Sumner Revetment Assessment

Christchurch City Council

Operational Review Sumner Revetment

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Jacobs New Zealand Limited

Level 2, Wynn Williams Building
47 Hereford Street
Christchurch Central
PO Box 1147, Christchurch 8140
New Zealand
T +64 3 940 4900
F +64 3 940 4901
www.jacobs.com

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Executive Summary

Jacobs NZ Ltd were commissioned by Christchurch City Council (CCC) to undertake an operational review of the Sumner rock armour revetment from Cave Rock to Scarborough. The purpose of this review is for long-term strategic planning of maintenance requirements to the revetment to deal with both current and future conditions due to sea level rise because of climate change.

The tasks involved in this operational review included:

1) Reporting on the present condition of the rock revetment, in particular its height, shape, slope and rock volume.
2) Identifying low or weak points and critical areas for rock replenishment or regrading.
3) Reporting on the optimal design slope, volume and size of the rocks of the wall in its current form required to retain the functionality of the sea wall. This functionality developed in consultation with Council Parks staff included limiting rock displacement to less than 5% and overtopping volumes to less than deemed dangerous to pedestrians on the promenade (e.g. <0.3 l/s/m) in a 1% AEP storm event.
4) Providing recommendations to assist council staff to enable the most efficient maintenance practices to restore the effectiveness of the sea wall within its present form.

A site walk over was undertaken in December 2017 to make visual and photographic assessments of general condition of the revetment to identify potential low or weak points that may require rock replenishment or regrading. Visual qualitative assessment of revetment elevations, slope and rock size were made in the field at 36 critical locations where it was considered that these parameters were unlikely to meet the design requirements for the functional criteria given above. The qualitative assessment was supplemented by elevation data from a 2015 LiDAR survey, and data from 28 years of ECan beach profiles at three locations along Sumner Beach.

This data indicated that:

- The crest elevation of the revetment ranged from 3.2 m at the southern end to 4.3 m LVD[1]
- The promenade behind the revetment has elevations in the order of 3.4 – 3.6 m LVD
- The revetment slope ranges from 1:2.4 to 1: 3.8
- Beach elevation at the toe of the revetment is highly variable in both time and alongshore. Different sections of the beach have responded differently to wave and storm events.
- The greatest fluctuations, up to 2.2 m, have occurred in the northern section of the revetment (Mariner Street). This section of beach has generally had the highest beach elevations, particularly since 2007.
- The lowest beach elevation is generally in the middle section of the revetment (Hardwicke Street), particularly since 1997.
- The southern section of beach (Head Street) generally experiences less elevation fluctuations than the other sections.

Governing design conditions for revetment design were:

- Current 1% AEP storm tide level 2.11 m LVD.
- Minimum recorded beach elevation of -0.99 m LVD at the toe of the revetment (from Hardwicke St profiles).
- Maximum water depth at the revetment toe of 3.10m, and
- 1% AEP wave height at toe of 2.4m (based on the minimum recorded beach elevation).

Based on the above design criteria, the following revetment design is required to meet the overtopping and damage thresholds under **existing sea level conditions**:

[1] LVD: Lyttelton Vertical Datum 1937

- Rock Size: Primary Armour Layer: M50 **2.3t**. Dn50 **1 m**
  Underlayer: M50 **0.2t**. Dn50 **0.4 m**
- Revetment Slope: **1: 3.5**
- Revetment Crest: **Elevation: 4.8m LVD,** with Armoured crest **width of Approx. 4.75m,** and **inclusion** of an **impermeable crest wall** at the back to limit overtopping volumes onto the threshold limits for safe pedestrian passage along the promenade.
- Toe Design: As per CIRIA (2007) Rock Manual for areas of moderate scour potential:
  Toe width in the order of 3m (e.g. 3 x Dn50),
  Excavation of the beach material to the depth of anticipated scour, approximately 2.4m, being the maximum wave height at the revetment toe for the minimum profile elevation at Hardwicke St. Hence, toe excavation would need to be to a depth of -3.4m LVD.

A sensitivity analysis of the crest elevation required for higher frequency storm events revealed that to prevent dangerous overtopping for a two-year return period event would require a crest elevation of 4.05m LVD, an increase of up to 0.4 - 1m on existing elevations.

For this project, consideration of SLR is limited to the next 50 years based on the RCP 8.5 scenario, being 0.45 m rise. This scenario is for a continuing high greenhouse gas emission baseline with no effective global emission reduction. The range of time for the onset of this magnitude of SLR ranges from 2060 (RCP8.5+) to 2100 (RCP2.6). Under these conditions, the required revetment crest elevation requirement to meet the overtopping threshold would be increased to 5.6m LVD, and toe excavation depth increased to approximately 3m. Rock size, slope and revetment crest width parameters would remain the same as for the current conditions.

Based on the optimum revetment design, a key finding from the assessment is the entire revetment structure is below the optimum design elevation of 4.8m LVD required to meet the functional requirement of safe pedestrian passage along the promenade in current 1% AEP conditions. To meet this criteria would require a major upgrade involving raising the revetment crest by 1.2 to 1.8 m and increasing the revetment crest width to 4.75 m over the entire 1.2 km length of the structure. This is considered to be capital works requiring significant capital expenditure rather than maintenance, so is not included in assigning priority areas for revetment maintenance. Instead, in the interim, a possible alternative mitigation measure that could be put in place is managing access to the promenade during large storm events. Heavy overtopping flows with future SLR could be managed with the upgrade of the existing setback wall separating the promenade from the Esplanade to prevent inundation of key infrastructure during extreme storm events.

Therefore, it is recommended that maintenance priorities focus on the critical areas when repairs are required to increase the durability of the existing structure. This includes the following 19 sites from the walkover inspection:

- Three sites with small armour rock size and steep slopes (classed as 3a in the critical area ranking), are the highest priority sites for maintenance given the consequence of this combination for further rock displacement (damage) within the revetment structure.
- Five sites with small armour rock size and flat slopes (classed as 3b in the critical area ranking) have a slightly lower priority relative to the steep sloped revetment sites, as they are likely to suffer less rock displacement in storm events.
- The seven medium priority sites (e.g. critical rank 2) where armour rock size are an issue should be the third priority to be maintained, so that sufficient size armour material is in place to reduce the likelihood of further rock displacement, which may result in slope issues.
- The other four medium priority areas with slope issues are a lower priority for maintenance as displacement of the sufficiently sized existing armour rock is less likely than for small rocks. For these sites, additional armour rock may still be required and existing armour rock repositioned to achieve optimum design slopes. There may be additional areas not identified in the initial walk-over which also do not meet the design slope criteria.

Maintenance of the identified high priority sites could involve the addition of large basalt armour rocks which meet the optimum rock size criteria and ensuring the slope at which these are placed fits the optimum structure criteria. Preparation work would be required at each site, and rock placement is recommended to be undertaken from the toe to the top using land based earthmoving equipment working from the promenade. Each placed layer shall be protected by the subsequent layer as soon as possible after placement in order to minimise damage in the case of a storm event.

1. Introduction

Jacobs NZ Ltd were commissioned by Christchurch City Council (CCC) to undertake an operational review of the Sumner rock armour revetment from Cave Rock to Scarborough. The purpose of this review is for long-term strategic planning of maintenance requirements to the revetment to deal with both current and future conditions due to sea level rise because of climate change.

The nature of the revetment is shown in Figure 1.1, with a length of approximately 1.2km and is comprised of randomly placed large volcanic boulders (mainly local basalt) in the order of 0.5 m to 1.5 m in diameter. A plan showing locations referred to in the text is included in Appendix A. Note the Esplanade is the road landward of the vertical wall, and walkway between the wall and the revetment is referred to as the Promenade.

Figure 1.1: Sumner Beach rock armour revetment

The alignment of the revetment is not consistent with the alignment of the shoreline, with the structure being promoted convex seaward in the centre (around Hardwicke St) and slightly concave landward for approximately 200 m north of this (e.g. Stroke St) (refer Figure 1.1 and Appendix A). Although it is unclear, it is assumed that the revetment is generally two layers of armour rock, that has been placed over historical fill material. At the southern Scarborough end the revetment is replaced by concrete steps, that have been repaired by council in 2018 under a separate contract. The beach in front of the revetment is only exposed at low tide.

It is assumed that the revetment was constructed in the 1940's to 1950's period based on the age of the Esplanade beach wall, constructed in 1932, and the photograph reproduced in Figure 1.2 from Menzies (1941) that does not show the revetment being present..

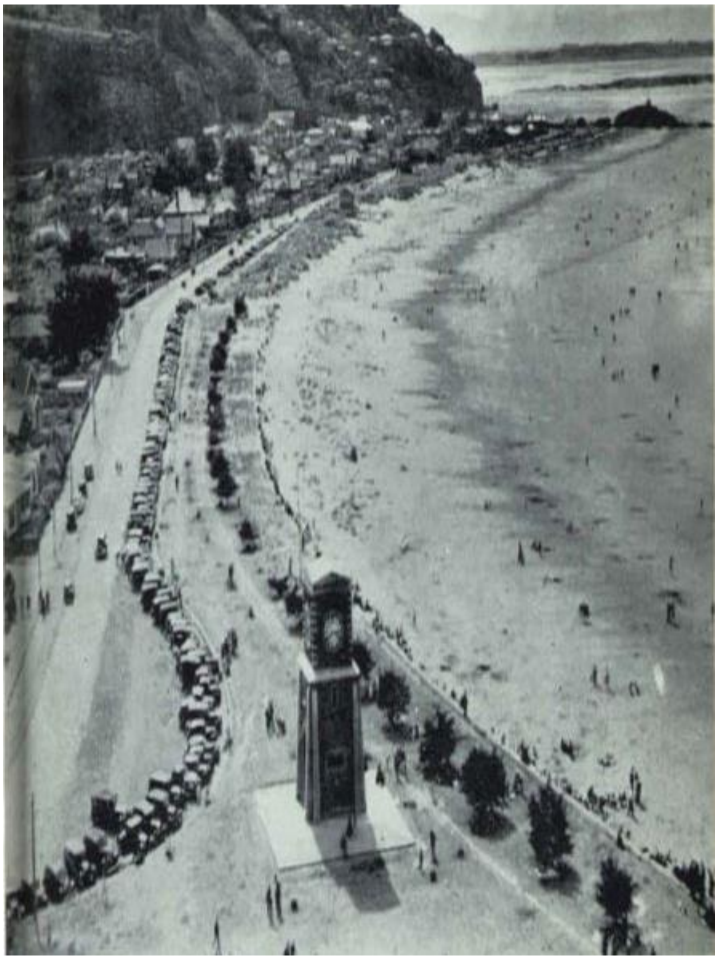

Figure 1.2: Sumner Beach circa 1930's. (Source: Menzies, 1941)

Top-up of boulders is assumed to have occurred at various times over the past 60-70 years. Rock volumes and heights are variable along the revetment, and in some areas require additional replenishment. It is understood that during periodic extreme storm events in recent years that wave run-up has overtopped the revetment and deposited displaced small revetment rocks on the promenade.

The tasks involved in this operational review include:

1) Reporting on the present condition of the rock revetment, in particular its height, shape, slope and rock volume.
2) Identifying low or weak points and critical areas for rock replenishment or regrading.
3) Reporting on the optimal design slope, volume and size of the rocks of the wall in its current form required to retain the functionality of the sea wall.
4) Providing recommendations to assist council staff to enable the most efficient maintenance practices to restore the effectiveness of the sea wall within its present form.

It is noted that this current condition assessment has a different focus from the Tonkin & Taylor (2017) Christchurch coastal hazard assessment, which involved modelling areas at risk from coastal inundation and erosion with sea level rise. It is further noted that for Sumner the Tonkin & Taylor assessment modelled inundation with the assumption of the seawall between the Esplanade and the promenade not being present (due to gaps in the wall), and for erosion the assumption that sea level rise will have the same erosion effects at the revetment as on the open coast shorelines.

2. Methodology

The following methodology was undertaken to meet the tasks requirements of the operational review.

Met-ocean design conditions

Information on the met-ocean conditions (e.g. water levels and wave climate) are required to assess the design slope, heights, and rock size for the revetment to perform its required standard of protection, and the presence of weak and/or low spots where the existing revetment does not meet the required standard of protection.

Information on extreme water levels and wave conditions were obtained from the NIWA Coastal Calculator (Stephens *et al*, 2015) for the Sumner site, with extreme water levels being updated for more recent events (including the most extreme on record in February 2018) from Goring (2018b).

Sea level rise from the RCP8.5 scenario from MfE (2017) was used to determine design sea levels in 50 years.

Revetment condition assessment

The initial condition assessment involved a site walk over in December 2017 to undertake a visual inspection of the general condition of the revetment to identify locations with potential issues with height, slope or rock size that may require refurbishment. The co-ordinations of each issue location were recorded by hand held GPS, with observations of elevations, slope and rock size being made subjectively in the field. The following observations of perceived locations with issues of revetment damage or potential poor performance were recorded:

- Locations identified as having a localised lower area relative to its surroundings.
- Locations identified as having an armour rock size that was considered to be too small. For these locations, visual estimates of mean rock size (Dn50) were made. No estimates of rock size were made in areas perceived to have suitably sized armour rock.
- Locations identified as having an inconsistent revetment slope from slumping of the profile (e.g. loss of rock).
- Locations where the revetment was visually identified as being relatively narrow in relation to the surrounding widths.
- Locations where large concrete blocks were found to be present among the revetment material. The presence of these blocks was considered to be a potential durability issue.

The location of the identified issue areas was georeferenced for presentation on location maps. CCC LiDAR data (2015) and ECan beach profiles (available at three locations along seawall) were used to determine revetment height, width and slope estimates at these potential low/weak points for comparison with the optimum design.

It should not be discounted that other areas of the revetment which were not identified in the initial visual assessment may not fit the optimum design criteria for crest elevation, rock size and slope. A long-shore LiDAR profile along the crest of the revetment was used to test this for revetment elevation over the total length of the structure.

Optimum revetment design

Accepted methods from international literature (e.g. CIRIA Rock Manual 2007, EurOtop 2016) for determining revetment design heights, slopes, volumes and rock size/grading were used to determine revetment design configurations for the current and future design met-ocean conditions present at Sumner.

Sites confirmed to be below the optimum design were presented on location maps, and maintenance requirements calculated. Maintenance recommendations include best practice approaches and construction methodology to the local site conditions found at Sumner.

3. Met-ocean Design Conditions

3.1 Storm tide water levels

Storm tide water levels are the combination of astronomical tide (AT), non-tidal anomalies in mean sea level (SLA) due to climate variability (e.g. ENSO & IPO), and storm surge (SS) from meteorological conditions (e.g. inverted barometer effect & wind stress). Since east coast locations have a monthly dominant perigean and apogean tides rather than fortnightly spring and neap tides, the mean high water perigean spring tide (MHWPS), which elevation is exceeded by the largest 10% of all astronomical high tides, is more relevant than the conventional MHWS for defining high astronomical tide levels at Sumner. This level provided in Table 3.1 as a point of reference for storm tide elevations that include ALA and SS components.

Table 3.1 presents the following three different calculations of extreme storm tide distribution for Sumner since 2015:

1. The levels from the Canterbury Coastal Calculator (Stephens *et al*, 2015) based on records from the Lyttleton Harbour Tide gauge, with the storm tide distributions being calculated by a Monte Carlo Joint-Probability (MCJP) method of calculating combined probabilities of AT, SLA, and SS.

2. The level from NIWA (2015) used in the Christchurch flood modelling also calculated from the MCJP method, but based on 20 years of measured water levels at the Sumner Head sea level recorder. Using the MCJP method allows this short record to be extended to stimulated distributions of thousands of years of combined AT, SLA and SS, therefore produce more storm tides that experienced in the short-term records.

3. The levels from a more recent analysis by Goring (2018) following a series of extreme water levels in the Avon-Heathcote estuary, with records from the Ferrymead gauge showing two events with water levels above the 100 year ARI level (July 2017), a further two events greater than the 10 year ARI level, and two more events greater than the 1 year ARI level. The dates and levels of these events are given in Table 3.2. It is noted that the level on 2nd February 2018 was the highest since recording began in 1960, being 0.74 m above MHWSP, and included a storm surge component of 0.49 m.

   The re-calculated extreme water level distribution in the Estuary (Bridge St and Ferrymead) and at Sumner were based on the actual water level records using the annual maxima method (EV1 or Gumbel distribution). Since the water level record at each site exceeded 20 years, it was considered that the annual maxima were satisfactory for fitting an extreme event probability curve. The resulting extreme storm tide distribution was +0.24 m and +0.28 m higher for the 50 year and 100 year ARI levels respectively than the NIWA (2015) distribution.

The updated water levels from Goring (2018) are now in use by CCC in flood assessments to determine floor level requirements in flood prone areas, so for consistency have been adopted for optimum design purposes in this operational review of the Sumner Coastal Revetment.

The storm tide elevations in Table 3.1 are given in terms of Lyttelton Vertical Datum (LVD1937). It is recognised that other datum's such as current MSL, Christchurch Drainage Datum (CDD) and New Zealand Vertical Datum (NZVD2016) may also be used at the site. Conversion factors to each of these datum's are supplied in the Table.

Table 3.1: MHWPS and extreme storm tide level distributions for Sumner. Levels in terms of LVD1937.

Source	MHWPS	Storm tide % Annual Exceedance Probability and Average Recurrence Interval								
		%AEP	63%	39%	18%	10%	5%	2%	1%	0.5%
		ARI (years)	1	2	5	10	20	50	100	200
Stephens *et al* (2015) From Lyttelton Data	1.24	MCJP Maximum Likelihood	1.68	1.71	1.76	1.79	1.81	1.85	1.88	1.90
NIWA (2015) From Sumner Data		MCJP Median 95% Conf Interval	1.63 ±0.001	1.66 ±0.002	1.71 ±0.002	1.74 ±0.003	1.77 ±0.004	1.81 ±0.006	1.83 ±0.007	1.86 ±0.009
Goring (2018)		Annual Maxima method		1.72	1.83	1.89	1.96	2.05	2.11	2.17
Current MSL = +0.165 m LVD1937 (from Stephens *et al*, 2015, on assumption that MSL is based on 1993-2012 tidal epoch) NZVD2016 = +0.356 m LVD1937 (from LINZ) CDD = +9.043 m LVD1937										

Table 3.2: Extreme Avon-Heathcote water levels at Ferrymead Bridge St since 2017. Levels in terms of LVD1937.

Date	Water Level	Date	Water Level
15-1-2017	1.63	21-7-2017	1.89
29-4-2017	1.64	6-1-2018	1.74
24-6-2017	1.73	2-2-2018	1.98

3.2 Wave conditions

Extreme wave heights are from statistical extreme wave analysis presented by Stephens *et al* (2015), which involved transforming 30 years (1970-2000) hindcast of storm surge and waves at 50m water depth (WASP data) to a 10 m water depth at 29 inshore locations along the Canterbury coast, including Sumner. Due to the very flat nearshore seabed gradient at Sumner, the 10 m water depth occurs approximately 1.8 km offshore from the Sumner revetment. The resultant extreme wave heights for Sumner extracted offshore at a depth of 10m are provided in Table 3.3.

Table 3.3: Extreme significant wave heights for Sumner at 10 m water depth. Source: Stephens *et al* (2015).

Statistic	Significant wave height %AEP (Annual Exceedance Probability)							
	63% (1yr ARI)	39% (2 yrs ARI)	18% (5yrs ARI)	10% (10yrs ARI)	5% (20yrs ARI)	2% (50yrs ARI)	1% (100yrs ARI)	0.5% (200yrs ARI)
Maximum likelihood estimate	2.60m	2.80m	3.00m	3.12m	3.21m	3.29m	3.34m	3.38m
Upper 68% confidence interval	2.78m	3.03m	3.28m	3.42m	3.53m	3.65m	3.72m	3.77m
Upper 95% confidence interval	2.98m	3.27m	3.58m	3.76m	3.91m	4.06m	4.16m	4.23m

There is a reasonably large confidence interval for these wave height estimates and hence a large uncertainty in the estimated wave heights for each return period. For example, for a 2% AEP wave height, the difference between the most likely estimate and the upper 95% confidence interval wave height is 0.85m, which is considerably greater than the difference between the 2% and the 1% AEP wave height (0.05 – 0.1m). For optimum design purposes, both the 1% and 2% AEP wave heights at 95% confidence interval are used to determine wave runup and overtopping sensitivity to extreme wave heights. Waves of these heights will break in water depths greater than 4.5m (applying standard relationship of H=0.78d), which occurs approximately 750m from the shore, and will interact with other waves and surf across these extended surf zone widths.

Waves that can break directly on the revetment will be limited by the water depth at the toe of the revetment which limits the maximum wave height in the order of 2.4m for a water depth at the revetment toe of 3.06m assuming a 1%AEP water level (2.11m) and minimum recorded beach profile elevation at the revetment toe (-0.99m LVD1937 from 50 surveys over the last 26 years -refer section 4.1). From Table 3.3 waves of this magnitude are likely to occur at least once a year.

However, a more likely estimate of the limiting wave heights at the revetment toe for 1% AEP water level is 1.4m based on the mean profile elevation at the toe of the revetment of 0.33m LVD1937. Waves of this magnitude are likely to occur more frequently than once a year.

Storm wave period is not given by Stephens *et al* (2015). However, based on wave periods recorded at the Steep Head wave buoy during coastal storm events, wave periods associated with extreme storm events are assumed to be in the order of 8 seconds.

3.3 Joint storm tide and wave set up levels

Stephens *et al* (2015) notes that there is a high dependency of storm tides and wave height in the lee of Banks Peninsula due to storm surge and large waves both being driven by local weather systems, therefore, design sea levels for coastal protection should be calculated by joint probability of storm tide and wave set-up.

Wave set-up occurs in the surf zone, being the increase in water level due to the presence of breaking waves, with the magnitude of set-up being dependent on the beach slope and wave height. In Sumner there are two sets of conditions to consider:

1) Maximum sized waves breaking on very flat nearshore slopes (range of 1:50 to 1:100) in front of the revetment.

   For this condition, even with maximum wave heights, the flat nearshore slopes limit wave set-up to magnitudes of less than 0.1m for slopes of 1:100 and less than 0.2m for slopes of 1:50. Applying the joint probability approach from Stephens *et al* (2015) resulted in the maximum combined storm tide and wave set-up water levels for 2% and 1% AEP events being very similar (e.g. 0.02m lower) to the storm tide levels alone for the corresponding return period. Therefore, the storm tide levels are appropriate for adopted design water levels. However, the results of the joint probability from Stephens *et al* (2015) needs to be adjusted upwards due to the higher storm tide levels for corresponding return periods from the Goring (2018) analysis.

   So the resulting adopted design water levels are:
   1.96 m for a 5% AEP event
   2.05m for a 2% AEP event, and
   2.11m for a 1% AEP event

2) Depth limited smaller waves breaking on the very steep face of the revetment (average slope of 1:3).

   For this condition, the influence of the steep slope with result in wave set-up being in the order of 1 - 2m, and hence will have a significant effect on the water level and run-up elevations at the revetment face. For these conditions wave set-up is included in the calculation of run-up elevations, which are also depend on type and nature of the beach or structure surface. These calculations are included in the consideration of Optimum Design in Section 6.

3.4 Projected Sea Level Rise

MfE (2017) presents four scenarios of projected SLR for New Zealand based on the IPCC AR5 (2014) projections with a small offset for New Zealand conditions. The median value 2070 (e.g. approx. 50-year) and 2120 (approx. 100-year) SLR projections for each of these scenarios are presented in Table 3.4.

Table 3.4: Projected sea level rise for New Zealand from 1985-2005 baseline. Source: MfE (2017).

Scenario	Projected SLR to 2070	Projected SLR to 2120
RCP2.6	+0.32 m	+0.55 m
RCP4.5	+0.36 m	+0.67 m
RCP8.5	+0.45 m	+1.06 m
RCP8.5+	+ 0.51 m	+1.36 m

For this project, consideration of SLR is limited to the next 50 years based on the RCP 8.5 scenario, being 0.45 m rise. This scenario is for a continuing high greenhouse gas emission baseline with no effective global emission reduction. The range of time for the onset of this magnitude of SLR ranges from 2060 (RCP8.5+) to 2100 (RCP2.6).

Climate change and associated sea level rise will also potentially affect future storm surge elevations and wave climates. MfE (2017) present these possible affects for New Zealand as being:

- Storm Surge: For all of New Zealand except South Taranaki Bight and the South Otago coast; only small increases or decreases in storm surge height with no significant consistent changes in the 99th percentile heights over all modelled scenarios.
- Wave Climate: Generally increases of 0.5 % in the 99th percentile of significant wave height would apply around New Zealand by 2070-2100, with biggest increases in the swell exposed west and south coasts (e.g. not Canterbury Bight)
- Storm frequency & intensity: *Likely* that global frequency of tropical cyclones will remain essentially unchanged or decrease slightly over the 21st century, but is *likely* that maximum wind speeds and rainfall rates will increase. However, there is low confidence in region-specific projections.
- In summary the projected changes in storm frequency, wave heights, storm surge and winds overall for New Zealand is described as being relatively modest or inconclusive. The guidance is to consider generic likely future increases across New Zealand of 0-5% for storm surge, waves and winds, particularly for 100-year planning time frames.

In the light of the above points, it is considered that over a 50-year timeframe, a nil increase in these parameters is appropriate of revetment optimum design.

4. Beach and Revetment Profile Conditions

4.1 Beach profiles

Beach profile changes in front of the revetment are important, as waves breaking on the revetment and therefore run-up heights and overtopping volumes are dependent on water depths at the toe of the structure.

Information on beach profile changes are available from six monthly surveys since 1990 at three ECan revetment beach profile monitoring sites located along the Sumner Esplanade. The locations of these sites (C0070 Head St, C0112 Hardwicke St, and C0150 Mariner St) are shown in Appendix B and the profile envelopes (first, last, min, max) over the 55 surveys at each site up to February 2018 are presented in Figures 4.1 to 4.3. A summary of the range and mean beach elevations at the exposed toe of the revetment at each site is presented in Table 4.1 and the time series of exposed toe elevations is presented in Figure 4.4.

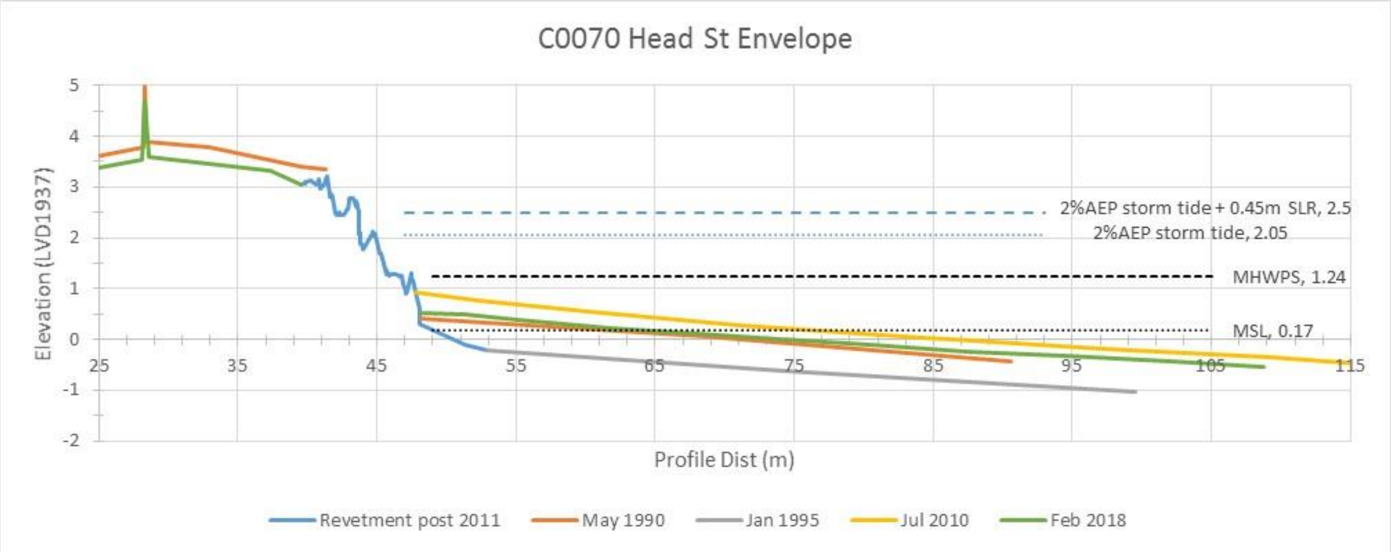

Figure 4.1: ECan monitoring Site C0070 Head Street beach profile envelopes

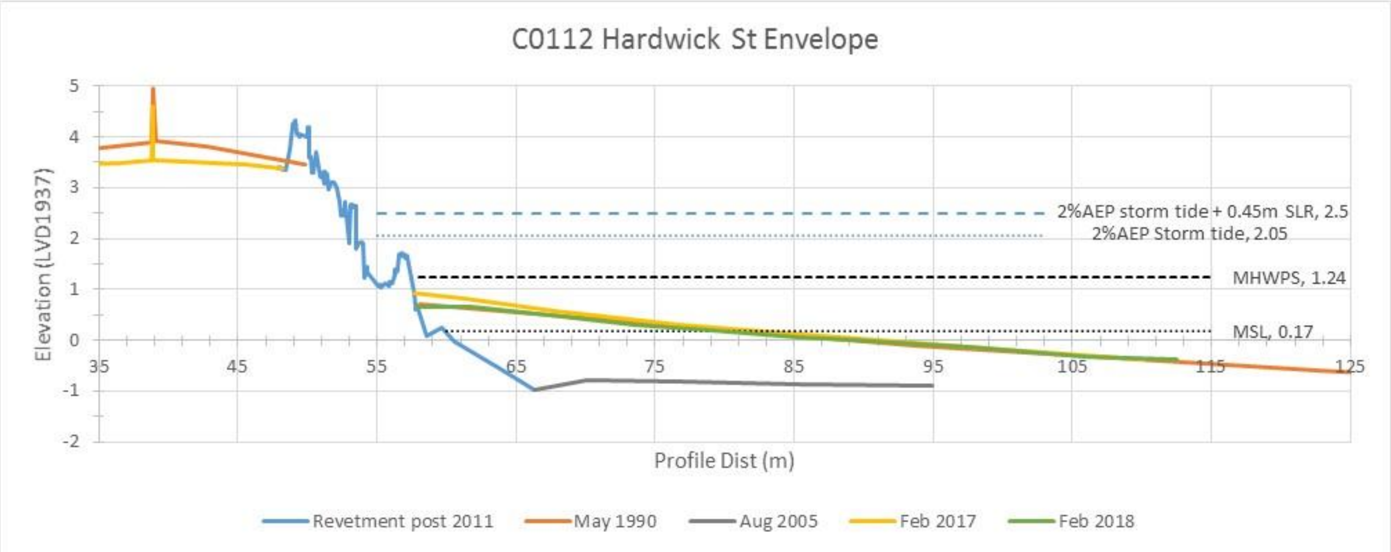

Figure 4.2: ECan monitoring Site C0112 Hardwicke Street beach profile envelopes

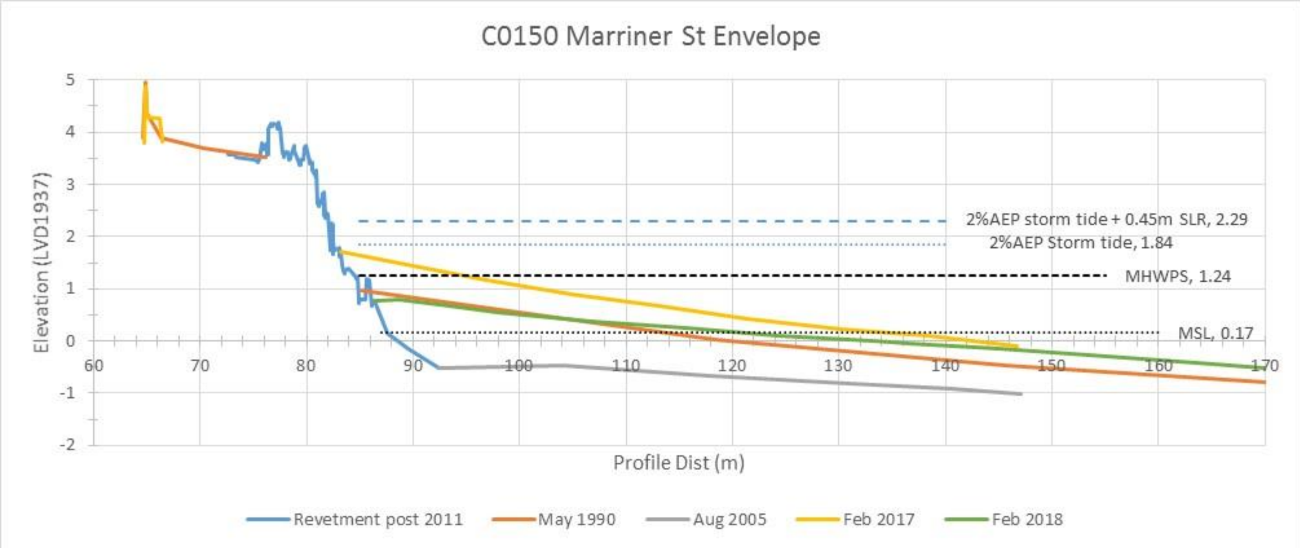

Figure 4.3: ECan monitoring Site C0150 Marriner Street beach profile envelopes

Table 4.1: Surveyed beach elevations at exposed toe of revetment from 55 ECan surveys 1990-2018

	Beach Toe elevation in LVD1937		
	Min Elevation	**Max Elevation**	**Average Elevation**
C0070 Head Street	-0.21 m (Jan 1995)	0.94 m (Jul 2010)	0.34 m
C0112 Hardwicke Street	-0.99 m (Aug 2005)	0.93 m (Feb 2017)	0.22 m
C0150 Marriner Street	-0.51 (Aug 2005)	1.71 (Feb 2017)	0.49 m

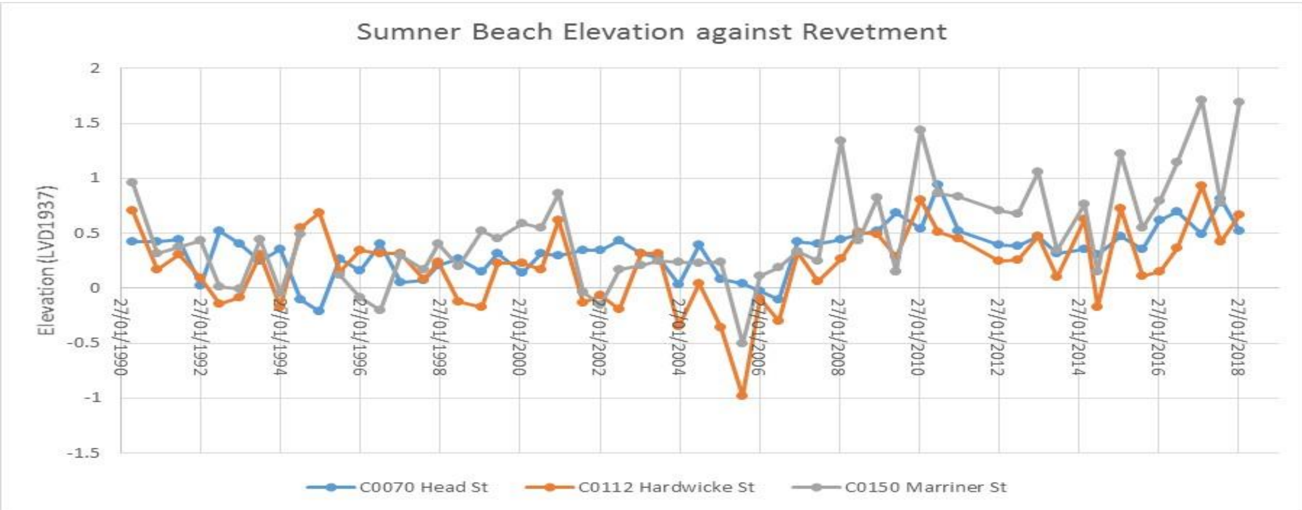

Figure 4.4: Beach elevations against toe of Sumner revetment

The following points can be made from the presented information in the figures and table.

- Beach elevation at the toe of the revetment is highly variable in both time and space. Different sections of the beach have responded differently to wave and storm events.
- For the central (Hardwicke St) and northern (Marriner St) sections of the revetment, lowest beach elevation adjacent to the toe of the revetment was surveyed in August 2005, possibly as a result of a southerly storm in April 2005. However, lowered beach responses at the southern end (Head St) were delayed till 2006.
- From the minimum profiles at Hardwicke and Marriner Streets, the minimum elevations include in the order of 0.4 m of scour at the toe of the revetment.

- For all three sites, the minimum beach toe elevation, is below the 95% confidence interval for the distribution of toe elevations, and for Hardwicke street is below the 99% confidence level.
- All sites have had higher beach levels since February 2012 than prior to the Canterbury Earthquake Sequence, with the only surveyed beach elevations adjacent to the revetment toe being below MSL being recorded at Hardwick St following storm events in March – June 2014, and April - June 2015. However, it is noted that the trend towards higher beach levels were evident from 2007, so pre-date the Canterbury Earthquake Sequence.
- The greatest fluctuations, up to 2.2 m, have occurred in the northern section of the revetment (Marriner Street). This section of beach has generally had the highest beach elevations, particularly since 2007.
- The lowest beach elevation is generally in the middle section of the revetment (Hardwicke Street), particularly since 1997.
- The southern section of beach (Head Street) generally experiences less elevation fluctuations than the other sections.

The profile envelopes in Figures 4.1 to 4.3, also include changes to the land level as a result of the Christchurch Earthquake Sequence, with the elevation of survey pins in the promenade wall dropping by the following amounts between the January 2011 and January 2012 surveys:

- C0070 Head St: -0.273 m
- C0112 Hardwick St: -0.351 m
- C0150 Mariner St: -0.066 m

Unfortunately, the January 2011 and 2012 surveys across the revetment were not sufficiently detailed to determine if the structure also suffered subsidence or rock displacement as a result of the earthquake. Although all sites experienced a drop in beach level over this period, it cannot be determined whether and how much of this was due to the effect of earthquakes or coastal processes. As stated above, it is also noted that all sites have experienced a net increase in beach elevation at the toe of the revetment since this time, with average elevation at each site since February 2012 being in the range of 0.15 m to 0.40 m higher than the average for the total record.

4.2 Revetment profiles

The pre-earthquake surveys across the revetment generally only included survey points at the top and bottom of the revetment, hence was not possible to draw a profile of the surface of the revetment. Surveys since 2012 have generally included more points on the revetment, that has allowed the composite revetment profiles presented in Figures 4.1 to 4.3 to be constructed. It is assumed in these profiles that rocks in the revetment have not altered position and that no new rock has been added over this period. The revetment toe foundation elevations and widths include exposed revetment points from minimum profile surveys prior to 2012. Again, it is assumed that the rocks in the toe foundation have not changed position or elevation since they were surveyed.

A summary of the revetment characteristics from the composite profiles are presented in Table 4.3. Note that the information presented for the toe foundation is only the known limits from the surveys and does not necessarily represent the actual width and depth of the foundation. This would only be able to be determined by either trenching to expose the whole foundation or Ground Penetrating Radar to determine its limits.

Table 4.3: Revetment characteristics from ECan surveys

		C0070 Head St	C0112 Hardwicke St	C0150 Marriner St
Promenade most seaward elevation		3.32	3.38	3.59
Land elevation immediately behind revetment		3.06	3.36	3.53
Max revetment elevation		3.21	4.31	4.17
Revetment slope		1: 3.2	1: 2.4	1: 3.8
Toe foundation	**Start elevation**	0.42	0.09	0.15
	Width (m)	4.7	7.7	5.0
	Slope	1: 7.4	1: 7.1	1: 7.6
	Min known depth	-0.21	-0.99	-0.51

5. Initial Condition Assessment

5.1 Site Walk Over Results

The initial condition assessment during the site walk over in December 2017 identified 36 locations which were visually identified to having either/or; localised low spots in the revetment crest, small armour rock size or missing armour rock, slumping of the revetment profile, steep revetment gradients resulting in localised narrow width, and the presence of large concrete units in the revetment material (considered to be a potential durability and aesthetic issue).

An overview of the locations of these initially assessed areas of poor condition are shown in Figure 5.1, with the more detailed insert maps A1 to A5 being presented in Appendix C. The map key highlights the type of issue or combination of issues at each location. Details of information and photographs collected on the site walk over plus information generated from the 2015 LiDAR surveys at each site are presented in Appendix D.

However, as pointed out in Section 2, it should not be discounted that other areas of the revetment may also not fit the optimum design criteria for elevation, rock size and slope.

The visual assessment identified in total 285 m of the total 1.2 km revetment length as having at least one poor condition (e.g. 24%), with around 180 m displaying a combination of at least two poor conditions (e.g. 15%). In several locations, rocks displaced from the revetment were also evident in the beach in front of the structure. The revetment lengths observed to be potentially inadequate to meet the optimum design conditions were:

- Too small armour rock size: 15 sites covering approx. 126 m (11% of total)
- Localised low revetment crest elevation: 19 sites covering approx.136 m (11%)
- Slumping of revetment profile: 12 sites covering approx. 96 m (8%)
- Over steepened revetment slope/narrow width: 7 sites covering approx. 59 m (5%)
- Concrete blocks present in revetment armour material: 8 sites covering approx. 76 m (6%)

From Appendix C, it is notable that the majority of the issue locations are in the northern section of the revetment, particularly from Marriner Street to Hardwicke Street, which contains half of the identified areas within a 320 m length.

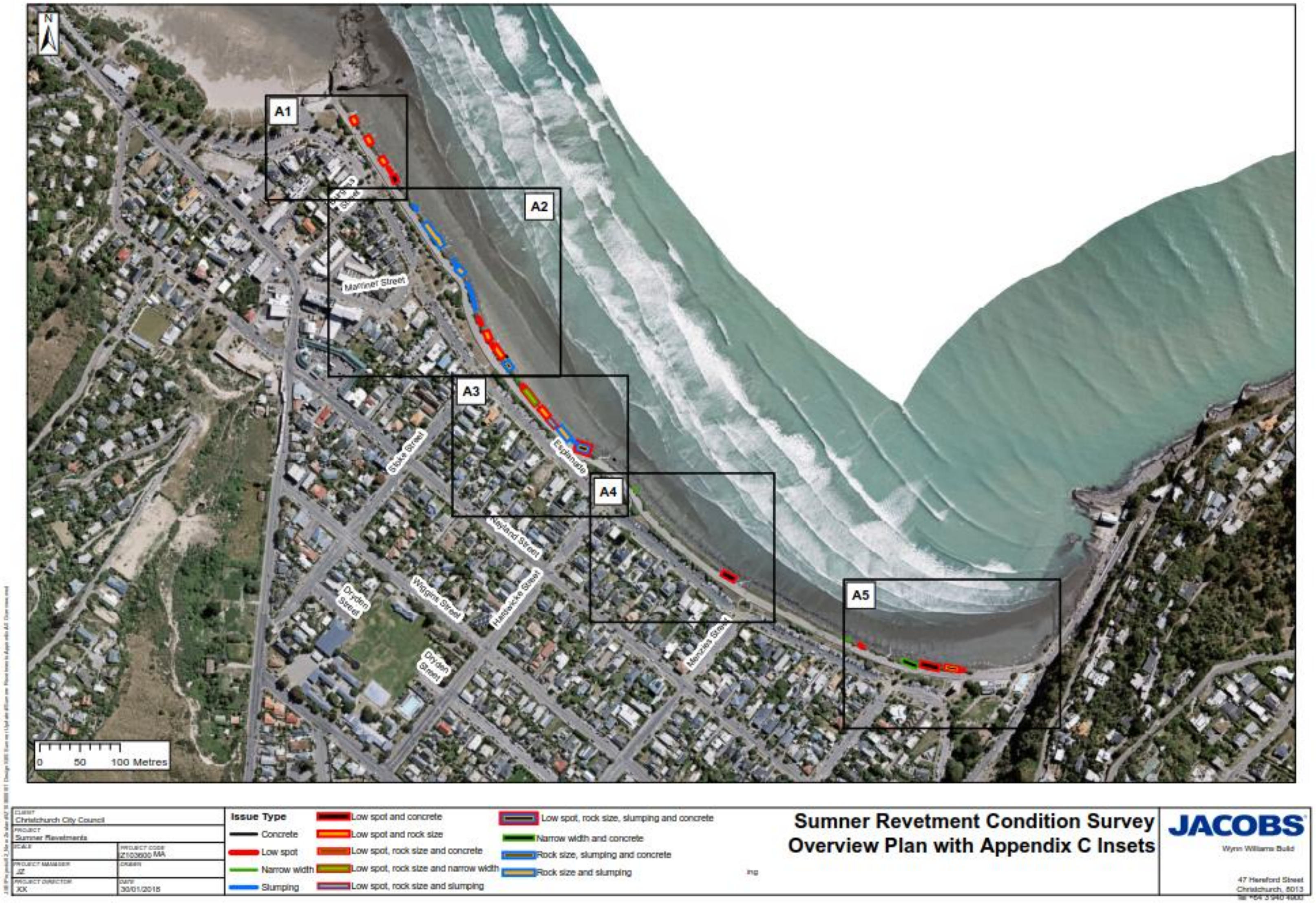

Figure 5.1: Overview of Issue locations identified from initial walk-over condition assessment

5.2 Total Revetment Crest Elevation Assessment

The results of the long-shore profile along the crest of the revetment generated from the LiDAR (2015) data is presented in Figure 5.2. While there is some uncertainty with the accuracy of the profile due to difficulty in accurately locating the top of the revetment on the images, its provides a good indication of the general crest elevation along the length of the revetment.

The results indicate that the revetment is higher in the northern end, generally being above 3.4m VLD to the north of Stroke St, and in the range 2.8 to 3.2 m at Scarborough to the south of Head Street. The lowest elevation shown on the graph is a beach access way north of Menzies Street, which was identified as a critical location in the walkover assessment. These elevations are assessed against the optimum design elevations in sections 6 and 7.

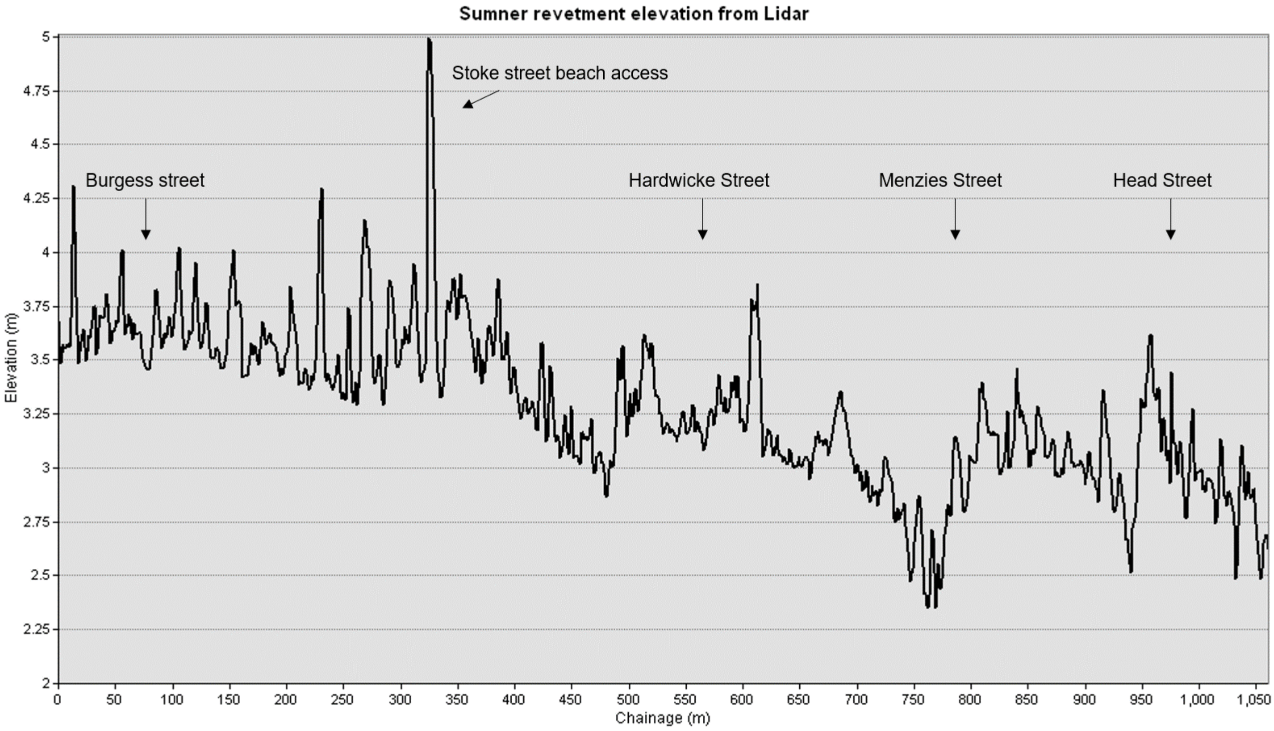

Figure 5.2: Revetment crest elevation long-section from LiDAR (2015) data

6. Optimum Revetment Design

6.1 Under current conditions

6.1.1 Design Parameters

Based on the met-ocean and beach profile information presented in Sections 3 and 4 above, the following design parameters in Table 6.1 are applied to the calculation of the optimum design heights, slopes, and size/grading for current water levels. The parameters are presented for the minimum beach elevation adjacent to the revetment toe sampled from the profile surveys at each of Head, Hardwicke and Marriner Street.

For optimum design, the beach elevation at the revetment toe is a key driver behind the selection of the revetment crest height as it dictates the size of the design wave conditions reaching the wall. To take account of possible scour and storm profile adjustments, the minimum recorded beach elevation has been used. It is recognised that this approach could result in a conservative assessment of required revetment crest height, but in the absence of justification of a higher profile elevation, is considered the most appropriate approach.

The wave levels applied to the calculation of the design parameters are the 1% AEP storm tide from Goring (2018). There is a 50% chance of a 1% AEP (100 yr ARI) event occurring over the next 50 years. However, a sensitivity testing of the resulting revetment crest elevation for higher percentage AEP (e.g. lower return period) events is presented in section 6.1.4.

Table 6.1: Design parameters for current water level conditions

Design Parameter	With 1%AEP current water levels from Goring (2018)		
	Head Street	Hardwicke St	Marriner St
Beach elevation	-0.21 m	-0.99 m	-0.51
Beach slope	1:50	1:55	1:55
Max Water depth at toe	2.32	3.10	2.62
Max Wave height at toe	1.80	2.40	2.04
Wave period	8 sec	8 sec	8 sec

6.1.2 Design assumptions

Following discussions with Council Parks staff, the following design and damage criteria assumptions were made for the optimum design:

- No geotextile for the main slope, with any additional rock to be placed over the existing revetment.
- Generally two layers of armour rock, and 2 layers of underlayer rock over the historical fill material.
- Rock density of 2650 kg/m^3 for volcanic rock (basalt)
- Rock size such that only minor damage would occur to the revetment under design conditions. Minor damage is defined as 0-5% of rock displaced in design conditions (e.g. 1%AEP storm tide levels).
- Revetment height and slope overtopping to be such that overtopping rates not be dangerous to pedestrians on the promenade behind the revetment. As recommended by the EurOtop Manual (2018) the adopted overtopping criteria for safe pedestrian access behind the revetment has been set at less than 0.3 litres/s/m.

6.1.3 Resulting Design Characteristics

The resulting design characteristics of the revetment to meet the above input parameters and assumed design required under the current sea levels are given below and presented in schematic form in Figure 6.1:

- Rock Size: Primary Armour Layer: M50[2] **2.3t**. Dn50[3] **1 m**
  Underlayer: M50 **0.2t**. Dn50 **0.4 m**
- Revetment Crest Elevation: **4.8m LVD**
- Armoured crest width: **Approx. 4.75m**
- Revetment Slope: **1: 3.5**
- Toe Design: As per CIRIA (2007) Rock Manual for areas of moderate scour potential:
  Toe width in the order of 3m (e.g. 3 x Dn50),
  Excavation of the beach material to the depth of anticipated scour, approximately 2.4m, being the maximum wave height at the revetment toe for the minimum profile elevation at Hardwicke St. Hence, toe excavation would need to be to a depth of -3.4m LVD.

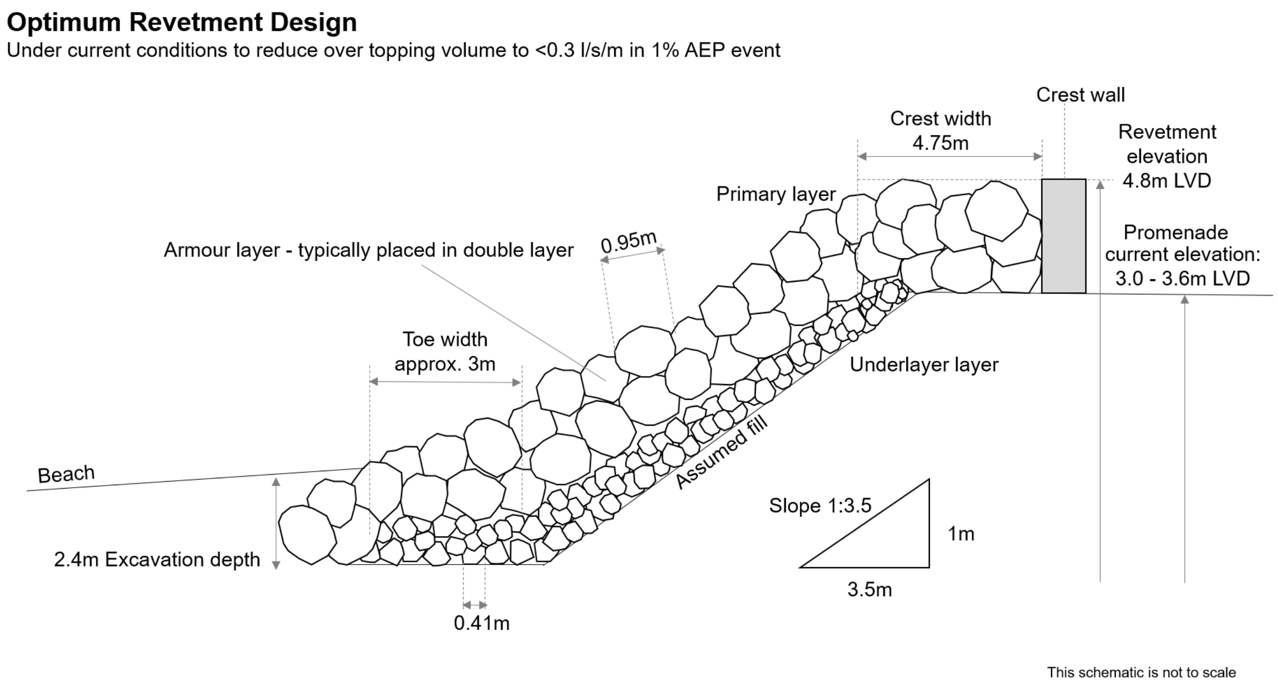

Figure 6.1: Schematic of Optimum Revetment Design

From comparing the above optimum design crest elevation to the actual crest elevations in Figure 5.2, the whole 1.2 km of the revetment length is below the crest elevation required to meet the design criteria for safe pedestrian access along the promenade under 1% AEP storm event water levels. For the northern end of the revetment, the crest elevations are in the order of 1.2 m below required, while at the southern Scarborough end, the revetment crest is up to 1.8m below the required elevation.

6.1.4 Sensitivity Testing of Crest Elevation

Due to the above result of unsafe magnitudes of overtopping for pedestrian access along the promenade in design storm events, sensitivity testing of the required revetment crest elevation to meet the design overtopping criteria (<0.3 l/s/m) was undertaken for higher percentage AEP (e.g. lower return period) events. For this sensitivity testing all other revetment optimum design parameters remained the same as above. The results of the sensitivity testing are presented in Table 6.2.

[2] M50: The median (e.g 50th percentile) mass of the rocks

[3] Dn50: The median (e.g 50th percentile) diameter of the rocks

Table 6.2: Sensitivity of Revetment crest elevation to design water level

%AEP	1%	2%	5%	10%	18%	39%
ARI	100yr	50yr	20yr	10yr	5yr	2yr
Crest elevation (m LVD)	4.80	4.65	4.50	4.35	4.25	4.05

Comparing these results to the crest elevations in Figure 5.2, indicate that apart from isolated spots, even a 2 year return period event would overtop the total length of the revetment by a magnitude that would exceed the safe criteria for pedestrian access on the promenade.

6.2 Future sea level rise conditions

6.2.1 Design Parameters

As per section 3.4, the design sea level rise to be applied over the next 50 years is 0.45m under the RCP8.5 climate change scenario (MfE, 2017). It is noted that under the full range of RCP scenarios, this magnitude of sea level rise could occur between 40 years (e.g. 2010) and 80 years (2100).

Table 6.3 presents the design conditions under this scenario, which includes 0.4m of drop in beach profile elevation at the revetment toe as estimated by the Bruun Rule (1962), which is added to SLR for depth of water at the revetment toe.

Table 6.3: Design parameters for future conditions with sea level rise of 0.45 m

	With 1%AEP water levels from Goring (2018)		
	Head Street	**Hardwicke St**	**Lower 25th percentile conditions**
Beach elevation	-0.6 m	-1.4 m	-0.25
Beach slope	1:50	1:55	1.50
Max Water depth at toe	3.15	3.95	2.80
Max Wave height at toe	2.45	3.10	2.20
Wave period	8 sec	8 sec	8 sec

6.2.2 Design assumptions

The design and damage assumptions for the optimum design with 0.45m of sea level rise are the same as given in section 6.1.2 for the current conditions.

6.2.3 Resulting Design Characteristics

The resulting design characteristics of the revetment to meet the above input parameters with sea level rise and assumed design are given below:

- Rock Size: Primary Armour Layer: M50 **2.3t**. Dn50 **1 m**
  Underlayer: M50 **0.2t**. Dn50 **0.4 m**
- Revetment Slope: **1: 3.5**
- Revetment Crest: **Elevation: 4.8m LVD,** with Armoured crest **width of Approx. 4.75m,** and **inclusion** of an **impermeable crest wall** at the back to limit overtopping volumes onto the threshold limits for safe pedestrian passage along the promenade.
- Toe Design: As per CIRIA (2007) Rock Manual for areas of moderate scour potential:
  Toe width in the order of 3m (e.g. 3 x Dn50),
  Excavation of the beach material to the depth of anticipated scour, approximately 2.4m, being the maximum wave height at the revetment toe for the minimum profile elevation at Hardwicke St. Hence, toe excavation would need to be to a depth of -3.4m LVD.

The results indicate that the optimum revetment rock size and slopes to meet the design criteria current conditions will be sufficient to meet damage criteria with a 0.45 m sea level rise, however crest elevation will need to be progressively increased by 0.8m to maintain design protection standards for overtopping with sea level rise over the next 50 years.

7. Condition Assessment Against Optimum Design

7.1 Under current conditions

This assessment focuses on the 36 locations with potential design issues identified in the initial site walk over in December 2017. For each of these sites, a ranking of critical issues is assigned to the site relating to the number of issues that do not meet the optimum design criteria, as per Table 7.1. For critical slope criteria, a tolerance of 1:0.5 has been applied, such that slopes flatter than 1:4 are assigned as being slumped flat slopes, and slopes steeper than 1:3 are assigned as being over-steepened, implying that rock size is more critical to reduce potential displacement of rock units. Since the whole revetment length is below the optimum design elevation of 4.6 m LVD, all the sites have been assigned as being critical for elevation. Note that the presence of concrete blocks in the profile is not included in the critical issue ranking.

This ranking has also been adopted to determine the priority for maintenance which is addressed in Section 8. The spatial locations of critical issues are presented in Figure 7.1, with the more detailed insert maps A1 to A5 being presented in Appendix E.

Table 7.1: Assessment Criteria for determining priority of maintenance.

Critical Issue Rank	Non-compliance to optimum design criteria	Number of Sites
3a	High priority: Three issues: Steep slope, rock size, elevation.	3
3b	High priority: Three issues: Flat slope, rock size, elevation.	5
2	Medium priority: Two issues: Rock size and elevation. Slope and elevation	7 4
1	Low priority: Elevation	17

In summary, the following points can be made:

- All 36 initially identified locations do not meet at least one of the optimal design criteria (rock size, slope, elevation) for current conditions. It is noted that critical elevation is not restricted to these identified areas.
- There are 8 high priority sites that did not meet any of the three critical design criteria, hence are most likely to be subjected to revetment damage and overtopping under current extreme storm conditions. The three sites classed as 3a (sites 1,3 and10 at the northern end of the revetment) are highest priority sites given the risk of rock displacement due to having small rock sizes and steep slopes.
- Of the 11 medium priority sites, the 7 sites with rock size issue are considered the higher priority to reduce storm damage potential, with slope regrades being a lower priority.
- 17 of the identified sites only require an increase in crest elevation to meet the design criteria to prevent overtopping to dangerous levels. This is assigned the lowest priority as with sufficient rock size and slopes, there should not be damage to the revetment in design storm conditions However, as stated above, the failure to meet optimum crest elevations to prevent overtopping to dangerous levels for pedestrians on the promenade is a revetment wide issue, not restricted to the identified critical areas.

7.2 Under future sea level rise conditions

The optimum design revetment crest elevation under a 0.45m sea level scenario raises to 5.6 m LVD. Hence, the frequency and magnitude of potentially dangerous overtopping onto the promenade will increase in the future, and may become an annual occurrence without increases in crest elevation.

Since the optimum design rock size and slopes are the same with future sea level rise, the number of critical sites breaching these design criteria should not increase, with damage most likely concentrated on the 15 sites identified as having rock size issues.

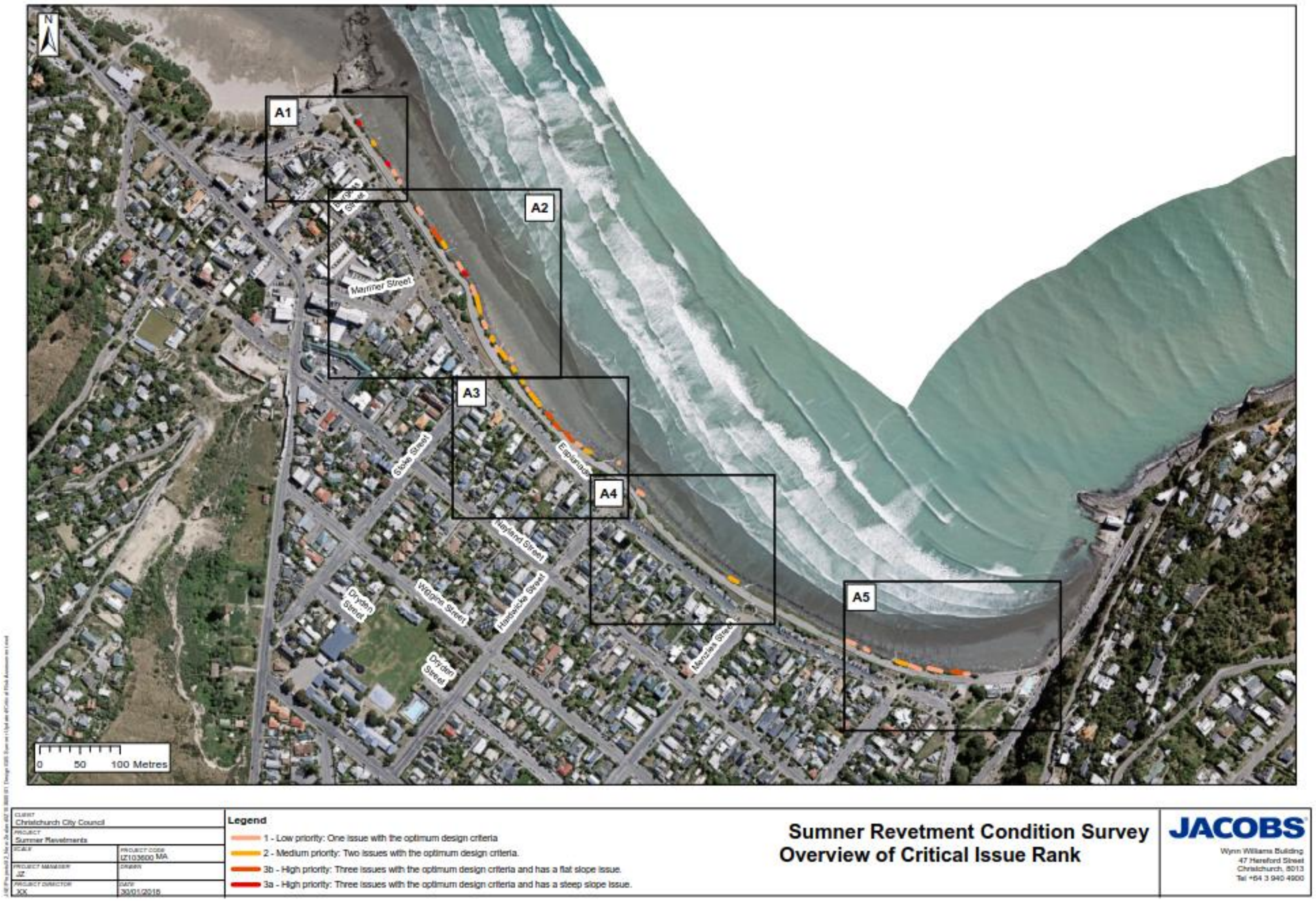

Figure 7.1: Location of Critical Issue Ranks

8. Maintenance Recommendations

As identified in Section 6.1, under the current conditions the total length of the revetment does not meet the crest elevation criteria of the optimal design, and many of the observed critical locations also do not meet the additional slope and rock size criteria. Priority maintenance rankings are presented in Table 7.1 and locations presented in figure 7.1 and in more detail in Appendix E.

Sites classed as 3a are the highest priority sites given the consequences of having small rock sizes and steep slopes, meaning the structure is more likely to suffer future damage (rock displacement) at these locations, which in turn could result in additional risk of overtopping onto the promenade. There are three sites in this category (sites 1,3 and10 at the northern end of the revetment). Sites classed as 3b (5 sites from Marriner St to Hardwicke St) also do not meet all three design criteria but have a slightly lower priority relative to the steep sloped revetment sites, as they are likely to suffer less rock displacement in storm events.

Maintenance of these identified high priority sites could involve the addition of large basalt armour rocks which meet the optimum rock size criteria (e.g Dn50 = 1 m) and reprofiling to meet the optimum revetment slope criteria (min slope 1:3.5). Before placing the armour rock, slope trimming and preparation should be undertaken. This should include removal of loose, soft or spongy material, and any large elements projecting through the slope (e.g. existing concrete blocks). The resulting minor potholes or hollows should be filled with selected non-cohesive underlayer materials (e.g. quarry run) to achieve the design slope of the revetment. It is recommended that rock placement be undertaken using land based earthmoving equipment working from the promenade, with some work from the tidal flats during sufficiently low tides as required. Materials would be delivered to site by road trucks. Placement should be made from the toe to the top and shall ensure interlocking with the core material, as well as a finished surface which is stable, tight and uniform. Each placed layer shall be protected by the subsequent layer as soon as possible after placement in order to minimise damage in the case of a storm event.

The seven medium priority (e.g. critical rank 2) sites where armour rock size are an issue should be the third priority to be maintained, so that sufficient size armour material is in place to reduce the likelihood of further rock displacement, which may result in slope issues. The majority of these sites are to the north of Hardwicke St. The above recommended site preparation and rock placement stages should be followed.

The other four medium priority areas with slope issues are a lower priority for maintenance as displacement of the sufficiently sized existing armour rock is less likely than for small rocks. For these sites, additional armour rock may still be required and existing armour rock repositioned to achieve optimum slopes. It is noted that there may be additional areas not identified in the initial walk-over which also do not meet the optimum slope criteria

8.1 Crest elevation considerations.

As previously identified, the whole 1.2 km revetment crest is below the optimum design elevation (4.6 m LVD) required to meet the design overtopping threshold. Although it is recognised that the design storm is likely to be an infrequent occurrence, the sensitivity analysis indicates that overtopping to dangerous levels could occur in events that have the probability of occurring every two years. Significant works would be required along the total length to increase the elevation even to the magnitude required to provide protection in a two-year return period overtopping event, let alone the 1% AEP design storm, or the added effects of sea level rise. It is considered that such works would be capital works rather than maintenance, with costs likely to be beyond current funding allocations. It is also understood that Council do not wish to take any land on the promenade for placement of material to increase crest width and elevation. Therefore, a different approach to the risk of overtopping is likely to be required.

Since the main concern surrounding overtopping is the safety of pedestrians along the promenade, a possible mitigation measure that could be put in place in the interim period is managing access to the promenade during large storm events. This would lower the design performance of the seawall and would result in lower seawall crest levels and associated capital expenditure. Heavy overtopping flows could be managed with the upgrade of the existing setback wall separating the promenade from the Esplanade to prevent inundation of key infrastructure located on the landward side during existing design storm scenarios. The existing wall could also be upgraded in the future to adapt to future sea level conditions.

9. Conclusions

This review involved a condition assessment of the Sumner revetment to identify areas which would be subjected to over topping and structure damage in current and future storm events. An initial walk over inspection identified 36 critical areas where there were potential issues with combinations of rock size, revetment height and slope which may affect the functionality of the structure.

The development of an optimum design was used to comparatively assess vulnerability of the critical areas identified from a walk over inspection, and to determine what areas along the revetment should be a priority for maintenance. Following discussions with Council Parks Staff, the threshold damage and overtopping limits to be limiting rock displacement to less than 5% % and overtopping volumes to less than deemed dangerous to pedestrians on the promenade in a 1% AEP storm event. Based on the above thresholds and the met-ocean conditions, the optimum revetment design included the following:

- Rock Size: Primary Armour Layer: M50 **2.3t**. Dn50 **1 m**
  Underlayer: M50 **0.2t**. Dn50 **0.4 m**
- Revetment Slope: **1: 3.5**
- Revetment Crest: **Elevation: 4.8m LVD,** with Armoured crest **width of Approx. 4.75m,** and **inclusion** of an **impermeable crest wall** at the back to limit overtopping volumes onto the threshold limits for safe pedestrian passage along the promenade.
- Toe Design: As per CIRIA (2007) Rock Manual for areas of moderate scour potential:
  Toe width in the order of 3m (e.g. 3 x Dn50),
  Excavation of the beach material to the depth of anticipated scour, approximately 2.4m, being the maximum wave height at the revetment toe for the minimum profile elevation at Hardwicke St. Hence, toe excavation would need to be to a depth of -3.4m LVD.

A sensitivity analysis of the crest elevation required for higher frequency storm events revealed that to prevent dangerous overtopping for a two-year return period event would require a crest elevation of 4.05m LVD, an increase of up to 0.4 - 1m on existing elevations.

Consideration of SLR was limited to the next 50 years based on the RCP 8.5 scenario, being 0.45 m rise. Under this scenario, the required revetment crest elevation requirement to meet the overtopping threshold would be increased to 5.6m LVD, and toe excavation depth increased to approximately 3m. Rock size, slope and revetment crest width parameters would remain the same as for the current conditions.

Based on the optimum revetment design, a key finding from the assessment is the entire revetment structure is below the optimum design elevation of 4.8m LVD required to meet the functional requirement of safe pedestrian passage along the promenade in current 1% AEP conditions. To meet this criteria would require a major upgrade involving raising the revetment crest by 1.2 to 1.8 m and increasing the revetment crest width to 4.75 m over the entire 1.2 km length of the structure. This is considered to be capital works requiring significant capital expenditure rather than maintenance, so is not included in assigning priority areas for revetment maintenance. Instead, in the interim, a possible alternative mitigation measure that could be put in place is managing access to the promenade during large storm events. Heavy overtopping flows with future SLR could be managed with the upgrade of the existing setback wall separating the promenade from the Esplanade to prevent inundation of key infrastructure during extreme storm events.

Therefore, the it is recommended that maintenance priorities focus on the critical areas when repairs are required to increase the durability of the existing structure. This includes the following 19 sites from the walkover inspection:

- Three sites with small armour rock size and steep slopes (classed as 3a in the critical area ranking), are the highest priority sites for maintenance given the consequence of this combination for further rock displacement (damage) within the revetment structure.
- Five sites with small armour rock size and flat slopes (classed as 3b in the critical area ranking) have a slightly lower priority relative to the steep sloped revetment sites, as they are likely to suffer less rock displacement in storm events.

- The seven medium priority sites (e.g. critical rank 2) where armour rock size are an issue should be the third priority to be maintained, so that sufficient size armour material is in place to reduce the likelihood of further rock displacement, which may result in slope issues.
- The other four medium priority areas with slope issues are a lower priority for maintenance as displacement of the sufficiently sized existing armour rock is less likely than for small rocks. For these sites, additional armour rock may still be required and existing armour rock repositioned to achieve optimum design slopes. There may be additional areas not identified in the initial walk-over which also do not meet the design slope criteria.

Maintenance of the identified high priority sites could involve the addition of large basalt armour rocks which meet the optimum rock size criteria (dn50 = 1 m) and ensuring the slope at which these are placed fits the optimum structure criteria. Preparation work would be required at each site, and rock placement is recommended to be undertaken from the toe to the top using land based earthmoving equipment working from the promenade. Each placed layer shall be protected by the subsequent layer as soon as possible after placement in order to minimise damage in the case of a storm event.

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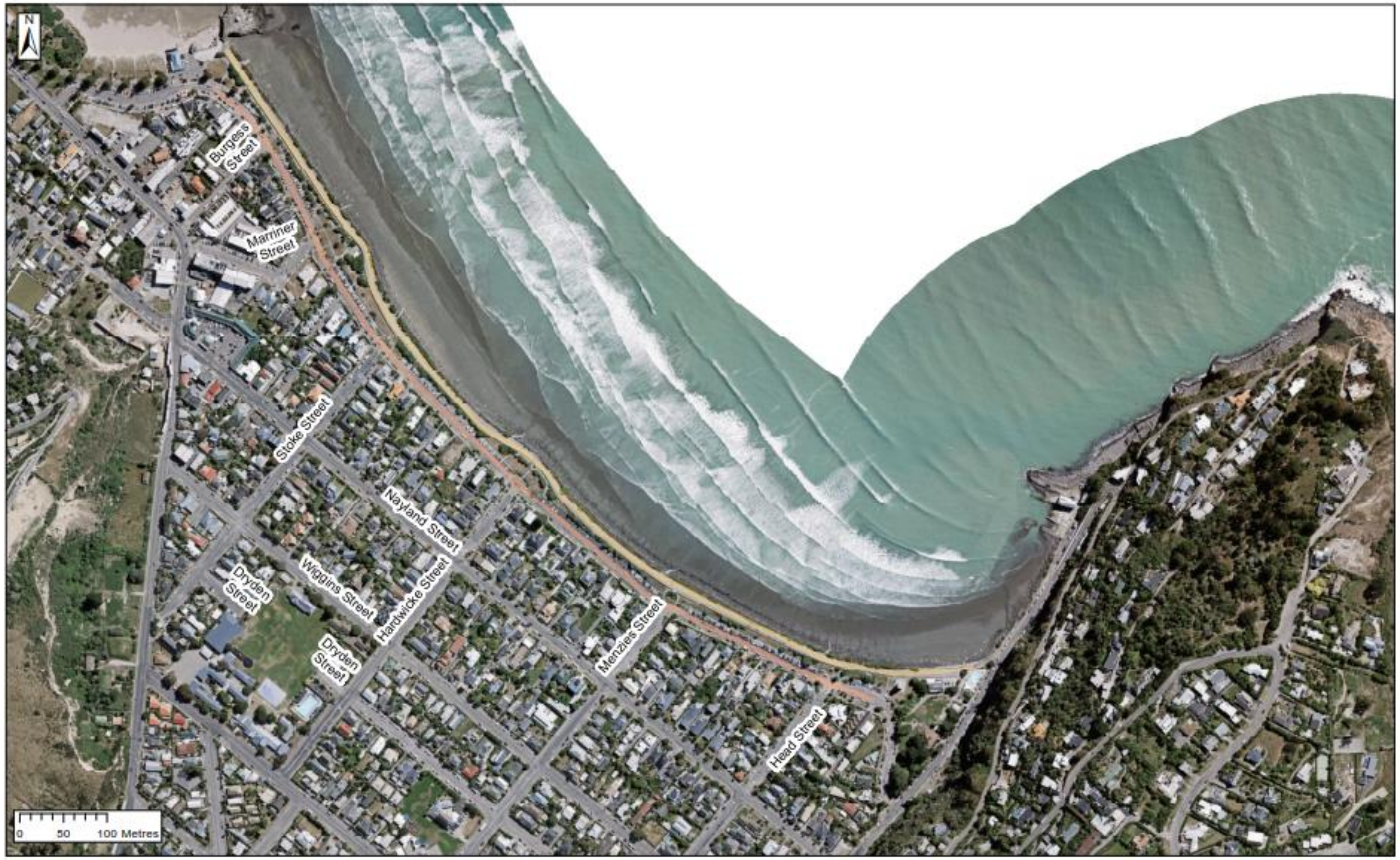
Appendix A. Study Area



CLIENT Christchurch City Council	
PROJECT Sumner Revetments	
SCALE	PROJECT CODE IZ103600
PROJECT MANAGER IW	DRAWN
PROJECT DIRECTOR	DATE 30/01/2018

Appendix A: Study Area

Promenade

Esplanade

Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900

Appendix B. Environment Canterbury Survey lines

CLIENT Christchurch City Council	
PROJECT Sumner Revetments	
SCALE	PROJECT CODE IZ103600
PROJECT MANAGER IW	DRAWN
PROJECT DIRECTOR XX	DATE 30/01/2018

Appendix B: Environment Canterbury survey lines

Control points

Profile lines

Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900

Appendix C. Sumner Revetment Condition Survey Insets

CLIENT Christchurch City Council		
PROJECT Sumner Revetment Condition Survey		
SCALE	PROJECT CODE IZ103600 MA	
PROJECT MANAGER JZ	DRAWN	
PROJECT DIRECTOR XX	DATE 30/01/2018	

Issue Type
- Low spot
- Low spot and concrete
- Low spot and rock size

Sumner Revetment Condition Survey
Appendix C: A1 Esplanade to Burgess Street

JACOBS
Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900

CLIENT Christchurch City Council	
PROJECT Sumner Revetments	
SCALE	PROJECT CODE IZ103600 MA
PROJECT MANAGER JZ	DRAWN
PROJECT DIRECTOR XX	DATE 30/01/2018

Issue Type

- Concrete
- Low spot
- Narrow width
- Slumping
- Low spot and concrete
- Low spot and rock size
- Rock size, slumping and concrete
- Rock size and slumping

Sumner Revetment Condition Survey
Appendix C: A2 Burgess Street to Stoke Street

JACOBS
Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900

CLIENT: Christchurch City Council		**Issue Type**	
PROJECT: Sumner Revetments		Concrete	Low spot and rock size
SCALE	PROJECT CODE: IZ103600 MA	Low spot	Low spot, rock size and narrow width
PROJECT MANAGER: JZ	DRAWN	Narrow width	Low spot, rock size and slumping
PROJECT DIRECTOR: XX	DATE: 30/01/2018	Slumping	Low spot, rock size, slumping and concrete
			Rock size and slumping

Sumner Revetment Condition Survey

Appendix C: A3 Stoke Street to Hardwicke Street

Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900

CLIENT Christchurch City Council	
PROJECT Sumner Revetments	
SCALE	PROJECT CODE IZ103600 MA
PROJECT MANAGER JZ	DRAWN
PROJECT DIRECTOR XX	DATE 30/01/2018

Issue Type

- Narrow width
- Low spot and concrete

Sumner Revetment Condition Survey

Appendix C: A4 Hardwicke Street to Menzies Street

Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900

Issue Type

- Concrete
- Low spot
- Narrow width
- Low spot and concrete
- Low spot, rock size and concrete
- Narrow width and concrete

CLIENT Christchurch City Council	
PROJECT Sumner Revetments	
SCALE	PROJECT CODE IZ103600 MA
PROJECT MANAGER JZ	DRAWN
PROJECT DIRECTOR XX	DATE 30/01/2018

Sumner Revetment Condition Survey
Appendix C: A5 Head Street to Esplanade

Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900

Appendix D. Identified critical sites with walkover survey and Lidar summary

Site 1							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5176220	1580619	2.2	3.61	5.8	2.89	0.3-0.6	3a
Other issues identified: Localised low spot.							

Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 2							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5176199	1580636	3.8	3.5	8	3.48	0.2-0.3m	2
Other issues identified: Localised low spot at track from promenade to top of revetment.							

Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 3							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5176167	1580659	3.2	3.6	7.5	2.94	0.2-0.3m	3a
Other issues identified: Localised low spot.							

Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 4							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5176167	1580662	5.8	3.4	7.6	3.04	No issue	1
Other issues identified: Localised low spot at track from promenade to top of revetment.							

Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 5							
North End Co-ordinates (NZTM)		**Length of Area (m)**	**Crest Elevation from Lidar (m LVD)**	**Revetment Width from Lidar (m)**	**Revetment Slope**	**Est. Armour Rock size if considered issue**	**Actual Critical Analysis Rank for Priority Assessment**
Northings	**Eastings**						
5176145	1580668	2.8	3.50	9.2	3.54	No issue	1
Other issues identified: Localised low spot at narrow track from promenade to top of revetment, concrete units							

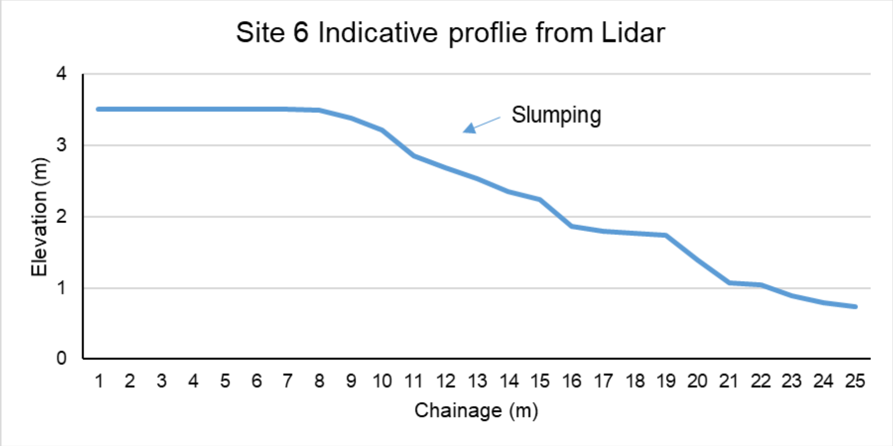
Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 6							
North End Co-ordinates (NZTM)		**Length of Area (m)**	**Crest Elevation from Lidar (m LVD)**	**Revetment Width from Lidar (m)**	**Revetment Slope**	**Est. Armour Rock size if considered issue**	**Actual Critical Analysis Rank for Priority Assessment**
Northings	**Eastings**						
5176113	1580693	7.3	3.5	10.9	3.92	No issue	1
Other issues identified: Slumped section in front of high crest rocks.							

Site photos:

Slumped profile:

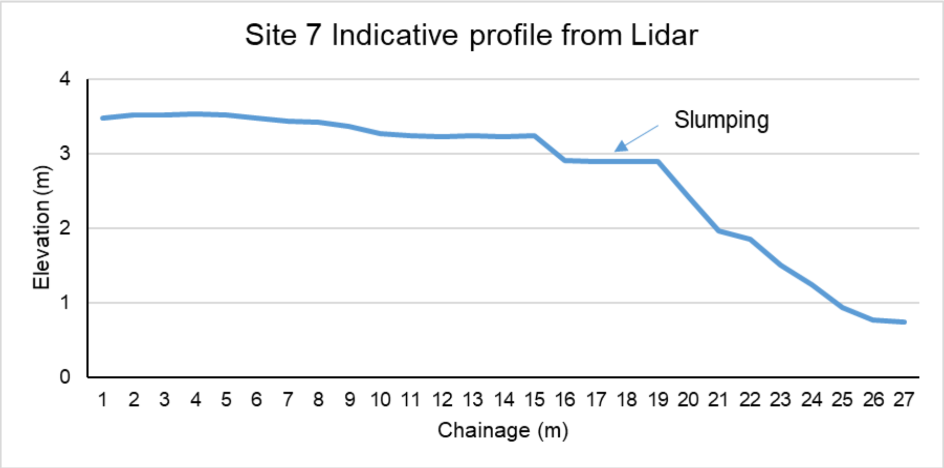


Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 7							
North End Co-ordinates (NZTM)		**Length of Area (m)**	**Crest Elevation from Lidar (m LVD)**	**Revetment Width from Lidar (m)**	**Revetment Slope**	**Est. Armour Rock size if considered issue**	**Actual Critical Analysis Rank for Priority Assessment**
Northings	**Eastings**						
5176088	1580710	18.4	3.44	11.4	4.16	0.25-0.3m	3b
Other issues identified: Flat slope to front of revetment.							

Site photos:

Slumped profile:

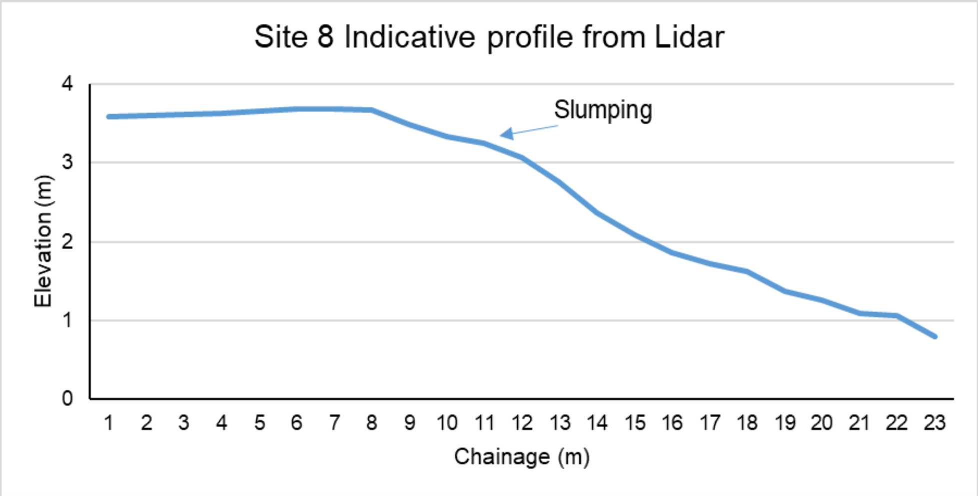


Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 8							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5176071	1580724	7.0	3.55	9.1	3.14	0.3-0.4m	2
Other issues identified: Slumped profile							

Site photos:

Slumped profile:

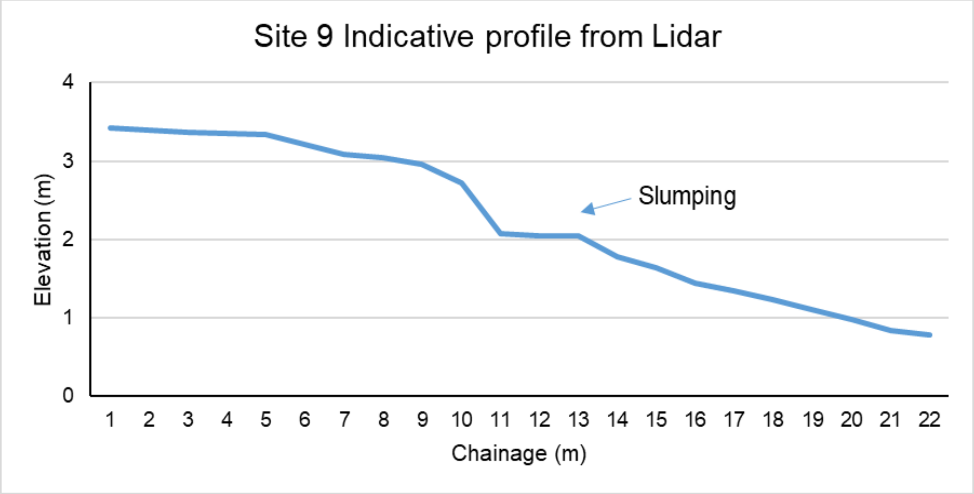


Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 9							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5176045	1580743	5.8	3.35	9.8	3.66	No issue	1
Other issues identified: Slumped in front of high crest rocks. Large rock in middle of area.							

Site photos:

Slumped profile:

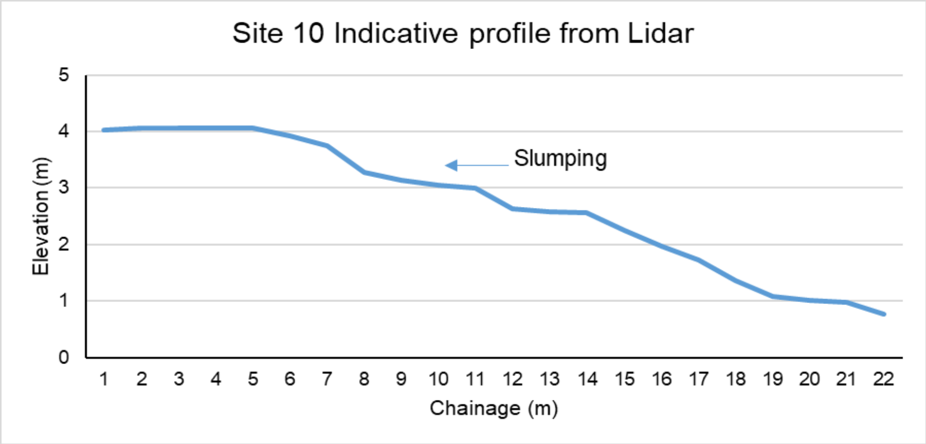


Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 10							
North End Co-ordinates (NZTM)		**Length of Area (m)**	**Crest Elevation from Lidar (m LVD)**	**Revetment Width from Lidar (m)**	**Revetment Slope**	**Est. Armour Rock size if considered issue**	**Actual Critical Analysis Rank for Priority Assessment**
Northings	Eastings						
5176035	1580753	4.2	4.07	9.5	2.91	0.3m	3a
Other issues identified: Slumped infront of high crest rocks.							

Site photos:

Slumped profile:

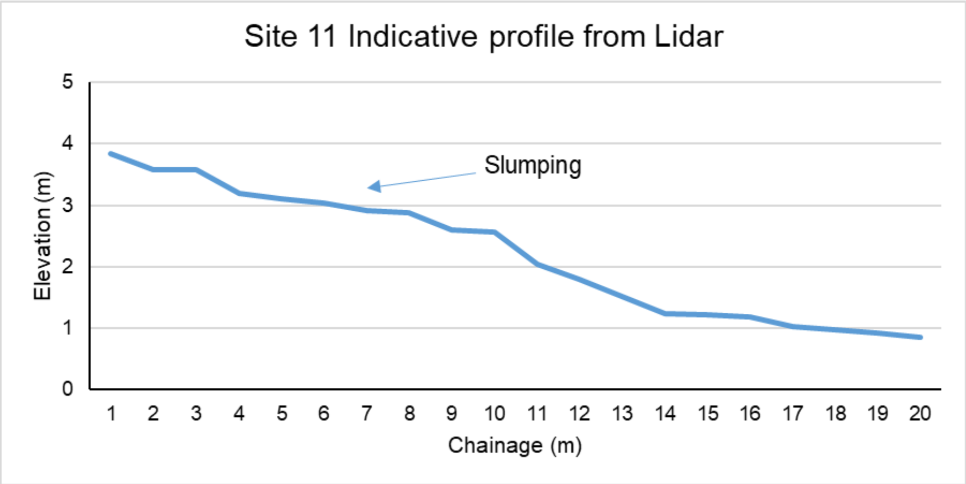


Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 11							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5176019	1580765	10.8	3.57	8.1	3.12	No issue	1
Other issues identified: Slumped infront of high crest rocks.							

Site photos:

Slumped profile:

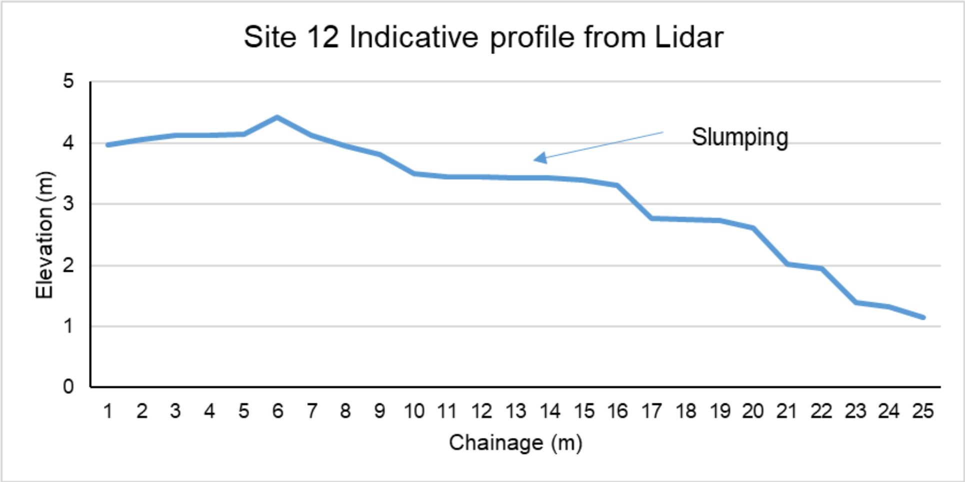


Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 12								
North End Co-ordinates (NZTM)		**Length of Area (m)**	**Crest Elevation from Lidar (m LVD)**	**Revetment Width from Lidar (m)**	**Revetment Slope**	**Est. Armour Rock size if considered issue**	**Actual Critical Analysis Rank for Priority Assessment**
Northings	**Eastings**						
5176005	1580775	20.0	3.39	7.2	2.75	No issue	2
Other issues identified: Slumped section (potential track) on upper revetment between high front and back rocks.							

Site photos:

Slumped profile:



Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 13							
North End Co-ordinates (NZTM)		**Length of Area (m)**	**Crest Elevation from Lidar (m LVD)**	**Revetment Width from Lidar (m)**	**Revetment Slope**	**Est. Armour Rock size if considered issue**	**Actual Critical Analysis Rank for Priority Assessment**
Northings	**Eastings**						
5175976	1580777	5.4	3.55	7.2	3.51	No issue	1
Other issues identified: Two localized low points. Lacks bulk in front of revetment.							

Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 14							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5175955	1580788	3.2	3.37	6.8	3.64	0.35-0.5m	2
Other issues identified: Localised low point							

Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 15							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5175949	1580793	5.1	3.5	7.0	3.5	No issue	1
Other issues identified: Localised low spot.							

Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 16							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5175941	1580797	11.7	3.50	6.5	3.42	0.3-0.5m	2
Other issues identified: Localised low spot							

Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 17							
North End Co-ordinates (NZTM)		**Length of Area (m)**	**Crest Elevation from Lidar (m LVD)**	**Revetment Width from Lidar (m)**	**Revetment Slope**	**Est. Armour Rock size if considered issue**	**Actual Critical Analysis Rank for Priority Assessment**
Northings	**Eastings**						
5175924	1580858	2.8	3.75	7.4	3.29	No issue	1
Other issues identified: Concrete units							

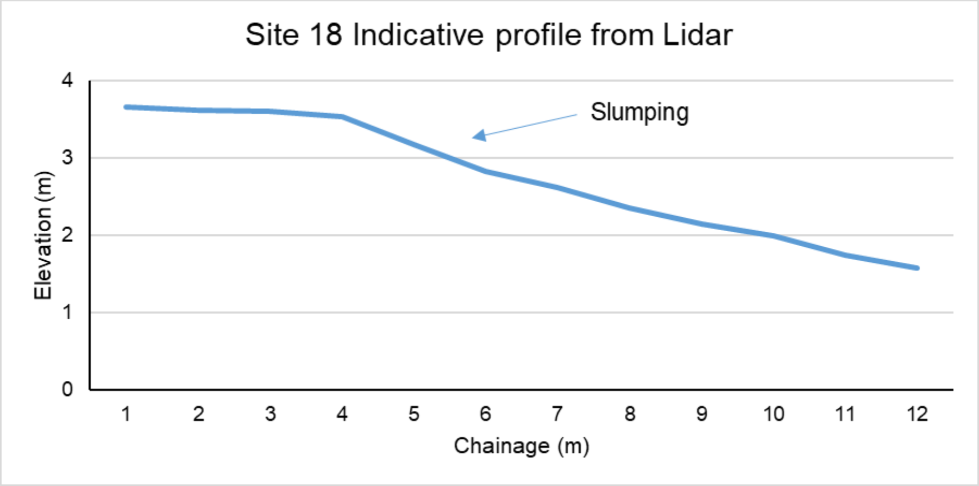
Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 18							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5175917	1580813	3.6	3.66	6.5	3.12	0.2-0.3m	2
Other issues identified: Slumped in front of high crest rocks. Narrow width. Concrete units.							

Site photos:

Slumped profile:

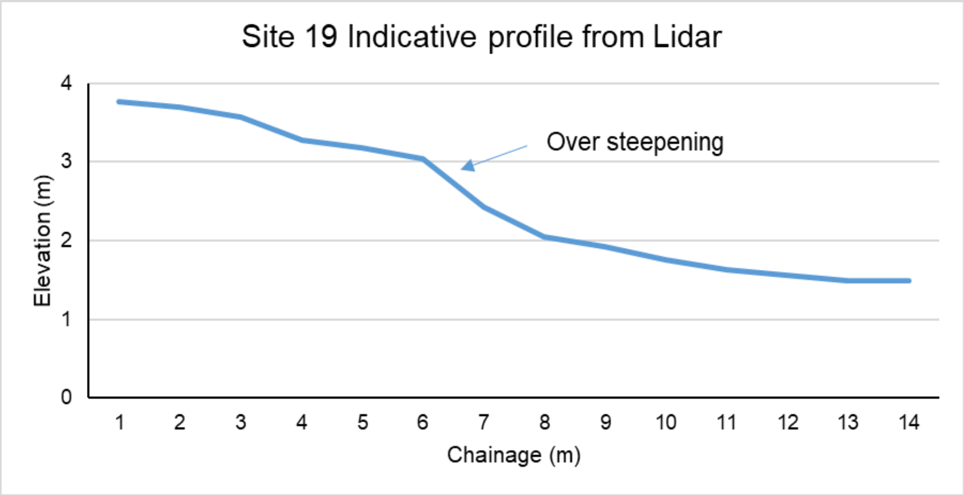


Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 19							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5175901	1580824	3.6	3.59	6.7	2.94	No issue	2
Other issues identified: Oversteepened toe due to loss of rock at bottom of revetment.							

Site photos:

Over steepened profile:



Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 20							
North End Co-ordinates (NZTM)		**Length of Area (m)**	**Crest Elevation from Lidar (m LVD)**	**Revetment Width from Lidar (m)**	**Revetment Slope**	**Est. Armour Rock size if considered issue**	**Actual Critical Analysis Rank for Priority Assessment**
Northings	**Eastings**						
5175890	1580832	2.4	3.25	6.1	3.43	No issue	1
Other issues identified: Localised low spot, narrow width.							

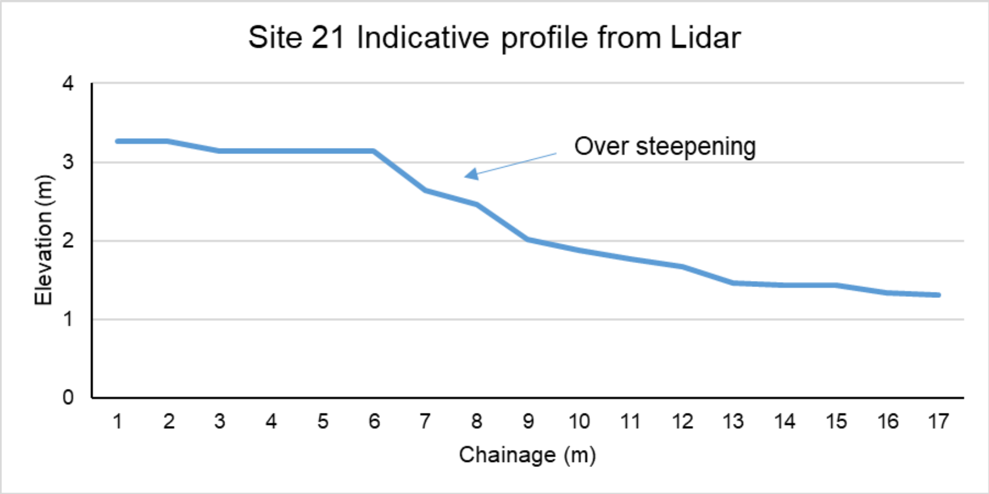
Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 21							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5175884	1580835	17.8	3.30	7.4	3.79	0.3-0.5m	2
Other issues identified: Localised low spot at narrow track from promenade to top of revetment. Oversteepened toe due to loss of rock at bottom of revetment (except one large rock). Concrete units.							

Site photos:

Over steepened profile:



JACOBS

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 22							
North End Co-ordinates (NZTM)		**Length of Area (m)**	**Crest Elevation from Lidar (m LVD)**	**Revetment Width from Lidar (m)**	**Revetment Slope**	**Est. Armour Rock size if considered issue**	**Actual Critical Analysis Rank for Priority Assessment**
Northings	**Eastings**						
5175863	1580855	8.5	3.16	7.1	4.03	0.3-0.5m	3b
Other issues identified: Localised low spot.							

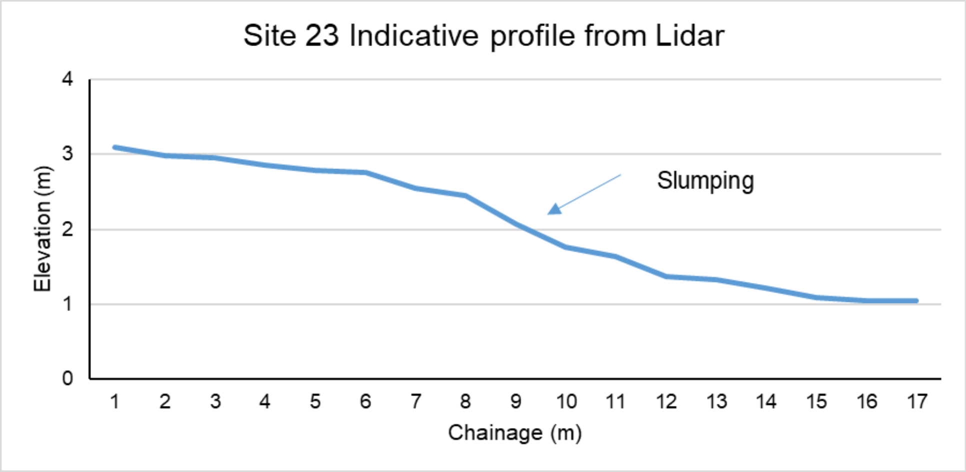
Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 23							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5175849	1580866	12.0	3.10	8.5	4.15	0.2-0.3	3b
Other issues identified: Localised low spot. Slumped in front of high crest rocks.							

Site photos:

Slumping profile:

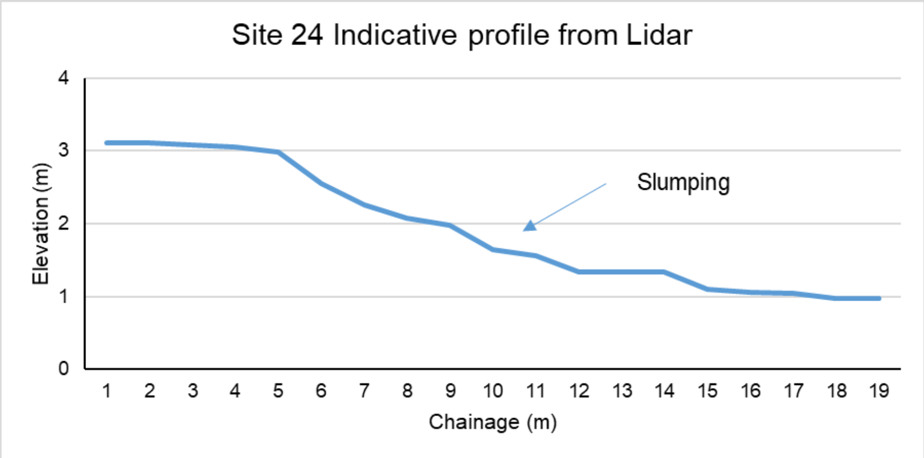


Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 24							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5175838	1580882	12.8	3.11	9.1	4.28	0.5m	3b
Other issues identified: Slumped in front of crest rocks, which lack volume – only single rock depth.							

Site photos:

Slumping profile:

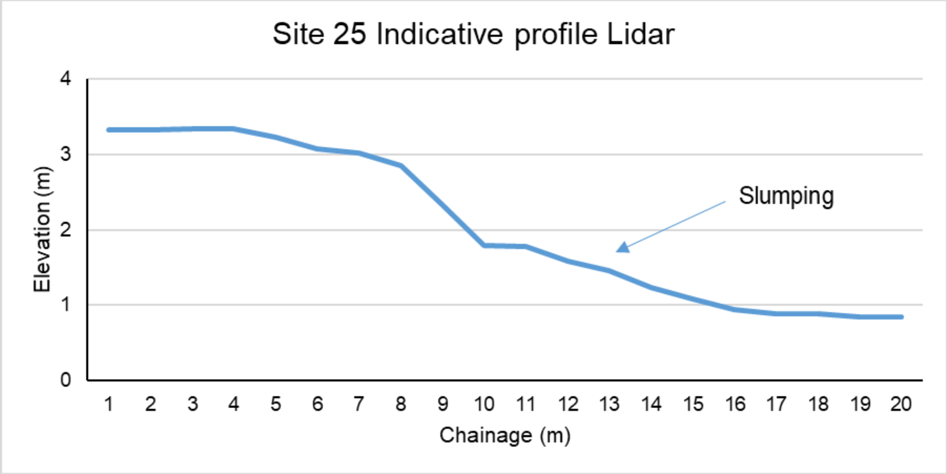


Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 25							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5175825	1580892	5.8	3.16	8.6	3.53	No issue	1
Other issues identified: Slumped profile lacking rock at the top of revetment.							

Site photos:

Slumping profile:

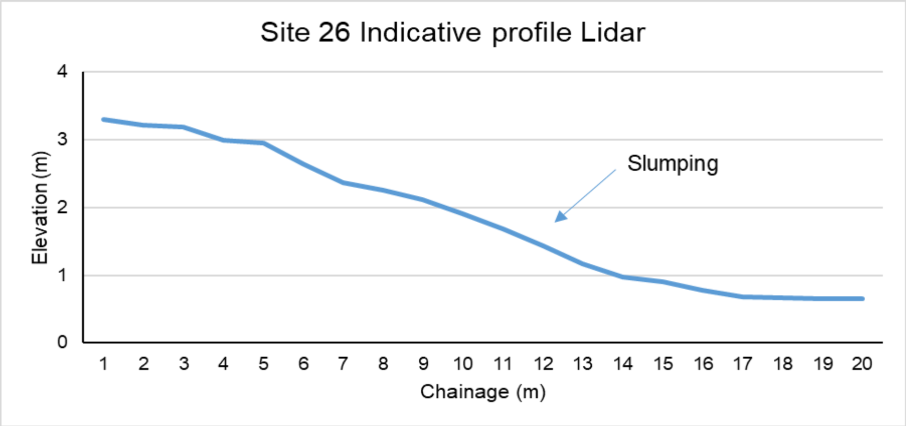


Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 26							
North End Co-ordinates (NZTM)		**Length of Area (m)**	**Crest Elevation from Lidar (m LVD)**	**Revetment Width from Lidar (m)**	**Revetment Slope**	**Est. Armour Rock size if considered issue**	**Actual Critical Analysis Rank for Priority Assessment**
Northings	**Eastings**						
5175816	1580904	6.3	3.27	10.25	3.91	0.5m	2
Other issues identified: Localised low spot. Slumped profile lacking rock with evidence of rock roll down onto the beach. Concrete units.							

Site photos:

Slumping profile:



Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 27							
North End Co-ordinates (NZTM)		**Length of Area (m)**	**Crest Elevation from Lidar (m LVD)**	**Revetment Width from Lidar (m)**	**Revetment Slope**	**Est. Armour Rock size if considered issue**	**Actual Critical Analysis Rank for Priority Assessment**
Northings	**Eastings**						
5175796	1580943	2.0	3.25	9.2	3.35	No issue	1
Other issues identified: Concrete units (with brick) near stormwater outlet.							

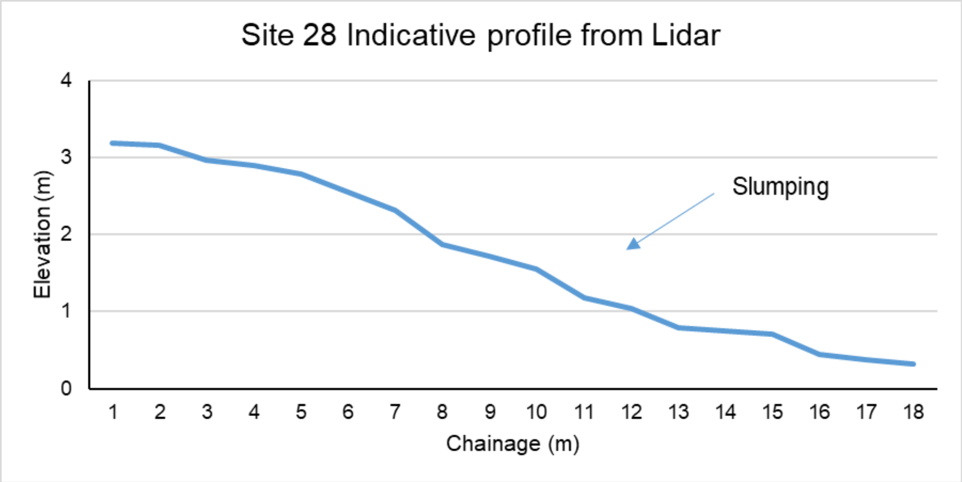
Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 28							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5175766	1580971	7.2	3.25	9.0	3.22	No issue	1
Other issues identified: Narrow width							

Site photos:

Slumped profile:



Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 29							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5175663	1581088	11.2	2.66	11.2	4.55	No issue	2
Other issues identified: Localised low spot. Concrete units.							

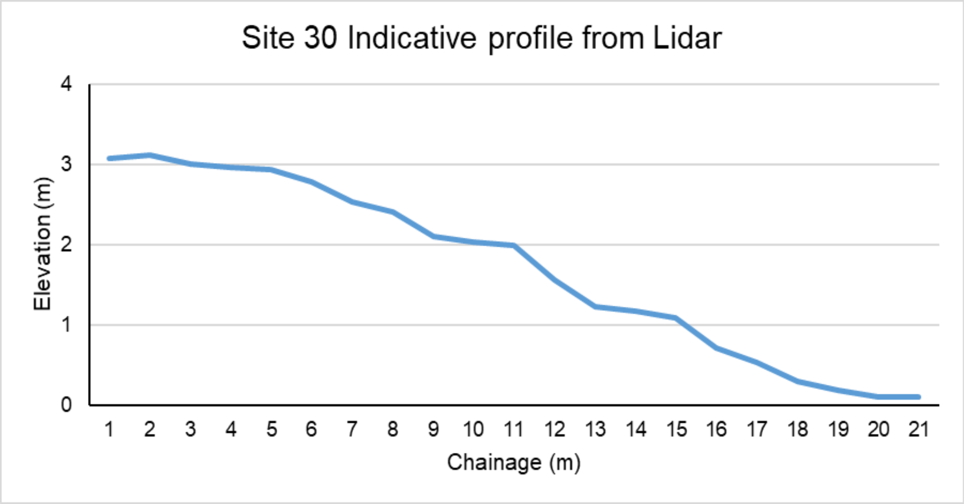
Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 30							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5175574	1580943	10.2	3.12	9.5	3.19	No issue	1
Other issues identified: Narrow width with evidence of rock roll down onto the beach.							

Site photos:

Slumped profile:



Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 31							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5175576	1581255	5.0	2.85	10.4	3.85	No issue	1
Other issues identified: Localised low spot							

Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 32							
North End Co-ordinates (NZTM)		**Length of Area (m)**	**Crest Elevation from Lidar (m LVD)**	**Revetment Width from Lidar (m)**	**Revetment Slope**	**Est. Armour Rock size if considered issue**	**Actual Critical Analysis Rank for Priority Assessment**
Northings	**Eastings**						
5175560	1581294	11.7	2.95	11.9	4.58	No issue	2
Other issues identified: Concrete units.							

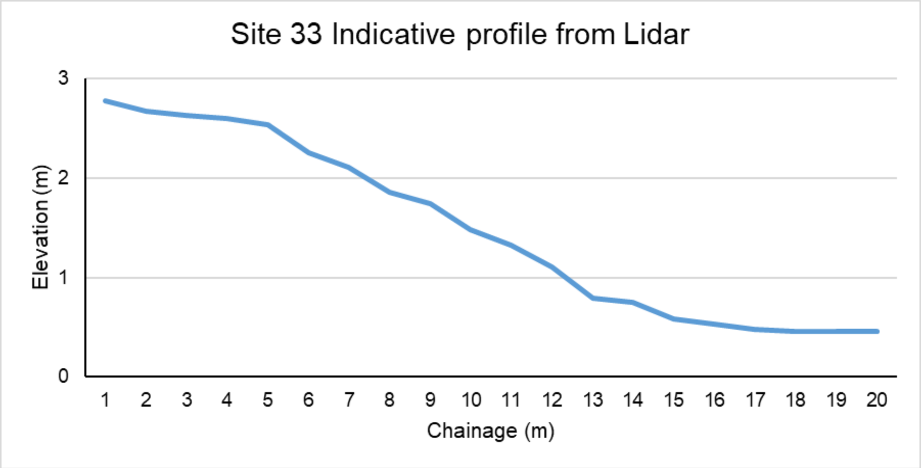
Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 33							
North End Co-ordinates (NZTM)		**Length of Area (m)**	**Crest Elevation from Lidar (m LVD)**	**Revetment Width from Lidar (m)**	**Revetment Slope**	**Est. Armour Rock size if considered issue**	**Actual Critical Analysis Rank for Priority Assessment**
Northings	**Eastings**						
5175553	1581308	13.9	2.77	8.6	3.74	No issue	1
Other issues identified: Narrow width – appears to lack rock, concrete units.							

Site photos:

Narrow profile:



Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 34							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5175550	1581329	16.5	2.60	7.8	3.92	No issue	1
Other issues identified: Localised low spot, concrete units.							

Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 35							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5175542	1581360	11.2	2.56	7.9	4.25	0.25-0.4m	3b
Other issues identified: Localised low spot. Concrete units.							

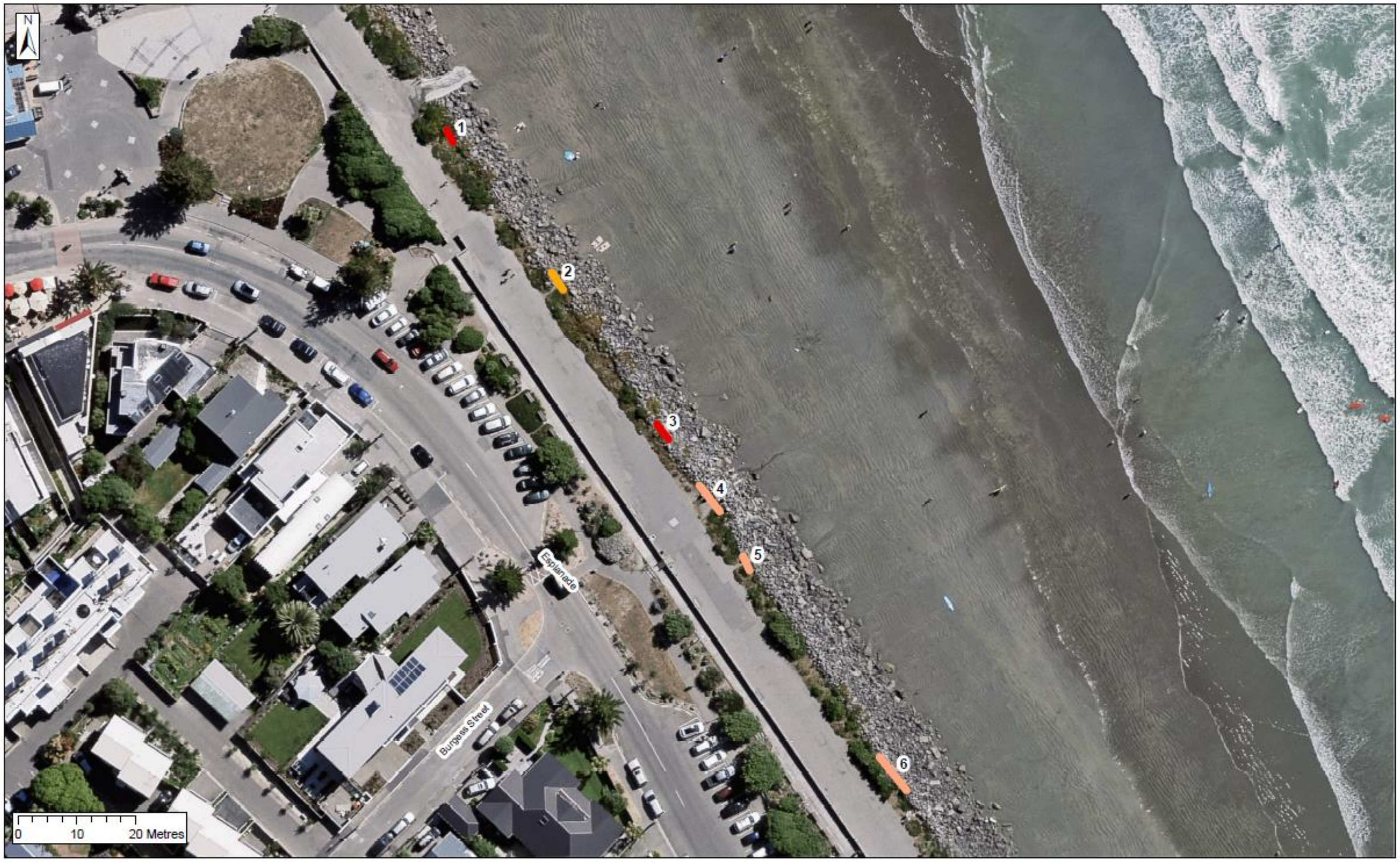
Site photos:

Appendix D: Identified critical sites with walkover survey and Lidar summary

Site 36							
North End Co-ordinates (NZTM)		Length of Area (m)	Crest Elevation from Lidar (m LVD)	Revetment Width from Lidar (m)	Revetment Slope	Est. Armour Rock size if considered issue	Actual Critical Analysis Rank for Priority Assessment
Northings	Eastings						
5175540	1581376	4.1	2.80	6.8	3.4	No issue	1
Other issues identified: Localised low spot.							

Site photos:

Appendix E. Critical Analysis



CLIENT Christchurch City Council	
PROJECT Sumner Revetment Condition Survey	
SCALE	PROJECT CODE IZ103600
PROJECT MANAGER MA	DRAWN JZ
PROJECT DIRECTOR XX	DATE 30/01/2018

Legend

- 1 - Low priority: One issue with the optimum design criteria
- 2 - Medium priority: Two issues with the optimum design criteria.
- 3b - High priority: Three issues with the optimum design criteria and has a flat slope issue.
- 3a - High priority: Three issues with the optimum design criteria and has a steep slope issue.

Sumner Revetment Condition Survey
Appendix E: A1 Esplanade to Burgess Street
Priority of Maintenance

JACOBS
Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900

CLIENT Christchurch City Council	
PROJECT Sumner Revetment Condition Survey	
SCALE	PROJECT CODE IZ103600
PROJECT MANAGER MA	DRAWN JZ
PROJECT DIRECTOR XX	DATE 30/01/2018

Legend

- 1 - Low priority: One issue with the optimum design criteria
- 2 - Medium priority: Two issues with the optimum design criteria.
- 3b - High priority: Three issues with the optimum design criteria and has a flat slope issue.
- 3a - High priority: Three issues with the optimum design criteria and has a steep slope issue.

Sumner Revetment Condition Survey
Appendix E: A2 Burgess Street to Stoke Street
Priority of Maintenance

JACOBS
Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900

CLIENT	
Christchurch City Council	
PROJECT Sumner Revetment Condition Survey	
SCALE	PROJECT CODE IZ103600
PROJECT MANAGER MA	DRAWN JZ
PROJECT DIRECTOR XX	DATE 30/01/2018

Legend

- 1 - Low priority: One issue with the optimum design criteria
- 2 - Medium priority: Two issues with the optimum design criteria.
- 3b - High priority: Three issues with the optimum design criteria and has a flat slope issue.
- 3a - High priority: Three issues with the optimum design criteria and has a steep slope issue.

Sumner Revetment Condition Survey
Appendix E: A3 Stoke Street to Hardwicke Street
Priority of Maintenance

JACOBS

Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900

CLIENT Christchurch City Council		
PROJECT Sumner Revetment Condition Survey		
SCALE	PROJECT CODE IZ103600	
PROJECT MANAGER MA	DRAWN JZ	
PROJECT DIRECTOR XX	DATE 30/01/2018	

Legend

- 1 - Low priority: One issue with the optimum design criteria
- 2 - Medium priority: Two issues with the optimum design criteria.
- 3b - High priority: Three issues with the optimum design criteria and has a flat slope issue.
- 3a - High priority: Three issues with the optimum design criteria and has a steep slope issue.

Sumner Revetment Condition Survey
Appendix E: A4 Hardwicke Street to Menzies Street
Priority of Maintenance

Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900

CLIENT Christchurch City Council		
PROJECT Sumner Revetment Condition Survey		
SCALE	PROJECT CODE IZ103600	
PROJECT MANAGER MA	DRAWN JZ	
PROJECT DIRECTOR XX	DATE 30/01/2018	

Legend

- 1 - Low priority: One issue with the optimum design criteria
- 2 - Medium priority: Two issues with the optimum design criteria.
- 3b - High priority: Three issues with the optimum design criteria and has a flat slope issue.
- 3a - High priority: Three issues with the optimum design criteria and has a steep slope issue.

Sumner Revetment Condition Survey
Appendix E A5: Head Street to Esplanade
Priority of Maintenance

Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900