Kaituna River Re-diversion and Ongatoro/Maketū Estuary Enhancement Project

Numerical Modelling

Final Report

June 2014

Bay of Plenty
REGIONAL COUNCIL

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Numerical Modelling

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APPENDICES

1 Executive Summary

The Bay of Plenty Regional Council (BoPRC) have commissioned DHI Water and Environment Ltd. (DHI) to carry out a numerical modelling assessment to assess the impact of a proposed re-diversion of the Kaituna River to the Ongatoro / Maketū Estuary and creation of new wetland areas. The assessment focuses on changes in the hydrodynamics, morphology and water quality of the lower river and estuary.

Historically the Kaituna River entered the sea via the Ongatoro / Maketū Estuary. Naturally occurring events and human intervention have regularly changed the amount of river water entering the estuary with evidence that the health of the estuary has deteriorated with the reduction of freshwater inflows to the estuary. A proposed option has been developed by BoPRC, to increase the volume of water entering the estuary from the river. This option will reduce or even reverse sedimentation within the estuary and in particular change the estuary entrance from a flood dominated system to ebb dominated system. This will reduce the further expansion of the flood delta, thereby hopefully reduce the risk of a breakthrough for the spit to the north of the flood delta. The proposed option is also designed to maximise the ratio of fresh water to salt water entering the estuary with the aim of re-establishing areas of salt marsh within the upper estuary.

To assess the potentially positive and negative impacts of the proposed option for typical and extreme conditions, a suite of numerical models were developed. An extensive field data collection campaign was carried out which included bathymetry, sediment grab samples, salinity profiles, wind and hydrographic data from selected locations within river, estuary and near shore environment. This data was then collated with existing data (from a variety of sources) to provide the field dataset used for setting up, calibrating and validating the models.

The numerical models were utilised to assess the hydrodynamic, morphological and water quality impacts of the proposed option, with emphasis on:

- Volume of additional water that will enter the estuary from the river through the proposed re-diversion channel.
- Morphology of lower river, estuary (particularly Papahikahawai Creek and flood tide delta), spit and river and estuary entrances for typical and extreme conditions.
- Flood risk for **lower Kaituna River**, estuary and in particular Maketū township.
- Overall salinity within the estuary for typical and extreme conditions.
- Risk of non-compliance with blue-green algae, shellfish collection and bathing suitability New Zealand guidelines within the lower estuary, due to increased pollutant loads from the river; and
- Nutrients concentrations for typical and extreme conditions within the estuary due to increased pollutant loads from the river.

There was no long term wave record for the study area; therefore a ten year wave hindcast was generated using Pacific Ocean and regional Bay of Plenty wave models. Based on this hindcast dataset a coastal sediment budget was performed for the study area using LITDRIFT, a numerical model for predicting littoral transport rates. The predicted easterly rate of 52,000 m^3/yr at the study site coastline is consistent with previous estimates calculated for this location. Previous estimates of the sediment budget for the Kaituna River have been assessed and were not considered significant compared with the sediment supplied by littoral transport to the site.

The predictions from the numerical modelling assessment produced the following key findings for the proposed option:

- The proposed option will significantly increase the volume of water that enters the estuary from the river and will significantly reduce the volume of water which enters the estuary through the estuary mouth.
- Within the lower river, it is unlikely there will be new areas of deposition of sediment.
- At present there is a risk of erosion of the inside of the spit north of the existing flood tide delta for typical conditions unless the delta reduces in size. This risk is increased for an extreme flood event with the proposed option in the short term, but will decrease in the long term subject to erosion of the flood tide delta.
- There is an increase in the risk of scour of the Ongatoro / Maketū Estuary entrance rock wall for significant flood events.
- The current rate of infilling for the estuary will be reduced. There is also the potential for long term erosion to occur within parts of the estuary, however depending on sediment supply from the river there is also the potential for deposition to occur in some areas, especially in the upper estuary.
- Although there will be additional flow through Papahikahawai Creek, there is no evidence that this will increase the risk of scour of the spit to the north of Papahikahawai Creek.
- The estuary mouth will switch from a flood dominated to an ebb dominated system. The current expansion of the flood tide delta will reduce and areas of the delta may even erode.
- There will not be a significant impact on swimming safety within the lower estuary.
- The proposed option will not have a significant impact on the morphological behaviour of the river mouth or estuary entrance for adverse or typical conditions.
- There will be an increase in the flood risk for low-lying parts of Maketū, however these areas of Maketū are already at risk from flooding (especially from elevated sea levels) for the existing situation. The flood risk decreases within the lower Kaituna River.
- Overall mean salinities will decrease throughout the estuary. The extent of this decrease in salinity is dependent on river flow and the location within the estuary.
- For mean flow conditions there will be no significant impact on the maximum upstream extent of the salt wedge in the Kaituna River, while for low river flow the maximum upstream extent of the salt wedge in the Kaituna River will shift 200 – 250 m upstream.
- There will be an impact on the flow to the Kaituna Wetland, however a way of compensating for this reduction in flow has been identified.
- There will be an increase in the salinities at the Titchmarsh intake within the lower Kaituna River, however BoPRC have provided a mitigation option to compensate for the increase in salinities.
- There will not be a significant impact on the percentage of time that the New Zealand guidelines for blue-green algae will be exceeded within the lower estuary.
- There will be a small impact on the percentage of time that the New Zealand guidelines for bathing suitability will be exceeded within the lower estuary.

- For the existing situation the New Zealand guidelines for shellfish gathering (specifically that concentrations of 43 faecal coliforms should only be exceeded 10% of the time) is not met. The proposed option further exacerbates this non-compliance.
- For the baseline and rain event nutrient assessments, it is predicted that the proposed option will only have a small impact on mean nutrient levels within the estuary

2 Introduction

BoPRC have commissioned DHI to carry out a numerical modelling assessment to assess the impact of a proposed re-diversion of the Kaituna River to the Ongatoro / Maketū Estuary and associated creation of new wetland areas. The numerical modelling study has focused on changes in hydrodynamics, morphology and water quality of the lower river and estuary.

2.1 Description of Study Area and Study Background

The Kaituna River and Ongatoro / Maketū Estuary are located in the central Bay of Plenty. The Kaituna River drainage catchment is approximately 1,250 km^2, about half of which drains into Lakes Rotorua and Rotoiti. The headwaters of the river are at the outlet of Lake Rotoiti at Okere Arm. The river passes through a steep, narrow gorge, before meandering through alluvial terraces of the mid Kaituna River and the peat and sand deposits of the lower Kaituna basin. The Kaituna River enters the sea through Te Tumu Cut (to the west of the township of Maketū). The managed outflows of the Rotorua and Rotoiti lakes contribute a large proportion of the Kaituna River baseline flows. Flood flows are significantly influenced by the Mangorewa River. Other significant tributaries include the Waiari Stream, Raparapahoe Canal and Kopuroa Canal. An overview of the study area is presented in Figure 2-1.

Figure 2-1 Study area overview.

There has been a long history of changes to the way that waters from the Kaituna River interact with the Ongatoro / Maketū Estuary as a result of both naturally occurring events and human intervention. Historically the Kaituna River entered the sea via the Ongatoro / Maketū Estuary. The river entered the estuary at the western end close to Papahikahawai Island. Previous drawings and photos suggest that the majority of flow was then directed to the south of

Papahikahawai Island with a small portion of flow passing through what is known as Papahikahawai Creek or Papahikahawai Channel.

Periodically the river would breach the spit and flow directly to the sea through what is now known as Te Tumu Cut. A large flood event caused this to occur in 1907. In 1922 a canal called Ford's Cut was excavated to encourage Te Tumu Cut to close and force the river flow back into the estuary; however a subsequent flood in 1928 caused another breach to occur close to Te Tumu Cut.

In 1957 as a part of the Kaituna Flood protection scheme a decision was made to force Te Tumu Cut to remain open and not allow the Kaituna River to flow into Ongatoro / Maketū Estuary. The Ford's Cut channel was closed off from the estuary. In this configuration only a small amount of river water was able to enter the estuary via seepage through stop banks between the river and estuary. It is widely acknowledged that the health of the estuary has deteriorated since this time, with a significant loss of marsh in the upper estuary (KRTA, 1986) and the reduction in the size of Papahikahawai Island. Ecological studies for this proposal have confirmed that the estuary, especially in its upper reaches, is in poor condition and is now dominated by sheets of macroalgae and cyanobacteria. The decomposition of this organic matter combined with the lack of currents to flush them out of the estuary have created anoxic conditions unsuitable for many of the organisms expected in such environments (River Lake Ltd, 2014).

Without the additional flushing from the river a large amount of sedimentation has occurred within the estuary. Domijan (2000) calculated that 150,000 m^3 or 13,640 m^3/yr was lost from inter tidal storage between 1985 and 1996. During this period the Ongatoro / Maketū Estuary entrance also changed from an ebb tide dominated entrance to a flood tide dominated entrance. The flood tide delta has significantly grown since the river was diverted from the estuary and is now seen as a major reason for periodic breaches of the spit that occur to the north of the flood delta. When these breaches occur there is a significant increase in the amount of sediment which enters the estuary from the sea, which further increases the infilling rate for the estuary.

In 1996 a partial re-diversion of river flows from the river to the estuary was achieved by constructing four flap gated culverts to allow limited flow through Ford's Cut channel. The flap gates were designed to allow 100,000 m^3 of river water through Ford's Cut channel per mean tidal cycle, however subsequent studies predict that this volume of river water is approximately 150,000 m^3 (DHI, 2009).

Although the Ford's Cut re-diversion has been shown to reduce the salinity in the upper part of the estuary (Park, 2003), there is no evidence that the additional volume of water to the estuary has reduced the infilling of the estuary or restored any wetlands. The estuary is still flood tide dominated, and there is a continued risk of the breakthrough of the spit to north of the flood tide delta.

For this reason, numerous studies (including unpublished reports and technical notes) have been carried out since the 1996 Ford's Cut partial re-diversion to determine realistic options for further increasing the volume of water which enters the estuary from the river. These include the following key reports:

- Re-diversion of Kaituna River into Ongatoro / Maketū Estuary: Hydraulic Modelling and Costing, Phil Wallace (2007).
- Kaituna River to Ongatoro / Maketū Estuary Re-diversion – Recommended Options, Phil Wallace (2008).
- Kaituna River to Ongatoro / Maketū Estuary Re-diversion: Model Calibration and Initial Hydrodynamic Impact Assessment, DHI (2009).

- Lower Kaituna River – Ongatoro / Maketū Estuary: Initial Water Quality Modelling, DHI (2011).

Proposed options have had to balance the following three main requirements:

- the local community and Iwi's wish for the river and estuary to be returned to its natural state;
- local governments requirement that Te Tumu Cut remain open for flood release; and
- cost of construction and maintenance.

With awareness of these constraints, a re-diversion option has been proposed that attempts to maximise the volume of water which enters into the estuary from the river per tidal cycle while also maximising the freshwater component of this total volume of water into the estuary. This option also has the benefit of the creation of a new wetland area as shown in Figure 2-2. The new entrance from the river to the re-diversion channel is significantly further upstream than the existing situation. The reason for this is that the salt wedge that propagates upstream within the river on the flood tide will have to travel further upstream to be able to enter the estuary through the re-diversion channel.

Figure 2-2 Overview of proposed re-diversion option.

2.2 Study Objectives

The objective of the hydrodynamic and morphological aspects of the study was to carry out an assessment of the impact of the proposed option on the hydrodynamics and morphology of the Kaituna River and Ongatoro / Maketū Estuary so that the following could be assessed:

- The additional volume of water to the estuary from the river and the changes to the overall hydrodynamics of river and estuary?
- Changes to the current rate of infilling of the estuary and behaviour of the flood tide delta at the estuary entrance;
- Potential for scour to occur in the estuary in undesirable locations;
- Swimmer safety within the lower estuary;
- Changes to the morphological response of the estuary entrance and river mouths for adverse and typical conditions with emphasis on navigation through both entrances; and
- Any increase in flood risk for the estuary and specifically the Maketū township.

The objective of the water quality component of the study was to make a broad comparative assessment of the impact of the proposed option on the water quality of the Ongatoro / Maketū Estuary with emphasis on the following:

- Changes to the overall salinities that will occur within the estuary;
- Any increase to the risk of a blue-green algae bloom occurring in the estuary;
- Negative impacts on bathing water suitability and shellfish collection at key sites within estuary from the additional polluted river water entering the estuary; and
- Likely changes to nutrient concentrations within the estuary with additional nutrient rich river water entering the estuary.

2.3 Modelling Approach

The detailed numerical modelling assessment described within this report investigates and compares the performance and impact of a proposed option for diverting additional flow from the Kaituna River flow to the Ongatoro / Maketū Estuary to the existing situation. A suite of numerical models has been developed, calibrated and applied to aid in this assessment. Table 2-1 presents an overview of all the numerical models that were used for this study and how the models were applied.

Table 2-1 Outline of models applied in study.

Area of Application	**Model**	**Purpose**	**Input Data**	**Provides Data to ..**
Wave climate	DHI Pacific Ocean wave model (MIKE 21 SW).	Generate boundary conditions for regional wave model.	CCMP global winds.	Regional wave model.
	Regional Bay of Plenty wave model (MIKE 21 SW).	Generate 10 year wave data time series at study site.	Pacific Ocean wave model and NOAA global winds.	LITPACK, local wave model component of morphological model.
	Local wave model (MIKE 21 SW)	Wave component of morphological model	Wave data from regional wave model	Local morphological model.
Littoral sediment processes	LITPACK (LITDRIFT module).	Calculate long term littoral sediment transport rates.	10 year wave data time series, water levels, beach profiles and sediment properties.	Coastal impact assessment.
Coastal hydrodynamics	Regional hydrodynamic model (MIKE 21 HD FM)	Generate boundary conditions for 2D local hydrodynamic model.	KMS predicted tides and NOAA global winds.	Local 2D hydrodynamic model.
Coastal, river and estuary hydrodynamics	Local 2D hydrodynamic model (MIKE 21 HD FM)	Hydrodynamic component of morphological model and generate boundary conditions for 3D hydrodynamic model.	Tide, river and other significant inflows and estuary wind data.	Local morphological model and local 3D hydrodynamic model.
Salinity distribution	Local 3D hydrodynamic model (MIKE 3 HD FM)	Assess salinity distribution within river and estuary	River flow and other significant inflows, downstream boundary conditions from Local 2D hydrodynamic model	Salinity distribution assessment
Water quality	Local 3D hydrodynamic model – river only (MIKE 3 HD FM)	Assess blue-green algae, bacteria and nutrient concentrations which enter estuary from river.	River flow and other significant inflows, downstream boundary conditions from Local 2D hydrodynamic model	Local 2D hydrodynamic model – no river
	Local 2D hydrodynamic model – no river (MIKE 21 HD FM)	Assess blue-green algae, bacteria and nutrient concentrations within estuary	Upstream boundary conditions from Local 3D hydrodynamic model – river only, tide	Water quality assessment

Area of Application	Model	Purpose	Input Data	Provides Data to ..
River mouth and estuary (including estuary mouth) hydraulics and morphology	Morphological model - sediment transport (MIKE 21 ST) coupled with local hydrodynamic (MIKE 21 HD FM) and wave models (MIKE 21 SW)	Assess effects of coastal sediment processes and river and estuary processes including impact of flood events on water levels	Tide, river and other significant inflows inflow data, sediment properties, estuary wind data.	Assessment of behaviour of morphological river and estuary including flood level assessment.

2.4 Projection and Datum

The study was carried out using Moturiki Vertical Datum and New Zealand Transverse Mercator coordinate system.

3 Data Collection

This chapter focuses on data made available for the study from existing sources and new data that were collected specifically for the study. Data collection campaigns were carried out by Discovery Marine Ltd (DML), Cawthron Institute (Cawthron), New Zealand Institute of Water and Atmosphere (NIWA) and BoPRC. An overview of the data is provided in Table 3-1 along with a description of how the data has been utilised for this study.

Table 3-1 Overview of data utilised for this study.

Data Type	Description	Supplier	Time Frame	How Data Utilised	Issues
Bathymetry	Single and multibeam survey	DML	March / April 2013	Estuary ebb delta, surf zone, lower Kaituna River including ebb delta.	None
	Single beam survey	BoPRC	March / April 2013	Kaituna River bathymetry upstream of DML survey.	None
	C-MAP	DHI	N/A	Open ocean model bathymetry offshore of LiDAR coverage.	None
	LiDAR	BoPRC	May 2013	Estuary and open ocean bathymetry.	Surf zone turbidity affected data.
	Beach profiles	BoPRC	1978 to 2013	Long term littoral processes assessment using LITPACK.	None
Hydrographic	Ford's Loop - Water levels	BoPRC	March / April 2013	Calibration of 2D and 3D local hydrodynamic models.	None
	Ford's Cut – Water levels and currents	Cawthron	March / April 2013	Calibration of 2D and 3D local hydrodynamic models.	None
	Mid estuary – Water levels and currents	Cawthron	March / April 2013	Calibration of 2D and 3D local hydrodynamic models.	Instrument sunk in mud, therefore currents unusable.
	Estuary entrance – Water levels and currents	Cawthron	March / April 2013	Calibration of 2D and 3D local hydrodynamic models.	Instrument periodically covered with Ulva, therefore current data patchy.
	Offshore of Okurei Point – Water levels and currents	Cawthron	March / April 2013	Calibration of 2D and 3D local hydrodynamic models.	None
	Offshore of Okurei Point – Significant wave height, mean wave direction,	Cawthron	March / April 2013	Calibration of local wave model.	None
	13km off Pukehina	BoPRC	2003 to	Calibration of regional	None

Data Type	Description	Supplier	Time Frame	How Data Utilised	Issues
	Beach Significant wave height, mean wave direction, wave period.		2010	wave model.	
Sediment Grab Profiles	River, estuary and open ocean	DML	April 2013	Sediment characteristics for morphological and LITPACK models.	None
Flow Transects (Full Tidal Cycle)	River mouth, Ford's Cut culverts, estuary entrance	BoPRC and NIWA	4th April 2013	Calibration of 2D local hydrodynamic model.	None
	Offshore of Okurei Point	DML	4th April 2013	Validation of 2D local hydrodynamic model.	None
Freshwater inflows	Inflows for significant freshwater sources	BoPRC	1990 – 2013 or March / April 2013	Analysis of flow occurrence. Inflows for local 2D and 3D hydrodynamic and water quality models.	None
	1% and 5% AEP design hydrographs for significant sources	BoPRC	N/A	Inflows for morphological model	None
Drains flows	Base and rain event inflows for significant contributors of pollutant to estuary.	BoPRC	N/A	Inflows for local 2D and 3D hydrodynamic and water quality models.	None
Salinity Profiles	River and estuary	BoPRC	4th April 2013	Calibration of 3D local hydrodynamic model	None
Salinity	Ford's Cut, mid estuary and estuary entrance	Cawthron	March/ April 2013	Calibration of 3D local hydrodynamic model	Mid estuary instrument stuck in mud, therefore salinity data unusable.
Water Quality	Blue-green algae, bacteria and nutrient data within estuary and river.	BoPRC	1990 - 2013	Generation of appropriate model boundary conditions. Water quality model validation.	A lot of data set not collected simultaneously
Climate	CCMP wind	PODACC	2000 – 2010	Forcing for regional and local wave models.	None
	NOAA wind	NCEP	March/ April 2013	Forcing for regional wave and hydrodynamic models.	Very patchy data set both temporally and spatially
	Wind from estuary	NIWA	March/ April 2013	Forcing for local wave and hydrodynamic models.	None
	Tauranga Atmospheric Pressure	BoPRC	March/ April 2013	Assess impact of atmospheric pressure on water levels.	None

3.1 Bathymetry

An accurate and reliable bathymetry is a key component of a hydraulic model. A good bathymetry will significantly improve the calibration and therefore accuracy of such a model and will ensure important processes (such as flow and wave behaviour) can be simulated by the model. The bathymetry data used for this study, obtained from a number of sources, has been described below.

3.1.1 DML Survey – Estuary, Nearshore, Entrances

DML were commissioned to carry out a bathymetry survey for the lower Kaituna River, navigable areas of Ongatoro / Maketū Estuary, both the river and estuary entrances and the nearshore area in the vicinity of the Ongatoro / Maketū Estuary and around Okurei Point. Data was collected as a combination of single beam or multi beam surveys, DML (2013). Surveys were undertaken in early March through to mid-May 2013 with the final coverage of surveys as shown in Figure 3-1.

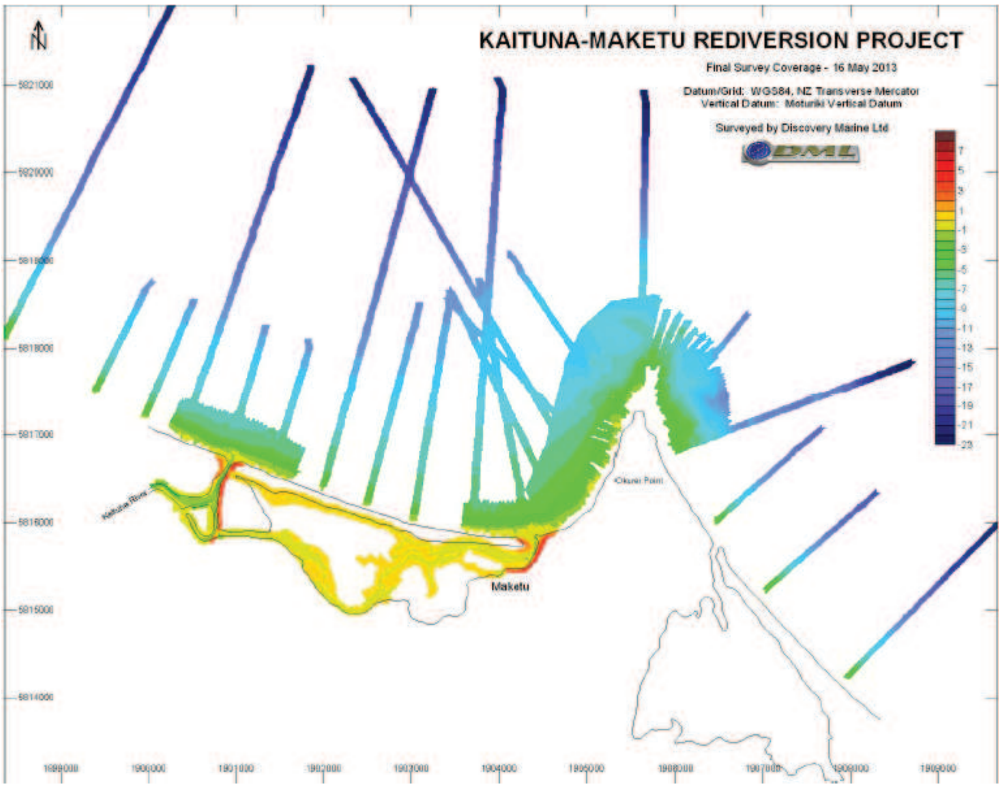


Figure 3-1 DML bathymetry survey (source: DML (2013)).

After a heavy rainfall event occurred in the Bay of Plenty partway through the study, resulting in elevated flows in the Kaituna River, DML were requested to re- survey the Kaituna River mouth, to determine the changes to the bathymetry of the river mouth as a result of the flood. The pre flood survey for the Kaituna River mouth was undertaken 1st – 2nd April 2013, while the post flood survey was undertaken between 17th - 26th April 2013. The pre and post flood surveys are presented in Figure 3-2.

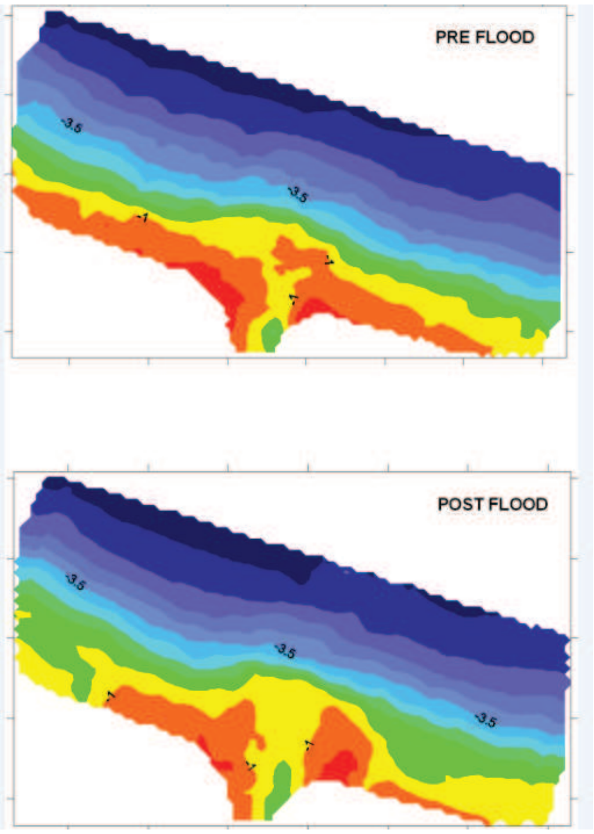


Figure 3-2 Pre (top) and post (bottom) flood bathymetry surveys for Kaituna River mouth (source: DML, (2013)). Depth contours at 0.5 m intervals.

3.1.2 BoPRC Survey – Kaituna River

BoPRC carried out a bathymetry survey of the lower Kaituna River downstream of the Te Matai Bridge in March 2013 using a single beam sounder. The coverage of the survey data is shown in Figure 3-3.

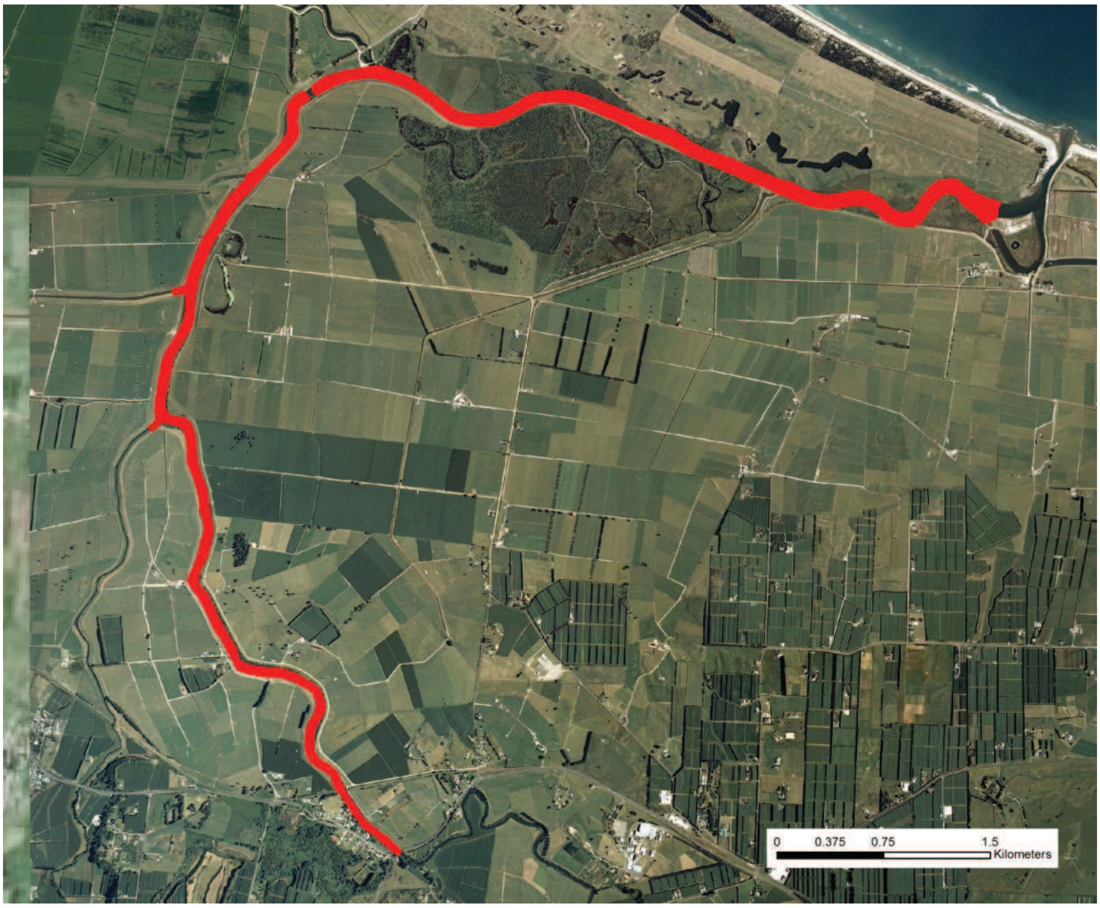


Figure 3-3 BoPRC bathymetric survey of Kaituna River.

3.1.3 C-MAP – Offshore

Bathymetry data from offshore areas was obtained from MIKE C-MAP. C-MAP^{TM} is a world electronic chart database which provides easy extraction of depth data from almost any location in the world relative to Chart Datum.

3.1.4 LiDAR – Shallow Water and Topography

LiDAR data was provided for the study area by BoPRC. The LiDAR survey was undertaken in May 2013 by Fugro LADS Corporation Pty Ltd (Fugro) and through the use of two different sensors, both topographic (above water surface), through LADS MK3 sensor, and bathymetric (below water surface) data, though a RIEGL sensor, was obtained. An overview of the LiDAR survey is presented in Figure 3-4. Further details of the survey can be found in Fugro (2013). DML carried out a comparison of their surveyed bathymetry data compared with the LiDAR data (DML, 2013). DML concluded that the spatial resolution of the LiDAR data provided a superior source for bathymetry data within the estuary and deeper areas of the near-shore zone. However, within the surf zone there was an issue with LiDAR data due to high turbidity so that DML data was used in preference to LiDAR in this area.

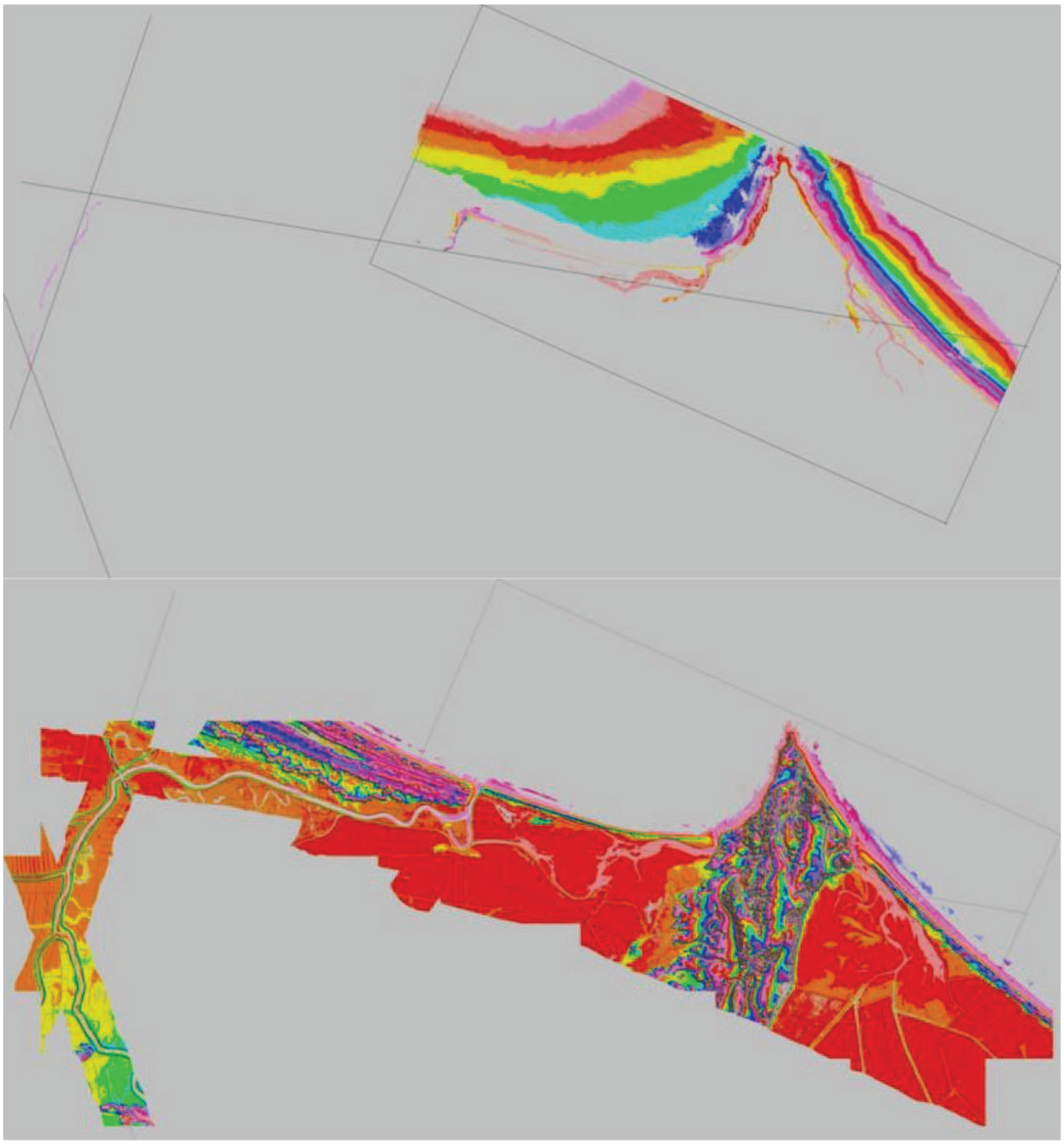


Figure 3-4 Overview of LiDAR survey - RIEGL Coverage below the water surface (top) and LADS Mk3 Coverage above the water surface (bottom) – (Source: DML, 2013).

3.1.5 Beach Profiles

Historical beach profiles have been collected by BoPRC since 1978 at numerous locations along the Bay of Plenty coastline. BoPRC provided the profiles within the vicinity of Maketū. The location of the profiles which were utilised in this study are shown in Figure 3-5. The profiles provide useful insight into the long shore sediment processes for the study area.

Figure 3-5 Historical beach profile locations in the vicinity of Maketū.

3.2 Hydrographic Data Collection

Hydrographic data within the vicinity of the study site during March and April 2013 was collected by Cawthron, DML, BoPRC and NIWA. An overview of the hydrographic data which was collected is shown in Figure 3-6.

Figure 3-6 Locations for all hydrographic data collection (top) and hydrographic data collection within river and estuary only (bottom).

3.2.1 Water Level, Current, Salinity and Wave Measurements

3.2.1.1 River

BoPRC provided water levels from Kaituna River at the permanent water level gauge in Ford's Loop for the period 20th March to 29th April 2013. The water level measurements (in Moturiki Vertical Datum) are presented in Figure 3-7. Two significant rainfall events resulting in elevated river levels (especially for the low tide water levels) occurred on the 17th and 22nd April 2013.

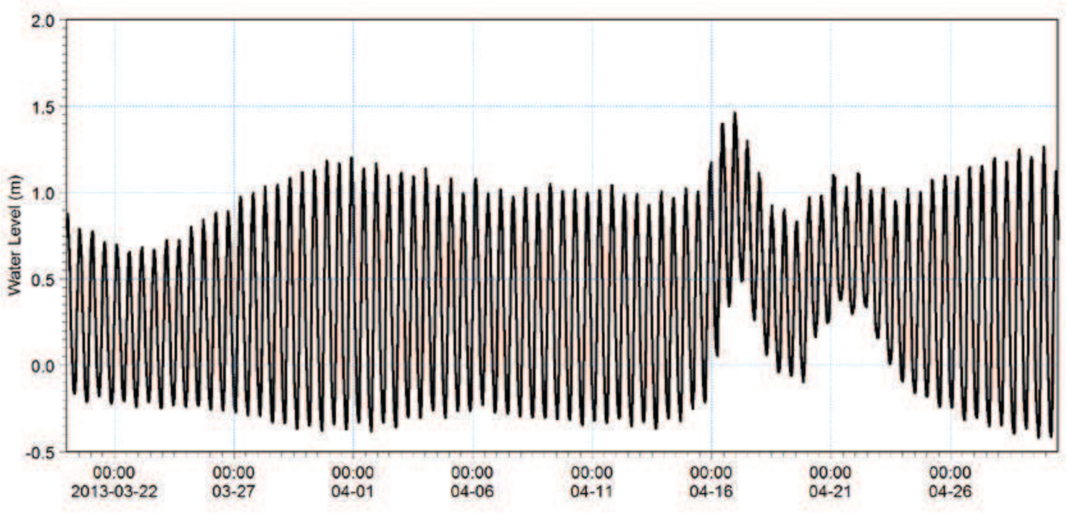


Figure 3-7 Measured water levels (Moturiki Datum) in the Kaituna River at Ford's Cut.

3.2.1.2 Estuary

Cawthron deployed current meters with pressure sensors (to measure water depth) and conductivity measuring devices (to measure salinity) at three locations within the estuary as shown in Figure 3-6.

These three instruments were deployed from 20th March to 29th April 2013. There were some issues with the current measurements for two of these instruments. Cawthron observed that the instrument deployed in the mid estuary had sunk into the mud when it was retrieved. We suspect that this may have happened reasonably early during the deployment period and unfortunately the resulting data appears to be mostly erroneous. There was also an issue with the instrument located within the vicinity of the estuary entrance due to the build-up of Ulva over the instrument as shown in Figure 3-8. A local resident was employed to periodically clean the instrument to deal with the Ulva, however we suspect that the Ulva returned at a faster rate than expected after cleaning of the instrument. This unfortunately has affected the current speeds recorded by the instrument.

Currents speeds from the estuary entrance instrument and times when the instrument was cleaned (12 cleanings in total) are presented in Figure 3-9. It is apparent after cleaning that current speeds typically increased (i.e. period after 3rd and 9th cleaning) with evidence of relatively rapid decline in observed currents between cleanings (i.e. period towards 3rd and 12th cleaning). As a consequence we believe for the majority of the time that the measured current speeds were less than those that were occurring at this location.

Figure 3-8 Fouling of current meter by Ulva. Instrument was deployed in vicinity of estuary entrance (see Figure 3-6).

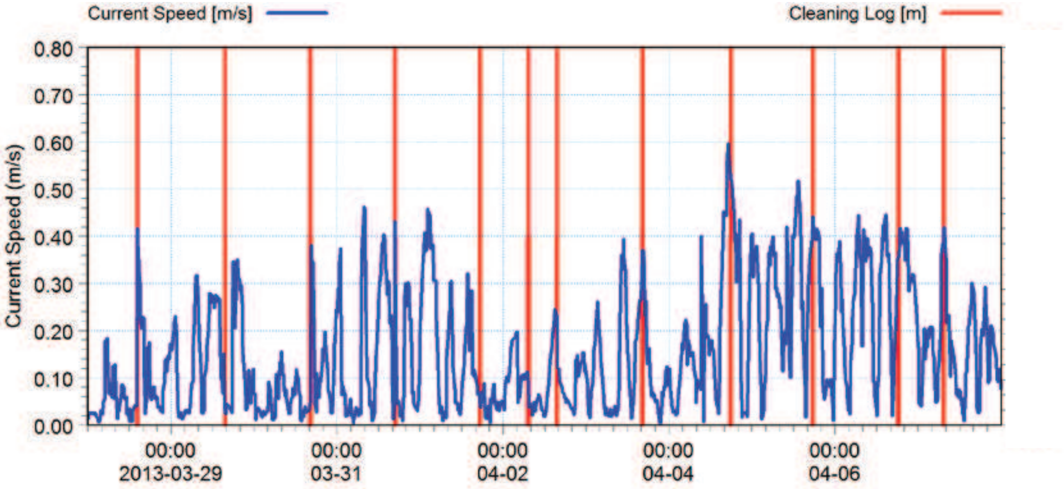


Figure 3-9 Current speed from estuary entrance instrument. Red line indicates times when the instrument was cleaned of Ulva.

Currents rose plots for the current measurements are presented in Figure 3-10. The current data from the Ford’s Cut channel location was as expected, with the highest currents speeds in an easterly direction as a result of the flow through the Ford’s Cut culverts. The direction of flow from the estuary entrance location is as expected with a predominant flow direction consistent with the direction of the estuary channel. The current rose plot from the mid estuary location is only in one direction which is not as would be expected for this location. The instrument was either located in an unexpected local eddy or the data has been compromised by the fact the instrument has sunk into the soft mud.

The water level measurements (in Moturiki Datum) from the three locations within the estuary are presented in Figure 3-11. Similar to the permanent gauge at Ford Loop, elevated water levels are evident for the higher river flows on the 17th and 22nd April 2013.

The salinity measurements are presented in Figure 3-12. The measurements from the mid estuary appears to trend downwards throughout the deployment period. This maybe a result of fouling of the conductivity measuring device or the device sinking into the soft mud which was observed for the mid estuary site. Unfortunately this data had to be treated as erroneous.

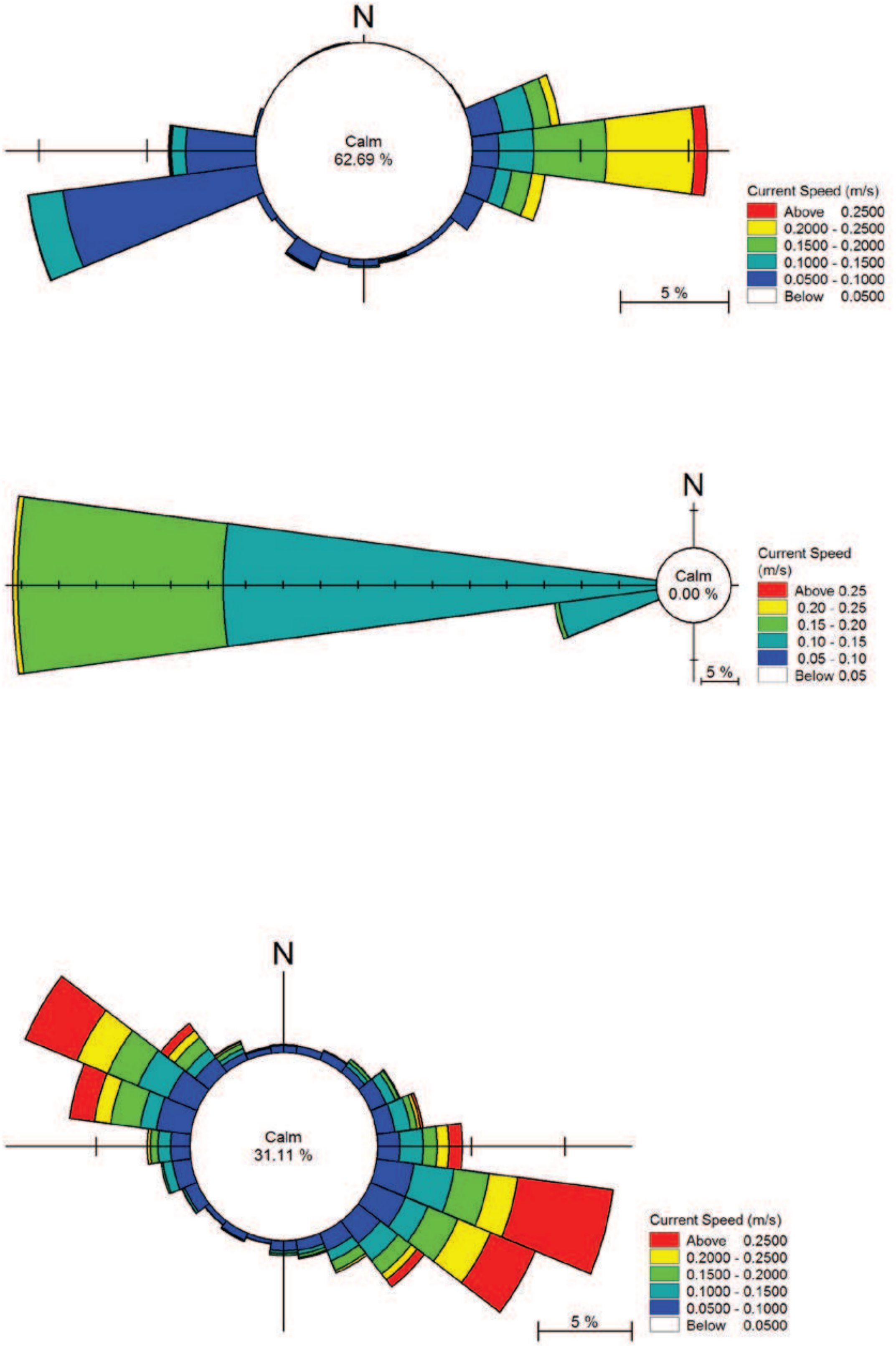


Figure 3-10 Current roses of current data from instruments deployed within Ongatoro / Maketū Estuary at Ford’s Cut channel (top), mid estuary (middle) and estuary entrance (bottom).

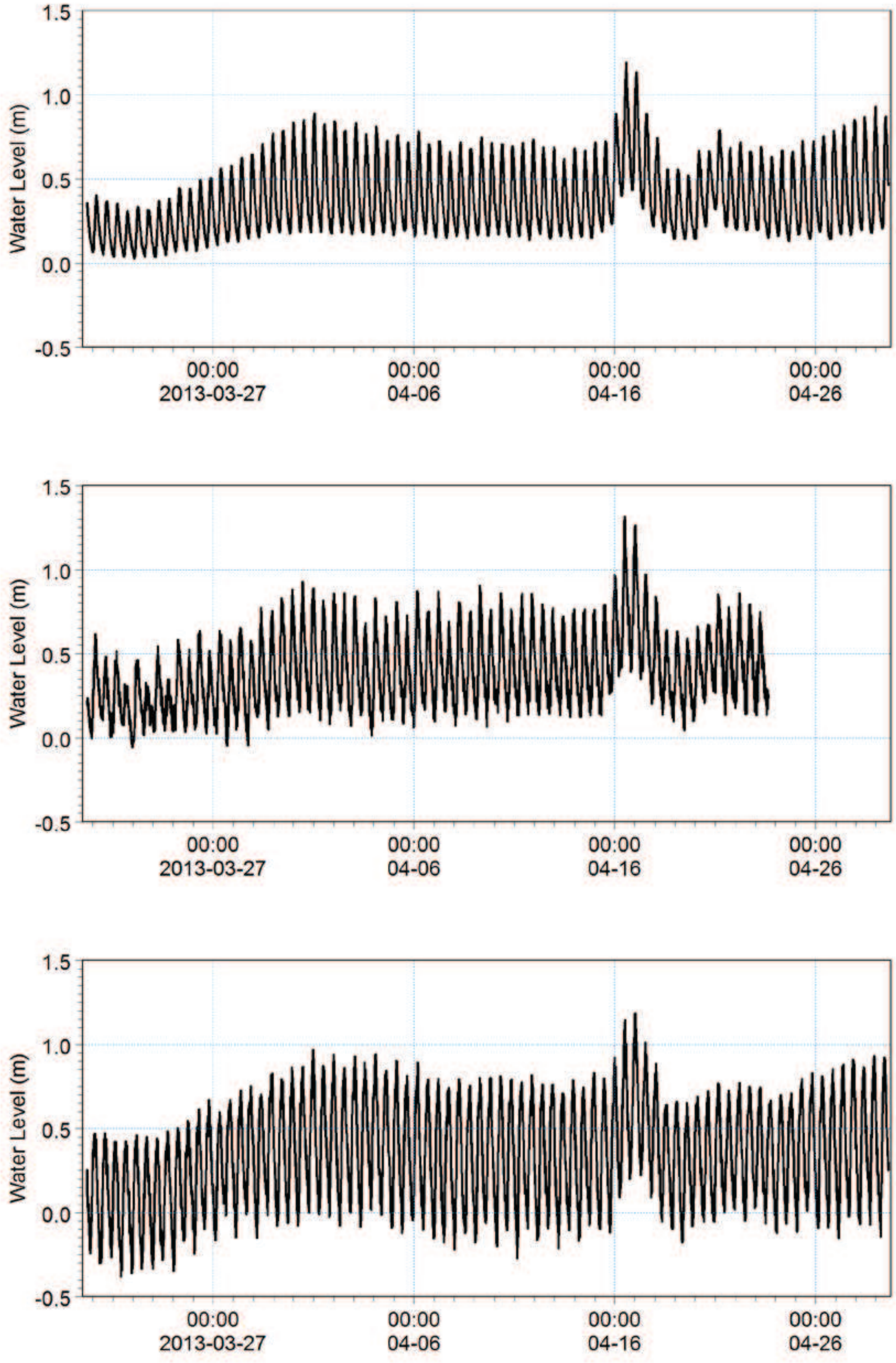


Figure 3-11 Water level measurements (Moturiki Datum) from instruments deployed within Ongatoro / Maketū Estuary at Ford’s Cut channel (top), mid estuary (middle) and estuary entrance (bottom).

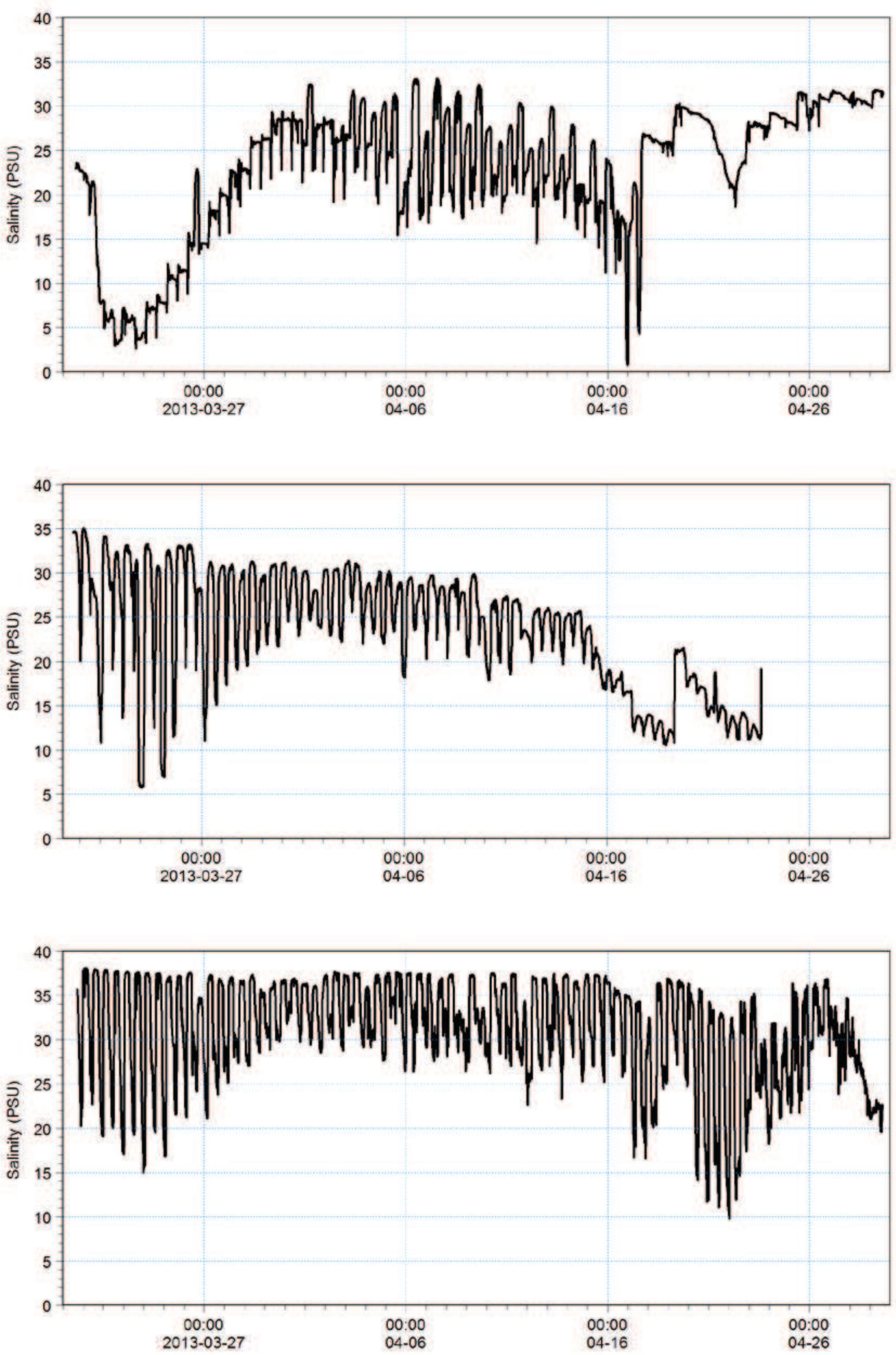


Figure 3-12 Salinity measurements from instruments deployed within Ongatoro / Maketū Estuary at Ford’s Cut channel (top), mid estuary (middle) and estuary entrance (bottom).

3.2.1.3 Nearshore

An ADCP with a wave gauge was deployed by Cawthron for the period 21st March to 30th April 2013 offshore from Okurei Point at a depth of approximately 20 m. The ADCP measured currents, water levels (derived from pressure) and waves. Currents from 2 m, 10 m and 19 m above the seabed are presented in Figure 3-13. Depth averaged currents have also been calculated and are presented in Figure 3-13. For the currents from the middle of the water column and the depth averaged currents, the current direction is in predominantly in an easterly and westerly direction. The current direction at the sea bed is predominantly in a south-westerly and easterly direction. There is a higher variation in current directions at the sea surface. Observed water levels are presented in Figure 3-14.

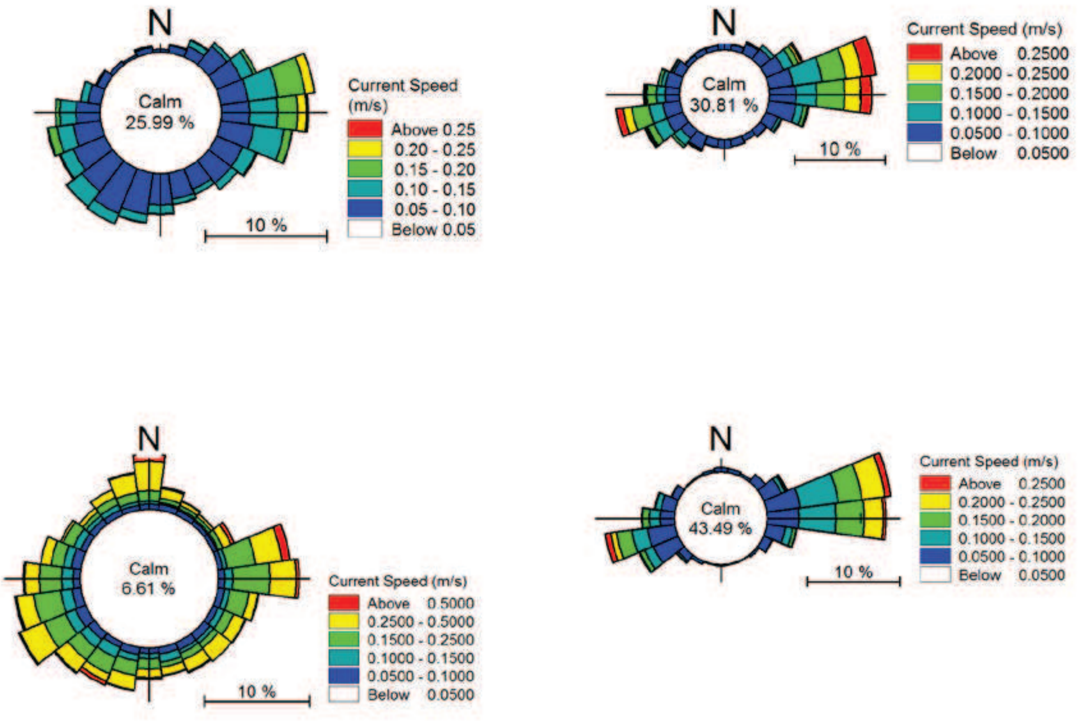


Figure 3-13 Current roses of current data from ADCP deployed offshore from Okurei Point. Current roses presented for 2 m above seabed (top left), 10 m above seabed (top right), 19m above seabed (bottom left) and for depth averaged currents (bottom right).

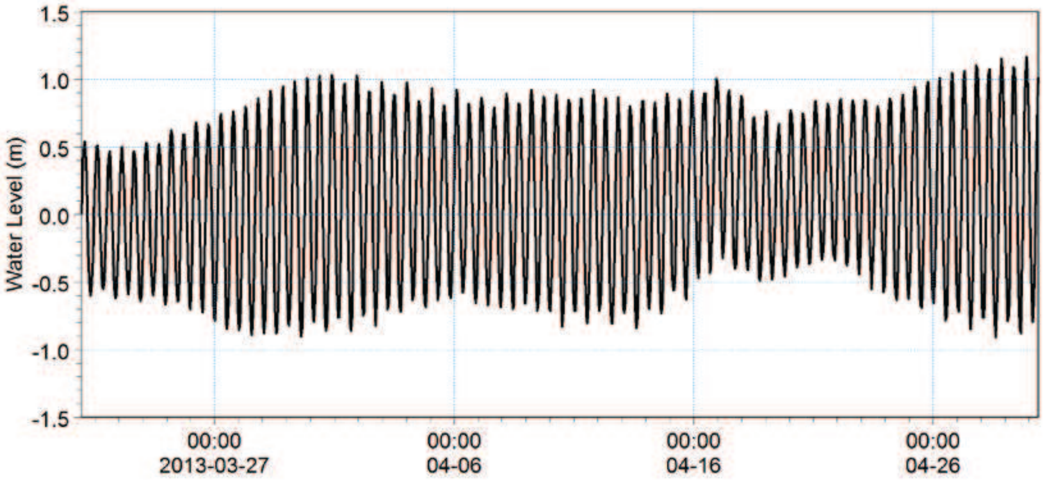


Figure 3-14 Measured water level (Moturiki Datum) offshore from Okurei Point.

The wave data from the deployment is presented in Figure 3-15. There are several significant wave events that occurred during the deployment period, with large events (significant wave heights > 2.0 m) occurring on the 17th and 20th of April 2013 (concurrent to the observed elevated river levels shown in Figure 3-7). For the whole deployment period the waves direction is predominantly from the north westerly direction which is consistent with the predicted wave climate in Bay of Plenty for March and April (see Section 4.2).

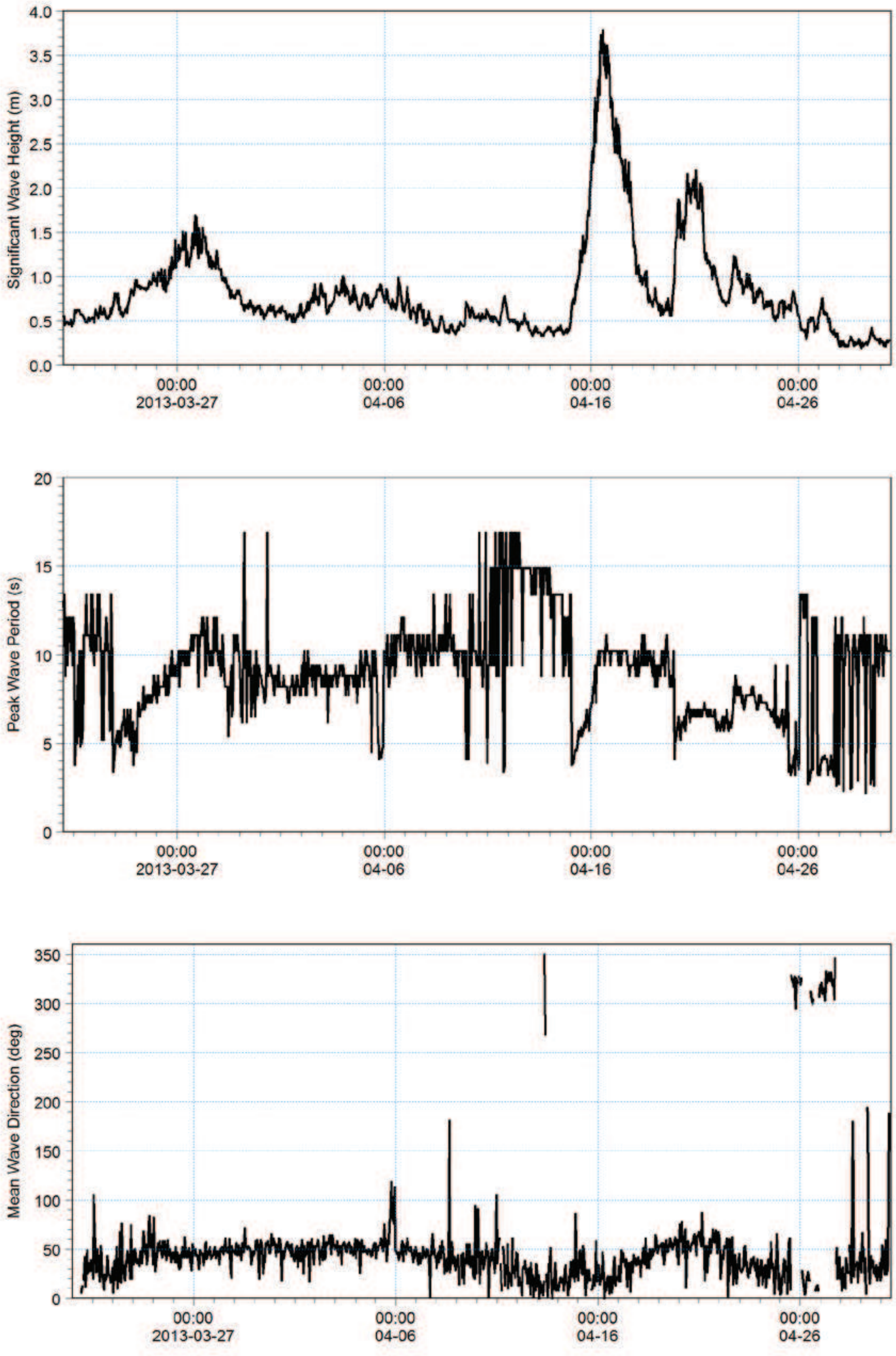


Figure 3-15 Significant wave height (top), peak wave period (middle) and Mean Wave Direction (bottom) offshore from Okurei Point.

3.2.2 ADCP Flow Transects

Flow measurements were collected using a downward facing ADCP along the transects shown in Figure 3-6 as follows;

- the Kaituna River mouth;
- the Ongatoro / Maketū Estuary entrance;
- the river side of the Ford’s Cut culverts; and
- an offshore normal transect from Okurei Point.

3.2.2.1 ADCP Transects at Kaituna River Mouth and Ford’s Cut Channel

BoPRC collected flow measurements on the 4th April 2013 along two transects, one inside the entrance of Kaituna River mouth and the other on the river side of the Ford’s Cut culverts. For the Kaituna River mouth, transect measurements were carried out for approximately a full tide cycle, while for the Ford’s Cut channel measurements were only made around the time when flow was able to pass through the flap gated culverts. The flow measurements for the two transects are shown in Figure 3-16. There was flow through the Ford’s Cut culverts for approximately four and a half hours, commencing at approximately 10:00 am and concluding at 2:30 pm.

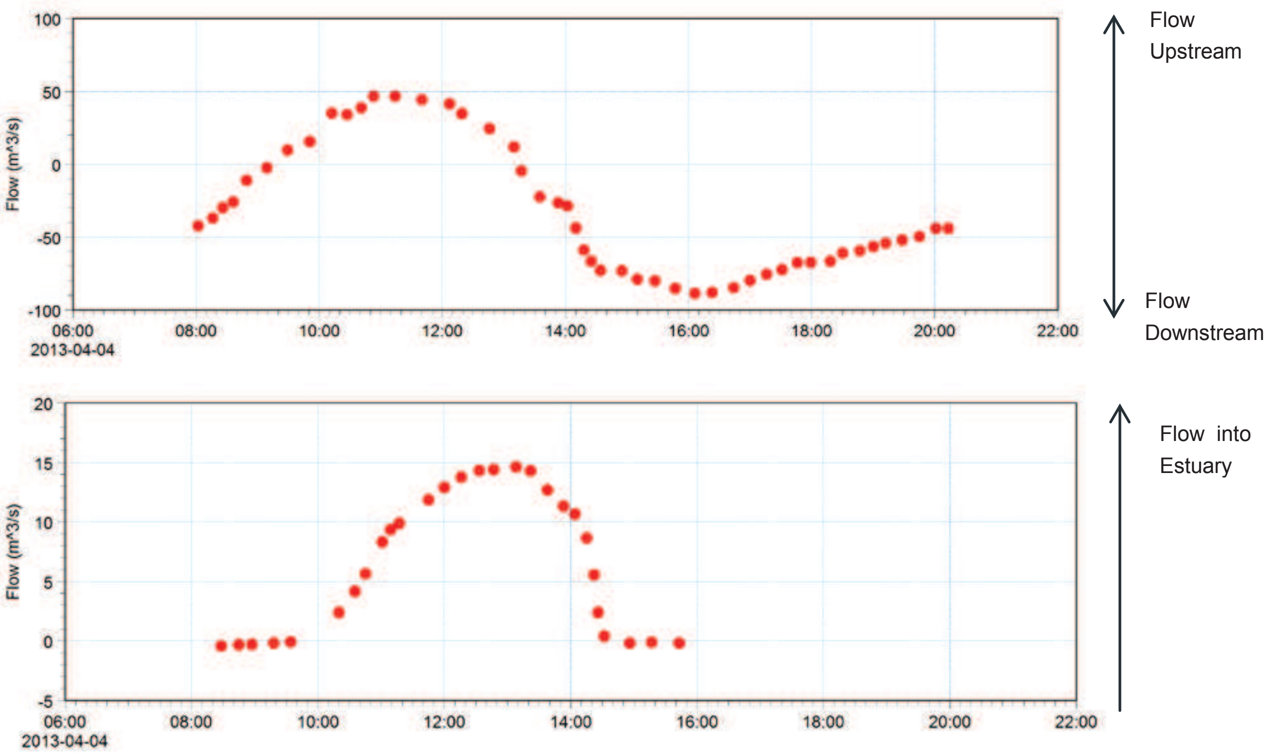


Figure 3-16 Measured flow through transect at Kaituna River Mouth (top) and at Ford’s Cut channel (bottom). Positive flow indicates flow upstream or into the estuary.

3.2.2.2 ADCP Transect at Ongatoro / Maketū Estuary Entrance

NIWA collected flow measurements on the 4th April 2013 within the estuary entrance. Measurements were collected for a full tidal cycle and are shown in Figure 3-17.

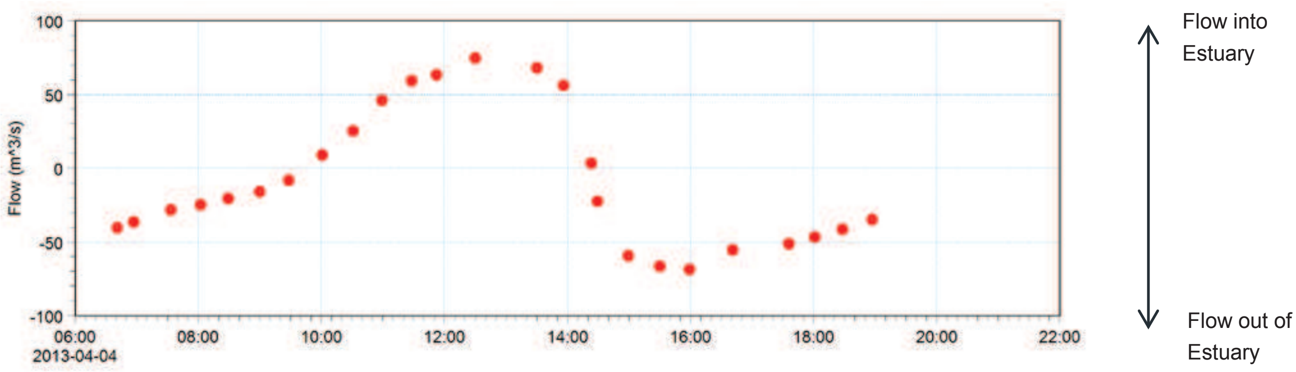


Figure 3-17 Measured flow through transect within estuary entrance. Positive flow indicates flow into estuary.

3.2.2.3 ADCP Transect Normal of Okurei Point

DML collected flow measurements on the 4th April 2013 along a 9 km transect normal from Okurei Point. Measurements were collected for a full tidal cycle and are shown in Figure 3-18.

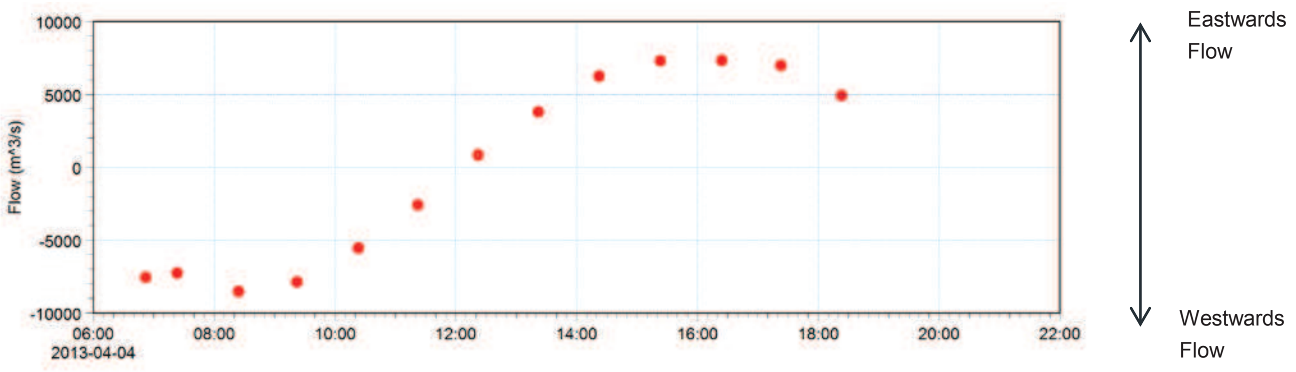


Figure 3-18 Measured flow through transect off Okurei Point. Positive flow indicates flow towards the east.

3.2.3 Water Level Data from Moturiki Island

Water level data was provided by NIWA from Moturiki Island for the period 16th to 27th May 2005 to coincide with flooding that occurred in Maketū area 18th to 19th May 2005.

3.3 River Flow Data

BoPRC have provided flow data for the Kaituna River at Te Matai bridge and Raparapahoe Canal (a significant tributary downstream of Te Matai bridge) for the period 1st January 2000 to 1st January 2013 and 1st March to 1st May 2013. NIWA provided flow data for Waiari Stream which is another significant tributary downstream of Te Matai bridge, for the period 1st January 2000 to 1st January 2013 and 1st March to 1st May 2013. The flow data for March and April 2013 is presented in Figure 3-19. Flow data for the Kaituna River at Te Matai bridge from 1990 to 2000 was available from a previous study (DHI, 2009).

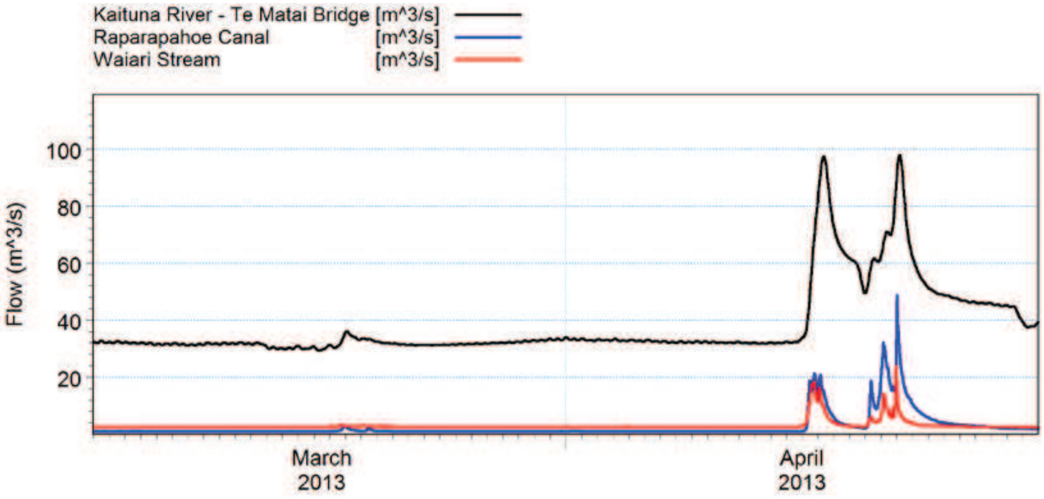


Figure 3-19 River inflow data for Kaituna River at Te Matai bridge, Waiari Stream and Raparapahoe Canal.

The flow data at Te Matai included tidal spikes as shown Figure 3-20. The flow at the gauge is derived from a rating curve which calculates the flow resulting from a measured water level, when the flow is low enough in the river, the tide is able to propagate up to the gauge, which results in an increase in the water level at high tide. The rating curve assumes that the increased water level is associated with an increased river flow, which results in a tidal spike in the flow data.

It is acknowledged that since the Te Matai gauge is influenced by the tide unfortunately it is not an ideal location for assessing low flows within the Kaituna River. For this reason BoPRC have a technique for removing the influence of the tide from the flow record for low river flows. A section of the de-tided flow is also shown in Figure 3-20.

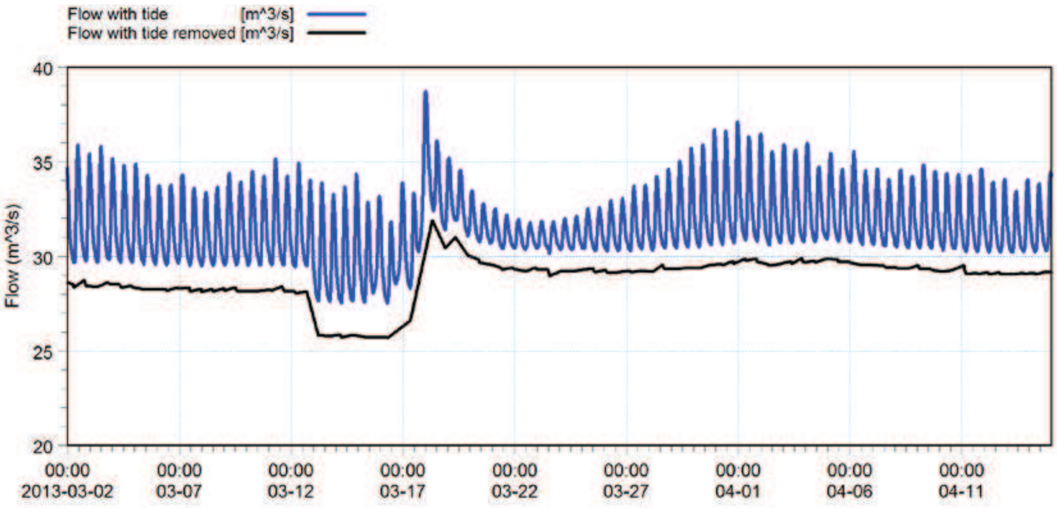


Figure 3-20 Flow at Te Matai gauge with influence of tide (blue) and derived de-tided flow (black) for period 2nd March to 15th April 2013.

Further investigation of the de-tided flow data and resulting discussion with BoPRC indicated that there is a possibility that it is overestimated for the period 2nd March to 15th April 2013. There were two main reasons for this:

1. Tree clearance, engineering works and flooding within the Kaituna River may be having an effect on the Te Matai rating curve (Ellery, pers Comms, 2013). The last rating curve was derived in 2005 and historic revisions of the rating curve have resulted in lower flows for a given water level.

2. On the date of the extensive data collection (4th April 2013) the de-tided flow provided by BoPRC was approximately 29.5 m^3/s. The measured flow at the two upstream gauges was 5.0 m^3/s for Mangorewa Stream (a major tributary to the Kaituna River) and 13.2 m^3/s at Taaheke (close to Okere gates which is the source of the Kaituna River). The combined flow for these gauges accounted for 62% of predicted de-tided flow at Te Matai. It is unlikely that a further 38% of flow for the Kaituna River would come from other locations. This was supported by a simple approximation model that BoPRC have derived to determine flow at Te Matai based on flow at the Mangorewa and Taaheke gauges. The approximation model calculated a likely flow of 25 m^3/s at Te Matai, a reduction in flow of 15% compared to the de-tided estimate. It should be noted that a flow of 29.5 m^3/s was still within the deviation associated in the approximation model (Ellery, pers Comms, 2013).

BoPRC also provided predicted inflows at other sites for the flood event that occurred over 16th to 24th April 2013 for the following locations (shown in Figure 3-21).

- Waiari Stream below NIWA gauge;
- Raparapahoe Canal below BoPRC gauge;
- Kopuroa Canal;
- Bell Road Drain;
- Diagonal Drain;
- Ford’s Road Drain;
- Ongatoro / Maketū Estuary south-western drain (Kaituna Road Drain); and
- Ongatoro / Maketū Estuary southern drain (Singletons Drain / Waitipuia Stream).

Figure 3-21 Predicted significant inflow locations into the estuary and river for the flood event that occurred over 17th to 24th April 2013.

The predicted flows for 15th to 24th April 2013 for the significant inflows are presented in Figure 3-22. The Waiari Stream and Raparapahoe Canal include flow measured at gauges.

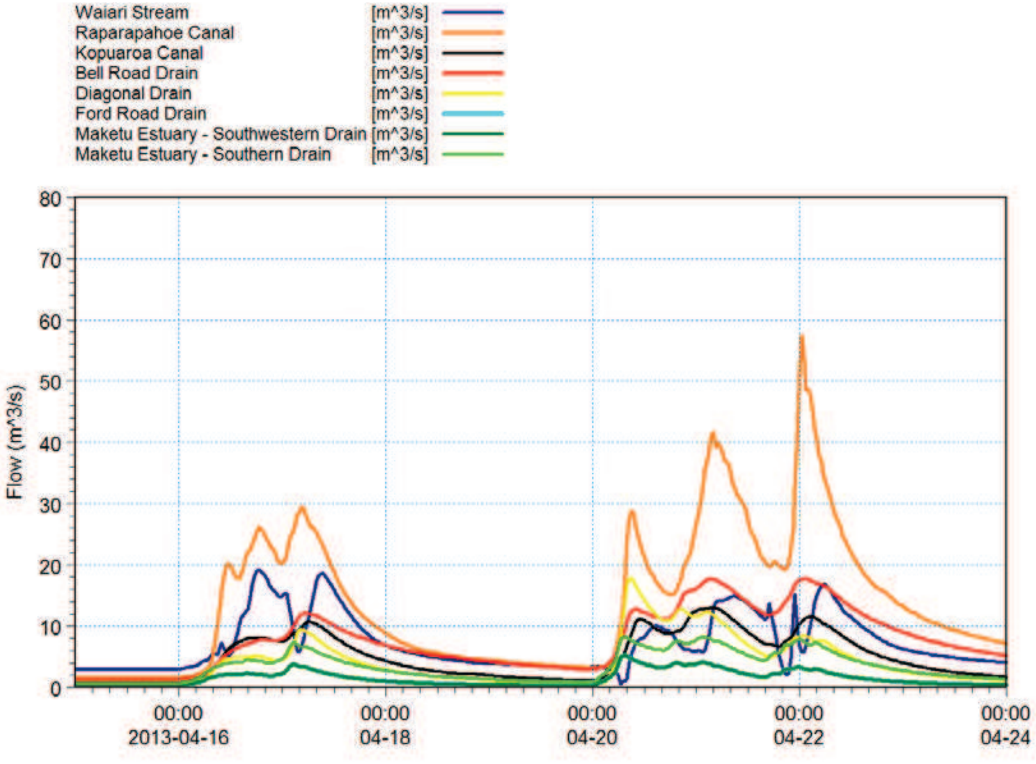


Figure 3-22 Predicted significant inflows into the estuary and river for the flood event that occurred over 16th to 24th April 2013.

Mean and seven day five year low flows were also provided by BoPRC for the Kaituna River at Te Matai Bridge, Waiari Stream and Raparapahoe Canal, which are the largest freshwater contributors downstream of Te Matai Bridge. These flows are presented in Table 3-2.

Table 3-2 Mean and seven day five year low flows for Kaituna River at Te Matai Bridge, and Waiari Stream and Raparapahoe Canal.

Freshwater Inflow	**Mean Flow (m^3/s)**	**Seven Day Five Year Low Flow (m^3/s)**
Kaituna River	35.5	21.6
Waiari Stream	4.0	2.9
Raparapahoe Canal	1.9	0.6

Annual Exceedance Probability (AEP) design hydrographs were provided by BOPRC for the Kaituna River at Te Matai Bridge, Waiari Stream, Raparapahoe Canal and Kopuroa Canal for both 1% and 5% AEP's (see Figure 3-23 and Figure 3-24). Similar design hydrographs were provided for 2100 climate change scenarios.

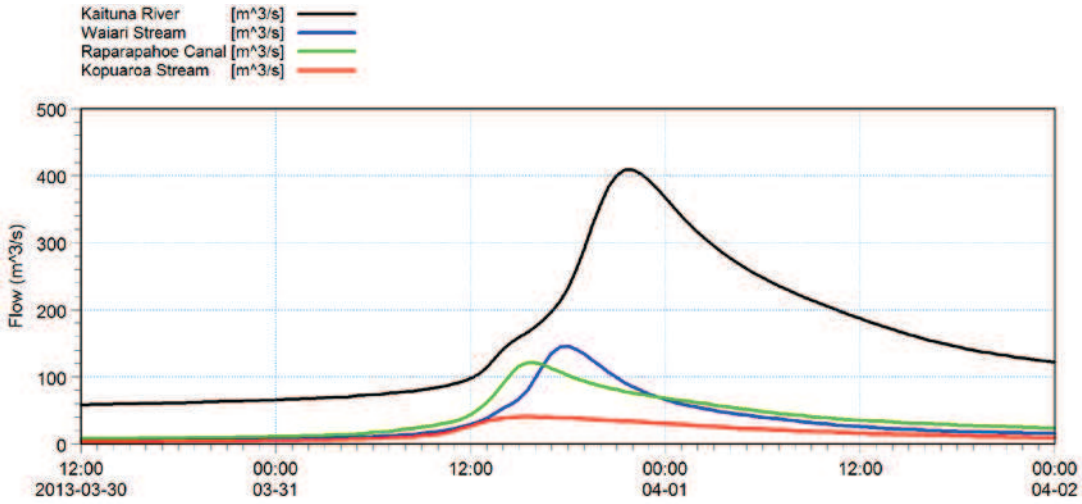


Figure 3-23 1% AEP design flow hydrographs.

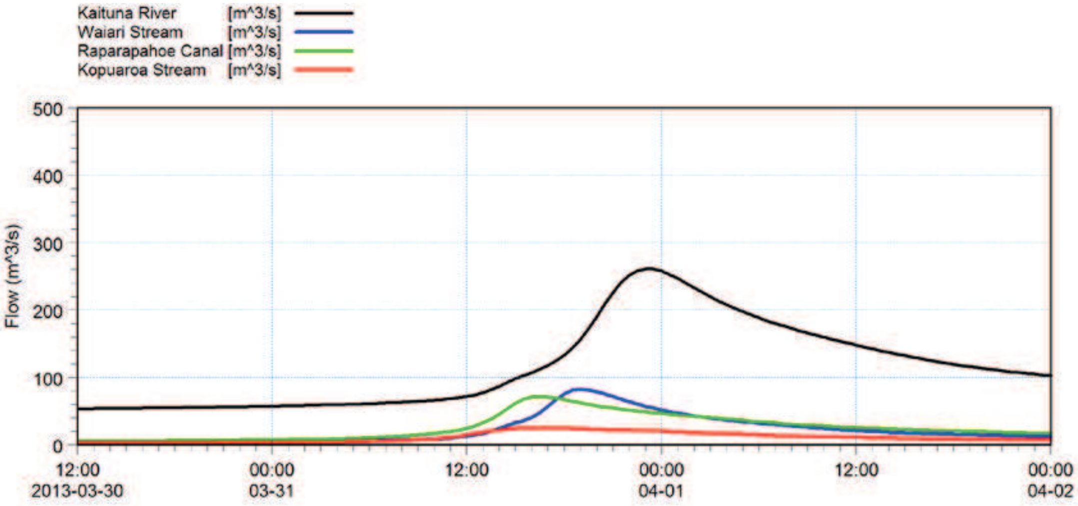


Figure 3-24 5% AEP design flow hydrographs.

The BoPRC project team identified drains that were deemed likely to be significant contributors of pollutant to the estuary. Base flows were then calculated and provided for these drains by BoPRC, based on drainage catchment area size. The locations of these drains are provided in Figure 3-25 and the associated base flows are provided in Table 3-3.

Figure 3-25 Location of significant drains with regard to pollutants to estuary.

Table 3-3 Calculated base flow for significant drains with regard to pollutants to estuary.

Drain Name	**Base Flow (m^3/s)**
Ford Rd	0.1352
Maketū Cut	0.0104
Armstrongs	0.0064
Upper Estuary	0.0036
No 3	0.0028
Kaituna Road	0.0712
Singletons	0.0164
Waitipuia Stream	0.2540
Township North (north of wetland)	0.0016
Township South (south of rugby field)	0.0264

3.4 Sediment Grab Samples

For the study an extensive sediment grab sampling exercise was undertaken by DML over the period 30th April to 2nd May 2013. 85 grab samples were collected within the river, estuary and along the coast as shown in Figure 3-26 and Figure 3-27. The samples were analysed by BoPRC for grain size distribution into the class sizes in Table 3-4. Further details of the grain size distribution for each grab sample are provided in Appendix A. The sediment class based on the calculated D_{50} for each grab sample is also provided in Figure 3-26 and Figure 3-27.

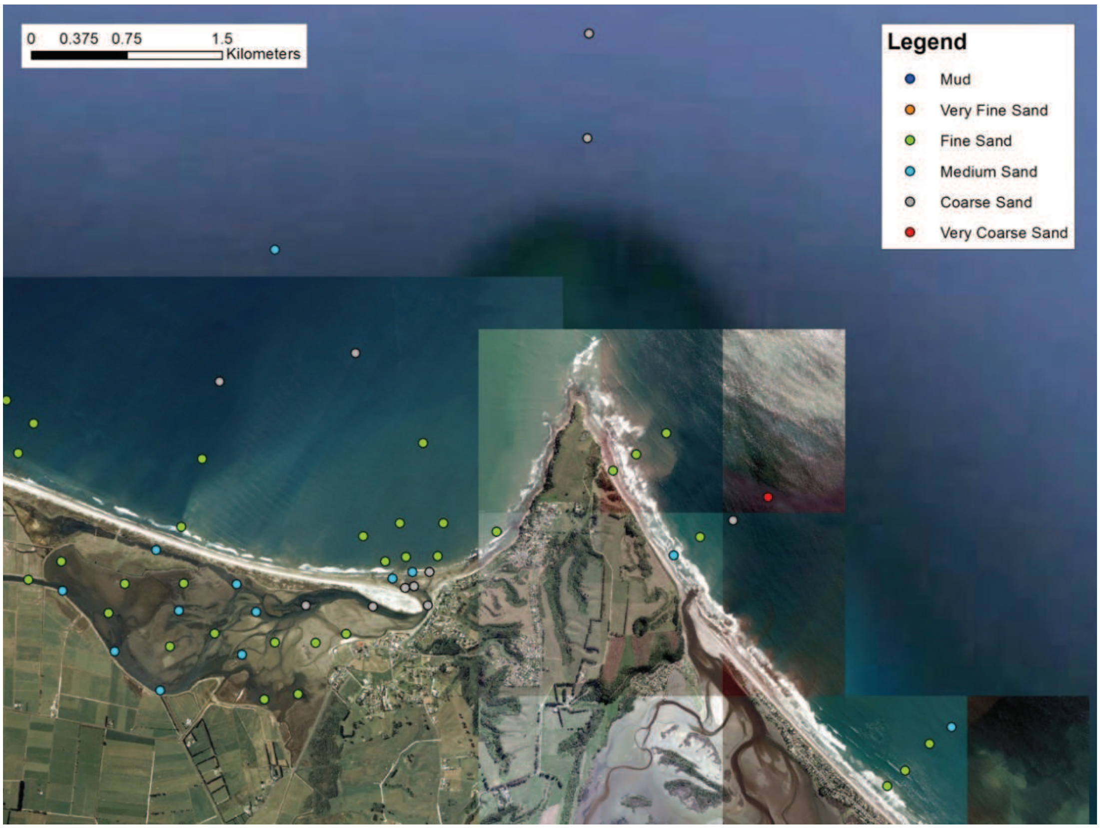


Figure 3-26 Sediment sampling sites within the vicinity of the Ongatoro / Maketū Estuary and around Okurei Point. and sediment class based on the calculated $D_{50.}$ Samples

Figure 3-27 Sediment sampling sites within vicinity of Kaituna River with sediment class based on the calculated D_{50}.

Table 3-4 Sediment grain size classes

Sediment Class	Sediment Diameter
Very Coarse Sand	<2mm & >1mm
Coarse Sand	<1mm & >500µm
Medium Sand	<500µm & >250µm
Fine Sand	<250µm & >125µm
Very Fine Sand	<125µm & >63µm
Mud	<63µm

The data indicates the following sediment distribution within the river and estuary:

- The estuary is predominantly fine to medium sand with some coarse sand in the estuary entrance;
- The river is mostly medium to coarse sand;
- In the near shore area outside of the river and estuary the samples are predominantly fine sand, with coarser fractions at greater depths; and
- The upper Ford's Loop is the only site where mud dominates.

It is also worth noting that some of the sites in the upper estuary have anoxic organic matter over laying the sediment, particularly in channels with little flow (per comms, Keith Hamill, River Lake Ltd).

3.5 Bed Forms – Flood Delta

On 22nd May 2013 on a low tide, observations were recorded of the types of bed forms within flood delta inside mouth of Ongatoro / Maketū Estuary entrance. The observations were made by members of project team from DHI and BoPRC and the bed form locations are presented in Figure 3-28. The bed forms mostly indicated both flood and ebb tide sediment transport with mostly a flood tide dominance.

Figure 3-28 Bed form observations for flood delta within Ongatoro / Maketū Estuary.

3.6 Salinity Profile Data

On the 4th April 2013, BoPRC undertook a comprehensive salinity profiling campaign. The measurements were carried out using a CTD (Conductivity Temperature Depth) meter. An overview of the locations where all CTD casts were performed is shown in Figure 3-29. The CTD could only measure salinity from approximately 0.15 m below the water surface.

Figure 3-29 Overview of salinity profile locations.

3.6.1 River Salinity

Salinity profiles were measured within the Kaituna River and Ford's Loop from approximately 8:00 am to 2:44 pm on 4th April 2013 to measure the salinity distribution (specifically the salinity intrusion) within the river. There were approximately 14 sites within the river and loop where salinity measurements were collected as shown in Figure 3-30. An initial salinity profile measurement was collected at Site 1 and then subsequent measurements collected from Site 2 to Site 14 before returning back to Site 1 to repeat the process again. Following this process, eight sets of profile data were collected, to measure the salinity distribution for different parts of tidal cycle. It should be noted that depending on the extent of the salinity intrusion, on some occurrences it was not deemed necessary to collect salinity data for all sites in the Kaituna River.

To illustrate the salinity distribution along the Kaituna River and Ford Loop, for each set of salinity data, the salinity data has been interpolated between the CTD cast locations. Each set of salinity data has been split up into two groups of data to represent salinity distribution in the river, Sites 6 – 14 (Transect One) and Ford's Loop, Sites 1 – 7 (Transect Two) also shown in Figure 3-30.

Figure 3-30 Approximate locations in Kaituna River and Ford's Loop including distance upstream from Site 6.

It should be noted that there was a significant amount of time between the first and last casts (a maximum of 40 minutes), however it was deemed acceptable to assume that the data provides an instantaneous observation of the salinity distribution within the Kaituna River and Ford's Loop at different parts of the tidal cycle. The assumed time of the observed salinity distribution is based on when the salinity profile was collected at Site 6. The state of the tide when the salinity distribution was observed based on measured water levels at Ford's Loop is presented in Figure 3-31.

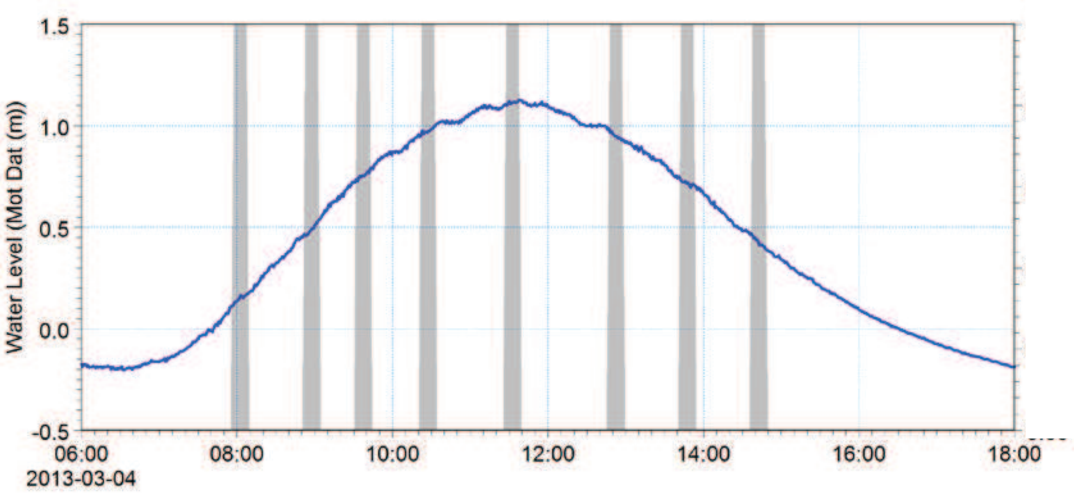


Figure 3-31 Timing of observed salinity distributions relative to measured water levels at Ford's Loop.

The salinity distribution within the Kaituna River at different parts of the tidal cycle are presented in Figure 3-32 and Figure 3-33, while the salinity distribution within the Ford's Loop at different parts of the tidal cycle are presented in Figure 3-34 and Figure 3-35.

The observed salinity intrusion is as expected, however some interesting observations from the salinity distribution are that the salt wedge is observed to intrude more than 3,300 m upstream of the entrance (Site 6). Also on the ebb tide (at approximately 2:44pm) less saline water from Ford's Loop is observed at the Kaituna River mouth.

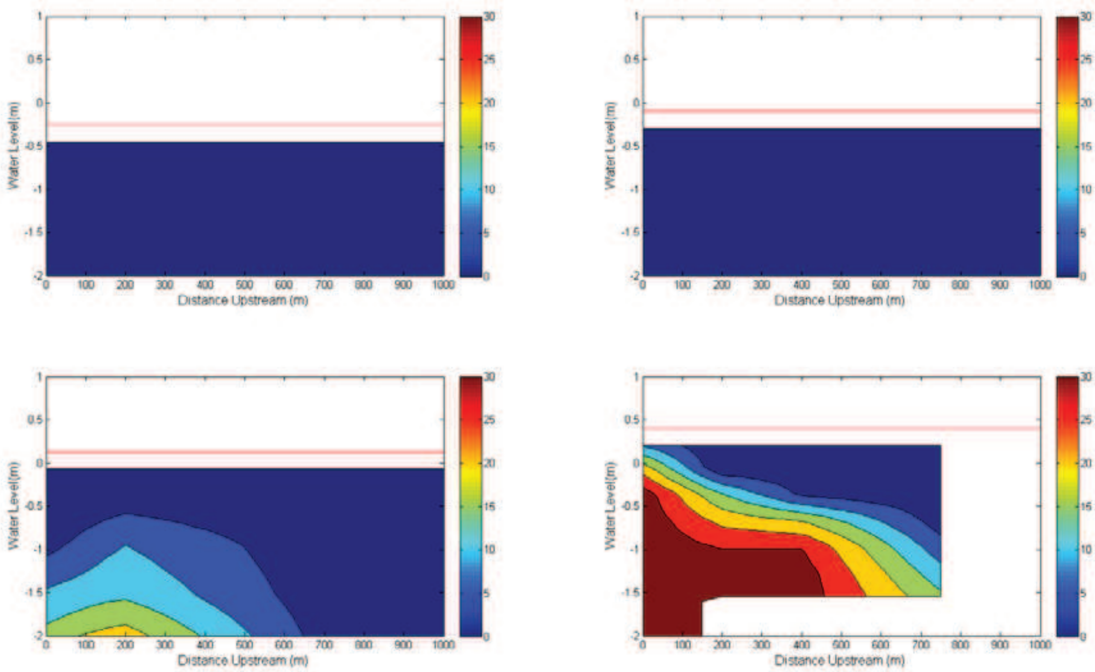


Figure 3-32 Observed salinity distribution (PSU) in river along Transect One (up to 1,000m upstream) at approximately 8:00 am (top-left), 8:55 am (top-right), 9:37 am (bottom-left) and 10:25 am (bottom-right). Water levels in Moturiki Datum with red line indicating measured water level in Ford's Loop.

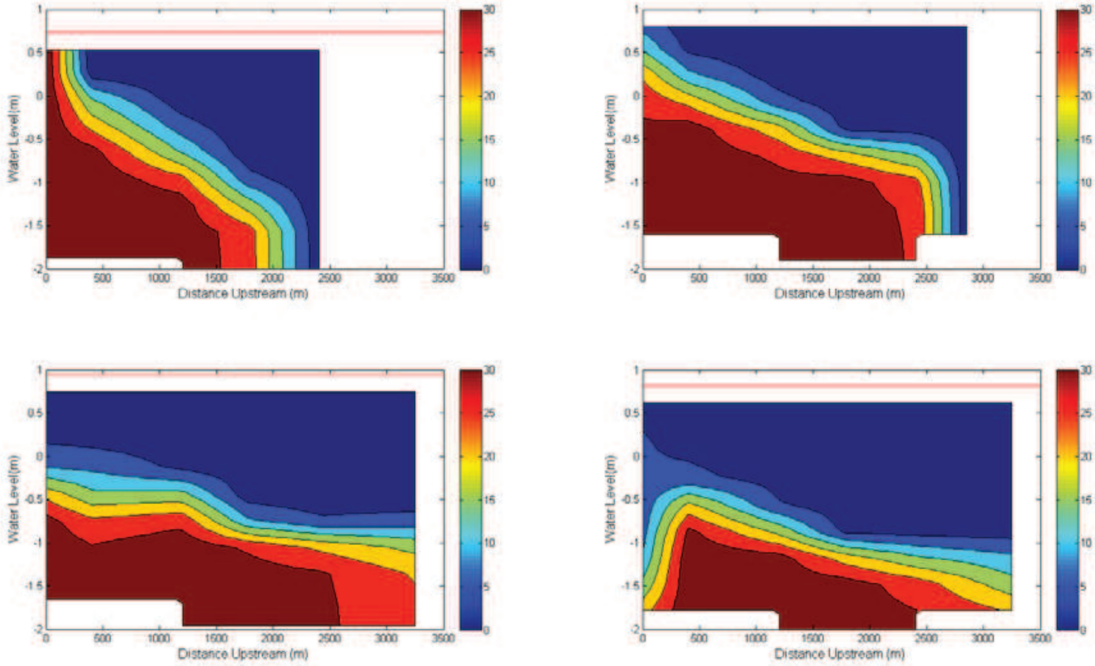


Figure 3-33 Observed salinity distribution (PSU) in river along Transect One (up to 3,200m upstream) at approximately 11:32 am (top-left), 12:50 pm (top-right), 1:45 pm (bottom-left) and 2:44 pm (bottom-right). Water levels in Moturiki Datum with red line indicating measured water level in Ford's Loop.

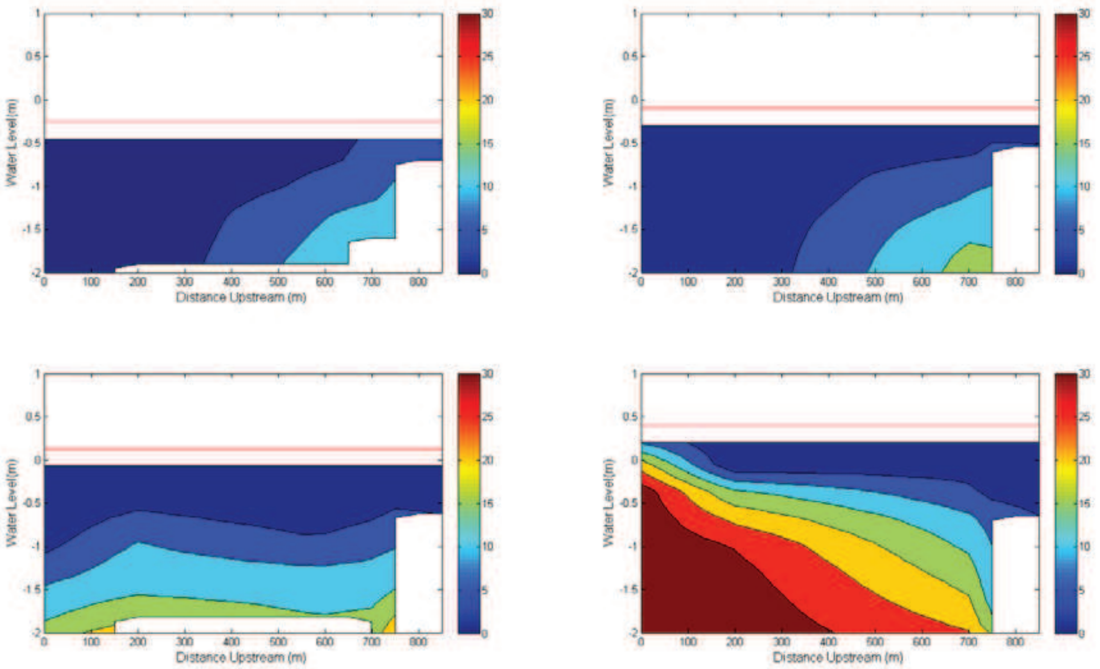


Figure 3-34 Observed salinity distribution (PSU) in river and Ford's Loop along Transect Two at approximately 8:00 am (top-left), 8:55 am (top-right), 9:37 am (bottom-left) and 10:25 am (bottom-right). Water levels in Moturiki Datum with red line indicating measured water level in Ford's Loop.

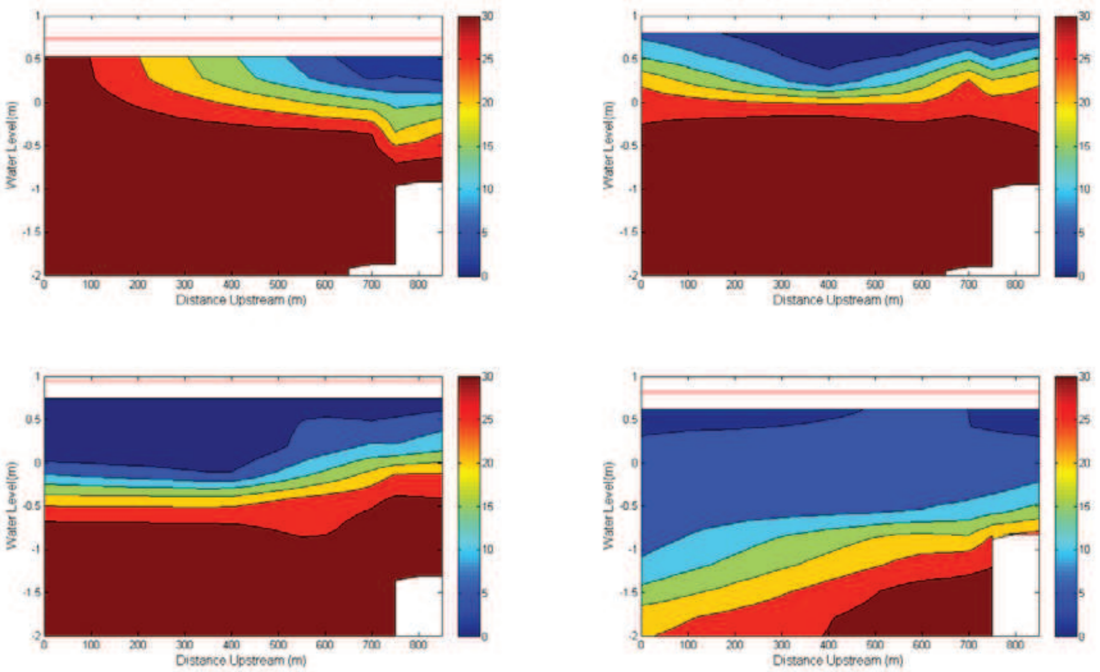


Figure 3-35 Observed salinity distribution (PSU) in river and Ford's Loop along Transect Two at approximately 11:32 am (top-left), 12:50 pm (top-right), 1:45 pm (bottom-left) and 2:44 pm (bottom-right). Water levels in Moturiki Datum with red line indicating measured water level in Ford's Loop.

3.6.2 Estuary Salinity

Salinity profiles were measured within the estuary on 4th April 2013, at the approximate locations shown in Figure 3-36. There were three periods when the data was collected:

- 7:56 am to 10:36 am;
- 11:45 am to 1:15 pm; and
- 2:43 pm to 3:55 pm.

The state of the tide based on measured water levels at Ford's Loop relative to these periods are presented in Figure 3-37. The salinity profiles are presented in Figure 3-38 and Figure 3-39.

Figure 3-36 Approximate locations within the Ongatoro / Maketū Estuary where salinity profiles were measured.

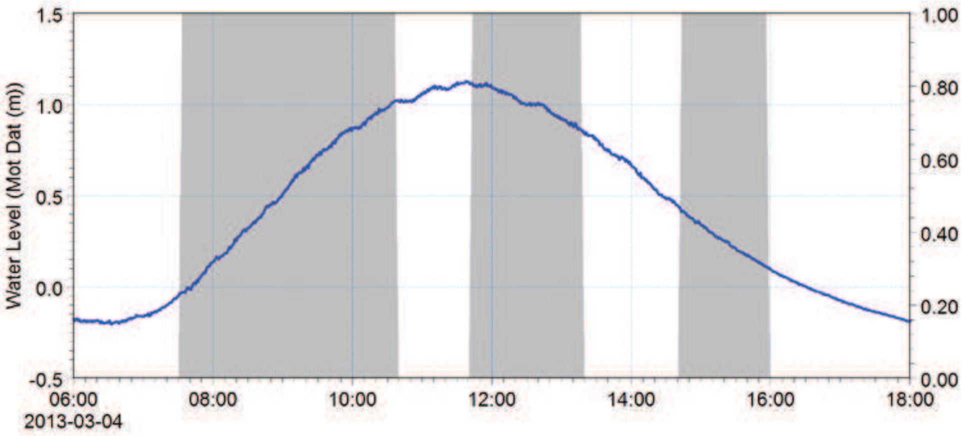


Figure 3-37 State of tide (measured at Ford's Loop) for the salinity profiles collected on the 4th of April 2013 within Ongatoro / Maketū Estuary.

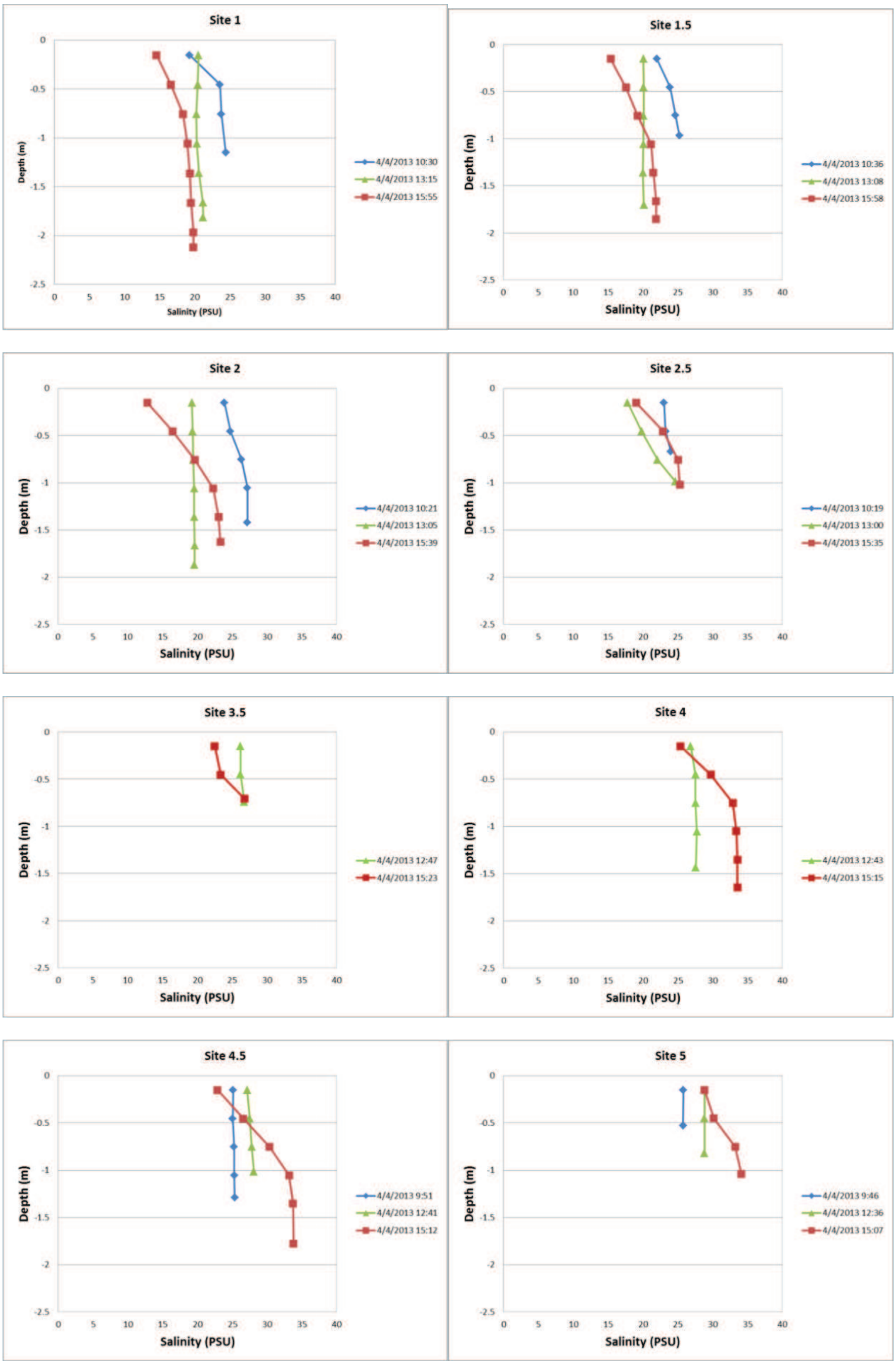


Figure 3-38 Salinity profiles from within Ongatoro / Maketū Estuary for Sites 1 to 5.

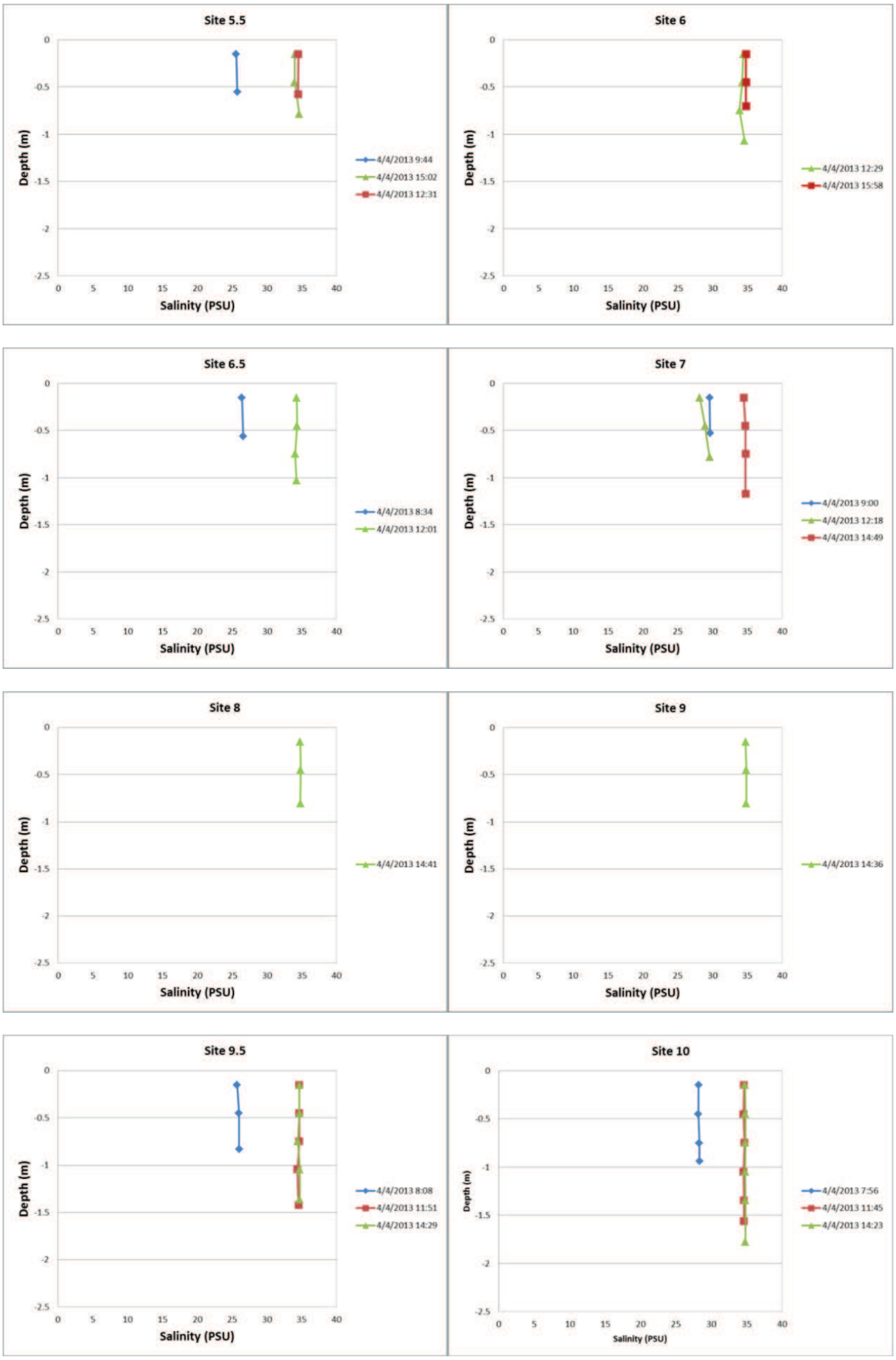


Figure 3-39 Salinity profiles from within Ongatoro / Maketū Estuary for Sites 5.5 to10.

3.7 Water Quality Data

3.7.1 Overview

The water quality within estuarine ecosystems results from the dynamic balance between catchment inputs and flow regime. Therefore any assessment around the significant alteration of estuarine hydrodynamics should include a specific biological component. Water quality outcomes will depend largely on the interactions between the;

- freshwater and nutrient loading from Kaituna River;
- nutrient loading from the drains;
- dilution processes within the estuary, i.e. mixing of fresh water with sea water; and
- flushing/retention time within the estuary.

The intricate nature of the flow-tide relationship within the estuary and the lower Kaituna River required a sampling regime at a range of locations throughout the estuary (i.e. transport of material through estuary, identifying point sources) and that covered a range of tidal conditions (i.e. changes in flow and dilution).

Long-term monitoring, over the period 1985 to 2013 at a range of sites in the Kaituna River and Ongatoro / Maketū Estuary has provided an overview of water quality within the river and estuary. However much of this sampling was not closely synchronised to tides or across enough sites to provide high quality information for models. Preliminary water quality modelling for Kaituna River and Ongatoro / Maketū Estuary (DHI, 2011) indicated that more in-depth sampling would improve any future water quality assessments.

A more synchronous data collection campaign was developed for the period 2011 – 2013. In total there were 14 water quality sampling sites for this period, four in Kaituna River, five in the Ongatoro / Maketū Estuary and five in selected drains to the river and estuary. The locations of these sampling sites are presented in Figure 3-40.

Figure 3-40 Locations of water quality sampling sites in the Kaituna River and Ongatoro / Maketū Estuary. Note Maketū inflow 3 alternatively called Ongatoro / Maketū Estuary southern drain and Waitipuia Stream / Singletons drain elsewhere in report.

The following should be noted for the 2011 to 2013 data collection:

- There was an improved sampling of the impact of the tide on water quality; with sampling at high and low tide on the same day.
- Sampling was carried out for both baseline and rain events during this period.
- Compared with previous water quality sampling there were three additional sampling sites within estuary; sites 4 and 5 on the southern edge, and site 9 in the channel.
- Sampling was carried out at drains connected to the estuary; sites Inflow 1, 2, and 3, Kaituna drain, and of particular importance, Ford drain where initial sampling showed a high variation in concentrations of nutrients and bacteria at Ford's Cut. It should be noted that drains were sampled less frequently than other sites.
- There was greater attention to sampling at the upper and lower boundaries (Te Matai / Wetland pump in river and boat ramp in estuary respectively).
- On the 4th April 2013, more intensive sampling was undertaken to combine with other extensive data collection; almost all sites were sampled three times, at low, mid, and high tide.

Water quality parameters that were collected that were relevant to this study are:

- Chlorophyll *a* (chl.*a*);
- Bacteria (Faecal coliforms and Enterococci); and
- Nutrients (Total Nitrogen, Dissolved Inorganic Nitrogen, Total Phosphorous and Dissolved Reactive Phosphorous).

A summary of the timing and the location of water quality sampling over the period 2011 – 2013 is provided in Figure 3-41.

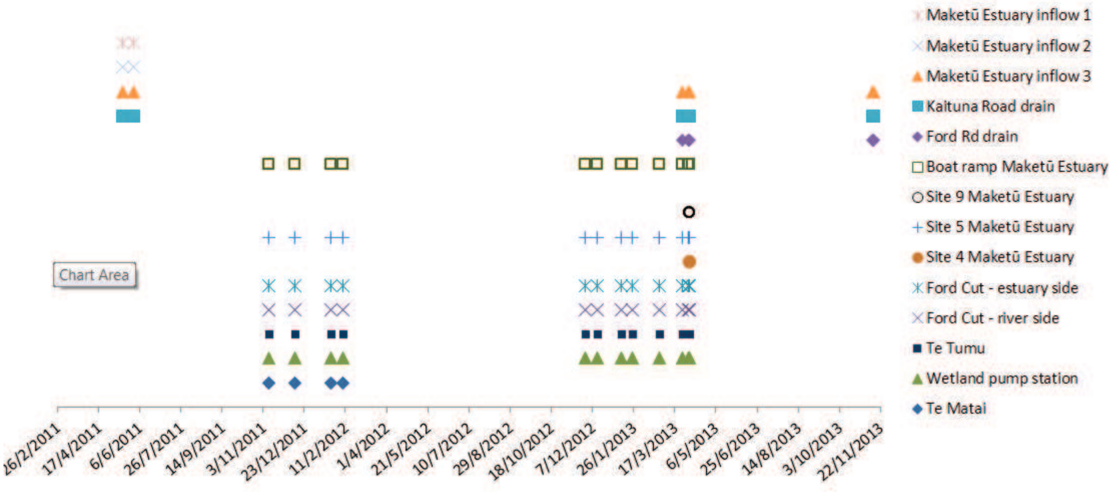


Figure 3-41 Summary of timing and location of water quality sampling (2011 – 2013).

It is worth noting that the boat ramp site in the estuary is very close to the open ocean and therefore measured concentrations at the site may not be representative of the estuary in general due to the range of dilutions that could occur at this site due to mixing with ambient seawater.

It was considered important to sample at rain events as this is when concentrations of pollutants entering the estuary are likely to be highest – pollutant loads entering the system are much greater than usual and pollutants previously stored in sediments are likely to be mobilised due to higher flows and higher river levels.

It is also important to note that while the new sampling programme did provide an improved data set, great care was still required in interpreting results. The extreme nature of the variability of bacteria in coastal environments is well documented (e.g. Boehm, 2007) and given only one sample was taken at each site for each sampling round (due to budget and timing constraints) a high degree of uncertainty must be attached to the observed values.

3.7.2 Chl.*a* (and blue-green algae)

Cell counting for blue-green algae has been carried out historically for some sites in the Kaituna River for the period March 2005 to May 2010. No cell counting of water samples were available for the Ongatoro / Maketū Estuary. In the absence of cell count data, chl.*a* has been used as a proxy for blue-green algae.

Chl.*a* represents the concentration of suspended phytoplankton in the water, and indicates how micro algae are responding to fluctuations in nutrients levels and conditions. It therefore can be used to indicate the potential for algae bloom (blue-green in particular) in an estuary. Concentrations of Nitrogen and Phosphorus usually show a strong relationship to chl.*a* concentrations. Temporary elevations in chl.*a* are not as significant to water quality as long-term high levels e.g. high annual median values. Strong mixing has a significant dampening effect on chl.*a* concentrations due to reduced time in the photic zone.

Chl.*a* concentrations can indicate blue-green algae concentrations and the potential for bloom, and consequently blue-green concentrations are usually only of concern when chl.*a* concentrations are high. Every time there is a high chl.*a* concentration does not mean that there is a high concentration of blue-green algae, however there is a risk that this is the case and the risk increases with higher chl.*a* concentrations. Therefore using the Chl.*a* as proxy for blue-green algae can be considered a conservative approach.

Within the modelling area, Te Tumu (close to the mouth of the river) was the only station to have available data for both cell counting and chl.*a* analysis (see Figure 3-42). Both variables were monitored coincidently at two dates only. However, the period November 2008 to November 2009 does indicate a positive correlation overall.

Overall the data was too sparse and not synchronized enough to give a sound analysis of a relationship between chlorophyll and potential risk of a high number to blue-green algae cells. However the data does indicate that the chl.*a* levels of greater than 20 µg/l need to occur before the estuary is at risk of having more than 1,000 cells/ml of blue-green algae.

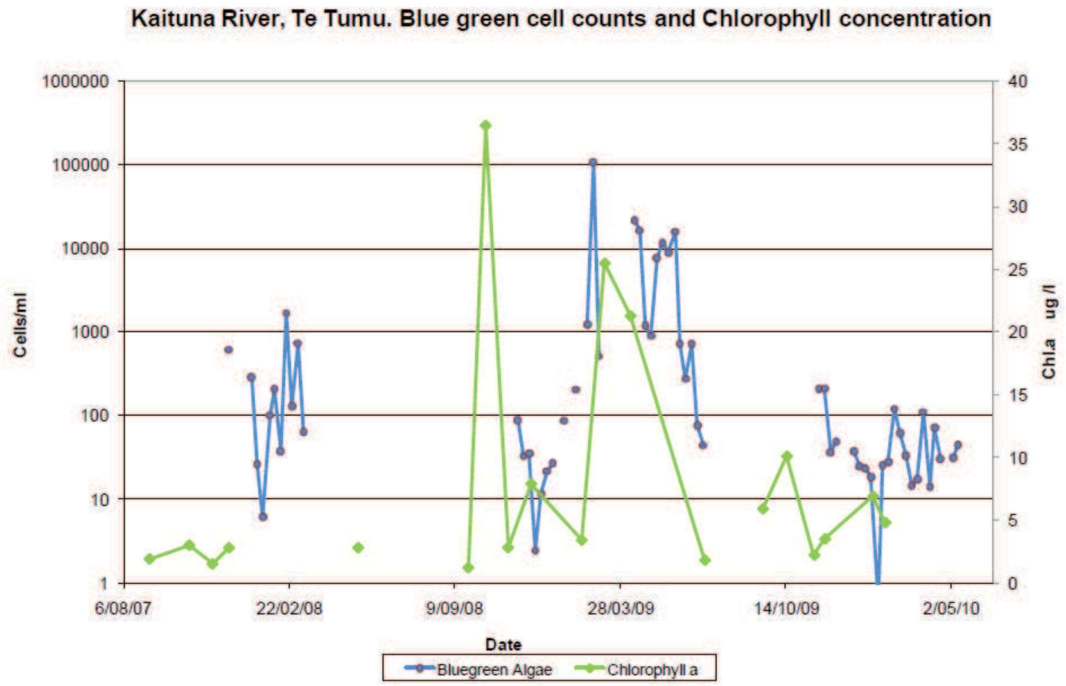


Figure 3-42 Chlorophyll concentrations and blue green algae cell count at Te Tumu station.

The observed chl.*a* / algae biomass concentrations in the river and estuary at selected site for the period 2007 to 2013 are shown in Figure 3-43. The data shows no trend up to 2012 and then lower concentrations for 2012. As a general rule chl.*a* concentrations are higher in the river and lower within the estuary. Concentrations rarely exceed 10 mg/m^3 but on seven occasions concentrations reached 10 - 37 mg/m^3 (Figure 3-43).

For the latest sampling carried out October 2011 – April 2013, the mean chl.*a* concentrations for all sites in river and estuary are presented in Figure 3-44. Concentrations are generally higher at low tide because less mixing with ocean waters occurs resulting in significantly less dilution. Concentrations of chl.*a* are higher in the river and drains, and lower within the estuary - the observed maximum concentration at Site 5, low tide, indicates the significant impact of the Kaituna Drain.

For the extensive sampling carried out on the 4th April 2013, the chl.*a* concentrations at all sites in the river and estuary is presented in Figure 3-45. This is the only instance when sampling was also carried out at mid tide. Interestingly concentrations of chl.*a* are higher at the estuary mouth than upstream in the estuary. This may be the result of re-suspension of micro-phytobenthos and settled phytoplankton from sediments due to strong currents at mid-tide.

Chl.*a* was not sampled for any of the drains sites. To compensate for this for modelling purposes, it was determined that chl.*a* concentrations could be estimated using a relationship developed between chl.*a* and Enterococci concentrations (Appendix F).

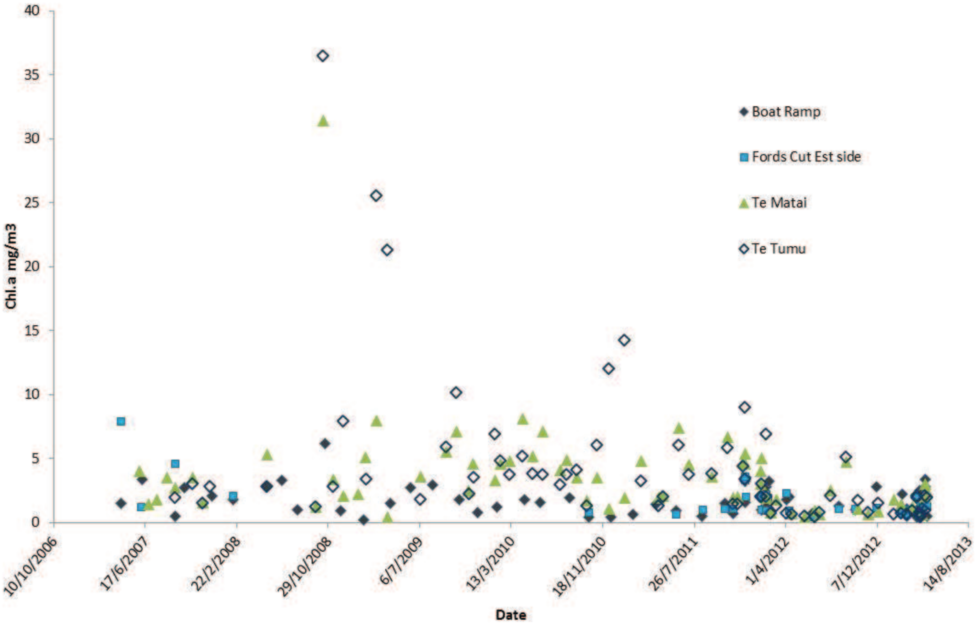


Figure 3-43 Chl.*a* concentrations from long term monitoring 2007 - 2013 at four selected sites, at the upper Kaituna River (Te Matai), Kaituna river mouth (Te Tumu), just within the estuary (Ford's cut – river side) and the estuary mouth (Boat ramp).

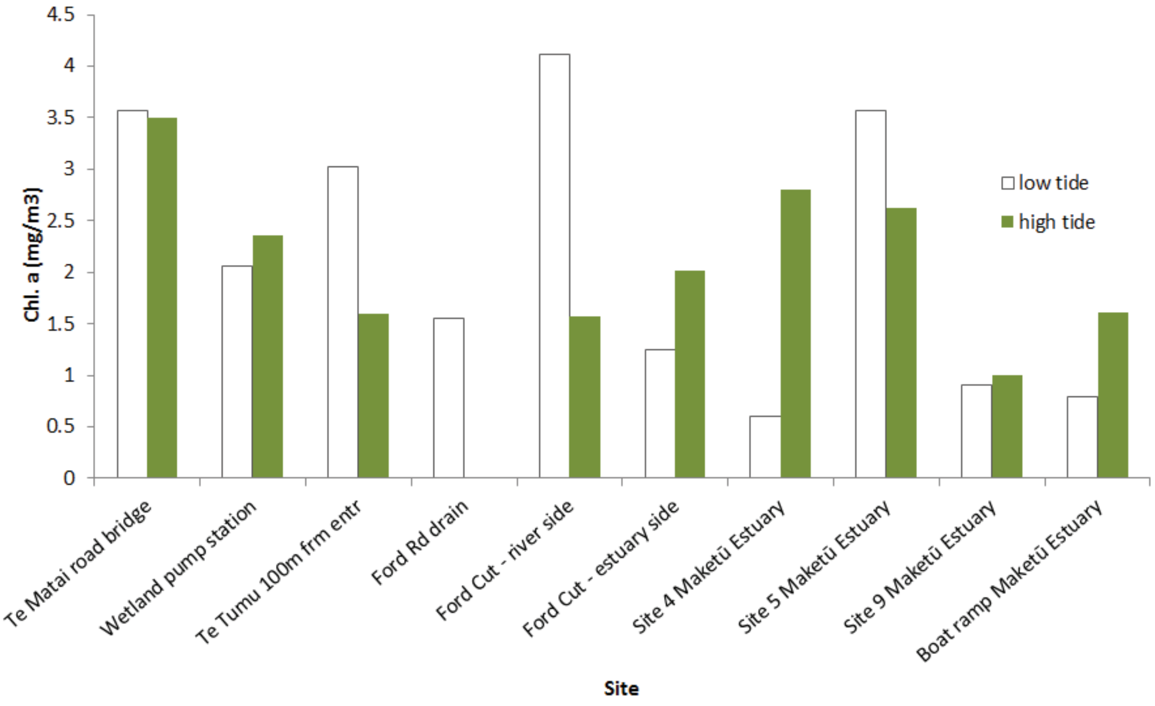


Figure 3-44 Mean high tide and low tide chl.*a* concentrations for all sites in river and estuary sampled October 2011 – April 2013.

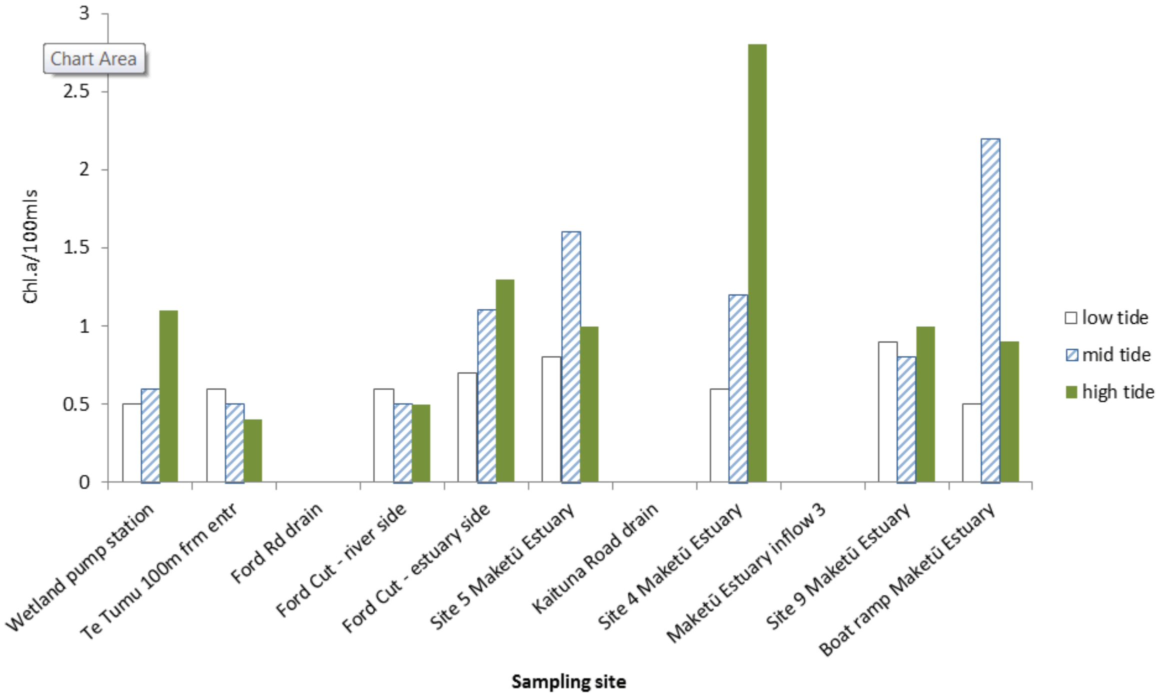


Figure 3-45 Chl.*a* concentrations at each site in river and estuary sampled on 4th April 2013. Sampling occurred at high, mid, and low tide between 7:30 am and 4:00 pm.

3.7.3 Bacterial Sampling

3.7.3.1 Faecal Coliforms

Faecal coliforms are an indicator of potential pathogens or faecal contamination in water (for example the faecal coliforms group includes *Escherichia coli).* Note that, while faecal coliforms are found predominantly in the intestinal tract of humans and animals, some species do exist naturally.

The guidelines for water quality acceptable for shellfish gathering state that the median faecal coliform content (of samples taken) should not exceed 14 faecal coliforms /100ml, and not more than 10% of samples should exceed 43 faecal coliforms /100ml. The median bacterial content in fresh and marine waters should not exceed 150 faecal coliform/100ml over a bathing season for contact/recreational values.

Concentrations of faecal coliforms at Te Matai for the sampling period 1990 to 2013 are presented in Figure 3-46. There is a slight downward in trend in faecal coliforms concentration throughout the sampling period, potentially due to improved farming practice, however, sampling is limited and the variation between samples is high.

An overview of how measured faecal coliforms concentration change throughout the lower river and estuary is provided in Figure 3-47, which shows the mean faecal coliforms concentration at specified sites for October 2011 – April 2013 during low and high tide. Figure 3-48 presents the faecal coliforms concentration across all sampling sites for a single day of sampling (one full tidal cycle). The sampling occurred between 7:30 am and 4:00 pm on the 4th April 2013, with samples taken at low, mid and high tide.

Faecal coliforms concentration are high at Ford's drain, indicating a possible high load coming from the drain. Measured concentrations at Ford's cut – estuary side, however, are low indicating high variation in bacterial concentrations flowing into the estuary. Possible explanations for the latter are that at low tide the gate is closed and no river water flows into the estuary. At high tide dilution with incoming sea water occurs.

Higher concentrations of faecal coliforms appear to enter the estuary both from Kaituna River and the surrounding drains. The drains to the south of the estuary appear to have particularly high concentrations, which could indicate high potential nutrient load. Sparse data prevents any definitive conclusions, but high concentration at low tide at site 4 and 5 indicates significant impact from drains.

Mid tide samples are not higher at the estuary mouth for faecal coliforms suggesting that the effect seen in mid tide chl.*a* samples does not occur with bacteria i.e. the increase in re-suspension proposed as explanation for the observed higher chl.*a* has not impacted on bacteria concentrations. The concentration of bacteria in the estuary water is low and there is also die-off of the bacteria which occurs, so there probably is minimal accumulation in the sediments. In contrast micro algae grow and accumulate on the estuary sediment - providing a source of micro algae into the water column via suspension. This also indicates that the drains are mainly responsible for the bacteria concentrations, i.e. are the primary source. Re-suspension of sediments and particles, however, is part of a complex process and the data available is not sufficient to make firm conclusions.

Solar irradiation is often a significant factor in diurnal changes in faecal coliforms concentration which is another reason why the observed low tide values may have been higher than the observed high tide values (i.e. less faecal coliforms concentration at high tide due to combined effect of more sea water dilution and more time for solar irradiation to occur in the afternoon).

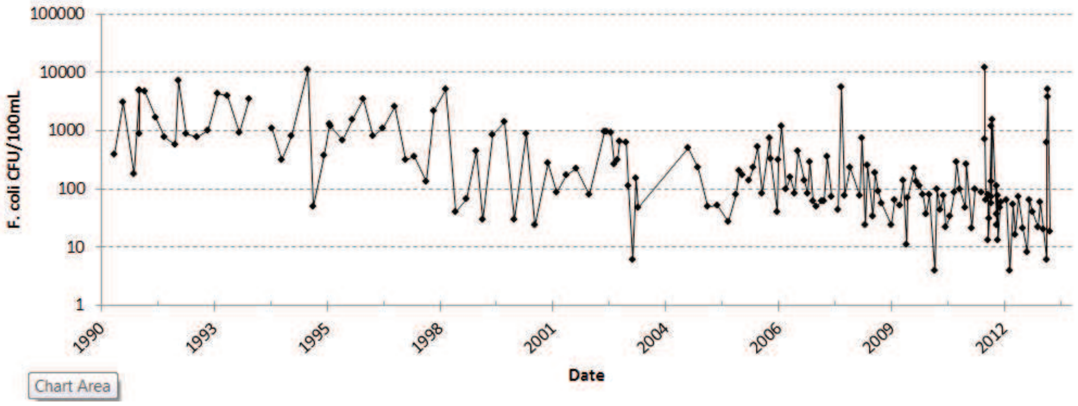


Figure 3-46 Faecal coliform concentrations from long term monitoring 1990 - 2013 at the upper Kaituna River (Te Matai).

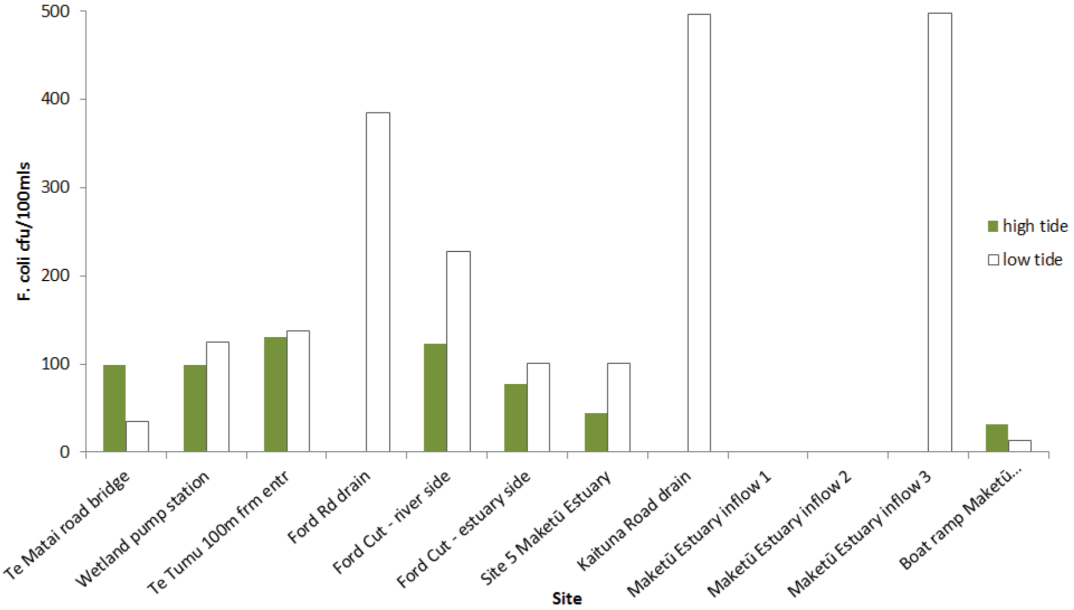


Figure 3-47 Mean faecal coliforms concentration at each site for October 2011 – April 2013. Observations from updated sampling regime that sampled a greater number of sites within the estuary and river system than prior to 2011. Samples were taken at low and high tide.

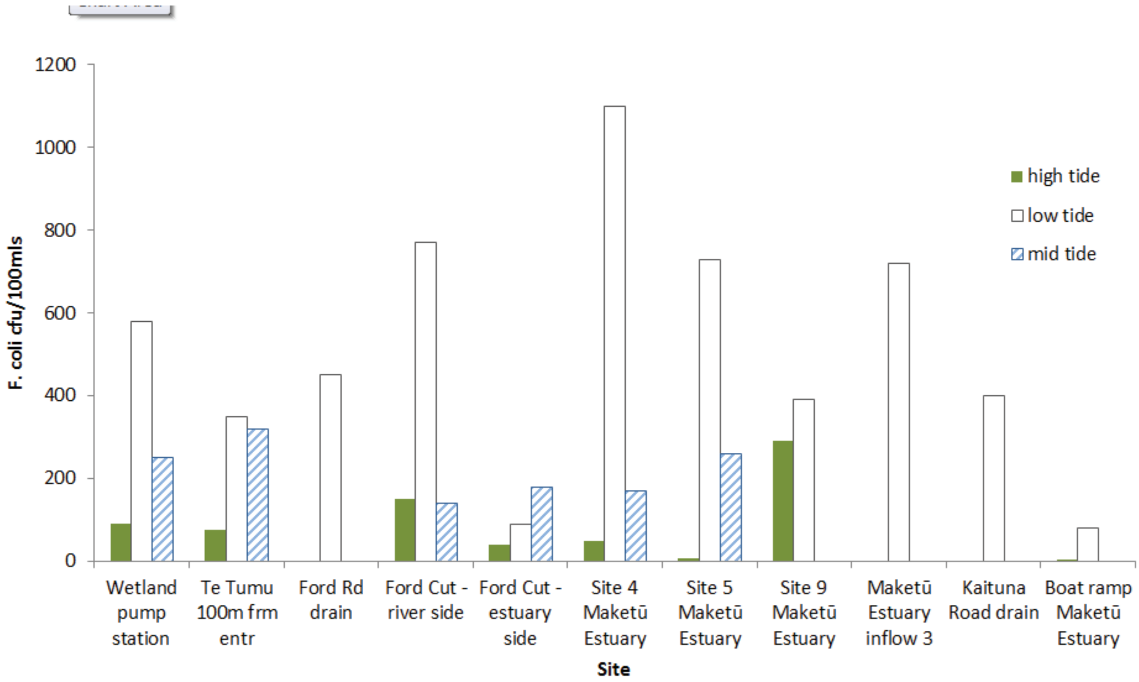


Figure 3-48 Faecal coliforms concentration across all sampling sites for a single day of sampling (one full tidal cycle). Sampling occurred between 7:30 am and 4:00 pm on the 4th April 2013. Samples were taken at low (approx. 7:00 am), mid and high tide (1:00 pm).

3.7.3.2 Enterococci

Enterococci is often a better indicator of bacteria concentrations in saline environments as they show a slower decay rate in saline environment and are thought to more closely mimic many pathogens than do other indicators. Concentrations below 140 cfu/100mls are considered acceptable under the MfE Recreational guidelines (2002). Under the above guidelines, when single samples exceeding 140 cfu/100mls occur, resampling must occur. When a single sample exceeds 280 cfu/100mls action must be taken.

The Enterococci concentrations measured for the Kaituna River at Te Matai for the period 1990 to 2013 are presented in Figure 3-49. This provides an overview of the variation in Enterococci concentrations within the river.

An overview of how measured Enterococci concentrations change throughout the lower river and estuary is provided in Figure 3-50, which is the average Enterococci concentrations at specified sites for October 2011 – April 2013 for only low and high tide. Figure 3-51 presents the Enterococci concentrations across all sampling sites for a single day of sampling (one full tidal cycle). The sampling occurred between 7:30 am and 4:00 pm on the 4th April 2013, with samples taken at low, mid and high tide.

Similar to the observations for faecal coliforms, Enterococci concentrations are normally highest at low tide, and at drains and inflows, but low at the estuary mouth. Similar to faecal coliforms solar irradiation can be responsible for die off of Enterococci bacteria. Concentrations at Kaituna drain and at the three inflows greatly exceed the MfE guidelines for safe water quality. Significant dilution, however, seems to occur closer to the estuary mouth where observed concentrations are low.

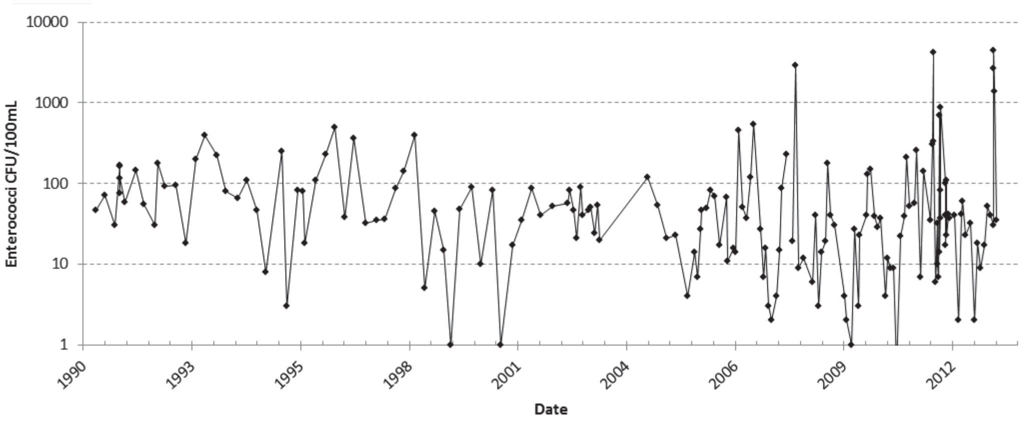


Figure 3-49 Enterococci concentrations from long term monitoring 1990 - 2013 at the upper Kaituna River (Te Matai).

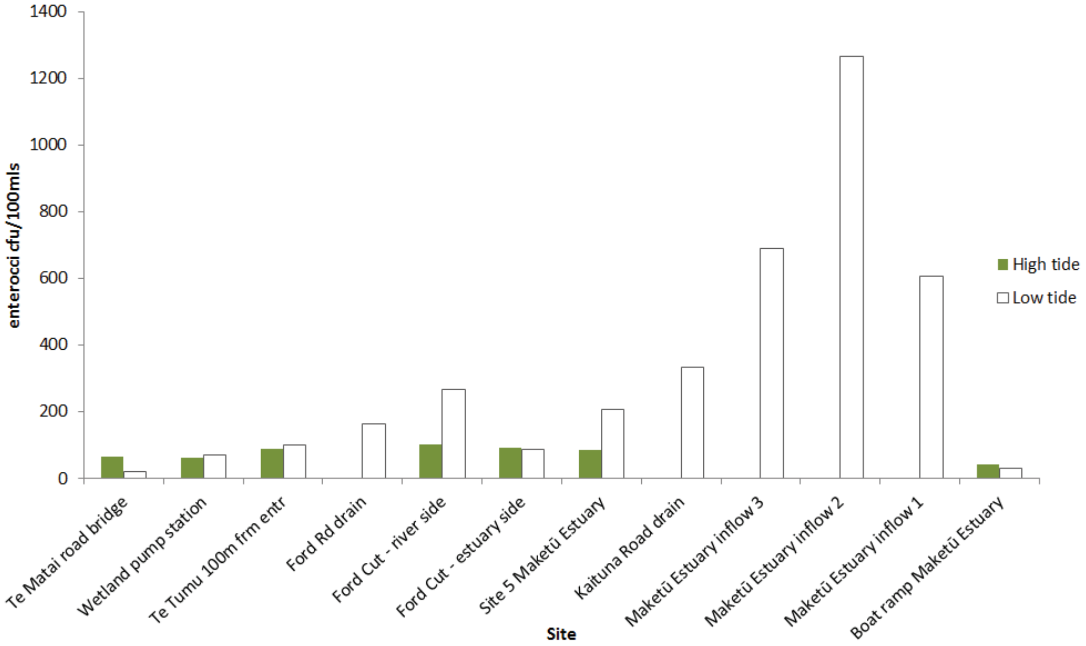


Figure 3-50 Mean Enterococci concentrations at specified sites for period October 2011 – April 2013.

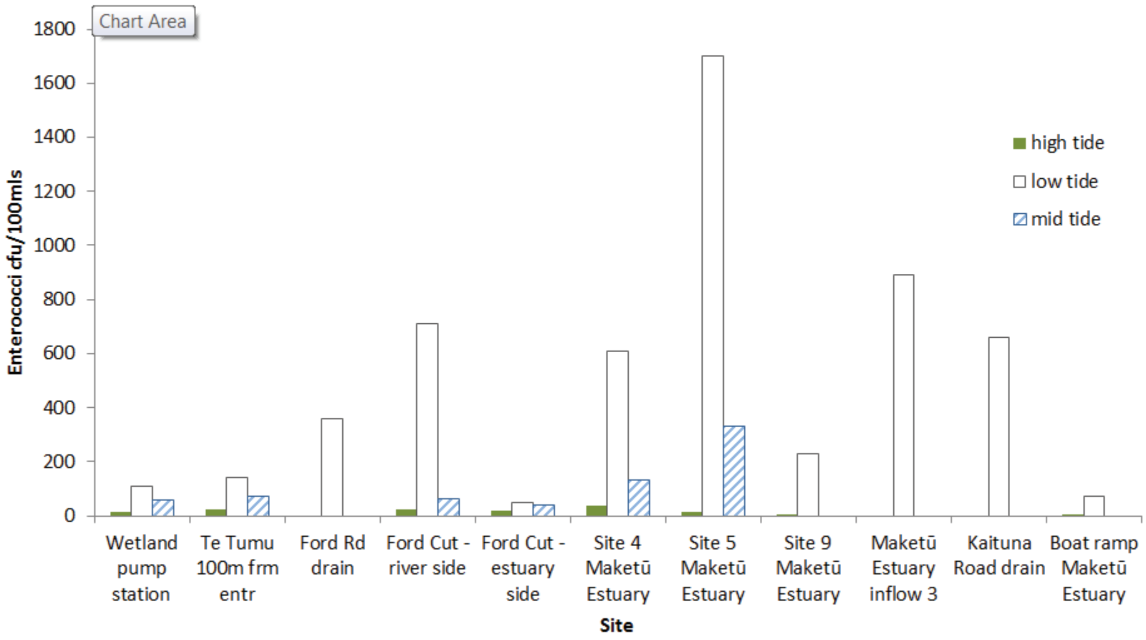


Figure 3-51 Enterococci concentrations across all sampling sites for a single day of sampling (one full tidal cycle). Sampling occurred between 7:30am and 4:00pm on the 4th April 2013. Samples are grouped as either at low (approx. 7:00 am), mid and high (1:00 pm) samples.

3.7.4 Nutrients

A range of nutrients were also sampled at each site, including total Nitrogen (TN), Ammonium nitrogen (NH4-N), nitrate nitrogen (NO3-N) and total Phosphorus (TP) and dissolved reactive Phosphorus (DRP). These parameters provide useful insight into the nutrient load entering the estuary from the river and drains. Only a small number of samples were collected for the drains. Sampling occurred at Ford Rd drain, Kaituna Rd drain, and Ongatoro / Maketū Estuary inflow 3 on the 26th March, 2nd April and 4th April 2013. For the Kaituna River at Te Matai bridge samples have been collected since 1985. The range and mean for measured nutrients concentrations for the primary sources of nutrients into the Ongatoro / Maketū Estuary is presented in Table 3-5.

Table 3-5 Range and mean of measured nutrients concentrations for the primary sources of nutrients into the Ongatoro / Maketū Estuary.

Source		TN	NH4-N	N03-N	TP	DRP
Te Matai (Kaituna river)	Range	0.31-2.19	0-0.45	0.19-0.8	0.03-0.14	0.002-0.078
	Mean	0.73	0.07	0.46	0.05	0.03
Ford Rd drain	Range	0.53-0.99	0.002-0.53	0.1-0.57	0.08-0.13	0.008-0.04
	Mean	0.81	0.25	0.25	0.09	0.02
Kaituna Rd drain	Range	0.69-1.95	0.15-0.79	0.02-0.03	0.09-0.28	0.01-0.02
	Mean	1.26	0.55	0.03	0.16	0.02
Ongatoro / Maketū Estuary inflow 3	Range	0.81-1	0.06-0.1	0.49-0.65	0.08-0.12	0.03-0.05
	Mean	0.89	0.09	0.55	0.10	0.04

Safe environmental concentrations of ammonium and nitrogen/nitrate are difficult to establish due to species differences, re-suspension processes, and the complexity of evaluating effects of low-level exposure. But a level of around 0.05 - 0.1 g/m^3 is considered acceptable for ammonium concentrations, in salt water environments. Nitrate is usually the most prominent form of Nitrogen found in ecosystems, and is the least toxic. Total Phosphorus levels exceeding around 0.1 g/m^3 are associated with algae bloom.

3.7.5 Relationship of Pollutant Levels with River Flow

Typically higher concentrations of nutrients, chl.*a* and bacteria were observed during rain events especially from the drains. There is not always a significant correlation between higher pollutant concentrations and river flow.

As an example, Figure 3-52 to Figure 3-54 present the relationship between the measured concentrations of chl., faecal coliforms and Enterococci with river flow at the Te Matai road bridge for the period, 2000 to 2013. There is no clear correlation apparent from these comparisons.

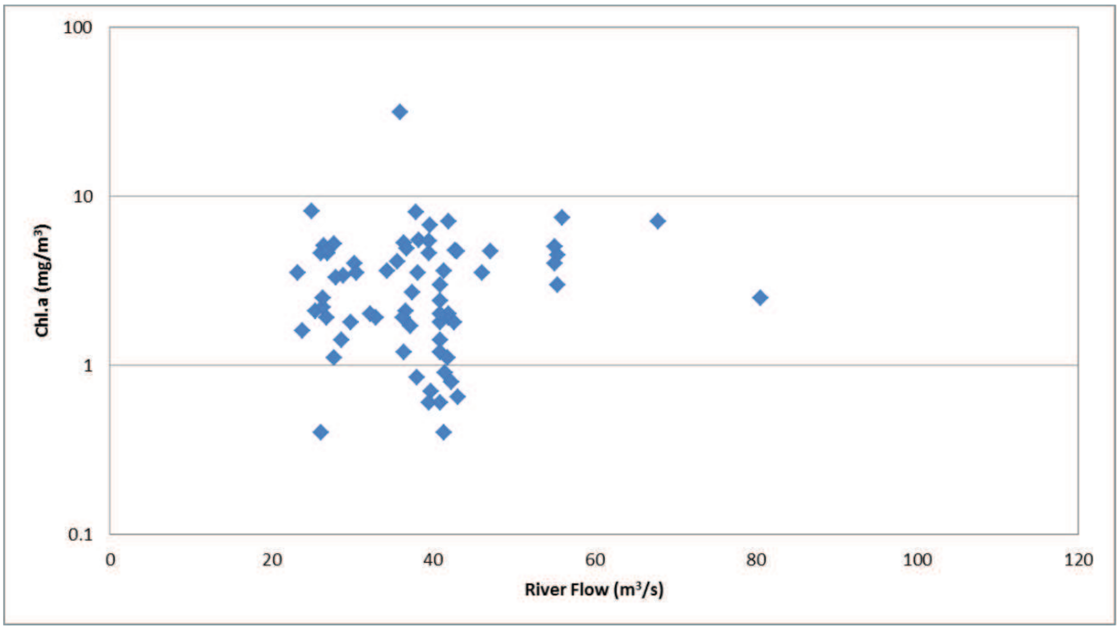


Figure 3-52 Relationship between measured concentrations of chl.*a* and river flow at the Te Matai road bridge for the period, 2000 to 2013. Note log scale on y-axis.

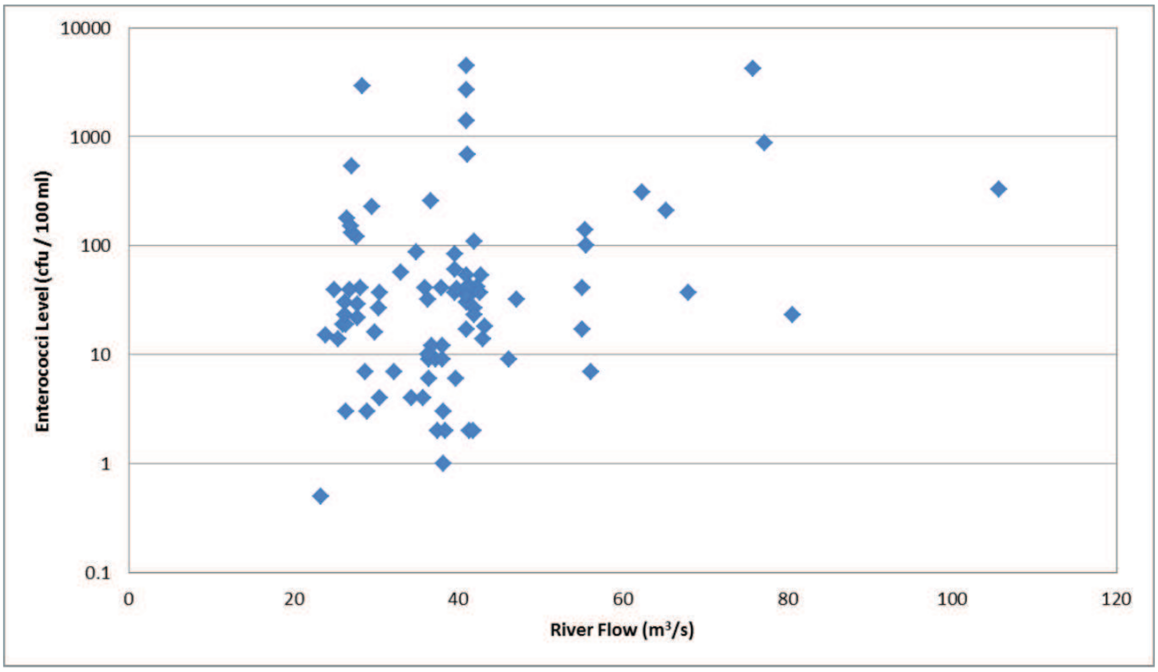


Figure 3-53 Relationship between measured concentrations of faecal coliforms and river flow at the Te Matai road bridge for the period, 2007 to 2013. Note log scale on y-axis.

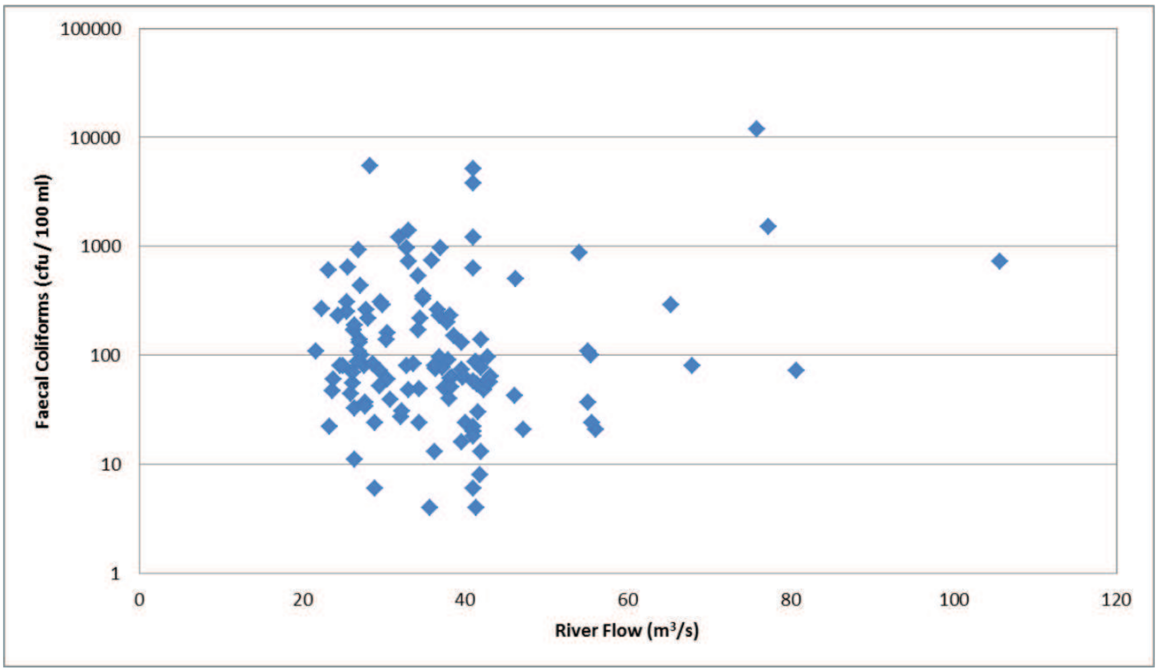


Figure 3-54 Relationship between measured concentrations of Enterococci and river flow at the Te Matai road bridge for the period, 2007 to 2013. Note log scale on y-axis.

3.8 Nearshore Wave Data

A wave buoy operated by BoPRC has been deployed since 2003 approximately 13 km off Pukehina Beach in about 50 depth water in Western Bay of Plenty as shown in Figure 3-55. Wave data was obtained from BoPRC for the period September 2003 to January 2010.

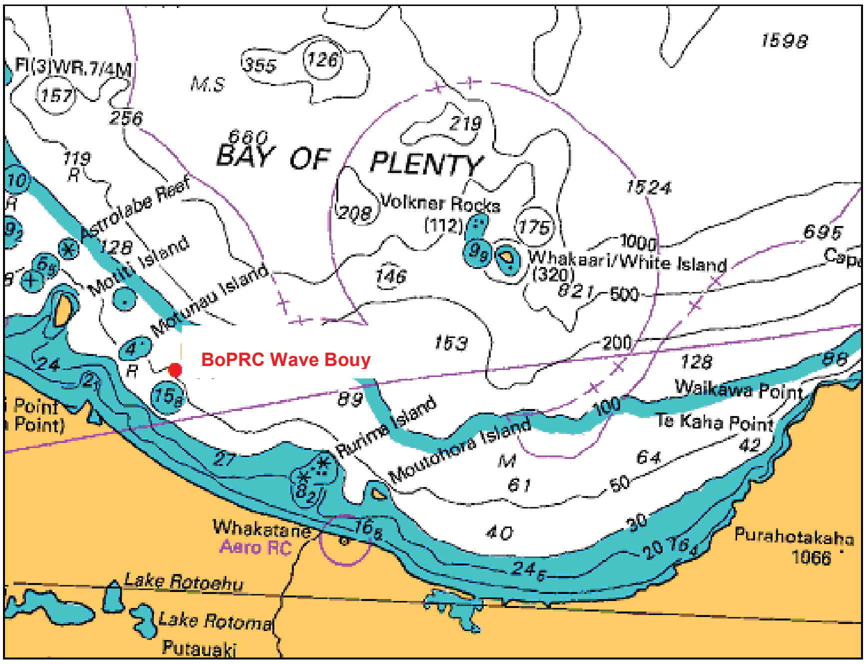


Figure 3-55 Location of BoPRC wave buoy.

3.9 Climate

A variety of climate data has been collected for this study including, wind and atmospheric pressure data. This data is described in the section below.

3.9.1 Wind Data from Ongatoro / Maketū Estuary

NIWA collected wind data from the western side of the estuary for the period 26th March to 30th April 2013. The wind rose for the measurements is presented in Figure 3-56. The highest wind speeds are from the north easterly direction. The distribution of wind directions for the period when the wind data was collected is relatively uniform with no obvious predominant wind direction.

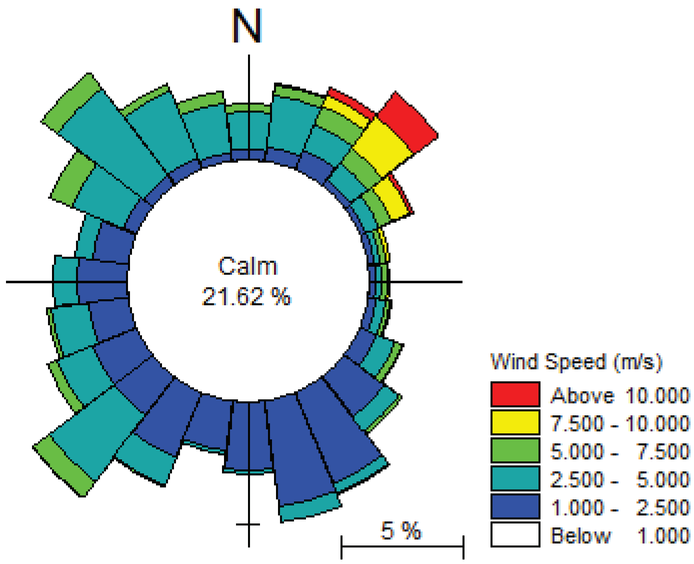


Figure 3-56 Wind rose for wind data collected on western side of estuary for period 26th March to 30th April 2013.

3.9.2 CCMP Wind Data

Six hourly global Cross-Calibrated Multi-Platform (CCMP) wind data derived from satellites has been obtained from Physical Oceanography Distributed Active Archive Center (PODACC) for the period 1st January 2000 to 1st January 2011. The wind data is gridded with a resolution of 0.25°. The data is derived by blending observations from multiple satellites, which is then combined with in situ measurements. The process of combining with in situ measurements improves the accuracy of the data set, however the process takes a significant amount of time, therefore no CCMP data is currently available for 2012 and 2013.

3.9.3 NOAA Wind Data

Six hourly global wind data derived from satellites was been obtained from National Oceanic and Atmospheric Administration (NOAA) for the period March to April 2013. The wind data is gridded with a resolution of 0.25°.

3.9.4 Atmospheric Pressure Data

Atmospheric pressure from Tauranga was provided by BoPRC for the period 1st March 2013 to 30th April 2013 and is shown in Figure 3-57.

Atmospheric pressure changes can significantly increase or decrease ocean water levels. A change in barometric pressure of 1 hPa may cause approximately a 1 cm variation in sea level (Singh, 2005). An increase in atmospheric pressure will decrease the sea level and vice versa. Assuming a mean atmospheric pressure of 1013 hPa, it is probable that water levels were decreased by approximately 20 cm on 22nd March 2010. It is expected during periods like this, predicting water levels which match observed water levels may be problematic unless the changes in water level due to changes in atmospheric pressure are accounted for in the open ocean boundary conditions.

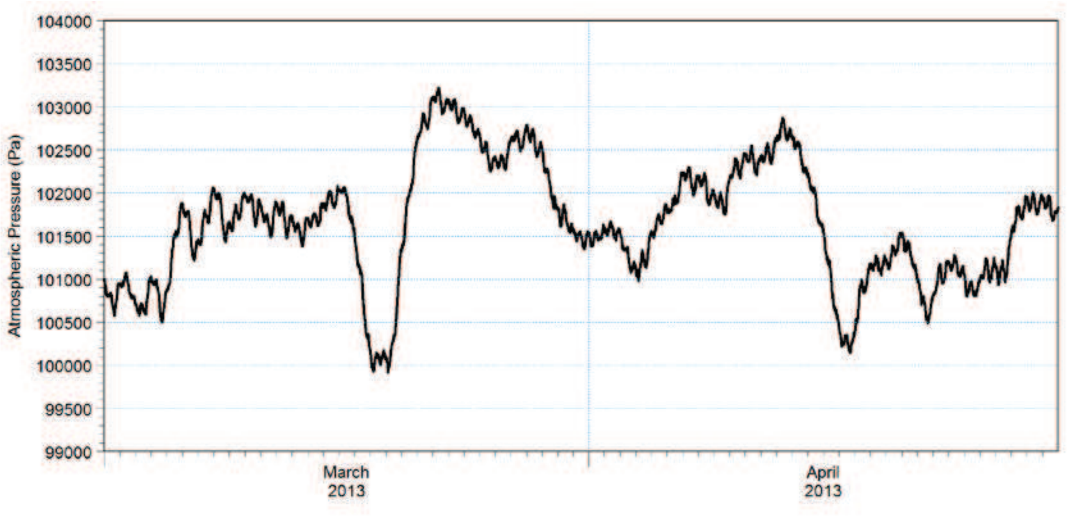


Figure 3-57 Atmospheric pressure measurements from Tauranga.

4 Wave Climate

The section focuses on the development of wave models which have been used to determine the wave climate for Bay of Plenty and at the study site. No wave data is available for the study site; hence it was required to generate a long term hindcast through numerical modelling.

DHI's Pacific Ocean model has been utilised to provide boundary conditions for a regional Bay of Plenty model, from which a ten year (1st January 2000 to 1st January 2010) time series of wave data has been generated for the study site. A local wave model for the study area was also developed.

The ten year time series of wave data was used to assess the wave climate for the study area. The data was also used for the littoral transport assessment carried out using LITPACK and described in Section 5.1.

The wave modelling was undertaken using DHI's MIKE 21 SW (Spectral Wave) model which is able to calculate the propagation of waves from deep water into near shore areas. For further details of MIKE 21 SW, see Appendix B.

All model domains were developed using a flexible mesh which allows the computational domain to be discretized into a mixture of tessellating triangular elements of various sizes. This enables high resolution definition where necessary and low resolution in other areas reducing the computational requirements.

4.1 Evaluation of Offshore Wave Climate

No long term wave observations exist for the study site, therefore one had to be derived from a wave models. A Pacific Ocean wave model was used to generate appropriate boundary conditions for a regional scale Bay of Plenty wave model. The model bathymetry for the Pacific Ocean model is shown in Figure 4-1.

CCMP wind data (as described in Section 3.9) was used for the Pacific Ocean wave model to generate waves within the model domain. The Pacific Ocean model was run for the period 1st January 2000 to 1st January 2010 to provide regional scale boundary conditions. The regional Bay of Plenty wave model was developed to determine the wave climate for the study site. Bathymetry data for the model mesh was obtained from the navigational chart database, C-MAP™. The model mesh and bathymetry is shown in Figure 4-2.

The model resolution is only sufficient to determine the near shore wave climate at the study site at a reasonable depth (> 15 m). For the near shore shallower than 15 m depth, waves undergo significant transformation due to refraction, shoaling and wave dissipation through bottom friction and wave break breaking. A much higher model resolution would be required to resolve these processes.

Wind generated waves within the model domain were included using the CCMP wind data to force the model. Water depth has an impact on behaviour of waves as they propagate into near shore. Varying water levels were included in the model using DHI global KMS tidal model (DHI, 2012) which derived water levels from the study site. The KMS global model is based on TOPEX/POSEIDON altimetry and represents major tidal constituents (K1, O1, P1, Q1, S1, M2, S2, N2, M4 and K2) with a spatial resolution of 0.125° × 0.125.

The regional Bay of Plenty wave model was calibrated against wave data collected by BoPRC 13 km off Pukehina Beach to ensure its predictive ability. Further details of the model calibration can be found in Appendix B.

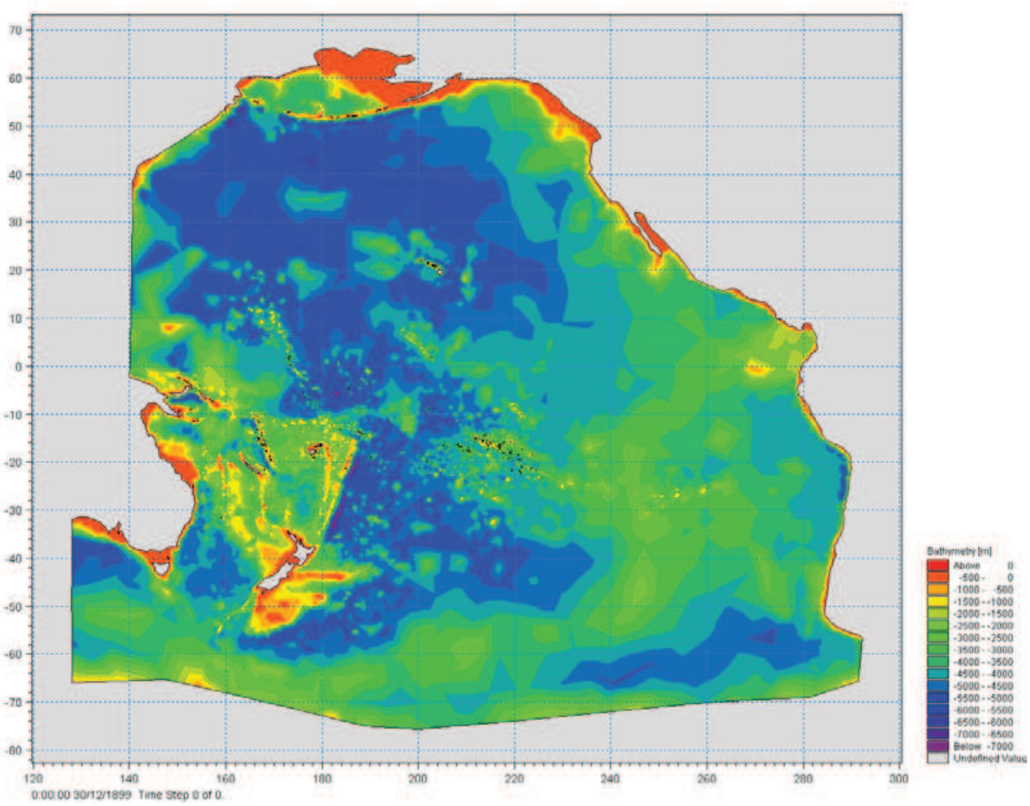


Figure 4-1 Model bathymetry for Pacific Ocean wave model.

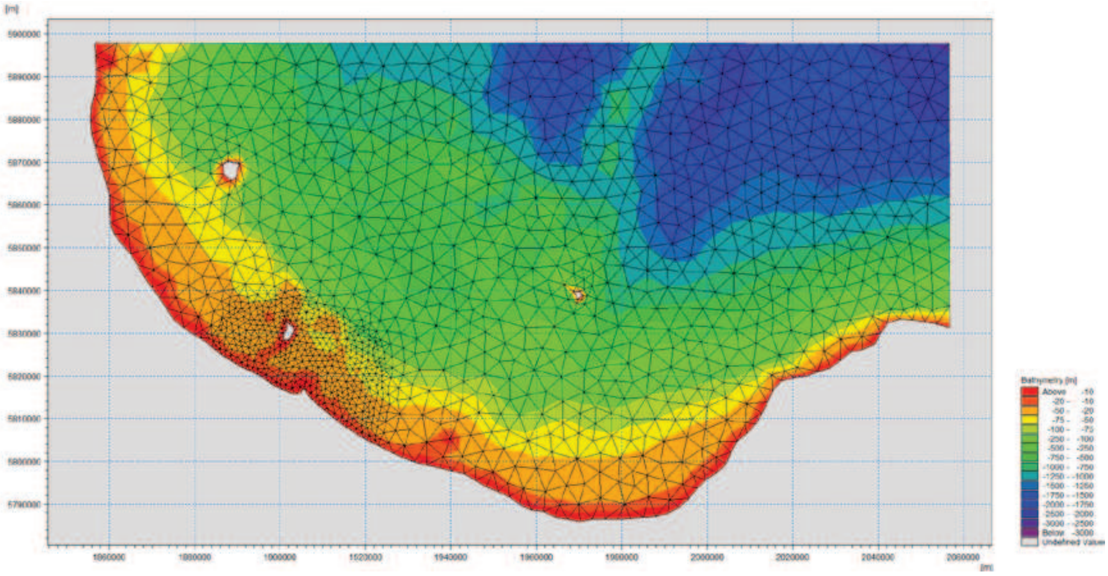


Figure 4-2 Model mesh and bathymetry for regional Bay of Plenty wave model.

4.2 Near-shore Wave Climate

The wave climate of the Bay of Plenty is a driving force for the littoral sediment transport along the Bay of Plenty coastline which plays a significant role in the morphological evolution of the Kaituna River and Ongatoro / Maketū Estuary mouths. During periods of high energy waves offshore sand bars are likely to build across the river mouth and estuary entrance.

Wave time series were extracted along the Maketū coastline at the 15 m depth contour from the Regional Bay of Plenty wave model. Wave roses of this data are presented in Figure 4-3. It is apparent that Motiti Island has a sheltering effect on wave climate for waves from both north westerly and north easterly directions. Further evidence of this sheltering effect is the salient to the west of Maketū and smaller depth values inshore of Motiti Island (Figure 4-2).

At the study site, there will be sheltering of waves from a north easterly direction due to Okurei Point with the most sheltering occurring at Ongatoro / Maketū Estuary mouth. Conversely there will also be sheltering of north westerly waves to the east of Okurei Point.

To investigate the seasonal wave climate for the study site, monthly wave roses from the ten year wave time series off Okurei Point were generated. The monthly wave roses are presented in Figure 4-4 and Figure 4-5. From December to April the dominant wave direction is from the north east and is most likely dominated by swell generated waves. From May to November, wind generated waves are more apparent and wave directions range from north westerly to north easterly directions.

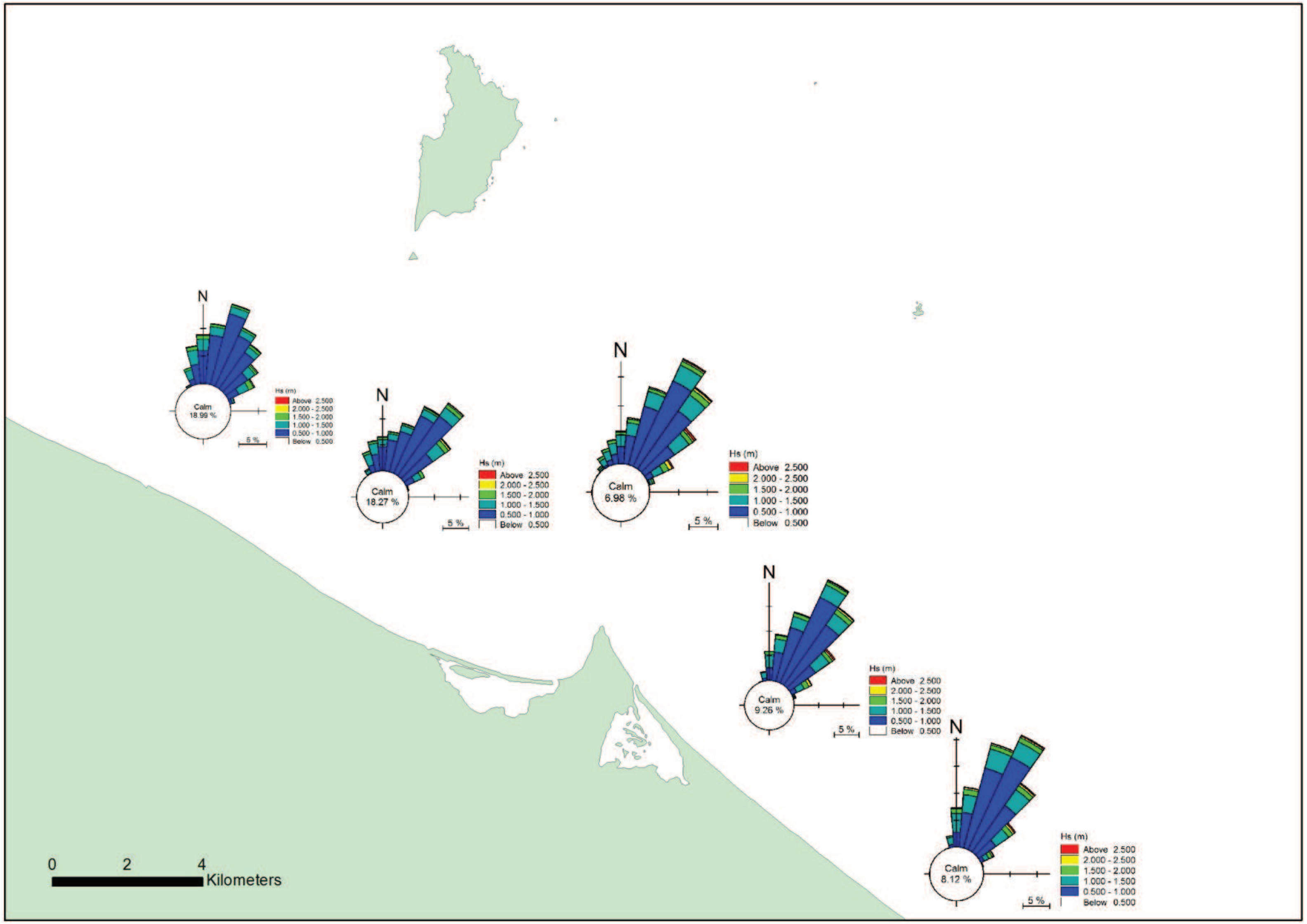


Figure 4-3 Wave climate for 2000 – 2010 at 15m depth contour for Maketū coastline.

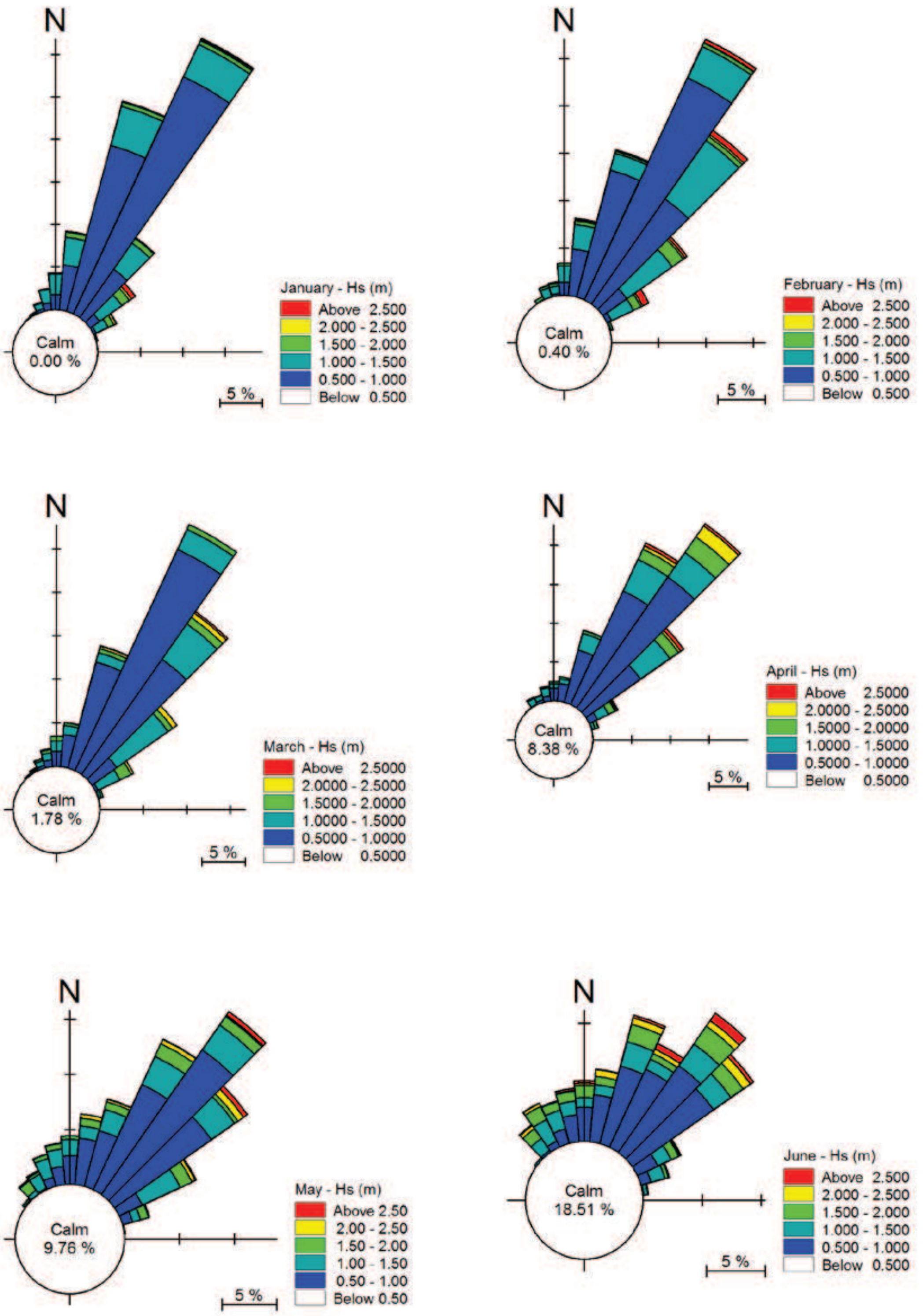


Figure 4-4 Monthly significant wave heights (Hs) from 15 m contour off Okurei Point (January to June).

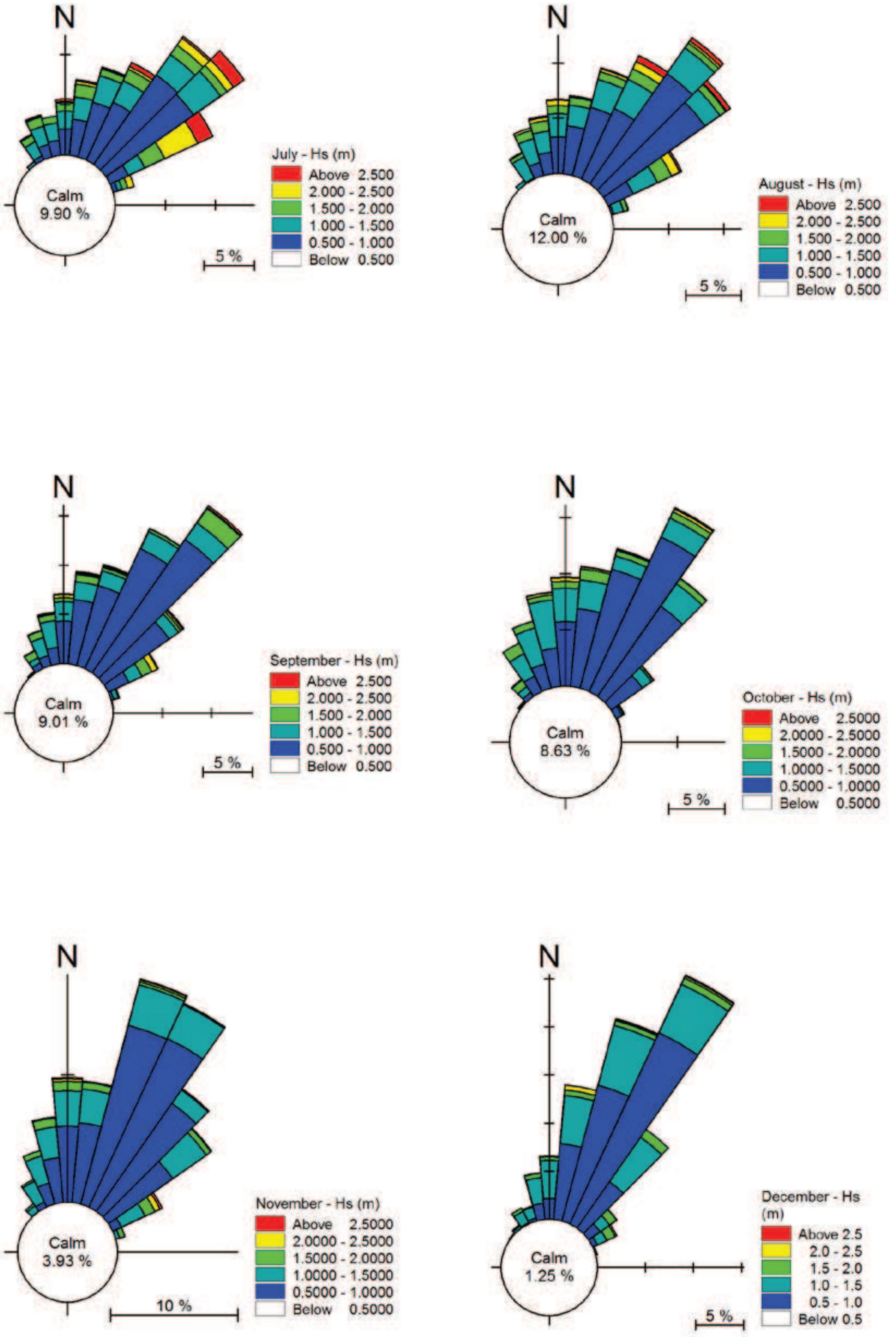


Figure 4-5 Monthly significant wave heights (Hs) from 15 m contour off Okurei Point (July to December).

4.3 Local Wave Model

A high resolution wave model was developed to be able to predict the evolution of offshore waves into the study area. The local wave model mesh was the same as the 2D hydrodynamic model mesh described in Appendix D. The local wave model is an integral component of the morphological model developed for this study.

The local wave model was calibrated using measured wave data collected off Okurei Point. Details of the local wave model calibration are provided in Appendix B.

The local sheltering effect of Okurei Point is illustrated in Figure 4-6, which shows the predicted wave field at the study site for a significant wave event that occurred on 16th April 2013. The mean wave direction is from approximately 40° and it is apparent that waves refract around Okurei Point with a significant reduction in wave height at the Ongatoro / Maketū Estuary entrance compared with the Kaituna River entrance.

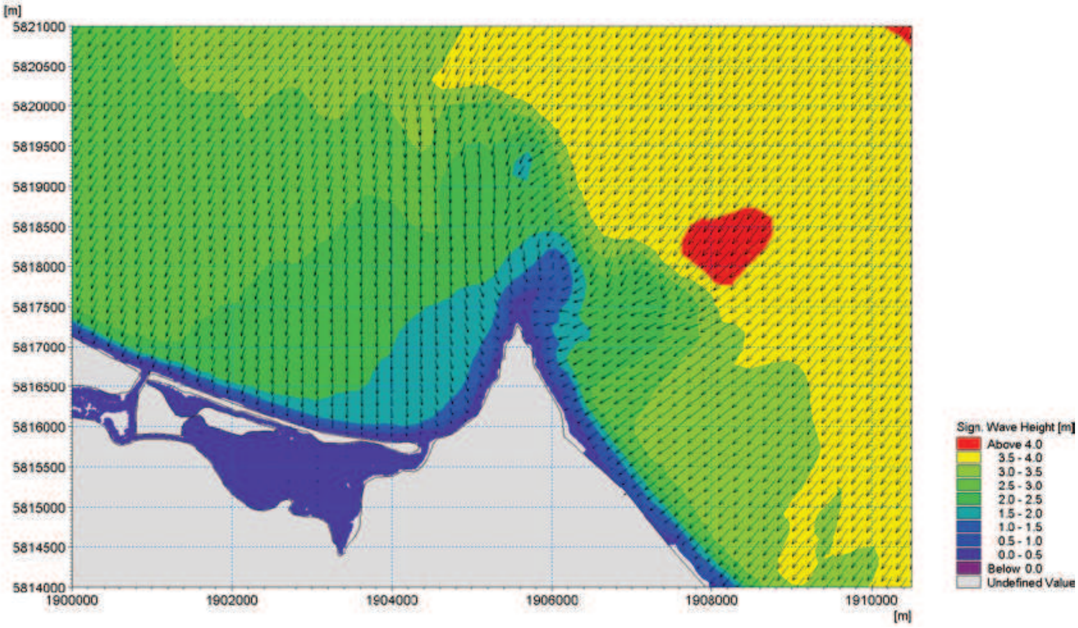


Figure 4-6 Predicted significant wave height field during peak of high energy wave event on 16th April 2013.

5 Sediment Budget

This section provides information on the coastal and river sediment budget estimates that have been determined for the study site.

5.1 Coastal Sediment Budget

A sediment budget has been estimated for the coastline in the vicinity of Maketū. This is to help inform the understanding of the morpho dynamics of the study site. Burton & Healy (1985) estimated a net littoral transport rate at Maketū of 40,000 m^3/year. A net littoral transport rate of 22,000 m^3/year was estimated to occur at Pukehina Beach (10 km to the east of the study site) by Easton (2002). Both estimates are for net transport in a south easterly direction.

There are two main drivers for the transport of sediment along the coastline, waves and currents. Wave generated turbulence is able to re-suspend sediment, while breaking waves generate currents, which combined with wind and tidally driven currents transports suspended sediment. Transport rates are governed by the angle of the incident waves and the grain size of the sediments being considered.

To assess the littoral transport rates along the Maketū coastline. DHI's LITDRIFT model, from the LITPACK coastal process modelling system has been used. LITDRIFT is the littoral sediment module for simulating drift along a uniform coastline with an arbitrary coastal profile. For more details of the LITDRIFT model, see Appendix C.

5.1.1 Evolution of Shoreline

BoRPC have periodically collected surveys of coastal profiles along the Bay of Plenty coastline since 1978 as described in Section 3.1. Coastal profiles from CCS 27 to CSS 35 have been analysed to assess whether there is any obvious pattern of erosion or accretion occurring along this part of the Bay of Plenty coastline. To carry out this analysis the distance that 0 m Moturiki Datum has moved historically from 0 m Moturiki Datum from the first survey was calculated for each profile (see Figure 5-1 to Figure 5-7).

The overall changes in 0 m Moturiki Datum for each profile suggests that for this part of Bay of Plenty coastline the shoreline is in a state of dynamic equilibrium – that is more or less stable with a few periods where there is significant accretion or erosion occurring.

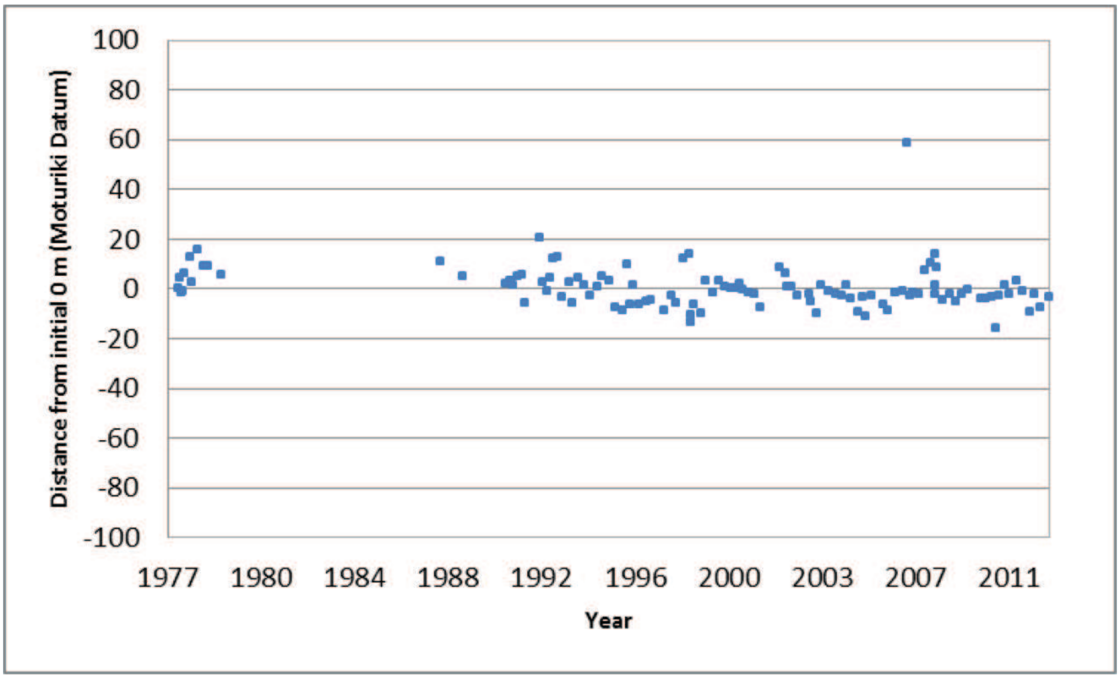


Figure 5-1 Change in position of historical 0 m, Moturiki Datum for CCS27 profile compared with initial profile. A positive change in distance corresponds to accretion and a negative change, erosion.

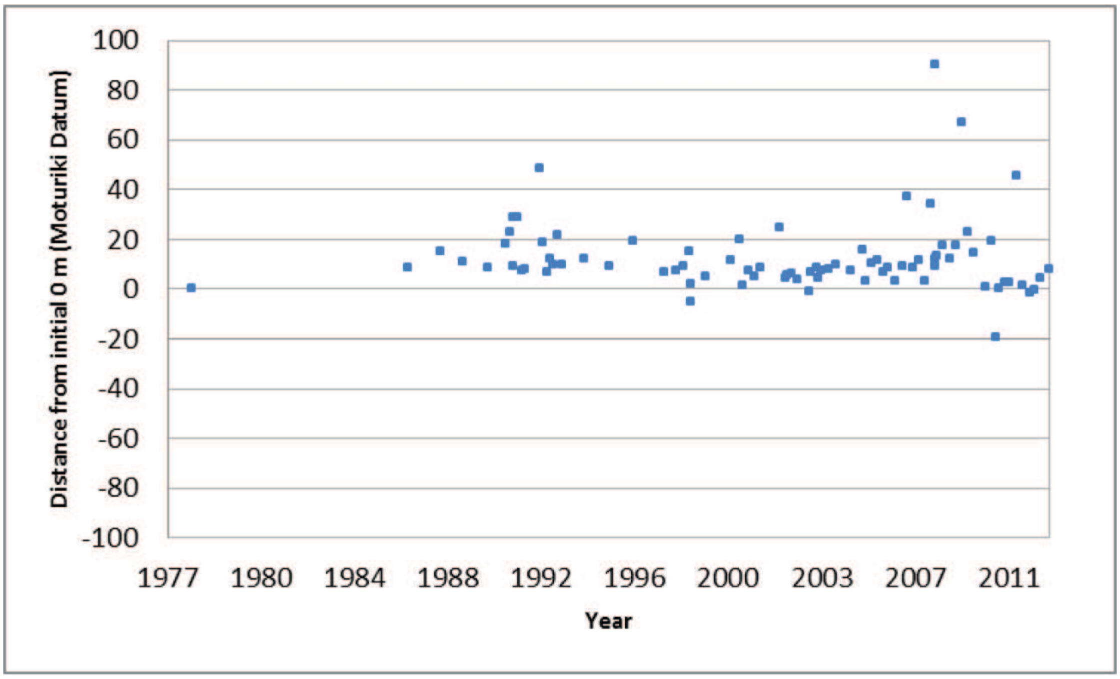


Figure 5-2 Change in position of historical 0 m, Moturiki Datum for CCS28 profile compared with initial profile. A positive change in distance corresponds to accretion and a negative change, erosion.

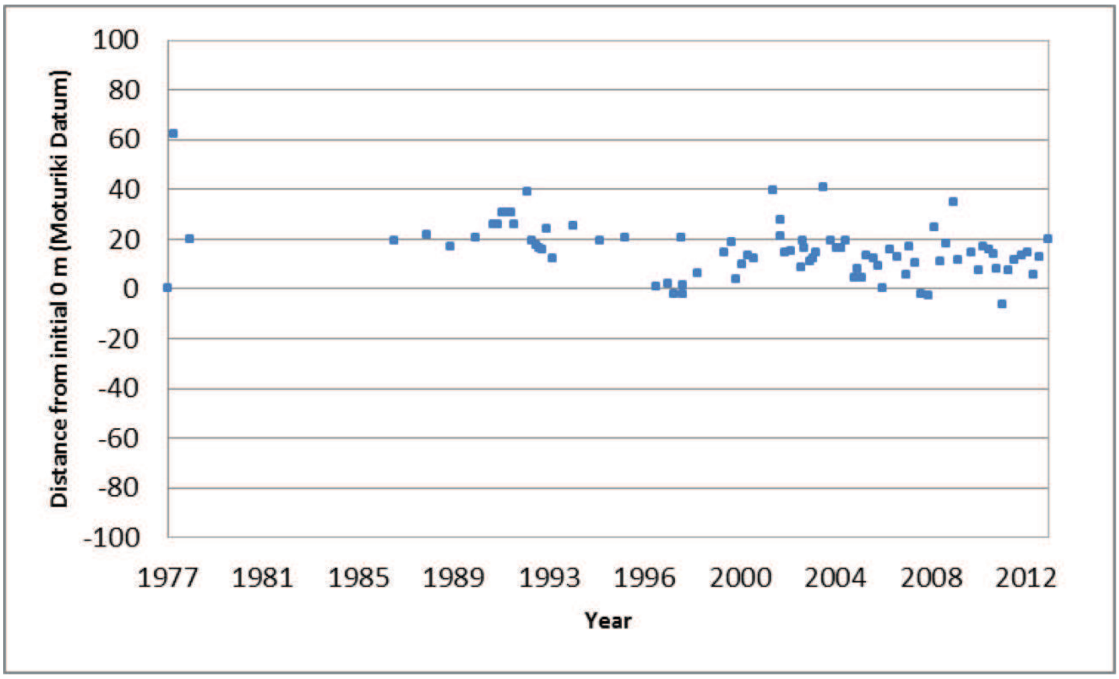


Figure 5-3 Change in position of historical 0 m, Moturiki Datum for CCS29 profile compared with initial profile. A positive change in distance corresponds to accretion and a negative change, erosion.

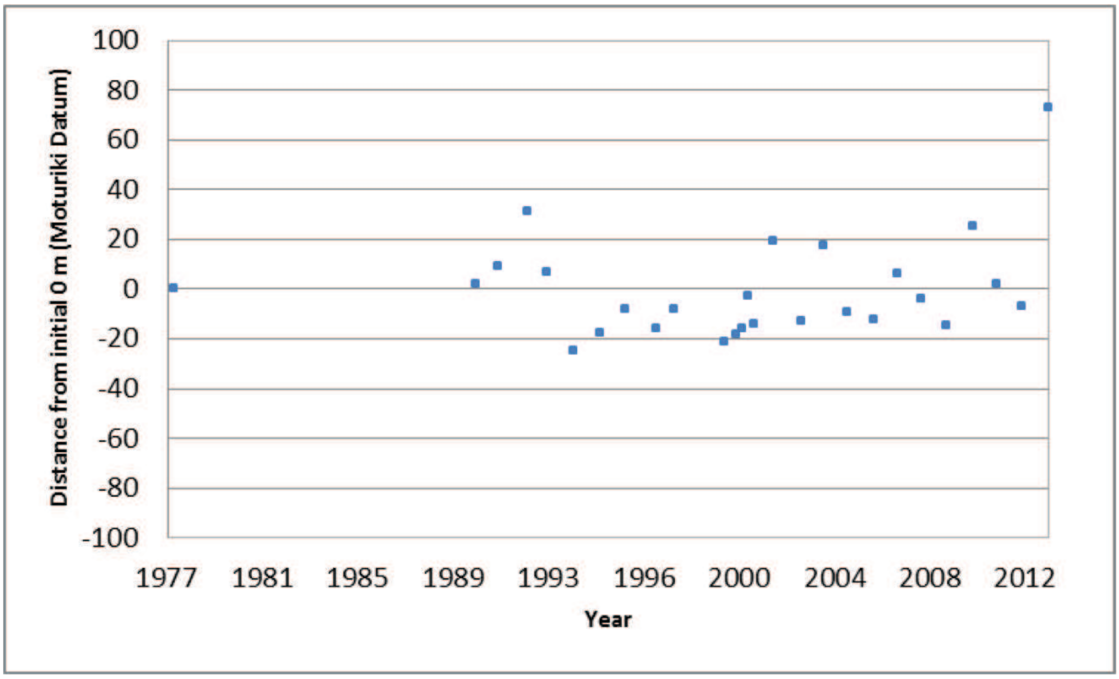


Figure 5-4 Change in position of historical 0 m, Moturiki Datum for CCS30 profile compared with initial profile. A positive change in distance corresponds to accretion and a negative change, erosion.

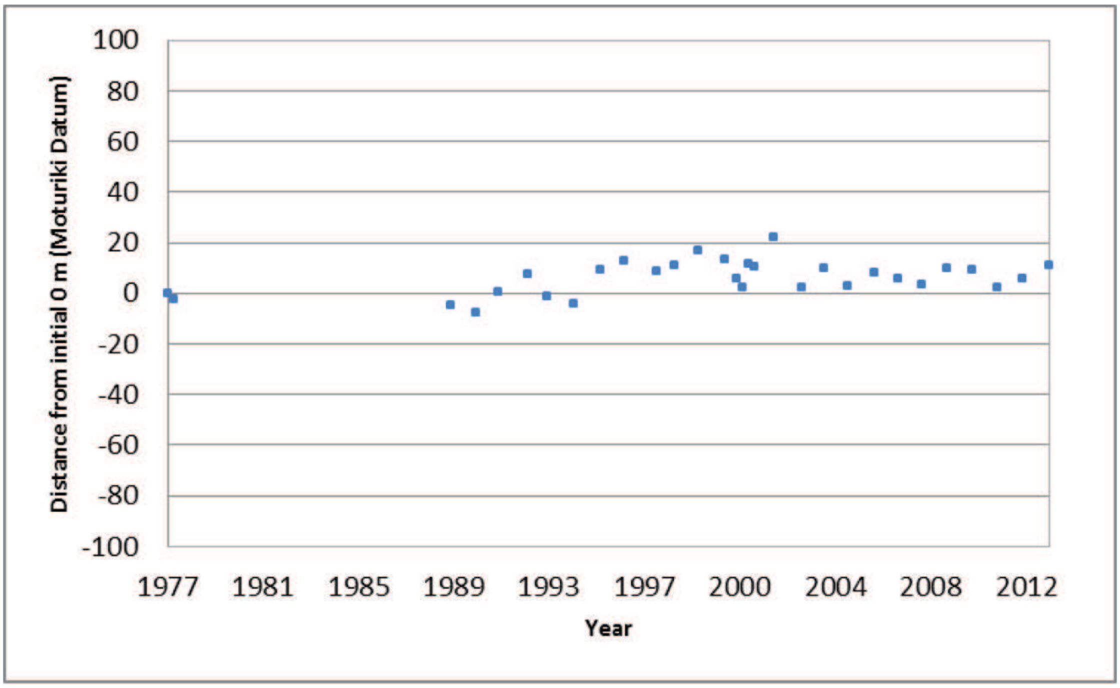


Figure 5-5 Change in position of historical 0 m, Moturiki Datum for CCS32 profile compared with initial profile. A positive change in distance corresponds to accretion and a negative change, erosion.

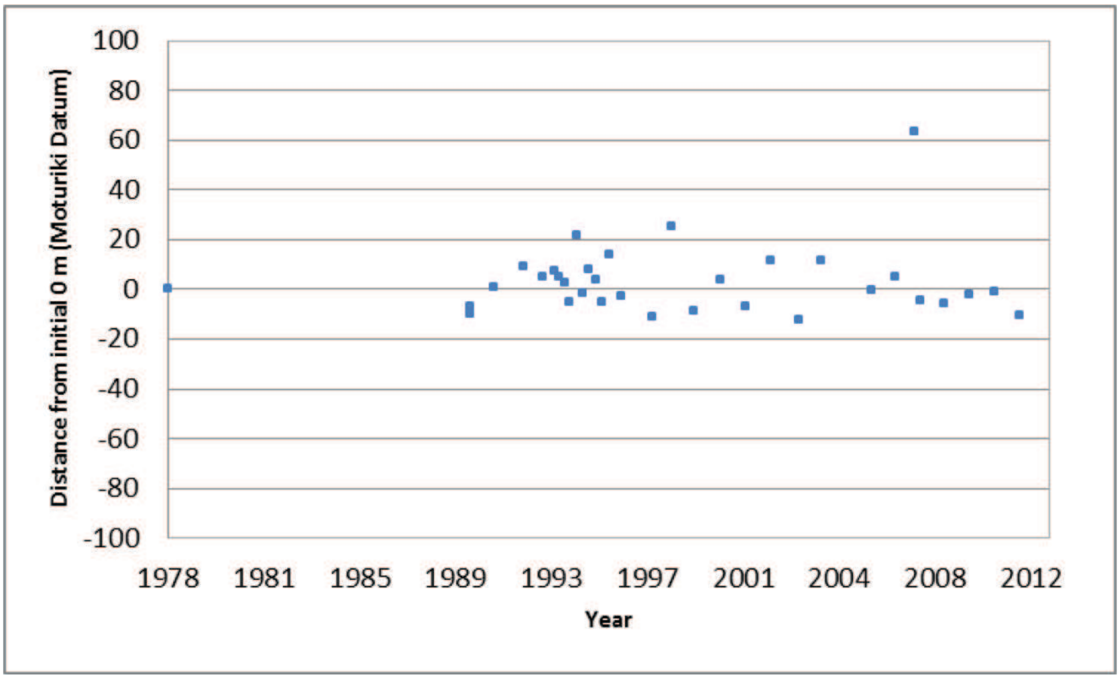


Figure 5-6 Change in position of historical 0 m, Moturiki Datum for CCS33 profile compared with initial profile. A positive change in distance corresponds to accretion and a negative change, erosion.

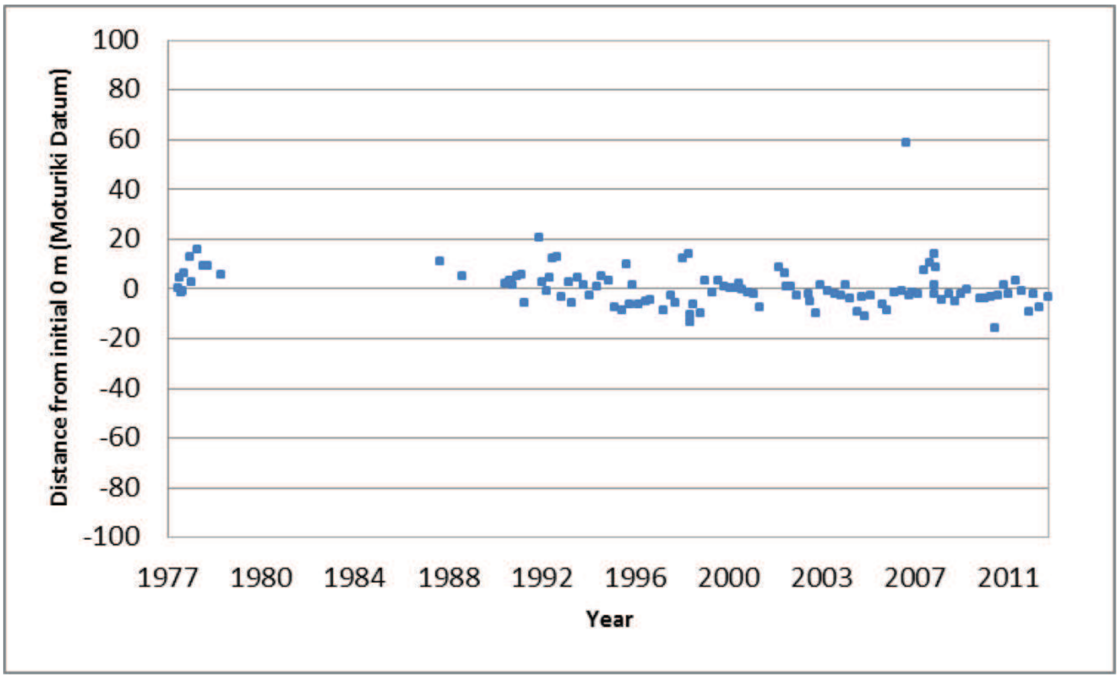


Figure 5-7 Change in position of historical 0 m, Moturiki Datum for CCS35 profile compared with initial profile. A positive change in distance corresponds to accretion and a negative change, erosion.

5.1.2 LITDRIFT Model Inputs

5.1.2.1 Profiles

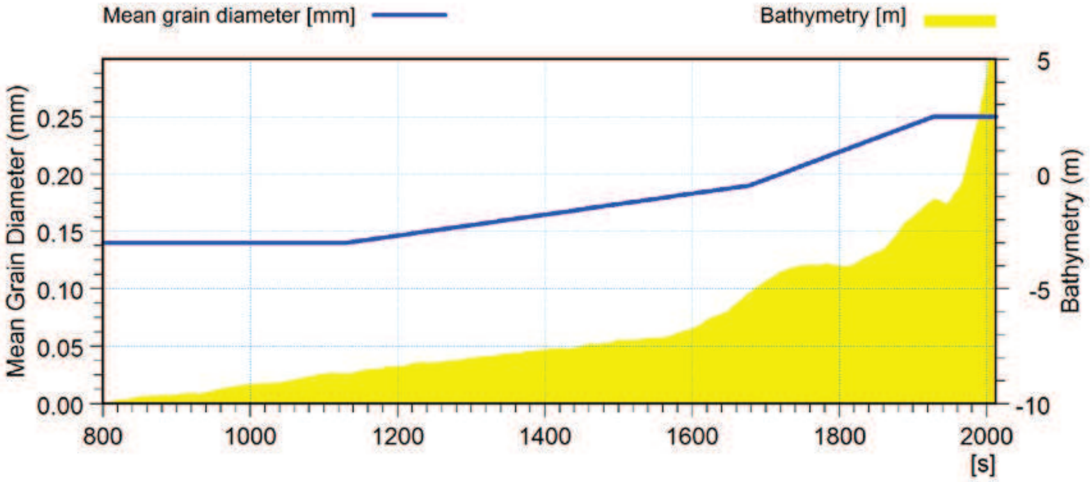
For the LITDRIFT analysis coastal profiles have been selected from two locations considered representative of the shoreline to east and west of Okurei Point. The two locations are to west of Kaituna River mouth (CCS 33) and to east of Okurei Point (CCS 27). The assumed orientation of the profiles is critical for littoral drift processes. For CCS 33 the orientation has been estimated as 30°, while for CCS 27 it has been estimated as 35°, as shown in Figure 5-8. The orientation of the coastline to the west of Okurei Point is variable due to a large scale salient caused by Motiti Island which is evident along this section of the coastline.

Figure 5-8 Location of coastal profiles CCS 33 and CCS 27 with approximate coastline orientation.

For these profile locations, although the profiles are surveyed regularly, only some profiles extend into and past the surf zone. Two surveys of CCS 33 were selected that were suitable for the LIDRIFT analysis (May 1992 and June 1997). These profiles are shown in Figure 5-9. For CCS 27 only the coastal profile surveyed in May 2003 (see Figure 5-10) was chosen for LITDRIFT analysis. All selected profiles extended out to the 15 m depth contour.

5.1.2.2 Sediments

The sediment grab samples that were collected by Cawthron have been used to determine mean grain size (D_{50}) distribution for the coastal profiles as shown Figure 5-9 and Figure 5-10. As expected the sediment in the surf zone is coarser than sediment in deeper water since the breaking waves tend to wash away finer sediment fractions which then deposit in deeper water.



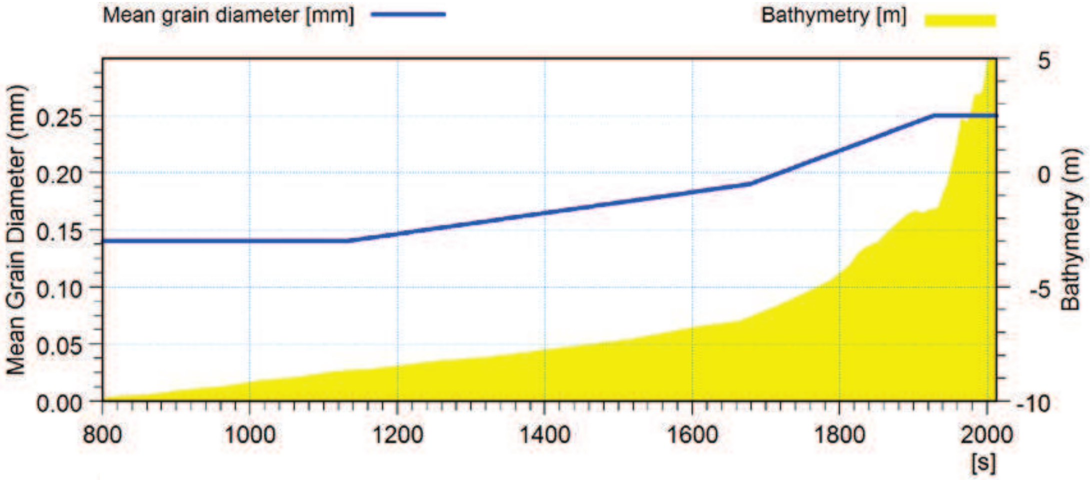


Figure 5-9 Coastal profile CCS 33 (Moturiki Datum) and distribution of D_{50} for June 1997 (top) and May 1992 (bottom).

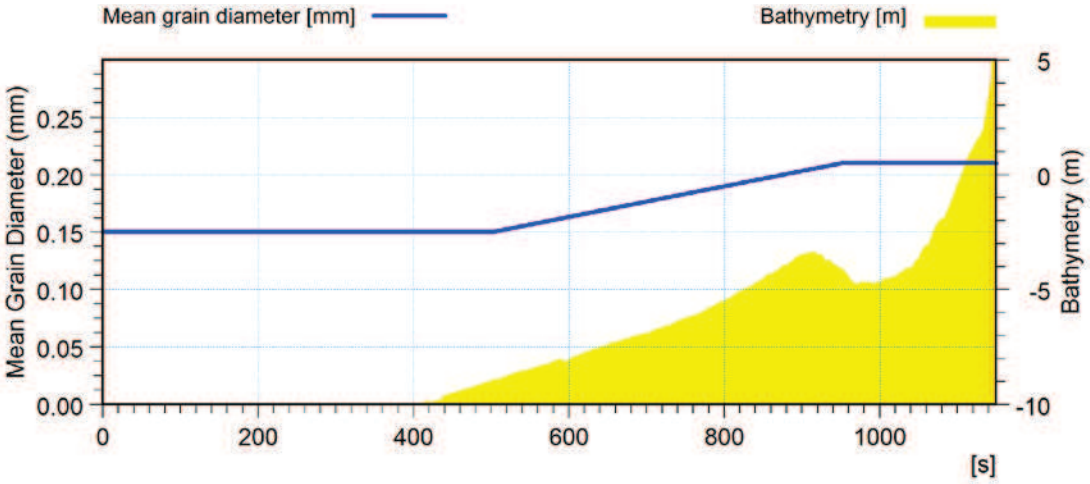


Figure 5-10 Coastal profile CCS 27 (Moturiki Datum) and distribution of D_{50} for May 2003.

As well as the grain size distribution, the density of sediment is also important for littoral sediment transport. The less dense that sediment is, the easier it is to stay in suspension. Previous experience suggests that for most New Zealand beaches, quartz sand dominates, with a specific gravity (density relative to water) of 2.65 (e.g. Kwoll and Winter, 2011).

Bed roughness (determined by sediment size and the presence of bedforms) also has a significant impact on sediment transport. The level of roughness alters the dynamics of the near-bed boundary layer and directly effects the amount of sediment suspended during wave events. Typically values of 10 – 100 times the mean sediment size are used for bed roughness. For this study we have used 50 times the mean sediment size.

5.1.2.3 Wave Climate and Tidal Elevations

The wave climate for the LITDRIFT analysis was taken from the ten year (2000 – 2010) wave hindcast generated by Bay of Plenty regional model, extracted from the 15 m depth contour at the location of the coastal profiles. Water levels were generated for 2000 – 2010 using DHI's KMS global tide model.

5.1.3 Net and Gross Rates for CCS27 and CCS33

The net and gross transport rates for the coastal profiles CCS 33 and CCS 27 have been predicted for 2000 to 2010 using the LITDRIFT model. For an equilibrium orientation of the coastline, the overall transport would balance each other out and the net transport would be zero.

5.1.3.1 Littoral Transport to the West of Okurei Point

The net and gross transport rates for CCS 33 (surveyed June 1997) are shown in Figure 5-11. LITDRFIT predicts that for the assumed coastline orientation of 30° a net transport of 52,000 m^3/year and a gross transport of approximately 400,000 m^3/year. The predicted coastline orientation where zero net transport would occur is approximately 27°. This suggests that the coastline at this location only just encourages a net south easterly transport of sediment. The predicted net transport of 52,000 m^3/year is consistent with previous estimate of 40,000 m^3/year from Burton & Healy (1985).

The yearly net transport rates for CCS 33 are presented in Figure 5-12. As expected the net transport is predominantly to the south-east, however there are significant variations from year to year ranging from 60,000 m^3 north-westward to 260,000 m^3 south-eastward.

The CCS 33 profile which was surveyed in May 1992 was utilised to assess what impact a different state of the beach profile would have on littoral transport rates. The 1992 profile at this time had a bar at a depth of -4 m compared to the 1997 profile which the bar is not present. A comparison of the predicted net transport rates for 2000 – 2010 for different coastline orientation is presented in Table 5-1. There was not much variation in transport rates between the two states of the profile suggesting that state of bar does not significantly affect the transport rates along this coastline

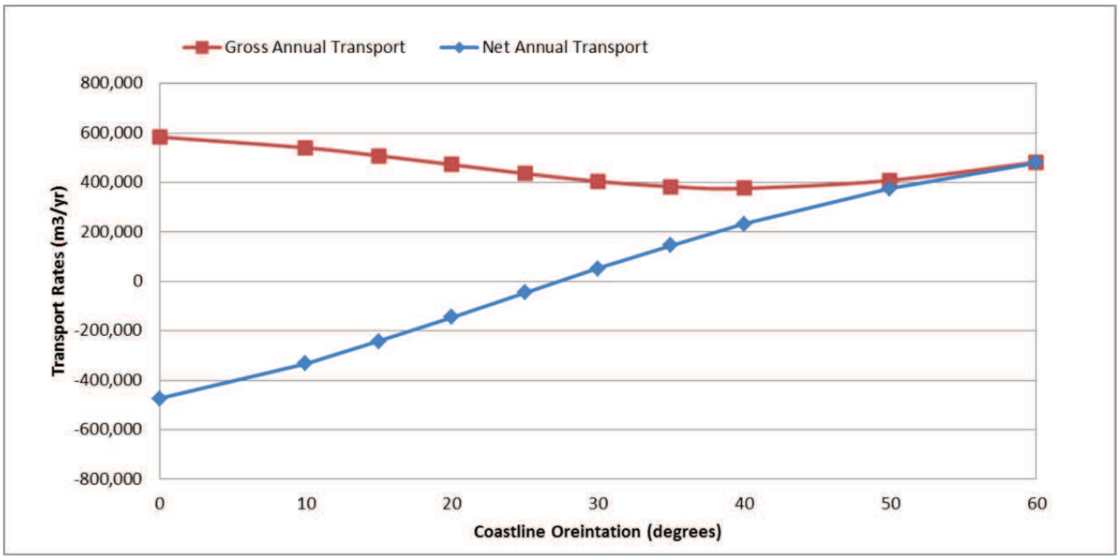


Figure 5-11 Variations of the gross and net transport rates for the coastal profile CCS 33 surveyed June 1997. Coastline orientation is defined as the orientation of the shoreline normal with respect to north.

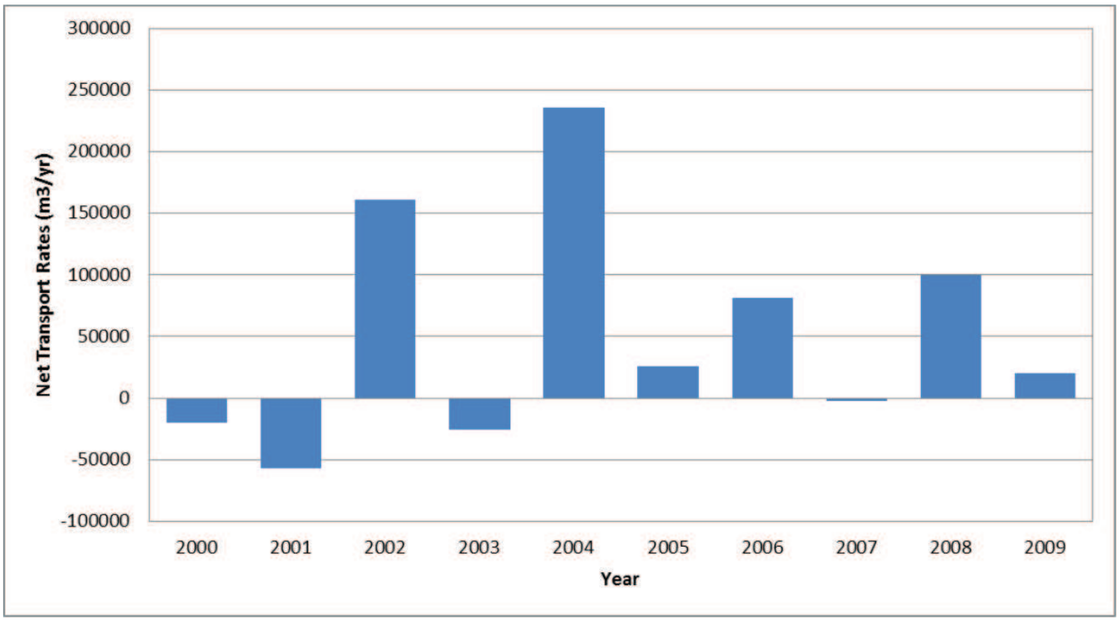


Figure 5-12 Computed net yearly transport rates for CCS33 surveyed in June 1997 for 2000 – 2010. A positive transport rate is towards south east while a negative transport rate is towards the north west.

Table 5-1 Comparison of net transport rates predicted by different CCS33 profiles.

Profile	Coastline Orientation		
	25°	30°	35°
June 1997	-46,000 m^3/yr	52,000 m^3/yr	145,000 m^3/yr
May 1992	-44,000 m^3/yr	45,000 m^3/yr	128,000 m^3/yr

The cross shore distribution of sediment transport rates for two states of CCS 33 coastal profile with an assumed shoreline orientation of 30° is shown in Figure 5-13. The majority of the transport occurs in shore of the 5 m depth contour. There is very little transport across the secondary bar present in profile surveyed in June 1997.

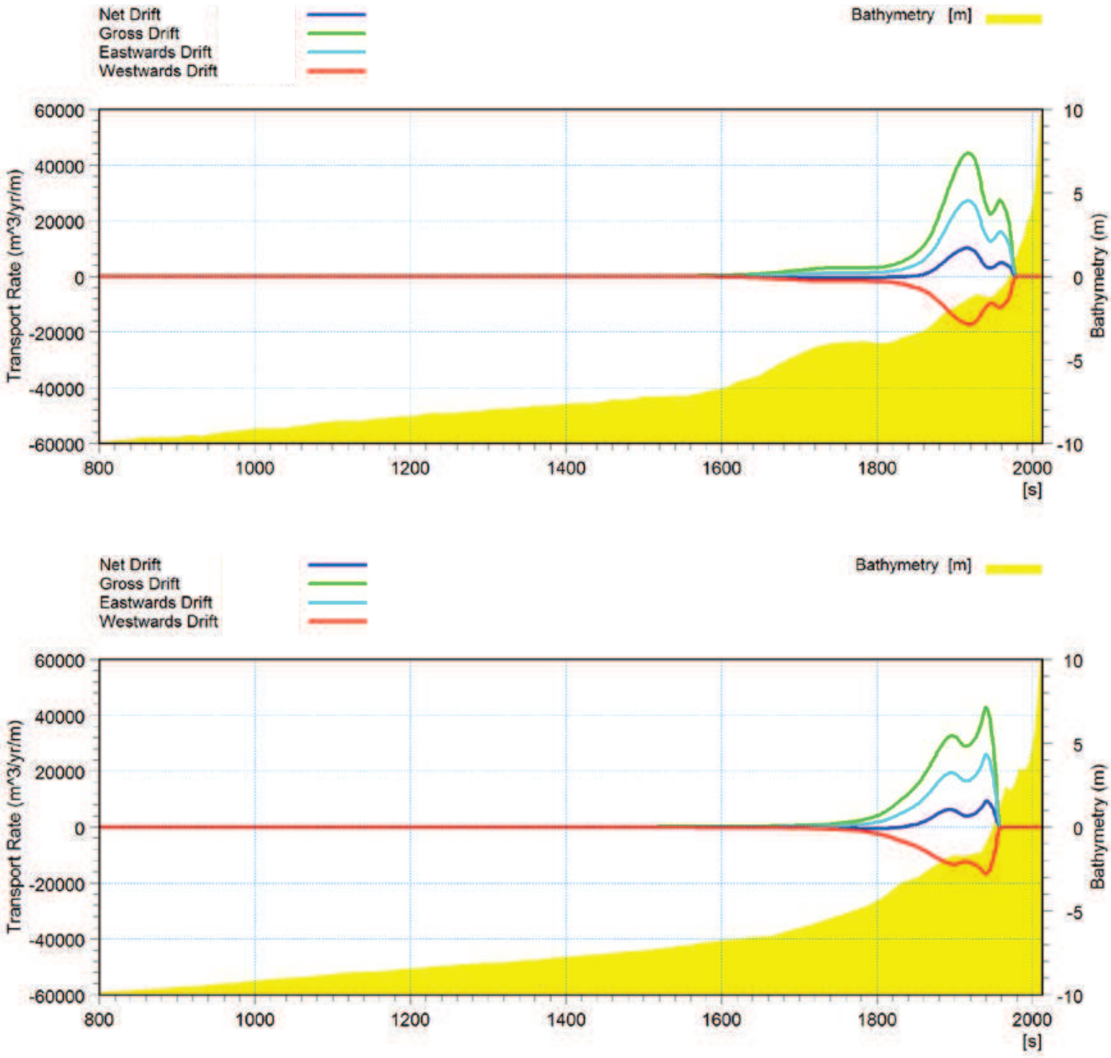


Figure 5-13 Littoral transport results for CCS 33 coastal profile (Moturiki Datum) surveyed in June 1997 (top) and May 1992 (bottom) with a coastline orientation of 30°. The results show net transport (dark blue), gross transport (green), eastward transport (light blue) and westward transport (red).

The distribution of the sediment transport rates with regard to wave height and direction is presented in Figure 5-14. As expected waves which approach normal to coastline (i.e. 30°) produce the least amount of sediment transport, while waves approaching at an angle will produce the most sediment transport. The two wave directions that encourage the most littoral transport are approximately 355° and 60°.

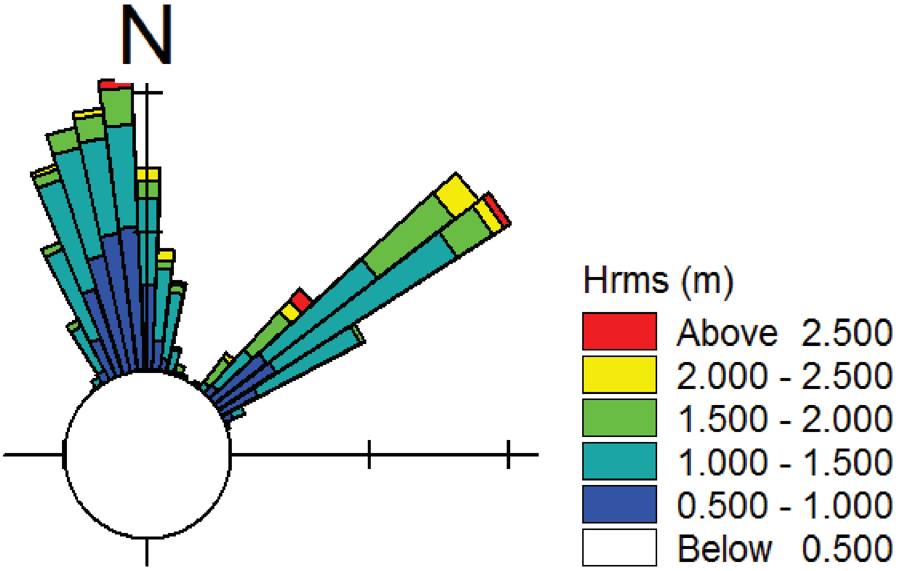


Figure 5-14 Distribution of average annual net sediment transport rates (m^3/yr) for CCS33 surveyed in June 1997.

5.1.3.2 Littoral Transport to the East of Okurei Point

For the coastal profile CCS 27 (surveyed in May 2003) with an assumed orientation of coastline of 35°, the predicted gross transport rates was 214,000 m^3 and a net south eastwards transport rate of 41,000 m^3. This is higher than previous estimates for this coastline of 22,000 m^3/year (Easton, 2002). The cross shore distribution for the CCS 27 coastal profile with an assumed shoreline orientation of 35° is shown in Figure 5-15. Similar to CCS 33 profile, the majority of sediment transport is occurring in shore of the 5 m depth contour.

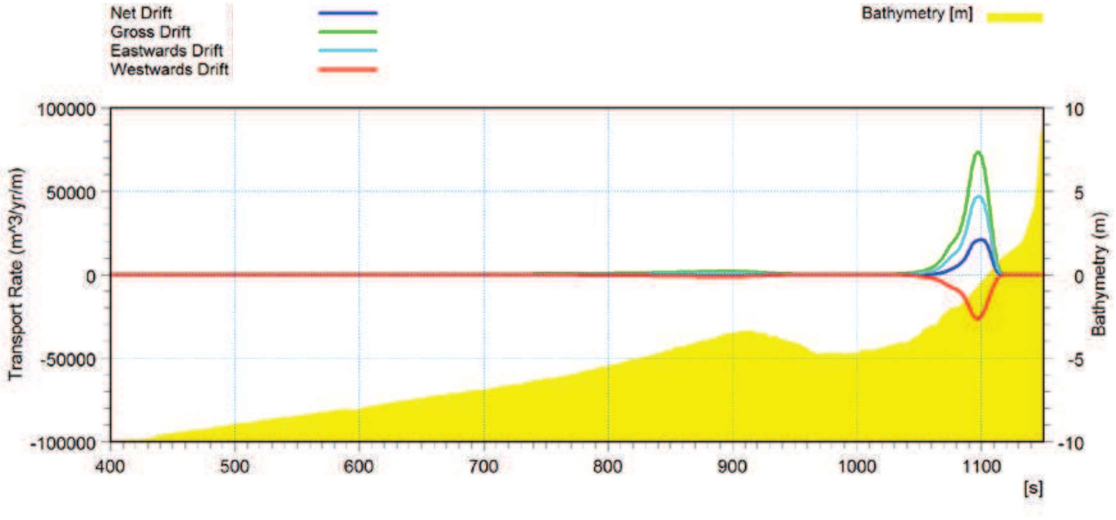


Figure 5-15 Littoral transport results for CCS 27 coastal profile (Moturiki Datum) surveyed in May 2003 with a coastline orientation of 35°. The results show net transport (dark blue), gross transport (green), eastward transport (light blue) and westward transport (red).

5.1.4 Overall Assessment

The littoral transport assessment shows that the local coastline orientation to the west of the site is very close to the long term equilibrium orientation. Motiti Island plays an important role for the local wave climate west of the site, which is reflected in the vague salient centred along the coastline to the SSW of the Island, approximately 10 km northwest of Maketū. With the predominant north-easterly waves, Motiti Island has limited effect along the Maketū spit.

Close to the Maketū Entrance, the local wave sheltering of the Maketū heads and the shallower water stretching from Okurei Point out to Town Shoals play an important role in determining the local spit orientation. The wave sheltering and wave refraction leads to an anti-clockwise rotation of the dominant wave direction, and a corresponding anti-clockwise rotation of the orientation of the spit.

The average net annual littoral transport is estimated to be moderate and directed towards the Ongatoro / Maketū Estuary entrance. This is consistent with a variable but largely stable seaward face of the sand spit, and a growing flood delta and overall sedimentation of the Ongatoro / Maketū Estuary as the littoral transport is flushed into the estuary during flood tide.

The large variability in the net littoral transport rates indicate the potential for variability in the stability of the sand spit with potential overall erosion during years with significant westerly directed transport, and accretion of the sand spit during years with larger than normal easterly directed transport. It is, however, noted that for instance 60,000 m^3 westerly transport eroded over the length of the spit in the order of 3 km and over a depth of for instance 5 m corresponds to 4 m average retreat of the beach - well within the observed range of fluctuations (e.g. Figure 5-5). The cross-shore mobility of the coastline will furthermore be affected by cross-shore variability in the profile.

There is approximately a 11,000 m^3 difference in the estimated net easterly littoral transport rate for the coastline to the west of Okurei Point compared with the coastline to the east of Okurei Point. With no evidence of accretion of the coastline at Maketū, some of this sediment can be accounted for by what is lost from the system and enters both the Ongatoro / Maketū Estuary and Waihi Estuary (to east of Okurei Point).

The distribution of average annual net sediment transport rates (Figure 5-14) have been used to determine two wave conditions that are predicted to encourage the most littoral sediment transport (see Table 5-2). These wave scenarios have been used for the morphological assessment (see Section 7).

Table 5-2 Wave conditions for morphological model assessment derived from LITDRIFT analysis.

Parameters	Wave Scenario 1	Wave Scenario 2
Mean Wave Direction (°)	355	55
Significant Wave Height (m)	2.5	2.5
Peak Wave Period (s)	10	10

5.2 River Sediment Budget

A potential source of sediment to the study site (specifically the Kaituna River mouth) is sediment supplied from the Kaituna River. Estimates of the sediment supply from Kaituna River range from 26,000 m^3 to 150,000 m^3 (Mawer, 2012). These estimates are likely to include wash load, which is fine suspended sediment that will have very little effect on the morphology of the Kaituna River mouth or Ongatoro / Maketū Estuary. What is of importance for the morphological behaviour of the river mouth and estuary is bed material load. Bed material load contains coarser sediment such as sand and gravel which maybe either transported along the bed or in suspension and interacts with the bed, thus contributing to erosion and deposition of the bed.

It has been estimated that the bed material load to the coast for the Kaituna River is 19,000 tonnes (NIWA, 2006). Assuming this material is predominately quartz and feldspar with an average density of 2650 kg/m^3, this is the equivalent to approximately 7,000 m^3 of bed load sediment per year (Mawer, 2012). The geology of the surrounding catchments for Kaituna River actually suggests that the bed material is also likely to consist of pumice sand, which has an average density of approximately 2230 kg/m^3 (Marks et al., 1998) therefore equivalent to approximately 8,500 m^3 of bed load sediment per year.

Whether river supplied bed material is either quartz or pumice sand, the sediment supply from littoral transport is significantly greater (45,000 to 52,000 m^3 compared with 7,000 to 8,500 m^3), therefore bed material supplied from the Kaituna River has not been considered for the morphological assessment in Section 7.

This observation is consistent with the fact that no delta has formed at the Kaituna River mouth. If the river sediment load was comparable to or greater than the littoral transport capacity, a delta would form at the river mouth. Only a small and variable ebb delta which facilitates sediment bypass of the river mouth exists, whereas the local coastline orientation is largely uninterrupted.

6 Proposed Option

A re-diversion option has been proposed that attempts to maximise the volume of water which enters the estuary from the river per tidal cycle while also maximising the ratio of freshwater and total volume of water into the estuary. An overview of the proposed option is shown in Figure 6-1.

Figure 6-1 Overview of proposed re-diversion option

The main features of the proposed option are the following:

- Widening of the existing Ford's Cut channel.
- A new channel on the river side of Ford's Cut, utilising the existing Ford's Loop, with a new entrance to river, further upstream to minimise saltwater intrusion into the new channel.
- Construction of additional culverts either side of the existing Ford's Cut culverts.
- Infilling of the current downstream section of Ford's Loop.
- Removal of the Papahikahawai Creek stop banks; and

- Removal of stop banks adjacent to the area known as Brain's Land and creation of a wetland.

The following inlet structures at Ford's Cut are proposed:

- 19 flap gated box culverts with 2 m height, 2 m width, 5 m length, with an invert of -1 m Moturiki Datum to the north of the existing culverts.
- The four existing flap gated circular Ford's Cut culverts (i.e. 1.8 m diameter flap gated culverts with 4.8 m length with an invert of -0.47 m Moturiki Datum).
- Two flap gated box culverts with 2 m height, 2 m width, 5 m length, with an invert of -1 m Moturiki Datum to the south of the existing culverts.

The bridge / road on top of the culverts will have a crest level of 2.8 m Moturiki Datum.

The proposed new re-diversion channel is 60 m wide at 0 m Moturiki Datum; invert level at -1.5 m Moturiki Datum approximately 63 metres wide at 0 m Moturiki Datum and 57 metres wide at -1.5 m Moturiki Datum). The channel cross section is shown in Figure 6-2.

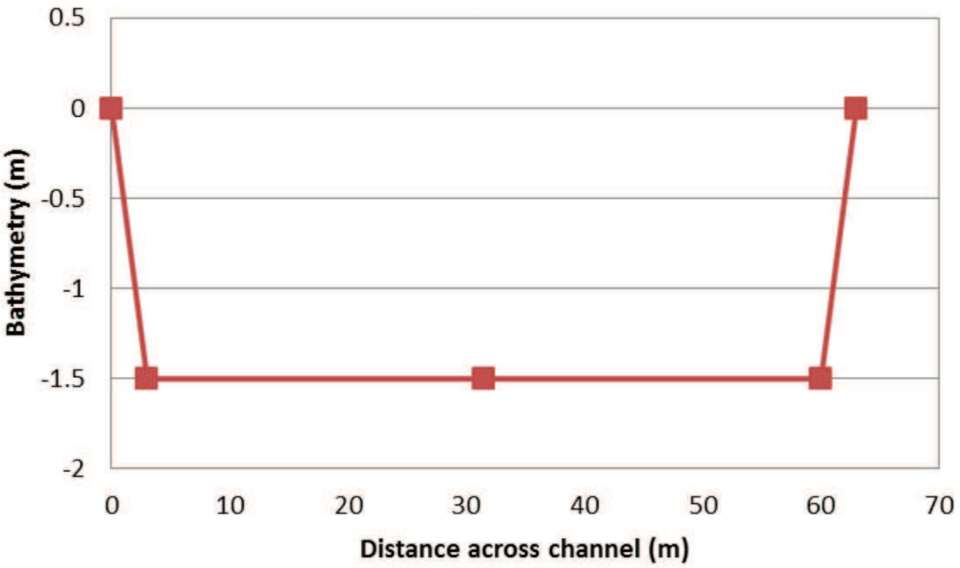


Figure 6-2 Channel dimensions for new channel.

The model bathymetry for the lower river and estuary for both the existing situation and the proposed option is shown in Figure 6-3 and Figure 6-4. The model bathymetry for the proposed option where modifications have been made to the existing bathymetry is shown Figure 6-5, while the bathymetry and mesh is shown in Figure 6-6. The new re-diversion channel was schematised using quadrangular elements.

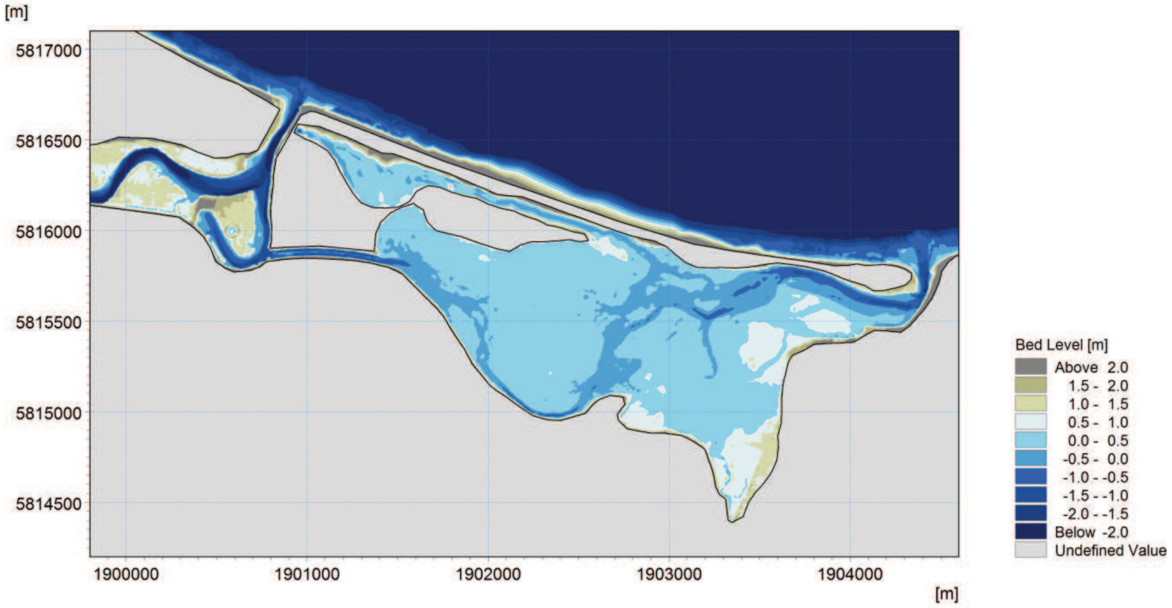


Figure 6-3 Model bathymetry (Moturiki Datum) for existing situation.

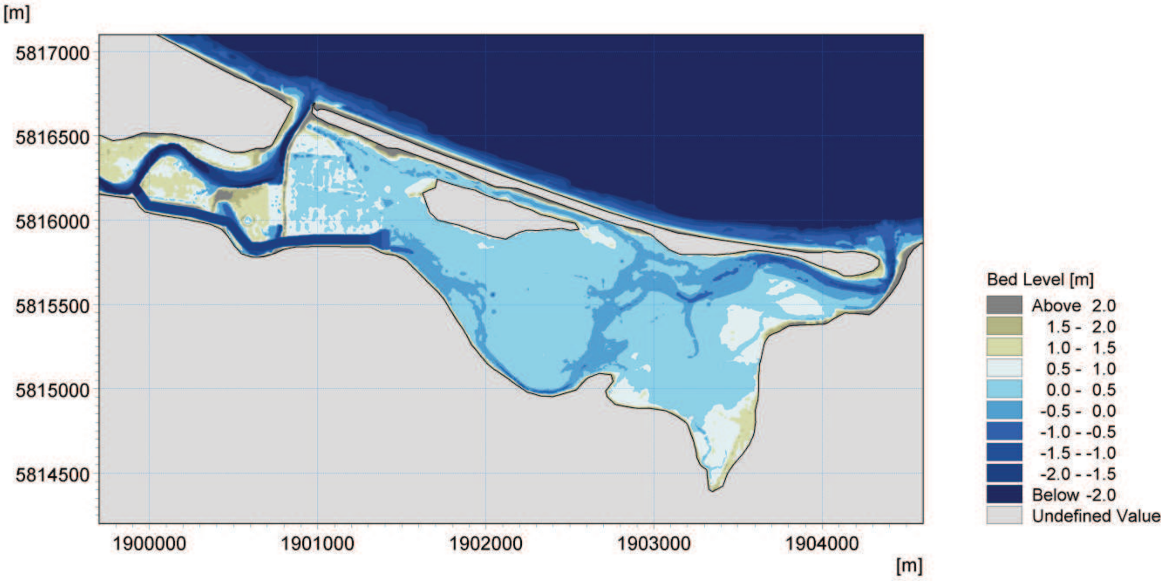


Figure 6-4 Model bathymetry (Moturiki Datum) for proposed option.

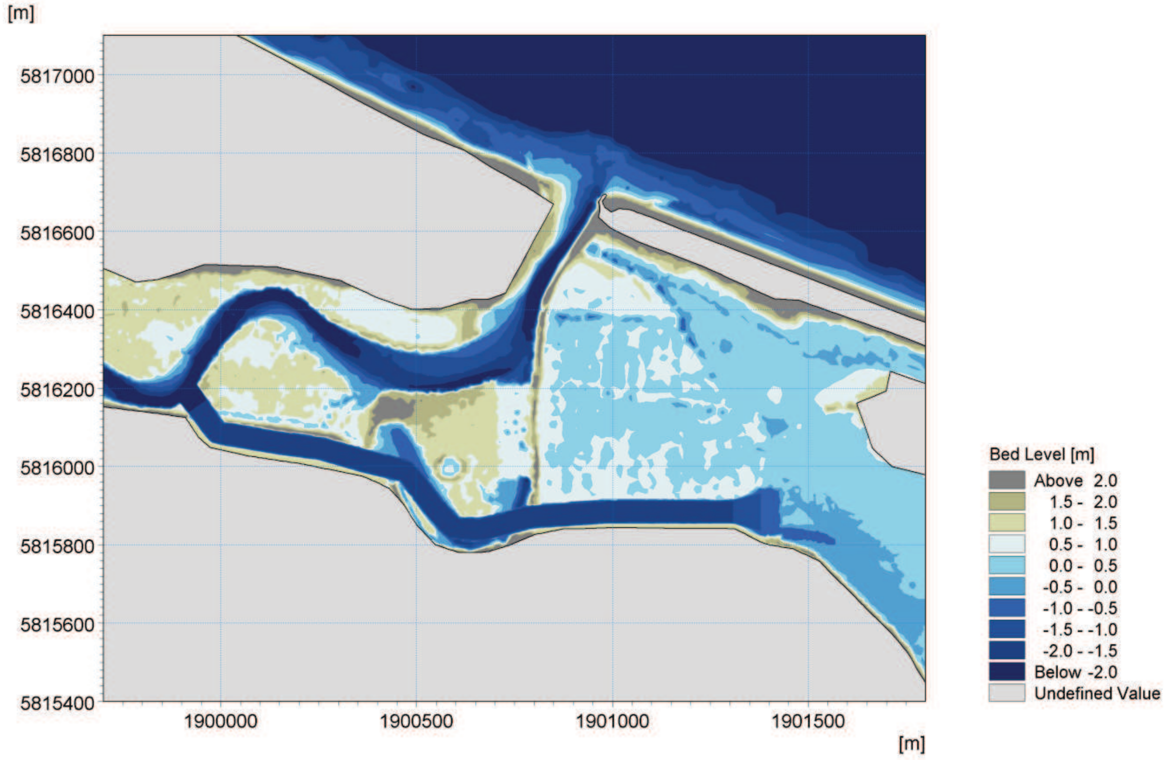


Figure 6-5 Model bathymetry (Moturiki Datum) for proposed option – re-diversion channel.

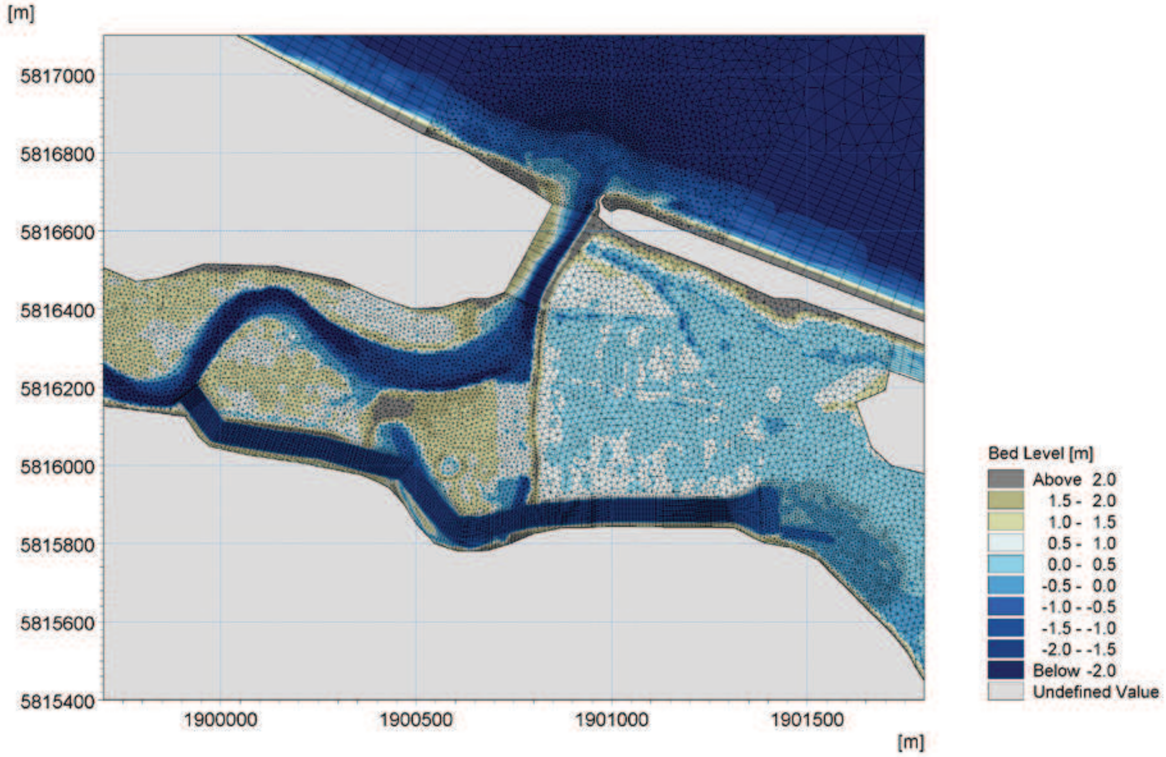


Figure 6-6 Model bathymetry (Moturiki Datum) and mesh for proposed option – re-diversion channel.

7 Morphological Assessment

The morphological model (described in Appendix E) has been utilised to investigate the following in relation to hydrodynamic and morphological impacts of the proposed option:

- For typical conditions, how will the proposed option impact the overall hydrodynamics and sediment transport behaviour of the river and estuary?
- For a typical year how will sediment transport patterns change within the river and estuary with emphasis on estuary and river mouths?
- For adverse wave conditions and low river flow how will sediment transport patterns change within the river and estuary with emphasis on estuary and river mouths?
- For an extreme flood event how will sediment transport patterns change within the estuary.

For all morphological simulations the model bathymetry described in Appendix D (Section D.2.2) for the existing situation and Section 6 for the proposed option have been used for the initial model bathymetry.

7.1 Typical Conditions

An assessment of the morphological behaviour of the flood delta, Papahikahawai Creek, landward extent of the spit, Ongatoro / Maketū Estuary entrance and Te Tumu Cut was carried out for mean river flow conditions for both the existing and proposed situations. The change in hydrodynamic behaviour of the estuary and the river was also assessed by determining changes to the volume of water entering and exiting estuary and river for different times during a neap/spring tidal cycle. The changes in flows in terms of potential impacts on swimming safety in the lower estuary and potential scour of the rock wall at estuary entrance has also been assessed.

Simulations were carried out for mean river flow for Kaituna River at Te Matai (35.5 m^3/s), Waiari Stream (4.0 m^3/s) and Raparapahoe Canal (1.9 m^3/s) for a 15 day neap/spring tidal cycle. A two day warm period was applied. The offshore boundary conditions for the simulation are predicted tides for the period 21st March 2013 to 6th April 2013 (see Figure 7-1). The tidal range for the neap, mean and spring tide respectively is approximately 0.99 m, 1.50 m, and 2.04 m.

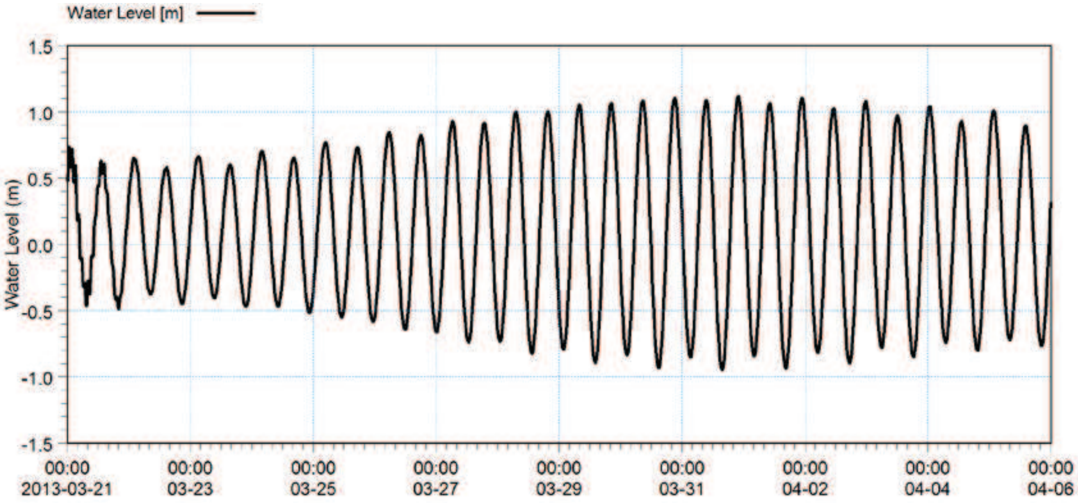


Figure 7-1 Predicted water levels (Moturiki Datum) off Okurei Point for neap/spring tidal cycle.

7.1.1 Impact to Volume Entering and Exiting Kaituna River and Ongatoro / Maketū Estuary per Tidal Cycle

The changes to volume of water which will enter and exit the Kaituna River and Ongatoro / Maketū Estuary as a result of the proposed option for different parts of the neap / spring tidal cycle have been determined from the typical condition simulations and are presented in Table 7-1 to Table 7-3.

Results from the model during the period of the mean tidal range provide a good overview of the impact of the proposed option. For mean tide, the volume of water which will enter the estuary from the river (through the diversion channel) increases by 432,500 m^3, a percentage increase of 286%. The volume of water which enters the estuary through the estuary mouth will decrease by 143,700 m^3, a percentage decrease of 17%, while the volume of water which exits through the estuary mouth will increase by 278,100 m^3, a percentage increase of 29%. The volume of water which enters the river through the river mouth will increase by 367,400 m^3, a percentage increase of 273%, while the volume of water which exits through the river mouth will decrease by 67,300 m^3, a percentage decrease of 4%.

Comparing the proposed situation with the existing situation for all parts of the neap / spring tidal cycle, the ratio for water exiting versus entering the estuary through the estuary mouth increases from approximately 1.2 to 1.9.

Table 7-1 Comparison of volume of water entering Ongatoro / Maketū Estuary from Kaituna River for existing and proposed situations.

Tide	Volume (m^3)			Percentage Difference (%)
	Existing	Proposed	Difference	
Neap	97,200	317,300	220,100	226
Mean	151,000	583,500	432,500	286
Spring	198,800	814,700	615,900	310

Table 7-2 Comparison of volume of water entering and exiting Ongatoro / Maketū Estuary through estuary mouth for existing and proposed situations.

Tide	Flood or Ebb Tide	Volume (m^3)			Percentage Difference (%)
		Existing	Proposed	Difference	
Neap	Flood	473,000	392,600	-80,400	-17
	Ebb	588,300	734,900	146,600	25
Mean	Flood	824,600	680,900	-143,700	-17
	Ebb	959,300	1,237,400	278,100	29
Spring	Flood	1,240,000	954,800	-285,200	-23
	Ebb	1,423,300	1,772,000	348,700	24

Table 7-3 Comparison of volume of water entering and exiting Kaituna River mouth for existing and proposed situations.

Tide	Flood or Ebb Tide	Volume (m^3)			Percentage Difference (%)
		Existing	Proposed	Difference	
Neap	Flood	3,100	120,100	117,000	3774
	Ebb	1,722,800	1,622,800	-100,000	-6
Mean	Flood	134,600	502,000	367,400	273
	Ebb	1,846,300	1,779,000	-67,300	-4
Spring	Flood	423,800	1,007,700	583,900	138
	Ebb	2,039,400	1,989,400	-50,000	-2

7.1.2 Morphological Impact

The morphological impact of the proposed option has been assessed for typical conditions with emphasis on the river, the estuary as a whole and the flood tide delta of the estuary. To assess the morphological impact residual sediment transport rates have been assessed. Similar to a residual current which is defined as the actual water movement when the current is averaged over a specified amount of time, the residual sediment transport rate is the sediment transport rate when averaged over the whole simulation period.

7.1.2.1 River and Upper Estuary

For the typical condition simulations the residual sediment transport patterns within the lower river and upper estuary have been generated and are presented in Figure 7-2 and Figure7-3. Within the river although there is a relatively large increase in the volume of water which enters the river on the flood tide, there is very little impact on the residual sediment transport patterns within the lower river. This suggests that no new areas of deposition are likely to develop in the lower river with the proposed option in place.

In the upper estuary the comparison in the residual transport patterns suggests that there is the potential for long term erosion of sediment in the area opened up to the west of Papahikahawai Island. However this will depend on the supply of sediment from the river to the estuary associated with the additional volume of water from the river. If the supply of sediment from the river to the estuary is significant there is the possibility that some areas of deposition may occur within the upper estuary.

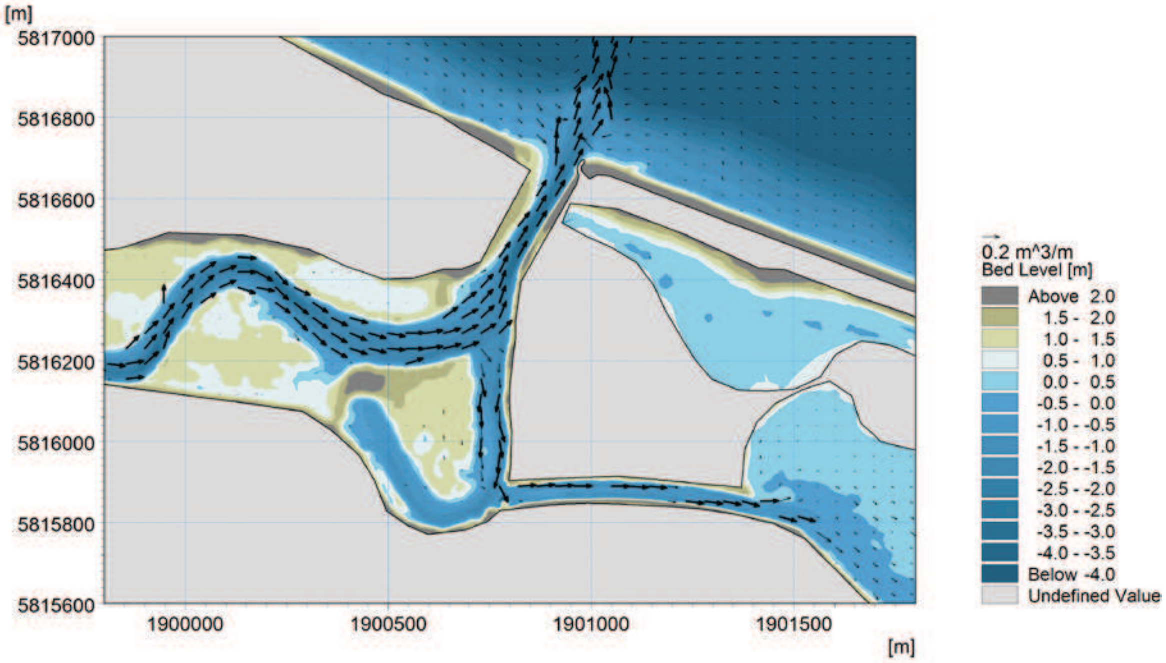


Figure 7-2 Residual sediment transports rates (m^3/m) for river and Ford's Cut channel with existing situation for mean river flow and neap/spring tidal cycle. Note vectors limited to 0.2 m^3/m.

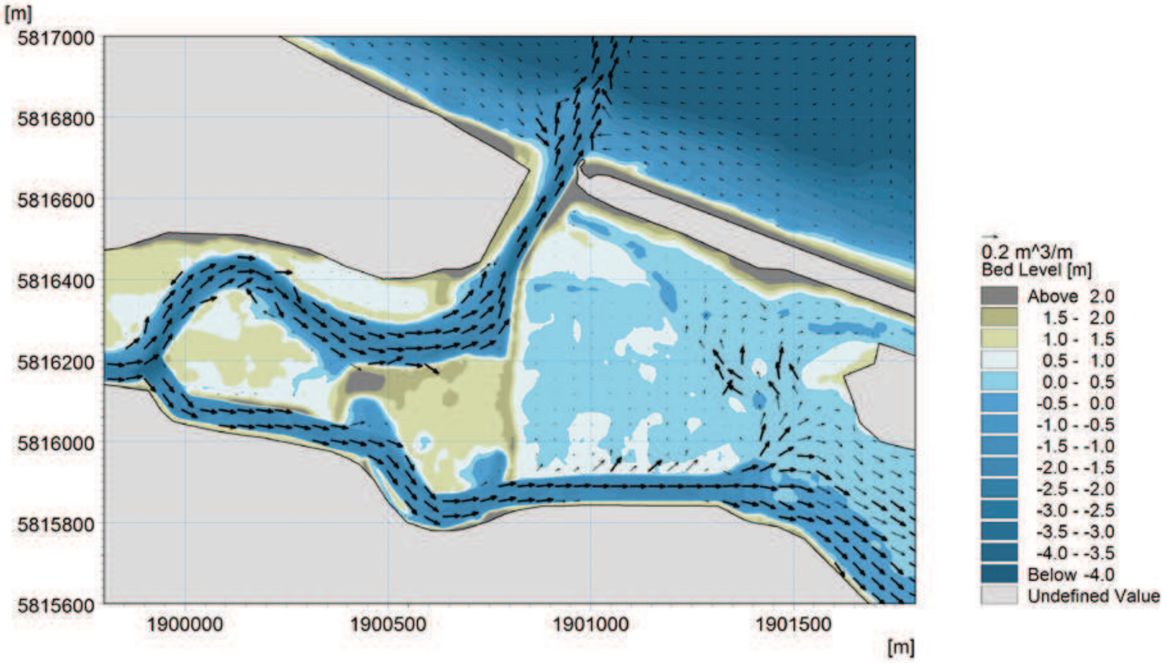


Figure 7-3 Residual sediment transports rates (m^3/m) for river and new channel for proposed option for mean river flow and neap/spring tidal cycle. Note vectors limited to 0.2 m^3/m.

7.1.2.2 Estuary

For the typical conditions simulations the residual sediment transport patterns within the majority of the estuary have been generated and are presented in Figure 7-4 and Figure 7-5. The comparison of the residual sediment transport patterns suggest that there is potential for long term erosion of sediment for some areas of the upper part of the estuary especially close to the exit of the proposed re-diversion channel. It can be assumed that the current rate of infilling of the estuary will be greatly reduced. However there maybe some areas of deposition dependant on the sediment supply from the river.

The additional flow through Papahikahawai Creek (maximum of 2.5 m^3/s for spring tide and 1.2 m^3/s for neap tide) should encourage erosion of the creek channel. However it does not appear that significant scour of the spit north of the Papahikahawai Creek will occur.

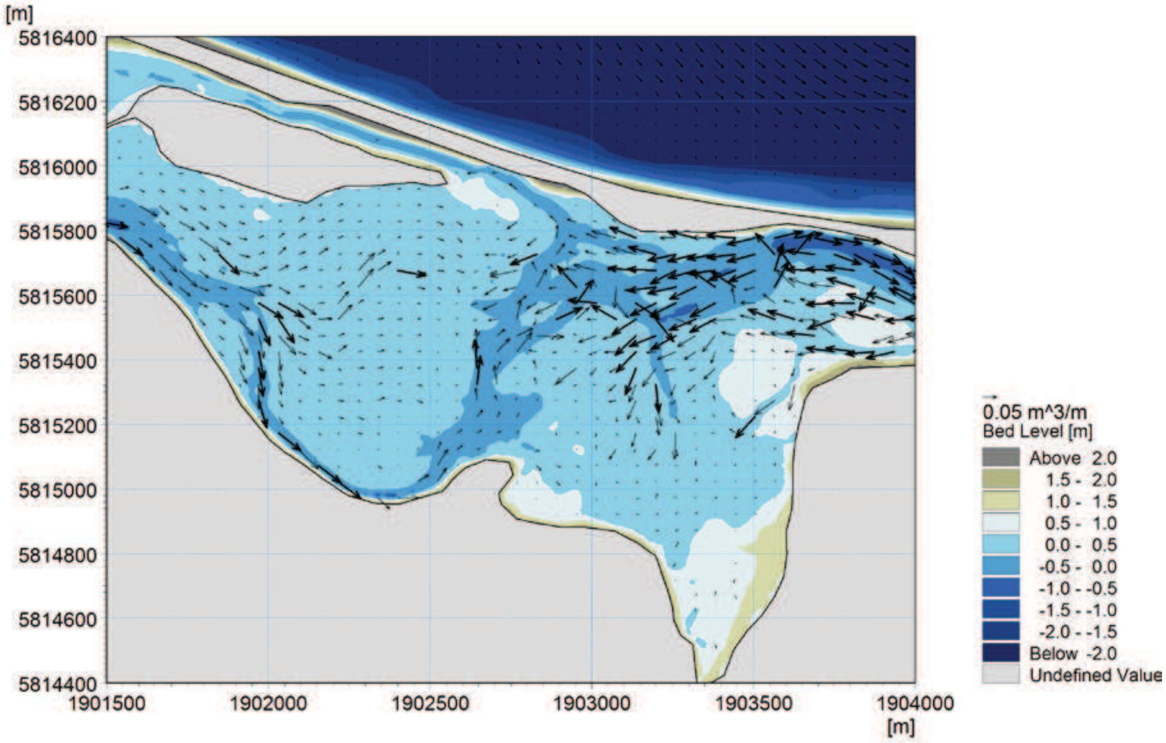


Figure 7-4 Residual sediment transports rates (m^3/m) for estuary with existing situation for mean river flow and neap/spring tidal cycle. Note vectors limited to 0.1 m^3/m.

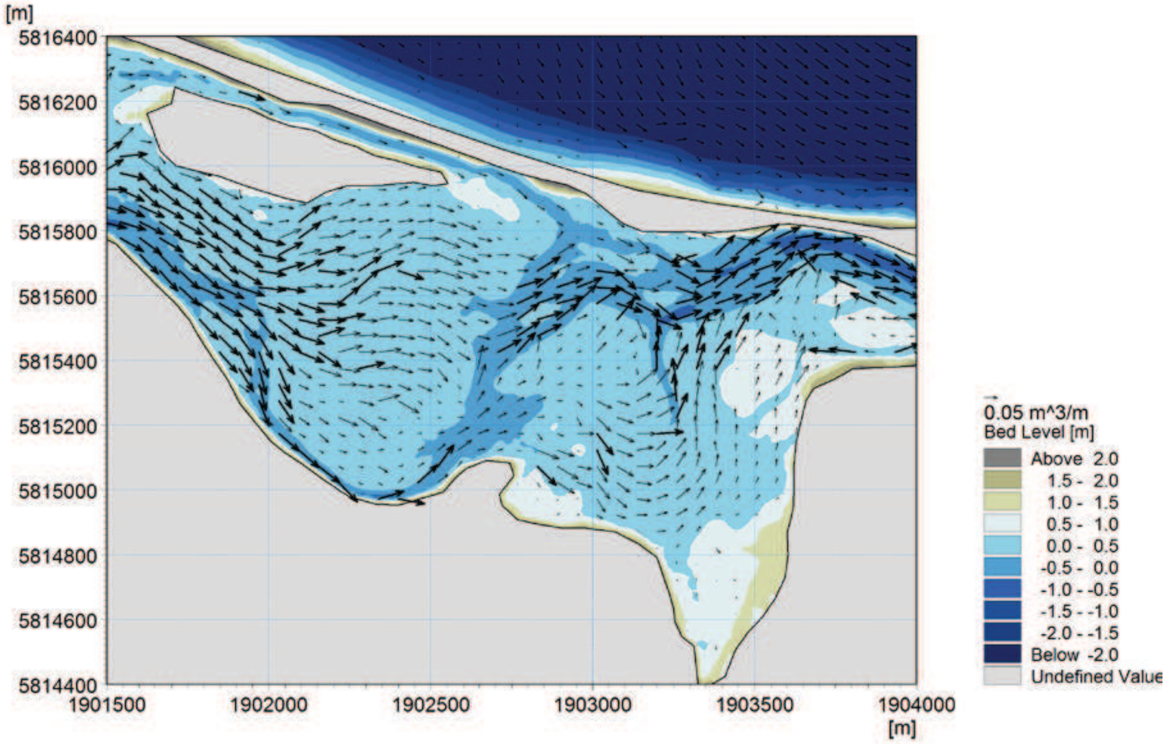


Figure 7-5 Residual sediment transports rates (m^3/m) for estuary for proposed option for mean river flow and neap/spring tidal cycle. Note vectors limited to 0.1 m^3/m.

7.1.2.3 Estuary Flood Tide Delta

For the typical condition simulations the residual sediment transport patterns for the flood tide delta of the estuary have been generated and are presented in Figure 7-6 and Figure 7-7. The comparison of the residual sediment transport patterns suggest that for the existing situation the flood tide dominates the residual currents across the flood tide delta, which has resulted in the continuing build up of sediment on the flood tide delta. With the proposed option significant parts of the western and middle sections of the existing flood tide delta the residual sediment transport patterns will reverse (and for some areas rates will increase) indicating the current expansion of the flood tide delta will reduce or even begin to erode. For the eastern part of the flood delta the residual patterns are still dominated by the flood tide, however if the flood tide delta begins to erode over time it is probable that the influence of the flood tide on this part of the existing flood delta will further reduce.

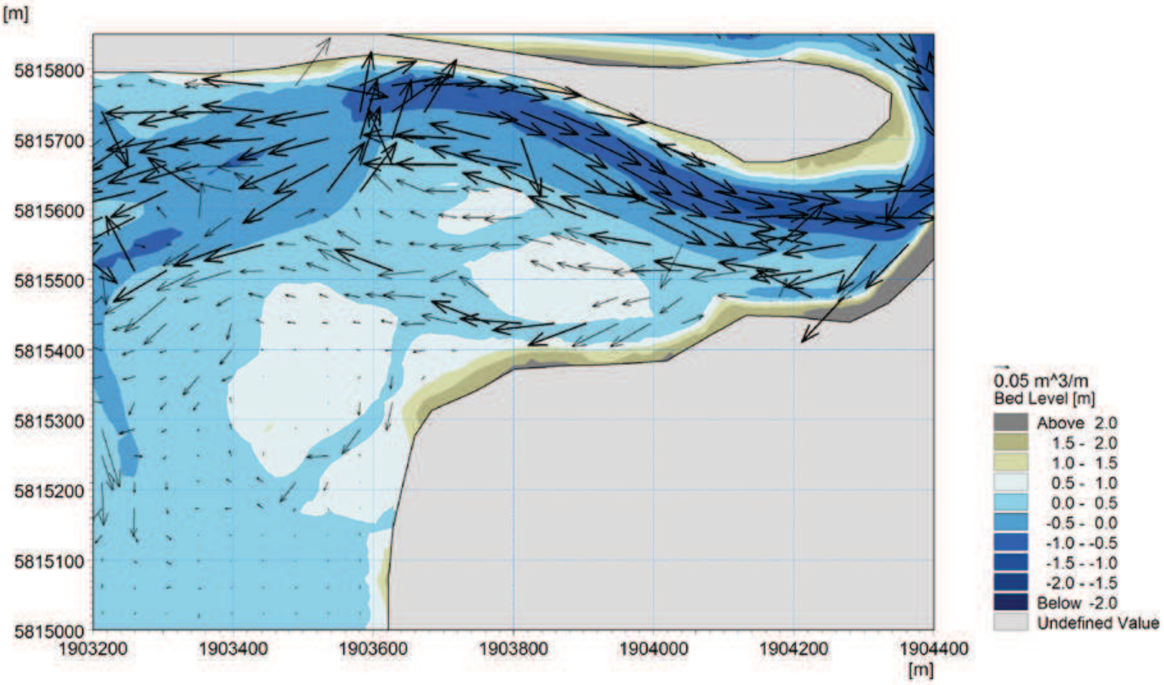


Figure 7-6 Residual sediment transports rates (m^3/m) for flood tide delta of estuary with existing situation for mean river flow and neap/spring tidal cycle. Note vectors limited to 0.2 m^3/m.

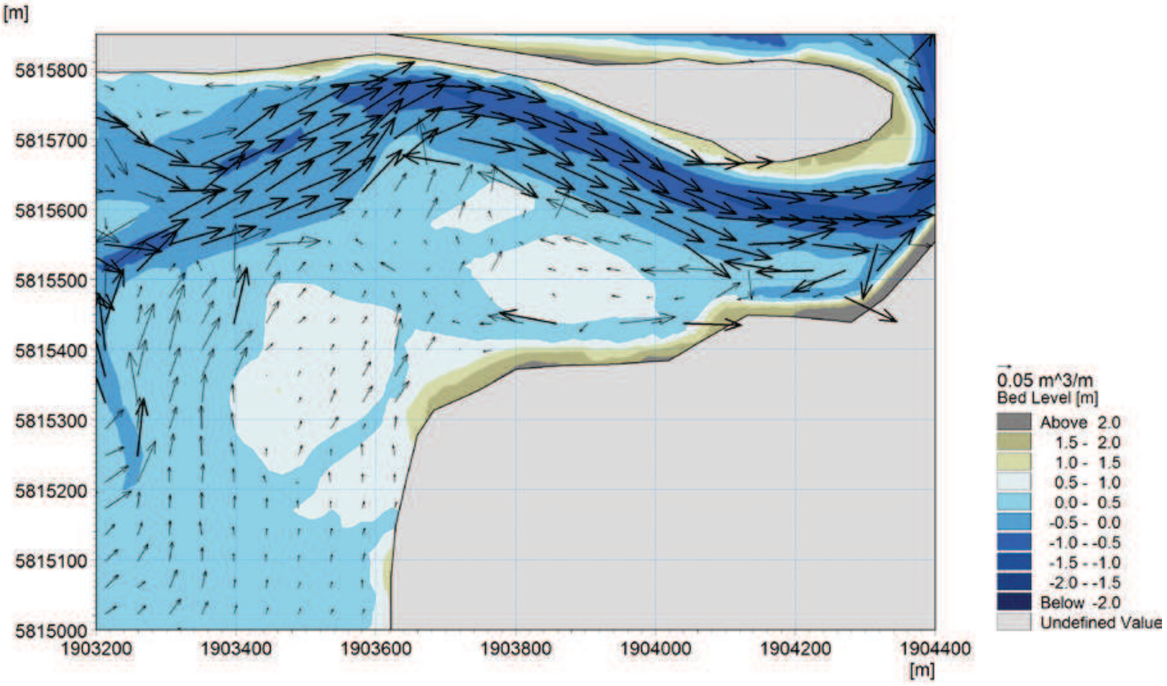


Figure 7-7 Residual sediment transports rates (m^3/m) for flood tide delta of estuary for proposed option for mean river flow and neap/spring tidal cycle. Note vectors limited to 0.2 m^3/m.

Current speeds were extracted for typical conditions for the locations shown in Figure 7-8. The extracted current speeds are presented in Figure 7-9. It is interesting to note that for Pt 1 and Pt 2 that although the ebb tide currents are increased, the largest current speeds are associated with the flood tide for the existing situation. The flood tide peak currents are reduced for the proposed option. At Pt 3 the peak current speeds are similar for both the existing situation (associated with flood tide) and the proposed option (associated with ebb tide). This suggests that there is not a in the risk of spit break through with the proposed option.

Although the modelling does not provide any clear evidence that additional erosion of the inside of the spit is likely to occur for typical conditions. However with the additional flow associated with the ebb tide and with the bathymetry of the current flood tide delta, intuitively we suggest that there is an increased risk of additional scour of the inside of the spit. This situation is comparable with the scour that would occur of the outside bend of a river if there was a significant increase in typical flow for the river. The risk would be further magnified if there is a period of significant westerly littoral transport which may cause erosion of the spit from the seaward side.

The overall risk of spit break through will decrease if the flood tide delta were to erode, as it is likely that the current speeds would decrease on the inside of the spit and erosion potential of the spit would in fact decrease. However after construction of the proposed option we believe that there is an increased risk of additional scour of the inside of the spit compared with the existing situation and some type of dredging of the flood tide delta maybe required to reduce this risk.

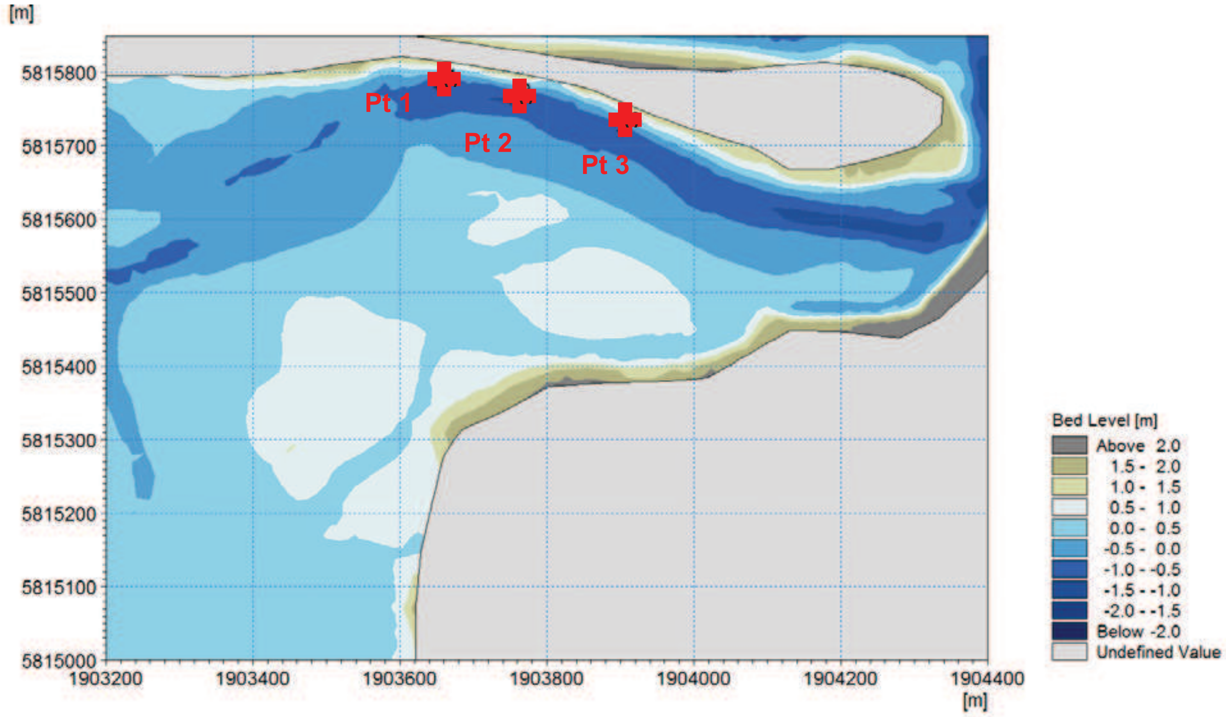


Figure 7-8 Locations in vicinity of spit where time series of current speed extracted.

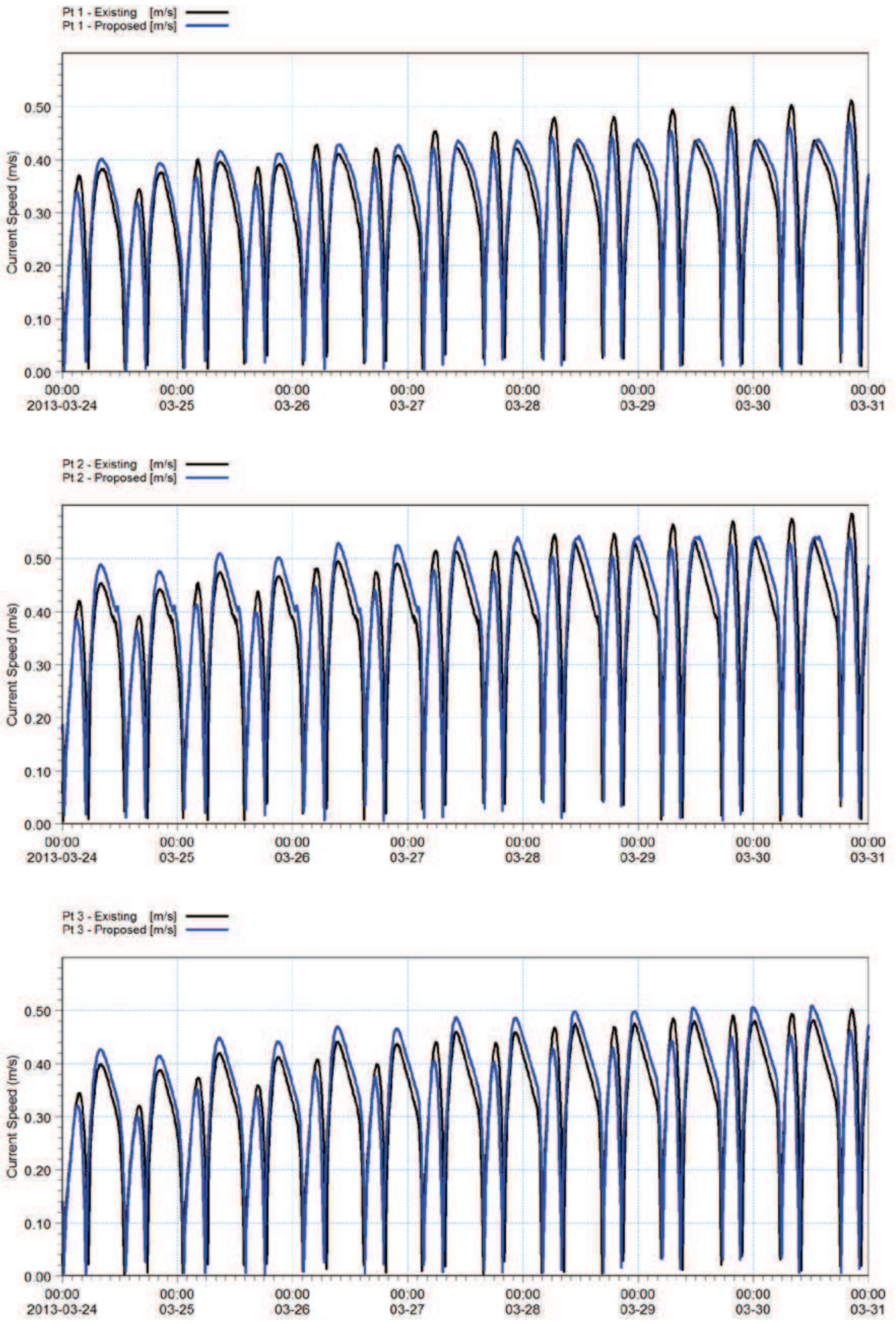


Figure 7-9 Current speeds at selected locations Pt 1 (top), Pt 2 (middle) and Pt 3 (bottom) in vicinity of spit for existing situation and proposed option for typical conditions. Note only seven day period (i.e. neap to spring tide) shown.

There a concern from the local community about the potential for additional scour to occur for the land in front of the Maketū surf club and the rock wall at the Ongatoro / Maketū Estuary entrance. Current speeds have been extracted for typical conditions for the locations shown in Figure 7-10. The extracted current speeds are presented in Figure 7-11.

In front of the surf club (Pt 1) there is no significant change in the predicted current speeds. For the rock wall at the estuary entrance there is an increase in the peak ebb current speed from 0.7 to 0.8 m/s at Pt 2 and from 1.2 to 1.5 m/s at Pt 3. The increase in current speed occurs for a duration of less than 30 minutes. The increase in the peak ebb current speed is unlikely to increase the potential for scour of the rock wall; however a more detailed engineering assessment maybe required to confirm this conclusion.

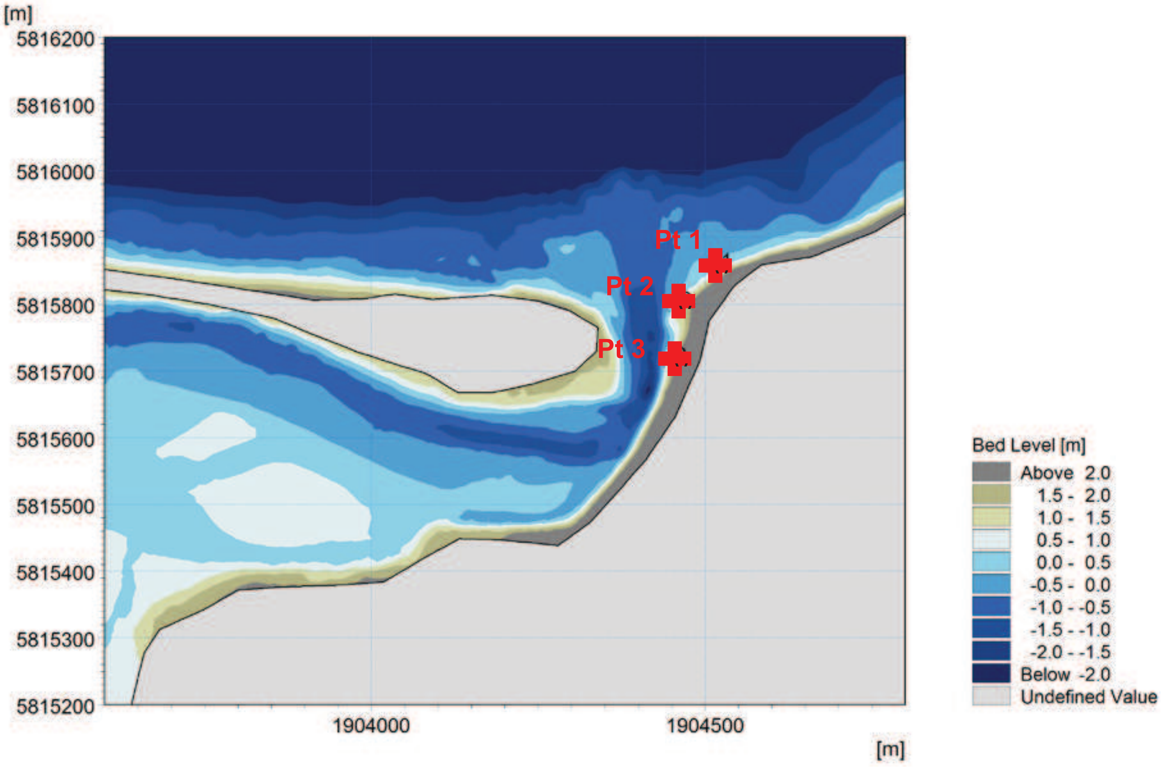


Figure 7-10 Locations in vicinity of surf club and rock wall at Ongatoro / Maketū Estuary entrance where time series of current speed extracted.

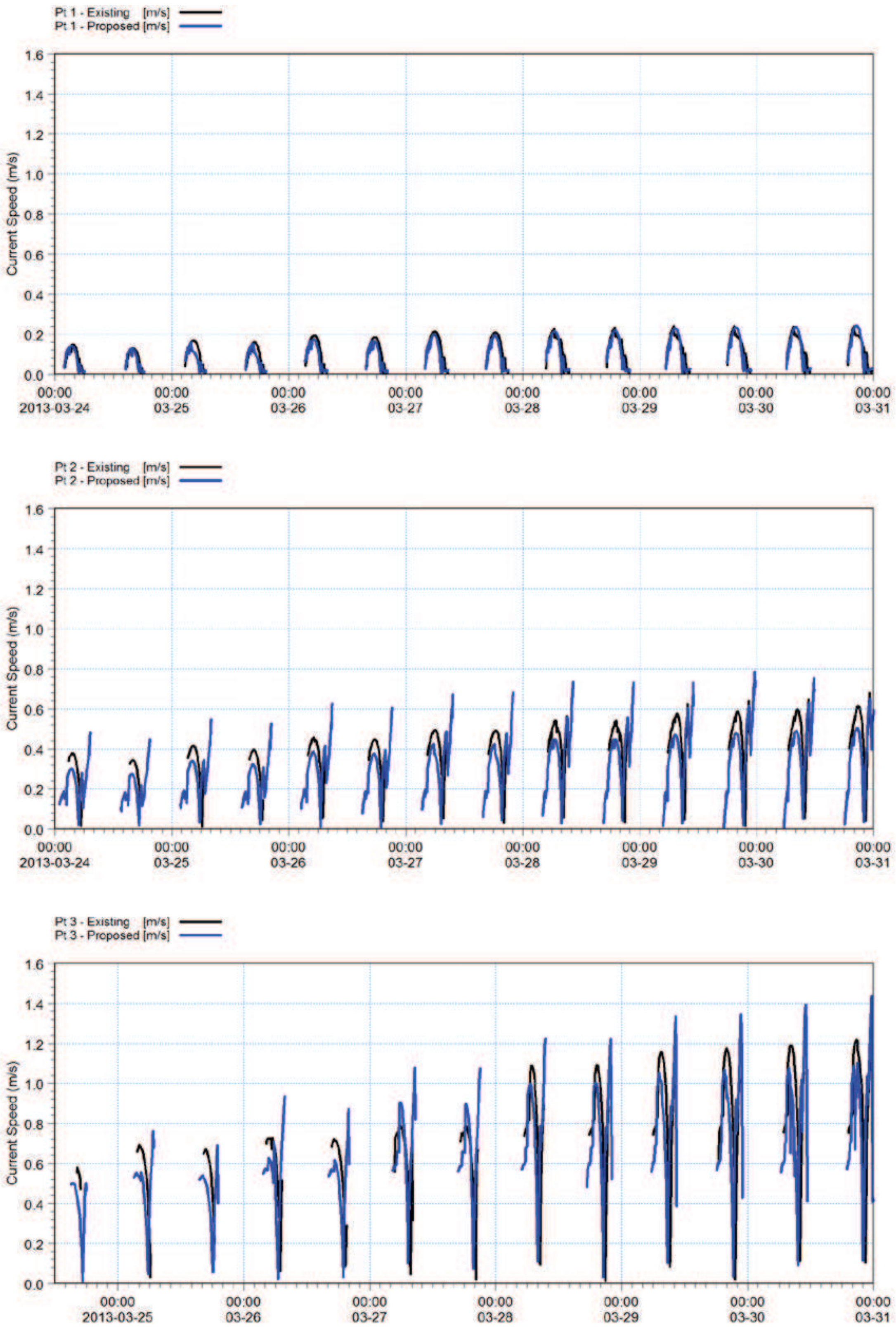


Figure 7-11 Current speeds at selected locations Pt 1 (top), Pt 2 (middle) and Pt 3 (bottom) in vicinity of spit for existing situation and proposed option for typical conditions. Note only seven day period (i.e. neap to spring tide) shown.

7.1.3 Water Velocities and Potential Impact for Swimming.

Currently the area inside the estuary mouth is a popular place for swimming and there is a concern that the additional volume of water entering the estuary from the river may have an impact on the safety of swimming within these areas, The mean and maximum predicted current speeds from the typical condition simulations are presented in Figure 7-12 and Figure 7-13.

Time series of current speed have been extracted from the vicinity of diving platform inside the Ongatoro / Maketū Estuary entrance for typical conditions for the existing situation and proposed option and are presented in Figure 7- 14. Peak spring tide currents increase from 1.27 m/s to 1.40 m/s (a percentage increase of 10%). It can be concluded that currents speeds will not increase significantly for the swimming area and therefore there will not be a significant effect on safety of swimming for this area for typical conditions. Care will still be required if a flood event in the Kaituna River is occurring, since significantly more water will enter the estuary from the river with the proposed option compared with the existing situation which will result in stronger currents.

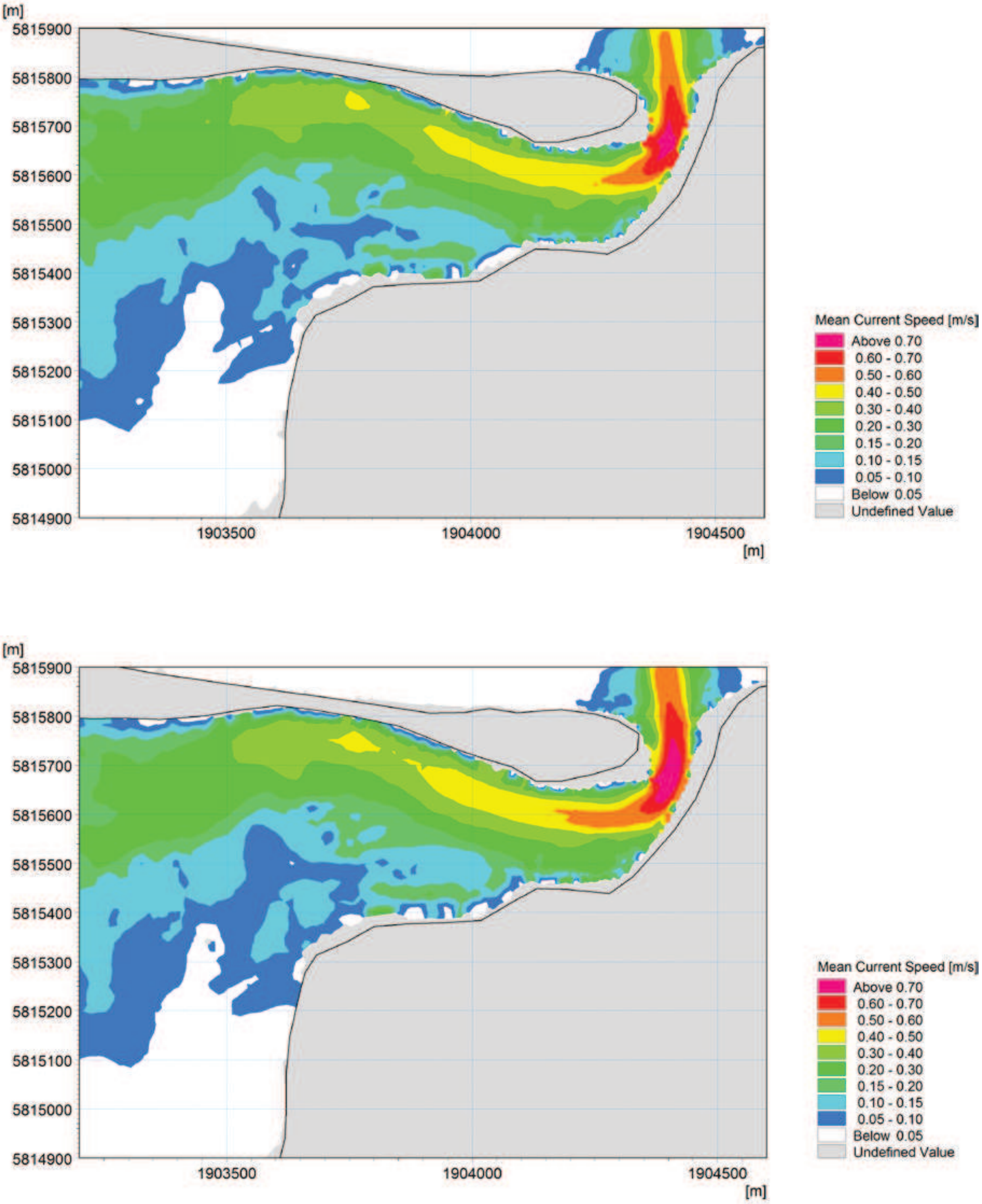


Figure 7-12 Mean current speed with existing situation (top) and proposed option (bottom) for typical conditions.

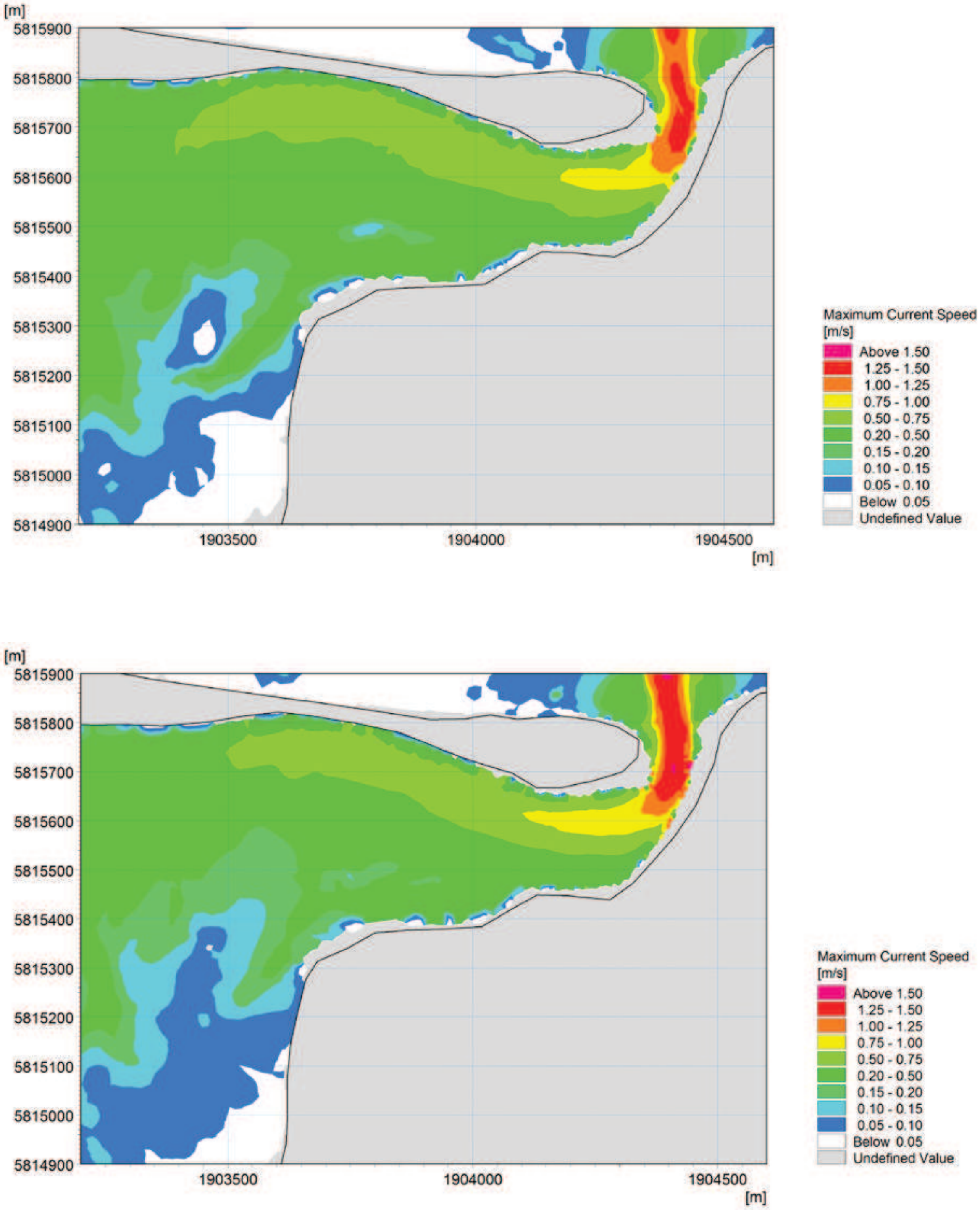


Figure 7-13 Maximum current speed with existing situation (top) and proposed option (bottom) for typical conditions.

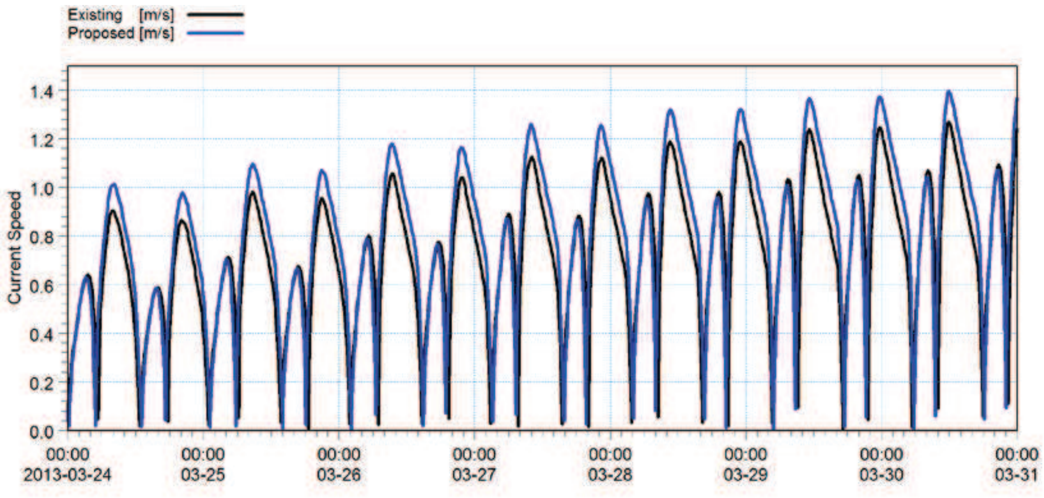


Figure 7-14 Times series of current speeds at in vicinity of diving platform for typical conditions. Note only seven day period (i.e. neap to spring tide) shown.

7.2 One Year Simulation

A one year simulation under normal conditions was carried out to provide a realistic picture of the morphological impacts of the proposed option (with a main emphasis on river and estuary entrances).

The year which most closely matched the long term easterly net transport rate of 52,000 m^3/yr was 2006. For this year the predicted net transport rate was 81,000 m^3 (see Section 5.1). The wave conditions off Okurei Point and river flow for 2006 are shown in Figure 7-15.

A common approach used when assessing morphological impacts is to apply a morphological scaling factor. Such a factor is applied because morphological changes take place over a much longer time periods compared to hydrodynamic changes. Running longer time-frame sediment transport models is still relatively time consuming. Therefore to provide realistic estimates of longer-term morphological changes and reduce model simulation time, model inputs (i.e. wave and flow data) and bathymetric changes are sped up by a user-defined morphological scaling factor. Note that water level variations are not scaled as this would lead to incorrect current calculations.

This technique has been successfully used for assessing the morphological response of dynamic river entrances (Zimmerman et. al., 2012 and Moerman, 2011) and other studies (Lesser et al., 2003, Grunnet et al., 2004 and Reniers et al., 2004) have indicated that morphological scaling factor in the range of 10 to 100 can be applied in coastal zones. For the year long simulations a morphological scaling factor of 10 was applied. Therefore for the wave and flow input data (Figure 7-15) a 5 minute time step becomes a time series with a 30 second time step.

The scaling factor method is suitable for a comparative assessment of the morphological response of the entrances for the existing situation and proposed option; however absolute values should be interpreted with care since morphological changes (both erosion and deposition) can be overestimated using this method.

The initial bed levels at the Kaituna River mouth and Ongatoro / Maketū Estuary entrance are shown in Figure 7-16.

The focus of the assessment of the potential morphological impacts of the proposed option is in the river and estuary entrances.

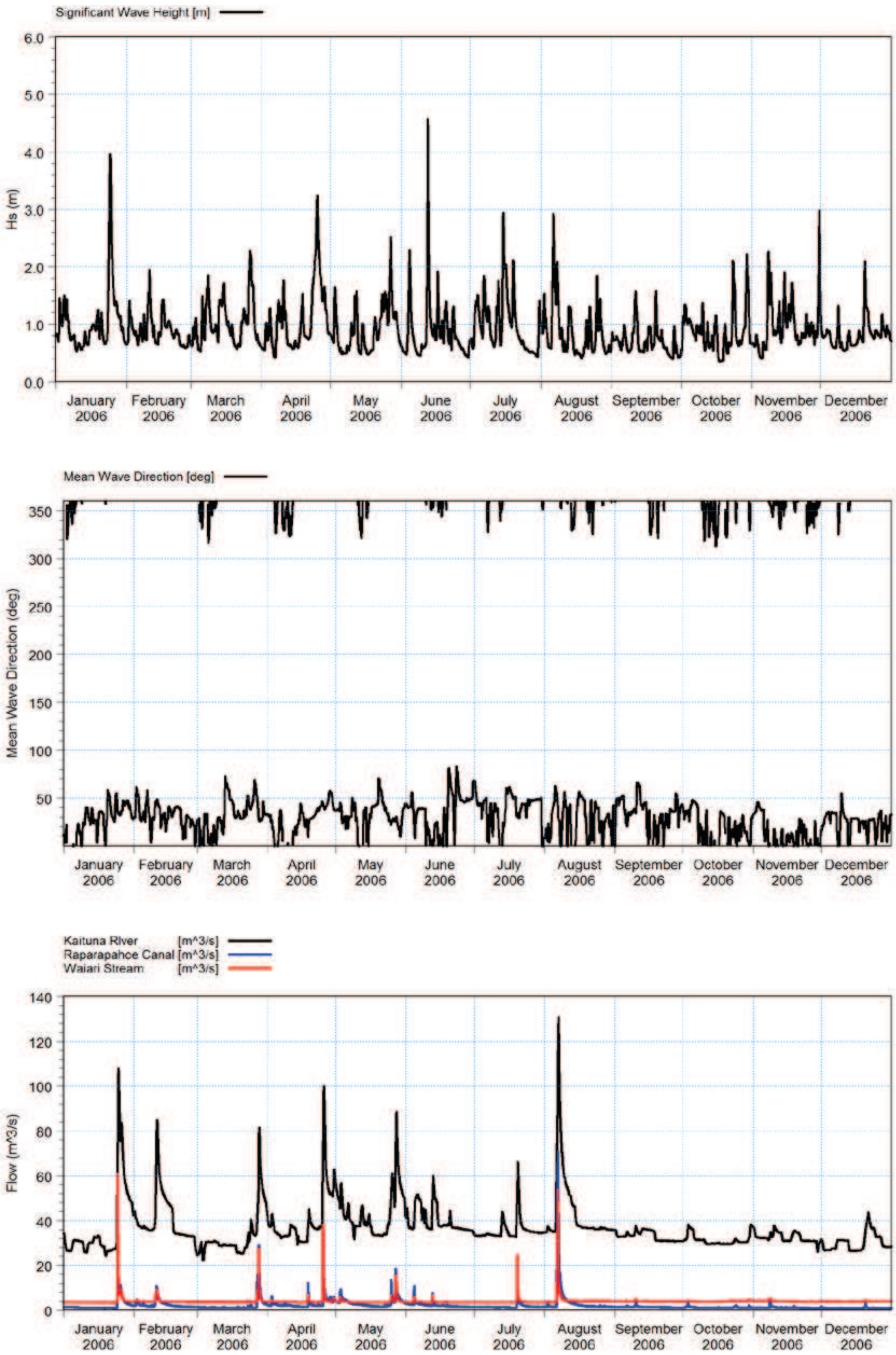


Figure 7-15 Wave and river flow data for 2006 used in one year simulation.

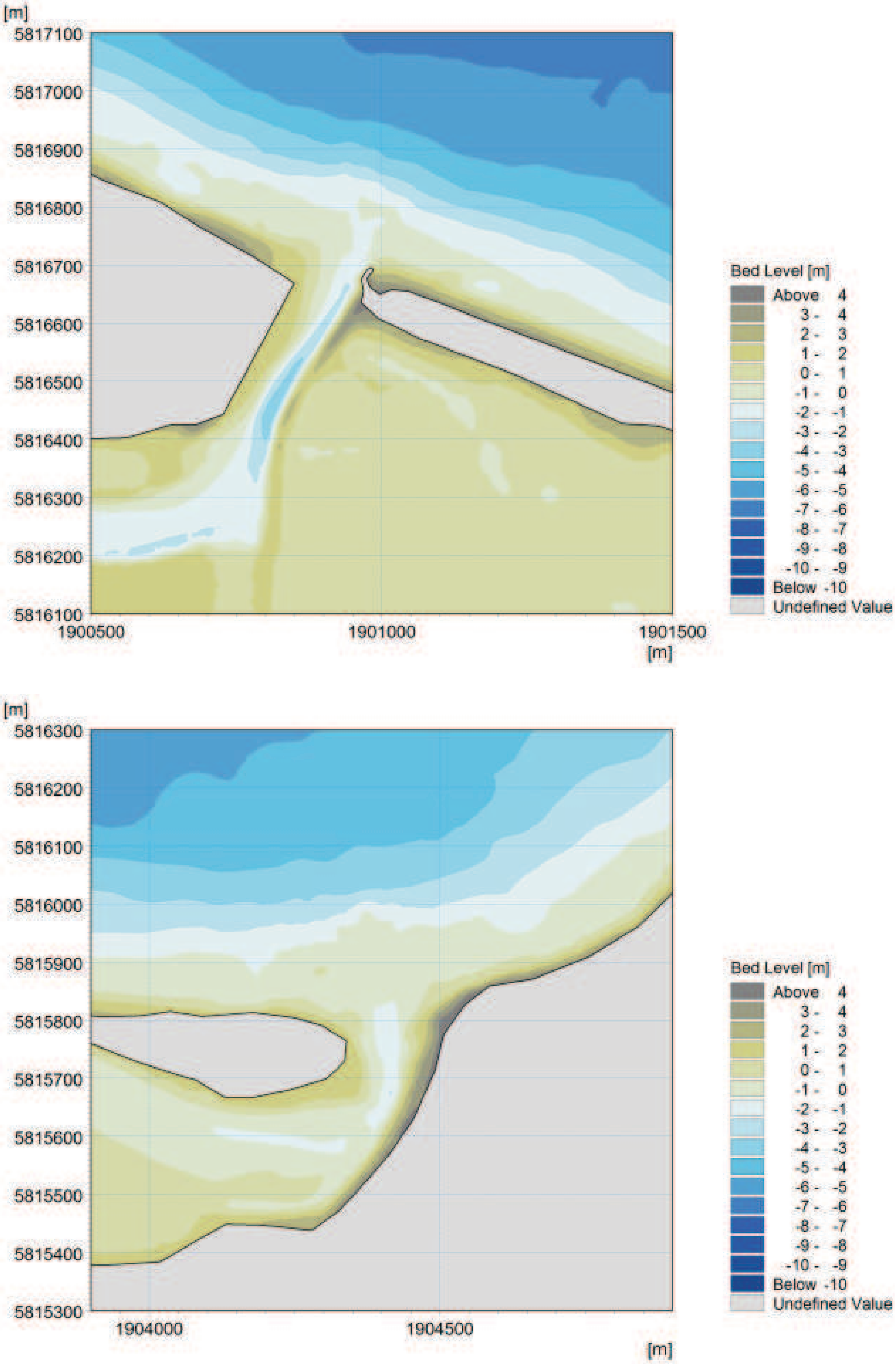


Figure 7-16 Initial bed levels for one year simulation for Kaituna River mouth (left) and Ongatoro / Maketū Estuary entrance (right).

The comparison of the predicted evolution of the bathymetry at Kaituna River mouth for the existing and proposed situations during the year long simulation is shown in Figure 7-17 to Figure 7-22 while the same comparison for the predicted evolution of the bathymetry at Ongatoro / Maketū Estuary entrance is shown in Figure 7-23 to Figure 7-28.

The difference between bed level for the typical one year simulation after twelve months between the proposed and existing situations for the Kaituna River mouth and Ongatoro / Maketū Estuary entrance is presented in Figure 7-29.

Although the simulation predicted a noticeable difference in the pattern of the final bed levels in the vicinity of the Ongatoro / Maketū Estuary entrance, it can be concluded the entrance is not negatively impacted when comparing the proposed option with the existing situation. To illustrate this, bed levels were extracted along two cross sections after twelve months for the proposed and existing situations. The location of the cross sections is presented in Figure 7-30 and the comparison of bed levels along the cross sections for the proposed and existing situations is shown in Figure 7-31. Importantly with the proposed option the overall depth and width of the entrance channel is not reduced (the minimum depth of the entrance channel actually increases). It can therefore be concluded that the long term dynamics of the estuary entrance morphology will not be negatively altered with the proposed option.

The assessment of the potential impacts of the proposed option on the Kaituna River mouth is best understood by examining three different periods of the year. For the first six months of the year (1st January to 1st July 2006) there were some significant wave events as well as some events with elevated river flow. In early August the largest flood event occurred and during the last four months of the simulation (1st September 2006 to 1st January 2007) there was no significant elevated river flows but a reasonably high energy wave climate.

For the first six months of the year the bed levels at Kaituna River mouth are not significantly altered by the proposed option. There even appears to be a slight decrease of bed levels through some of the river mouth bar with the proposed option compared to the existing situation.

When the largest flood event occurs (peak flow = 130 m^3/s at Te Matai) on 7th August 2006, the flow that passes through the Kaituna River mouth is reduced for the proposed option as some of the flood water is diverted to the estuary (a decrease in the volume of water through Kaituna River mouth of approximately 8%). Subsequently after eight months (1st September 2006) the morphology of the river mouth changes between the existing situation and the proposed option. There is predicted to be an increase in bed levels through some of the river mouth bar with the proposed option compared to the existing situation. It should be noted that the predicted deepening of bed level for this area is overestimated due to the scaling method of the year long simulation (see below for further investigation).

Over the next four months (1st September 2006 to 1st January 2007) the combination of lower river flows and reasonably high wave energy results in a bar forming over the river mouth again. Although there is an area through the river mouth bar with shallower depths with the proposed option, the overall morphology of the river mouth is very similar for the existing situation and the proposed option after 12 months. It is most likely that with a period of ongoing high wave energy events deeper parts of the river mouth bar would infill and the predicted morphology changes of the river mouth with or without the proposed option would begin to converge.

Many studies have shown (e.g. Stive et al., 2012) that there is a strong correlation between inlet cross sectional area and tidal prism. Therefore the volume of water exchanged between the open ocean and the river ultimately determines the overall cross-sectional area of the entrance and ensures that the Kaituna River mouth remains open. The year long morphological simulations indicate that changes in river mouth morphology for the Kaituna River mouth may occur following large flood events, for the proposed option compared to the existing situation. However it can be concluded that the long term dynamics of river mouth morphology will not be significantly altered with the proposed option.

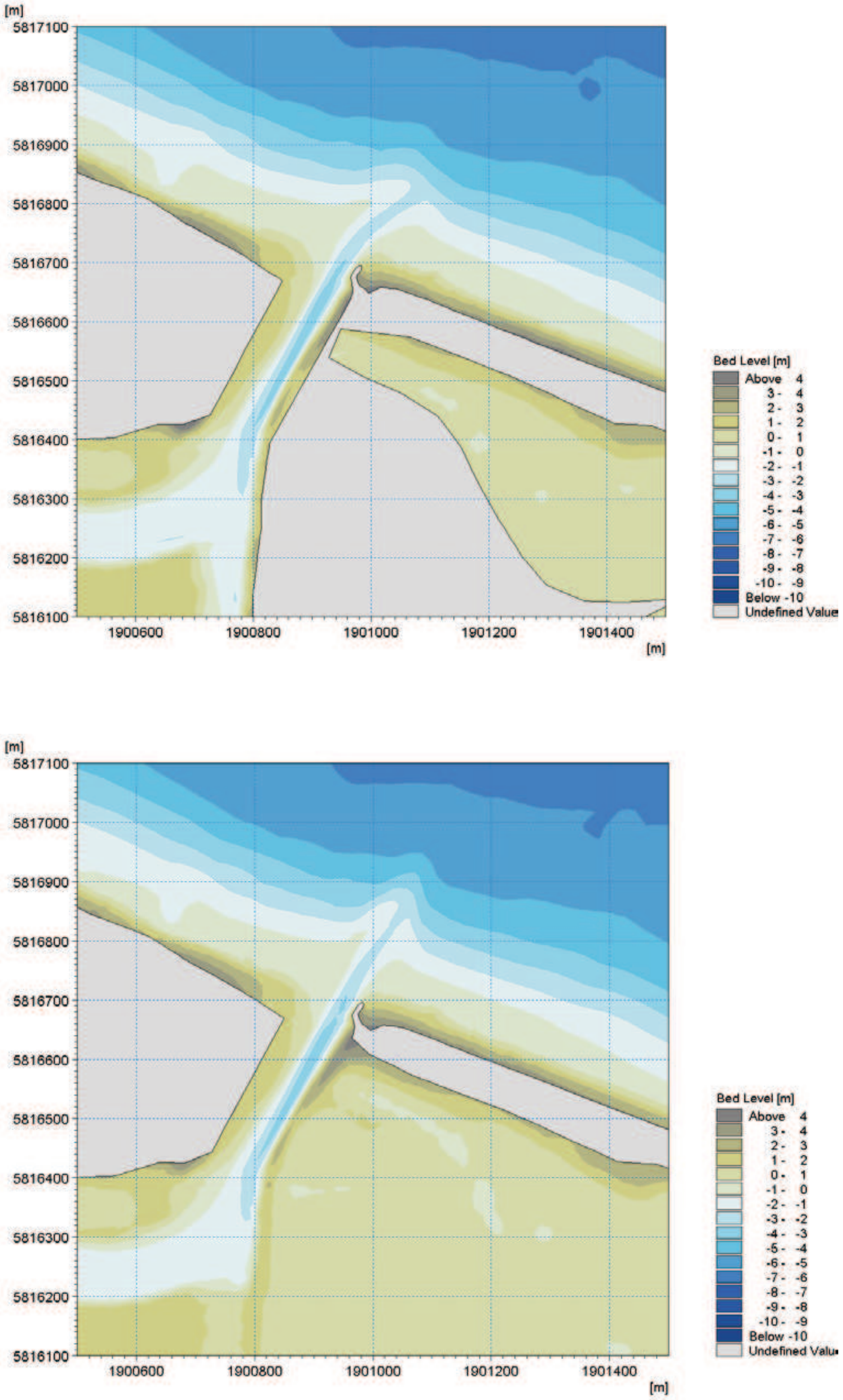


Figure 7-17 Kaituna River mouth bed level for typical one year simulation after two months for existing (top) and proposed situations (bottom).

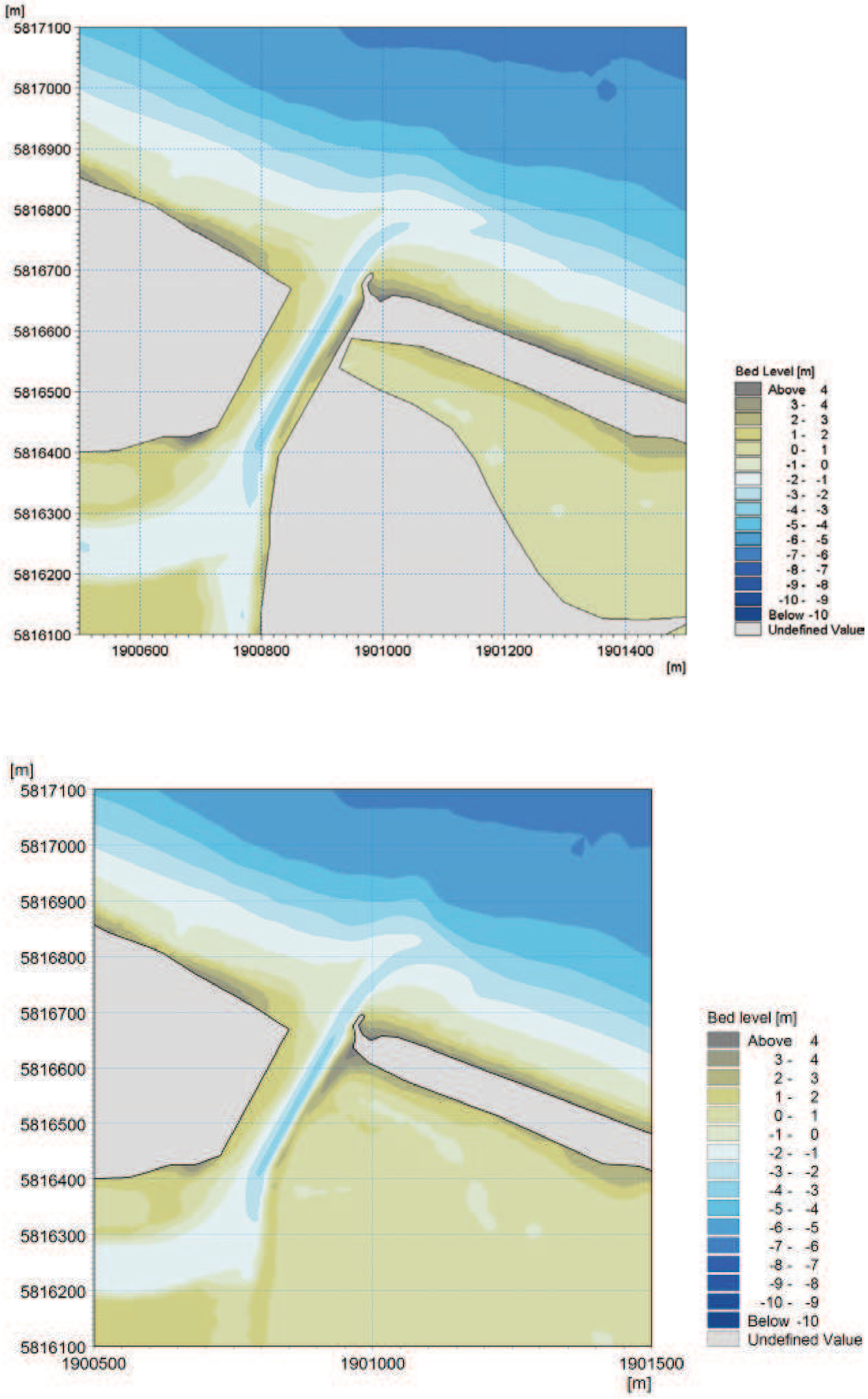
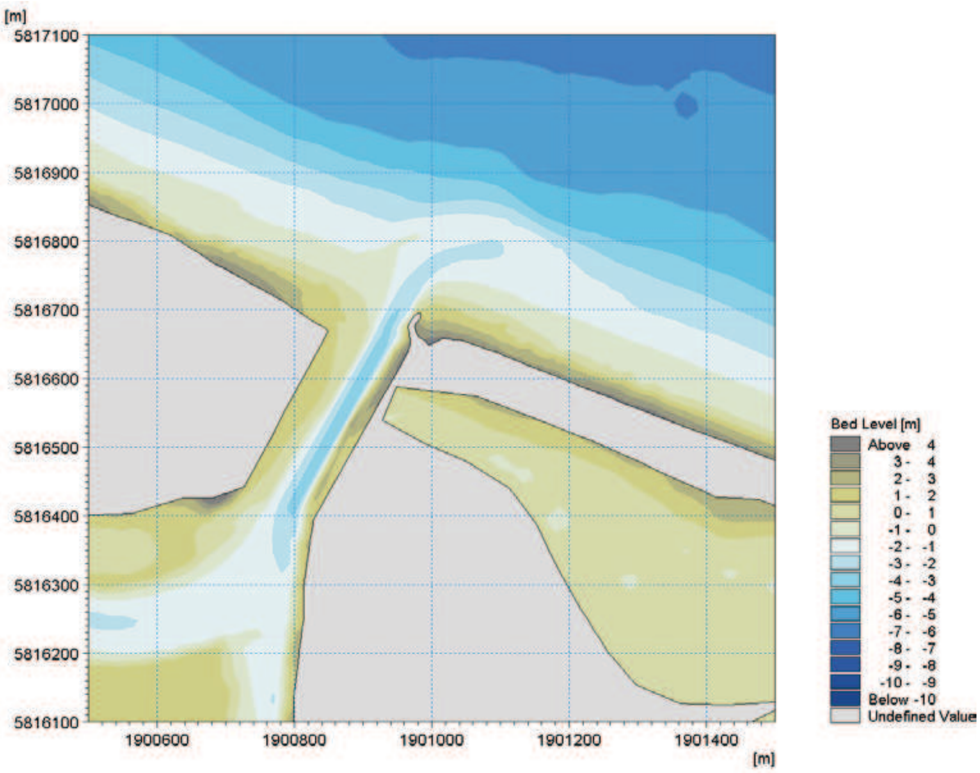


Figure 7-18 Kaituna River mouth bed level for typical one year simulation after four months for existing (top) and proposed situations (bottom).



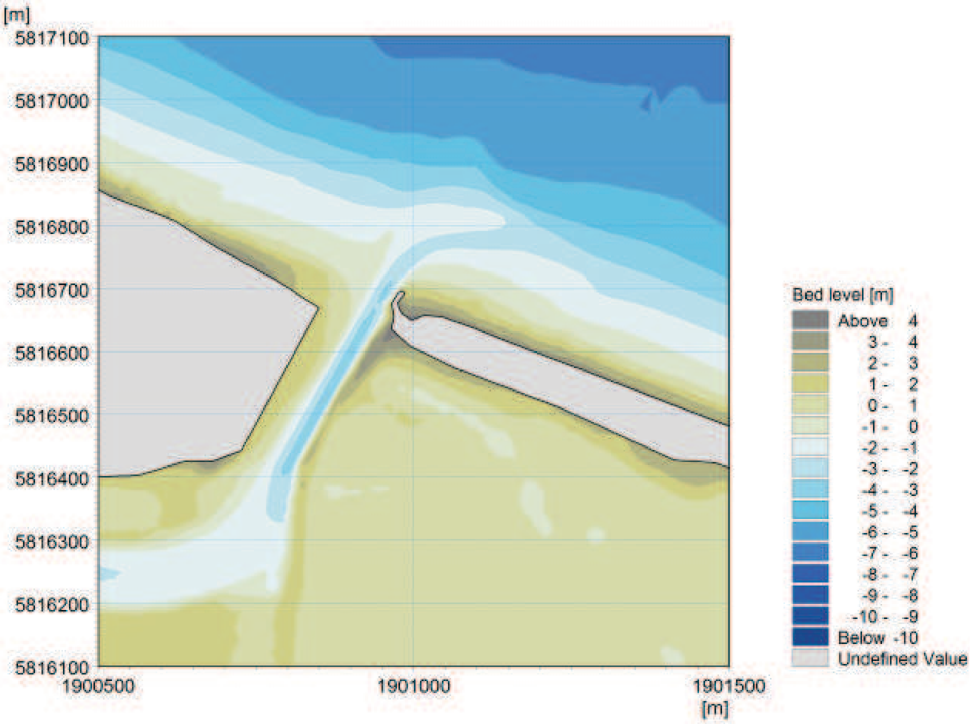


Figure 7-19 Kaituna River mouth bed level for typical one year simulation after six months for existing (top) and proposed situations (bottom).

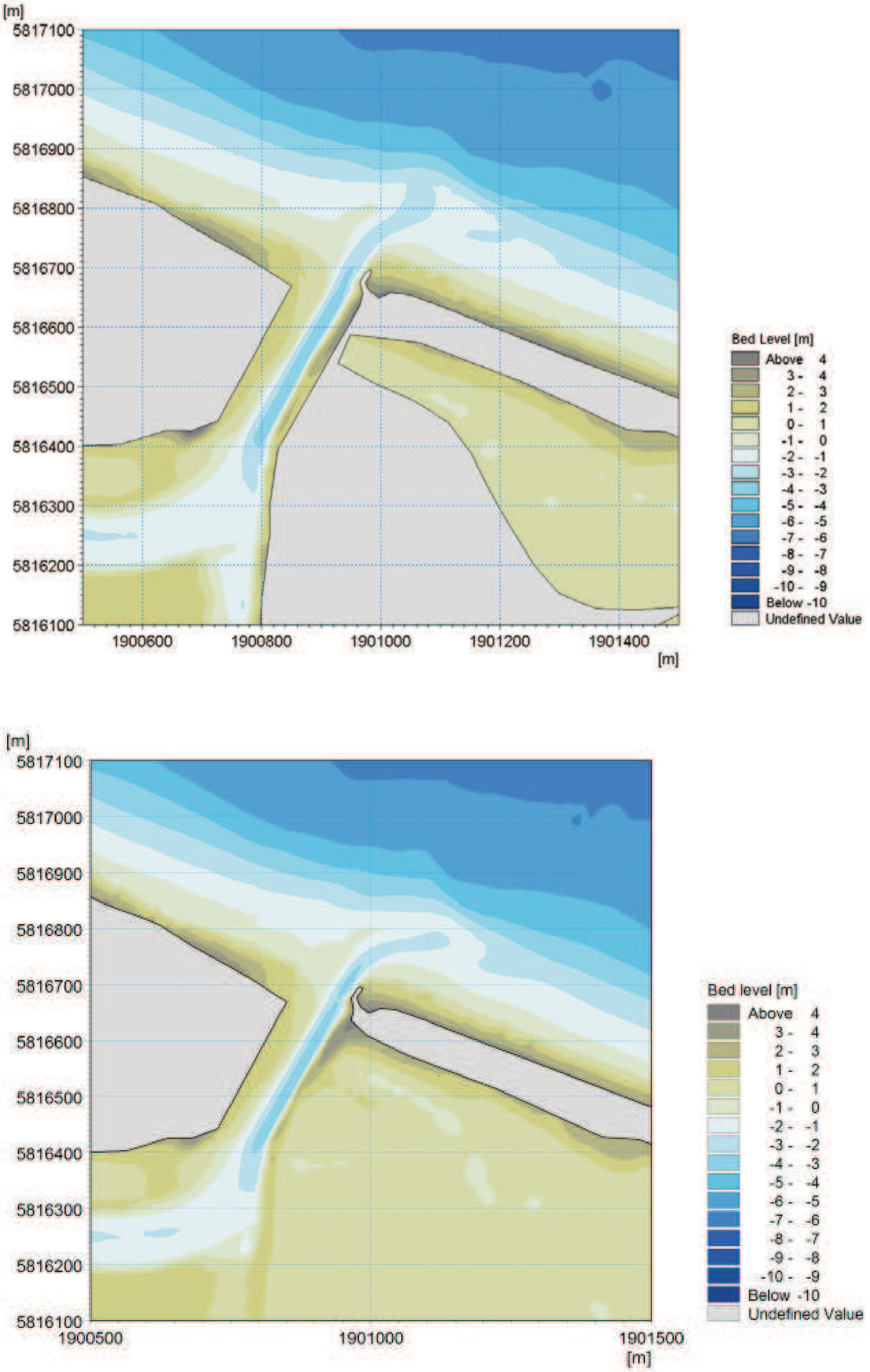


Figure 7-20 Kaituna River mouth bed level for typical one year simulation after eight months for existing (top) and proposed situations (bottom).

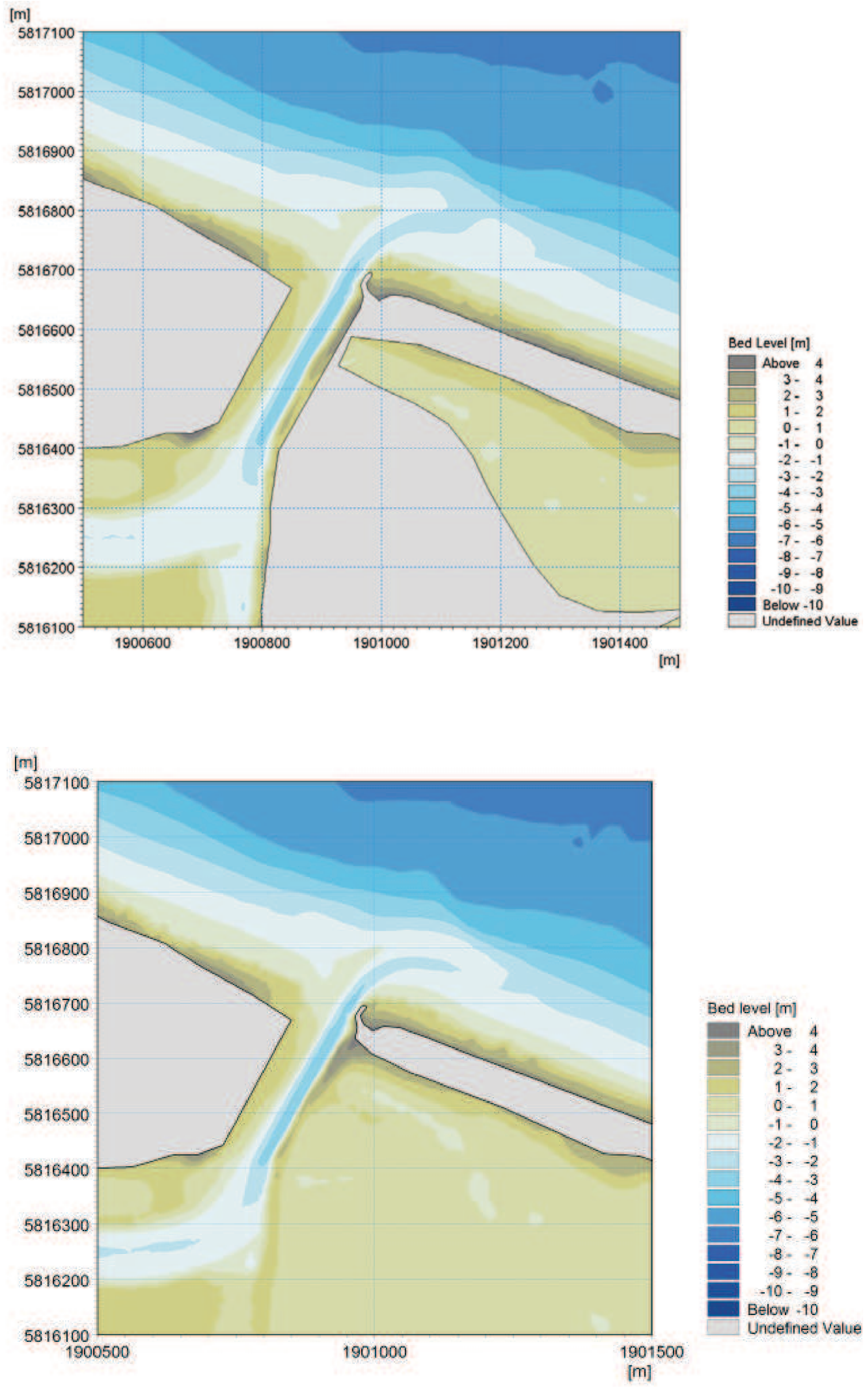


Figure 7-21 Kaituna River mouth bed level for typical one year simulation after ten months for existing (top) and proposed situations (bottom).

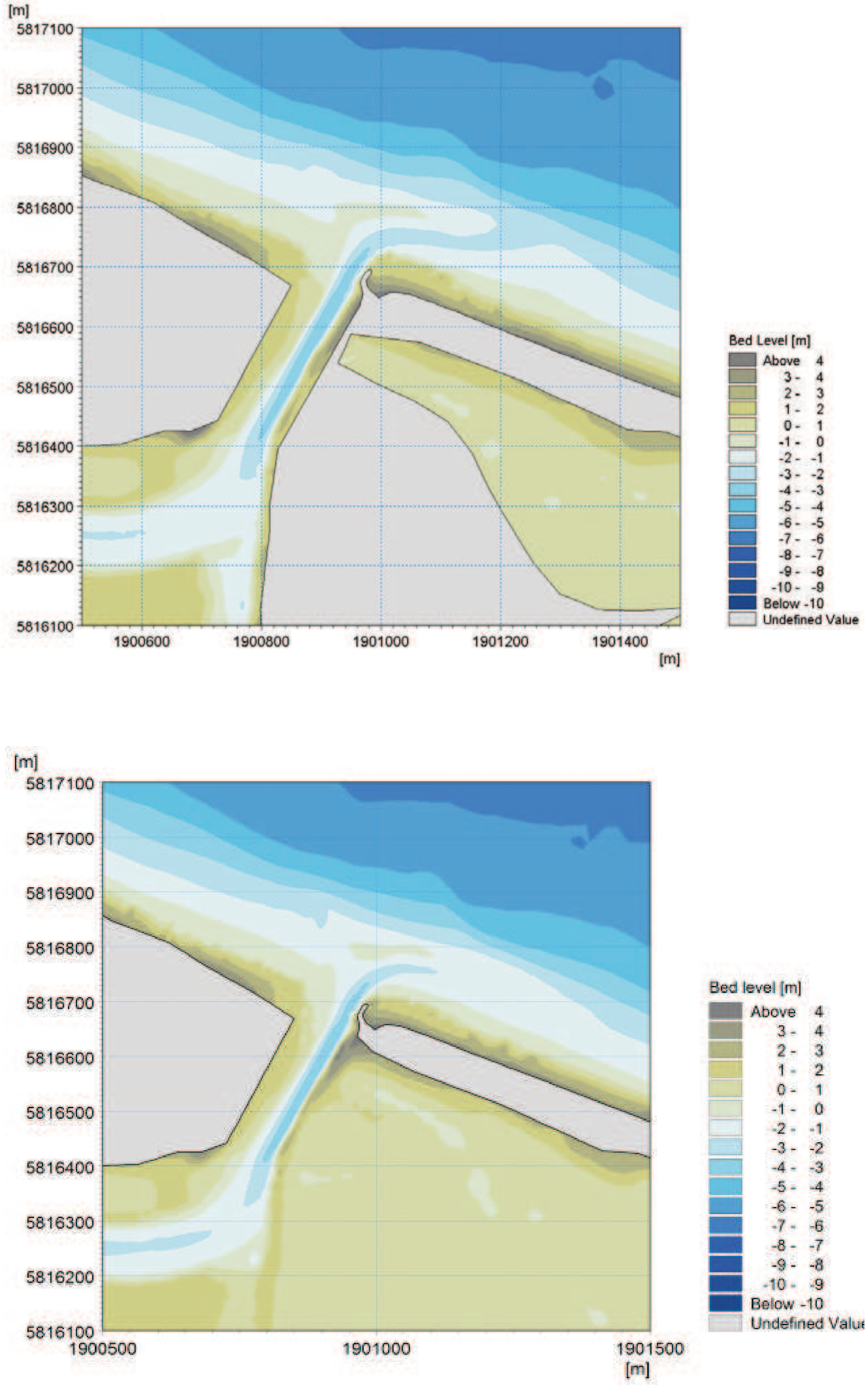


Figure 7-22 Kaituna River mouth bed level for typical one year simulation after twelve months for existing (top) and proposed situations (bottom).

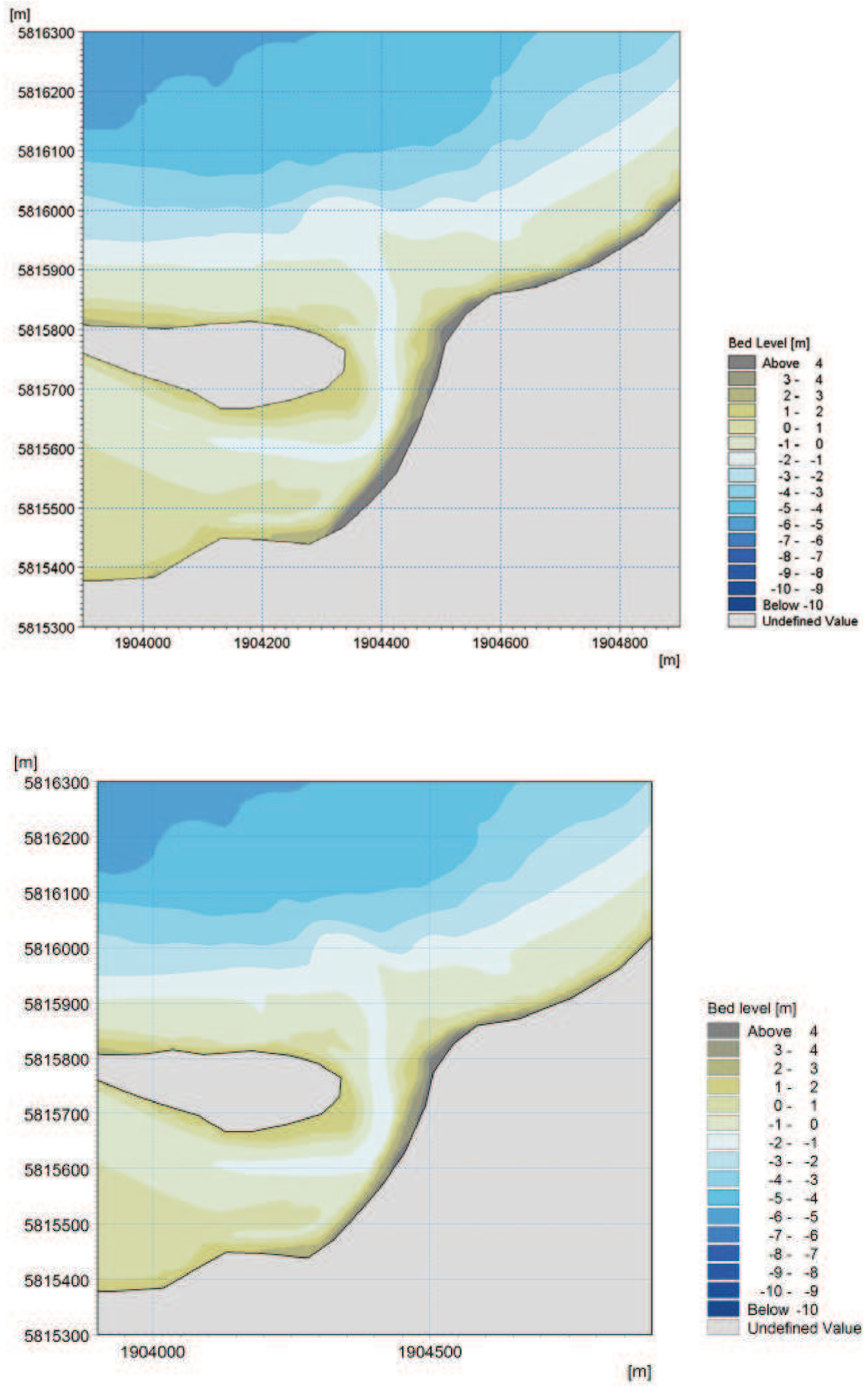
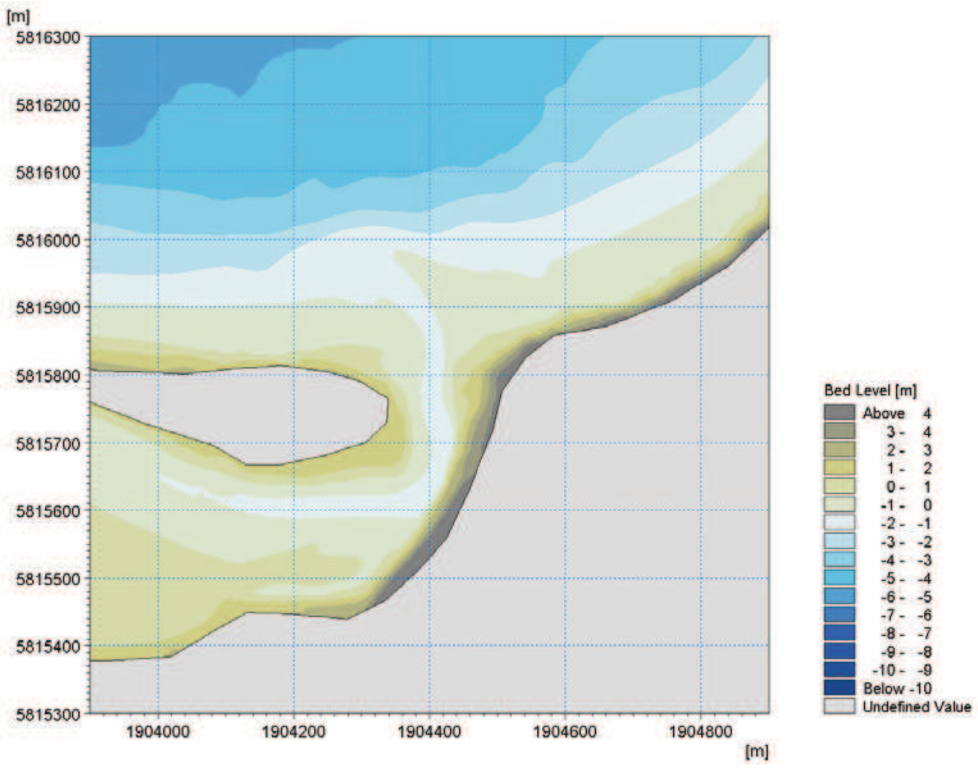


Figure 7-23 Ongatoro / Maketū Estuary entrance bed level for typical one year simulation after two months for existing (top) and proposed situations (bottom).



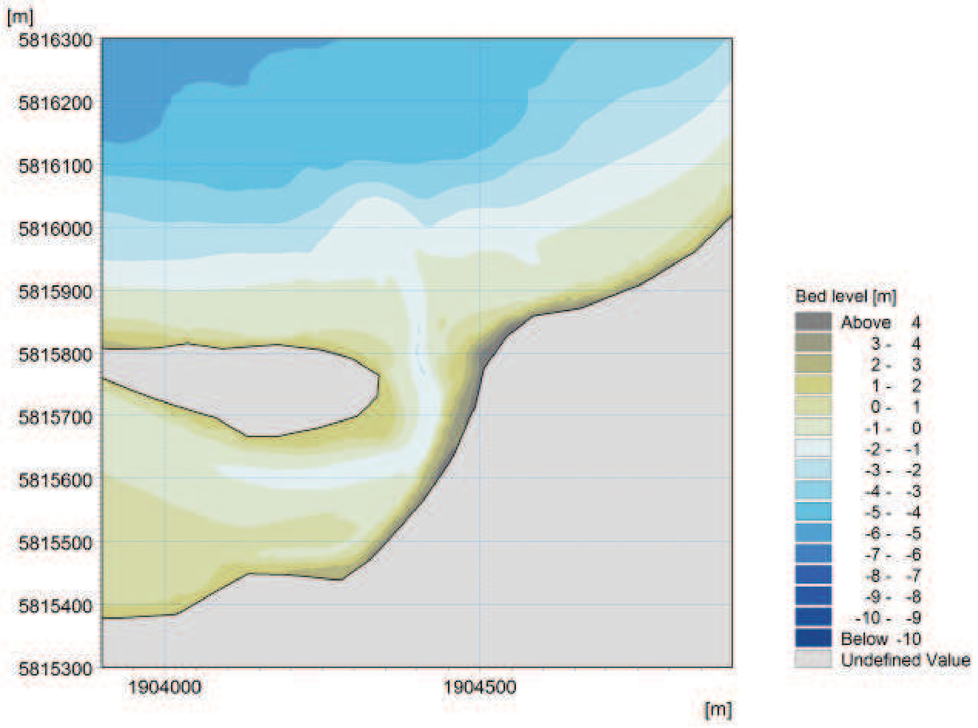
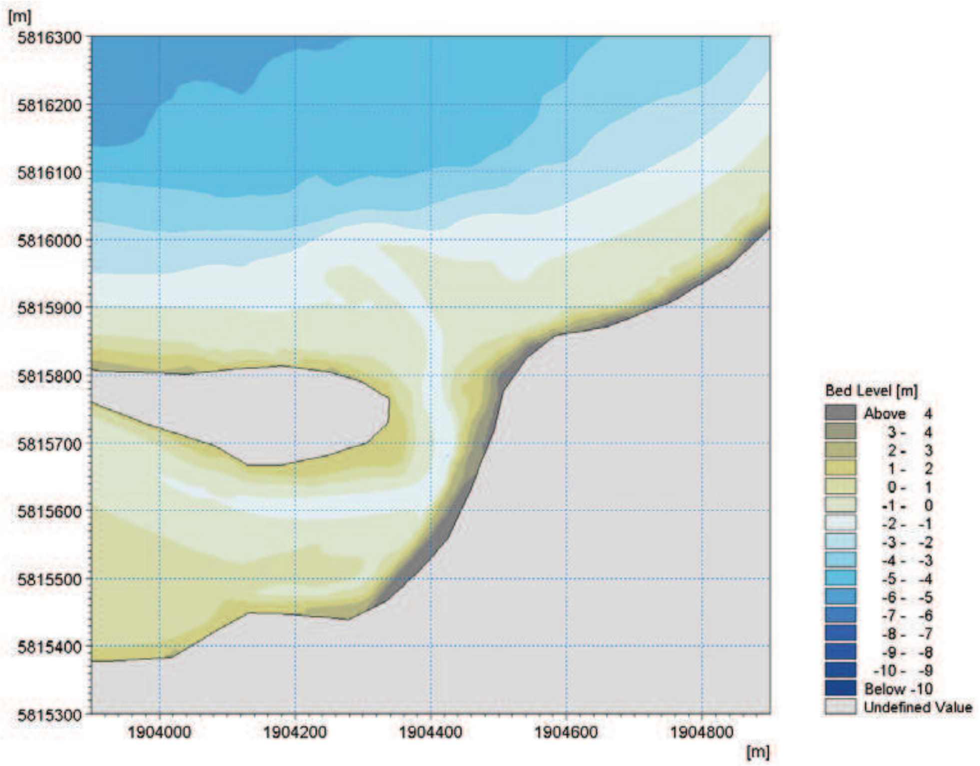


Figure 7-24 Ongatoro / Maketū Estuary entrance bed level for typical one year simulation after four months for existing (top) and proposed situations (bottom).



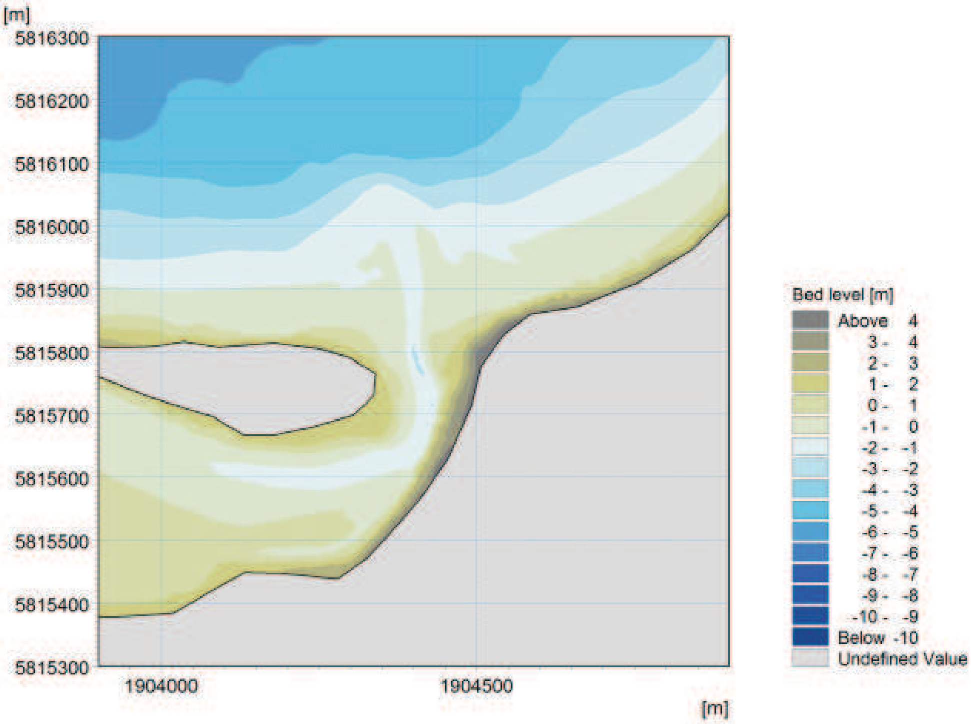


Figure 7-25 Ongatoro / Maketū Estuary entrance bed level for typical one year simulation after six months for existing (top) and proposed situations (bottom).

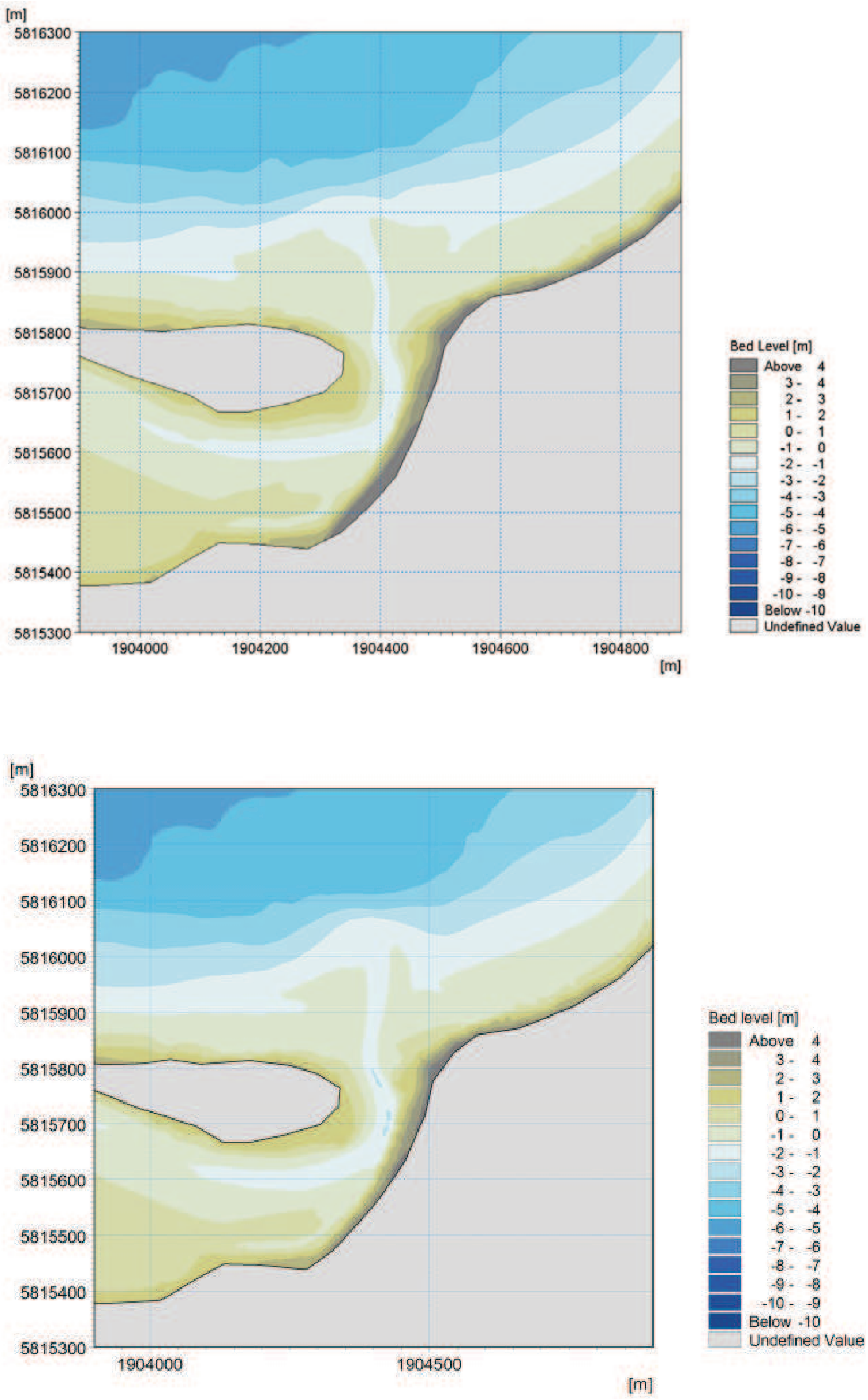


Figure 7-26 Ongatoro / Maketū Estuary entrance bed level for typical one year simulation after eight months for existing (top) and proposed situations (bottom).

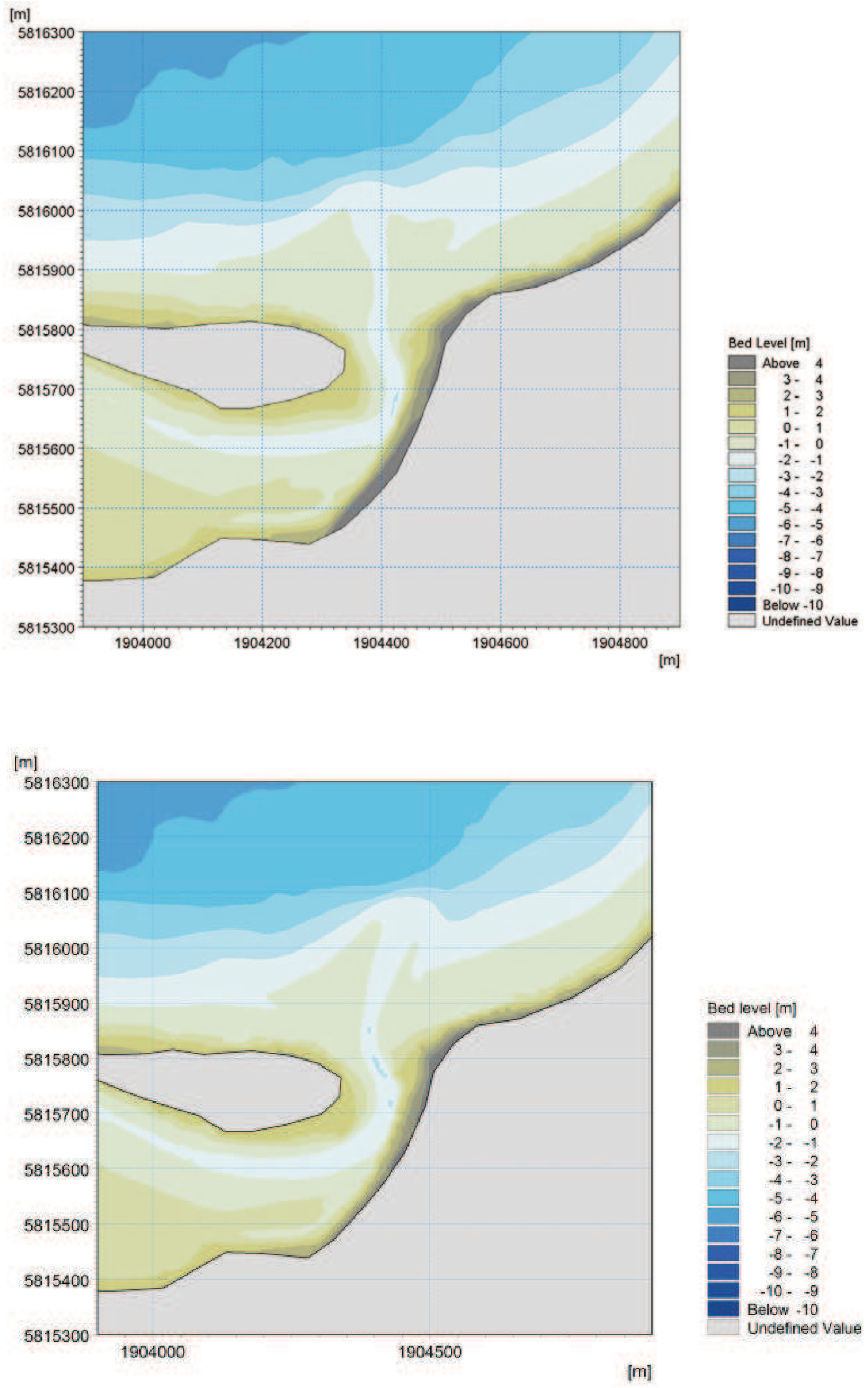


Figure 7-27 Ongatoro / Maketū Estuary entrance bed level for typical one year simulation after ten months for existing (top) and proposed situations (bottom).

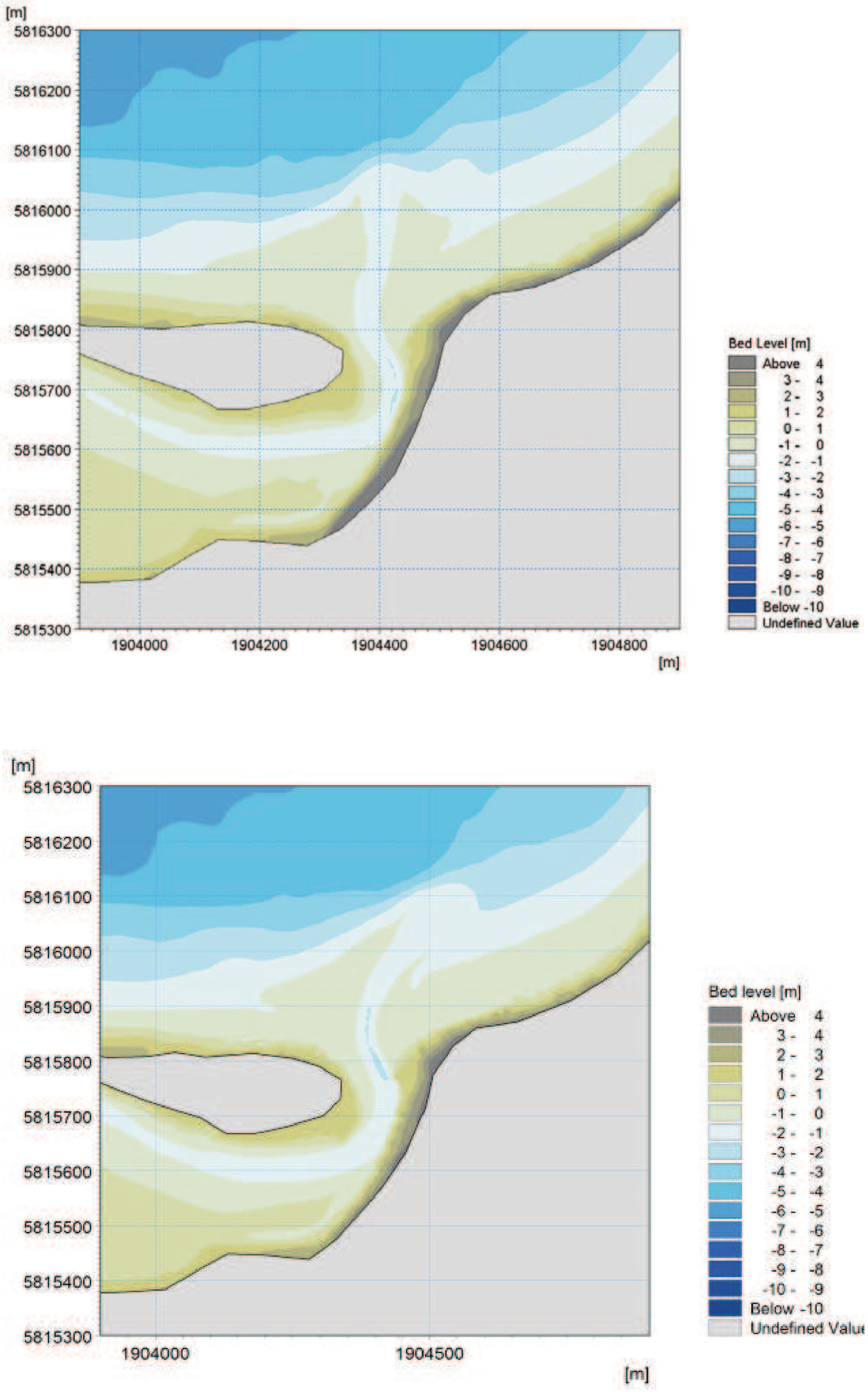


Figure 7-28 Ongatoro / Maketū Estuary entrance bed level for typical one year simulation after twelve months for existing (top) and proposed situations (bottom).

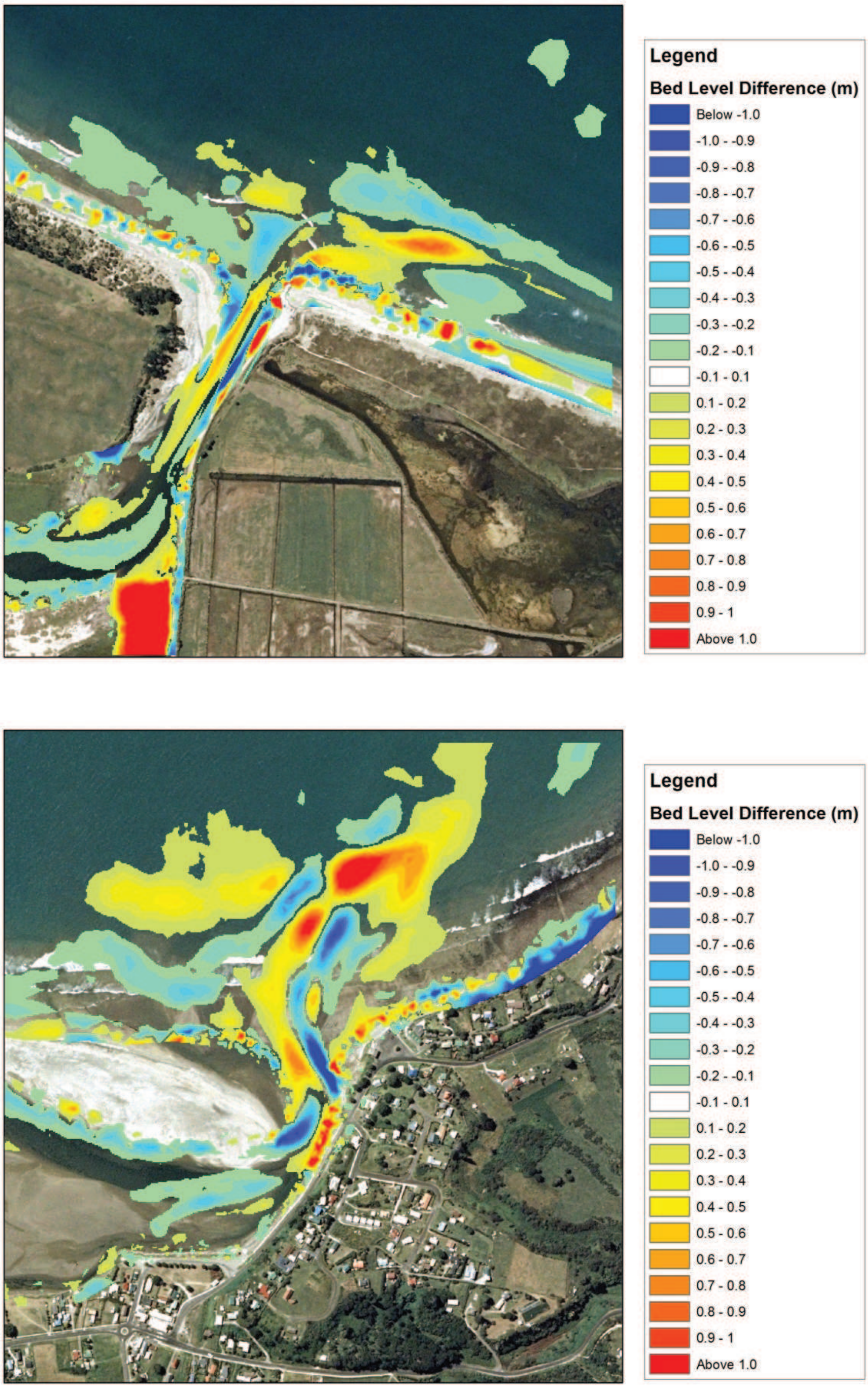


Figure 7-29 Difference between bed level for typical one year simulation after twelve months between the proposed and existing situations for Kaituna River mouth (top) and Ongatoro / Maketū Estuary entrance (bottom).

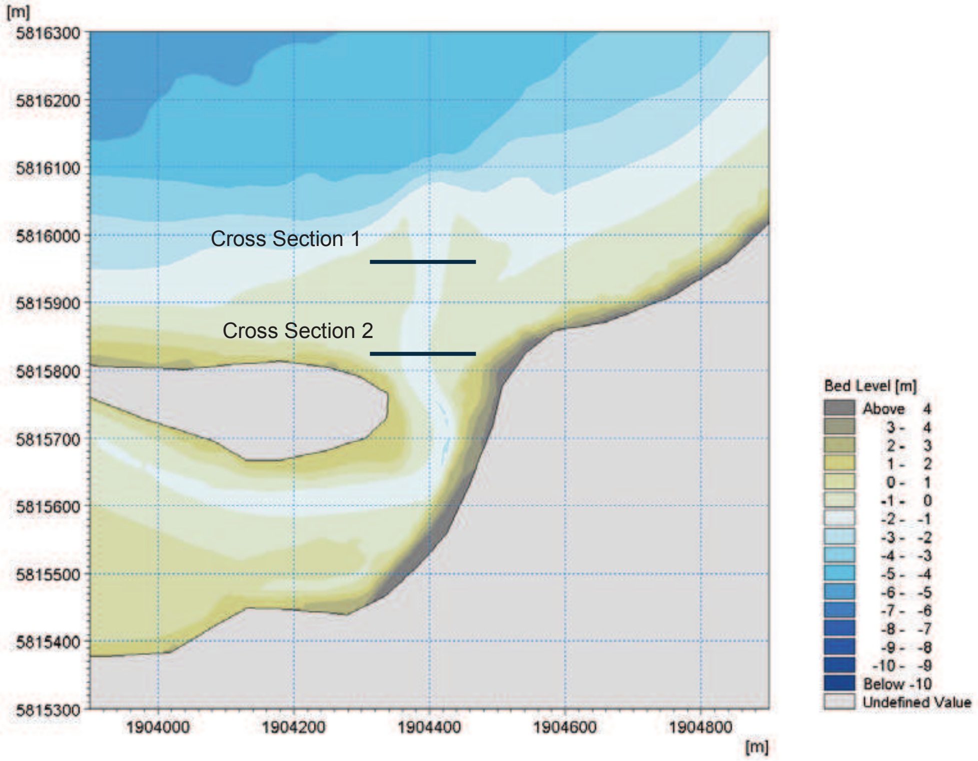


Figure 7-30 Locations of cross sections where bed levels extracted for typical one year simulation after twelve months for the proposed and existing situations.

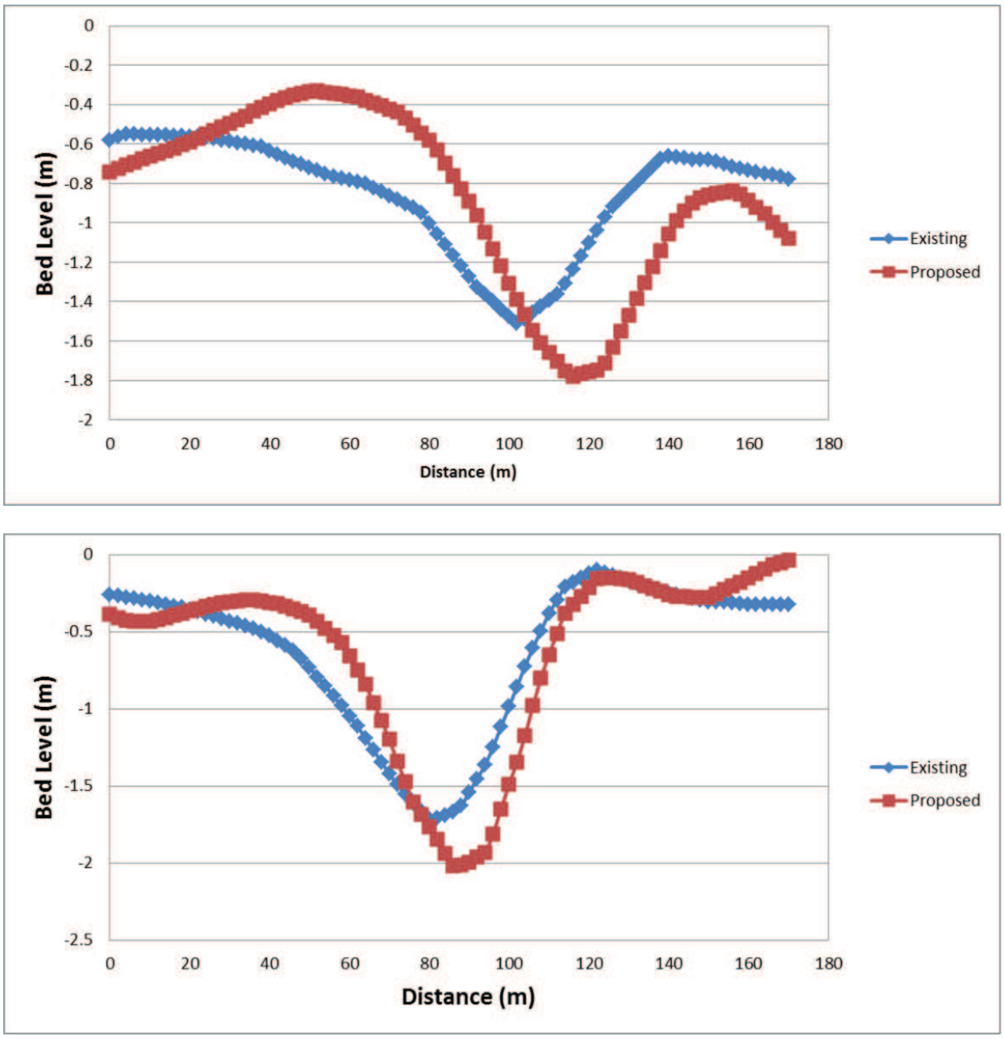


Figure 7-31 Comparison of bed levels along cross section 1 (top) and cross section 2 (bottom) for typical one year simulation after twelve months for the proposed and existing situations. Distance scale from west to east.

To illustrate that the scaling method overestimated the impacts of the proposed option on the river mouth morphology, for the 7th August 2006 flood event during the year long simulation, the same flood event has been simulated for the existing and proposed situations with no scaling method applied (including no temporal scaling of river flows). The initial bed levels for the simulations were obtained from the year long simulations before the 7th August 2006 flood event and are shown in Figure 7-32.

Similar to the 7th August 2006 flood event simulated in the year long simulation, a higher proportion of flood waters was diverted into the estuary for the proposed option compared with the existing situation (a decrease in the volume of water through Kaituna River mouth of approximately 10%).

The comparison of the predicted evolution of the bathymetry at Kaituna River mouth for the existing and proposed situations after the flood event is presented in Figure 7-33. The simulation predicted no significant impact on the bed levels confirming that the year long simulation overestimated the impact of the proposed option for this flood event.

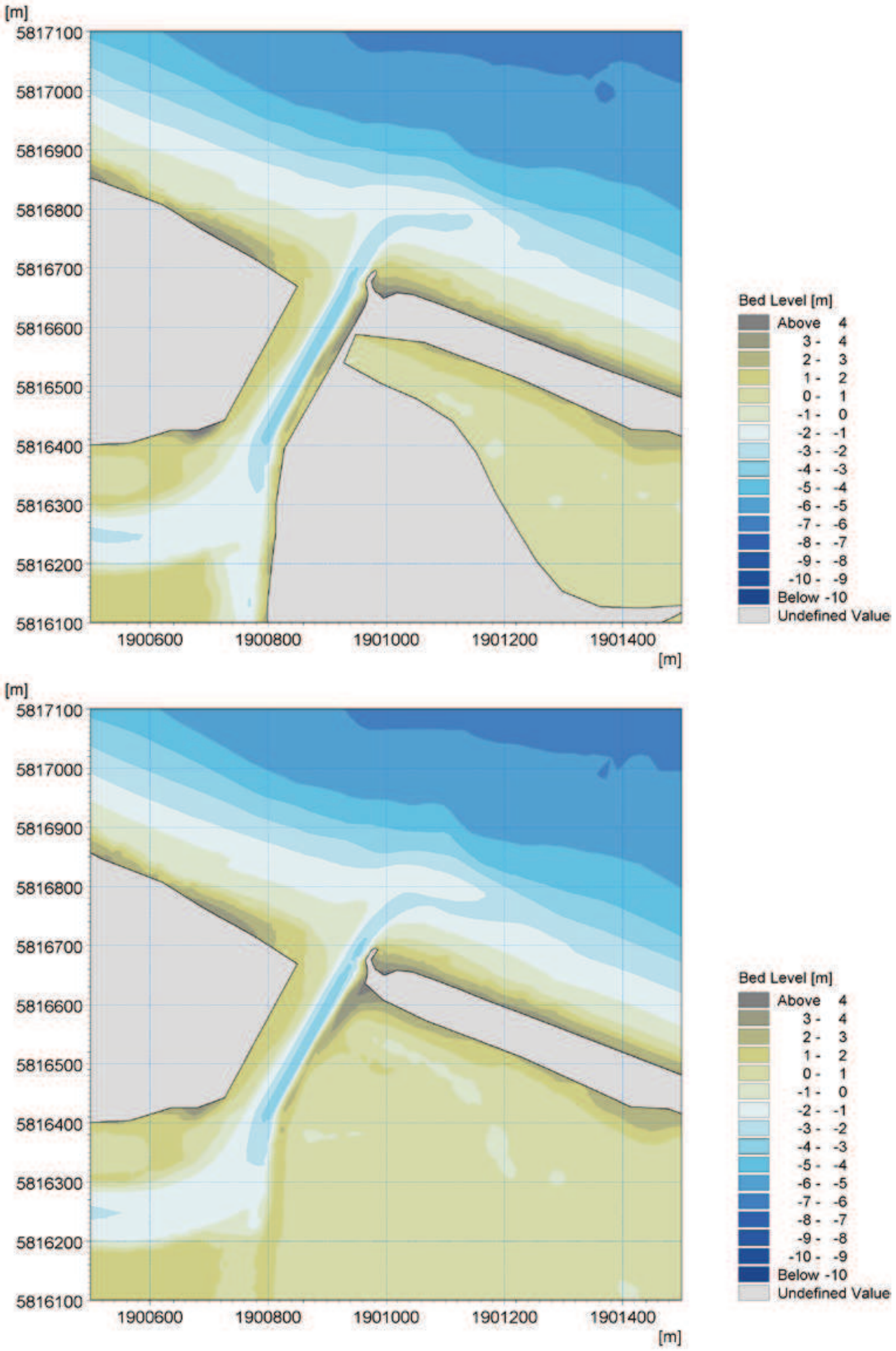


Figure 7-32 Initial bed levels for Kaituna River mouth for 7th August 2006 flood event simulation for existing (top) and proposed situations (bottom).

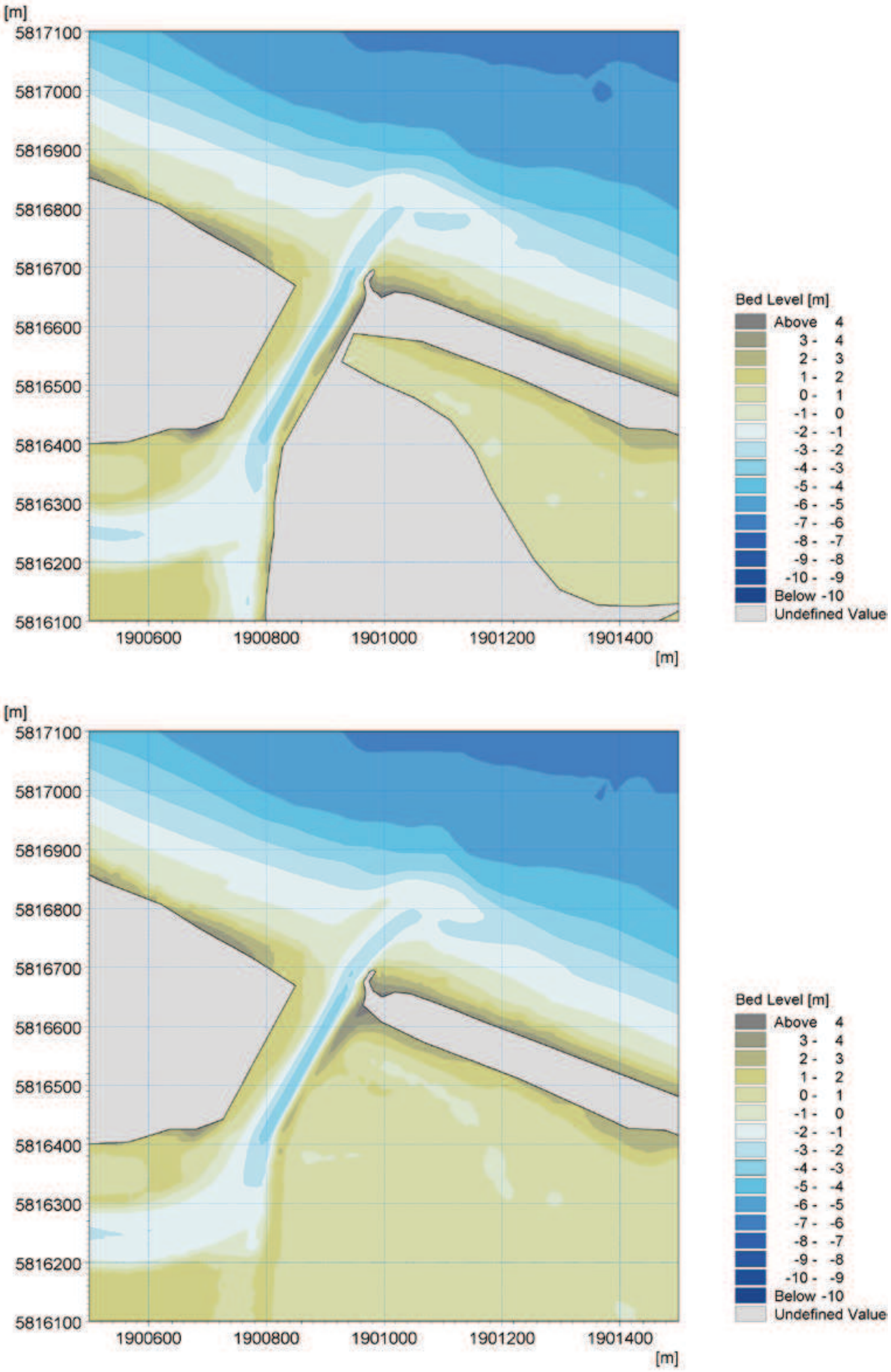


Figure 7-33 Kaituna River mouth bed levels after 7th August 2006 flood event for existing (top) and proposed situations (bottom).

To further complement the one year simulation (and ensure that any limitations of the scaling factor method does not affect the conclusions of the entrance morphology assessment) a sensitivity test was also carried out with only a hydrodynamic model (i.e. sediment transport model not included), to assess if there will always be a reduction in peak flood flow through the Kaituna River during a high river flow event (as a result of river flow being diverted from river to estuary through new re-diversion channel). Although it is the tidal prism which ultimately ensures the Kaituna River mouth remains open, high river flow events scour open the mouth significantly until littoral transport carries sediment back into the vicinity of the river mouth and bars form across the river mouth again.

Four high river flow events that were obtained from the Te Matai flow record have been combined to occur sequentially within a short duration. The flows for the four high river flow events and the predicted offshore water levels are presented in Figure 7-34.

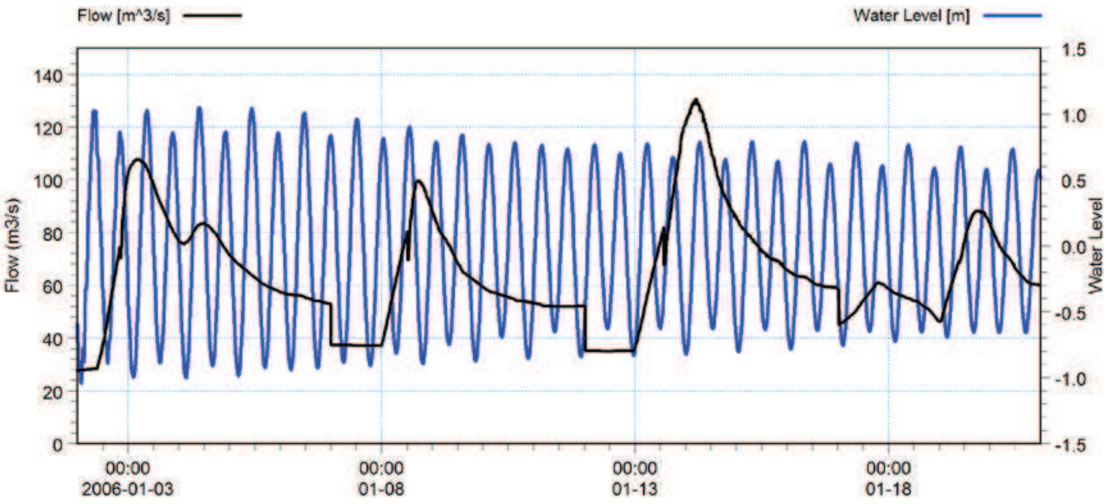


Figure 7-34 Kaituna River flow at Te Matai for four sequential high river flow events and predicted water levels (Moturiki Datum) off Okurei Point.

A comparison of the predicted flow through Kaituna River mouth and the associated current speed in the middle of the river mouth for the existing situation and the proposed option are presented in Figure 7-35. For the majority of the high river flow events there is no difference in the peak flow or current speed through Te Tumu. The only difference is for around +/- 90 minutes around high tide, when flow rates are significantly different but so low that no significant scour of the river mouth is likely to occur. When the peak of the flood event coincides with high tide for the third high flow event, there is a slight reduction in the peak flow (143 to 136 m^3/s) and peak current speed (2.02 to 1.96 m/s), however it can concluded this would only have a limited impact on the morphology in the vicinity of the river mouth.

This further supports the finding of the long term morphological model simulations, that the proposed option is unlikely to have a significant impact on the long term morphological behaviour of the river mouth.

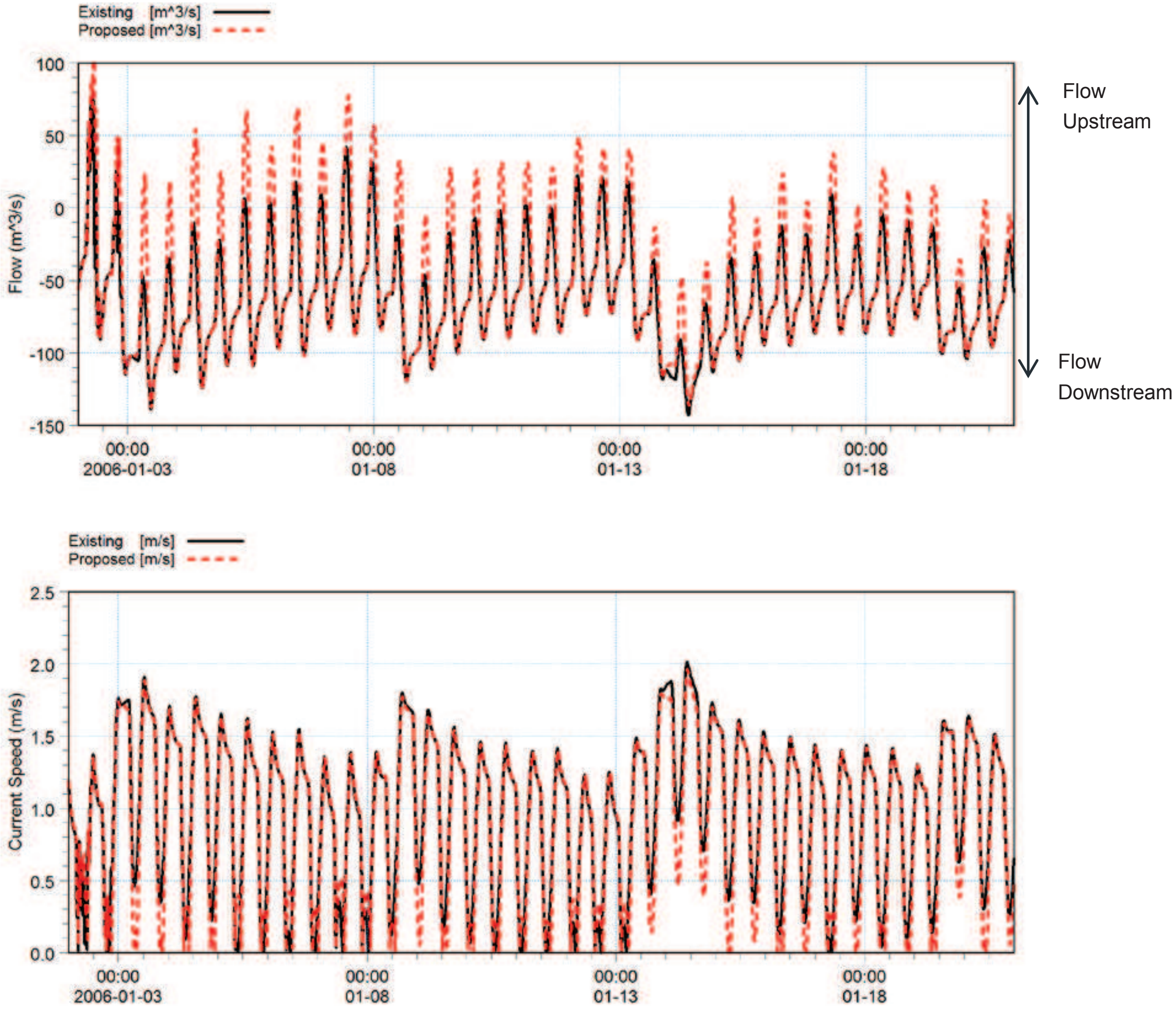


Figure 7-35 Comparison of predicted flow through Kaituna River mouth (top) and associated current speed in the middle of river mouth (bottom) for the existing situation and the proposed option for four combined high river flow events simulation. Note negative flow out through river mouth.

7.3 Prolonged Low River Flow with Adverse Wave Climate

During periods of low river flow with significant wave conditions, sediment is likely to be transported towards the mouths of both the Kaituna River and Ongatoro / Maketū Estuary and may contribute to the development of bars at the mouths which can make navigation through the mouths problematic. Simulations have been carried out to assess if there is a significant impact due to the proposed option on sedimentation within the vicinity of the estuary and river entrances.

The two wave scenarios defined in Table 5-2 are the wave directions which will generate the greatest amount of littoral sediment transport. These wave conditions have been simulated for one month with a constant freshwater inflow equal to the seven day five year low river flow for Kaituna River (21.6 m^3/s), Raparapahoe Canal (0.6 m^3/s) and Waiari Stream (2.9 m^3/s). The initial bathymetry for Kaituna River mouth and Ongatoro / Maketū Estuary mouth are the same as presented in Figure 7-16.

The comparison of the predicted evolution of the bathymetry at Kaituna River mouth and Ongatoro / Maketū Estuary entrance for the existing and proposed situations for the adverse wave conditions simulations are shown in Figure 7-36 to Figure 7-39.

Similar to the year long scenario, the simulations illustrate there are only small differences in the predicted bed levels for the existing and proposed situations. This indicates that the proposed option is unlikely to have a significant impact on the bathymetry of the river mouth or estuary entrances during adverse wave conditions. It does appear that for the wave scenario with 55° mean wave direction the proposed option inhibits the build-up of a small bar seen to form on the eastern side of the Ongatoro / Maketū Estuary mouth. However, the impact of the proposed option on the bar formation is not significant in terms of improving navigation.

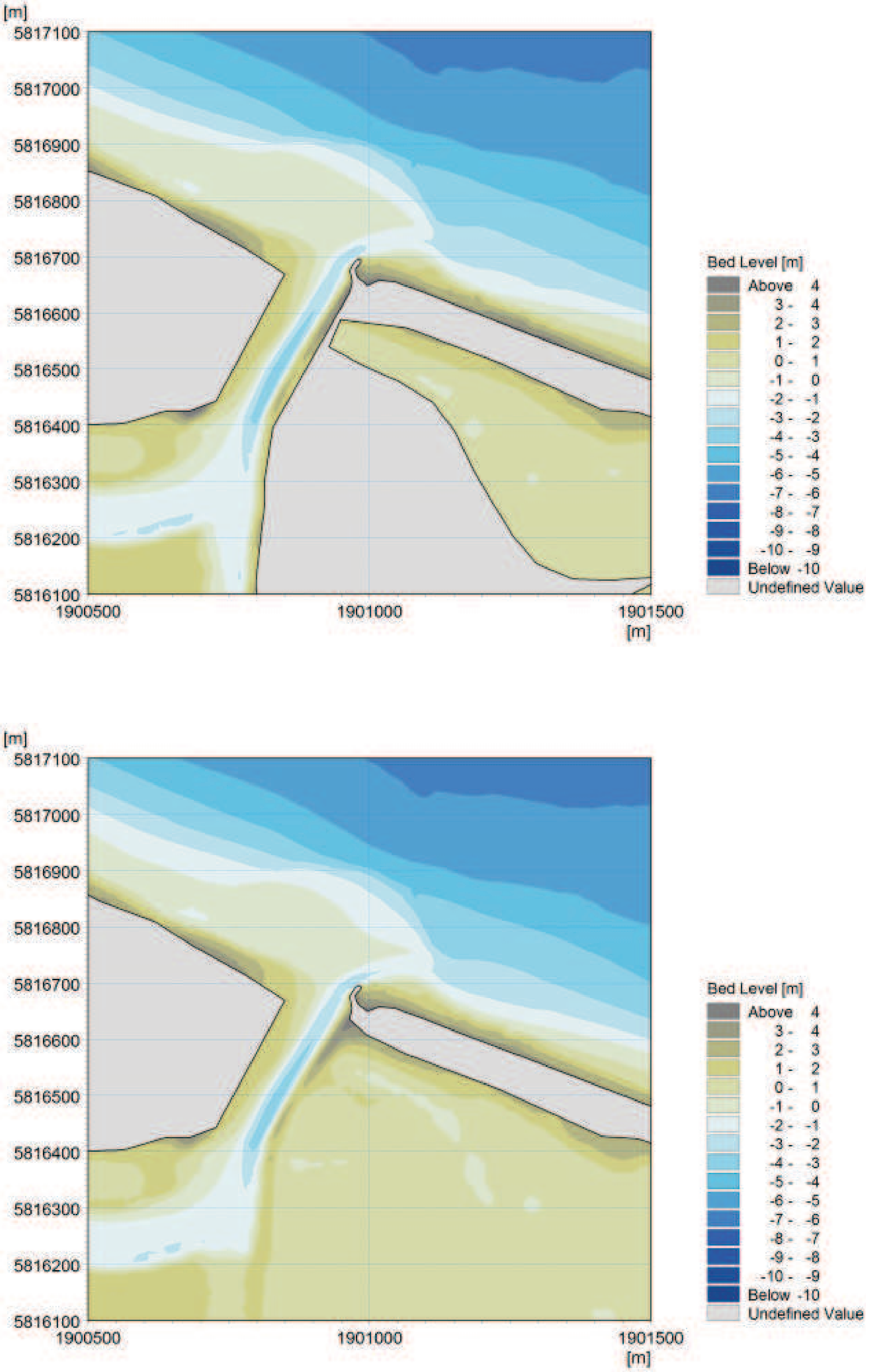
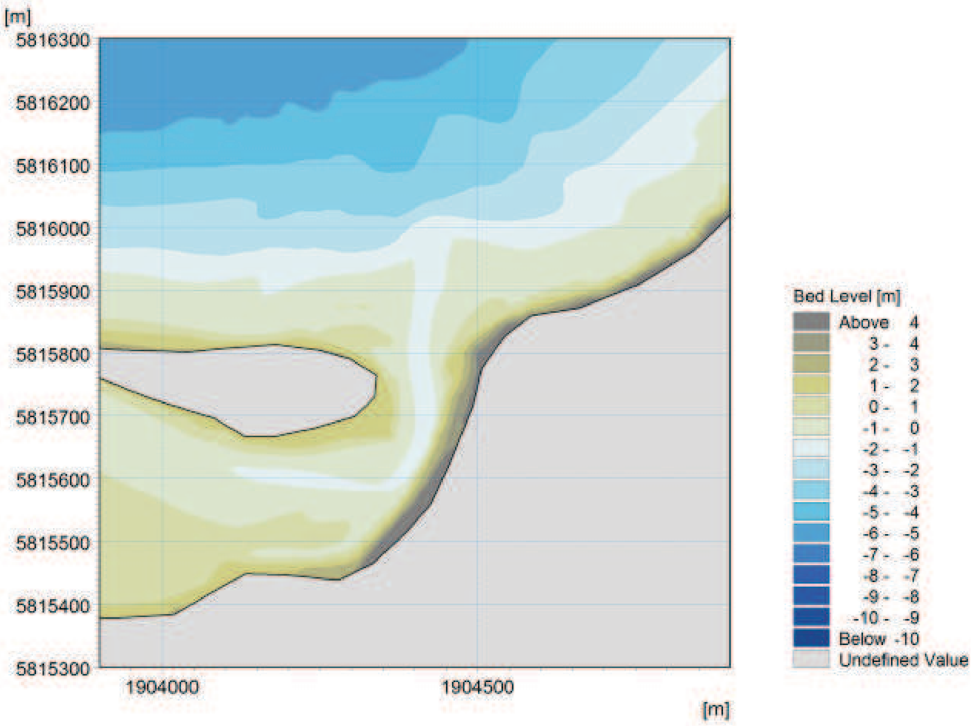


Figure 7-36 Kaituna River mouth bed level after one month of adverse wave conditions and low river flow for existing (top) and proposed situations (bottom). H_s = 2.5 m, Mean Wave Direction = 355° and T_p = 10s.



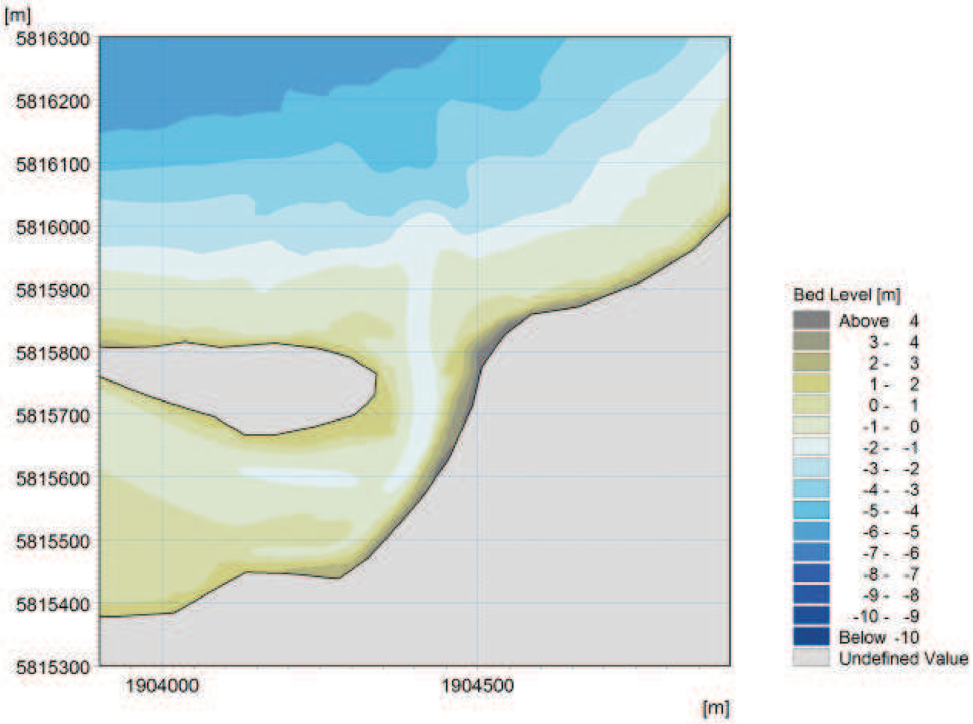


Figure 7-37 Ongatoro / Maketū Estuary mouth bed level after one month of adverse wave conditions and low river flow for existing (top) and proposed situations (bottom). H_s = 2.5 m, Mean Wave Direction = 355° and T_p = 10s.

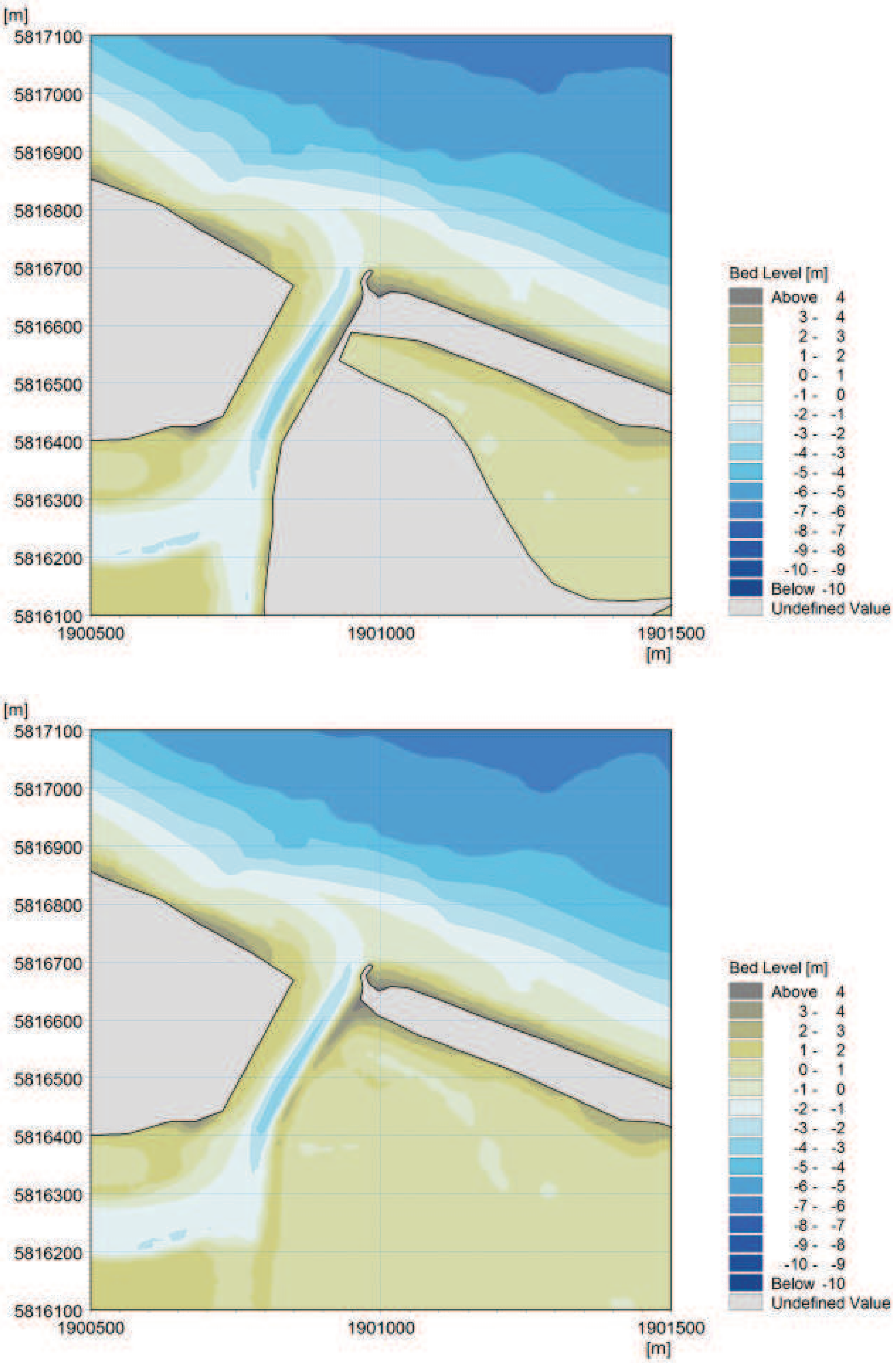
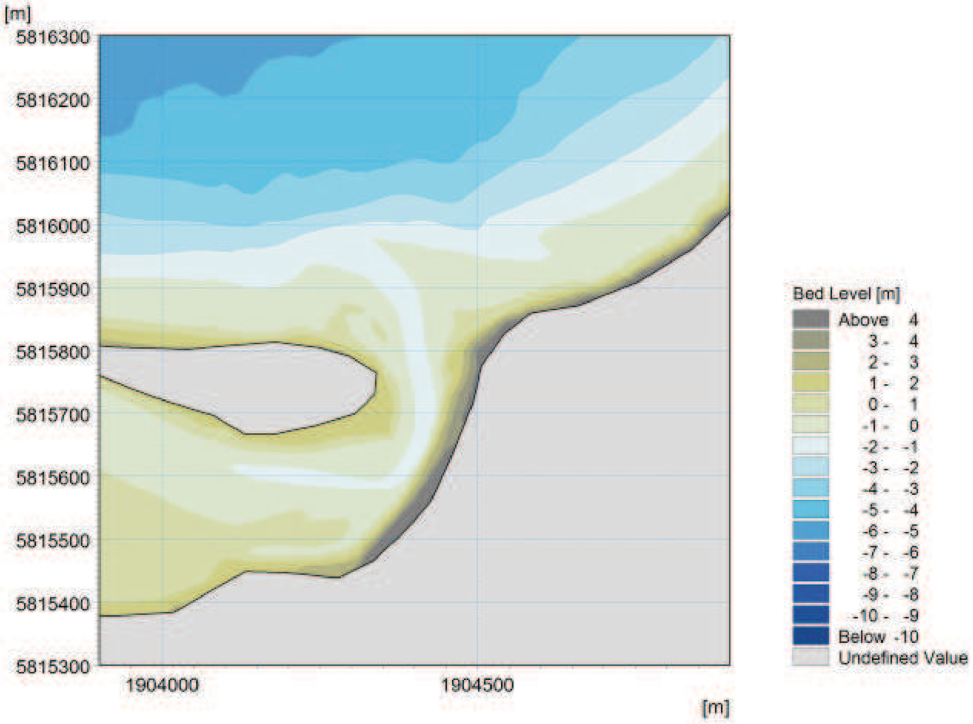


Figure 7-38 Kaituna River mouth bed level after one month of adverse wave conditions and low river flow for existing (top) and proposed situations (bottom). H_s = 2.5 m, Mean Wave Direction = 55° and T_p = 10s.



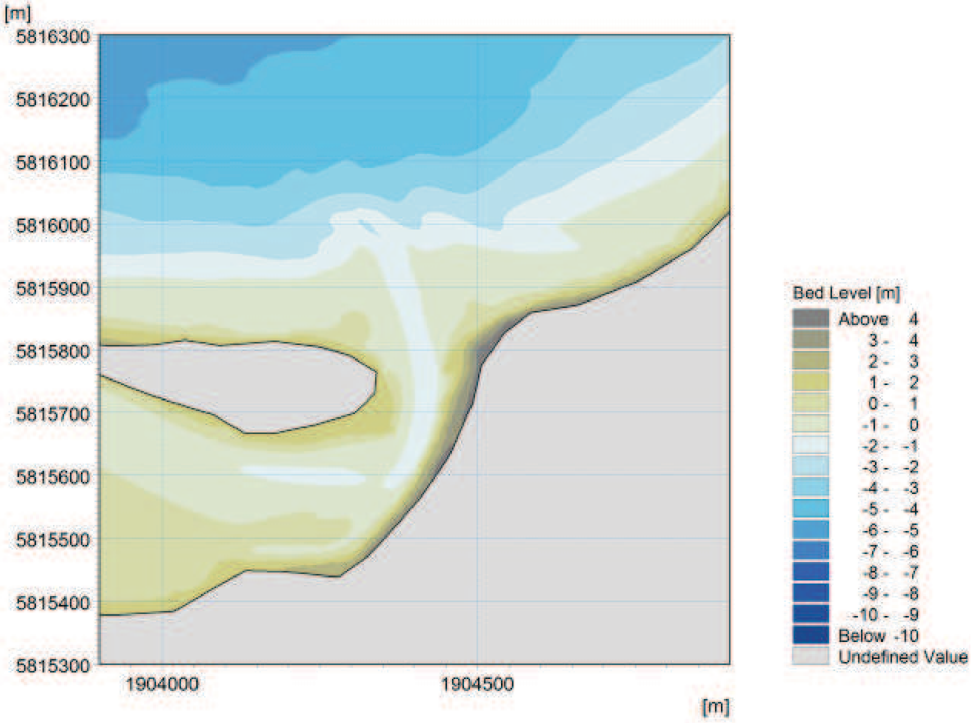


Figure 7-39 Ongatoro / Maketū Estuary mouth bed level after one month of adverse wave conditions and low river flow for existing (top) and proposed situations (bottom). H_s = 2.5 m, Mean Wave Direction = 55° and T_p = 10s.

7.4 Extreme Flood Effects on Morphology

The morphological response of the estuary for the proposed option compared with the existing situation was assessed for an extreme flood event by simulating a 1% AEP flood flow for Kaituna River, Waiari Stream, Raparapahoe Canal and Kopuroa Stream coinciding with a mean tide. The hydrographs for the extreme flood event are shown in Figure 7-40, while the corresponding water levels for the simulation are shown in Figure 7-41.

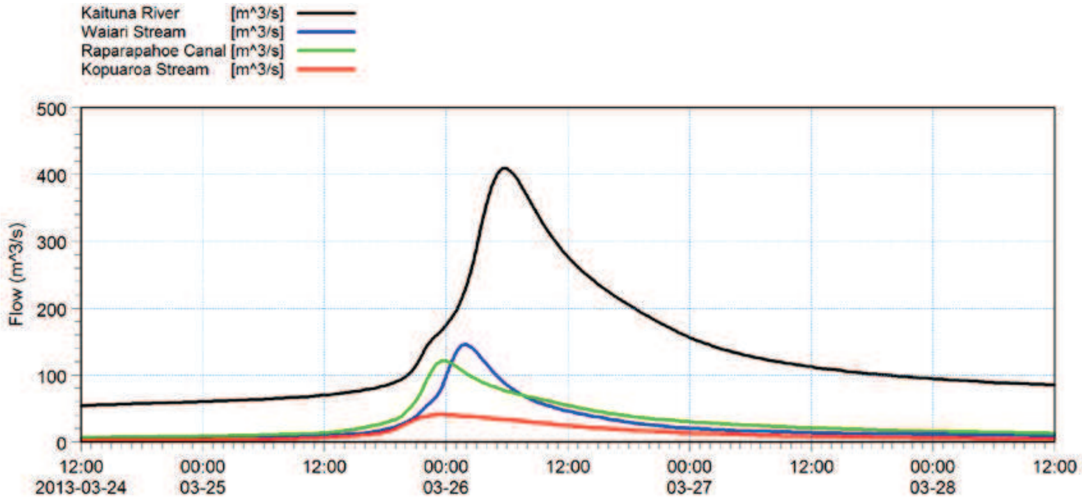


Figure 7-40 1% AEP hydrograph used for extreme flood simulation.

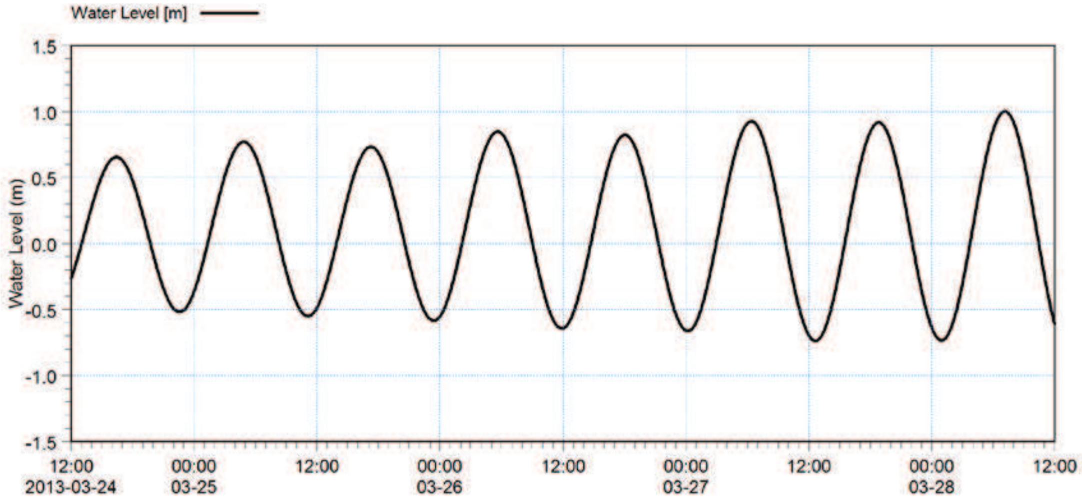


Figure 7-41 Water levels off Okurei Point for extreme flood simulation.

For the 1% AEP flood event the only significant changes in bed levels occur within the estuary and river mouths as shown in Figure 7-42. Over significant areas of the estuary bed level change is less than 1 mm. Thus, it can be concluded that an extreme flood event will not have a large morphological impact within the estuary with the proposed option in place. During a large flood event there is likely to be a significant supply of sediment from the river which may result in some areas where deposition of sediment occurs in the upper parts of the estuary, where currents speeds are not large enough to keep the river supplied sediment in suspension. However even accounting for possible areas of deposition within the upper estuary the conclusion that the overall a flood event will not have a large impact on morphology of the estuary is still valid.

To determine if there are areas where there is an increase of scour occurring during an extreme flood such as the spit or Papahikahawai Creek, the residual sediment transport patterns have been generated for the estuary for existing and proposed situations and are presented in Figure 7-43 and Figure 7-44. The comparison in sediment transport patterns suggests there will be some areas where erosion may take place. The additional flow through Papahikahawai Creek appears to encourage erosion of the channel. However it does not appear that significant scour of the spit to the north of the Papahikahawai Creek would occur.

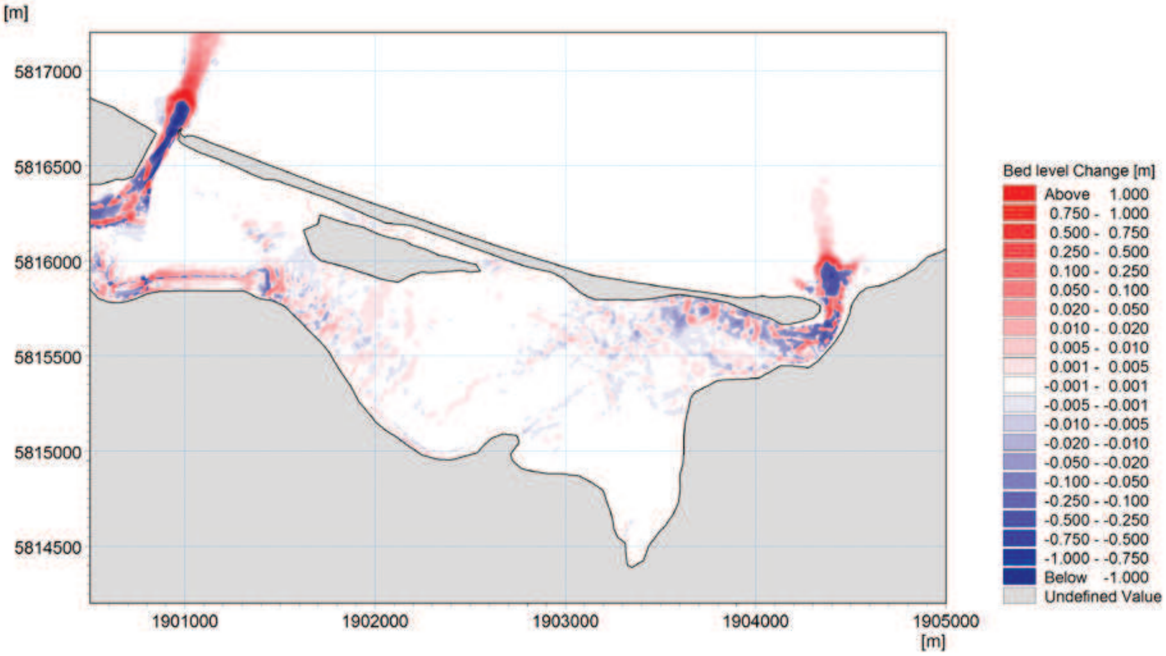


Figure 7-42 Change in bed level with proposed option for 1% AEP flood event coinciding with mean tide.

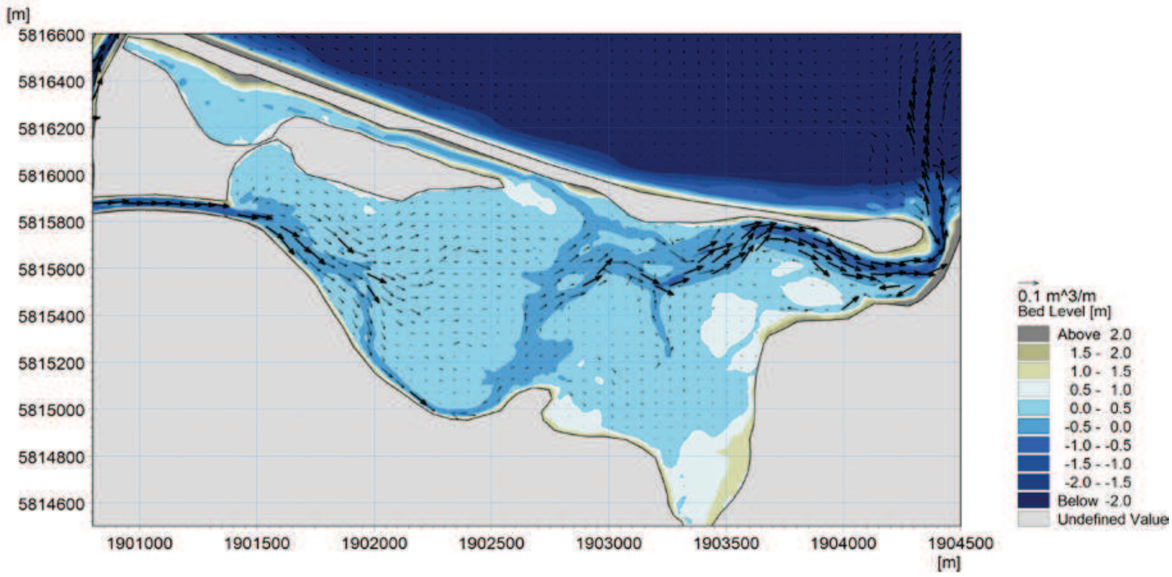


Figure 7-43 Residual sediment transports rates (m^3/m) for estuary with existing situation for 1% AEP flood event coinciding with mean tide. Note vectors limited to 0.1 m^3/m.

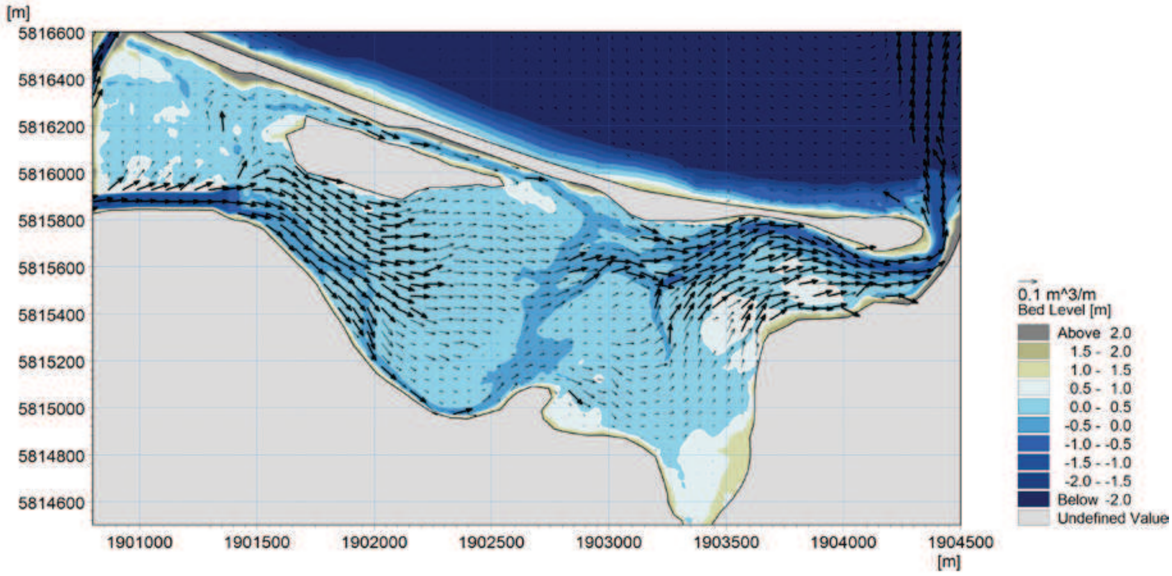


Figure 7-44 Residual sediment transports rates (m^3/m) for estuary with proposed option for 1% AEP flood event coinciding with mean tide. Note vectors limited to 0.1 m^3/m.

The residual sediment transport patterns have also been generated for the flood tide delta for existing and proposed situations to determine if there is an increase in risk of scouring inside of the spit at this location. These plots are presented in Figure 7-45 and Figure 7-46. The residual transport rates are larger at this location for the proposed option compared with the existing situation, therefore it can be concluded that there is a risk of additional scour on the inside of the spit. If the flood tide delta is eroded over time, it can be assumed that this risk will reduce and in time the risk of scour will in fact become less than the risk associated with the existing situation (assuming significant scour of delta occurs). However for a period after the implementation of the proposed option (before the flood delta erodes) there is a risk that the proposed option may encourage additional scour of the spit compared to the scour that may occur under the existing conditions.

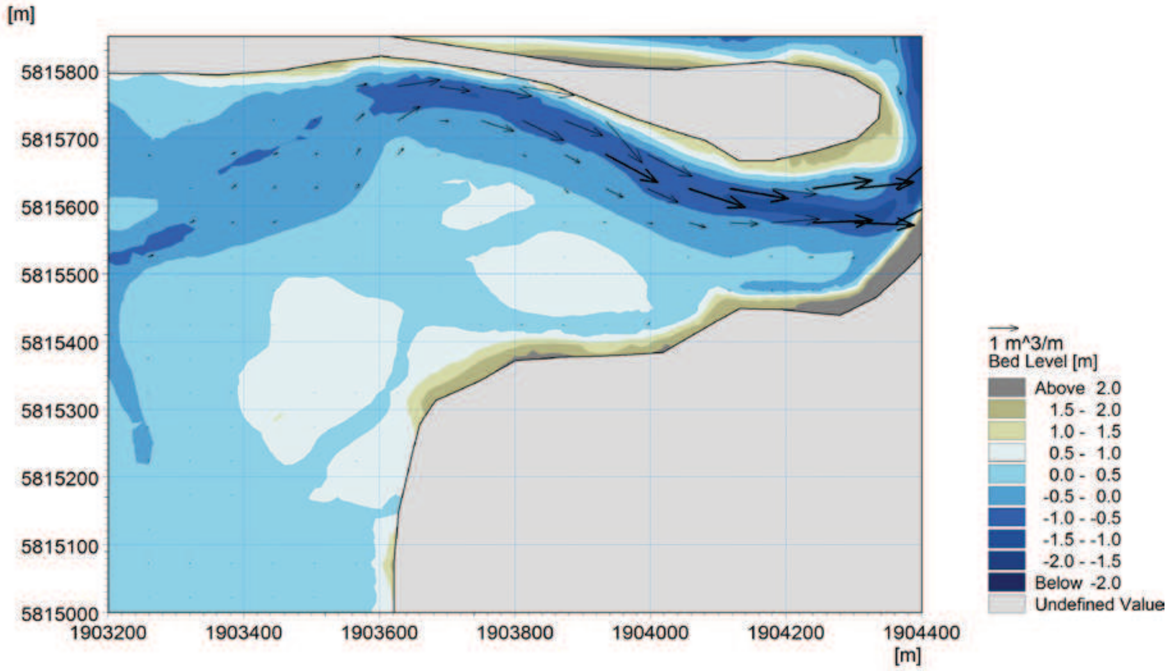


Figure 7-45 Residual sediment transports rates (m^3/m) for flood tide delta of estuary for existing situation for extreme flood event. Note vectors limited to 2 m^3/m.

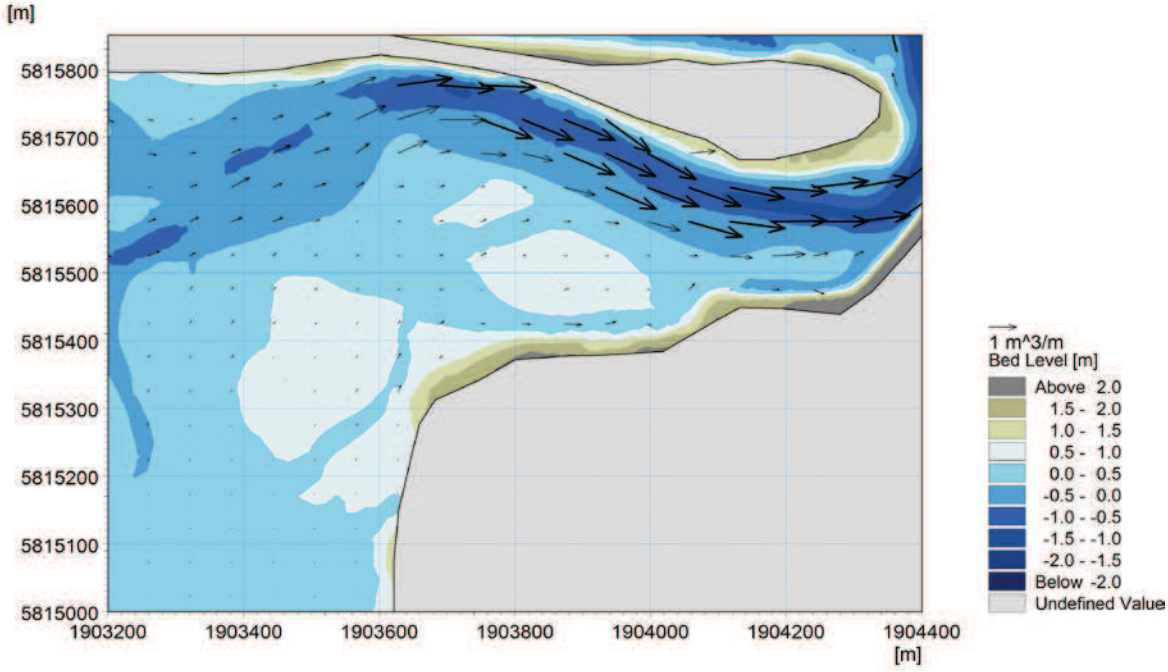


Figure 7-46 Residual sediment transports rates (m^3/s/m) for flood tide delta of estuary for proposed option for extreme flood event. Note vectors limited to 2 m^3/m.

Current speeds have been extracted for the extreme flood event for the locations shown in Figure 7-47. The extracted current speeds are presented in Figure 7-48. Peak current speeds are only slightly increased with the proposed option compared with the existing situation. This indicates that risk of additional scour of the inside of the spit is actually minimal, however still should still be considered a potential risk.

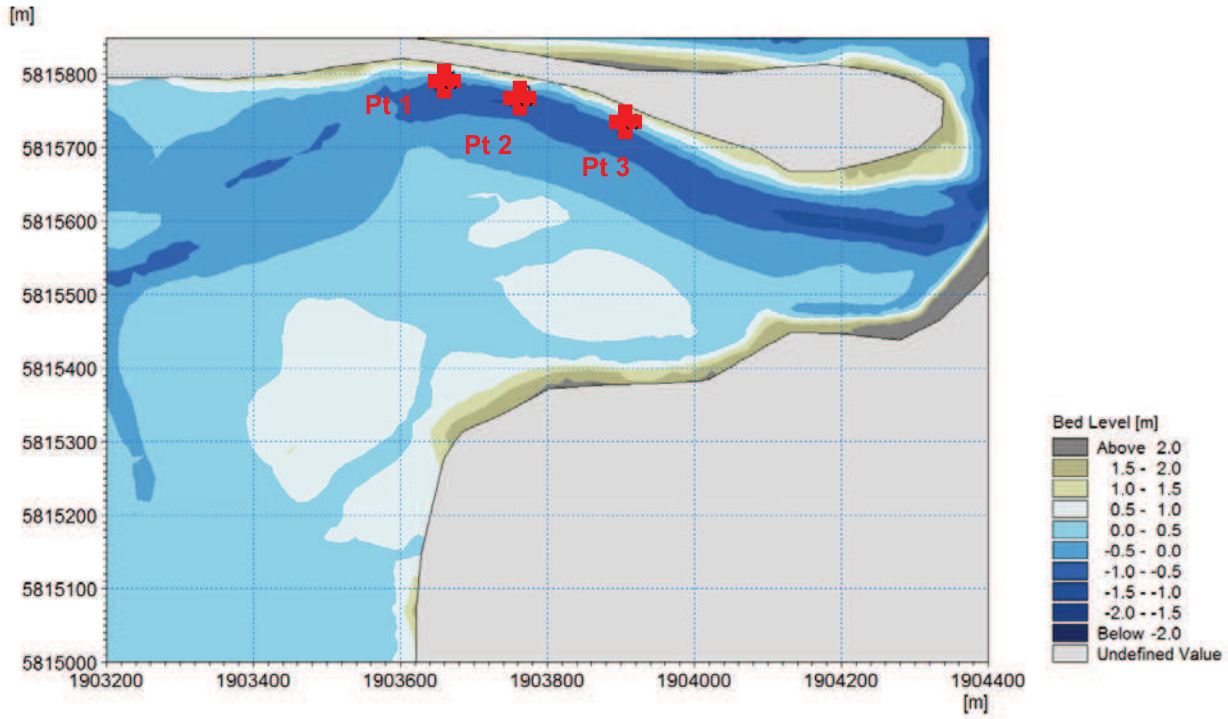


Figure 7-47 Locations in vicinity of spit where time series of current speed extracted.

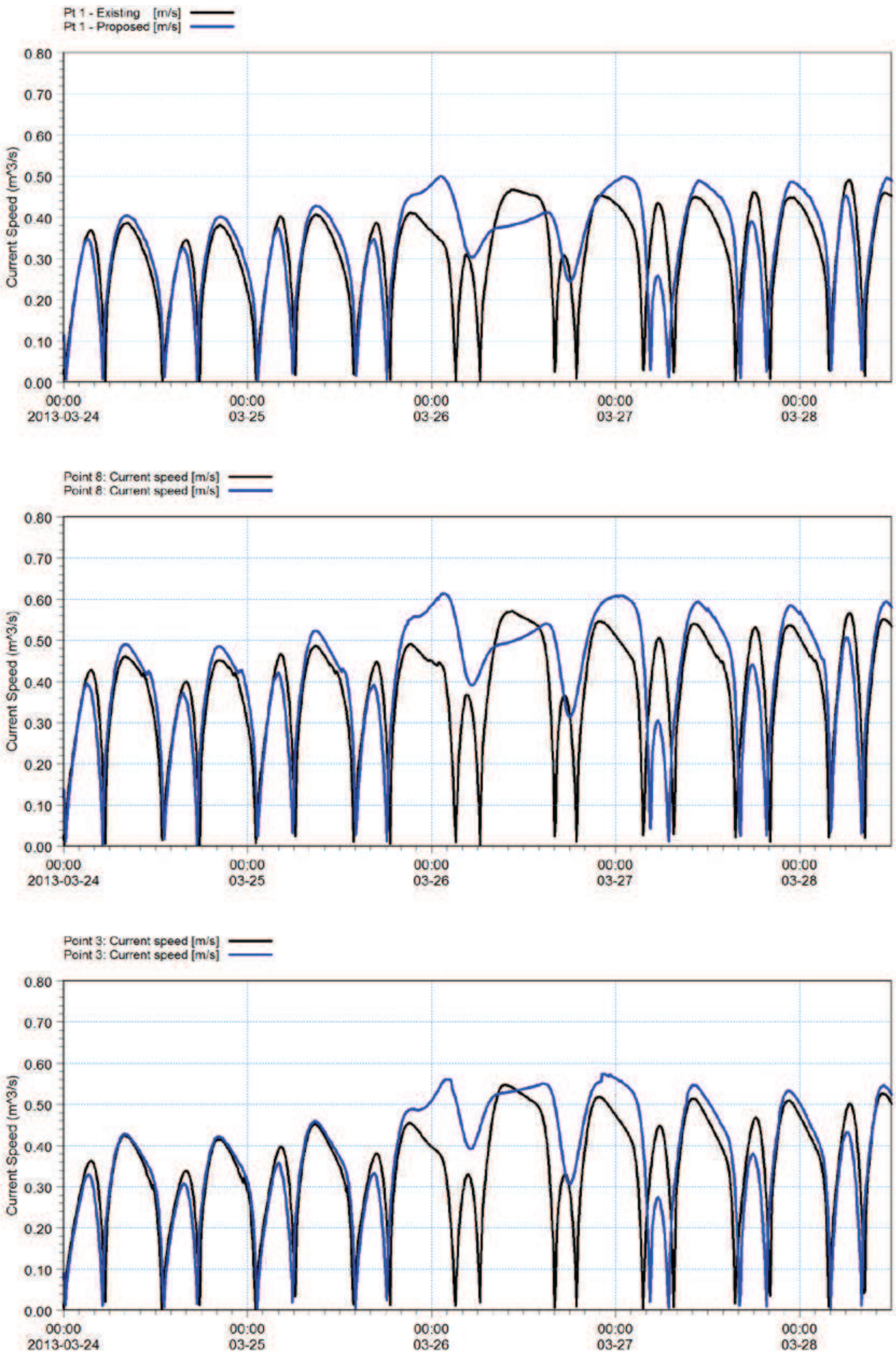


Figure 7-48 Current speeds at selected locations Pt 1 (top), Pt 2 (middle) and Pt 3 (bottom) in vicinity of spit for existing situation and proposed option for extreme flood event. Note only seven day period (i.e. neap to spring tide) shown.

There a concern from the local community about the potential for additional scour to occur for the land in front of the Maketū surf club and the rock wall at the Ongatoro / Maketū Estuary entrance. The maximum predicted current speeds from the extreme flood event simulation are presented in Figure 7-49. There is a significant increase in maximum current speed through the Maketū entrance, but only a minimal change in front of the surf club.

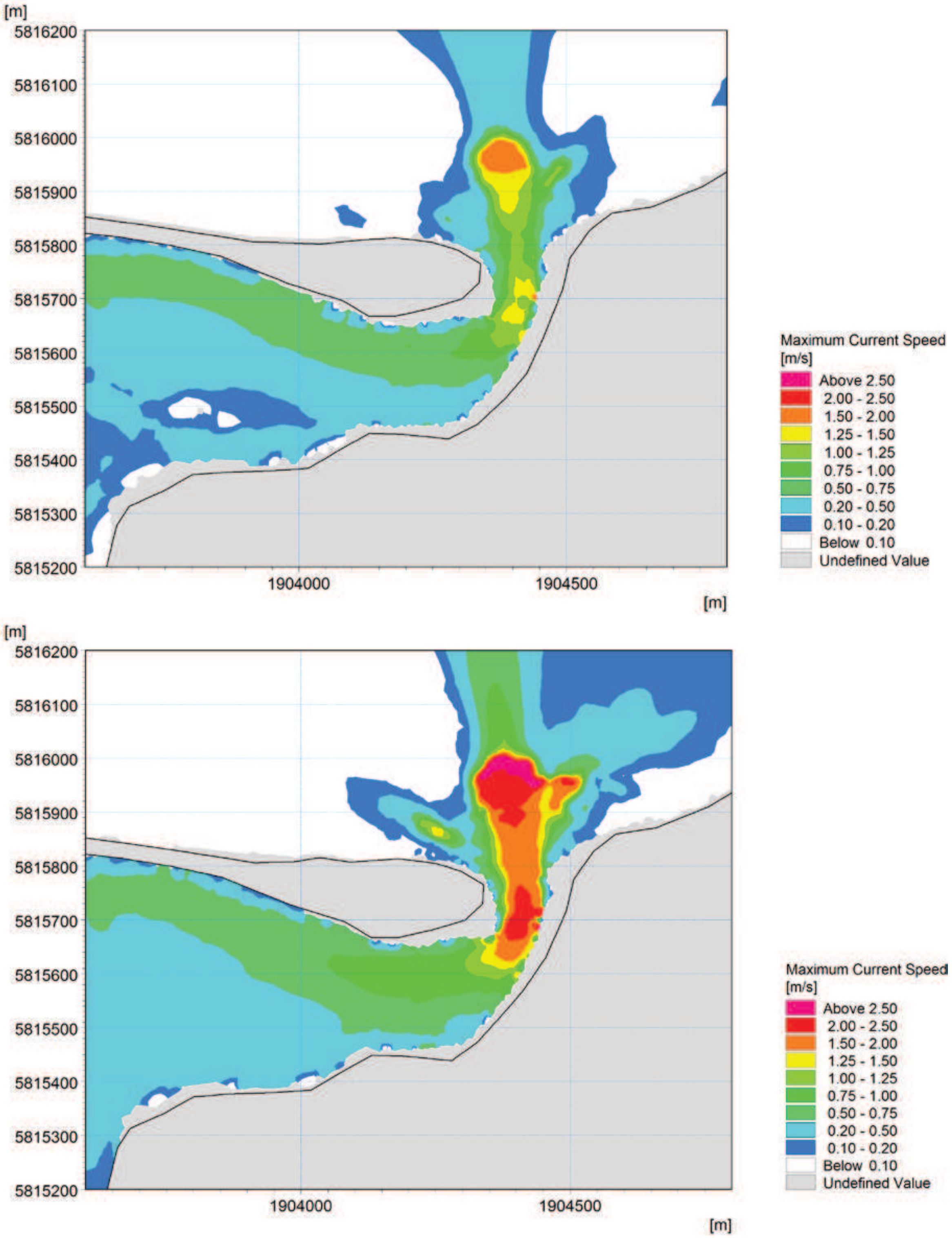


Figure 7-49 Maximum current speed with existing situation (top) and proposed option (bottom) for extreme flood event.

Current speeds have been extracted for the extreme flood event for the locations shown in Figure 7-50. The extracted current speeds are presented in Figure 7-51.

In front of the surf club (Pt 1) there is no significant change in the predicted current speeds. For the rock wall at the estuary entrance there is an increase in the peak speed of 0.5 to 1.6 m/s at Pt 2 and 1.7 to 2.1 m/s at Pt 3. The increase in current speed occurs for a duration of greater than 12 hours. The increase in the current speeds increases the potential for scour of the rock wall. A more detailed engineering assessment is required, which takes into account the characteristics of the wall (i.e. depth of toe), to quantify the increase in the risk.

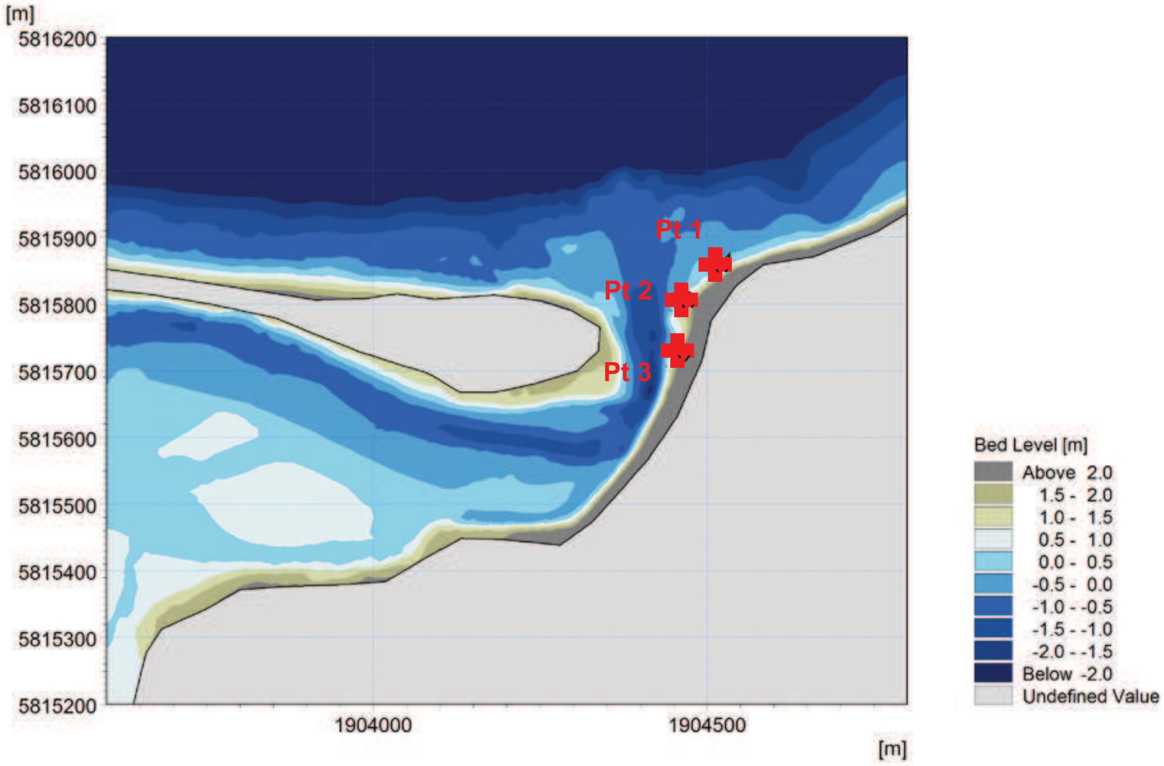


Figure 7-50 Locations in vicinity of surf club and rock wall at Ongatoro / Maketū Estuary entrance where time series of current speed extracted.

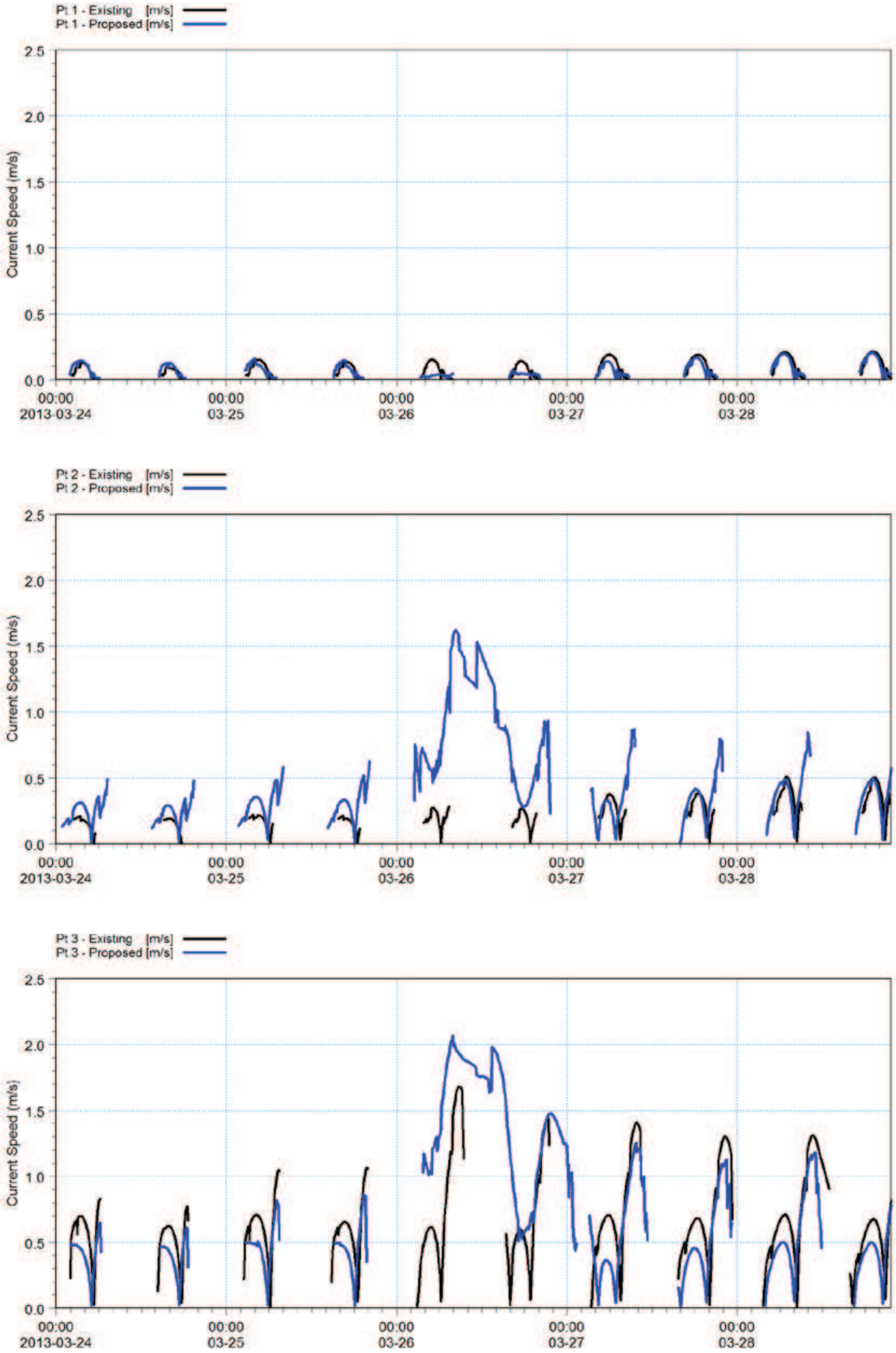


Figure 7-51 Current speeds at selected locations Pt 1 (top), Pt 2 (middle) and Pt 3 (bottom) in vicinity of spit for existing situation and proposed option for extreme flood event. Note only seven day period (i.e. neap to spring tide) shown.