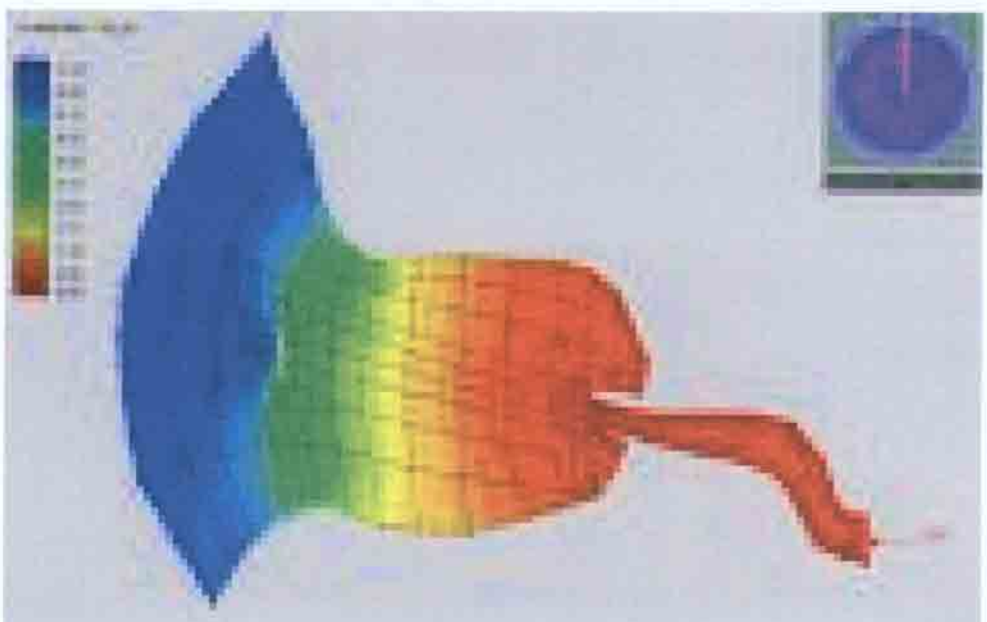
The Port Authority of Jamaica

HYDRODYNAMIC MODEL WITH FLOOD CONDITIONS

FALMOUTH CRUISE SHIP TERMINAL DEVELOPMENT



JUNE 2009

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June 9th, 2009

Mr. Gary Lawrence, Vice President Engineering
The Port Authority of Jamaica
15 – 17 Duke Street, Kingston

Dear Sir,

Re: Falmouth Cruise Ship Facility – Hydrodynamic Model with Flood Conditions

Based on the meeting held with NEPA and PAJ on April 17th 2009, there were concerns that even though the hydrodynamic model displayed reasonable results outside of the inner harbour, NEPA was not convinced that the model was capable of accurately simulating currents inside the inner harbour where the dinoflagellates actually reside. NEPA therefore requested that additional data collection be carried out inside the inner harbour to determine the existing current speeds and direction during a spring and neap tidal cycle.

This new data collected would then be used in the hydrodynamic model to see if the model predicts similar current speeds and directions. If the model then predicts the currents and directions, further modeling of a typical flood condition would be investigated in relation to salinity concentrations within the inner harbour.

Data Collection

The location of the current meter is shown in Figure 1. It was deployed in approximately 1.9 meters of water depth. The current meter was attached to an aluminum frame and placed as close to the sea floor as possible.

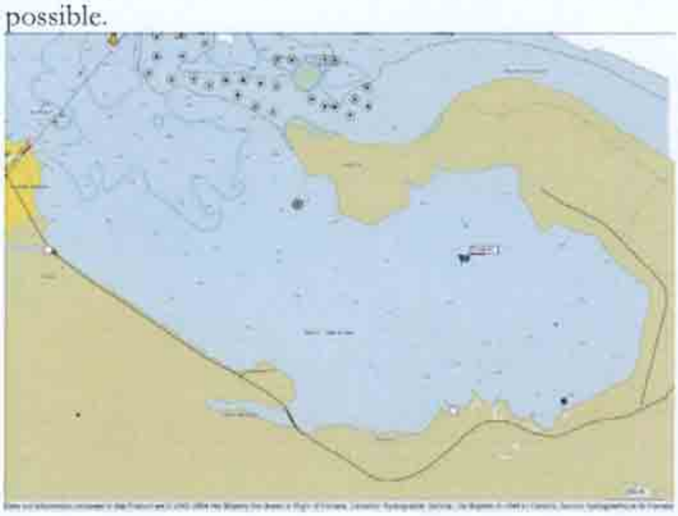

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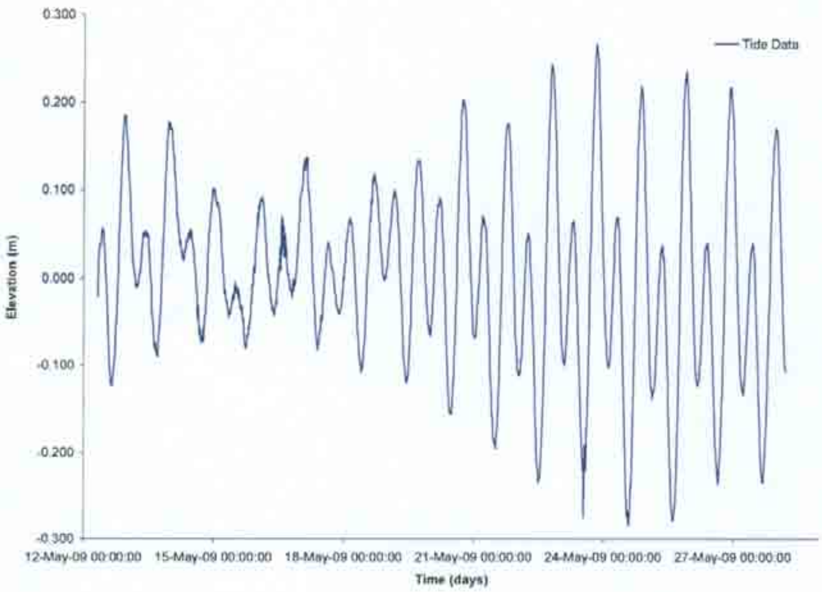
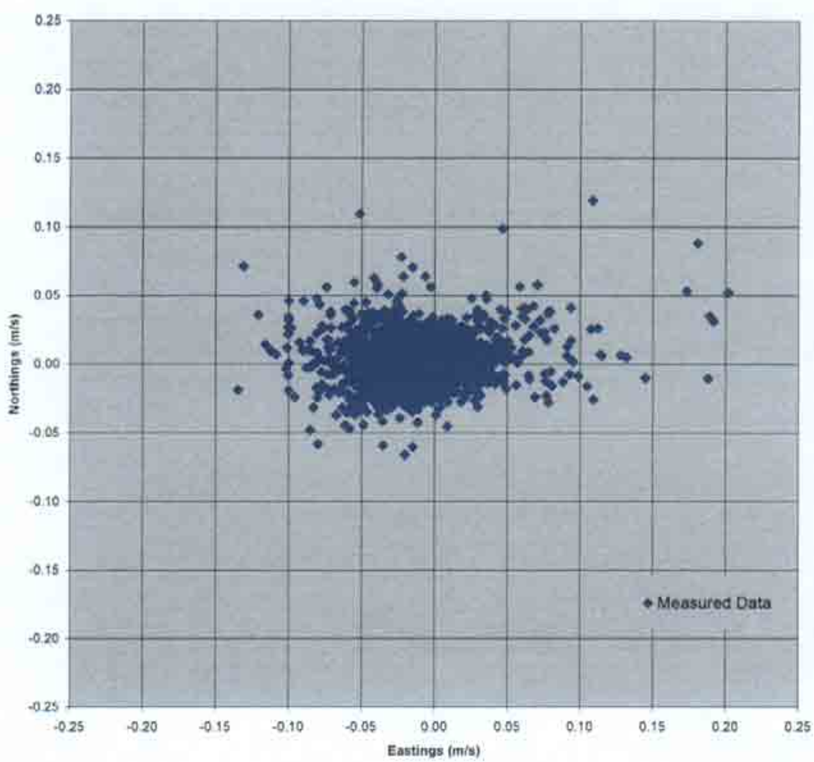
Figure 1 **Location of current meter**



This plot shows the measured tides and indicates the presence of Spring and Neap tides with a maximum range of approximately 0.6m. The tide signal also reveals a semi-diurnal tide, meaning that there are two highs and lows per day, often of unequal magnitude

Figure 2 **Measured tides**



This scatter plot shows the main flow moving in an east-west direction with an average speed of around +/- 0.10 m/s. There are some outliers that have speeds up to 0.20 m/s in the easterly direction. Some peak flow speeds of around 0.14 m/s also occur in the westerly direction. The measured flow in the north-south direction is minimal with speeds of +/- 0.05m/s.

Figure 3 **Scatter plot of measured currents**

Figures 4 to 6 show the correlation of the current speeds in the main (East-West) direction with the tide, river flow and wind data. Figure 7 shows the correlation between sea temperature and river flow. These plots are presented in order to confirm our understanding of the main forces that influence the hydrodynamics of the inner bay.

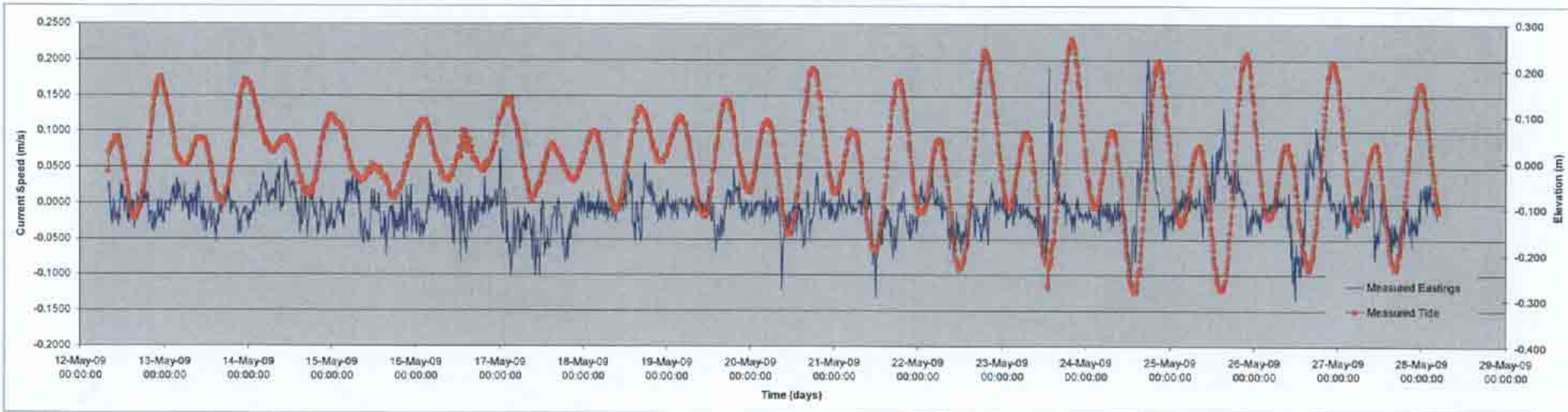


Figure 4 **Measured Tide vs Measured Eastings currents**

It can be seen from Figure 4 that the tidal cycle does has the strongest influence on the current speeds and direction within the inner bay. During rising tides, there is a tendency for the currents to move in a positive direction which means the water body is moving to the east and vice versa for when the tide is falling. However, there are some instances when the tide is falling yet the flow is positive or showing a rising tide current direction. This means there are other forces acting upon the water body that might have the same amount of influence as the tides.

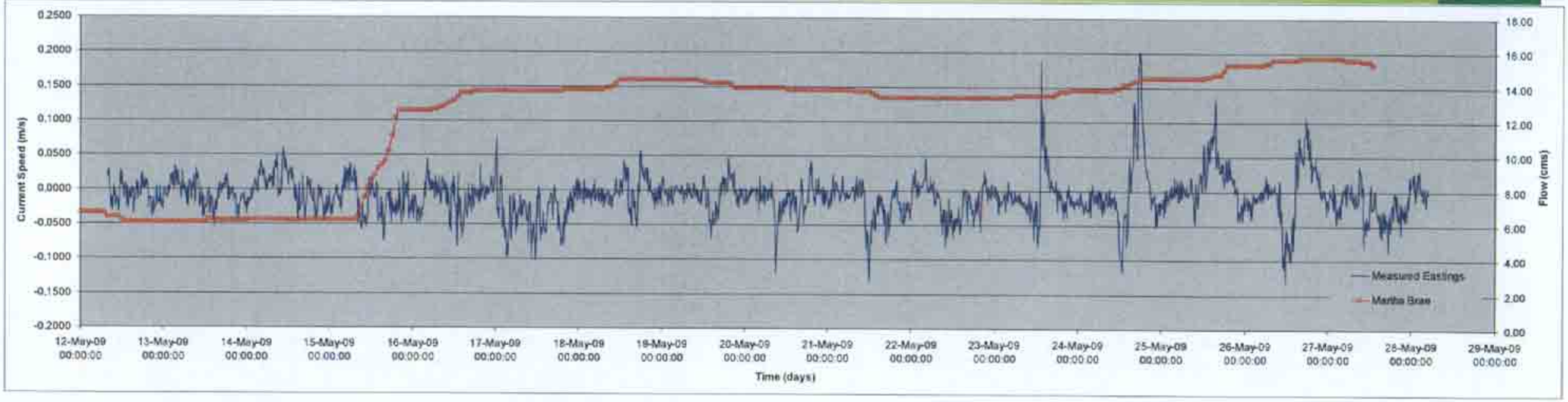


Figure 5 **Measured River Flow vs Measured Eastings currents**

Figure 5 shows the measured river flow data and the current speed data. This shows that the river flow basically has very little influence on the magnitude and direction of the currents within the inner bay under normal flow conditions. This measurement period represents "base flow" of approximately 6.0 m^3/s until May 15th, and then a period of sustained river flow approximately twice the base flow.

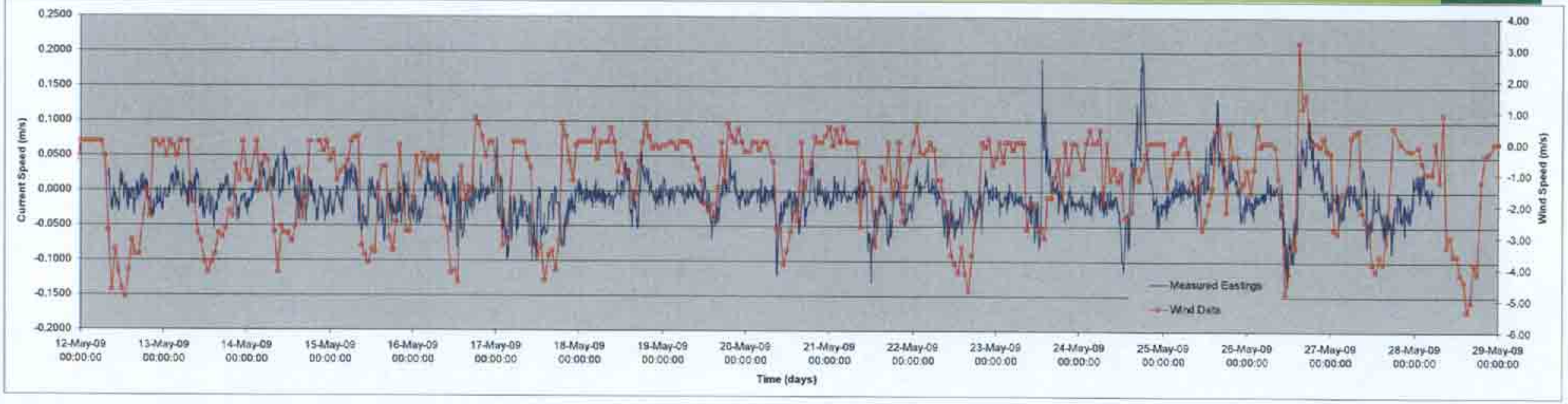


Figure 6 **Wind Speed vs Measured Eastings currents**

Figure 6 shows the measured wind from Montego Bay and the current speeds. It appears from this comparison that the effect of the wind is of significant importance within the inner bay. It shows that the wind effect was stronger than the tidal effect around the May 25th as that was during a falling tide and the flow at this location was moving in a positive or easterly direction.

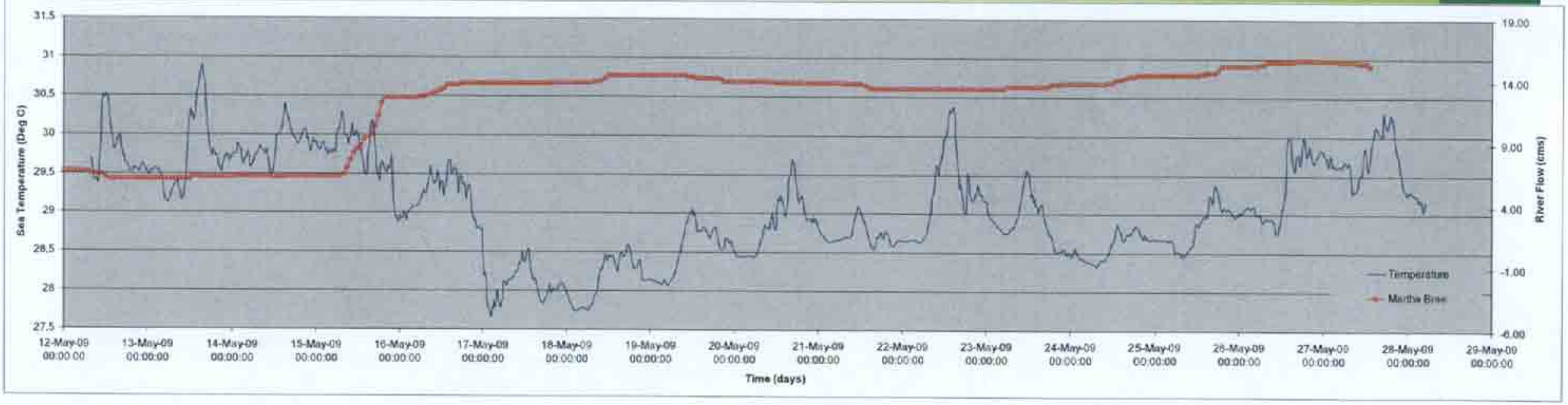


Figure 7 **Measured river flow vs Measured Sea Temperature**

Figure 7 shows the effect the river flow has on the sea temperature. The data shows that as the river flow increases, the sea temperature starts to fall. The lag between the increase in flow and the drop in temperature relates to the time required for lateral and vertical mixing of the cooler fresh water with the warmer waters of the inner bay. As there was very little influence of the river flow on the current speeds, it appears that the main impact of river flow is on the water temperature within the inner bay.

Drogue tracks were carried out during the deployment of the current meter, shown below is a photo of one of the drogues being deployed in the inner bay. A GPS was attached to the drogues in order to have continuous tracking of the drogue so as to have a better understanding of the spatial movement of the water mass.

Figure 8 Drogues being deployed in the inner bay

Figure 9 shows the drogue tracks for May 12th 2009. The first deployment occurred in the morning when a falling tide was occurring. As seen below, Drogue 1 traveled a shorter distance than Drogue 2. This may have been because the underwater portion of Drogue 1 was closer to the sea surface than Drogue 2, which means it could have been more influenced by the wind. Drogue 2 shows some gyre effects occurring near the entrance of the Falmouth harbour. The first deployment was retrieved around 1:00pm as shown below. A next deployment was done in order to capture a rising tide, however, only the start of the rising tide was caught as the drogues were retrieved around 4:20pm.

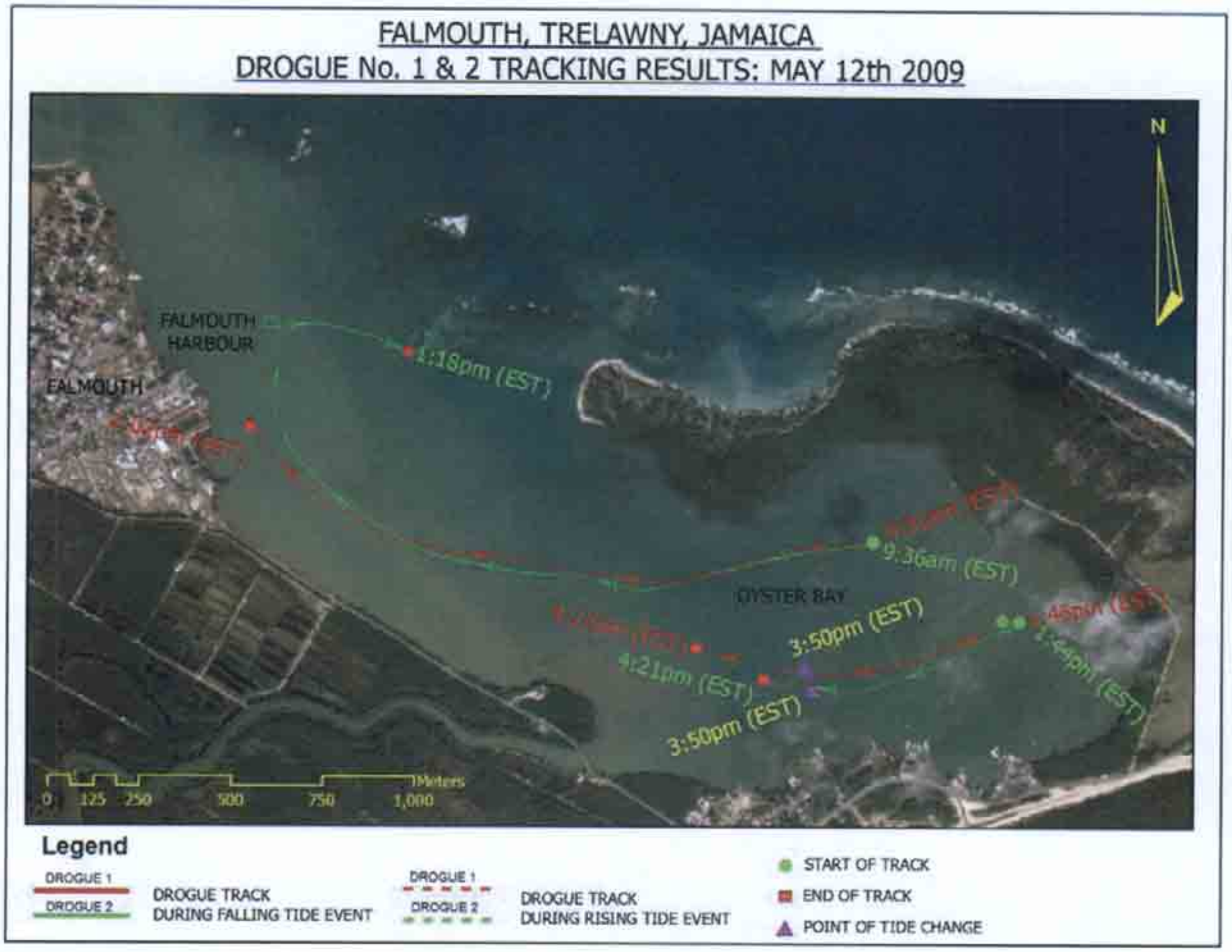


Figure 9 **Drogue tracks on May 12th 2009**

Hydrodynamic Modeling of New Data

The hydrodynamic model RMA was run using the tides, wind and river flow values that were measured. The purpose of this was to determine if the model that was calibrated using data collected in the Falmouth Harbour entrance is able to produce reliable predictions within the inner bay. The only changes that have been done to the model involve the use of the tide data, the river flow data and the wind data.

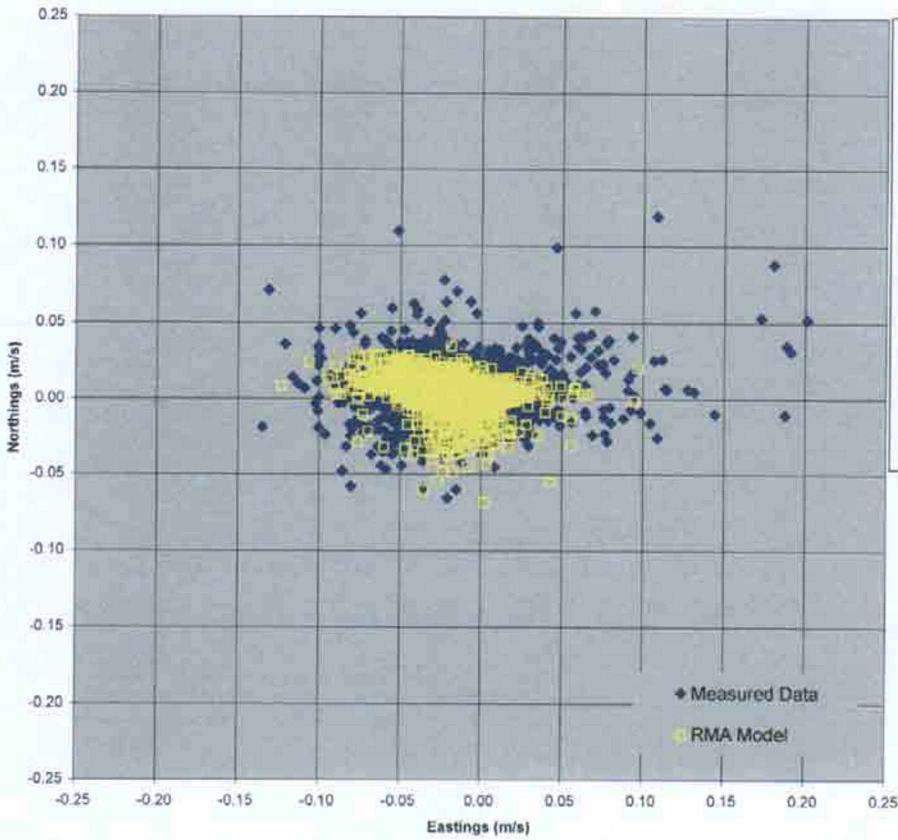


Figure 10 shows the scatter plots of both the measured and modeled currents. The model seems to capture the main flow speeds much better than the cross flow and seems to underestimate the peaks in the measured data.

Figure 10 Scatter Plot showing measured and modeled current speed and directions

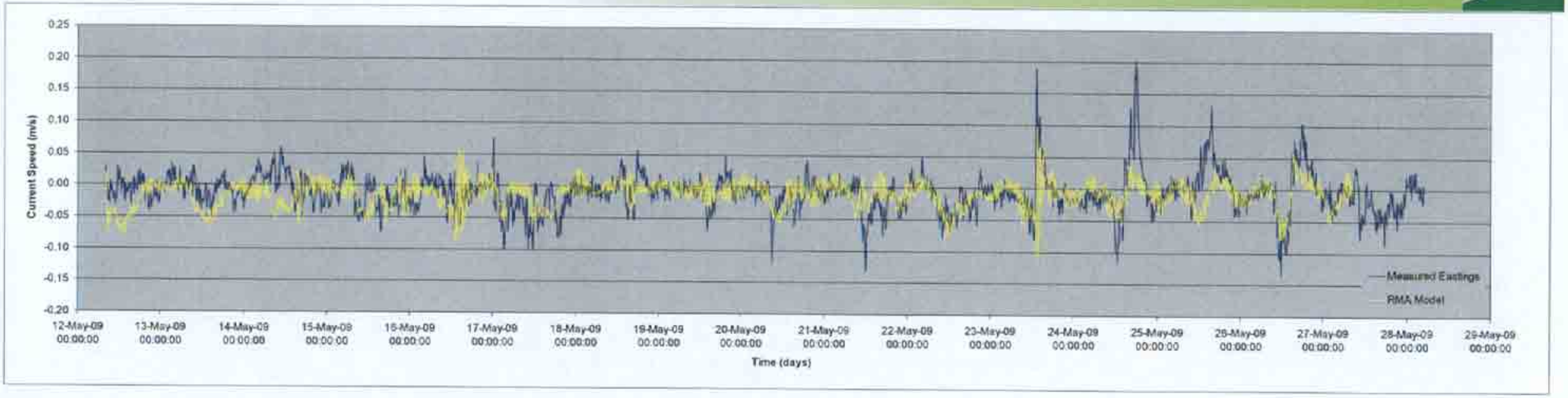


Figure 11 Measured data versus RMA 10 in the Eastings direction (m/s)

Figures 11 and 12 show the time series plots of both the Easting and Northing current speeds for measured and modeled currents. The hydrodynamic model tends to follow the measured data in both phase and direction, however, it seems to underestimate the peaks of the measured data. This underestimation could be due to high friction values within this area. In the Northing direction, the model also underestimates the peak flows, however, it falls within the general current speeds.

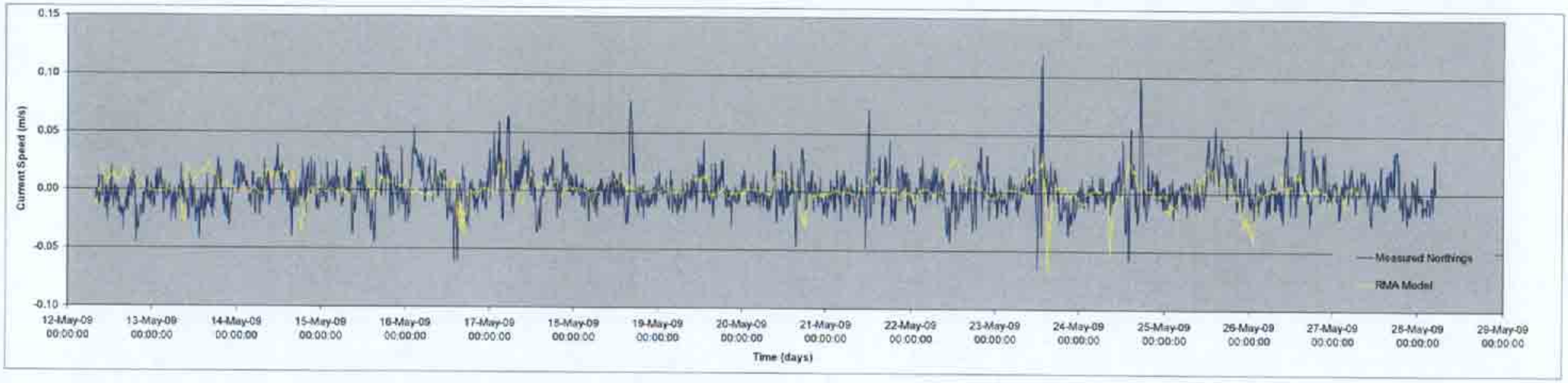


Figure 12 Measured data versus RMA 10 in the Northing direction (m/s)

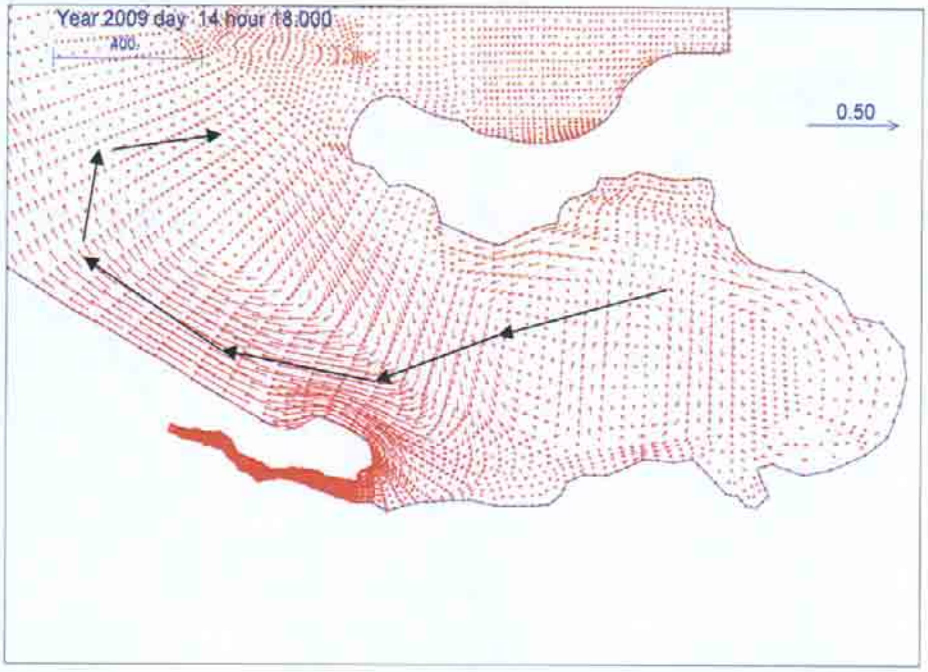


Figure 13 Comparison of hydrodynamic model and Drogue No. 2 (May 12, 2009)

Figure 13 shows a drogue track comparison alongside the model. Both the drogue and the model display the gyre effects which seem to occur within the bay. This quite clearly demonstrates shows the spatial capability of the hydrodynamic model.

Overall, the performance of the model in simulating the dynamics of the outer and inner harbour is within expected limits from a physical stand point. **The model is shown to be capable of simulating both the inner and outer harbour, therefore the findings and conclusions drawn in previous reports are substantiated.**

25 Year Flood Event and Time to Return to Normal Conditions (Salinity)

Since the model has been verified by the new measured data and current comparisons, the next step is to investigate the change in retention time that the proposed pier and the proposed pier with vessels would have on the existing conditions. A typical tide signal will be used in this investigation along with a typical mean river flow and wind conditions. The mean river flow was worked out to be around 7.5m³/s, while the 25 year peak flow conditions were 84.30m³/s.

Two locations were chosen to compare the different scenarios. The locations were the northern section of the inner bay and the eastern section of the inner bay as shown in Figure 14.

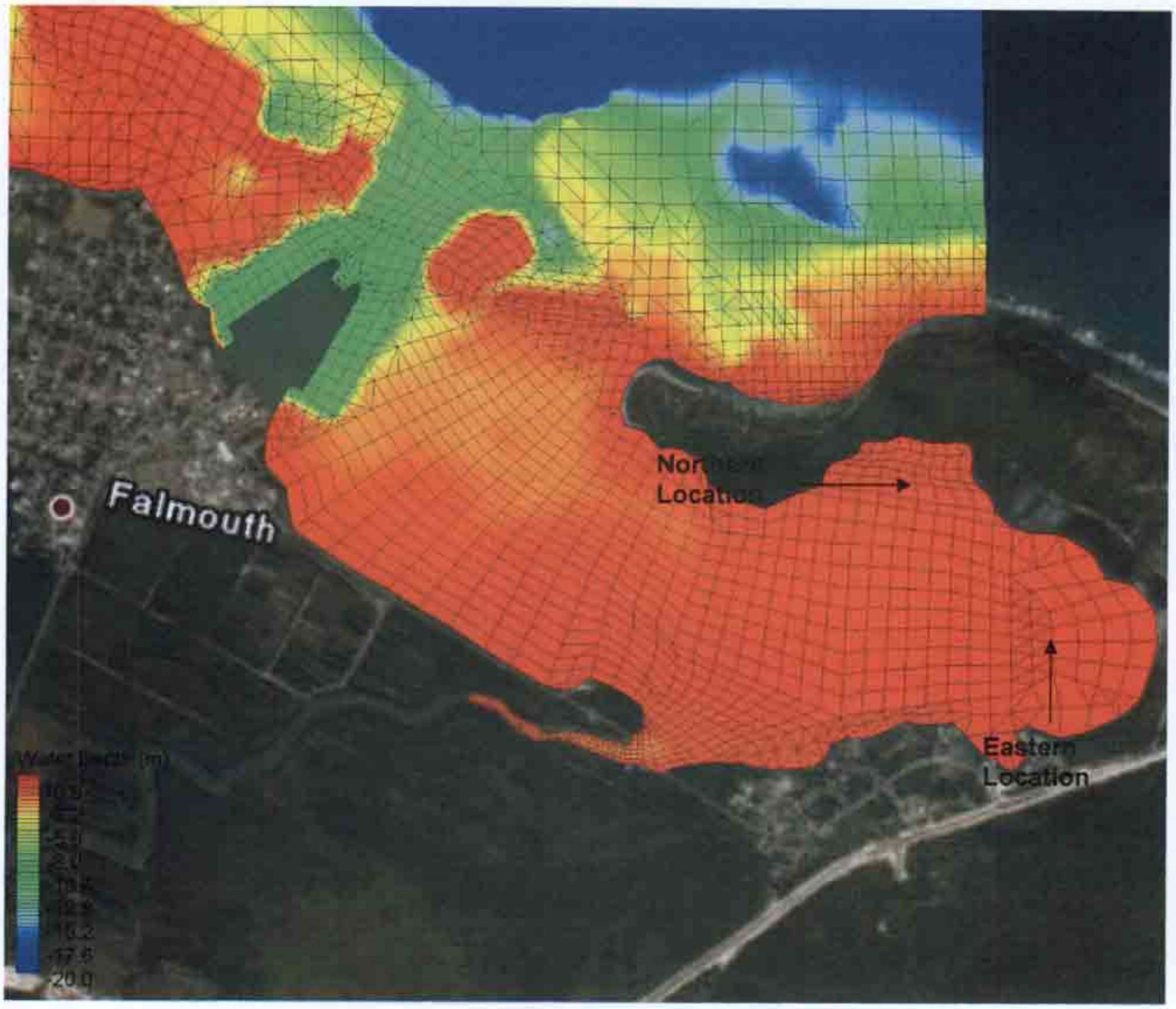


Figure 14 **Locations chosen for salinity comparisons**

Figures 15 & 16 show the salinity concentrations at both locations where the Dinoflagellates reside. The model shows that the differences in salinity are fairly small in these locations, however, there is a slightly higher concentration in the existing scenario as would be expected as both the proposed and the proposed with vessels would behave as a barrier. However, this slightly higher concentration in salinity is at most 0.35 ppt.

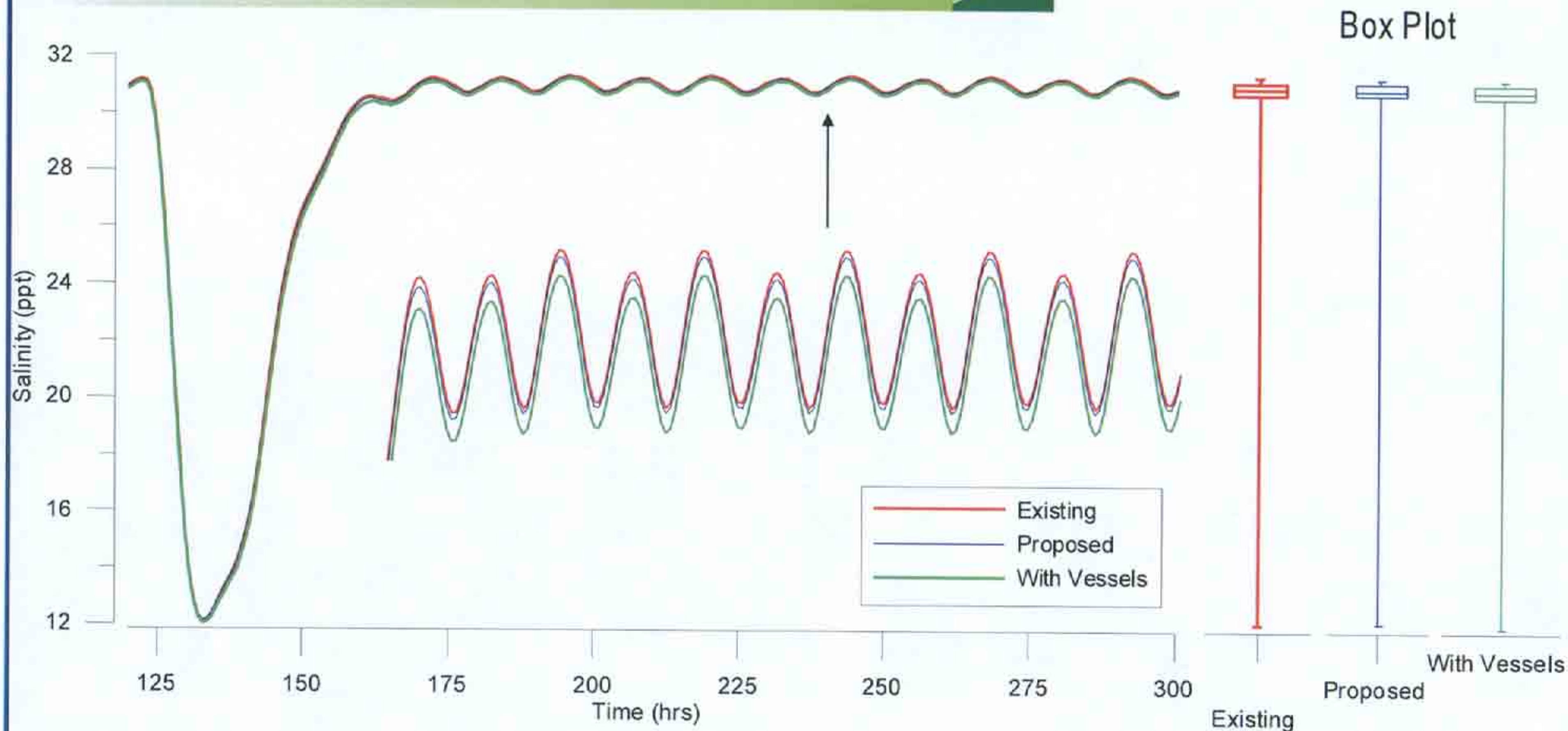


Figure 15 **Salinity Comparison at the northern section of the Inner Bay**

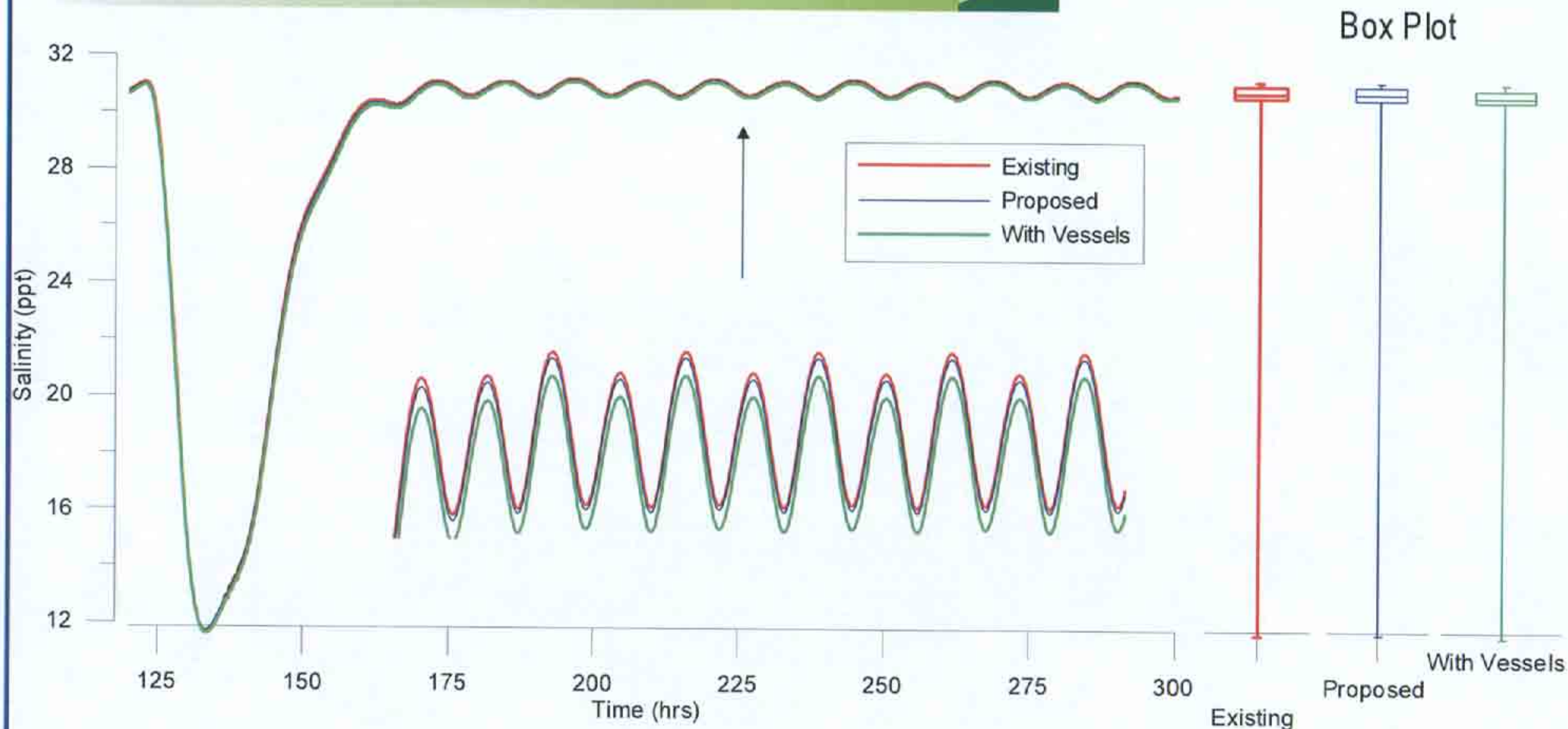


Figure 16 **Salinity Comparison at the eastern section of the Inner Bay**

Conclusion

Based on the new study carried out, the model has been shown to be robust in its ability to accurately predict currents in both the outer harbour and the inner harbour.

The model also demonstrates that it can predict typical drogue movements within the harbour.

The model also shows that the salinity change inside the inner harbour is fairly small.

Since the model has been shown to accurately predict this new data collection, the assumptions used in the previous investigations are substantiated. This means, the previous investigations on sediment transport are still valid.

If you have any further questions or require clarification of any aspect at this time, please do not hesitate to contact me.

Yours sincerely,
Smith Warner International Ltd.

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HydroInformatics Engineer