4 COMPUTER MODEL DEVELOPMENT

4.1 Scope and Objectives

This section of the report details the establishment, calibration and validation of a coastal hydrodynamic and morphodynamic numerical model capable of simulating tidal hydrodynamics, waves, sediment transport and geomorphology for the Port Stephens / Myall Lakes estuary.

The primary application model prepared for this study was to investigate and assess existing environmental conditions to provide further understanding of estuarine processes (e.g. sedimentary, flushing, tidal and freshwater flow processes). The numerical model has also been used to validate key issues and concerns for the Lower Myall River and quantify changes that may result from implementation of potential management options.

4.2 Model Establishment

Development of the coastal hydrodynamic model requires a considerable amount of data to adequately represent hydrodynamic, advection / dispersion, waves and sediment transport processes occurring within the study area. The numerical model therefore requires the following datasets to simulate and / or calibrate hydrodynamics:

- **Bathymetric survey data** – used to describe the topography of the bed and coastline over the domain of a numerical model incorporating the full tidal extents of the estuary;
- **Wave, Water level and flow data** – used to calibrate and / or validate model predictions. Wave, Water level and flow data are most commonly used to ensure the model adequately represents the tidal prism of a waterway; and

For the present study, the two-dimensional hydrodynamic model (TUFLOW-FV), coastal wave model (SWAN) and sediment morphology model (TUFLOW-MORPH) were selected to satisfy the modelling scope and objectives (Figure 4-1). More detail on the selected models is provided in Appendix E.

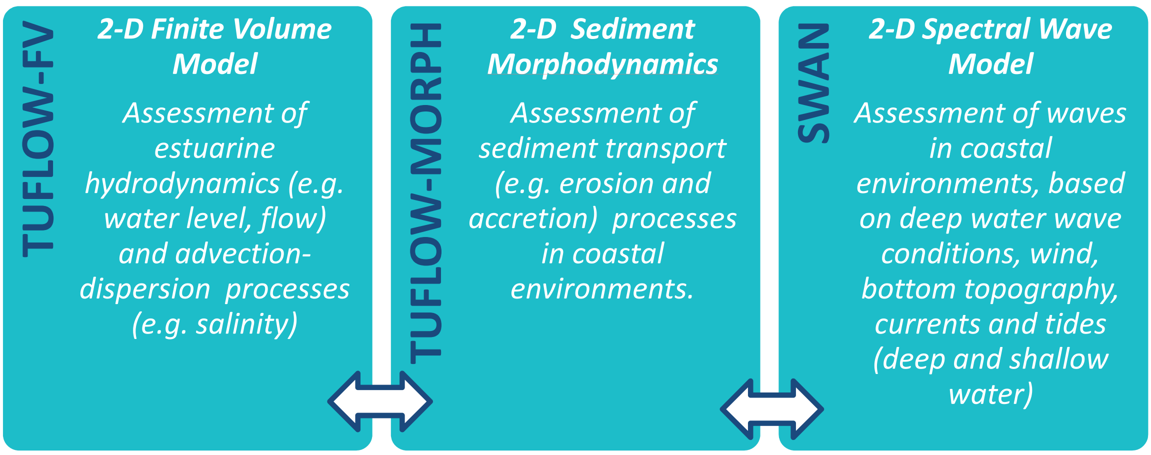

Figure 4-1 Numerical Models Adopted for the Investigations

For numerical modelling investigations, tidal flows occurring within the study area are predicted by the hydrodynamic model (TUFLOW-FV) with the effect of waves introduced from the wave model (SWAN). Sediment supply to the entrance may result from the combined effects of waves and tidal flows. As waves approach the coast, they refract, diffract, shoal (rear up) and break. These processes generate forces which act to:

- Drive longshore currents; and
- Set up the water level at the shoreline.

In order to properly model coastal sediment transport processes, it is important to provide the resulting wave forces (also known as wave radiation stresses) to the hydrodynamic model. The waves also have a direct effect in stirring sediment from the bed and thus making it more available for transport by the currents. For this reason the spatial wave field needs to be supplied to the sand transport model (TUFLOW-MORPH) as well.

Using the numerical models outlined above, the overall morphological modelling process, including the effects that waves and tidal flows have on sediment transport, follow the structure outlined in Figure 4-2. In all cases, the TUFLOW-FV hydrodynamic model is linked with the SWAN wave model, allowing the passage of wave stresses and the wave field to the hydrodynamic and sediment transport model, and bed elevations / current fields back to the wave model. This approach incorporates the important coastal processes occurring within the Estuary that influence its environmental condition and introduce changes to bathymetry over time.

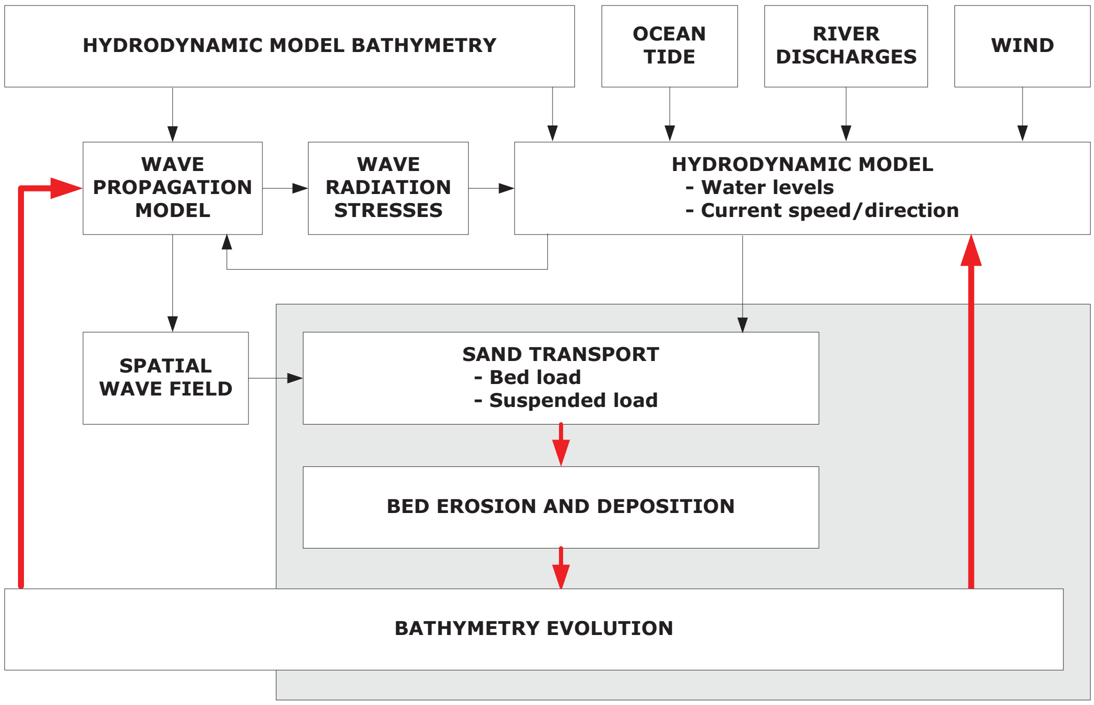

Figure 4-2 Combined Hydrodynamic, Wave and Morphological Modelling

The TUFLOW-FV mesh, which indicates the hydrodynamic and morphological model extents and resolution, is shown on Figure 4-3. The extents of the SWAN wave model, including a 'regional' model to bring in waves from deep water and a smaller 'nested' model providing more detail within Port Stephens, is shown on Figure 4-4. More details are provided in Appendix E.

Title:

Model Mesh for Port Stephens and the Lower Myall River

Figure: 4-3

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Approx. Scale

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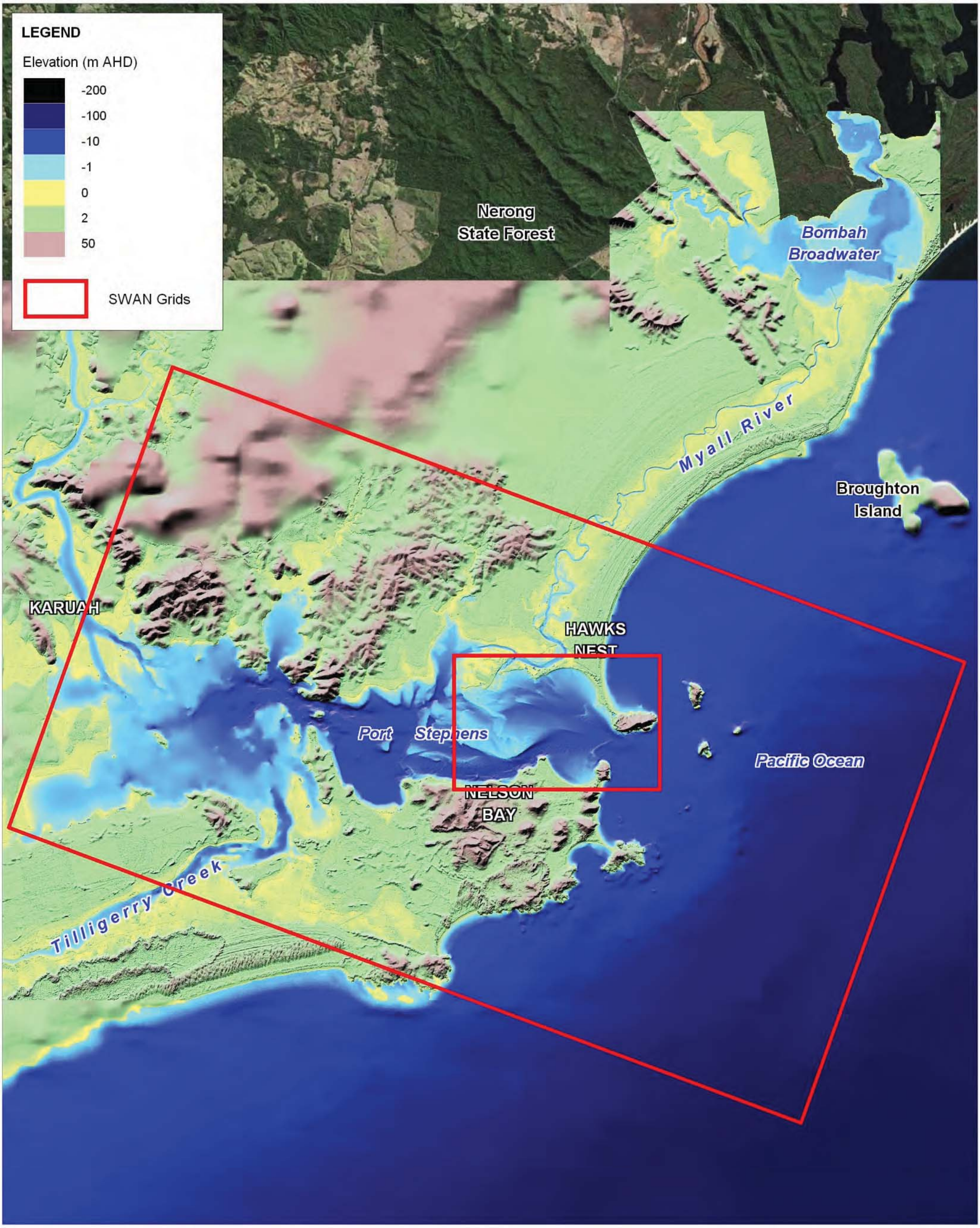

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SWAN Model Grid extents

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4.3 Calibrating and Evaluating the Model

4.3.1 Availability of data

A number of tidal data collection campaigns have been undertaken by various government agencies for the Lower Myall region over the past 30 years or so. Our review of data collection during the late 1970's, revealed incomplete or missing datasets. These were subsequently not used. The tidal data collection undertaken by the DECCW and MHL in September 2009 represents the most up-to-date and relevant dataset for the study area.

4.3.2 Gauging locations

The data collection exercise is discussed in Section 3.2.1. The data collection locations for ADCP water levels and salinities are shown in Figure 3-2.

4.3.3 Approach to model calibration

The approach to model validation included preparing the model geometry to fit the hydrosurvey undertaken in 2009, definition of boundary conditions and adjustment of model parameters to represent the measured estuarine hydrodynamics (i.e. tidal range, current velocity / flow, water level) from 21st to 24th September, 2009.

The wave model was executed using the significant wave height, wave period and wave direction measured at Sydney over the calibration period. The outputs from the regional wave model were then fed into the nested wave model to acquire output wave forces, heights, directions and periods within the study area.

The nested wave model was run interactively with the hydrodynamic model, with the wave outputs passed through the hydrodynamic model as the simulation progressed.

The coupled hydrodynamic and wave model was run for the period 1 August to 30 September so that the model was 'warmed up' prior to the period of detailed measurement from 21st to 24th September. This means that processes such as the establishment of water level gradients through tidal pumping were appropriately represented over the model period.

4.3.4 Results of Hydrodynamic Calibration

Results including water levels and flows were extracted from the numerical model and compared to data collected during the tidal gauging. Water levels measured by MHL from permanent recorders at Mallabula and Bombah Point were obtained for September 2009 and used as an additional data source for informing calibration of model hydrodynamics.

During calibration, model parameters (i.e. bed roughness or Manning's *n* values were adjusted to match the propagation of tides, observed tidal gradients and flood / ebb flow discharges at measured locations.

The Manning's 'n' roughness values which were used in the final calibration are presented inTable 4-1.

Table 4-1 Bed Roughness Parameters Adopted

Bathymetric Feature	Manning's n Roughness
Embayment of Port Stephens	0.02
Elevated wetlands / mangroves areas	0.05
Mud flats / intertidal areas	0.03

4.3.4.1 Flow

The calibrated hydrodynamic model represents tidal conditions during the gauging period accurately with peak flood and ebb tide flow matching measured data closely at the three gauging sites. The phasing of the flow discharge curve (i.e. the rate of incline and recession between high and low water slack) is also simulated by the hydrodynamic model well as shown by Figure 4-5, Figure 4-6 and Figure 4-7.

The model results show that the relative distribution of flow into the Lower Myall River via the Northern Channel and Eastern Channel are close to those measured.

The quality of the model predictions provides a solid foundation for processes that are driven by the hydrodynamics such as mixing and morphology which are discussed further in Section 4.3.5 and Section 4.3.6.

When comparing the modelled results against the measured data there are some factors about measurement of the data that need to be considered. One factor is the transect location of the measured ADCP data, as seen in Figure 4-8, where the peak ebb and peak flood discharge plots for the eastern (i.e. 'shortcut') channel do not cover the same channel extents (i.e. different bed depths and shape). This will impact upon the measured flow volumes through these cross sections, and some discrepancy between modelled and measured values must be expected.

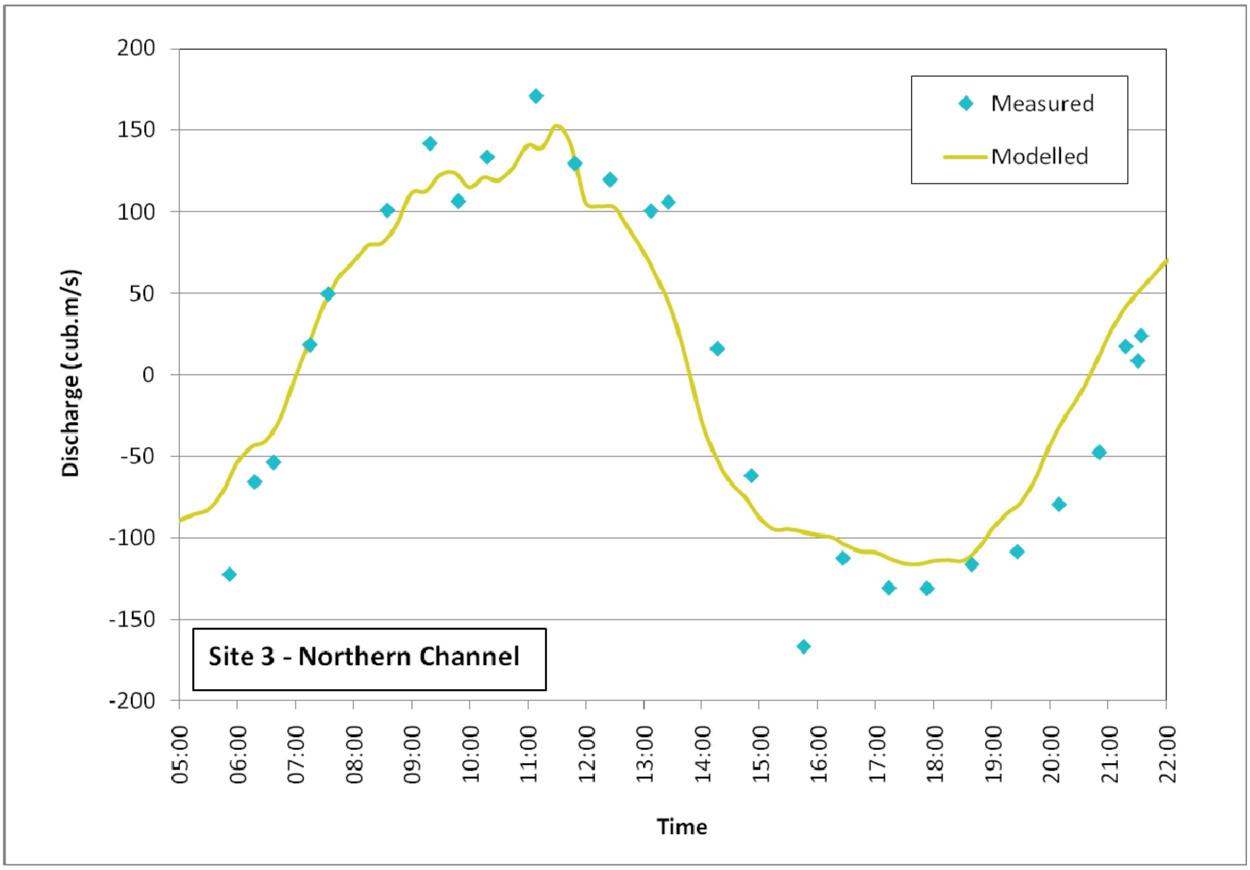


Figure 4-5 Flow Results for Northern Channel

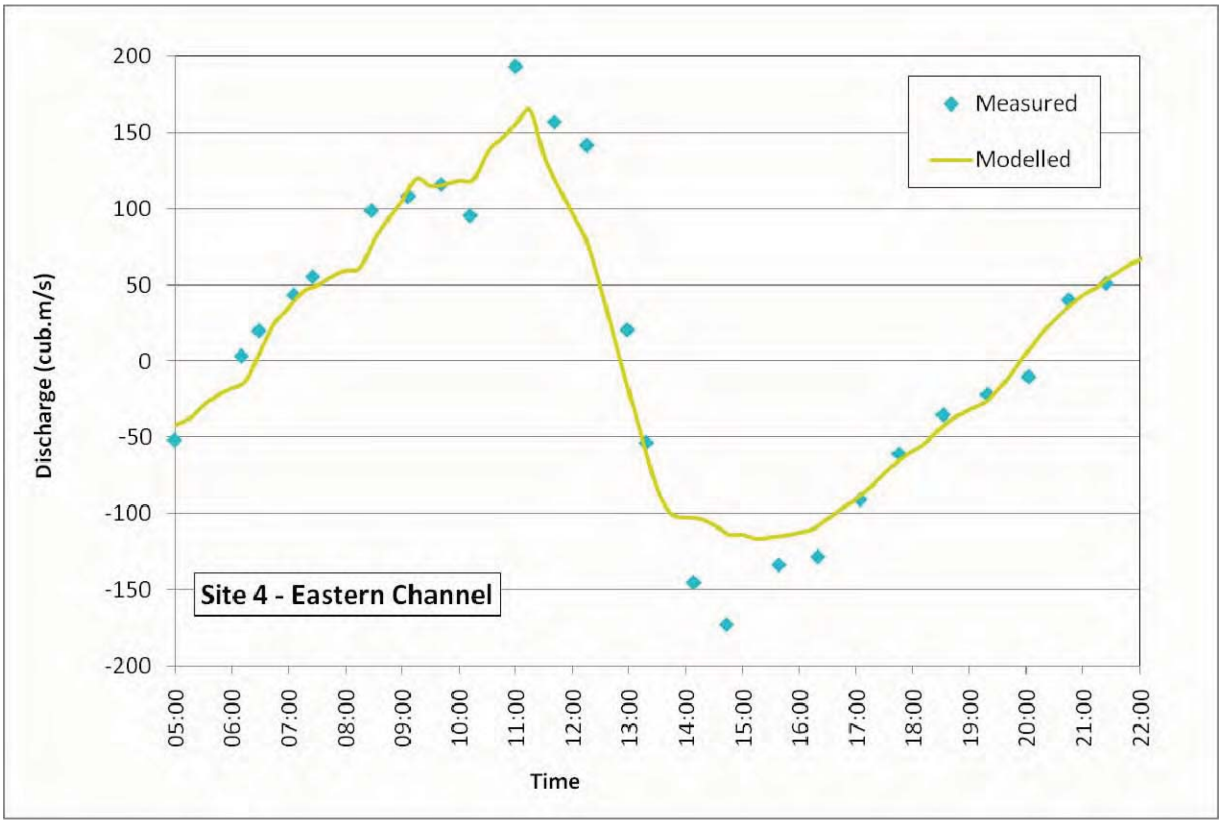


Figure 4-6 Flow Results for the Eastern Channel

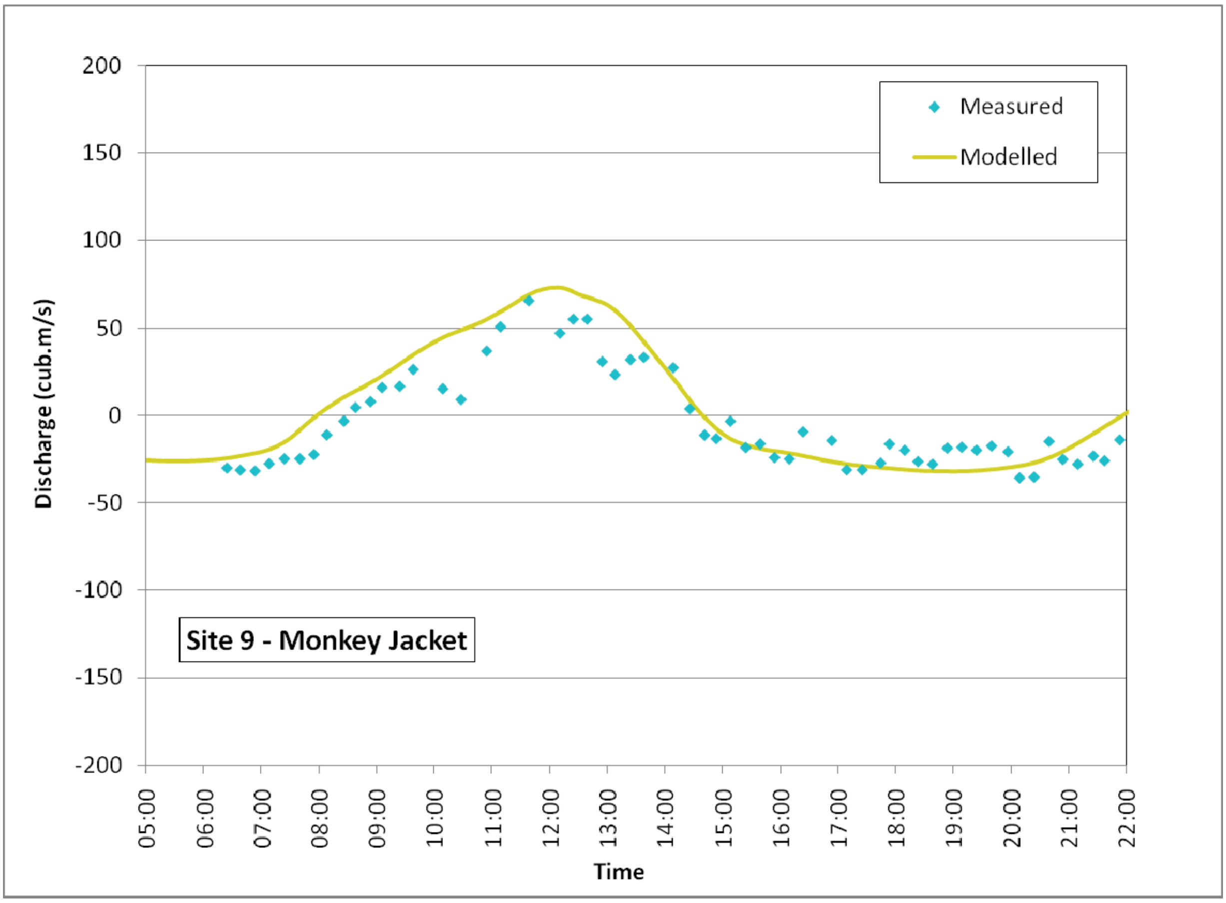


Figure 4-7 Flow Results for Monkey Jacket

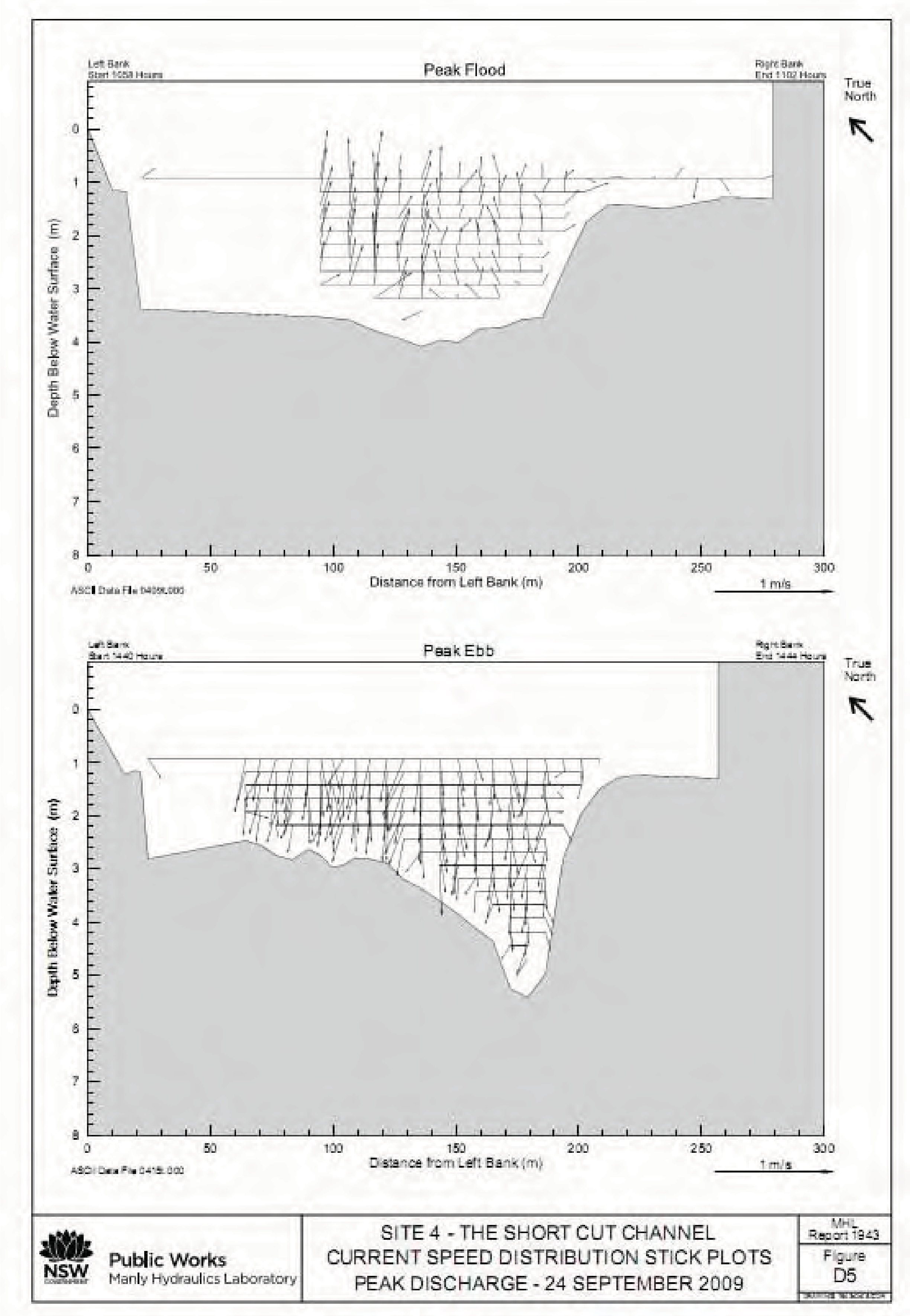


Figure 4-8 Eastern Channel Flow Vectors (MHL 2009)

4.3.4.2 *Water level*

Results of the water level calibration within the immediate vicinity of the study area and at other locations within the estuary are presented in Figure 4-9 to Figure 4-14. Modelled water levels compare well with observed water level data collected during the calibration period particularly around the study area (i.e. Site 3 and Site 4). The results show a good match with respect to the timing and magnitude of peak water levels during the flood and ebb tides at all gauging locations.

In the Myall Lakes at Bombah Point the model does not predict the decline in water levels as seen by the measured data (Figure 4-14). Reasons may be rainfall and evaporation or groundwater dynamics. However, as the site is well removed from the main area of interest, and the modelled results downstream are excellent, these discrepancies are acceptable.

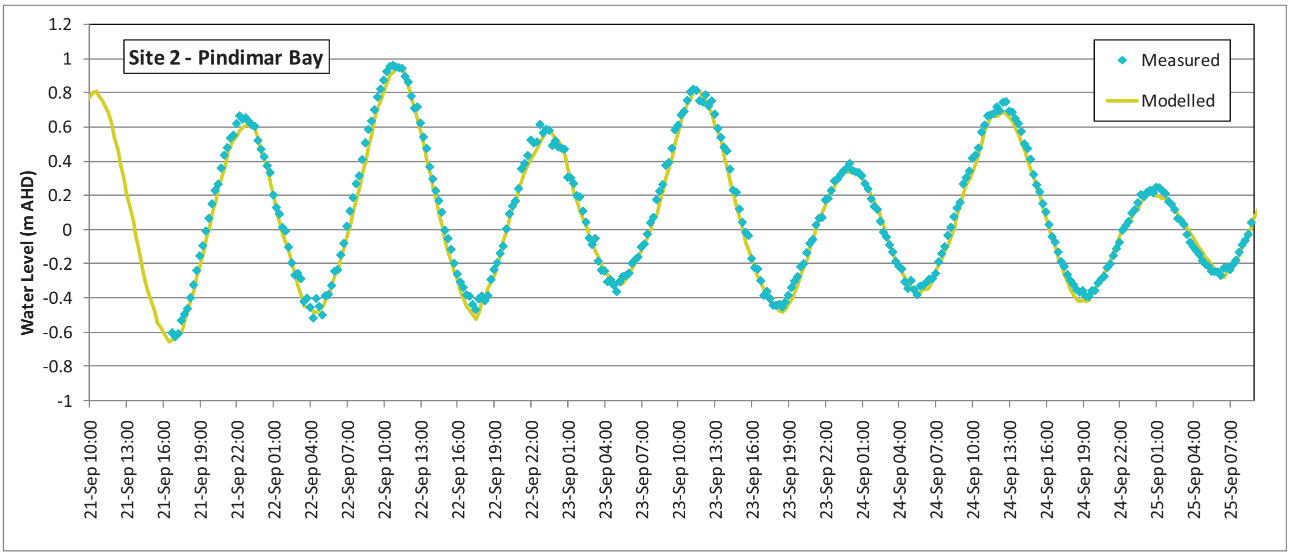


Figure 4-9 Water Level Results at Pindimar Bay

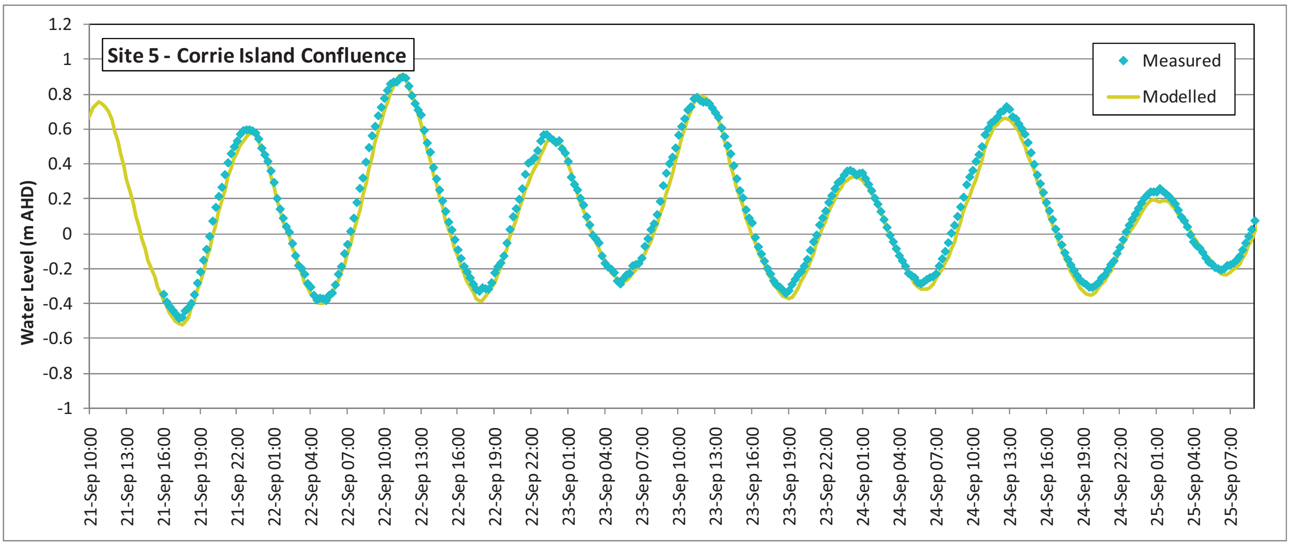


Figure 4-10 Water Level Results at the Confluence to Corrie Island

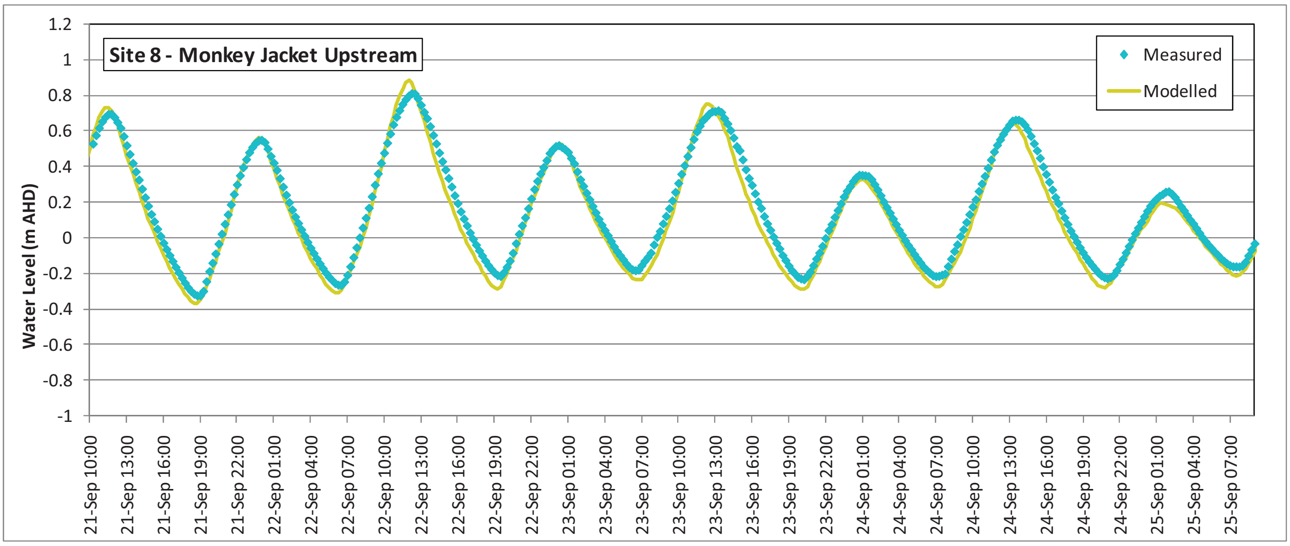


Figure 4-11 Water Level Results Upstream of Monkey Jacket

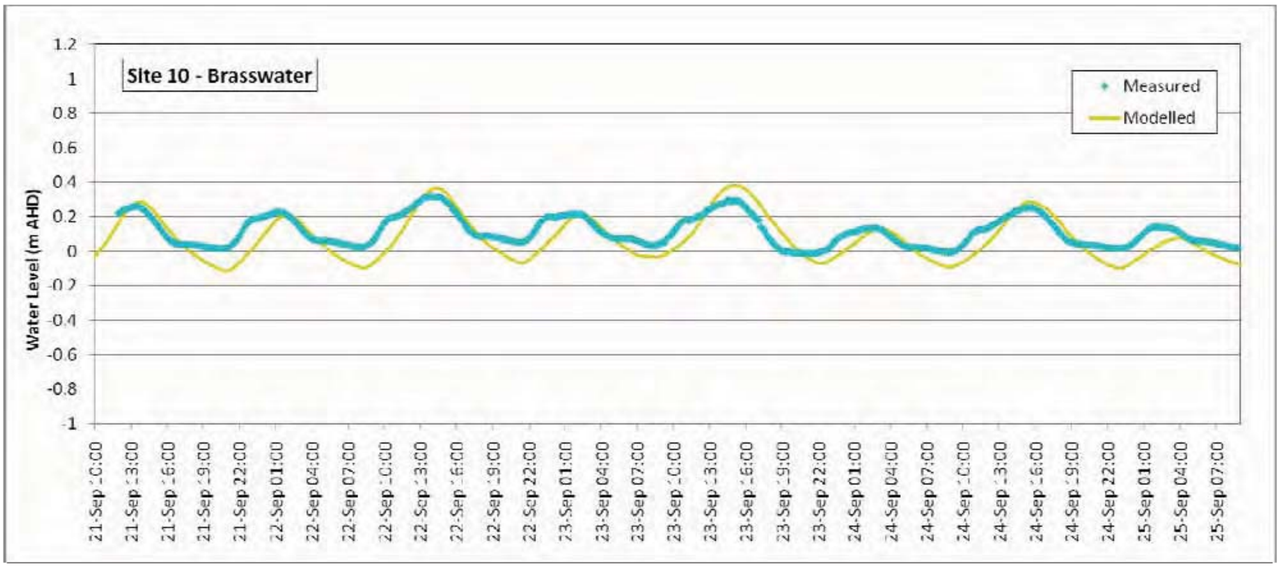


Figure 4-12 Water level Results at Brasswater

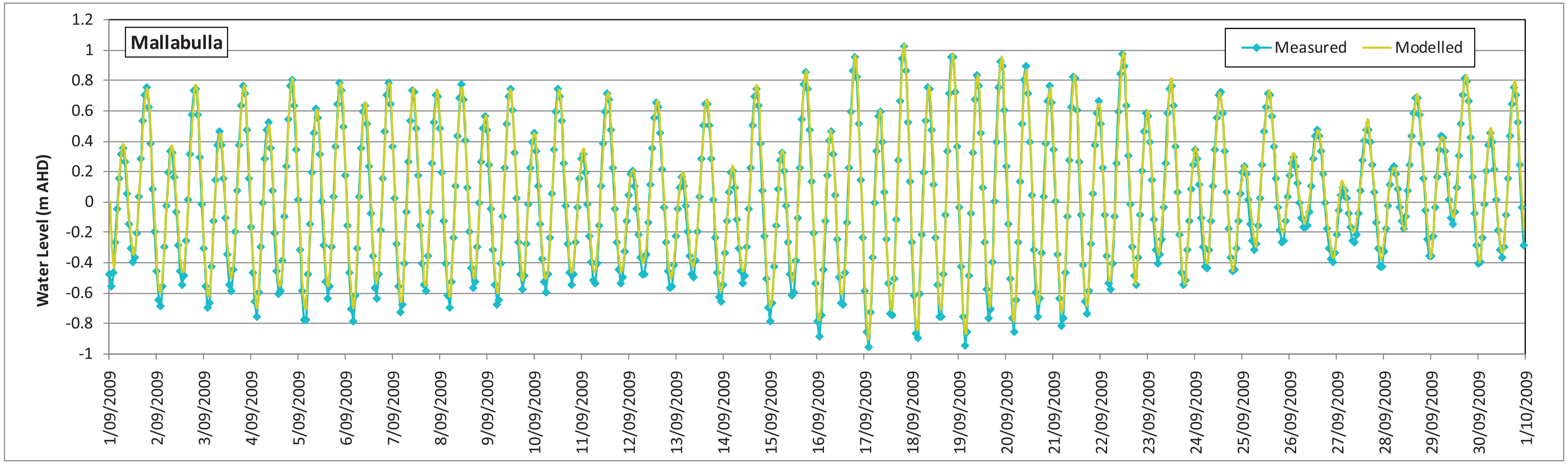


Figure 4-13 Water Level Results at Mallabulla, Port Stephens

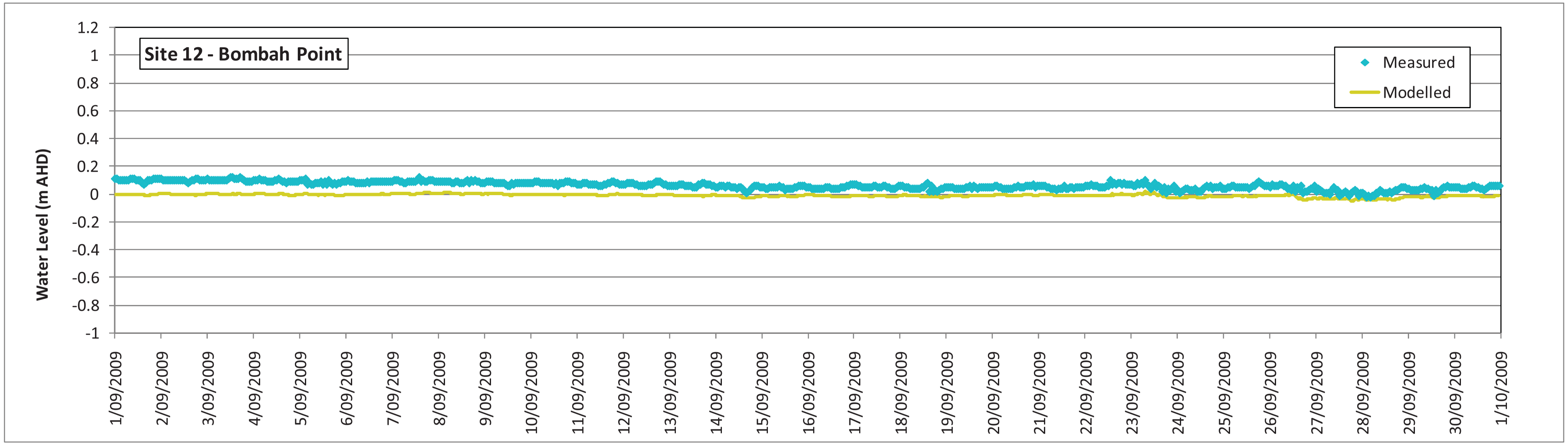


Figure 4-14 Water Level Results at Bombah Point, Myall Lakes

4.3.5 Results of Mixing and Transport (Salinity) Calibration

The primary objective of the salinity calibration was to match modelled salinity data to measured salinity data at specific locations around the study site. The field sites can be seen in Figure 3-2.

A good correlation between the modelled and measured data ensures that adequate representation of processes such as advection; dispersion and mixing within the model domain are attained.

Influences on salinity within and along the Lower Myall River and Port Stephens are driven by a number of sources and sinks including river inflows, catchment runoff, groundwater, tidal flows, rainfall and evaporation. The model developed for this project includes tidal flows, direct rainfall and evaporation (i.e. rainfall and evaporation that exchanges directly at the water surface), but does not include river inflows, groundwater or catchment runoff.

There is not enough information presently available to account for groundwater inflows. Over the calibration period, it has been assumed that catchment runoff to the Lakes was not significant enough to drive significant flow from the Myall Lakes through the Lower Myall River.

The immediate study area is dominated by tidal flows and therefore, the exclusion of both groundwater and catchment inflows during the calibration period was not considered necessary.

4.3.5.1 Approach to validation

The model results were compared to measured salinity. The measurements are from September 2009 (MHL 2009).

The main boundary condition impacting upon salinity within Port Stephens is the ocean boundary. The ocean salinity was referenced from ARGO data (http://www.argo.ucsd.edu/index.html). These data are obtained from a dispersed array of thousands of floats that traverse the ocean measuring salinity and temperature. The data indicate that salinities offshore from Port Stephens during September 2009 ranged from 34.5 – 35.5 ppt, varying with depth. As a result the depth averaged salinity, assigned to the model domain ocean boundary was set to a salinity of 35 ppt.

Salinity was calibrated to measured values from 21st to 25th of September. The hydrodynamics at the start of this period were obtained from a restart or 'hot-start' from the hydrodynamic calibration. The initial salinity values were obtained by utilising a Geographic Information System to interpolate salinities across the model domain from those discrete locations where measurements were available from the 21st September. The sparse nature of available measurements means that the model simulation can be sensitive to the way values are interpolated between sites.

4.3.5.2 Results

At all sites the modelled salinities were typically within 1-2 ppt of the measured salinities and the trend of increasing salinity upstream along the Myall River was well correlated.

At Pindimar Bay the modelled salinities were found to correlate well with measured data (Figure 4-15), although the modelled data did begin to slightly overestimate (<1ppt) salinity towards the end of the field data record.

At the Corrie Island confluence modelled results underestimated salinity by approximately 1-1.5 ppt, with measured salinities increasing from ~34 ppt to 35.5 ppt and modelled salinities increasing from ~33 – 34 ppt (Figure 4-16). A closer examination of modelled salinities at this site identified that, at this locations, two streams of flow from the eastern and northern channels converge. Therefore, the degree of mixing of the two streams will strongly affect the overall salinity at this location. Furthermore, the absolute salinity here is strongly influenced by the salinity applied at the ocean boundary and the relatively sparse nature of the ARGO data means that errors may be introduced at that boundary.

Overall, the trends at the confluence are good, and the calibration further upstream is not unduly affected.

At Monkey Jacket the model initially overestimated salinity by approximately 1 ppt, however the diurnal fluctuations correlated quite well (Figure 4-17). Towards the end of the field data period, modelled and measured data correlate well with differences of <1 ppt.

At Brasswater (18km upstream from the study region), the observed trend of increasing salinity correlates well to the modelled data, especially given the large increase of ~15 ppt over a short period of time (3 days). The model does not, however fully replicate the scale of diurnal fluctuations in salinity (Figure 4-18).

At Bombah Point (Myall Lakes) the modelled data overestimates salinity by 1-2 ppt for the majority of the model run (Figure 4-19). This may be due to the lack of freshwater inflows or groundwater in the model. This site is a long way from the study site and not of primary concern. However, the processes discussed above should be examined further if the model were required to provide reliable salinity predictions in Myall Lakes..

The salinity calibration is very good. On the basis of these results, we can assume that the advection and dispersion processes that mix different water quality constituents through the system are well represented. This means the model is suitable for undertaking assessments such as flushing time calculations, which are described later.

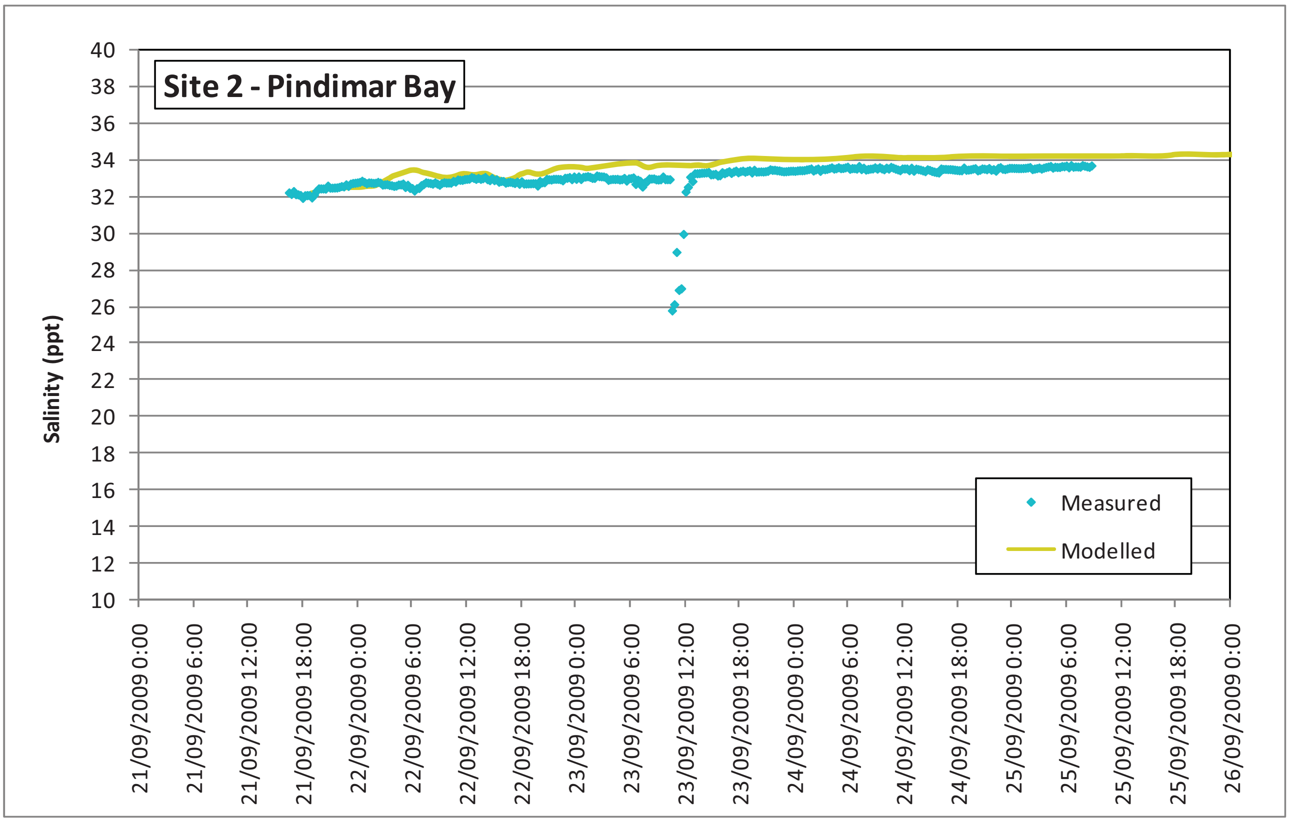


Figure 4-15 Salinity Results for Pindimar Bay

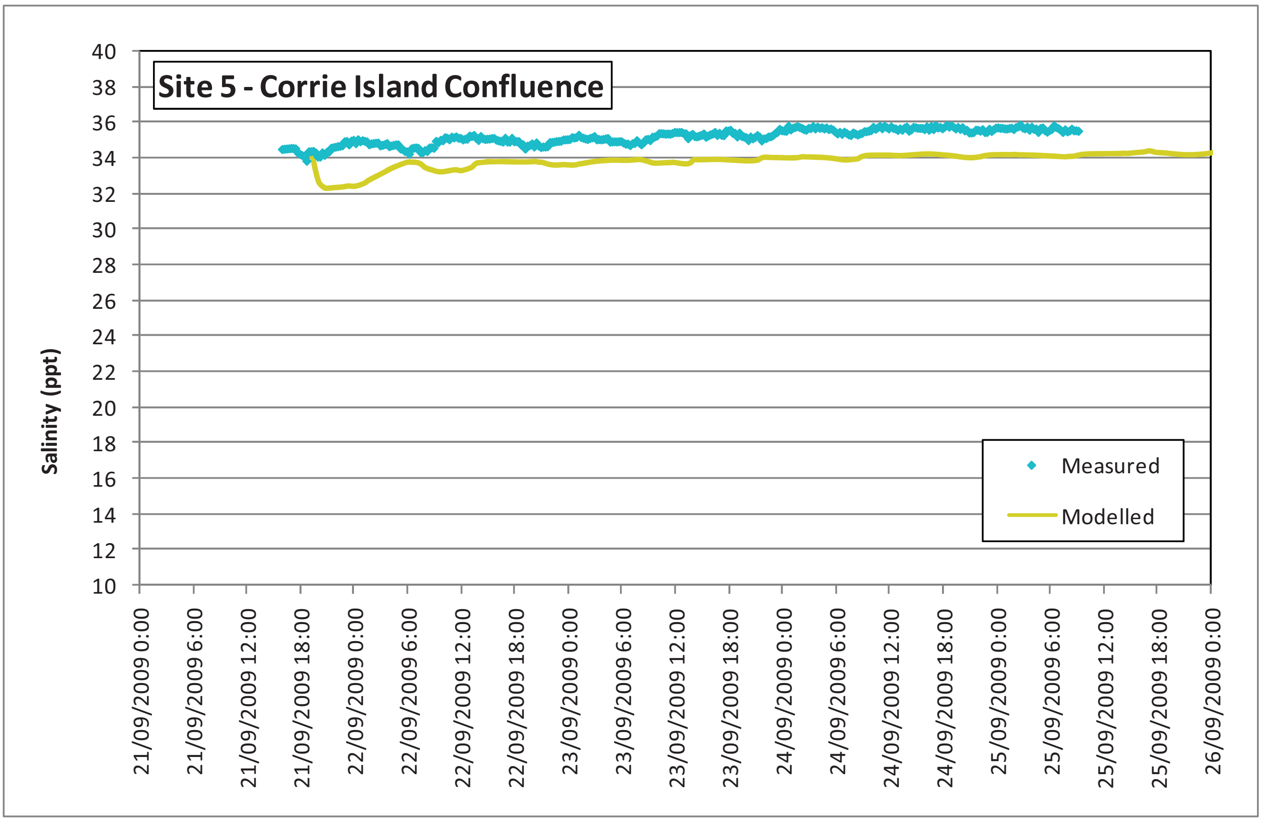


Figure 4-16 Salinity Results for Corrie Island Confluence

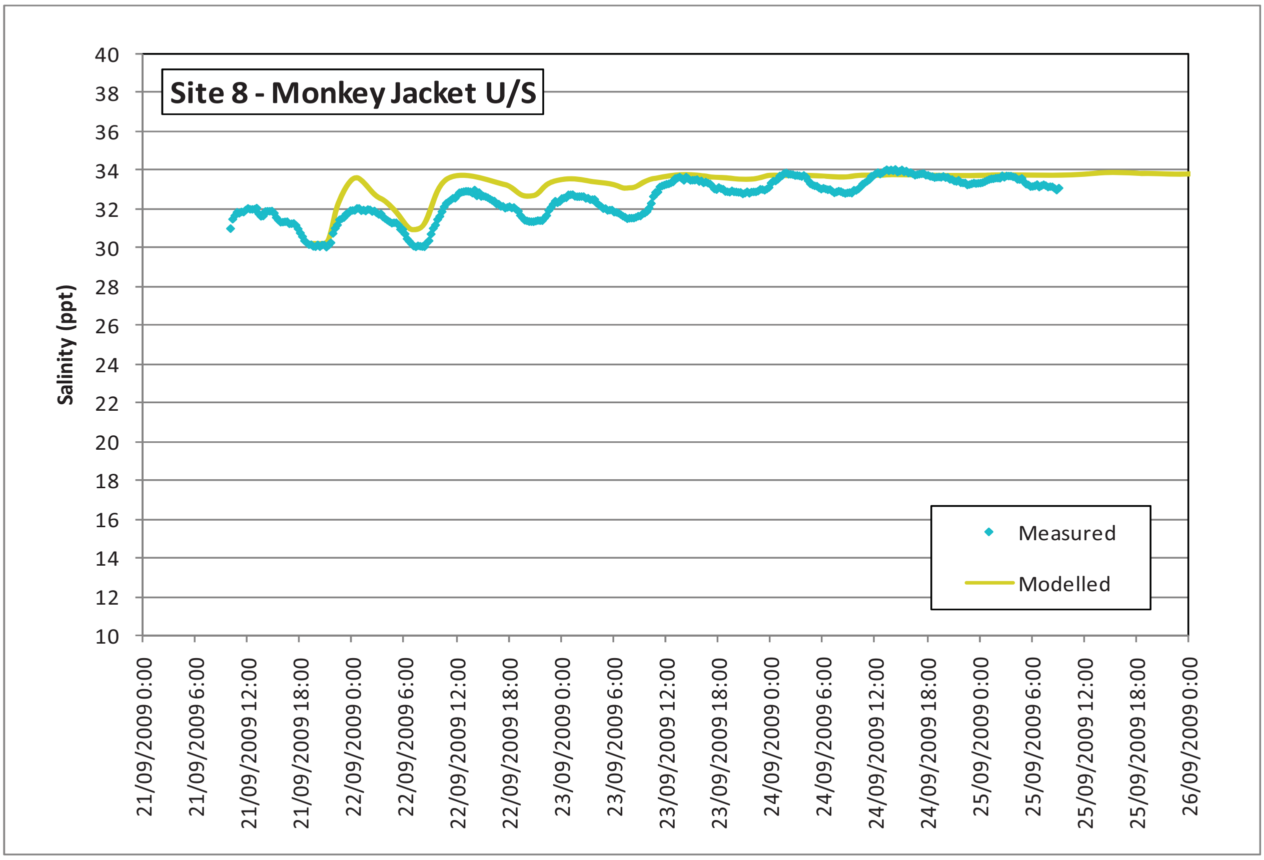


Figure 4-17 Salinity Results from Monkey Jacket

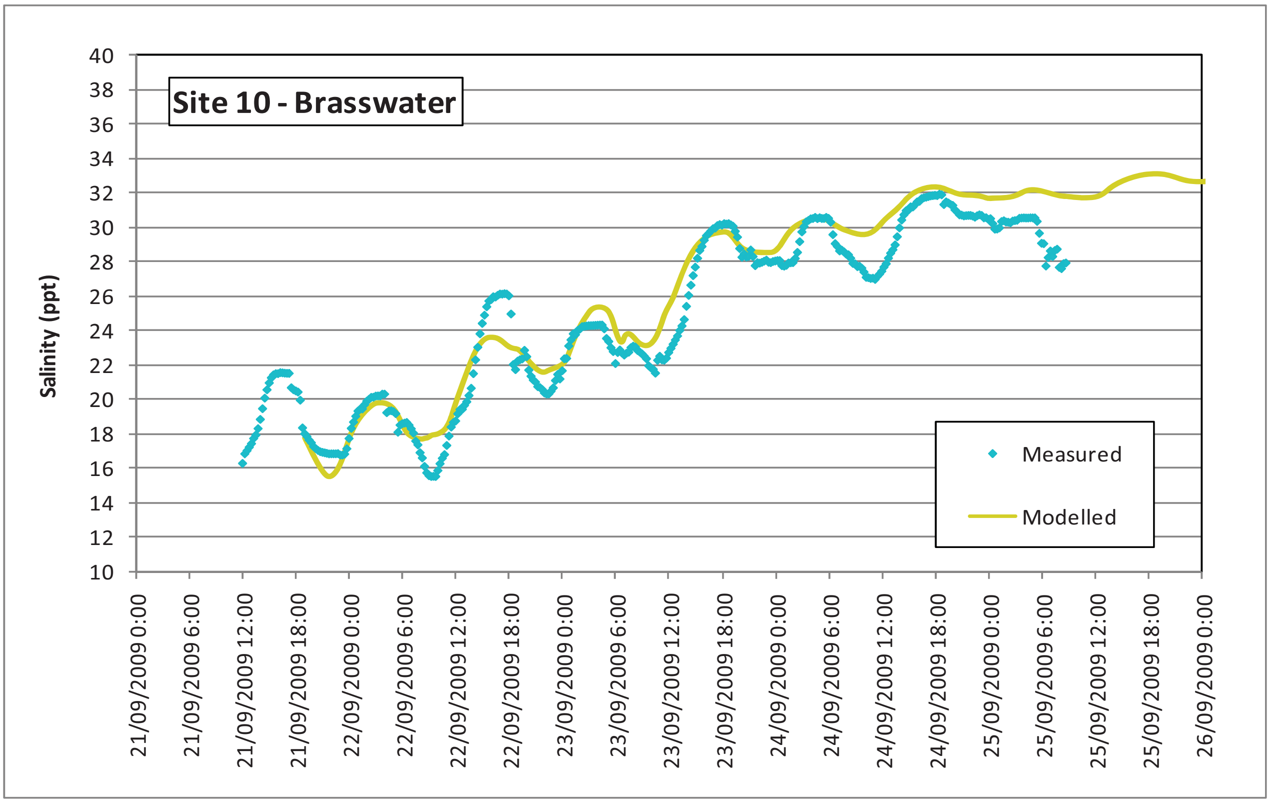


Figure 4-18 Salinity Results from Brasswater

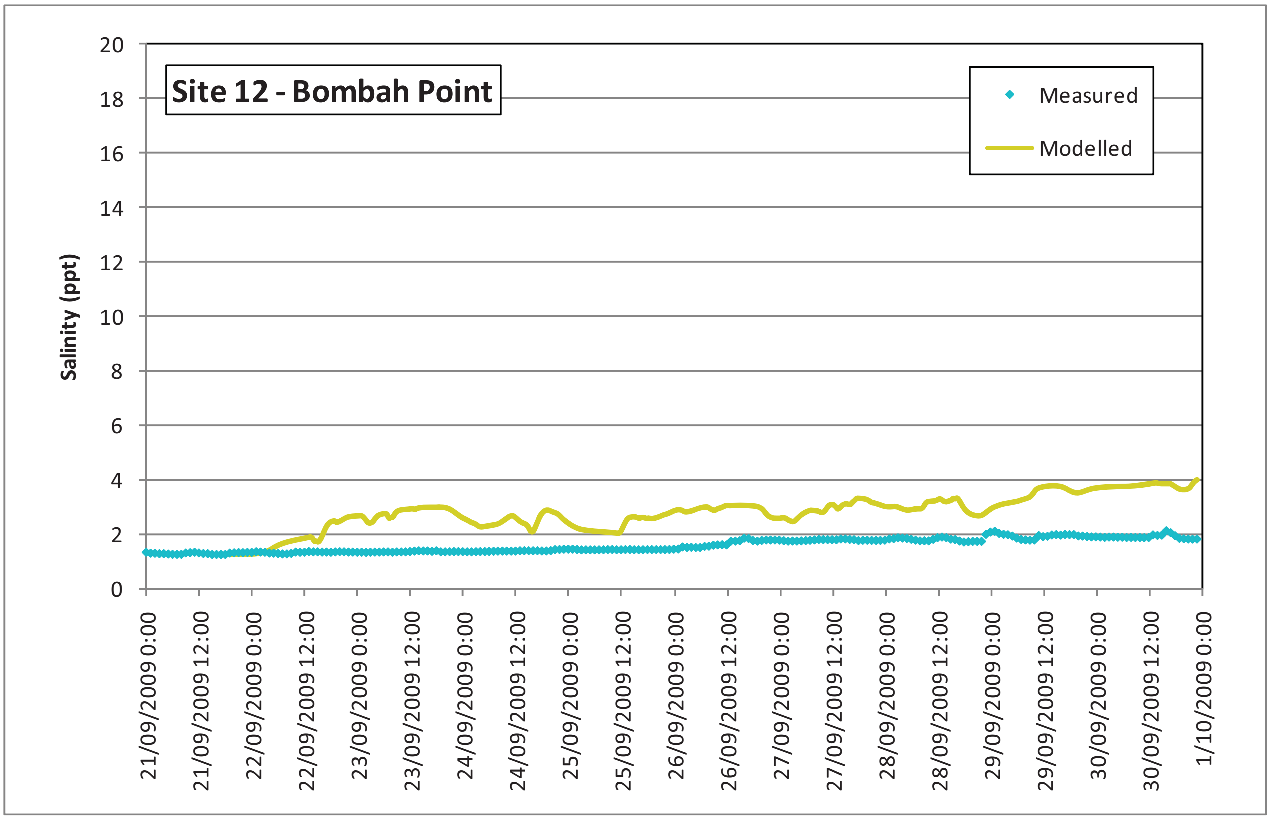


Figure 4-19 Salinity Results for Bombah Point

4.3.6 Performance of the Morphodynamic Model

4.3.6.1 Approach to Assessment

There is no quantitative morphological data available that would be suitable for calibration of the morphodynamic model.

Results from morphological models need to be approached with caution. The issue arises from a general inability of any available sediment transport algorithm to predict transport rates accurately within all possible transport conditions. It is generally considered reasonable if an algorithm predicts rates within 50 – 200% of values measured in the laboratory and field (van Rijn, (1993), Soulsby (1997)). Furthermore, the adjustment of bed elevations, and feedback of that process into the hydrodynamics of the model means that any diversion from the actual transport that is occurring can be amplified over time.

One other aspect of the morphological calculations that requires consideration is the morphological model does not predict swash zone sediment dynamics well. There presently exist no reliable methods for modelling swash related sediment transport that are also tractable for use in a numerical hydrodynamic model. Recent work by Jiang *et al* (2010) concludes that swash related transport at Jimmy's Beach is a significant component of the overall longshore transport. It is likely that this is also the case at the western end of the Winda Woppa Spit, where sand is washed by swash action across into the Eastern Channel.

To assess performance of the model, we have run a month long simulation and examined the bed changes afterwards to see if the general morphological patterns are feasible.

The following characteristics were adjusted within the model to achieve qualitative general trends in morphology:

- Resolution of the bathymetric mesh was refined in areas which demonstrated active sediment transport e.g. Eastern Channel, steep banks of the Lower Myall River and Corrie Island;
- Model parameters, including the dry slumping angle, were adjusted to accommodate for the local geology and soils e.g. coffee rock on the eastern edge of Corrie Island is unlikely to actively erode even though the bed angle is quite steep.

4.3.6.2 Results

The short term patterns and processes in key morphological features, as identified at the end of the 30 day model simulation, include the following:

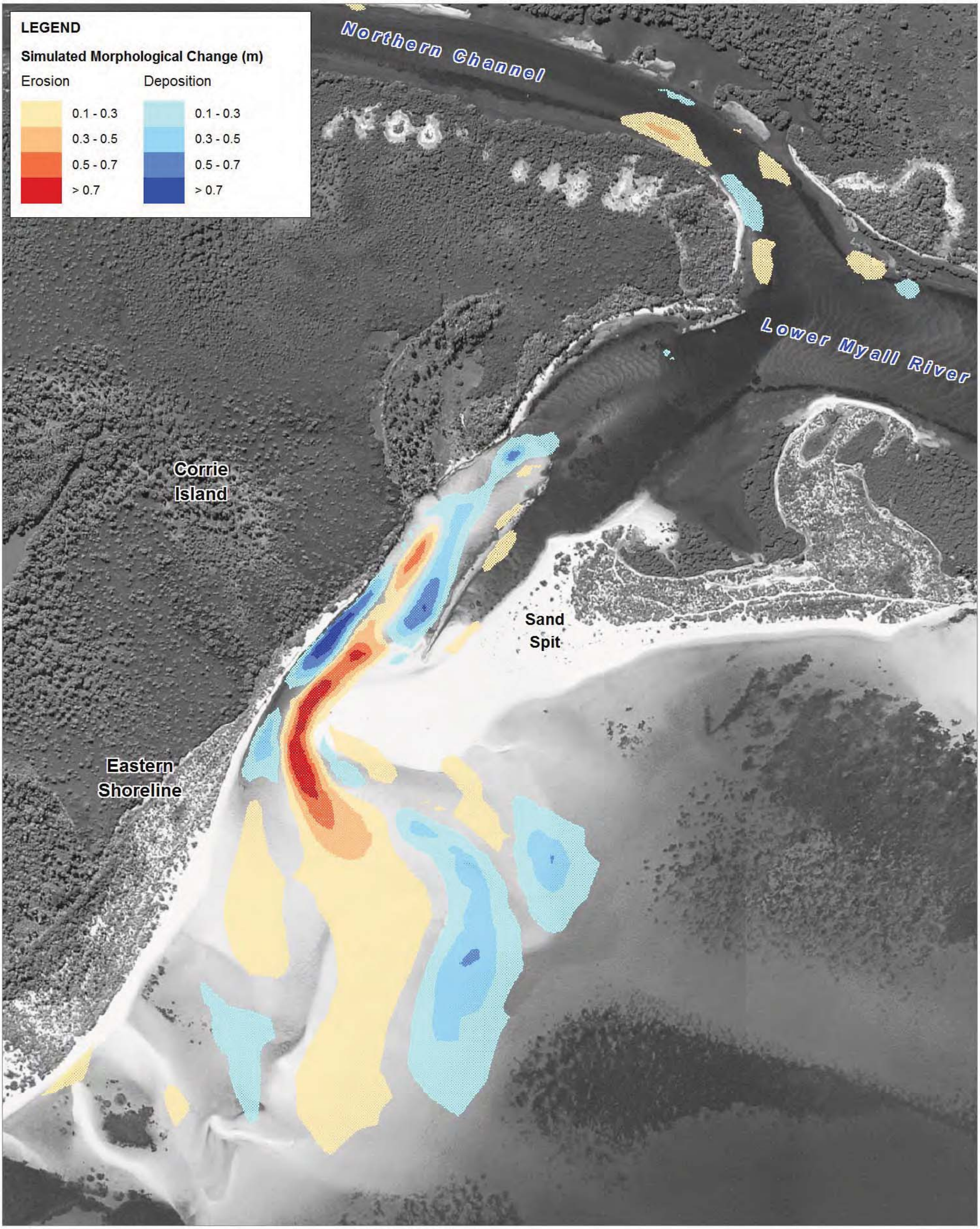
- The Eastern Channel experienced active sediment transport (Figure 4-20) especially around the ocean end of the channel. Erosion typically occurred in the higher velocity central areas of the channel (red areas) whilst corresponding deposition occurred at the channel fringes in the deeper and lower velocity areas (blue). The resulting patterns show some indication of the extension of the spit, to the south west, as seen in historical trends (Section 3.4). However, due to the limited representation of swash zone transport by the model, this is likely underestimated;
- The front edge of the flood tide delta and the dropover region within Port Stephens both exhibited active erosion and deposition within the model (not shown). These regions have been identified previously as active sediment transport areas, especially the flood tide delta which has shallow depths often experiencing breaking waves (refer section 2.1.2);
- The edges of the Lower Myall River experienced some minor sediment transport, typically on bends, which are characteristic patterns for riverine environments; and
- Minimal erosion and deposition occurred throughout the rest of the model domain.

Overall, the modelled patterns demonstrate some narrowing and deepening of the main Eastern Channel, with a slight tendency of migration towards the West. This is felt only slightly on Winda Woppa Spit, which is likely related to the previous point made regarding an inability to accurately represent swash zone dynamics. In reality, the degree to which infilling occurs at the tip of Winda Woppa would probably be more pronounced. The effects of wave action pushing the front edge of the marine delta against the edge of Corrie Island (i.e. to the south of Winda Woppa) are being represented, although the interaction of tides with wave action at this location make it difficult to separate this effect out from the transport caused by the tides.

The dynamics of the hard coffee rock edge at Corrie Island are also not perfectly represented. Firstly, the full extent of the coffee rock is not known. Secondly, the model presently considers this whole edge to be sandy, and the steep bathymetry results in slopes that the model considers unstable.

Modelled slumping in this area causes a simulated deposit of sand and the degree to which the channel would have otherwise migrated westwards is likely underestimated.

Aside from these limitations, the general trends in morphological patterns and processes within the model results are reasonable and form a useful basis for careful consideration of different management options.



Title: **Simulated Morphological Changes After One Month**

Figure: 4-20

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