5 STAGE 1 NUMERICAL MODELLING

5.1 Development of Numerical Model

5.1.1 Prior History of Numerical Model

The model used for this study is a two-dimensional, transient hydrodynamic and water quality model that extends offshore from the Lake Macquarie entrance to the 40 m depth contour and encompasses the entrance channel and whole lake area. The main areas of interest in the immediate vicinity of Swansea Channel have been modelled using an increased density of model elements. The extent of the model is shown in Figure 5-1 and detail of the model in the study area is shown on Figure 5-2.

The original hydrodynamic model of Lake Macquarie was established during the Lake Macquarie Estuary Processes Study (AWACS, 1995) and uses the RMA-2 software, which adopts a 2-dimensional finite element solution. This model has been used by WBM Oceanics Australia in the past for the Lake Macquarie Estuary Management Study and for a study of remedial options for Fennell and Edmunds Bays.

The original mesh geometry was updated for the Lake Macquarie Estuary Management Study to accommodate additional hydrographic survey data (undertaken in 1996 by DLWC) in Swansea Channel and the drop-over area. In addition, the model was updated by WBM in 1998 for Lake Macquarie City Council (LMCC) during an investigation of the impacts on tidal hydraulics of dredging the upstream end of Swansea Channel. Additional survey information provided by LMCC for this area was incorporated into the model.

The model was upgraded in 2001 to include coastal bathymetry, which enabled the integration of the hydrodynamic model with a coastal wave model for the Lake Macquarie Entrance Study (WBM, in prep). During this study, additional detail was added to the entrance compartment downstream of Swansea Bridge.

5.1.2 Additional Modifications

In order to properly model the complex processes present at the southern entrance to Swan Bay, and within the entire study area in general, it was necessary to refine the model mesh. The resulting mesh detail is shown in Figure 5-2. In addition, where more recent survey information was available, the bathymetry of the channel was upgraded in the model.

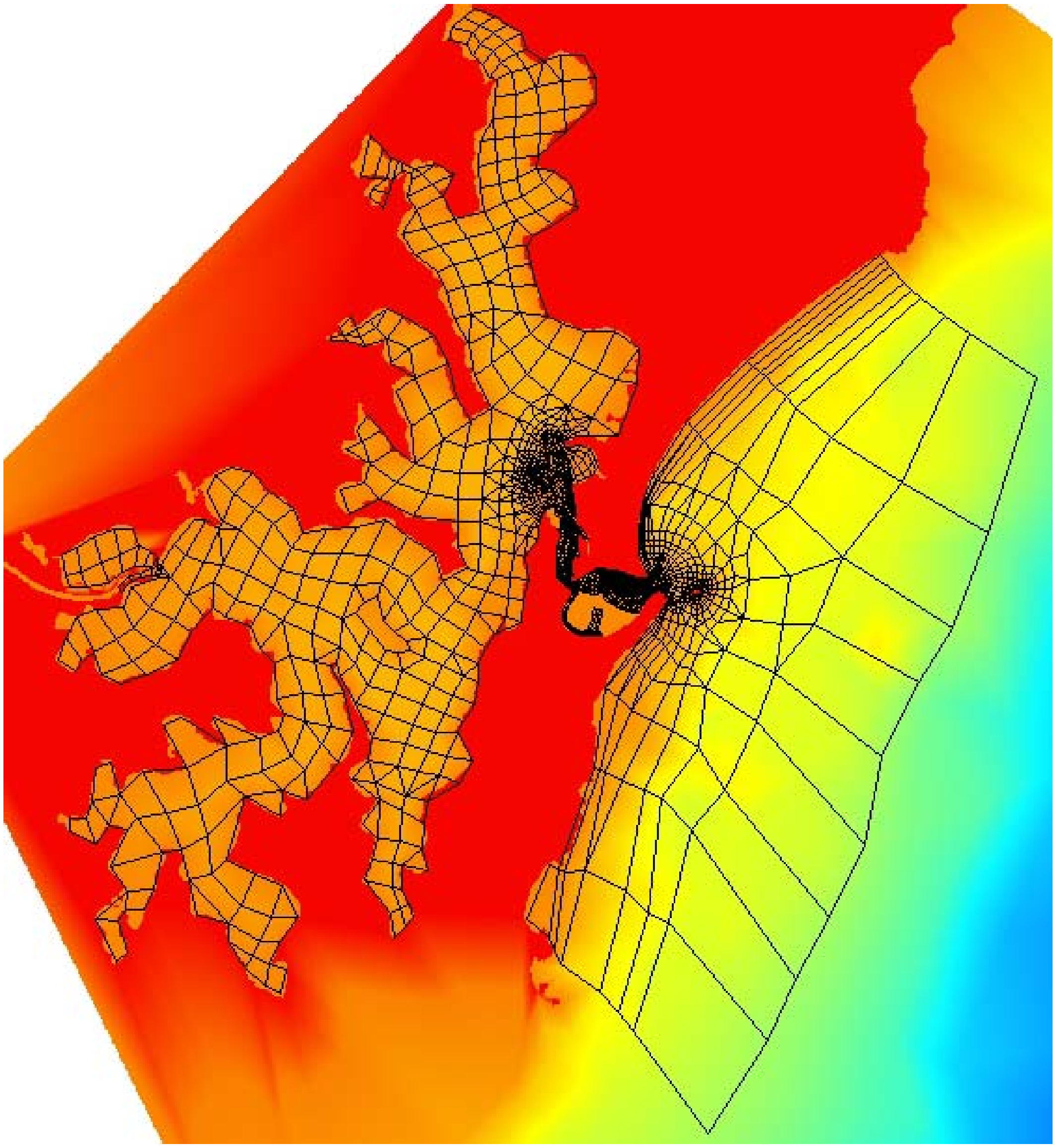

Figure 5-1 RMA Model Mesh for Lake Macquarie

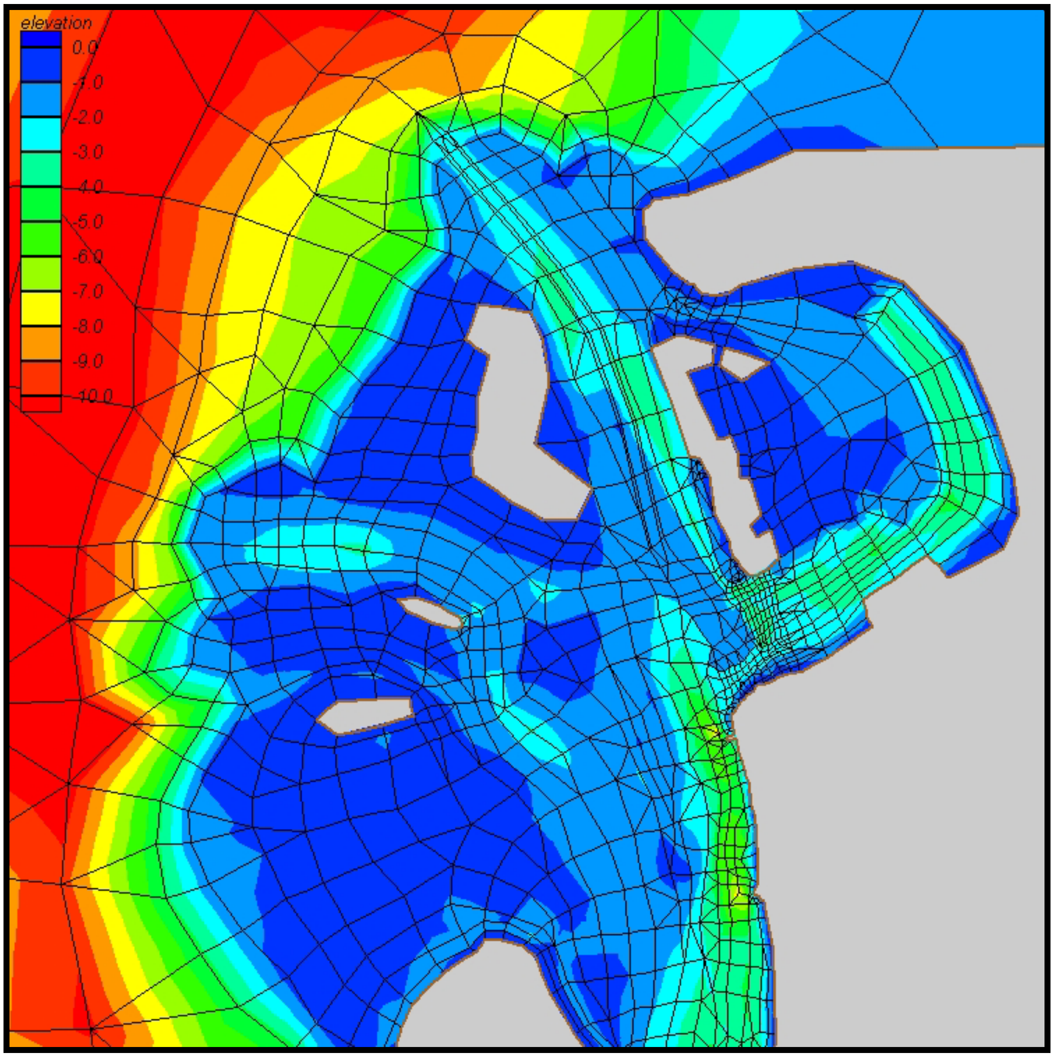

Figure 5-2 RMA Model Mesh for Study Area

5.2 Model Calibration

5.2.1 Hydrodynamic Calibration

The model has been calibrated previously using various sets of data during the Estuary Processes Study (AWACS, 1995), the Estuary Management Study (WBM, 1997) and the Lake Macquarie Entrance Management Study (WBM in prep). For this study, it was considered necessary to undertake additional calibration to ensure that the most recent modifications to the channel configuration in the study area were properly represented.

Accordingly, the flow and water level measurements taken during a data collection exercise in late February, 2002 (refer Section 2.3.3) were used for calibration purposes. The tidal record from Sydney was obtained from the Department of Public Works and Services' Manly Hydraulics Laboratory for the calibration period and was used as downstream boundary conditions.

The results of the calibration are presented in Appendix F. A very good fit was achieved for the three gauged flow lines with simulated discharge values generally within 10% of the measured values. The water level calibration indicates that while low water is well represented, the simulated peaks at Pelican Marina are generally overestimated by 5-7 cm (approximately 15% of the tidal range at this location). A better fit for water levels would have been desirable however, variation of calibration parameters in the model did not improve the resulting calibration. As the fit was reasonably close, and the simulated values for flow were very close, the calibration was considered acceptable for the purpose of this investigation.

5.2.2 Sediment Transport Calibration

Calibration of sediment transport within the study area utilised a number of variables available within RMA for that purpose. These parameters included:

- CLDE – which is the characteristic length factor for deposition;
- CLER – which is the characteristic length factor for erosion;
- Falling velocity of the sediment; and
- Transport model formulation.

In order to obtain an indication of sediment transport processes within the entrance to Swan Bay a control volume was established and the net amount of accretion calculated by comparing the Digital Elevation Models of March 2001 and August 2001. Actual survey work for the August 2001 survey produced by the Waterways Authority was undertaken in late July, 2001. In this way, it was established that a net volume of approximately 1400m^3 was deposited within the control volume during that period.

The model was run for a variety of combinations of the above input parameters and the net amount of accretion calculated by the model, within the control volume and over a single tidal cycle was calculated. A mean spring tide boundary condition was applied in recognition of the non-linear nature of sediment transport processes which result in significantly greater transport as a result of large tide (such as large spring or king tides) when compared to a mean tide.

The net accretion from a single tidal cycle was then factored to represent the period between the surveys of March 2001 and August 2001 and a comparison between the recorded and simulated volumes of accretion was made. Using this procedure, it was determined that appropriate values for calibration (which gave an agreement to within 5%) were as follows:

- CLDE = 1.0 (as recommended in RMA documentation)
- CLER = 10 (as recommended in RMA documentation)
- Falling Velocity = 0.29 (theoretical value would be around 0.05 m/s for quiescent, fresh water conditions)
- The Van Rijn methodology was adopted for transport.

Any sediment transport or geomorphological calculation of this nature is subject to a significant amount of uncertainty. The underlying processes involved are complicated and not fully understood at present. As a result, sediment transport models are typically based upon empirical relationships which vary in their applicability to various studies. Nevertheless, the model is a particularly useful tool when analysing trends or comparing the effectiveness of various management strategies.

This methodology provided a good basis to ensure that the calculated transport rates were of the order of magnitude actually occurring within the study area. This indicates that reasonable estimates of infill rates for dredging works could be obtained.

On balance, it is considered that the sediment transport model has been calibrated to a suitable level and is capable to enable comparison between the different management options.

Based on WBM’s experience with sediment transport models, the quantities calculated are estimated to be within a range of 1/3 to 3 times the values that could actually occur. Of course, the actual values would be largely dependant on prevailing environmental conditions.

5.3 Modelling of Existing Condition

5.3.1 Hydraulics

The peak flood and peak ebb flow patterns in the study area are shown on Figure 5-3 and Figure 5-4 respectively. Velocity magnitude can be determined from the colour gradation and is also indicated by the length of the velocity vectors on these figures. The directions of flow can be determined by the orientation of the velocity vectors.

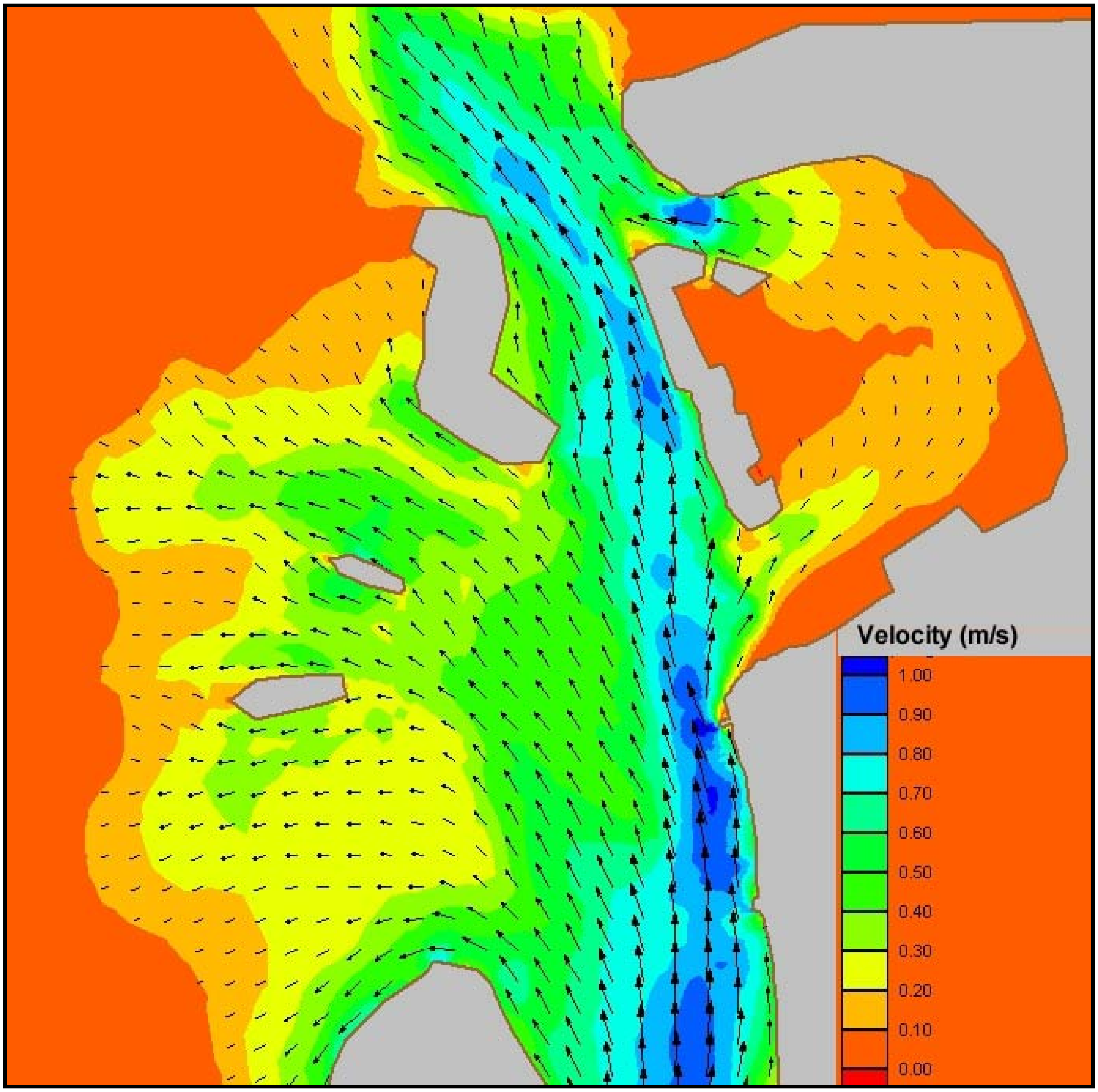

Figure 5-3 Simulated Peak Flood Velocity Patterns within Study Area

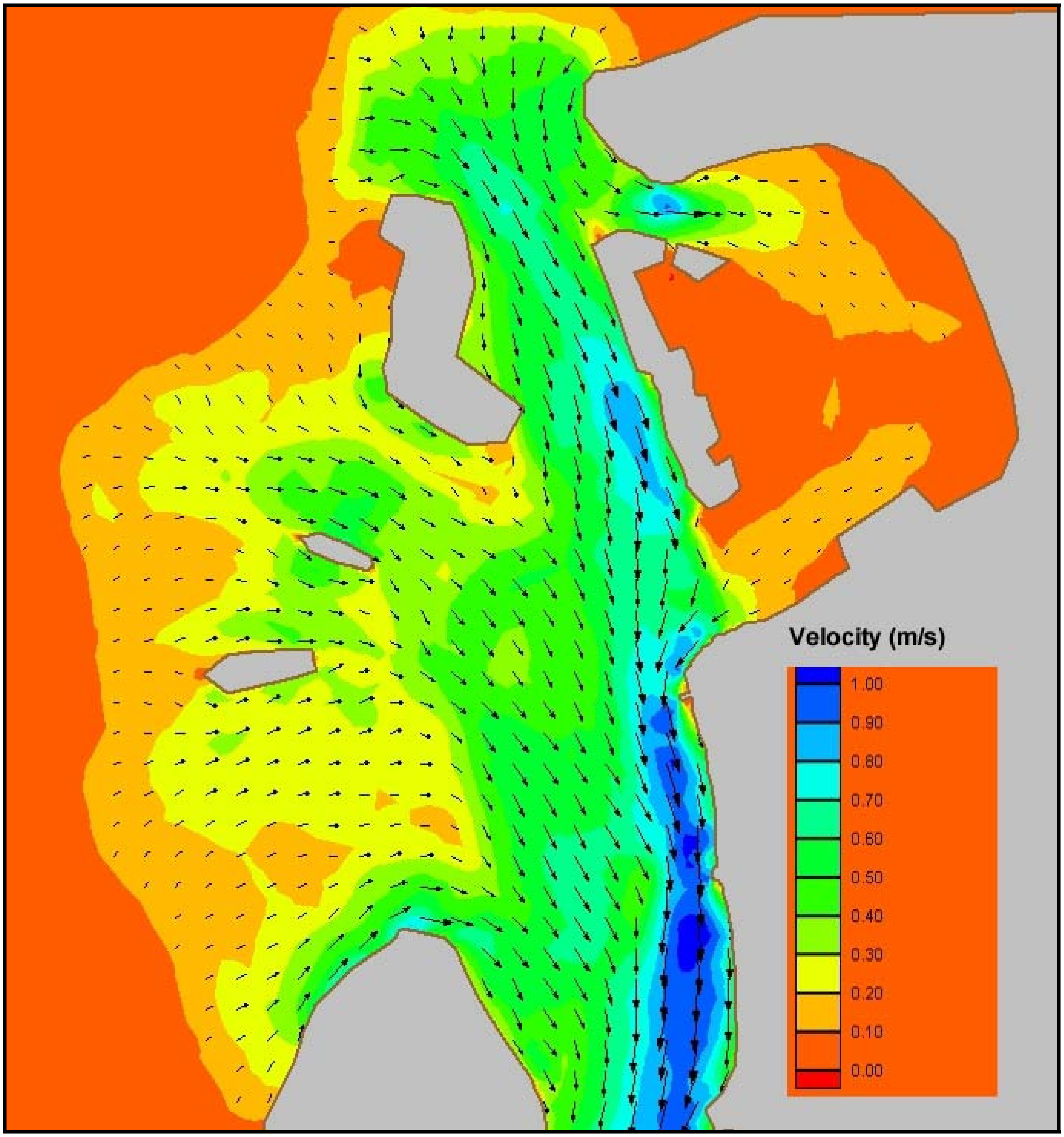

Figure 5-4 Simulated Peak Ebb Flow Patterns within Study Area

Key points of interest associated with these two figures include:

- During the flood tide, flow enters Swan Bay via the southern entrance and exits via the northern entrance;
- During the ebb tide, flow enters via the northern entrance and exits via the southern entrance;
- Both the flood and ebb tides show that the navigation channel past Marks Point still carries the largest portion of the flow entering and leaving the lake during average tidal conditions

(50%). However, there are also significant flow concentrations through the Airforce Channel and to the north of Coon Island. Modelling indicates that approximately 10% of the flow into the lake passes through Swan Bay at present;

- The path of ebb tide flows is deflected into Swan Bay to a greater extent than the flood flows;
- Strong ebb tide currents are present adjacent to Naru Point, which is consistent with field observations, whereas the flood flows do not encroach as closely upon Naru Point;
- Very strong flows occur adjacent to Pelican Flat and the Western edge of the spoil island within Swan Bay. These locations are known to be significant erosion areas; and
- The northern entrance to Swan Bay is subject to strong flows.

Overall, the hydraulics predicted by the model are consistent with field observations, analysis of data and information from the background literature.

5.3.2 Sediment Transport

The peak flood and peak ebb sediment transport patterns are shown on Figure 5-5 and Figure 5-6 respectively. The magnitude of sediment transport can be determined from the colour grading and is also indicated by the length of the vectors on these figures. The direction of transport can be determined from the orientation of the vectors. Note that the ebb tide vectors are plotted at a larger scale than the flood tide vectors for clarity.

Points of interest from these two figures include the following:

- The simulated upstream sediment transport rates during the flood tide are significantly higher than the simulated ebb tide sediment transport rates. This is consistent with a net upstream transport of sediment throughout the system which is reflected by the continual growth of the tidal dropover into the lake;
- Ebb tide transport patterns are affected to a much greater extent by the southern entrance to Swan Bay than the flood tide transport patterns;
- The flood tide patterns show a relative reduction in transport magnitude to the north-west of the southern entrance (compared to transport values in the channel to the north and south), this is commensurate with a location where accretion is occurring;
- The ebb tide patterns show transport along the northern edge of the ‘dog-leg’. This transport rate reduces with distance inside the entrance, meaning that there is an area of accretion at the point of the dog-leg during the ebb tide;
- Relatively large transport rates at Naru Point and along the south western foreshore of the spoil island in Swan Bay during the ebb tide represent areas of erosion; and
- The groyne immediately south of Naru Point plays a significant role in the orientation of sediment transport pathways in the southern entrance of Swan Bay, particularly during the Ebb tide.

Again, the sediment transport patterns simulated by the model are consistent with field observations and analysis undertaken elsewhere as part of this study. Accordingly, the model is considered suitable for assessment of the various management options being considered as part of this study.

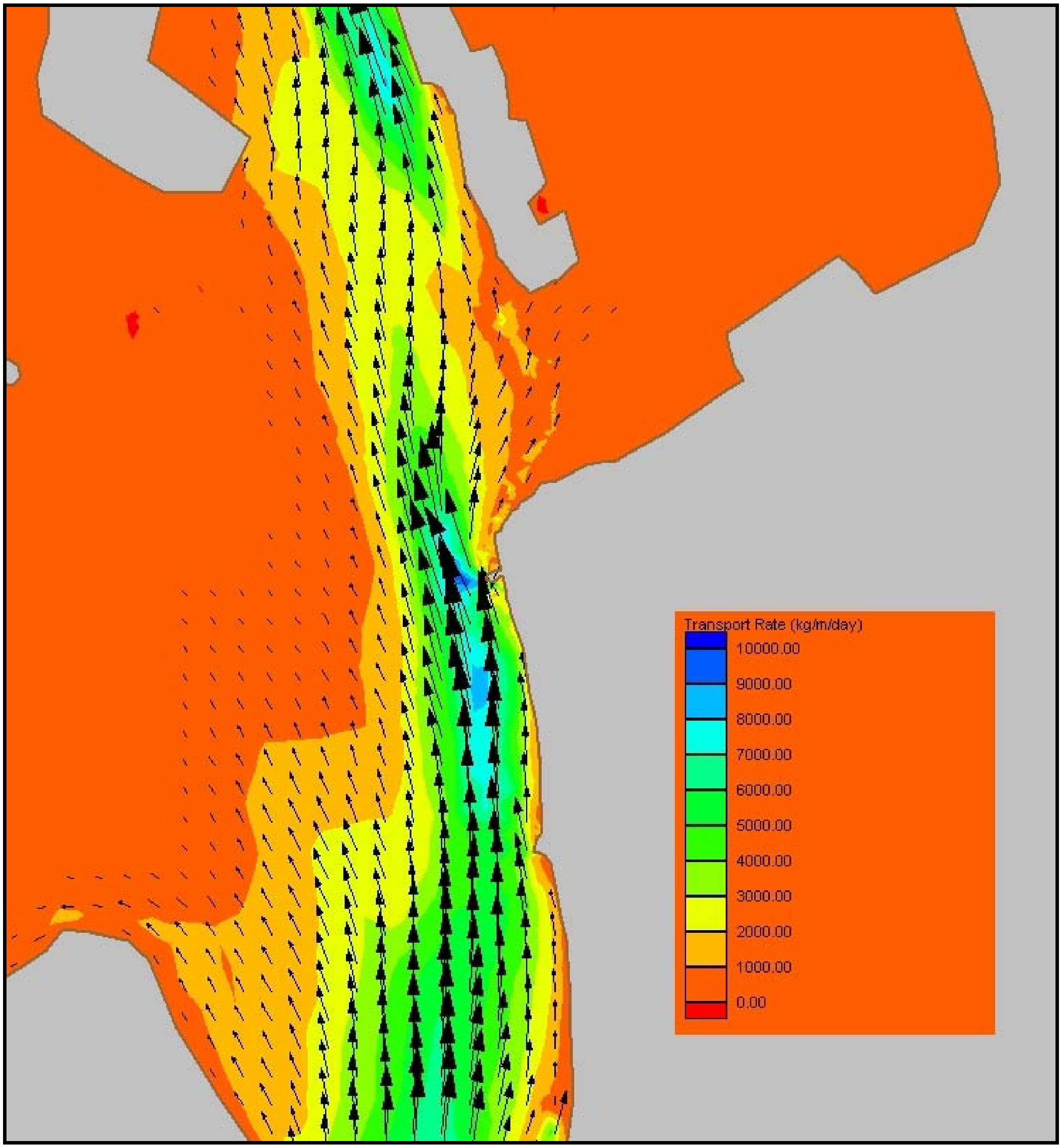

Figure 5-5 Peak Flood Sediment Transport Patterns

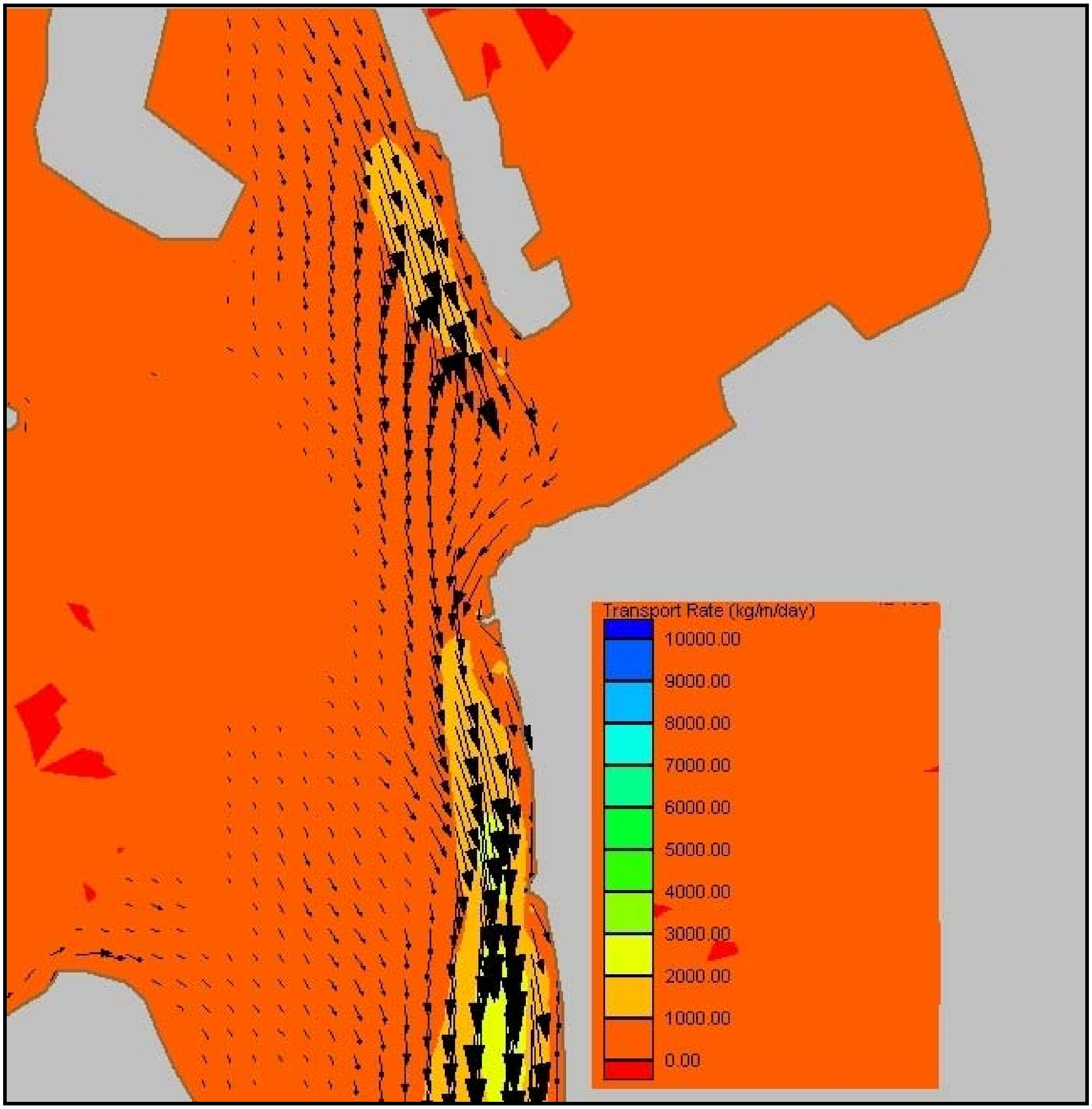

Figure 5-6 Peak Ebb Sediment Transport Patterns

(Ebb current vectors are exaggerated for emphasis.)