8 Flood Hazard Assessment

The morphological model (described in Appendix E) has been utilised to carry out a comparative assessment of the potential increase of flood risk from the proposed option. The morphological model was necessary since scouring of the river and estuary entrances has a significant influence on flood release.

The flood scenarios that were investigated to predict any increase in flood levels within the river and estuary for the proposed situation compared with the existing situation are outlined in Table 8-1.

Table 8-1 Flood risk assessment scenarios

Scenario	River Flow	Sea Level	Climate Change
1	1% AEP	Normal	No
2	5% AEP	Normal	No
3	1% AEP	5% AEP	No
4	5% AEP	1% AEP	No
5	1% AEP	5% AEP	Yes
6	5% AEP	1% AEP	Yes

The 1% and 5% AEP design flow hydrographs for significant freshwater inflows (Kaituna River, Raparapahoe Canal, Waiari Stream and Kopuroa Stream) were provided by BOPRC and are presented in Figure 8-1 and Figure 8-2.

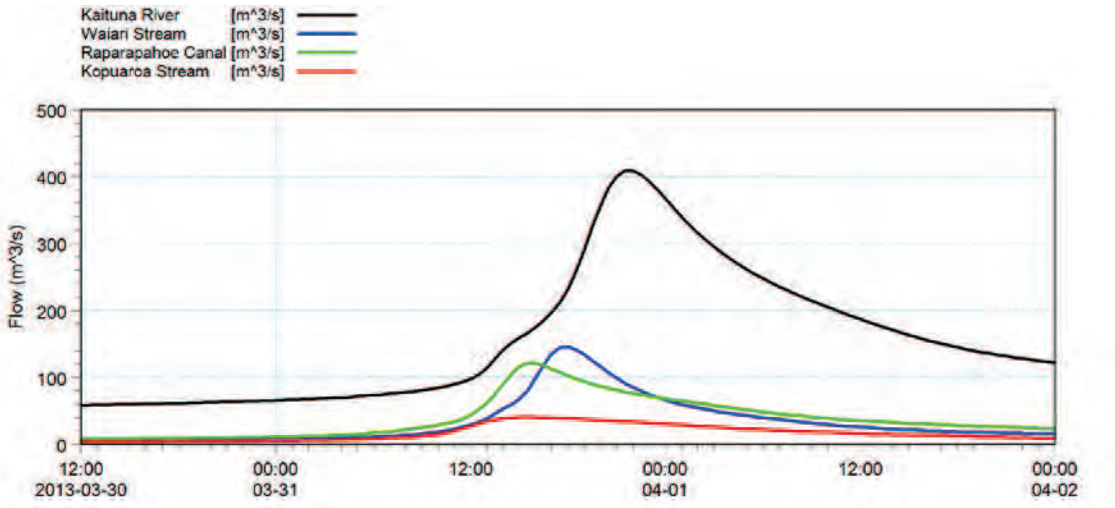

Figure 8-1 1% AEP design flow hydrographs.

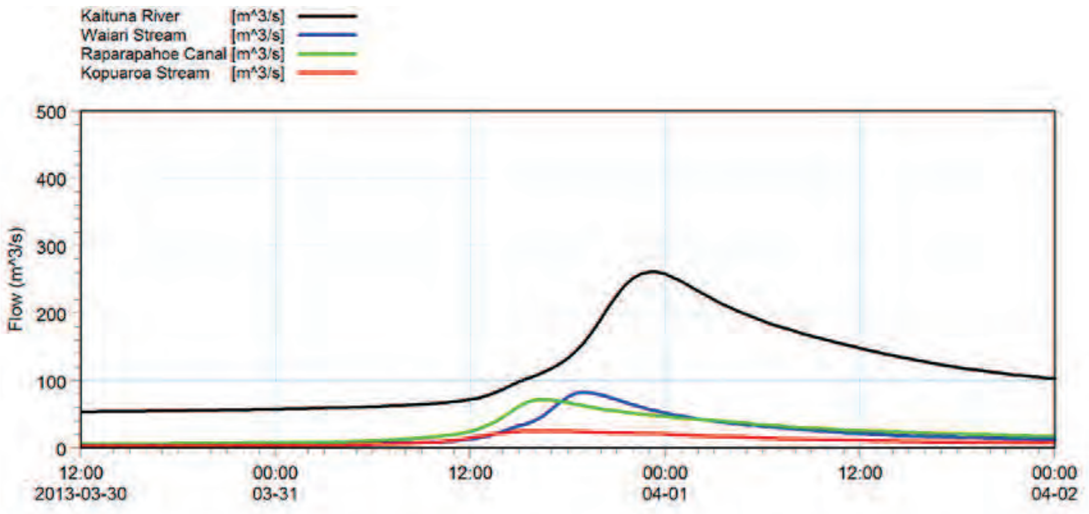

Figure 8-2 5% AEP design flow hydrographs.

BoPRC also provided the sea level to be used for design purposes. For the western Bay of Plenty coastline the 1% AEP sea level is 2.0 m Moturiki Datum while the 5% AEP sea level is 1.6 m Moturiki Datum. A storm surge profile was adopted for the modelling, assuming a triangular rise and fall distribution over 72 hours. This has been superimposed on a spring tide water level to provide the 1% and 5% AEP sea level conditions. The resulting water levels off Okurei Point are shown in Figure 8-3.

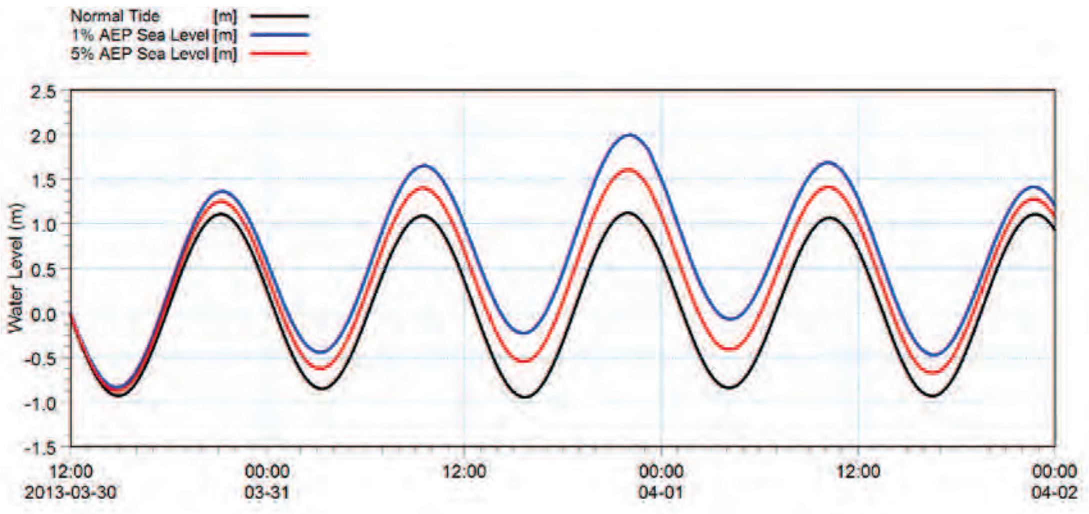

Figure 8-3 Normal, 1% AEP and 5% AEP water levels off Okurei Point for flood risk scenarios.

The effect of climate change to the year 2100 on sea level was included by increasing sea level by 0.49 m as advised by BoPRC. The 1% and 5% AEP design inflows including the increase due to climate change were provided by BoPRC and are presented in Figure 8-4 and Figure 8-5.

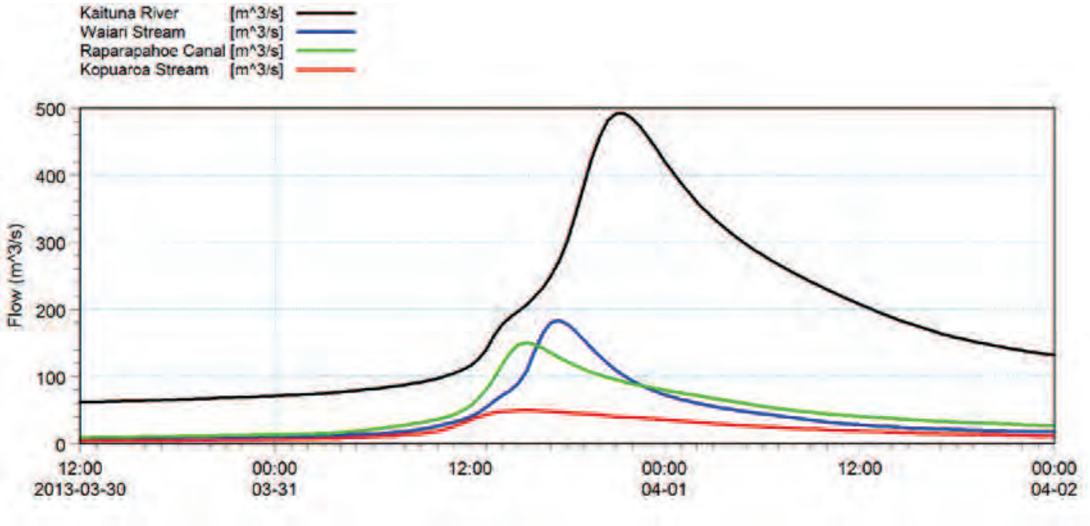

Figure 8-4 1% AEP design flow hydrographs with climate change.

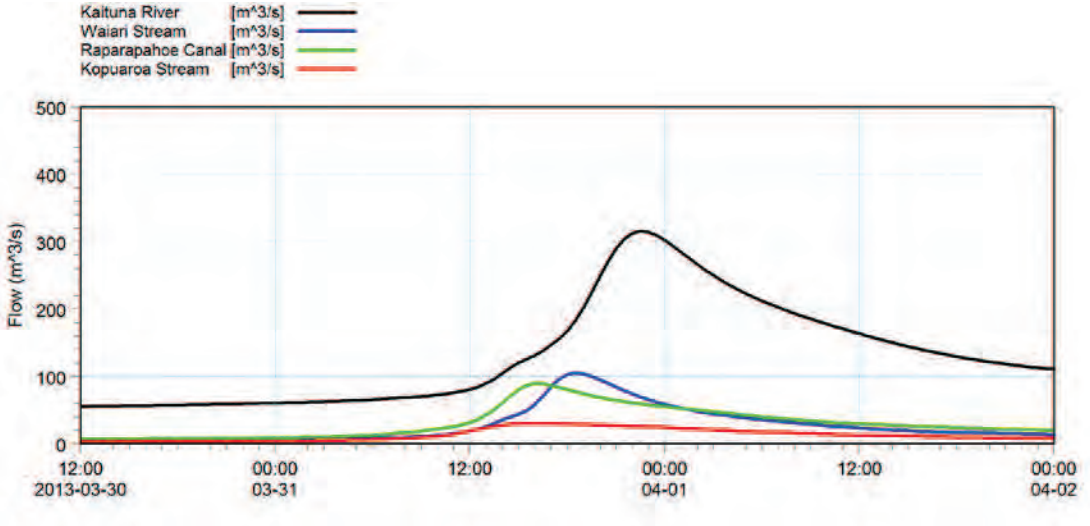

Figure 8-5 5% AEP design flow hydrographs with climate change.

It should be noted that for the flood risk scenarios no flow was allowed from the river to the estuary except for through the re-diversion culverts. It was determined that this was not an issue, since the crest of the stop bank to the west of Brains Land is above 2.6 m, which is approximately the highest water levels that were predicted within the Kaituna River from the scenarios defined above. The proposed option structures crest level will be 2.8 m, therefore no over topping would occur for the flood risk scenarios. The existing structure at Ford's Cut has a crest level of 2.2 m so over topping would occur at this location. This has not been accounted for with the model set up. This was not determined as an issue for reasons outlined below.

8.1 Water Levels in Estuary

Water levels were extracted from flood risk simulations at the locations indicated in Figure 8-6. The locations were selected to provide an overall picture on flood levels predicted within estuary. The predicted peak flood levels at each of these sites for each scenario are presented in Table 8-2.

The time series of predicted water levels for what was determined as the most critical scenario with respect to the impact of the proposed option are presented in Figure 8-7.

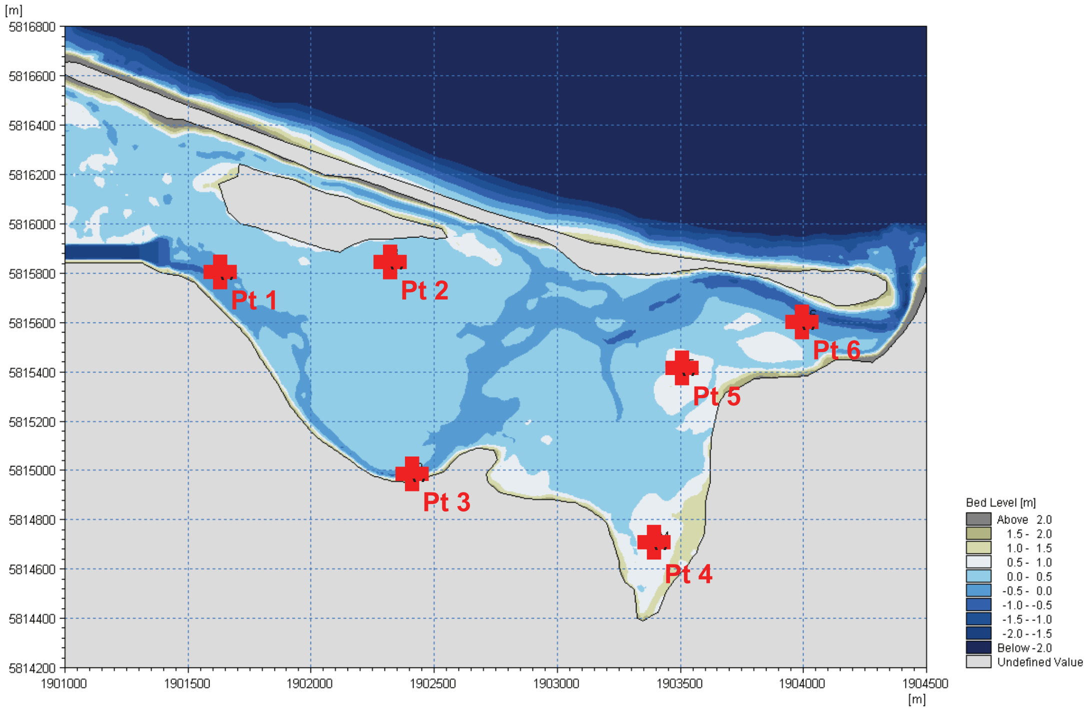

Figure 8-6 Locations within estuary where water levels extracted for flood risk assessment.

Table 8-2 Comparison of peak flood levels at selected locations in estuary for existing and proposed situations for simulated flood scenarios.

Scenario	**Situation**	**Peak Flood Level (m)**					
		Pt 1	**Pt 2**	**Pt 3**	**Pt 4**	**Pt 5**	**Pt 6**
1	**Existing**	1.10	1.09	1.09	1.09	1.08	1.07
	Proposed	1.50	1.46	1.47	1.45	1.44	1.35
	Difference	*0.40*	*0.37*	*0.37*	*0.36*	*0.36*	*0.29*
2	**Existing**	1.03	1.03	1.03	1.03	1.02	1.00
	Proposed	1.27	1.24	1.24	1.23	1.22	1.18
	Difference	*0.24*	*0.21*	*0.22*	*0.21*	*0.20*	*0.17*
3	**Existing**	1.60	1.60	1.60	1.59	1.59	1.57
	Proposed	1.79	1.78	1.78	1.77	1.76	1.72
	Difference	*0.19*	*0.18*	*0.18*	*0.18*	*0.17*	*0.15*
4	**Existing**	2.00	2.00	2.00	2.00	1.99	1.98
	Proposed	2.06	2.05	2.05	2.05	2.05	2.03
	Difference	*0.06*	*0.05*	*0.05*	*0.05*	*0.05*	*0.05*
5	**Existing**	2.14	2.14	2.14	2.13	2.13	2.12
	Proposed	2.25	2.24	2.24	2.23	2.23	2.20
	Difference	*0.11*	*0.10*	*0.10*	*0.10*	*0.10*	*0.09*
6	**Existing**	N/A	N/A	N/A	N/A	N/A	N/A
	Proposed	2.53	2.53	2.53	2.52	2.52	2.52
	Difference	N/A	N/A	N/A	N/A	N/A	N/A

The following can be concluded from the flood risk assessment within the estuary:

- The impact on peak flood levels from the proposed option within the estuary are most pronounced for scenario 1 and 2, when there was a normal open ocean boundary condition. For scenario 1, peak water levels increased by 0.40 m in the upper estuary (Pt 1) to 0.29 m close to the estuary mouth (Pt 6). For scenario 2, peak water levels increased by 0.24 m in the upper estuary (Pt 1) down to 0.17 m close to the estuary mouth (Pt 6). It should be noted that for these scenarios even with the significant increase in peak flood levels within the estuary, flood waters would still most likely remain contained within the estuary and there is no additional flood risk to the Maketū township.

- For scenario 3, there is an increase in peak flood levels with the proposed option. Peak water levels increased by 0.19 m in the upper estuary (Pt 1) to 0.15 m close to the estuary mouth (Pt 6). There is an increase in flood risk for limited areas of the Maketū township which are lower than 1.6 m the peak flood level for the existing situation.

- For scenario 4, there is only a small increase in peak flood levels (approximately 0.05 m), since the main contributor to the peak flood levels in the estuary is the elevated water levels from the open ocean. Under this scenario significant areas of Maketū would already be at risk from flooding for the existing situation as a result of the extreme sea levels.

- For scenario 5, there is a 0.09 to 0.11 m increase in peak flood levels throughout the estuary with the proposed option. However significant areas of Maketū would already be at risk from flooding for the existing situation for this scenario as a result of the extreme sea levels.

- For scenario 6, the existing situation was not assessed. Since over topping of the Ford's Cut structure (crest level 2.2 m) was not included in the model, it was assumed that the predictions would not be reasonable. It can be assumed that since the predicted peak flood levels within the estuary for the proposed option are equivalent to the open ocean boundary conditions applied for scenario 6, that the proposed option is having little impact on peak flood levels.

It should be noted that although scenario 3 is the worst case for the increase in peak flood levels with the proposed option compared with the existing situation, the elevated peak flood levels for scenario 3 (peak flood levels with the proposed option (1.72 – 1.79 m) are still considerably less than the peak flood levels for the existing situation for scenario 4 (1.98 – 2.00 m). Scenario 4 poses the maximum flood risk with existing sea levels and for this scenario the effect of the diversion on the peak flood levels is relatively small (an increase of 0.05 – 0.06 m).

It should be noted that work is ongoing investigating the increase in flood risk within the estuary and how it can be resolved from a risk management perspective.

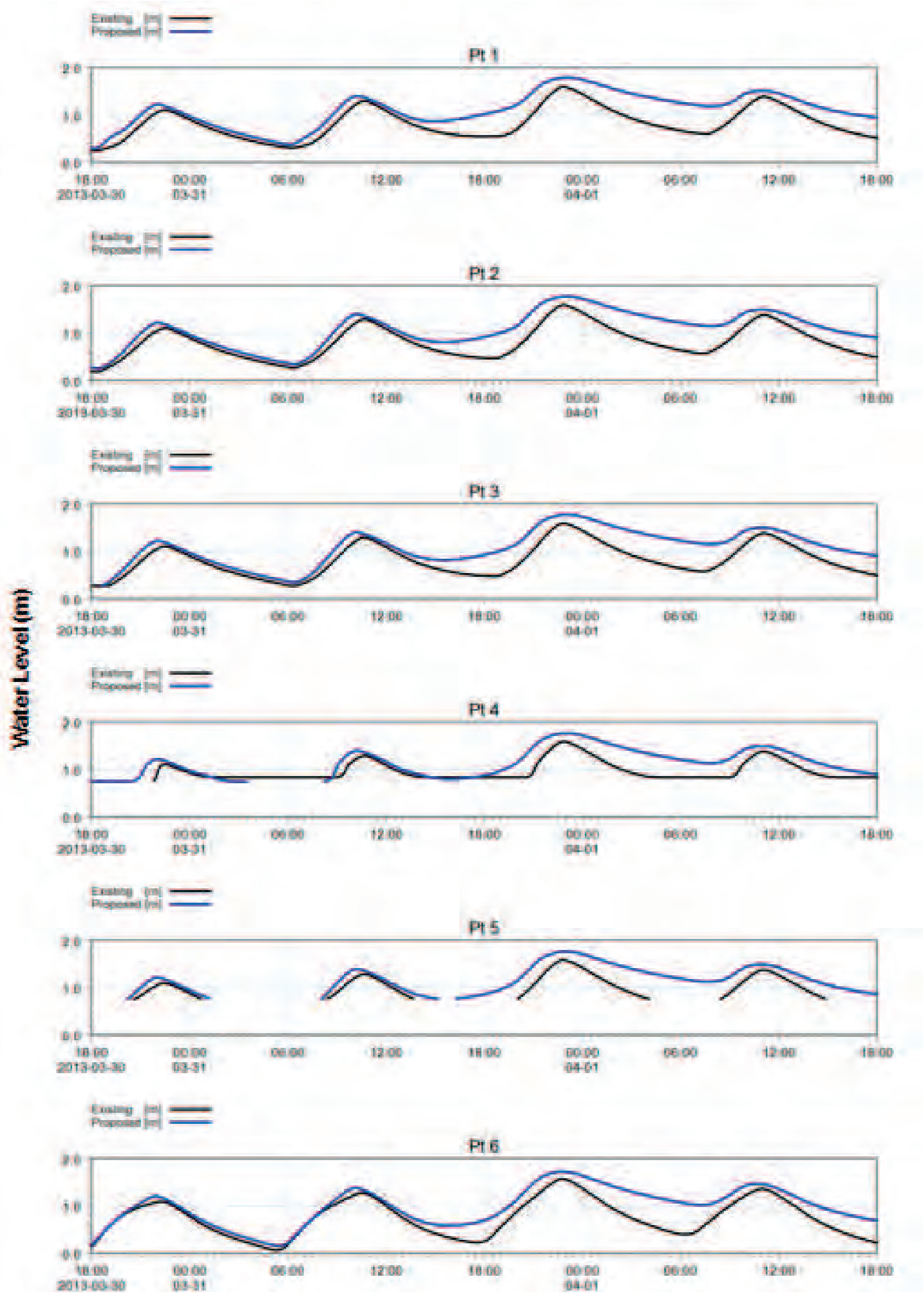

Figure 8-7 Comparison of predicted water levels at selected locations for existing and proposed situations for flood risk scenario 3.

8.2 Water Levels in River

Water levels were extracted from flood risk simulations at the locations indicated in Figure 8-8. The locations were selected to provide an overall picture on flood levels predicted within the river. The predicted peak flood levels at each of these sites for each scenario are presented in Table 8-3. Note that Scenario 6 has not been included, since this could not be simulated properly (see above for reasons), however there is no reason that peak flood levels would increase within the river with the proposed option for this scenario.

Peak flood levels within the river for all scenarios will decrease with the proposed option compared with the existing situation.

The time series of predicted water levels for what was determined as a representative scenario with respect to the impact of the proposed option are presented in Figure 8-9.

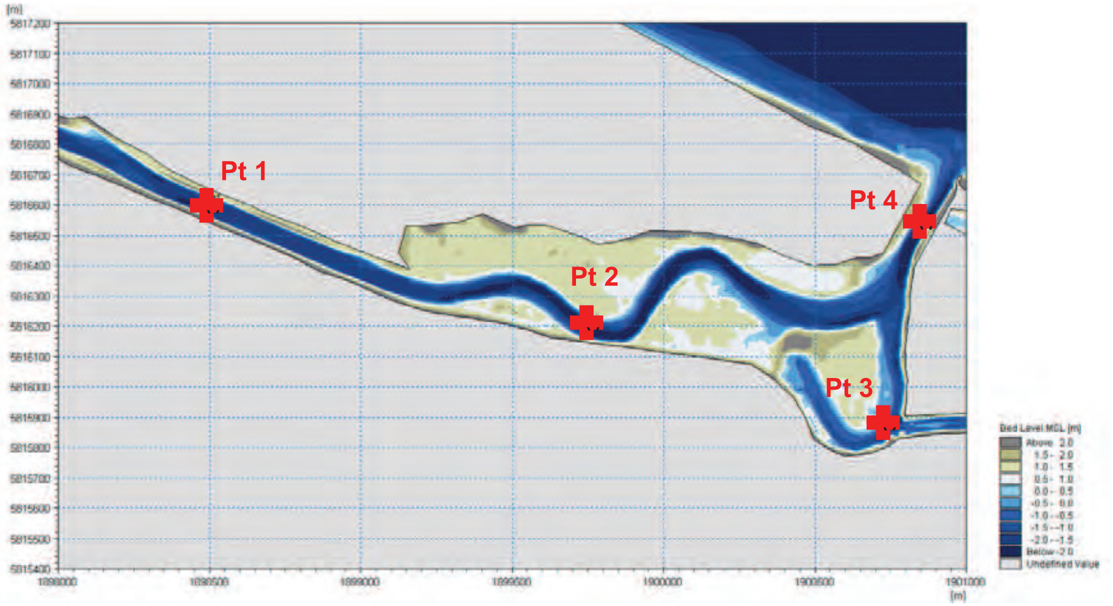

Figure 8-8 Locations within river where water levels extracted for flood risk assessment.

At the request of the project team the proportion of flow into the estuary through the re-diversion channel and through Te Tumu Cut at the peak of the flood events has been calculated and is shown in Table 8-4. Generally the flow split for flood events for the existing situation is 7% through Fords Cut and 93% through Te Tumu, while for the proposed option the flow split is 30% through the re-diversion channel and 70% through Te Tumu.

Table 8-3 Comparison of peak flood levels at selected locations in river for existing and proposed situations for simulated flood scenarios.

Scenario	Situation	Peak Flood Level (m)			
		Pt 1	Pt 2	Pt 3	Pt 4
1	**Existing**	2.80	2.55	2.34	1.78
	Proposed	2.48	1.99	1.78	1.39
	Difference	*-0.32*	*-0.56*	*-0.56*	*-0.39*
2	**Existing**	2.13	1.88	1.59	1.32
	Proposed	1.94	1.53	1.41	1.21
	Difference	*-0.18*	*-0.35*	*-0.18*	*-0.11*
3	**Existing**	2.85	2.62	2.44	1.96
	Proposed	2.59	2.20	2.04	1.75
	Difference	*-0.27*	*-0.43*	*-0.40*	*-0.20*
4	**Existing**	2.46	2.32	2.21	2.06
	Proposed	2.35	2.19	2.14	2.03
	Difference	*-0.11*	*-0.13*	*-0.07*	*-0.03*
5	**Existing**	3.24	3.02	2.90	2.42
	Proposed	2.95	2.62	2.51	2.23
	Difference	*-0.29*	*-0.40*	*-0.39*	*-0.19*

Table 8-4 The proportion of flow into the estuary through the re-diversion channel (or Fords Cut) and through Te Tumu at the peak of the flood events.

Scenario	Situation	Te Tumu	Fords Cut / Re-diversion Channel
1	**Existing**	93%	7%
	Proposed	66%	34%
2	**Existing**	93%	7%
	Proposed	70%	30%
3	**Existing**	93%	7%
	Proposed	68%	32%
4	**Existing**	91%	9%
	Proposed	70%	30%
5	**Existing**	93%	7%
	Proposed	67%	33%
6	**Existing**	N/A	N/A
	Proposed	71%	29%

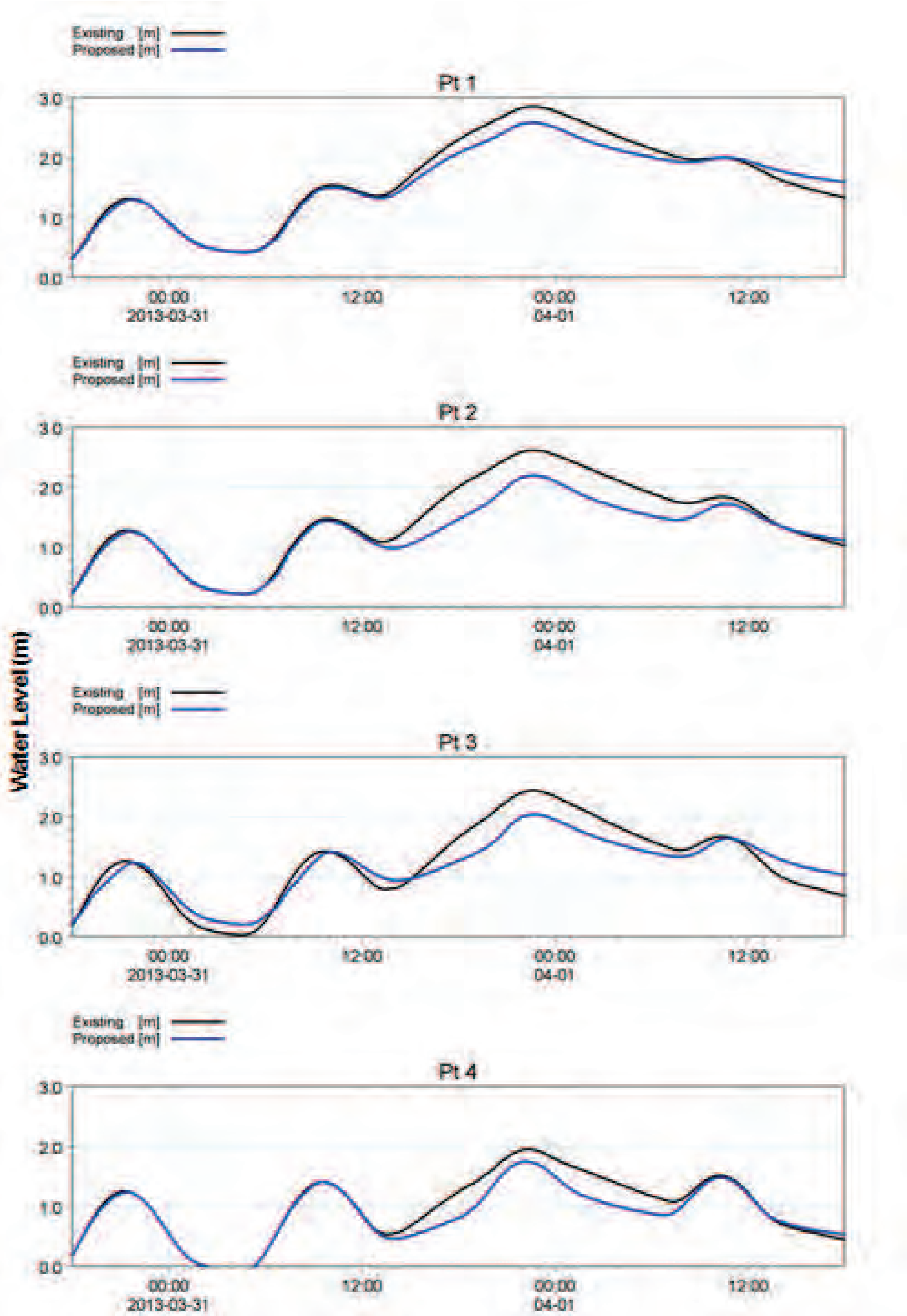

Figure 8-9 Comparison of predicted water levels at selected locations within the river for existing and proposed situations for flood risk scenario 3.

8.3 May 2005 Flood Event

At the request of local land owners in the vicinity of Lower Kaituna River and Ongatoro / Maketū Estuary, a flood event that occurred on 18th and 19th May 2005 was simulated. Significant flooding occurred in the land within the vicinity of the lower river and estuary. This was mostly due to high intensity rainfall on the Bay of Plenty coast (per comms, Steve Everitt, Waterline) since river flow although elevated was not extremely high as shown in Figure 8-10. There was also no significant elevation in open ocean water levels at this time as shown in Figure 8-11. The flooding most likely occurred since the rain which fell on the land surrounding the lower and estuary was unable to drain into the river and estuary quickly enough.

The flood risk assessment above indicates that the proposed option will actually decrease water levels within the river and therefore will not have a negative impact on drainage into the river, however, since flood events were shown to increase water levels within the estuary, there is the potential for drainage to the estuary to be effected.

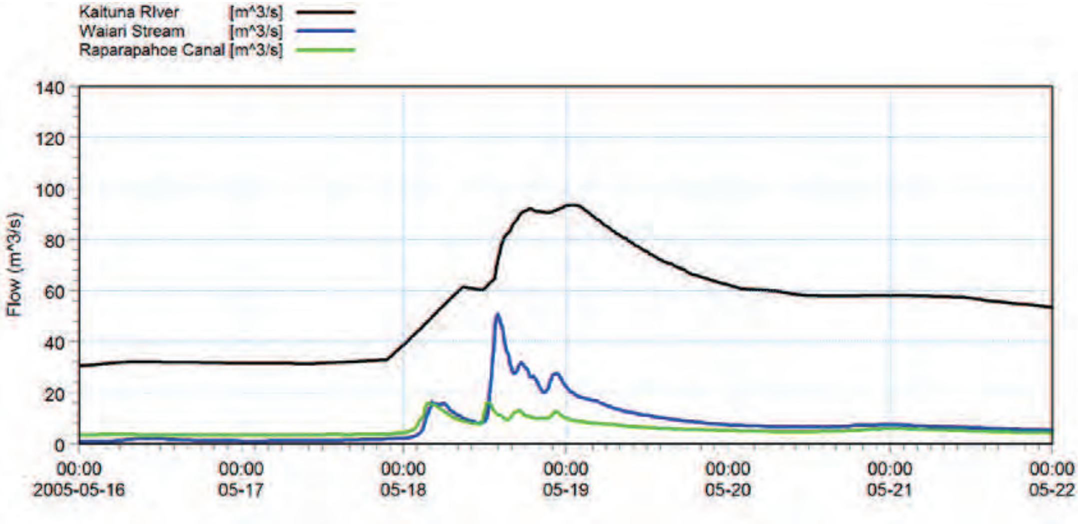

Figure 8-10 Flow for Kaituna River, Waiari Stream and Raparapahoe Canal for period 16th May to 25th May 2005.

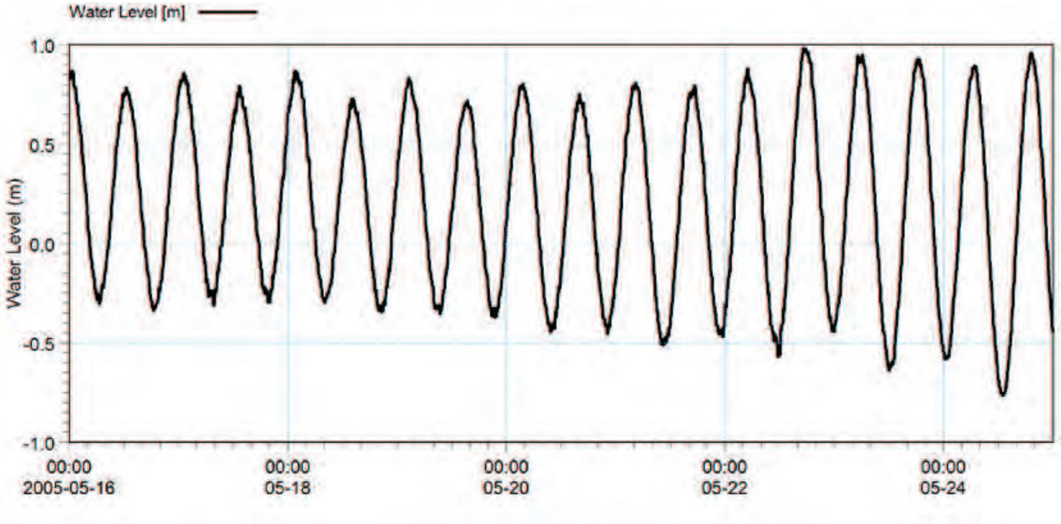

Figure 8-11 Water levels at Moturiki Island (Moturiki Datum) for period 16th May to 25th May 2005.

To assess the impact of the proposed option on drainage into the estuary, the predicted water levels representative of water levels in vicinity of southern drains (see Figure 8-12) where the majority of water from flood plain drains into deeper channels of the estuary have been extracted for the existing situation and proposed option. The extracted water levels are shown in Figure 8-13. There is only a small impact on the drainage within the estuary.

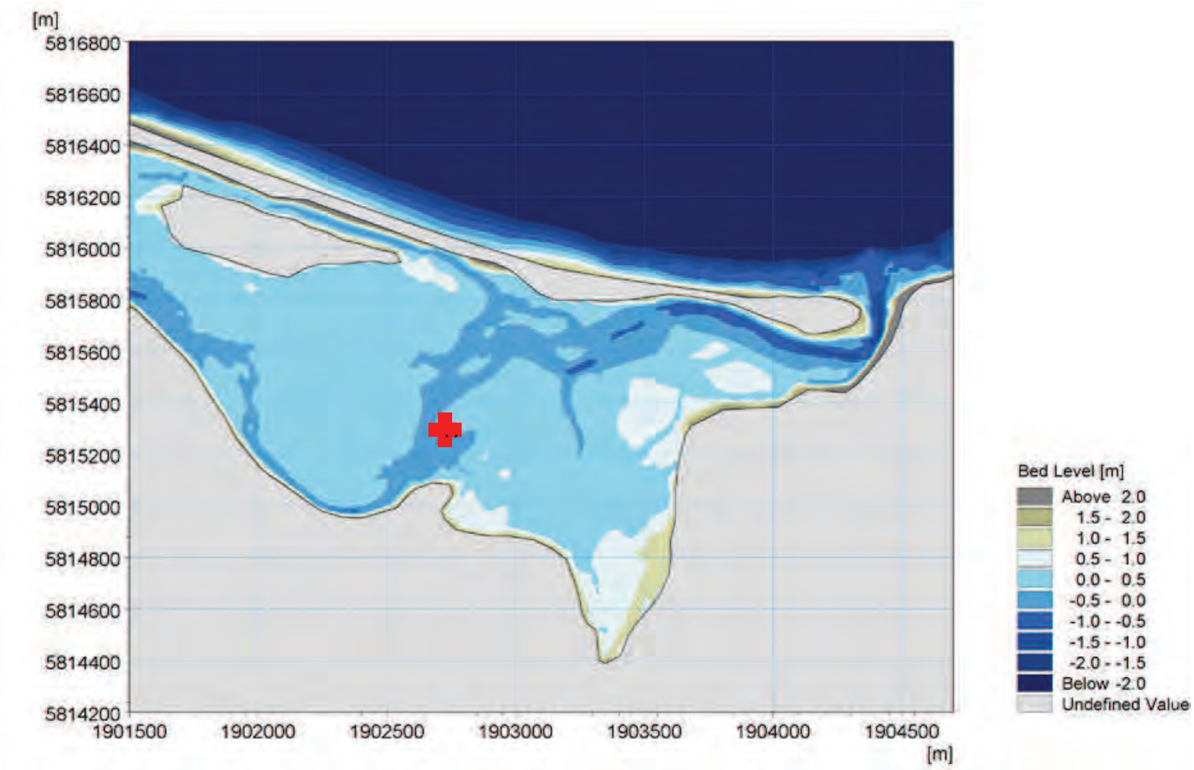

Figure 8-12 Water level extraction location.

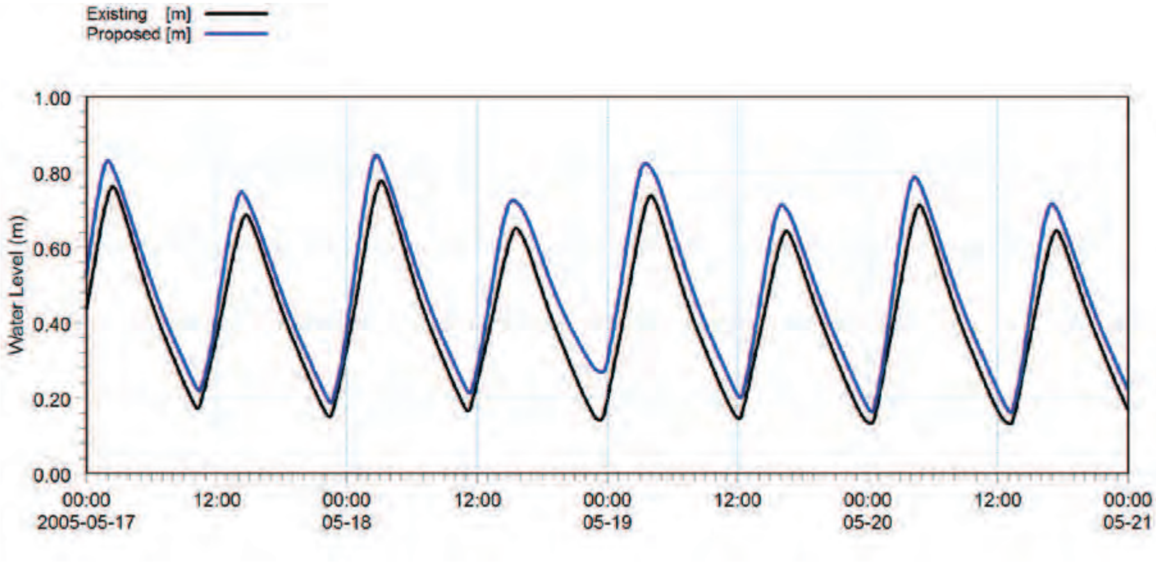

Figure 8-13 Comparison of predicted water levels in the vicinity of southern drains for existing and proposed situations for May 2005 flood event.

9 Water Quality Assessment

This section outlines the water quality assessments that have been carried out to determine the impact of the proposed option on:

- overall salinity within the estuary;
- additional risk for blue-green algae blooms within the estuary;
- shellfish collection and bathing suitability within the estuary; and
- nutrient concentrations within the estuary.

9.1 Salinity Assessment

The local 3D hydrodynamic model (described in Appendix D) was utilised to assess the impacts of the proposed option on salinity characteristics within the river and estuary, with focus on the following:

- the ratio of freshwater to saltwater that will enter the estuary through the re-diversion channel for different states of neap / spring tidal cycle;
- the overall change to salinity within the estuary; and
- the impact on the extent of the saltwater wedge within the Kaituna River.

To determine the type of habitat / vegetation which may re-establish within the estuary with the addition of more freshwater to the estuary the effects of the proposed option in terms of spatial changes in salinity was quantified. Should the proposed option have an impact on the propagation of the saline wedge up the Kaituna River this could also have ecological impacts. The calibrated 3D model was used to provide an understanding of how the proposed option may change the dynamics of the saline wedge.

For both the existing and proposed situations 15 day simulations (plus three day warm up period) were carried out to cover a neap / spring tidal cycle for two freshwater inflow scenarios:

- seven day five year low river flow; and
- mean river flow.

The constant inflows that were selected for the two freshwater inflow scenarios are presented in Section 3.3.

The water levels in the open ocean off Okurei Point for the simulations are presented in Figure 9-1. These boundary conditions for the 3D model are derived from the 2D model (see Appendix D).

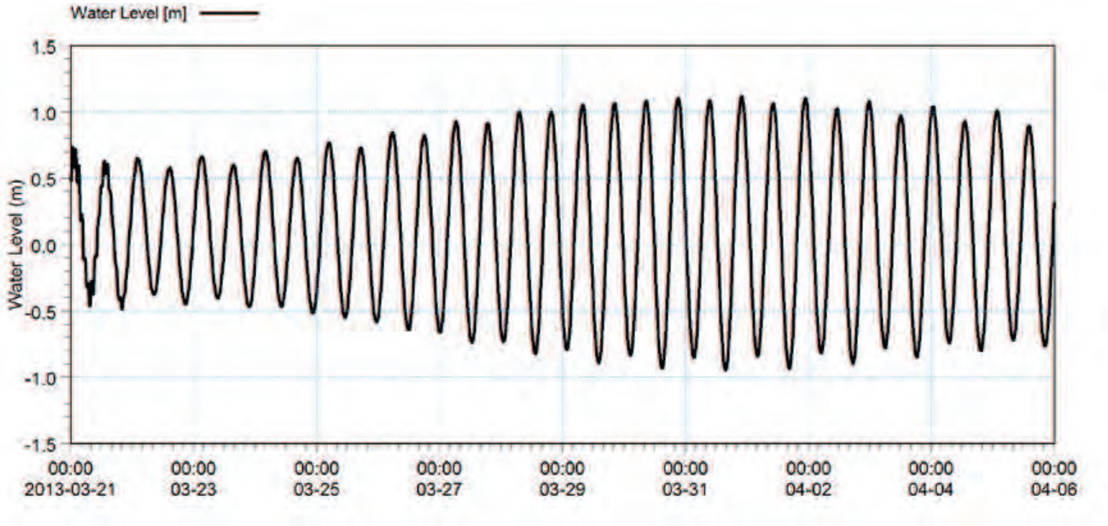

Figure 9-1 Predicted water levels (Moturiki Datum) off Okurei Point for the three-dimensional salinity assessment simulations.

The drains that were described in Section 3.3 were included in the salinity assessment simulations with constant flows equal to the base flows calculated by BoPRC, with an associated salinity of 0 PSU.

9.1.1 Salinity through Re-diversion Channel

The comparison for the existing and proposed situations of the predicted volume of water and associated freshwater fraction for the two river flow scenarios for different parts of the neap / spring tidal cycle are presented in Table 9-1 and Table 9-2.

The following should be noted for the re-diversion channel under the seven day five year low river flow scenario:

- The proposed option will increase freshwater inflows to the estuary by between 127,100 m^3 to 170,800 m^3 per tidal cycle.
- The ratio of fresh to saline water entering the re-diversion channel will range from 0.21 to 0.80 for the proposed option, compared with 0.14 to 0.75 for the existing situation.

The following should be noted for the re-diversion channel under the mean river flow scenario:

- The proposed option will increase freshwater inflows to the estuary by between 202,300 m^3 to 302,900 m^3 per tidal cycle.
- The ratio of fresh to saline water entering the re-diversion channel will range from 0.47 to 0.96 for the proposed option, compared with 0.54 to 0.99 for the existing situation.

Table 9-1 Ratio of freshwater and salt water entering estuary through Ford's Cut for seven day five year low river flow and neap/spring tidal cycle.

Tide	Situation	Total Volume of Water (m^3)	Freshwater Fraction	Volume of Freshwater (m^3)	Freshwater Inflow Increase (m^3)
Neap	**Existing**	94,600	0.75	71,000	164,300
	Proposed	294,100	0.80	235,300	
Mean	**Existing**	144,200	0.44	63,400	170,800
	Proposed	532,200	0.44	234,200	
Spring	**Existing**	183,500	0.14	25,700	127,100
	Proposed	727,500	0.21	152,800	

Table 9-2 Ratio of freshwater and salt water entering estuary through Ford's Cut for mean river flow and neap/spring tidal cycle.

Tide	Situation	Total Volume of Water (m^3)	Freshwater Fraction	Volume of Freshwater (m^3)	Freshwater Inflow Increase (m^3)
Neap	**Existing**	101,300	0.99	100,300	202,300
	Proposed	315,200	0.96	302,600	
Mean	**Existing**	153,700	0.87	133,700	302,900
	Proposed	574,500	0.76	436,600	
Spring	**Existing**	186,600	0.54	100,400	269,900
	Proposed	787,800	0.47	370,300	

9.1.2 Salinity within Estuary

The comparison of the spatial plots of mean salinity for the seven day five year low river flow for the existing scenario and proposed situations at different parts of the water column are presented in Figure 9-2 to Figure 9-4. The comparison of the existing and proposed situations for the mean river flow are presented in Figure 9-5 to Figure 9-7.

The following should be noted for the seven day five year low river flow scenario (further summarised in Table 9-3):

- Under the proposed option the mean salinity across the majority of the new proposed wetland (on Brain's Land) ranges from approximately 20 to 25 PSU;
- In the upper estuary, at the water surface, predicted mean salinities are approximately 20 to 25 PSU for both the existing situation and the proposed option;
- In the upper estuary, at the estuary bed, predicted mean salinities will increase from approximately 20 to 25 PSU for the existing situation to 20 to 30 PSU with the proposed option;

- In the mid estuary, at the water surface, predicted mean salinities will decrease from approximately 25 to 30 PSU for the existing situation to 20 to 25 PSU with the proposed option;
- In the mid estuary, at the estuary bed, predicted mean salinities will decrease from approximately 25 to 35 PSU for the existing situation to 20 to 30 PSU with the proposed option;
- In the lower estuary, at the water surface, predicted mean salinities will decrease from approximately 30 to 35 PSU for the existing situation to 25 to 35 PSU with the proposed option;
- In the lower estuary, at the estuary bed, predicted mean salinities will decrease from approximately 30 to 35 PSU for the existing situation to 25 to 35 PSU with the proposed option; and
- There is no significant change in the predicted salinities within the area of the southern drains of the estuary.

The following should be noted for the mean river flow scenario (further summarised in Table 9-3):

- For the proposed option there was a predicted mean salinity of approximately 10 to 15 PSU for the majority of the new proposed wetland on Brain's land
- In the upper estuary, at the water surface, predicted mean salinities will increase from approximately 5 to 15 PSU for the existing situation to 10 to 15 PSU with the proposed option;
- In the upper estuary, at the estuary bed, predicted mean salinities will increase from approximately 10 to 15 PSU for the existing situation to 10 to 20 PSU with the proposed option;
- In the mid estuary, at the water surface, predicted mean salinities will decrease from approximately 15 to 25 PSU for the existing situation to 10 to 20 PSU with the proposed option;
- In the mid estuary, at the estuary bed, predicted mean salinities will decrease from approximately 15 to 30 PSU for the existing situation to 15 to 25 PSU with the proposed option;
- In the lower estuary at the water surface predicted mean salinities will decrease from approximately 25 to 35 PSU for the existing situation to 20 to 30 PSU with the proposed option in the lower estuary;
- In the lower estuary, at the estuary bed, predicted mean salinities will decrease from approximately 25 to 35 PSU for the existing situation to 20 to 30 PSU with the proposed option; and
- There is no significant change in the predicted salinities within the area of the southern drains of the estuary.

Table 9-3 Summary of predicted salinity within estuary

Location	River Flow	Salinity (PSU)			
		Water Surface		Estuary Bed	
		Existing	Proposed	Existing	Proposed
New Wetland (Brains Land)	Seven Day Five Year Low	N/A	20 - 25	N/A	20 - 25
	Mean	N/A	10 - 15	N/A	10 - 15
Upper Estuary	Seven Day Five Year Low	20 - 25	20 - 25	20 - 25	20 - 30
	Mean	5 - 15	10 - 15	10 - 15	10 – 20
Mid Estuary	Seven Day Five Year Low	25 - 30	20 - 25	25 -35	20 - 30
	Mean	15 - 25	10 – 20	15 - 30	15 - 25
Lower Estuary	Seven Day Five Year Low	30 - 35	25 – 35	30 - 35	25 - 35
	Mean	25 - 35	20 – 30	25 - 35	20 -30
Southern Drains	Seven Day Five Year Low	0 - 20	0 - 20	0 - 20	0 - 20
	Mean	0 - 20	0 - 20	0 - 20	0 - 20

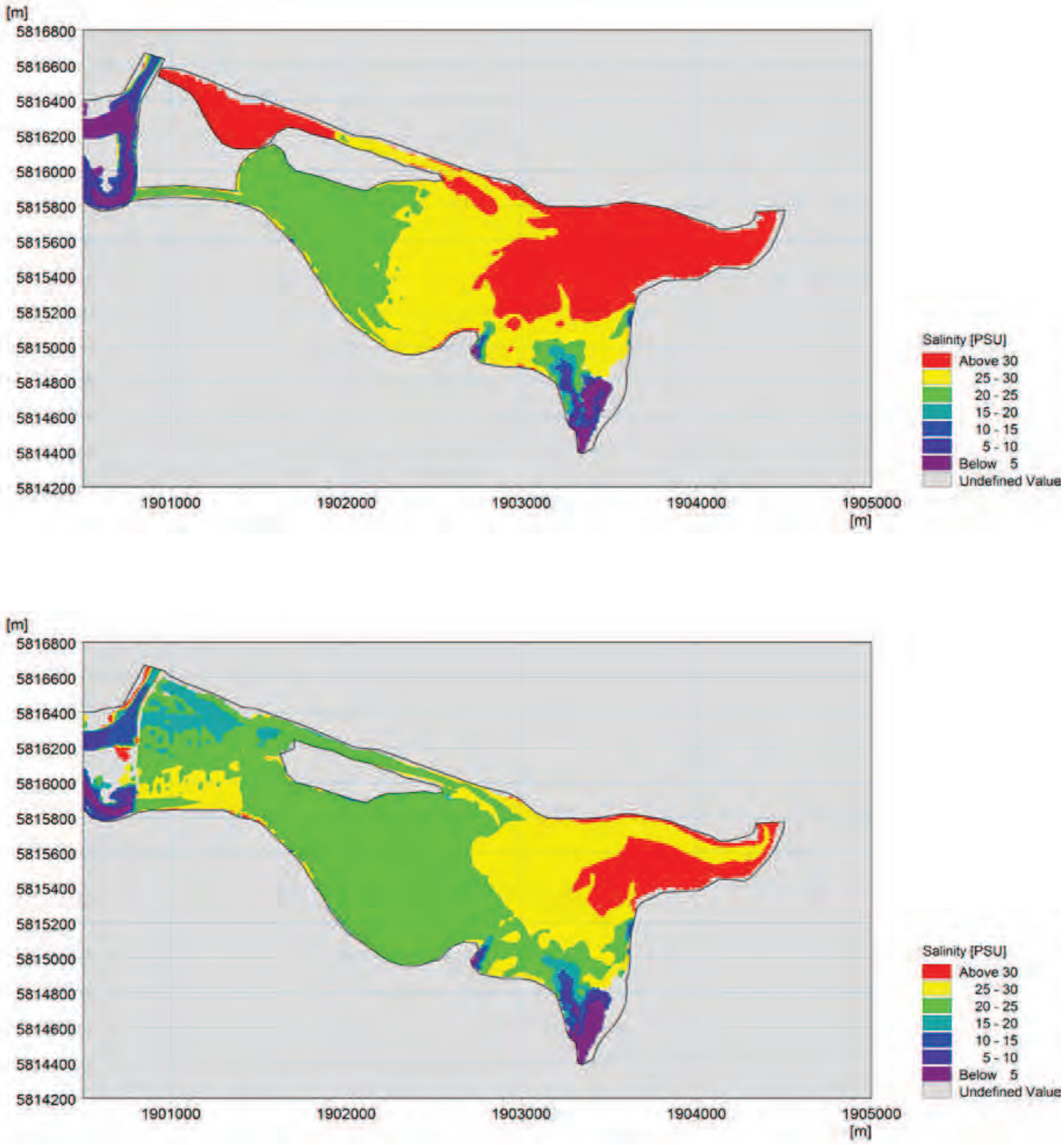

Figure 9-2 Mean salinity at water surface for existing (top) and proposed situations (bottom) for seven day five year low river flow and neap/spring tidal cycle. Note for existing situation, no flow possible in area north-west of Papahikahawai Island, hence initial condition of 35 PSU.

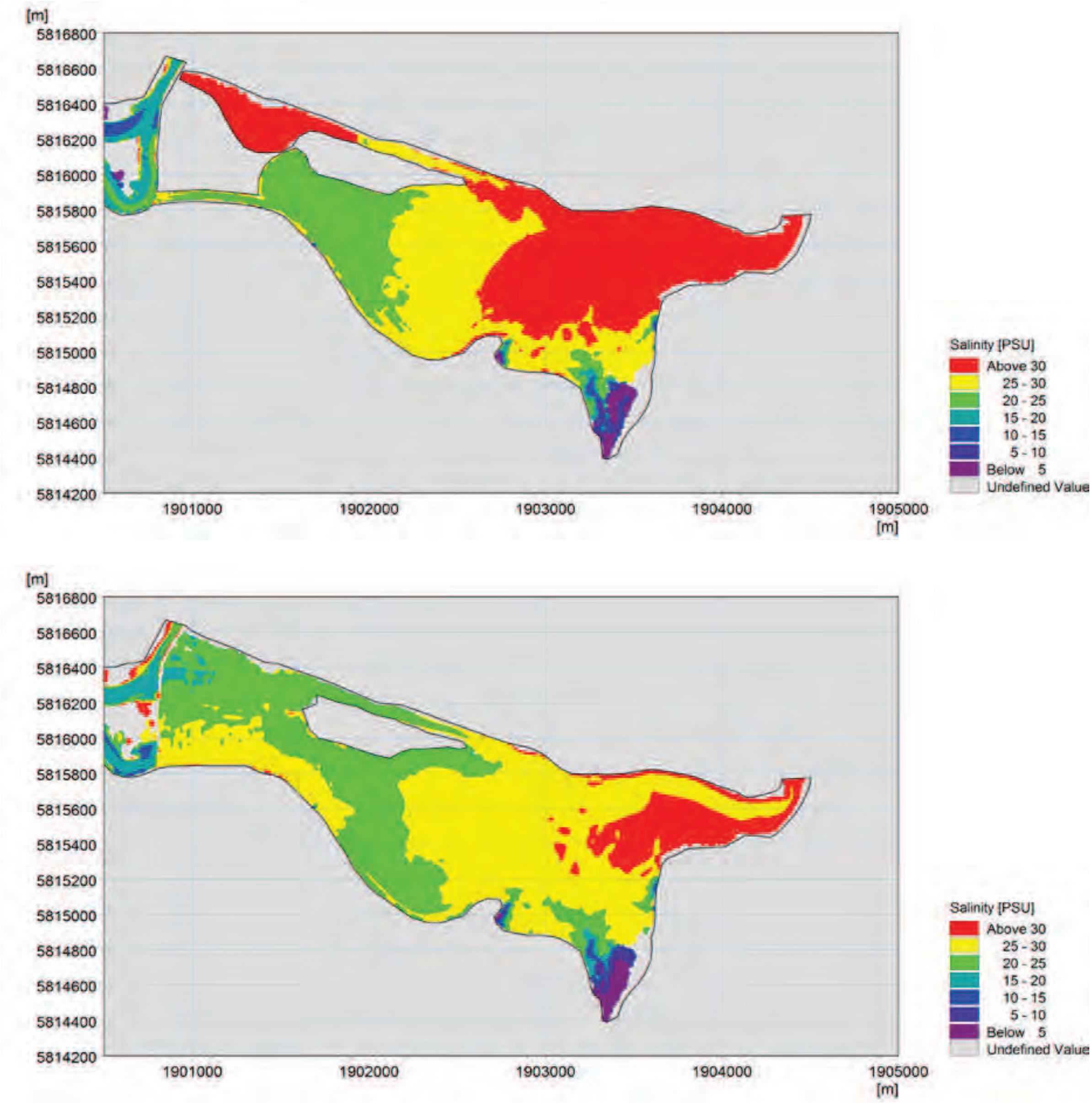

Figure 9-3 Mean salinity at mid water column for existing (top) and proposed situations (bottom) for seven day five year low river flow and neap/spring tidal cycle. Note for existing situation, no flow possible in area north-west of Papahikahawai Island, hence initial condition of 35 PSU.

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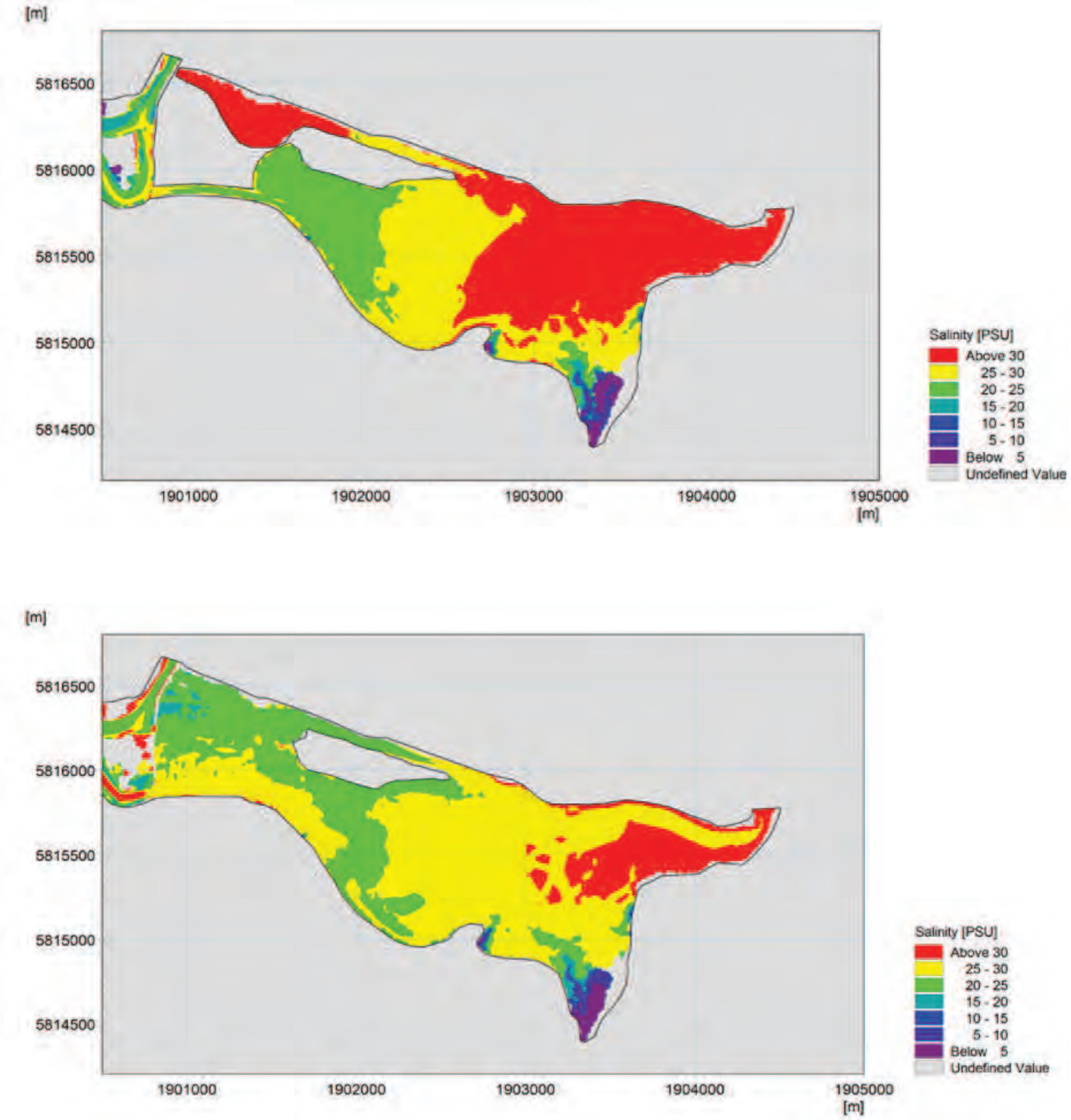


Figure 9-4 Mean salinity at estuary bed for existing (top) and proposed situations (bottom) for seven day five year low river flow and neap/spring tidal cycle. Note for existing situation, no flow possible in area north-west of Papahikahawai Island, hence initial condition of 35 PSU.

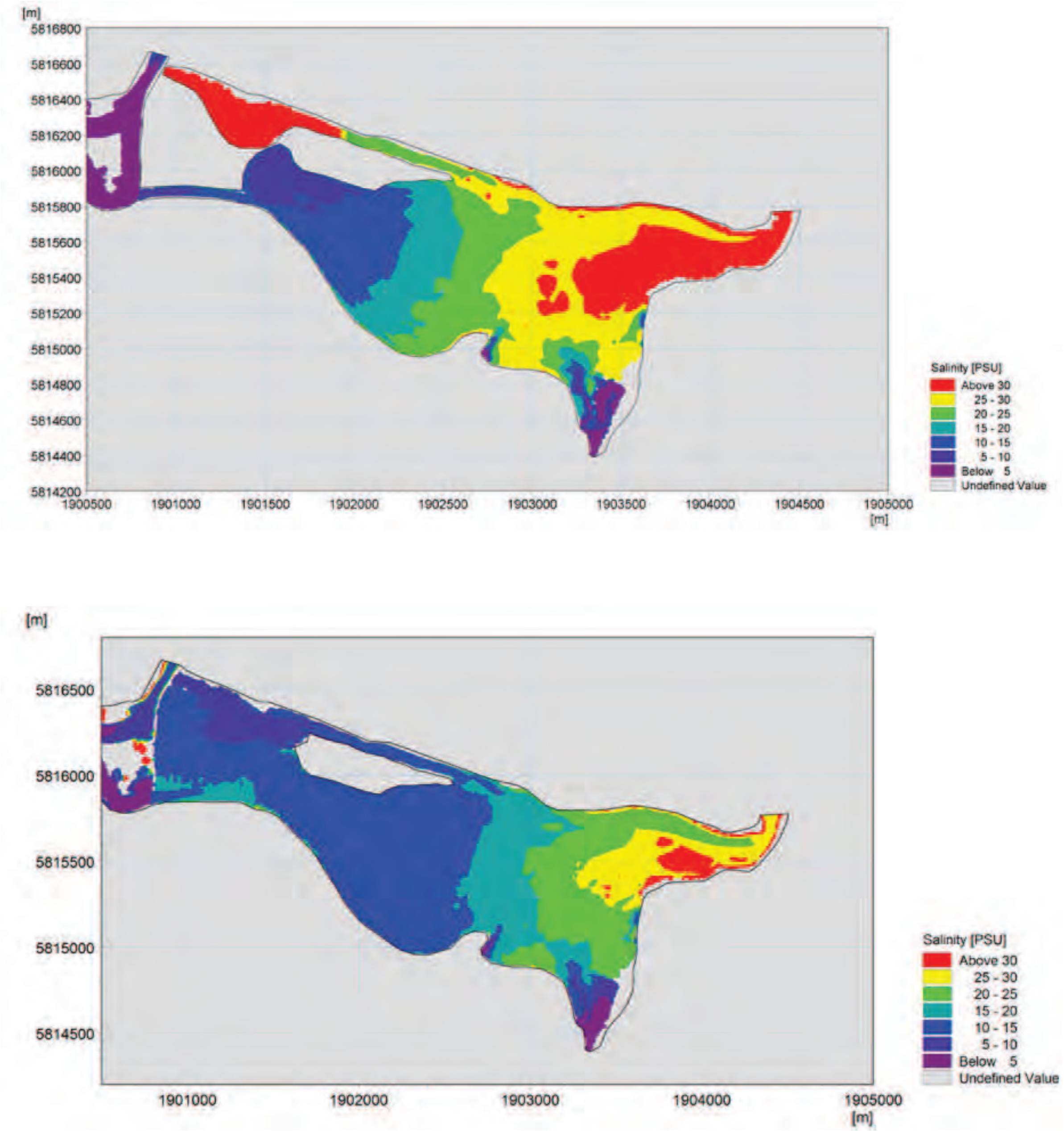


Figure 9-5 Mean salinity at water surface for existing (top) and proposed situations (bottom) for mean river flow and neap/spring tidal cycle. Note for existing situation, no flow possible in area north-west of Papahikahawai Island, hence initial condition of 35 PSU.

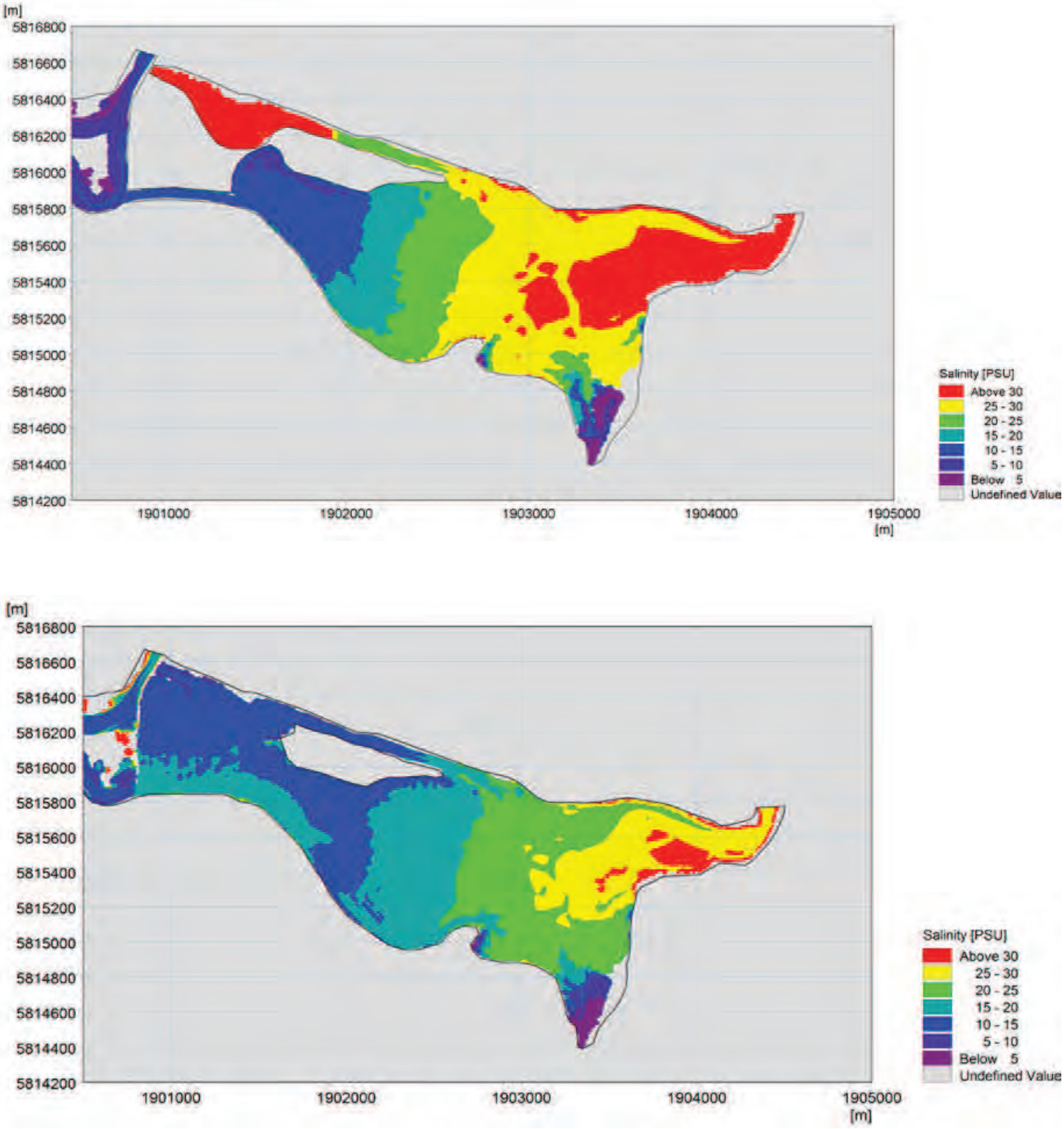


Figure 9-6 Mean salinity at mid water column for existing (top) and proposed situations (bottom) for mean river flow and neap/spring tidal cycle. Note for existing situation, no flow possible in area north-west of Papahikahawai Island, hence initial condition of 35 PSU.

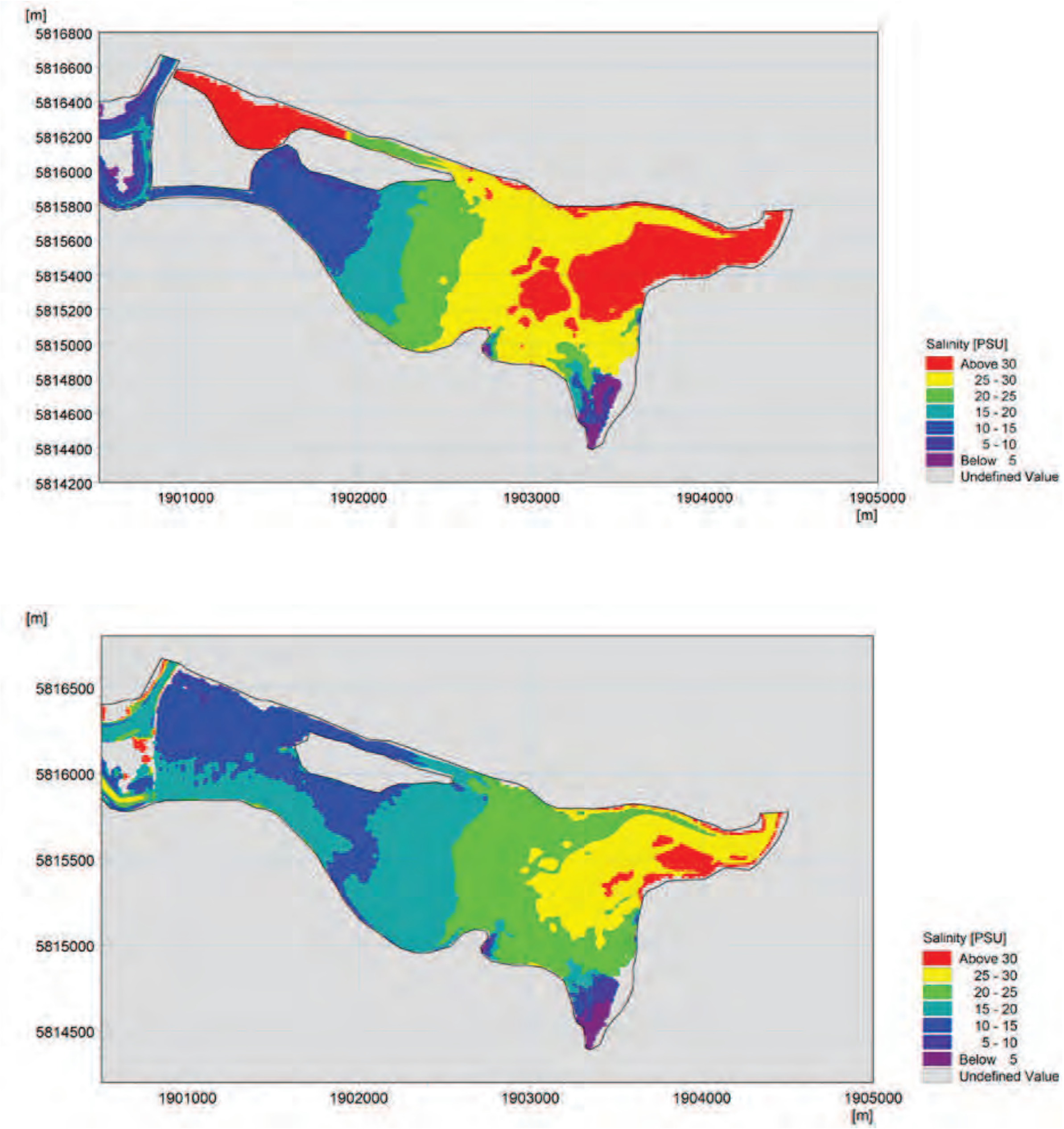


Figure 9-7 Mean salinity at estuary bed for existing (top) and proposed situations (bottom) for mean river flow and neap/spring tidal cycle. Note for existing situation, no flow possible in area north-west of Papahikahawai Island, hence initial condition of 35 PSU.

To provide further information for comparing the predicted salinity within the estuary, for both the seven day five year low and mean river flow scenarios, for the existing situation and proposed option, time series of salinities were extracted from the locations presented in Figure 9-8. These time series were then analysed and the 10th, 20th, 50th, 80th and 90th percentiles were calculated and are presented in Table 9-4 and Table 9-5.

Similar to the spatial plots of mean salinity, the analysis of the time series indicates that there will be a slight increase in salinities in the upper estuary for mean river flow and no significant difference for low river flow. For the mid and lower estuary there will be a reduction in overall salinity, with the greatest reduction for mean river flow.

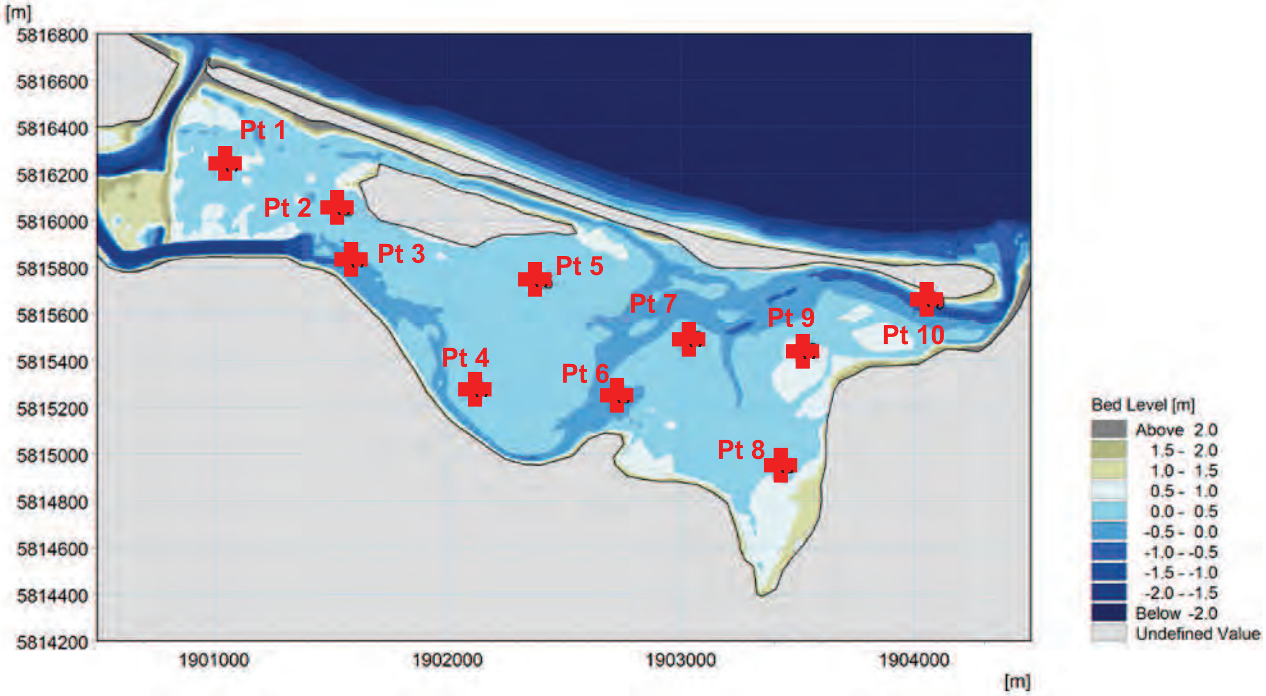


Figure 9-8 Locations within estuary where times series of salinity extracted for seven day five year low and mean river flow scenarios.

Table 9-4 Analysis of extracted salinity time series for seven day five year low river flow scenario.

Location		Situation	Percentile Salinity (PSU)				
			10th	20th	50th	80th	90th
Pt 1	Water Surface	Existing	N/A	N/A	N/A	N/A	N/A
		Proposed	9.7	17.7	25.0	27.7	28.4
		Difference	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
	Estuary Bed	Existing	N/A	N/A	N/A	N/A	N/A
		Proposed	11.3	22.0	27.8	30.5	31.7
		Difference	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*
Pt 2	Water Surface	Existing	10.8	15.7	26.1	28.8	29.3
		Proposed	9.2	13.5	26.7	29.3	32.1
		Difference	*-1.6*	*-2.2*	*0.6*	*0.5*	*2.8*
	Estuary Bed	Existing	11.2	16.6	27.3	29.3	29.7
		Proposed	10.2	16.8	27.9	31.1	32.4
		Difference	*-1.0*	*0.2*	*0.6*	*1.8*	*2.7*
Pt 3	Water Surface	Existing	11.4	13.2	26.6	29.5	30.2
		Proposed	10.1	15.7	27.9	30.5	31.8
		Difference	*-1.3*	*2.5*	*1.3*	*1.0*	*1.6*
	Estuary Bed	Existing	12.3	14.7	28.3	30.9	31.4
		Proposed	13.2	19.7	30.1	32.1	33.0
		Difference	*0.9*	*5.0*	*1.8*	*1.2*	*1.6*
Pt 4	Water Surface	Existing	12.7	18.7	28.5	30.0	30.2
		Proposed	8.7	11.5	25.3	30.5	31.2
		Difference	*-4.0*	*-7.2*	*-3.2*	*0.5*	*1.0*
	Estuary Bed	Existing	12.7	18.9	28.8	30.1	30.3
		Proposed	13.0	19.8	27.9	30.9	31.5
		Difference	*0.3*	*0.9*	*-0.9*	*0.8*	*1.2*
Pt 5	Water Surface	Existing	13.2	17.3	28.0	30.0	30.4
		Proposed	12.4	15.7	26.6	30.6	31.1
		Difference	*-0.8*	*-1.6*	*-1.4*	*0.6*	*0.7*
	Estuary Bed	Existing	13.4	20.0	29.7	32.4	34.3
		Proposed	15.1	21.5	29.5	31.0	31.6
		Difference	*1.7*	*1.5*	*-0.2*	*-1.4*	*-2.7*
Pt 6	Water Surface	Existing	19.7	23.2	30.1	31.4	31.9
		Proposed	12.6	16.9	25.6	30.2	30.9
		Difference	*-7.1*	*-6.3*	*-4.5*	*-1.2*	*-1.0*
	Estuary Bed	Existing	22.0	27.6	32.0	34.6	34.9
		Proposed	16.9	22.7	30.1	32.0	33.7
		Difference	*-5.1*	*-4.9*	*-1.9*	*-2.6*	*-1.2*
Pt 7	Water Surface	Existing	27.6	30.4	32.3	35.0	35.0
		Proposed	17.8	22.6	27.8	34.3	35.0
		Difference	*-9.8*	*-7.8*	*-4.5*	*-0.7*	*0.0*
	Estuary Bed	Existing	27.7	30.8	32.6	35.0	35.0
		Proposed	20.5	25.7	29.9	34.9	35.0
		Difference	*-7.2*	*-5.1*	*-2.7*	*-0.1*	*0.0*

Location		Situation	Percentile Salinity (PSU)				
			10th	20th	50th	80th	90th
Pt 8	Water Surface	Existing	23.5	25.1	30.8	31.8	32.1
		Proposed	19.0	22.9	29.6	30.9	31.4
		Difference	*-4.5*	*-2.2*	*-1.2*	*-0.9*	*-0.7*
	Estuary Bed	Existing	23.5	25.1	30.8	31.8	32.1
		Proposed	19.0	22.9	29.6	30.9	31.4
		Difference	*-4.5*	*-2.2*	*-1.2*	*-0.9*	*-0.7*
Pt 9	Water Surface	Existing	33.9	34.3	34.9	35.0	35.0
		Proposed	31.0	31.4	33.6	34.9	34.9
		Difference	*-2.9*	*-2.9*	*-1.3*	*-0.1*	*-0.1*
	Estuary Bed	Existing	33.9	34.3	34.9	35.0	35.0
		Proposed	31.0	31.4	33.6	34.9	34.9
		Difference	*-2.9*	*-2.9*	*-1.3*	*-0.1*	*-0.1*
Pt 10	Water Surface	Existing	27.1	30.6	33.5	35.0	35.0
		Proposed	20.2	26.6	30.0	35.0	35.0
		Difference	*-6.9*	*-4.0*	*-3.5*	*0.0*	*0.0*
	Estuary Bed	Existing	27.1	30.6	33.5	35.0	35.0
		Proposed	20.2	26.6	30.0	35.0	35.0
		Difference	*-6.9*	*-4.0*	*-3.5*	*0.0*	*0.0*

Table 9-5 Analysis of extracted salinity time series for mean river flow scenario.

Location		Situation	Percentile Salinity (PSU)				
			10th	20th	50th	80th	90th
Pt 1	Water Surface	Existing	N/A	N/A	N/A	N/A	N/A
		Proposed	4.9	6.7	10.8	14.2	15.8
		Difference	N/A	N/A	N/A	N/A	N/A
	Estuary Bed	Existing	N/A	N/A	N/A	N/A	N/A
		Proposed	5.4	8.7	13.7	18.2	20.5
		Difference	N/A	N/A	N/A	N/A	N/A
Pt 2	Water Surface	Existing	0.7	1.9	10.9	15.3	16.5
		Proposed	2.1	3.4	14.0	18.3	21.5
		Difference	*1.4*	*1.5*	*3.1*	*3.0*	*5.0*
	Estuary Bed	Existing	0.7	2.9	11.4	16.2	17.2
		Proposed	2.2	4.1	16.0	22.1	25.8
		Difference	*1.5*	*1.2*	*4.6*	*5.9*	*8.6*
Pt 3	Water Surface	Existing	0.9	2.1	11.3	16.5	18.1
		Proposed	1.5	4.0	16.0	20.3	21.5
		Difference	*0.6*	*1.9*	*4.7*	*3.8*	*3.4*
	Estuary Bed	Existing	0.9	2.6	14.5	19.3	20.5
		Proposed	1.8	6.6	20.6	25.3	26.9
		Difference	*0.9*	*4.0*	*6.1*	*6.0*	*6.4*
Pt 4	Water Surface	Existing	3.8	8.4	19.0	22.4	23.1
		Proposed	1.8	3.2	15.6	21.4	22.4
		Difference	*-2.0*	*-5.2*	*-3.4*	*-1.0*	*-0.7*

Location		Situation	Percentile Salinity (PSU)				
			10th	20th	50th	80th	90th
	Estuary Bed	Existing	5.0	11.2	21.5	24.9	26.2
		Proposed	2.9	8.8	18.2	21.9	22.9
		Difference	*-2.1*	*-2.4*	*-3.3*	*-3.0*	*-3.3*
Pt 5	Water Surface	Existing	3.5	7.9	17.5	21.0	22.5
		Proposed	1.9	5.0	15.8	21.3	22.3
		Difference	*-1.6*	*-2.9*	*-1.7*	*0.3*	*-0.2*
	Estuary Bed	Existing	4.1	12.4	21.0	30.3	33.5
		Proposed	4.0	11.4	20.0	23.2	26.3
		Difference	*-0.1*	*-1.0*	*-1.0*	*-7.1*	*-7.2*
Pt 6	Water Surface	Existing	16.2	19.7	25.2	27.2	28.2
		Proposed	4.6	7.9	17.1	22.0	23.1
		Difference	*-11.6*	*-11.8*	*-8.1*	*-5.2*	*-5.1*
	Estuary Bed	Existing	19.1	23.8	28.4	34.1	34.8
		Proposed	8.6	14.5	23.2	29.0	31.9
		Difference	*-10.5*	*-9.3*	*-5.2*	*-5.1*	*-2.9*
Pt 7	Water Surface	Existing	22.8	24.4	27.3	35.0	35.0
		Proposed	10.7	13.8	20.5	24.4	34.9
		Difference	*-12.1*	*-10.6*	*-6.8*	*-10.6*	*-0.1*
	Estuary Bed	Existing	23.3	25.7	28.6	35.0	35.0
		Proposed	13.0	18.8	24.1	34.4	34.9
		Difference	*-10.3*	*-6.9*	*-4.5*	*-0.6*	*-0.1*
Pt 8	Water Surface	Existing	21.9	24.3	29.7	31.5	31.8
		Proposed	14.9	17.6	26.3	28.6	29.3
		Difference	*-7.0*	*-6.7*	*-3.4*	*-2.9*	*-2.5*
	Estuary Bed	Existing	21.9	24.3	29.7	31.5	31.8
		Proposed	14.9	17.6	26.3	28.6	29.3
		Difference	*-7.0*	*-6.7*	*-3.4*	*-2.9*	*-2.5*
Pt 9	Water Surface	Existing	33.3	33.8	34.8	35.0	35.0
		Proposed	23.3	24.1	31.8	34.6	34.8
		Difference	*-10.0*	*-9.7*	*-3.0*	*-0.4*	*-0.2*
	Estuary Bed	Existing	33.3	33.8	34.8	35.0	35.0
		Proposed	23.3	24.1	31.8	34.6	34.8
		Difference	*-10.0*	*-9.7*	*-3.0*	*-0.4*	*-0.2*
Pt 10	Water Surface	Existing	23.8	27.0	30.8	35.0	35.0
		Proposed	14.5	19.8	24.5	35.0	35.0
		Difference	*-9.3*	*-7.2*	*-6.3*	*0.0*	*0.0*
	Estuary Bed	Existing	23.8	27.0	30.8	35.0	35.0
		Proposed	14.5	19.8	24.5	35.0	35.0
		Difference	*-9.3*	*-7.2*	*-6.3*	*0.0*	*0.0*

The ecologists from the project team requested that depth current speeds and salinity from the estuary bed were extracted for selected locations as shown in Figure 9-9. The extracted depth averaged current speeds and salinities for both the seven day five year low and mean river flow scenarios are presented in Figure 9-10 to Figure 9-21. Note only a seven day period (i.e. neap to spring tide) is shown.

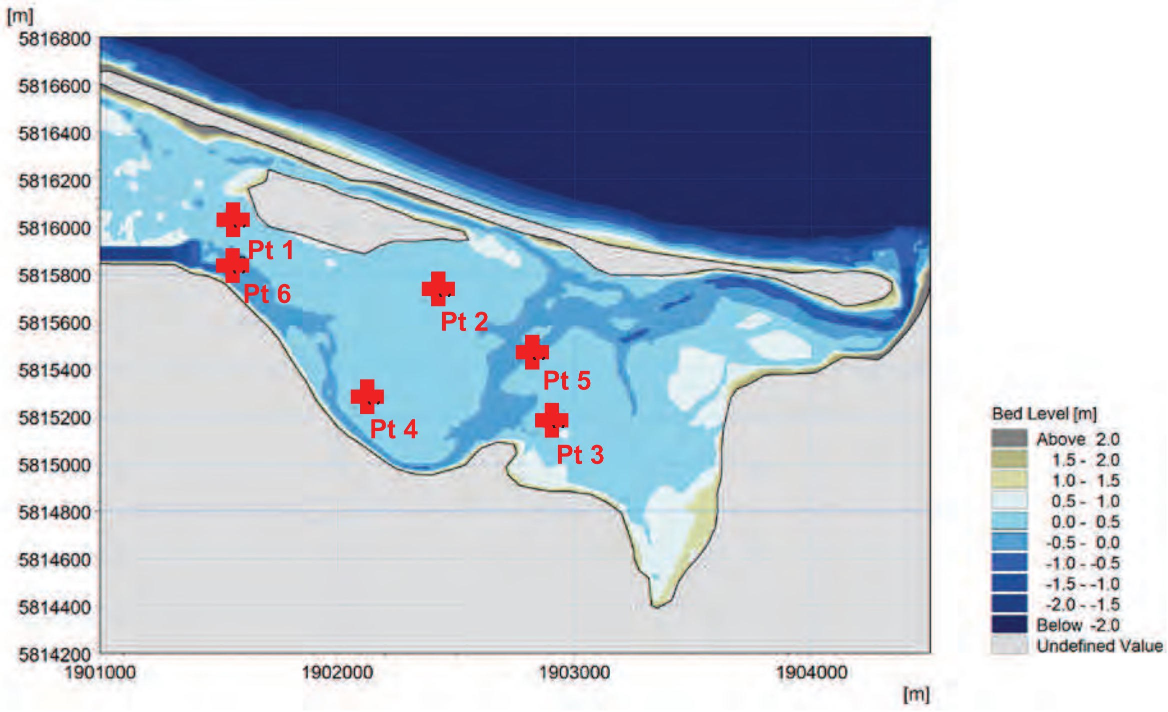


Figure 9-9 Locations within estuary where current speed and salinity extracted.

For the majority of the locations the current speed is increased for the proposed option compared with the existing situation for both scenarios, with Pt 2 and Pt 5 exceptions where current speeds are actually slightly reduced. At Pt 1 and Pt 6 there is an increase in peak and overall salinities for both scenarios, while at Pt 2 to Pt 5 there is either little change or a significant reduction in overall predicted salinities.

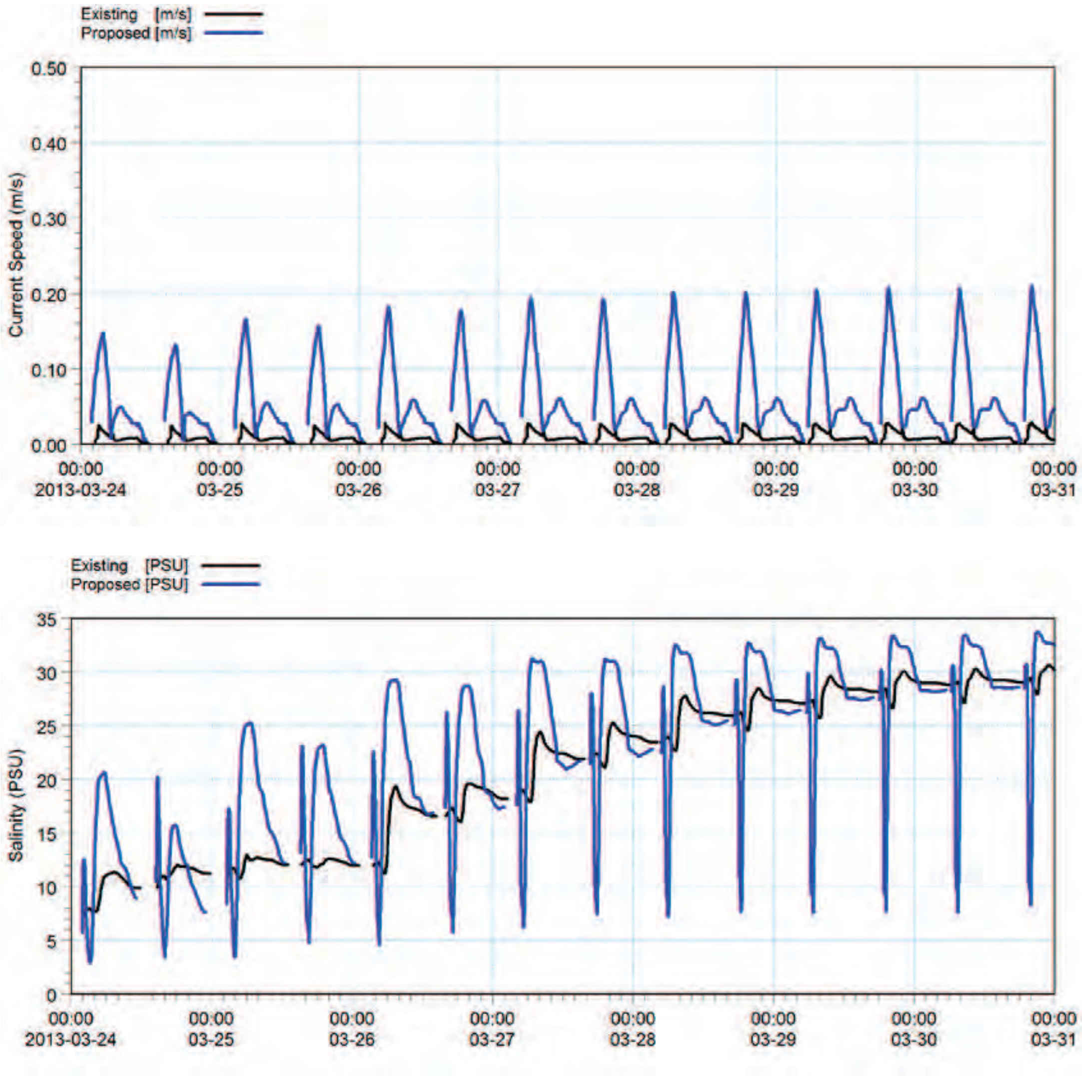


Figure 9-10 Depth averaged current speed (top) and salinity at estuary bed (bottom) for existing and proposed situations at Pt 1 for seven day five year low river flow and neap spring tidal cycle. Note only seven day period (i.e. neap to spring tide) shown.

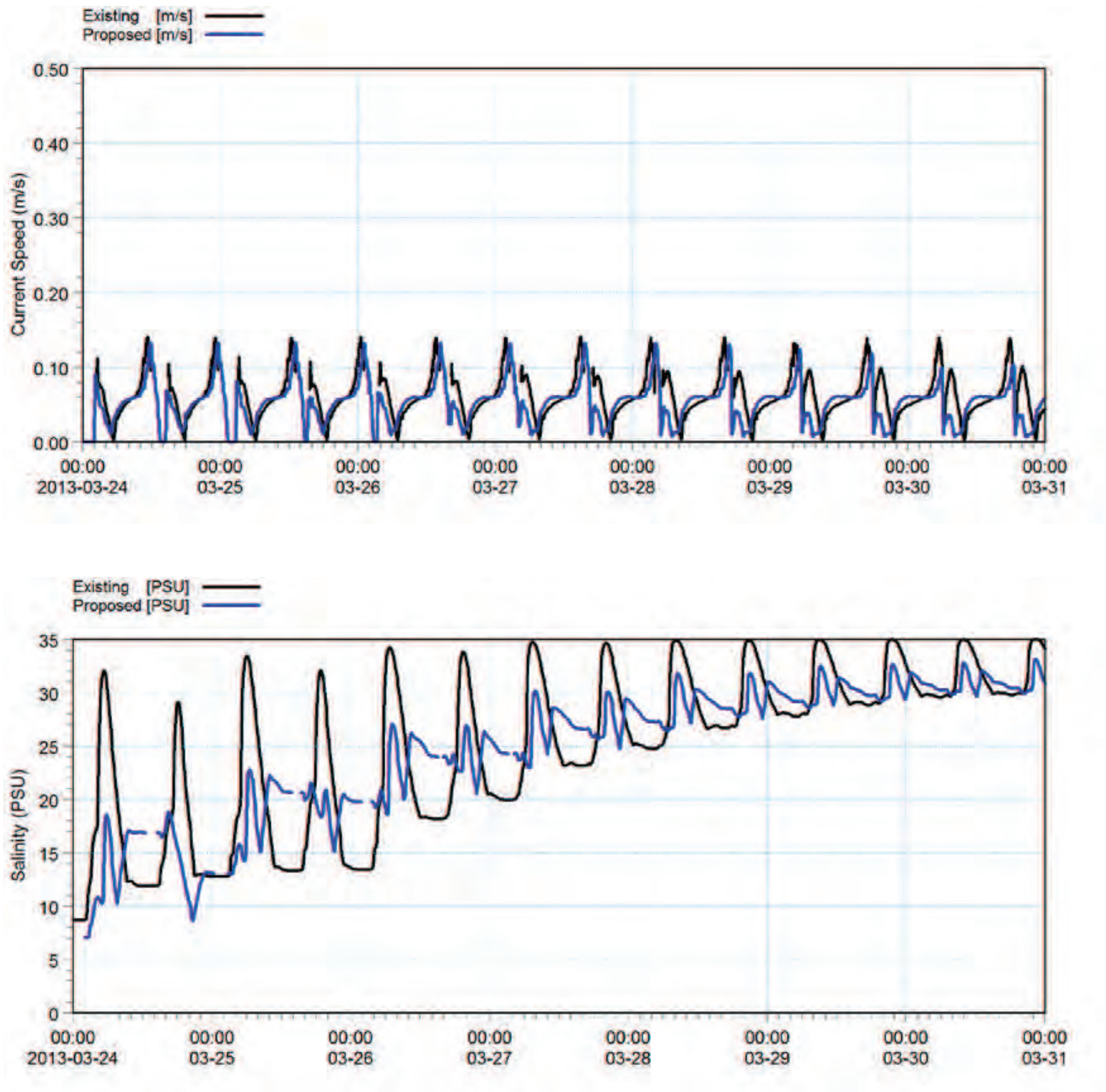


Figure 9-11 Depth averaged current speed (top) and salinity at estuary bed (bottom) for existing and proposed situations at Pt 2 for seven day five year low river flow and neap spring tidal cycle. Note only seven day period (i.e. neap to spring tide) shown.

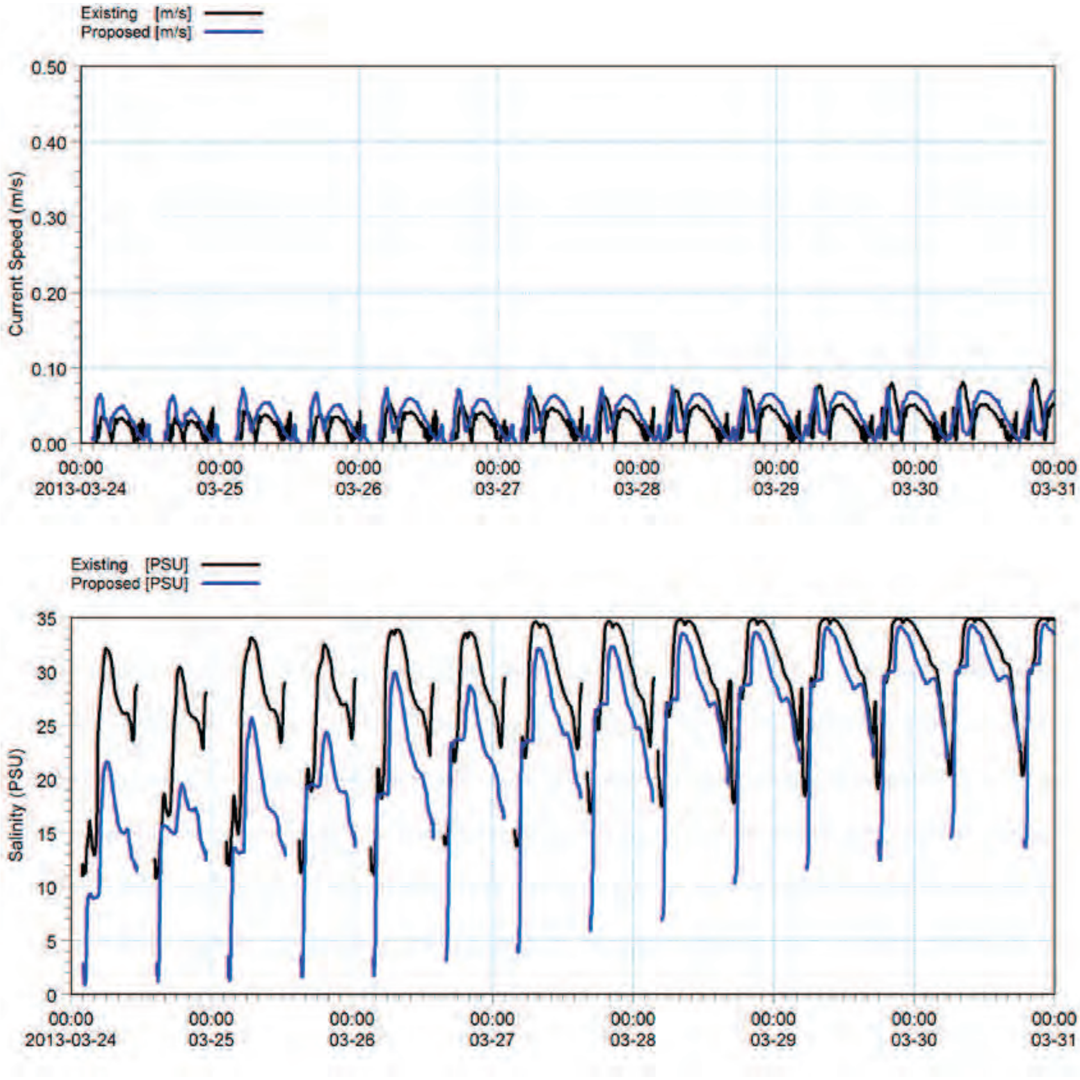
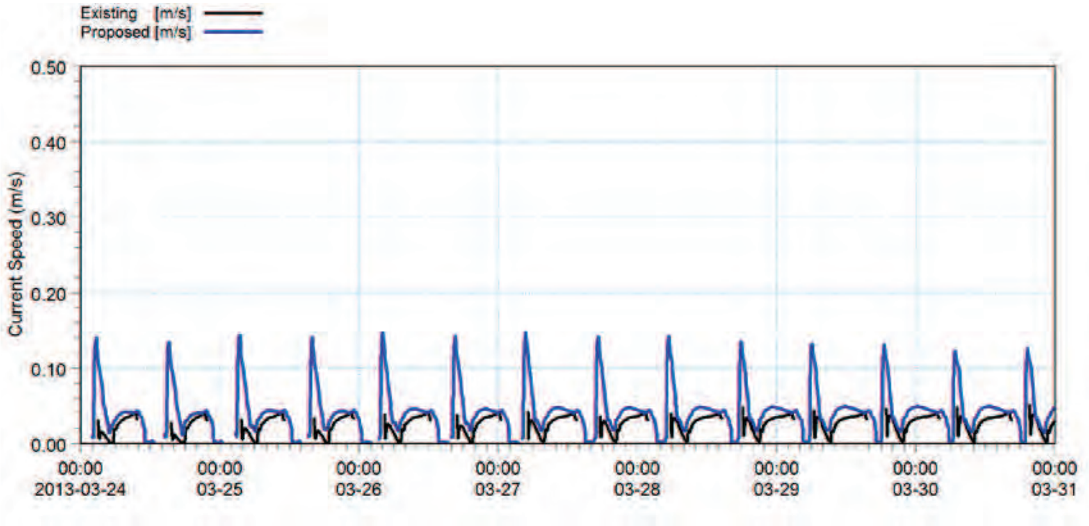


Figure 9-12 Depth averaged current speed (top) and salinity at estuary bed (bottom) for existing and proposed situations at Pt 3 for seven day five year low river flow and neap spring tidal cycle. Note only seven day period (i.e. neap to spring tide) shown.



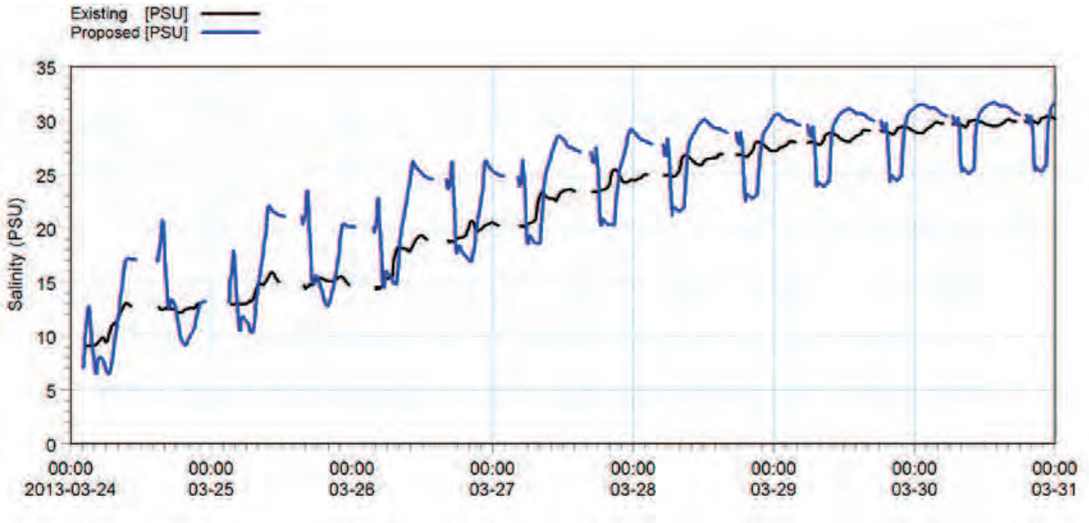


Figure 9-13 Depth averaged current speed (top) and salinity at estuary bed (bottom) for existing and proposed situations at Pt 4 for seven day five year low river flow and neap spring tidal cycle. Note only seven day period (i.e. neap to spring tide) shown.

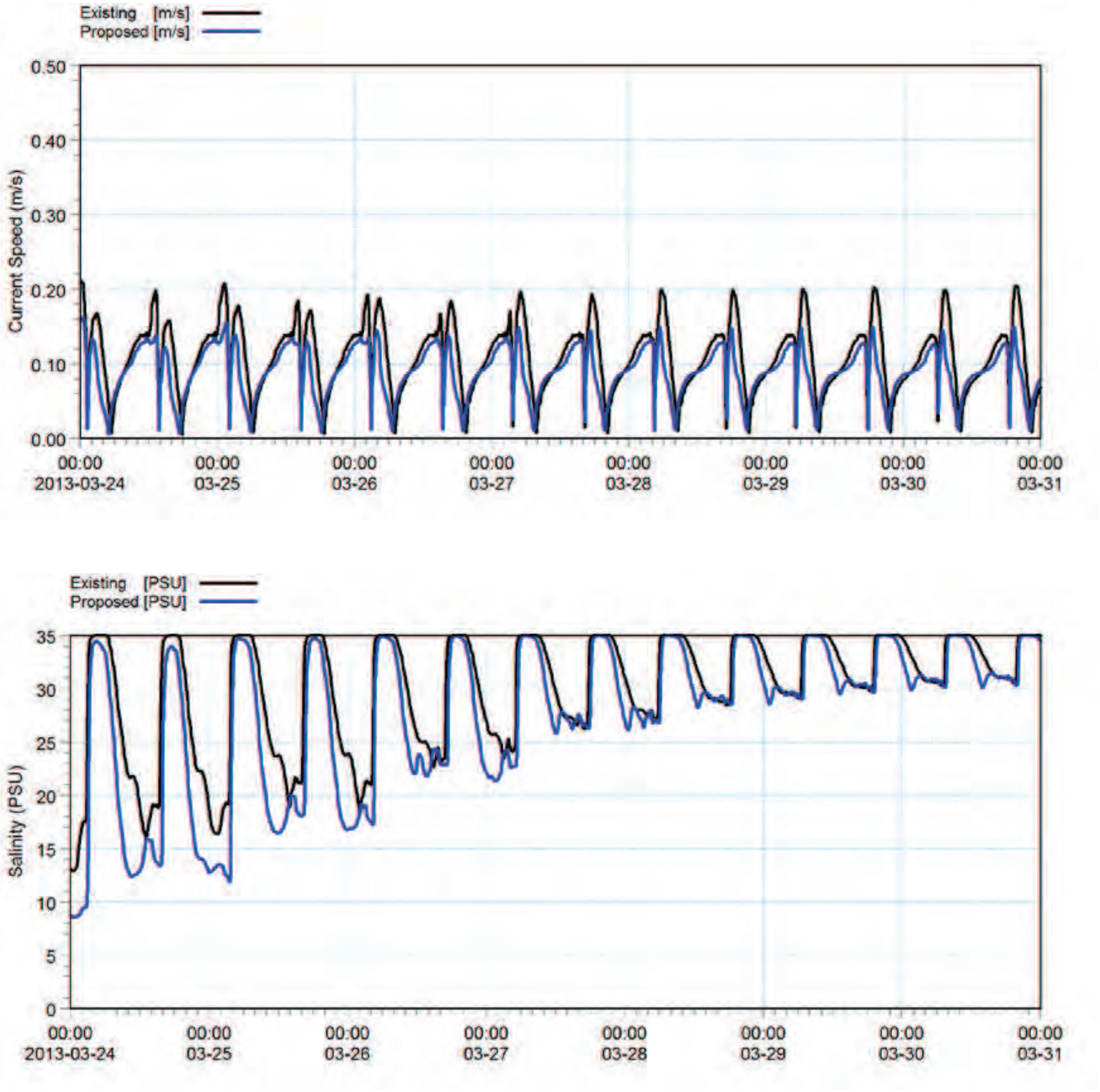


Figure 9-14 Depth averaged current speed (top) and salinity at estuary bed (bottom) for existing and proposed situations at Pt 5 for seven day five year low river flow and neap spring tidal cycle. Note only seven day period (i.e. neap to spring tide) shown.

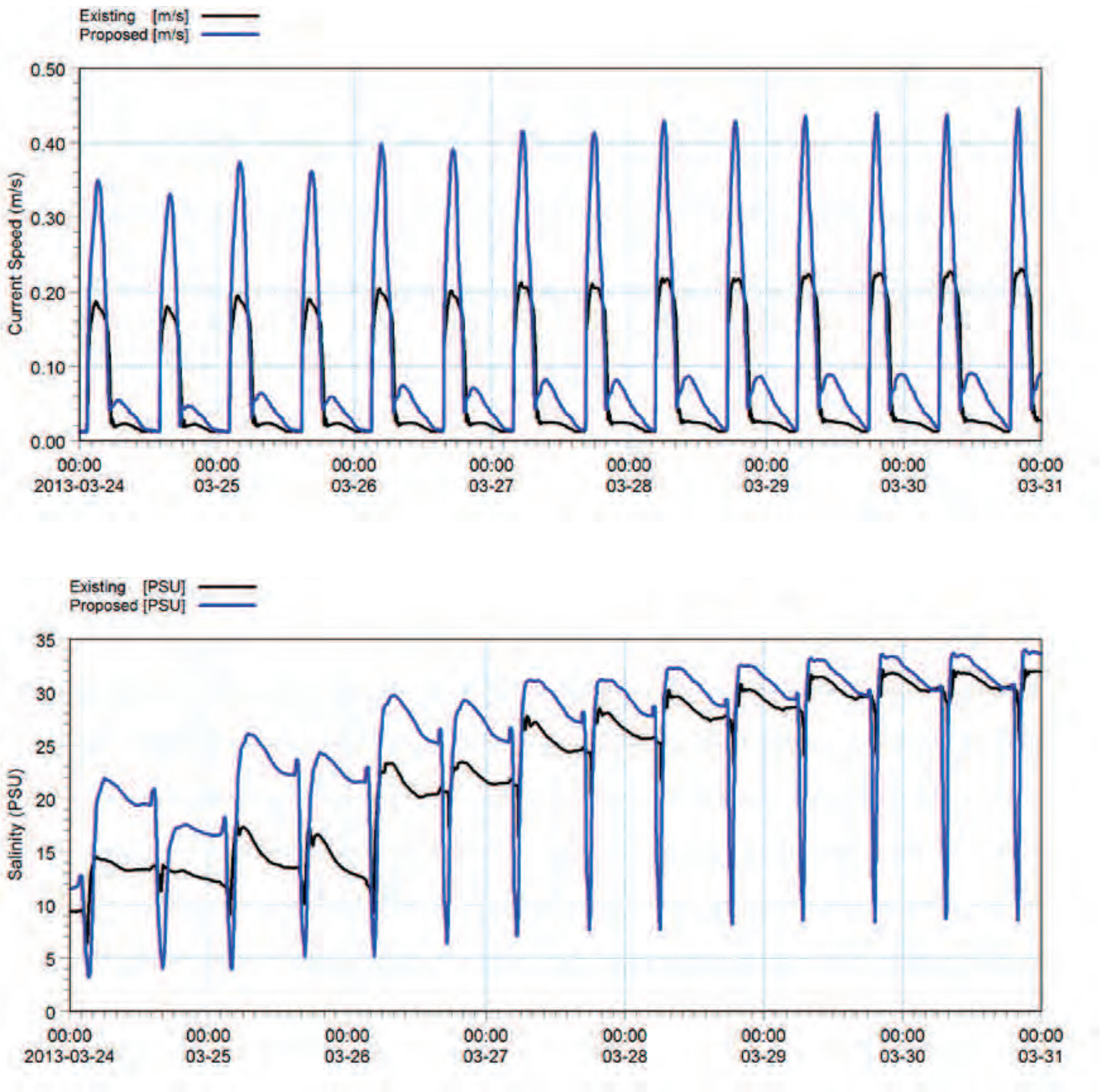


Figure 9-15 Depth averaged current speed (top) and salinity at estuary bed (bottom) for existing and proposed situations at Pt 6 for seven day five year low river flow and neap spring tidal cycle. Note only seven day period (i.e. neap to spring tide) shown.

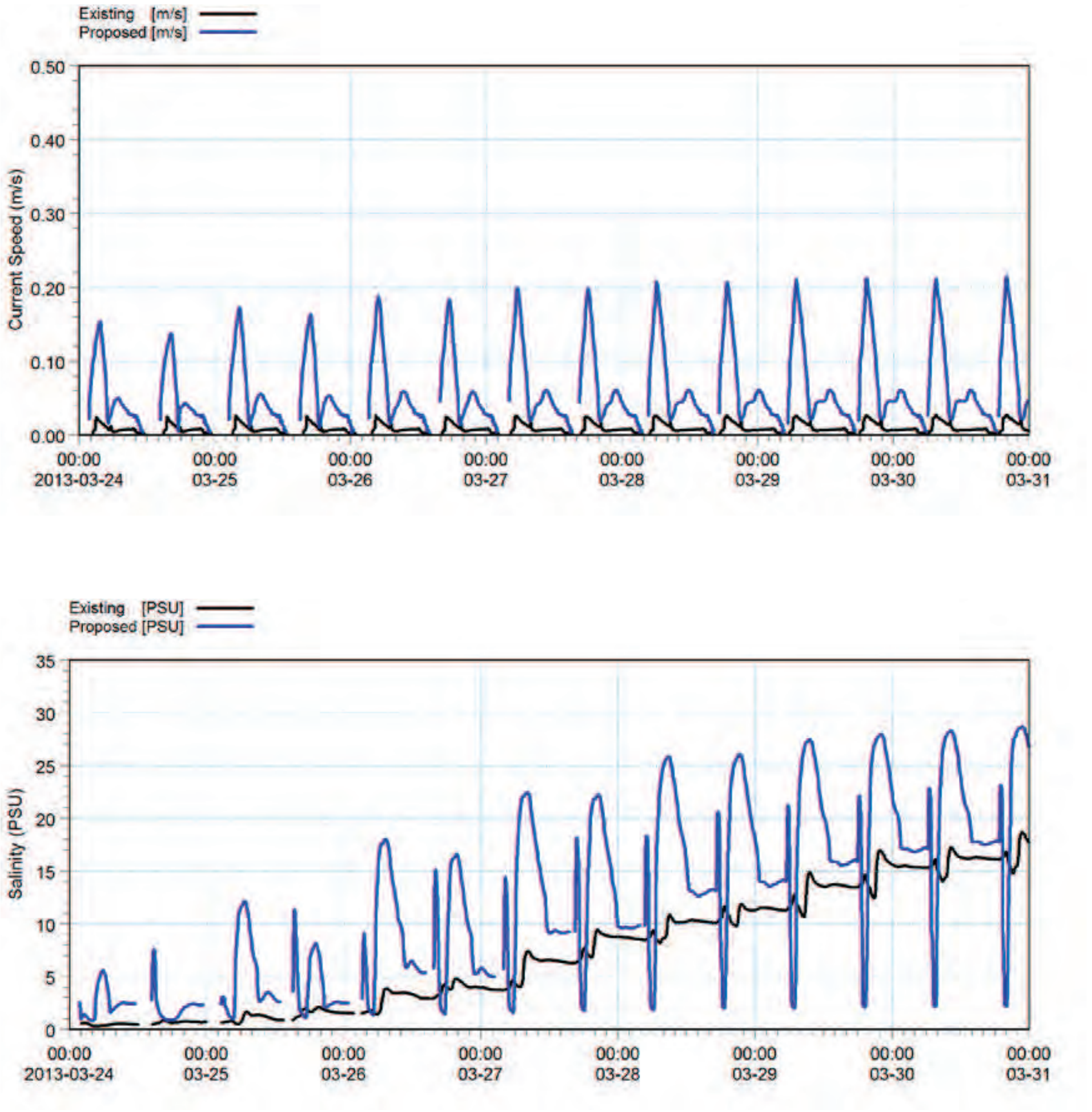


Figure 9-16 Depth averaged current speed (top) and salinity at estuary bed (bottom) for existing and proposed situations at Pt 1 for mean river flow and neap spring tidal cycle. Note only seven day period (i.e. neap to spring tide) shown.

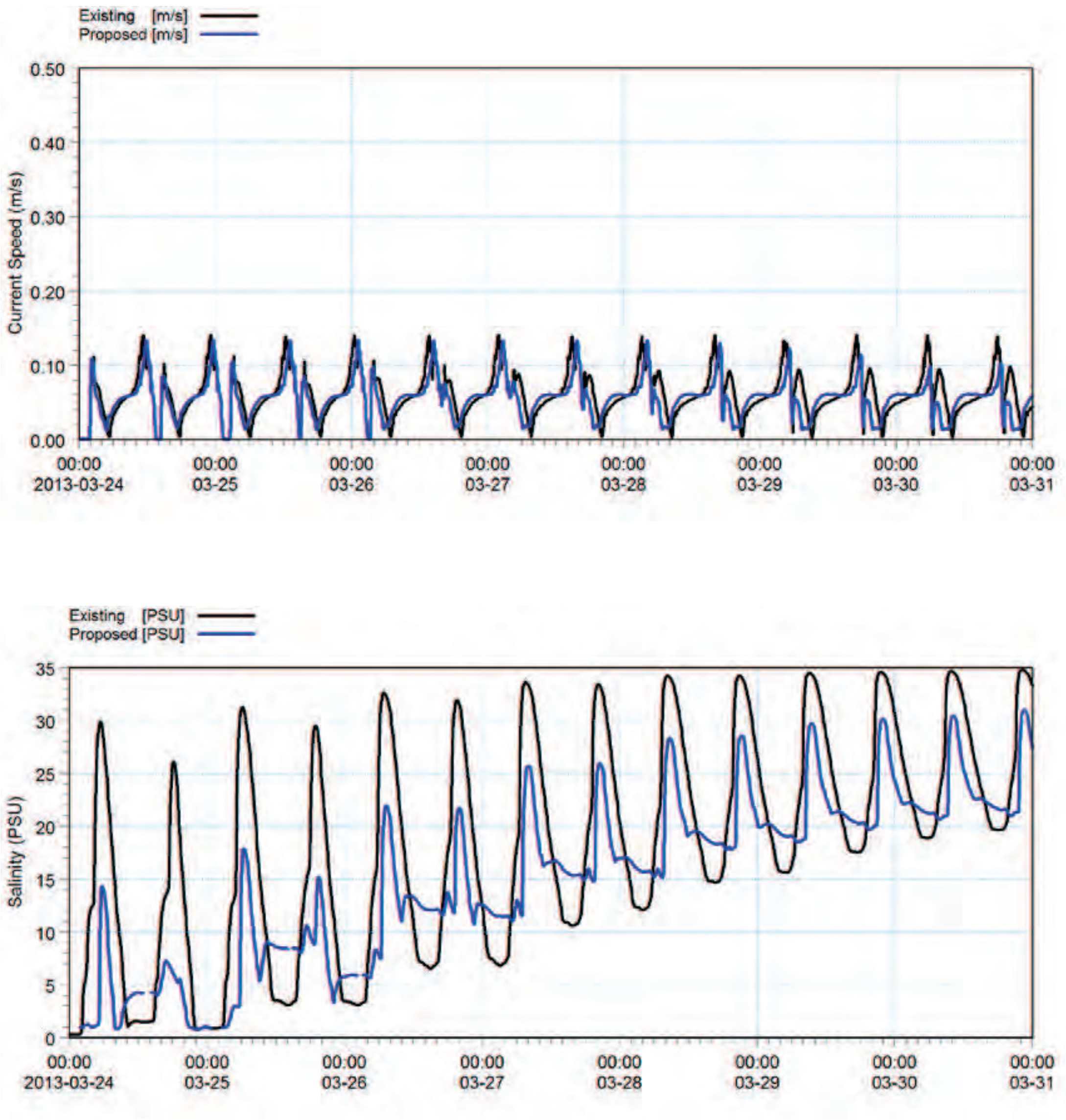
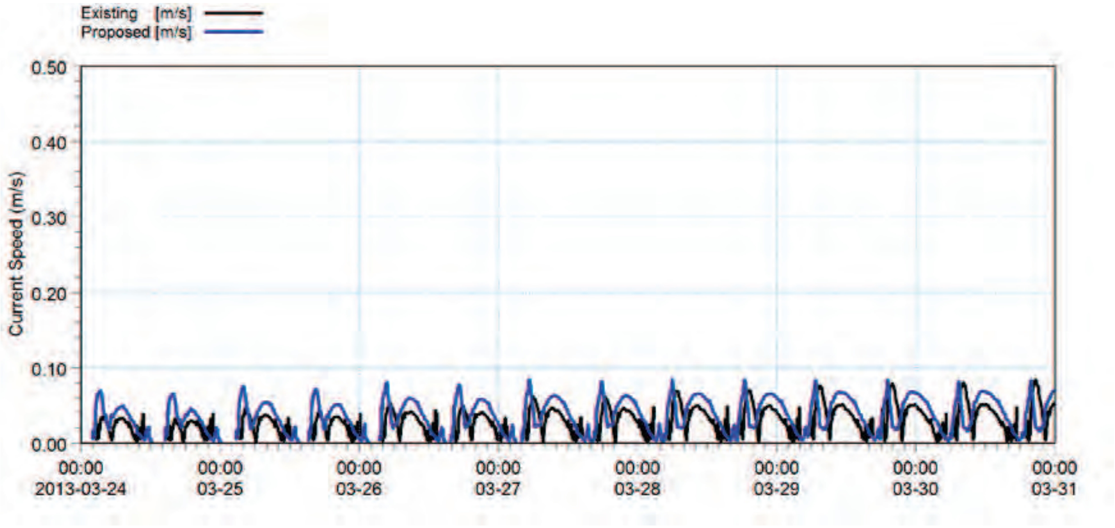


Figure 9-17 Depth averaged current speed (top) and salinity at estuary bed (bottom) for existing and proposed situations at Pt 2 for mean river flow and neap spring tidal cycle. Note only seven day period (i.e. neap to spring tide) shown.



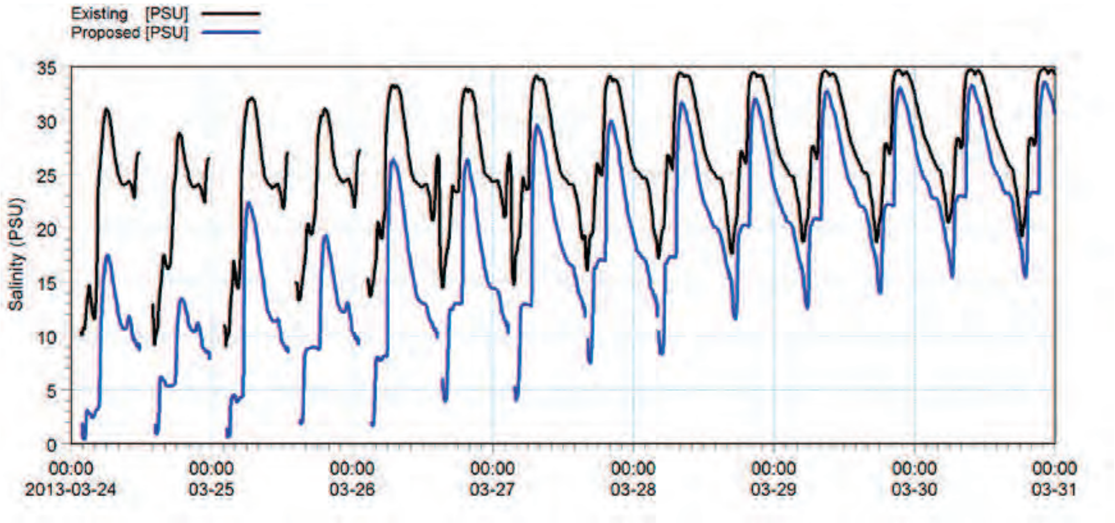
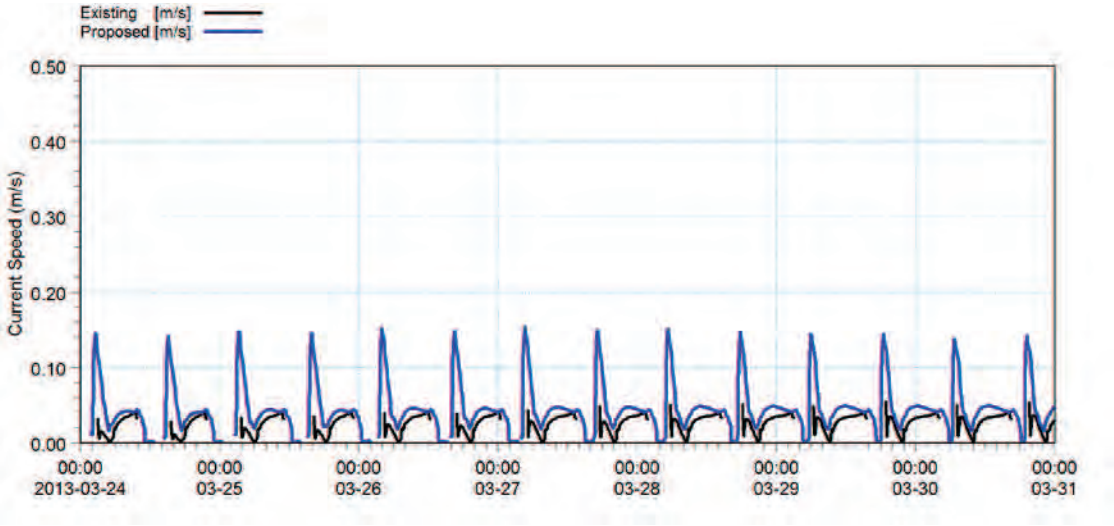


Figure 9-18 Depth averaged current speed (top) and salinity at estuary bed (bottom) for existing and proposed situations at Pt 3 for mean river flow and neap spring tidal cycle. Note only seven day period (i.e. neap to spring tide) shown.



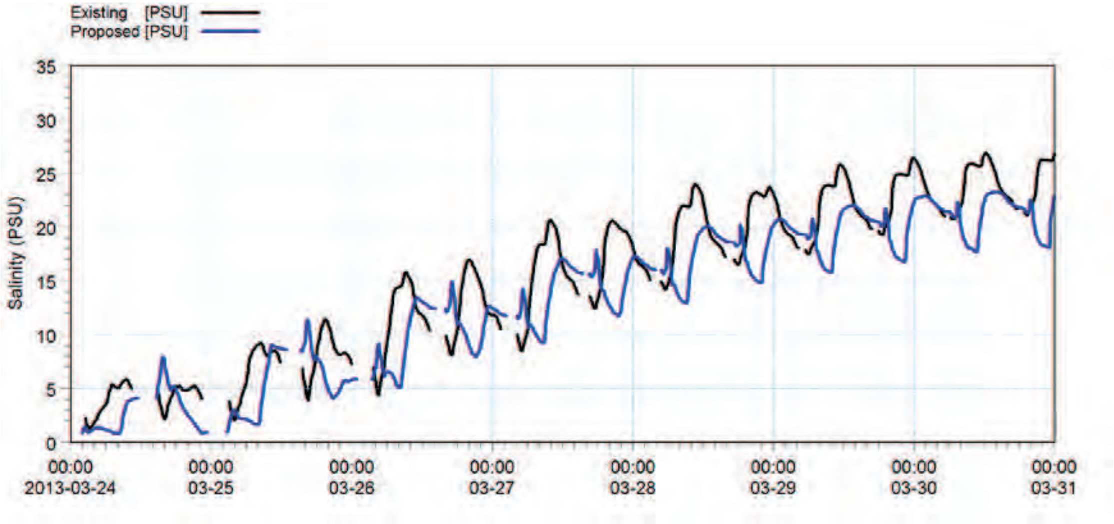
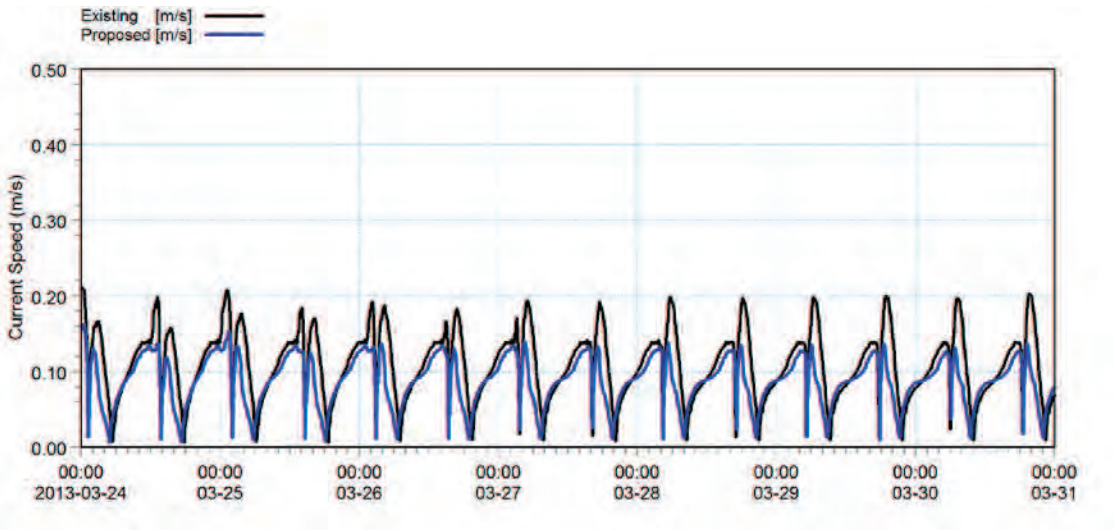


Figure 9-19 Depth averaged current speed (top) and salinity at estuary bed (bottom) for existing and proposed situations at Pt 4 for mean river flow and neap spring tidal cycle. Note only seven day period (i.e. neap to spring tide) shown.



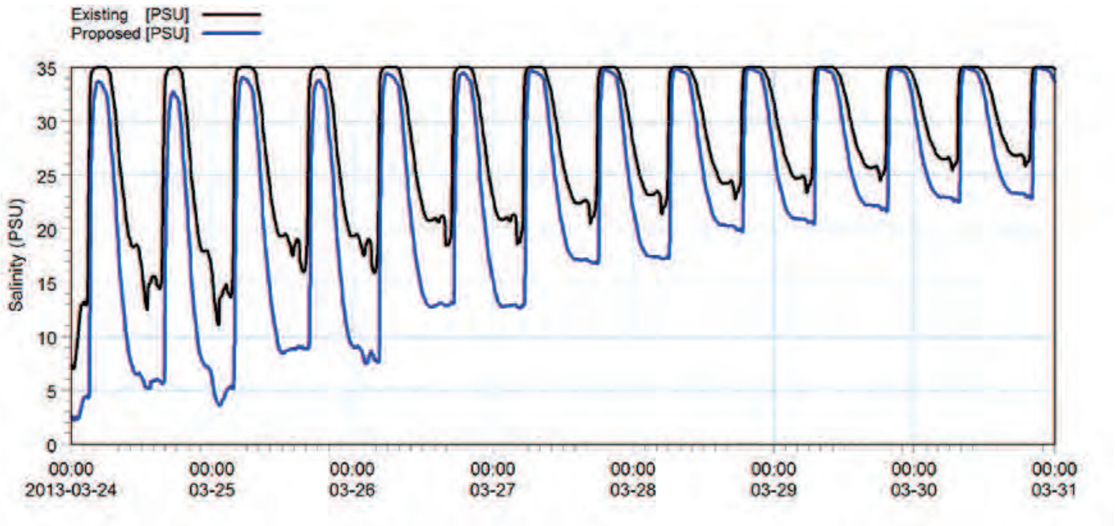


Figure 9-20 Depth averaged current speed (top) and salinity at estuary bed (bottom) for existing and proposed situations at Pt 5 for mean river flow and neap spring tidal cycle. Note only seven day period (i.e. neap to spring tide) shown.

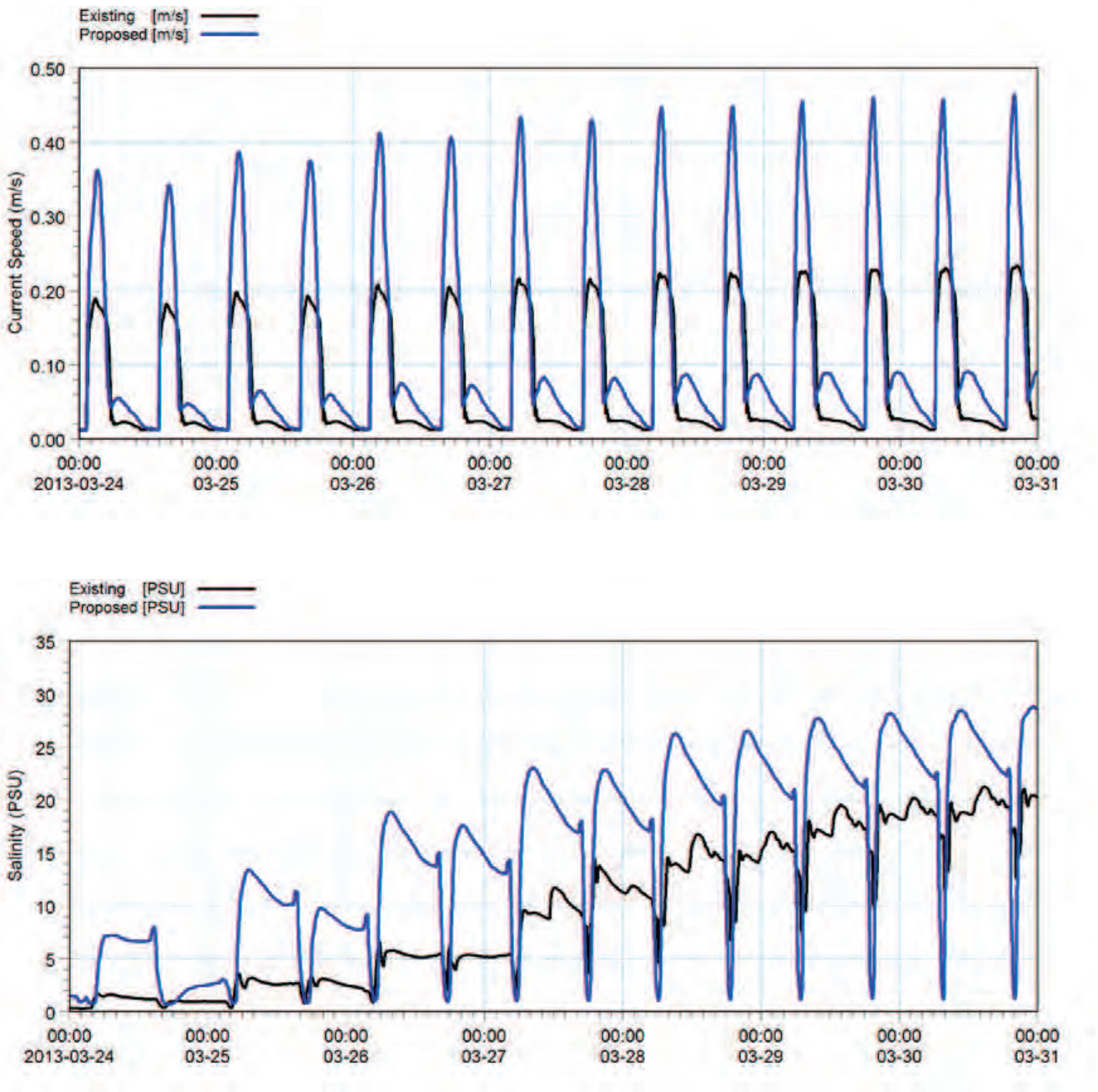


Figure 9-21 Depth averaged current speed (top) and salinity at estuary bed (bottom) for existing and proposed situations at Pt 6 for mean river flow and neap spring tidal cycle. Note only seven day period (i.e. neap to spring tide) shown.

Also at the request of the ecologists of the project team, the mean and spring tide depth averaged residual currents have been calculated for existing situation and proposed option. These are presented in Figure 9-22 and Figure 9-23 along with the mean current speed for the mean or spring tide. There is a significant increase in both the mean and spring tide residual currents in the upper estuary, especially in the upper estuary north of the main estuary channel.

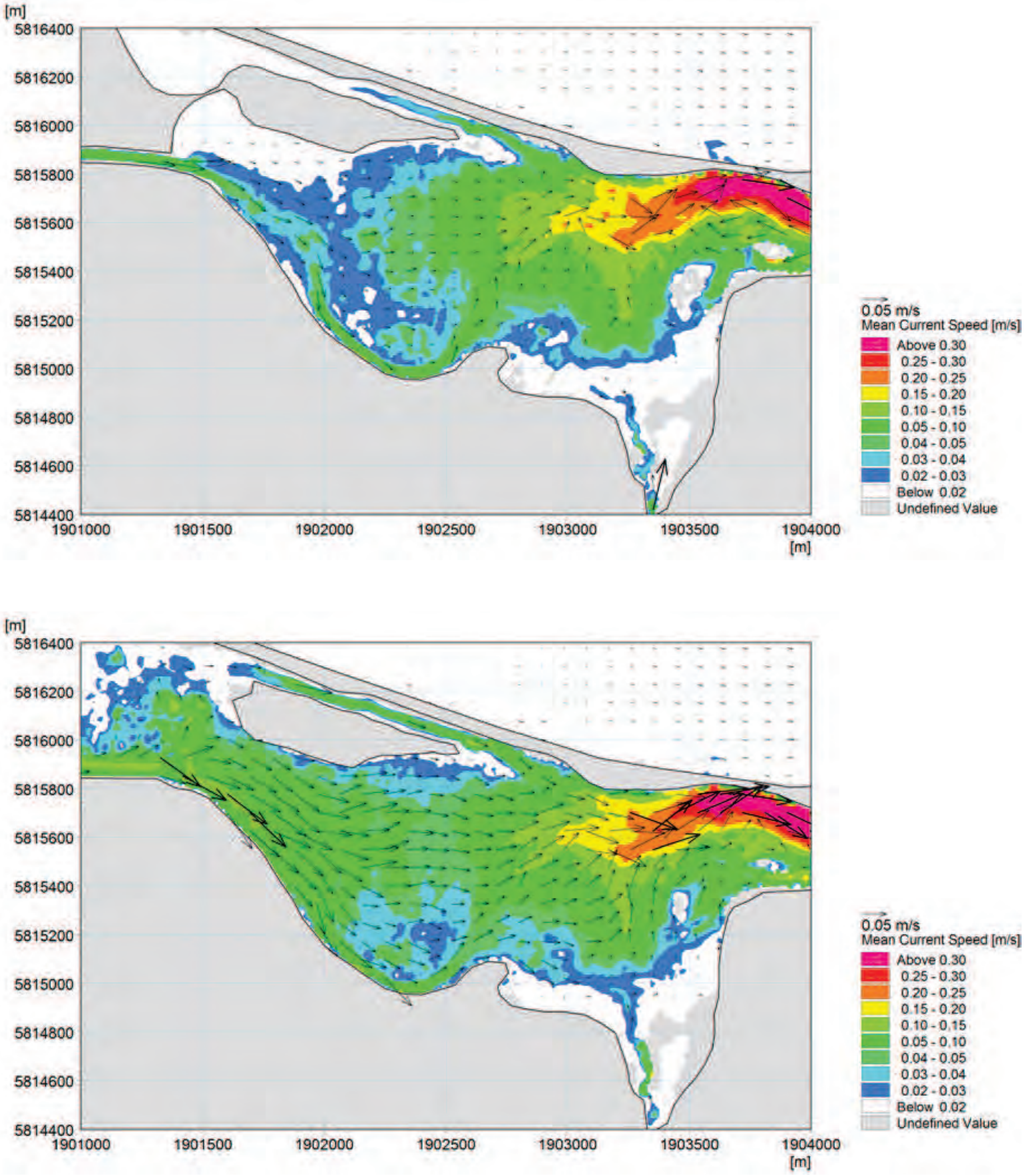


Figure 9-22 Mean tide depth averaged residual current and mean current speed for existing (top) and proposed situations (bottom) for mean river flow and neap/spring tidal cycle.

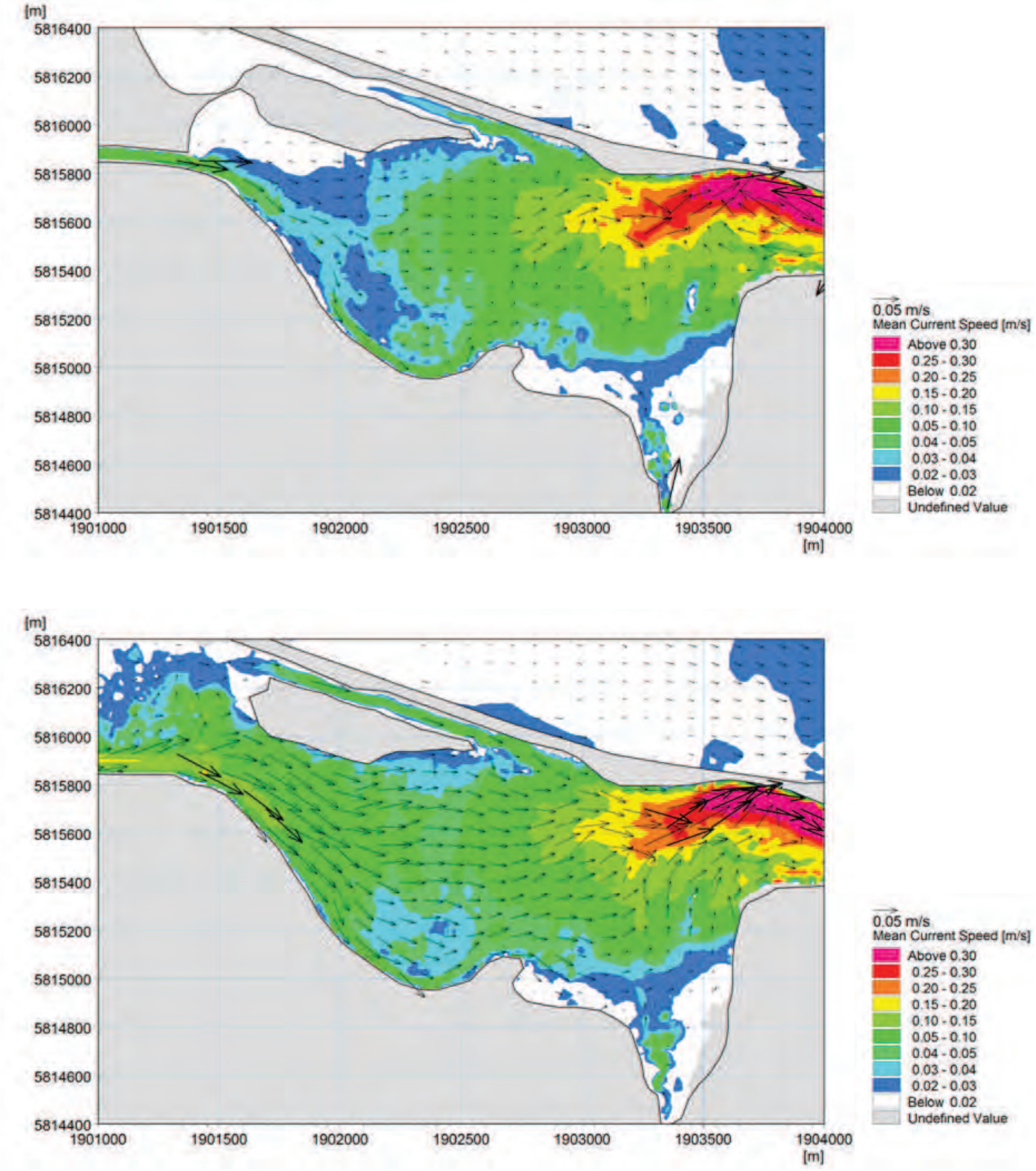


Figure 9-23 Spring tide depth averaged residual current and mean current speed for existing (top) and proposed situations (bottom) for mean river flow and neap/spring tidal cycle.

9.1.3 Maximum Extent of Salt Wedge

The maximum extent of the salt wedge has been determined for the existing situation and the proposed option for both river flow scenarios being considered by calculating the maximum salinity that occurs within the river at the water surface and the river bed over the 15-day simulation period. The comparisons of the maximum extent of the salt wedges at the water surface and river bed are presented in Figure 9-24 to Figure 9-27.

For the seven day five year low river flow scenario there is not a significant impact on the predicted extent of the salt wedge at the water surface, past the entrance of the new proposed re-diversion channel. There is not a significant impact on the predicted extent of the salt wedge at the river bed.

For the mean river flow scenario there is not a significant impact on the predicted extent of the salt wedge at the water surface, past the entrance of the new proposed re-diversion channel. The predicted maximum extent of the salt wedge at the river bed will move some 200 – 250 m upstream.

With the modelled bathymetry for the proposed option, the simulations indicate that there will be some overtopping from the river channel to the proposed channel through the adjacent wetland (i.e. the model shows highly saline water linking the river and new channel through this wet land). However this volume of water is minimal compared to what was transported into the channel from river through the proper proposed channel entrance. It is now proposed that a 1.3 m Moturiki Datum bund will be constructed to prevent any flow through the wetland from river to proposed channel, except for when river levels are elevated and freshwater will be able to overtop the bund.

At the request of the ecologists of the project team the peak extent of the salt wedge at spring tide has been extracted for the existing situation and proposed option for both river flow scenarios and is shown in Figure 9-28 and Figure 9-29. There is not a significant impact on the predicted salinities at the water surface, past the entrance of the new proposed re-diversion channel.

It should be acknowledged that the local 3D hydrodynamic model was shown to under predict the maximum extent of the salt wedge (see Appendix D), however the model still provides a relative prediction of the likely impact of the proposed option on the maximum extent of the salt wedge.

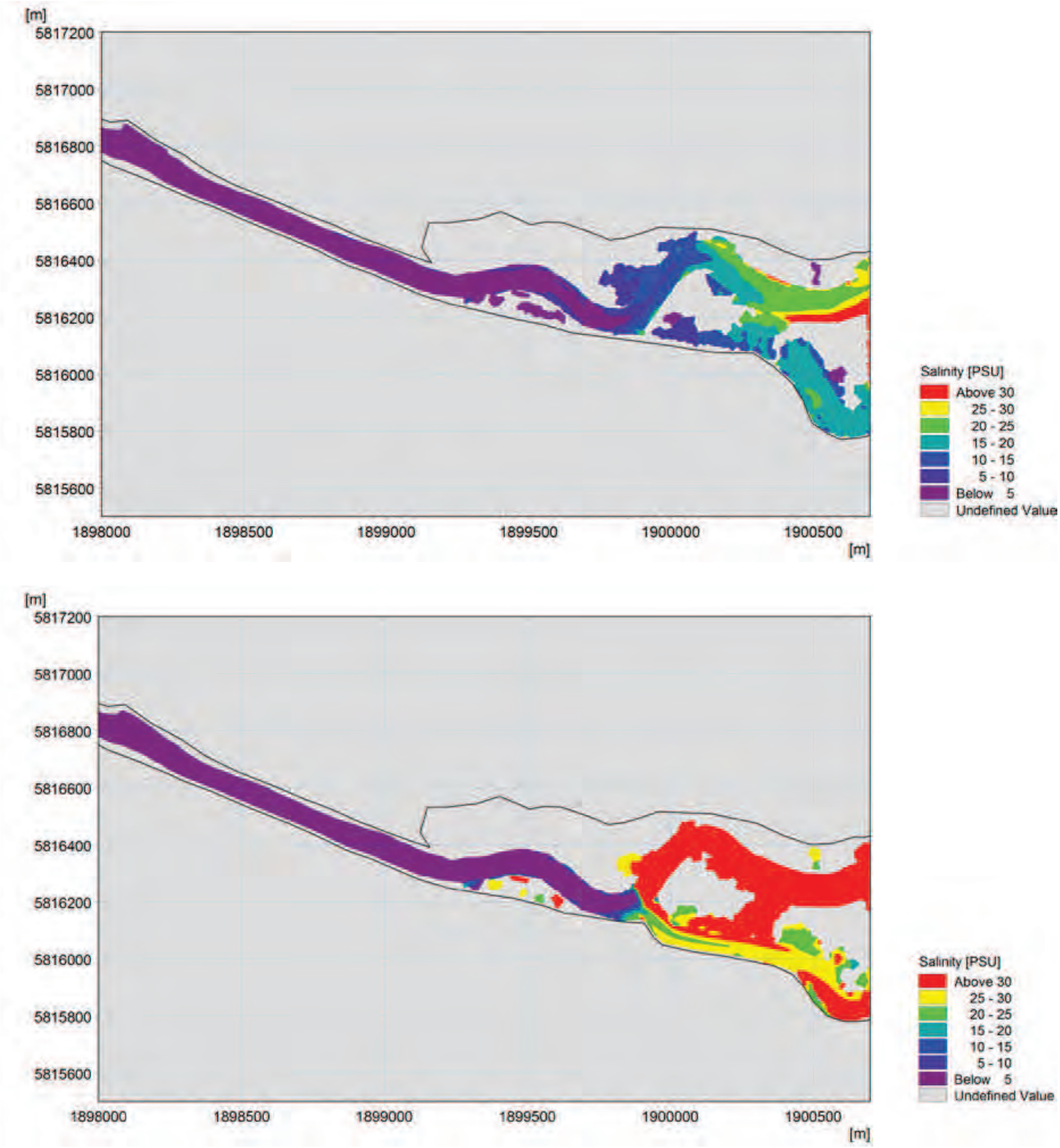


Figure 9-24 Maximum salinity for lower Kaituna River at water surface for existing (top) and proposed situations (bottom) for seven day five year low river flow and neap/spring tidal cycle.

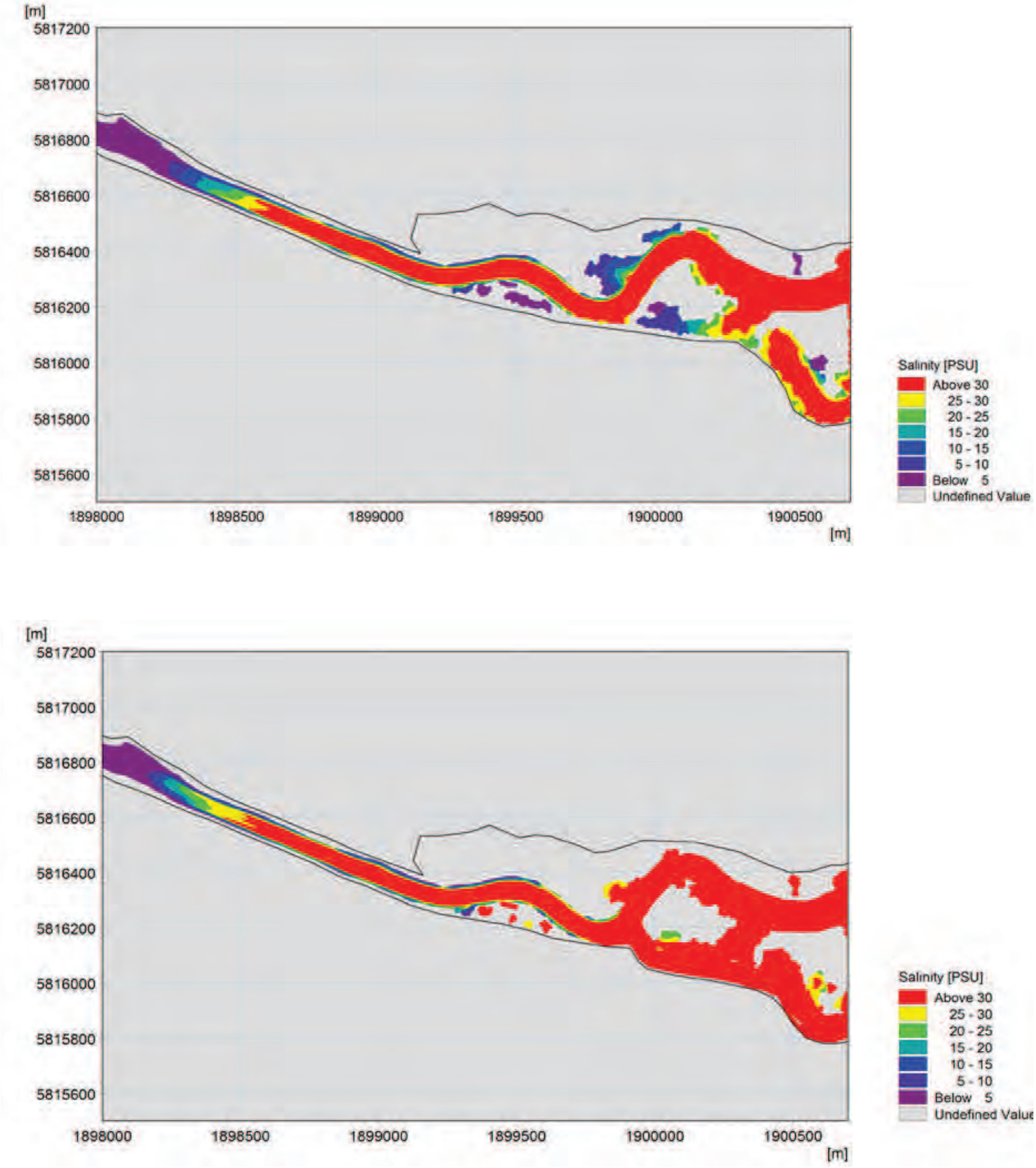


Figure 9-25 Maximum salinity for lower Kaituna River at bed for existing (top) and proposed situations (bottom) for seven day five year low river flow and neap/spring tidal cycle.

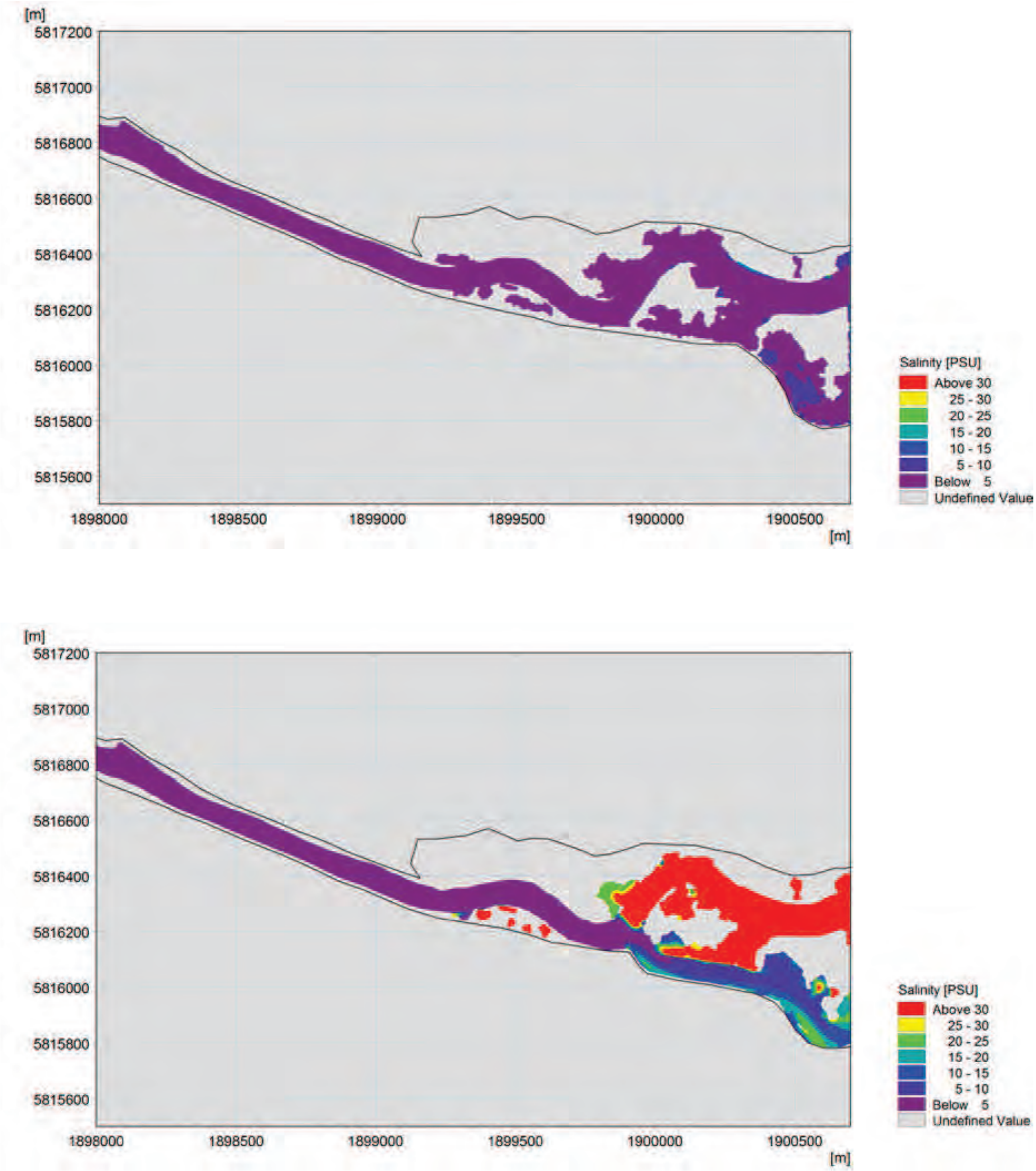


Figure 9-26 Maximum salinity for lower Kaituna River at water surface for existing (top) and proposed situations (bottom) for mean river flow and neap/spring tidal cycle.

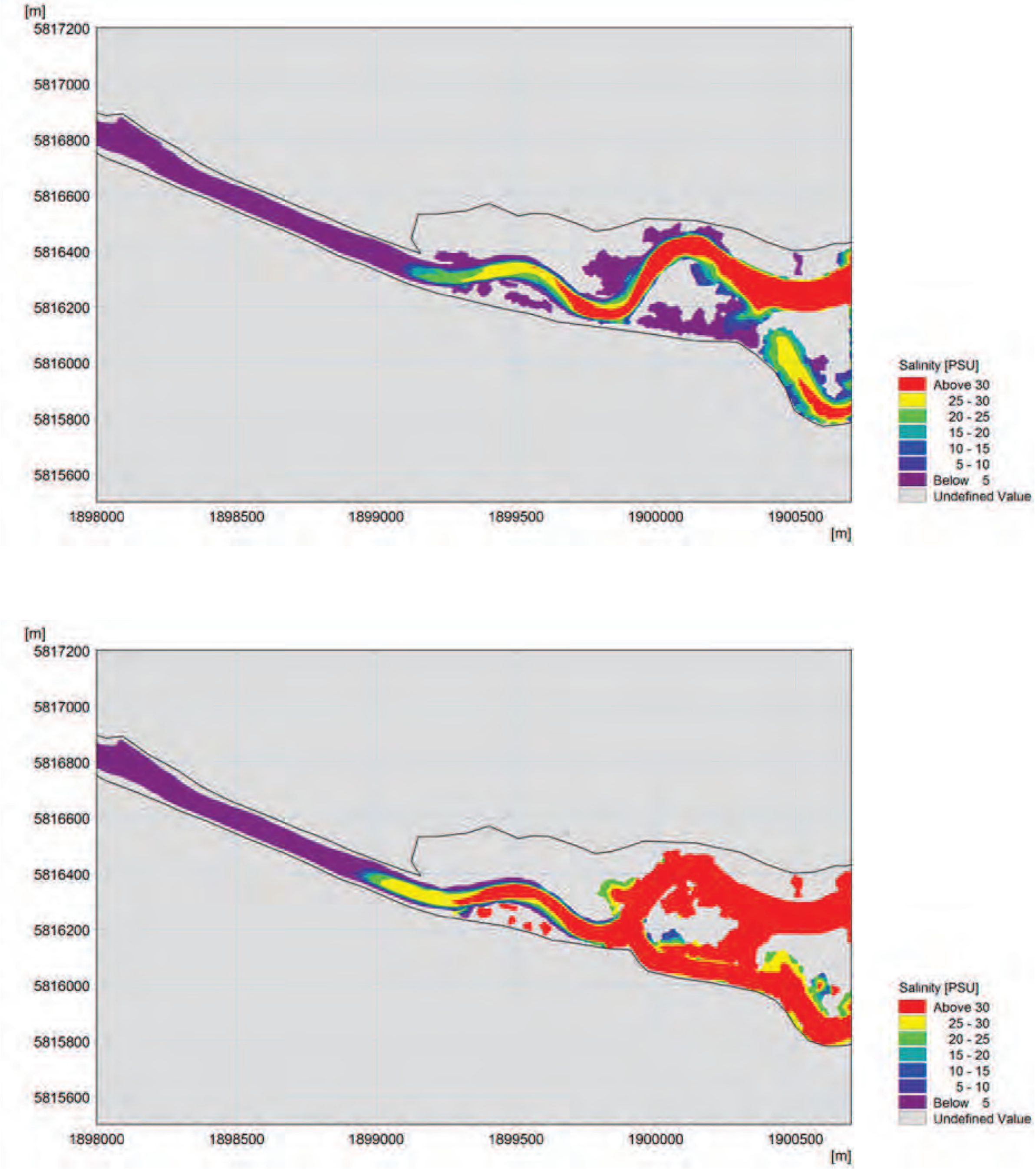


Figure 9-27 Maximum salinity for lower Kaituna River at bed for existing (top) and proposed situations (bottom) for mean river flow and neap/spring tidal cycle.

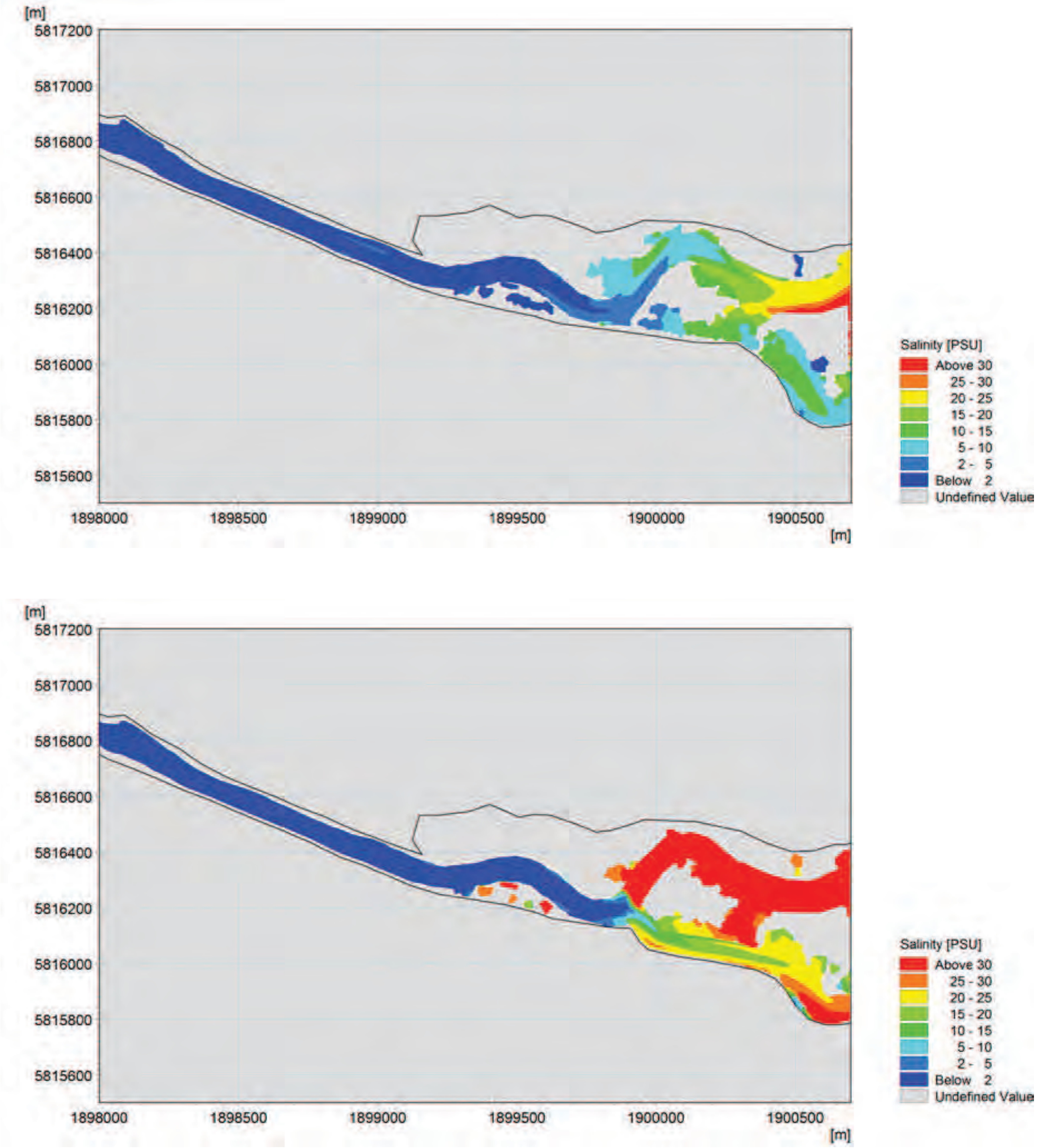


Figure 9-28 Peak spring tide salinity for lower Kaituna River at water surface for existing (top) and proposed situations (bottom) for seven day five year low river flow.

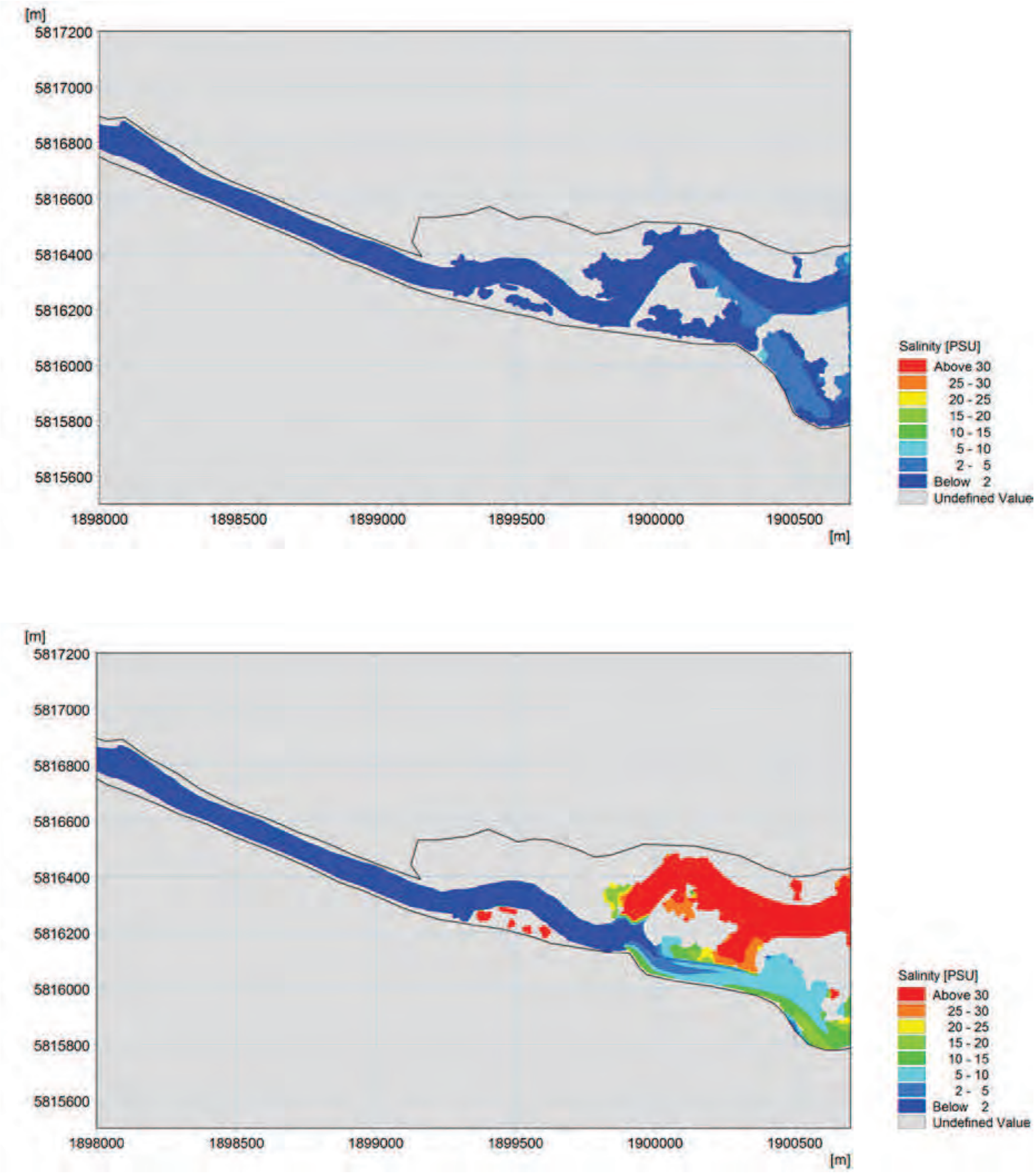


Figure 9-29 Peak spring tide salinity for lower Kaituna River at water surface for existing (top) and proposed situations (bottom) for mean river flow.

9.2 Effects on Water Levels and Intakes into Kaituna Wetland

There are currently three intakes which take water from the Kaituna River into the Kaituna Wetland. There is a concern that any reduction in water levels within the river as a result of the proposed option will have a negative impact on the wetland as less water will enter the wetland from the river for each tidal cycle. The Kaituna Wetland and location of intakes are presented in Figure 9-30.

Figure 9-30 Kaituna wetland and location of intakes.

The proposed option will slightly reduce water levels at the intake locations as shown in Figure 9-31, which presents water levels at intake 2 for the seven day five year low river flow scenario over the spring part of neap/spring tidal cycle. Peak water levels are reduced by approximately 5 cm.

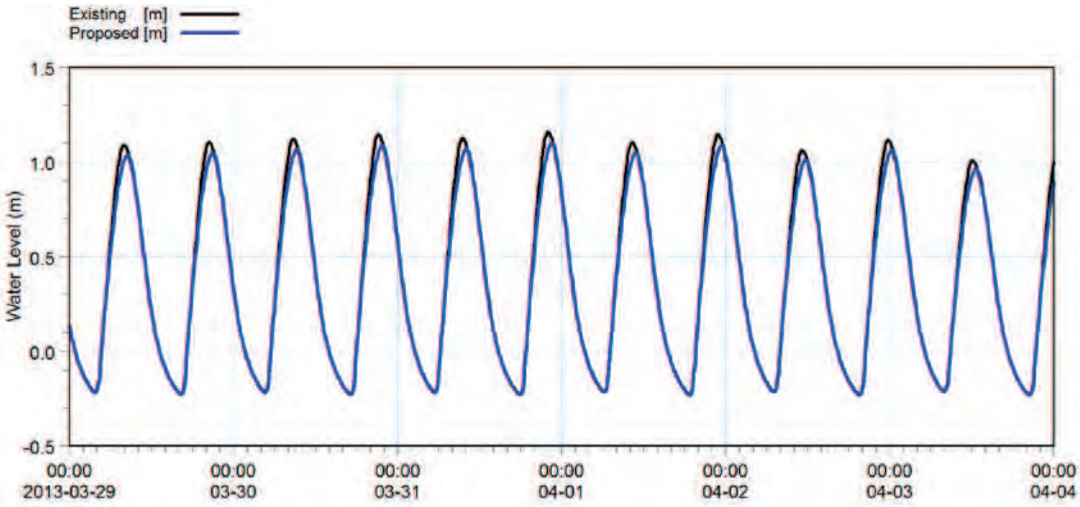


Figure 9-31 Comparison of predicted water levels (Moturiki Datum) at intake 2 to Kaituna Wetland for the seven day five year low river flow scenario over the spring part of neap /spring tidal cycle.

To assess the impact of the reduction in water levels at the water intakes a simplified model of the river and wetland was developed (see Appendix F). The volume of water which will enter through the intakes from the river to wetland was simulated for the existing situation and the proposed option for the seven day five year low river flow scenario over a spring tide as shown in Figure 9-32. The following was calculated from the model with regard to the volume of water through the intakes for the spring tide:

- For intake 1, the volume of water through the intake decreased from 15,500 m^3 for the existing situation to 13,800 m^3 for the proposed situation (a percentage decrease of 11.0%).
- For intake 2, the volume of water through the intake decreased from 87,900 m^3 for the existing situation to 79,600 m^3 for the proposed situation (a percentage decrease of 9.4%).
- For intake 3, the volume of water through the intake decreased from 1,900 m^3 for the existing situation to 1,400 m^3 for the proposed situation (a percentage decrease of 26.3%).
- The total volume of water through the intakes decreased from 105,300 m^3 for the existing situation to 94,800 m^3 for the proposed situation (a percentage decrease of 10.0% and a total decrease in the volume of water through the intakes of 10,500 m^3).

To compensate for the reduction of water levels and associated flow to the wetland (10,500 m^3 for spring tide) as a result of the proposed option, simulations were carried out to assess the required dimensions of an additional intake to ensure the same volume of water will enter the wetland for a spring tide. It was predicted that an additional flap gated culvert at intake 2 with a diameter of 0.9 m, invert of -0.5 m (Moturiki Datum) and length 10 m would be required. This would allow an additional 13,300 m^3 to the wetland for a spring tide with the proposed option.

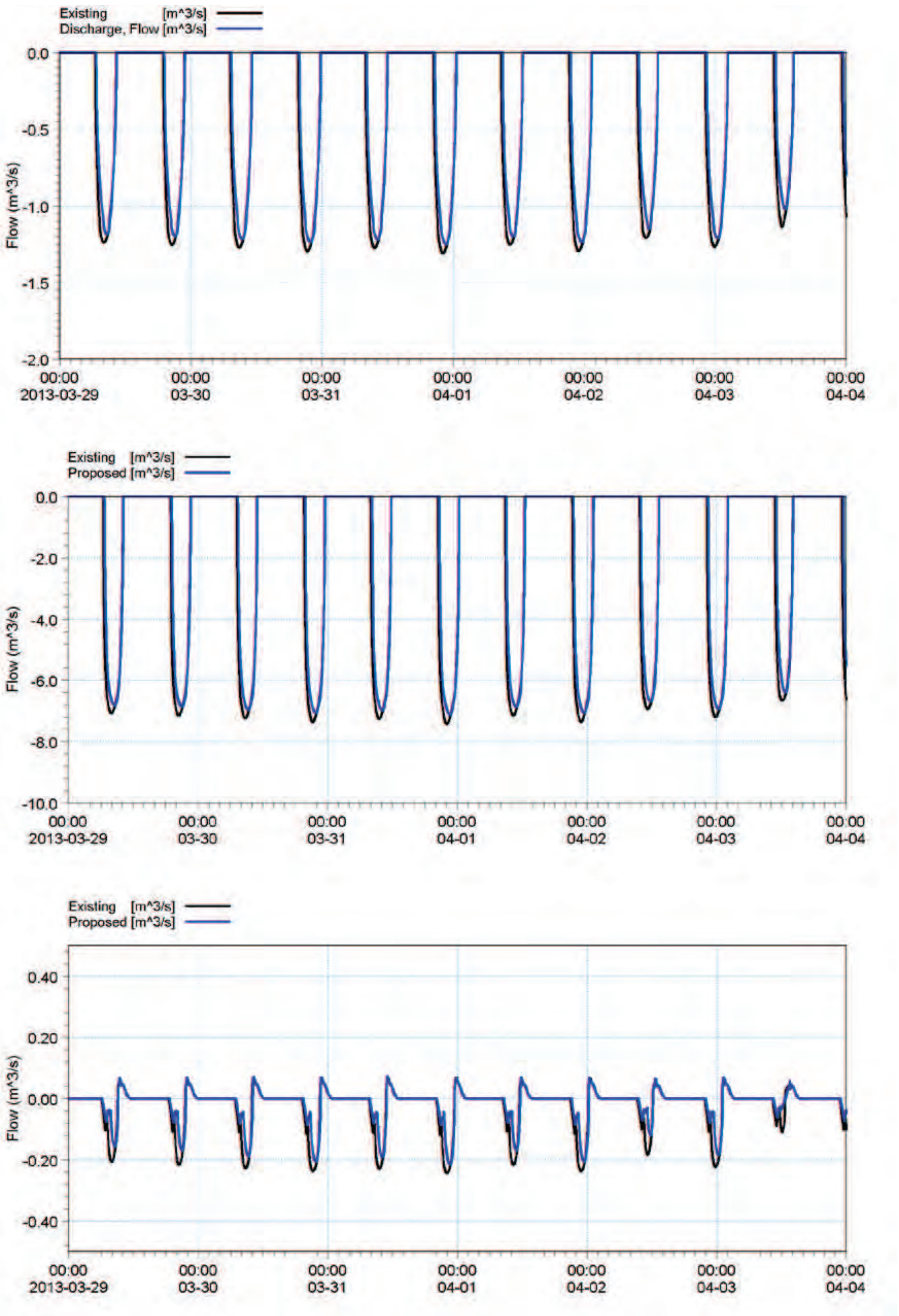


Figure 9-32 Flow from the river to the wetland through intake 1 (top), intake 2 (middle) and intake 3 (bottom) for the seven day five year low river flow scenario over a spring tide. Note negative flow is flow from river to the Kaituna wetland.

9.3 Effects on Salinity at Titchmarsh Intake.

Alan Titchmarsh has an irrigation and stock water intake which extracts water from the top 0.3 m of the water column at the location indicated in Figure 9-33. He has acknowledged that he already has a salinity problem he has to manage (i.e. the salt wedge is able to propagate up to the intake), especially during low flows, which he does so but extracting from the river at the right time to suit the tide (per comms, Steve Everitt, Waterline).

To assess what impact the proposed option will have on the propagation of the salt wedge up to the Titchmarsh intake, salinities have been extracted from for seven day five year low and mean river flow scenarios for the existing situation and the proposed option at the intake location at appropriate locations within the water column. The predicted salinities are presented in Figure 9-34.

Figure 9-33 Location of Alan Titchmarsh water intake.

The seven day five year low flow scenario is the worst case scenario for the impact on salinities at the Titchmarsh intake. For this scenario the effect of the proposed option will be to increase the salinity at the intake around high tide, however the duration of this increase is only slightly longer than for the existing situation.

BoPRC propose that in order for Alan Titchmarsh to better manage the extraction of water from the river, they will install a salinity monitor in the river at the intake to ensure that water is not extracted during periods with high salinities. Other mitigation options may also be considered, such as creating additional storage for his stock water. However this will depend on his demand. This mitigation will also help during period of mean river flow when the proposed option is predicted to increase the salinity from 0 PSU to 3 PSU over a four hour period during spring tide.

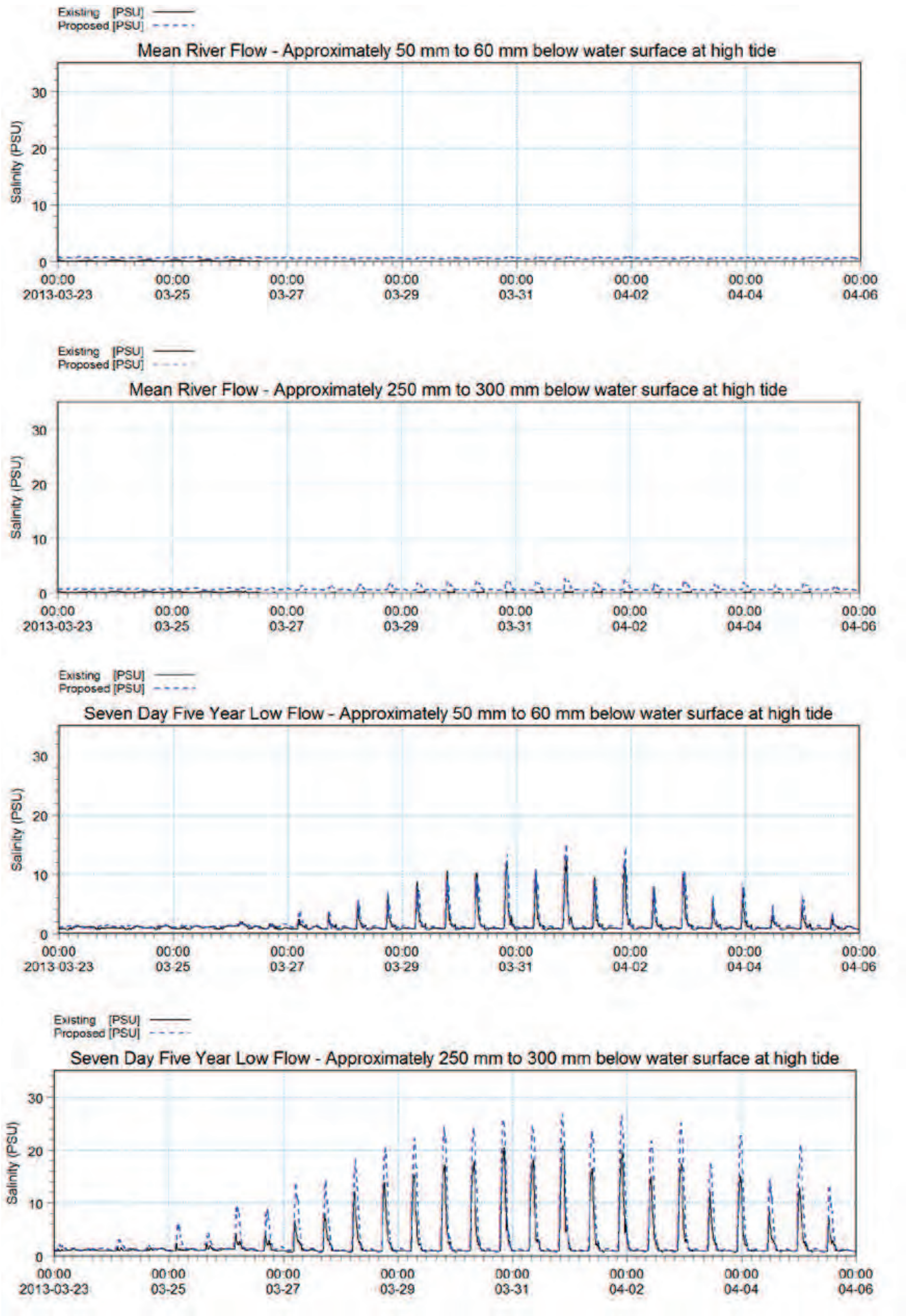


Figure 9-34 Predicted salinities for salinities at Titchmarsh intake for existing situation and proposed option at appropriate locations within the water column for seven day five year low and mean river flow scenarios.

9.4 Blue-Green Algae, Shellfish Collection and Bathing Suitability Assessments

A qualitative assessment of the impact of the additional freshwater from the proposed option on the risk of a blue-green algae bloom, shellfish collection and bathing suitability within the estuary has been carried out.

The behaviour of blue-green algae has been simulated using chl.*a* as a proxy for blue-green algae (see Section 3.7). The impacts were assessed at one site within the lower estuary where contact recreation is likely to occur (see Figure 9-35).

For contact recreation 15,000 cells/ml is considered critical for blue-green algae (per comms, Stephen Park, BoPRC). This value has been used as the threshold criteria for this study.

The water quality parameter selected to assess the impact on shellfish collection was faecal coliforms and the impacts were assessed at one site (see Figure 9-35) within the lower estuary where shellfish beds are known to exist (Gaborit-Haverkort, 2012). It should be noted that the accumulation of faecal coliforms within shellfish has not been accounted for in this study, only the water quality in the vicinity of the shellfish has been assessed.

For shellfish gathering, there are two relevant criteria in the Ministry for Environment Guidelines. The first criterion is that faecal coliform concentration should not exceed 14 faecal coliforms per 100 ml more than 50% of the time. In addition, the concentrations should only exceed 43 faecal coliforms per 100 ml 10% of the time (MfE, 2002).

The parameter used to assess bathing water suitability was Enterococci and the impacts on Enterococci were assessed at the boat ramp location within the estuary (see Figure 9-35). This location is representative of where the majority of swimming occurs within the estuary.

For bathing water, the water quality criterion is 280 Enterococci per 100 ml in water bodies (MfE, 2002).

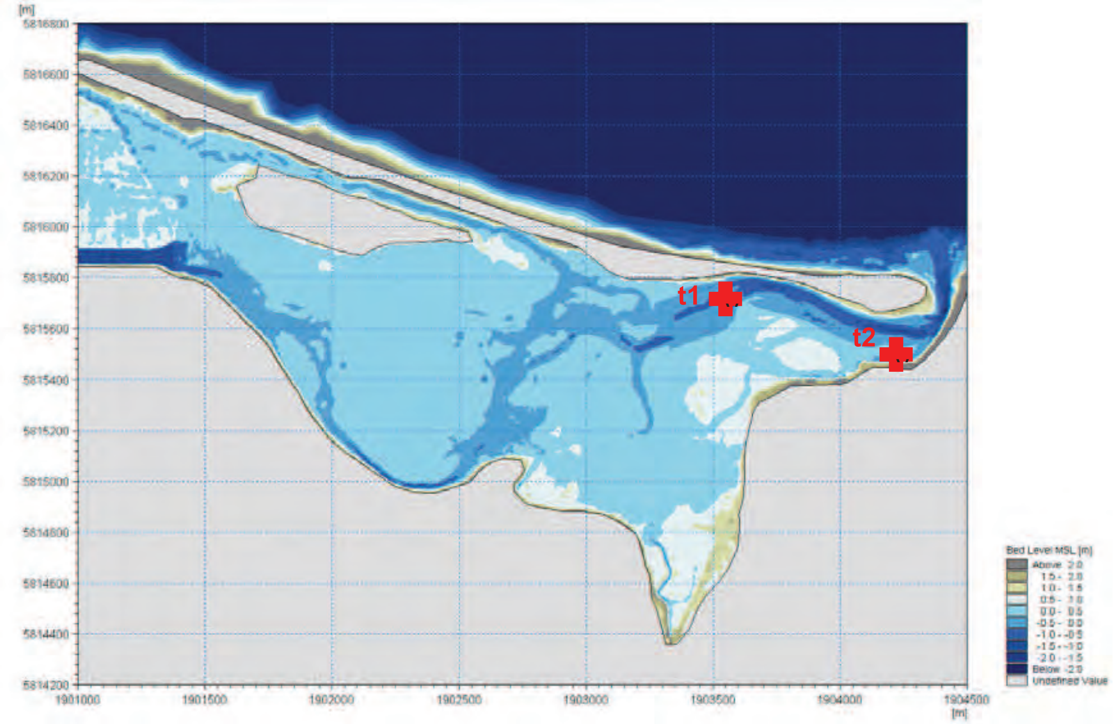


Figure 9-35 Locations were impact of proposed option has been assessed for blue-green algae, shellfish collection (t1) and bathing water suitability (t2).

Details of the development and validation of the bacteria and chl.*a* water quality models can be found in Appendix F.

To assess whether the proposed option will increase the risk of non-compliance with New Zealand guidelines for blue-green algae, bathing and shellfish collection, a statistical approach was taken where a number of simulations with different river flows were carried out to assess the resulting dilution of blue-green algae and bacteria within the estuary.

The predicted dilutions have then been assigned probabilities which were then related to actual blue-green algae and bacteria concentration from the river to provide the probability of exceeding the guideline values within the estuary.

It is important to note that this assessment compares only the bacterial load from the Kaituna River and main drains. It excludes internal estuary sources of bacteria such as waterfowl, septic tank leachate, direct run-off from farmland etc. The model also uses a conservative rate of bacterial decay by assuming no UV light (bacteria is killed by UV rays from the sun during the day). For both these reasons the percentage differences shown below between the existing and proposed situation are higher than they would be if these factors had been incorporated. Also worthy of note is the long-term downward trend in bacterial concentration in the lower Kaituna River from a median of approximately 1,000 FCU/100ml in 1989 to a median of 201 in the 2007-2008 period (Park, 2010). This downward trend appears to have continued in recent years and may be expected to continue further with changes to Fonterra's dairy farm requirements for riparian fencing (mandatory for all suppliers in the catchment from December 2013) and improvements to the way effluent is discharged.

9.4.1 Assessing Dilution of Blue-Green Algae and Bacteria within Estuary

The dilution of algae and bacteria entering the estuary from the river depends on tidal exchange as well as the inflow from the Kaituna River. Over a long period there is a large variation in river flows and tidal range. Therefore to assess the range of dilution that will occur for algae and bacteria within the estuary, a number of 15 day simulations (to cover neap/ spring tidal cycle) were carried out with different constant river flows (representing different ranges of discharge within lower Kaituna River) and the resulting dilution within the estuary was calculated. Conservative die off / decay rates have been included for the bacteria modelling (see Appendix F).

The discharge frequency distribution was calculated for the Kaituna River (at Te Matai bridge) for a ten year period (1990 – 2010) The river flow was analysed and the resulting frequency distribution is presented in Table 9-6 and Figure 9-36. This indicates how often a given flow is exceeded in the discharge data set recorded at Te Matai Bridge.

Table 9-6 Frequency distribution of flow (m^3/s) in Kaituna River at Te Matai Bridge (1990-2010)

Occurrence (%)	Flow (m^3/s)
100	12
99	22
95	23
90	25
80	27
70	28
60	30
50	32
40	34
30	36
20	39
10	45
5	51
1	70
0.5	86
0	>257

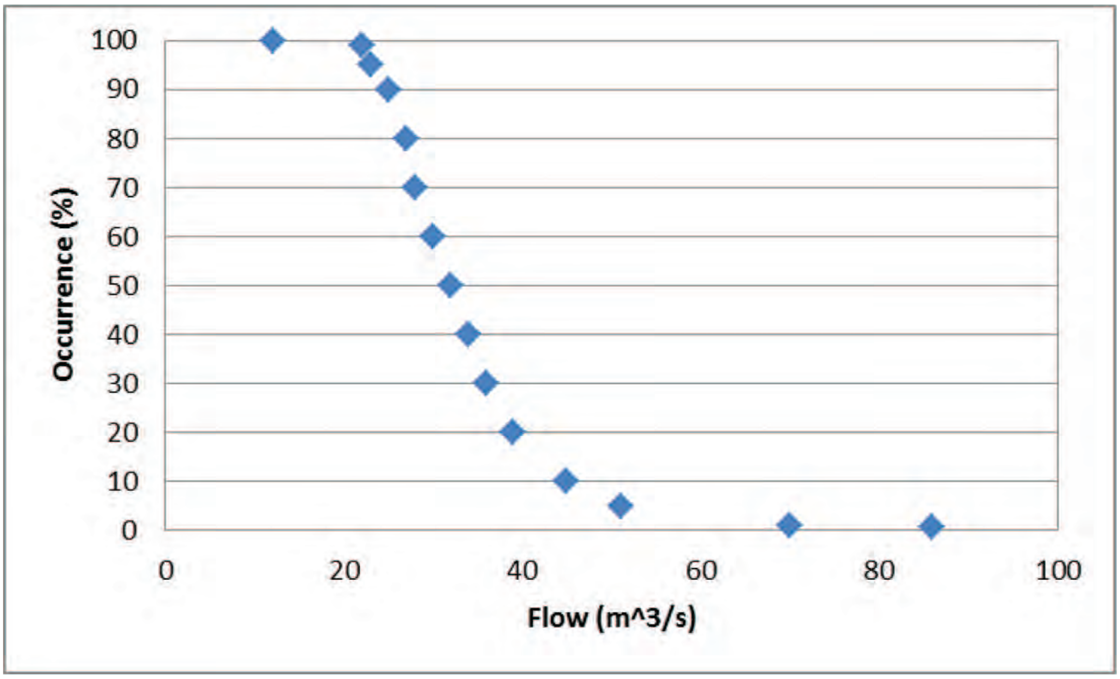


Figure 9-36 Frequency distribution of flow (m^3/s) in Katina River at Te Matai (1990-2010).

For the blue-green assessment, the frequency distribution was based only on the period of the year from which sampling for algae were carried out March 2005 to May 2010. The river flow analysis for this period is presented in Table 9-7 and Figure 9-37.

Table 9-7 Frequency distribution of flow (m^3/s) in Kaituna River at Te Matai Bridge during blue-green algae sampling periods.

Occurrence (%)	Flow (m^3/s)
100	13
99	21
95	23
90	25
80	26
70	28
60	31
50	32
40	34
30	37
20	39
10	42
5	47
1	51
0.5	62
0	>156

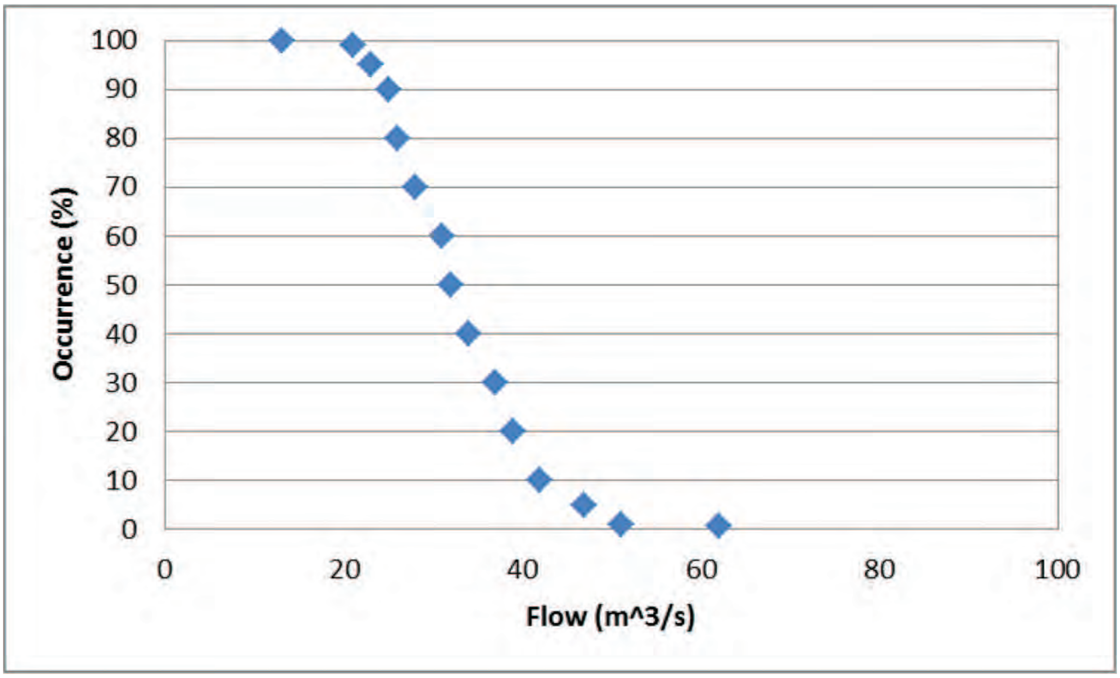


Figure 9-37 Frequency distribution of flow (m^3/s) in Katina River at Te Matai – algae sampling periods.

Based on the calculated frequency distribution, five different constant Kaituna river flows were selected (see Table 9-8). Each of these flows represents a flow interval which occurs for a certain percentage of time. The corresponding constant flow included in simulations for Waiari Stream and Raparapahoe Canal is also shown in Table 9-8. These were calculated by determining the corresponding exceedance flow compared with the Kaituna River flow.

Table 9-8 Discharges used for simulations.

Kaituna River Flow Q (m^3/s)	Representing the interval of Q (m^3/s)	Percentage of Full Year Period	Percentage of Algae Sampling Period	Waiari Stream Flow (m^3/s)	Raparapahoe Canal Flow (m^3/s)
51	Q > 51	5	3	5.5	4.4
39	51 > Q < 35	30	32	4.3	2.5
32	35 > Q < 30	25	20	3.7	1.5
28	30 > Q < 26	24	25	3.4	1.1
26	Q < 26	16	20	3.2	0.9

Each of these discharges were run for both the existing situation and the proposed option with a constant inflow over a period of 15 days (excluding a two day warm up period) with a tidal ocean boundary condition covering a neap / spring tidal cycle. The dilution within the estuary was then determined at selected locations for the constant river flow with a constant inflow concentration applied at the river upstream boundary.

The concentrations that were used for boundary conditions and inflows to river and estuary are presented in Table 9-9. The river concentrations were calculated by averaging values of all samples collected at the Te Matai, while the drain concentrations were calculated by taking the average of all samples collected from selected drains within river and estuary. Due to the fact there was no chl.*a* data collected within the drains, chl.*a* concentrations for the drains were calculated using the equation described in Appendix F.

Table 9-9 Concentrations used for blue-green algae and bacteria simulations.

Location	Chl.*a* (mg/m^3)	Faecal coliforms (counts / 100ml)	Enterococci (counts / 100ml)
River	3.6	820	170
Drains	6.9	1100	580
Open Ocean	0	0	0

For each of the simulations the percentage of time that a given dilution was achieved over the 15 day simulation was calculated as shown in Table 9-10 to Table 9-15 (and Figure 9-38 to Figure 9-43). The absolute occurrence of a given dilution is determined by weighting the results by the occurrence of the associated flow interval being simulated.

The cumulative durations where a given dilution can be expected to be exceeded can be calculated by summing the percentage duration of each discharge multiplied by the percentage of time that discharge is exceeded. These values are reported in the last columns of Table 9-10 to Table 9-15.

It should be noted that the contribution from the drains can reduce dilution of chl.*a* and bacteria within the estuary, which will result in higher concentrations of chl.*a* and bacteria compared with if the contribution from the drains was not included.

Table 9-10 Existing situation – frequency of dilution for blue-green algae at location in lower estuary.

Dilution	Percentage of Time During 15 day Simulation where Dilution is Exceeded					Percentage of Time Represented by Discharge					Percentage of Time Exceeding Dilution (%)
	26 m^3/s	28 m^3/s	32 m^3/s	39 m^3/s	51 m^3/s	26 m^3/s	28 m^3/s	32 m^3/s	39 m^3/s	51 m^3/s	
500	0.00	0.00	0.00	0.00	0.00	0.20	0.25	0.2	0.32	0.03	0.0
200	0.00	0.00	0.00	0.00	0.00	0.20	0.25	0.2	0.32	0.03	0.0
100	0.00	0.00	0.00	0.00	0.00	0.20	0.25	0.2	0.32	0.03	0.0
50	0.00	0.00	0.00	0.00	0.00	0.20	0.25	0.2	0.32	0.03	0.0
25	3.02	0.50	0.00	0.00	0.00	0.20	0.25	0.2	0.32	0.03	0.7
20	7.76	3.39	0.00	0.00	0.00	0.20	0.25	0.2	0.32	0.03	2.4
15	13.05	9.84	2.00	0.00	0.00	0.20	0.25	0.2	0.32	0.03	5.5
10	22.04	19.44	12.51	4.90	0.04	0.20	0.25	0.2	0.32	0.03	13.3
5	41.88	39.47	33.24	26.71	20.36	0.20	0.25	0.2	0.32	0.03	34.1
4	47.54	45.89	40.75	35.59	30.20	0.20	0.25	0.2	0.32	0.03	41.4
3	54.33	52.26	47.67	43.51	39.59	0.20	0.25	0.2	0.32	0.03	48.6
2	76.04	70.38	59.78	54.24	50.36	0.20	0.25	0.2	0.32	0.03	63.6
1.5	86.24	84.78	79.31	63.79	58.25	0.20	0.25	0.2	0.32	0.03	76.5
1.25	92.96	91.07	86.21	76.73	64.06	0.20	0.25	0.2	0.32	0.03	85.1
1.1	99.27	98.80	91.25	87.89	72.17	0.20	0.25	0.2	0.32	0.03	93.1
1	100.00	100.00	100.00	100.00	100.00	0.20	0.25	0.2	0.32	0.03	100.0

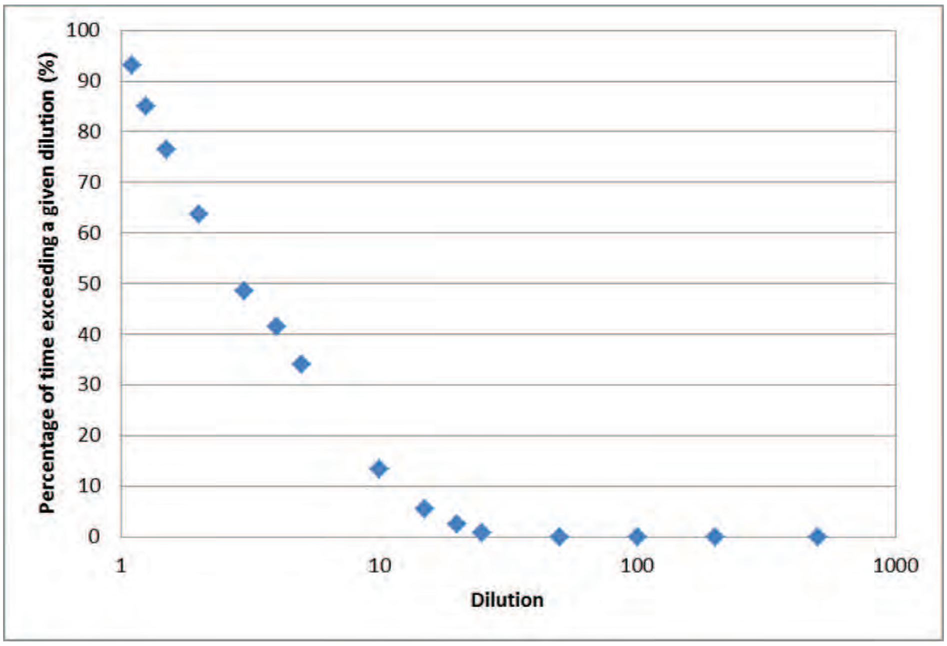


Figure 9-38 Existing situation – frequency of dilution for blue-green algae at location in lower estuary. Note log scale on x-axis.

Table 9-11 Proposed option – frequency of dilution for blue-green algae at location in lower estuary.

Dilution	Percentage of Time During 15 day Simulation where Dilution is Exceeded					Percentage of Time Represented by Discharge					Percentage of Time Exceeding Dilution (%)
	26 m^3/s	28 m^3/s	32 m^3/s	39 m^3/s	51 m^3/s	26 m^3/s	28 m^3/s	32 m^3/s	39 m^3/s	51 m^3/s	
500	0.00	0.00	0.00	0.00	0.00	0.20	0.25	0.2	0.32	0.03	0.0
200	0.00	0.00	0.00	0.00	0.00	0.20	0.25	0.2	0.32	0.03	0.0
100	0.00	0.00	0.00	0.00	0.00	0.20	0.25	0.2	0.32	0.03	0.0
50	17.88	8.20	1.17	1.61	0.83	0.20	0.25	0.2	0.32	0.03	6.4
25	26.62	25.23	24.24	20.19	5.59	0.20	0.25	0.2	0.32	0.03	23.1
20	28.12	26.98	26.20	24.86	12.13	0.20	0.25	0.2	0.32	0.03	25.9
15	29.67	28.85	27.62	27.19	21.35	0.20	0.25	0.2	0.32	0.03	28.0
10	31.74	31.33	29.59	29.03	25.57	0.20	0.25	0.2	0.32	0.03	30.2
5	39.08	35.71	34.00	32.04	29.86	0.20	0.25	0.2	0.32	0.03	34.7
4	44.68	38.64	35.83	33.28	31.24	0.20	0.25	0.2	0.32	0.03	37.4
3	54.96	45.26	39.99	36.18	33.51	0.20	0.25	0.2	0.32	0.03	42.9
2	79.73	68.11	55.38	44.63	38.82	0.20	0.25	0.2	0.32	0.03	59.5
1.5	87.17	83.26	78.86	64.92	45.17	0.20	0.25	0.2	0.32	0.03	76.1
1.25	92.45	88.21	85.63	80.40	61.31	0.20	0.25	0.2	0.32	0.03	85.2
1.1	97.60	92.16	89.54	86.15	77.81	0.20	0.25	0.2	0.32	0.03	90.4
1	100.00	100.00	100.00	100.00	100.00	0.20	0.25	0.2	0.32	0.03	100.0

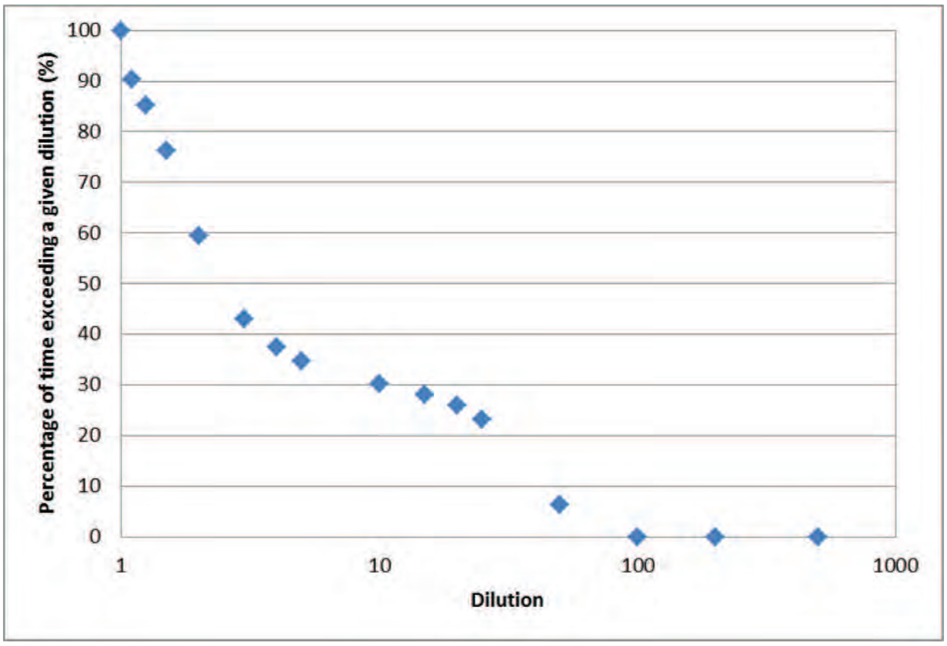


Figure 9-39 Proposed situation – frequency of dilution for blue-green algae at location in lower estuary. Note log scale on x-axis.

Table 9-12 Existing situation – frequency of dilution for faecal coliforms at location in lower estuary.

Dilution	Percentage of Time During 15 day Simulation where Dilution is Exceeded					Percentage of Time Represented by Discharge					Percentage of Time Exceeding Dilution (%)
	26 m^3/s	28 m^3/s	32 m^3/s	39 m^3/s	51 m^3/s	26 m^3/s	28 m^3/s	32 m^3/s	39 m^3/s	51 m^3/s	
500	0.00	0.00	0.00	0.00	0.00	0.16	0.24	0.25	0.3	0.05	0.0
250	0.39	0.00	0.00	0.00	0.00	0.16	0.24	0.25	0.3	0.05	0.1
200	2.02	0.00	0.00	0.00	0.00	0.16	0.24	0.25	0.3	0.05	0.3
150	6.79	2.28	0.00	0.00	0.00	0.16	0.24	0.25	0.3	0.05	1.6
100	14.10	10.10	2.56	0.05	0.00	0.16	0.24	0.25	0.3	0.05	5.3
75	19.69	16.84	9.37	2.73	0.00	0.16	0.24	0.25	0.3	0.05	10.4
50	26.77	24.63	19.50	11.39	2.64	0.16	0.24	0.25	0.3	0.05	18.6
37.5	33.84	31.29	26.88	19.97	10.87	0.16	0.24	0.25	0.3	0.05	26.2
25	43.18	41.65	38.35	32.72	24.96	0.16	0.24	0.25	0.3	0.05	37.6
22.5	44.82	43.50	40.40	35.29	28.59	0.16	0.24	0.25	0.3	0.05	39.7
20	46.75	45.30	42.39	37.81	31.94	0.16	0.24	0.25	0.3	0.05	41.9
17.5	48.76	47.32	44.53	40.39	35.20	0.16	0.24	0.25	0.3	0.05	44.2
15	50.94	49.64	46.78	43.10	38.77	0.16	0.24	0.25	0.3	0.05	46.6
12.5	53.64	52.36	49.51	46.06	42.46	0.16	0.24	0.25	0.3	0.05	49.5
10	57.99	56.50	53.57	49.95	46.27	0.16	0.24	0.25	0.3	0.05	53.5
7.5	64.51	63.02	59.82	55.69	52.01	0.16	0.24	0.25	0.3	0.05	59.7
5	83.12	79.94	70.12	64.48	60.00	0.16	0.24	0.25	0.3	0.05	72.4
4.5	86.65	84.49	76.71	67.39	62.31	0.16	0.24	0.25	0.3	0.05	76.7
4	90.47	89.00	84.35	70.89	64.97	0.16	0.24	0.25	0.3	0.05	81.4
3.5	96.91	94.62	91.87	78.57	69.10	0.16	0.24	0.25	0.3	0.05	88.2
3	100.00	100.00	99.58	92.82	76.05	0.16	0.24	0.25	0.3	0.05	96.5
2.5	100.00	100.00	100.00	100.00	96.64	0.16	0.24	0.25	0.3	0.05	99.8
2	100.00	100.00	100.00	100.00	100.00	0.16	0.24	0.25	0.3	0.05	100.0
1.75	100.00	100.00	100.00	100.00	100.00	0.16	0.24	0.25	0.3	0.05	100.0
1.5	100.00	100.00	100.00	100.00	100.00	0.16	0.24	0.25	0.3	0.05	100.0
1.38	100.00	100.00	100.00	100.00	100.00	0.16	0.24	0.25	0.3	0.05	100.0
1.25	100.00	100.00	100.00	100.00	100.00	0.16	0.24	0.25	0.3	0.05	100.0
1.18	100.00	100.00	100.00	100.00	100.00	0.16	0.24	0.25	0.3	0.05	100.0
1.1	100.00	100.00	100.00	100.00	100.00	0.16	0.24	0.25	0.3	0.05	100.0

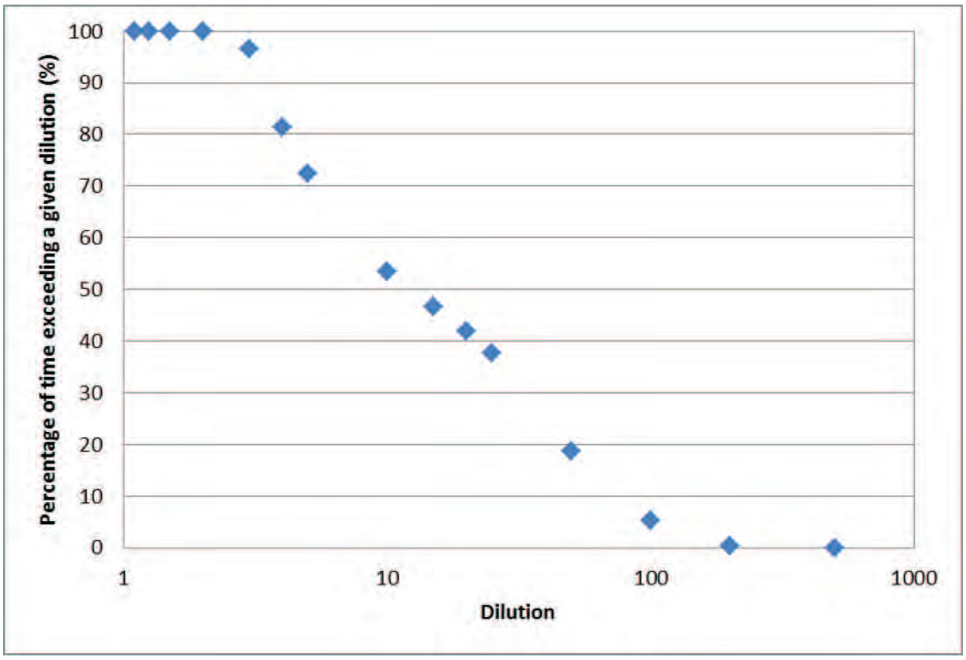


Figure 9-40 Existing situation – frequency of dilution for faecal coliforms at location in lower estuary. Note log scale on x-axis.

Table 9-13 Proposed option – frequency of dilution for faecal coliforms at location in lower estuary.

Dilution	Percentage of Time During 15 day Simulation where Dilution is Exceeded					Percentage of Time Represented by Discharge					Percentage of Time Exceeding Dilution (%)
	26 m^3/s	28 m^3/s	32 m^3/s	39 m^3/s	51 m^3/s	26 m^3/s	28 m^3/s	32 m^3/s	39 m^3/s	51 m^3/s	
500	0.04	0.00	0.00	0.00	0.00	0.16	0.24	0.25	0.3	0.05	0.0
250	18.55	12.39	4.43	2.73	1.55	0.16	0.24	0.25	0.3	0.05	7.9
200	21.48	18.70	9.97	3.85	2.77	0.16	0.24	0.25	0.3	0.05	11.7
150	23.66	21.77	19.00	11.31	4.06	0.16	0.24	0.25	0.3	0.05	17.4
100	25.73	24.56	24.21	20.46	7.87	0.16	0.24	0.25	0.3	0.05	22.6
75	27.04	26.07	25.64	23.89	13.74	0.16	0.24	0.25	0.3	0.05	24.8
50	29.08	28.19	27.02	26.64	21.10	0.16	0.24	0.25	0.3	0.05	27.2
37.5	30.29	29.44	28.16	27.78	23.27	0.16	0.24	0.25	0.3	0.05	28.4
25	32.49	31.72	30.10	29.21	25.99	0.16	0.24	0.25	0.3	0.05	30.4
22.5	33.08	32.25	30.74	29.54	26.50	0.16	0.24	0.25	0.3	0.05	30.9
20	33.70	32.93	31.51	29.95	27.02	0.16	0.24	0.25	0.3	0.05	31.5
17.5	34.58	33.68	32.17	30.40	27.73	0.16	0.24	0.25	0.3	0.05	32.2
15	36.10	34.51	32.92	30.94	28.70	0.16	0.24	0.25	0.3	0.05	33.0
12.5	38.93	35.67	33.93	31.78	29.61	0.16	0.24	0.25	0.3	0.05	34.3
10	43.81	38.02	35.60	32.87	30.79	0.16	0.24	0.25	0.3	0.05	36.4
7.5	48.81	43.69	38.51	35.29	32.81	0.16	0.24	0.25	0.3	0.05	40.1
5	70.63	53.02	47.37	40.55	36.87	0.16	0.24	0.25	0.3	0.05	49.9
4.5	78.27	60.79	49.86	43.31	38.22	0.16	0.24	0.25	0.3	0.05	54.5
4	82.30	70.87	56.44	46.34	40.14	0.16	0.24	0.25	0.3	0.05	60.2
3.5	86.18	79.62	67.93	49.78	42.28	0.16	0.24	0.25	0.3	0.05	66.9
3	89.91	85.44	79.57	60.79	46.38	0.16	0.24	0.25	0.3	0.05	75.3
2.5	95.08	90.33	87.27	78.46	53.75	0.16	0.24	0.25	0.3	0.05	84.9
2	100.00	99.07	95.53	89.78	81.27	0.16	0.24	0.25	0.3	0.05	94.7
1.75	100.00	100.00	100.00	99.03	93.63	0.16	0.24	0.25	0.3	0.05	99.4
1.5	100.00	100.00	100.00	100.00	100.00	0.16	0.24	0.25	0.3	0.05	100.0
1.38	100.00	100.00	100.00	100.00	100.00	0.16	0.24	0.25	0.3	0.05	100.0
1.25	100.00	100.00	100.00	100.00	100.00	0.16	0.24	0.25	0.3	0.05	100.0
1.18	100.00	100.00	100.00	100.00	100.00	0.16	0.24	0.25	0.3	0.05	100.0
1.1	100.00	100.00	100.00	100.00	100.00	0.16	0.24	0.25	0.3	0.05	100.0

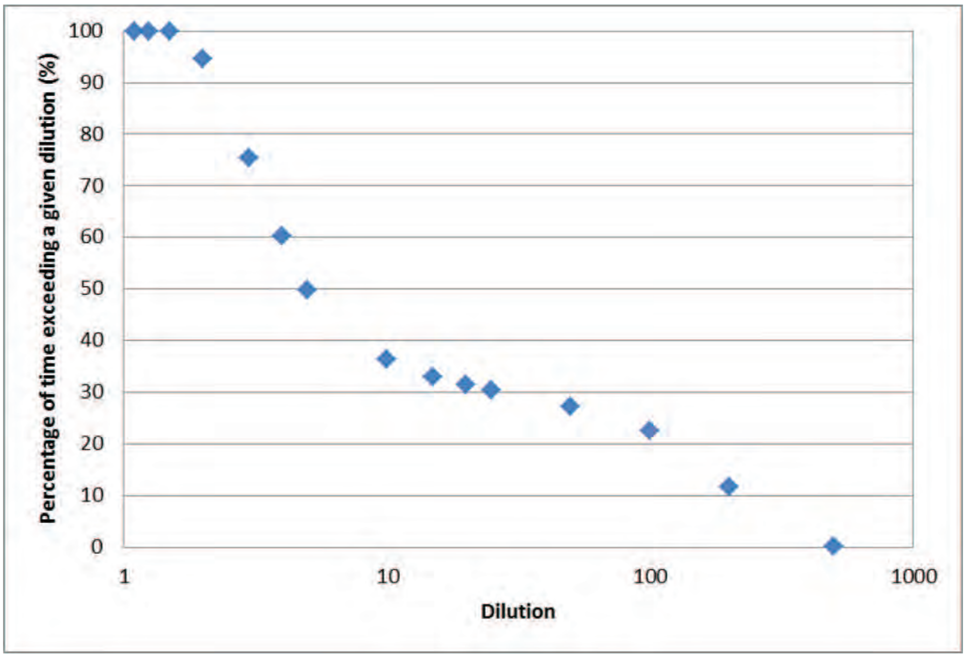


Figure 9-41 Proposed situation – frequency of dilution for faecal coliforms at location in lower mid estuary. Note log scale on x-axis.

Table 9-14 Existing situation – frequency of dilution for Enterococci at Boat Ramp in Ongatoro / Maketū Estuary.

Dilution	Percentage of Time During 15 day Simulation where Dilution is Exceeded					Percentage of Time Represented by Discharge					Percentage of Time Exceeding Dilution (%)
	26 m^3/s	28 m^3/s	32 m^3/s	39 m^3/s	51 m^3/s	26 m^3/s	28 m^3/s	32 m^3/s	39 m^3/s	51 m^3/s	
500	0.00	0.00	0.00	0.00	0.00	0.16	0.24	0.25	0.30	0.05	0.0
250	0.00	0.00	0.00	0.00	0.00	0.16	0.24	0.25	0.30	0.05	0.0
200	0.00	0.00	0.00	0.00	0.00	0.16	0.24	0.25	0.30	0.05	0.0
150	0.00	0.00	0.00	0.00	0.00	0.16	0.24	0.25	0.30	0.05	0.0
100	0.00	0.00	0.00	0.00	0.00	0.16	0.24	0.25	0.30	0.05	0.0
75	0.00	0.00	0.00	0.00	0.00	0.16	0.24	0.25	0.30	0.05	0.0
50	0.00	0.00	0.00	0.00	0.00	0.16	0.24	0.25	0.30	0.05	0.0
37.5	0.00	0.00	0.00	0.00	0.00	0.16	0.24	0.25	0.30	0.05	0.0
25	1.60	0.05	0.00	0.00	0.00	0.16	0.24	0.25	0.30	0.05	0.3
22.5	2.88	0.65	0.00	0.00	0.00	0.16	0.24	0.25	0.30	0.05	0.6
20	4.82	1.48	0.00	0.00	0.00	0.16	0.24	0.25	0.30	0.05	1.1
17.5	8.29	3.02	0.00	0.00	0.00	0.16	0.24	0.25	0.30	0.05	2.0
15	11.45	7.71	0.21	0.00	0.00	0.16	0.24	0.25	0.30	0.05	3.7
12.5	17.84	14.01	8.18	0.00	0.00	0.16	0.24	0.25	0.30	0.05	8.3
10	27.52	24.23	15.12	6.84	0.00	0.16	0.24	0.25	0.30	0.05	16.1
7.5	47.56	43.68	34.72	27.58	12.35	0.16	0.24	0.25	0.30	0.05	35.7
5	75.62	72.75	61.02	51.99	45.50	0.16	0.24	0.25	0.30	0.05	62.7
4.5	81.86	80.08	72.16	61.74	49.88	0.16	0.24	0.25	0.30	0.05	71.4
4	85.20	83.97	80.51	76.74	59.58	0.16	0.24	0.25	0.30	0.05	79.9
3.5	87.00	86.43	84.80	83.30	80.83	0.16	0.24	0.25	0.30	0.05	84.9
3	88.54	88.00	86.61	85.24	83.48	0.16	0.24	0.25	0.30	0.05	86.7
2.5	91.06	90.27	88.73	87.48	85.86	0.16	0.24	0.25	0.30	0.05	89.0
2	95.95	95.42	92.96	90.35	88.74	0.16	0.24	0.25	0.30	0.05	93.0
1.75	98.67	97.86	96.48	92.90	90.44	0.16	0.24	0.25	0.30	0.05	95.8
1.5	99.91	99.89	99.07	98.97	93.83	0.16	0.24	0.25	0.30	0.05	99.1
1.38	100.00	99.98	99.97	99.89	97.84	0.16	0.24	0.25	0.30	0.05	99.8
1.25	100.00	100.00	100.00	100.00	100.00	0.16	0.24	0.25	0.30	0.05	100.0
1.18	100.00	100.00	100.00	100.00	100.00	0.16	0.24	0.25	0.30	0.05	100.0
1.1	100.00	100.00	100.00	100.00	100.00	0.16	0.24	0.25	0.30	0.05	100.0

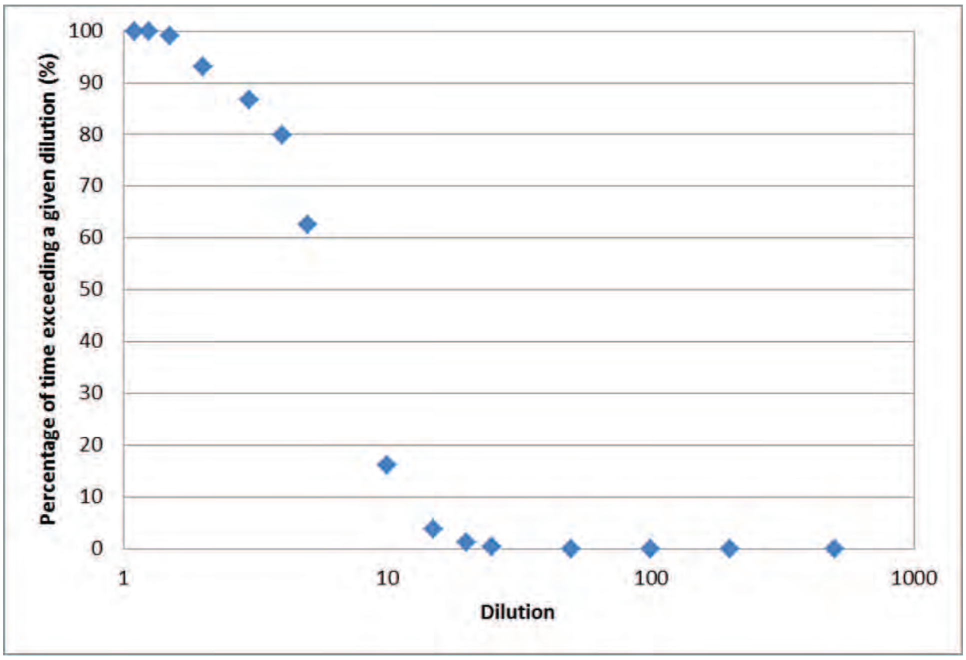


Figure 9-42 Existing situation – frequency of dilution for Enterococci at Boat Ramp in Ongatoro / Maketū Estuary. Note log scale on x-axis.

Table 9-15 Proposed option – frequency of dilution for Enterococci at Boat Ramp in Ongatoro / Maketū Estuary.

Dilution	Percentage of Time During 15 day Simulation where Dilution is Exceeded					Percentage of Time Represented by Discharge					Percentage of Time Exceeding Dilution (%)
	26 m^3/s	28 m^3/s	32 m^3/s	39 m^3/s	51 m^3/s	26 m^3/s	28 m^3/s	32 m^3/s	39 m^3/s	51 m^3/s	
500	0.00	0.00	0.00	0.00	0.00	0.16	0.24	0.25	0.30	0.05	0.0
250	0.00	0.00	0.00	0.00	0.00	0.16	0.24	0.25	0.30	0.05	0.0
200	0.10	0.00	0.00	0.00	0.00	0.16	0.24	0.25	0.30	0.05	0.0
150	2.56	0.18	0.05	0.00	0.00	0.16	0.24	0.25	0.30	0.05	0.5
100	16.60	11.79	5.70	4.00	2.09	0.16	0.24	0.25	0.30	0.05	8.2
75	23.22	20.52	14.34	6.72	5.93	0.16	0.24	0.25	0.30	0.05	14.5
50	26.69	27.20	22.92	18.32	9.97	0.16	0.24	0.25	0.30	0.05	22.5
37.5	28.17	28.49	26.13	26.15	15.64	0.16	0.24	0.25	0.30	0.05	26.5
25	30.08	30.25	29.37	29.50	22.26	0.16	0.24	0.25	0.30	0.05	29.4
22.5	30.68	30.85	29.89	30.01	24.16	0.16	0.24	0.25	0.30	0.05	30.0
20	31.28	31.45	30.55	30.56	25.23	0.16	0.24	0.25	0.30	0.05	30.6
17.5	31.93	32.25	31.03	31.10	26.91	0.16	0.24	0.25	0.30	0.05	31.3
15	32.68	33.10	31.61	31.68	28.73	0.16	0.24	0.25	0.30	0.05	32.0
12.5	34.09	33.91	32.93	32.31	30.47	0.16	0.24	0.25	0.30	0.05	33.0
10	35.43	34.96	34.03	33.00	31.45	0.16	0.24	0.25	0.30	0.05	34.0
7.5	36.94	36.54	35.44	34.12	32.67	0.16	0.24	0.25	0.30	0.05	35.4
5	43.94	38.96	37.09	35.89	34.53	0.16	0.24	0.25	0.30	0.05	38.1
4.5	48.72	41.21	37.85	36.39	35.09	0.16	0.24	0.25	0.30	0.05	39.8
4	53.28	45.52	39.17	37.05	35.75	0.16	0.24	0.25	0.30	0.05	42.1
3.5	66.45	51.40	43.95	37.89	36.75	0.16	0.24	0.25	0.30	0.05	47.2
3	76.02	64.92	51.76	40.89	37.93	0.16	0.24	0.25	0.30	0.05	54.8
2.5	85.63	78.22	69.52	50.51	39.43	0.16	0.24	0.25	0.30	0.05	67.0
2	93.92	92.21	86.47	73.93	51.25	0.16	0.24	0.25	0.30	0.05	83.5
1.75	95.32	94.34	92.25	84.96	68.95	0.16	0.24	0.25	0.30	0.05	89.9
1.5	97.40	95.96	95.11	93.06	87.11	0.16	0.24	0.25	0.30	0.05	94.7
1.38	99.05	97.53	96.28	95.00	90.91	0.16	0.24	0.25	0.30	0.05	96.4
1.25	99.86	99.49	98.63	96.83	94.71	0.16	0.24	0.25	0.30	0.05	98.3
1.18	99.96	99.75	99.76	98.80	96.88	0.16	0.24	0.25	0.30	0.05	99.4
1.1	100.00	99.94	99.93	99.73	99.58	0.16	0.24	0.25	0.30	0.05	99.9

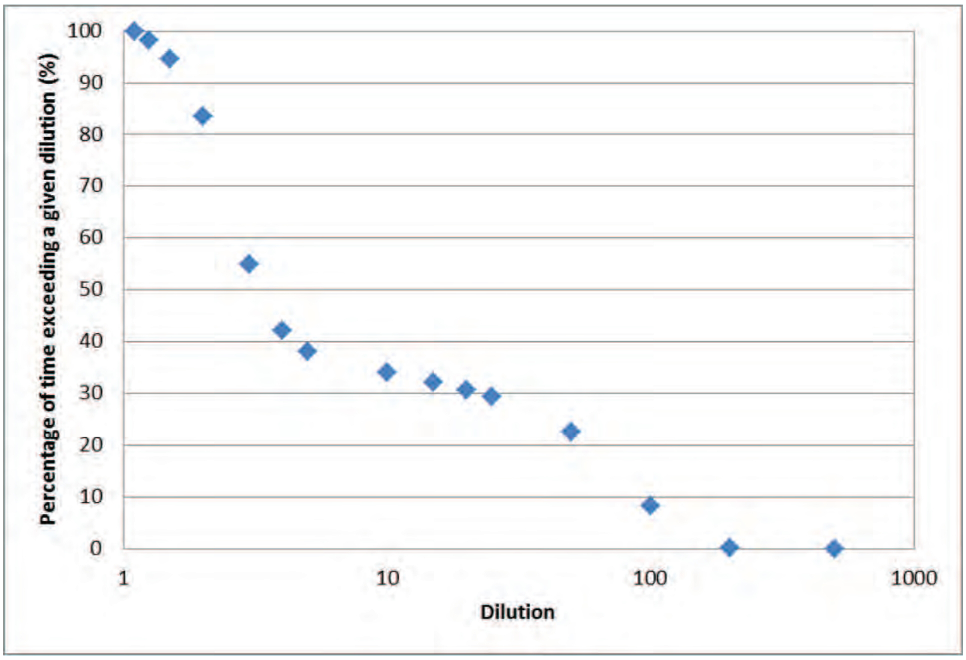


Figure 9-43 Proposed situation – frequency of dilution for Enterococci at Boat Ramp in Ongatoro / Maketū Estuary. Note log scale on x-axis.

9.4.2 Blue Green Algae Assessment

The portion of time when the critical concentration of blue-green algae (15,000 cells/ml) is exceeded at the lower estuary site for the existing and proposed situations was assessed using the dilution calculations presented in Section 9.4.1.

The percentage of time that the blue-green algae guidelines were violated was calculated by multiplying the percentage of time that each dilution interval was predicted to occur, with the percentage of time that the blue-green algae concentrations within the river exceeded a calculated critical threshold required to achieve the critical level within the estuary. These calculated values were then summed to give a total percentage of time that the critical level exceeded.

The frequency distribution of blue-green algae concentrations in the Kaituna River was determined using the monitoring data at Waitangi location for the period March 2005 to May 2010. This data is presented in Figure 9-44.

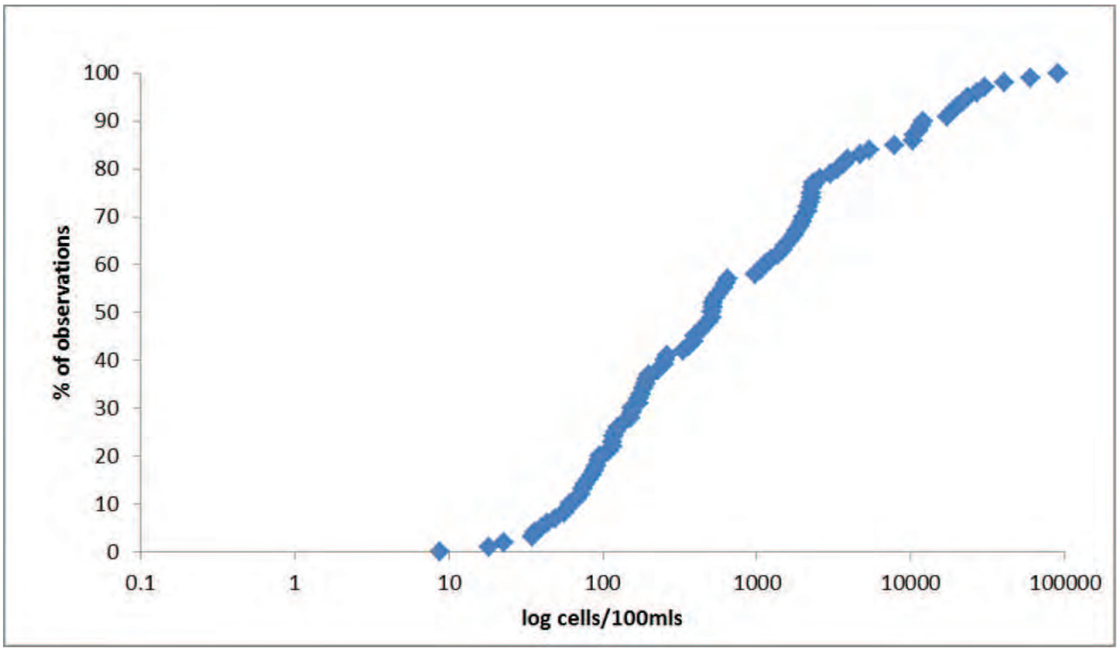


Figure 9-44 Frequency distribution of blue-green algae concentration in lower Kaituna River at Waitangi location based on monitoring data. Note log scale on x-axis.

The percentage of time that dilutions were calculated to occur for the lower estuary site for the existing and the proposed situations is presented in columns 2 and 3 of Table 9-16 and Table 9-17 which was derived in Table 9-10 and Table 9-11 .

To combine the blue-green concentration frequency (see Figure 9-44) with these dilutions, it was assumed that there was no correlation between the river flow and the blue-green algae concentration (see Section 3.7).

Using the minimum dilution within each of the flow intervals in Table 9-16 and Table 9-17 the concentration required for the river was calculated for when a count of greater than 15,000 cells/ml would be exceeded for the lower estuary site. These maximum concentrations are given in column 4 of Table 9-16 and Table 9-17.

The percentage of time when the blue-green algae concentration was higher than this maximum acceptable concentration in the river was then calculated based on the frequency distribution from Figure 9-44. The frequencies are given in column 5 of Table 9-16 and Table 9-17.

The contribution to the exceedance of the critical level for each dilution interval was then calculated in column 6 of Table 9-16 and Table 9-17 by multiplying the percentage of time that each dilution interval was predicted to occur, with the percentage of time that the blue-green algae concentrations exceeded the calculated critical threshold within the river. These calculated values were then summed to give a total percentage of time that the critical blue-green algae concentration of 15,000 cells/ml is exceeded.

It is predicted that for the existing situation the critical blue-green algae concentration of 15,000 cells/ml will be exceeded 3.5% of the time, while for the proposed option it is estimated that the critical concentration will be exceeded 3.6% of the time. Therefore there is not a significant increase in risk for potential for blue-green algae blooms with the proposed option within the lower estuary.

Table 9-16 Existing situation – exceeding critical level of 15,000 cells/ml of blue-green algae at lower estuary site

Minimum Dilution (fold)	Dilution Interval	Occurrence of this Dilution Interval (%)	Maximum Inflow Concentration Required to Exceed Critical Level	Percentage of Time that Concentration is Exceeded in lower Kaituna River at Waitangi Location (%)	Percentage of Time Exceeded (%)
100	100 - 200	0.0	1,500,000	0.0	0.0
50	50 - 100	0.0	750,000	0.0	0.0
25	25 - 50	0.7	375,000	0.0	0.0
20	20 - 25	1.7	300,000	0.0	0.0
15	15 - 20	3.1	225,000	0.7	0.0
10	10 – 15	7.9	150,000	0.7	0.1
5	5 – 10	20.7	75,000	0.7	0.2
4	4 – 5	7.4	60,000	0.7	0.1
3	3 – 4	7.2	45,000	0.7	0.1
2	2 – 3	15.0	30,000	2.2	0.3
1.5	1.5 - 2	12.8	22,500	5.9	0.8
1.25	1.25 - 1.5	8.6	18,750	7.4	0.6
1.1	1.1 - 1.25	8.0	16,500	8.9	0.7
1	1 - 1.1	6.9	15,000	10.4	0.7
Sum		**100.0**	**Sum**		**3.5**

Table 9-17 Proposed situation – exceeding critical level of 15,000 cells/ml of blue-green algae at lower estuary site.

Minimum Dilution (fold)	Dilution Interval	Occurrence of this Dilution Interval (%)	Maximum Inflow Concentration Required to Exceed Critical Level	Percentage of Time that Concentration is Exceeded in lower Kaituna River at Waitangi Location (%)	Percentage of Time Exceeded (%)
100	100 - 200	0.0	1,500,000	0.0	0.0
50	50 - 100	6.4	750,000	0.0	0.0
25	25 - 50	16.7	375,000	0.0	0.0
20	20 - 25	2.8	300,000	0.0	0.0
15	15 - 20	2.1	225,000	0.7	0.0
10	10 – 15	2.1	150,000	0.7	0.0
5	5 – 10	4.5	75,000	0.7	0.0
4	4 – 5	2.7	60,000	0.7	0.0
3	3 – 4	5.5	45,000	0.7	0.0
2	2 – 3	16.6	30,000	2.2	0.4
1.5	1.5 - 2	16.7	22,500	5.9	1.0
1.25	1.25 - 1.5	9.1	18,750	7.4	0.7
1.1	1.1 - 1.25	5.1	16,500	8.9	0.5
1	1 - 1.1	9.6	15,000	10.4	1.0
Sum		**100.0**	**Sum**		**3.6**

9.4.3 Shellfish Collection Assessment

The portion of time when the critical concentration of faecal coliforms (14 and 43 counts per 100 ml) is exceeded at a lower estuary site within the estuary for the existing and proposed situations was assessed using the dilution calculations outlined in Section 9.4.1.

The percentage of time that the shellfish collection guidelines were violated was calculated by multiplying the percentage of time that each dilution interval was predicted to occur, with the percentage of time that the faecal coliform concentrations within the river exceeded a calculated critical threshold required to achieve the critical level within the estuary. These calculated values were then summed to give a total percentage of time that the critical level exceeded.

The frequency of faecal coliforms concentration in the Kaituna River was determined using the monitoring data at confluence of Waiari Stream to Kaituna River for the period 2007 - 2013. This data is presented in Figure 9-45.

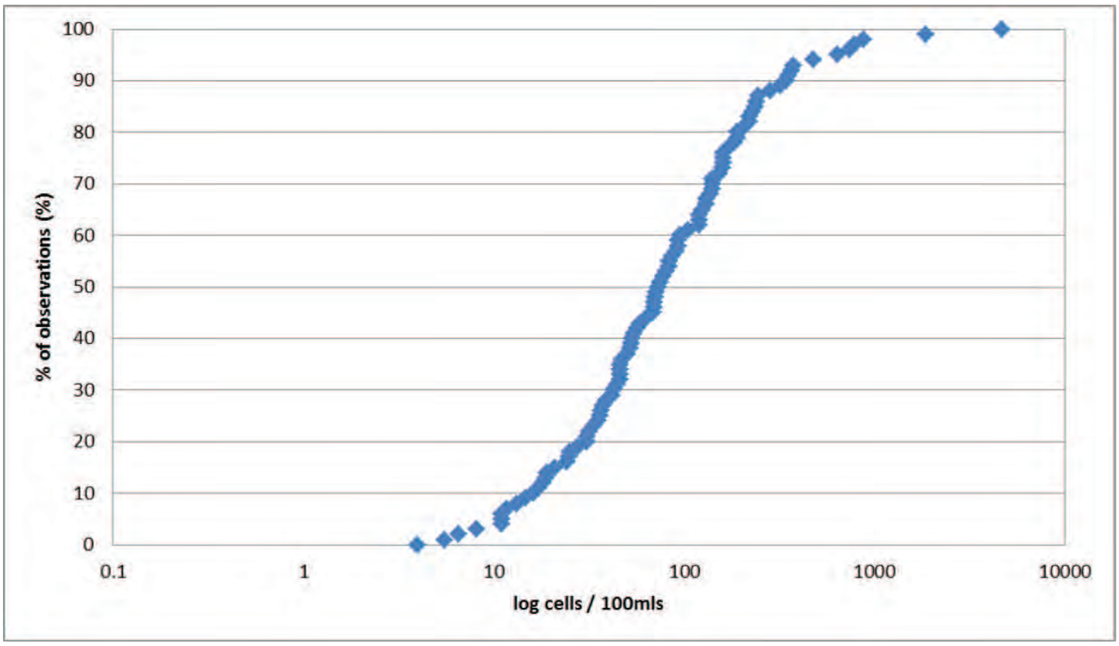


Figure 9-45 Frequency distribution of faecal coliforms concentration in lower Kaituna River at confluence of Waiari Stream to Kaituna River based on monitoring data.

The percentage of time that dilutions were calculated to occur for the lower estuary site for the existing and the proposed situations is presented in columns 2 and 3 of Table 9-18 to Table 9-21 which was derived in Table 9-12 and Table 9-13.

To combine the faecal coliforms concentration frequency (see Figure 9-45) with these dilutions, it was assumed that there was no correlation between the river flow and the faecal coliforms concentration (see Section 3.7).

Using the minimum dilution within each of the flow intervals in Table 9-18 to Table 9-21, the concentration for the river was calculated for when 14 and 43 counts per 100 ml would be violated at the lower estuary site. These maximum concentrations are given in column 4 of Table 9-18 to Table 9-21.

The percentage of time when the faecal coliforms concentration higher than this maximum acceptable concentration in the river was then calculated based on the frequency distribution from Figure 9-45. The frequencies are given in column 5 of Table 9-18 to Table 9-21.

The contribution to the exceedance of the critical level for each dilution interval was then calculated in column 6 of Table 9-18 to Table 9-21, by multiplying the percentage of time that each dilution interval was predicted to occur, with the percentage of time that the faecal coliforms concentration exceeded the calculated critical threshold within the river.

These calculated values were then summed to give a percentage of time that the critical faecal coliforms concentrations of 14 and 43 counts per 100 ml is predicted to be violated.

It is predicted that for the existing situation the critical faecal coliforms concentrations of 14 counts per 100 ml will be violated 32.2% of the time, while for the proposed option it is estimated that the critical concentration will be violated 44.1% of the time.

It is predicted that for the existing situation the critical faecal coliforms concentration of 43 counts per 100 ml will be exceeded 12.6% of the time. Therefore the existing situation is not within the New Zealand guidelines for shellfish gathering, specifically that concentrations of 43 faecal coliforms should only be exceeded 10% of the time. For the proposed option it is estimated that the critical faecal coliforms concentration will be exceeded 20.6% of the time – also in excess of the New Zealand guidelines for shellfish gathering.

Table 9-18 Existing situation – exceeding critical level of 14 counts per 100 ml of faecal coliforms at lower estuary site.

Minimum Dilution (fold)	Dilution Interval	Occurrence of this Dilution Interval (%)	Maximum Inflow Concentration Required to Exceed Critical Level	Percentage of Time that Concentration is Exceeded in lower Kaituna River at confluence of Waiari Stream (%)	Percentage of Time Exceeded (%)
500	> 500	0.0	7,000	1.8	0.0
250	250 - 500	0.1	3,500	1.3	0.0
200	200 - 250	0.3	2,800	1.3	0.0
150	150 – 200	1.3	2,100	1.3	0.0
100	100 – 150	3.7	1,400	1.3	0.0
75	75 – 100	5.0	1,050	1.3	0.1
50	50 – 75	8.3	700	5.2	0.4
37.5	37.5 – 75	7.6	525	6.5	0.5
25	25 – 37.5	11.4	350	9.1	1.0
22.5	22.5 – 25	2.2	315	11.7	0.3
20	20 – 22.5	2.2	280	13.0	0.3
17.5	17.5 – 20	2.3	245	13.0	0.3
15	15 – 17.5	2.5	210	19.5	0.5
12.5	12.5 – 15	2.8	175	23.4	0.7
10	10 – 12.5	4.1	140	28.6	1.2
7.5	7.5 – 10	6.2	105	39.0	2.4
5	5 – 7.5	12.6	70	51.9	6.6
4.5	4.5 – 5	4.3	63	55.8	2.4
4	4 – 4.5	4.8	56	58.4	2.8
3.5	3.5 - 4	6.8	49	63.6	4.3
3	3 – 3.5	8.3	42	70.1	5.8
2.5	2.5 – 3	3.3	35	75.3	2.5
2	2 – 2.5	0.2	28	80.5	0.1
1.75	1.75 – 2	0.0	24.5	83.1	0.0
1.5	1.5 – 1.75	0.0	21	84.4	0.0
1.38	1.38 – 1.5	0.0	19.32	84.4	0.0
1.25	1.25 - 1.38	0.0	17.5	88.3	0.0
1.18	1.18 – 1.25	0.0	16.52	89.6	0.0
1.1	1.1 - 1.18	0.0	15.4	89.6	0.0
Sum		**100.0**	**Sum**		**32.2**

Table 9-19 Proposed situation – exceeding critical level of 14 counts per 100 ml of faecal coliforms at lower estuary site.

Minimum Dilution (fold)	Dilution Interval	Occurrence of this Dilution Interval (%)	Maximum Inflow Concentration Required to Exceed Critical Level	Percentage of Time that Concentration is Exceeded in lower Kaituna River at confluence of Waiari Stream (%)	Percentage of Time Exceeded (%)
500	> 500	0.0	7,000	1.8	0.0
250	250 - 500	7.9	3,500	1.3	0.1
200	200 - 250	3.8	2,800	1.3	0.0
150	150 – 200	5.6	2,100	1.3	0.1
100	100 – 150	5.2	1,400	1.3	0.1
75	75 – 100	2.3	1,050	1.3	0.0
50	50 – 75	2.4	700	5.2	0.1
37.5	37.5 – 75	1.2	525	6.5	0.1
25	25 – 37.5	2.0	350	9.1	0.2
22.5	22.5 – 25	0.5	315	11.7	0.1
20	20 – 22.5	0.6	280	13.0	0.1
17.5	17.5 – 20	0.7	245	13.0	0.1
15	15 – 17.5	0.8	210	19.5	0.2
12.5	12.5 – 15	1.3	175	23.4	0.3
10	10 – 12.5	2.1	140	28.6	0.6
7.5	7.5 – 10	3.7	105	39.0	1.4
5	5 – 7.5	9.7	70	51.9	5.1
4.5	4.5 – 5	4.6	63	55.8	2.6
4	4 – 4.5	5.7	56	58.4	3.3
3.5	3.5 - 4	6.7	49	63.6	4.3
3	3 – 3.5	8.4	42	70.1	5.9
2.5	2.5 – 3	9.6	35	75.3	7.2
2	2 – 2.5	9.7	28	80.5	7.8
1.75	1.75 – 2	4.7	24.5	83.1	3.9
1.5	1.5 – 1.75	0.6	21	84.4	0.5
1.38	1.38 – 1.5	0.0	19.32	84.4	0.0
1.25	1.25 - 1.38	0.0	17.5	88.3	0.0
1.18	1.18 – 1.25	0.0	16.52	89.6	0.0
1.1	1.1 - 1.18	0.0	15.4	89.6	0.0
Sum		**100.0**	**Sum**		**44.1**

Table 9-20 Existing situation – exceeding critical level of 43 counts per 100 ml of faecal coliforms at lower estuary site.

Minimum Dilution (fold)	Dilution Interval	Occurrence of this Dilution Interval (%)	Maximum Inflow Concentration Required to Exceed Critical Level	Percentage of Time that Concentration is Exceeded in lower Kaituna River at confluence of Waiari Stream (%)	Percentage of Time Exceeded (%)
500	> 500	0.0	21,500	0.0	0.0
250	250 - 500	0.1	10,750	0.0	0.0
200	200 - 250	0.3	8,600	0.0	0.0
150	150 – 200	1.3	6,450	0.0	0.0
100	100 – 150	3.7	4,300	1.3	0.0
75	75 – 100	5.0	3,225	1.3	0.1
50	50 – 75	8.3	2,150	1.3	0.1
37.5	37.5 – 75	7.6	1,612.5	1.3	0.1
25	25 – 37.5	11.4	1,075	1.3	0.1
22.5	22.5 – 25	2.2	967.5	1.3	0.0
20	20 – 22.5	2.2	860	2.6	0.1
17.5	17.5 – 20	2.3	752.5	3.9	0.1
15	15 – 17.5	2.5	645	5.2	0.1
12.5	12.5 – 15	2.8	537.5	6.5	0.2
10	10 – 12.5	4.1	430	6.5	0.3
7.5	7.5 – 10	6.2	322.5	11.7	0.7
5	5 – 7.5	12.6	215	19.5	2.5
4.5	4.5 – 5	4.3	193.5	19.5	0.8
4	4 – 4.5	4.8	172	23.4	1.1
3.5	3.5 - 4	6.8	150.5	28.6	1.9
3	3 – 3.5	8.3	129	35.1	2.9
2.5	2.5 – 3	3.3	107.5	39.0	1.3
2	2 – 2.5	0.2	86	44.2	0.1
1.75	1.75 – 2	0.0	75.25	49.4	0.0
1.5	1.5 – 1.75	0.0	64.5	55.8	0.0
1.38	1.38 – 1.5	0.0	59.34	57.1	0.0
1.25	1.25 - 1.38	0.0	53.75	59.7	0.0
1.18	1.18 – 1.25	0.0	50.74	62.3	0.0
1.1	1.1 - 1.18	0.0	47.3	63.6	0.0
Sum		**100.0**	**Sum**		**12.6**

Table 9-21 Proposed situation – exceeding critical level of 43 counts per 100 ml of faecal coliforms at lower estuary site.

Minimum Dilution (fold)	Dilution Interval	Occurrence of this Dilution Interval (%)	Maximum Inflow Concentration Required to Exceed Critical Level	Percentage of Time that Concentration is Exceeded in lower Kaituna River at confluence of Waiari Stream (%)	Percentage of Time Exceeded (%)
500	> 500	0.0	21,500	0.0	0.0
250	250 - 500	7.9	10,750	0.0	0.0
200	200 - 250	3.8	8,600	0.0	0.0
150	150 – 200	5.6	6,450	0.0	0.0
100	100 – 150	5.2	4,300	1.3	0.1
75	75 – 100	2.3	3,225	1.3	0.0
50	50 – 75	2.4	2,150	1.3	0.0
37.5	37.5 – 75	1.2	1,612.5	1.3	0.0
25	25 – 37.5	2.0	1,075	1.3	0.0
22.5	22.5 – 25	0.5	967.5	1.3	0.0
20	20 – 22.5	0.6	860	2.6	0.0
17.5	17.5 – 20	0.7	752.5	3.9	0.0
15	15 – 17.5	0.8	645	5.2	0.0
12.5	12.5 – 15	1.3	537.5	6.5	0.1
10	10 – 12.5	2.1	430	6.5	0.1
7.5	7.5 – 10	3.7	322.5	11.7	0.4
5	5 – 7.5	9.7	215	19.5	1.9
4.5	4.5 – 5	4.6	193.5	19.5	0.9
4	4 – 4.5	5.7	172	23.4	1.3
3.5	3.5 - 4	6.7	150.5	28.6	1.9
3	3 – 3.5	8.4	129	35.1	2.9
2.5	2.5 – 3	9.6	107.5	39.0	3.7
2	2 – 2.5	9.7	86	44.2	4.3
1.75	1.75 – 2	4.7	75.25	49.4	2.3
1.5	1.5 – 1.75	0.6	64.5	55.8	0.3
1.38	1.38 – 1.5	0.0	59.34	57.1	0.0
1.25	1.25 - 1.38	0.0	53.75	59.7	0.0
1.18	1.18 – 1.25	0.0	50.74	62.3	0.0
1.1	1.1 - 1.18	0.0	47.3	63.6	0.0
Sum		**100.0**	**Sum**		**20.6**

9.4.4 Bathing Water Suitability

The portion of time at which the critical concentration of Enterococci (280 counts per 100 ml) is exceeded at the Boat Ramp within the estuary for the existing and proposed situations was assessed using the dilution calculations as set out in Section 9.4.1.

The percentage of time that the bathing water suitability guidelines were violated was calculated by multiplying the percentage of time that each dilution interval was predicted to occur, with the percentage of time that the Enterococci concentrations within the river exceeded a calculated critical threshold required to achieve the critical level within the estuary. These calculated values were then summed to give a total percentage of time that the critical level exceeded.

The frequency of Enterococci concentrations in the Kaituna River was determined using the monitoring data at confluence of Waiari Stream to Kaituna River for the period 2007 - 2013. This data is presented in Figure 9-46.

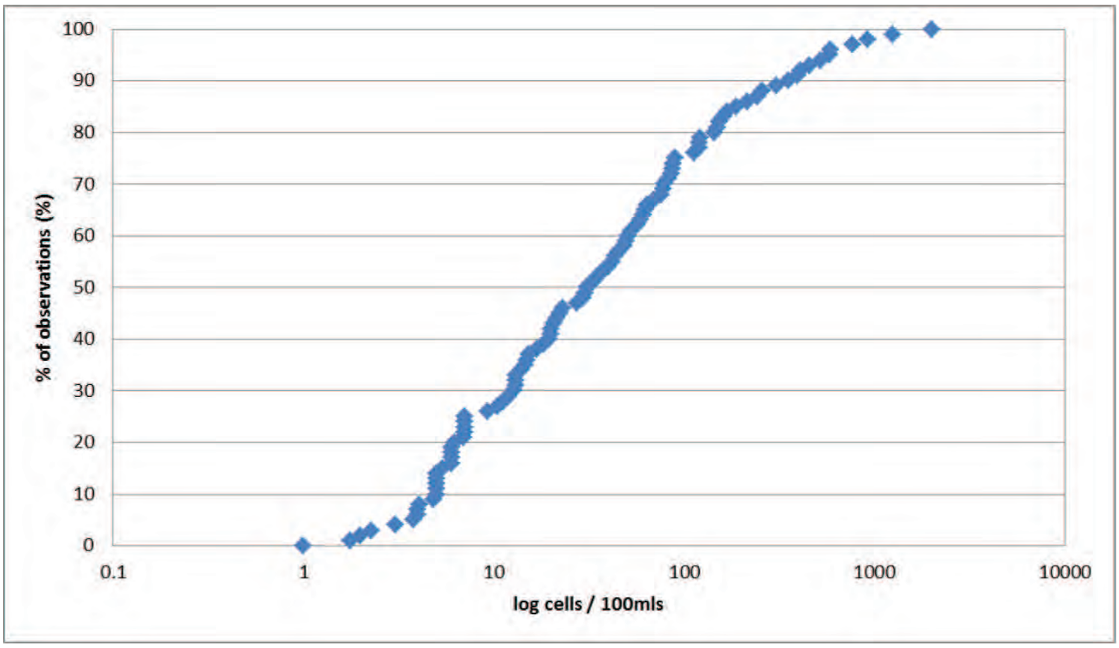


Figure 9-46 Frequency distribution of Enterococci concentration in lower Kaituna River at confluence of Waiari Stream to Kaituna River based on monitoring data.

The percentage of time that dilutions were calculated to occur for the lower estuary site for the existing and the proposed situations is presented in columns 2 and 3 of Table 9-22 and Table 9-23 which was derived in Table 9-14 and Table 9-15.

To combine the Enterococci concentrations frequency (Figure 9-46) with these dilutions, it was assumed that there was no correlation between the river flow and the Enterococci concentration. (see Section 3.7).

Using the minimum dilution within each of the flow intervals in Table 9-22 and Table 9-23 the concentration for the river was calculated for a count of 280 per 100 ml would be exceeded at the Boat Ramp. These maximum concentrations are given in column 4 of Table 9-22 and Table 9-23.

The percentage of time when the Enterococci concentrations higher than this maximum acceptable concentration in the river was then calculated based on the frequency distribution from Figure 9-46. The frequencies are given in column 5 of Table 9-22 and Table 9-23.

The contribution to the exceedance of the critical level for each dilution interval was then calculated in column 6 of Table 9-22 and Table 9-23, by multiplying the percentage of time that each dilution interval was predicted to occur, with the percentage of time that the Enterococci concentration exceeded the calculated critical threshold within the river.

These calculated values were then summed to give a percentage of time that the critical Enterococci concentration of 280 counts per 100 ml is predicted to be violated.

It is predicted that for the existing situation the critical Enterococci concentration of 280 counts per 100 ml will be violated 2.0% of the time, while for the proposed option it is estimated that the critical concentration will be violated 3.3% of the time.

Table 9-22 Existing situation – exceeding critical level of 280 counts per 100 ml of Enterococci at Boat Ramp.

Minimum Dilution (fold)	Dilution Interval	Occurrence of this Dilution Interval (%)	Maximum Inflow Concentration	Percentage of Time that Concentration is Exceeded in lower Kaituna River at confluence of Waiari Stream (%)	Percentage of Time Exceeded (%)
500	> 500	0.0	140,000	0.0	0.0
250	250 - 500	0.0	70,000	0.0	0.0
200	200 - 250	0.0	56,000	0.0	0.0
150	150 – 200	0.0	42,000	0.0	0.0
100	100 – 150	0.0	28,000	0.0	0.0
75	75 – 100	0.0	21,000	0.0	0.0
50	50 – 75	0.0	14,000	0.0	0.0
37.5	37.5 – 75	0.0	10,500	0.0	0.0
25	25 – 37.5	0.3	7,000	0.0	0.0
22.5	22.5 – 25	0.3	6,300	0.0	0.0
20	20 – 22.5	0.5	5,600	0.0	0.0
17.5	17.5 – 20	0.9	4,900	0.0	0.0
15	15 – 17.5	1.7	4,200	1.3	0.0
12.5	12.5 – 15	4.5	3,500	1.3	0.1
10	10 – 12.5	7.8	2,800	1.3	0.1
7.5	7.5 – 10	19.6	2,100	1.3	0.3
5	5 – 7.5	27.0	1,400	1.3	0.4
4.5	4.5 – 5	8.7	1,260	1.3	0.1
4	4 – 4.5	8.5	1,120	1.3	0.1
3.5	3.5 - 4	5.0	980	1.3	0.1
3	3 – 3.5	1.8	840	2.6	0.0
2.5	2.5 – 3	2.3	700	5.2	0.1
2	2 – 2.5	4.1	560	6.5	0.3
1.75	1.75 – 2	2.7	490	6.5	0.2
1.5	1.5 – 1.75	3.3	420	6.5	0.2
1.38	1.38 – 1.5	0.7	386.4	6.5	0.0
1.25	1.25 - 1.38	0.2	350	9.1	0.0
1.18	1.18 – 1.25	0.0	330.4	11.7	0.0
1.1	1.1 - 1.18	0.0	308	11.7	0.0
Sum		**100.0**	**Sum**		**2.0**

Table 9-23 Proposed situation – exceeding critical level of 280 counts per 100 ml of Enterococci at Boat Ramp.

Minimum Dilution (fold)	Dilution Interval	Occurrence of this Dilution Interval (%)	Maximum Inflow Concentration	Percentage of Time that Concentration is Exceeded in lower Kaituna River at confluence of Waiari Stream (%)	Percentage of Time Exceeded (%)
500	> 500	0.0	140,000	0.0	0.0
250	250 - 500	0.0	70,000	0.0	0.0
200	200 - 250	0.0	56,000	0.0	0.0
150	150 – 200	0.4	42,000	0.0	0.0
100	100 – 150	7.8	28,000	0.0	0.0
75	75 – 100	6.3	21,000	0.0	0.0
50	50 – 75	8.0	14,000	0.0	0.0
37.5	37.5 – 75	4.0	10,500	0.0	0.0
25	25 – 37.5	2.9	7,000	0.0	0.0
22.5	22.5 – 25	0.6	6,300	0.0	0.0
20	20 – 22.5	0.6	5,600	0.0	0.0
17.5	17.5 – 20	0.7	4,900	0.0	0.0
15	15 – 17.5	0.7	4,200	1.3	0.0
12.5	12.5 – 15	1.0	3,500	1.3	0.0
10	10 – 12.5	1.0	2,800	1.3	0.0
7.5	7.5 – 10	1.4	2,100	1.3	0.0
5	5 – 7.5	2.7	1,400	1.3	0.0
4.5	4.5 – 5	1.7	1,260	1.3	0.0
4	4 – 4.5	2.3	1,120	1.3	0.0
3.5	3.5 - 4	5.0	980	1.3	0.1
3	3 – 3.5	7.7	840	2.6	0.2
2.5	2.5 – 3	12.1	700	5.2	0.6
2	2 – 2.5	16.5	560	6.5	1.1
1.75	1.75 – 2	6.4	490	6.5	0.4
1.5	1.5 – 1.75	4.8	420	6.5	0.3
1.38	1.38 – 1.5	1.7	386.4	6.5	0.1
1.25	1.25 - 1.38	1.9	350	9.1	0.2
1.18	1.18 – 1.25	1.1	330.4	11.7	0.1
1.1	1.1 - 1.18	0.5	308	11.7	0.1
Sum		**99.9**	**Sum**		**3.3**

9.5 Nutrient Assessment

Two assessments have been carried out to assess the impact of additional nutrients from the river to the estuary using the nutrient model described in Appendix F. One assessment has been carried out for mean river flow as a baseline assessment and one assessment has been carried out for a rainfall event. The nutrient assessment was carried out to determine the overall impact of nutrients within the estuary as well as the impact of at the drains within the estuary, especially the drains in the southern part of the estuary where the inflows from the drains are greatest for the estuary.

9.5.1 Base Flow Assessment

For the nutrient baseline assessment, a constant mean river flow was used for the Kaituna River. Baseline inflows were used for drains identified as likely high contributors for pollutants to the estuary as outlined in Section 3.3.

The nutrient data available for river and drains was analysed and appropriate nutrient concentrations were selected for the river and drains in agreement with the BoPRC project team. The selected nutrient concentrations are provided in Table 9-24 and were derived in conjunction with ecologists from project team by analysing the water quality data outlined in Section 3.7.

Table 9-24 Selected baseline nutrient concentrations for significant freshwater inputs, drains and open ocean.

Nutrient	Concentration (g/m^3)				
	Significant Freshwater Inputs	Drains			Open Ocean
		Singletons / Waitipuia	Ford Road	All Other	
TN	0.800	1.300	0.700	0.950	0.100
DIN	0.600	0.950	0.400	0.400	0.030
TP	0.070	0.110	0.080	0.100	0.010
DRP	0.040	0.035	0.015	0.015	0.006

The nutrient baseline assessment simulations were carried out for 15 days to a cover neap / spring tidal cycle not including a two day warm up period.

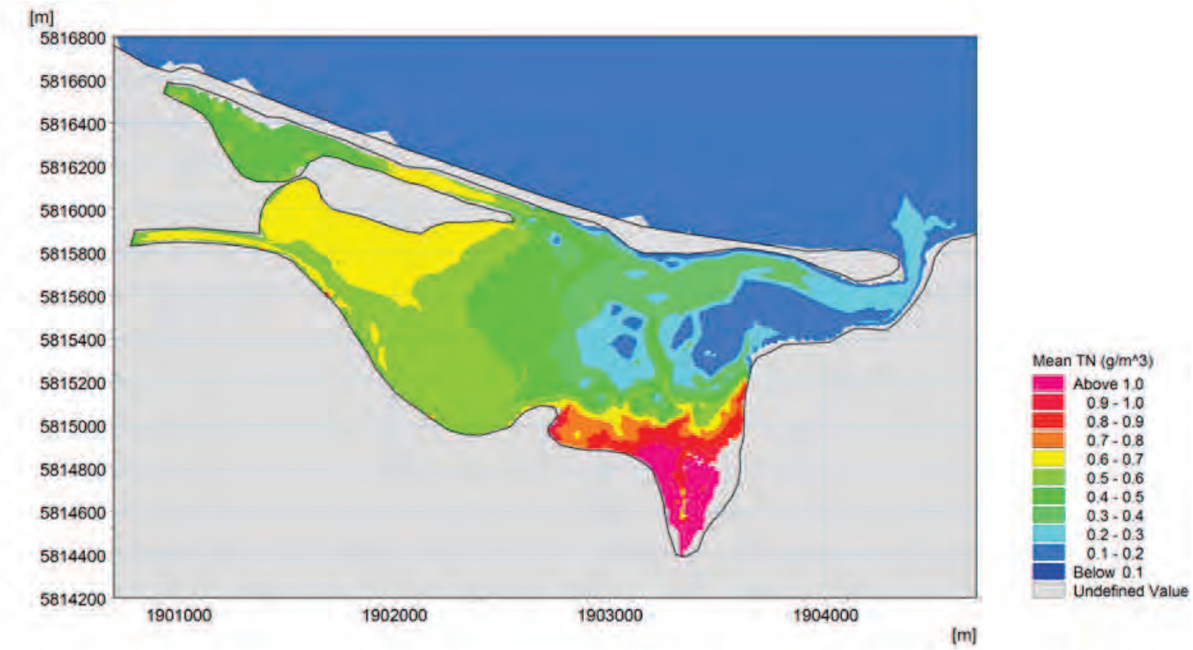
A comparison of the mean TN from the nutrient baseline assessment for the existing situation and the proposed option is presented in Figure 9-47. Similar comparisons for DIN, TP and DRP are presented in Figure 9-48 to Figure 9-50.

Time series of TN and TP have been extracted from selected locations shown in Figure 9-51. The comparison of predicted TN and TP at these locations for existing and proposed situations is presented in Figure 9-52 to Figure 9-56. The behaviour of DIN and DRP are similar to TN and TP respectively and therefore time series for these parameters have not been presented.

The reason why there are reasonably high nutrient levels within the wetland created from Brains Land is that a portion of the higher nutrient concentration freshwater normally associated with the initial flow of water from the river to the estuary through the re-diversion channel culverts is transported into this area.

For TN, TP, DIN and DRP the following is observed for the proposed option:

- there is an increase in mean nutrient concentrations in the mid to lower estuary;
- there is not a significant change in mean nutrient concentrations in the upper estuary;
- there is relatively high (compared with the rest of the estuary) mean nutrient concentrations in the wetland created from Brains Land; and
- there is a slightly larger area in the vicinity of the drains with higher mean nutrient concentrations. These higher values are also evident in the southern part of estuary, but interestingly the highest concentrations are slightly reduced.



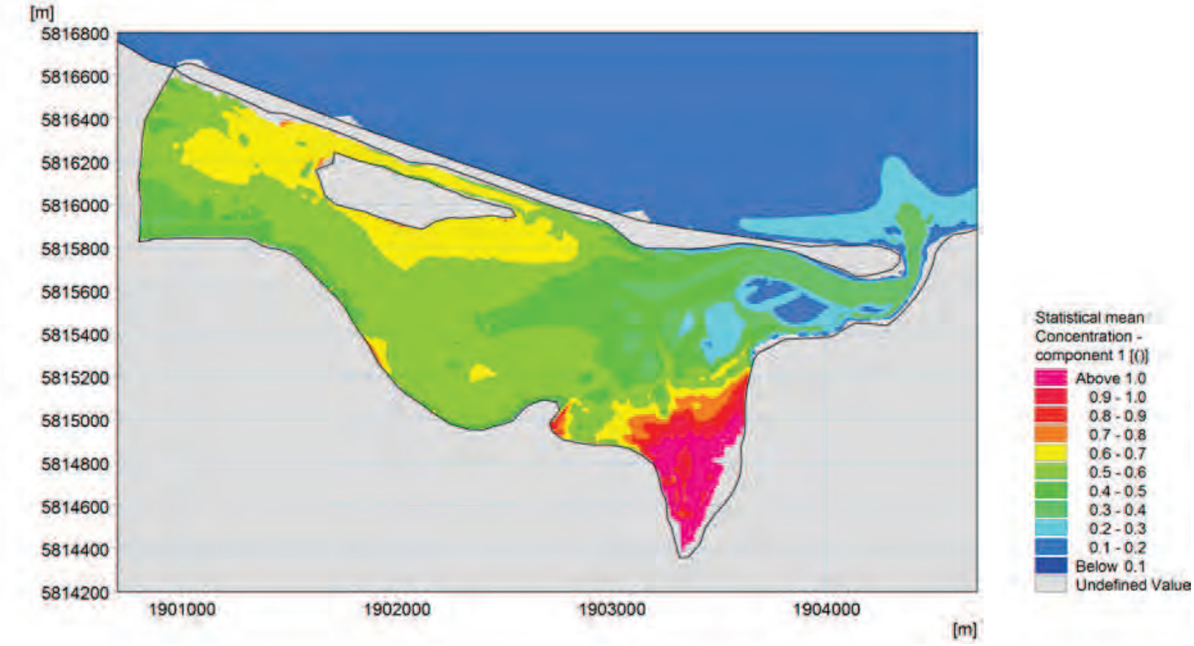
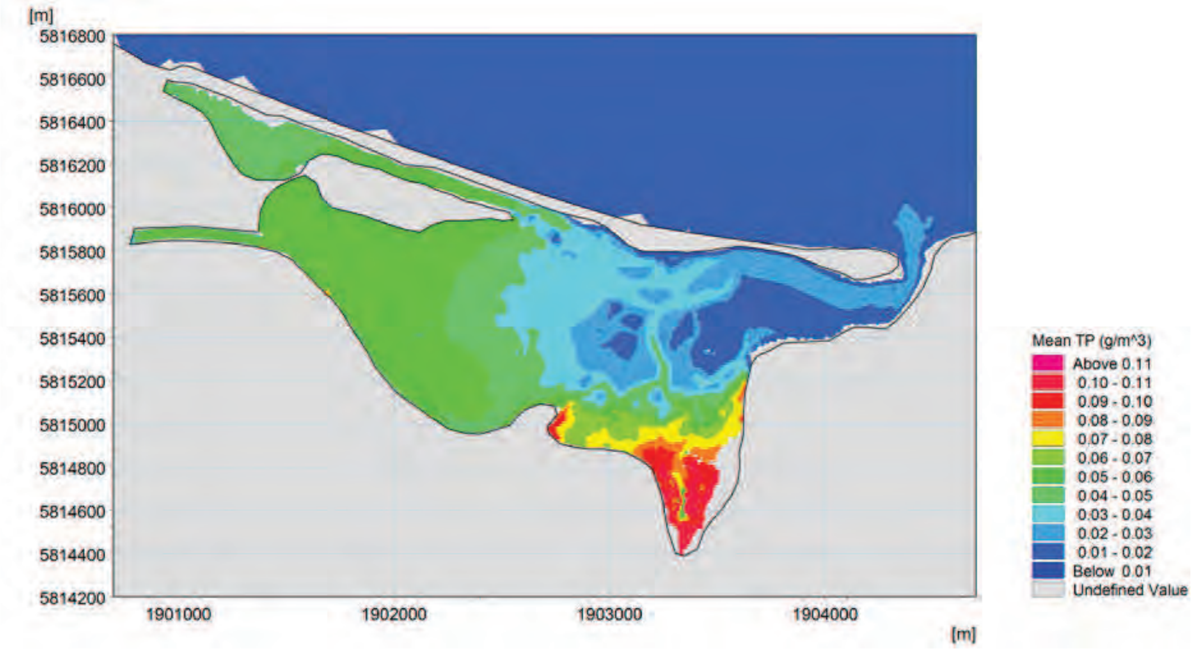


Figure 9-47 Depth averaged mean TN – nutrient baseline assessment with existing situation (top) and proposed option (bottom) for mean river flow and neap/spring tidal cycle. Note for existing situation, no flow possible in area north-west of Papahikahawai Island, hence only initial condition displayed.



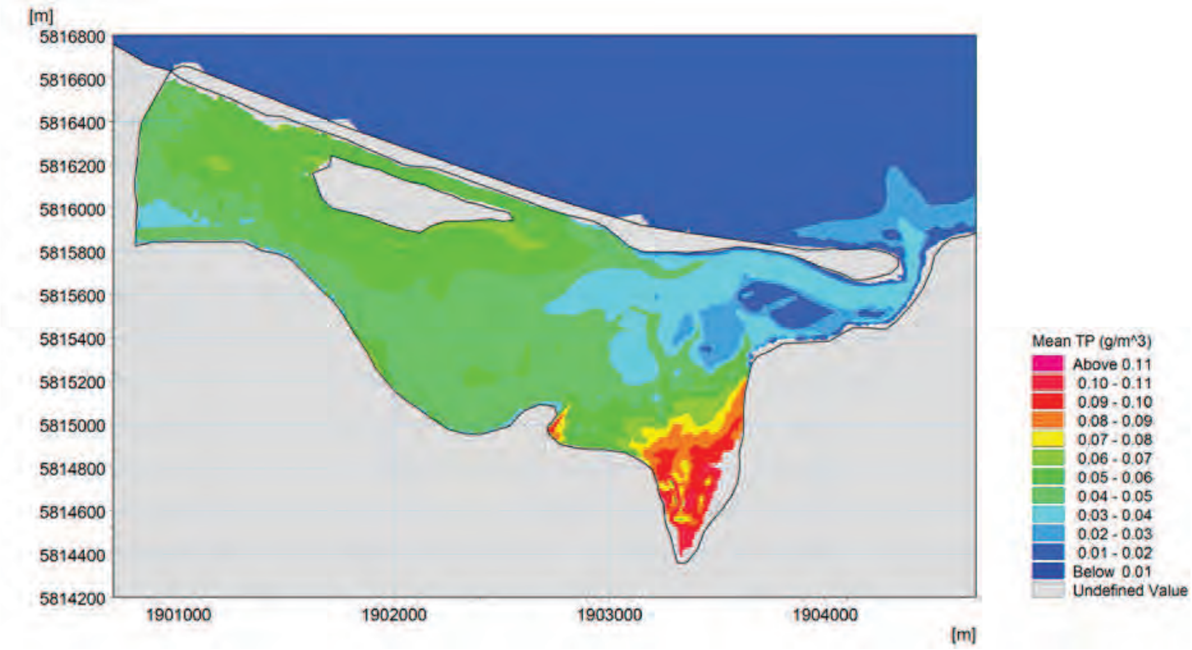
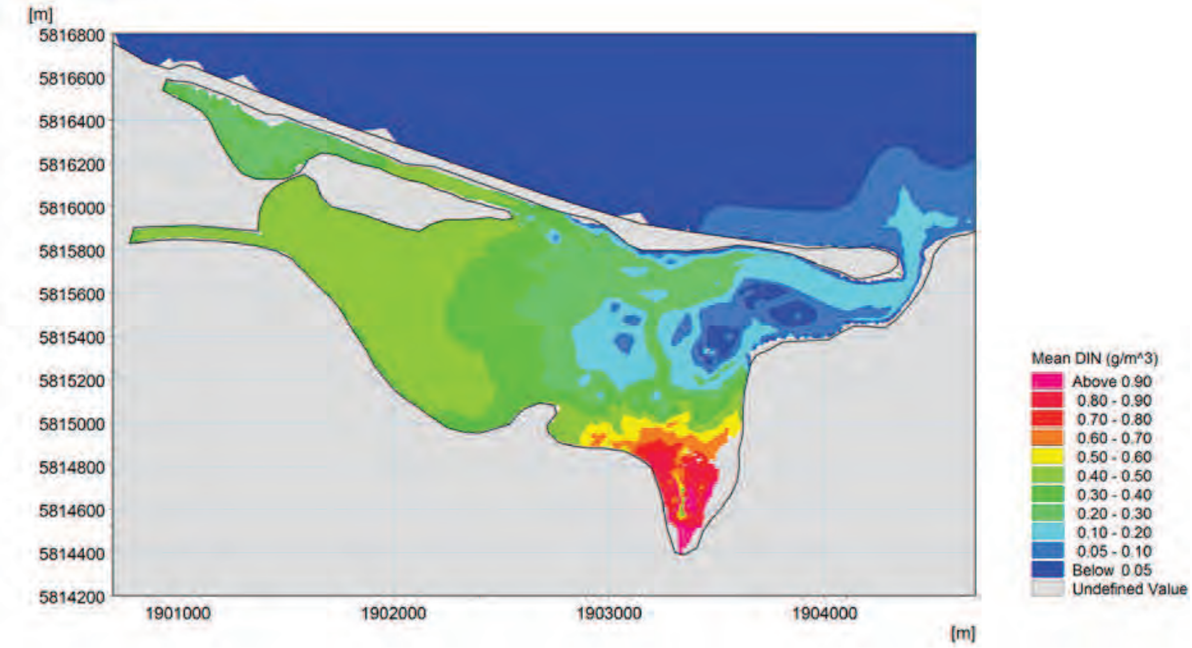


Figure 9-48 Depth averaged mean DIN – nutrient baseline assessment with existing situation (top) and proposed option (bottom) for mean river flow and neap/spring tidal cycle. Note for existing situation, no flow possible in area north-west of Papahikahawai Island, hence only initial condition displayed.



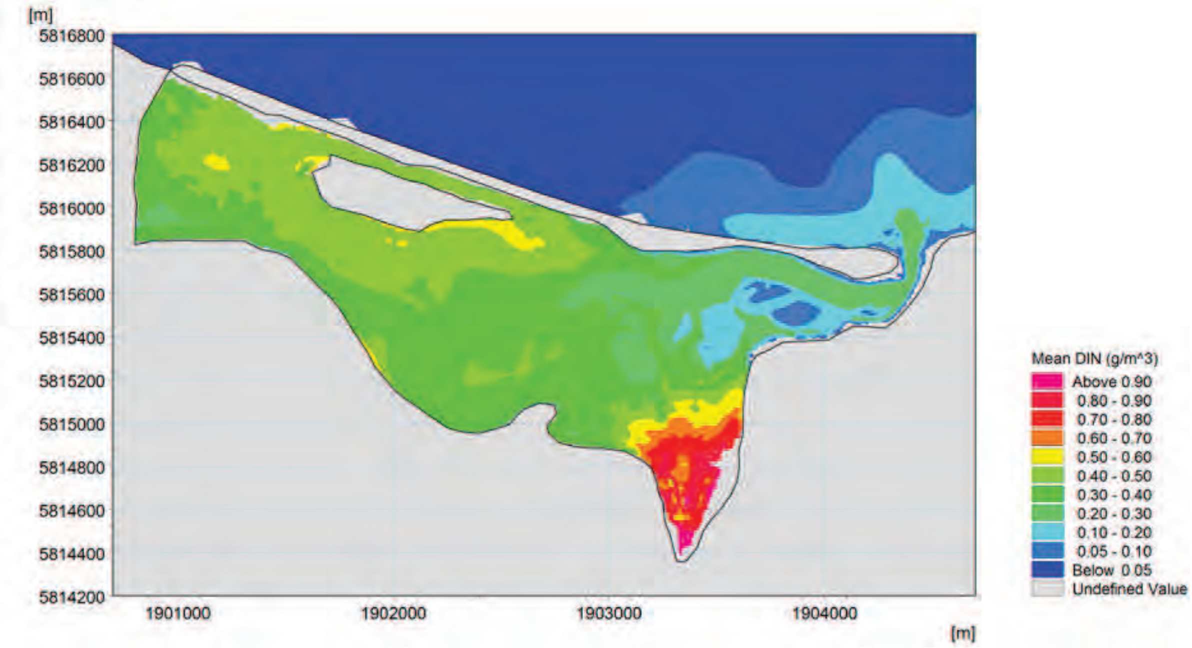


Figure 9-49 Depth averaged mean TP – nutrient baseline assessment with existing situation (top) and proposed option (bottom) for mean river flow and neap/spring tidal cycle. Note for existing situation, no flow possible in area north-west of Papahikahawai Island, hence only initial condition displayed.

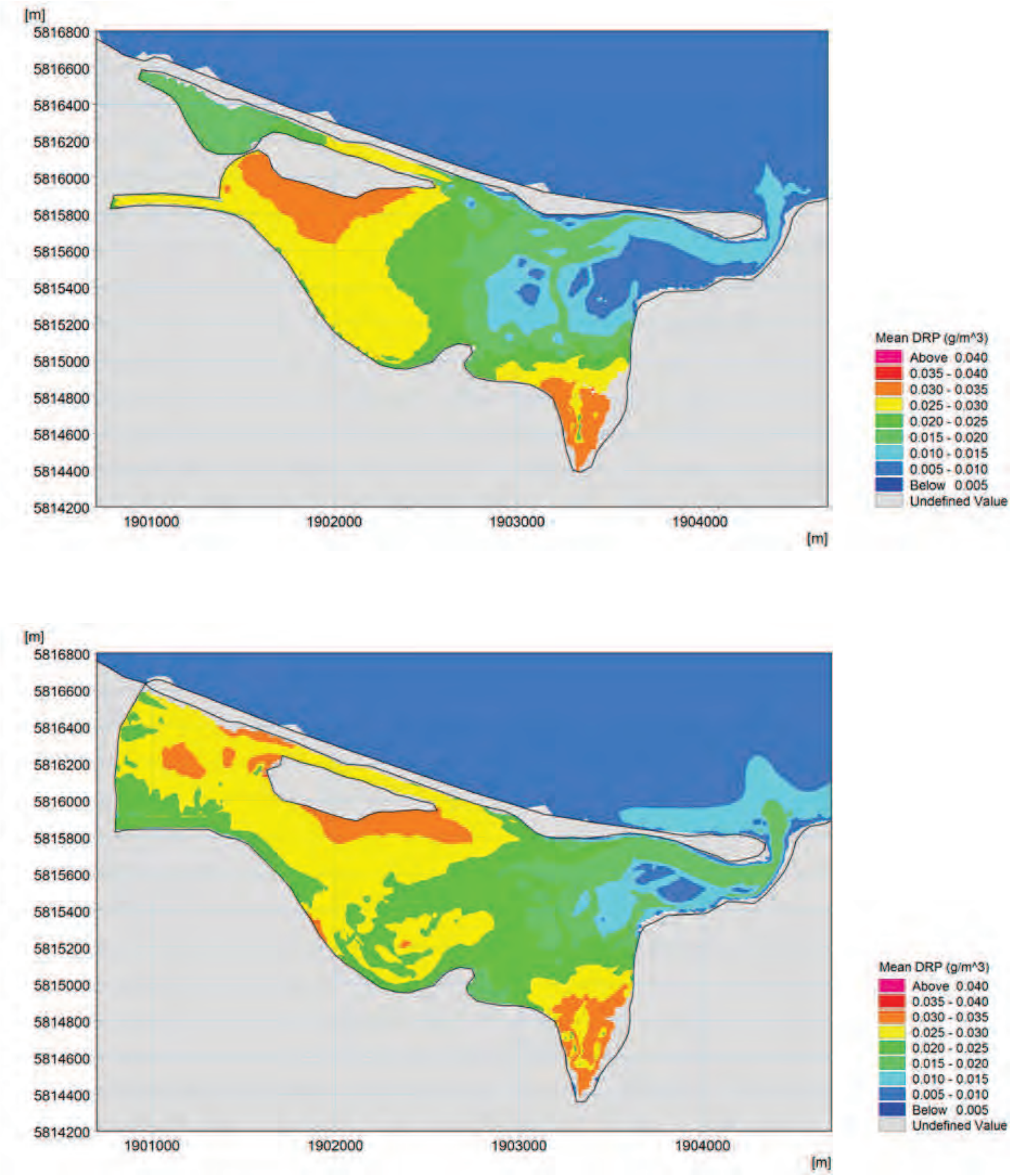


Figure 9-50 Depth averaged mean DRP – nutrient baseline assessment with existing situation (top) and proposed option (bottom) for mean river flow and neap/spring tidal cycle. Note for existing situation, no flow possible in area north-west of Papahikahawai Island, hence only initial condition displayed.

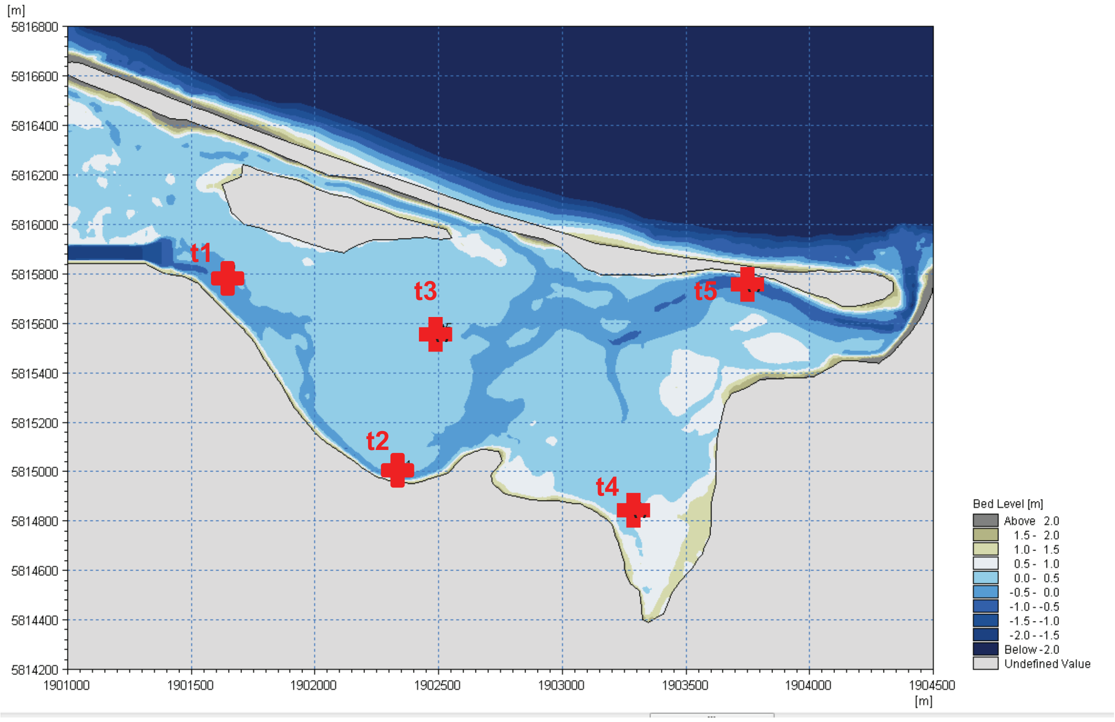


Figure 9-51 Extraction locations for TN and TP comparison.

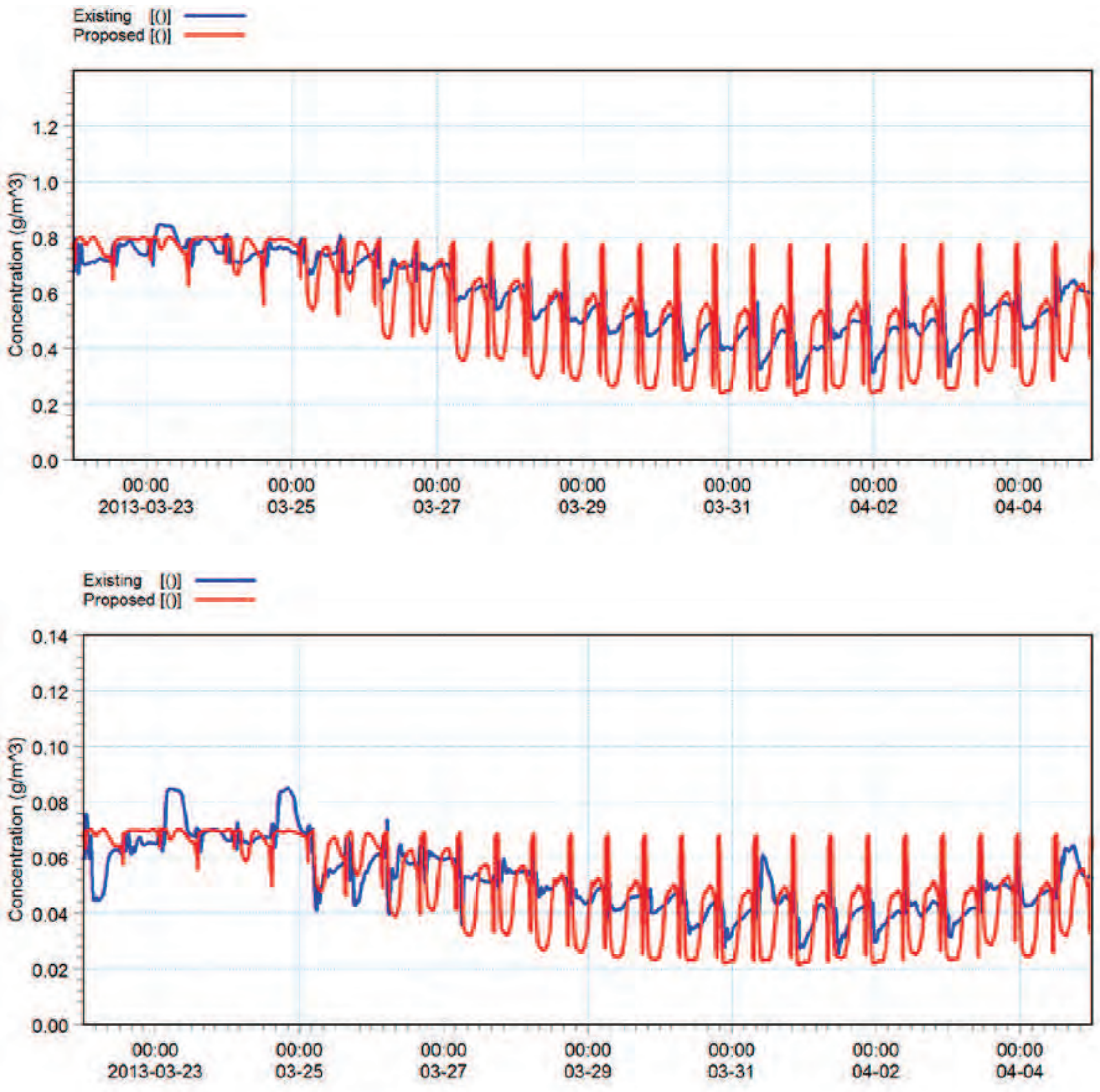
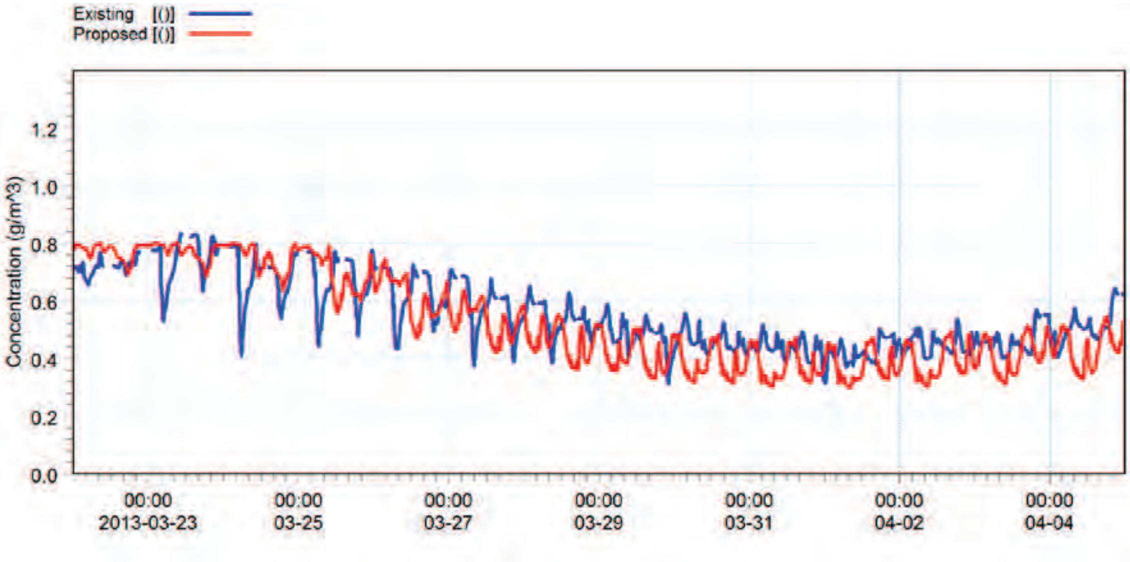


Figure 9-52 Nutrient baseline assessment - comparison of depth averaged TN (bottom) and depth averaged TP (top) for existing situation and proposed option at Ford's Cut location (t1). Mean river flow and neap/spring tidal cycle.



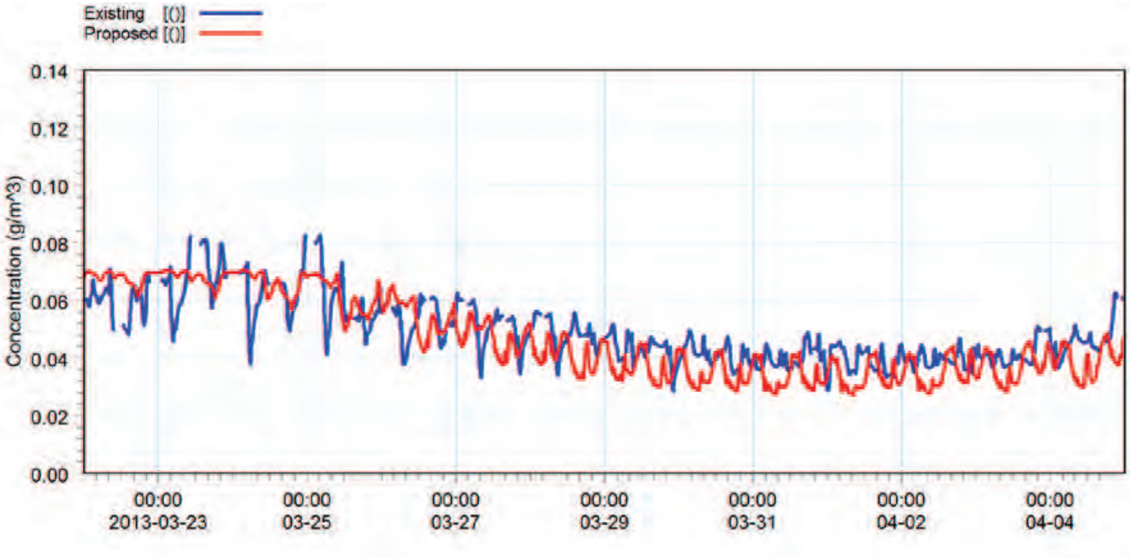
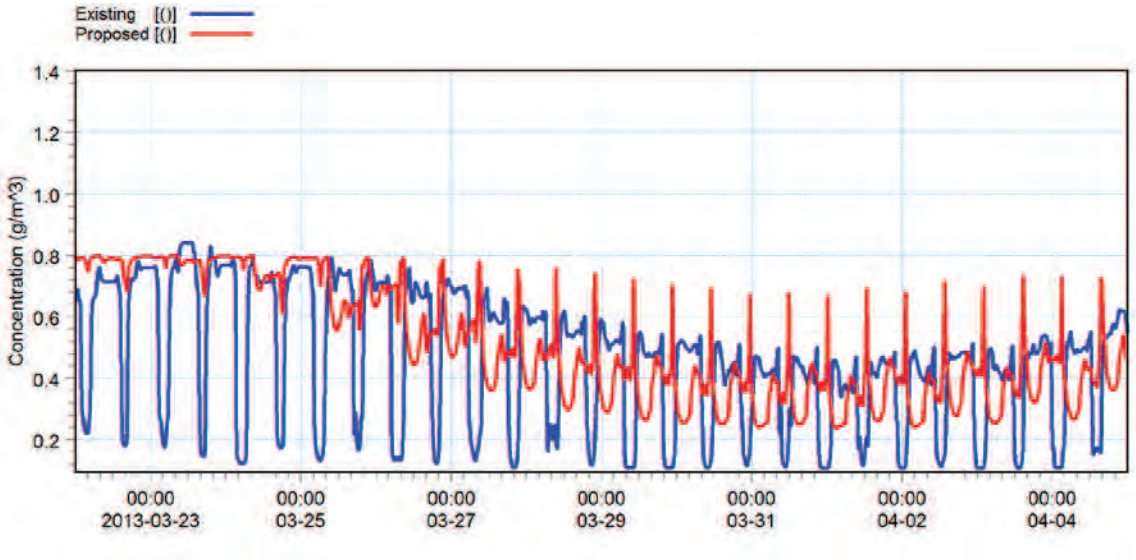


Figure 9-53 Nutrient baseline assessment - comparison of depth averaged TN (bottom) and depth averaged TP (top) for existing situation and proposed option at mid estuary channel location (t2). Mean river flow and neap/spring tidal cycle.



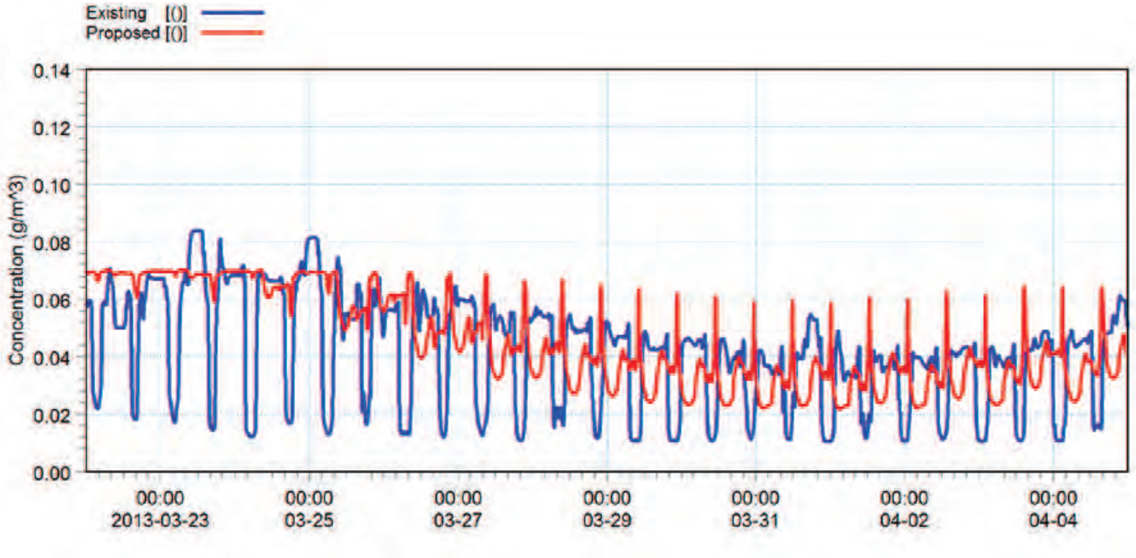


Figure 9-54 Nutrient baseline assessment - comparison of depth averaged TN (bottom) and depth averaged TP (top) for existing situation and proposed option at mid estuary tidal flat location (t3). Mean river flow and neap/spring tidal cycle.

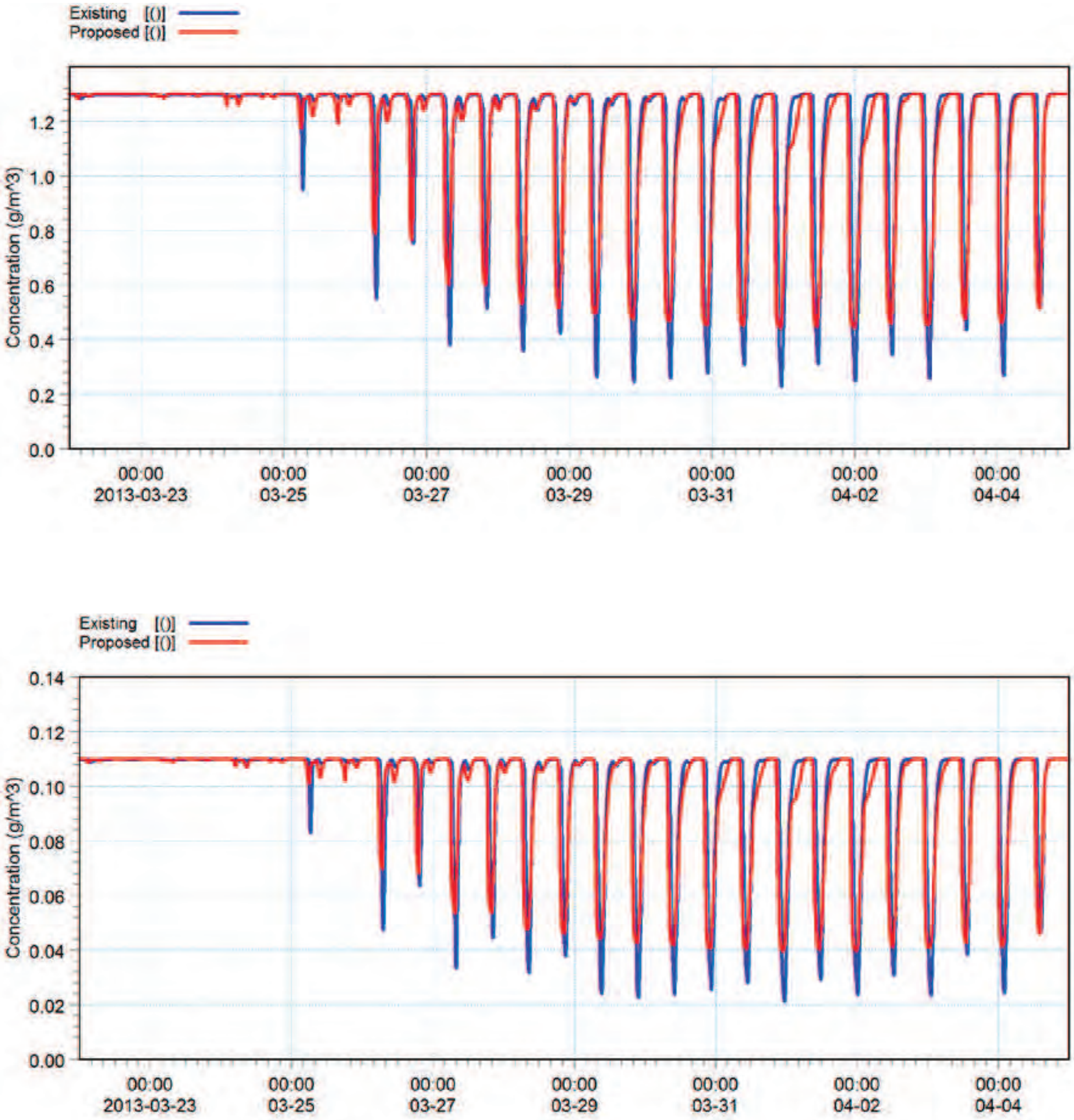
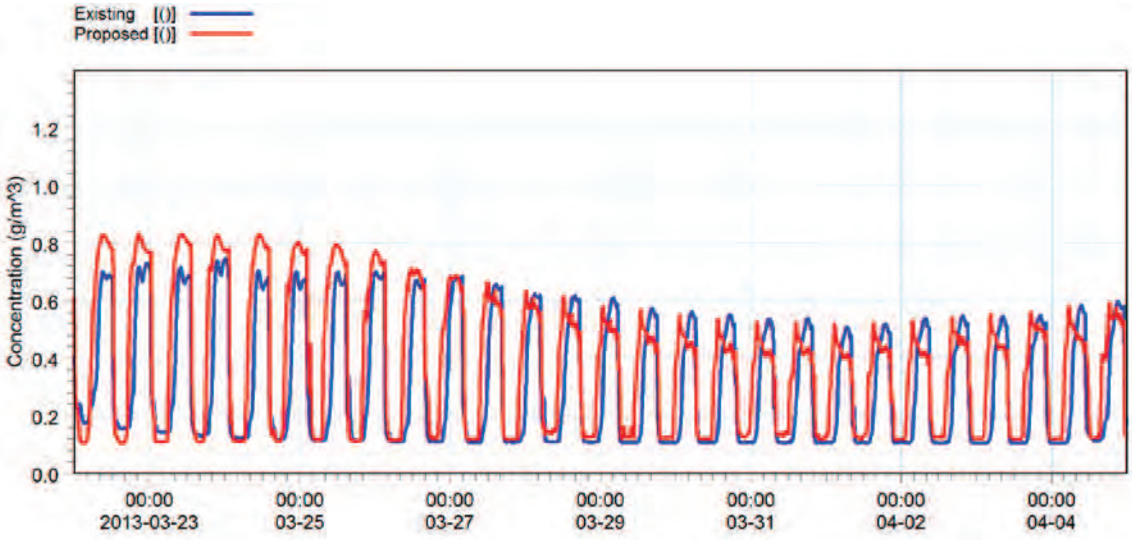


Figure 9-55 Nutrient baseline assessment - comparison of depth averaged TN (bottom) and depth averaged TP (top) for existing situation and proposed option at southern drains location (t4). Mean river flow and neap/spring tidal cycle.



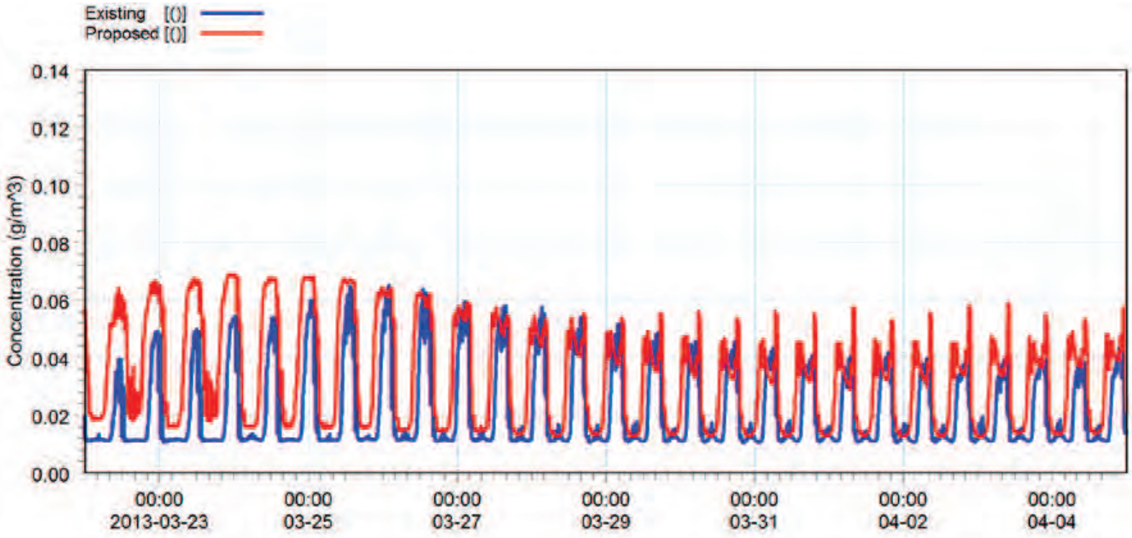


Figure 9-56 Nutrient baseline assessment - comparison of depth averaged TN (bottom) and depth averaged TP (top) for existing situation and proposed option at estuary entrance location (t5). Mean river flow and neap/spring tidal cycle.

9.5.2 Rain Event Assessment

For the nutrient rain event assessment, the significant river flows that occurred over the period 16th to 24th April 2013 were simulated. Flows provided by BoPRC for Kaituna River, Raparapahoe Canal and Kopuroa Canal for the event were used as inflows. Corresponding inflow data for Waiari Stream was provided by NIWA (see Section 3.3).

The rain event inflows for the drains identified as likely high contributors for pollutants to the estuary were provided by BoPRC as outlined in Section 3.3.

The nutrient data available for river and drains was analysed and appropriate nutrient concentrations were selected for the river and drains in agreement with the BoPRC project team. The selected nutrient concentrations are provided in Table 9-25.

Table 9-25 Selected rainfall event nutrient concentrations for significant freshwater inputs and drains.

Nutrient	Concentration (g/m^3)		
	Significant Freshwater Inputs	Drains	Open Ocean
TN	0.800	2.050	0.100
DIN	0.600	0.900	0.030
TP	0.070	0.230	0.010
DRP	0.040	0.040	0.006

The nutrient rain event assessment simulations were carried out for 11 days (13th April to 24th April 2013) to capture significant river flows that occurred. These simulations do not include a two day warm up period.

A comparison of the mean TN from the nutrient rain event assessment for the existing situation and the proposed option is presented in Figure 9-57. Similar comparisons for DIN, TP and DRP are presented in Figure 9-58 to Figure 9-60.

Time series of TN and TP have been extracted from selected locations shown in Figure 9-51. The comparison of predicted TN and TP at these locations for existing and proposed situations is presented in Figure 9-61 to Figure 9-65. The behaviour of DIN and DRP are similar to TN and TP respectively and therefore time series for these parameters have not been presented.

For the rain event, the nutrients that enter the estuary directly from the southern drains dominate the predicted highest mean concentrations in the vicinity of the southern drains and the lower estuary. This dominates any of the additional nutrients that enter the estuary with the proposed option. There is a slight increase in the mean TN, DIN, TP and DRP in areas of the mid to upper estuary. However it can be concluded that the impact of the proposed option on nutrient levels within the estuary is not significant for the rain event scenario.

The peaks in TN for the proposed option at the Ford’s Cut time series extraction location (see Figure 9-61) is a result of all of the pollutant from Ford’s Road drain entering the estuary compared with the existing situation where some of the pollutant from the drain is transported into the upper part of Ford’s Loop instead.

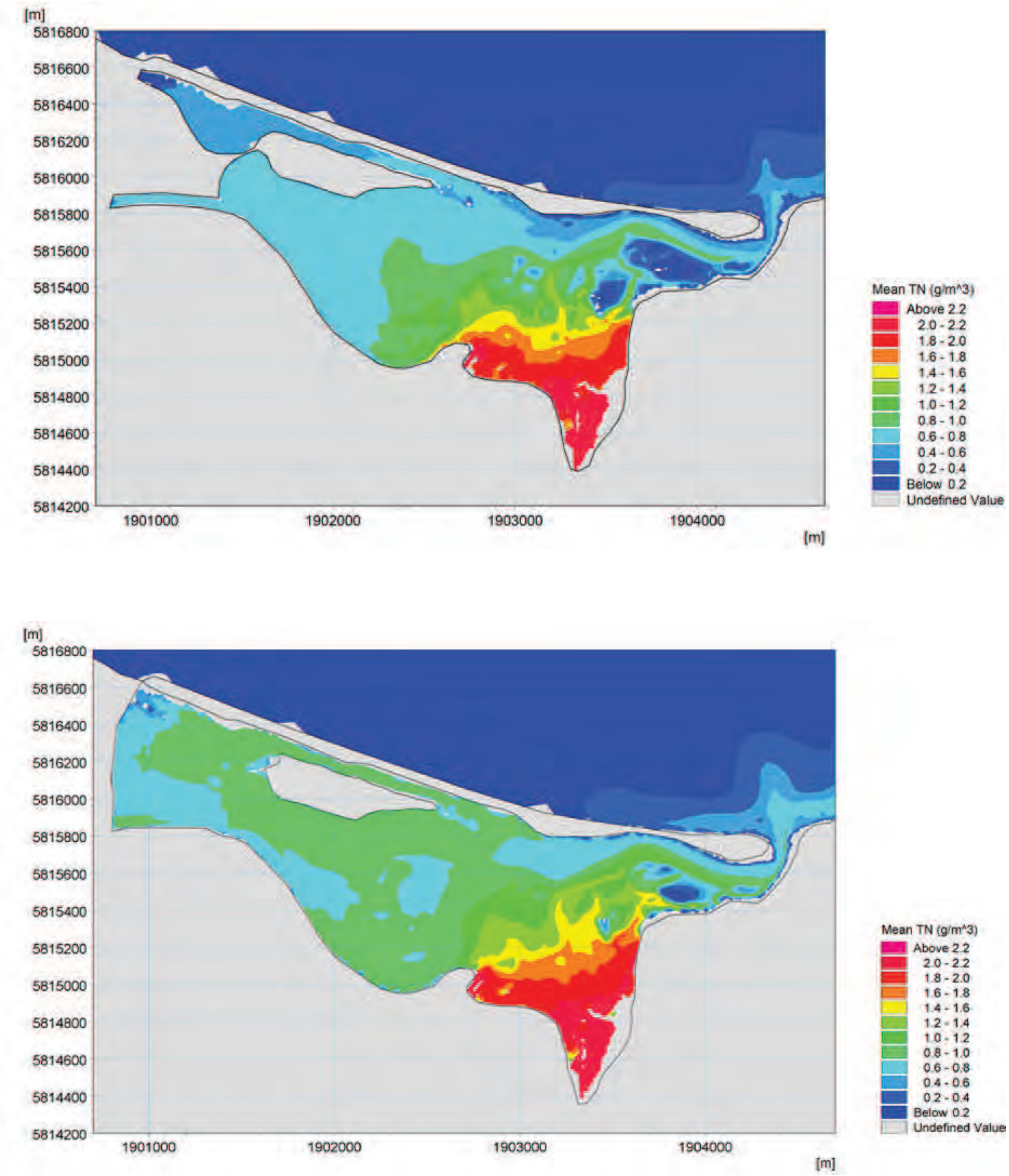


Figure 9-57 Depth averaged mean TN – nutrient rain event assessment with existing situation (top) and proposed option (bottom) for mean river flow and neap/spring tidal cycle. Note for existing situation, no flow possible in area north-west of Papahikahawai Island, hence only initial condition displayed.

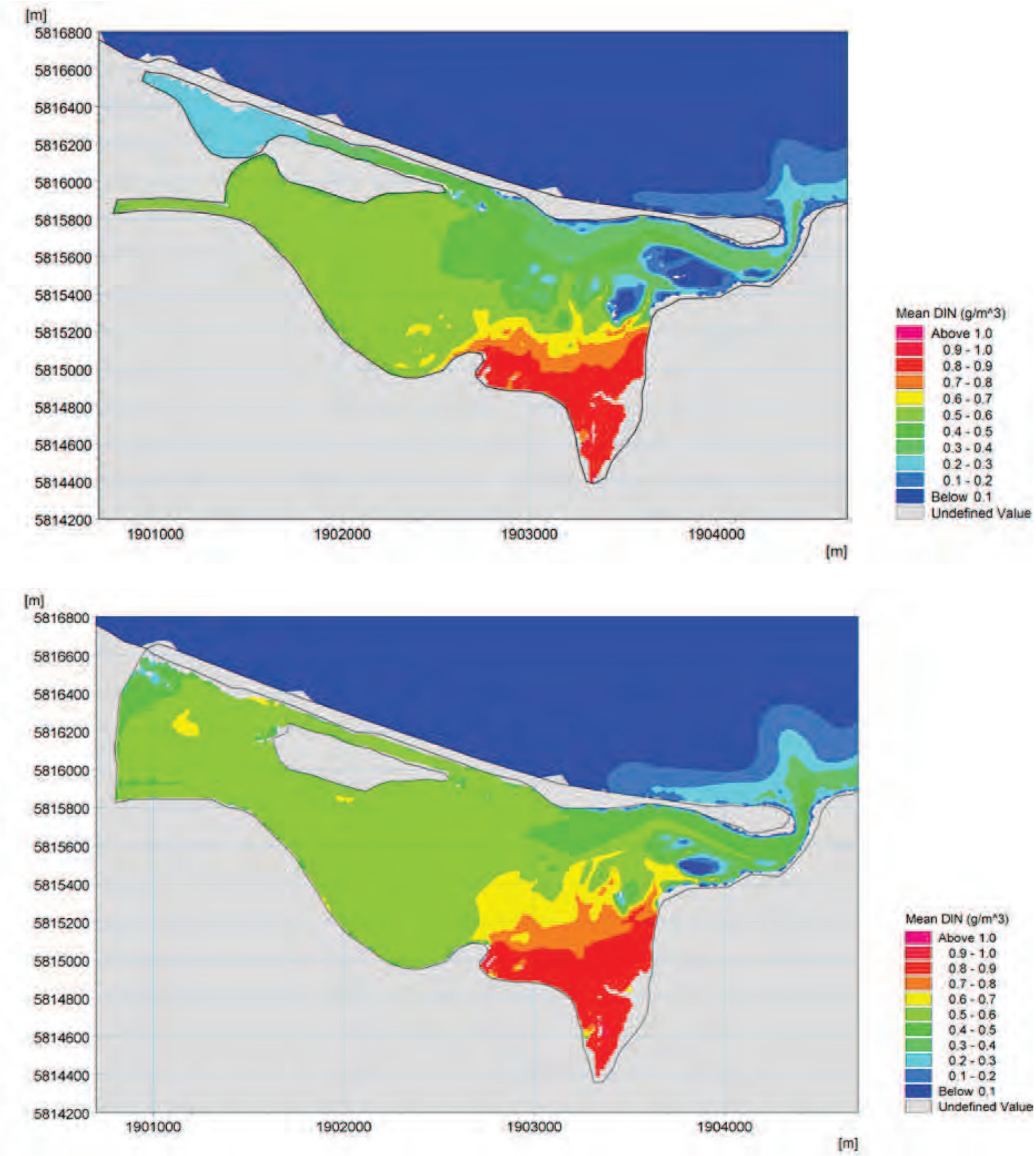


Figure 9-58 Depth averaged mean DIN – nutrient rain event assessment with existing situation (top) and proposed option (bottom) for mean river flow and neap/spring tidal cycle. Note for existing situation, no flow possible in area north-west of Papahikahawai Island, hence only initial condition displayed.

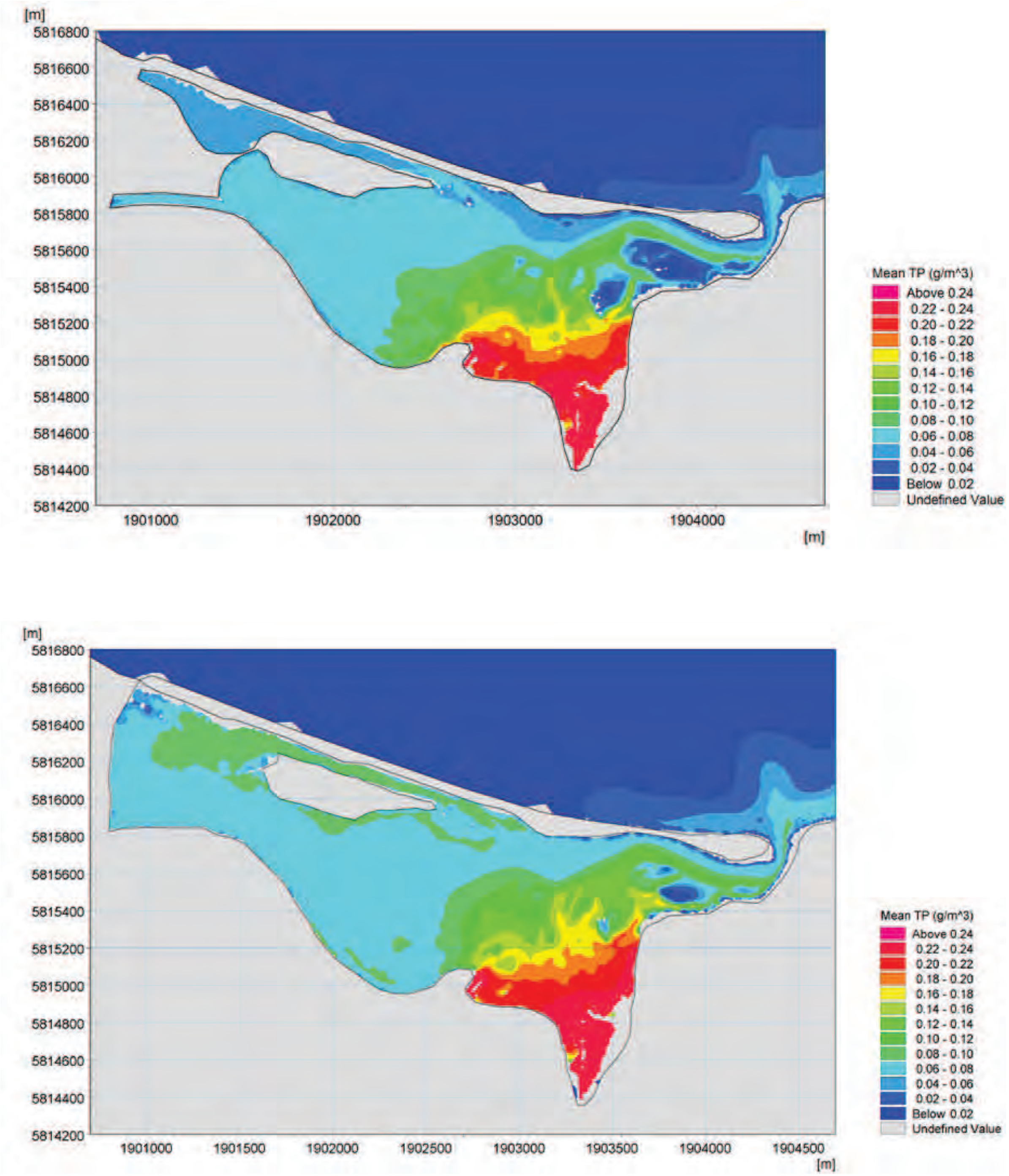


Figure 9-59 Depth averaged mean TP – nutrient rain event assessment with existing situation (top) and proposed option (bottom) for mean river flow and neap/spring tidal cycle. Note for existing situation, no flow possible in area north-west of Papahikahawai Island, hence only initial condition displayed.

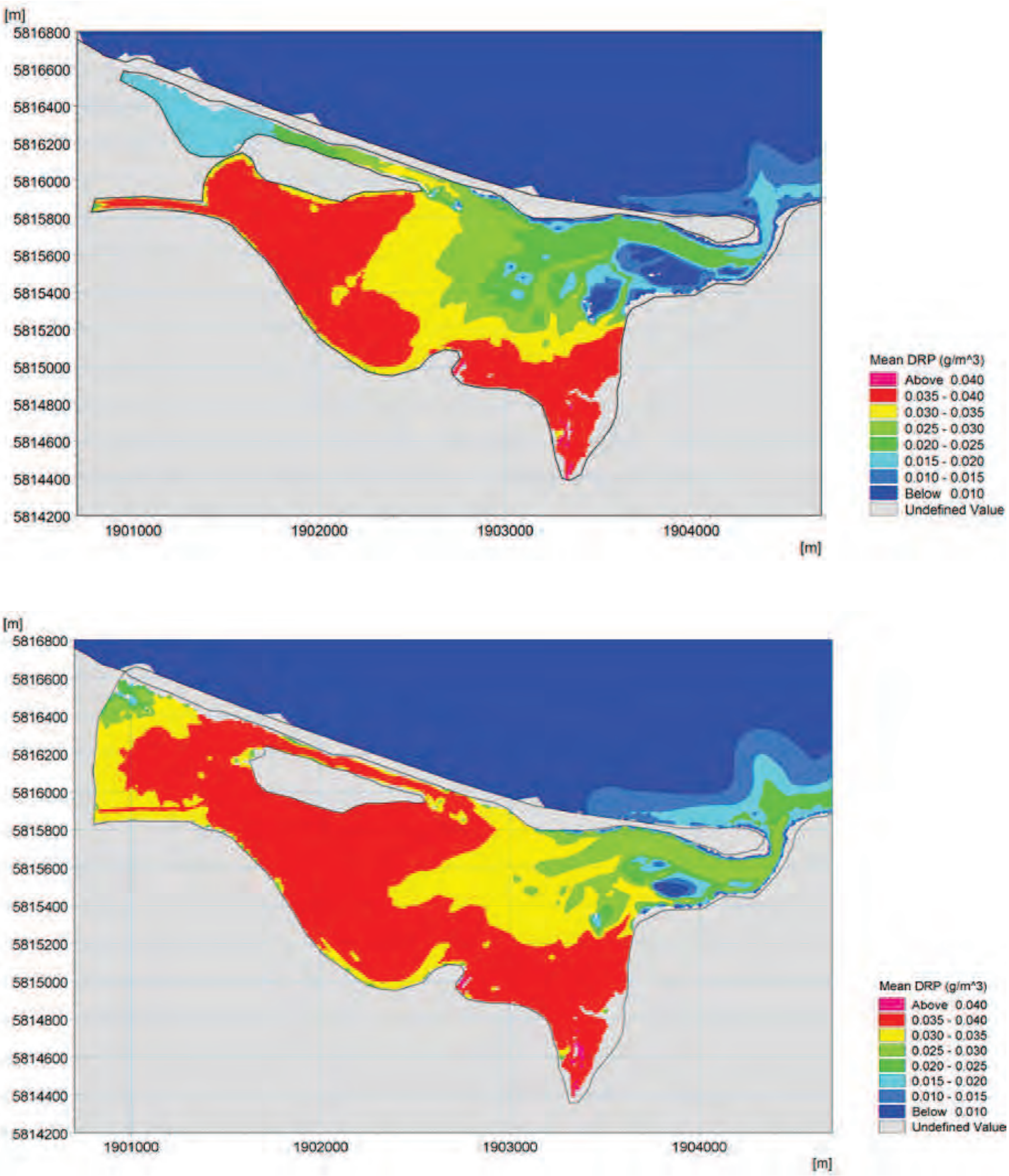
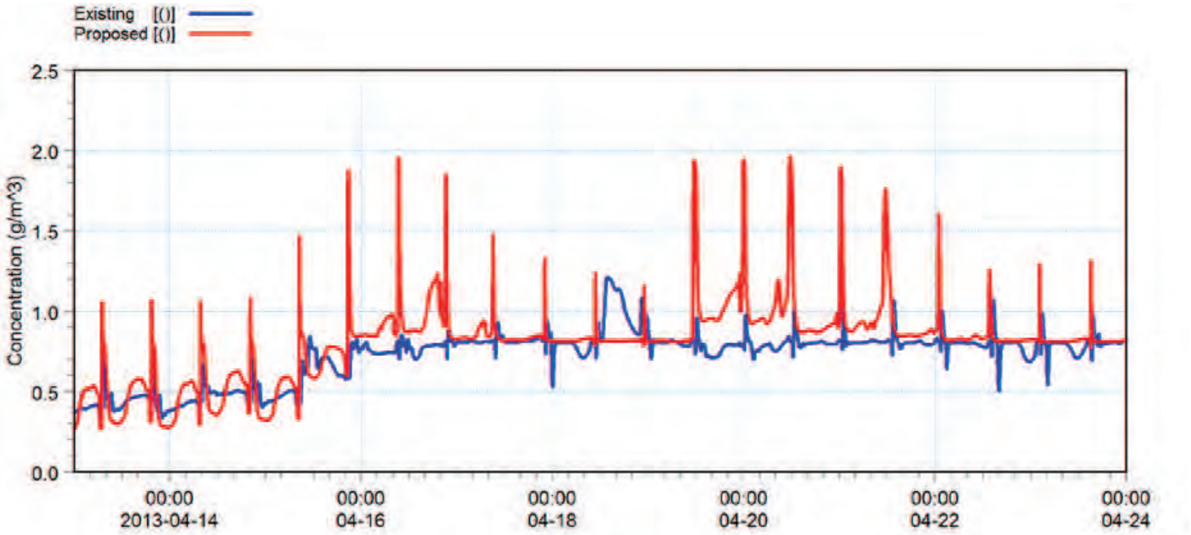


Figure 9-60 Depth averaged mean DRP – nutrient rain event assessment with existing situation (top) and proposed option (bottom) for mean river flow and neap/spring tidal cycle. Note for existing situation, no flow possible in area north-west of Papahikahawai Island, hence only initial condition displayed.



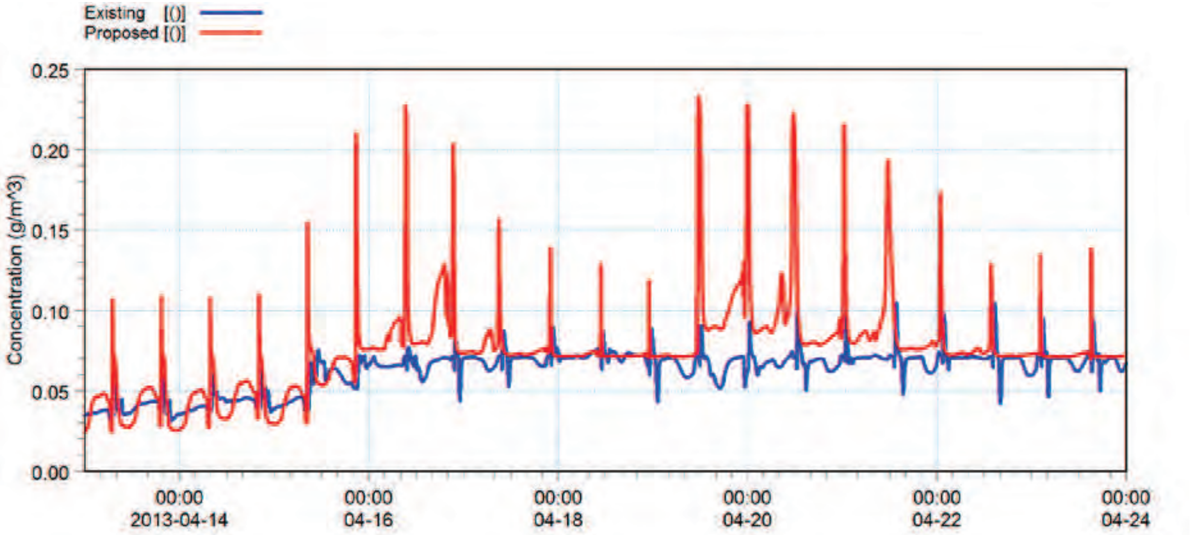
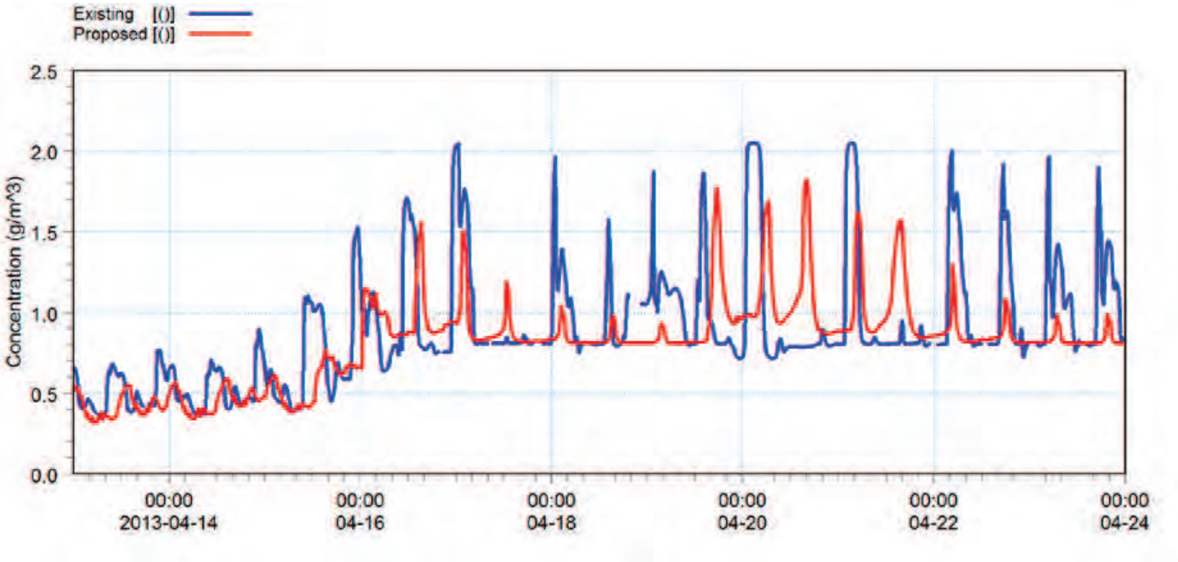


Figure 9-61 Nutrient rain event assessment - comparison of depth averaged TN (bottom) and depth averaged TP (top) for existing situation and proposed option at Ford's Cut location (t1). Mean river flow and neap/spring tidal cycle.



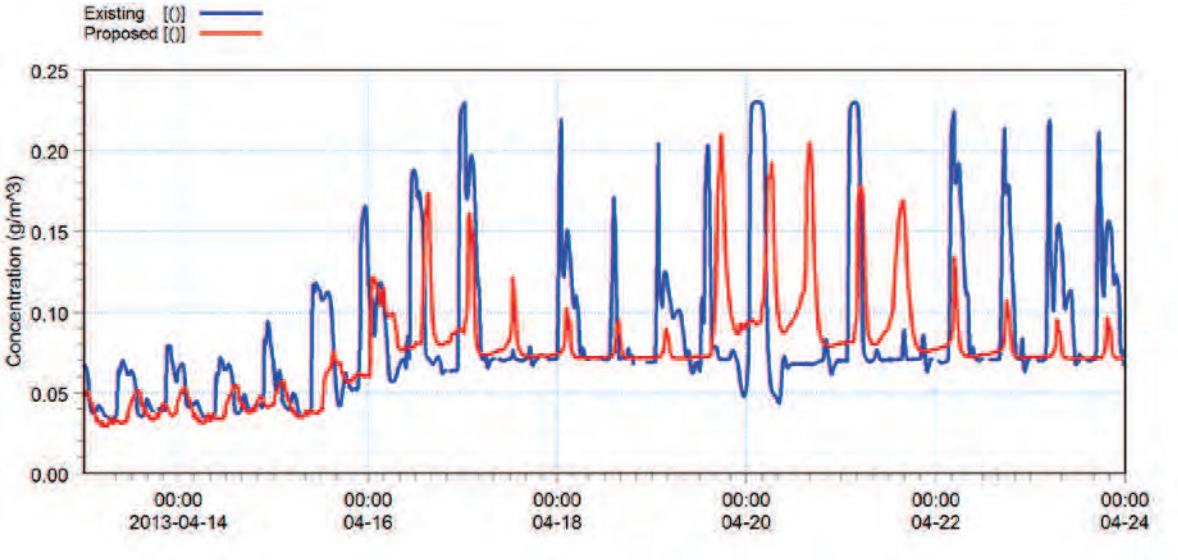
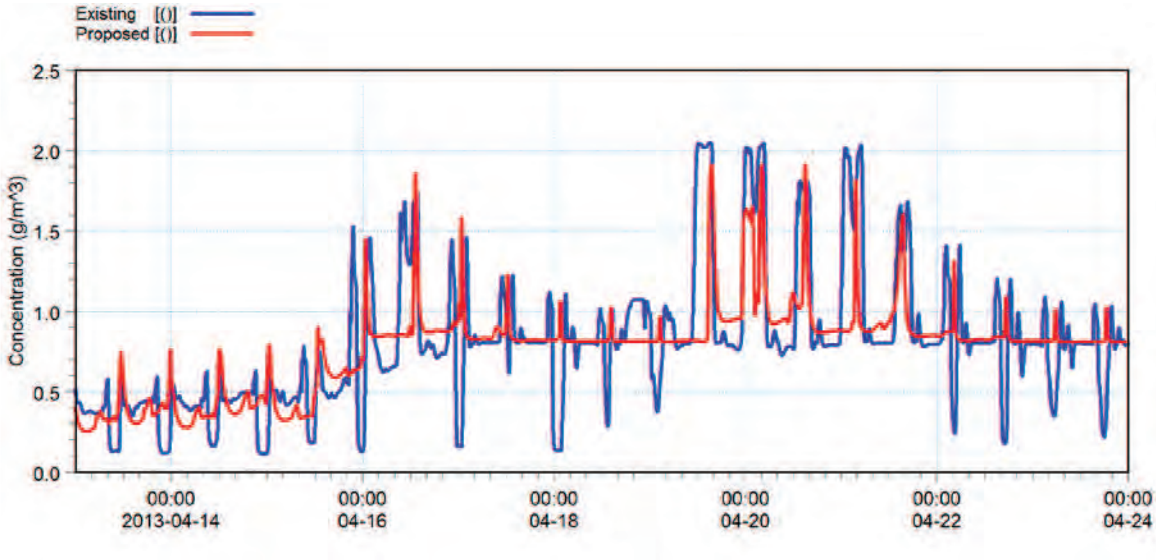


Figure 9-62 Nutrient rain event assessment - comparison of depth averaged TN (bottom) and depth averaged TP (top) for existing situation and proposed option at mid estuary channel location (t2). Mean river flow and neap/spring tidal cycle.



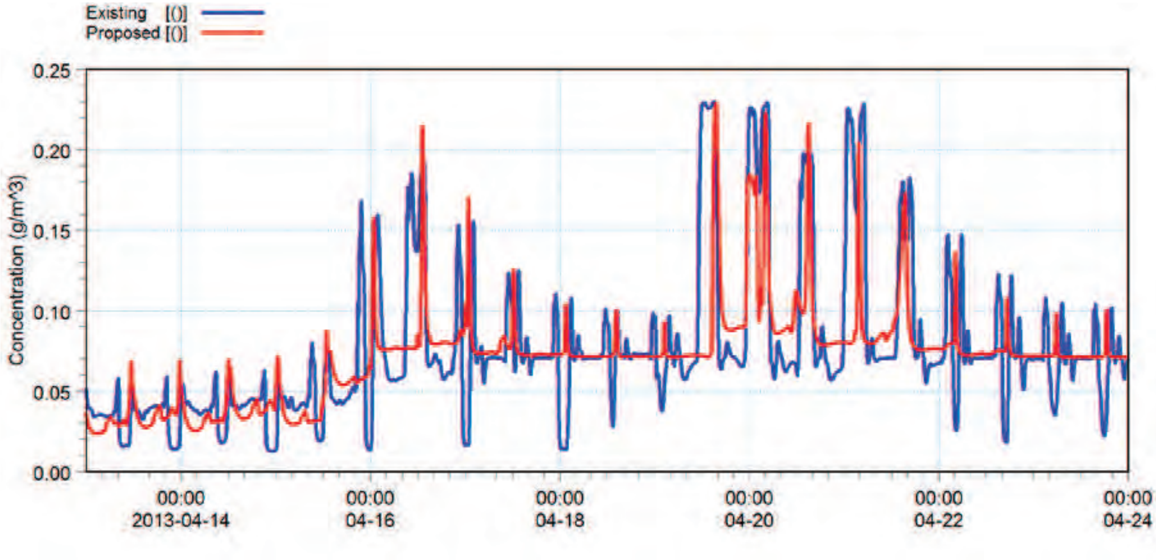
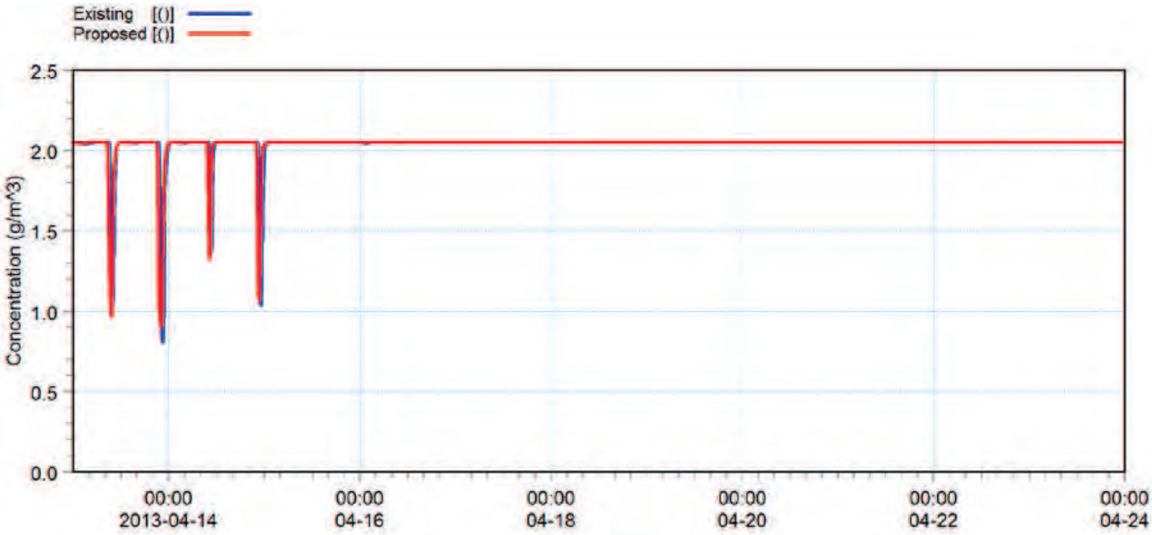


Figure 9-63 Nutrient rain event assessment - comparison of depth averaged TN (bottom) and depth averaged TP (top) for existing situation and proposed option at mid estuary tidal flat location (t3). Mean river flow and neap/spring tidal cycle.



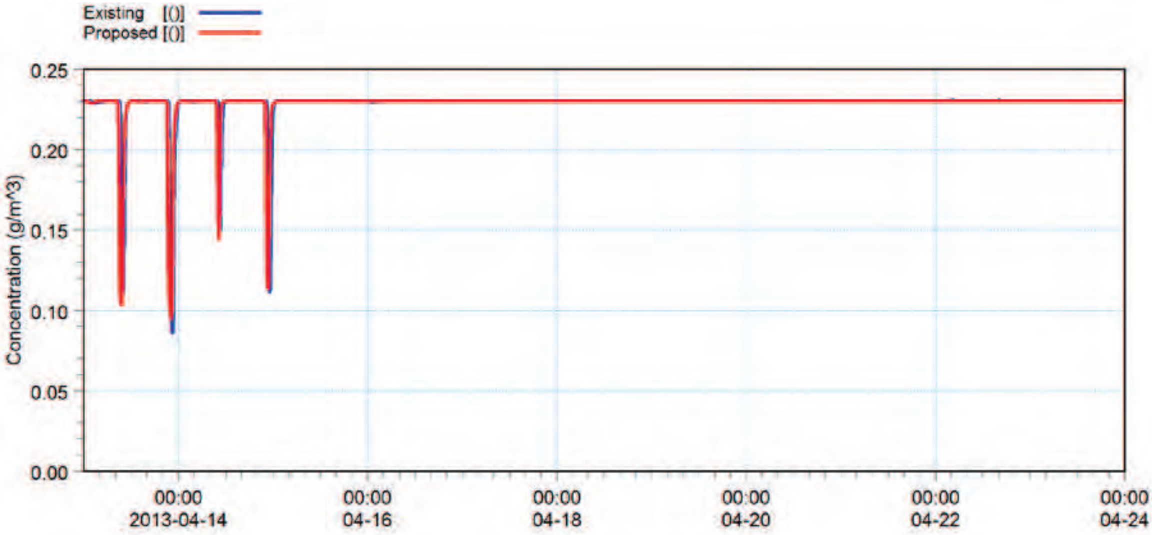
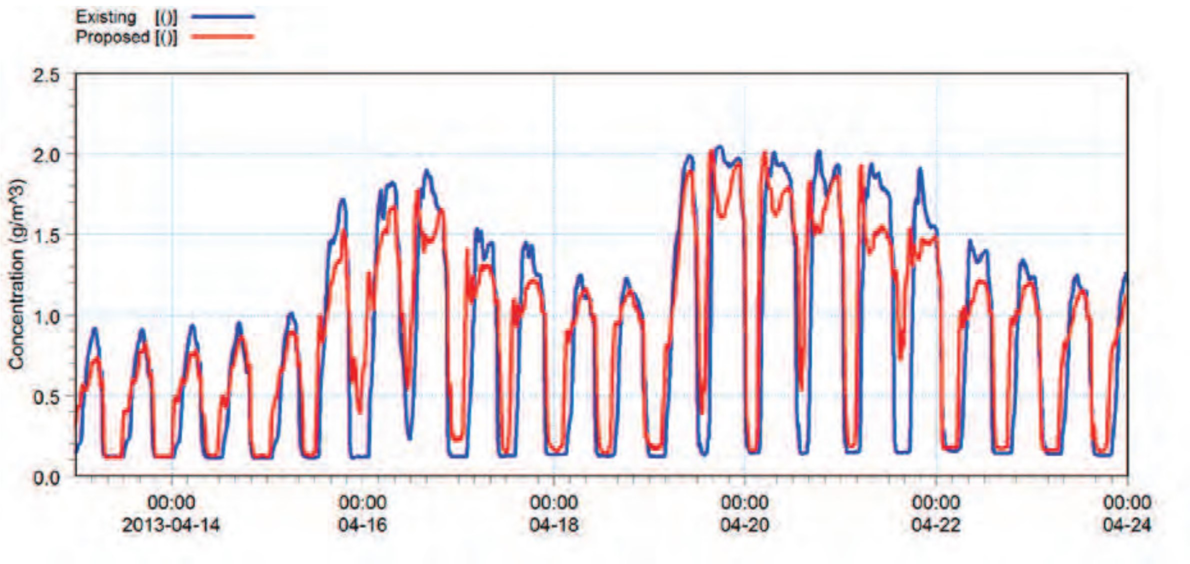


Figure 9-64 Nutrient rain event assessment - comparison of depth averaged TN (bottom) and depth averaged TP (top) for existing situation and proposed option at southern drains location (t4). Mean river flow and neap/spring tidal cycle.



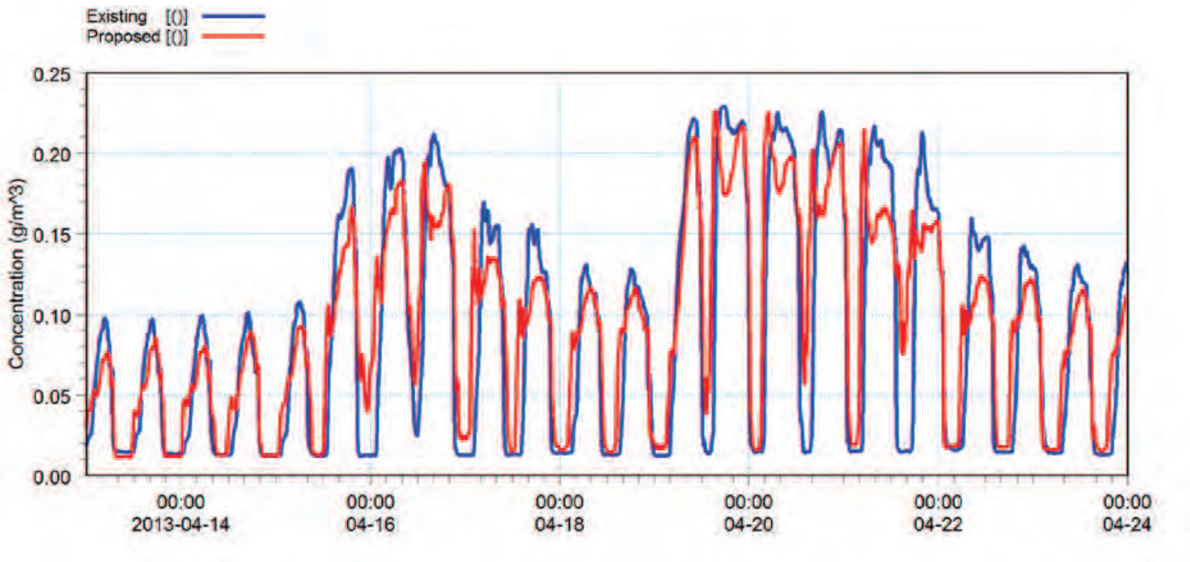


Figure 9-65 Nutrient rain event assessment - comparison of depth averaged TN (bottom) and depth averaged TP (top) for existing situation and proposed option at estuary entrance location (t5). Mean river flow and neap/spring tidal cycle.

10 Conclusions

A numerical modelling study has been carried out 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 study focusses on assessing changes in hydrodynamics, morphology and water quality that may occur in the lower Kaituna River and Ongatoro / Maketū Estuary.

A comprehensive data collection campaign was carried out to provide inputs to the numerical models and provide data for calibrating/validating these models.

A ten year wave hindcast was generated for the study site using a Pacific Ocean and regional scale Bay of Plenty wave model. There is evidence of a sheltering effect from Motiti Island at the study site. There is also a sheltering of waves from a north easterly direction due to Okurei Point with the most sheltering occurring at Ongatoro / Maketū Estuary mouth. There is an obvious seasonal component for the wave climate at the study site with predominantly north east swell generated waves from December to April and wind generated waves more apparent for May to November.

A sediment budget was determined for both the study site coastline and the Kaituna River. Historical coastal profiles indicate that the coastline appears to be relatively stable. A LITDRIFT analysis was performed for the coastlines to west and east of Okurei Point. For the coastline to the west of Okurei Point net sediment transport of 52,000 m^3/year was calculated, while for the east of Okurei Point a net sediment transport of 41,000 m^3/year was calculated. The predicted variability of these estimates relate to both orientation of the coastline and the shape of the coastal profile. Previous studies have calculated that for the Kaituna River there is approximately 7,000 m^3 of bed load sediment per year - significantly less than sediment supplied by littoral transport.

A morphological model was developed by coupling hydrodynamic, wave and sand transport models. A good calibration / validation was achieved for both the hydrodynamic and wave models using collected field data from the study site. The predictive ability of the morphological model was assessed using bathymetry surveys carried out for the Kaituna River mouth, pre and post a significant flood event within the river. The morphological model was utilised to investigate the hydrodynamic and morphological impacts of the proposed option for typical and extreme conditions. The main findings from the morphological assessment were:

- 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, no new areas of deposition are likely to develop in the lower river with the proposed option in place.
- There is a risk of erosion of the inside of the spit north of the existing flood tide delta for typical conditions. This risk is increased for an extreme flood event. If the flood tide delta was to erode this risk will reduce. Some type of mitigation maybe required once the proposed option is implemented such as a dredging a channel through 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 flow through Papahikahawai Creek, there is no evidence that this will increase the risk of erosion of the spit to the north of Papahikahawai Creek.

- The estuary mouth will switch from being 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 should be negligible impact on swimming safety within the lower estuary.

- The proposed option should not have a significant impact with regard to the morphological behaviour of the river mouth or estuary entrance for adverse or typical conditions. The increase in the volume of water exiting the estuary may encourage some additional scour through the estuary entrance.

A flood risk assessment for the proposed option was also carried out for a number of flood event scenarios. For normal sea levels there is no additional flood risk to the Maketū township. The 1% AEP river flow and 5% AEP sea level scenario predicts that there will be an increase in flood risk to Maketū for the proposed option with an increase in peak levels of approximately 0.17 m. For the 5% AEP river flow, 1% AEP sea level and 1% AEP river flow, 5% AEP sea level with climate change scenarios the proposed option is also shown to increase peak water levels by 0.05 m and 0.10 m respectively. However under these scenarios significant areas of Maketū would already be at risk from flooding as a result of the elevated sea levels. For all scenarios the proposed option will decrease peak water levels in the lower Kaituna River. For a May 2005 flood event the proposed option was predicted to have a small impact of drainage from drains into Ongatoro / Maketū Estuary. It should be noted that work is ongoing investigating the increase in flood risk within the estuary and how it can be resolved from a risk management perspective.

Water quality models were developed to assess the impact of the proposed option on salinity within the estuary, flow to the Kaituna Wetland, salinity at Titchmarsh intake, blue-green algae concentrations, shellfish collection and bathing suitability (bacteria levels) and nutrients concentrations within the estuary. A 3D hydrodynamic model was required to predict the propagation of the salt wedge within the Kaituna River, which ultimately determines the ratio of salt and fresh water which will enter the estuary from the river. A satisfactory calibration of the 3D hydrodynamic model was achieved using salinity data collected within the river and estuary. The bacteria and blue-green algae models were validated using data collected from the estuary.

With regard to salinity within the estuary, the salinity assessment predicted that with the proposed option, the overall mean salinities will decrease throughout the estuary. The amount of this decrease in salinity is dependent on the location within the estuary and associated river flow. Although the volume of freshwater entering the estuary from the river will significantly increase, compared with the existing situation there will not be a large change in the range of the ratios of freshwater / saltwater entering the estuary from the river.

For low river flow conditions it is predicted that the proposed option will not have a significant impact on the maximum extent of the salt wedge, while for mean river flow the maximum extent of the salt wedge will migrate some 200 – 250 m further upstream.

The proposed option will slightly decrease water levels within the lower Kaituna River and therefore will decrease the flow into the Kaituna Wetland per tidal cycle. A 0.9m diameter flap gated culvert with a length of 10 m was predicted to compensate for the loss of flow to the wetland.

The proposed option will increase salinities at the Titchmarsh intake. BoPRC will install a salinity monitor in the river at the intake to ensure that water is not extracted during periods with high salinities.

To assess whether the proposed option will increase the risk of non-compliance with New Zealand guidelines for blue-green algae, bathing and shellfish collection, a statistical approach was taken where a number of simulations with different river flows were carried out to assess dilution of blue-green algae and bacteria within the estuary. The predicted dilutions were then assigned probabilities which were then related to observed blue-green algae and bacteria concentrations from the river to provide an estimate of the probability of the relevant guideline values being exceeded within the estuary.

Using this method the following was predicted for the proposed option:

- With regard to blue-green algae in the lower estuary, there is an increase in the percentage of time that blue green algae will exceed 15,000 algae cells / ml from 3.5% to 3.6%. This is not considered a significant increase in the risk for blue-green algae blooms to occur within the estuary.

- For shellfish collection in the lower estuary, there is an increase in the percentage of time that faecal coliforms will exceed 14 counts / 100 ml from 32.2% to 44.1% and 43 counts / 100 ml from 12.6% to 20.6%. It should be noted that under the existing conditions 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 does not improve this compliance.

- For bathing suitability at the boat ramp, there is an increase in the percentage of time that Enterococci exceed 280 counts / 100 ml from 2.0% to 3.3%. This is not considered a significant increase.

A nutrient model was applied to assess the impact of additional nutrients from the river to the estuary for a baseline scenario assuming a mean river flow and a rain event scenario. The nutrients investigated were TN, TP, DIN and DRP.

For the baseline nutrient assessment, it was predicted that there will not be a significant increase in mean nutrient levels within the estuary, however compared with nutrient levels in the majority of the estuary there will be relatively high nutrient levels in the newly created Brains Land wetland.

For the rain event nutrient assessment, it was predicted that that the proposed option will not have a significant impact on mean nutrient levels within the estuary.

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APPENDICES

APPENDIX A

Sediment Grab Sample Analysis

A.1 Sediment Grab Sample Analysis

Lab ID	Sample Number	East NZTM	North NZTM	Shell Dissolved	% Shell	2.36mm	1.18mm	0.6mm	0.3mm	0.21mm	0.15mm	0.09mm	0.075mm	<0.075mm
						Percentage Retained in Sieve (%)								
13/2625	1	1894894	5814133		0	3.88	12.32	39.83	37.77	5.21	0.57	0.21	0.06	0.15
13/2626	2	1895057	5816298		0	1.41	11.72	44.11	30.39	9.74	2.2	0.24	0.06	0.12
13/2627	3	1895093	5816277		0	0.71	5.44	58.06	34.55	0.91	0.14	0.11	0.04	0.04
13/2628	4	1896352	5817107		0	0.03	1.51	29.75	59.5	7.9	0.88	0.24	0.08	0.11
13/2629	5	1896362	5817125		0	12.19	27.27	41.01	18.19	1.07	0.15	0.05	0.01	0.05
13/2630	6	1898081	5816780		1	1.42	8.2	37.61	42.51	7.79	1.84	0.45	0.13	0.05
13/2631	7	1898091	5816806		0	7.29	12.55	36.86	38.32	4.21	0.52	0.18	0.05	0.01
13/2632	8	1899280	5816290		0	2.16	4.8	26.07	51.17	13.07	2.25	0.39	0.03	0.06
13/2633	9	1899283	5816324		0	1.36	6.69	29.46	49.07	10.78	1.88	0.48	0.11	0.17
13/2768	10	1899477	5817512		0	0.21	0.76	5.53	27.06	32.07	29.27	4.79	0.25	0.06
13/2769	11	1899600	5817725		0	0.07	0.33	0.88	6.6	23.15	44.62	20.79	2.06	1.51
13/2770	12	1899858	5818116		0	0.04	0.07	0.81	2.29	8.66	33.35	43.11	7.54	4.11
13/2771	13	1900150	5818578		0	0.34	0.32	1.54	5.41	6.28	23.58	54.93	5.24	2.35
13/2634	14	1900563	5816275		2	1.67	6.81	29.57	34	17.79	7.97	1.88	0.16	0.14
13/2635	15	1900571	5816240		0	0.73	2.01	9.65	28.85	34.21	17.45	4.96	0.89	1.24
13/2636	16	1900575	5815838		0	0.23	1.41	4.78	5.55	4.05	7.39	13.07	7.61	55.92
13/2637	17	1900593	5815870		0	0.12	0.58	3.38	4.88	3.61	6.21	12.97	8.23	60.03
13/2638	18	1900753	5816124		0	0.06	0.62	2.01	3.02	2.9	8.61	25.93	12.02	44.83
13/2639	19	1900771	5816124		0	0.23	1.08	3.27	4.39	4.22	10.29	23.59	10.5	42.43
13/2640	20	1900772	5816376		2	0.77	6.92	30.82	50.81	9.12	1.19	0.27	0.05	0.06
13/2772	21	1900800	5817313		0	0.08	0.34	1.48	3.56	15.04	40.7	31.48	4.65	2.66
13/2773	22	1900822	5816992		0	0.24	0.58	1.02	4.63	21.12	53.13	17	1.3	0.99
13/2774	23	1900865	5816878		0	0.03	0.61	2.65	19.58	32.59	35.91	8.27	0.29	0.07
13/2775	24	1900908	5816748		2	4.71	5.06	28.76	31.42	16.41	11.52	2.01	0.09	0.02
13/2641	25	1900908	5816590		0	1.85	3.55	23.79	54.46	11.53	3.29	1.12	0.19	0.23
13/2776	26	1900994	5816948		0	0.16	0.27	1.19	4.67	25.07	52.89	14.29	0.87	0.59

Lab ID	Sample Number	East NZTM	North NZTM	Shell Dissolved	% Shell	2.36mm	1.18mm	0.6mm	0.3mm	0.21mm	0.15mm	0.09mm	0.075mm	<0.075mm
						Percentage Retained in Sieve (%)								
13/2642	27	1901001	5815889		0	0.1	0.54	4.62	21.42	23.76	27.58	14.25	1.97	5.76
13/2777	28	1901020	5816791		2	6.32	6.24	39.35	36.07	8.37	3.07	0.55	0.02	0.01
13/2778	29	1901087	5817285		0	0.03	0.24	0.93	2.43	7.66	36.61	43.07	5.22	3.8
13/2779	30	1901180	5816869		0	0.11	0.2	1.16	4.67	30.4	49.08	13.07	0.76	0.54
13/2643	31	1901261	5815875		0	0.29	0.91	6.65	30.05	21.56	16.24	9.64	3	11.67
13/2780	32	1901303	5817103		0	0.06	0.49	1.34	5.37	8.67	36.71	39.32	4.72	3.31
13/2644	33	1901520	5816020		0	0.3	0.58	3.43	10.55	18.78	26.93	17.71	4.51	17.21
13/2645	34	1901530	5815789		0	2.8	2.88	12.49	34.39	26.8	14.12	4.37	0.61	1.53
13/2646	35	1901892	5815614		0	0.14	0.63	5.07	25.86	16.82	13.27	13.13	5.26	19.83
13/2647	36	1901940	5815312		0	1.37	4.96	19.88	28.76	9.75	7.55	6.01	2.18	19.54
13/2648	37	1902018	5815843		0	0.8	1.4	5.68	23.02	16.55	15.63	14.55	4.69	17.68
13/2649	38	1902266	5816110		0	0.21	0.79	11.59	51.91	19.29	8.6	2.53	1.62	3.46
13/2650	39	1902298	5815006		0	2.74	2.25	13.81	39.69	22.84	13.64	3.61	0.56	0.85
13/2651	40	1902375	5815351		0	0.95	1.32	3.63	14.17	14.39	28.12	28.02	4.08	5.33
13/2652	41	1902444	5815633		0	0.74	1.32	10.31	31.62	18.52	15	10.99	3.13	8.37
13/2781	42	1902462	5816290		0	0.61	1.12	4.42	17.94	30.09	37.76	7.61	0.41	0.02
13/2653	43	1902481	5815846		0	0.72	1.18	6.71	23.3	15.67	14.67	15.85	5.38	16.52
13/2782	44	1902625	5816825		0	0.03	0.34	3.63	11.57	5.8	17.9	44.14	9.17	7.41
13/2654	45	1902724	5815454		0	0.83	1.2	4.18	16.87	18.06	31.39	20.59	4.49	2.39
13/2783	46	1902763	5817433	yes	46.2	5.29	13.87	24.29	39.56	13.73	2.79	0.41	0.03	0.03
13/2655	47	1902897	5815839		1	0.07	0.9	19.26	51.24	17.37	7.16	2.11	0.68	1.19
13/2656	48	1902940	5815287		2	0.56	2.69	14.52	29.05	19.18	19.84	10.78	1.18	2.19
13/2657	49	1903053	5815621		1	0.37	1.86	17.58	30.22	15.63	23.23	9.53	0.88	0.71
13/2658	50	1903116	5814934		1	0.94	1.48	5.52	16.27	15.18	31.94	21.84	2.8	4.03
13/2659	51	1903198	5815384		2	3.47	1.13	7.81	22.65	21.69	30.95	10.54	1.21	0.55
13/2784	52	1903200	5818469		1	0.81	3.77	16	61.77	14.38	2.8	0.39	0.04	0.04
13/2660	53	1903381	5814976		0	1.06	1.36	4.23	11.15	21.34	43.69	14.15	1.43	1.6
13/2661	54	1903441	5815674		2	1.65	5.75	28.64	44.52	10.91	6.04	1.74	0.23	0.51
13/2662	55	1903518	5815378		1	0.31	1.81	11.75	23.26	24.28	26.08	7.94	2.19	2.39
13/2663	56	1903757	5815451		1	0.99	1.77	10.93	20.86	24.17	30.26	8.1	1.3	1.62
13/2785	58	1903831	5817655	yes	41.2	0	2.17	80.33	16.7	0.37	0.31	0.11	0.02	0
13/2786	59	1903892	5816218		0	0.03	0.57	2.99	3.17	13.42	44.64	26.76	5.44	2.97
13/2664	60	1903969	5815664	yes	21.2	6.38	17.31	21.97	21.73	19.45	11.61	1.52	0.03	0

Lab ID	Sample Number	East NZTM	North NZTM	Shell Dissolved	% Shell	2.36mm	1.18mm	0.6mm	0.3mm	0.21mm	0.15mm	0.09mm	0.075mm	<0.075mm
						Percentage Retained in Sieve (%)								
13/2787	61	1904064	5816018		0	0.1	0.57	1.86	12.6	34.61	41.97	8.11	0.04	0.13
13/2788	62	1904123	5815886		2	0.36	2.72	28.65	45.55	13.34	7.95	1.37	0.05	0.02
13/2789	63	1904179	5816318		0	0.12	0.52	7.07	3.6	6.09	35.95	33.1	6.57	6.97
13/2665	64	1904221	5815810		2	0.31	2.3	43.02	41.85	8.1	4.03	0.37	0.03	0
13/2790	65	1904229	5816053		0	1.21	0.24	0.48	3.73	23.3	52.41	16.47	1.39	0.78
13/2791	66	1904279	5815935		0	0.26	0.58	3.02	31	30.29	29.19	5.25	0.25	0.16
13/2792	67	1904293	5815824		5	10.08	15.09	46.66	19.57	4.28	2.47	1.01	0.36	0.49
13/2793	68	1904363	5816950		0	0.09	1.21	2.58	3.5	4.23	25.41	44.92	10.51	7.56
13/2666	69	1904400	5815674		3	5.65	10.3	41.51	33.75	4.11	2.88	1.31	0.19	0.29
13/2794	70	1904415	5815935		5	6.98	16.8	51.63	20.97	2.37	1.07	0.14	0.03	0.01
13/2795	71	1904479	5816061		0	0.34	1.11	3.35	14.42	26.56	40.84	11.89	1.31	0.19
13/2796	72	1904522	5816318		0	0.04	0.46	2.43	3.55	13.15	49.44	24.03	4.49	2.39
13/2797	73	1904942	5816253		0	0.29	0.57	1.1	3.52	12.7	50.36	28.15	2.18	1.13
13/2798	75	1905655	5819344	yes	15.5	0.68	9.66	71.06	17.71	0.55	0.13	0.11	0.04	0.06
13/2799	76	1905667	5820167	yes	66.9	6.26	9.93	35.09	39.6	6.3	1.98	0.65	0.17	0.04
13/2800	77	1905854	5816733		0	0.02	0.53	1.79	13.95	36.62	39.92	6.56	0.45	0.16
13/2801	78	1906039	5816859		0	0	0.41	2.34	13.14	30.68	43.94	8.84	0.45	0.19
13/2802	79	1906275	5817025		0	0.36	0.78	3.11	13.68	25.88	39.98	14.26	1.13	0.82
13/2803	80	1906331	5816068		0	2.6	3.49	8.79	31.19	30.01	20.78	2.94	0.17	0.03
13/2804	81	1906539	5816211		0	0.97	1.1	11.64	10.48	12.92	41.27	18.91	1.45	1.25
13/2805	82	1906800	5816341		2	5.95	6.72	29.72	39.44	14.05	3.28	0.65	0.14	0.05
13/2806	83	1907074	5816524	yes	14.6	34.14	11.83	26.92	23.14	3.12	0.77	0.06	0.03	0
13/2807	84	1908010	5814253		0	1.84	0.92	2.23	9.25	33.92	37.5	13.35	0.66	0.35
13/2808	85	1908150	5814375		0	0.02	0.61	1.31	4.08	23.95	49.92	19.69	0.04	0.39
13/2809	86	1908343	5814586		0	1.02	0.73	1.56	6.2	8.5	30.69	43.79	5.63	1.88
13/2810	87	1908517	5814717		1	0.42	0.62	10.7	59.14	18.27	7.4	3.21	0.17	0.06

APPENDIX B

Wave Models

B.1 Introduction

A regional wave model of the Bay of Plenty has been developed to obtain wave climate data for the study site. Boundary conditions for the regional wave model have been obtained from DHI's Pacific Ocean wave model. This appendix describes the MIKE 21 SW model, and focuses on the regional and local wave model set up and calibration.

B.2 MIKE 21 SW Model

The wave modelling has been undertaken using DHI's two dimensional (2D) numerical wave transformation model MIKE21 SW (Spectral Wave Model) which propagates waves from deep water into near shore areas. The model simulates the growth, decay and transformation of wind-generated waves and swell in offshore and near shore areas. MIKE 21 SW includes two different formulations:

- Fully spectral formulation; and
- Directional decoupled parametric formulation.

The fully spectral model includes the following physical phenomena:

- Wave growth by action of wind;
- Non-linear wave-wave interaction;
- Dissipation due to white-capping
- Dissipation due to bottom friction;
- Dissipation due to depth-induced wave breaking;
- Refraction and shoaling due to depth variations;
- Wave-current interaction; and
- Effect of time-varying water depth.

The discretization of the governing equation in geographical and spectral space is performed using a cell-centred finite volume method. In the geographical domain, an unstructured mesh technique is used. The time integration is performed using a fractional step approach where a multi-sequence explicit method is applied for the propagation of wave action.

Further details of the MIKE 21 SW model can be found in MIKE 21 SW Scientific Documentation (DHI, 2012).

B.3 Regional Wave Model Set Up

The conditions that were selected to obtain a satisfactory calibration for the regional wave model are summarised in Table B-1. Further explanation of these parameters can be found in the MIKE 21 SW User Manual (DHI, 2012).

Table B-1 Specifications for calibrated regional wave model.

Parameter	Value
Spectral Formulation	Fully spectral formulation
Time Formulation	Instationary formulation
Frequency discretization	Logarithmic Number of frequencies = 25 Minimum frequency = 0.005 Hz Frequency factor = 1.15
Direction discretisation	10 degrees
Bottom Friction	kn = 0.07 m
Wind Forcing	Coupled air-sea interaction (Background Charnock parameter = 0.01)
Energy Transfer	Quadruplet wave interaction
Wave Breaking Formulation	Ruessink *et. al.* (2003)
White Capping	Dissipation coefficient, Cdis = 1 and DELTA dis = 0.5

B.4 Regional Wave Model Calibration

The regional wave model was calibrated by comparing predicted model results against observed data collected 13 km offshore from Pukehina beach. Figure B-1, Figure B-2 and Figure B-3 show how the model results compared to measurements for the three month period 1st June to 1st September 2008.

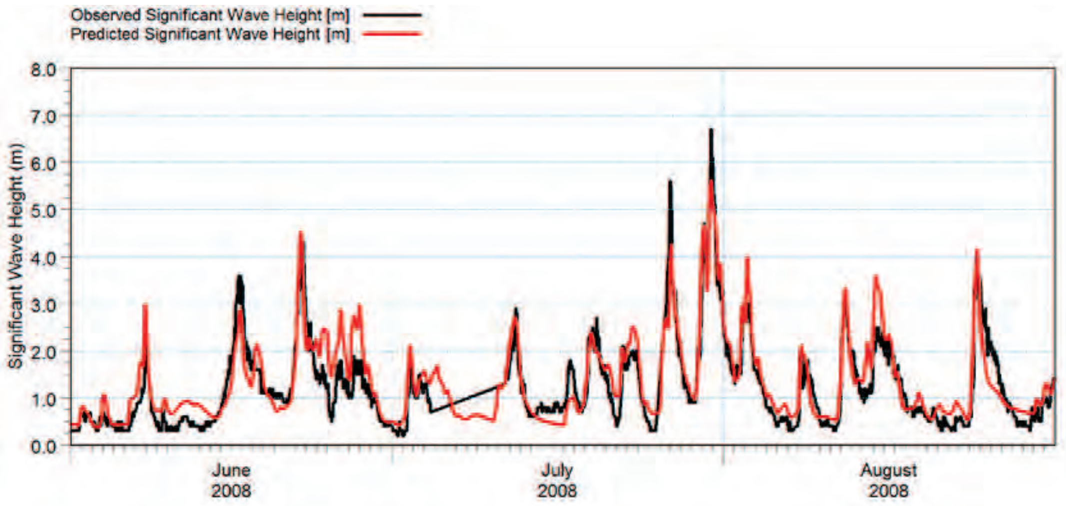


Figure B-1 Predicted and measured significant wave heights (Hs) at the BOPRC wave rider buoy.

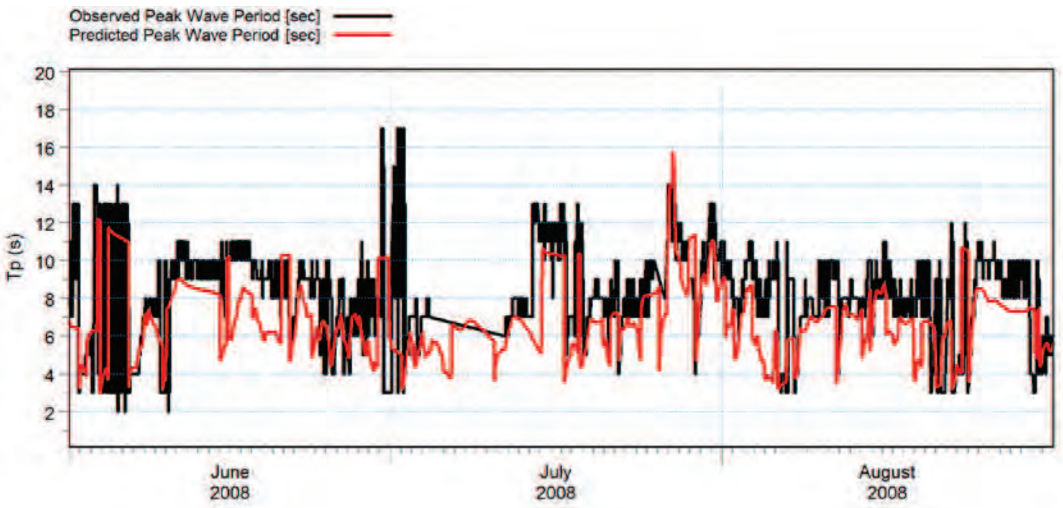


Figure B-2 Predicted and measured wave direction (MWD) at the BOPRC wave rider buoy.

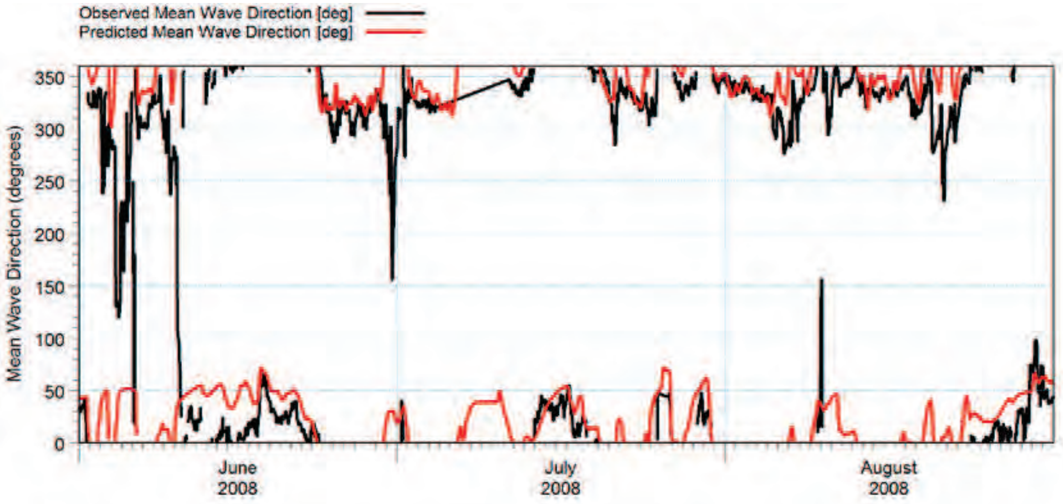


Figure B-3 Predicted and measured wave peak periods (Tp) at the BOPRC wave rider buoy

B.5 Statistical Analysis of Model Results

In order to quantify the model data against measurements, different statistical indices have been computed to verify the accuracy of the model results. The following statistical parameters have been evaluated:

$$\overline{m_e}(mean) = {}^{1}\!/_{N}\sum_{1}^{n} me_i$$

$$Bias = \overline{dif} = {}^{1}\!/_{N}\sum_{1}^{n} dif_i$$

$$RMS = \sqrt{{}^{1}\!/_{N}\sum_{1}^{n} dif^{2}{}_{i}}$$

$$\rho \quad (correlation) = \frac{\sum_{1}^{n}(me_i - \overline{me})(mo_i - \overline{mo})}{\sqrt{\sum_{1}^{n}(me_i - \overline{me})^2 \sum_{1}^{n}(mo_i - \overline{mo})^2}}$$

where:

me_i = Measured value
mo_i = Model value
$dif_i = mo_i - me_i$

The computed statistical values are presented in Table B-2, below.

Table B-2 Computed statistical values

Mean value (m)	bias (m)	RMS (m)	Bias Index (Bias/Mean)	Scatter Index (RMS/Mean)	Correlation/r^2
1.15	0.13	0.38	0.12	0.33	0.83/0.69

Bias refers to how far an average value lies from the parameter it is attempting to predict. A comparison of observed versus predicted significant wave height is presented in Figure B-4. The statistical analysis and visual comparison indicate that the regional wave model is able to be reasonably calibrated and sufficient for predicting waves in the Bay of Plenty.

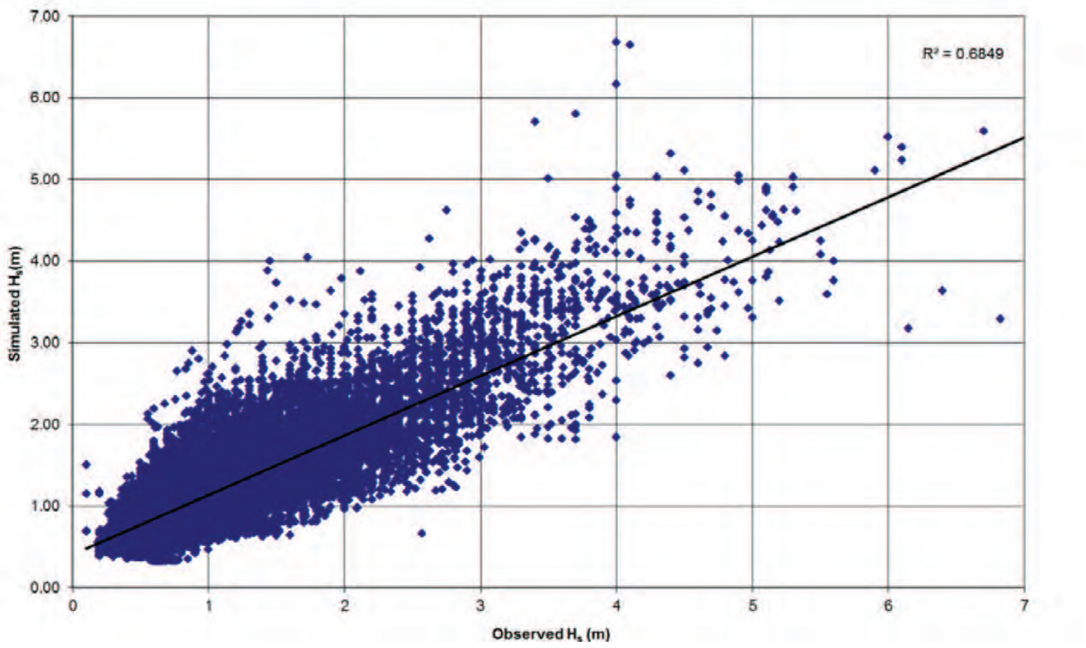


Figure B-4 Scatter plot of observed H_s versus simulated H_s.

B.6 Local Wave Model Set Up

The conditions that were selected to obtain a satisfactory calibration for the local wave model are summarised in Table B-3. Further explanation of these parameters can be found in the MIKE 21 SW User Manual (DHI, 2012).

Table B-3 Specifications for calibrated local wave model.

Parameter	Value
Spectral Formulation	Directionally decoupled parametric formulation
Time Formulation	Quasi stationary formulation
Direction discretisation	20 degrees
Energy Transfer	Quadruplet wave interaction
Bottom Friction	kn = 0.005m
Wave Breaking Formulation	Ruessink et. al. (2003)

B.7 Local Wave Model Validation

Wave data was collected by Cawthron offshore of Okurei Point for the period 21st March to 30th April 2013. A significant wave event occurred on approximately 17th April 2013 and this event has been utilised for validating the performance of the local wave model.

Boundary conditions for the local wave model were generated using the Bay of Plenty regional wave model. The wind data collected within the estuary has been used as wind forcing for the local wave model since other wind sources such as NOAA were not suitable (due to gaps in data) for this period. A comparison of the observed and predicted significant wave heights is shown in Figure B-5 and this suggests the local model is able to reasonably resolve significant wave events for the study area.

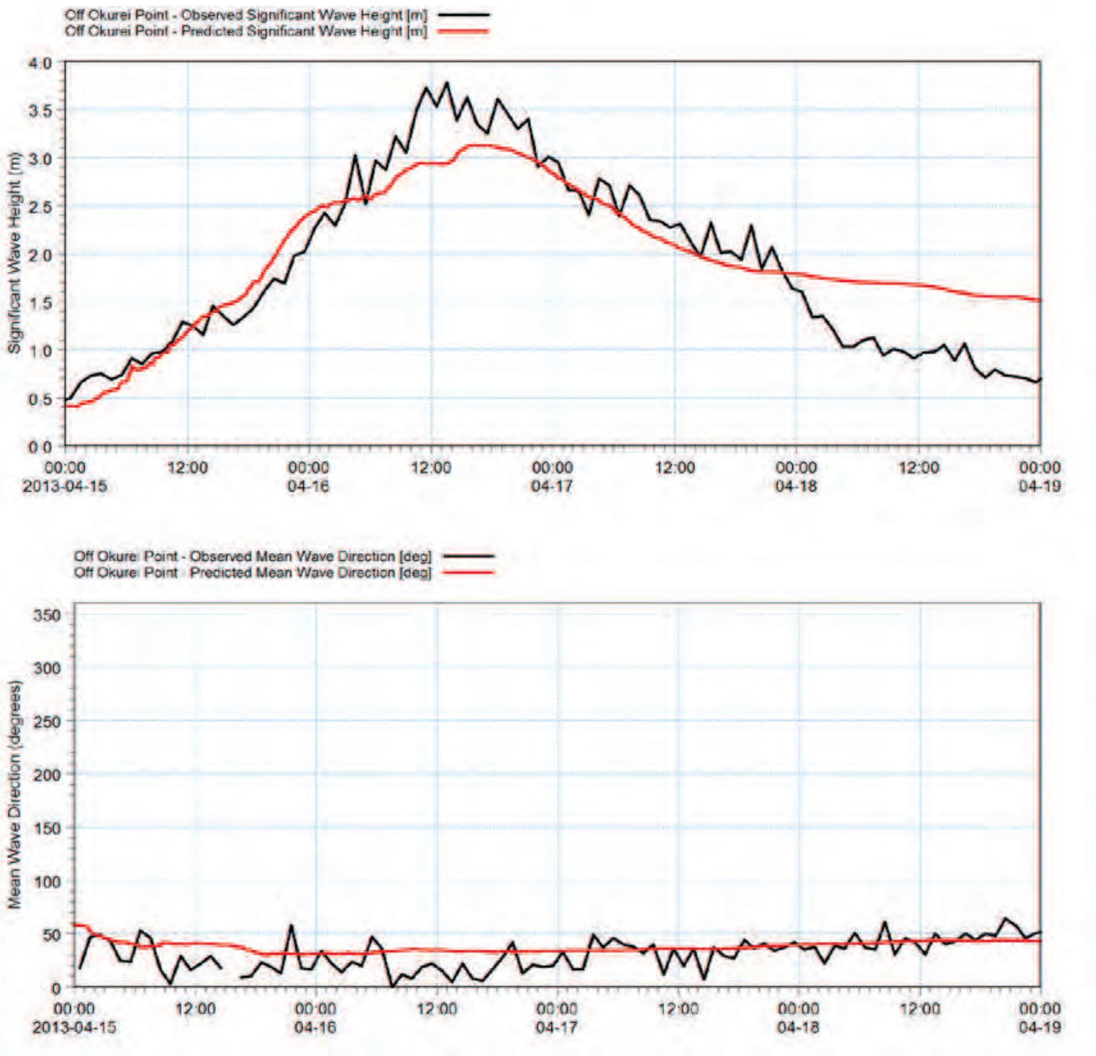


Figure B-5 Comparison of observed and predicted significant wave height off Okurei Point.

APPENDIX C

LITDRIFT Model

C.1 Introduction

A coastal sediment budget was performed for the coastline at Maketū by applying the littoral drift module, LITDRIFT, of DHI's LITPACK model. LITPACK is DHI's software for the simulation of littoral processes and coastline kinetics. LITPACK simulates wave/current scenarios and the combination of these for the prediction of littoral drift, development of coastal profiles and long-term coastline evolution.

C.2 LITDRIFT Model

LITDRIFT provides a powerful tool for sediment budget analysis which is of paramount importance to all coastal morphology studies. The module calculates the long-shore currents which are caused by gradients in the radiation stresses when waves break at an angle to the coast in the surf zone. It simulates the cross-shore distribution of wave height, setup and long shore current for an arbitrary coastal profile. It provides a detailed deterministic description of the cross-shore distribution of the longshore sediment transport for an arbitrary bathymetry for both regular and irregular sea states. One of the main assumptions in LITDRIFT is related to uniformity along the coast. A local equilibrium between the local driving forces and the long-shore current is assumed.

The long shore and cross-shore momentum balance equation are solved to give the cross-shore distribution of long shore current and setup. Wave decay due to breaking is included in the model. The net/gross littoral transport over a specific design period is calculated. Important factors, such as linking of the water level and the profile to the incident sea state, are included. LITDRIFT accounts for the following processes:

- Regular/irregular waves;
- Water levels;
- Tidal currents;
- Wind shear stresses;
- Non-uniform bottom friction;
- Wave refraction and shoaling;
- Breaking; and
- Non-uniform sediment distribution.

The outcome of the simulation of one single wave event is the cross-shore distribution of water level, longshore current, wave height and angle, water flux, bed load and suspended load transport, total load and cumulative total load transport. The total net annual drift is found as the weighted sum of contributions from all events in the hydro graphic database or from a time series of hydro graphic boundary conditions.

Further details of the LITDRIFT model can be found in the LITDRIFT user guide (DHI 2012) and scientific documentation (DHI, 2012).

APPENDIX D

Hydrodynamic Models

D.1 Introduction

This appendix provides details of the local two dimensional (MIKE 21 HD FM) and three dimensional (MIKE 3 HD FM) hydrodynamic models which form the major components of the morphological and water quality models used for this study. It provides a brief description of the models and details the model set up, calibration and validation for the hydrodynamic models.

A three dimensional model was required to reproduce the saline intrusion that occurs within the river and ultimately determines the salinity of water which enters into the estuary from the river.

D.2 MIKE 21 HD FM Model

MIKE 21 HD FM is a two dimensional (2D) hydrodynamic model which simulates the water level variations and flows in response to a variety of forcing functions in oceans, lakes, estuaries and coastal areas. MIKE 21 HD FM can be applied to a wide range of hydraulic and related phenomena such as tidal hydraulics, wind and wave generated currents, storm surges and flood waves. More details of the MIKE 21 HD FM model can be found in MIKE 21 HD FM User Guide (DHI, 2012) and Scientific Documentation (DHI, 2012).

A regional model of the Bay of Plenty and a local model of the study area have been built using MIKE 21 HD FM.

D.2.1 2D Regional Hydrodynamic Model

A regional hydrodynamic model of the Bay of Plenty was built to provide boundary conditions for a local hydrodynamic model of the study site. The model bathymetry and extent for the regional model are shown in Figure D-1.

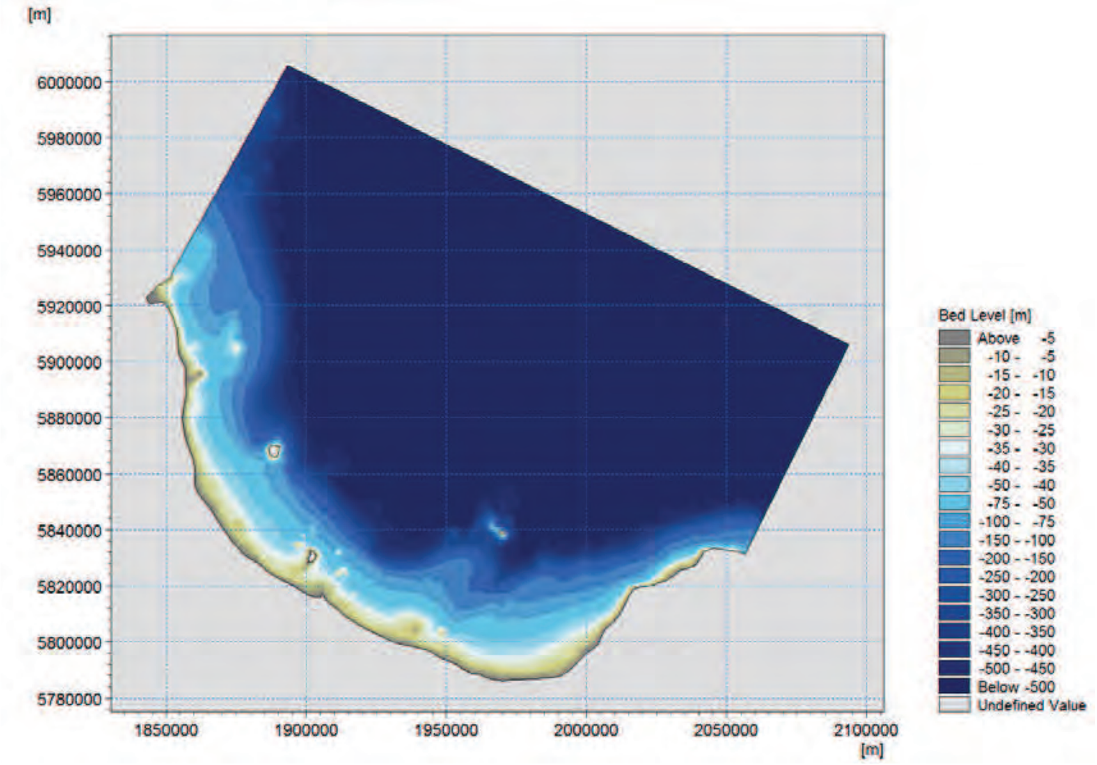


Figure D-1 Regional 2D model extent and bathymetry.

Boundary conditions for the regional hydrodynamic model of the Bay of Plenty were extracted from the DHI global KMS tidal model. 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°. Where appropriate NOAA wind data has been used for wind forcing (see Section 3.9).

D.2.2 2D Local Hydrodynamic Model Bathymetry and Set Up

A Flexible Mesh (FM) was built which allows the computational domain to be discretized into a mixture of triangular and quadrilateral elements of various sizes. This allows flexibility in defining and resolving the model domain, and features within the domain such as river channels. This enabled hi-resolution definition where necessary, but reduced computational requirements in other areas. Quadrilateral elements can be utilised for areas where flow is constrained along a stream-wise direction, such as channels or long-shore current generated within surf zone, offering a more efficient mesh than with only triangles alone.

Bathymetry for the model has been obtained from the variety of sources outlined in Section 3.1. The bathymetry source which was applied for specific areas of the model bathymetry is outlined below:

- C-MAP - Offshore areas not covered by LiDAR.
- DML Survey - Ongatoro / Maketū Estuary mouth ebb delta, surf zone and Lower Kaituna River including ebb delta. For Kaituna River mouth pre flood bathymetry used (see Section 3.1).
- BoPRC - Kaituna River upstream of DML survey.
- LiDAR – Near-shore (apart from surf zone), estuary and river (river only above mean water level).

The model extent and bathymetry is presented in Figure D-2. The model bathymetry and mesh for selected important areas of model domain are presented in Figure D-3 to Figure D-6.

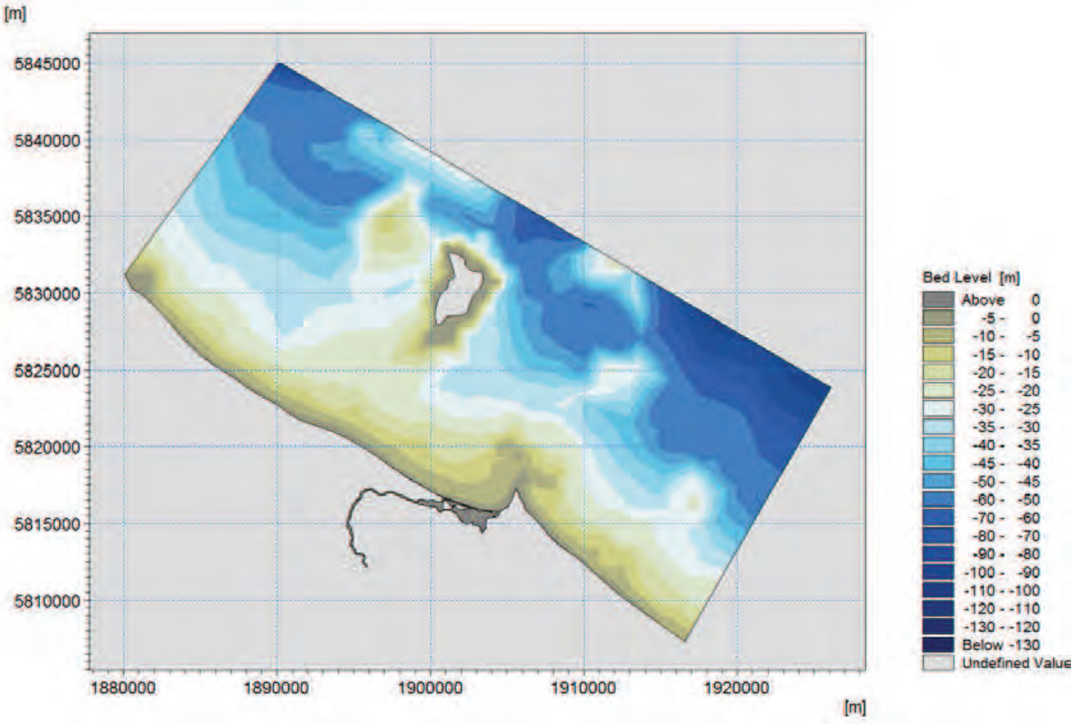


Figure D-2 Local 2D hydrodynamic model extent and bathymetry.

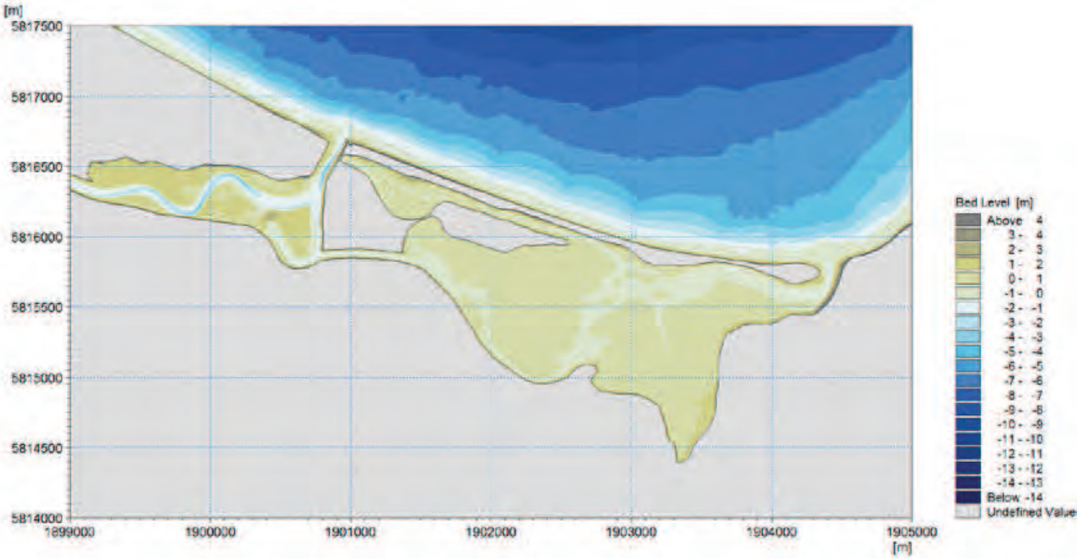


Figure D-3 Local 2D hydrodynamic model bathymetry lower Kaituna River and Ongatoro / Maketū Estuary.

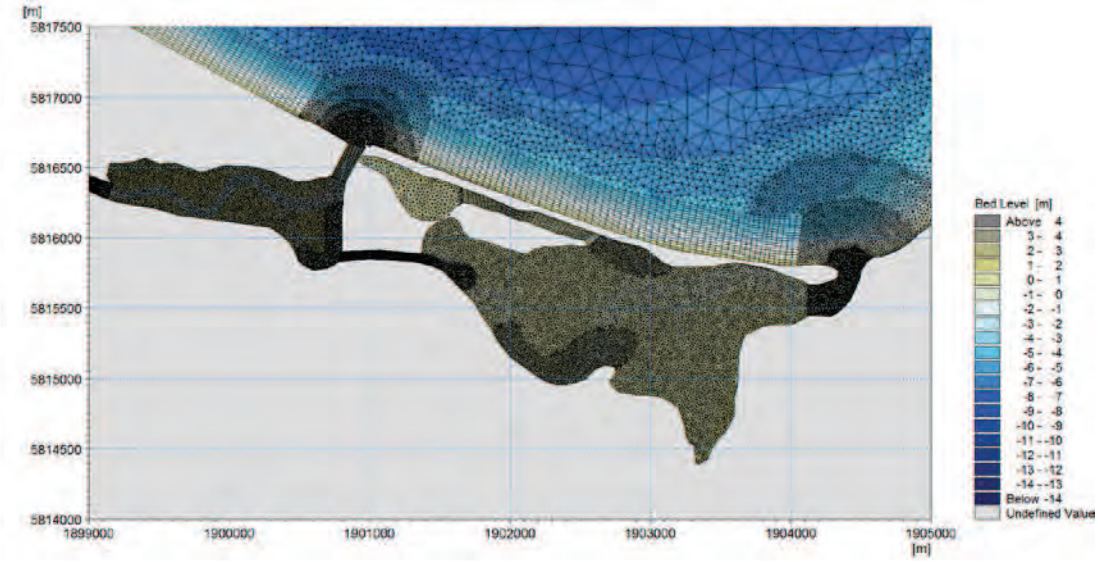


Figure D-4 Local 2D hydrodynamic model bathymetry and mesh lower Kaituna River and Ongatoro / Maketū Estuary.

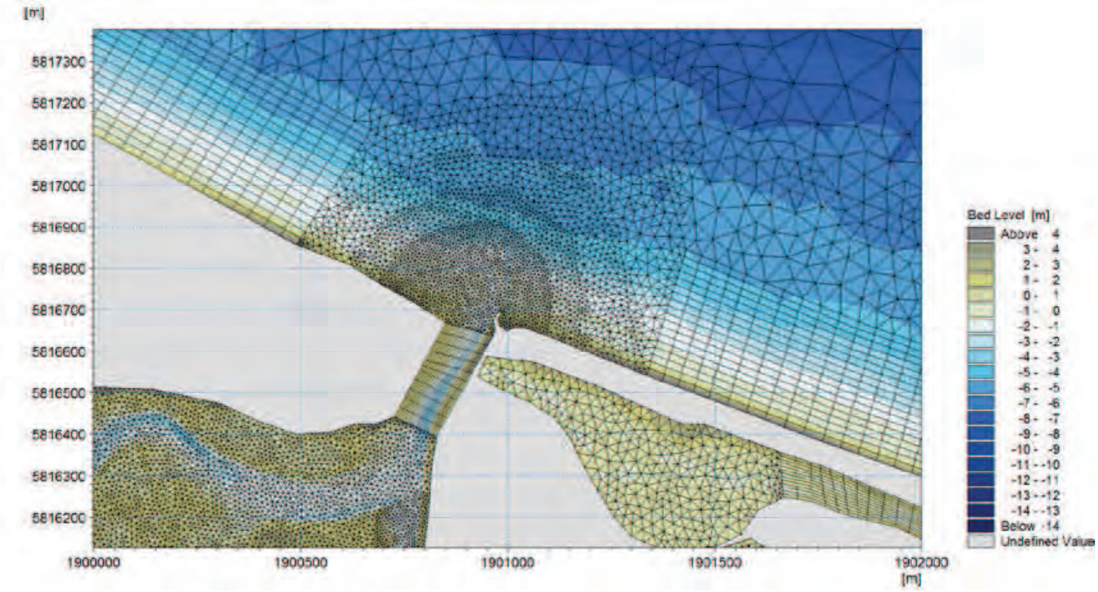


Figure D-5 Local 2D hydrodynamic model bathymetry and mesh Kaituna River mouth.

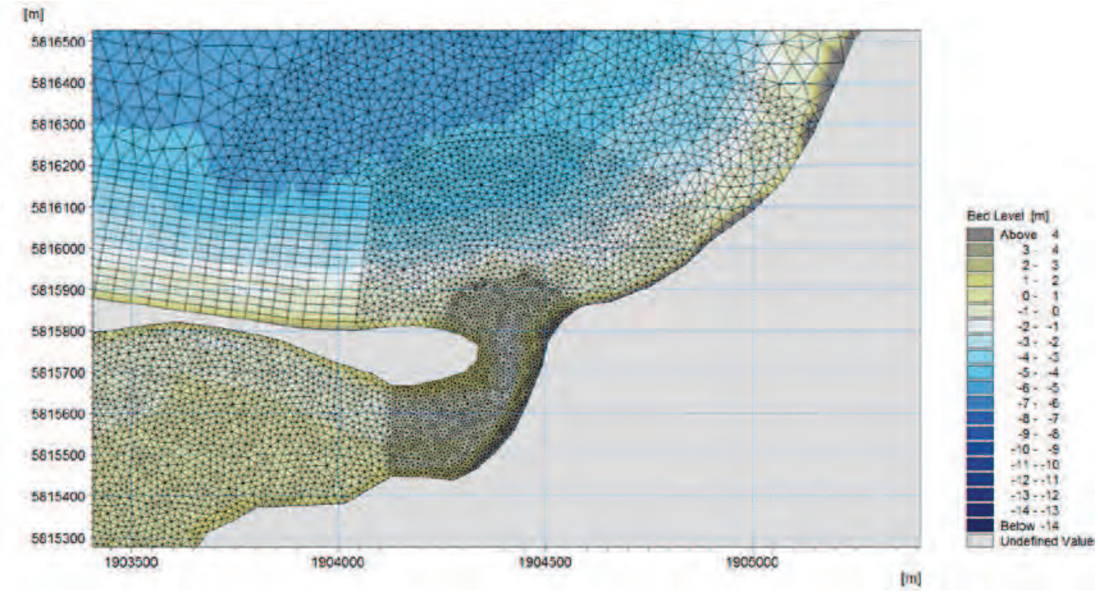


Figure D-6 Local 2D hydrodynamic model bathymetry and mesh Ongatoro / Maketū Estuary mouth.

Open ocean boundaries for the model were extracted from the regional hydrodynamic model while the upstream river boundary (located at Te Matai bridge) was flow from Te Matai gauge (see Section 3.3). Flow from Waiari Stream and Raparapahoe Canal were also included in the model as these are the only other significant inflows for typical conditions.

D.2.3 Local 2D Hydrodynamic Model Calibration

Hydrographic data was collected within the river, estuary and near-shore during March to April 2013. A comprehensive field campaign was carried out on the 4th April 2013, therefore a seven day period (30th March to 6th April 2013) which includes this date has been selected for calibrating the model.

Model calibration involves the refinement of hydraulic parameters to resolve important hydrodynamic processes for which the model is to be utilised. The aim of the local 2D hydrodynamic model calibration was to obtain a reasonable agreement between the observed and predicted water levels, flow into and out of river and estuary and currents within the estuary.

The specifications for the calibrated hydrodynamic model are summarised in Table D-1. Further explanation of these parameters can be found in the MIKE 21 HD FM User Guide (DHI, 2012).

Table D-1 Specifications for calibrated hydrodynamic model.

Parameter	Value
Solution Technique	Low order, fast algorithm Minimum time step: 0.01 s Maximum time step: 30 s Critical CFL number: 0.8
Enable Flood and Dry	Drying depth: 0.01 m Flooding depth: 0.05 m

Parameter	Value
	Wetting depth: 0.1 m
Wind	Varying in time, constant in domain (wind data from estuary)
Wind Friction	Constant = 0.002455
Eddy Viscosity	Horizontal: Smagoringsky formulation, constant 0.28
Resistance	Spatially varying Manning number
Boundary Conditions	Open Ocean: Regional Bay of Plenty hydrodynamic model River: Te Matai flow (see Section 3.3) minus 15%
Sources	Waiari Stream (see Section 3.3) Raparapahoe Canal: Derived flow (see Section 3.3) For flood event 17th to 22nd April 2013 other inflows as outlined in see Section 3.3).

A spatially varying Manning number has been used as shown in Figure D-7. A Manning number = 32 $m^{1/3}/s$ was selected where model bathymetry was greater than 0 m and Manning number = 60 $m^{1/3}/s$ elsewhere. The only exception is Ongatoro / Maketū Estuary and the estuary mouth where a Manning number = 32 $m^{1/3}/s$ was selected even if the model bathymetry was less than 0 m. Although a Manning number = 60 $m^{1/3}/s$ is reasonably high when compared to ‘typical’ experience, the MIKE 21 FM HD model requires a slightly higher value to account for diffusive effects of the numerical scheme.

To achieve a reasonable calibration it was necessary to reduce the de-tided Te Matai flows provided by BoPRC by 15%. This was deemed acceptable due to the uncertainty in de-tided flow data provided by BoPRC (see Section 3.3) .The improvement was most apparent for flow measurements at Kaituna River mouth (see Section D.2.3.2). The fact that a reasonable calibration was achieved for the salinity distribution in the river for the local 3D hydrodynamic model also supports the reduction of Te Matai flows (see Section 3.3).

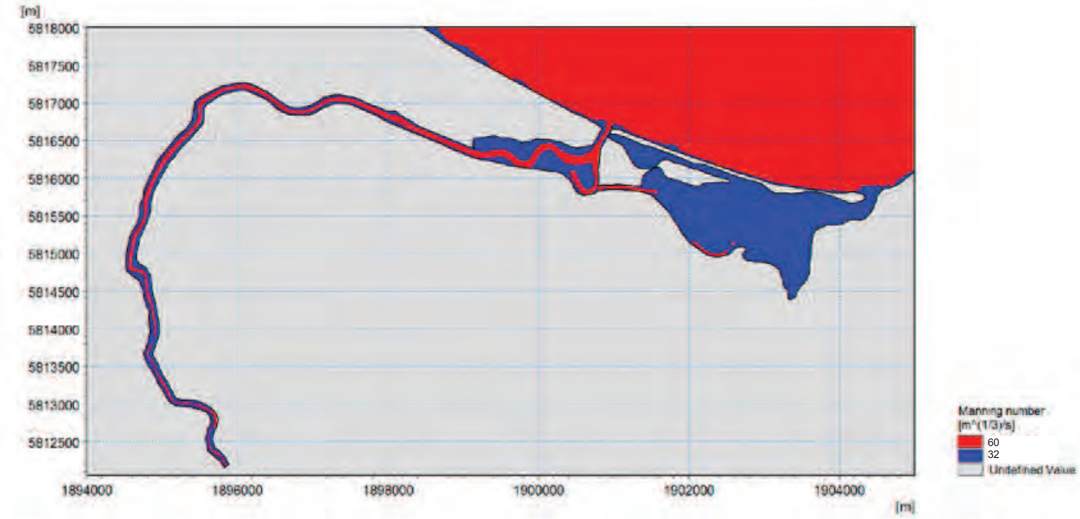


Figure D-7	Spatially varying Manning number used for 2D local hydrodynamic model (only estuary and river area of map shown).

D.2.3.1 Water Levels

A comparison of the observed and predicted water levels with the estuary is presented in Figure D-8 and off Okurei Point and within Ford's Loop is presented in Figure D-9. Generally there is a reasonable agreement between the observed and predicted water levels.

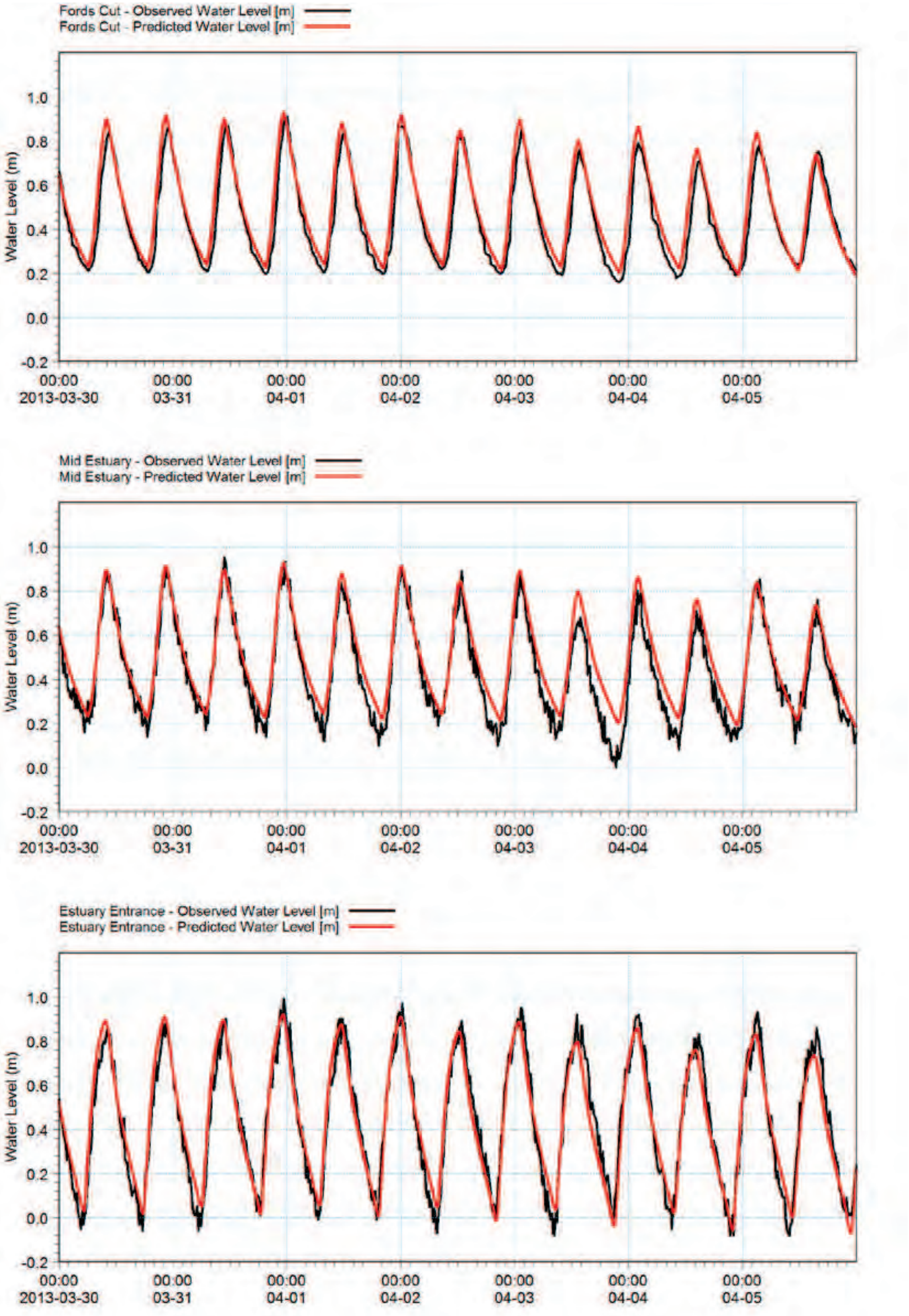


Figure D-8 Comparison of observed and predicted water levels (Moturiki Datum) within estuary at Ford's Cut top), mid estuary (middle) and at estuary entrance (bottom) for period 30th March to 6th April 2013.

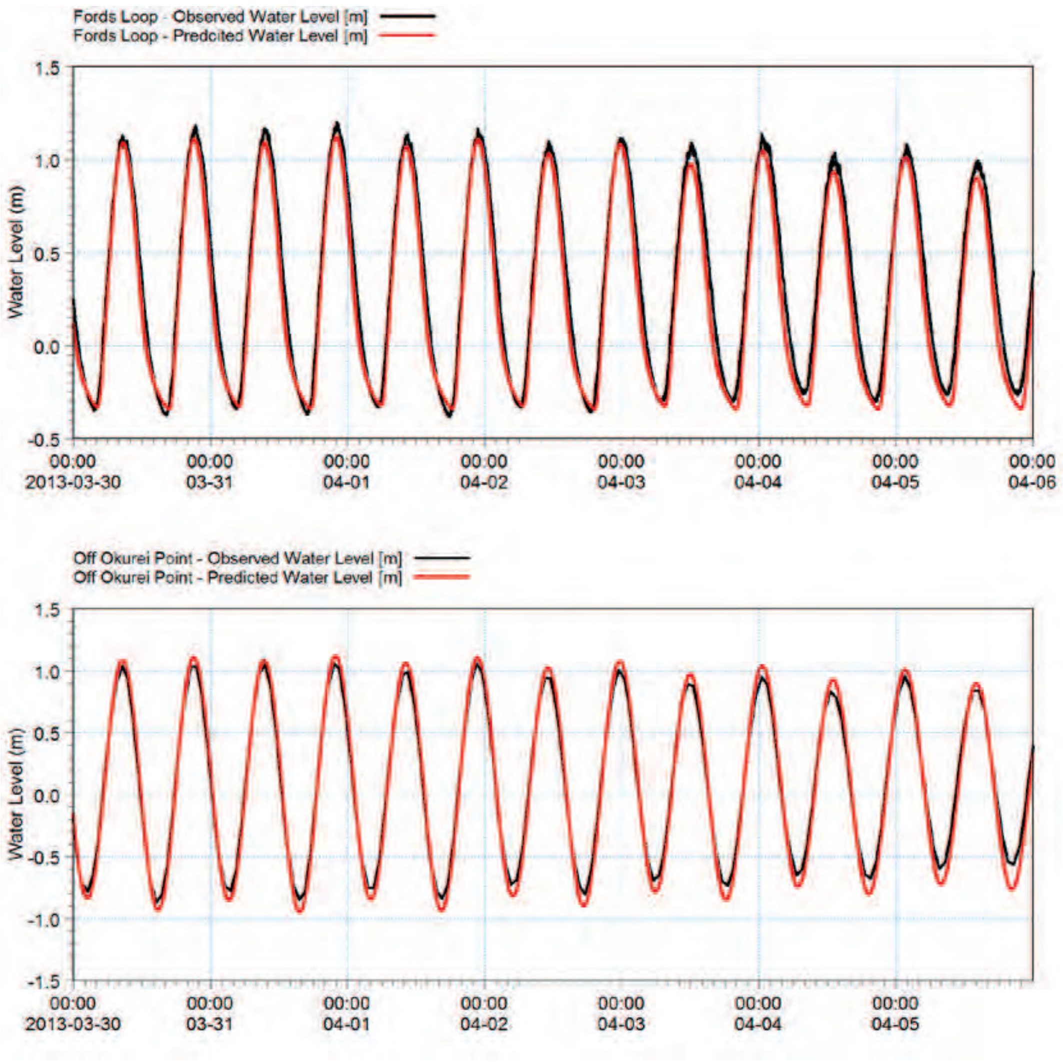


Figure D-9 Comparison of observed and predicted water levels (Moturiki Datum) off Okurei Point (top) and within Ford's Loop (bottom) for period 30th March to 6th April 2013.

D.2.3.2 Flow Transects

An important feature that the model must be able to replicate is the tidal prism for the river and the estuary. Although it can be difficult to match observed and predicted currents due to complex flow patterns in the horizontal or vertical, if the model is not able to replicate the tidal exchange it can be assumed there is something fundamentally wrong with the model.

The comparison between the observed and predicted flow through the transects carried out at the river entrance, Ford's Cut channel and estuary entrance is shown in Figure D-10. There is a very good agreement keeping in mind the uncertainties/error inherent with collecting this type of flow data and it can be assumed the model predicts to an acceptable level of accuracy with regard to the hydrodynamics of the estuary and river.

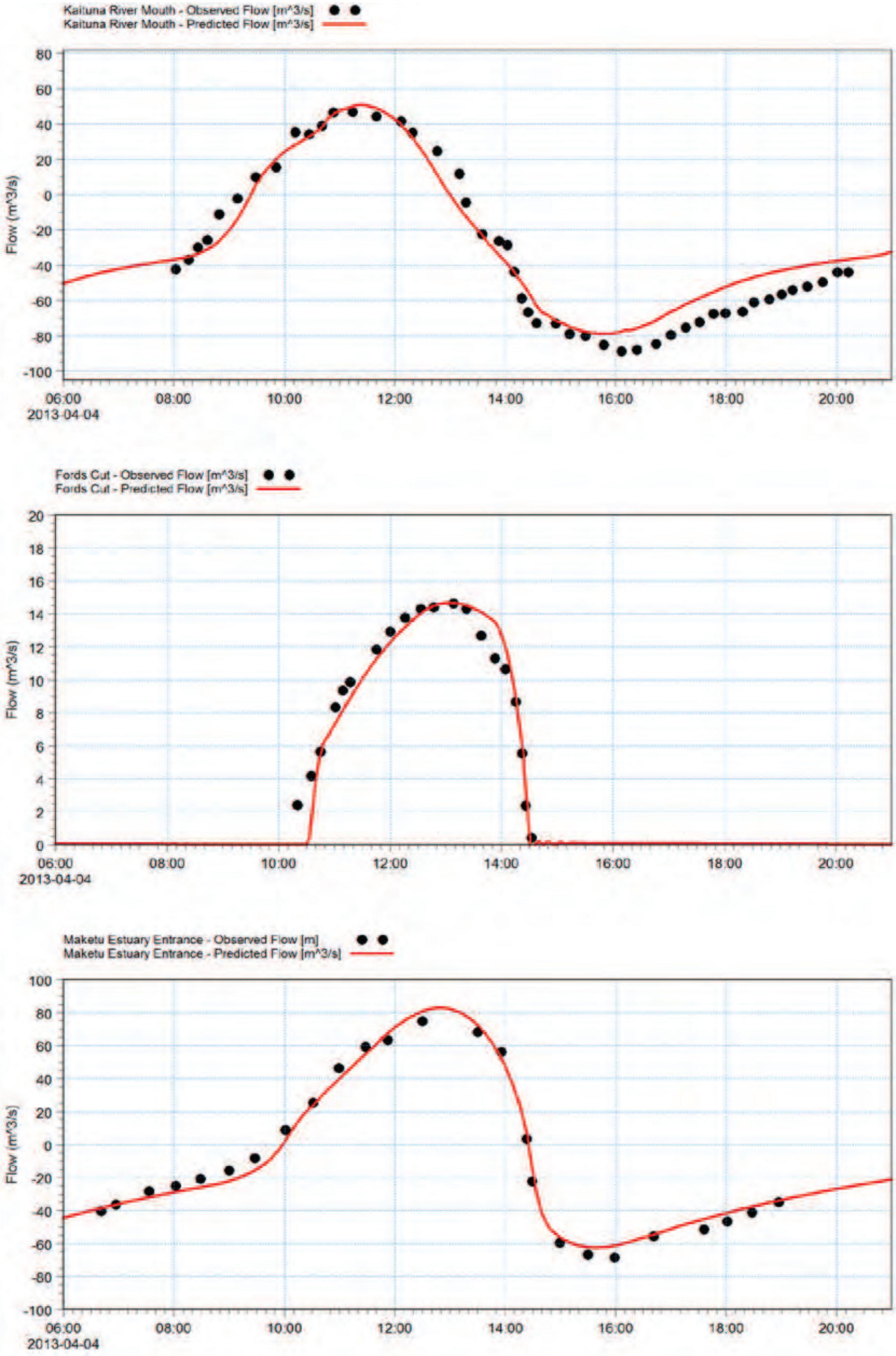


Figure D-10 Comparison of measured and predicted flow through transects in Kaituna River entrance (top), Ford’s Cut channel (middle) and Ongatoro / Maketū Estuary entrance (bottom). Positive flow indicates flow upstream or into estuary respectively.

D.2.3.3 Currents

A comparison of the observed and predicted currents within the estuary for the calibration period is presented in Figure D-11. There is a reasonable agreement in Ford’s Cut, with current speeds slightly over predicted. Predicted currents speeds at the estuary entrance appear to be significantly higher than what was observed. This can be explained by the periodic build-up of Ulva on the instrument as explained in Section 3.2. Data was collected close to the same location in 2008 and peak current speeds were consistently greater than 0.5 m/s (DHI, 2009) which is more consistent with predicted current speeds at this location. There is a reasonable match after 12:00pm on 4th April 2013 when it appears the instruments has been cleaned of Ulva (see Figure 3-9) and more realistic current speeds were measured.

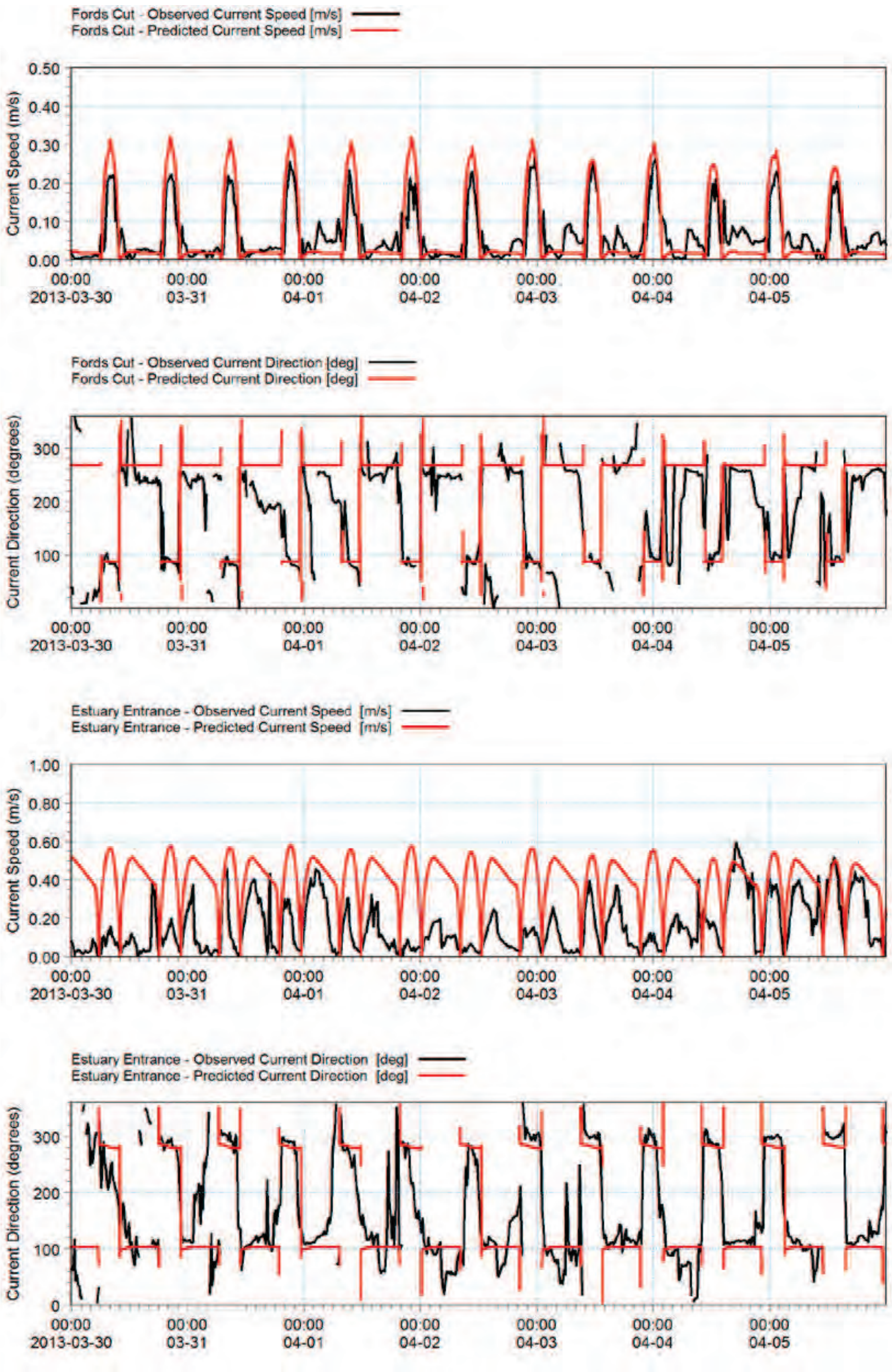


Figure D-11 Comparison of observed and predicted current speed and direction at Ford's Cut (top) and at estuary entrance (bottom) for period 30th March to 6th April 2013.

D.2.4 Local 2D Hydrodynamic Model Validation

Model validation involves using the calibrated model for a period different than which the model was calibrated for to assess whether the model still performs to an acceptable level.

The local 2D hydrodynamic model was validated using hydro graphic data collected by Cawthron during March to April 2013. During the data collection period there were several periods were wave heights of greater than 1.5 m were recorded at the wave gauge off Okurei Point. During these periods there are obvious increases in water level most likely due to a combination of storm surge and wave set up. There was also a significant event for Kaituna River during period, 16th to 22nd April 2013. To validate the local hydrodynamic model a seven day period (6th to 13th April 2013) has been selected where there is most likely no influence on water levels from factors such as storm surge and wave set up and where flow for Kaituna River was close to mean flow.

D.2.4.1 Water Levels

A comparison of the observed and predicted water levels within the estuary is presented in Figure D-12 and off Okurei Point and within Ford’s Loop is presented in Figure D-13. Generally there is a reasonable agreement between the observed and predicted water levels.

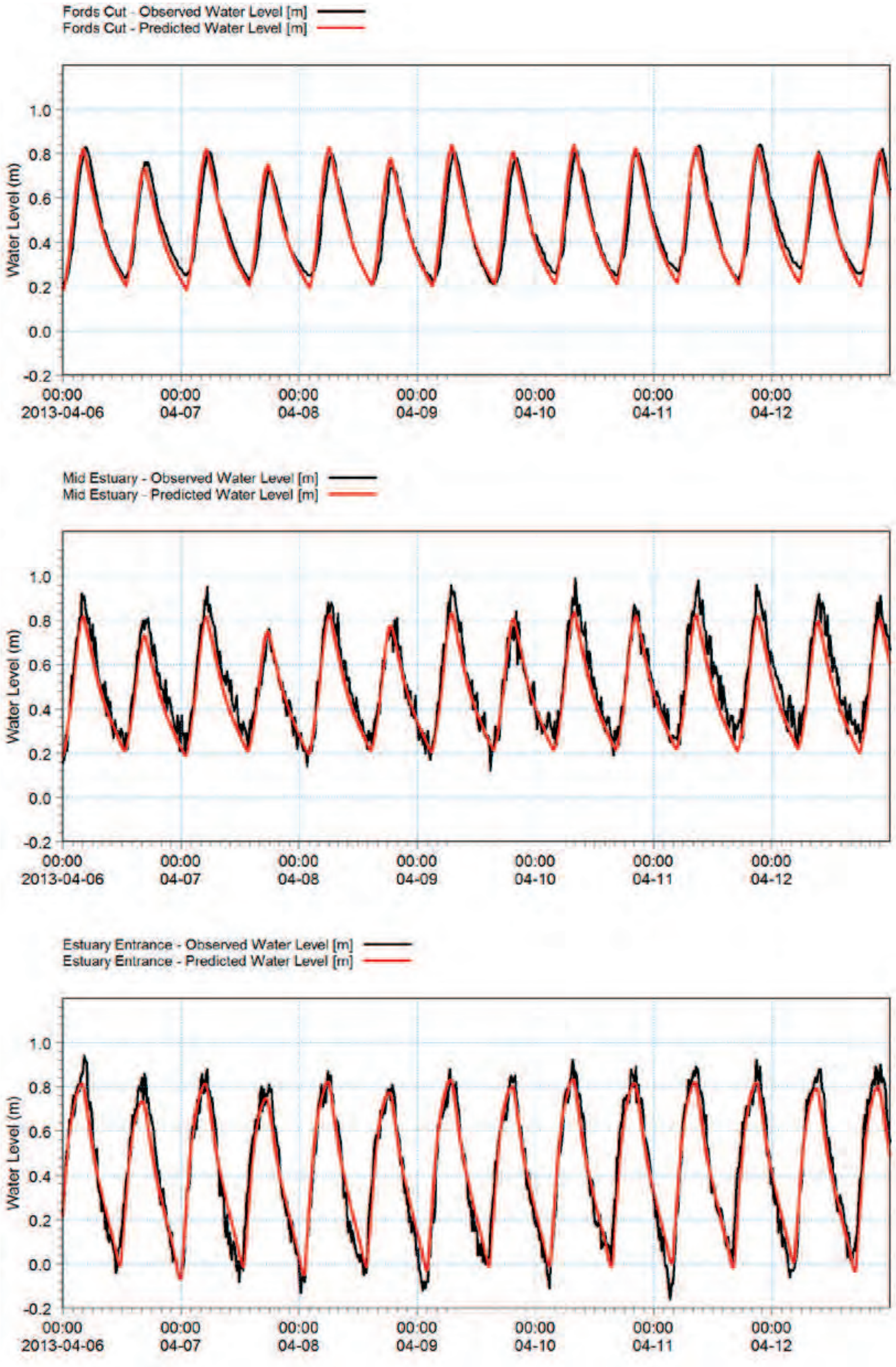


Figure D-12 Comparison of observed and predicted water levels (Moturiki Datum) within estuary at Ford's Cut top), mid estuary (middle) and at estuary entrance (bottom) for period 6th to 13th April 2013.

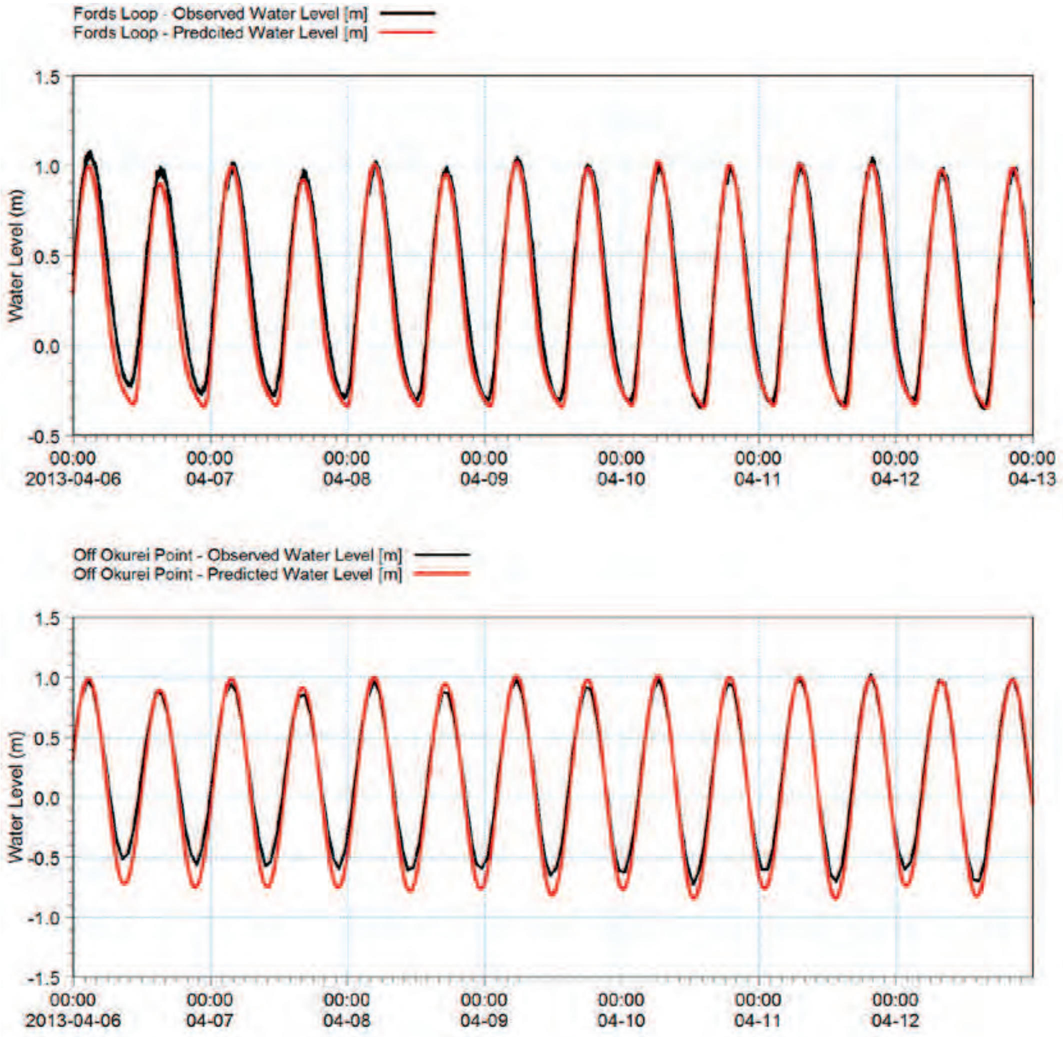


Figure D-13 Comparison of observed and predicted water levels (Moturiki Datum) off Okurei Point (top) and within Ford's Loop (bottom) for period 6th to 13th April 2013.

D.2.4.2 Currents

A comparison of the observed and predicted currents at the harbour entrance for the validation period is presented in Figure D-14. There is a good agreement with observed and predicted currents within Ford's Cut. Similar to the model calibration there is an issue with observed currents at estuary entrance. There is a reasonable agreement when it appears the instrument is clear of Ulva (6th to 7th April 2013 and 8th April 2013).

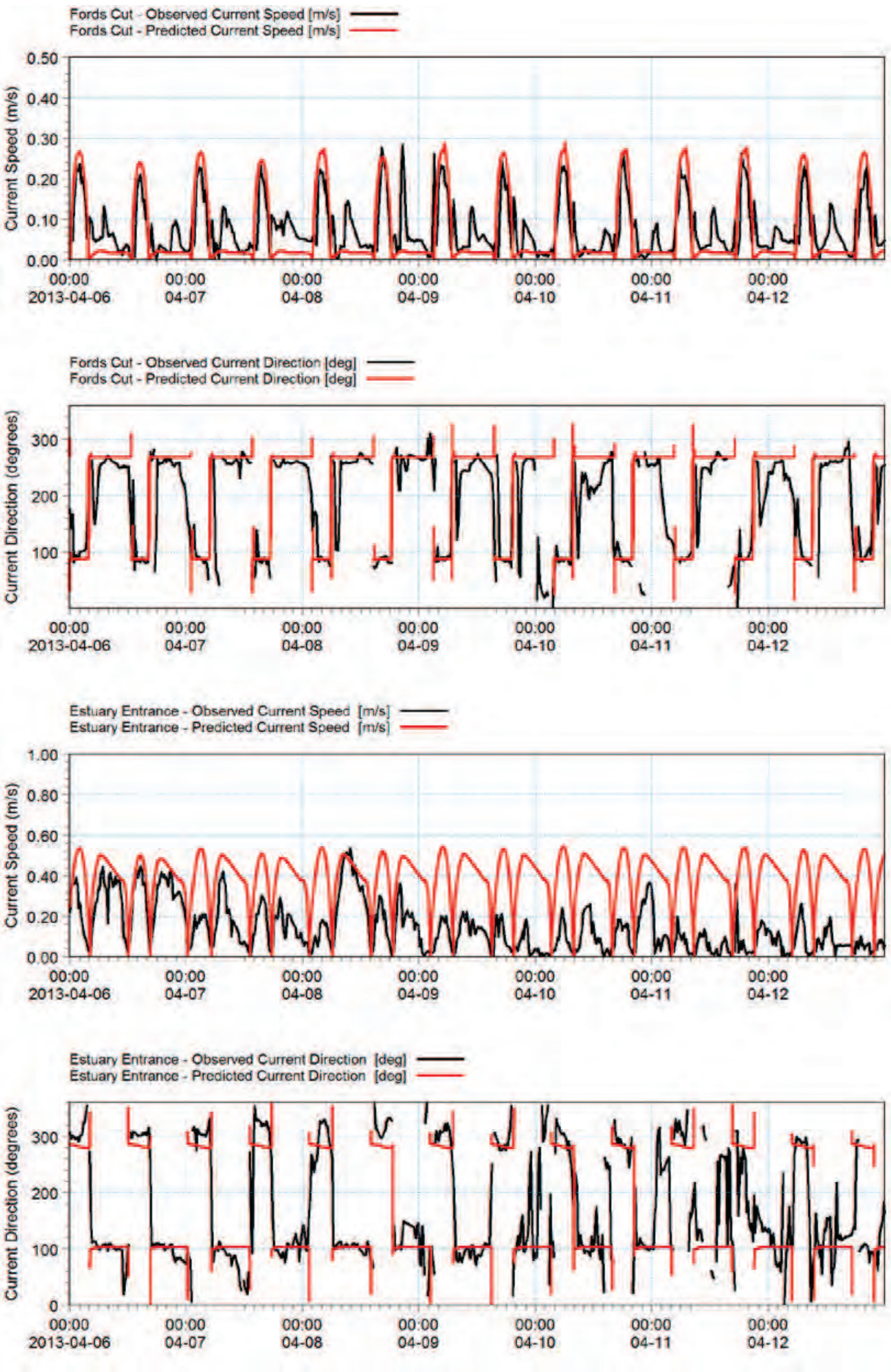


Figure D-14 Comparison of observed and predicted current speed (top) and current direction (bottom) at harbour entrance for period 27th September to 4th October 2010.

D.2.5 Local 2D Hydrodynamic Model Validation – Nearshore Area

The currents observed off Okurei Point at the edge of the nearshore area vary greatly due to the influence of regional and locally generated wind driven currents. The peak tidally generated currents are only in the order of 0.05 m/s. Without a very accurate spatial and temporal representation of the wind that occurred for the data collection period it was very difficult to reproduce these currents. We believe it was not a requirement for this study to accurately reproduce the nearshore currents, for the whole data collection period. Instead the local 2D hydrodynamic model has been validated to show that it is able to reasonably reproduce nearshore currents when there is a significant wind event, which there was sufficient wind data available to simulate.

A comparison of the observed and predicted nearshore currents (off Okurei Point) is shown in Figure D-15 for the period 15th to 22nd April 2013 when there was a significant wind event as shown in Figure D-16. By illustrating that the model is able to reproduce nearshore currents for significant wind events, it has been illustrated that the model can reproduce a possible mechanism for sediment bypassing around Okurei Point.

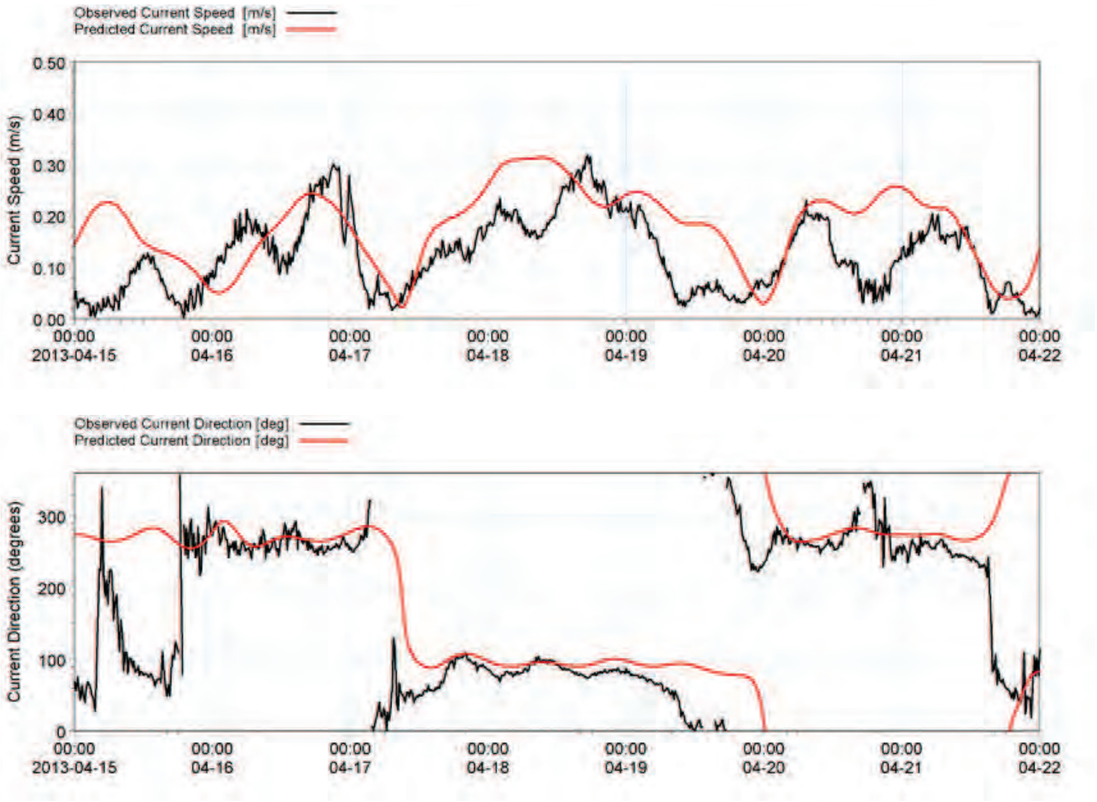


Figure D-15 Comparison of observed and predicted current speed (top) and current direction (bottom) Okurei Point.

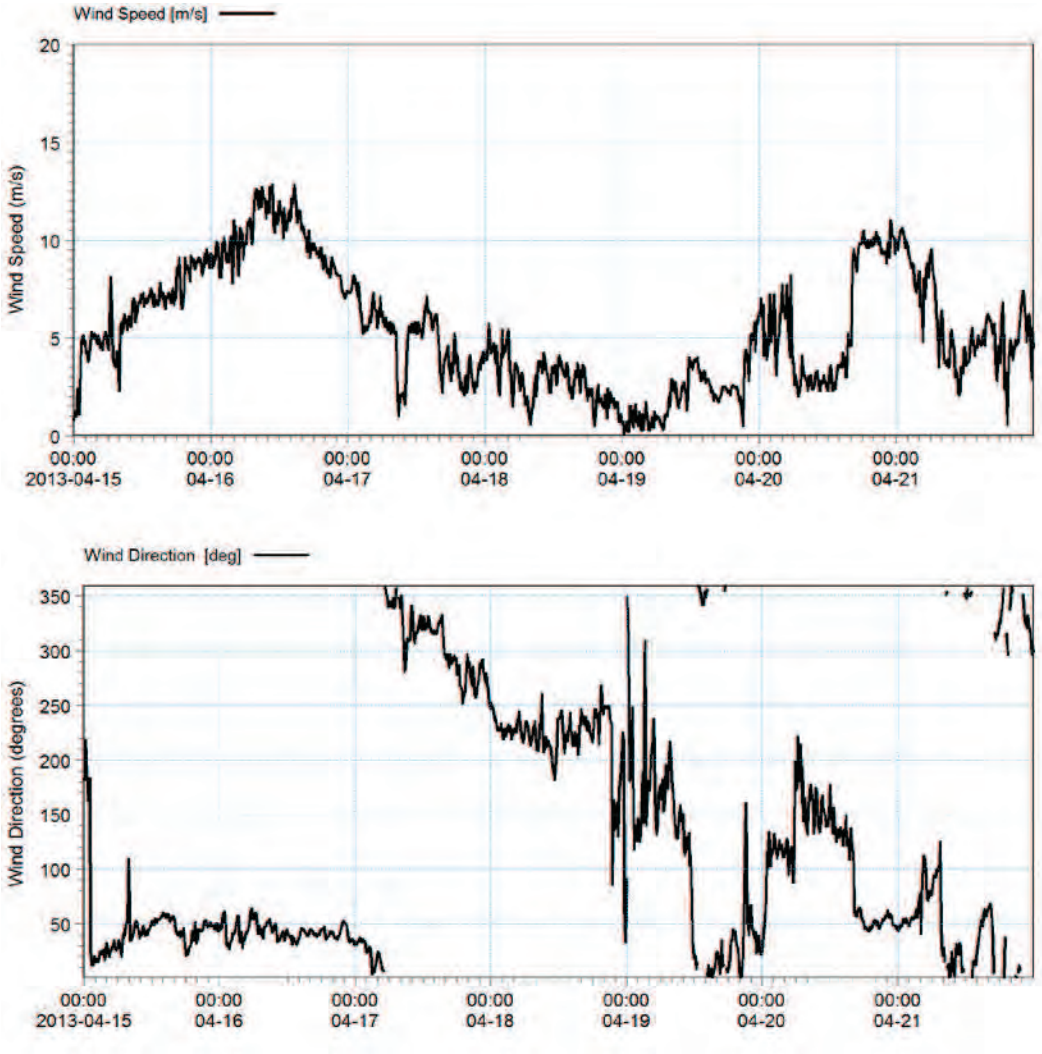


Figure D-16 Wind in estuary 15th to 22nd April 2013.

A flow transect was collected off Okurei point on 4th April 2013. Since the model was not able to reproduce the majority of the regional and locally wind generated nearshore currents, the model was not able to produce the measured flow around Okurei Point. However using the depth averaged current speeds collected of Okurei Point as a boundary condition, the model reproduced the flow around the point, as shown in Figure D-17.

This provided confidence that when investigating the morphological response of the estuary and river, flow can be accounted for around Okurei Point (possibly important for sediment supply to estuary and river entrances), since the model was shown to reasonably predict nearshore currents for significant wind events and therefore it can be assumed the associated flow around Okurei Pt.

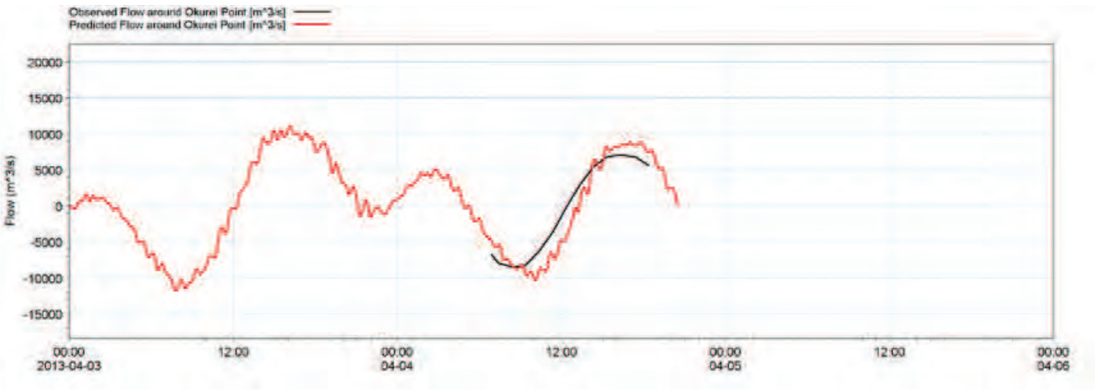


Figure D-17 Comparison of observed and predicted flow around Okurei Point (with velocity boundaries provide by measured depth averaged velocities off Okurei Point).

D.3 MIKE 3 HD FM Model

MIKE 3 HD FM is a three dimensional (3D) hydrodynamic model that solves the equations for the conservation of mass and momentum as well as for salinity and temperature in response to a variety of forcing functions. MIKE 3 HD FM simulates the water level variation and current velocities in response to a variety of forcing functions in lakes, estuaries, bays and coastal areas. MIKE 3 HD FM includes a wide range of hydraulic phenomena in the simulations and it can be used for almost any three dimensional application. It is particularly suitable for studying phenomena like tidal flows, storm surges, wave-driven flows, oceanographic circulations, density-driven flows and salinity intrusion. More details of MIKE 3 HD FM model can be found in MIKE 3 HD FM User Guide (DHI, 2012) and Scientific Documentation.

D.3.1 Local 3D Hydrodynamic Model Bathymetry and Set Up

The model extent and bathymetry for the local 3D hydrodynamic model is shown in Figure D-18. Due to the significant run times for the local 3D hydrodynamic model, the mesh only includes the river and estuary with boundaries at the river and estuary mouths. It was not possible to simplify the model mesh without affecting the ability of the model to replicate important hydrodynamic processes within the river and estuary. Discharge times series extracted from the local 2D hydrodynamic model have been utilised for the local 3D hydrodynamic model river and estuary mouth boundaries. The model mesh is the same as the local 2D hydrodynamic model mesh in the vicinity of the river and estuary.

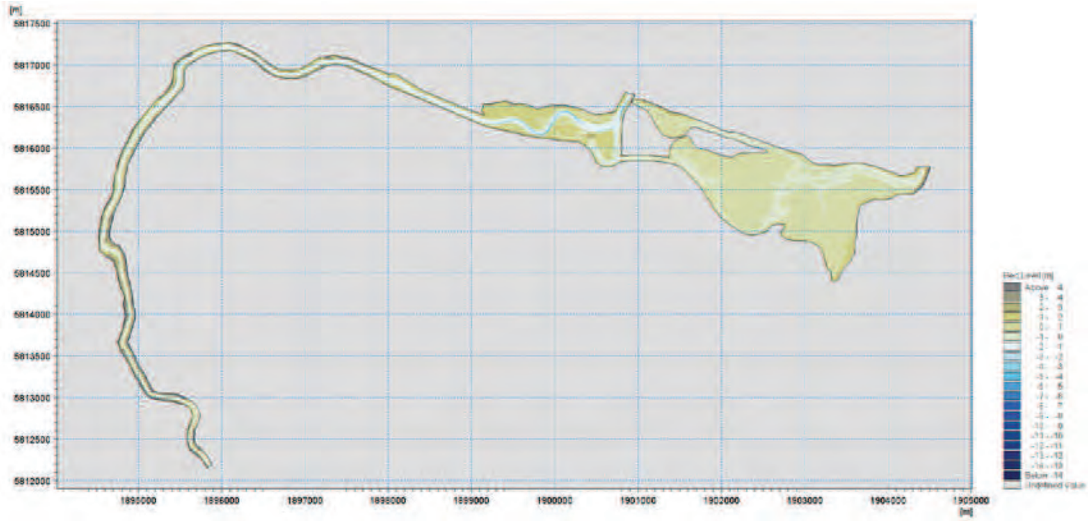


Figure D-18 Local 3D hydrodynamic model bathymetry

D.3.2 Local 3D Hydrodynamic Model Calibration

The aim of the local 3D hydrodynamic model calibration was to obtain a reasonable agreement between the observed and predicted salinities within the river and estuary. The model has been calibrated for the period 22nd March to 5th April 2013, a period when continuous salinity measurements where collected within the estuary.

On the 4th April 2013, comprehensive salinity profiles were collected in the river and estuary to measure behaviour of saline intrusion up Kaituna River and Ford's Loop and resulting salinity of water entering into Ford's Cut channel and mixing within the estuary.

Details of the model parameters selected are presented in Table D-2.

Table D-2 Specifications for model parameters.

Parameter	Value
Vertical Mesh	10 vertical layers with variable layer thickness.
Time Step Interval	300s
Solution Technique	Higher order, fast algorithm Minimum time step: 0.01sec Maximum time step: 10 sec Critical CFL number: 0.8
Enable Flood and Dry	Drying depth: 0.01m Flooding depth: 0.05m Wetting depth: 0.1m
Density	Function of Salinity
Eddy Viscosity	Horizontal: Smagorinsky formulation, constant 0.28

Parameter	Value
	Vertical: k – epsilon formulation
Resistance	Varying resistance height map
Dispersion	Horizontal: scaled eddy viscosity formulation: 1 Vertical: scaled eddy viscosity formulation: Varying
Boundary Conditions	Freshwater inflow = 0 PSU Open ocean = 35 PSU

A spatially varying roughness height has been used based on spatially varying Manning number derived for the 2D local hydrodynamic model (see Section D.2). The roughness height is equivalent to the Nikuradse roughness height (k, which is related to Manning number by the following formula:

$$M = 25.4/k^{1/6}$$

A spatially varying map was required for vertical dispersion. A lower value (0.0001) was used for the river to encourage the saline intrusion, while a high value (100) was used within Ford's Cut, since it seems reasonable to expect significant turbulence induced mixing of water which travels through the Ford's Cut culverts. The way culverts are implemented within the model assumes that no mixing occurs as water travels through the culverts, therefore this has to be produced by increasing mixing that occurs within Ford's Cut.

D.3.2.1 Comparison of Observed and Predicted Salinities - River

To assess the performance of the model in reproducing the behaviour of the saline intrusion within the Kaituna River and Ford's Loop a comparison was made between the observed and predicted salinities. The aim of the calibration was not to obtain a perfect match between observed and predicted salinities, but instead to replicate the general behaviour and extent of saline intrusion that occurs.

A comparison of the observed and predicted salinity distributions on 4th April 2013 within the Kaituna River and Ford's Loop (Transect 1 and Transect 2 in in Section 3.6 respectively) for different states of the tide is shown in Figure D-19 to Figure D-26.

Visually there is a very good agreement between the observed and predicted salinity distribution for the river. For most of the different parts of the tide within the rivers there is reasonable agreement between observed and predicted saline intrusion behaviour. The model does appear to under predict the maximum extent of the salt wedge by approximately 500 m.

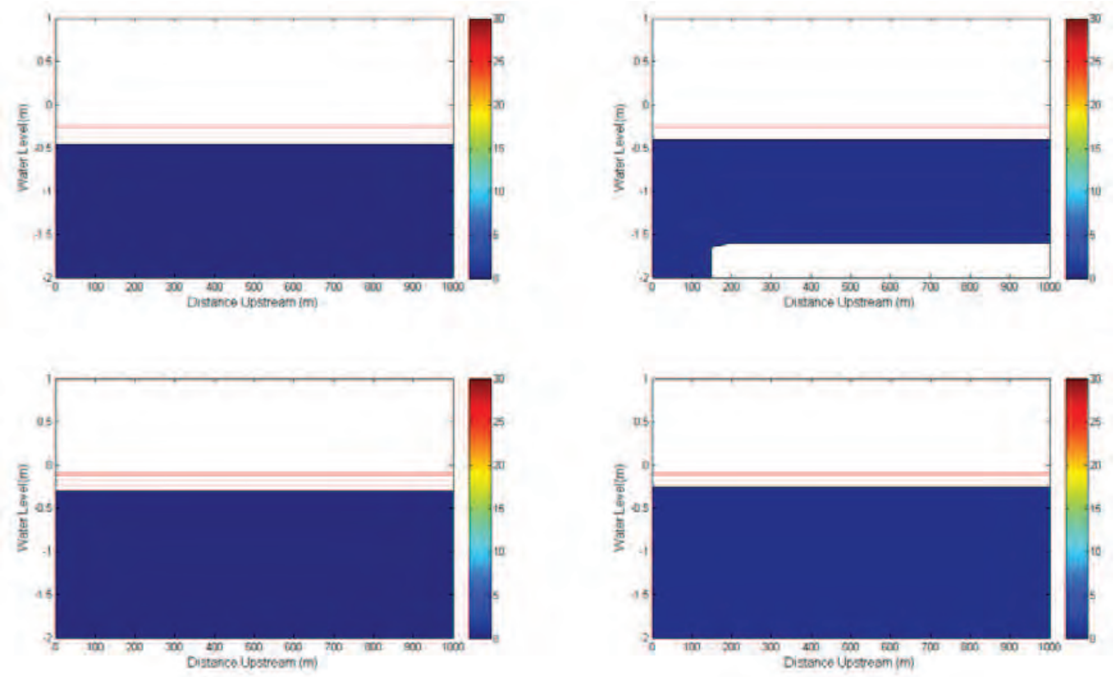


Figure D-19 Comparison of observed (left) and predicted (right) salinity (PSU) in Kaituna River at approximately 8:00 am (top) and 8:55 am (bottom) on 4th April 2013. Water levels in Moturiki Datum with red line indicating measured water level in Ford's Loop.

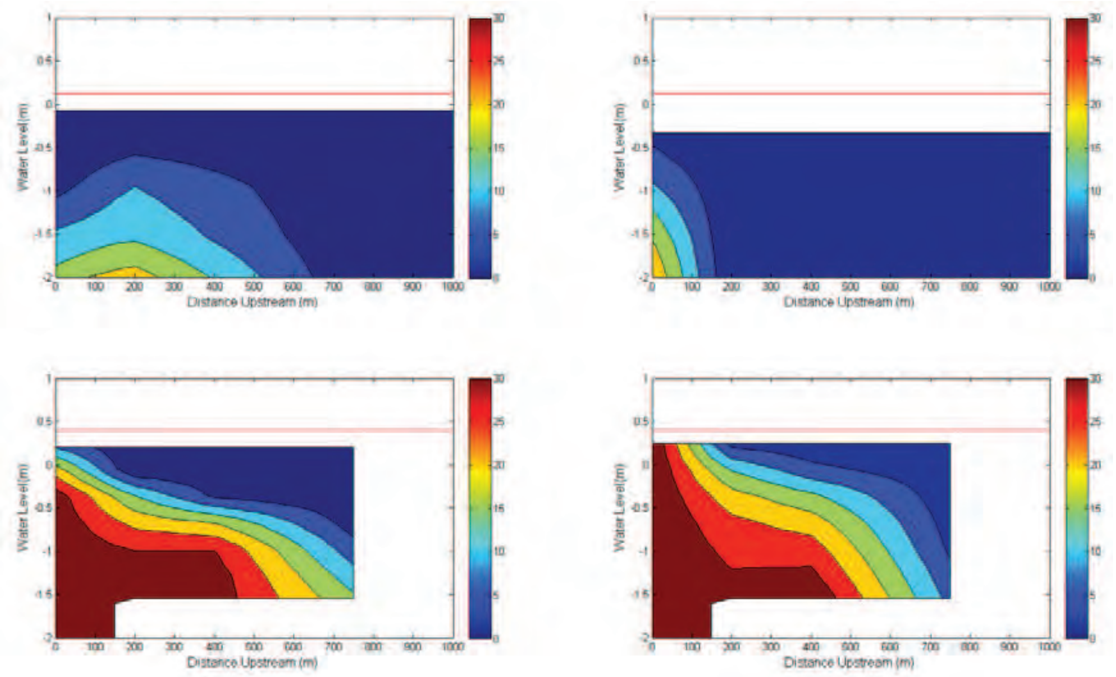


Figure D-20 Comparison of observed (left) and predicted (right) salinity (PSU) in Kaituna River at approximately 9:37 am (top) and 10:25 am (bottom) on 4th April 2013. Water levels in Moturiki Datum with red line indicating measured water level in Ford's Loop.

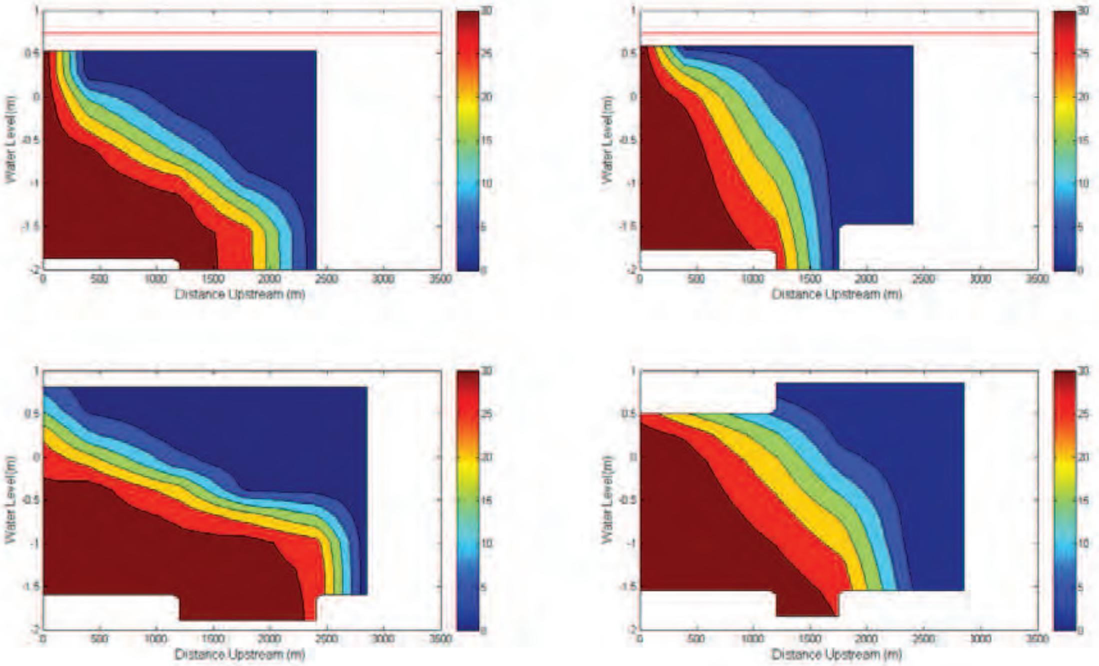


Figure D-21 Comparison of observed (left) and predicted (right) salinity (PSU) in Kaituna River at approximately 11:32 am (top) and 12:50 pm (bottom) on 4th April 2013. Water levels in Moturiki Datum with red line indicating measured water level in Ford's Loop.

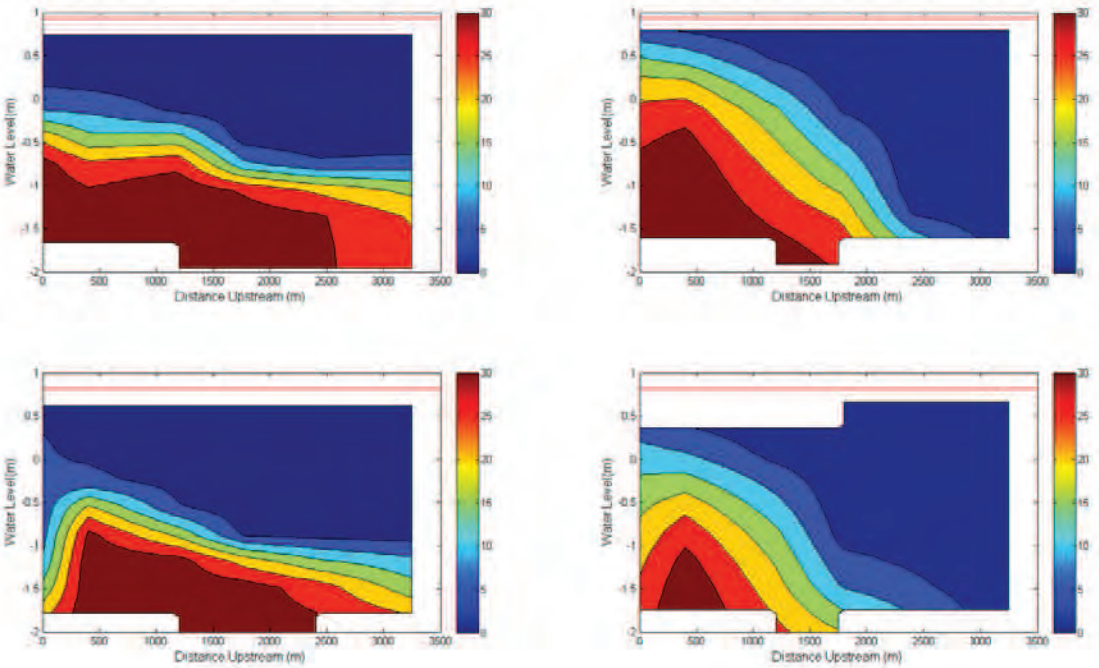


Figure D-22 Comparison of observed (left) and predicted (right) salinity (PSU) in Kaituna River at approximately 1:45 pm (top) and 2:44 pm (bottom) on 4th April 2013. Water levels in Moturiki Datum with red line indicating measured water level in Ford's Loop.

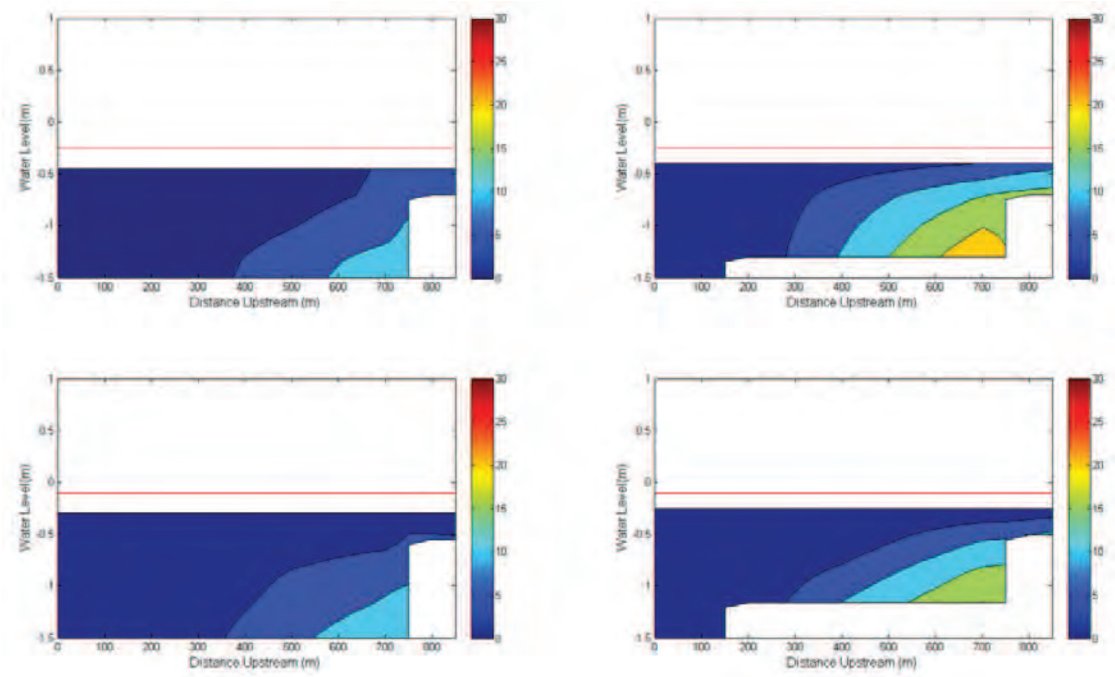


Figure D-23 Comparison of observed (left) and predicted (right) salinity (PSU) in Ford's Loop at approximately 8:00 am (top) and 8:55 am (bottom) on 4th April 2013. Water levels in Moturiki Datum with red line indicating measured water level in Ford's Loop.

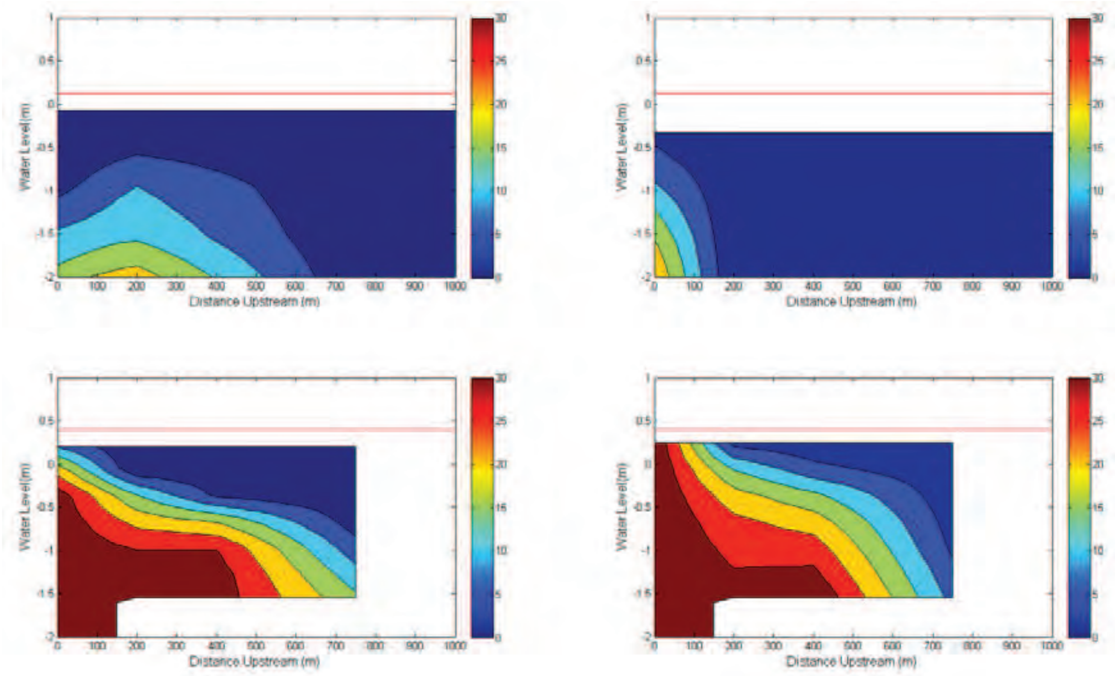


Figure D-24 Comparison of observed (left) and predicted (right) salinity (PSU) in Ford's Loop at approximately 9:37 am (top) and 10:25 am (bottom) on 4th April 2013. Water levels in Moturiki Datum with red line indicating measured water level in Ford's Loop.

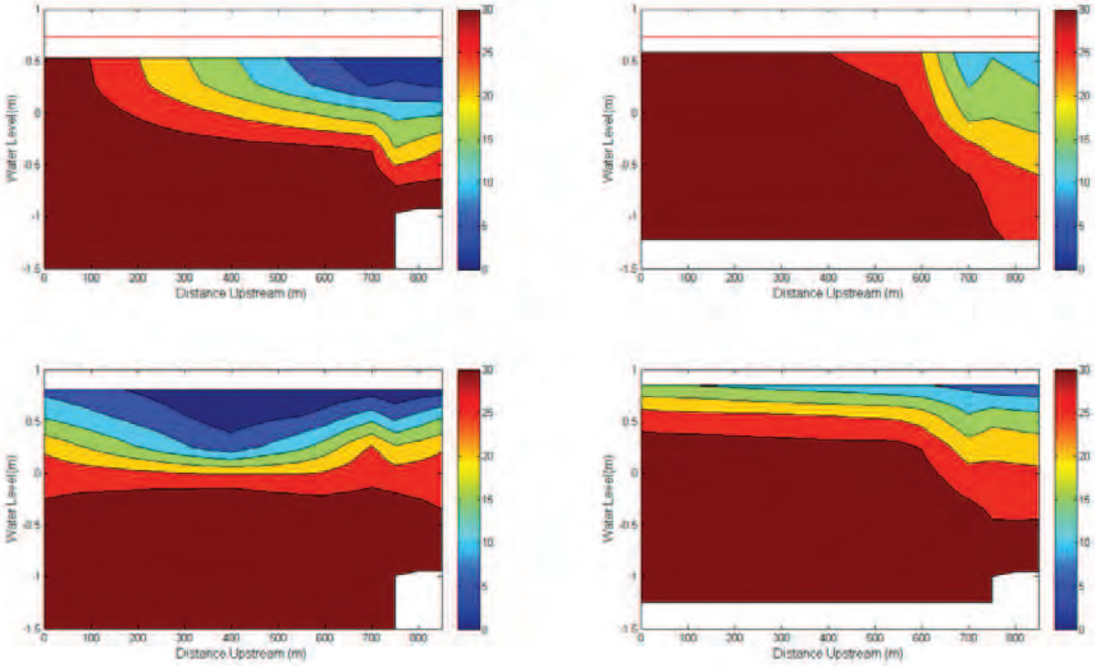


Figure D-25 Comparison of observed (left) and predicted (right) salinity (PSU) in Ford's Loop at approximately 11:32 am (top) and 12:50 pm (bottom) on 4th April 2013. Water levels in Moturiki Datum with red line indicating measured water level in Ford's Loop.

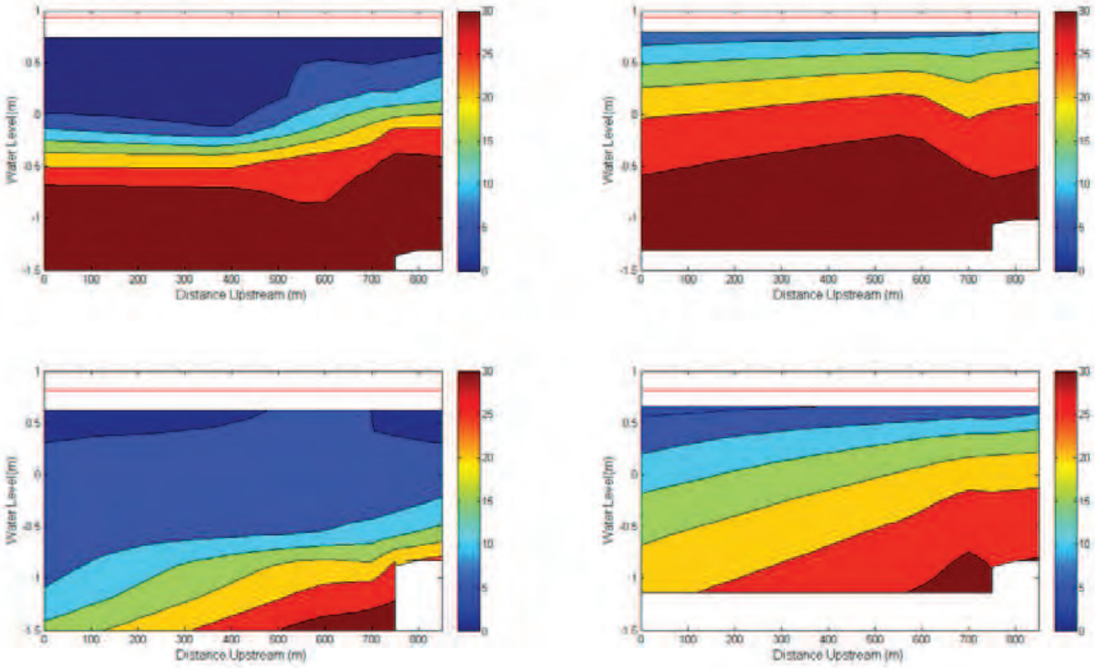


Figure D-26 Comparison of observed (left) and predicted (right) salinity (PSU) in Ford's Loop at approximately 1:45 pm (top) and 2:44 pm (bottom) on 4th April 2013. Water levels in Moturiki Datum with red line indicating measured water level in Ford's Loop.

A comparison between all observed and predicted salinities within Kaituna River (Transect 1) is shown in Figure D-27. It was calculated that 70% of the predicted salinities agree within 5 PSU of the measured salinities for Kaituna River, while 82% of the predicted salinities agree with 10 PSU of the measured salinities.

For the proposed diversion the most important location to get a good match between the observed and predicted salinities at the site closest to new diversion channel, Site 10. For this site, 70% of the predicted salinities agree within 5 PSU of the measured salinities, while 90% of the predicted salinities agree within 10 PSU of the measured salinities.

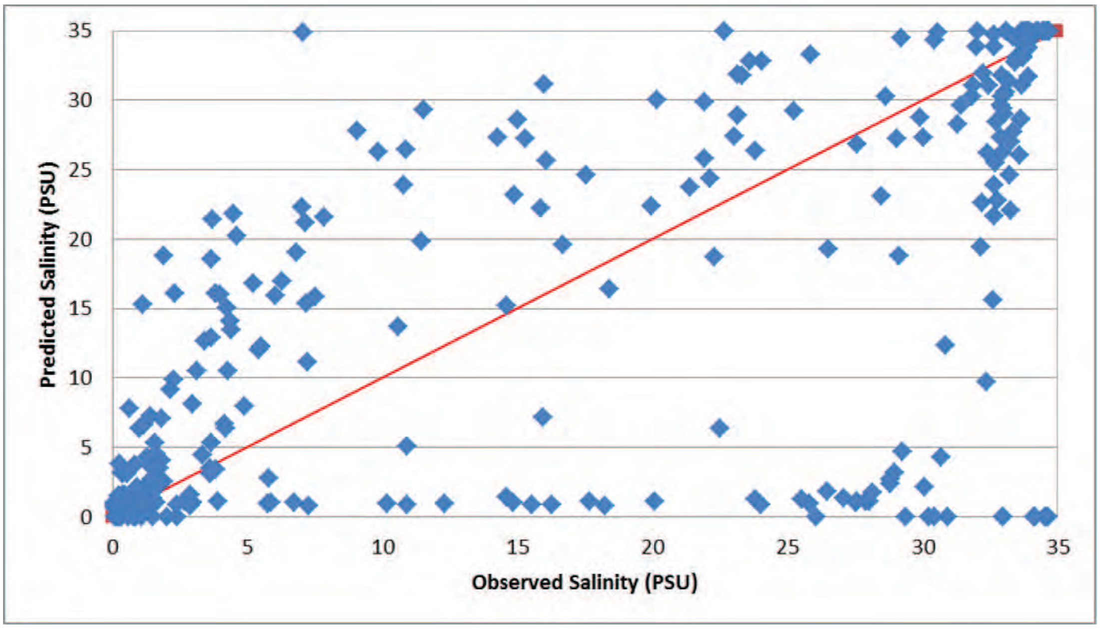


Figure D-27 Comparison of observed and predicted salinity (PSU) in Kaituna River.

A comparison of the observed and predicted depth averaged salinities at Site 10 is shown in Figure D-28. There is a very good agreement between observed and predicted depth averaged salinities at this location.

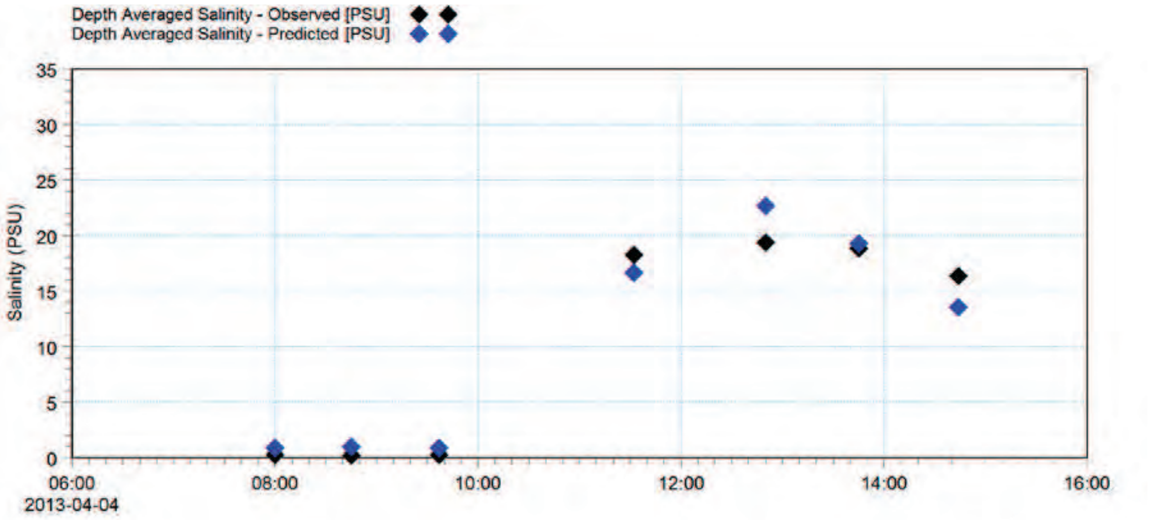


Figure D-28 Comparison of the observed and predicted depth averaged salinities at Site 10

A comparison between all observed and predicted salinities within Ford's Loop (Transect 2) is shown in Figure D-29. It was calculated that 63% of the predicted salinities agree within 5 PSU of the measured salinities for Ford's Loop, while 82% of the predicted salinities agree within 10 PSU of the measured salinities

For the existing situation the most important location to get a good match between the observed and predicted salinities is the site closest to Ford Cut. For Site 2 (site closest Ford's Cut) 68% of the predicted salinities agree within 5 PSU of the measured salinities for Ford's Loop, while 88% of the predicted salinities agree within 10 PSU of the measured salinities.

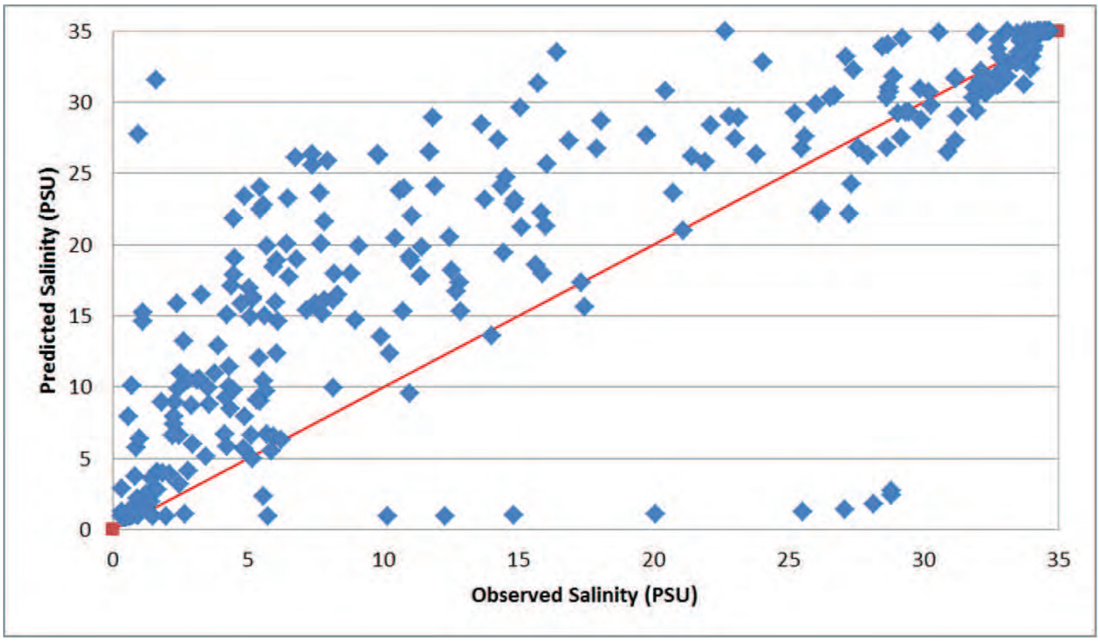


Figure D-29 Comparison of observed and predicted salinity (PSU) in Ford's Loop.

D.3.2.2 Comparison of Observed and Predicted Salinities - Estuary

A comparison of the observed and predicted salinity within Ford's Cut and within the estuary mouth close to the sea bed (see Section 3.2 for locations) is shown for the period 22nd March to 5th April 2013 is shown in Figure D-30 and Figure D-31. Visually there is a very good agreement between observed and predicted salinities for both locations. Within Ford's Cut, the predicted salinities agreed within 5 PSU of observed salinities 90% of the time, while at the estuary entrance predicted salinities agreed within 5 PSU of observed salinities 96% of the time.

The general trend of lower salinities observed within Ford's Cut and at the estuary mouth for neap tide (23rd March 2013) and vice versa higher salinities for spring tide (31st Match 2013) is well reproduced by the model. If the predicted volume of freshwater entering the estuary through Ford's Cut was not reasonably accurate, it would not be expected that a reasonable match for observed and predicted salinities within the estuary mouth could occur.

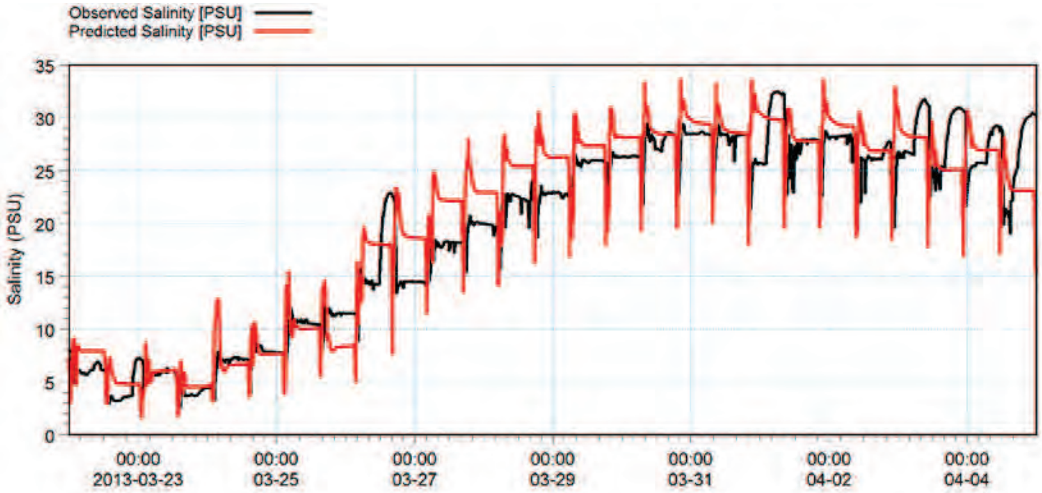


Figure D-30 Comparison of observed (black) and predicted (red) salinity (PSU) in Ford's Cut.

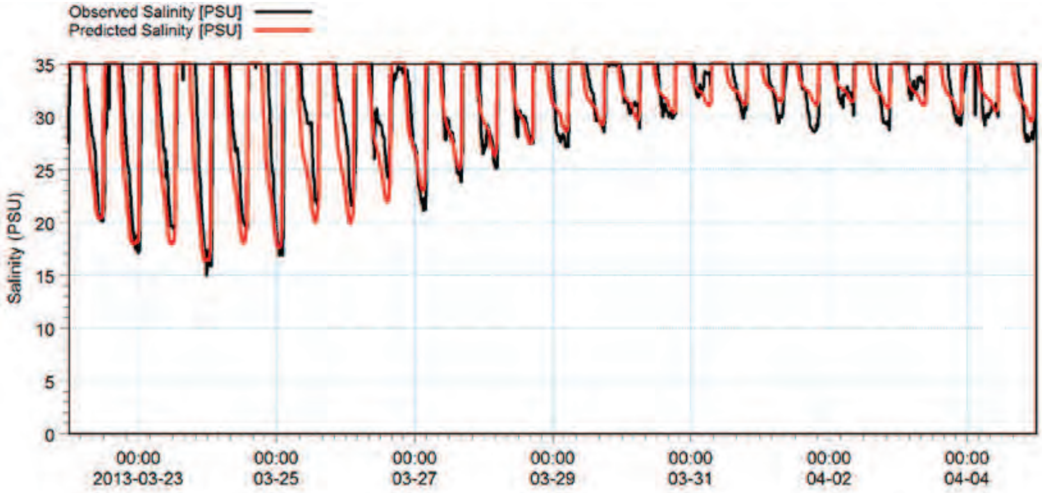


Figure D-31 Comparison of observed (black) and predicted (red) salinity (PSU) inside the estuary entrance.

As described in Section 3.6, a series of salinity profiles were collected throughout the estuary on 4th April 2013. The locations of the salinity profiles are shown in Figure D-32. A comparison of observed and predicted salinities for selected locations where salinity profiles collected is shown in Figure D-33 to Figure D-40.

Visually there is a reasonable agreement between the observed and predicted salinity profiles, with an agreement of within 5 PSU for all profiles. It appears that the model maybe slightly over predict the mixing of salinity throughout the vertical for sites within western part of estuary and the predicted salinities are slightly higher than what was observed for these locations. A closer inspection of Figure D-28 indicates that the model is over predicting salinities by approximately 4 PSU for the period when flow was entering the estuary through Ford's Cut, which would result in predicted salinities slightly higher than what was observed within the estuary, hence the likely reason for slightly higher salinities in western estuary when comparing the observed and predicted salinity profiles.

The model calibration was deemed satisfactory and the model fit for purpose for predicting saline intrusion within the river, the ratio of fresh and salt water which enters the estuary through

Ford’s Cut and the resulting salinity that occurs within estuary as water from Ford’s Cut mixes with water from the ocean.

Figure D-32 Locations where salinity profile data collected within in estuary.

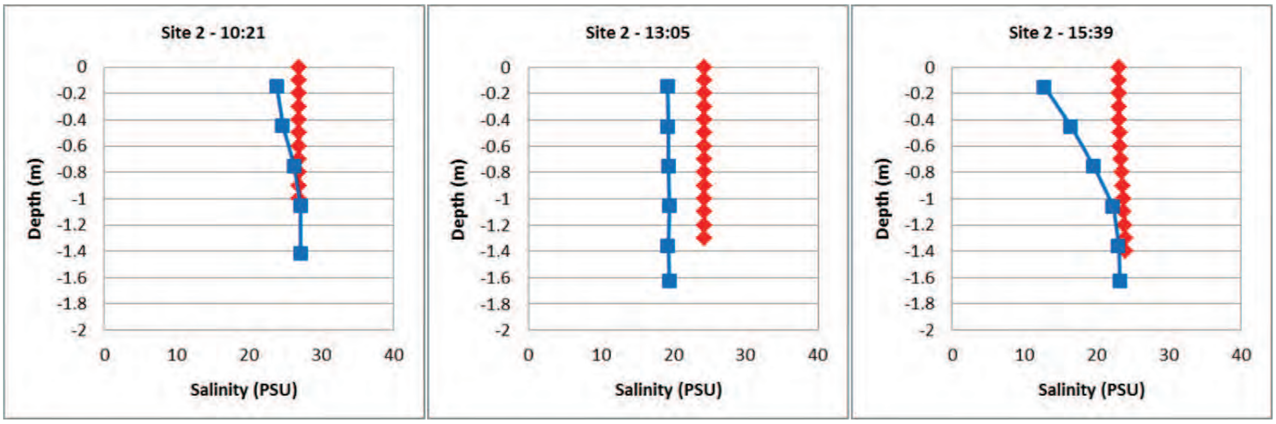


Figure D-33 Comparison between observed (blue) and predicted salinities (red) at approximately Site 2 on 4th April 2013 at 10:21, 13:05 and 15:39.

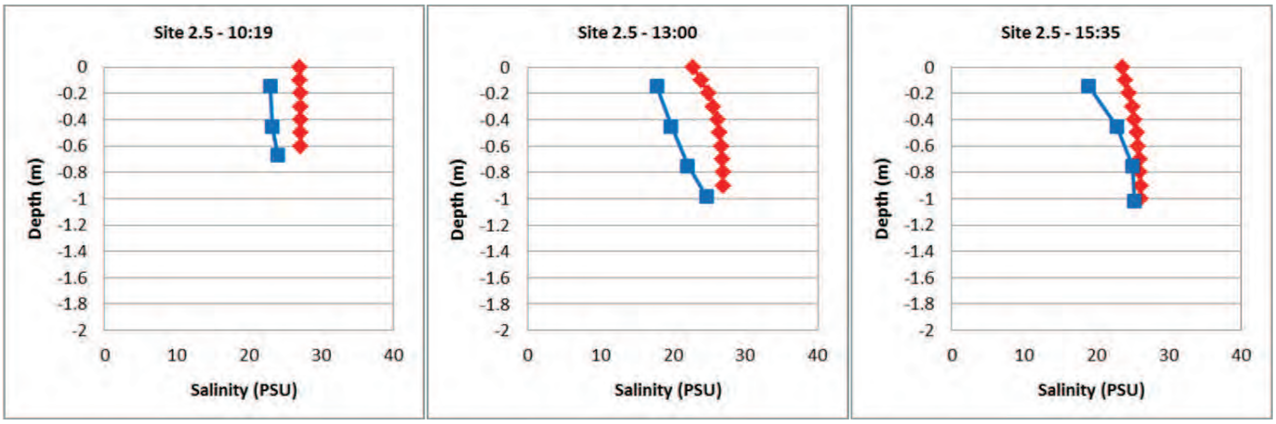


Figure D-34 Comparison between observed (blue) and predicted salinities (red) at approximately Site 2.5 on 4th April 2013 at 10:19, 13:00 and 15:35.

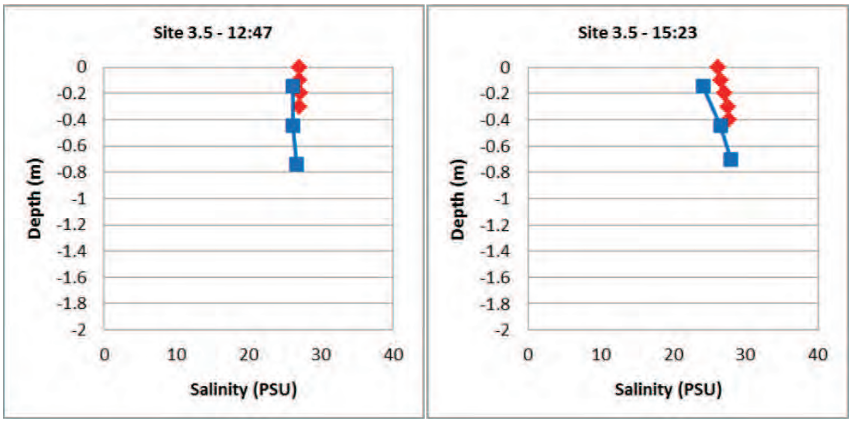


Figure D-35 Comparison between observed (blue) and predicted salinities (red) at approximately Site 3.5 on 4th April 2013 at 12:47, and 15:23.

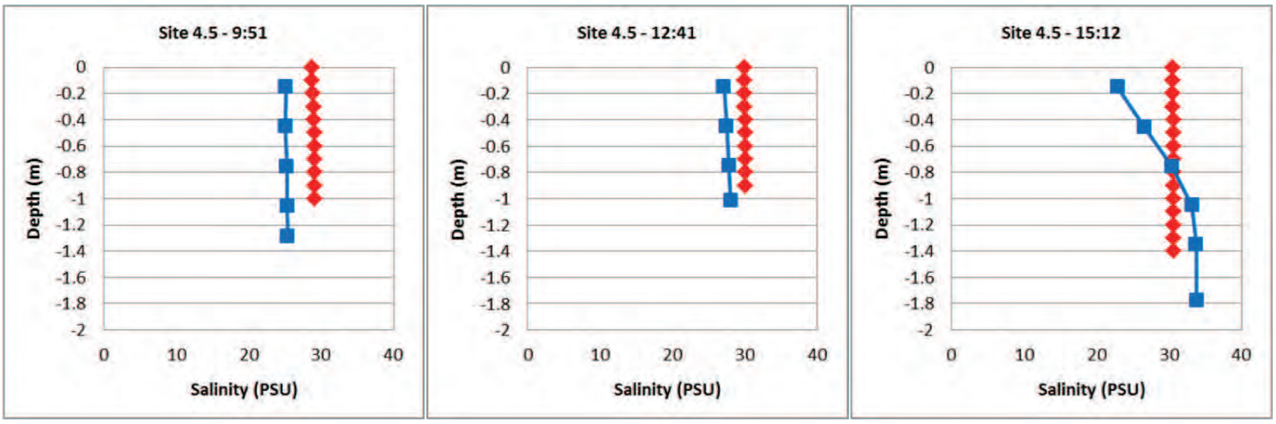


Figure D-36 Comparison between observed (blue) and predicted salinities (red) at approximately Site 4.5 on 4th April 2013 at 9:51, 12:41 and 15:12.

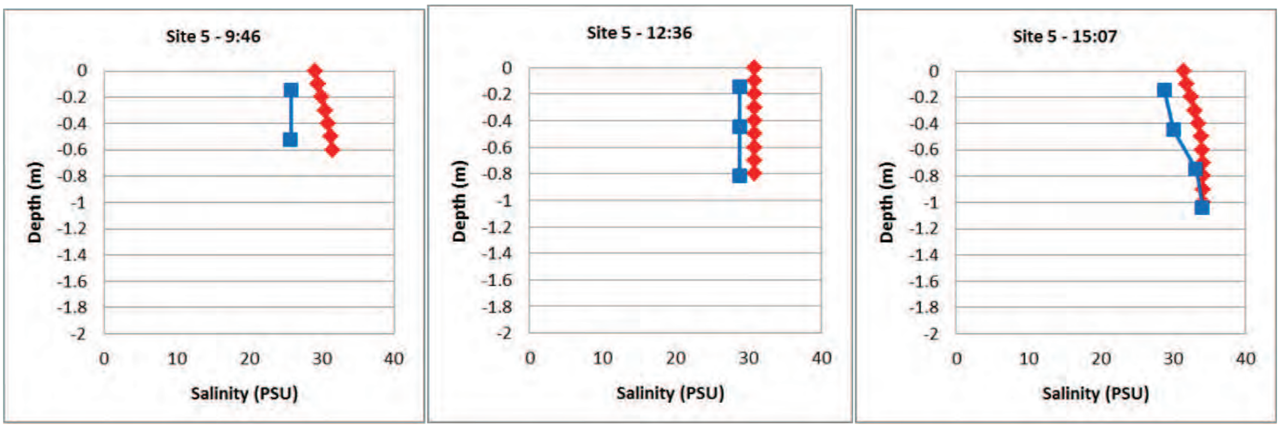


Figure D-37 Comparison between observed (blue) and predicted salinities (red) at approximately Site 5 on 4th April 2013 at 9:46, 12:36 and 15:07.

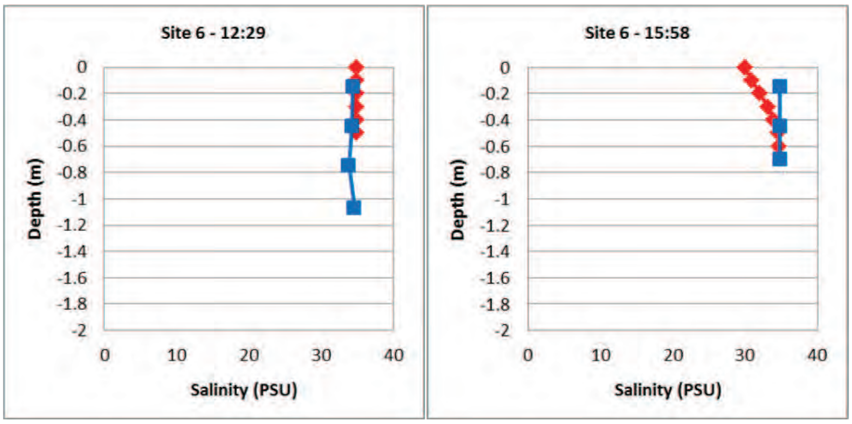


Figure D-38 Comparison between observed (blue) and predicted salinities (red) at approximately Site 6 on 4th April 2013 at 12:29 and 15:58.

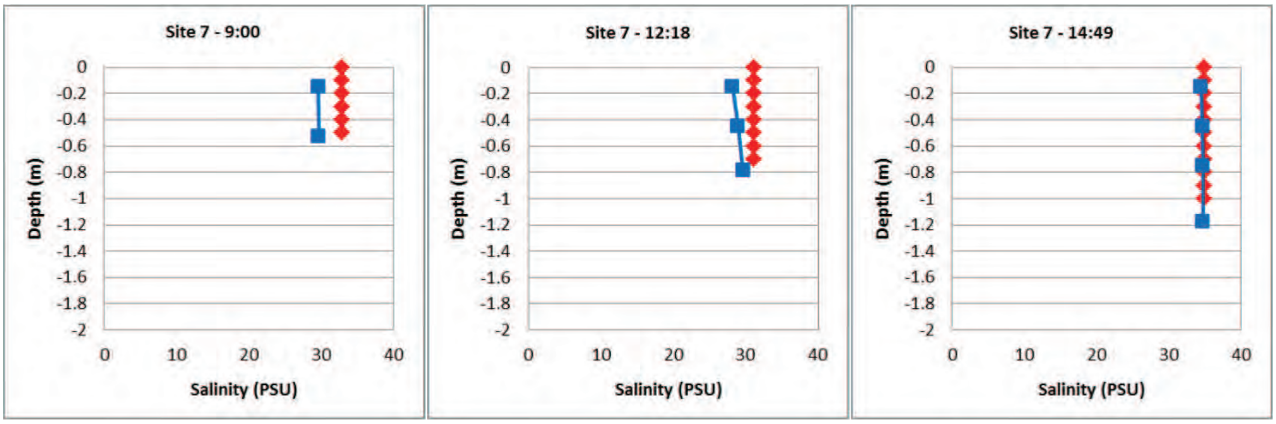


Figure D-39 Comparison between observed (blue) and predicted salinities (red) at approximately Site 7 on 4th April 2013 at 9:00, 12:18 and 14:49.

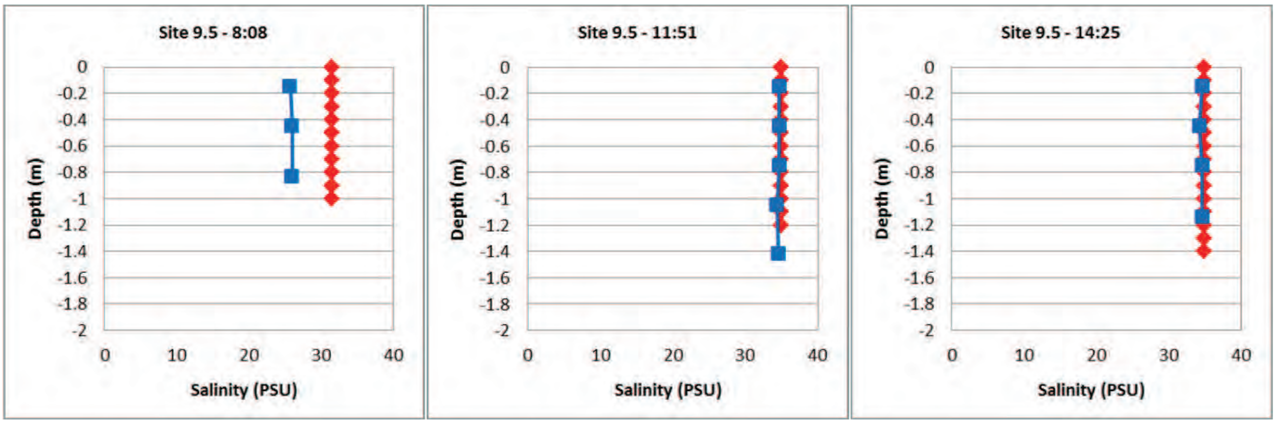


Figure D-40 Comparison between observed (blue) and predicted salinities (red) at approximately Site 9.5 on 4th April 2013 at 8:08, 11:51 and 14:25.

APPENDIX E

Morphological Model

E.1 Introduction

This appendix provides details of the morphological model (coupled MIKE 21 HD FM, MIKE 21 SW and MIKE 21 ST models). It provides a brief description of the model and details the model set up and validation.

The model was validated for a significant flood event within the Kaituna River to illustrate the model was able to reproduce the scour of the Kaituna River entrance and flood levels that occurred within both the river and estuary.

The model has also been validated for normal river flow and tidal conditions to illustrate the model reproduces the dominance of flood tide transport sediment within the flood tide delta of the Ongatoro / Maketū Estuary entrance.

E.2 MIKE 21 ST Model

The MIKE 21 ST (Sand Transport) model is a sand transport model for both pure and combined current and wave conditions, which simulates the erosion, transport and deposition of non-cohesive sediments. It includes the influence of breaking waves and non-breaking waves, currents due to various driving forces, coastal structures, complex bathymetry, sediment gradation, etc. Two modes of sediment transport are described:

- bed load transport; and
- suspended load transport

A third category is normally referred to as wash load. Wash load is not included in this model.

The model includes a dynamic morphological feedback, which means the model bathymetry dynamically adjusts depending on the sediment transport capacities within each part of the model domain.

Further detail of the MIKE 21 ST model can be found in the MIKE 21 ST FM User Manual (DHI, 2012) and Scientific Documentation (DHI, 2012).

E.3 MIKE 21 ST Model Set Up and Validation

The parameters that were used for the validated model are shown in Table E-1. Further explanation of these parameters can be found in the MIKE 21 ST FM User Manual (DHI, 2012) and Scientific Documentation (DHI, 2012).

Table E-1 Specifications for calibrated sediment transport model.

Parameter	Value
Model Type	Wave and currents
Solution Technique	Lower Order
Model Definition	Maximum bed level change = 1 m/day Include feedback on hydrodynamic, wave and sediment transport calculations
Sediment Diameter	Spatially varying sediment diameter map based on sediment grab samples.
Boundary Conditions	Taken from Regional Bay of Plenty 2D hydrodynamic model or when appropriate the ADCP located offshore.

MIKE 21 ST cannot explicitly include sediment supply from the model boundaries if using the combined waves and currents formulation as was the case for this study. Hence sediment supplied by the Kaituna River was not accounted for in any model predictions.

E.3.1 Model Validation – Flood Event

The morphological model was validated using a period which contained a significant flood event (16th to 22nd April 2013). The model was validated to determine whether it could reproduce scour that would occur at the Kaituna River mouth and reproduce the flood levels within both the river and estuary. The flows for Kaituna River at Te Matai for the flood event is presented in Figure E-1. The flood event is a two peaked event with the first peak coinciding with a high energy wave climate as shown in Figure E-2 (significant wave heights greater than 3.5 m observed). The observed water levels off Okurei Point indicate that there is a significant increase in water levels most likely a combination of changes in atmospheric pressure and storm surge. For this reason these observed levels have been used for the open ocean boundaries since it is outside the scope of this study to replicate this type of behaviour. For this model validation, the water levels measured within the estuary were adjusted to account for changes in atmospheric pressure (see Section 3.9).

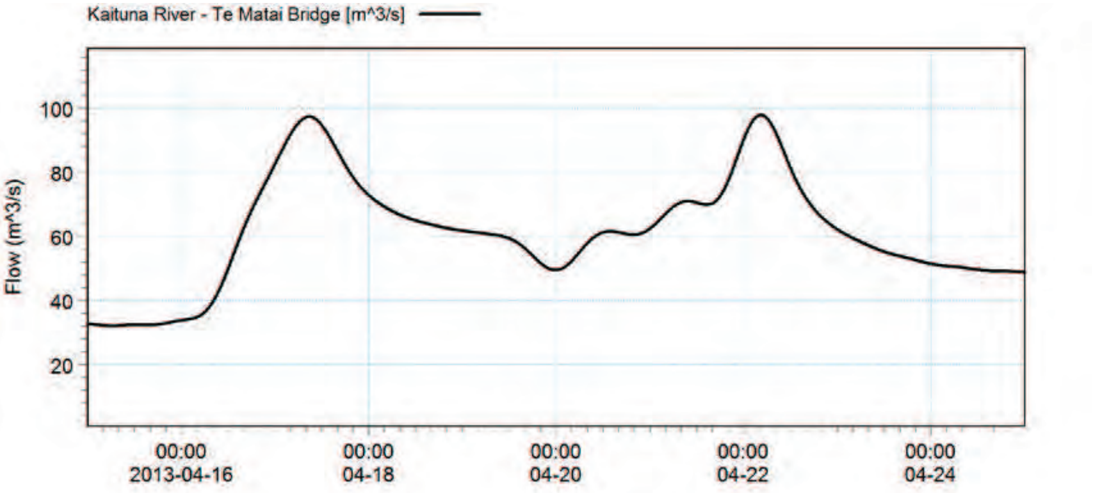


Figure E-1 Kaituna River flow at Te Matai for period 15th to 25th April 2013.

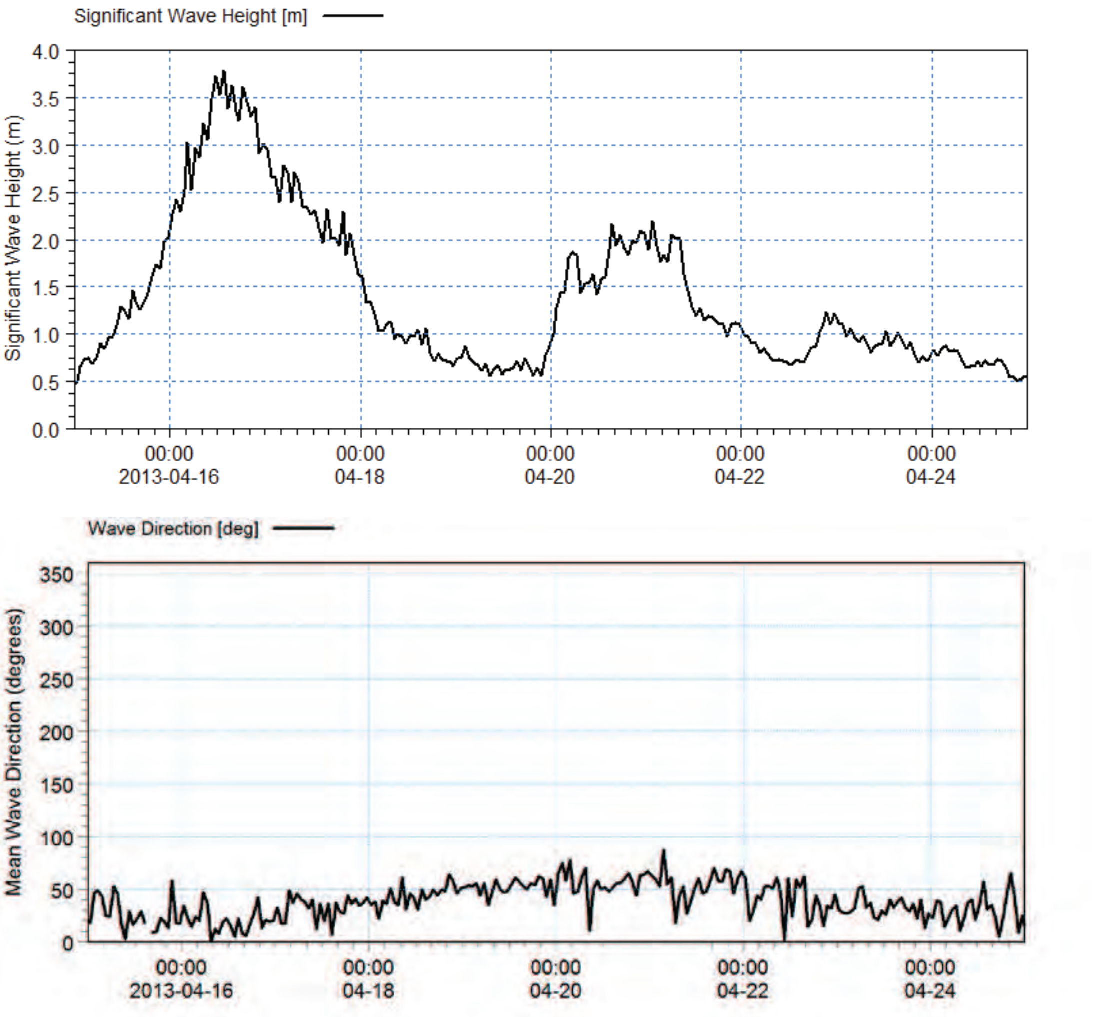
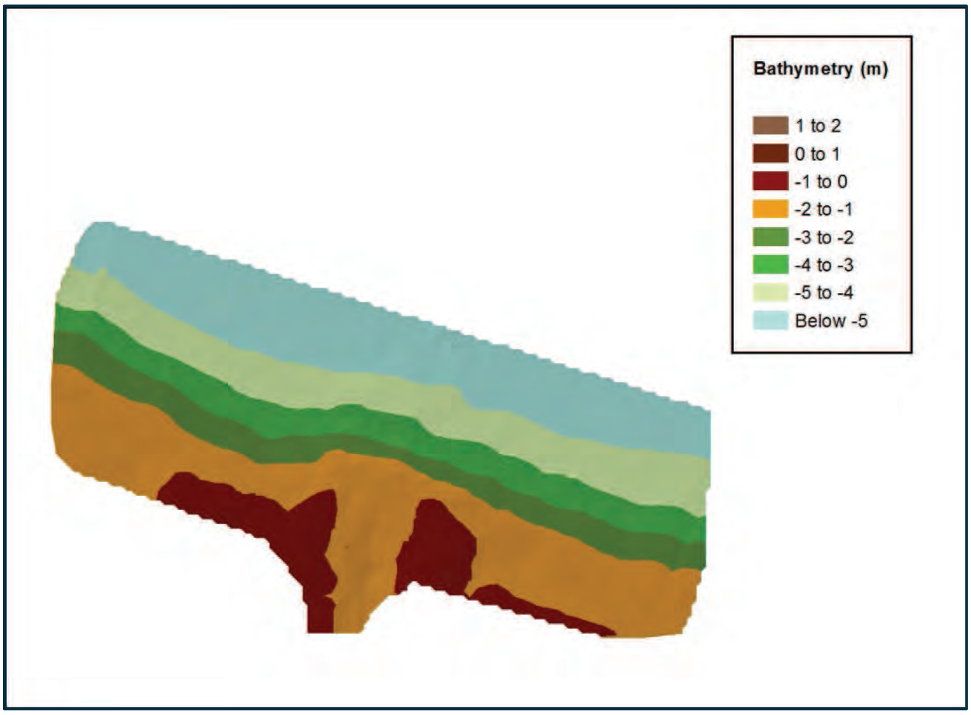


Figure E-2 Significant wave height (top) and mean wave direction (bottom) off Okurei Point for period 15th to 25th April 2013.

The local hydrodynamic model alone could not be used to reproduce flood levels occurring during the flood event, since the morphological behaviour of the mouths resulting from both the wave climate and elevated flows in the river will have had a direct impact on observed flood levels.

The comparison between the surveyed and predicted bathymetry from immediately after the April 2013 flood event is presented in Figure E-3. There is a good agreement for both the depth and extent of the scoured navigation channel. A cross section of the observed and predicted bed level in the Kaituna River mouth were extracted along the line indicated in Figure E-3 and are presented in Figure E-4. There is a reasonable agreement between the depth and width of the river mouth with the behaviour of the mouth widen and migrating to the west replicated by the model.



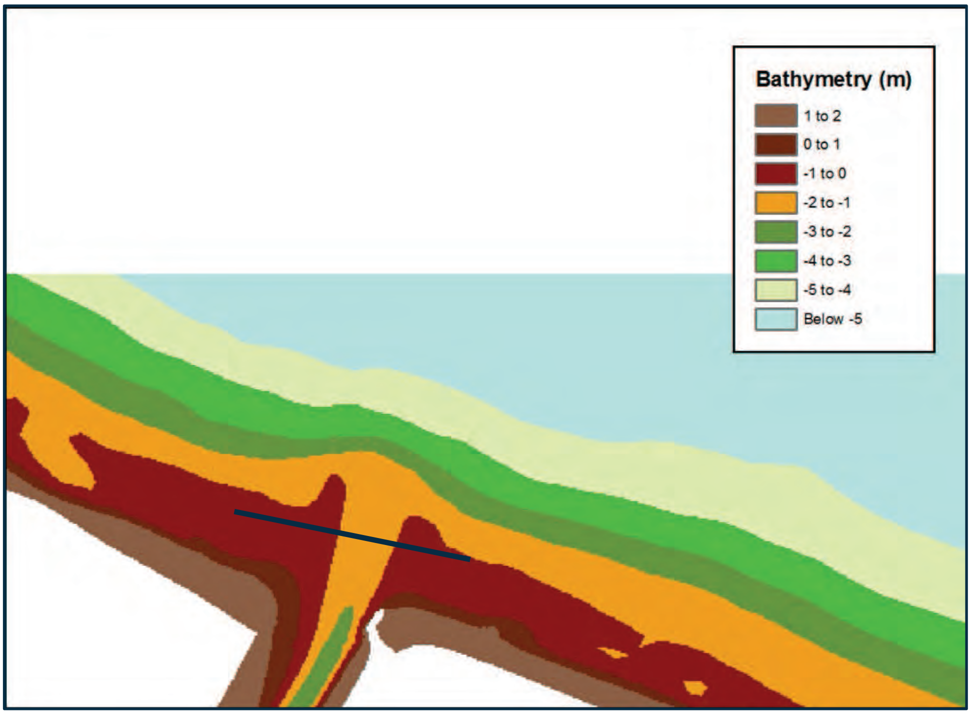


Figure E-3 Comparison of post flood bathymetry comparison on 24th April 2013 surveyed (top) and predicted (bottom).

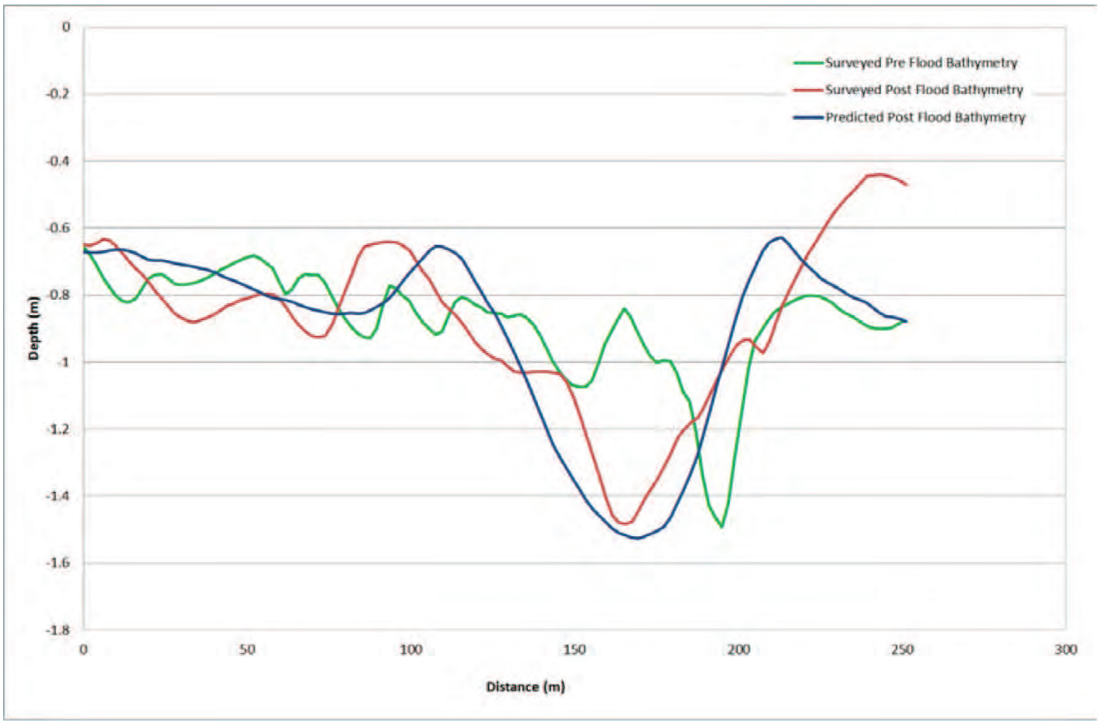


Figure E-4 Comparison of observed and predicted bed levels for cross section shown in Figure E-2.

The comparison of the observed and predicted water levels for the April 2013 flood event at Ford's Loop, Ford's Cut and the estuary entrance are presented in Figure E-5. The model was not able to match the water levels for the first flood peak. We believe this is because the model was unable to replicate the wave set up that occurred. There is a good match for water levels within 0.1 m for the second flood peak though when minimal wave set up was present. We believe it is outside the scope of this study to simulate wave set up, hence there was more emphasis on matching water levels for the second flood peak.

Presented in Figure E-6 is the significant wave height field is the current field during the peak of the high energy wave event at 4:00 pm 16th April 2013. Figure E-7 shows the current field in the vicinity of Okurei Point while Figure E-8 shows the current field in the vicinity of the river and estuary entrances. The associated sediment transports rates are presented in Figure E-9.

The effect of Okurei Point and the shallow bathymetry north of the point (rocky reefs) is apparent in the wave and current fields. To the east of the Kaituna river mouth, the waves are affected by the refraction over the shallow areas seaward of the headland and turned counter-clock wise so they are coming from west relative to the coastline normal, leading to an easterly flow / transport of sediment towards both the river and the estuary entrance, with rates of up to 5 x10^{-6} m^3/s/m within the surf zone.

The large scale current patterns that divide around the headland are probably a result of the shallow waters in vicinity of headland and therefore currents are really dominated by wave driven effects (rather than tides or winds) in this particular case.

It should be noted that this is just one wave condition and more northerly wave conditions would probably lead to more consistent easterly transport, while more easterly waves would probably lead to westerly transport.

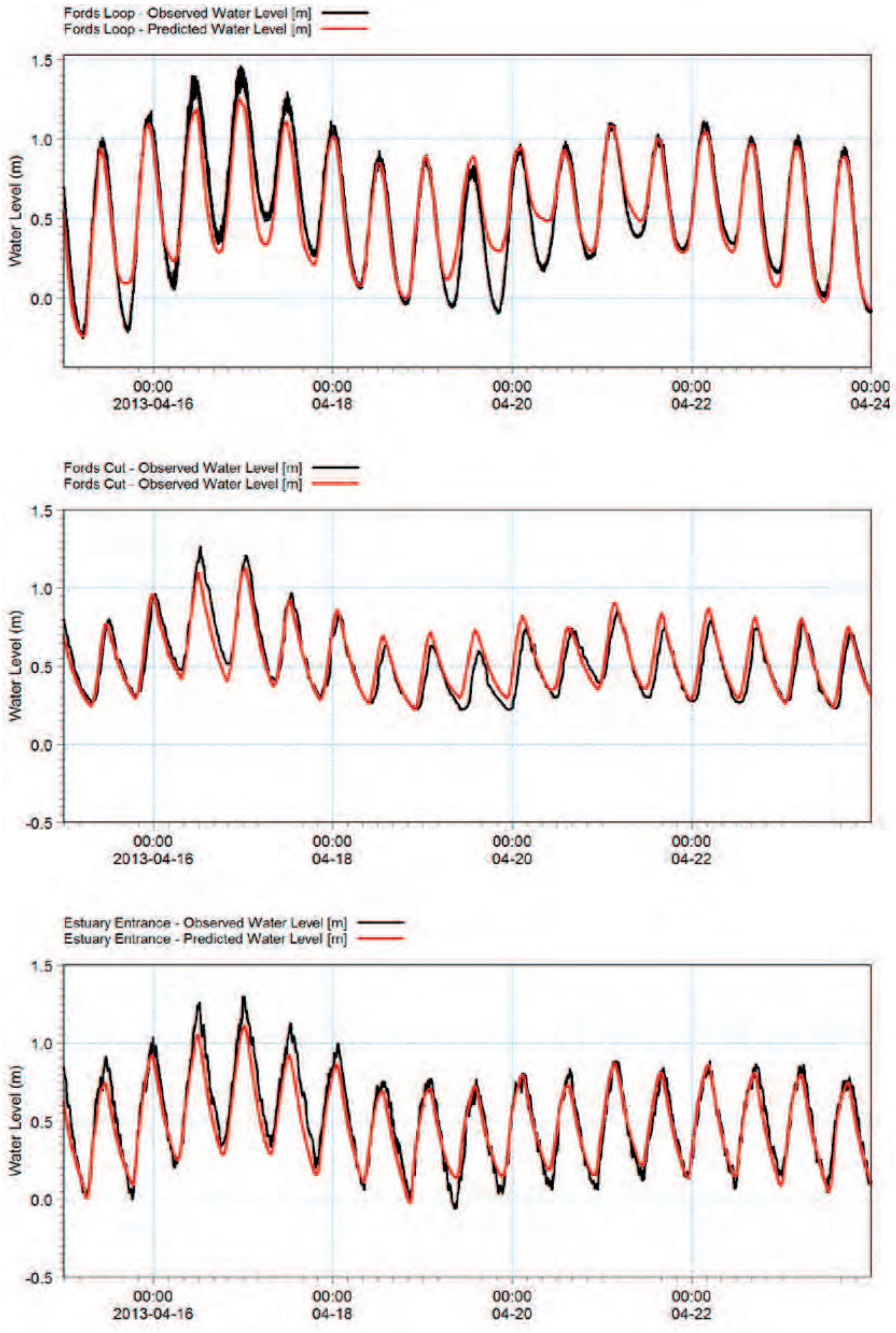


Figure E-5 Comparison of observed and predicted water levels at Ford's Loop (top), Ford's Cut (middle) and estuary entrance (bottom) during significant flood events, 15ht to 24th April 2014.

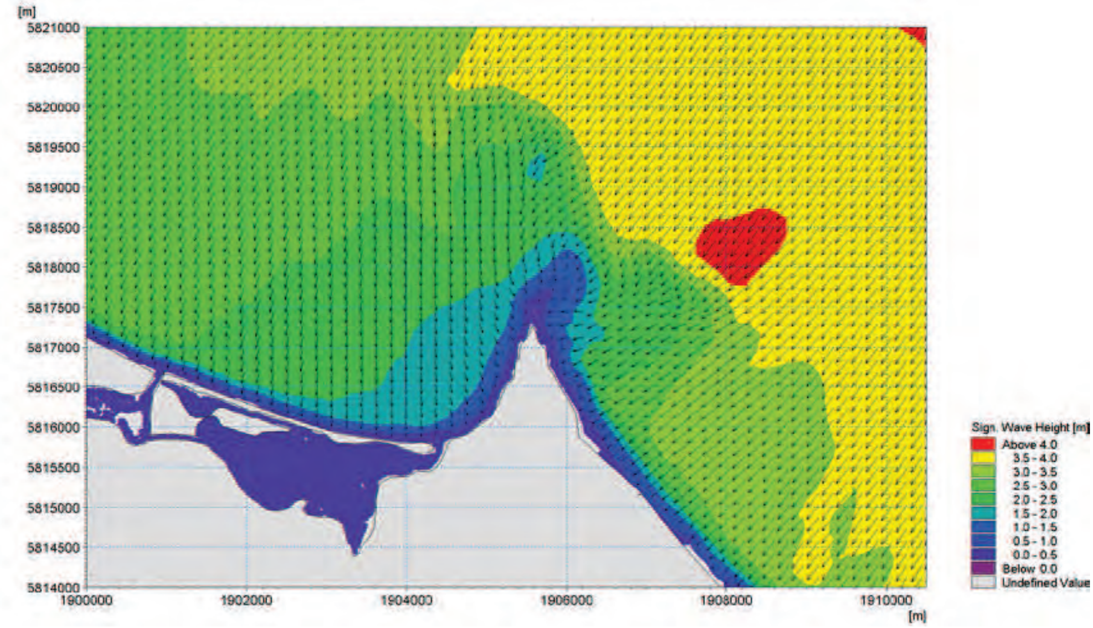


Figure E-6 Significant wave height field during peak of high energy wave event at 4:00 pm 16th April 2013.

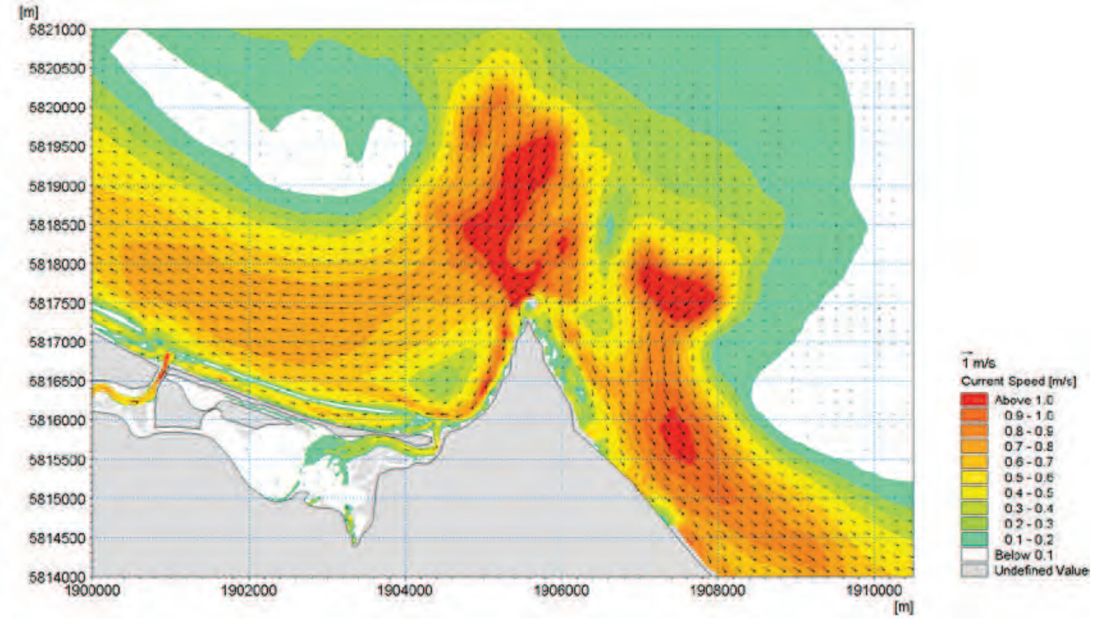


Figure E-7 Current field in the vicinity of Okurei Point during peak of high energy wave event at 4:00 pm 16th April 2013.

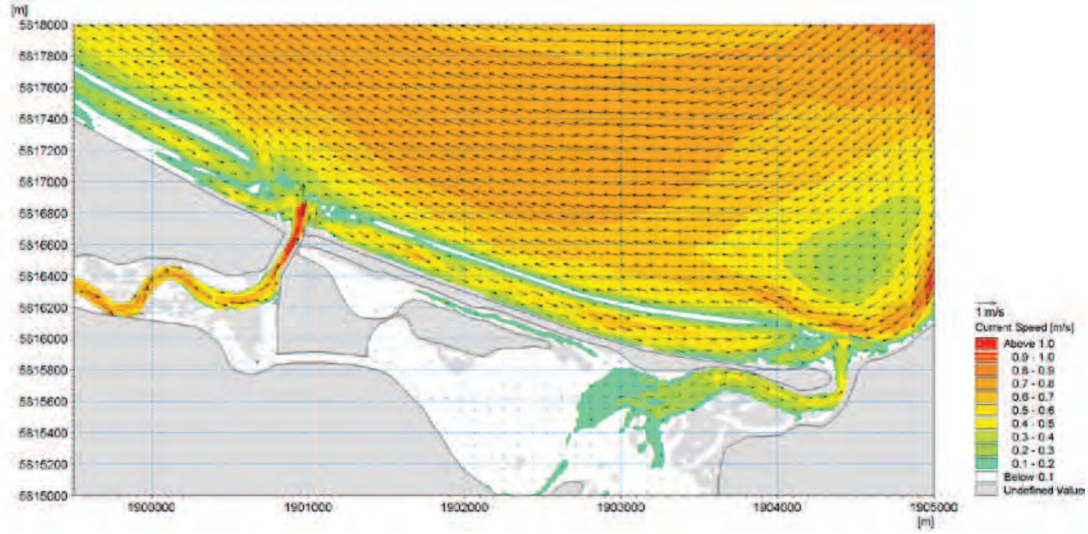


Figure E-8 Current field in the vicinity of the river and estuary entrances during peak of high energy wave event at 4:00 pm 16th April 2013.

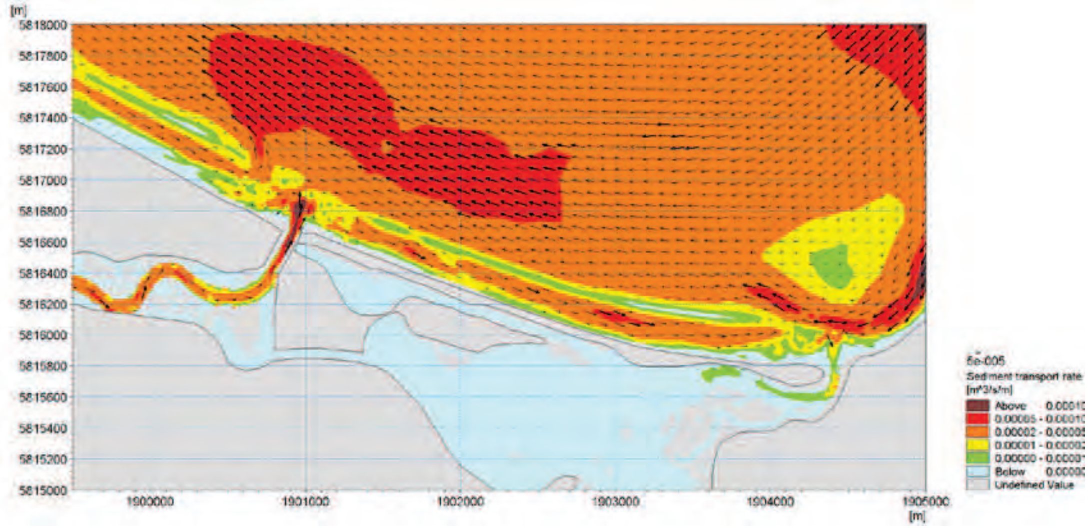


Figure E-9 Sediment transport rates in the vicinity of the river and estuary entrances during peak of high energy wave event at 4:00 pm 16th April 2013.

The model validation for flood levels and response of the Kaituna River mouth were deemed satisfactory while the resulting wave, current and sediment transport fields, although complex, were considered reasonable and realistic. Therefore the model was deemed fit for purpose for predicting flood levels in the lower Kaituna River and Ongatoro / Maketū Estuary and to predict morphological changes of the river and estuary mouths for existing situation and proposed re-diversion option.

E.3.2 Model Validation – Sediment Transport Behaviour for Flood Delta

To illustrate that the morphological model is able to reproduce the sediment transport behaviour over the flood tide delta within the Ongatoro / Maketū Estuary, which is critical for assessing fate of flood delta for proposed diversion option, the period, 28th March to 17th April 2013 was simulated. This period was selected to cover a neap/spring tidal cycle and since there was no significant wave or freshwater events which would influence sediment transport within estuary entrance. The accumulated sediment transports rates are presented in Figure E-10 and consistent with the bed form observations in Section 3.5 with the expected flood tide dominance for sediment transport.

The model validation for flood tide delta sediment transport behaviour was deemed satisfactory and the model fit for purpose for predicting fate of the flood tide delta in Ongatoro / Maketū Estuary for the proposed diversion option.

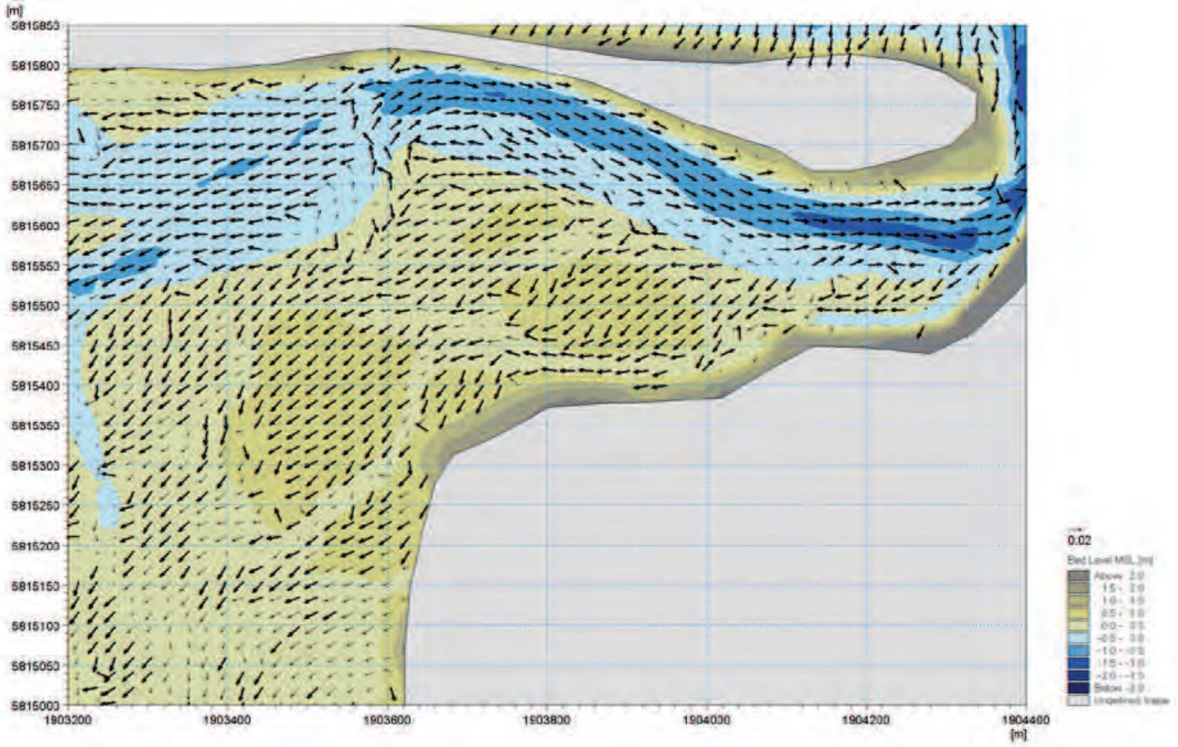


Figure E-10 Accumulated sediment transport rates over period 28th March to 17th April 2013. Note sediment transport rates in m^3/m and vectors limited to 0.02 m^3/m so that all vectors are visible across the flood tide delta.

APPENDIX F

Water Quality Models

F.1 Introduction

A number of water quality models have been developed to assess impact on water quality of estuary of proposed re-diversion option. The following models were developed:

- Blue-green algae model
- Bacteria (Enterococci and faecal coliforms) model; and
- Nutrient (Nitrogen and Phosphorous) model.

A model was also developed to assess the impact of reduced water levels within the river from proposed option on the volume of water able to flow into the Kaituna Wetland.

F.2 Hydrodynamic Model Set Up for Water Quality Models

The local 3D hydrodynamic model which was developed for simulating the propagation of the salt wedge within the Kaituna River and determining the ratio of freshwater to saltwater entering the estuary through the re-diversion (see Appendix D) required a horizontal and vertical resolution which resulted in very long run times. It was not feasible to use this exact model for the water quality assessments apart from assessment of the changes in the overall salinity to the estuary, due to the number of water quality simulations that were required and the fact that a higher resolution was required for the drains in the southern part of the estuary.

Instead a new 3D model was developed for only the river, to predict the ratio of fresh water and salt water that will enter the estuary from the river and the resulting concentration of pollutants (blue-green algae, bacteria or nutrients) from the river after mixing with ocean water. The Ford's Cut culverts were included in this 3D river model.

Similar to the local 3D hydrodynamic model of the river and estuary, the boundary conditions for the 3D model of the river were provided by the local 2D hydrodynamic model. The bathymetry for the 3D river model is shown in Figure F-1.

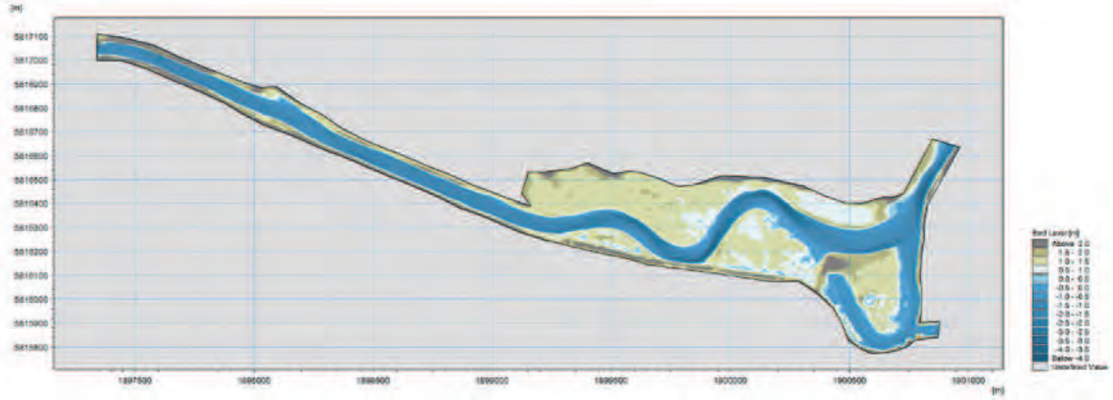


Figure F-1 3D model bathymetry of Kaituna River.

The 3D river model was then used to produce boundary conditions for a 2D model of the estuary and the open ocean. The model domain was equivalent to the local 2D hydrodynamic model without the river. A 2D model of estuary was deemed suitable since there is no evidence of significant stratification within the estuary. The boundary conditions produced by the 3D river model were the flow, salinity and concentration of pollutants entering the estuary through the

Ford's Cut culverts. The bathymetry of the 2D estuary model is presented in Figure F-2 for the estuary only. The open ocean boundaries for the 2D estuary model are the same as used for the local 2D hydrodynamic model in Appendix D.

The model resolution was increased for the southern drains of the estuary as shown in Figure F-3. The drains outlined in Section 3.3 have been included in the water quality models. The same process was followed for setting up water quality models of the proposed option.

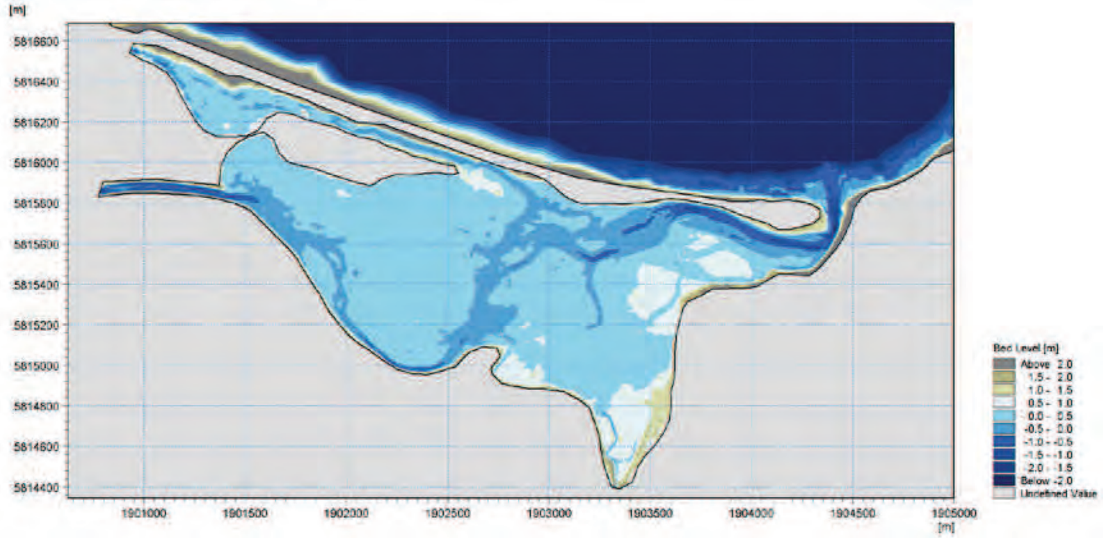


Figure F-2 2D model bathymetry of Ongatoro / Maketū Estuary. Note zoomed into estuary area only.

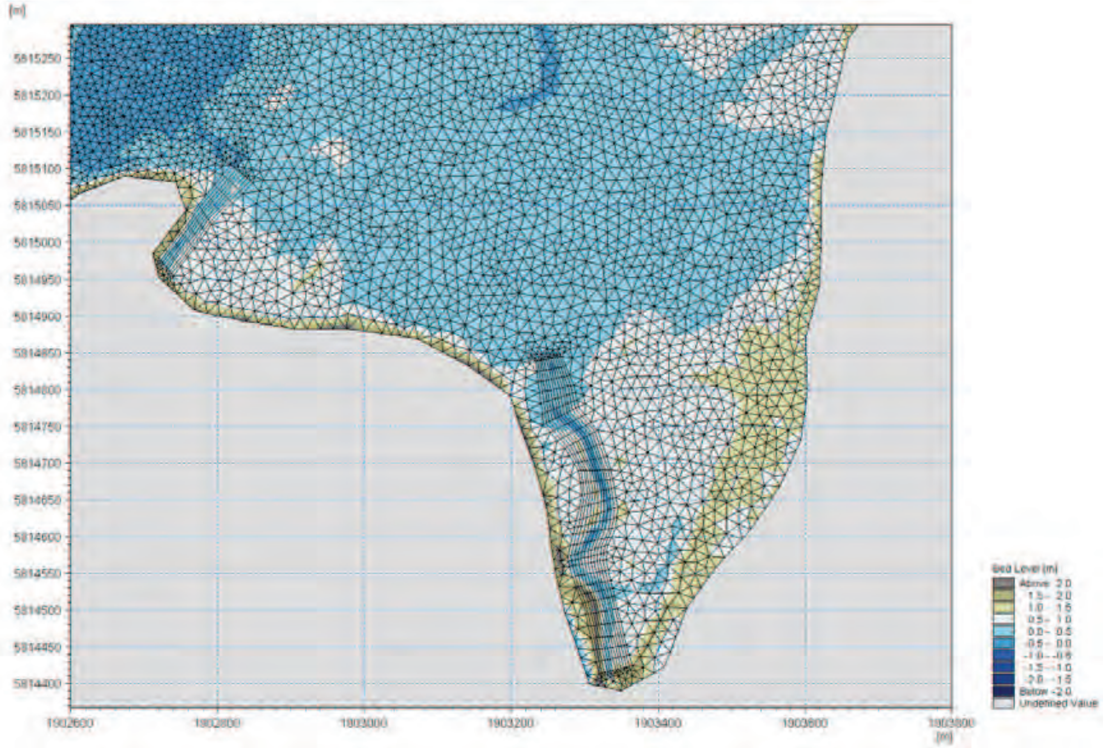


Figure F-3 2D model bathymetry and mesh for southern drains of Ongatoro / Maketū Estuary.

F.3 Blue-Green Algae Model Set Up

For the planktonic blue-green algae model, the algae was represented with a simple conservative tracer using the advection dispersion module, i.e. no decay or growth. Previous work (DHI, 2011) concluded that given the retention times of the estuary, no significant growth will occur. Decay of the blue-green algae may occur when exposed to saline water, however the blue-green algae can still cause toxic impacts as these may release the toxins when decaying, therefore it was determined that a conservative approach was to assume no decay.

F.4 Bacteria Model Set Up

Similar to the blue-green algae model, bacteria (Enterococci and faecal coliforms) was represented with a tracer, however decay of the bacteria has been included. The following decay rates have been selected (based on DHI experience with similar projects worldwide):

- Enterococci: 0.4 day^{-1}
- Faecal coliforms: 0.8 day^{-1}

These decays rates are considered conservative and are consistent with decay that would occur in turbid water or in non-sunlight hours.

F.5 Nitrogen Model Set Up

Four nutrient parameters have been identified by the project team as suitable for representing behaviour of nutrients as a whole within Kaituna River and Ongatoro / Maketū Estuary. These nutrients have been modelled as a conservative tracer with no decay and are as follows:

- Total Nitrogen (TN);
- Total Phosphorous (TP);
- Dissolved Inorganic Nitrogen (DIN); and
- Dissolved Reactive Phosphorous (DRP).

F.6 Validation of Blue-Green Algae and Bacteria Models

The blue-green algae and bacteria models have been validated using the data collected on 4th April 2013 when extensive data collection was carried out within the estuary. The aim of the validation was to illustrate that the balance between contribution of pollutants from the drains and river to the estuary was realistic and that there was no other process occurring not accounted for in blue-green algae and bacteria models.

A blue-green algae and bacteria model simulation was carried out for 4th April 2013 with a three day warm up period. The base flows outlined in Section 3.3 were used for drains to the river and estuary. The boundary condition concentrations that were selected for the validation simulation were defined using appropriate site specific data collected on 4th April 2013 and are presented in Table F-1.

Table F-1 Concentrations used for blue-green algae and bacteria validation simulation.

Location	Chl.*a* (mg/m^3)	Faecal coliforms (counts / 100ml)	Enterococci (counts / 100ml)
River	2.2	580	110
Drains	4.4	1,500	1,500
Open Ocean	0	0	0

The predicted Chl.*a*, faecal coliforms and Enterococci was then compared with observations at different locations as presented in Figure F-4 within the estuary on 4th April 2013.

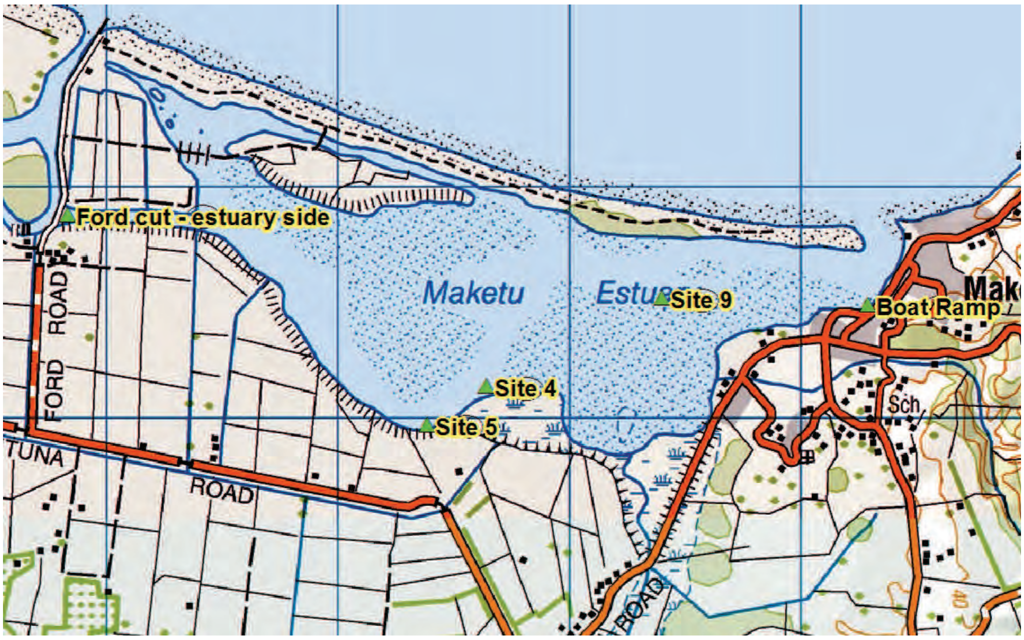


Figure F-4 Locations selected for comparison of observed and predicted Chl.*a*, faecal coliforms and Enterococci.

The simulated concentrations are plotted against the measured concentrations for chl.*a* (see Figure F-5), faecal coliforms (see Figure F-6) and Enterococci (see Figure F-7). Simulated concentrations of Bacteria (faecal coliforms and Enterococci) at the Boat Ramp and at Ford's cut are good representations of the measured concentrations. Site 9 (mid estuary) also shows a good relationship to measured concentrations.

The simulated concentrations at Sites 4, 5, and 9 are a good representation of measured values throughout most of the tidal cycle. However, they fail to reach the high values in concentration measured for bacteria at low – mid tide. Unfortunately the small sample size restricts interpretation of this result; however, it may due to sampling location. It appears that samples were taken over the mudflats and at the low tide low water levels would lead to a very low dilution factor. Sites 4 and 5 are also close to the shore and may be better representations of the drain concentrations than within estuary concentrations of bacteria.

A more complex model set-up, for example, setting drain discharge to the timing of the gates, including variation between drains, was not considered suitable in this case. This would have added unnecessary complexity to the model that may not have represented actual drain behaviour. In early test simulations the above additions did not have a significant impact on simulation results.

The blue-green algae and bacteria model validation suggests that the model is sufficient for predicting blue-green algae and bacteria concentrations within the estuary keeping in mind the large uncertainty associated with collecting this type of data.

The concentrations of chl.*a* in the drains were not available from collected data, and were therefore derived from the relationship between Enterococci and chl.*a* concentrations (see Figure F-8).

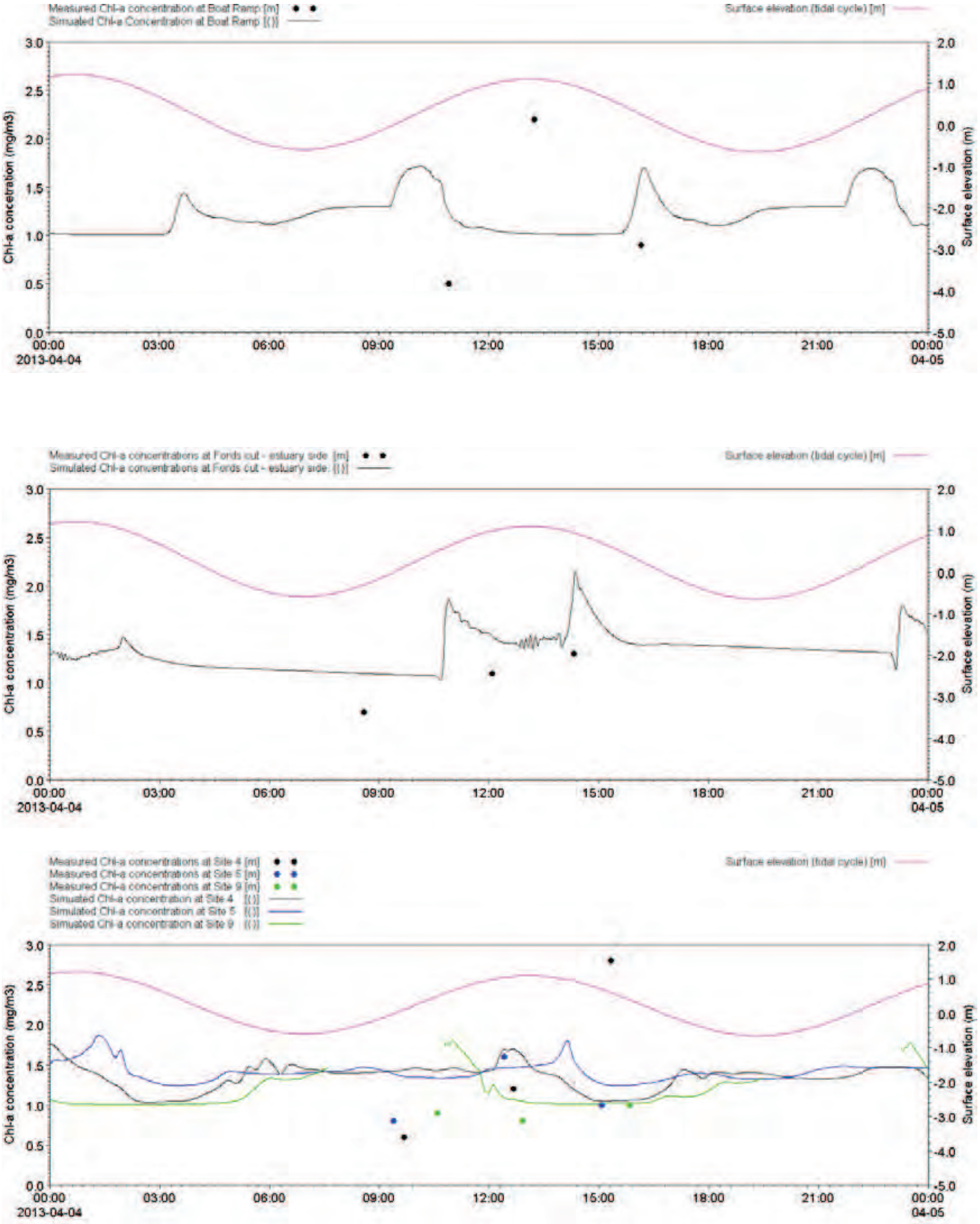


Figure F-5 Comparisons the observed and predicted concentrations of chl.*a* at the estuary mouth (Boat Ramp) (top), Ford's Cut – estuary side (middle), and three sites within the estuary (Sites, 4, 5, and 9) (bottom). The purple line represents the tidal cycle.

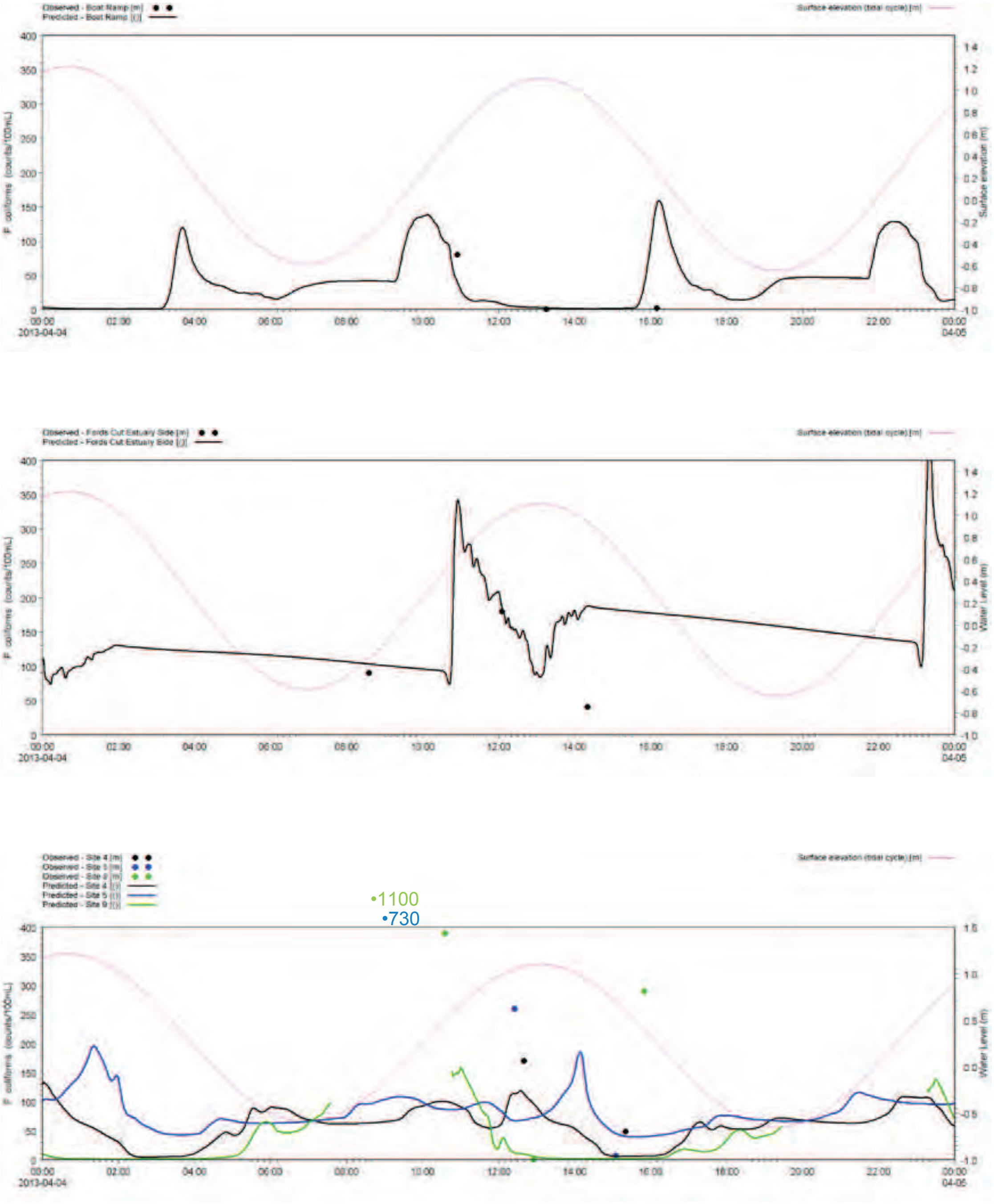


Figure F-6 Comparisons between the observed and predicted concentrations of faecal coliforms (cell counts / 100 ml) at the estuary mouth (Boat Ramp) (top), Ford's Cut – estuary side (middle), and three sites within the estuary (Sites, 4, 5, and 9) (bottom). The purple line represents the tidal cycle.

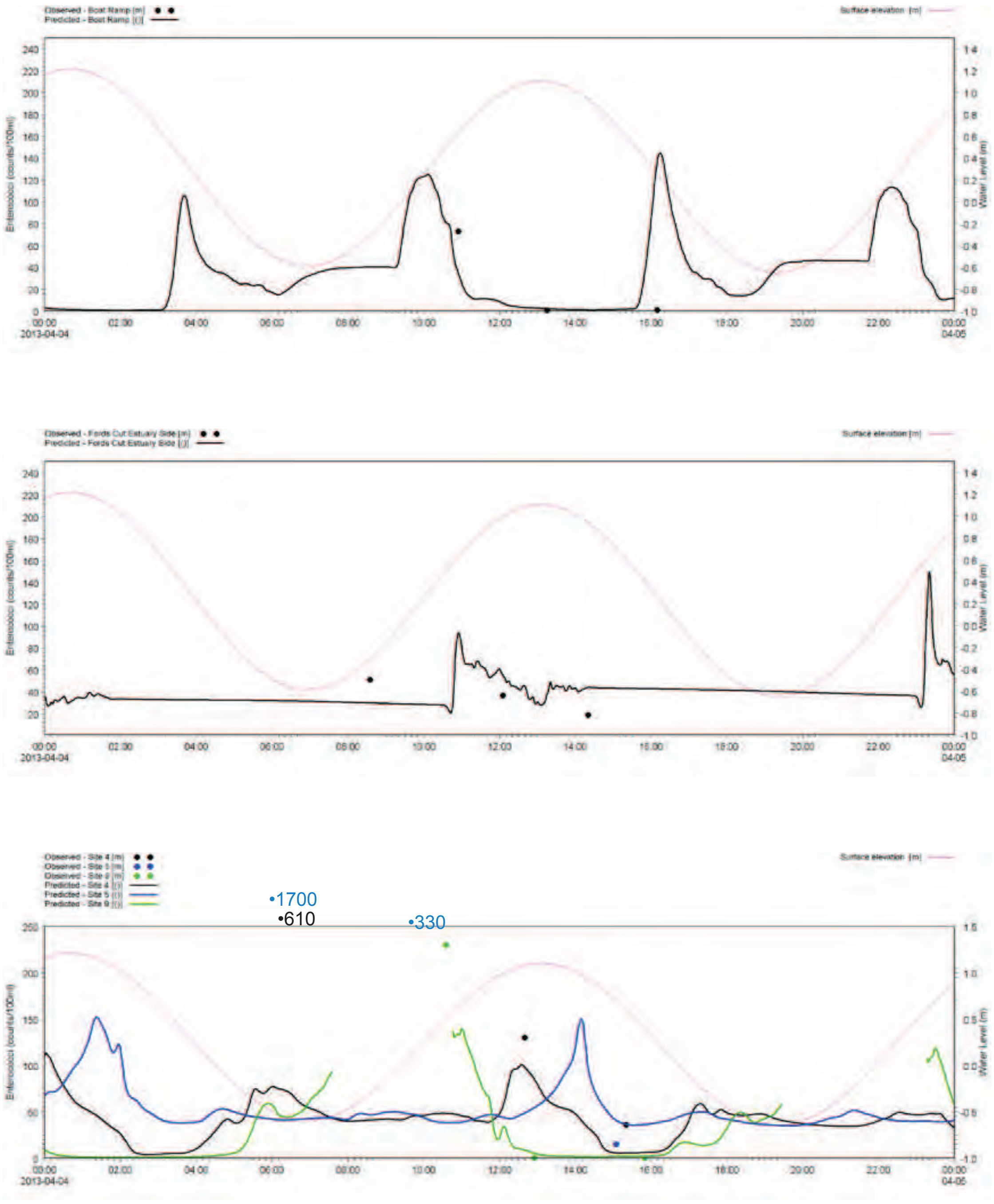


Figure F-7 Comparisons between the simulated and measured concentrations of Enterococci at the estuary mouth (Boat Ramp) (top), Ford's Cut – estuary side (middle), and three sites within the estuary (Sites, 4, 5, and 9) (bottom). The purple line represents the tidal cycle.

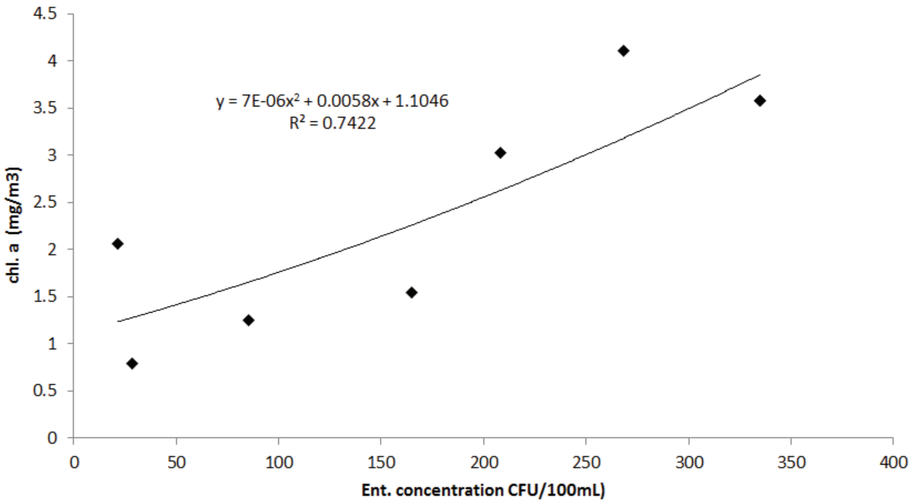


Figure F–8 Relationship between Enterococci concentrations and chl.*a* concentrations in the Ongatoro / Maketū Estuary.

F.7 Kaituna Wetland Model

To assess the impact of reduced water levels within the river from proposed option on the volume of water able to flow into the Kaituna Wetland a new 2D model was developed for only the section of river in the vicinity of the wetland. The bathymetry for the Kaituna Wetland model is shown in Figure F-9.

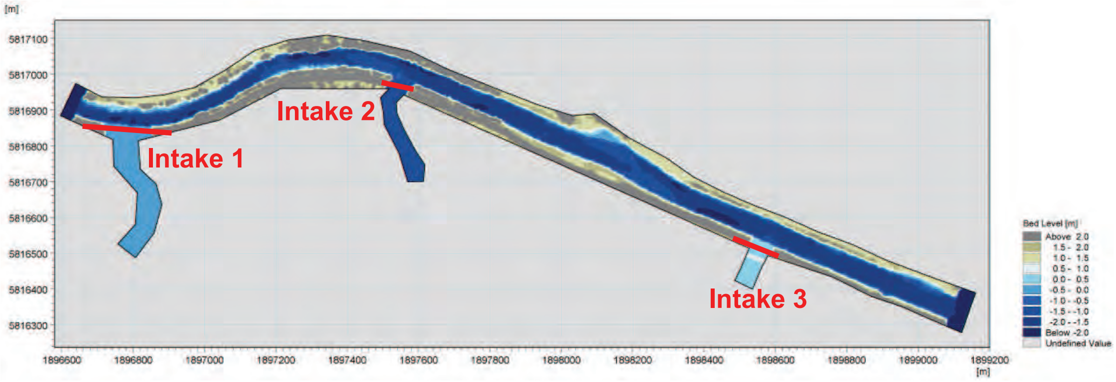


Figure F–9 Kaituna Wetland model bathymetry with intake locations/

The boundary conditions for the Kaituna Wetland model were provided by the local 2D hydrodynamic model. A constant water level of 0.75 m was assumed for the wetland boundary conditions. The intakes consist of the following structures which have been represented within the model:

- Intake 1 – Two 0.6 m diameter circular flap gated culverts with 0 m (Moturiki Datum) invert and length of 40 m.
- Intake 2 – 1.8 m diameter circular flap gated culvert with -1 m (Moturiki Datum) invert and length of 10 m.

- Intake 3 – 0.45 m diameter circular culvert with 0.5 m (Moturiki Datum) invert and length of 25 m with a 0.87 m (Moturiki Datum) crest level weir structure on the wetland side.

This modelling approach is a very conservative method for assessing the impact of change in water levels on the volume of water into the wetland between the existing situation and the proposed option, since it does not account for the constriction to flow from the river to the wetland that may occur due to the narrow channels within the wetland

APPENDIX G

Additional Plots Requested by Project Team

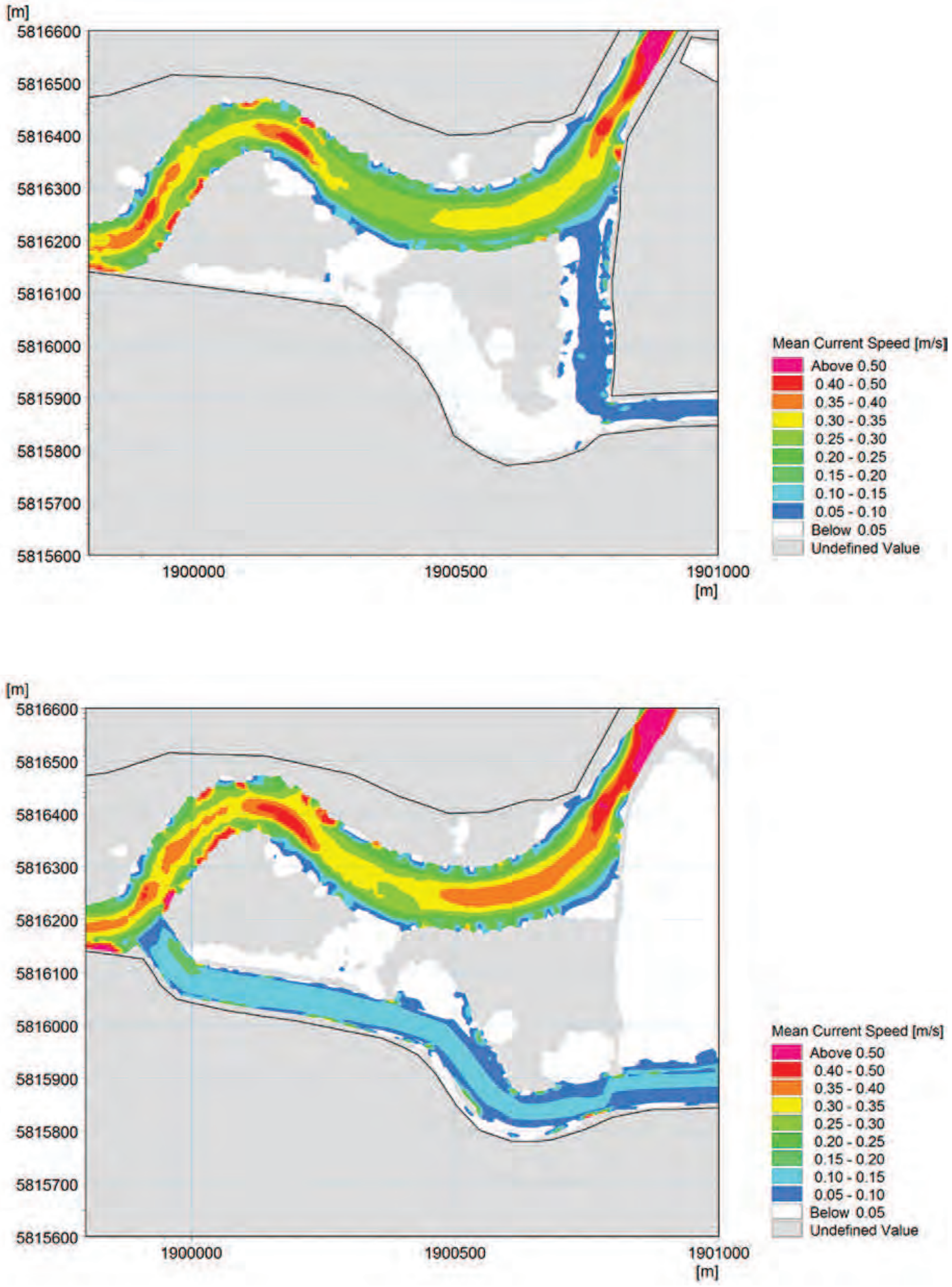


Figure G–1 Mean current speed for Ford’s Loop / new re-diversion channel for mean river flow and mean tide for existing situation (top) and proposed option (bottom).

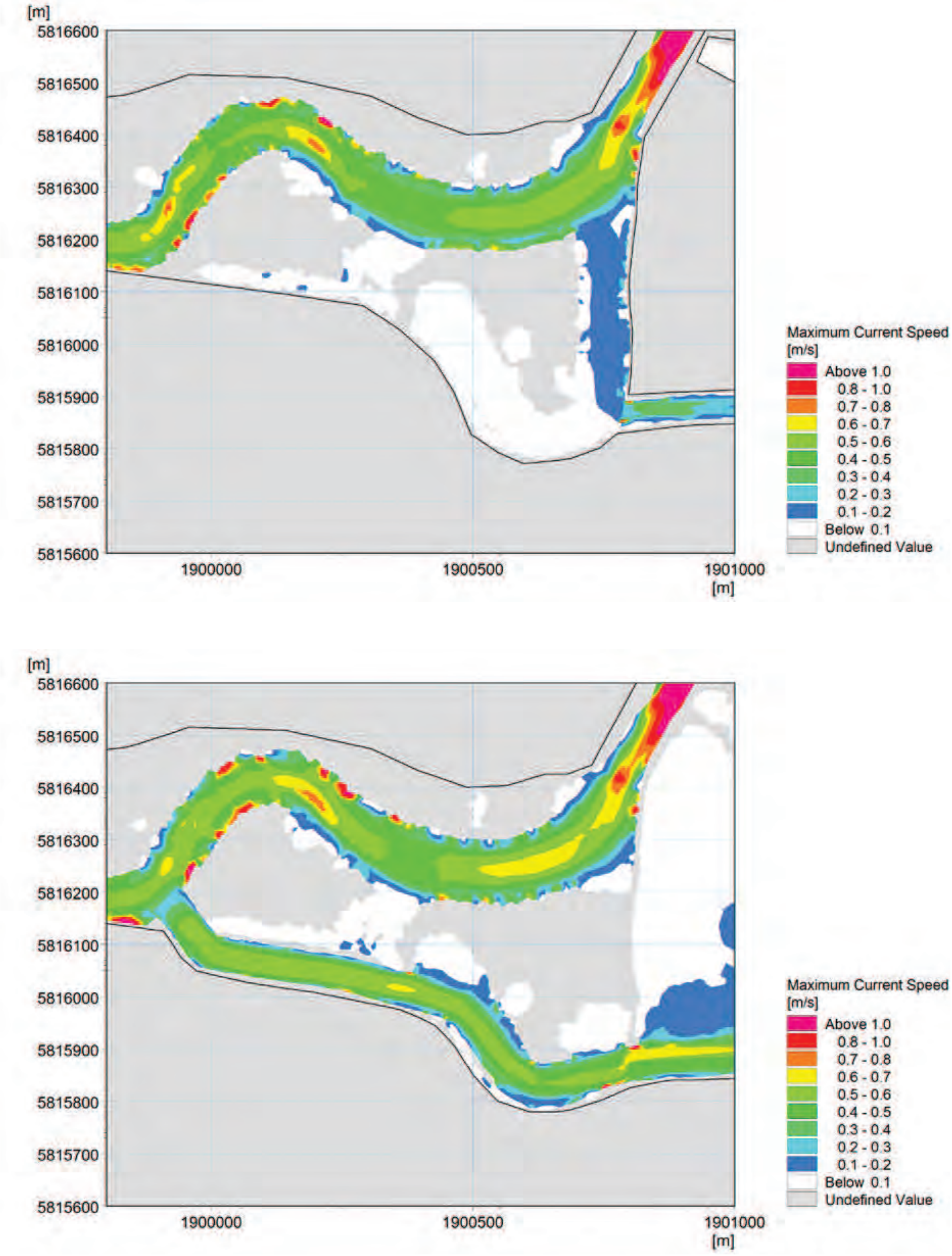


Figure G–2 Maximum current speed for Ford’s Loop / new re-diversion channel for mean river flow and mean tide for existing situation (top) and proposed option (bottom).

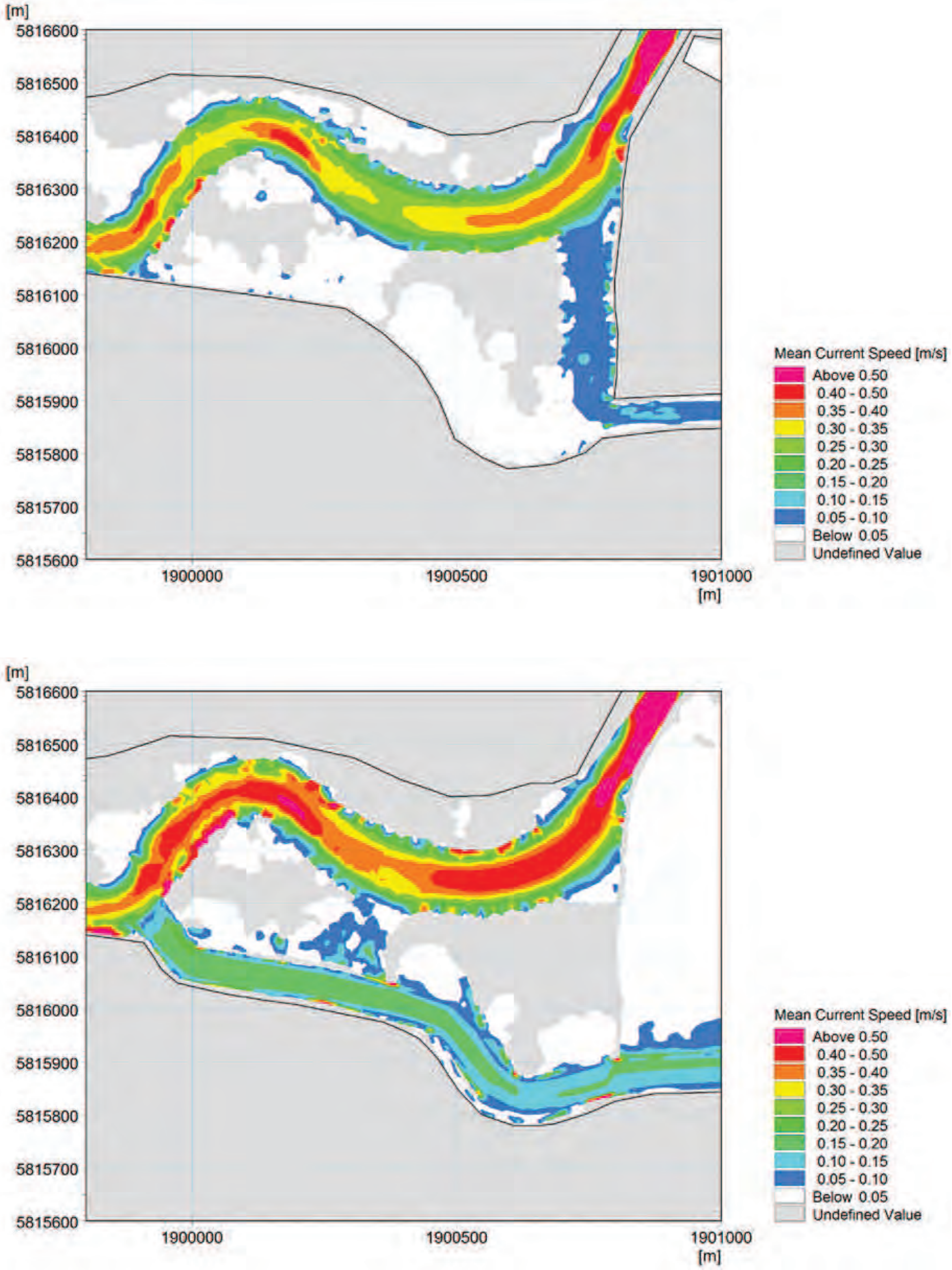


Figure G–3 Mean current for Ford's Loop / new re-diversion channel for mean river flow and spring tide for existing situation (top) and proposed option (bottom).

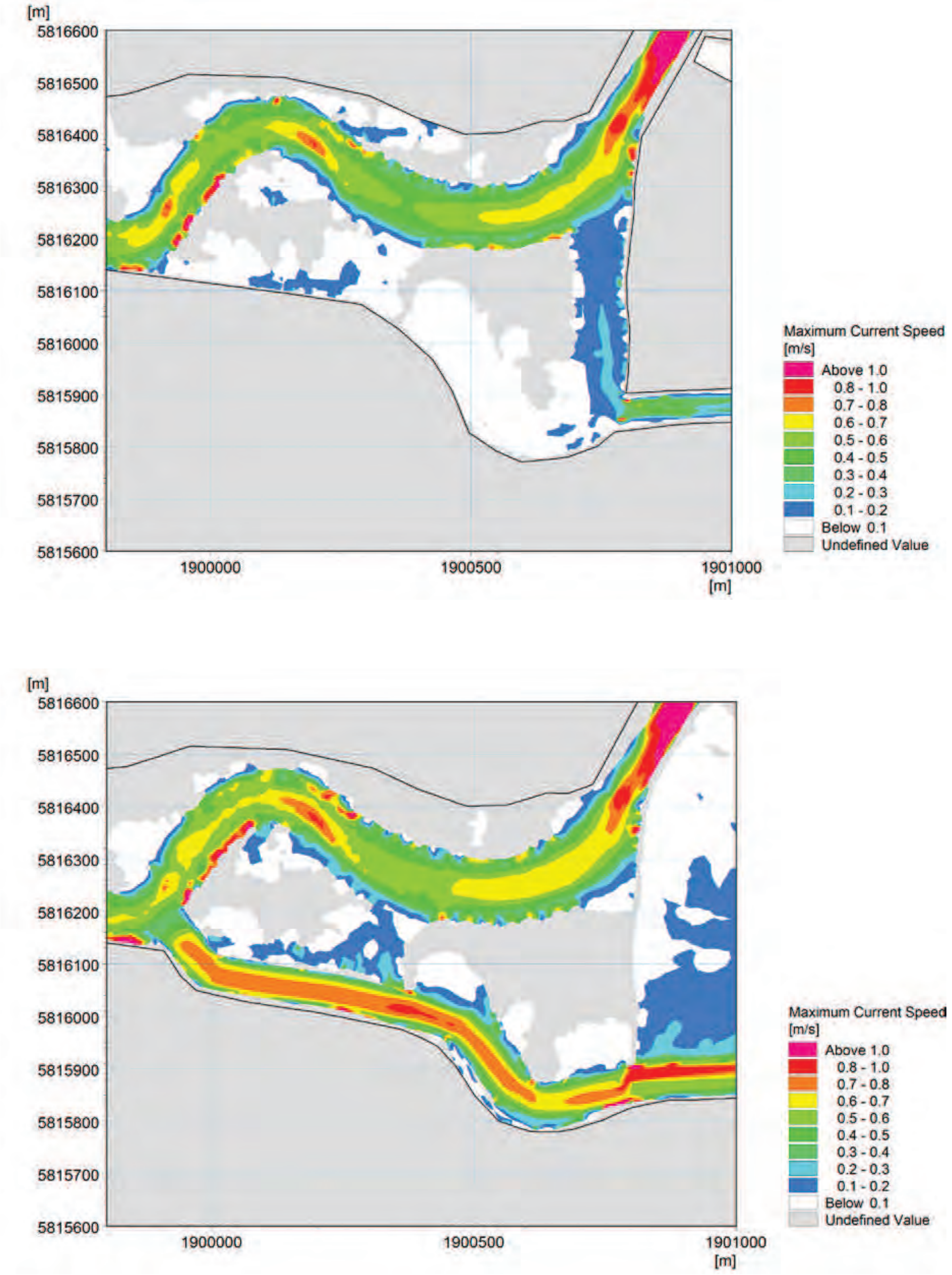


Figure G–4 Maximum current for Ford's Loop / new re-diversion channel for mean river flow and spring tide for existing situation (top) and proposed option (bottom).

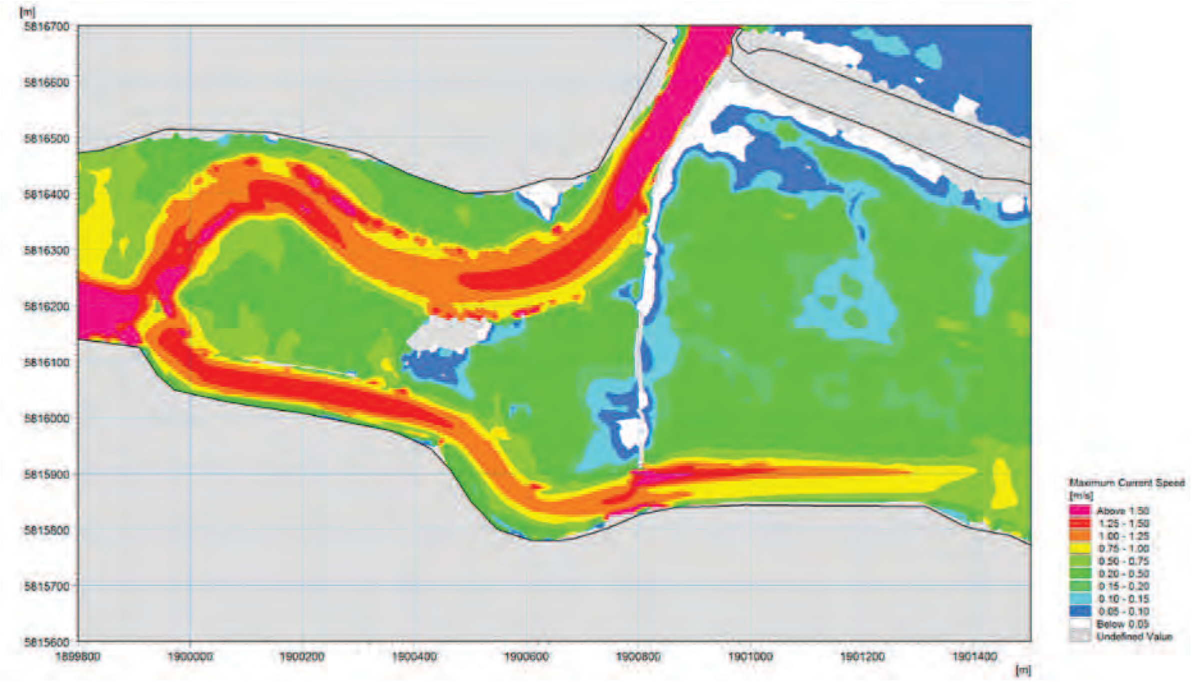


Figure G–5 Maximum current for new re-diversion channel of proposed option for 1% AEP flood event coinciding with spring tide.

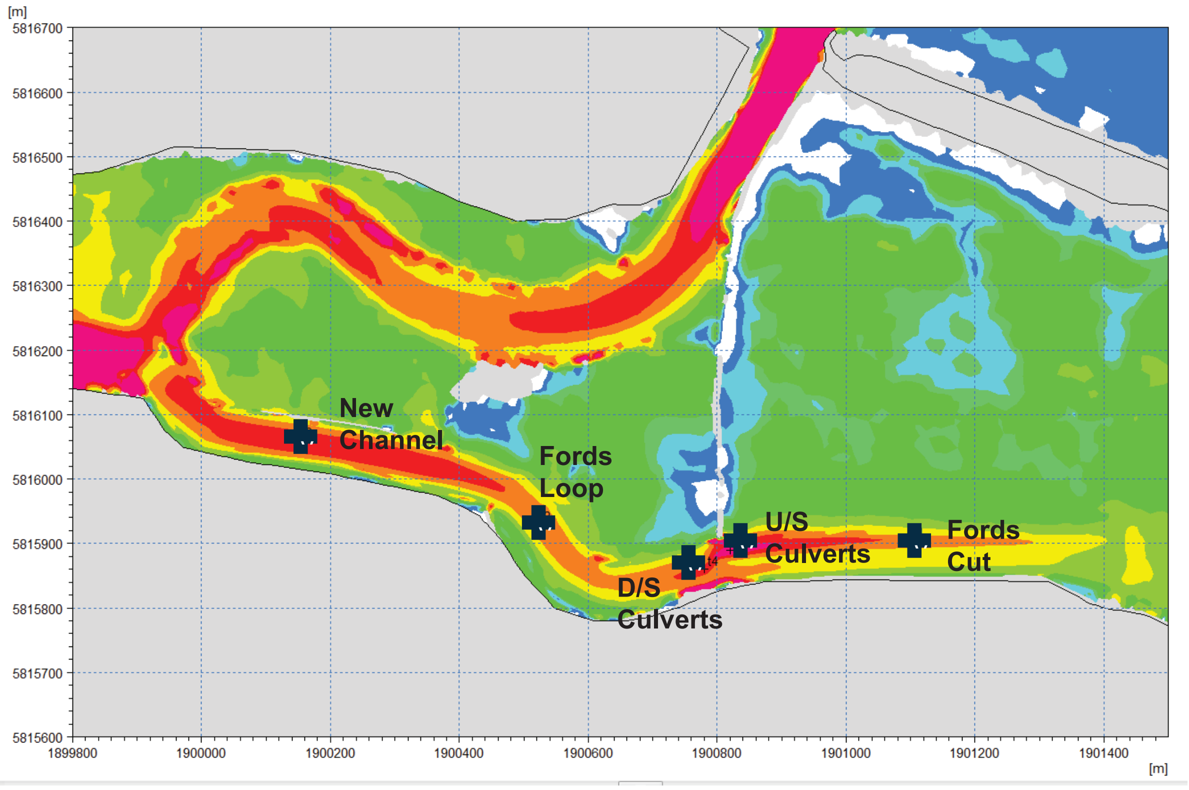


Figure G–6 Locations where current speed and surface elevation extracted for proposed option for 1% AEP flood event coinciding with spring tide.

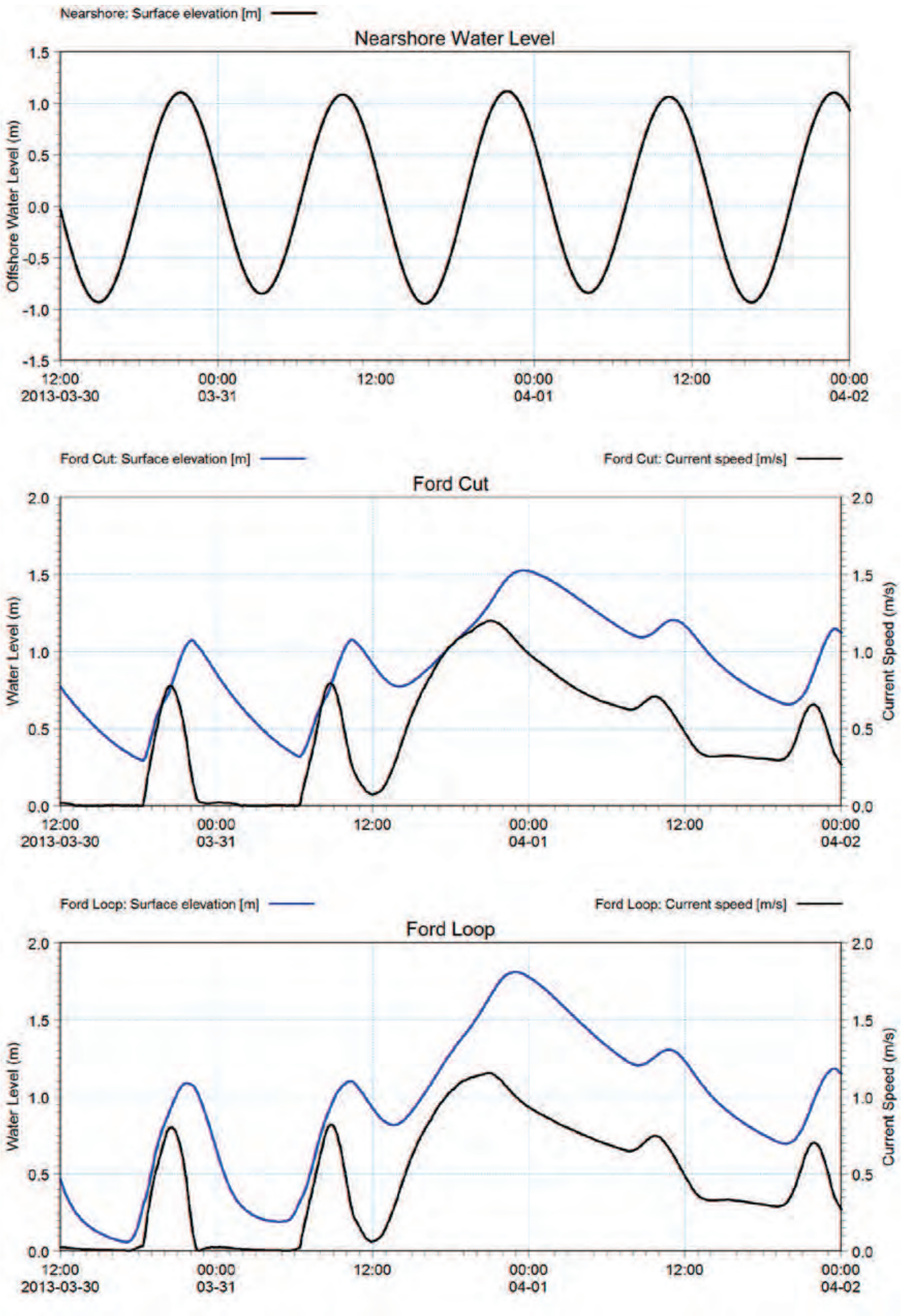


Figure G–7 Extracted current speed and surface elevation at selected locations for proposed option for 1% AEP flood event coinciding with spring tide.

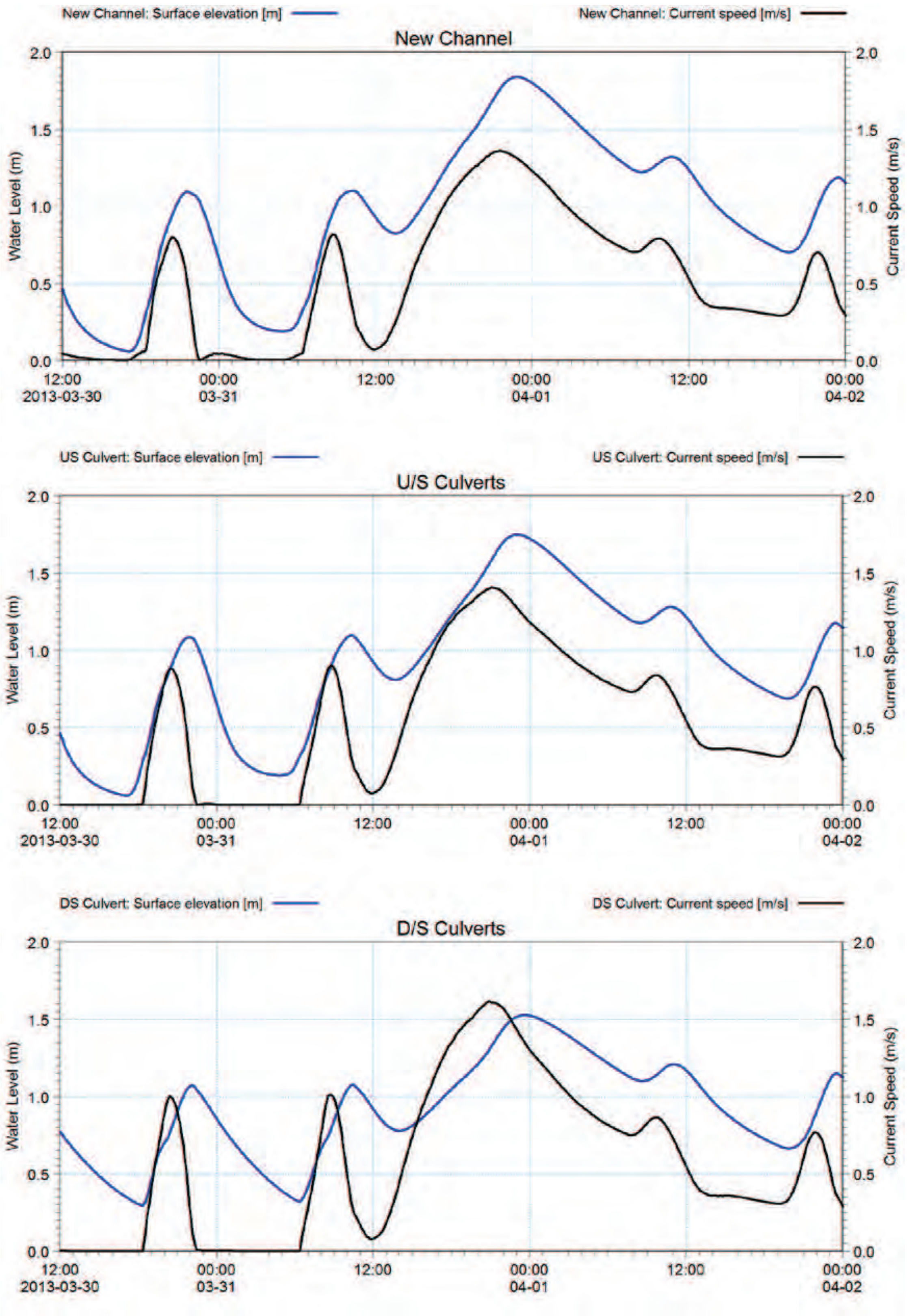


Figure G–8 Extracted current speed and surface elevation at selected locations for proposed option for 1% AEP flood event coinciding with spring tide.

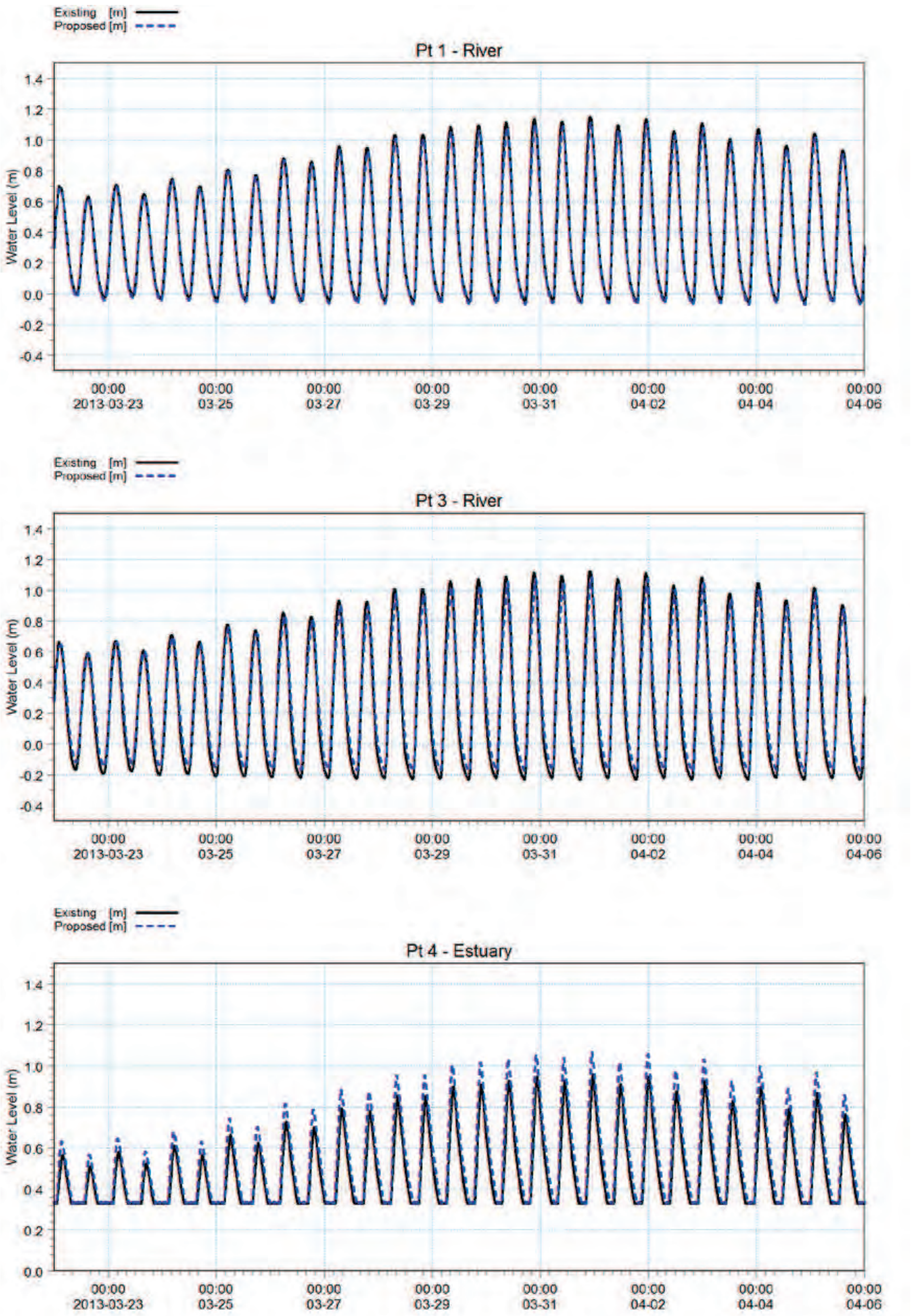


Figure G–9 Comparison of predicted water levels at selected locations for existing and proposed situations for mean river over neap/spring tidal cycle. See Section 8 for locations.

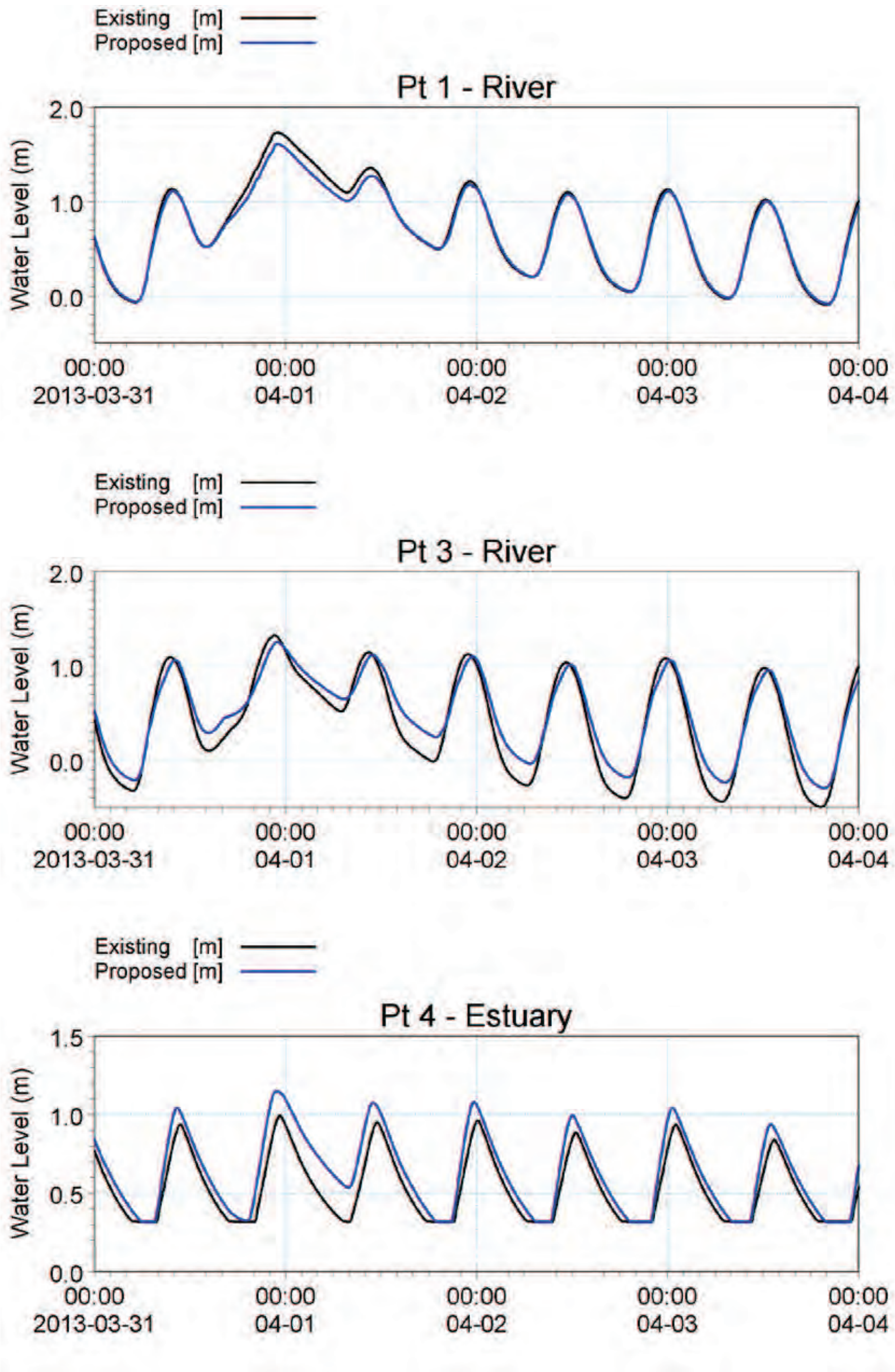


Figure G–10 Comparison of predicted water levels at selected locations for existing and proposed situations for 20% AEP flood event coinciding with spring high tide. See Section 8 for locations.

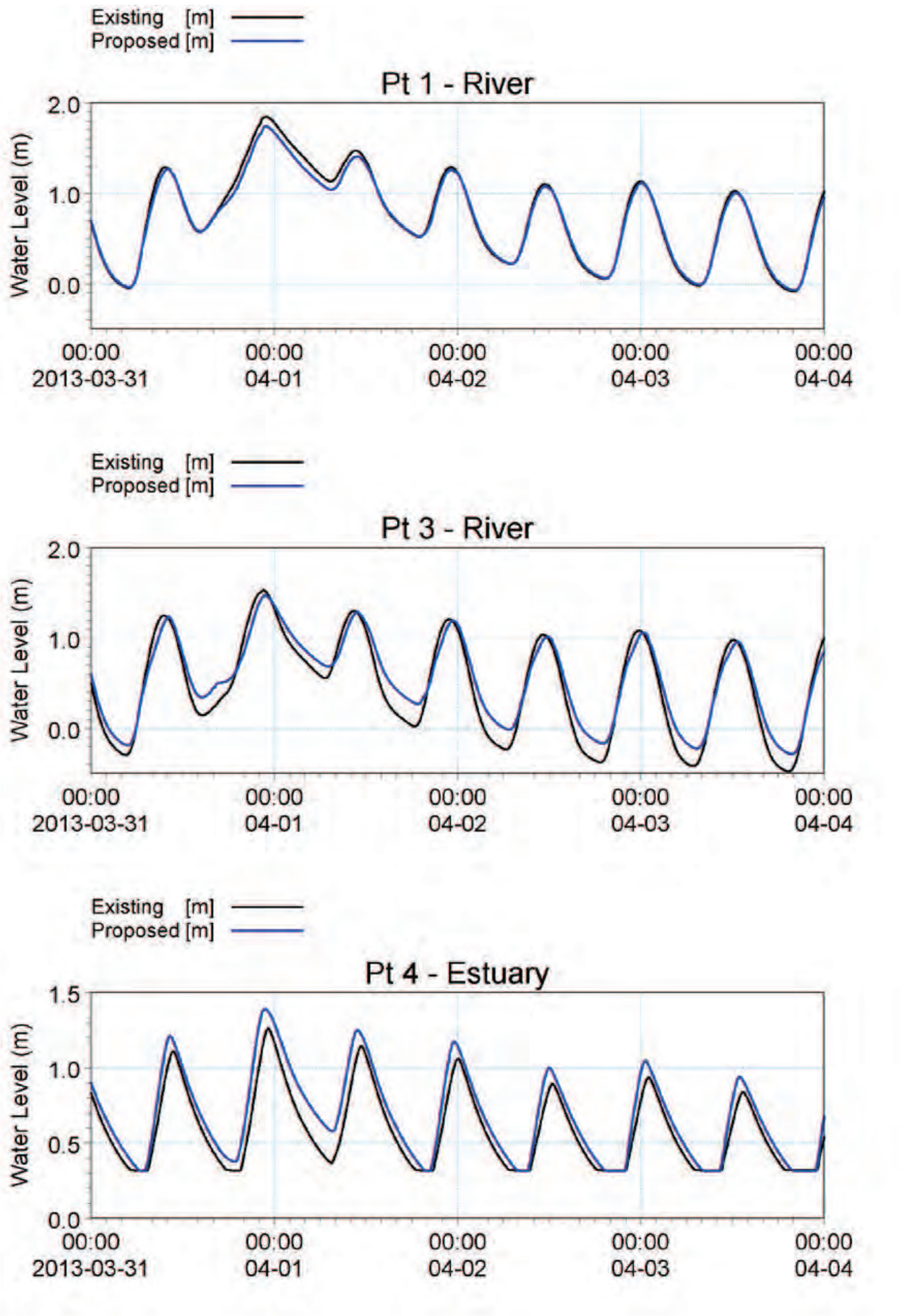


Figure G–11 Comparison of predicted water levels at selected locations for existing and proposed situations for 20% AEP flood event coinciding with 20% AEP sea level. See Section 8 for locations.