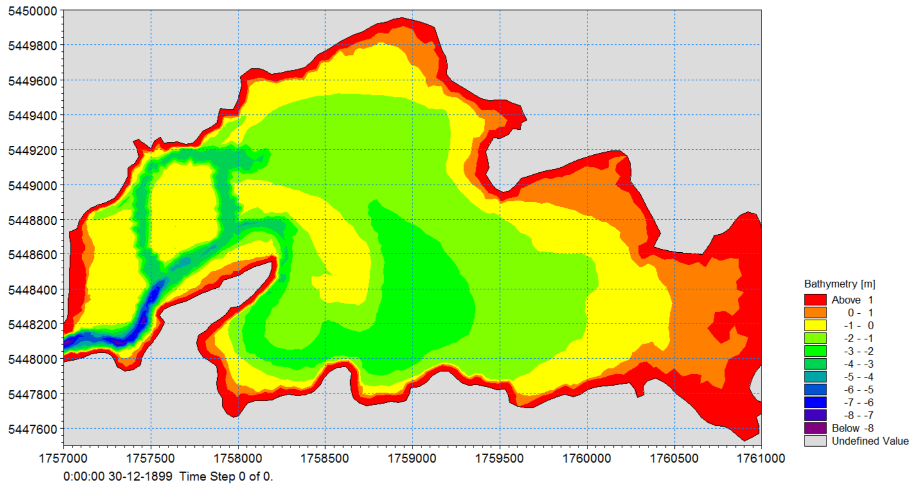
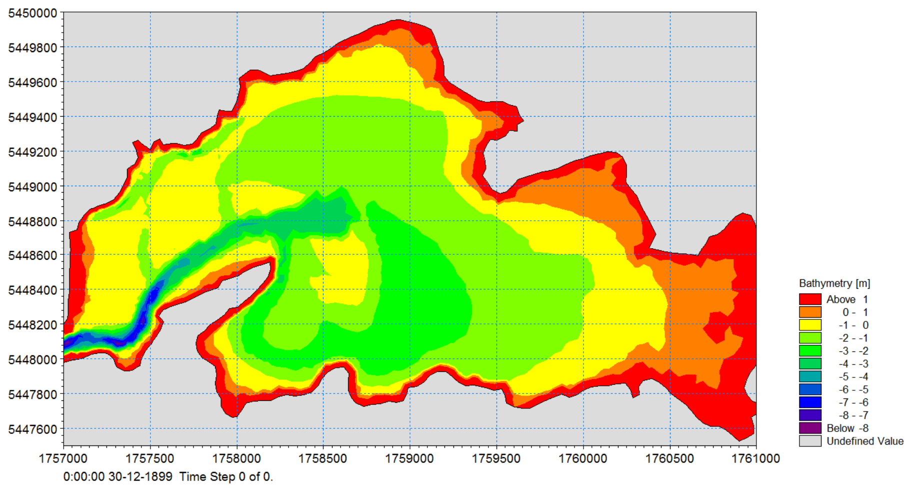
Porirua Harbour - Assessment of Effects on Hydrodynamics from Proposed Dredging





Final Report
November 2011

Porirua Harbour - Assessment of Effects on Hydrodynamics from Proposed Dredging

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CONTENTS

1 EXECUTIVE SUMMARY

Two potential options for dredging of the flood tide delta in Pauatahanui Inlet have been investigated using a mud transport and sand transport model. The options are:

- dredging existing channels in north west of inlet; and
- continuation of the main channel through the flood tide delta.

The mud transport model predicted that both options will only have a small impact on the existing muddy basin in the inlet and the behaviour of terrestrial based sediment entering the inlet during significant flood events.

The sand transport model predicted that both options will impede further deposition of sand onto the toe of flood tide delta in Browns Bay, however the channels in the north west of the inlet are likely to infill in a relatively short time frame.

As per the proposal a brief report detailing the work undertaken and finding has been provided.

2 INTRODUCTION

Porirua City Council (PCC) commissioned DHI Water and Environment Ltd (DHI) to investigate whether dredging sand from the flood tide delta in Pauatahanui Inlet will:

- inhibit the further build up of sand or even erode the flood tide delta; and
- encourage the flushing of silt/clay from terrestrial sources out of the harbour through hydrodynamic action.

The impact of dredging on water quality and ecology has not been considered. An overview of Porirua Harbour is shown in Figure 1.

Figure 1 Porirua Harbour (source: Google Maps)

The following methodology was proposed for the study:

- Utilise an existing Porirua Harbour coupled hydrodynamic (MIKE 21 HD) and spectral wave (MIKE 21 SW) model and couple it with a sand transport (MIKE 21 ST) model to assess response of the flood tide delta.
- Utilise an existing Porirua Harbour mud transport model (MIKE 21 MT) to assess whether dredging of the flood tide delta will encourage erosion of the muddy basin in middle of Pauatahanui Inlet or reduce deposition of silt/clay in central muddy basin during a large flood event.

3 MODEL SET UP

We have utilised existing 2D models developed for the New Zealand Transport Agency (NZTA) Transmission Gully Project (SKM and DHI, 2011). The calibrated hydrodynamic and wave models were used as the basis for both the mud transport and sand transport models. It should be noted 2D models predict depth averaged current velocities.

3.1 Mud Transport Model

Details of the model set up for the mud transport model used for this dredging assessment can be found in SKM and DHI report (2011), including validation of the hydrodynamic, wave and mud transport models. The report also summarises sensitivity tests that were carried out for the models.

It should be noted that although the mud transport model developed for the Transmission Gully Project included sand fractions, for this study only silt/clay has been included in the mud transport model. This is appropriate since the scenarios for which the mud transport has been utilised only require the prediction of the behaviour of silt/clay.

3.2 Sand Transport Model

MIKE 21 ST is the sand transport model which was used for this study. For further details of this model see DHI (2011). Similar to the mud transport model, the sand transport model is coupled with calibrated hydrodynamic and wave models.

For the Transmission Gully Project (SKM and DHI, 2011), a good sediment grab data set was collected throughout the harbour, which indicated a sand diameter of 0.2mm for the flood tide delta and entrance to Pauatahanui Inlet was appropriate for the model. It was assumed that there is no sand entering into the harbour from offshore, which is in line with the current understanding of the system (per comms, Keith Calder, PCC). The only sources of sand within the model are therefore from within the harbour and its approaches.

There was basically no data available for validating the sand transport model which is not unusual for sediment transport studies. Experience from similar projects was used for determining the appropriate model parameters to select. The following parameters were used:

- Combined wave and current formulation;
- Sand diameter of 0.2mm (with porosity of 0.4 and grading co-efficient of 1.1) and
- Morphological update of the bed included.

The sand transport model provides a qualitative assessment of the behaviour of the flood tide delta and for this reason we did not feel that sensitivity testing was required.

4 MODEL SIMULATIONS

4.1 Development of Dredging Options

There is a perception from the local community that dredging within Pauatahanui Inlet, will increase the tidal flushing within the inlet (per comms. Keith Calder, PCC). In reality dredging can only at the most change the current patterns within the inlet, since even if the whole of the flood tide delta was removed via dredging, the calculated increase in the tidal prism is only approximately 2% (based on calculated existing tidal volume of 5,184,000 m^3 and dredged volume of 92,000 m^3 to dredge flood tide delta to MLWS). This is not sufficient to alter the flushing capacity of the inlet.

The only way to significantly increase the tidal flushing of the inlet would be to either dredge the inter tidal regions around the fringes of the inlet, resulting in a maximum increase in the tidal prism of approximately 13% (based on a dredged volume of 676,000 m^3 to dredge the inter tidal regions to MLWS) or increase the surface area of the inlet, both of which we believe are not feasible for logistical, cost and ecological reasons.

The main objective of any realistic dredging in Pauatahanui Inlet would therefore be to modify the current patterns and corresponding sedimentation behaviour within the inlet. Two proposed dredging options have been developed in conjunction with PCC:

- dredging existing channels in north west of inlet; and
- continuation of the main channel through the flood tide delta.

The existing bathymetry for Pauatahanui Inlet (see SKM and DHI, 2011) is shown in Figure 2. The first proposed dredging option (herein referred to as Dredging Option One) that was assessed was dredging the existing channels in the north west of inlet as shown in Figure 3. These have been historically navigable but have now become too shallow due to the infill of sand (per comms, Keith Calder, PCC). The second proposed dredging option (herein referred to as Dredging Option Two) is to continue the main channel through the flood tide delta as shown in Figure 4.

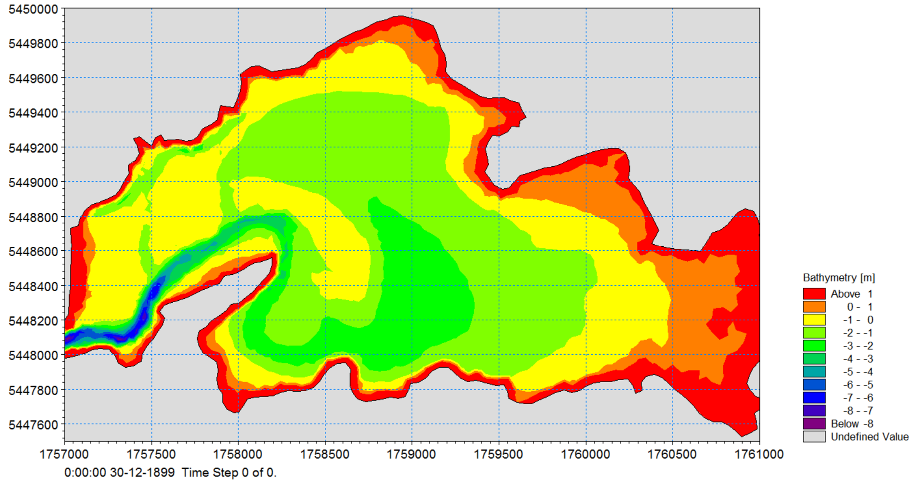

Figure 2 Pauatahanui Inlet - Existing bathymetry (MSL).

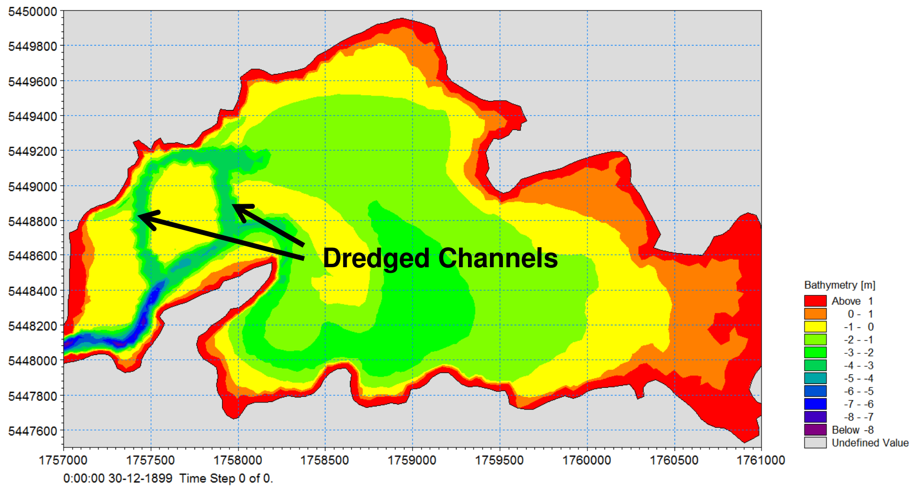

Figure 3 Pauatahanui Inlet - Dredging Option One (MSL).

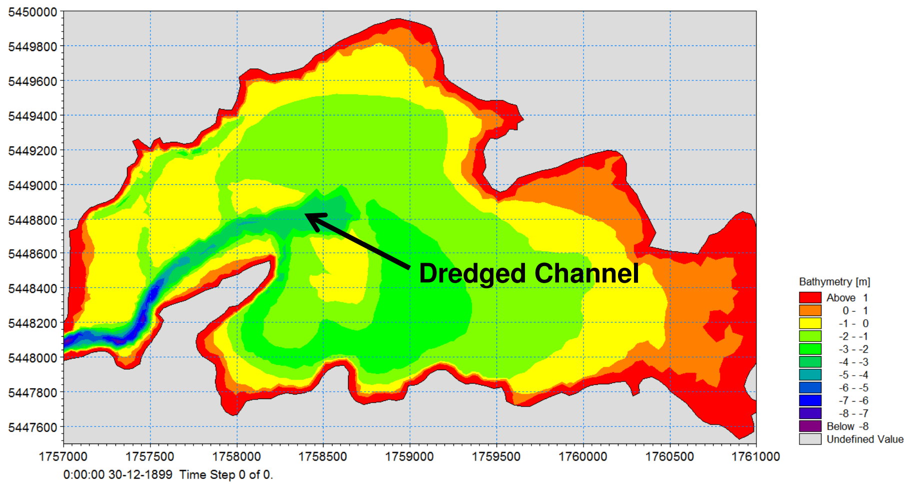

Figure 4 Pauatahanui Inlet - Dredging Option Two (MSL).

4.2 Scenarios Simulated

Three scenarios were investigated using the mud transport and sand transport models. Details of the scenarios are provided below:

Scenario One

The sand transport model was utilised to predict the impact of dredging of the flood tide delta in Pauatahanui Inlet on current sedimentation patterns to determine whether further erosion of the flood tide delta will occur, further build up of the flood tide delta will be impeded (with particular focus on the toe of the delta in Browns Bay) and whether the dredged area is likely to infill with sand.

Only the calm wind condition was investigated and the simulations were carried out for a 17 day period (excluding two day warm up period) to include the neap/spring tide cycle as shown in Figure 5.

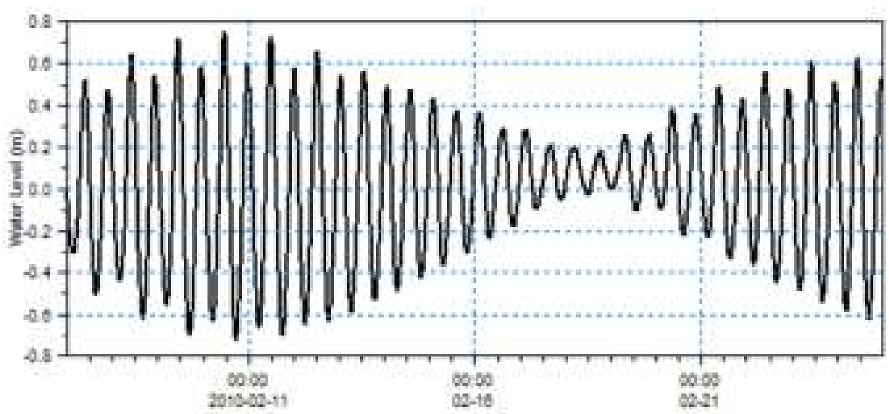

Figure 5 Open ocean boundary water levels (MSL) for scenarios.

Scenario Two

The mud transport model was utilised to predict the impact of dredging of the flood tide delta in Pauatahanui Inlet on the muddy basin within the inlet i.e. will the dredging change the current patterns enough to encourage erosion of the muddy basin.

Three wind conditions were investigated, a calm condition and two dominant wind conditions based on the scaled Mana Island wind record (SKM and DHI, 2011). The 90th percentile wind speed was calculated for these directions. The two winds scenarios were a 10.2 m/s south – south easterly wind (170°) herein referred to as a southerly wind and a 11.4 m/s north - north westerly wind (340°), herein referred to as the northerly wind.

The simulations were carried out for a 17 day period (excluding two day warm up period) to include the neap/spring tide cycle as shown in Figure 5

The initial bed layer used as initial conditions in the model is shown in Figure 6. Details of how this initial condition was developed are available in the SKM and DHI report (2011).

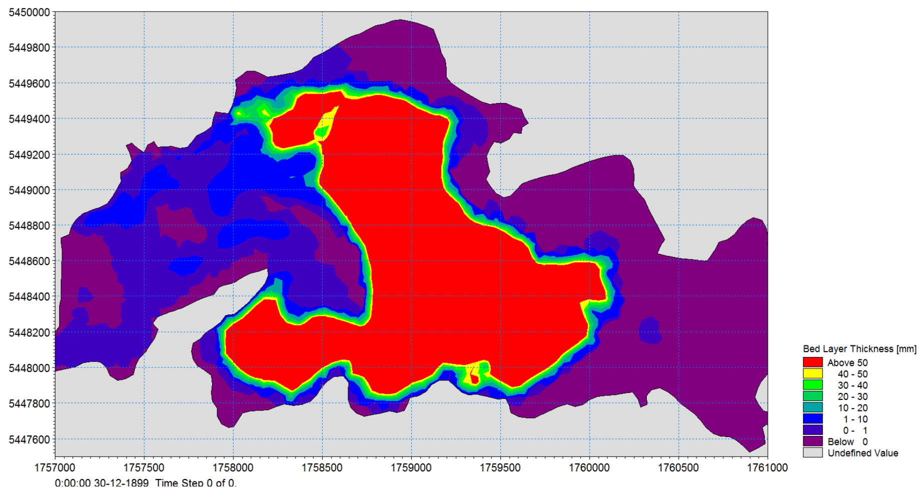

Figure 6 Initial bed layer thickness (mm).

Scenario Three

The mud transport model was utilised to predict the impact of dredging of the flood tide delta in Pauatahanui Inlet on sedimentation of terrestrial derived fine sediment within the inlet by simulating a two year Annual Recurrence Interval (ARI) flood event in the Pauatahanui catchment which enters the harbour via Pauatahanui Stream and Duck Creek. The Pauatahanui Stream catchment is the largest contributor of terrestrial sediment to Pauatahanui Inlet.

Three wind conditions were investigated, a calm condition and two dominant wind conditions based on the scaled Mana Island wind record (SKM and DHI, 2011). The 90th percentile wind speed was calculated for these directions. The two winds scenarios were a 10.2 m/s south – south easterly wind (170°) herein referred to as a southerly wind and a 11.4 m/s north - north westerly wind (340°), herein referred to as the northerly wind.

The simulations were carried out for a 17 day period (excluding two day warm up period) to include the neap/spring tide cycle as shown in Figure 5.

The two year ARI flood event for the Pauatahanui Stream catchment was timed to coincide with the spring tide. The flood hydrographs for Pauatahanui Stream and Duck Creek and the associated sediment loads are presented in Figure 7. Details of how the flood hydrographs and sediment loads were generated are in SKM and DHI report (2011).

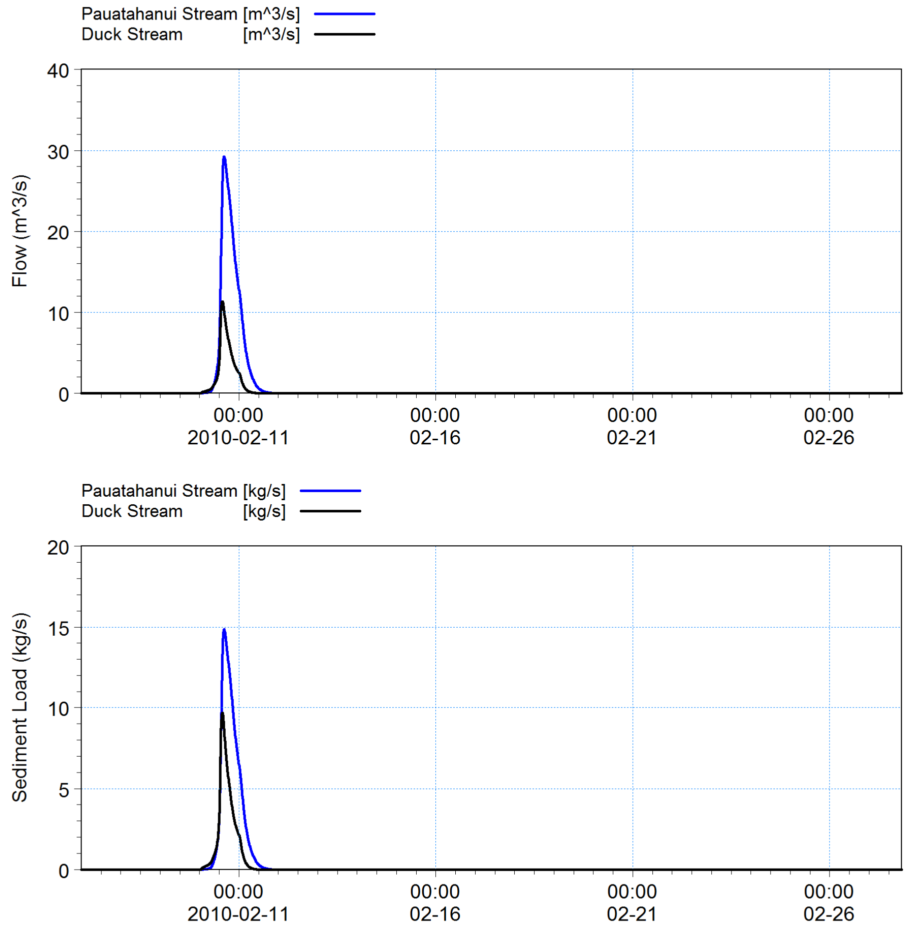

Figure 7 *The two year ARI flood event hydrographs and associated sediment loads for the Pauata-hanui catchment was timed to co-incide with the spring tide.*

5 RESULTS

5.1 Impact of Dredging on Flood Tide Delta

The MIKE 21 ST model has been applied to provide a qualitative indication of whether dredging a channel/s through the flood tide delta will encourage erosion of the flood tide delta or reduce further build up of the flood tide delta. The MIKE 21 ST model has also been utilised to provide insight into the likely stability of these dredged channels.

The predicted spring flood tide current patterns for each bathymetry with a calm wind condition are shown in Figure 8. The predictions suggest that while Dredging Option One does impact on the current pattern, Dredging Option Two has a more significant impact on the current pattern, with slightly higher current speeds extending into the inner inlet instead of following the existing channel into Browns Bay as occurs for the existing situation.

The corresponding predicted sediment transport rates for each bathymetry are shown in Figure 9 and the predicted change in bed level thickness of sand are shown in Figure 10. The predictions indicate that the dredging is unlikely to significantly erode the flood tide delta.

With regard to further build up of the flood tide delta, for Dredging Option One, although it appears the dredging will discourage the further build up of the flood tide delta into Browns Bay, significant sedimentation is likely to occur within the western dredged channel. This means that the effectiveness of this option will most likely be reduced over time and possibly in a relatively short time frame.

For Dredging Option Two it appears that not only will the build-up of sand onto the flood tide delta into Browns Bay be reduced, but the sedimentation within the dredged channel is minimal and the channel should remain open.

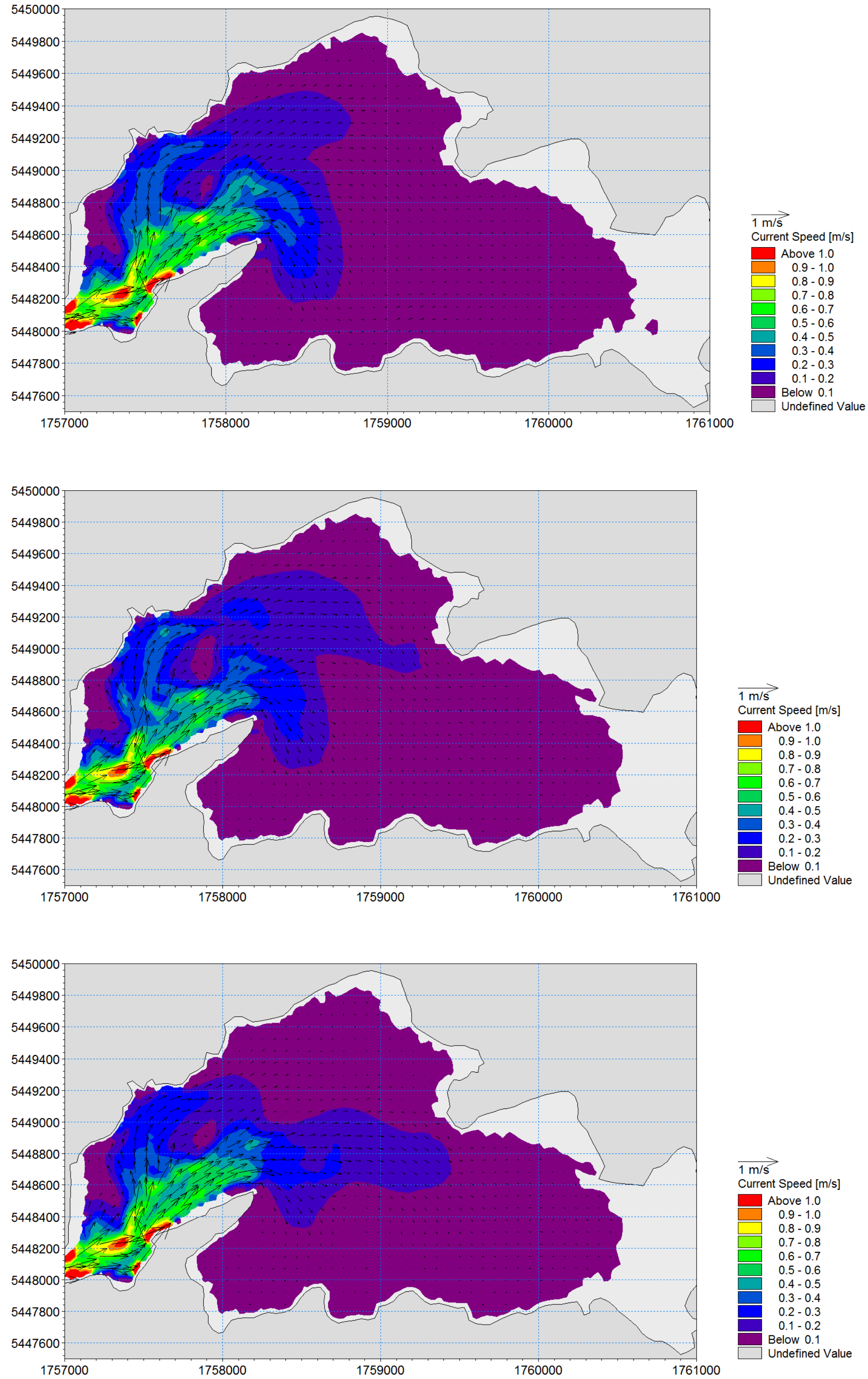

Figure 8 Spring flood tide current pattern for existing situation (top), Dredging Option One (middle) and Dredging Option Two (bottom) with calm wind condition.

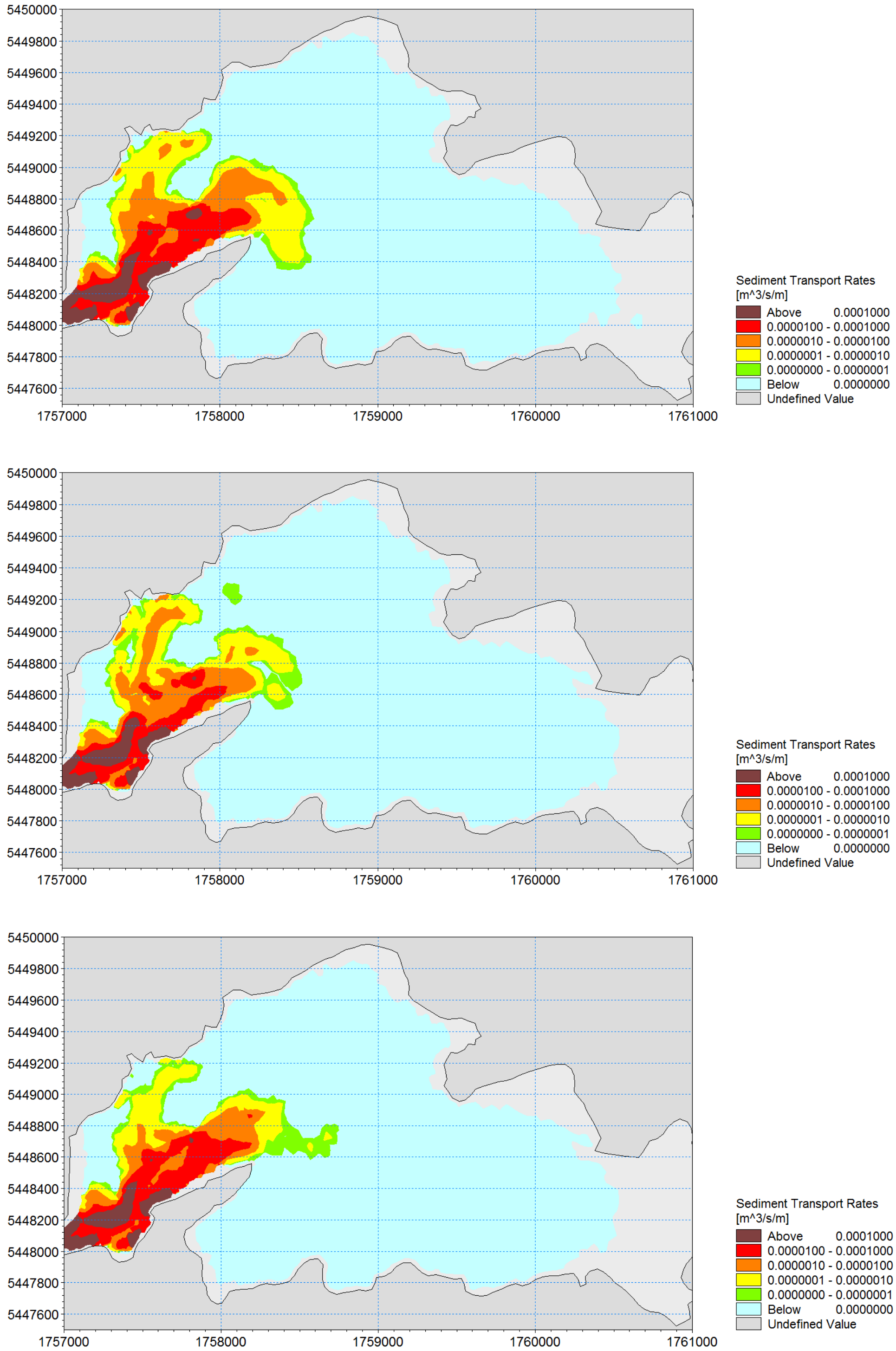

Figure 9 Spring flood tide sedimentation rates for existing situation (top), Dredging Option One (middle) and Dredging Option Two (bottom) with calm wind condition.

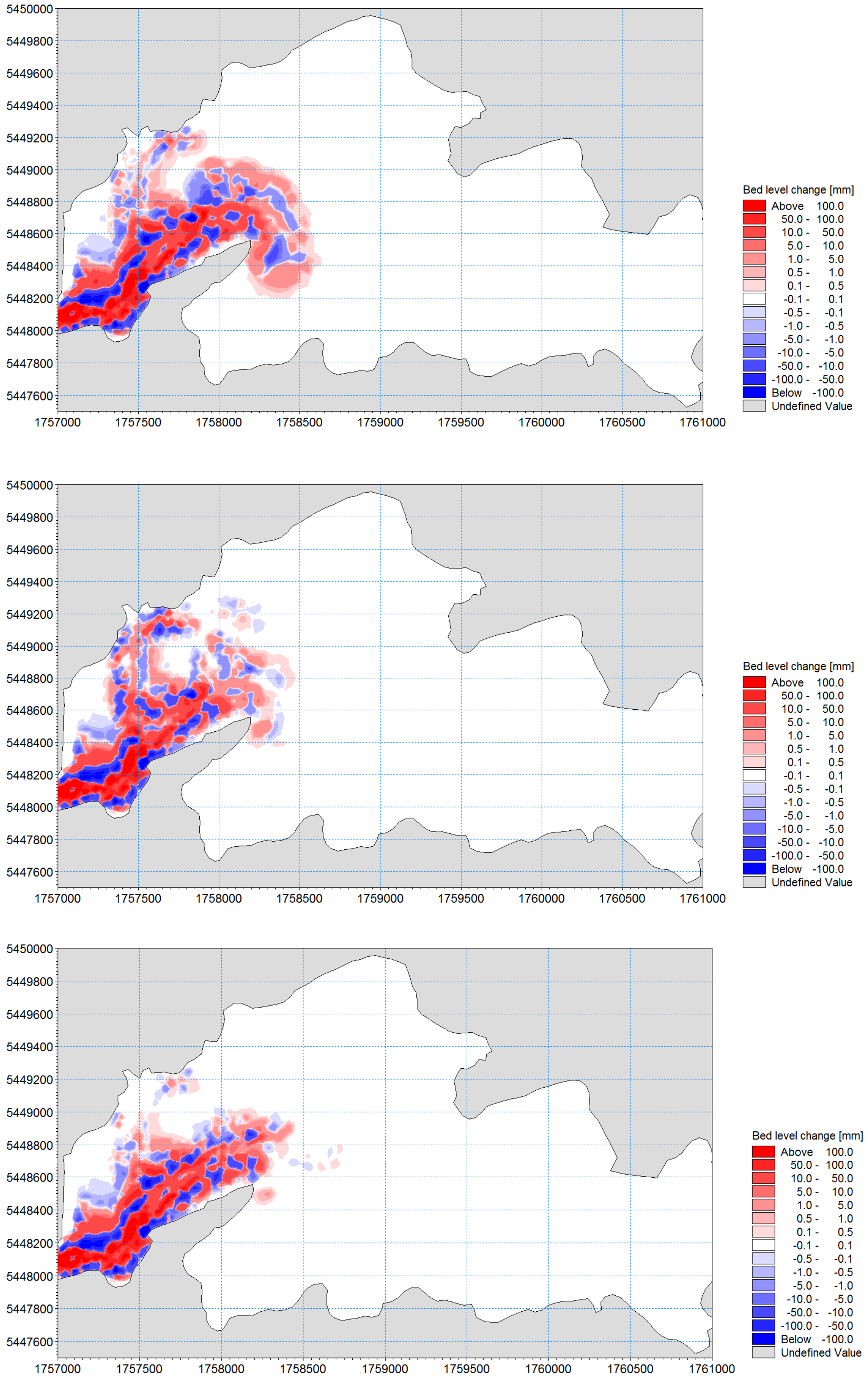

Figure 10 Predicted change in bed level thickness of sand for existing situation (top), Dredging Option one (middle) and Dredging Option Two (bottom) with calm wind condition.

5.2 Impact of Dredging on Central Muddy Basin

The MIKE 21 MT model has been applied to provide a qualitative indication of whether dredging a channel/s through the flood tide delta will encourage the erosion of the existing central muddy basin within Pauatahanui Inlet.

The predicted change in bed level thickness of mud for both dredging options are presented in Figure 11 and Figure 12. Both dredging options have minimal impact on the central muddy basin in Pauatahanui Inlet, with only some erosion occurring at the end of the new channel for Dredging Option Two.

The reason there is minimal impact is that for the muddy basin to erode current velocities would have to be increased in the vicinity of the central basin. Although the dredging options change the current pattern (see Figure 13 and Figure 14), it does not significantly increase the current velocities, except at the end of the new channel for Dredging Option Two, where the maximum current speed is increased from approximately 0.15 m/s to 0.25 m/s and erosion of the muddy basin is predicted to occur.

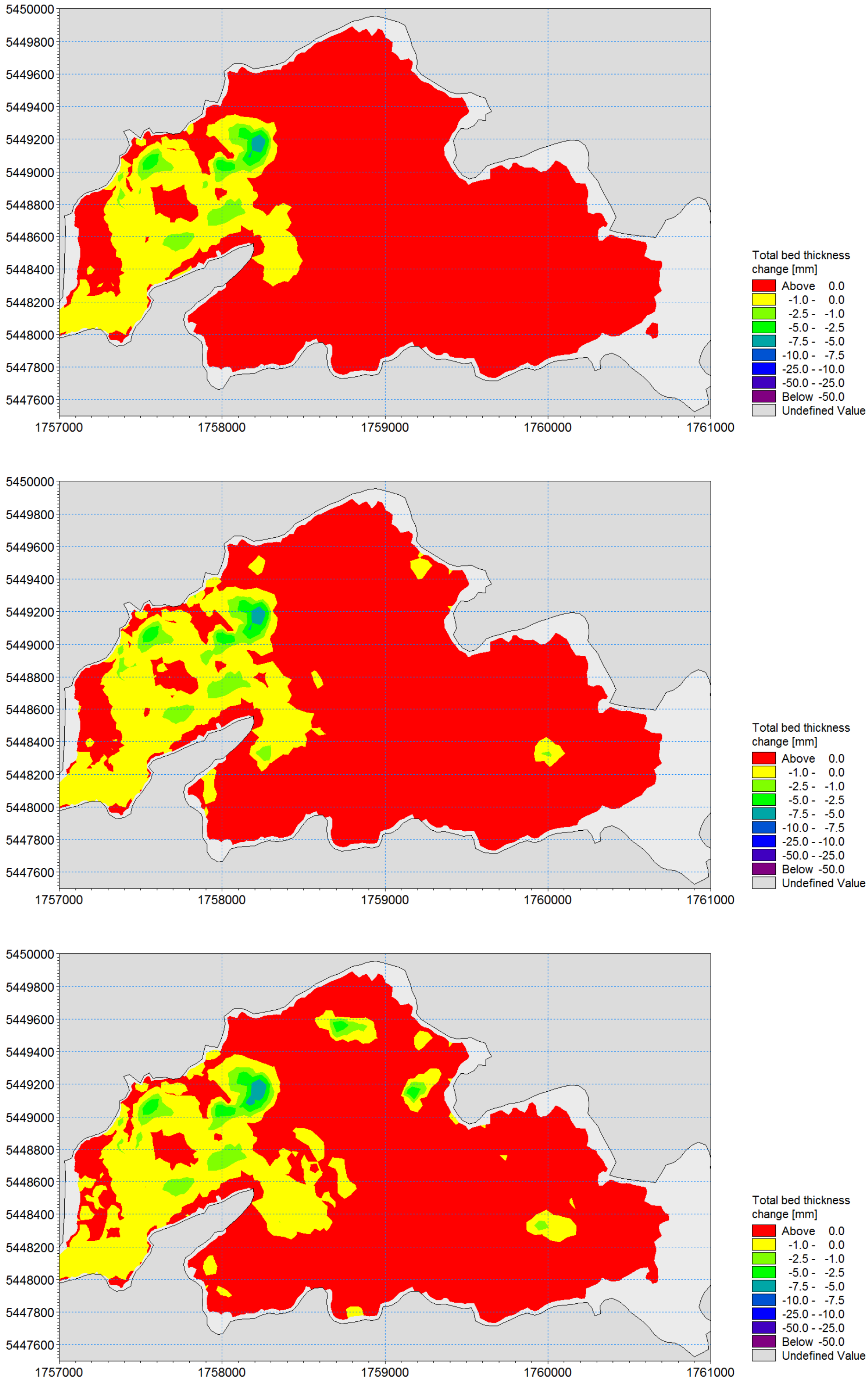

Figure 11 Predicted change in bed level thickness of mud for Dredging Option One with calm (top), southerly (middle) and northerly (top) 90th percentile wind conditions.

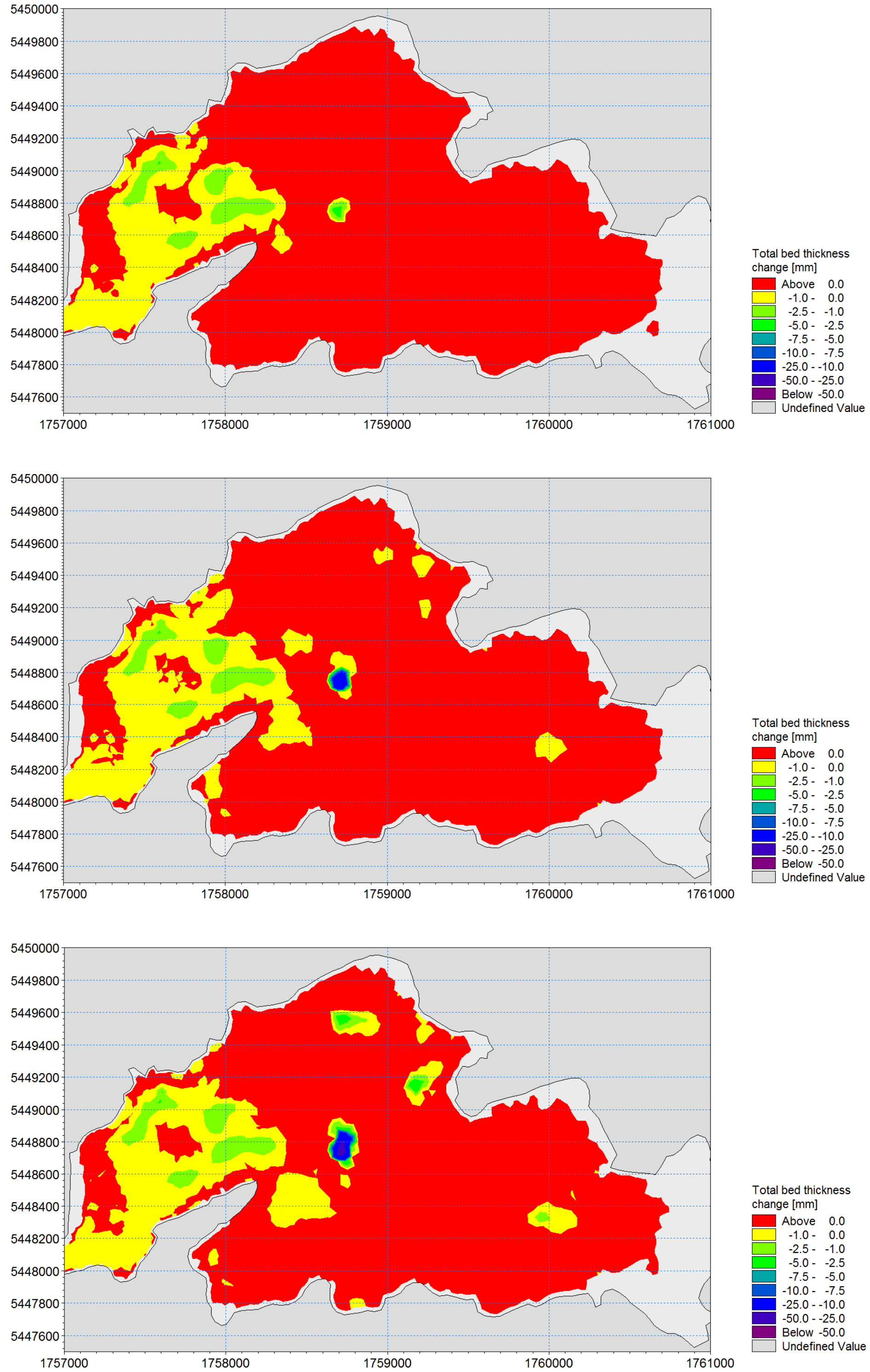

Figure 12 Predicted change in bed level thickness of mud for Dredging Option Two with calm (top), southerly (middle) and northerly (top) 90th percentile wind conditions.

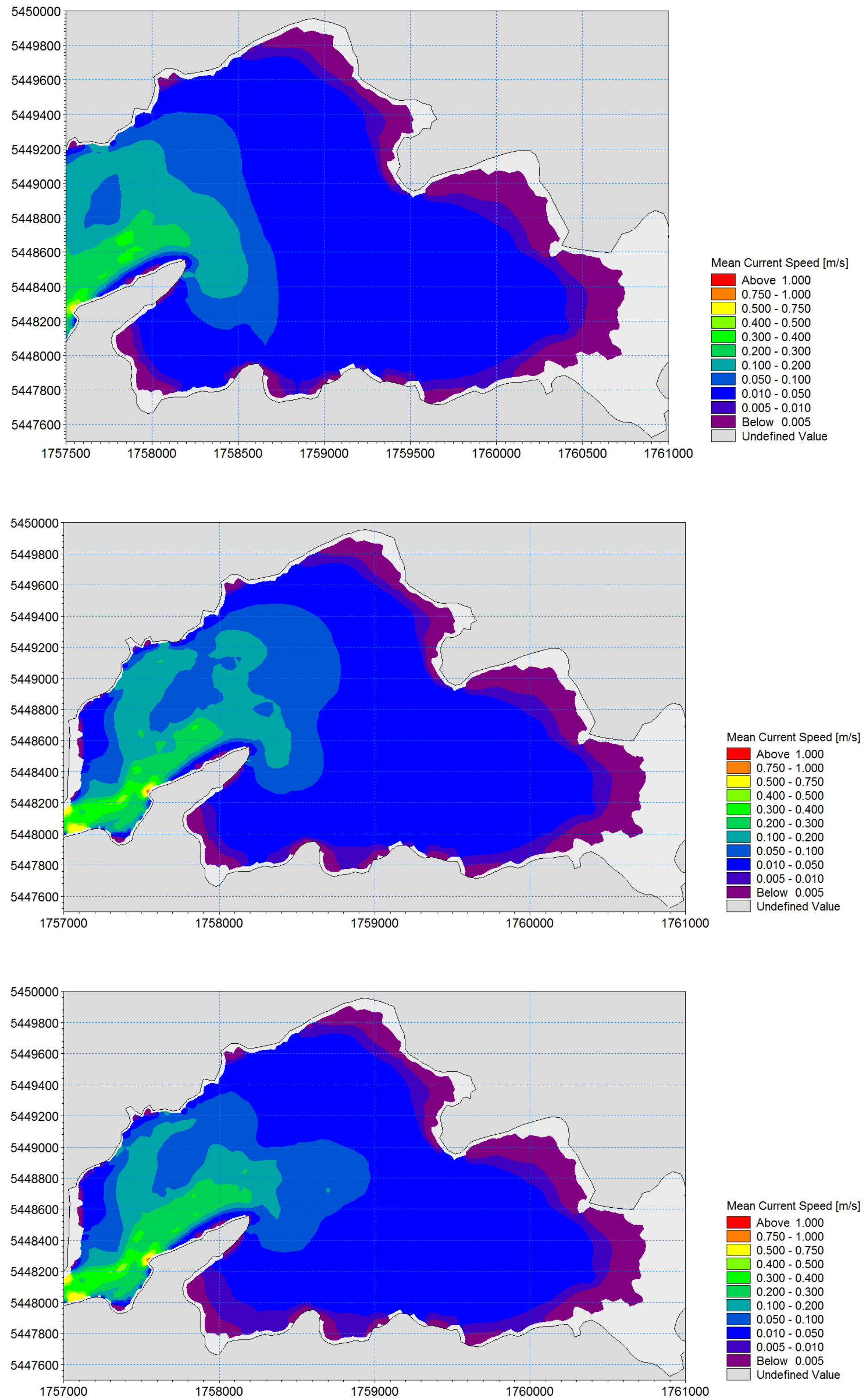

Figure 13 Mean current speed for existing situation (top), Dredging Option one (middle) and Dredging Option Two (bottom) with calm wind condition.

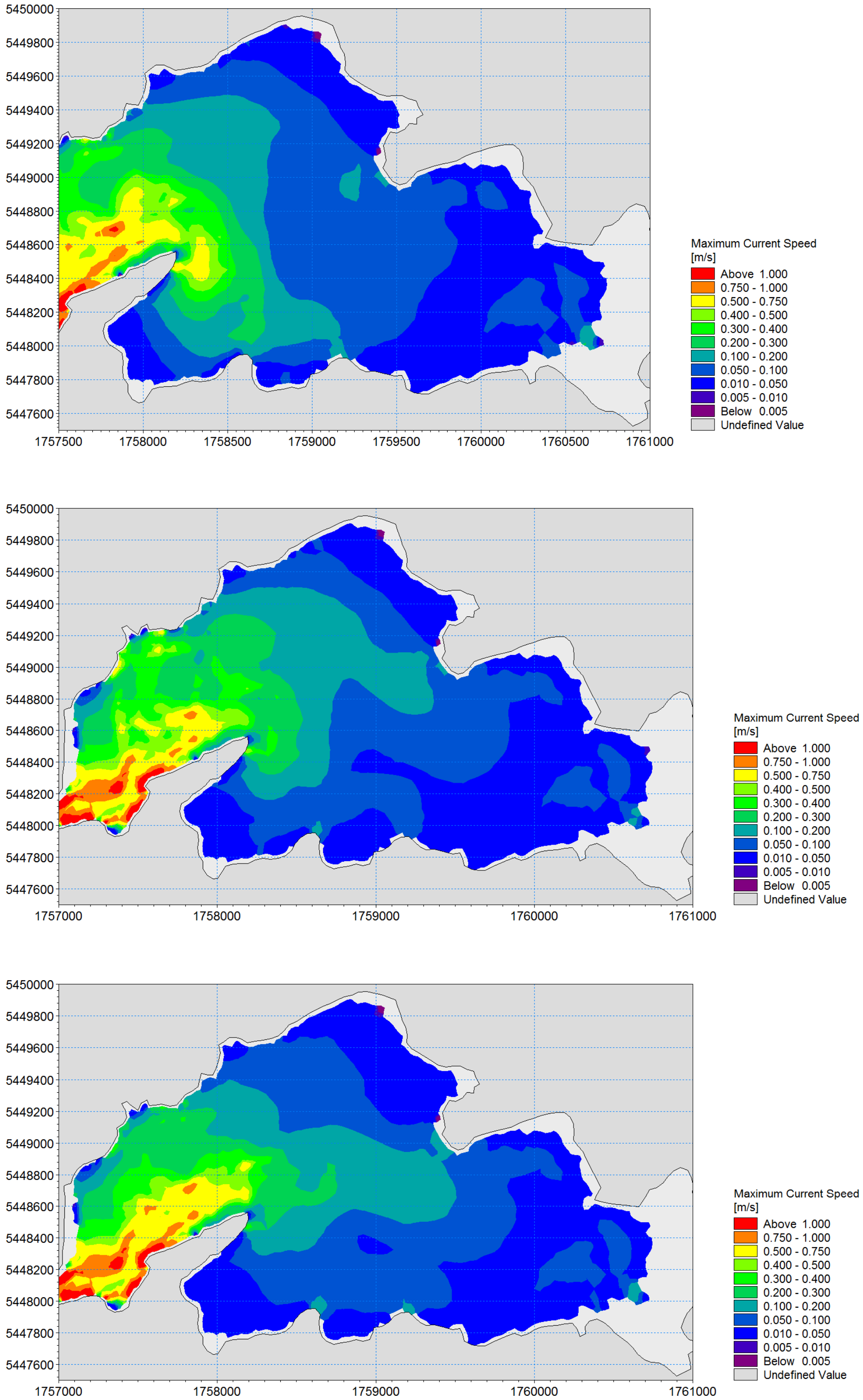

Figure 14 Maximum current speed for existing situation (top), Dredging Option one (middle) and Dredging Option Two (bottom) with calm wind condition.

5.3 Impact of Dredging on Terrestrial Sediment Entering into Pauatahanui Inlet

The MIKE 21 MT model has been applied to provide a qualitative indication of whether dredging a channel/s through the flood tide delta will keep terrestrial sediment which enters into Pauatahanui Inlet during significant flood events in suspension and not allow the sediment to settle in the central muddy basin as occurs with the existing situation.

The predicted sedimentation behaviour of terrestrial sediment entering into the harbour after a two year ARI flood event in the Pauatahanui catchment for the existing situation and both dredging options for three wind conditions is presented in Figure 15 to Figure 17.

Although dredging of the flood tide delta has an impact on the sedimentation patterns of the mud which enters into the inlet, the mud will still deposit within the inlet since the current velocities have not been increased significantly enough compared with existing situation to keep the sediment in suspension and allow the sediment to be flushed out of the harbour.

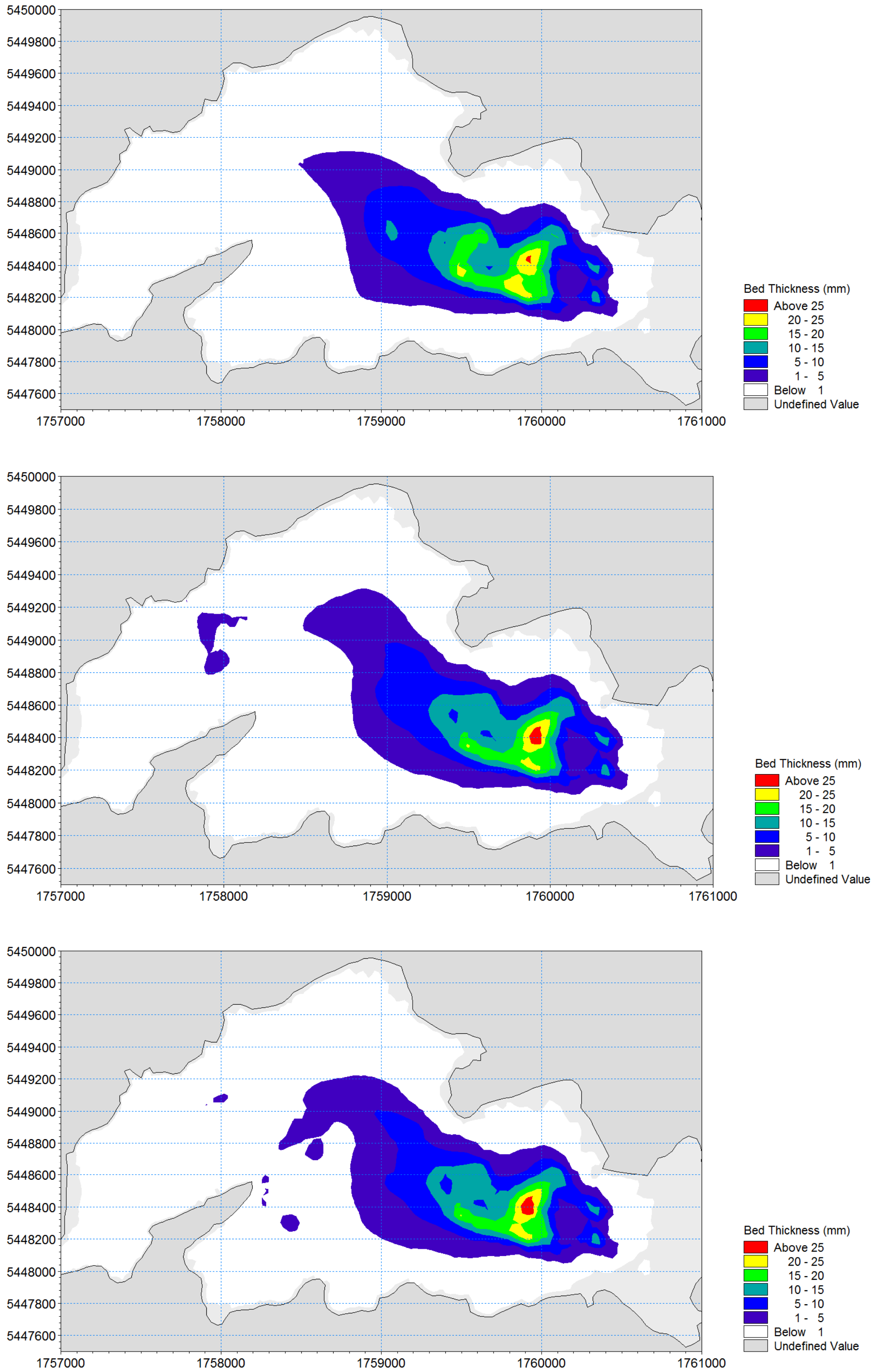

Figure 15 *Sedimentation pattern of mud from 10 year ARI flood event in Pauatahanui catchment with calm wind condition for existing situation (top), dredging option one (middle) and dredging option two (bottom).*

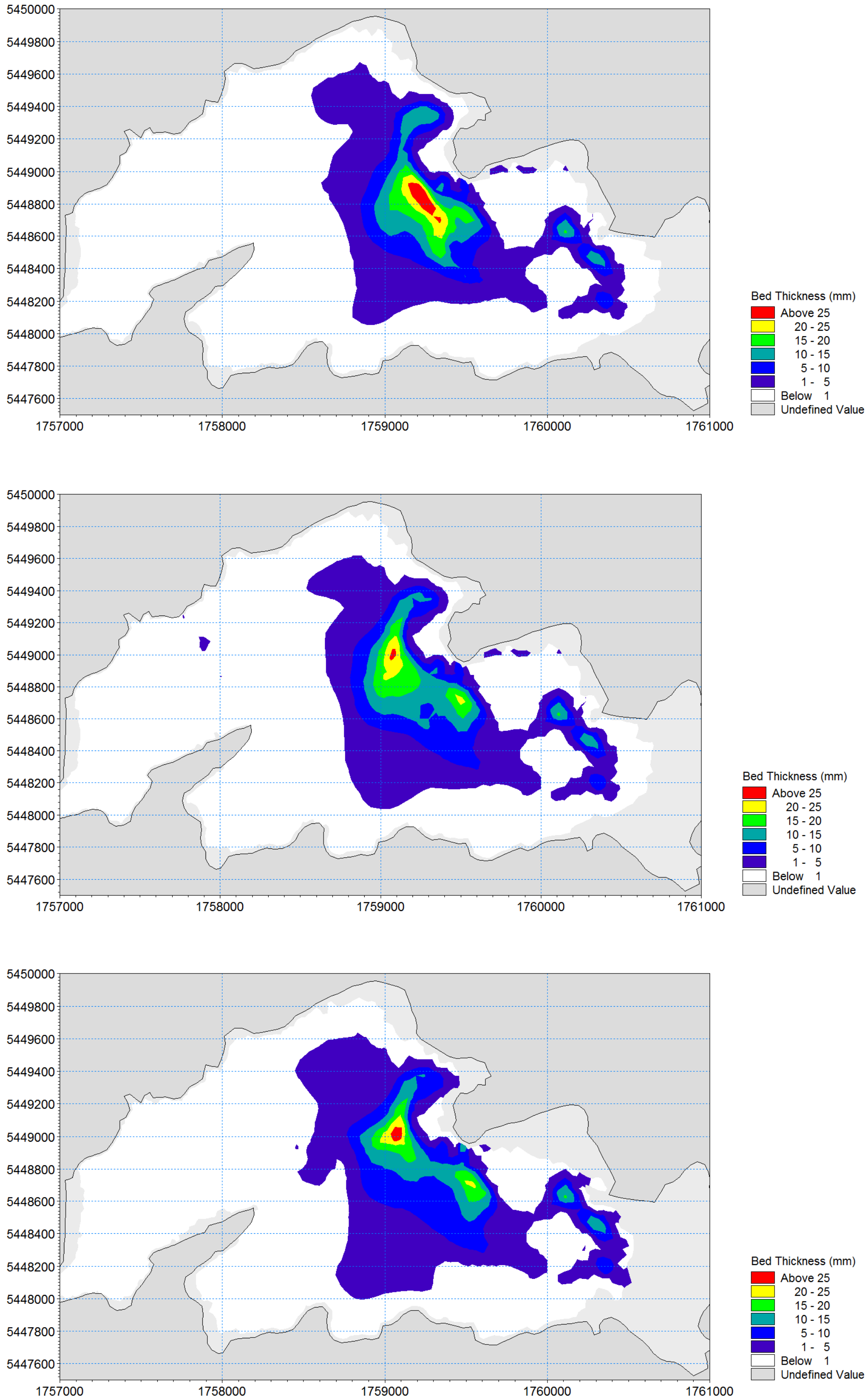

Figure 16 Sedimentation pattern of mud from 10 year ARI flood event in Pauatahanui catchment with southerly 90th percentile wind condition for existing situation (top), dredging option one (middle) and dredging option two (bottom).

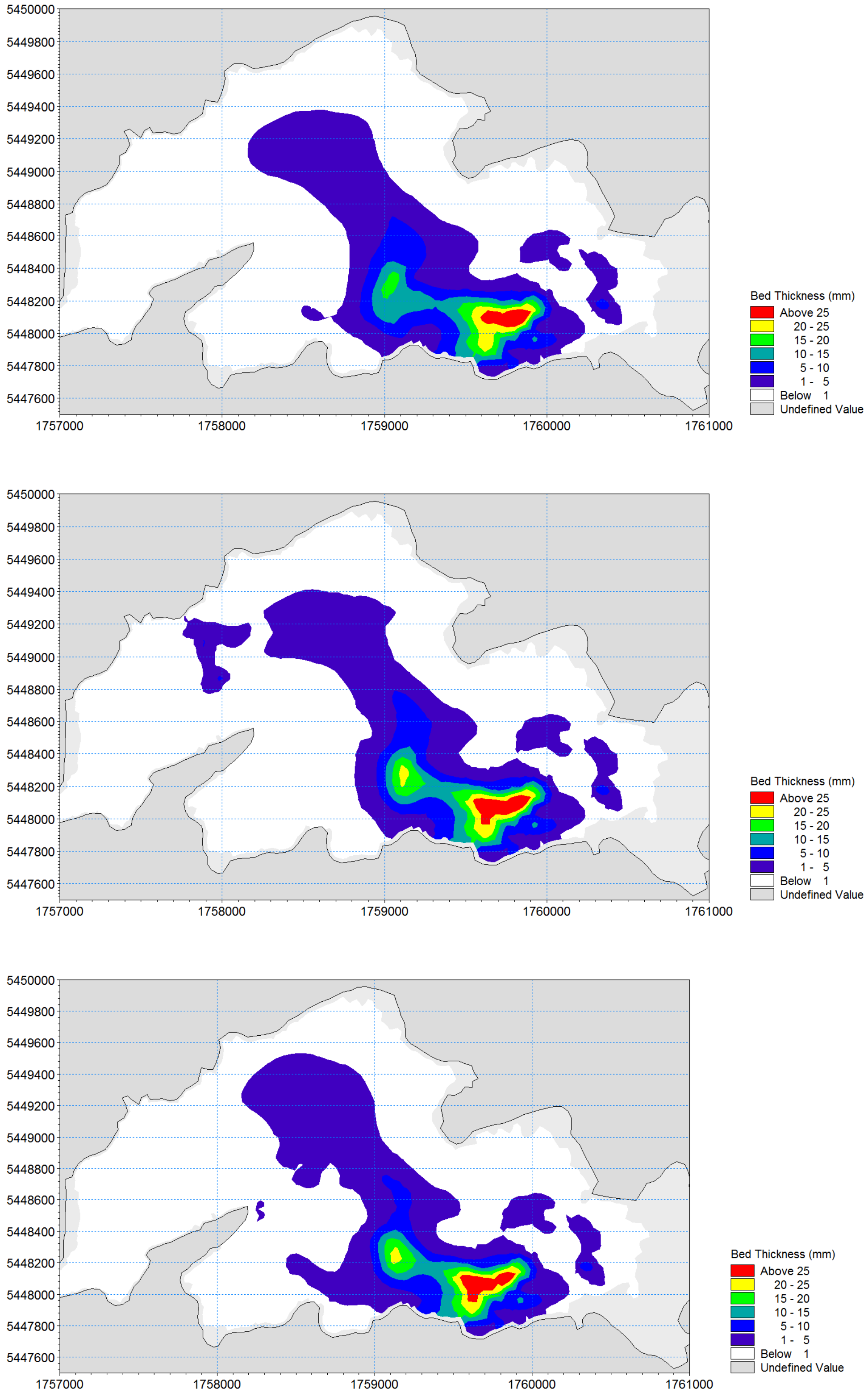

Figure 17 *Sedimentation pattern of mud from 10 year ARI flood event in Pauatahanui catchment with northerly 90th percentile wind condition for existing situation (top), dredging option one (middle) and dredging option two (bottom).*

6 CONCLUSIONS

Two proposed dredging options of the flood tide delta within Pauatahanui Inlet have been qualitatively assessed using a mud transport or sand transport model to determine whether dredging will:

- encourage further erosion of the flood tide delta or reduce further build up of the flood tide delta;
- encourage erosion of the muddy central basin within Pauatahanui Inlet; and
- encourage terrestrial sediment entering into the inlet to remain in suspension and allow the sediment to be flushed out of the harbour.

Model simulations predicted that dredging of existing channels within the flood tide delta (Dredging Option One) will not encourage erosion of the flood tide delta, however it will impede further build up of the toe of the delta into Browns Bay. However the predictions indicate that the channels are likely to infill with sand reasonably quickly. Similarly dredging of a new channel through the flood tide delta (Dredging Option Two) will not encourage erosion of the flood tide delta and will also impede build up of the delta into Browns Bay, however it also appears that sediment should not quickly in-fill the dredged channel.

Both potential dredging options were shown to not encourage significant erosion of the muddy central basin within Pauatahanui Inlet or encourage terrestrial sediment entering into the inlet to remain in suspension and allow the sediment to be flushed out of the harbour. The reason is that the dredging would not significantly increase current speeds within the inlet, which would be required for this to occur.

It is our opinion that there are only two ways for controlling sedimentation within Pauatahanui Inlet, since there no realistic way for increasing current speeds in Pauatahanui Inlet, which would be required to alter current sedimentation behaviour within the inlet. The two options are:

- Maintenance dredging of either the intertidal or sub tidal regions (or both) of the harbour. This will not stop further sedimentation from occurring but instead looks to maintain the harbour by simply removing the additional sediment which enters into the inlet.
- Controlling sediment loads from catchments surrounding Pauatahanui Inlet, to manage the current rate of sedimentation occurring within the inlet.

7 REFERENCES

SKM and DHI (2011). *Transmission Gully, Modelling of Sediment in the Streams and Harbour*. Report prepared for New Zealand Transport Agency.

DHI (2011); *MIKE 21 Flow Model FM, Sand Transport Module User Guide.*