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TE RAUHĪTANGA TAIAO

Mahurangi Estuary Numerical Modelling

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This report is part of a series of reports that were commissioned during the period 1993-1999 that were used to support the establishment of the Mahurangi Action Plan. They are being made available following a review of technical information.

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Prepared for
Auckland Regional Council

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Contents

1 Executive Summary

1. ARC Environment have recognised the Mahurangi Catchment as an important resource. To manage this resource in a sustainable manner will require careful consideration of the needs of the environment and the social and economic needs of those people with an interest in it.
2. This report describes the development and testing of computer models for the movement and circulation of water, the mixing processes and solute and sediment transport which will be used in the next phase to address specific management problems.
3. The numerical models 3DD and WGEN_3DD were used to determine water levels, waves and current flow within the estuary for a range of winds, tides and freshwater inflows.
4. The transport-dispersion model POL3DD used the outputs from these models to quantify the mixing of salinity, faecal coliform and suspended sediments.
5. The tidal-prism at the entrance to Mahurangi estuary during a spring tide is 50 million m^3. During a neap tide this figure is 32 million m^3. By comparison average freshwater inflows are of the order of 0.05 million m^3 per tide. During storms freshwater inflows are of the order of 1 million m^3 per tide.
6. The lower estuary (downstream of Scotts Landing) is vertically well mixed and dominated by the large tidal prism. The upper estuary (upstream of Hamilton Landing) typically has a layer of freshwater overlying saline water with little mixing between the two.
7. The primary process in determining the spatial distribution of suspended sediment concentrations within the estuary is physical dilution, due to horizontal and vertical mixing. Subsequent resuspension and settling of sediments have a secondary role.
8. For both a range of freshwater inflows and catchment-derived sediment loads the models agree well with field data. This suggests that the complex physical processes occurring within the estuary have been successfully understood and modelled.
9. The models are now calibrated and can be used as predictive tools to determine the fate of catchment-derived sediments within the estuary and assist with assessing the effects of contaminant discharges on the estuary including faecal coliform and nitrogen.

2 Introduction

The Auckland Regional Council have recognised the Mahurangi Catchment as an important resource (Harris 1993). To allow scientifically based management options to be formulated the ARC asked NIWA to conduct a series of studies in the Mahurangi Estuary and its catchment. Discussions held between NIWA and the ARC in late 1992 defined three areas of work for the study. These were:

1. Proposed development scenarios
   - ARC to formulate potential development options
2. Forecasting Catchment Loads
   - Use of Basin New Zealand catchment model to establish runoff and erosion mechanism
   - Collection of field data from selected sub-catchments to verify model
3. Effects on Estuary
   - Sedimentation rates and areas of sediment accumulation
   - Flow and transport modelling within the estuary
   - Water appearance study
   - Infaunal survey

This report gives details of the flow and transport modelling component of this study reports on other aspects of the study are as follows :

- Sediment history in the estuary (Swales et al. 1997);
- Sediment and nutrient loads to estuary (Stroud and Cooper 1997);
- Pesticide use and its risk of movement to waterways (Wilcock 1994);
- Colour and clarity of estuary water (Davies-Colley and Nagels 1995);
- Patterns and trends in ecology of the estuary (Cummings et al. 1994).

3 Mahurangi Estuary

The Mahurangi Estuary (Figure 1) is one of many picturesque estuaries along the western shores of the Hauraki Gulf situated to the south-east of Warkworth (Latitude 36° 0′ Longitude 174 ° 40′). It consists of a land catchment area of 121 km^2 and an open water surface area of 24.7 km^2 (Feenney 1984). The catchment is made up of areas of pastoral farming, lifestyle blocks and forestry with population centres at Warkworth, Snells Beach, Mahurangi and Jamiesons Bay. The estuary supports an oyster farming industry and is a haven for yachts. The estuary is typical of Hauraki Gulf tideways whose features include areas of mangroves, low freshwater input, shallow low-tide channels and extensive intertidal areas exposed at low water.

Figure 1.
Mahurangi Estuary location map

4 Field Data

To develop reliable models of water, solute and contaminant movement throughout an estuary requires:

- Data on tides, velocities, suspended sediments, bathymetry, winds and salinity
- Data collection under differing combinations of winds, tides and freshwater flows

To achieve this we carried out field studies from November 1993 - October 1994 which include periods of low, average and high freshwater inflow. On 10th-12th November 1993, various instruments to measure salinity, temperature, water levels and velocities were deployed throughout the estuary and tide boards installed at Hamilton Landing, Grants Island and Scotts Landing. A bathymetric survey to complement the Navy bathymetric data was also carried out. On 16th -18th November 1993, tidal gaugings were carried out at Scotts Landing and the Entrance. Additional velocity profile data was collected at other sites around the estuary. From the 18th of July through to 2nd August 1994, longitudinal sampling of salinity and suspended sediment was carried out at sites from Warkworth through to the Entrance. This period included a measured peak flow in the Warkworth River at the Warkworth College site of 35 m^3/s which is an estimated 1 in 2 year storm event. On 19th -21st of October 1994, instruments to measure temperature, pH, salinity, dissolved oxygen, water levels, velocities and turbidity were deployed at sites along the estuary and velocity profiling carried out at selected sites. ARC regularly monitor faecal coliform bacteria and nutrient levels at selected sites throughout the estuary. Figure 2 shows details of deployment and measurement sites for these surveys and Table 1 summarises the data collected.

Figure 2.
Mahurangi Harbour with sites where environmental data was collected during 1993 and 1994

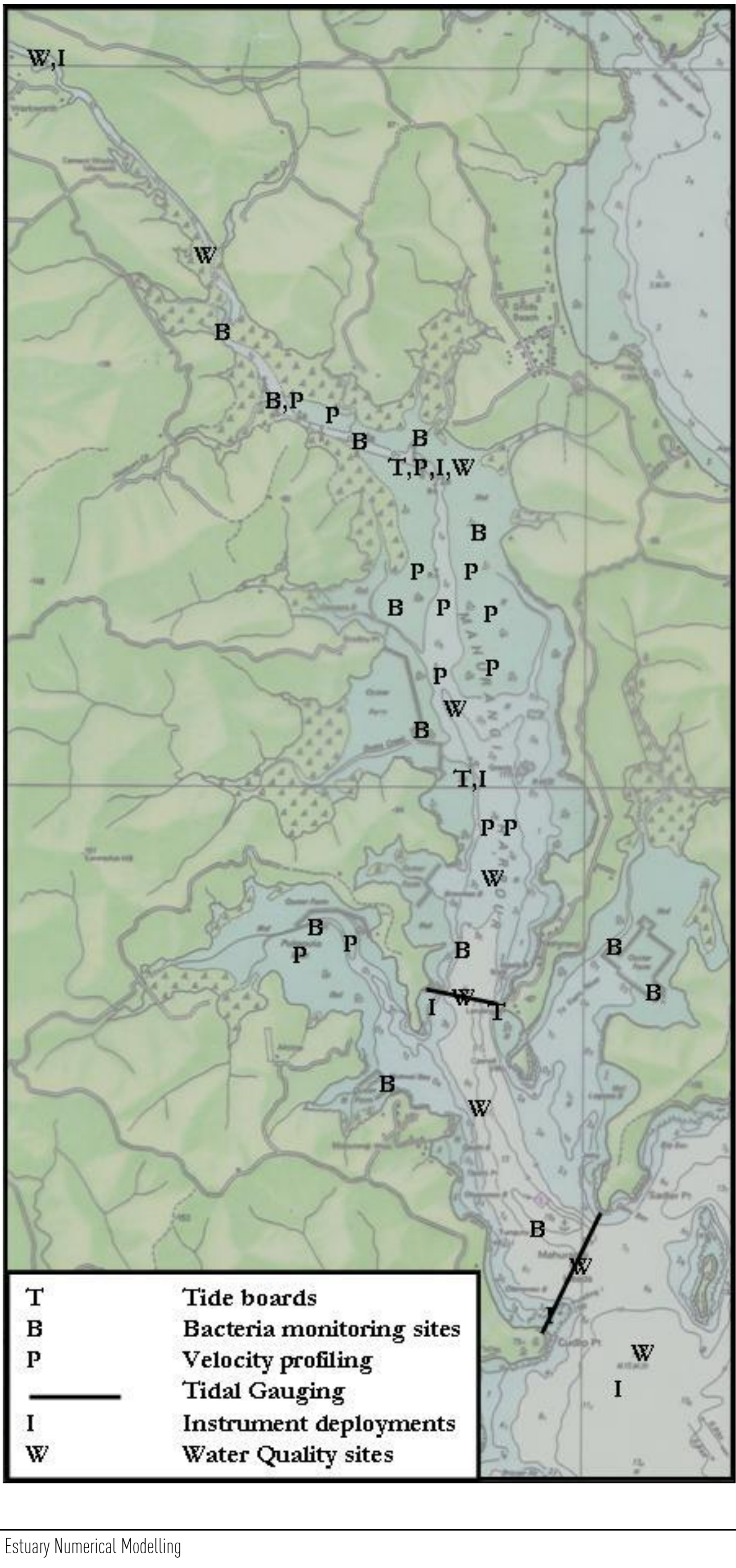


Table 1.

Summary of field data collected over the period of the study

SITE INSTRUMENT	ENTRANCE TIDE GAUGE	HAMILTON LANDING DATASONDE	ENTRANCE CURRENT METER	SCOTTS LANDING TIDE BOARD	ENTRANCE TIDE GAUGING	SCOTTS LANDING TIDE GAUGING	GRANTS ISLAND TIDE BOARD	HAMILTON LANDING TIDE BOARD	VARIOUS CURRENT METER
START DATE	11-Nov-93	11-Nov-93	11-Nov-93	16-Nov-93	16-Nov-93	16-Nov-93	16-Nov-93	16-Nov-93	17-Nov-93
END DATE	14-Dec-93	25-Nov-93	14-Dec-93	18-Nov-93	16-Nov-93	16-Nov-93	18-Nov-93	18-Nov-93	18-Nov-93
PARAMETERS MEASURED	Water Level	Water Level	Speed Salinity Depth Temperature	Water Level	Water Level Speed Discharge Cross Section	Water Level Speed Discharge Cross Section	Water Level	Water Level	Velocity Direction

SITE INSTRUMENT	HAMILTON LANDING DATASONDE	HAMILTON LANDING DATASONDE	SCOTTS LANDING TIDE GAUGE	HAMILTON LANDING DATASONDE	SCOTTS LANDING DATASONDE	HAMILTON LANDING CURRENT METER
START DATE	21-Sep-94	21-Sep-94	21-Sep-94	27-Sep-94	28-Sep-94	29-Sep-94
END DATE	28-Sep-94	12-Oct-94	31-Oct-94	4-Nov-94	5-Nov-94	31-Oct-94
PARAMETERS MEASURED	Temperature pH Conductivity Salinity Dissolved O_2 Water Level	Temperature pH Conductivity Salinity Dissolved O_2 Turbidity	Water Level	Temperature pH Conductivity Salinity Dissolved O_2 Turbidity	Temperature pH Conductivity Salinlty Dissolved O_2	Speed Direction Depth Turbidity

5 Instrument Records

Data collected from an instrument deployed at the entrance to the estuary showing temperature, current speed and salinity over a two week period are given in Figure 3. There is a clear semidiurnal (i.e. 12.42 hours) tidal signal in all three records and the current record indicates the variation in current strengths due to the fourteen day spring/neap tidal cycle.

Figure 3.

Data from Aanderaa current meter moored at the entrance to Mahurangi Estuary from 11/11/1993.

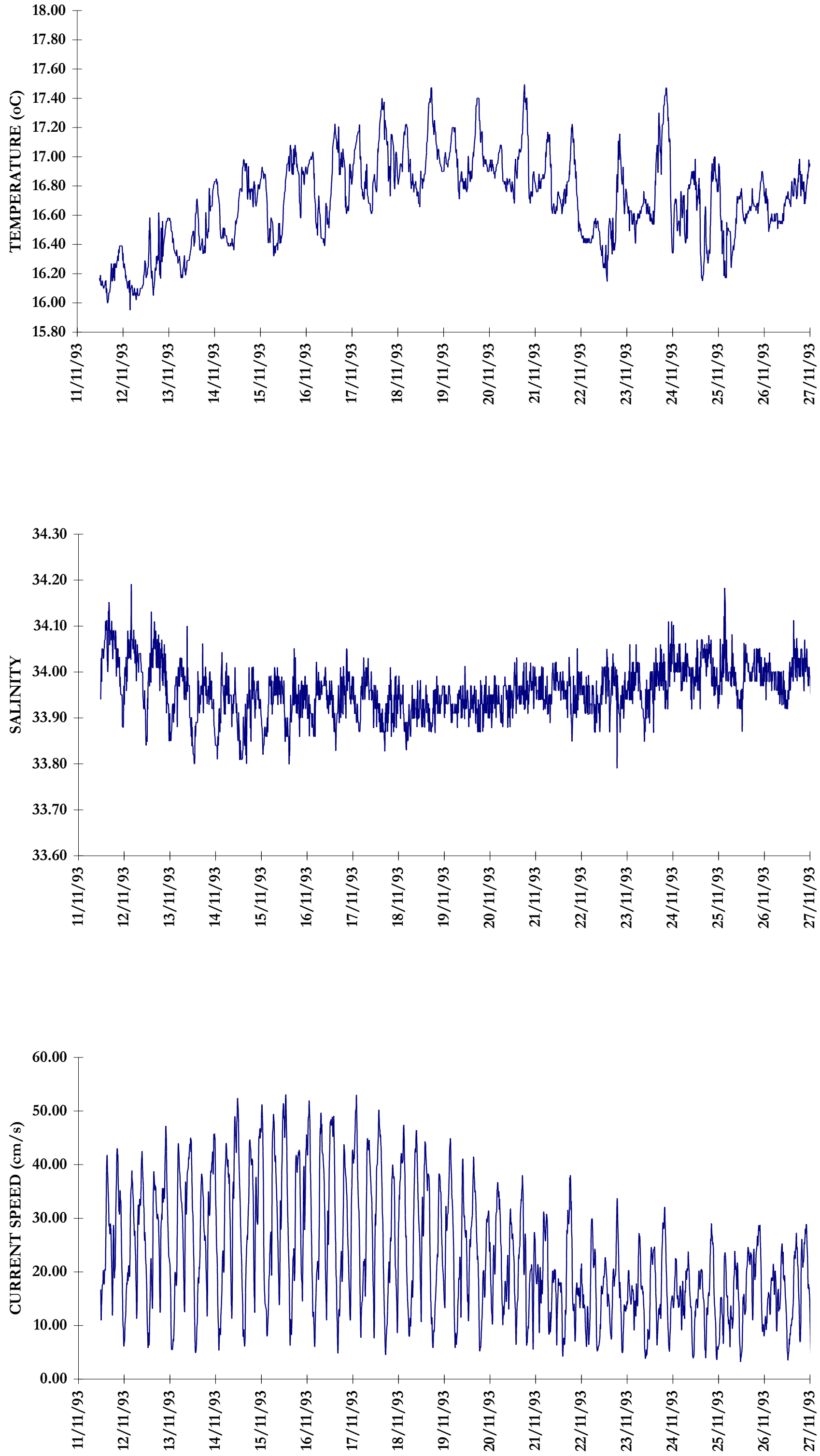
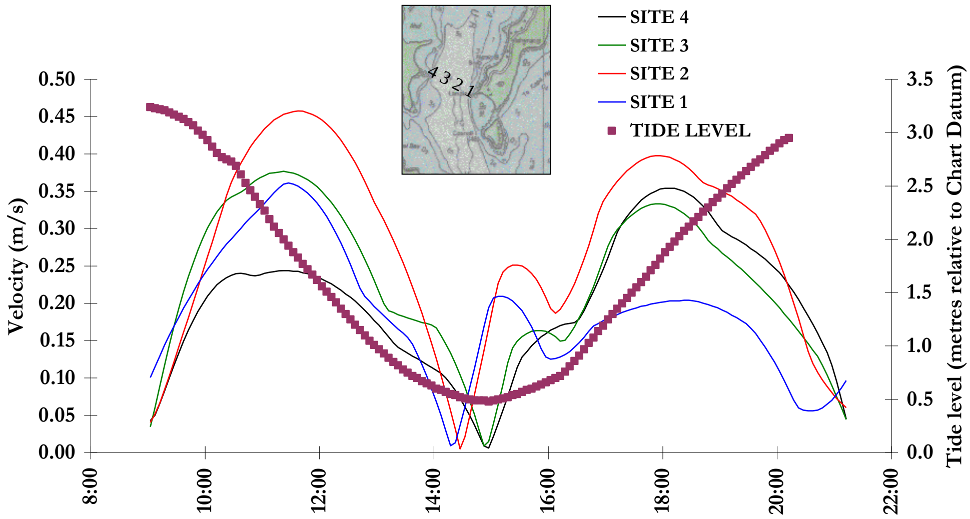


Figure 4 illustrates velocity and tide data collected during the tidal gauging of the 16th of November 1993 for the four sites across the Scotts Landing cross section. The data shows peak flows of between 0.25 and 0.45 m/s on the flood tide and 0.20 - 0.40 m/s on the ebb tide. One hour following low water there is a reduction in velocities at sites 1, 2 and 3 which may be attributable to a seiche as observed by Johnstone (1984). Data from the entrance tidal gauging shows a similar reduction in velocity. This seiching may be driven by either an internal wave within the estuary or is part of a larger seiche occurring within the Hauraki Gulf. Alternatively this reduction in velocities could be due to large areas of banks becoming submerged at this particular tide level.

Figure 4.

Scotts landing tidal gauging velocity and tide data. Site 1 - eastern end of cross section Site 2 - channel site Site 3 - channel site Site 4 - western end of cross section



Examples of mid-depth and surface suspended sediment concentrations collected in the estuary are illustrated in Figures 5 and 6. During the low-flow period (Fig. 5) suspended sediment concentrations are of the order of 30-40 mg/l in the upper estuary and reduce to around 10-20 mg/l at the entrance. Data collected before and after the storm event in July 1994 (Fig. 6) show suspended sediment concentrations of the order of 100 mg/l in the upper estuary which reduce to around 10-20 mg/l at Scotts Landing. Of interest is the increase in suspended sediment from the Warkworth Town Basin to the Cement Works site. This must be due to sources of suspended sediment entering the estuary between two sites rather than local resuspension off the bed. The higher maximum at the entrance site compared to Scotts Landing is thought to be caused by suspended sediment from nearby estuaries to the north and south of Mahurangi which has been transported alongshore.

Figure 5.

Suspended sediment concentrations taken during 11/11/1993. Minimum, mean and maximum recorded concentrations during the low flow event of November 1993

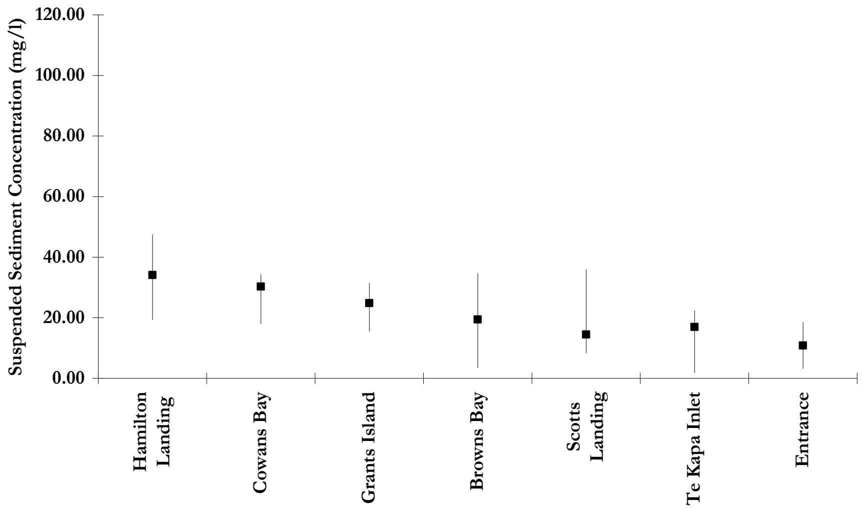
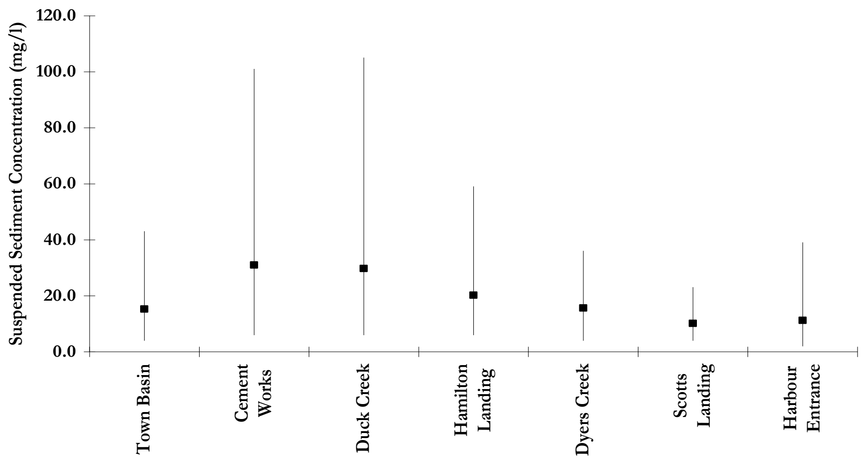


Figure 6.

Suspended sediment concentrations taken from 18/07/94 through to 01/08/94. Minimum, mean and maximum recorded concentration during the storm event of July 1994.



6 Hydrodynamic Modelling

To model the movement of water within the estuary, we used the hydrodynamic model 3DD (Black, 1995). For this study, the model was used in its two dimensional (vertically averaged) mode. The model predicts current velocity, speed, direction and sea levels.

The model covered the area from offshore of the estuary to upstream as far as the weir at Warkworth. The model grid size was a compromise between having a model which has large cells of the order of hundreds of metres that will run quickly and one that will run slowly, but have very good definition of intertidal banks and other sharply defined bathymetric features (i.e. cells of the order of metres). For this study, a cell size of 100 m gave a model which took three hours to run a tidal cycle. With this grid size, the only compromise to bathymetry was for the part of the estuary upstream of Duck Creek. Here the channel meanders varying in width from 75-180 m. The model channel had to be schematised as a single straight channel 100 m across.

For the model, bathymetric data from Navy charts and fair sheets, digitised shoreline and surveys carried out by NIWA were combined to give coverage of the whole estuary. The area offshore of the estuary and upstream as far as the weir at Warkworth was then divided into cells representing an area 100 by 100 metres. Each of these was then assigned a bed level derived from the bathymetric dataset. This gave a model consisting of 2869 non-land cells as indicated in the model schematic (Figure 7). The offshore boundary condition for the model was the rise and fall of the tides as measured using a tide gauge deployed at the entrance. To enable the prediction of the tide for any period a harmonic analysis was carried out using this tide record. The following table gives the four dominant constituents of the tide (Table 2). Spring tides occur when the M_2 and S_2 components coincide.

Figure 7.

Model schematic showing bathymetry as derived Navy and NIWA surveys.

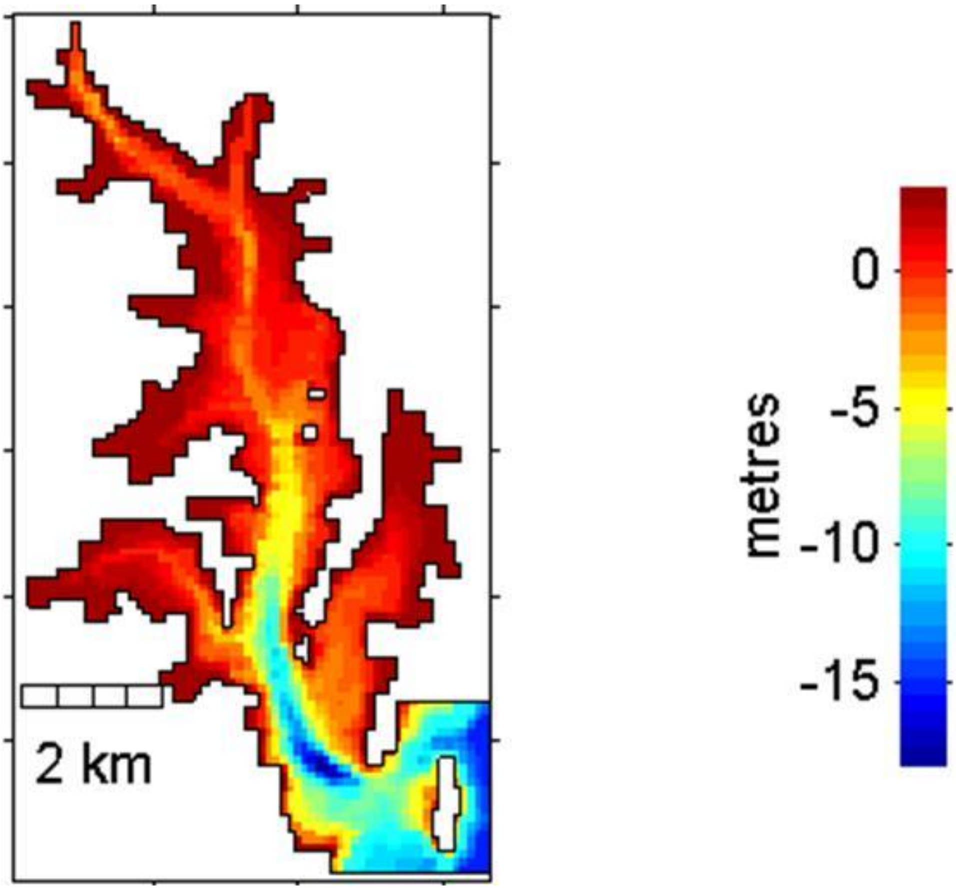


Table 2.

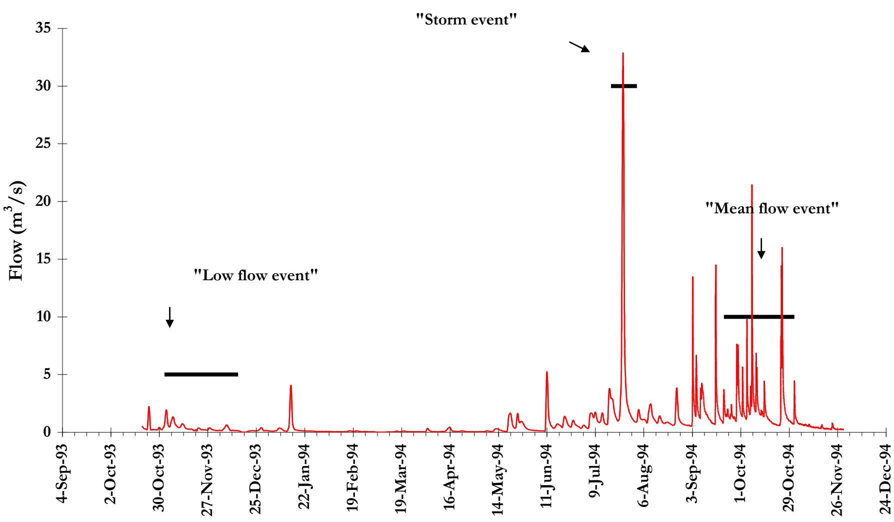
The four main tidal constituents for Mahurangi Estuary

Tidal component	Amplitude (m)	Period (hours)	Description
Z_0	1.6681	0.0	Mean sea level relative to Chart Datum
M_2	1.0204	12.42	Principal lunar cycle
N_2	0.2009	12.66	Ellipitical motion of moon
S_2	0.1380	12.00	Principal solar cycle

The upstream freshwater boundary condition for the model was the daily discharge value of the Warkworth River measured at the Warkworth College site provided by the ARC. Figure 8 shows the record from this site during the field programme and periods when field data was being collected. These have been identified as:

1. "low flow event" starting on 10/11/93 with inflows in the range of 0.1-2.0 m^3/s (average inflow 0.4 m^3/s)
2. "storm event" starting on 16/7/94 with inflows in the range of 0.9-32.9 m^3/s (average inflow 4.2 m^3/s)
3. "mean flow event" starting on 18/9/94 with inflows in the range of 0.6-15.2 m^3/s (average inflow 2.2 m^3/s)

Figure 8.
Inflows from Mahurangi College site during the period of field data collection

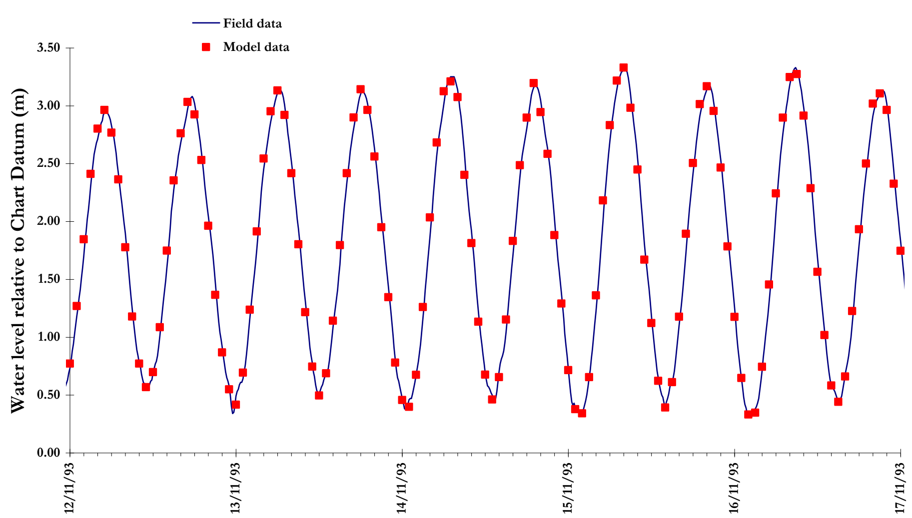


7 Calibration and Verification of Hydrodynamics

To calibrate the model, we simulated a period spanning the tidal gauging data of 16^{th} of November 1993. Firstly, measured and modelled water levels were compared and the model parameters adjusted to achieve a good agreement. Figure 9 gives the measured and modelled water levels at Hamilton Landing over a five day period around the time of the tidal gauging.

Figure 9.

Modelled versus field water levels at Hamilton Landing for the period spanning the tidal gauging of the 16/11/1993.



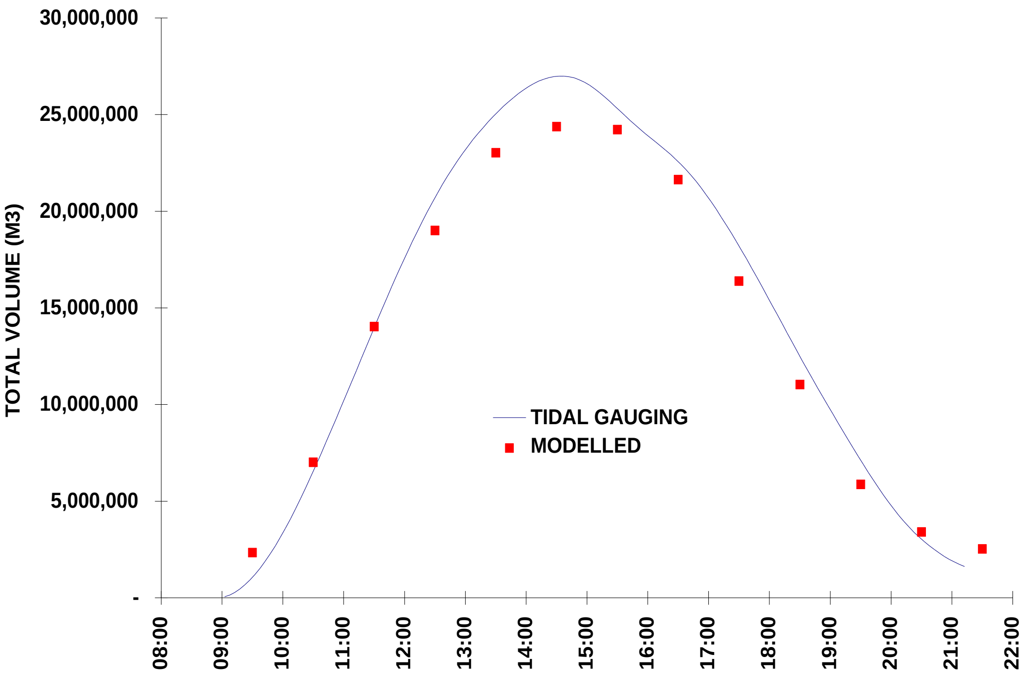
There is excellent agreement between the modelled and field data. Secondly, measured and modelled cumulative water volumes through cross section over a tidal cycle are compared. Volumes are considered as positive during the flood tide and negative during the ebb tide. The maximum cumulative volume during the tidal cycle defines the tidal prism. There are many factors that determine this volume at any one time i.e.:

- estuary volume upstream of the cross section;
- estuary volume downstream of the cross section;
- velocities at the section;
- tide range;
- bathymetry at the section.

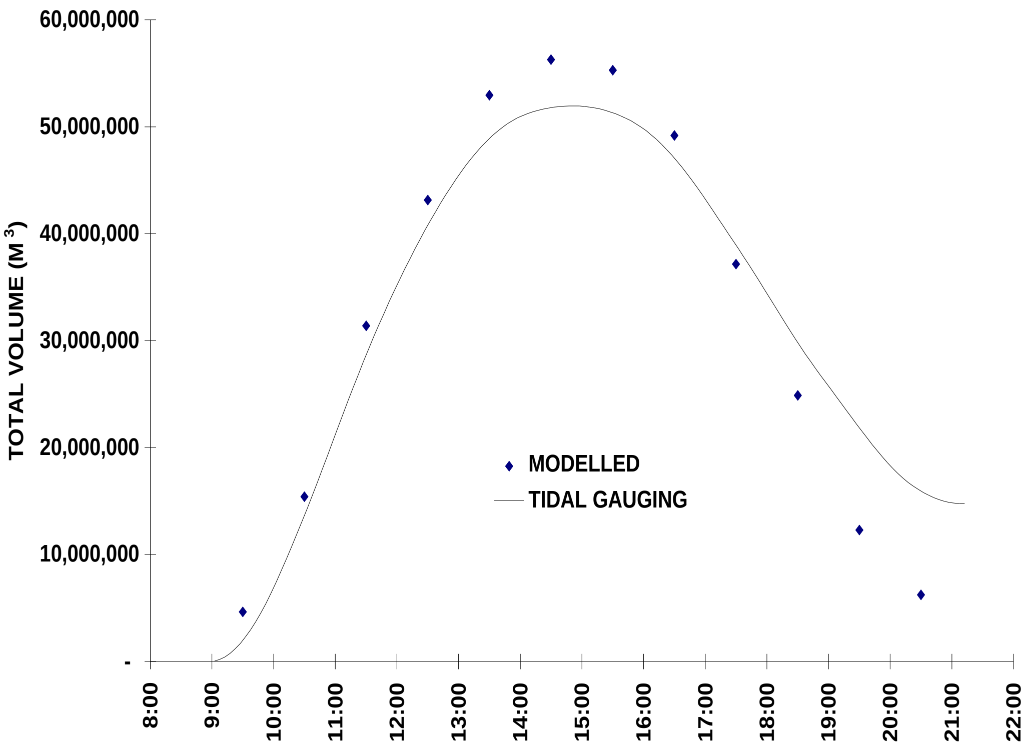
If any of these factors are not adequately represented the resulting model will not be in agreement with the field data. The measured and modelled tidal volume for the cross section at the estuary entrance and Scotts Landing during the tidal gauging of 16/11/1993 are indicated in Figure 10 which shows good agreement.

Figure 10.
Modelled versus measured cumulative volumes passing through cross sections at a) Scotts Landing and b) Entrance

(a)



(b)



Many other comparisons between field measurements and modelled data were carried out which are not reported here for the sake of brevity but ensure that the model parameters were optimised. We are confident that for a wide range of freshwater inflows and tides, currents and water level within the Mahurangi estuary can be predicted.

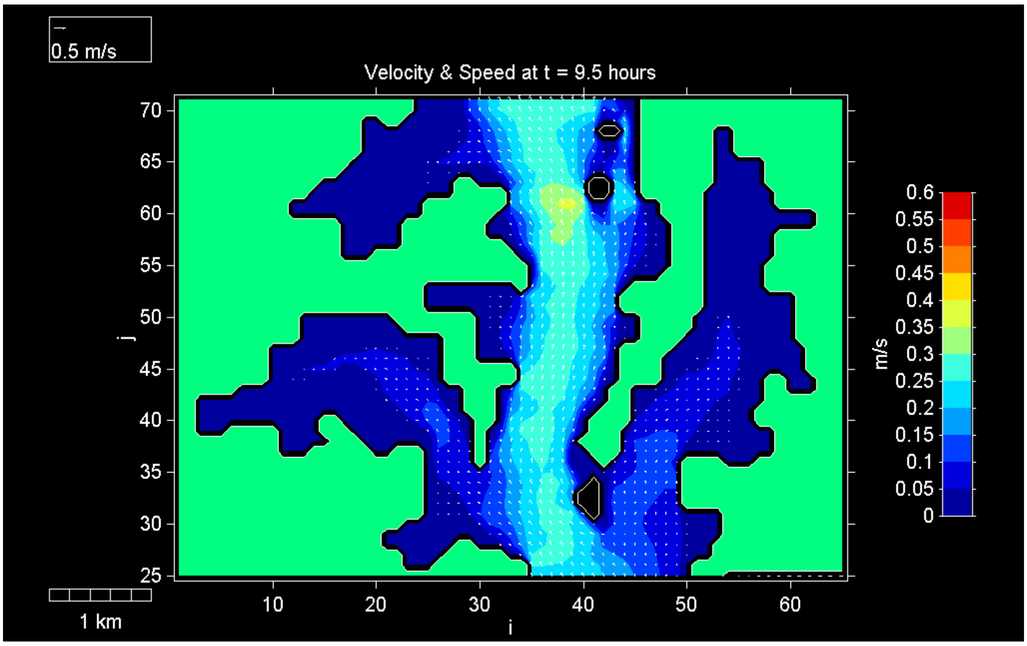
As an example of the predictive use of the model, Figures 11-14 show the peak ebb and flood velocities for both a neap and spring tide for the upper and lower estuary. The following should be noted :

- The imbalance between peak flood and ebb velocities for spring tides (as measured during the tidal gauging - see Figure 4)
- Neap tides result in velocities of the order of 50% of those during spring tides
- For a spring tide peak velocities of the order of 0.6 m/s occur in the main channel near Grants Island and Cowans Bay
- For a neap tide peak velocities of the order of 0.3 m/s occur in the main channel near Grants Island and Cowans Bay

Figure 11.

Peak velocities on ebb (a) and flood (b)tides for a neap tide in the lower estuary

(a)



(b)

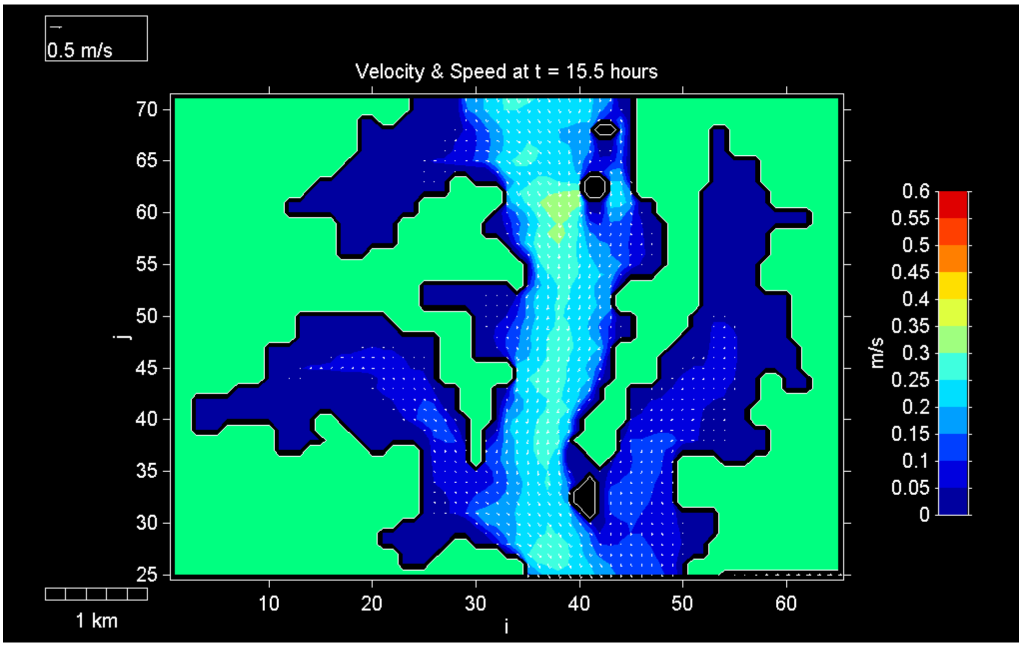
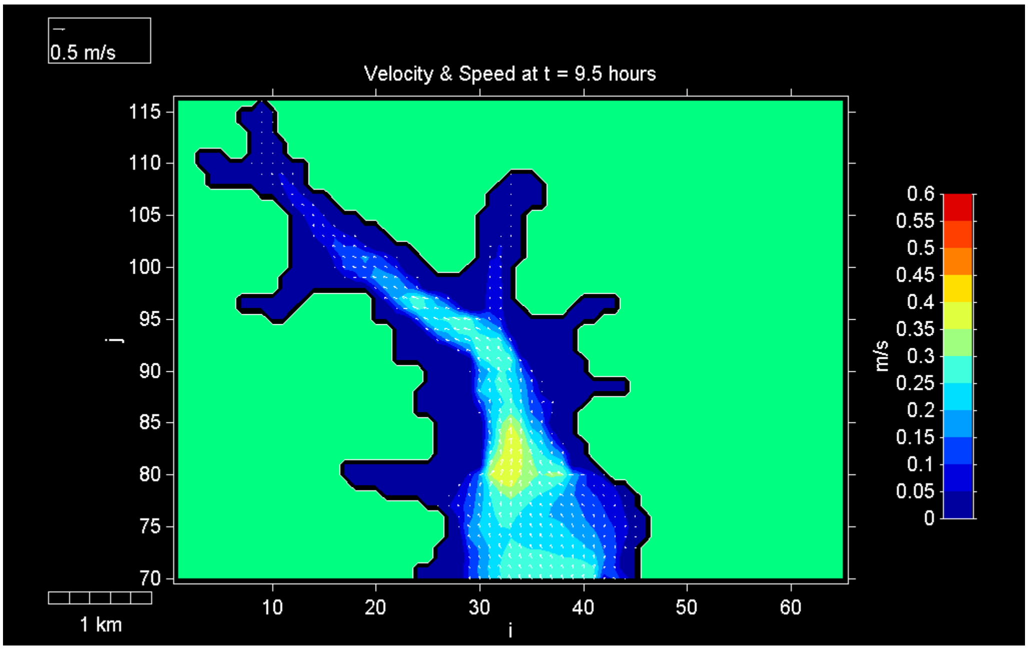


Figure 12.

Peak velocities on ebb (a) and flood (b)tides for a neap tide in the upper estuary

(a)



(b)

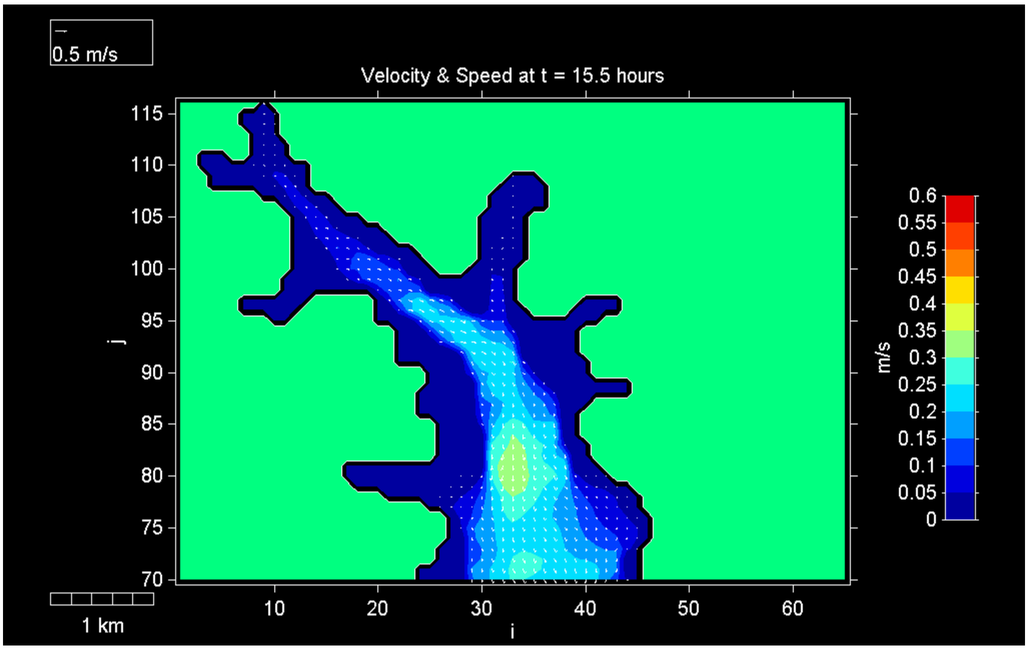
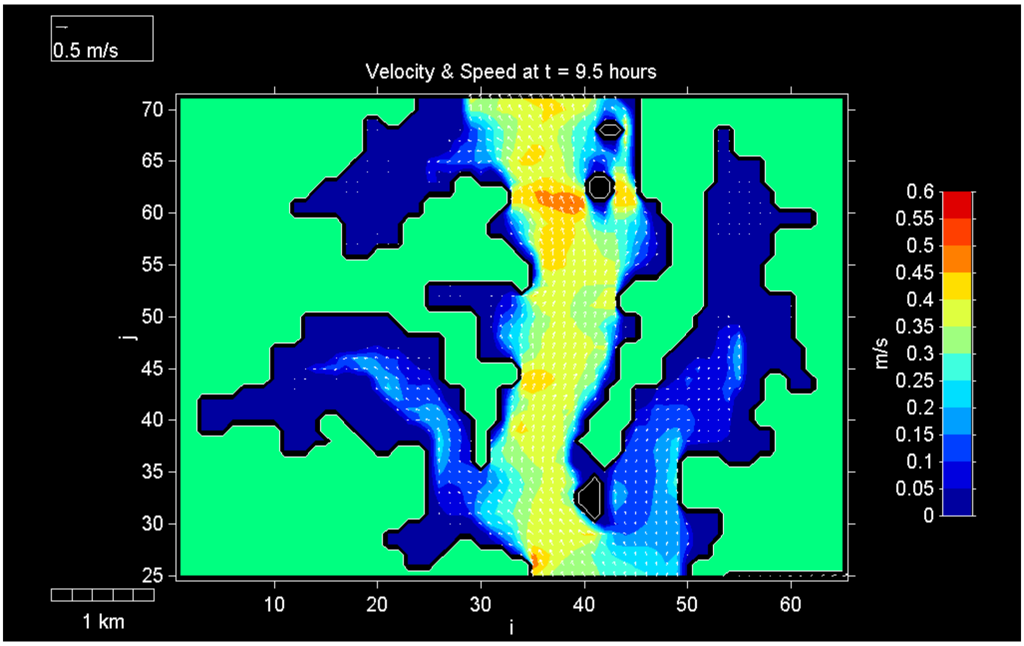


Figure 13.

Peak velocities on ebb (a) and flood (b)tides for a spring tide in the lower estuary

(a)



(b)

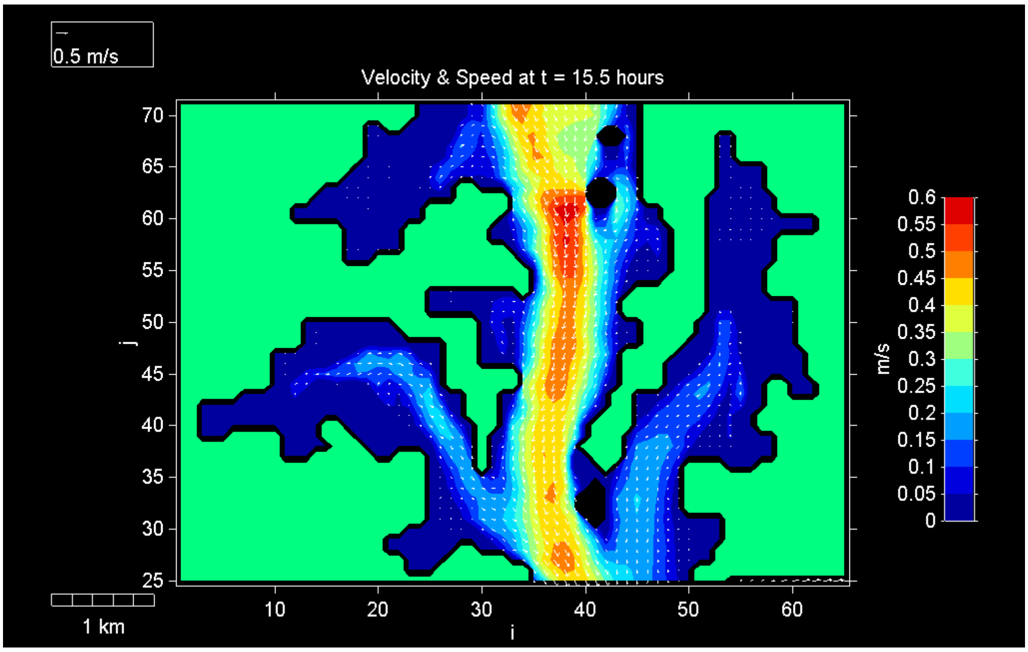
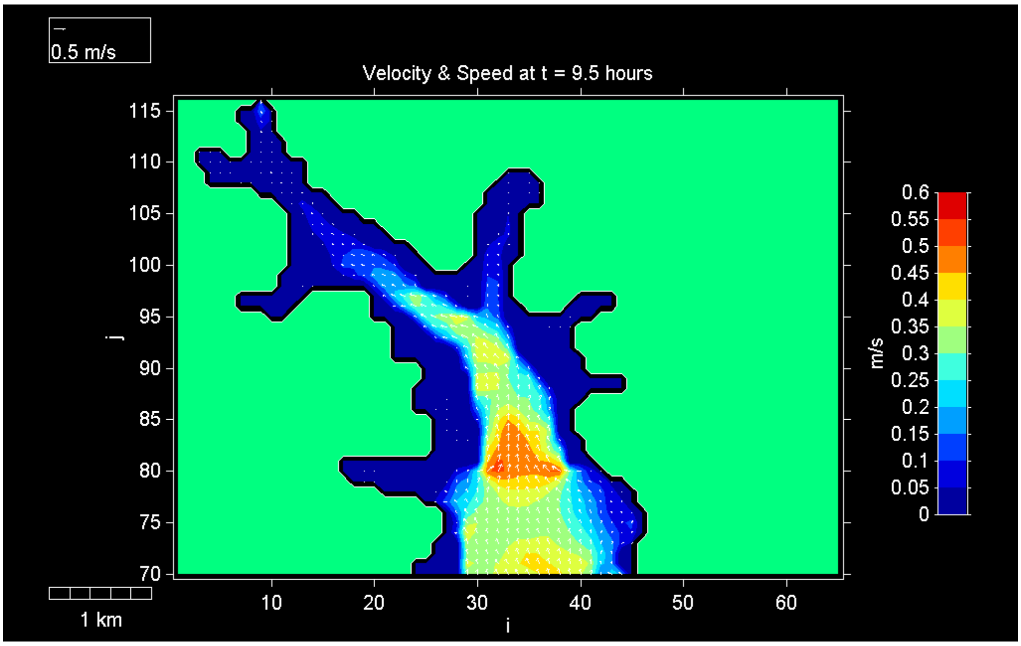


Figure 14.
Peak velocities on ebb (a) and flood (b)tides for a spring tide in the upper estuary

(a)



(b)

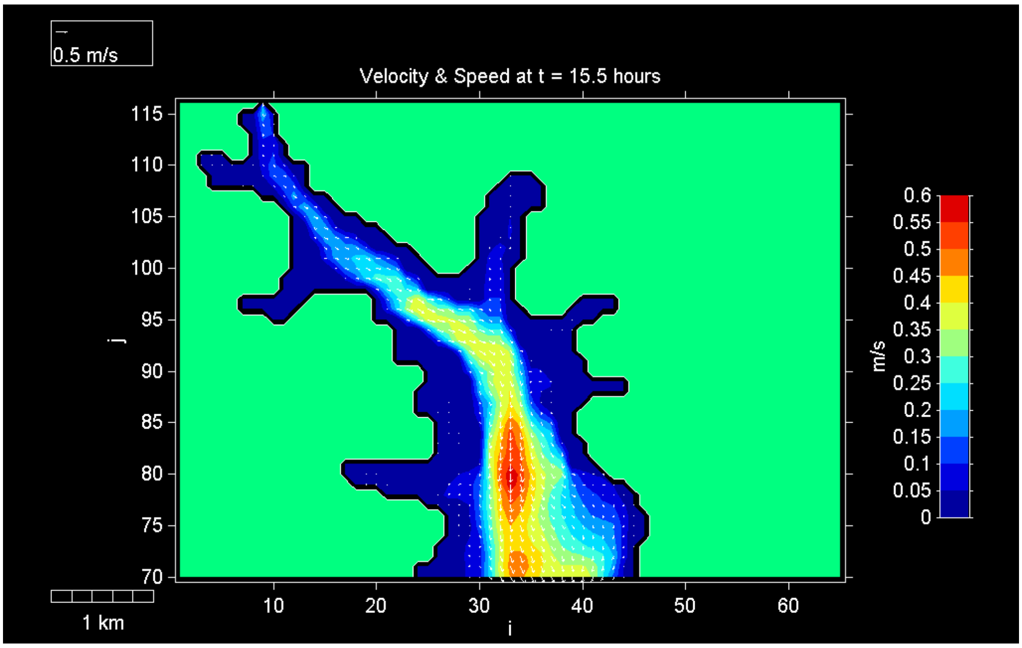
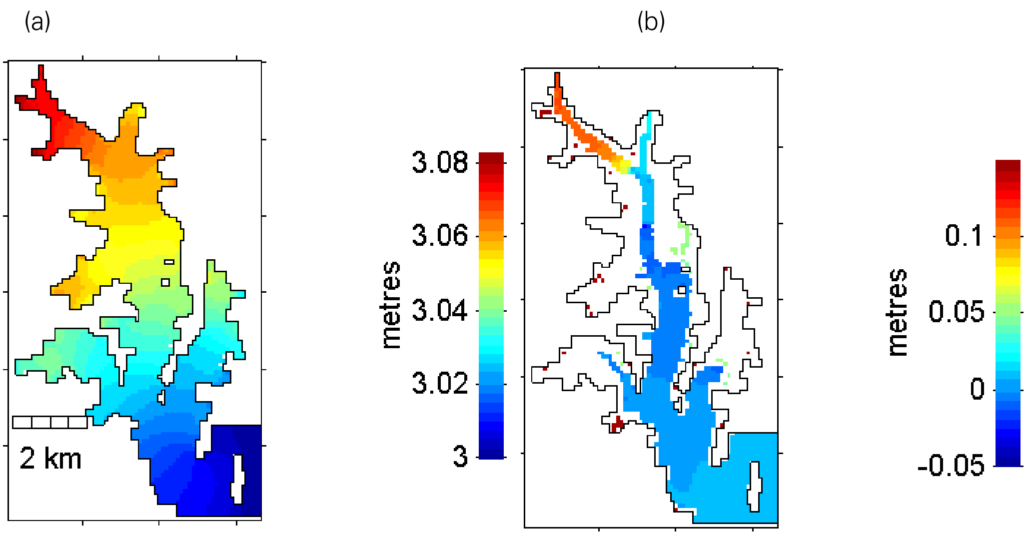


Figure 15 gives the predicted water levels at high water and low water for a spring tide for the whole estuary. At high water there is a level difference of the order of 10 cm up the estuary and all the estuary is under water. At low water there is a level difference of the order of 10 cm with 55% of the estuary being exposed mostly in the upper estuary and side arms. This figure is in agreement with data presented in Harris (1993).

Figure 15.

Modelled water levels at High water (a) and Low water (b) for a Spring tide

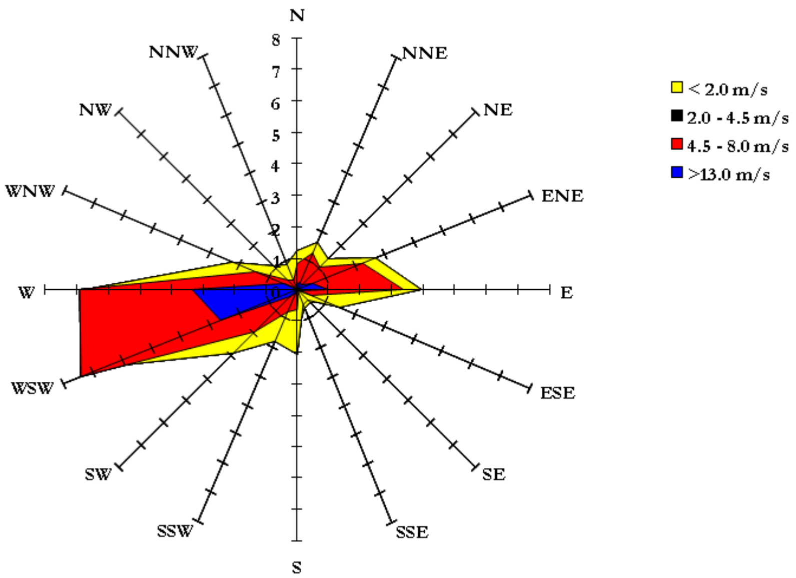


8 Wind-Wave Modelling

The impact of wind-generated waves on the movement of solutes and suspended sediments in a shallow intertidal estuary is significant. For example, Bell et al. (1996) and Black et al. (1997) conclude that wind driven waves are the dominant process on intertidal areas on the Manukau. While the wind climate for the Mahurangi estuary is significantly different from that of the Manukau the influence of wind driven waves will still be important. The wind rose for the Mahurangi estuary derived from a 26-year local wind record shows the westerly wind is dominant (Figure 16), with over 60 % of winds with a westerly component. Wind-generated waves in the Mahurangi were modelled using WGEN_3DD (Black, 1992). It incorporates shoaling, friction and energy losses due to wave breaking. It calculates the orbital velocity produced by a wave at any depth through the water column. The bed orbital velocities can then be used to compute seabed stirring and sediment entrainment. At each of the model grid cells the following statistics are calculated:

1. Significant Wave Height: A commonly used measure of wave amplitude. Historically it has been defined as the average of the largest third of the wave heights recorded.
2. Peak Spectral Period: The period (time between successive wave peaks) at which maximum wave energy occurs in the measured wave spectrum.
3. Orbital Velocity at the Bed: The orbital velocity is the high-frequency current oscillation at the bed caused by the surface wave action.

Figure 16.
Wind rose for Mahurangi Estuary based on a 26 year wind record

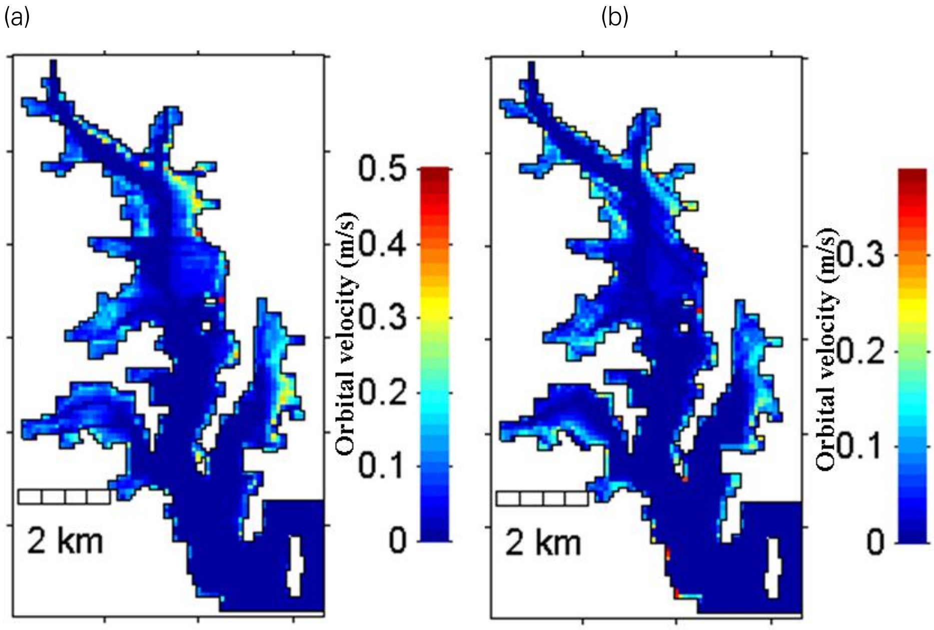


The wave model can be run using a real time-series of wind velocity or for a single wind condition. To illustrate the capabilities of the model, two representative cases of a steady wind from a fixed direction were run:

1. A 25 m/s westerly wind with a spring tide
2. A 15 m/s north-westerly with a spring tide

Figure 17 shows predicted bed orbital velocities for these two cases at high water. The model predicted wave heights in the bay north of Grants Island which were consistent with observations of waves during a westerly storm in October 1994 (Rob Davies-Colley pers. comm.). In the deeper water offshore from the intertidal banks, waves have no significant effect on the bed. It is only in the shallower water (1-2 m depths) that there are significant bed orbital velocities. For the 15 m/s north-westerly wind, bed orbital velocities are significantly lower.

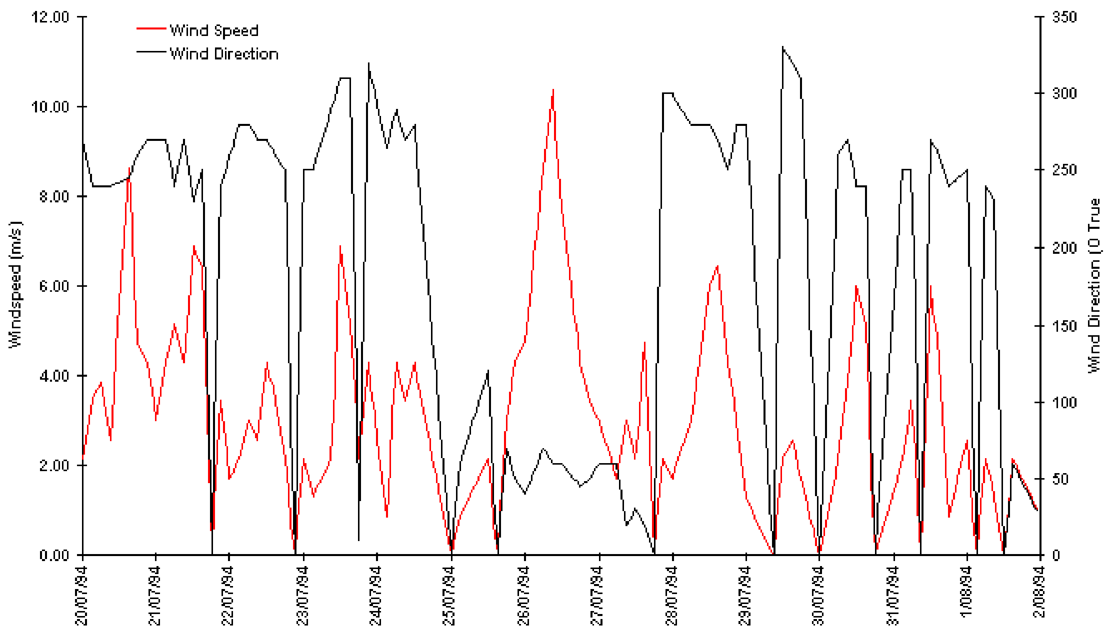
Figure 17.
Modelled bed orbital velocities for a) 25 m/s westerly and b) 15 m/s north-westerly at high water (spring tide)

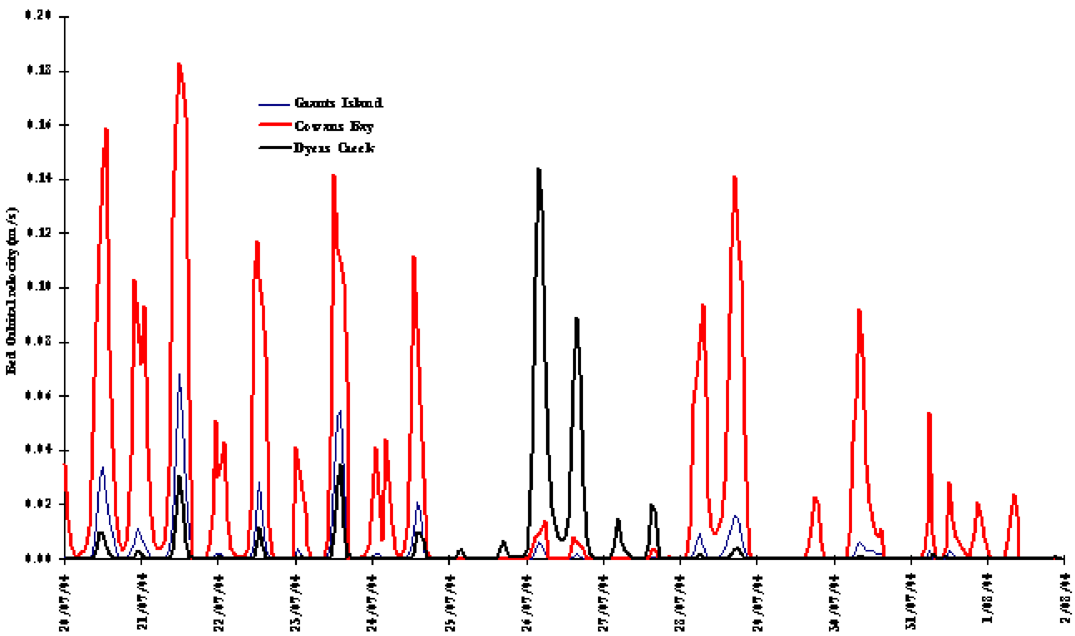


The model was also run using the time-series wind speed and direction observed during the storm event of July 1994. The resultant bed orbital velocities at selected inter-tidal areas are given in Figure 18. Both wind speed and direction play important roles in determining the wind induced wave climate. For example during the 22nd a wind of 4 m/s from the west produces bed orbitals of the order of 10 cm/s in Cowans Bay and only 1 cm/s in Dyers Creek. However, during the 26th winds of the order of 10 m/s (from the east) produce low bed orbitals at Cowans Bay but bed orbitals of the order of 15 cm/s at Dyers Creek.

Figure 18.

Windspeed and direction during the storm of 27/07/94 and modelled bed orbital velocities at selected inter-tidal sites





Swales et al. (1997) used thresholds for resuspension (based on grain size and density) to determine areas within the estuary where waves or tides were capable of resuspending sediment. The thresholds were derived from Komar and Miller (1975) and are consistent with values presented in Black and Healy (1986). For very fine sand and the typical wave period experienced in the Mahurangi a lower bound for the bed orbital velocity would be of the order of 0.12 m/s. Data from Figure 17 show that thresholds of this order are exceeded only over a small area of the estuary. At lower stages of the tide, shorter fetches decrease the bed orbital velocities resulting in even fewer threshold exceedences. Data from the storm event shows that at most 7% of the estuary is above this threshold and on average only 0.4% of the estuary is above this threshold. The above analysis shows that the area where resuspension is possible is limited to the inter-tidal areas (as also shown in Swales et al. (1997)) and the duration of such events short. The maps presented in Swales et al. (1997) give a good indication of the areas within the Mahurangi estuary where sediments are likely to be deposited or where there is likely to be erosion. However, to quantify the movement of sediment within the estuary it is necessary to determine the various sediment fluxes within the estuary. These fluxes are determined by the following:

- the duration of events which are capable of resuspending sediments,
- the redistribution of sediments around the estuary once within suspension,
- the consequent settling of sediments back onto the bed.

By linking the outputs from the models WGEN_3DD and 3DD it is possible to quantify the movement of sediments (and solutes) within the estuary using the transport/dispersion model POL3DD (Black, 1996).

9 Transport-Dispersion Modelling

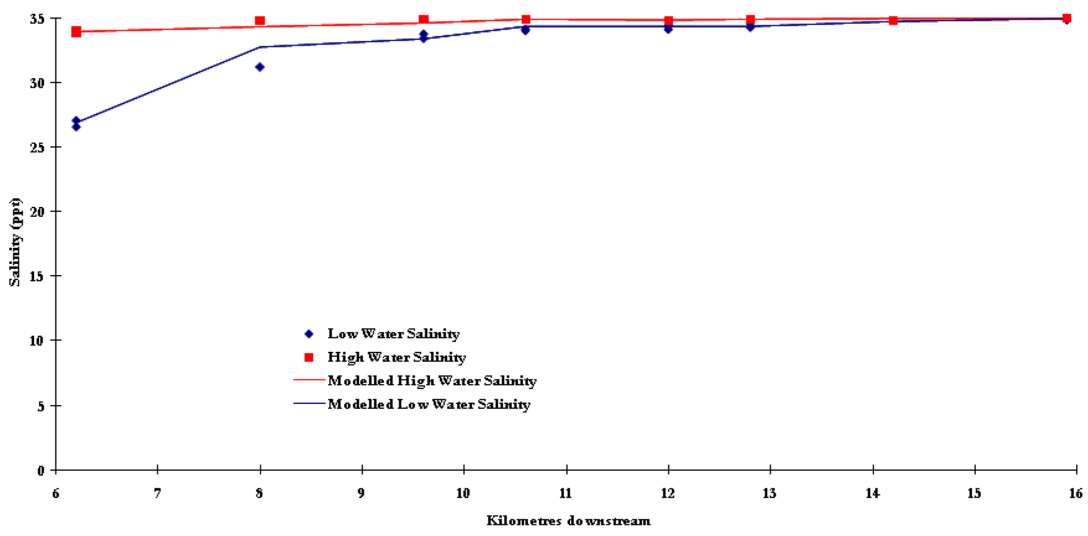
POL3DD is a 3-dimensional numerical dispersal model for application to the transport of dissolved and passive material such as larvae, effluent or sediment. The model solves transport/dispersion equations using a novel particle tracking technique. Details of the application of this model are given in Bell et al. (1996).

The model determines:

- spatial and temporal concentrations of tracers from multiple sources in 3-dimensions
- bedload and suspended load sediment transport
- sediment erosion/deposition
- die-off and other decay processes
- beachings of oil or contaminants and buoyant plumes.

To calibrate POL3DD, salinity was chosen as the natural, conservative tracer. The longitudinal profile of surface salinity as measured and modelled for the low flow event indicates good agreement both at high and low water (Figure 19).

Figure 19.
Longitudinal salinity profiles at High and Low water for the 11/11/1993 as measured and modelled



Spatial plots of surface salinity over a tidal cycle show the extent of the freshwater plume as it moves and disperses throughout the tide (Figure 20). Freshwater flows at this time were small and of the order of 1 m^3/s. To fully test the model, the storm event of July 1994 was also simulated. This period contains the highest freshwater inflows and therefore the biggest range of salinities measured during the field exercise. Figure 21 shows the field and modelled surface salinity at sites along the estuary on the 25th of July (the day of highest freshwater inflows). It shows the large gradient at both high and low water along the estuary and there is good agreement between model predictions and the field data. Over the period spanning the storm, surface samples of salinity were collected at sites along the estuary. Figure 22 shows this data (along with the modelled predictions) for the 7 days following the storm event for the Entrance and Hamilton Landing. Again there is good agreement between model predictions and the field data. Spatial plots of salinity over a tidal cycle show the extent of the freshwater plume as it changes throughout the tide (Figure 23).

Figure 20.

Salinity in Mahurangi estuary for low flow event of 11th November 1993 using actual tides and freshwater inflows. Plots at High Water (a) and every hour subsequent hour (b)-(l)

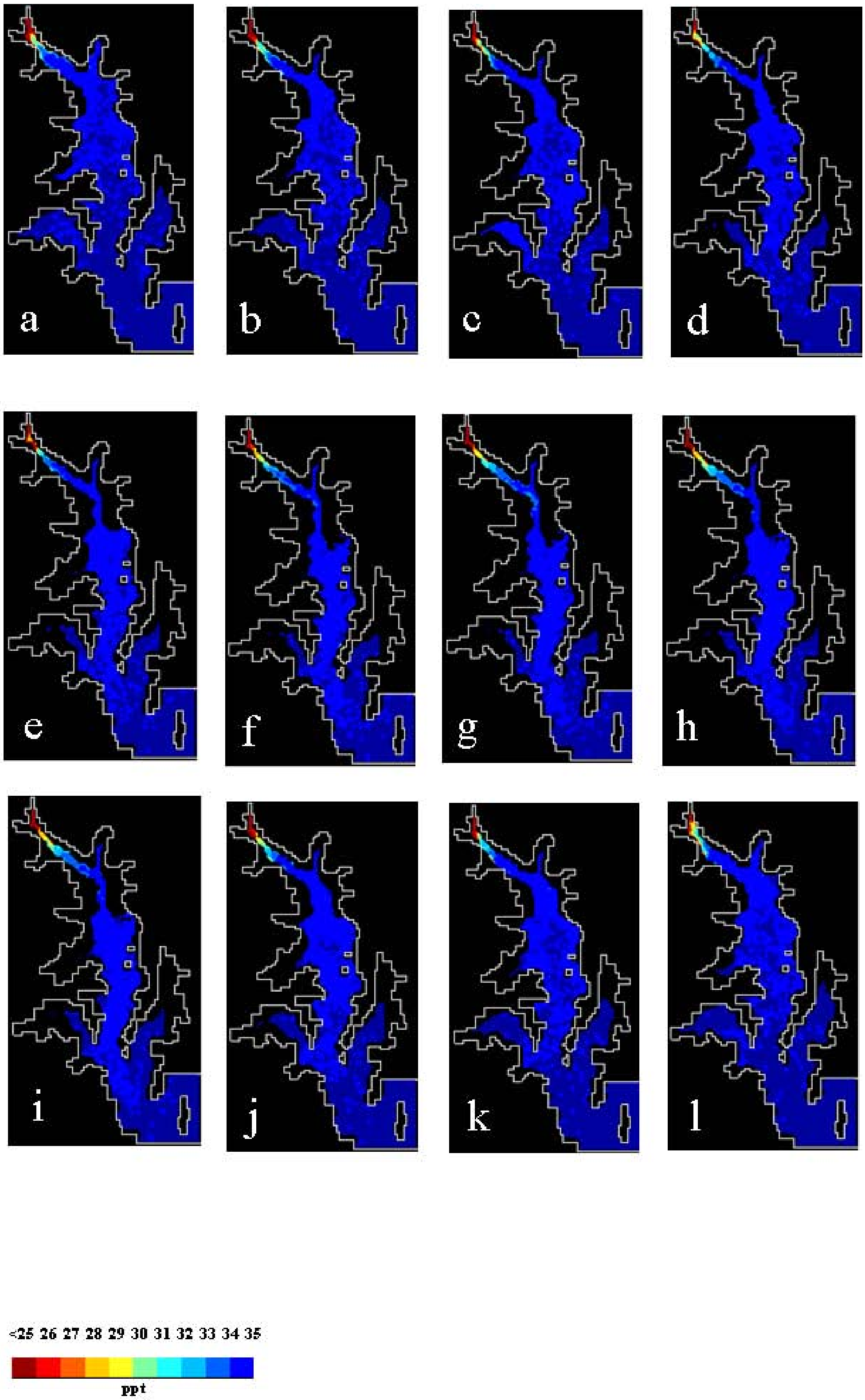


Figure 21.

Modelled and measured surface salinity values during the 25th of July 1994

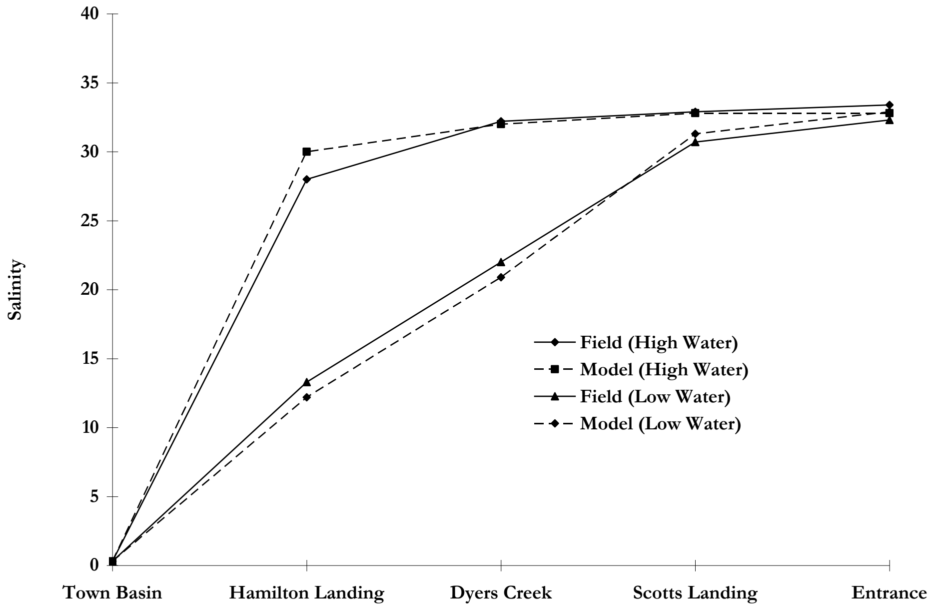


Figure 22.

Modelled and measured salinity values during the storm event July 1994 at the entrance (a) and at Dawsons Creek (b)

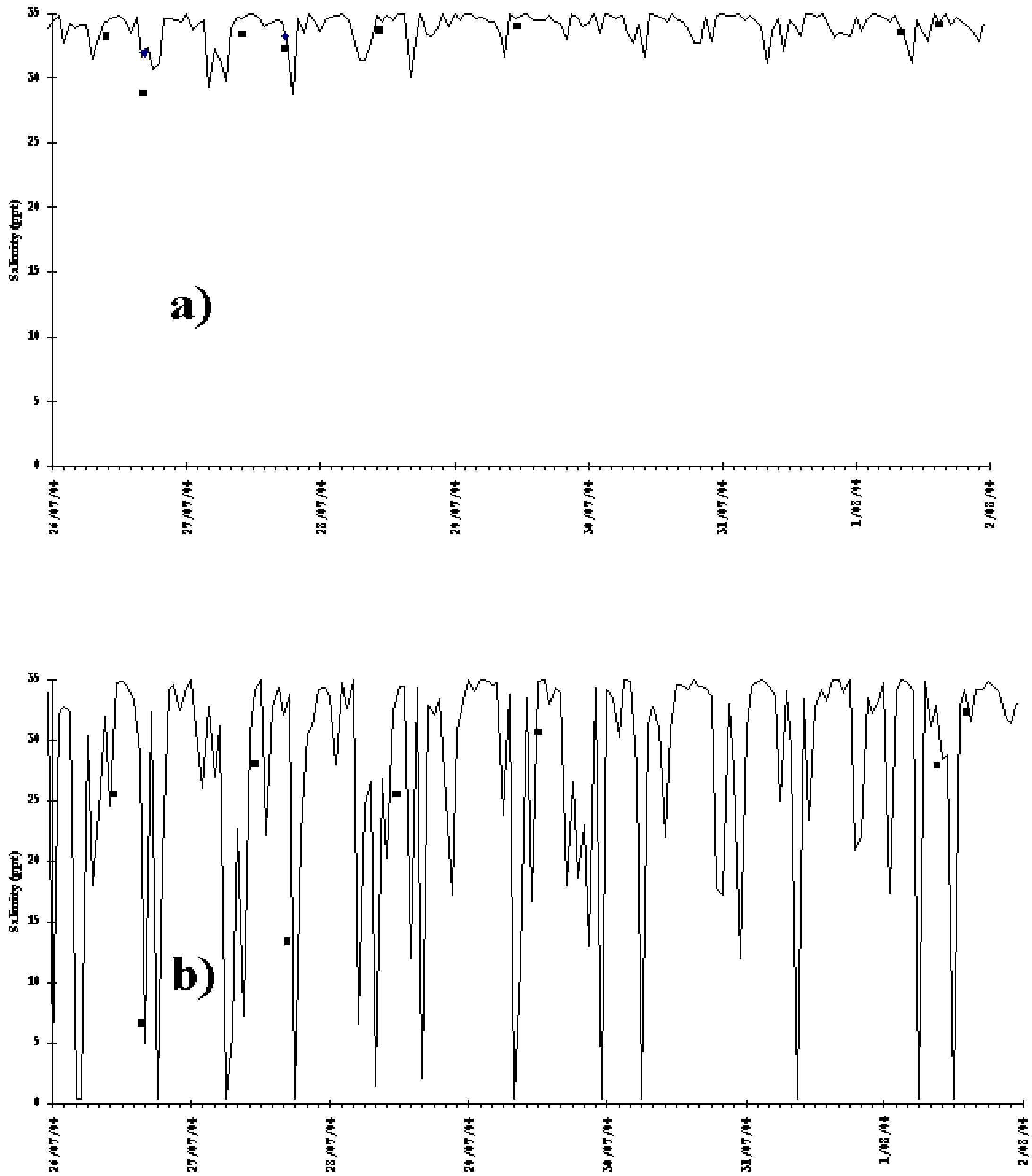
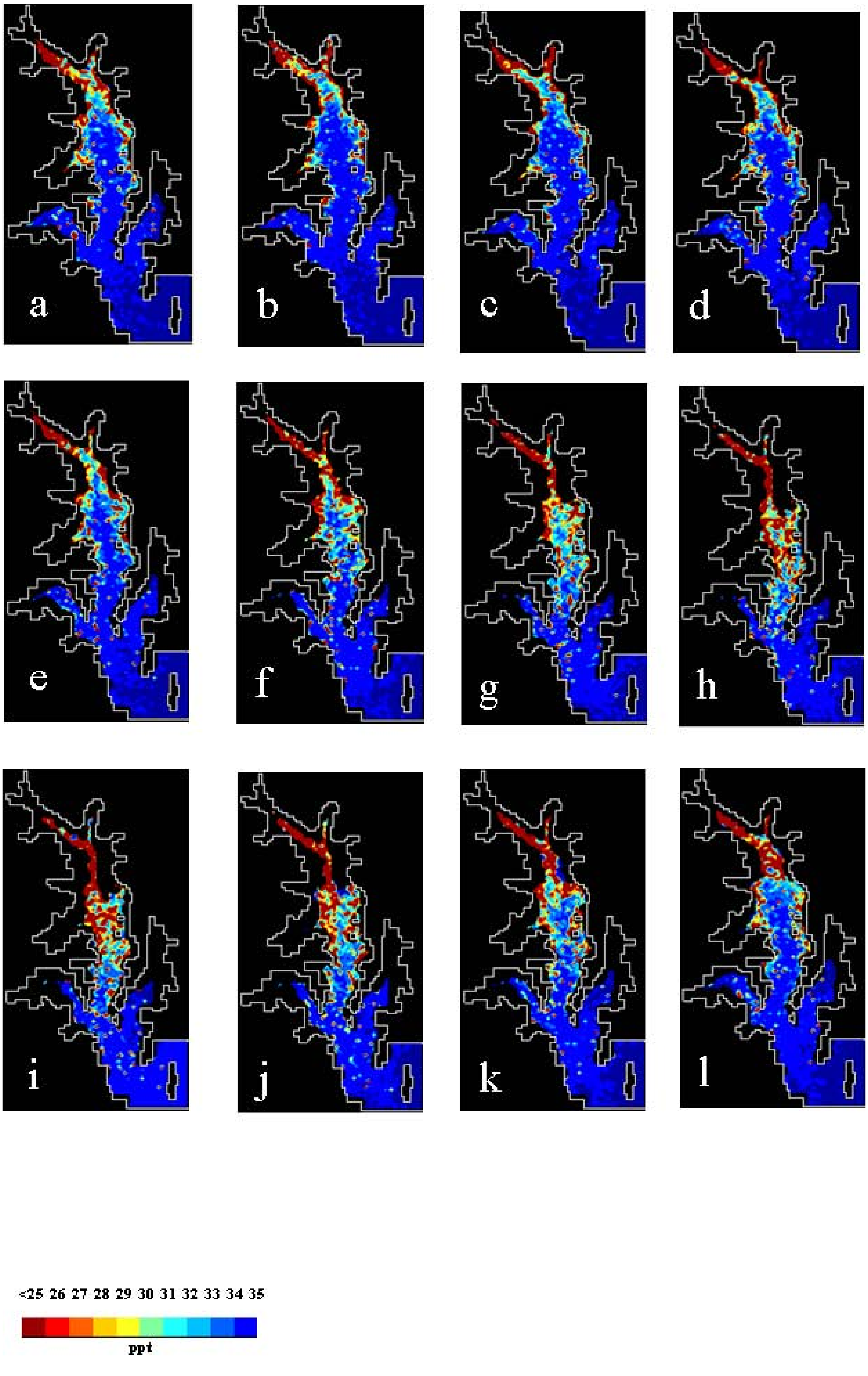


Figure 23.

Salinity in Mahurangi estuary for high flow event of 26th July 1994 using actual tides and freshwater inflows. Plots at High Water (a) and every hour subsequent hour (b)-(l)



Once the model has been successfully calibrated for a conservative tracer (in this case salinity), it is then possible to model non-conservative particles or solutes. This is done by assuming the same mixing coefficients and applying additional factors which represent the non-conservative nature of the particles being modelled. As an example of the application of the non-conservative transport-dispersion model, the fate of faecal coliform bacteria discharged from the Warkworth sewage treatment works was modelled using an exponential decay due to inactivation by solar radiation. This decay rate is different for summer or winter and , to a lesser extent, with time of day and salinity. To simplify this modelling exercise a single T_{90} value of 115 hours was used (equating to a dawn/dusk conditions in winter). Two model runs were considered both assuming spring tides, no winds and a freshwater inflow of 5 m^3/s.

These were:

1. Tidally staged effluent discharge - commencing one hour before high water and continuing for three hours
2. A continuous effluent discharge

For both runs the same volume of effluent per tidal cycle was released. The extent of the plumes (shown in terms of percentage effluent : 0% = no effluent ; 100% = pure effluent) for the whole estuary throughout a tidal cycle (Figures 24 and 25) indicate that the staged discharge generally results in a plume with higher concentrations but smaller extent compared to the continuous discharge.

Figure 24.
Relative concentrations for a staged discharge from the Warkworth sewage treatment works. Discharge commences 1 hour prior to high water and ends 2 hours after high water. Spring tide and 5 cumec freshwater inflow. Plots at High Water (a) and every hour subsequent hour (b)-(l).

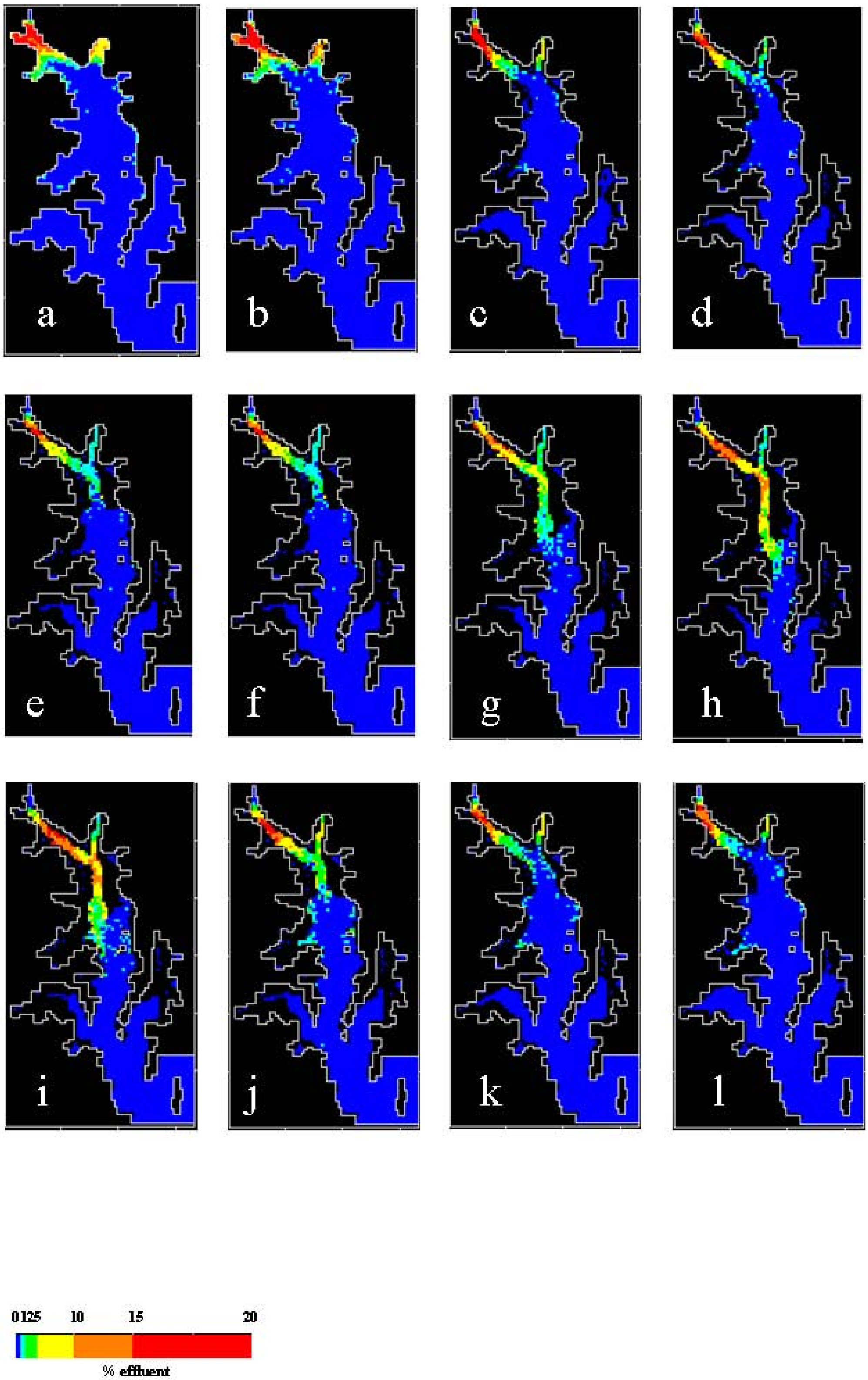
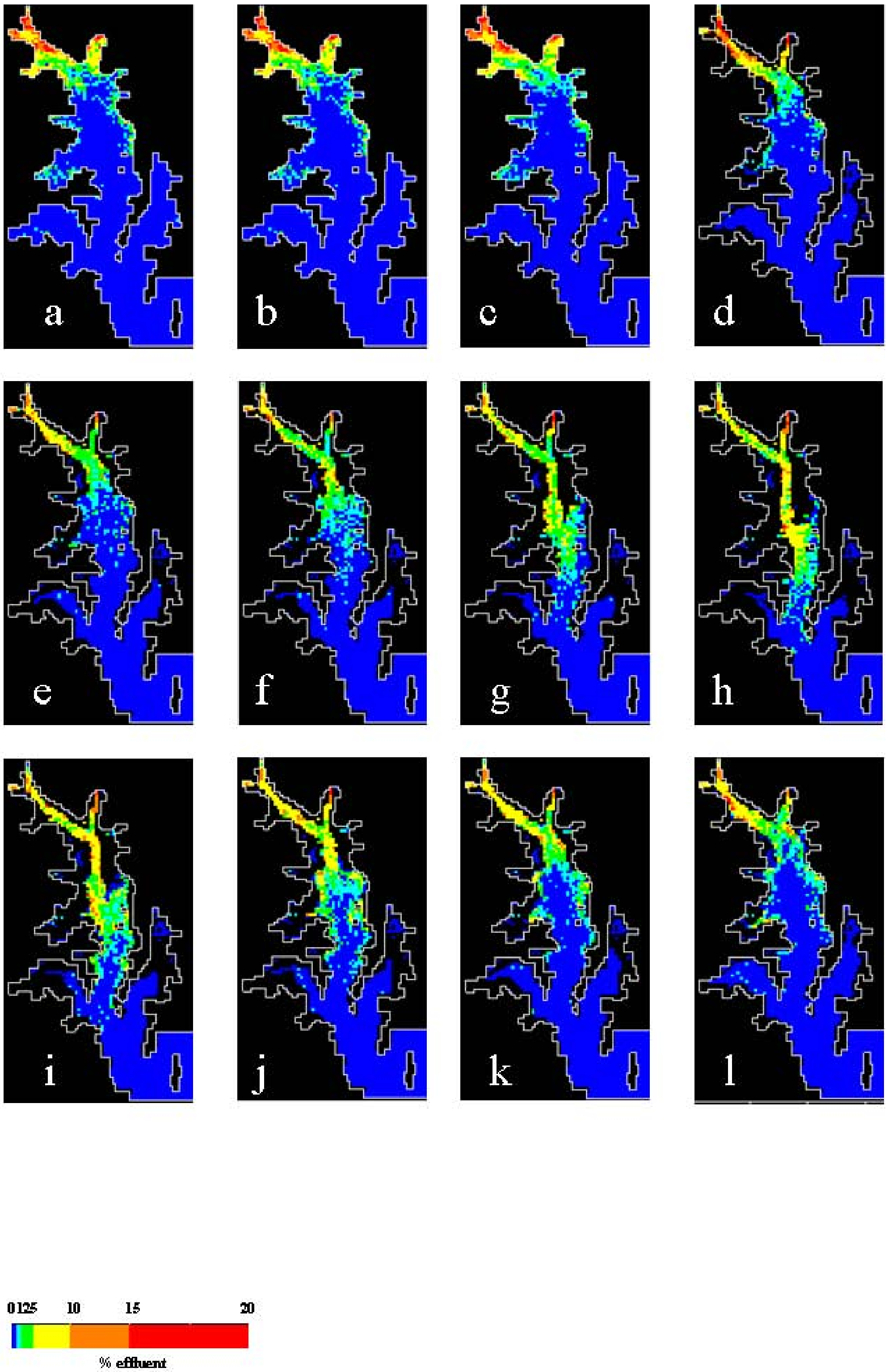


Figure 25.

Relative concentrations for a continous discharge from the Warkworth sewage treatment works. Spring tide and 5 cumec freshwater inflow. Plots at High Water (a) and every hour subsequent hour (b)-(l)



10 Sediment Transport Modelling

The next step in the transport-dispersion modelling was to model the movement of sediment within the estuary. An important factor in determining the settling and resuspension of suspended sediments is the grain size. Larger grain sizes fall more quickly through the water column and are consequently deposited closer to their source than smaller grains. They also require more energy (i.e. higher tidal currents or larger wave and orbital velocities) to be resuspended. To determine the distribution of grain size within the estuary, sediment samples were taken throughout the whole estuary and analysed using the University of Waikato Malvern sediment sampler. The following table (Table 3) gives the median grainsize data for a number of sites within the estuary.

Table 3.

Median grainsize for mid-channel sites in the Mahurangi Esturay

Site	Median Grainsize (μm)
Hamilton Landing	25.3
Grants Island	52.0
Te Kapa Inlet	16.2
Scotts Landing	55.2

Swales et al. (1997), using these grain sizes, the output from the hydrodynamic and wind model produced maps showing areas within the estuary where:

1. Wind generated waves were capable of entraining sediments;
2. Tidal currents were capable of entraining sediments;
3. Winds and tidal currents were not capable of entraining sediment.

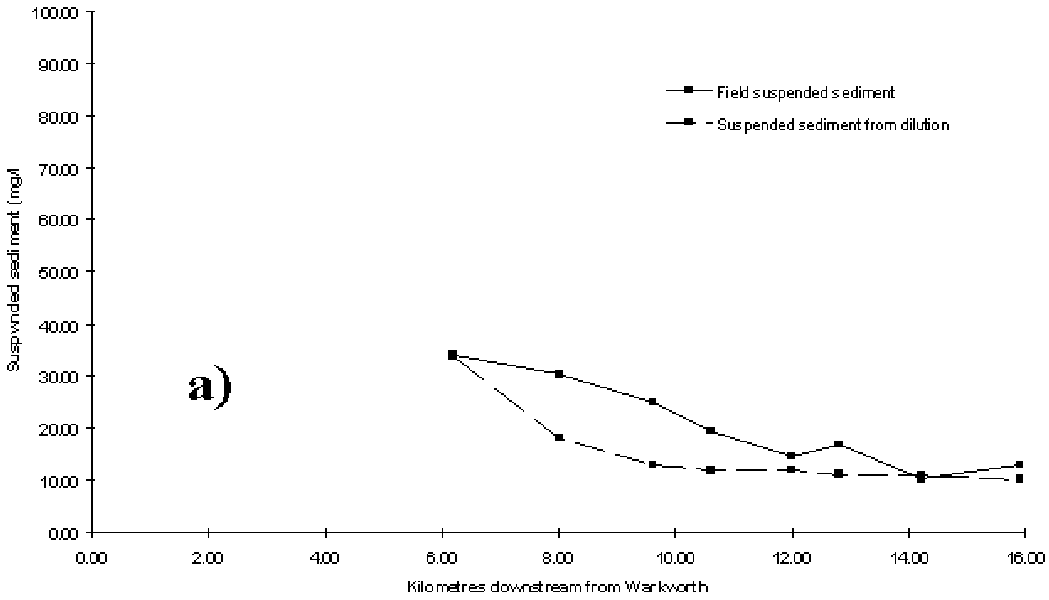
In addition to identifying such entrainment areas, it is necessary to know whether sediment is being transported away from the area and subsequently being deposited in the estuary following a storm event. This is done by treating the “particles” within POL3DD as suspended sediment with a known fall velocity (based on their grainsize). First, however we assess the importance of dilution on suspended sediment concentration, as we know from the previous sections that the river inputs are mixed within the estuary.

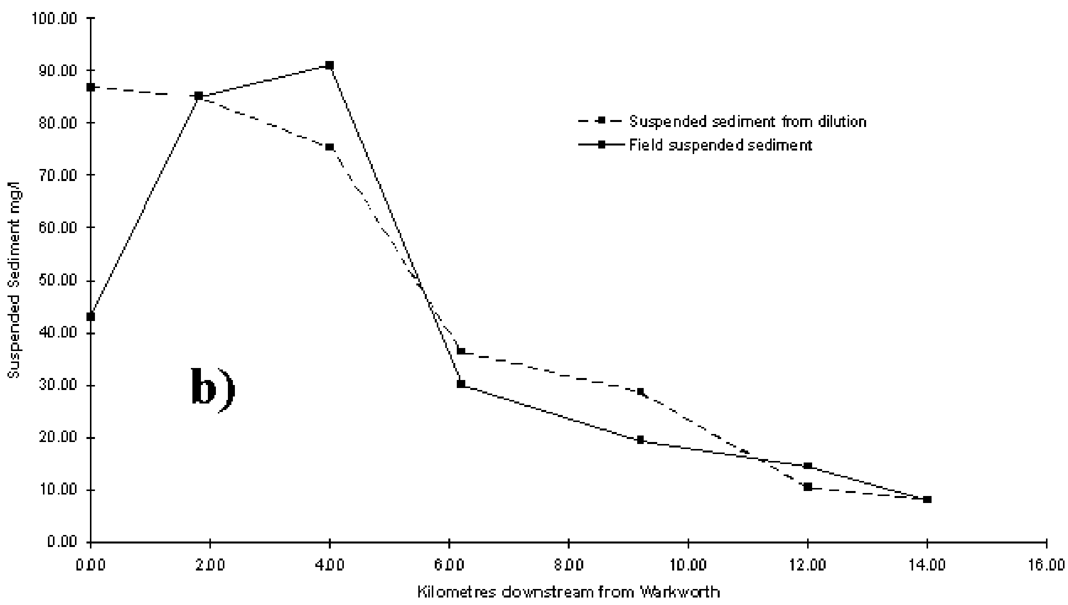
Field measurements of suspended sediment concentrations and salinity data were obtained for both the storm event of the July 1994 and the low flow event of the 11/11/93. For both these events, the salinity data was converted to a dilution value. This was done by determining the background salinity (i.e. the open coast salinity) and the freshwater salinity (i.e. the salinity at the Town Basin site). The degree of mixing of these two water bodies types determines the actual salinity at a site. Based on these dilution values an estimate of the mid-depth suspended sediment concentration was then obtained (i.e. assuming no settling of sediment). Longitudinal plots of measured and calculated mid-depth suspended sediment concentration in the main channel show reasonable agreement (Figure 26) except for the storm event data at the Warkworth Town Basin[1]. The discrepancies between measured and calculated suspended sediment indicate the limited extent to which sediment is affected by deposition and resuspension in the main channel. Were wave resuspended sediment to be carried into the main channels in large quantities, the match between observed and predicted concentration would not be as good as that shown in Figure 26. The general good agreement in this analysis shows that dilution is the major process determining suspended sediment concentration in the main channels. This is not to say that resuspension of sediments is not important. Swales et al. (1997) conclude that, for extreme wind events, there are significant areas of the estuary where wind-induced waves are capable of resuspending sediments. We infer that such resuspension is localised and that there is subsequent settlement.

[1]The salinity data for the storm event show a dilution of the order of seven between the Town Basin and Cement Works while suspended sediment actually increase by a factor of two. Therefore there must be an additional source of suspended sediment (but not freshwater) between the two sites.

Figure 26.

Estimates of suspended sediment concentrations based on dilution from filed salinity data and field suspended sediment data for the low flow event of 11/11/93 (a) and the storm event of July 1994 (b).





We can use the model simulations of freshwater dilution to show the relative amounts of freshwater reaching each model cell during a model run. This is then a measure of the amount of suspended sediment reaching these cells. Thus, POL3DD can be used to model suspended sediment concentrations and subsequent settling patterns for combinations of the following:

- Sediment grain size
- Tidal condition
- Wind strength
- Wind direction
- Freshwater inflow

As examples of the data that can be attained from using the above approach six scenarios are presented for the sediment model.

Table 4.

Scenario runs for sediment plume modelling

Scenario	Tide	Freshwater inflow
A	Spring tide	5 cumec
B	Spring Tide	35 cumec
C	Spring Tide	140 cumec
D	Neap Tide	5 cumec
E	Neap Tide	35 cumec
F	Neap Tide	140 cumec

Using the Basin New Zealand catchment model Stroud and Cooper obtained a mean catchment derived sediment load of 52,270 tonnes per annum. The Mahurangi River catchment attributes 29% of this total (i.e. 15,158 tonnes per annum). Assuming that this load was delivered during a 12 hour period, an indication of the likely sediment build-up was obtained for each of the above scenarios. This was done by assuming a bulk density of 1350 kg/m^3 for surficial sediments (which is derived from the coring data of Swales et al. (1997)) and then using the model to determine the number of settled particles for each scenario. This number was then converted to mm of sediment in each model cell at the end of the model run thus;

Total sediment load	:	15158 tonnes
Bulk density	:	1350 kg/m^3
Cubic metres of sediment	:	11,222 m^3
Number of particles released	:	50,000
One Particle equates to	:	0.0224 m^3

Thickness in a cell : 0.0224 mm of sediment

Figures 27-32 show the resulting plots of mm of sediment deposited in the estuary during the scenario run. It is evident from the plots that both the tidal range and freshwater inflow have a significant influence on the pattern of deposition following a storm event.

Figure 27.
Sedimentation (mm) assuming a spring tide with 5 cumec freshwater inflow and the annual average sediment load delivered to the estuary during a 12 storm event.

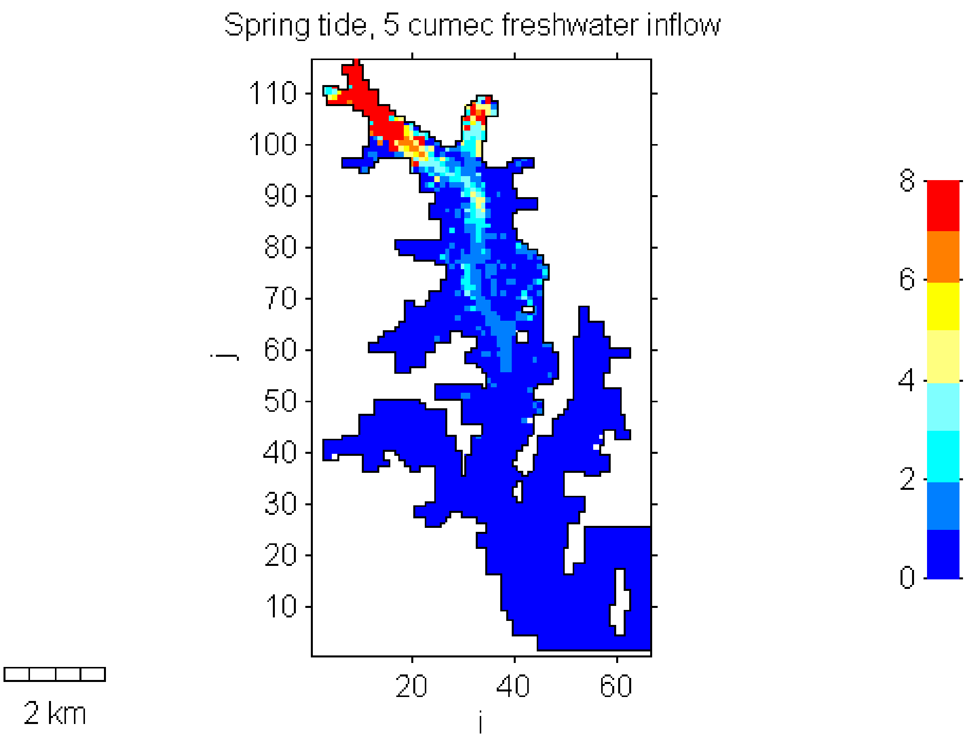


Figure 28.

Sedimentation (mm) assuming a spring tide with 35 cumec freshwater inflow and the annual average sediment load delivered to the estuary during a 12 storm event.

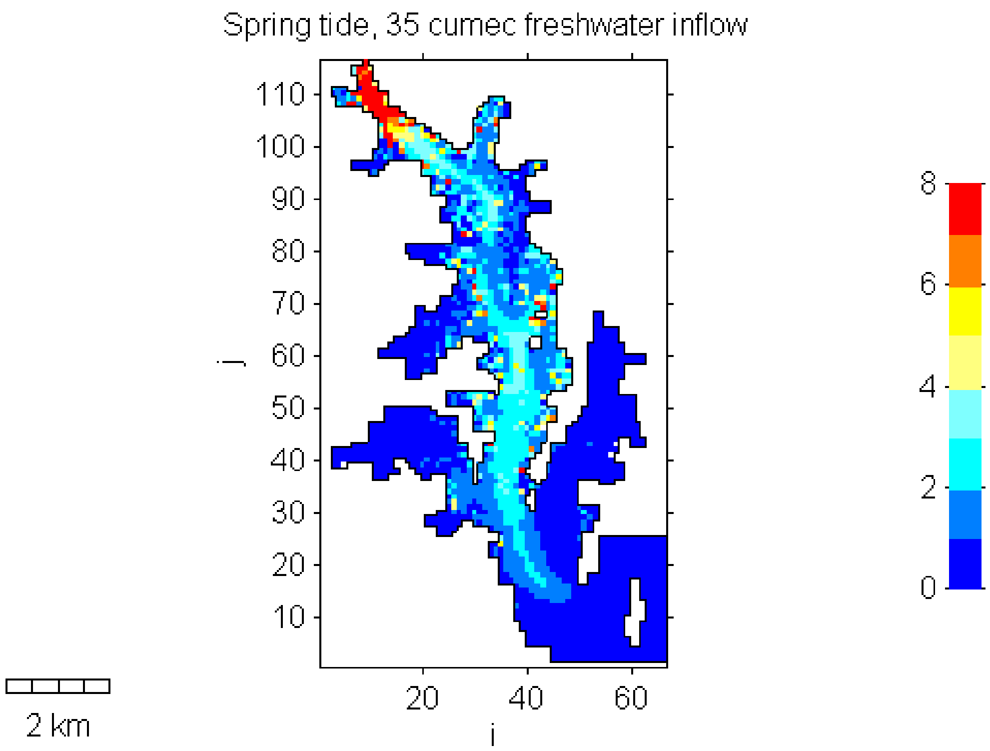


Figure 29.
Sedimentation (mm) assuming a spring tide with 140 cumec freshwater inflow and the annual average sediment load delivered to the estuary during a 12 storm event.

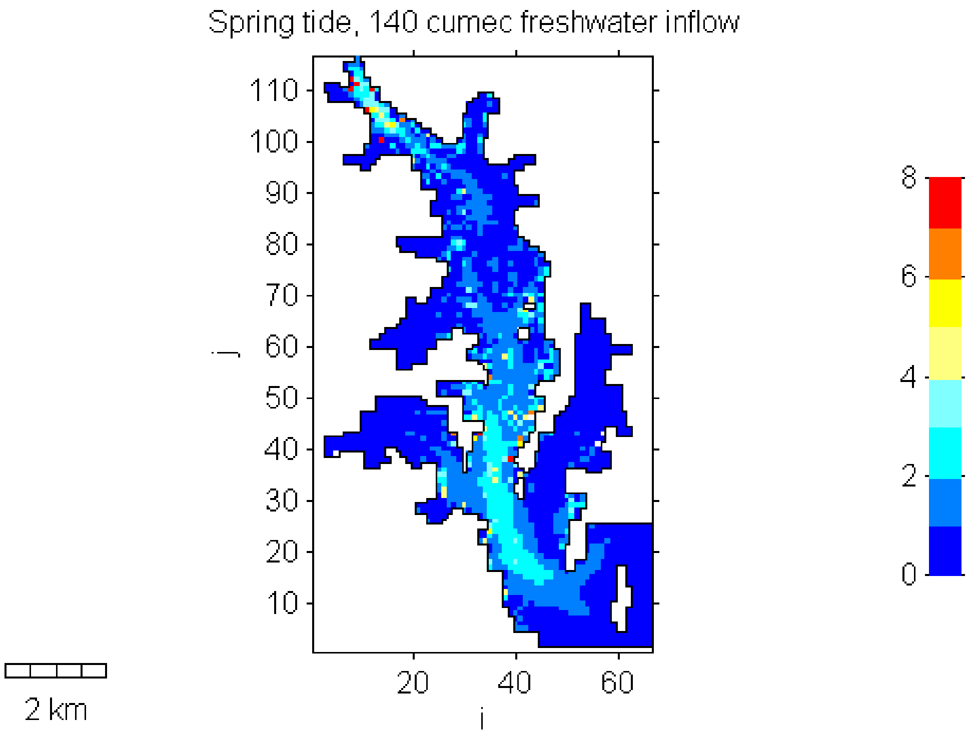


Figure 30.
Sedimentation (mm) assuming a neap tide with 5 cumec freshwater inflow and the annual average sediment load delivered to the estuary during a 12 storm event.

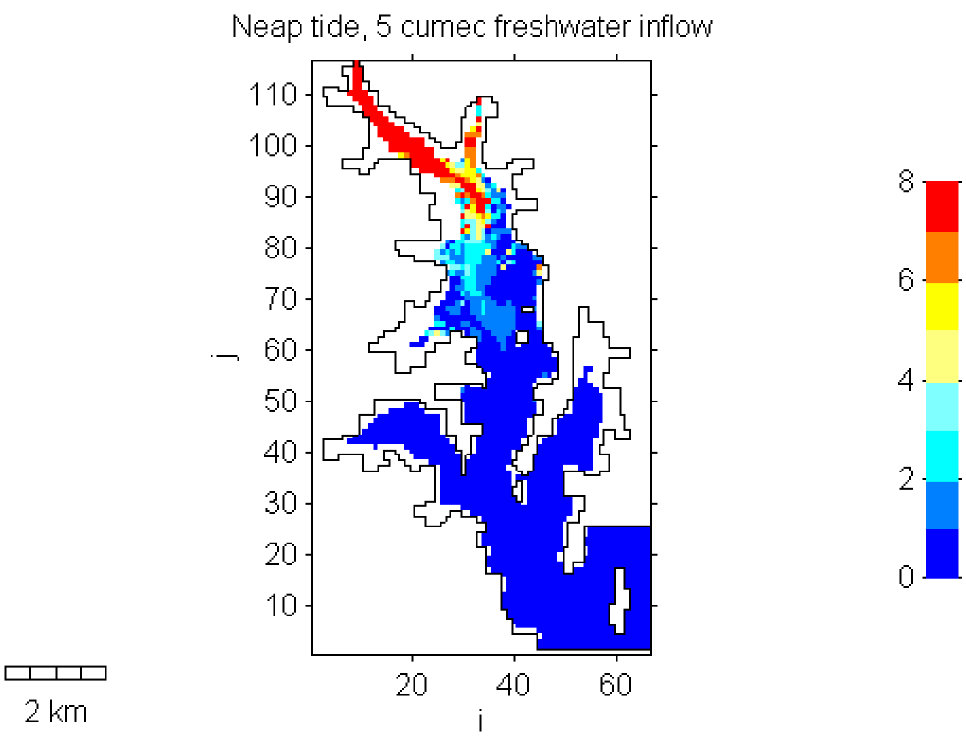


Figure 31.
Sedimentation (mm) assuming a neap tide with 35 cumec freshwater inflow and the annual average sediment load delivered to the estuary during a 12 storm event.

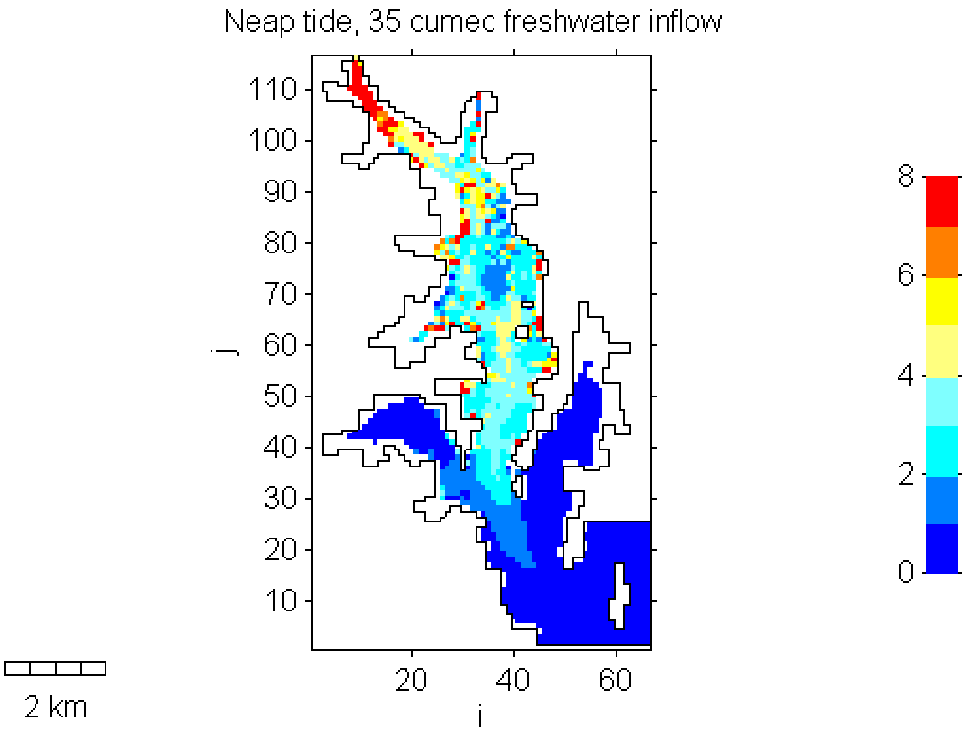
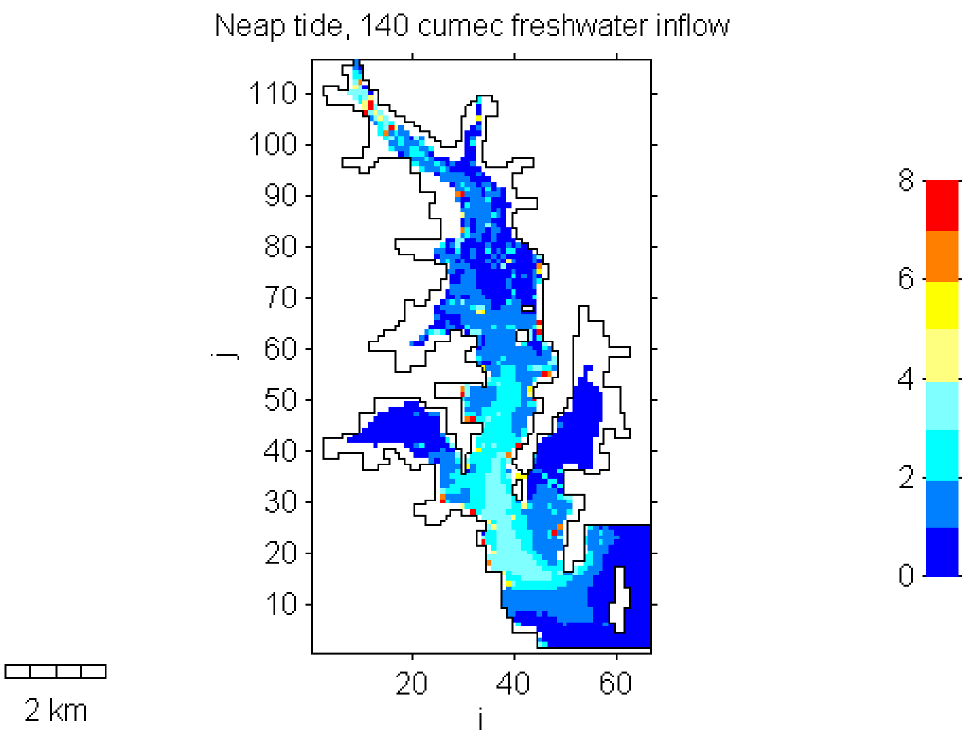


Figure 32.
Sedimentation (mm) assuming a neap tide with 140 cumec freshwater inflow and the annual average sediment load delivered to the estuary during a 12 storm event.



The following table gives the average build-up of sediment in the upper and lower estuaries:

Table 5.

Scenario runs for sediment plume modelling

Scenario	mm of sedimentation in Upper Estuary (upstream of Hamilton landing)	mm of sedimentation in Lower Estuary (downstream of Hamilton landing)
A	1.8	0.1
B	0.9	0.5
C	0.3	0.4
D	2.1	0.1
E	0.7	0.5
F	0.2	0.5

These deposition rates are in broad agreement with the figures predicted by Swales et al. (1997) from their coring investigations. Considering that the core data represents an integrated deposition rate, which includes significant change in estuary bathymetry, these results give us further confidence in the models capabilities to simulate the movement of suspended sediments within the estuary. Further model runs to investigate the role of different catchment derived sediment loads, duration of storms and timing of the arrival of the sediment to the estuary are to be carried out as part of the scenario modelling exercise in 1997.

11 Summary

This study set out to determine the movement and circulation of water in the Mahurangi estuary and the process of mixing within it. This has been achieved through the use of numerical hydrodynamic and transport/dispersion models. Use of these models will assist in assessing the effects of catchment-derived sediments and contaminants on the estuary environment.

12 Acknowledgements

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