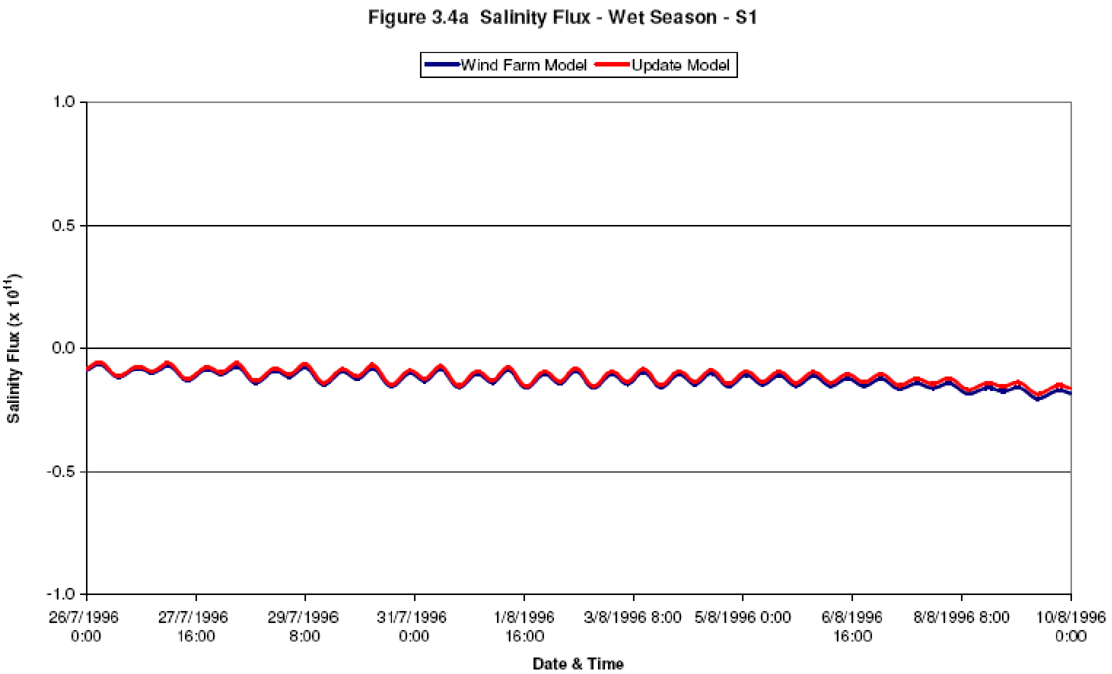
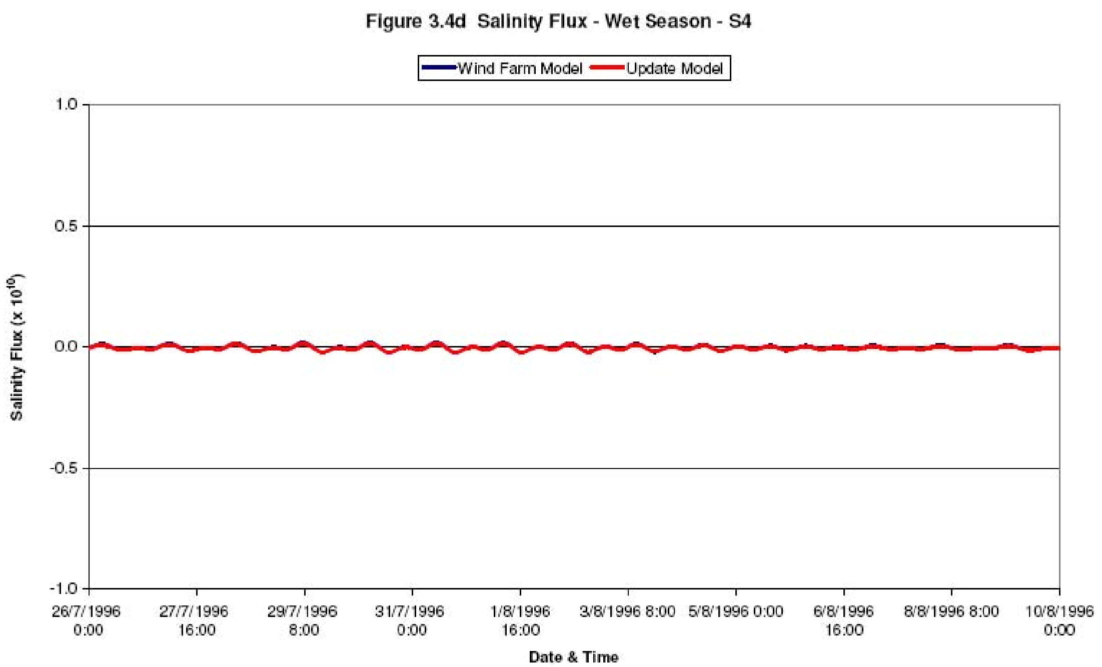


Figure 3-4 Salinity Flux at S1 and S4 during Wet Season





3.3 Salinity

Figure 3-5 and Figure 3-6 show the predicted salinity at observation points for dry and wet season respectively. A test has been conducted to rerun the Update model using a restart file generated at the last time step of the previous model run. The predicted salinity results are similar to the previous results. Since the fine grid model uses the same restart file of the Update model to start the model run, the tidal conditions at the beginning of the model run for the fine grid model are the same as those of the Update model. The predicted salinity results are rather stable in dry season. There were some fluctuations in salinity in wet season and the salinity levels were lower when compared to that in the dry season. In general, the salinity levels predicted by the Wind Farm Model compared well with those of the Update Model.

Figure 3-5 Surface Layer Salinity at H1 to H7 during Dry Season

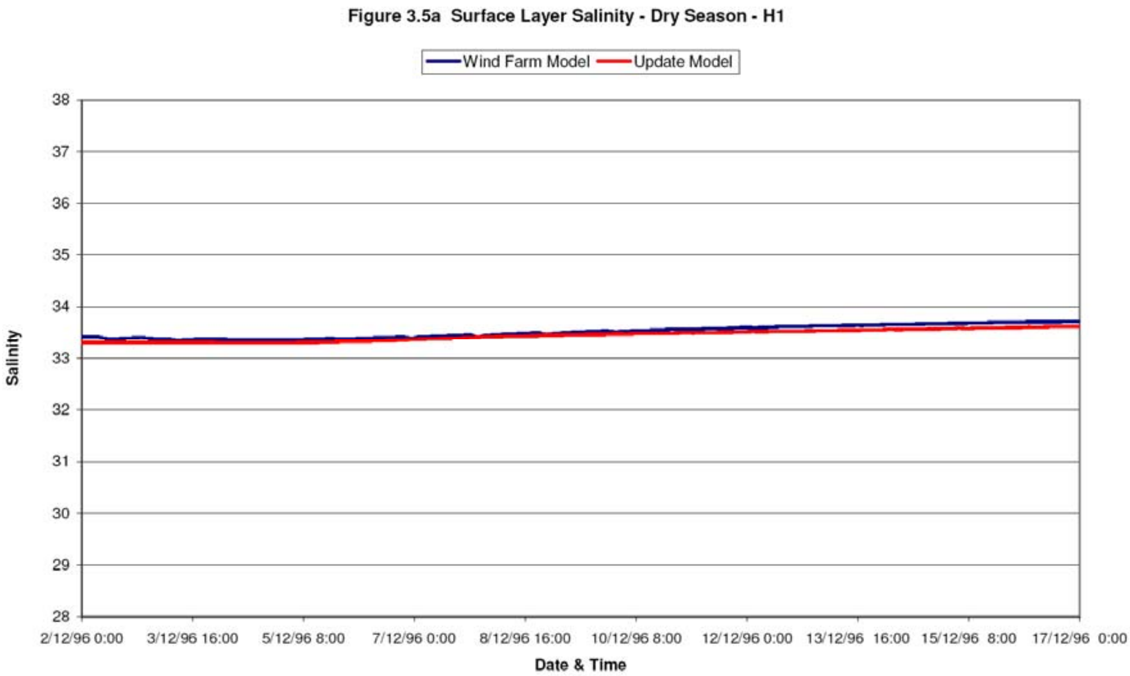


Figure 3.5b Surface Layer Salinity - Dry Season - H2

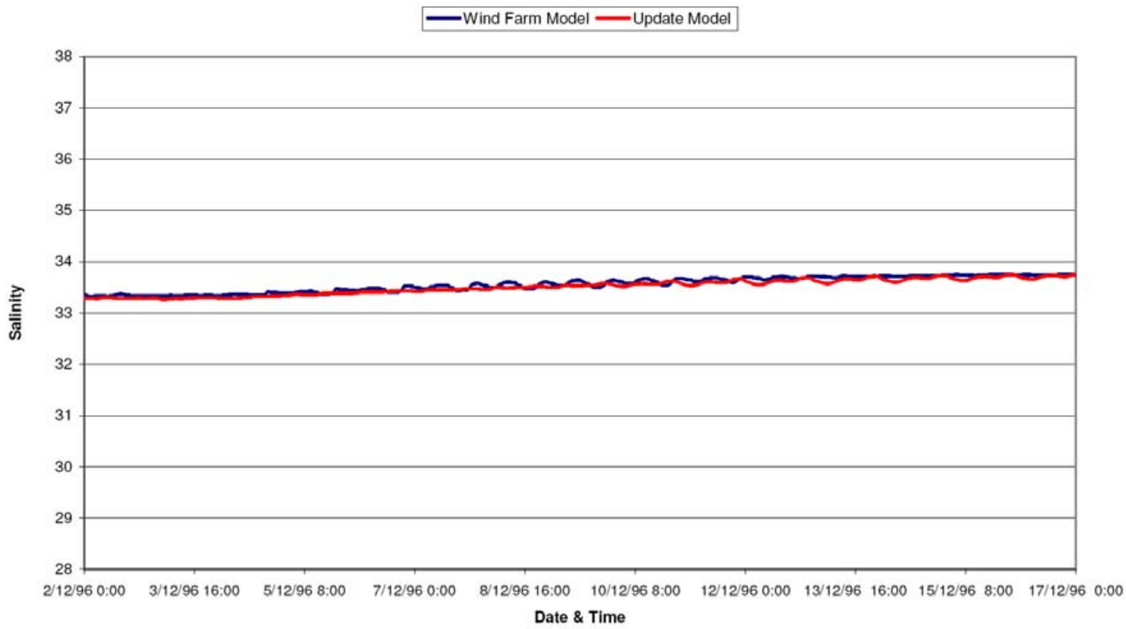


Figure 3.5c Surface Layer Salinity - Dry Season - H3

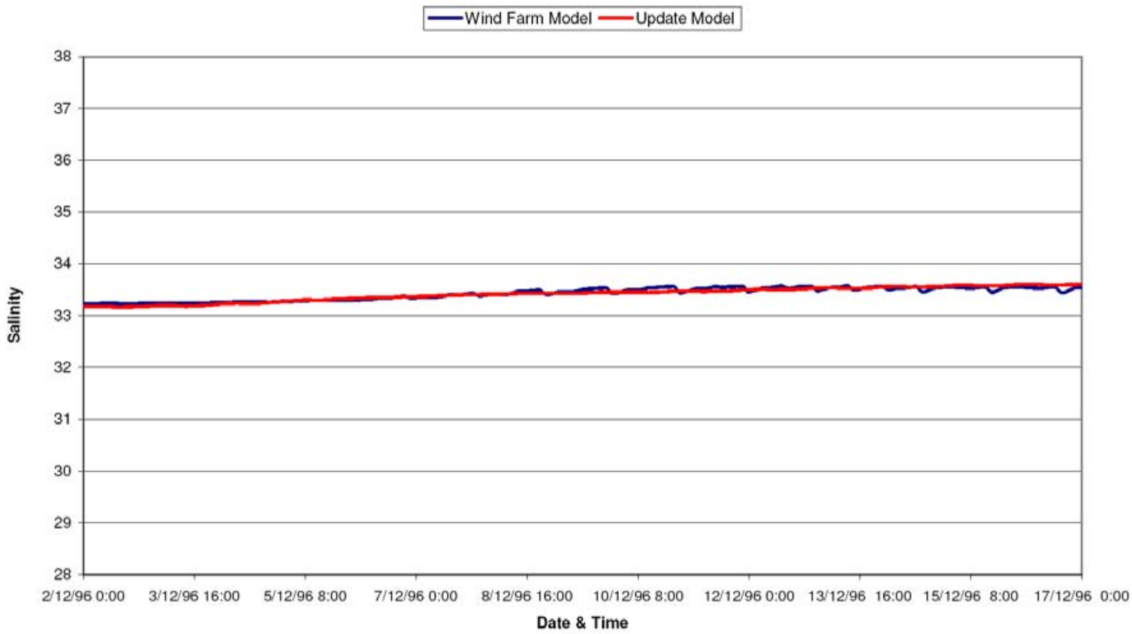


Figure 3.5d Surface Layer Salinity - Dry Season - H4

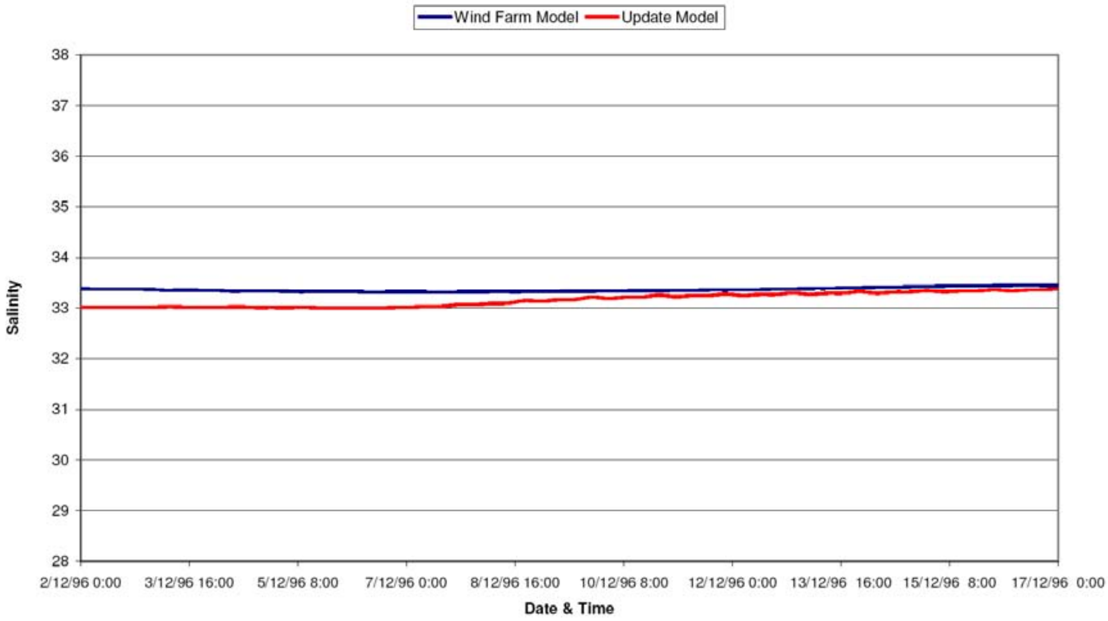


Figure 3.5e Surface Layer Salinity - Dry Season - H5

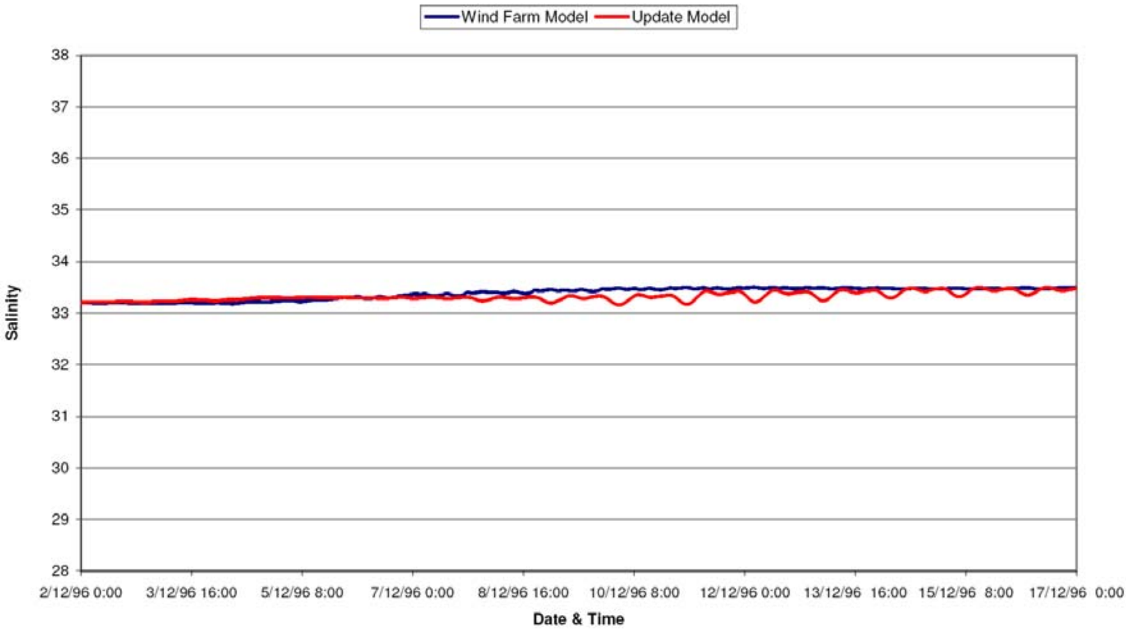


Figure 3.5f Surface Layer Salinity - Dry Season - H6

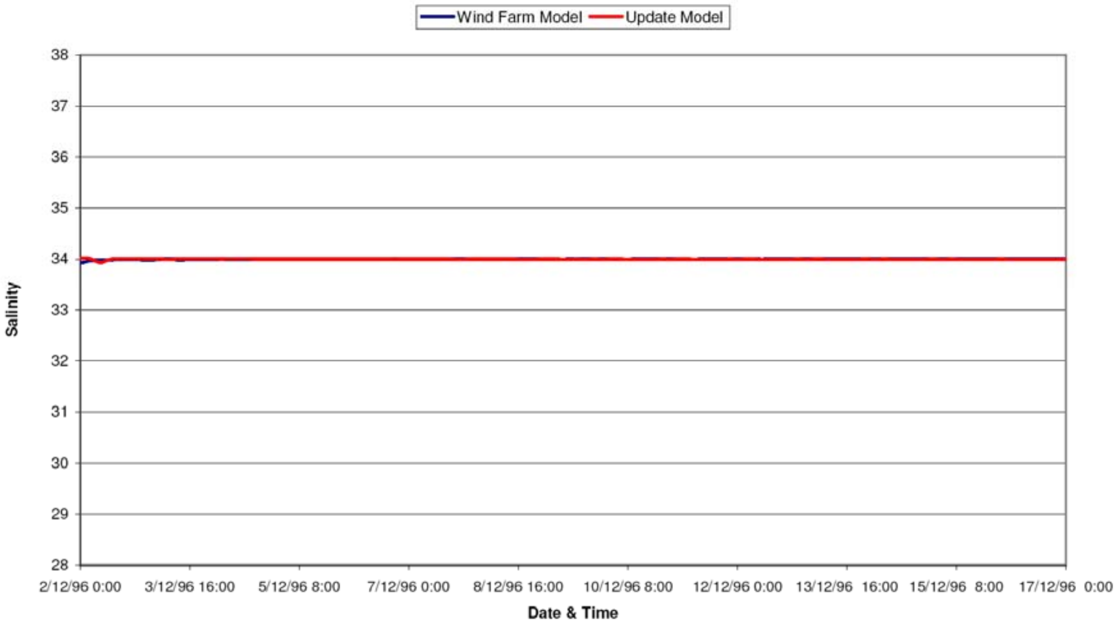


Figure 3.5g Surface Layer Salinity - Dry Season - H7

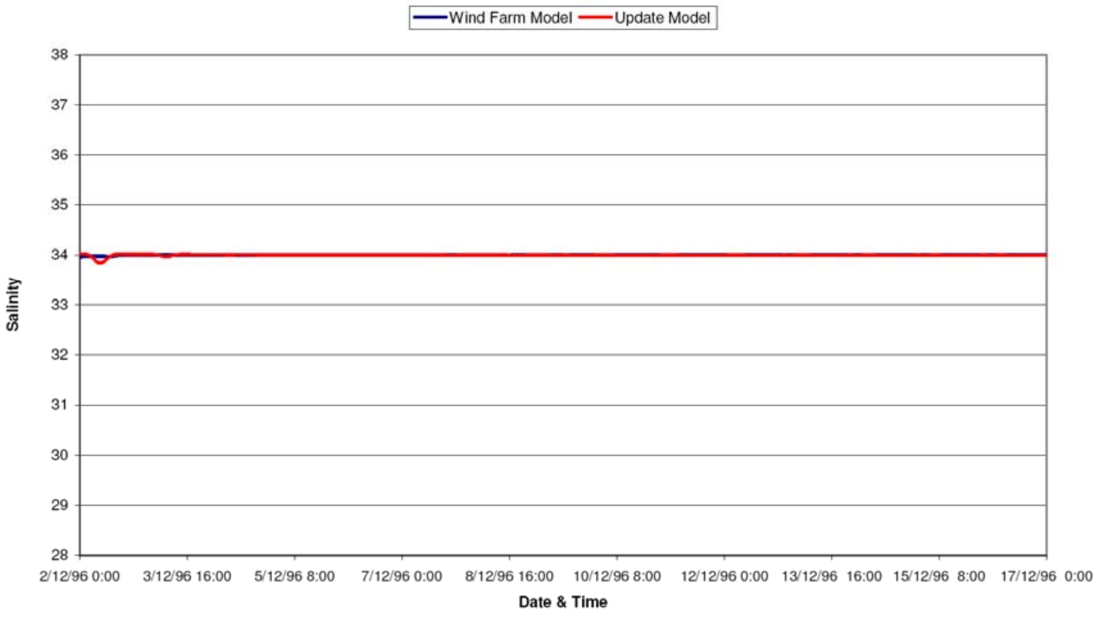
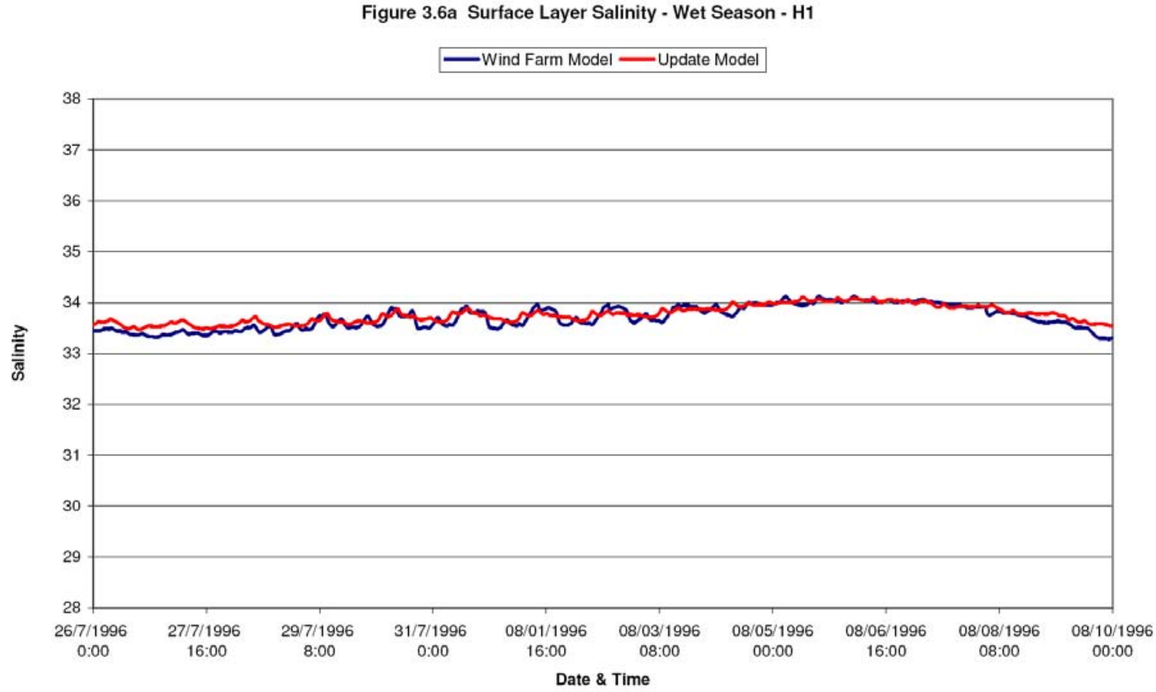


Figure 3-6 Surface Layer Salinity at H1 to H7 during Wet Season



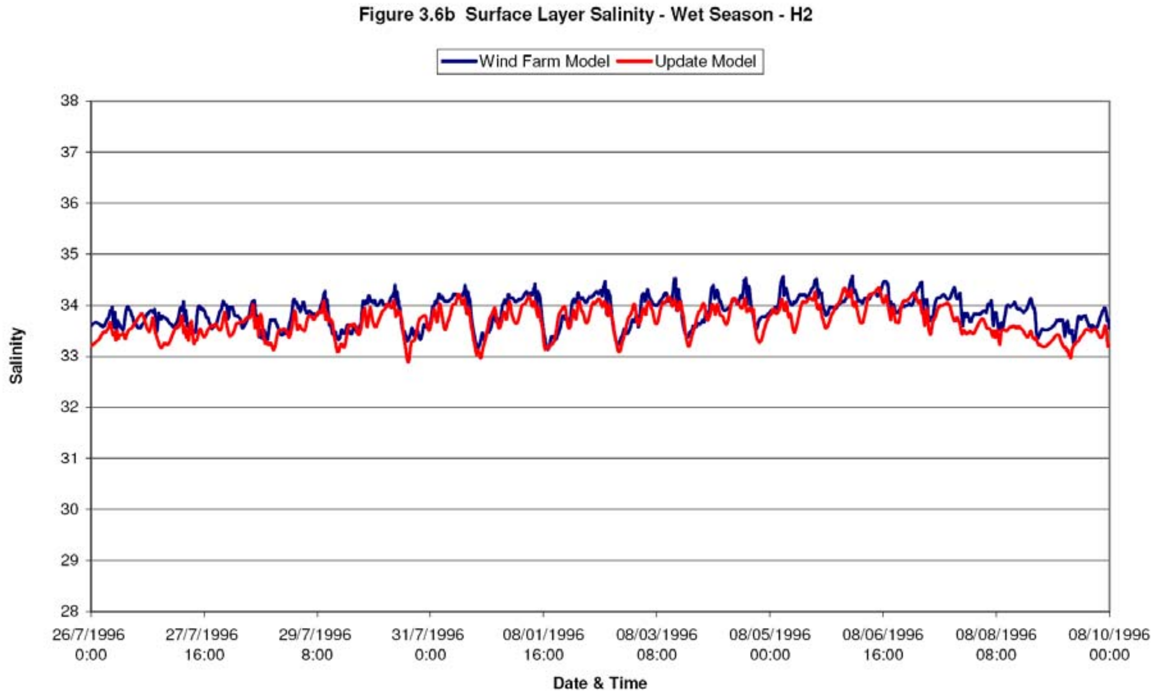


Figure 3.6c Surface Layer Salinity - Wet Season - H3

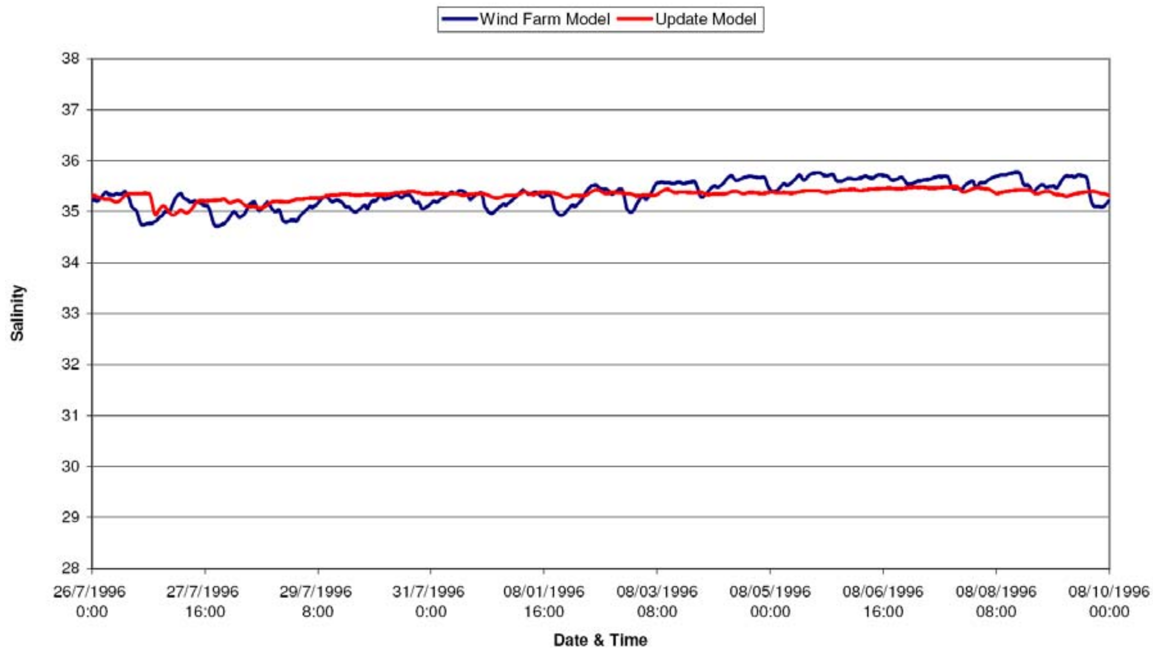


Figure 3.6d Surface Layer Salinity - Wet Season - H4

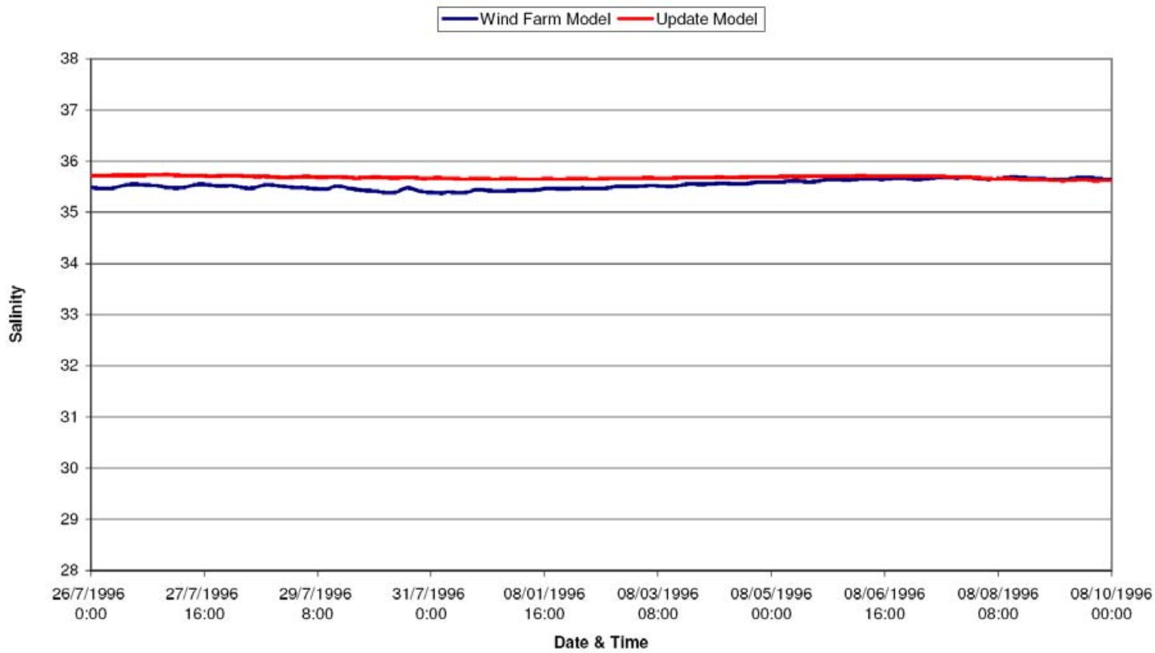


Figure 3.6e Surface Layer Salinity - Wet Season - H5

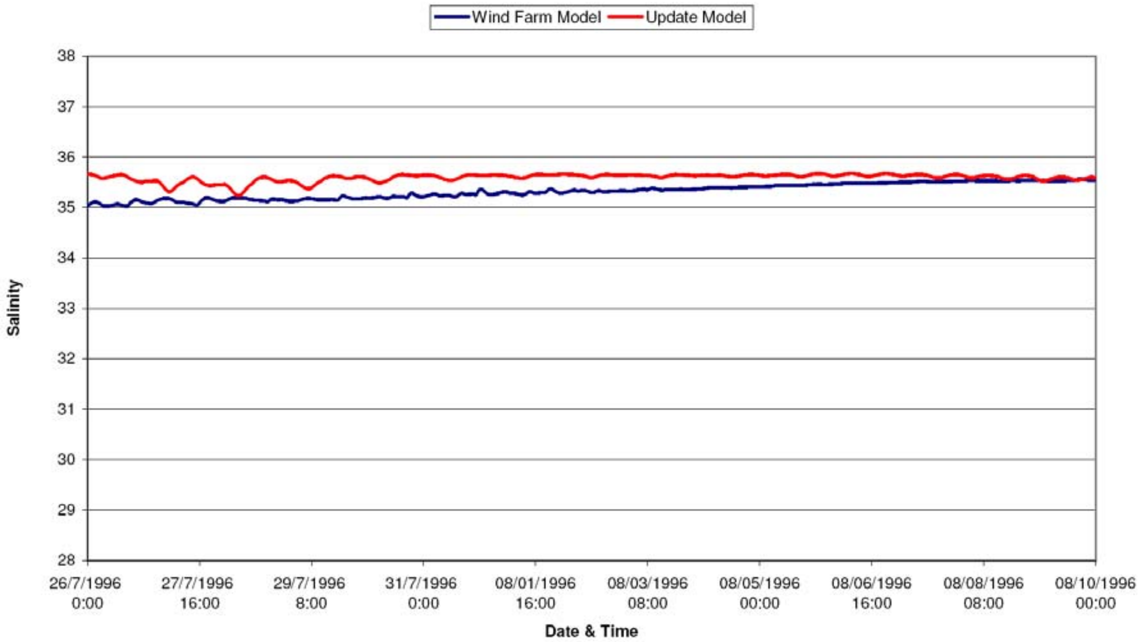


Figure 3.6f Surface Layer Salinity - Wet Season - H6

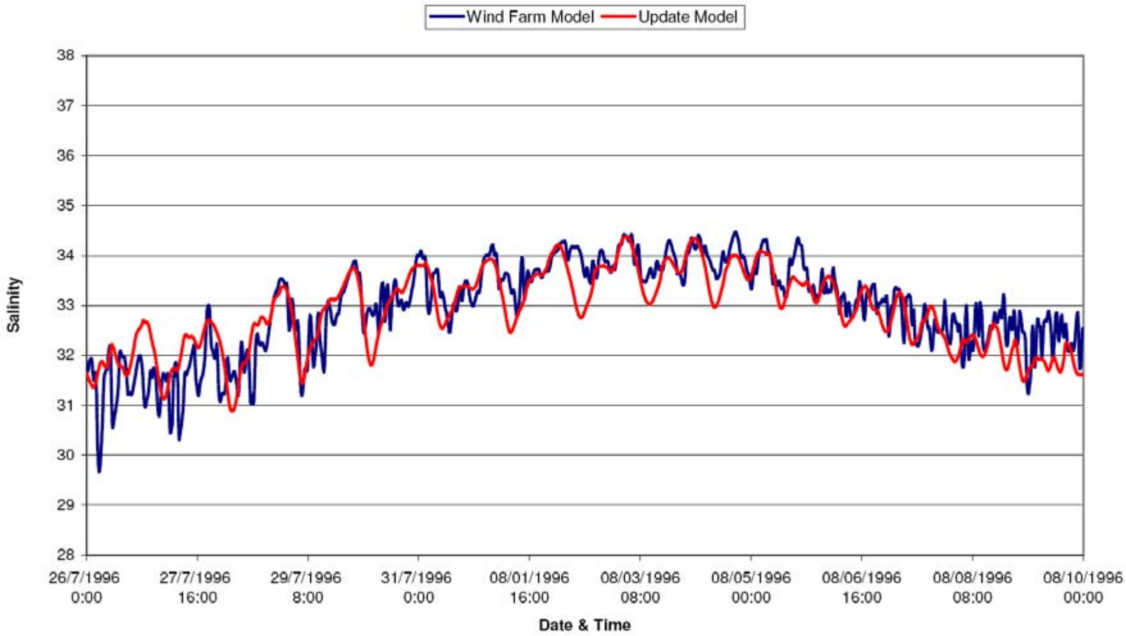
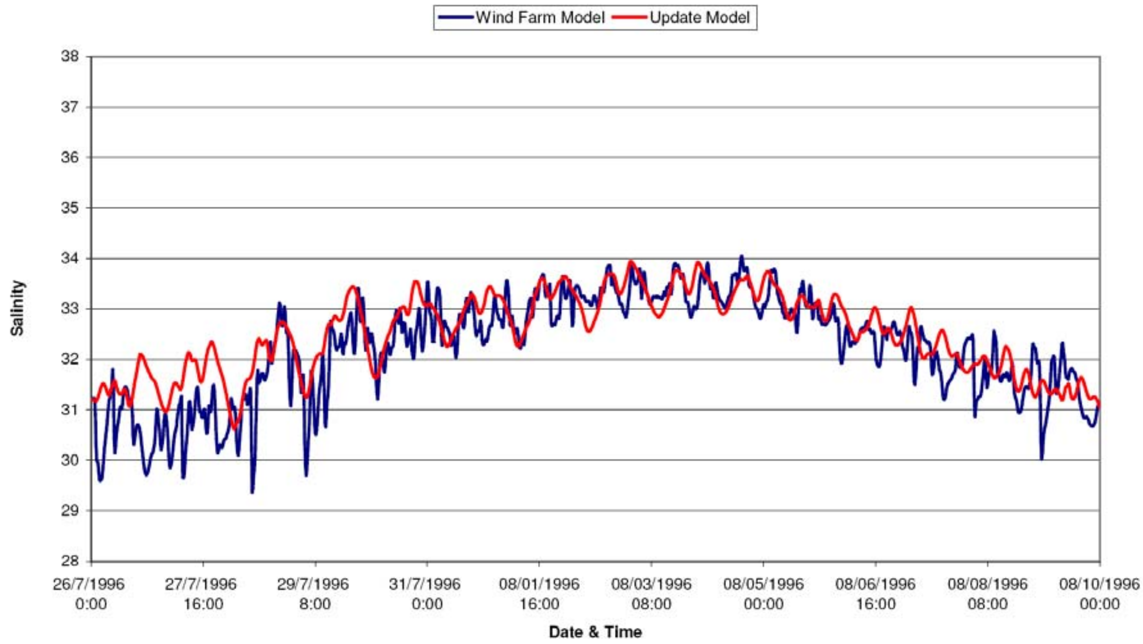


Figure 3.6g Surface Layer Salinity - Wet Season - H7

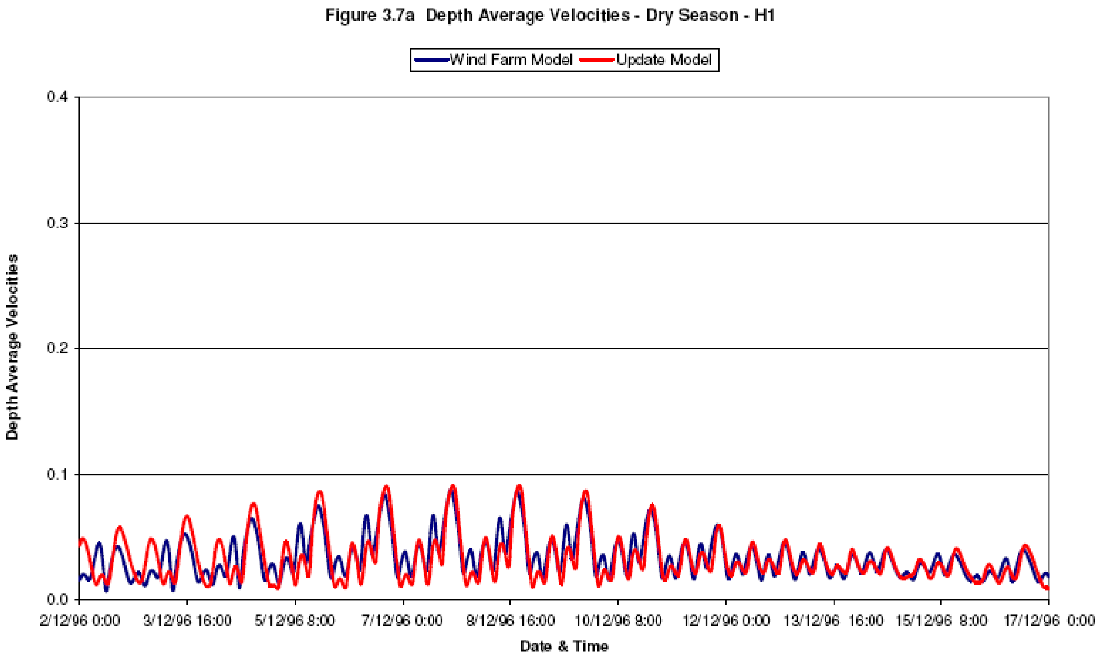


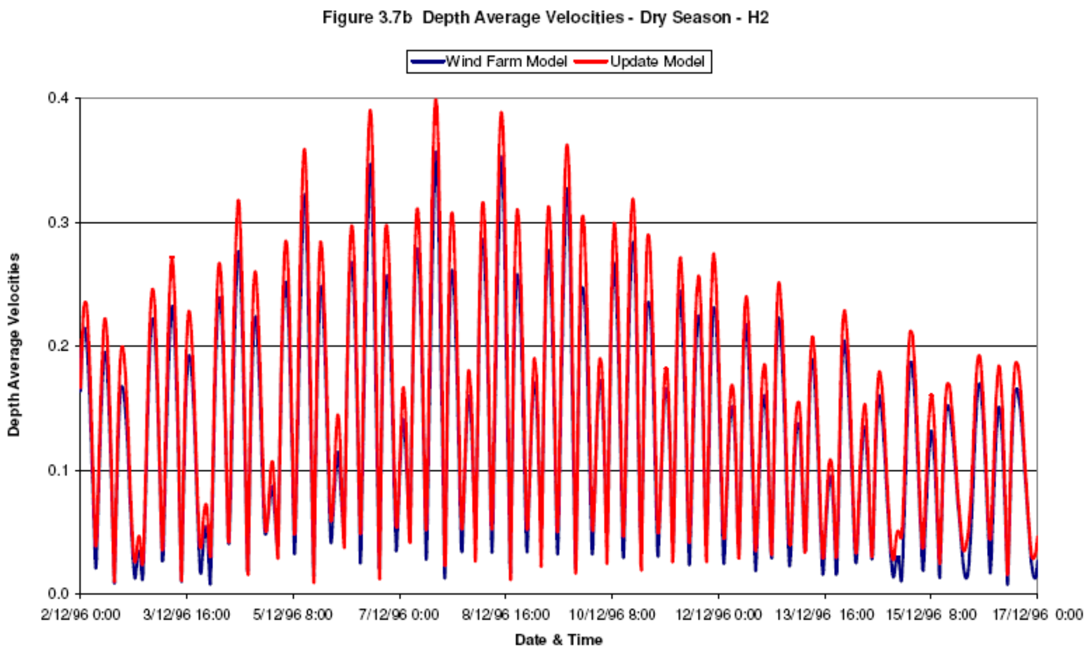
3.4 Velocity and Current Direction

Figure 3-7 and Figure 3-8 present the predicted depth-averaged velocities at observation points (H1 – H7) in the dry and wet seasons respectively. The majority of the Wind Farm Model predictions matched reasonably well with the Update Model predictions. However, small deviations in the predicted results were observed particularly in the wet season. The main reason was that the gird size in the Update Model is too large at these observation points. The small islands were presented as thin dams in the Update Model, whereas refined grids and dry points were used in the Wind Farm Model giving a better representation.

Figure 3-9 and Figure 3-10 present the predicted depth-averaged current directions at observation points in dry and wet seasons respectively. Due to the large difference in grid size at these observation points, some of the Wind Farm Model predictions did not match well with the Update Model predictions. However, the refined grid size of the Wind Farm Model should provide more accurate results to represent the actual current directions when compared to the Update Model.

Figure 3-7 Depth Averaged Velocities at H1 to H7 during Dry Season





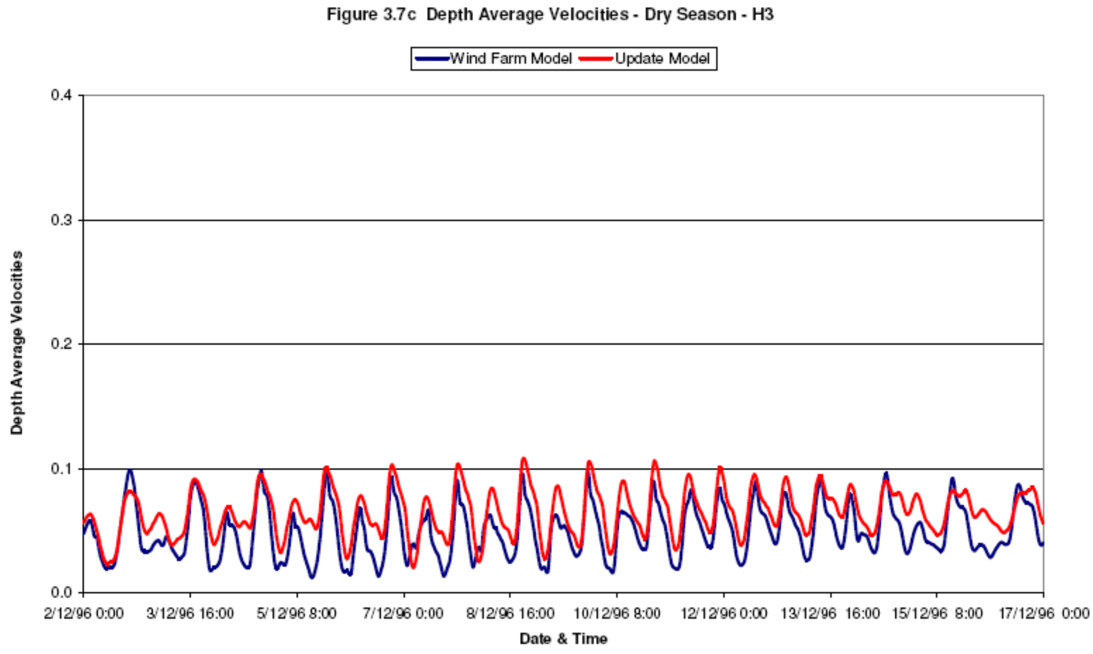


Figure 3.7c Depth Average Velocities - Dry Season - H3
Wind Farm Model
Update Model
Depth Average Velocities
0.4
0.3
0.2
0.1
0.0
2/12/96 0:00
3/12/96 16:00
5/12/96 8:00
7/12/96 0:00
8/12/96 16:00
10/12/96 8:00
12/12/96 0:00
13/12/96 16:00
15/12/96 8:00
17/12/96 0:00
Date & Time

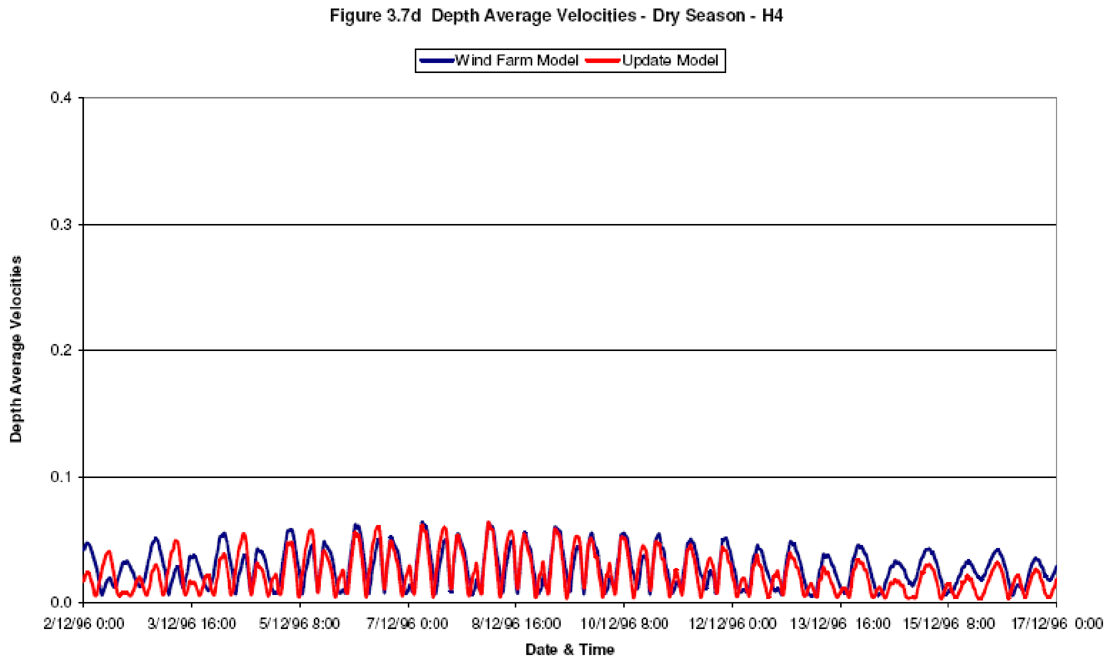


Figure 3.7d Depth Average Velocities - Dry Season - H4
Wind Farm Model
Update Model
Depth Average Velocities
0.4
0.3
0.2
0.1
0.0
2/12/96 0:00
3/12/96 16:00
5/12/96 8:00
7/12/96 0:00
8/12/96 16:00
10/12/96 8:00
12/12/96 0:00
13/12/96 16:00
15/12/96 8:00
17/12/96 0:00
Date & Time

Figure 3.7e Depth Average Velocities - Dry Season - H5

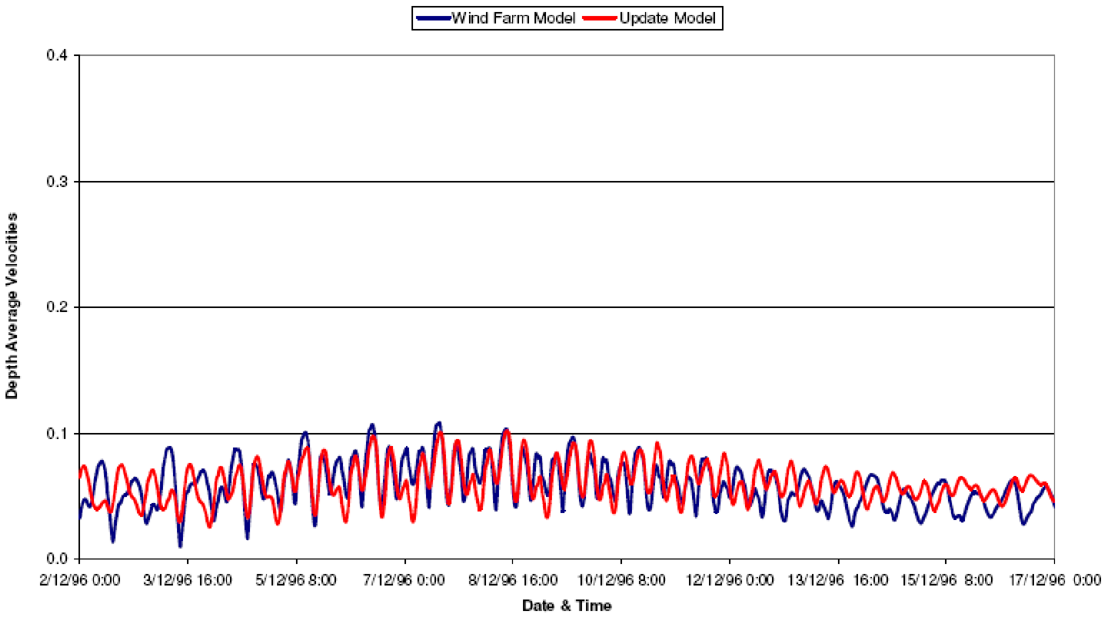
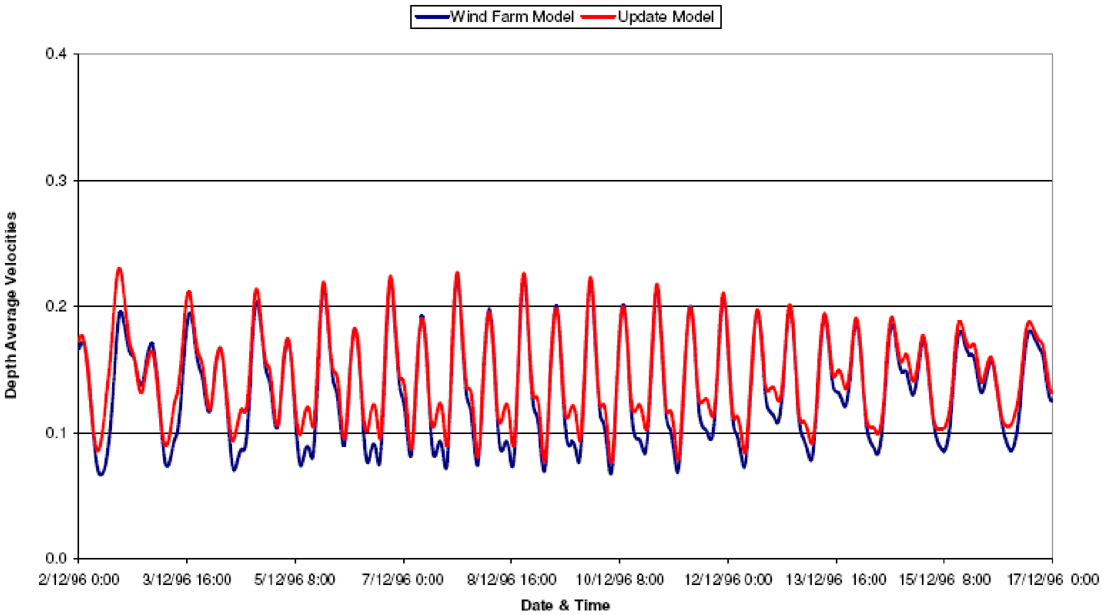


Figure 3.7f Depth Average Velocities - Dry Season - H6



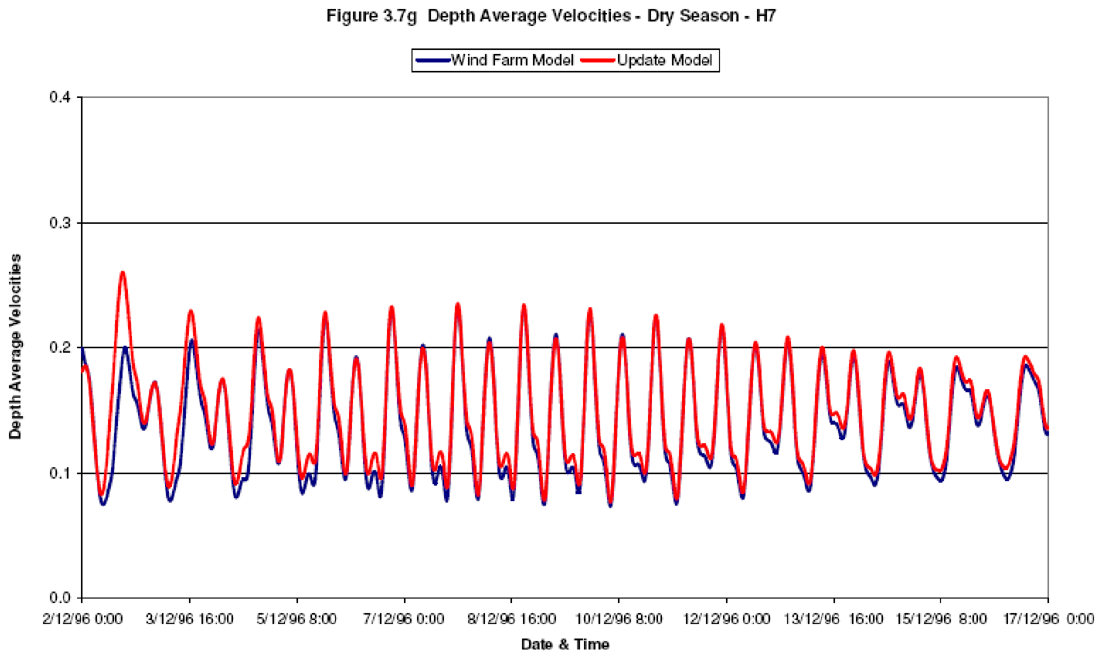


Figure 3-8 Depth Averaged Velocities at H1 to H7 during Wet Season

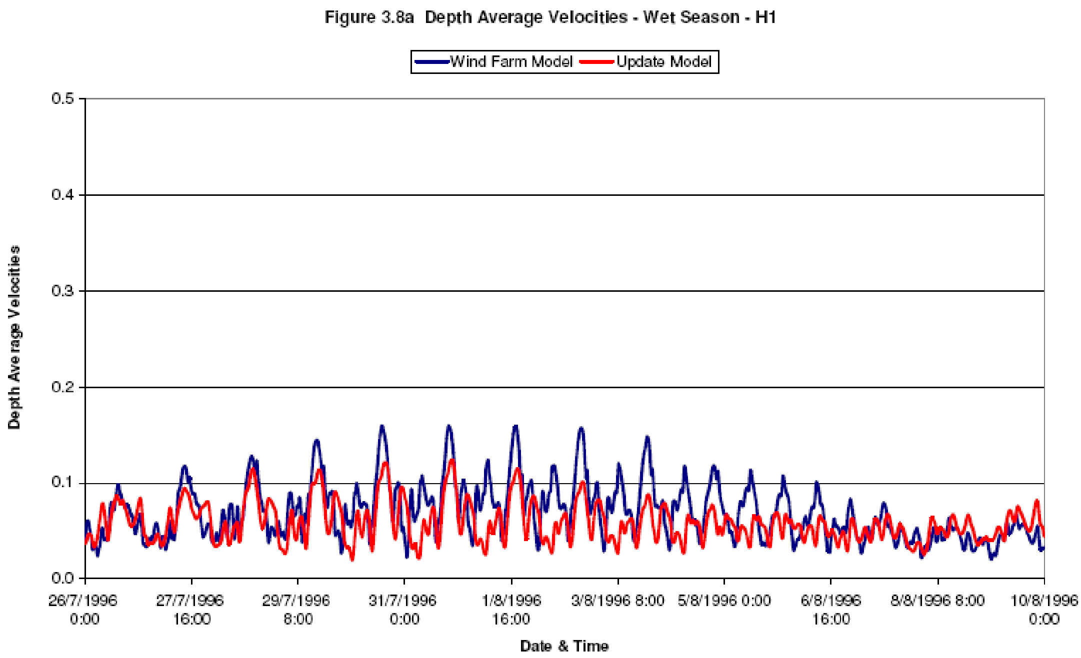


Figure 3.8b Depth Average Velocities - Wet Season - H2

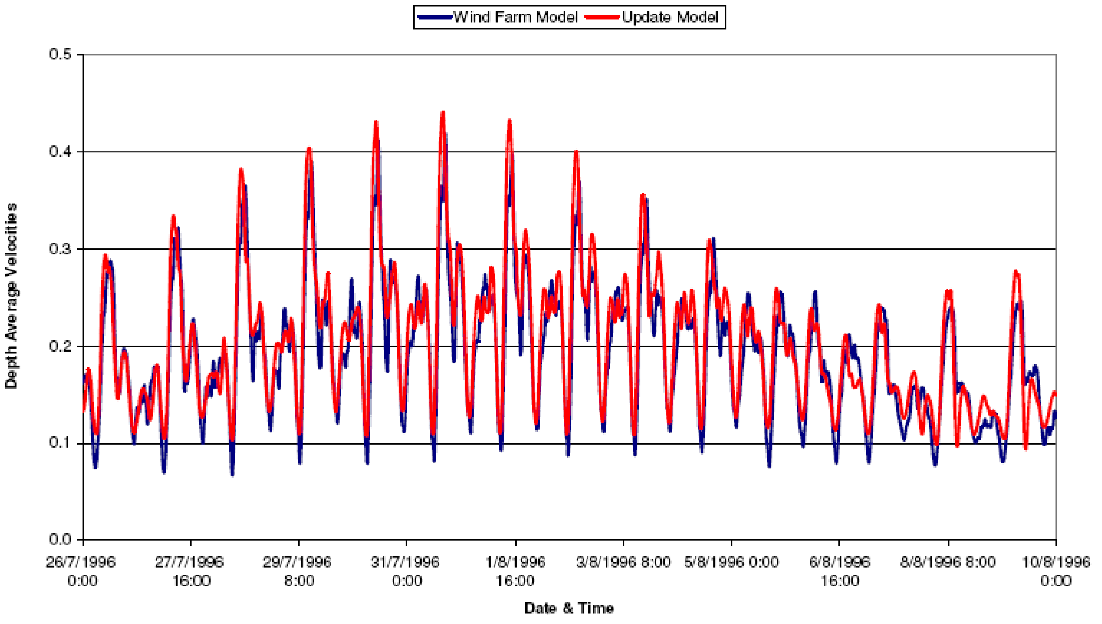


Figure 3.8c Depth Average Velocities - Wet Season - H3

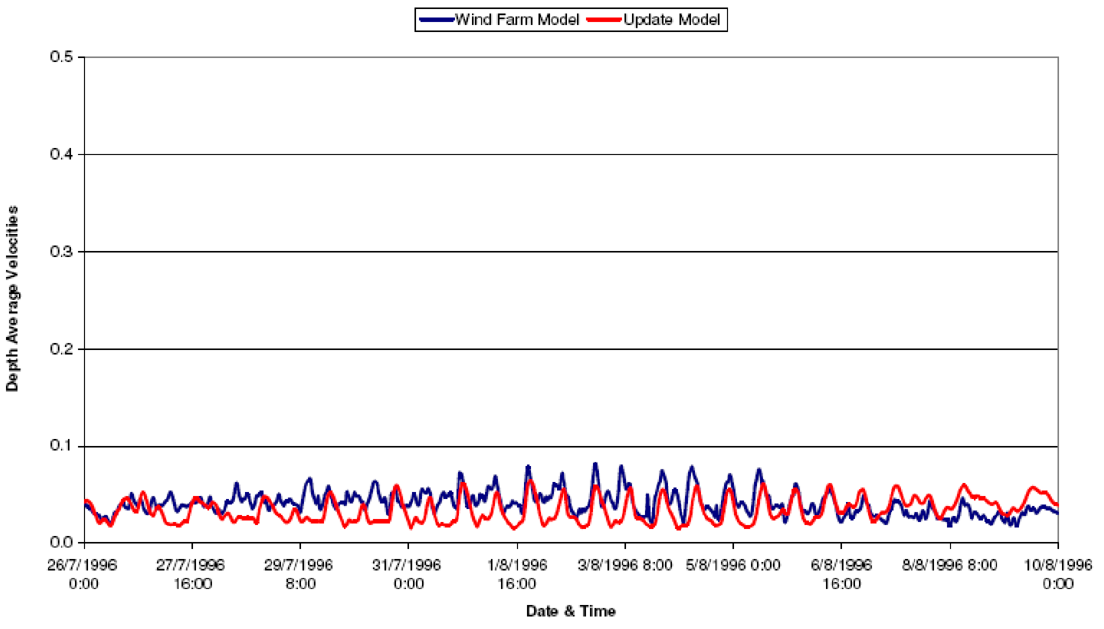


Figure 3.8d Depth Average Velocities - Wet Season - H4

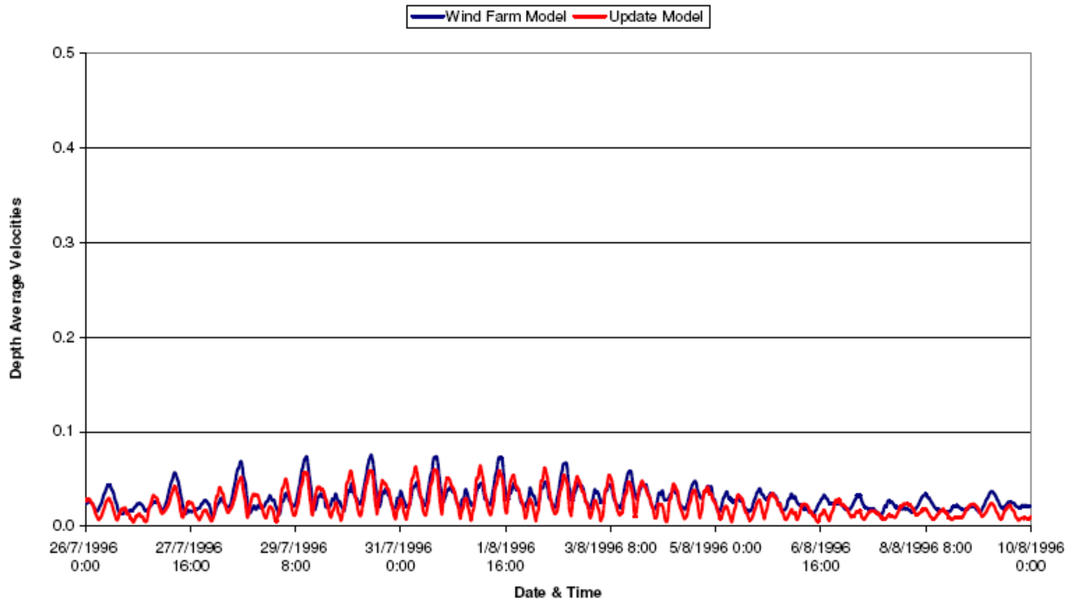


Figure 3.8e Depth Average Velocities - Wet Season - H5

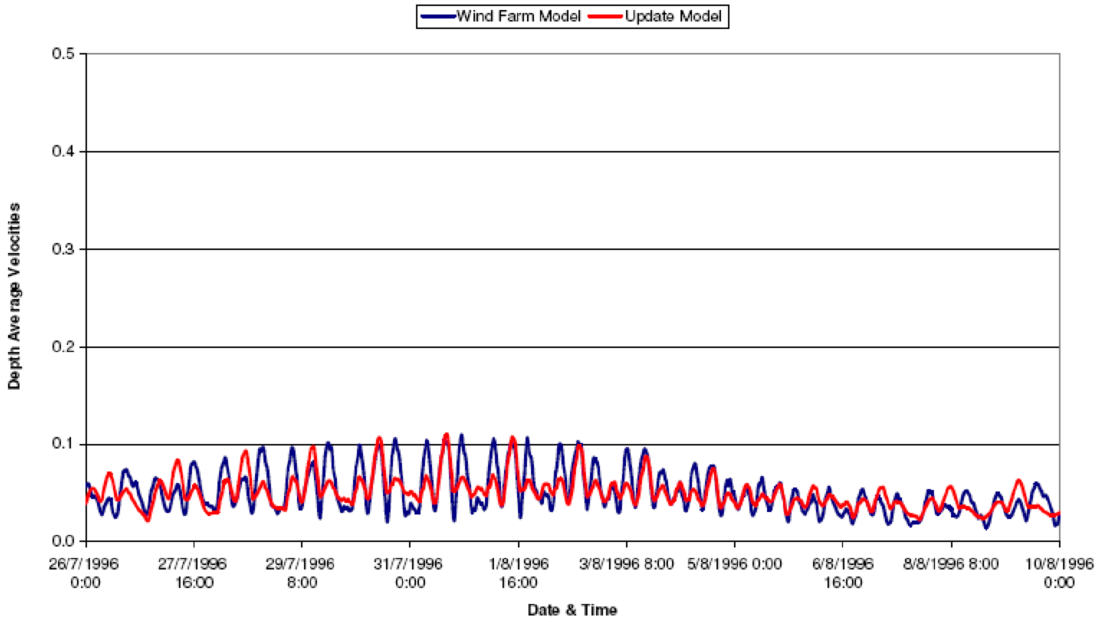


Figure 3.8f Depth Average Velocities - Wet Season - H6

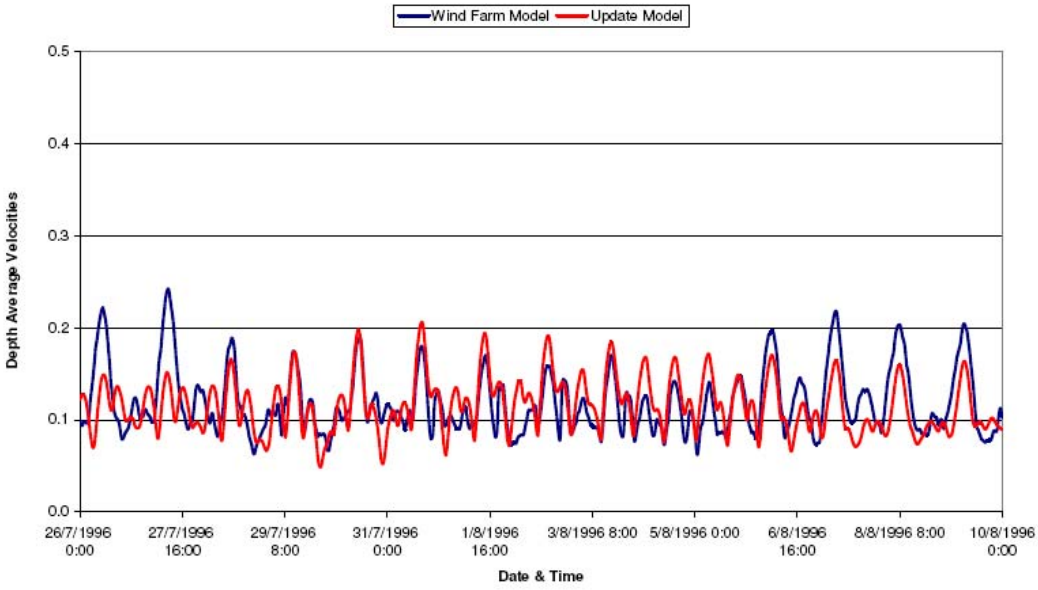


Figure 3.8g Depth Average Velocities - Wet Season - H7

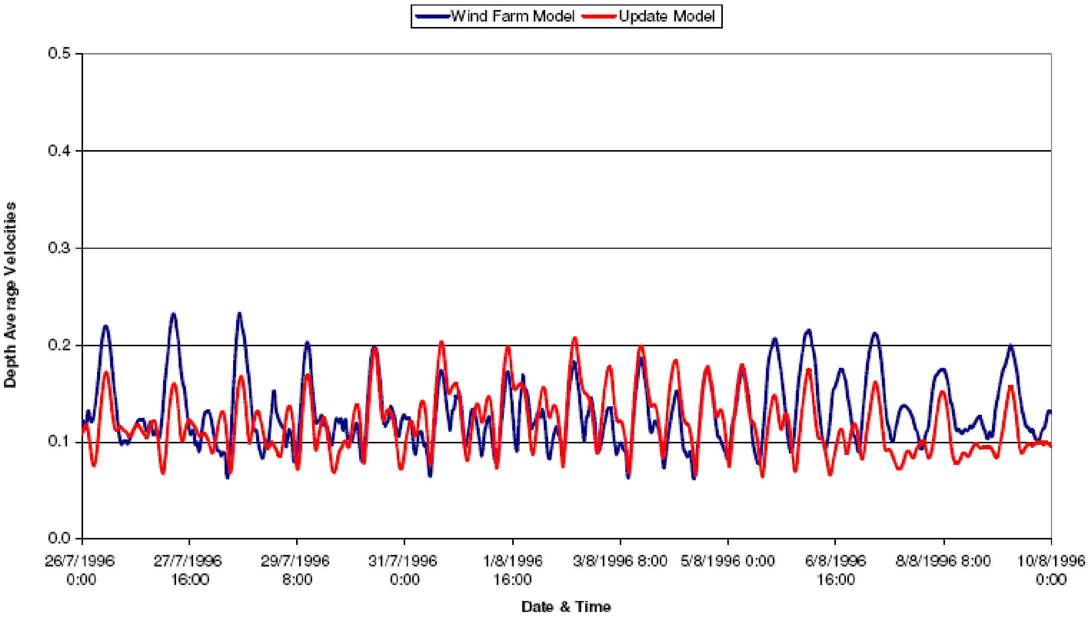
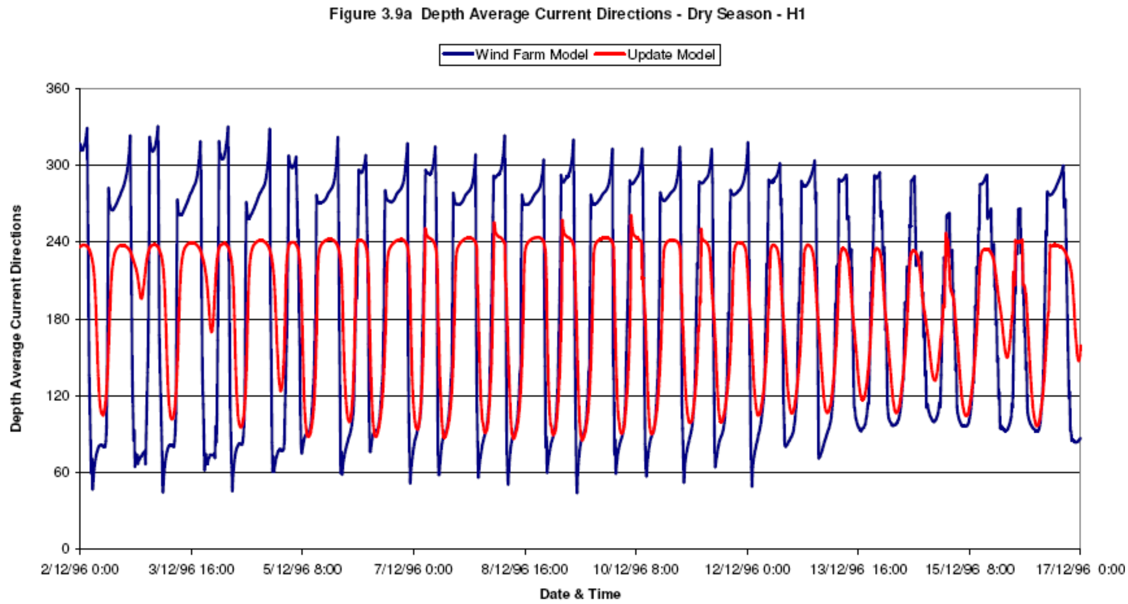


Figure 3-9 Depth Averaged Current Directions at H1 to H7 during Dry Season



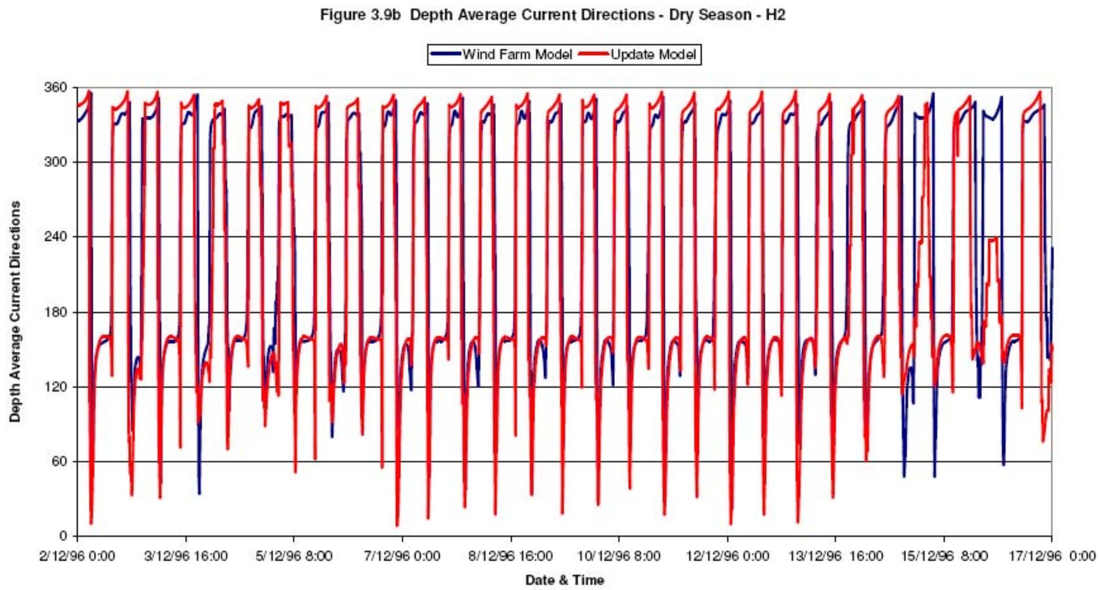


Figure 3.9c Depth Average Current Directions - Dry Season - H3

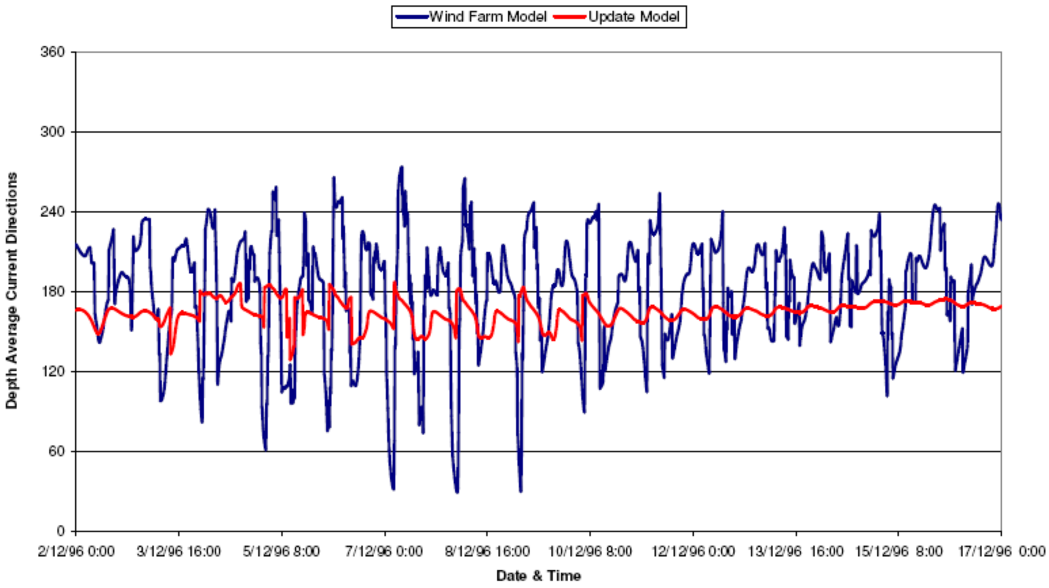


Figure 3.9d Depth Average Current Directions - Dry Season - H4

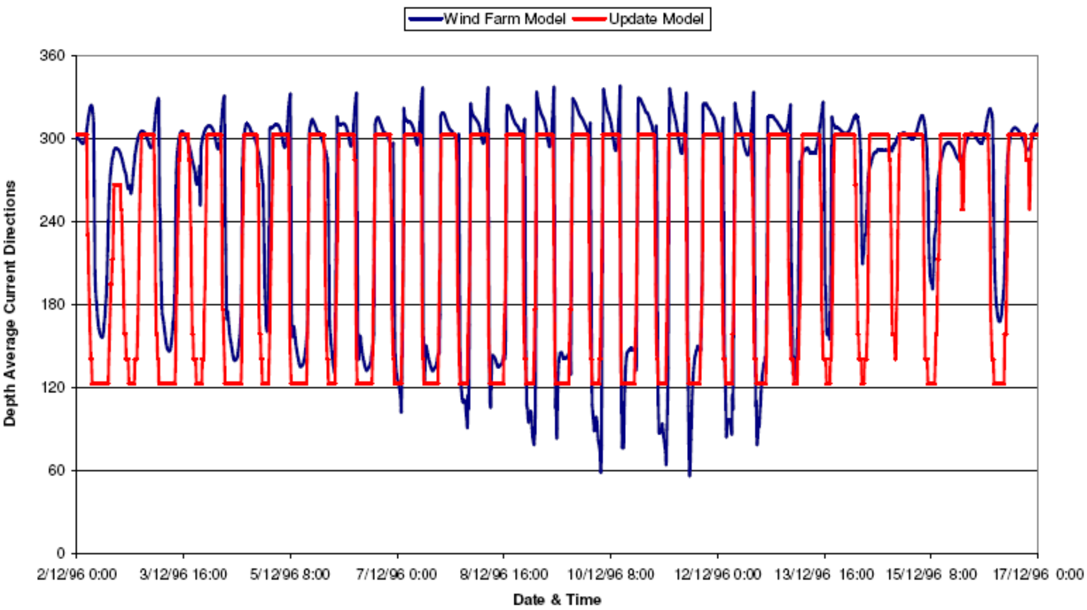


Figure 3.9e Depth Average Current Directions - Dry Season - H5

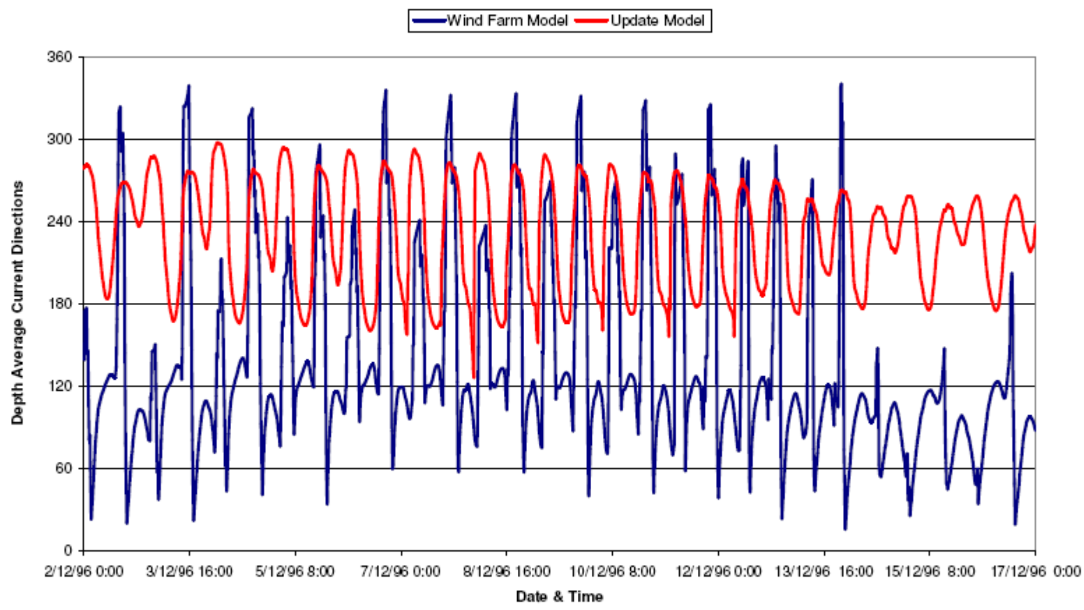
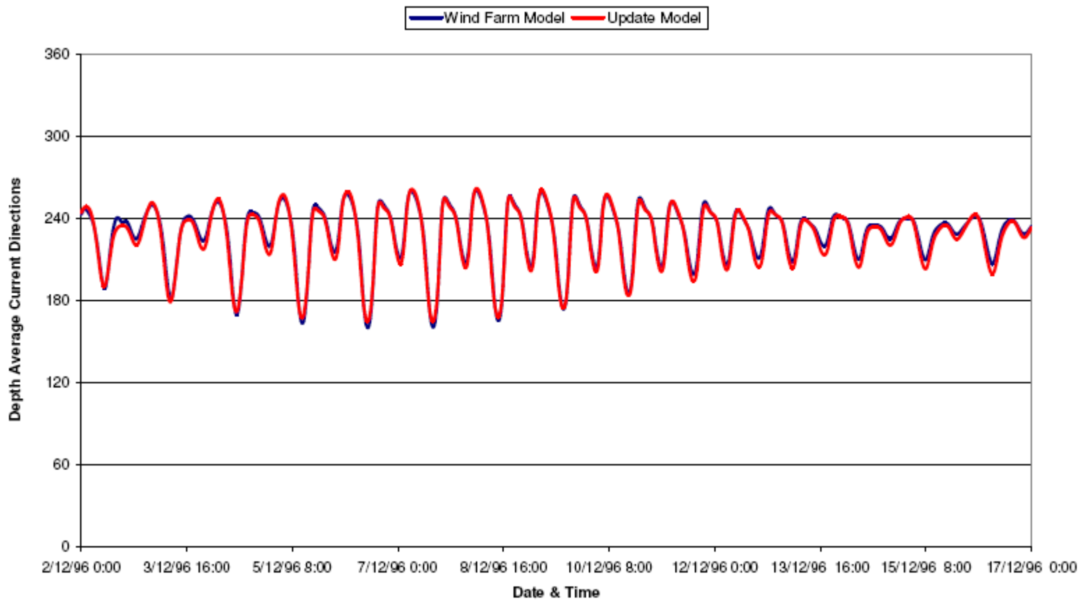


Figure 3.9f Depth Average Current Directions - Dry Season - H6



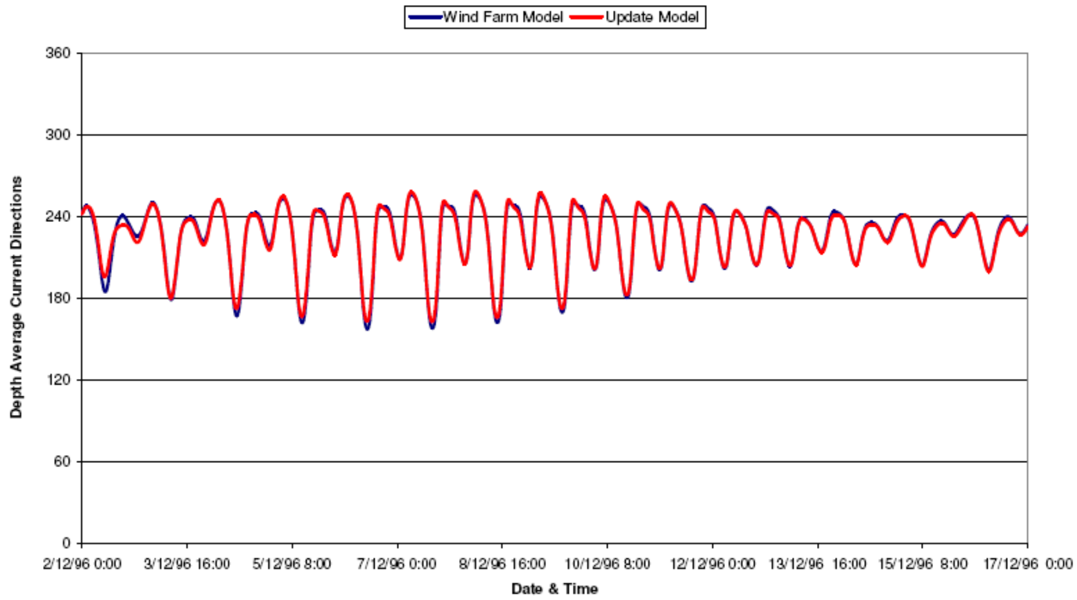


Figure 3.9g Depth Average Current Directions - Dry Season - H7

Figure 3-10 Depth Averaged Current Directions at H1 to H7 during Wet Season

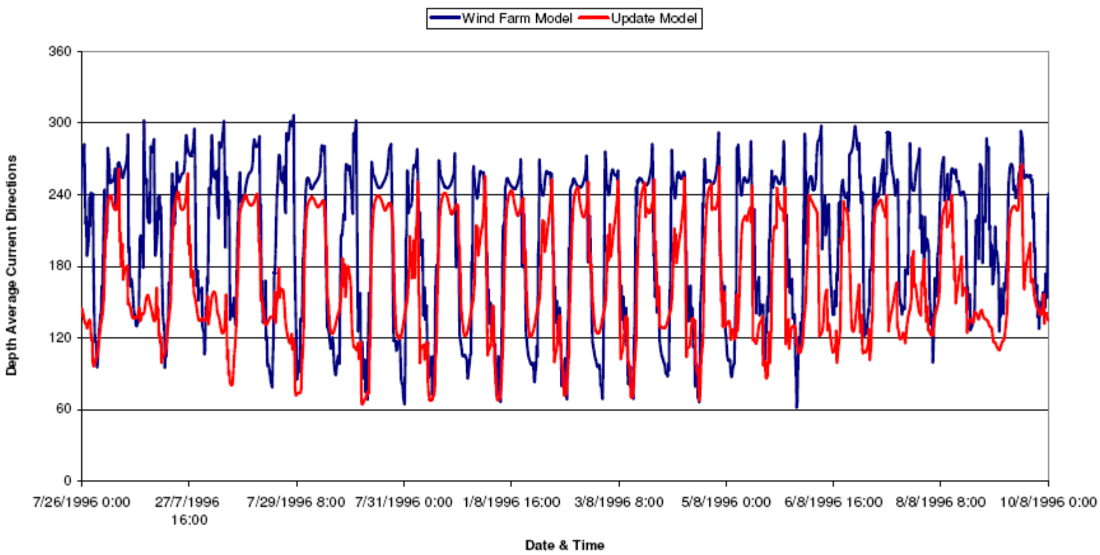


Figure 3.10a Depth Average Current Directions - Wet Season - H1

Figure 3.10b Depth Average Current Directions - Wet Season - H2

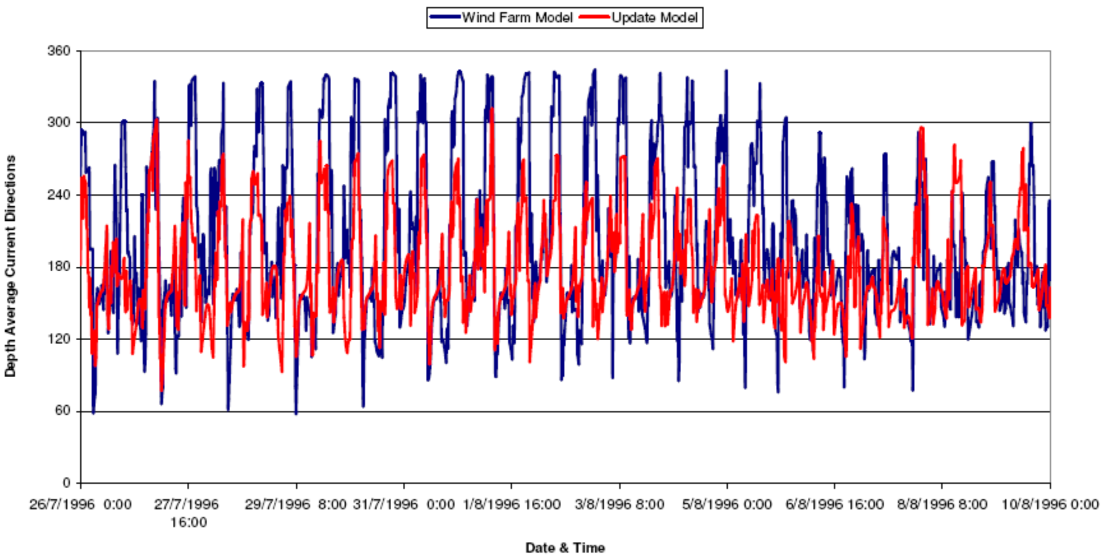


Figure 3.10c Depth Average Current Directions - Wet Season - H3

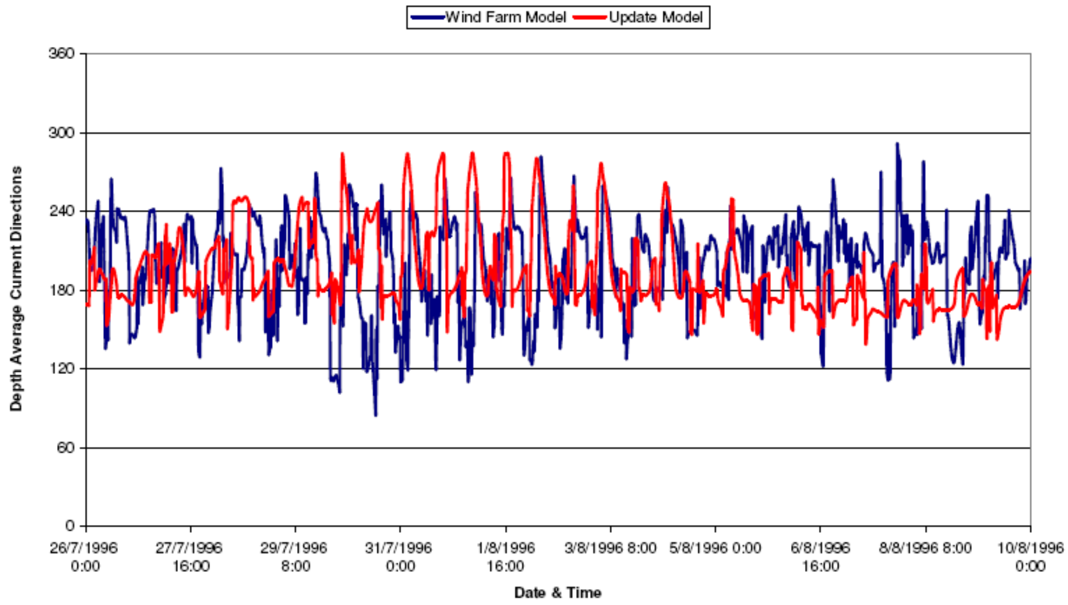


Figure 3.10d Depth Average Current Directions - Wet Season - H4

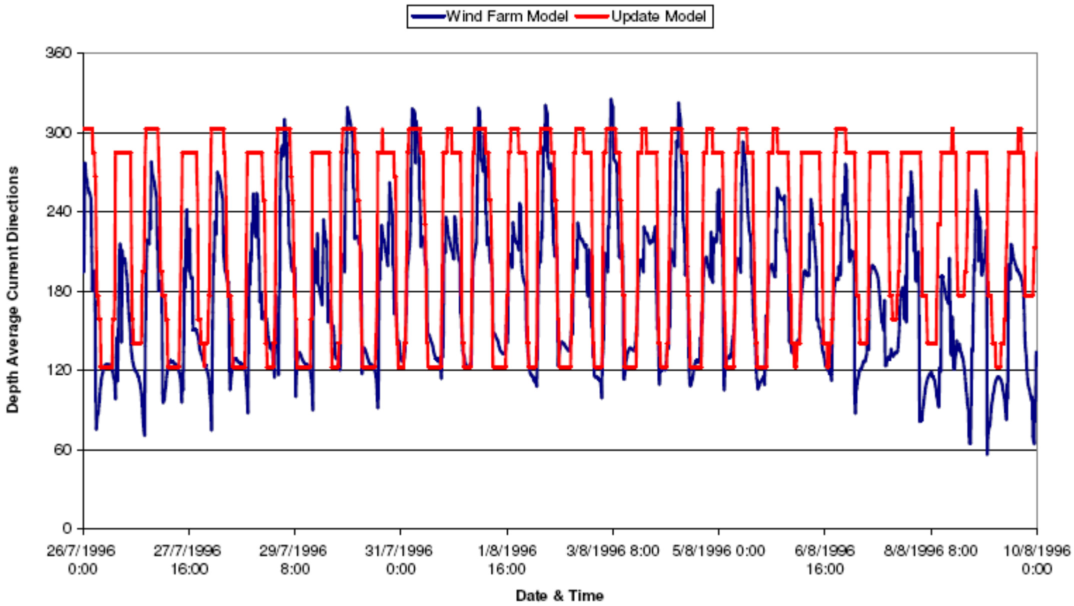


Figure 3.10e Depth Average Current Directions - Wet Season - H5

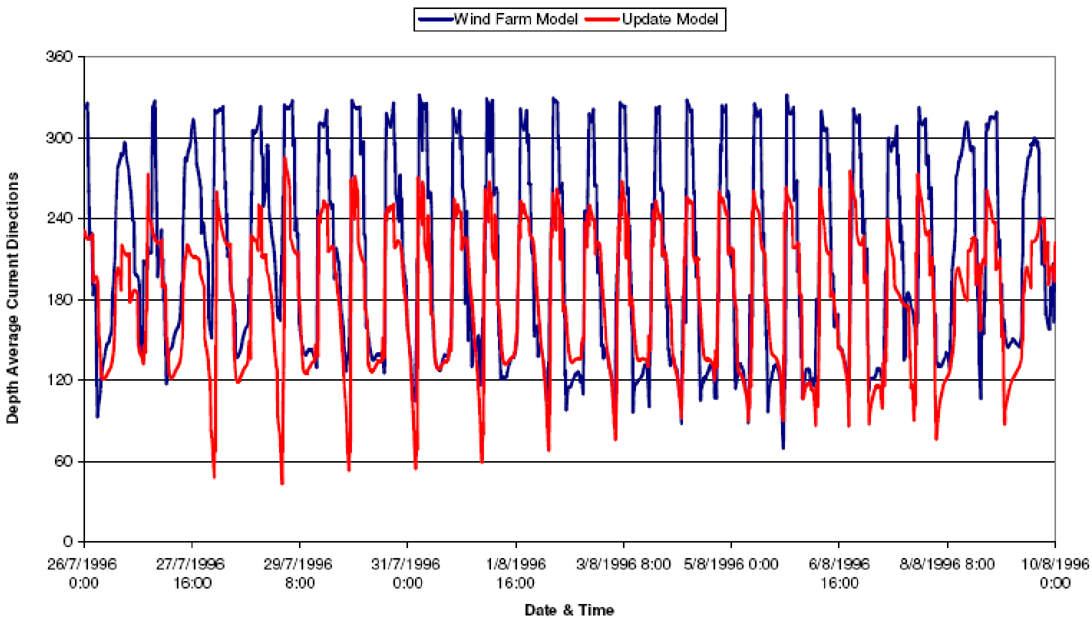


Figure 3.10f Depth Average Current Directions - Wet Season - H6

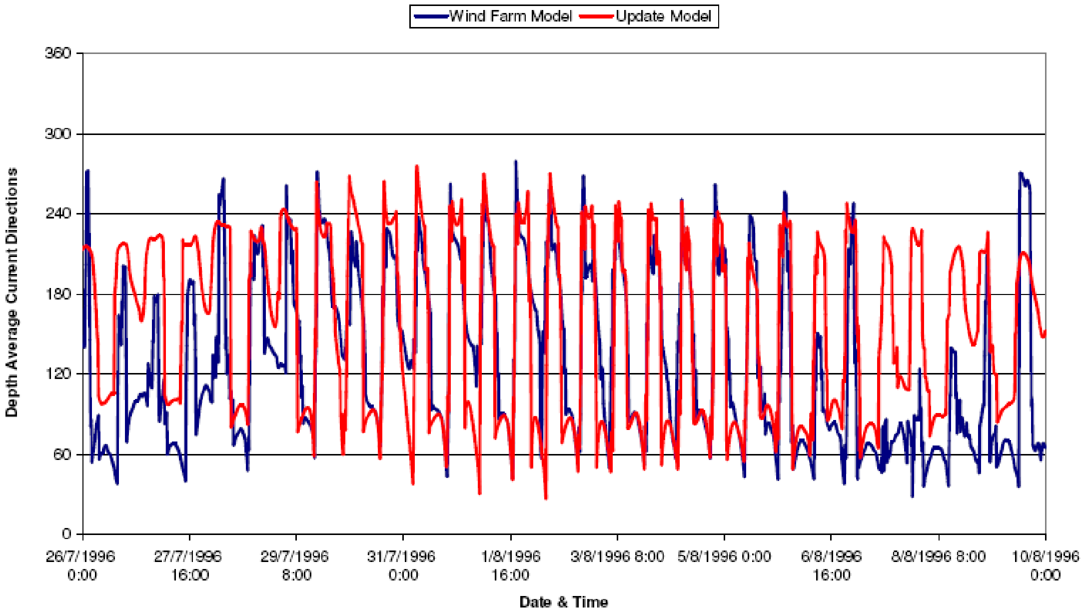
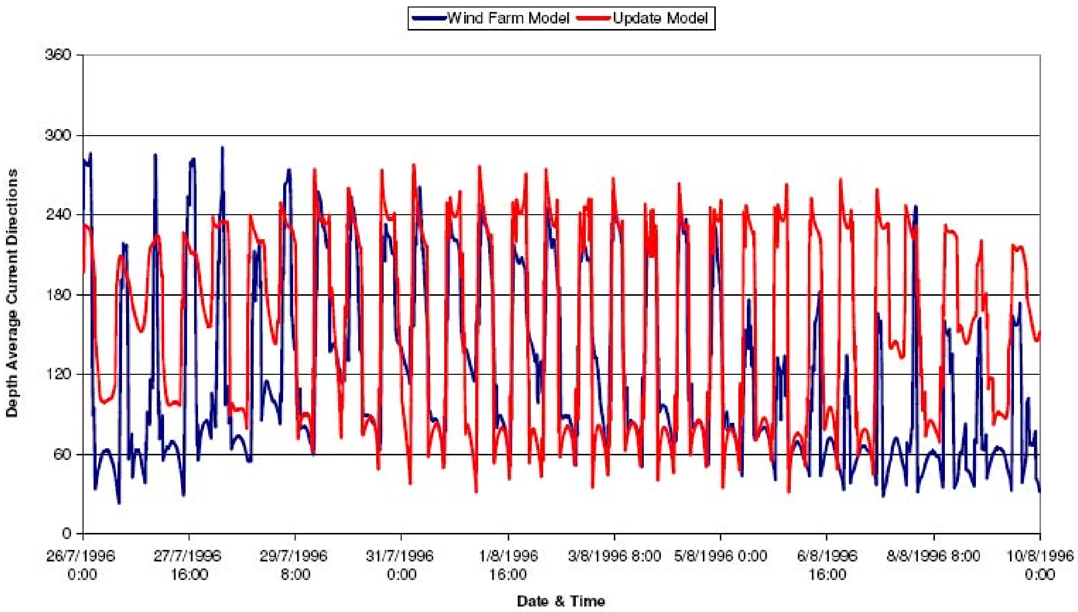


Figure 3.10g Depth Average Current Directions - Wet Season - H7



4 Conclusions

This calibration report has presented details of the Wind Farm Model setup and calibration. The predictions from the Wind Farm Model have been compared with the Update Model predictions. In most of the cases, the hydrodynamic predictions from the Wind Farm Model were very similar to the Update Model predictions. However, some differences were noted in the predicted results between Wind Farm Model and Update Model. The discrepancy was likely to be due to a more accurate representation of the bathymetry and coastline by the Wind Farm Model with refined grid size than by the Update Model.

In conclusion, the calibration results suggested that the Wind Farm Model is capable of predicting reliable hydrodynamic conditions in the study area and can be used for prediction of the construction and operational scenarios of the present Project.