PORT OTAGO DREDGE DISPOSAL GROUNDS

Proposed plans for dumping at Heyward Point and Aramoana Beach ground during the third quarter of 2016

Prepared for Port Otago Limited

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1. INTRODUCTION

The present report builds upon the suite of previous reports (P0140-05a,b,c,d,e,f, g) that have been prepared to provide guidance on the disposal of sediment by Port Otago.

The functional effects of the morphological features of the Heyward Point disposal ground on the local wave dynamics were investigated in report P0140-05a, using the nearshore wave models SWAN and CGWAVE, with a particular focus on how they influence the surfing conditions at Whareakeake point. The study provided valuable baseline information on the existing wave processes, which was used to elaborate subsequent disposal plans that would ensure conservation of processes beneficial for surfing (i.e. wave focusing). The report P0140-05a provided a disposal plan for 2014 Q1-Q2 and was followed by reports P0140-05b,c specifying disposal plans for 2014 Q3-Q4, and 2015 Q1-Q2.

Following a bathymetric survey of the ground areas in mid May 2015, the report P0140-05d provided disposal plans for up to 100,000 m^3 of sediment, split equally between the Heyward Point and Aramoana grounds for 2015 Q3-Q4. The sediment to be disposed at Heyward Point over the period was expected to include a significant proportion of silt material (~35,000 m^3) and it was suggested to undertake a new survey shortly after the start of the disposal to assess the morphological response of the ground under such loading conditions. A new comprehensive survey of the ground areas was undertaken in September 2015. An interim analysis then considered the disposal of an additional 30,000 m^3 over the 2015 Q3-Q4 period.

The disposal program for 2016 included a relatively important fraction of silt and an adaptive approach was recommended for the first half the year. A survey was undertaken in November 2015 and was used to define disposal plans segregating the sand and silt fractions for 2016 Q1. An interim survey in March 2016 was used to provide guidance on the disposal plans for 2016 Q2.

The present report presents analysis of the recent bathymetric surveys undertaken through the first half of 2016 in June. The effects of disposal on the seabed morphology and the important wave processes are assessed based on the surveyed bathymetries, modelling and field observations; recommendations for upcoming disposal activities are included.

2. METHODS

The reader is directed to report P0140-05a for a full outline of methods employed to assess the variations in wave focusing related to the disposal activities at the Heyward Point disposal ground. This includes wave simulations using both phase-averaged (SWAN) and phase-resolving (CGWAVE) wave models for a range of wave events.

3. RESULTS

3.1. Sediment disposal and morphological changes from March 2016 to June 2016

3.1.1. Heyward Point disposal ground

The sediment volumes disposed throughout the Heyward Point disposal ground between the March and June 2016 surveys are illustrated in Figure 3.2 and Figure 3.3. The cumulative volumes totalled 38,895 m^3 over the 3-month period, including 3,495 m^3 of silt, 35,400 m^3 of sand (9 and 91 % of total volume respectively). No rock was disposed over the period. As recommended in the previous report P0140-05g (MetOcean, 2015c), the silt material was disposed exclusively over the shallowest and most active parts of the circular mound (eastern-most cells). The sandy material was disposed around the base of the mound and along the ground edges (rows A and E) (Figure 3.3). The cumulative volumes over the first half of 2016 totals 106,310 m^3, including of 24,345 m^3 of silt, 75,830 m^3 of sand, and 6,135 m^3 of rock material.

The successive bathymetries surveyed in March and June 2016 and associated bathymetric changes are shown in Figure 3.4. Initial comparison of the bathymetry dataset suggested a possible offset of ~10 cm was present in depths surveyed over the Heyward Point ground region in the June 2016 survey. The zone was subsequently partially resurveyed for verification purposes and did indicate such an offset was present in the zone. The June 2016 bathymetry data was corrected accordingly, adding 10 cm to the surveyed depths in the Heyward Point region. It is though noted that this remains a best estimate only, and associated volumetric changes (see Figure 3.5) should be interpreted carefully.

Of particular interest during the monitoring period was the observation of significant wave breaking over the Heyward Point disposal ground (McComb, Mead, Rust pers.comm.). These observations expectedly coincided with an episode of long-period swell on May 23rd 2016, and wave breaking was observed throughout the day over extensive areas, at both high and low tides. Photographic evidence is provided in Figure 3.6. Archived nowcast conditions at the Otago Harbour entrance indicated significant wave height around 2.5 m with peak period of 12 s and incidence at ~90 degT. Such episodes of wave breaking are very problematic with respect to the subsequent surfing conditions at Whareakeake Point. Indeed, the disposal mound normally acts as a focusing point to the incidence wave a field which redirects enhanced wave energy towards the Point. The conservation of this wave focusing feature is a delicate balance whereby the incoming waves are ideally focused as much as possible while still remaining well before the wave breaking stage during which a significant fraction of the incoming wave energy is locally dissipated.

The occurrence of such wave breaking episodes suggests the disposal mound that has a level at ~8.5m MSL is currently too shallow to adequately accommodate the long-period swells that that are typically conducive of high quality surfing waves at Whareakeake Point. Regular site observations throughout the last decade suggest that intense wave breaking episodes in the past are not common (Rust, pers. comm.).

To supplement observations, the implemented wave models were used to investigate the potential for wave breaking and variations in response to the changing ground morphologies over the last few years. An idealized event with a significant wave height of 3.0 m, peak period of 12 seconds and offshore incidence of 70 degT which are typical surfing conditions was used as reference case. The predicted significant wave height fields and associated fractions of wave breaking are shown in Figure 3.7 and Figure 3.8 for historical bathymetries from 2010 to March 2016. The ratio of significant wave height to water depth is important metric with respect to wave breaking and was computed for the different scenarios in Figure 3.9.

As consistently observed in previous reports, there is significant wave focusing developing over the disposal mound at the Heyward Point ground. The predicted fraction of wave breaking for this idealized case is generally very limited for the tested bathymetries. Importantly though, there is relative increase in the proportion of wave breaking over the recent March 2016. Although the predicted proportion of wave breaking is clearly underestimated by the model when compared to observations, the relative increase in breaking in the recent March 2016 bathymetry is consistent with the observed wave breaking increase and could therefore be used as a relative proxy for assessing scenarios.

The maps of ratios of significant wave height to local water depth Hs/h presented in Figure 3.9 clearly illustrate the increased potential for wave breaking over the Heyward Point disposal ground relative to the surrounding areas. The successive maps show a recent increase of the actual ratio value over the Heyward Point, as well as a spreading over relatively larger areas. The predicted ratio over the mound, at mean sea level, is typically of order 0.4. Although this appears relatively small with respect to the typical limiting ratio of ~0.8 often referred to in the literature (e.g. Miche, 1944) it is important to note that such value was estimated for ideal solitary waves and may therefore not apply for realistic sea states, with complex bathymetries as in the present case.

Indeed literature on wave breaking over submerged structures, suggests wave breaking limits at ratio Hs/h within the range 0.3-0.6 (Iwata et al., 1997; Kawasaki and Iwata, 1999). The critical ratios were found decrease (i.e. waves starting to breaking in relatively shallower waters) for increased submerged structure length, and/or larger wave periods. Interestingly the wave breaking was found to typically first occur along the side edges of the submerged structures, eventually spreading towards the onshore centreline. The occurring of wave breaking in water depths much shallower than that expected for ideal solitary waves was actually attributed to the intense wave refraction effects developing around the edges of the structure due to the large depth gradients, making the incoming wave become unstable and triggering breaking. The critical wave breaking ratios were found to be possibly further lowered in the case of more realistic directional wave spectrum, with easier wave breaking for increasing directional spreading (Hur et al., 2003).

All these observations are fully relevant with respect to the wave processes developing over the disposal mound at Heyward Point ground. Notably, it is possible that the fact the overall mound morphology has grown wider and larger, in addition to simply being shallower, has also further enhanced the wave breaking potential on the existing morphology. The evolution of the seabed morphology including seabed slopes is included in Figure 3.10 and clearly shows that the disposal mound morphology now represents a much larger obstruction to the incident wave field relative to the 2010 configuration for example.

The processes responsible of the triggering of wave breaking involve non-linear behaviour that develop at very fine scale and are therefore very difficult to accurately reproduce with numerical modelling tools. This stresses the importance of field observations alongside the modelling effort in the adaptive management approach. Here, the observations of such wave breaking episode are a clear incentive to discontinue the sediment disposal at the Heyward Point ground. Previous monitoring has shown that the disposal ground is an active zone with respect to sediment transport with dispersal rates ranging from 30-150,000 m^3/year. In that sense any damage resulting from an excessively shallow mound is reversible in the sense that the mound morphology will be eroded back to an equilibrium level provided it is allowed sufficient time to adjust. It is expected that a level at 9.5 m MSL, which is consistent with historical levels experienced through 2002 to 2013 is a reasonable threshold for the shallowest level of the circular mound located in the southeast half of the ground.

It is recommended to purse the monitoring effort to ensure the occurrence of wave breaking is discontinued following the return to an equilibrium level. Besides the actual lowering of the shallowest levels of the circular mound, it is possible that the mound morphology may still require additional time to reduce its overall size, notably its north-directed spur, and reach back non-breaking conditions in typical surfing wave conditions.

3.1.2. Aramoana Beach disposal ground

In parallel to the disposal activities at Heyward Point ground over the Q1-Q2 period, the Aramoana ground has received ~49,880 m^3 of sand material. The disposal occurred from late November 2015 to late January 2016 and was purposely focused within an elongated area to the east of the ground polygon to trial a mound shape benefiting surfing conditions at Aramoana Beach, notably along its eastern half (see report P0140-05d; MetOcean, 2015a). The disposal boxes used and associated disposal loads are included in Figure 3.11. The successive bathymetries of the disposal ground in November 2015 (pre-disposal), January, March and June 2016 are shown in Figure 3.12. Associated bathymetric changes are included in Figure 3.13.

The formation of the disposal mound from November 2015 to January 2016 is evident. The mound feature is then progressively eroded from January onwards; estimation of dispersal rate over the period November 2015 to March 2016 yields magnitude of order 75-80,000 m^3/year. This is rate larger than recent historical rates during which no sediment was disposed in the ground (~20,000 m^3/year in average) which illustrates the response of the ground to more active sediment disposal. Note the dispersal rate is expected to be further stimulated given the relatively small disposal zone thereby producing relatively shallower depths.

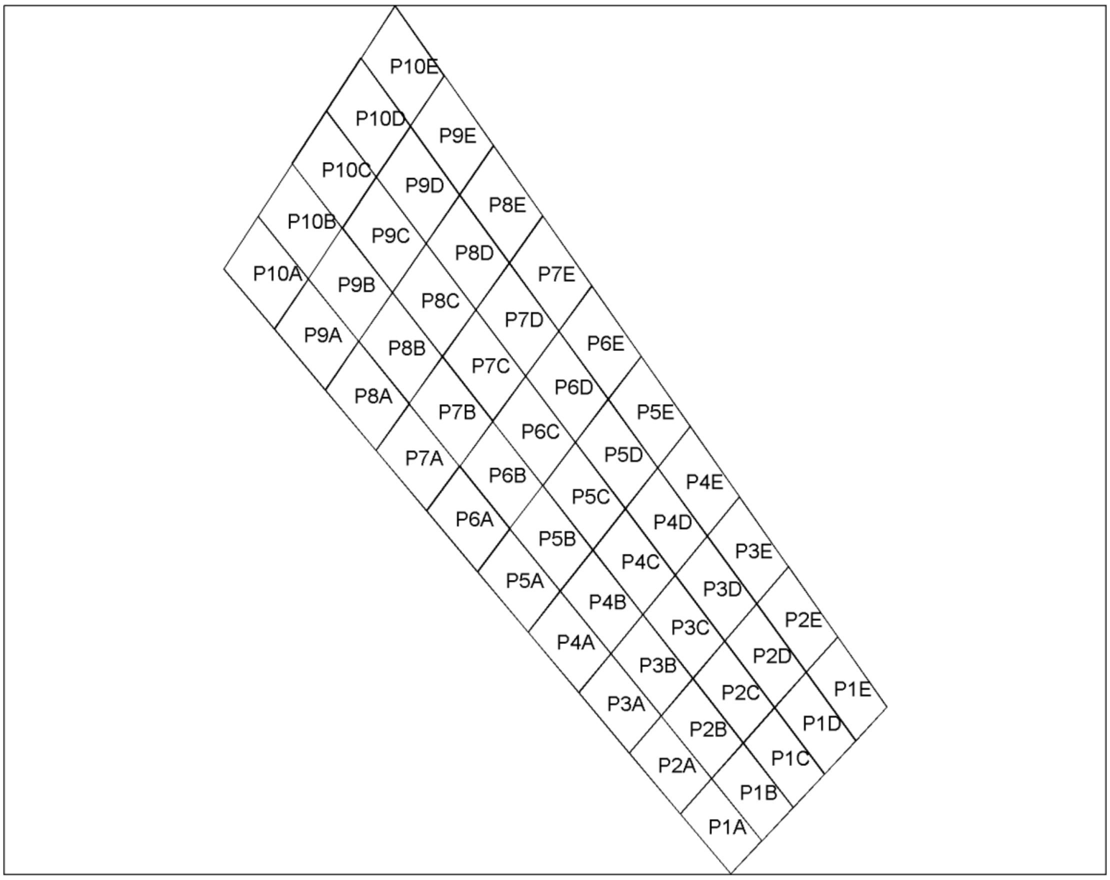

Figure 3.1 Delimitation of the 50 cells considered over the Heyward Point disposal ground.

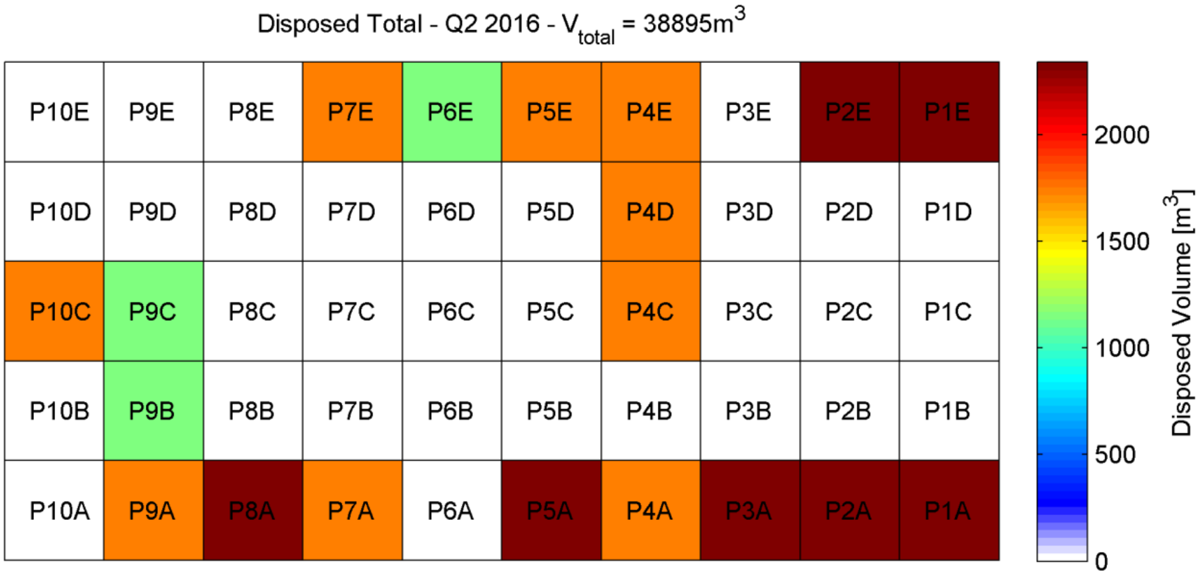

Figure 3.2 Recorded disposal volumes from March 2016 to June 2016. The total disposed volume over the period is + 38,895 m^3.

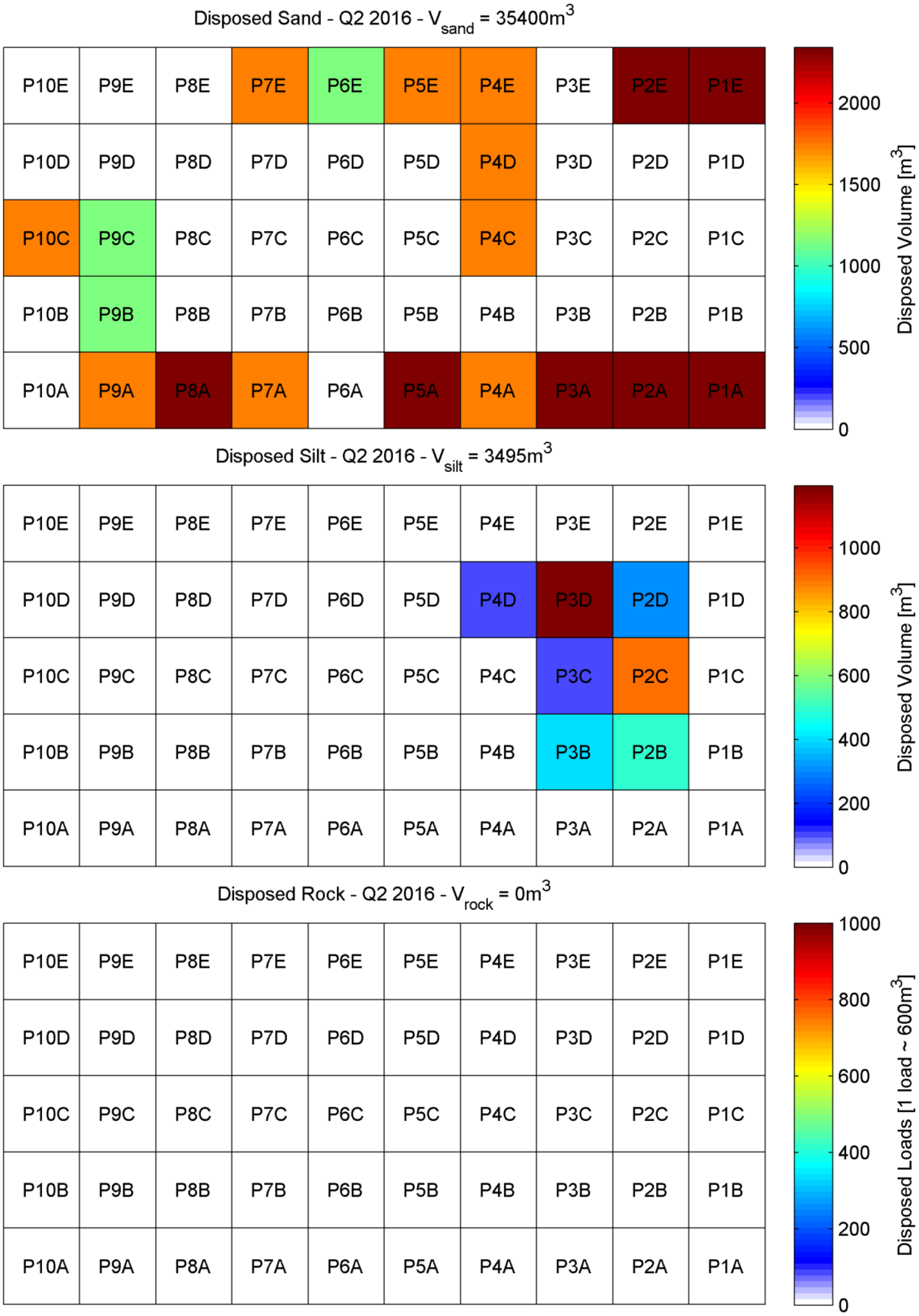

Figure 3.3 Recorded disposal volumes of sand, silt and rock from March 2016 to June 2016 (V-sand= 35,400 m^3; V-silt= 3,495 m^3; V-rock=0 m^3).

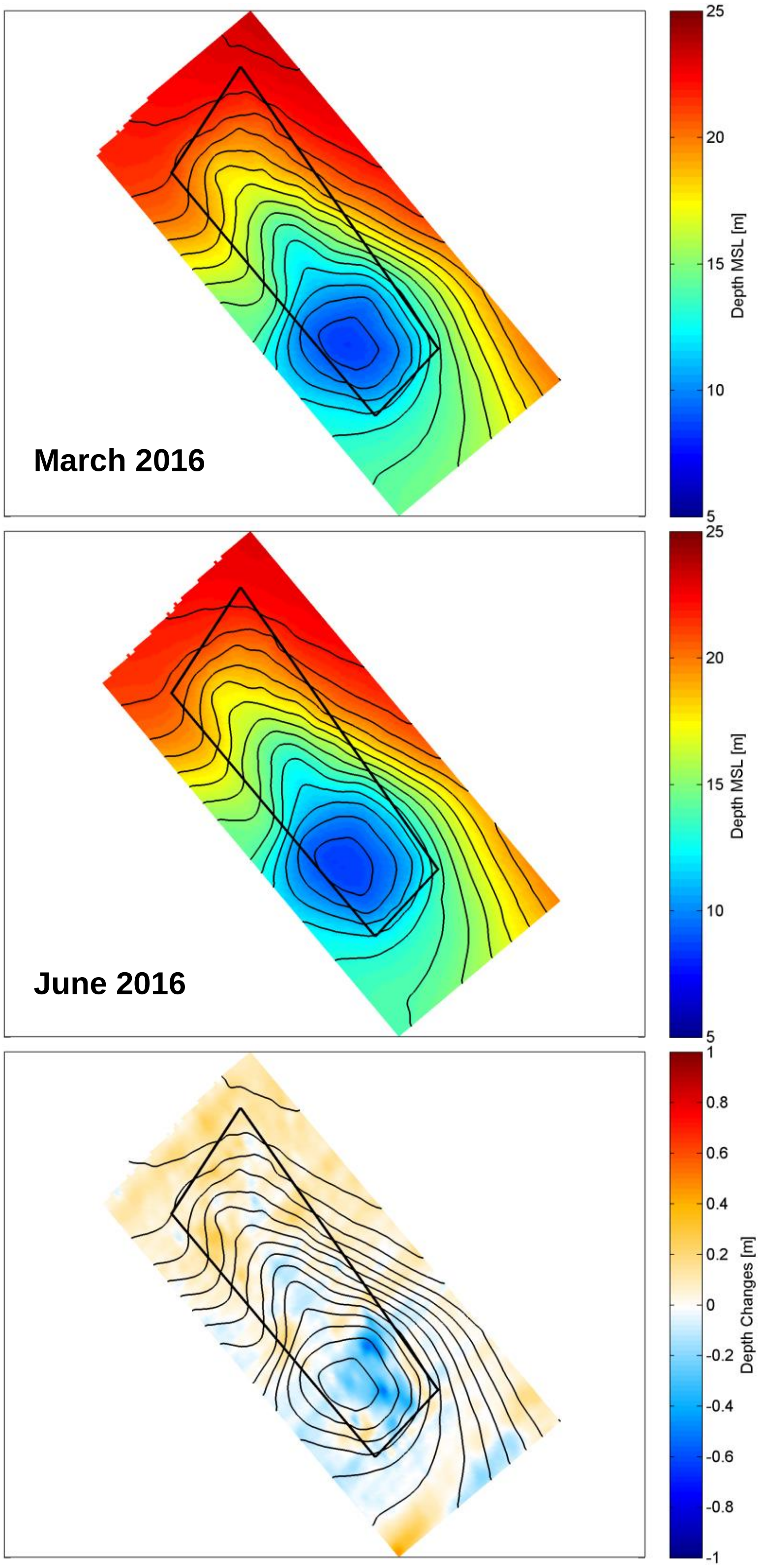

Figure 3.4 Comparison of the March and June 2016 bathymetries. The bottom picture shows the depth difference. A positive difference indicates sediment accretion.

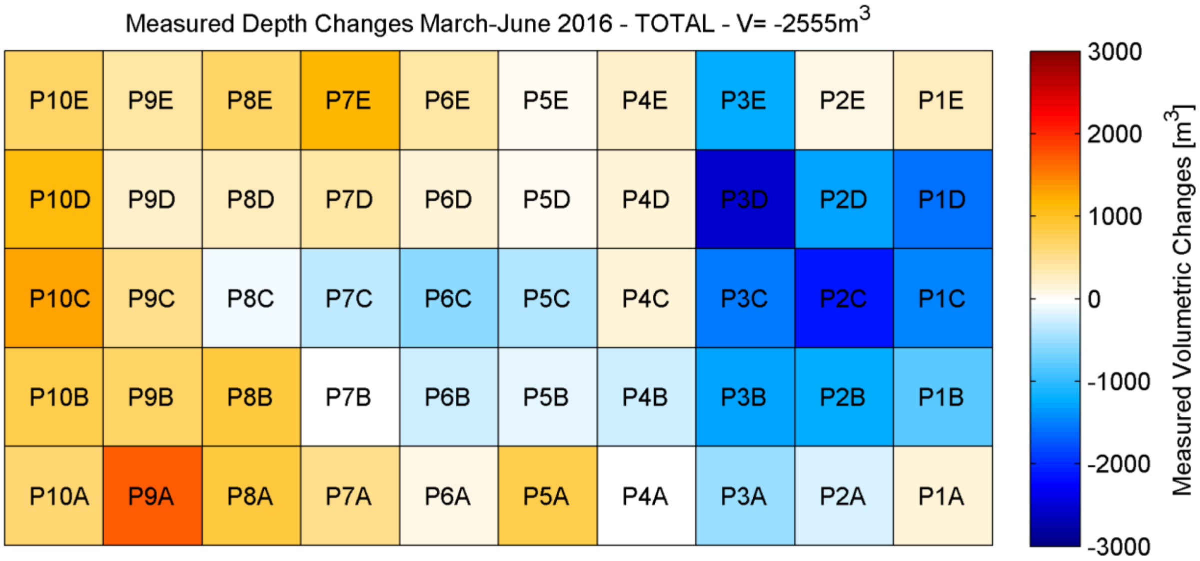

Figure 3.5 Total measured volumetric changes from March to June 2016. The net volumetric balance over the period is -2,555 m^3.

Figure 3.6 Photograph of the 23rd of May 2016 showing evidence of wave breaking (i.e. patch of white water) over the Heyward Point disposal ground. (photo provided by Rod Rust).

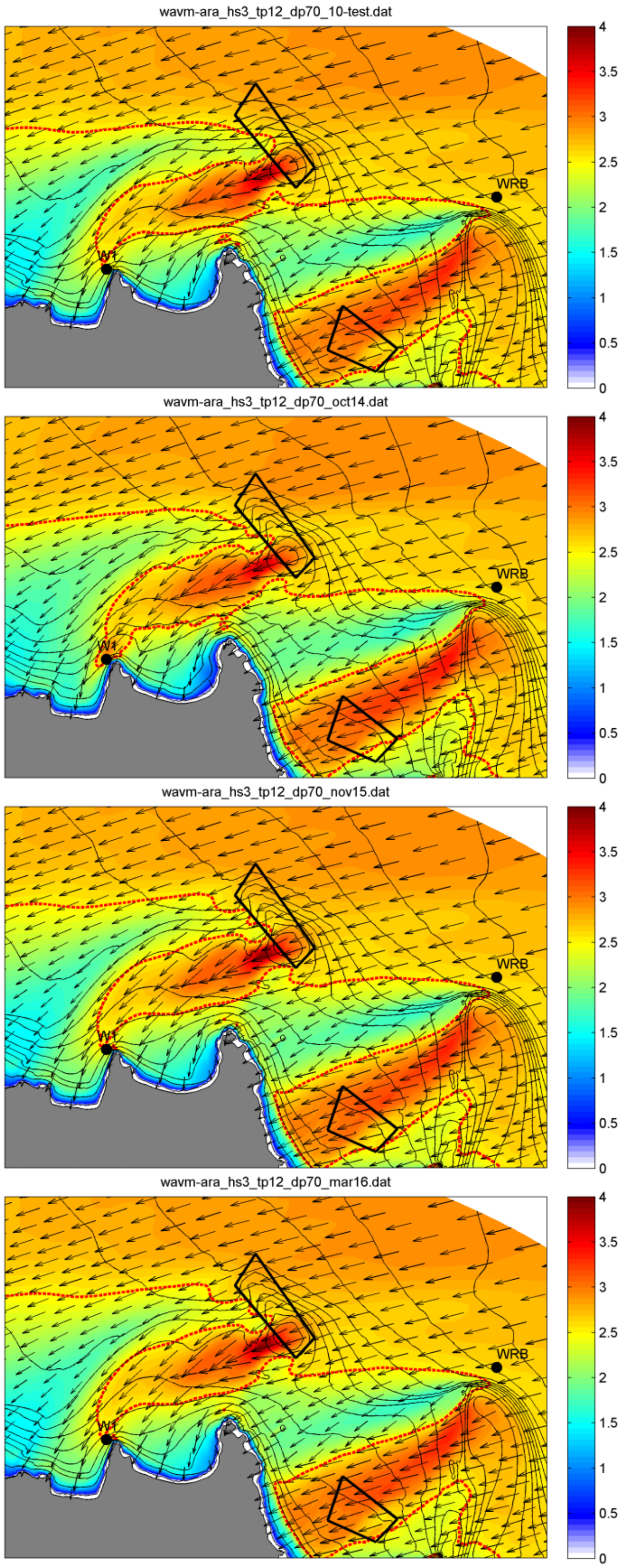

Figure 3.7 Predicted significant wave heights in the vicinity of the Heyward Point disposal ground over the 2010, Oct. 2014, Nov. 2015 and March 2016 bathymetries (Hs=3.0 m, Tp=12s., Dir=70 degT).

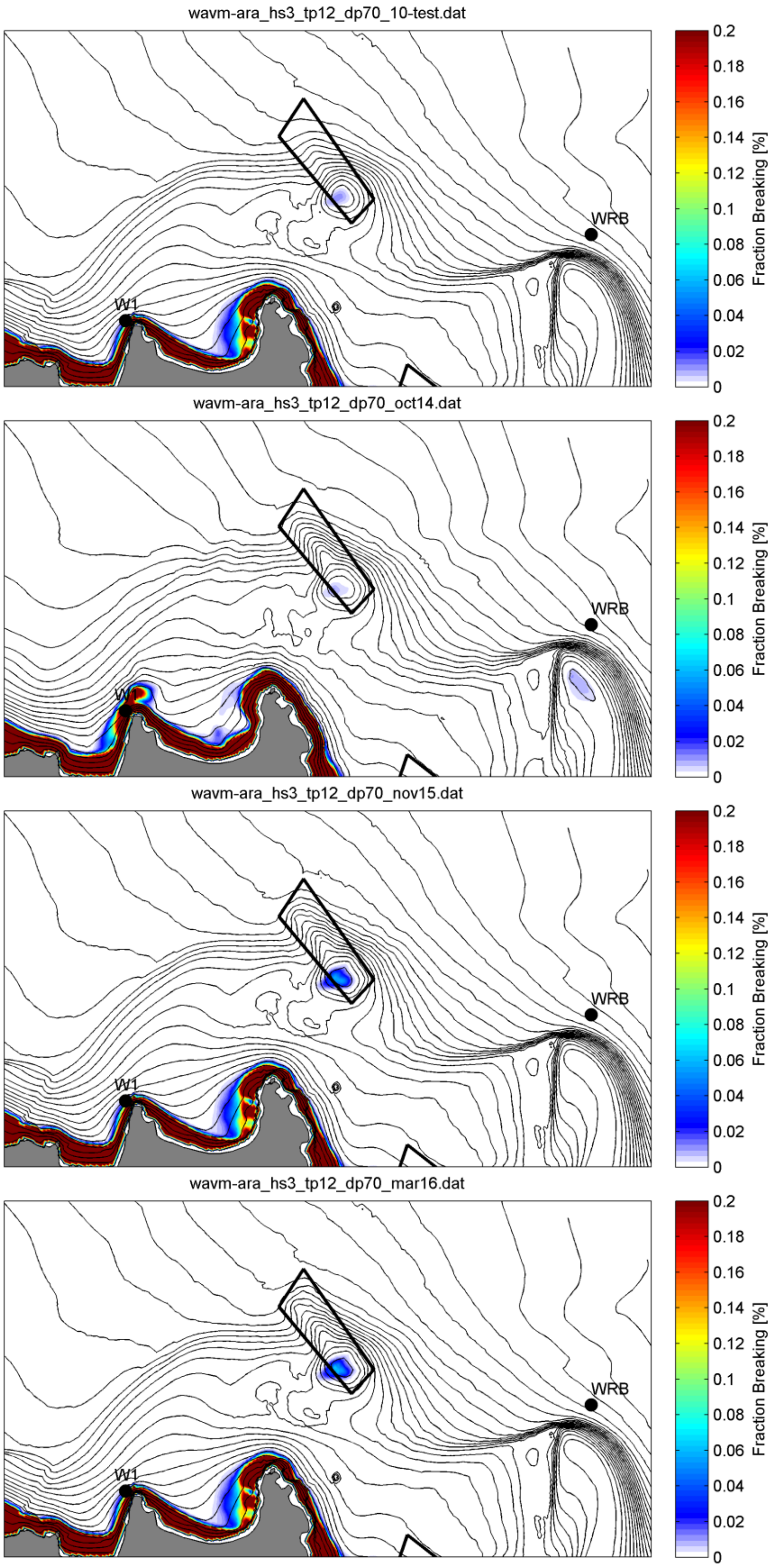

Figure 3.8 Predicted fraction of wave breaking in the vicinity of the Heyward Point disposal ground over the 2010, Oct. 2014, Nov. 2015 and March 2016 bathymetries (Hs=3.0 m, Tp=12s., Dir=70 degT).

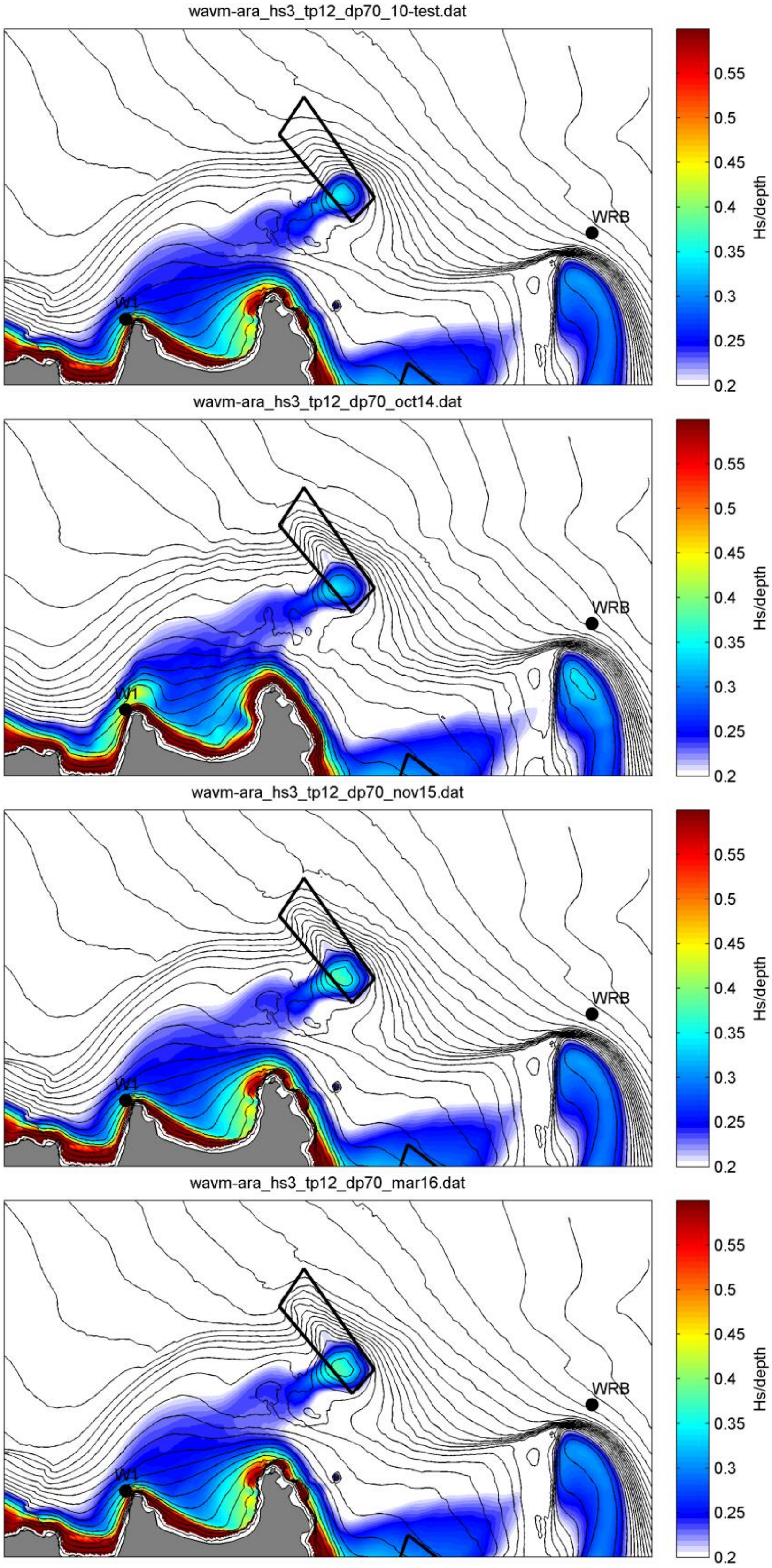

Figure 3.9 Predicted ratios of significant wave height to water depth (Hs/h) in the vicinity of the Heyward Point disposal over the 2010, Oct. 2014, Nov. 2015 and March 2016 bathymetries (Hs=3.0 m, Tp=12s., Dir=70 degT; mean sea level).

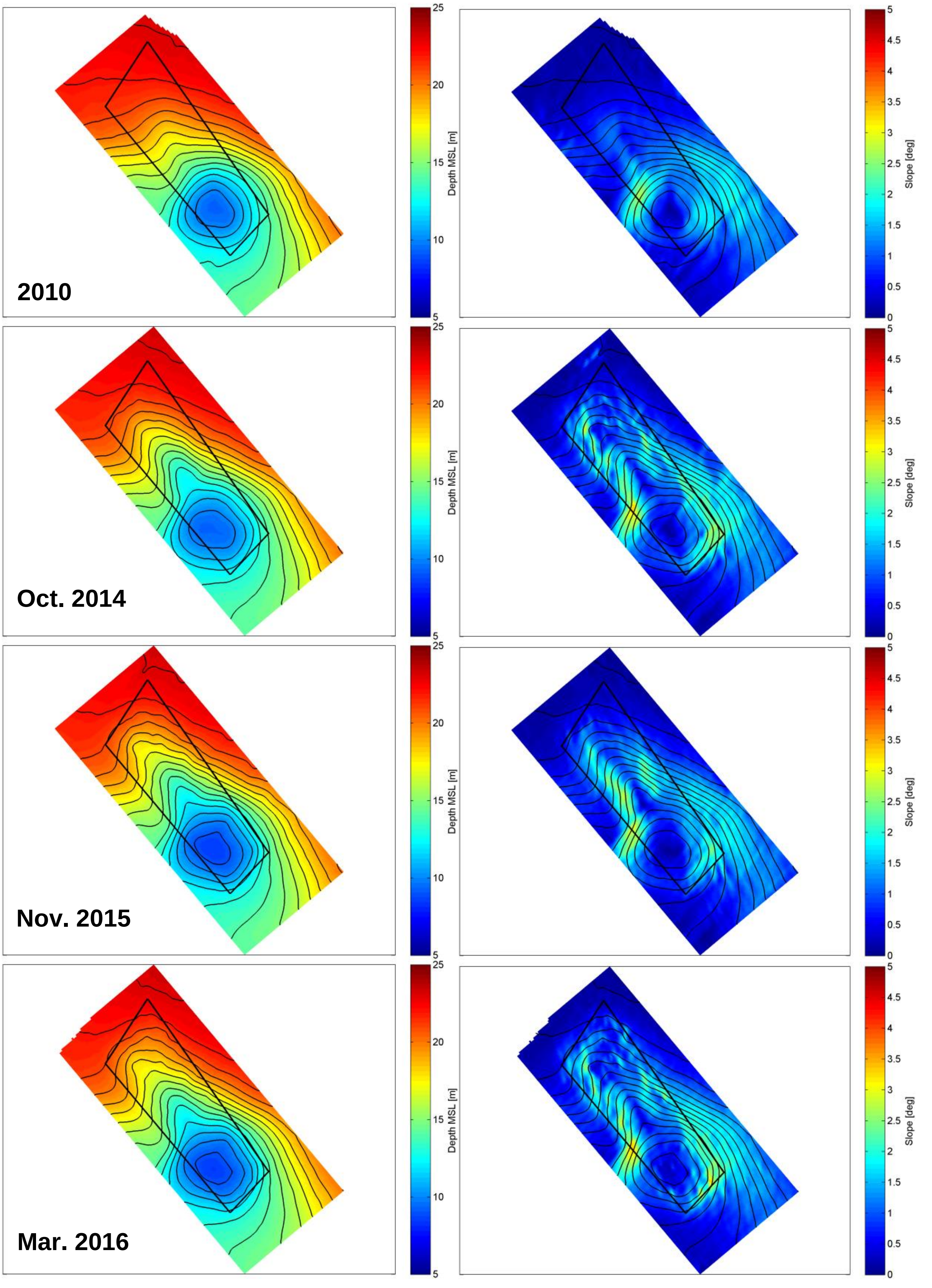

Figure 3.10 Water depths and seabed gradients in the vicinity of the Heyward Point in the 2010, Oct. 2014, Nov. 2015 and March 2016 bathymetries.

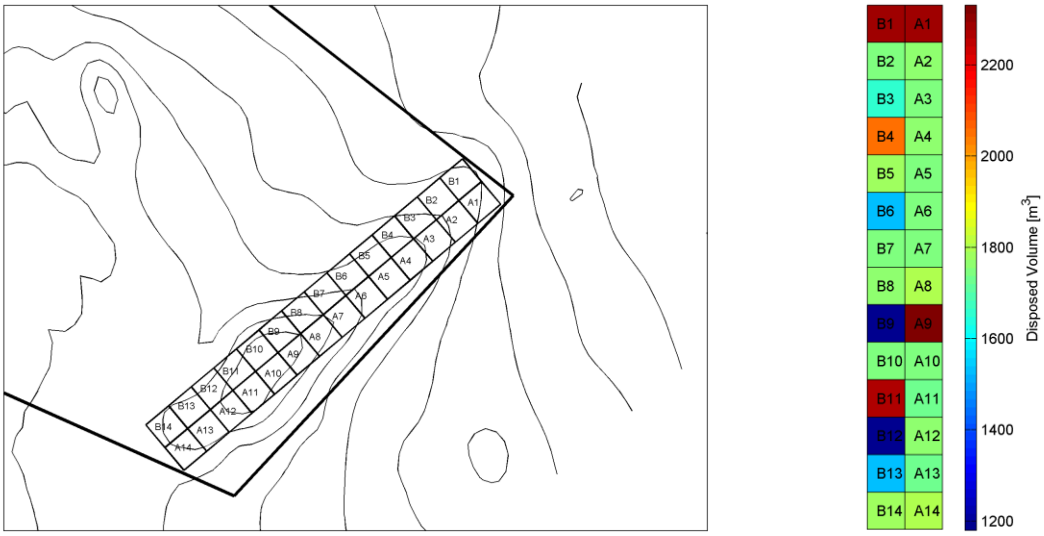

Figure 3.11 Disposal boxes recommended for the creation of an elongated mound within the Aramoana ground (left) and disposed volumes within each of the boxes (right). Total disposed volume is 49,880 m^3.

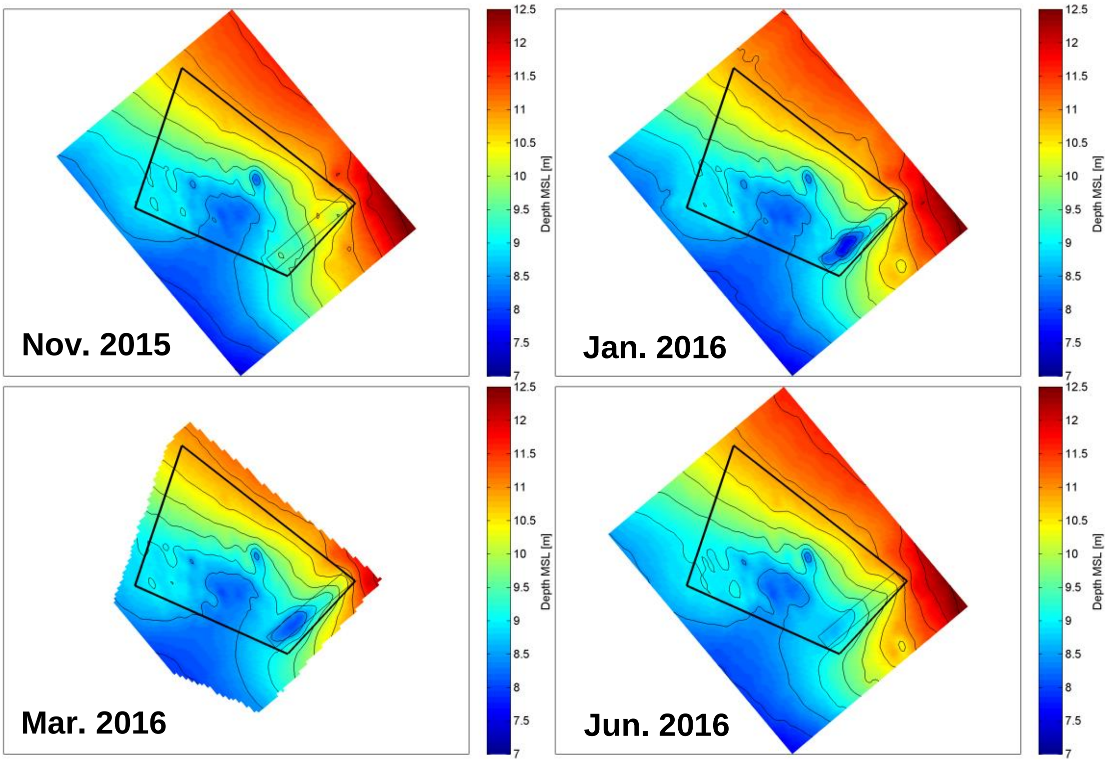

Figure 3.12 Successive bathymetries of the Aramoana Beach disposal ground in November 2015 and January, March and June 2016.

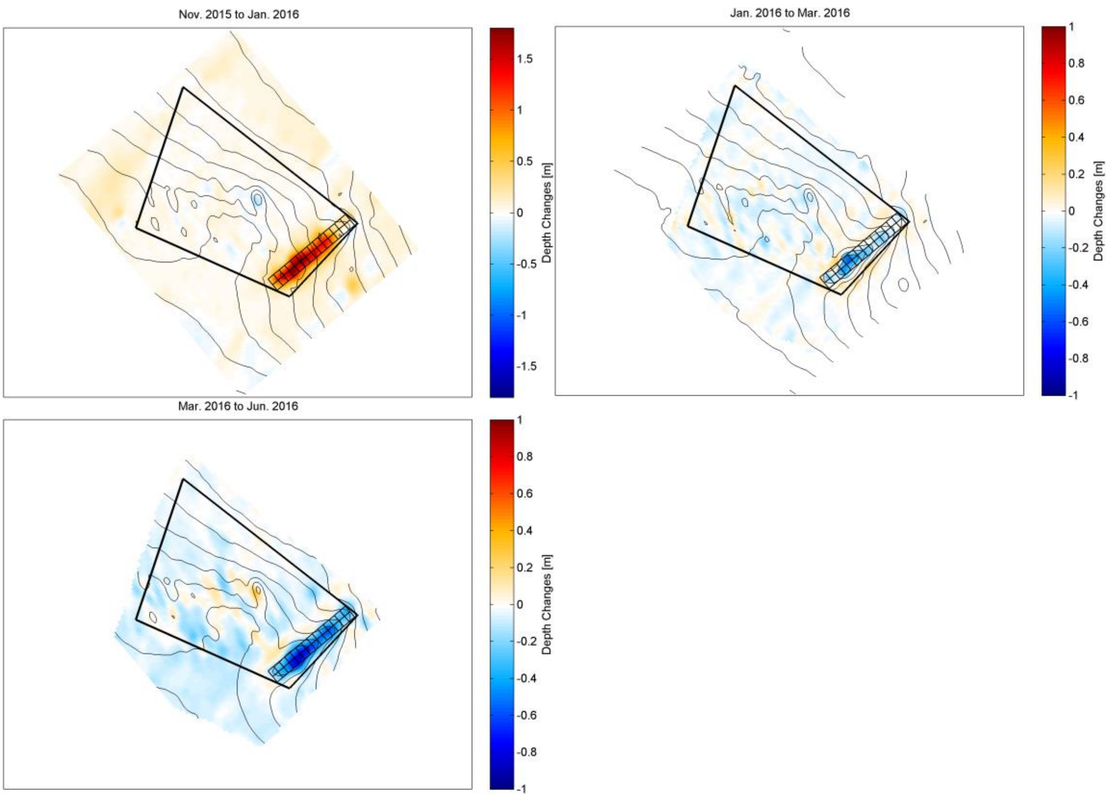

Figure 3.13 Successive bathymetric differences of the Aramoana Beach disposal ground from November 2015 to June 2016.

3.2. Proposed sediment disposal plan 2016 Q3

3.2.1. Heyward Point disposal ground

To mitigate the occurrence of wave breaking over the Heyward Point ground, it should not receive any more significant sediment volumes until further notice to allow the morphology to adjust and smooth back into an equilibrium state. Sediment volumes resulting from maintenance dredging should be directed to the Aramoana Beach or A0 grounds.

That being, the remaining sediment volumes to be dredged from the Dunedin Berth area cannot be disposed at Aramoana or A0 grounds due to the high silt content. Volumes are relatively small of order 5000 m^3 and it is recommended to dispose them into the deepest cells of the Heyward Point ground that did not receive sediment over the Q2 period (Figure 3.14).

3.2.2. Aramoana Beach ground

To compensate the stopping of sediment disposal at the Heyward Point ground, it is proposed to continue the trialling of the "surf mound" at the Aramoana Beach ground. As outlined, in section 3.1.2, the ground has received ~50,000 m^3 of sand around Dec. 2015/Jan 2016 to build an elongated mound along the southeast side of the ground that has significantly eroded since (see Figure 3.12 and Figure 3.13). The objective of such an elongated mound is to focus incident waves towards the eastern half of Aramoana Beach and possibly snap wave crests to improve the surfing wave quality there. It is purposely located to the eastern-most side of the ground to prevent any disturbance of the primary corridor of enhanced swell resulting from the intense wave refraction developing further offshore over the large submerged delta bar east of the Harbour Entrance that is generally reaching the northwest half of the beach.

Based on the expected disposal needs of Port of Otago for Q3 2016, two scenarios involving disposal of 38,000 and 50,000 m^3 of sand were considered. To accommodate these volumes within an elongated shape while keeping a mound crest deeper than 7 m MSL to reduce the wave breaking potential, it was decided to extend the mound area by a row of cells relative to the previous design (Figure 3.15). Suggested disposal plans are included in Figure 3.16. Post-disposal bathymetries were estimated by homogenously spreading the amount of disposed sediment within each cell (Figure 3.17).

The CGWAVE simulations of the idealized surfing event included in previous monitoring reports were reproduced over the recent and estimated post-disposal bathymetries. Wave height and wave crest patterns predicted over the November 2015 (i.e. pre mound build-up), June 2016, and post Q3 disposal bathymetries are compared in Figure 3.18 and Figure 3.19. The elongated surf mound does not dramatically modify the wave patterns but some subtle modulations of the wave field can still be observed. A relative increase in wave height between November 2015 and June 2016 can be seen in the lee of the mound. Magnitudes of change are limited notably due to the eroded mound morphology. The wave height increase though becomes more evident following the disposal of 38,000 or 50,000 m^3 within the mound area. Besides the relative wave height increase, the wave crest patterns (Figure 3.19) show more defined wave crest snapping features (i.e. shore normal white lines) which could potentially benefit the surfing conditions along the eastern half of the beach.

Proposed disposal plans for disposal for 2016 Q3

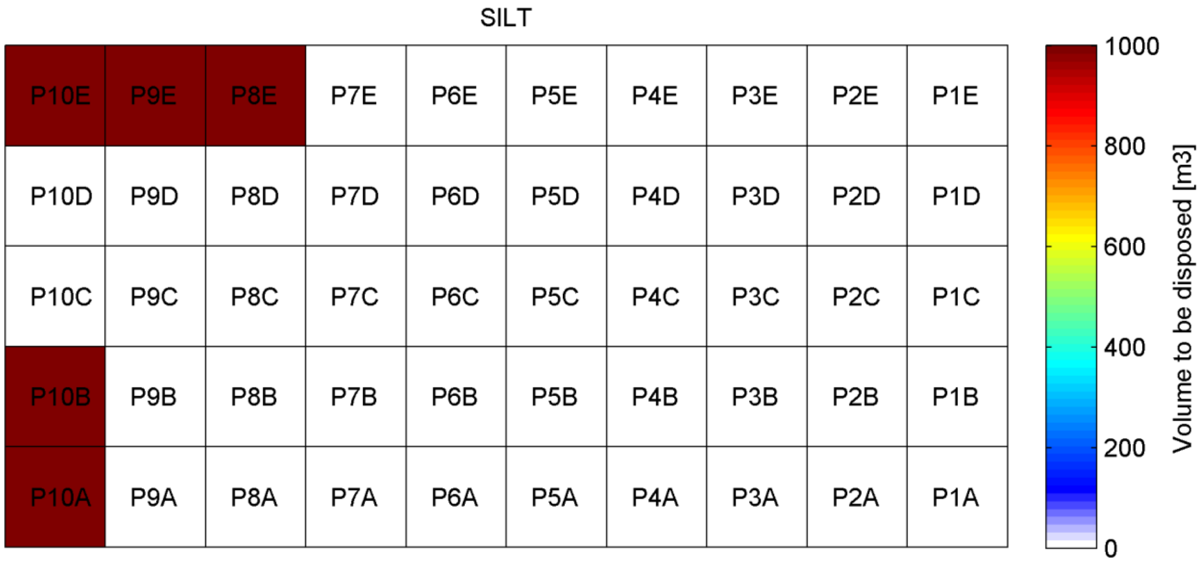

Figure 3.14 Proposed plan for the disposal of ~5,000 m^3 of silt at the Heyward Point disposal ground over 2016 Q3.

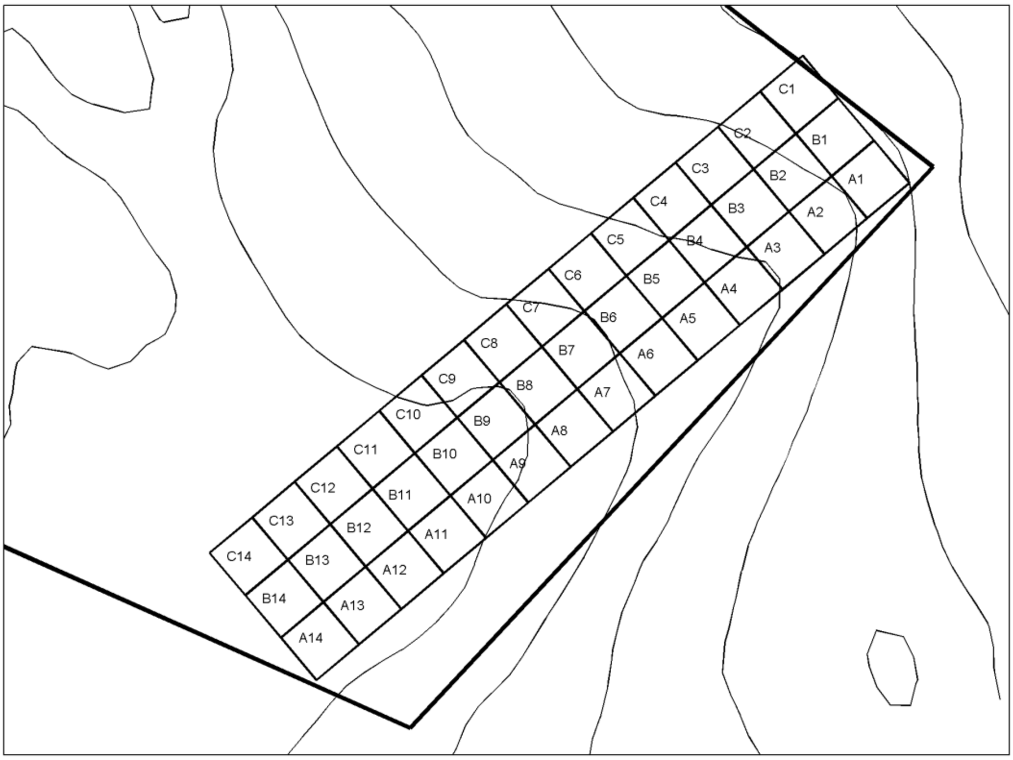

Figure 3.15 Delimitation of the cells considered over the Aramoana Beach disposal ground for the re-nourishment of the elongated “surf mound”. Each cell is 25x25 m. Note only the cells A and B were used in the previous delimitation (see Figure 3.11).

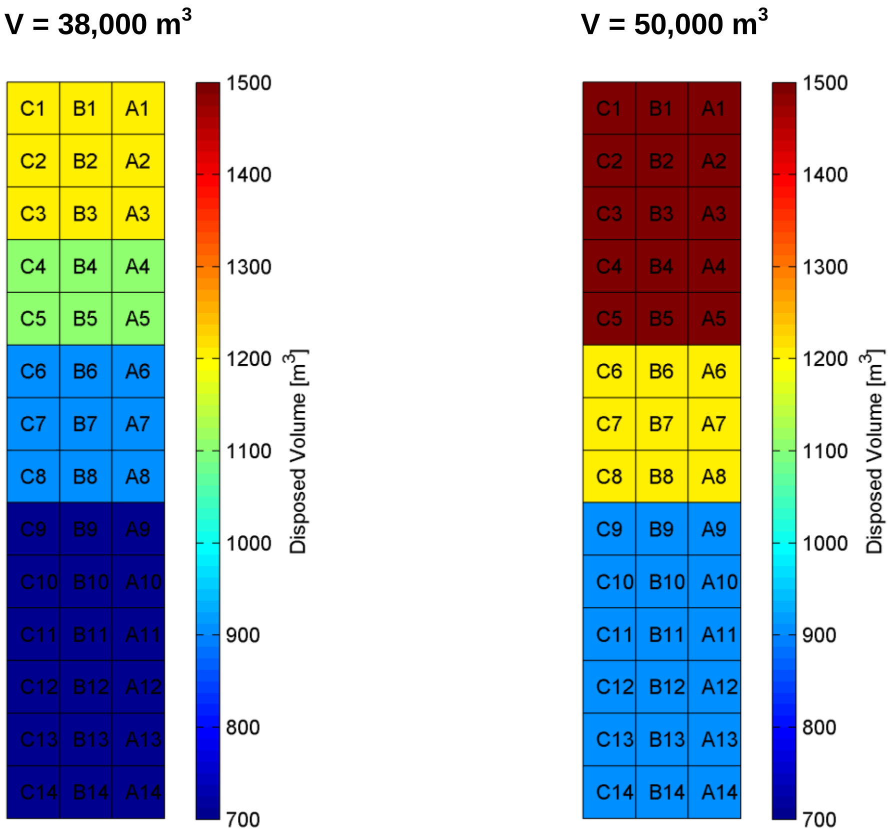

Figure 3.16 Recommended plans for the disposal of 38,000 and 50,000 m^3 of sand at the Aramoana Beach ground. Cell delimitation is shown in Figure 3.15.

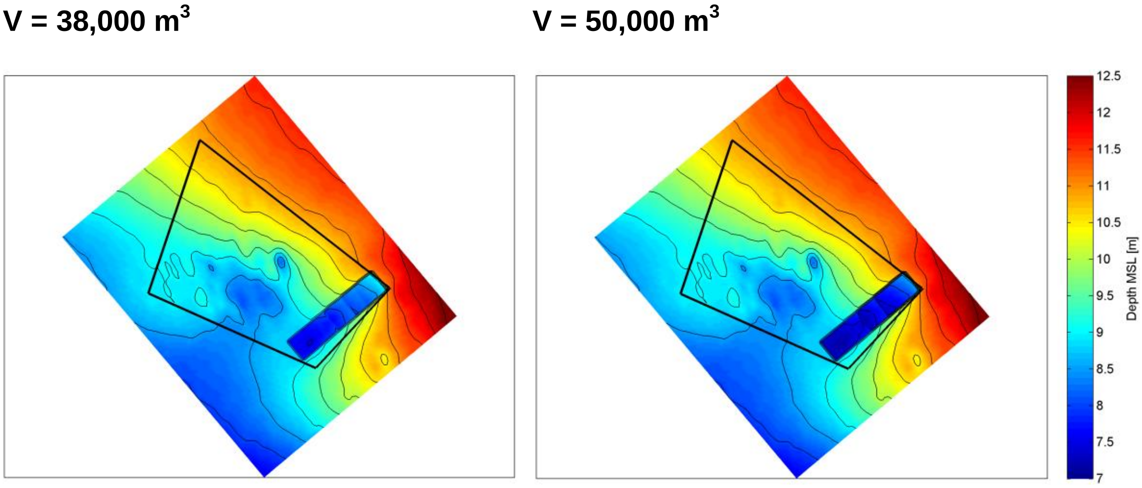

Figure 3.17 Estimated post-disposal bathymetries assuming disposal of 38,000 (left) and 50,000 m^3 (right) of sand at the Aramoana Beach ground in the cells shown in Figure 3.15.

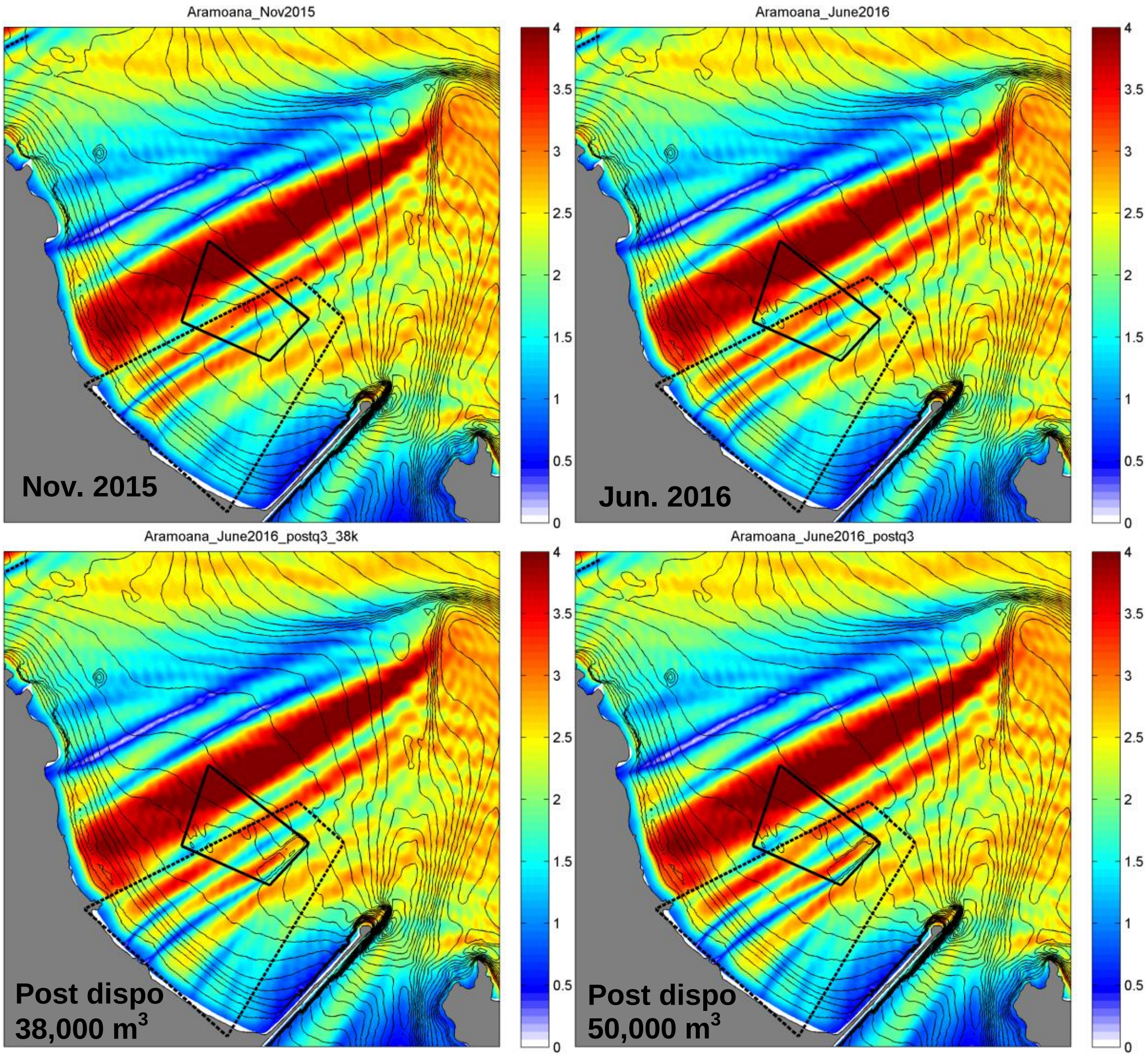

Figure 3.18 Predicted wave height patterns for a monochromatic wave event with Hs=2.6 m Dir=75 deg, Tp=12 sec, over the November 2015 (pre mound build-up), June 2016 and estimated post-disposal bathymetries (see Figure 3.17). The dotted black polygon indicates the general area of influence of the mound.

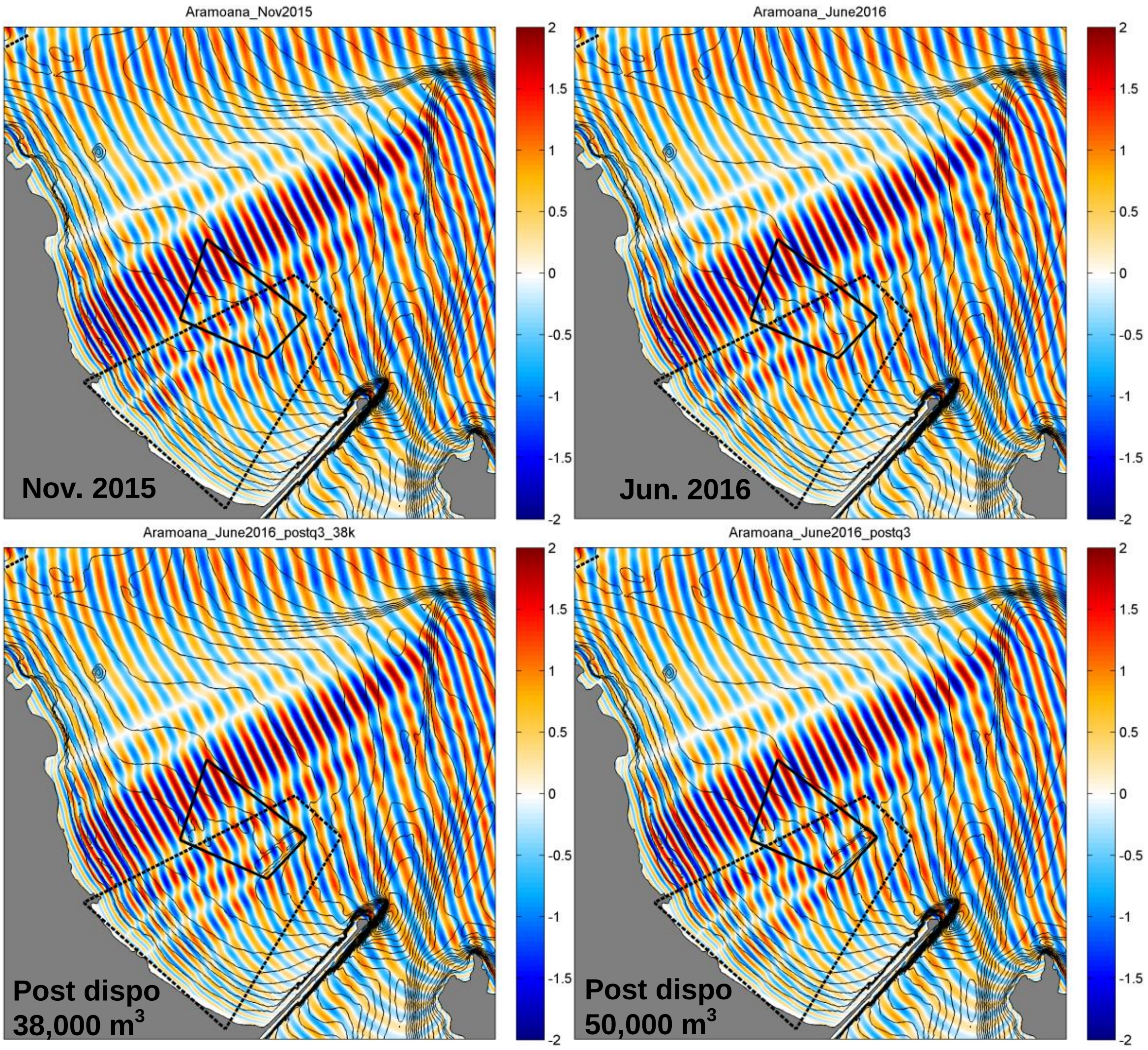

Figure 3.19 Predicted wave crest patterns for a monochromatic wave event with Hs=2.6 m Dir=75 deg, Tp=12 sec, over the November 2015 (pre mound build-up), June 2016 and estimated post-disposal bathymetries (see Figure 3.17). The dotted black polygon indicates the general area of influence of the mound.

4. CONCLUSIONS AND RECOMMENDATIONS

The present report assesses the morphological changes of the Heyward Point and Aramoana Beach disposal grounds over the period Q1-Q2 2016 based on surveyed bathymetries.

Following observations of wave breaking over the Heyward Point disposal ground, it is recommended to stop sediment disposal there until further notice to leave some time for the morphology to adjust back to an equilibrium level. Wave breaking over the ground can have adverse effects on the surfing conditions at Whareakeake Point as the disposal mound would act as a dissipative rather than focusing point to the incident wave field. Such adverse effects are however expected to be reversed as the mound adjusts back to equilibrium depths.

At the Aramoana Beach ground, the elongated disposal mound built in December 2015-Jan. 2016 has significantly eroded over the first half of 2016. It is proposed to direct the Q3 disposal of sandy sediment to the same ground zone to re-nourish the mound; two plans for disposal of up to 38,000 and 50,000 m^3 are proposed.

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