NIWA
Taihoro Nukurangi

Managing and adapting to coastal erosion at Granity, Ngakawau and Hector

Prepared for West Coast Regional Council

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Executive summary

This report has been prepared for West Coast Regional Council (WCRC) to aid the decision-making processes associated with ongoing erosion problems at the villages of Granity, Ngakawau and Hector. The advice relates to ongoing coastal erosion issues along the frontage and options for coastal defence structures aimed at protecting residential land and property.

At Granity, Ngakawau and Hector, as in most coastal areas, the problem is not due to the ongoing changes in the coastline but rather that development historically (and ongoing) has been located too close to the sea to accommodate natural changes and trends in shoreline. The ongoing coastal erosion and shoreline retreat is occurring because of a long-term region-wide deficit in new sediment reaching and resupplying the beach face after erosion episodes or storm events.

The report outlines a number of potential measures, as a basis for future discussion between the Regional Council and residents, which could assist in reducing the impact and/or slowing down the rate of coastal retreat along the coastal frontage in the short-medium term and long-term time frames.

The 5 km coastal frontage of the villages was divided into 12 individual sections from observations about the current level of coastal protection and likely ongoing protection needs. Short to medium term coastal management actions have been recommended to improve the level of protection in each section. These actions are intended to ‘buy some time’ to permit development of a long-term strategy or adaptation pathway which addresses the coastal erosion and improves community resilience. The options reflect typical coastal defence designs suitable for this stretch of coastline and include recommendations of a timeframe for implementation. Large-scale engineering approaches, such as rock groynes, whole-coastline armouring or beach nourishment, remain uneconomic and unsuitable for this stretch of coastline.

Independent of the section-specific recommendations, the community should be involved with a developing a long-term adaptation strategy, should monitor the beach (surveys, photographs) and undertake active vegetation management (planting, replanting washed out plants).

The specific recommendations to implement or put into place (design, costing, consent, construction) over a short term (0-2 years) timeframe include:

- Gaps in the beachfront revetment at northern Hector should be filled (total length 70-80 m) to provide a continuous line of defence and eliminate out-flanking erosion within already defended sections.
- Tie-in or wrap-around walls are recommended for the southern edge of Granity school to reduce outflanking erosion and wash-around sediment deposition which is causing vegetation die-back and reducing the level of protection.
- Gabion- basket backstop defences and aggressive replanting along the private property boundaries of northern Granity frontage from Chair Rock to Lovers Rock are recommended to reduce the impact of storm washover events.
- While not a new task, the Buller District Council should continue to clear the back-shore drains and re-form the narrow beach berm to allow drainage of any overwash flows and allow sediment to reach the active beach face through stream flow.

The actions which should be prepared/planned by considering the design (location, length, height), fully scope the cost and resource consent, on a timeframe of 2-5 years from now include hard defences as either upper-beach rock revetments or backstop defences. This approach is recommended for the central and southern Granity frontages, northern Ngakawau and central Hector. The frontages are recommended to begin this process as an adaptive management strategy by planning/preparing and agreeing on erosion thresholds (decision points) for when action will be taken.

The actions to consider into the future for most coastal frontages are beach nourishment and relocating of buildings within private property boundaries. These options should be considered for the future (5 years) at northern Granity and northern Ngakawau and at locations where future monitoring indicates whether the actions are necessary.

Volumetric material estimates for a typical rock revetment, gabion backstop wall or beach nourishment defences relevant for each frontage section have been established to aid community/Council decision making through eventual cost-benefit analysis. All recommendations are subject to change when critical risks arise from coastal storm events which cause large or severe erosion, inundation and overtopping.

Development of a specific and long-term adaptation plan for the Granity, Ngakawau and Hector coastline is recommended. The adaptation pathway is a process for achieving change over time to enable people and communities to adjust to changing conditions and to minimise or reduce the risk to themselves and to property from the effects of natural coastal hazards. An adaptation plan may be implemented in stages, but it should set out the overall context and strategic directions for managing coastal areas at a large scale, and draw together community aspirations.

The options presented here are actions to implement before the existing occupation of the coastline becomes untenable and risk to property is critical. **The options and actions presented must not be considered long-term solutions and should be considered short-medium term options to 'buy some time' while planning for a long-term adaptation strategy or until the situation changes**. Ultimately, the lowest-risk long-term solution will be to retreat away from the coastline, either through moving houses inland within the property boundaries or relocation building off-site.

1 Introduction

1.1 Scope

This study was initiated by West Coast Regional Council (WCRC) in partnership with the local community to advance previously proposed coastal management options for Granity, Ngakawau and Hector. It has been funded by an Envirolink medium advice grant (Contract Number C01X1503).

Its scope includes:

- a field inspection
- review of recent literature relevant to coastal erosion and management on the West Coast
- examination of potential medium-term options, and
- material volume estimates for rough costing to inform community-based decision making.

The initial options proposed were from NIWA (2006, 2007) and were developed for WCRC with an earlier EnviroLink advice grant.

1.2 Site visit

A full walk-over inspection of the Granity, Ngakawau and Hector coastal frontages was performed on 22 September 2015, covering a 5 km stretch from southern Granity to northern Hector, including river and stream mouths. Weather, wave and tide conditions on the day were suitable for a thorough inspection of the beach status and existing coastal management approaches.

Discussions concerning the issues of coastal erosion and management were held with Paulette Birchfield and Mike Meehan of WCRC. Buller District Council (BDC) staff members, Steve Griffin (Manager, Operations) and Tony Robertson, were also met onsite and discussed the coastal erosion extent and periodic drain clearance along the Granity frontage. Several informative, long-term residents also discussed beach conditions during the site inspection, including Lisa McDowell (who operates a small nursery at Ngakawau), the Charming Creek publican and patrons over lunch, and Hugh Tyler (who holds a resource consent for a 50 m long rock groyne at the south bank of the Ngakawau River mouth).

2 Previous studies

2.1 Key studies: NIWA (2006, 2007)

The key studies are NIWA (2006, 2007). These reports were commissioned to aid decision-making associated with ongoing erosion problems by providing overview advice on the potential options to reduce and/or slow down the rate of coastal retreat along the coastal frontage of the three villages. The reports addressed the coastal changes by identifying possible causes for the worsening erosion problem, provided indicative options for short-medium term interventions to 'buy some time', and suggested that retreat is the appropriate long-term mitigation measure.

In relation to structures to provide effective short-medium term protection, NIWA (2006, 2007) presented general guidance for appropriate defence design. This included options for suitable generic designs for back-stop defences and rock revetments, including revegetation and importing beach 'nourishment' material.

NIWA (2007) also included a series of questions and answers addressing the causes, effects, changes and descriptions of coastal erosion along the coastal frontage. These are summarised below:

1. **Why does erosion seem to be worse in some parts of the coastline than at other locations?**

   Coastlines adjacent to river mouths tend to be highly dynamic due to the interactions between coastal and river processes, and the resulting impact on sediment movements. The nearshore sand bars that occur at the river mouth are constantly shifting both alongshore and offshore. Whilst these bars can protect the coastline by causing waves to break and dissipate energy further offshore, they can also focus (or disperse) waves approaching the coastline and create wave induced currents, such as rip currents. This results in patterns of coastal change that vary along the coastline, and which also vary with time in response to changes in the position of these offshore bars. Furthermore human actions, such as building ad hoc coastal defences (particularly if such defences extend below the Mean High Water Spring mark), the clearing of vegetation from the beach crest, or previous attempts at land reclamation over the foreshore, can also exacerbate localised rates of erosion.

2. **Is this erosion part of a long-term trend?**

   Patterns of coastal erosion are not constant. Cycles of short to medium term accretion and erosion patterns occur depending on the particular complex interactions between wave climate variability, storm occurrence, storm tracks and how often storms occur (i.e., the impacts due to a particular series of storms), and river flood events (which are the dominant source of sand and gravel supply to the coastline). Landslides in river catchments due to historic earthquakes also have had a significant influence on sediment supplied to the coast on the West Coast. Generally, long-term observed retreat rates average about 0.3 - 0.4 m/year at Ngakawau and Hector and 0.6 – 0.8 m/yr at Granity (NIWA 2007, DTEC 2002).

3. **Is erosion getting worse?**

   Changes in the position of the coast are occurring all the time but people tend to become more aware of these changes after a significant storm. There is nothing to suggest that erosion in general is getting worse at Granity, Ngakawau and Hector, or indeed at most other locations in New Zealand. In most coast areas, the problem is not due to the ongoing changes in the coastline but rather that development historically has been located too close to the sea to accommodate these natural changes and trends, with the resulting impact of erosion now more financially significant. However, the awareness of the problem, and the risk and vulnerability are increasing as a consequence of more development and infrastructure on the coastline.

4. **What are the expected influences of climate change and sea level rise?**

   Climate change has already had an impact on a number of factors which are linked to coastal erosion. This includes sea-level rise which increases the mean level of sea which elevates the tides, waves and storm surges. Climate change impacts will also alter rainfall and river flow patterns (which cause a change in sediment supply from the Ngakawau River and onto beaches) and possibly cause changes in storm intensity and wave climate (which affect how beach sediments are moved around within the coastal zone). Assessing how climate change will influence coastal change (either positively or negatively) over and above that caused by natural climate variability is extremely difficult to identify, particularly where the complex interaction between river and coastal processes have a significant influence, i.e., Granity-Hector frontages.

5. **What is likely to happen over the next 10-20 years?**

   Retreat of the coastline (primarily due to episodic storm events) will continue in a similar pattern to that occurring in the past (i.e., dominated by natural climate variability not climate change impacts). Notwithstanding another major earthquake on the west coast (causing abrupt changes to river/stream sediment supply and possible land uplift), other possible changes include: an increased likelihood of short-term positive (sea-level increase) fluctuations (timeframes of months) in mean sea level of up to +0.25 m; and an increased likelihood of ex-tropical cyclones and other storms affecting the New Zealand region compared to the last couple of decades. However, this is most likely to impact on the north and east facing coastlines.

For extended answers to these questions, see NIWA (2007). Note that these questions and answers have been reviewed for this report and remain valid.

2.2 Other studies

The issue of coastal change on the West Coast, and specifically Granity, Ngakawau and Hector has been studied from many perspectives for many years. Previous studies include those of Mangin (1973), Gibb (1978), Neale (1989a, 1989b), with summaries and further interpretation provided by Hicks (1996) and DTEC (2002).

Since NIWA (2006, 2007) there have been several reports addressing the environmental effects of constructing hard-structure coastal defences along the Granity, Ngakawau and Hector frontages. These include DTEC (2007) for review of coastal protection works at 12-14 Main Rd, Ngakawau (referred to as Merrett's wall), and Single (2009) for review of the coastal effects for a proposed groyne on the south bank of the Ngakawau river mouth. Also, 11 km north up the coast, Tonkin & Taylor (2009) assessed coastal management options at the Mokihinui River mouth for the proposed Mokihinui hydropower scheme.

To fully summarise all reports is out of scope of this project.

2.3 Summary of coastal processes – from previous studies

The beaches of Granity, Ngakawau and Hector can be broadly described as mixed sandy gravel. The proportional composition of sand and gravel is locally variable depending on cross-shore position, sediment supply and sediment mobilisers (waves, wind, currents). Generally, at low-water levels, the beaches are wide and sand-dominated, while at high-water levels the beach is steep and gravel-dominated. Local sediment sources are riverine (Ngakawau River, Granity and Bradley Streams, Morris Creek and storm water drains) along with littoral drift transported alongshore, which are locally re-worked by waves and wind.

The main findings of the reviewed studies suggest that the shoreline "*shows evidence of short-medium term (1-20 years' time-frame) cycles of accretion and erosion superimposed on a trend of long-term erosion. The short-medium term shoreline movements are characterised by accretionary "lenses" and erosion "bites" from several to 10 m in width and spanning 500-1000 m segments of shore*" (Hicks, 1996).

Historic erosion rates identified over the last 50 to 100 years vary between the reports, reflecting the different locations along the frontage and different time periods over which shoreline position measurements were made. Generally, long-term observed retreat rates average about 0.3 - 0.4 m/year at Ngakawau and Hector and 0.6 – 0.8 m/yr at Granity (NIWA 2007, DTEC 2002). The retreat will occur episodically, being primarily caused by storm events. This retreat rate will be modulated by vegetation, defences and sediment supply.

Overall, the available evidence suggests that the region-wide coastal erosion experienced on the West Coast is a consequence of long term (decadal to century) changes to the balance between waves and sediment supply along the coast. Causes of this include, but are not limited to, changes in wave climate, lack of earthquake/landslide derived sediment input to rivers associated with movements on the alpine fault and an underlying rising sea level.

There is nothing to suggest that erosion in general is getting worse at Granity, Ngakawau and Hector, or indeed at most other locations in New Zealand (NIWA, 2007). However, the awareness of the problem and the risk and vulnerability are increasing as there is more development and infrastructure on the coastline. In most coast areas, the problem is not due to the ongoing changes in the coastline but rather that development historically has been located too close to the sea to accommodate these natural changes and trends (NIWA, 2007).

The large scale erosional trend was confirmed through on-site observations along with discussions long-term residents who knew of no nearby West Coast beaches which were currently accreting.

3 Observations along the Granity, Ngakawau and Hector frontage

For this study, observations were made of the coastal environment along the village frontages with comments on current level of protection, defence suitability, setback distances and future coastal adaptation needs. Whilst there is no property presently at critical risk of being significantly damaged due coastal erosion, such risk will increase over the foreseeable future as the coastline continues to retreat.

The observations are separated into twelve frontage sections (Table 3-1, Figure 3-1) and arranged sequentially from southern Granity to northern Hector. Each section is defined by particular changes in coastal protection from existing defences, river/stream mouths or distinct features which influence the coastal dynamics.

Table 3-1: Coastal frontage section boundaries. See Figure 3-1 for schematic map.

Village	ID	Section boundaries	Length (m)
Granity	G1	50 Domain Road to southern boundary of Granity School	320
	G2	Southern boundary of Granity School to south bank of Granity Stream (100 Torea St)	350
	G3	North bank of Granity Stream (101 Torea St) to Chair Rock (141 Torea St, Granity)	500
	G4	Chair Rock (141 Torea St, Granity) to Lovers Rock (165 Torea St, Granity)	850
	G5	Lovers Rock (165 Torea St, Granity) to southern limit of Merrett's wall (14 Main Rd, Ngakawau)	780
Ngakawau	N1	Southern limit of Merrett's wall (11 Main Rd, Ngakawau) to south bank of Morris Creek (14 Main Rd, Ngakawau)	180
	N2	North bank of Morris Creek (14 Main Rd, Ngakawau) to 19 Main Rd, Ngakawau	100
	N3	19 to 26 Main Rd, Ngakawau	200
	N4	26 Main Rd – south bank Ngakawau River mouth	300
Hector	H1	North bank Ngakawau River mouth to Corbett St, Hector	320
	H2	Corbett St to 25 Main Rd, Hector	550
	H3	25 to 37 Main Rd, Hector	350

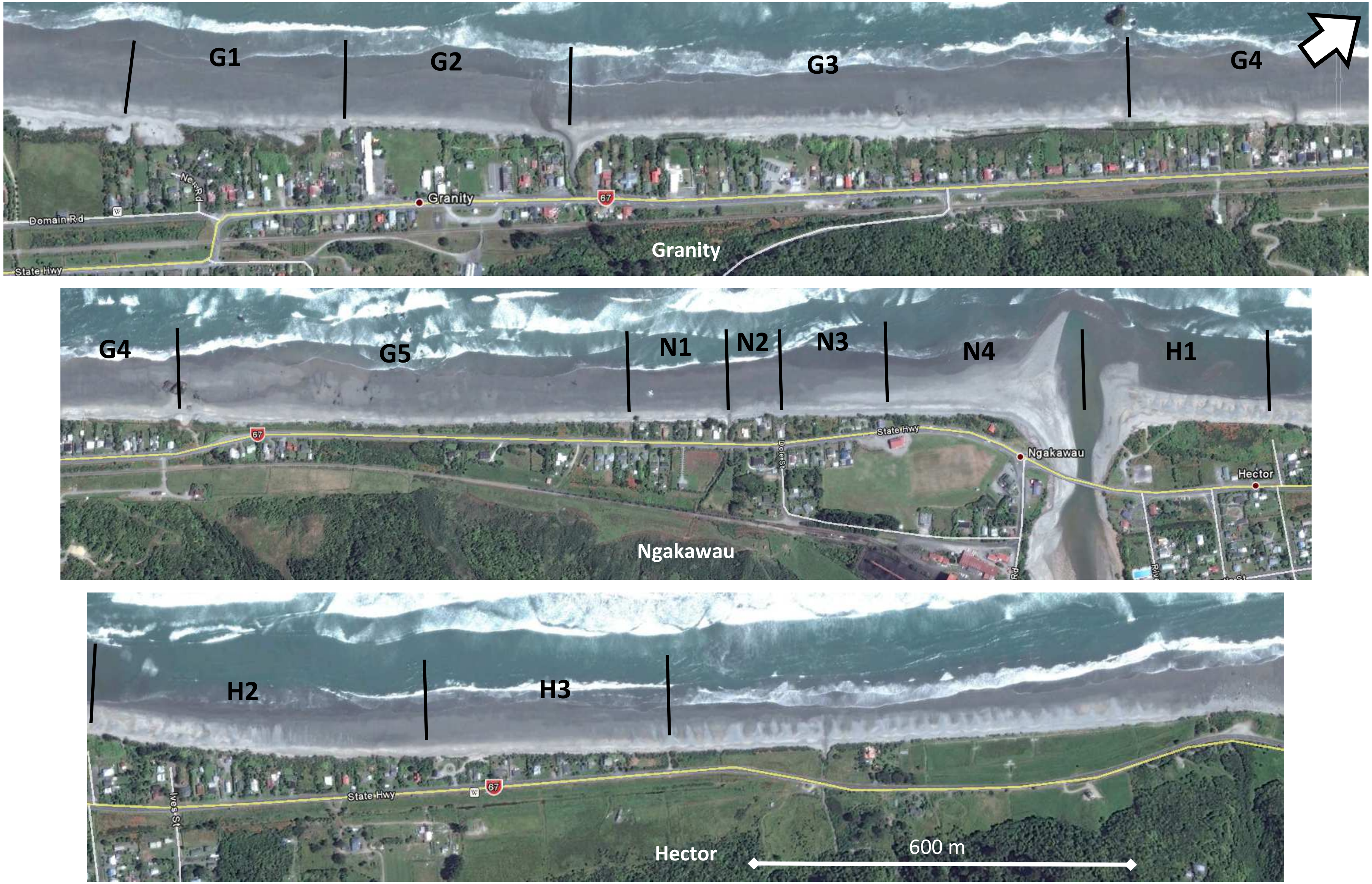


Figure 3-1: Aerial overview of Granity (top), Ngakawau (centre) and Hector (bottom) with coastal frontage sections (annotations) relating to observations and discussions. Scale as indicated. [Google Earth imagery, 17 August 2013].

3.1 Granity

The coastal frontage along Granity is generally characterised by intermittent 'bites' of active erosion between spans with relatively stable vegetation buffers. The eroding areas are where the beach is retreating toward private property with inadequate beach material or vegetation to act as a buffer. The relatively stable areas are those where wide flax swamps/drains or vegetation occupy historic overwash lagoons and act as a natural buffer to shoreline retreat.

G1 - Along the southern section of Granity (from 50 Domain Rd to southern flank of Granity School) there are areas with small gravel bunds (one, two or none) created by BDC through drain clearance, fronting pond or vegetation (flax, bamboo) with private land immediately behind lagoon. The small bunds (<1 m above natural beach level) do not withstand significant wave action on a high tide and are periodically reformed through drain clearance. Regular overwash of water and sediment is apparent (Figure 3-2) and is causing the vegetation to die-back in various places. There is little sediment available for natural (or mechanical) rebuilding of a gravel barrier. However, the current dwellings are set back from the beach crest approximately 50 m along New Rd and at least 80 m along Domain Rd, many with small bunds along their boundary which is sufficient to allow natural beach retreat over the short term. The continued and regular drain clearance by BDC will aid beach recovery and prolong vegetation longevity by restricting overtopping during minor storms. Ceasing vegetation clearance and re-planting robust vegetation will also aid longevity.

Figure 3-2: Overwash of beach material through vegetation in absence of gravel barrier. Evidence of vegetation die-back within infilled lagoon. Photograph looking north along-beach towards school buildings (centre) from approximately 65 Domain Road, Granity. [22 September 2015].

G2 - North along the coast from the southern boundary of Granity School to the southern bank of Granity Stream (100 Torea St, Granity) there are two rock revetments (total length 230 m) separated by a 120 m gap. The gap is protected by a barrier made from the BDC drain-clearance material and there is a thick vegetation buffer. The revetments themselves were both recently constructed (the School structure was completed winter 2015) but differ significantly in their construction quality and level of protection provided:

- The northern revetment extends approximately 60 m along the beach face and wraps around a further 40 m up Granity Stream, has vegetation growing within and above the rocks, and was overall in good condition at the time of inspection.
- However, the school revetment is poorly constructed and does not meet good practice for revetment design and construction. It is currently projected out about 5 m onto the active beach face and 'sticks out' compared to the adjacent natural storm berms and beach crest. This means the school structure has a shorter expected lifespan as waves regularly reach it even during minor storms or spring tides (waves during the last high-tide before the inspection were within 5 m horizontal distance or less than 1 m elevation from the structure toe, see Figure 3-3). Further, the revetment size (rock diameter, crest height) may not be sufficient to withstand large coastal storms intact, and there is evidence of waves outflanking the southern side of the revetment. This out-flanking erosion increases the risk to the school property and contributes to vegetation die-back (as per Figure 3-2). The level of protection provided by the revetment will improve slightly if the recently planted vegetation is able to permanently establish itself along the school revetment before an erosion event (see Figure 3-3). School buildings are within 20 m of the beach face. A sensible option for the school is to relocate buildings on site and rebuild the revetment to be in-line with the adjacent gravel berm barriers.

Vegetation die-back and overwash is also seen between the two revetments (Figure 3-4). However, the dwellings between the revetments are typically set back 50 m from the vegetation line and do not appear to be at critical risk. Filling the gap between the two revetments with a similar rock structure is a sensible option should the outflanking erosion threaten these dwellings.

Figure 3-3: Recently constructed revetment at Granity school. Photograph looking north along-beach towards Torea Rocks (foreshore at upper left) from on top of revetment. [22 September 2015].

Figure 3-4: Unprotected section of coastline between Granity Stream revetment (centre left) and Granity school revetment (centre far-right). Photograph looking south along-beach towards school from Granity Stream (100 Torea St, Granity). [22 September 2015].

G3 - Along the stretch of coastline north from Granity Stream to Chair Rock, the beach is presently in a healthier state with a larger volume of gravel on the upper beach compared to adjacent beach sections. The gravel berm is regularly topped-up by BDC drain clearance (approx. 2.5 m above beach level at time of inspection) and there is a 40-60 m wide vegetation/swamp buffer to the dwellings (Figure 3-5). Barrier washover will still occur, particularly along sections where residents have cleared the natural vegetation up to the back of the beach crest.

Figure 3-5: Example gravel barrier and wide vegetation/swamp buffer between beach and houses between Granity Stream to south (left, not visible) and Chair Rock (right, visible at centre). Photographs looking south (left) and north (right) at about 138 Torea St. [22 September 2015].

G4 - North along the Granity frontage from Chair Rock to Lover's Rock, including the northward diverted Bradley Stream, there is a gravel stopbank/bund composed of material cleared from drains by BDC (typically 1 m above beach elevation) with evidence of recent overwash deposits and vegetation die-back within the private property fences (Figure 3-6). These properties were most effected by the overwash and erosion during the 2006 storms (NIWA, 2007). Dwellings are typically set back 30-50 m from the beach face, with the buffer zone comprising flax swamp and fenced backyards (Figure 3-7). At various points along this stretch (notably 154 Torea St) vegetation removal and private vehicle access have lowered the berm height, increasing overwash and erosion. The beach is slightly wider, flatter and with a gravel component in the lee of Lover's Rock at the drain outlet, probably due to the wave sheltering from the nearshore rocks and to stream sediment supply.

Given the low-lying nature of the land behind and the lowering of the beach crest that has occurred, overwashing and inundation of the land behind will become a more regular feature in the future. With this susceptibility, the diversion of Bradley Stream to an outlet behind Lover's Rock exacerbates this risk, and it will become increasingly difficult to maintain an open channel immediately behind the beach. However, simply opening up a direct outlet to the sea further south for Bradley Stream would result in lowering of the beach and the potential for considerable erosion adjacent to the outlet.

Figure 3-6: Overwash deposits and vegetation dieback behind mechanically cleared drain within private property. Berm approximately 1 m above beach level. Photograph looking northeast across diverted Bradley stream at approximately 155 Torea St, Granity. [22 September 2015].

Figure 3-7: Narrow and low mechanically created gravel berm with diverted Bradley Stream and low-lying buffer space between houses at 155-165 Torea St. Photograph looking south towards Chair Rock (centre right) from 164 Torea St. [22 September 2015].

G5 - Between Granity and Ngakawau villages (165 Torea St, Granity to 11 Main Rd, Ngakawau) where no dwellings are present on the seaward side of the road, the natural gravel bund and vegetation provide a slim line of defence for the electricity poles and for the road. This shoreline appears to be retreating slowly but the rate is being controlled by the vegetation and the gravel salient formed in the wave shadow of large rocks on the beach.

3.2 Ngakawau

Along the coastal frontage at Ngakawau there are several examples of coastal defences, both successful and unsuccessful, along with an undefended section. This stretch of coastline has minimal setbacks to buildings, and properties are constrained on their rear boundaries by the adjacent SH67.

N1 - The privately built rock and gabion structure from 11 - 14 Main Rd (referred to as Merrett's wall, Figure 3-8, see also DTEC 2007) is an example of cooperative defence construction which has so far been successful in defending the properties and has a small gravel fillet beach at present. Merrett's wall also wraps around the south side of Morris Creek exit. The revetment size (rock diameter, crest height) is adequate for moderate storms, but is likely to be damaged by large coastal storms. The combination of rock and gabions is not good practice for revetment design/construction due to lack of gabions-rock interlocking when compared to rock-rock interlocking, along with the eventual corrosion and slumping of gabion baskets. There is evidence that the storms experienced have caused some undermining, outflanking and occasional overtopping. At the creek mouth, the streambed is infilling with sand and erosion of the upper foreshore has caused the shoreline to retreat on its northern side where several protection attempts have been made (Figure 3-9). This erosion and infilling will continue to cycle between streambed flushing by strong runoff events or large waves on a high tide and sediment accumulation by wind and wave coastal processes during lower wave conditions. Dwellings are within 5-10 m of the active beach face, behind the revetment and a narrow vegetation buffer.

Figure 3-8: Coastal defence "Merrett's wall" along 11-14 Main Rd, Ngakawau. Privately funded structure built in 2007. Photograph looking north east along Ngakawau frontage from 11 Main Rd, Ngakawau. [22 September 2015].

Figure 3-9: Erosion on northern side of Morris Creek exit showing proximity of houses (top centre) with eroding defences and nearby ad-hoc rubble defences (centre left). Photograph looking north from Morris Creek mouth at 14 Main Rd Ngakawau. [22 September 2015].

N2 - Various ad-hoc defences protect 15-20 Main Rd and extend 200 m north from Morris Creek, including dumped mining carts, reinforced concrete rubble and rocks (Figure 3-10). Generally this defence has been assisted by vegetation behind it to resist erosion. However, with low-lying land and little buffering vegetation behind the ad-hoc walls, the level of protection is low. Further, the ad-hoc nature of the rubble may have the adverse effect of stripping sediment from the beach face on immediately adjacent sections of coast. This section of Ngakawau frontage may require a cooperative seawall, similar to Merrett's wall, to increase the level of protection in the short to medium term as there is little or no backyard buffer space and no option to relocate dwellings further away from the beach.

Figure 3-10: Ad-hoc rubble and steel defences along Ngakawau frontage between Morris Creek and 21 Main Rd. Photograph looking south east toward Morris Creek (annotation). [22 September 2015].

N3 - Immediately north of the dumped debris wall, at 25-26 Main Rd, Ngakawau, the post and rail fence with wire mesh along property frontages is acting as a buffer to minor storm erosion by accumulating a wedge of driftwood and beach material, increasing the beach crest height by 0.5 m (Figure 3-11, note top of fence is 0.8 m above ground level behind the fence). This defence is effective because there is currently enough sediment and driftwood to accumulate at this point along the beach, plus the thick vegetation buffer behind the fence also intercepts overwash flows. However, the beach face is over-steepened and without substantial fence foundations it is unlikely to be an effective medium-long term defence against erosion during large storms. The fence is unlikely to survive if the sediment regime changes to be in deficit (such as 300 m south at 18 Main Rd on the north side of Morris Creek, Figure 3-9). A dwelling at 25 Main Rd is within 5 m of this fence (chimney visible in Figure 3-11), and could be relocated towards the road if erosion encroaches past the fenceline and vegetation buffer.

Figure 3-11: Accumulated driftwood and beach material in front of fence creating storm buffer and increasing elevation of beach crest. Ad-hoc dumped material visible 100 m along-beach. Photograph looking southeast. The visible chimney is at 25 Main Rd, Ngakawau. [22 September 2015].

N4 - The sole abandoned building on the seaward side of the road near the Ngakawau River bridge (28 Main Rd, Ngakawau) is currently fronted by a wide beach with dumped concrete rubble and well-established vegetation behind the active beach face (Figure 3-12). This stretch of coastline appears to be currently accumulating beach material and is relatively healthy. The Ngakawau River contributes to the sediment supply along this stretch and at times the river bar reduces the wave energy and increases the sediment longevity – although the shoreline change rates are more variable because of the river mouth dynamics (NIWA, 2007). A resource consent has been granted at this location to construct a 50 m long rock groyne extending perpendicular offshore from 28 Main Rd, Ngakawau (WCRC consent RC08175). Single (2009) considers the groyne is unlikely to prolong or cause significant adverse effects on the coastal environment of the nearby shore and river mouth. This side of the river mouth is currently accreting (i.e., building the erosion buffer) therefore constructing a groyne for land protection seems redundant at this time. Further, combined with the current deficit of sediment causing erosion on the Hector side (see Section 3.3 below), and considering that the effect of a groyne would be to trap and prevent northward sediment drift, there are potentially adverse effects from such a structure. In the long-term and as seen historically, the shoreline around the river mouth will experience episodic erosion and accretion in response to sediment, coastal and fluvial interactions, irrespective of groyne placement.

Figure 3-12: Wide upper beach face, accumulating sediment and driftwood with advancing vegetation on the southern bank of the Ngakawau River mouth. Photograph looking north across the Ngakawau River mouth from frontage of 28 Main Rd, Ngakawau. [22 September 2015].

3.3 Hector

The Hector coastline has a typically sandier beach material composition, does not have backshore overwash lagoons like Granity and has a lower-lying backshore than Ngakawau. The whole Hector coastline appears to be retreating, with a rock revetment protecting sections at the northern end. The Hector beach also has a slightly flatter beach profile relative to Ngakawau and Granity beaches – related in part to its sandier composition.

H1 - The coastline from the northern bank of the Ngakawau River to Corbett St is relatively wide and sandy but currently is experiencing a deficit of sediment with current erosion scarps up to 2 m above beach level (Figure 3-13) and extending for 300 m south from Corbett St to the river mouth. This retreat into sand/gravel berm/dunes would appear to be an episodic occurrence as indicated by the old building rubble exposed at the base of the eroded beach scarp which indicates the shoreline has been landward of its current position within the last 100 years. This area was also mentioned as an old dumping ground by the Charming Creek Tavern publican and patrons – if this is confirmed, then the councils may want to intervene and prevent landfill material making its way onto the beach face. This loss of sediment on the north of the river mouth appears to be offset by a gain on the southern side (Ngakawau side, see Section 3.2). This fluctuating pattern of erosion/accretion on the north/south bank is natural and is expected to occur at some point in the future in response to wave and river driven sediment transport. The current shoreline retreat will continue into the future but it will not threaten adjacent dwellings which have at least 100 m of vegetated setback buffer.

Figure 3-13: Erosion scarp of retreating shoreline along the southern Hector frontage (north of Ngakawau River mouth). Note old building rubble was exposed near the base of the scarp. Photograph looking north from opposite Greenfield St, Hector. [22 September 2015].

H2 - North along the beach front from Corbett St to 25 Main Rd, Hector, the backshore is low lying and sparsely vegetated without any substantial dune or defence structure to resist erosion. This has allowed the beach crest or erosion scarp to advance inland through the foremost tree barrier, washing sand into the vegetation buffer and causing large patches of die-back (Figure 3-14). This pattern continues for 300 m north and is evidence of the deficit of beach material along the Hector coast. Dwellings are set back by 20-50 m, within and behind vegetation buffers, although several outbuildings are within 10 m of the active beach face (e.g., 3, 7, 21 and 23 Main Rd) and vegetation has been cleared in places. Episodic shoreline retreat is likely to continue for some time with little resistance from beach material or a thick vegetation buffer.

Figure 3-14: Beach crest retreating within vegetation buffer and evidence of windblown and overwashed sand in low-lying backshore causing vegetation die-back. Photograph looking northeast from Corbett St beach access. [22 September 2015].

H3 - Along the northern Hector frontage from 25 to 37 Main Rd, beach erosion is predominantly defended by a private rock revetment (Figure 3-15). The beach profile is flattening to the same degree as the southern Hector, but beach crest retreat has been halted by the structure where present. However, there are gaps between revetment structures which are clearly susceptible to erosion and have had ad-hoc attempts to mitigate this (Figure 3-16). Completing the revetment by filling the gaps (approximately 70-80 m length) would present a single line of defence and is recommended to prevent future out-flanking erosion from threatening the properties which are currently defended. The revetment size (rock diameter, crest height) is adequate for moderate storms but is likely to be damaged by large coastal storms. There is evidence that the storms experienced have caused some undermining, outflanking and overtopping of the structure.

Figure 3-15: Intermittent defensive structure along beach at north Hector from 25A - 37 Main Rd. Gaps in beachfront revetment at 25A and 29 Main Rd. Note 25A has a small defensive line of rock behind beach front flaxes (annotation). Photograph looking north east from 25A Main Rd, Hector. [22 September 2015].

Figure 3-16: Ad-hoc defensive filling of 20 m wide gap in existing revetment at 29 Main Rd, Hector. Photograph looking north from 29 Main Rd, Hector. [22 September 2015].

4 Managing the impacts of coastal change

4.1 Existing approaches to manage coastal erosion

4.1.1 Natural buffer zone

This remains the most effective approach in preventing coastal erosion from affecting property or associated infrastructure. It is where property has been built sufficiently far back from the beach and a buffer zone of natural vegetation left in place between the beach and the back-garden to permit natural changes in position of the coastline to occur.

In conjunction with the natural buffer zones, the mechanical deposition of drain-clearance material along the Granity frontage during BDC's regular drain clearance operations effectively creates a barrier berm to resist run-up and overtopping flows. The berm is reformed approximately every 3 months but is often partially or fully washed away over this period. Landowners should not rely on the reformation of beach berm as a coastal defence as the level of protection offered is minimal (only sand/gravel excavated, no revegetation, irregular timeframes) and it is unclear for how long BDC will continue this action.

4.1.2 Ad-hoc coastal defences

There has been a marked reduction in ad-hoc defensive structure extension since NIWA reported in 2006 and 2007 due to replacement with privately funded rock revetments (see Section 4.1.3 below). However, there are several locations where ad-hoc building rubble/steel defences remain (e.g., Figure 3-10, Figure 3-16). These remaining sections are unlikely to provide a sufficient level of protection in the short-medium term, and they pose a risk of exacerbating erosion on the adjacent sections of coast.

4.1.3 Recent coastal defences

Several new coastal defences have been constructed along the Granity, Ngakawau and Hector frontages since NIWA (2006, 2007), totalling about 700 m length of hard-defence structure. These structures replace failing seawalls and ad-hoc dumped debris. These include:

- A 200 m long rock revetment fronting Granity School with some tie-in extension at each end (e.g., Figure 3-3). This replaced the failing stopbank/revetment and was constructed in September 2015. Representative rock diameter is 0.3-0.6 m, with geotextile underlay, which is small for the wave climate although it may be an outer layer of small rock covering a larger rock core (which is not a recommended construction approach). Construction price was approximately $750 per metre length (pers. comm P. Birchfield). This wall has not yet been tested in moderate storm conditions. The structures also sits out on the beach face compared to the adjacent beach berm and is thus more susceptible to wave attack. Larger rock armour is likely to be required to ensure the defence provides an adequate level of protection and service.
- An approximately 60 m long rock revetment fronting 95-100 Torea St, Granity, which includes a 40 m wrap-around wall along the southern bank of Granity Stream (e.g., Figure 3-4). Representative rock diameter is 0.7-0.9 m.

- A 180 m long rock revetment with some gabion sections, known as Merrett's wall at 14-16 Main Rd, Ngakawau (e.g., Figure 3-8). Construction price was approximately $300 per metre length (pers. comm. P. Birchfield). Representative rock diameter is 0.5-0.8 m. See DTEC (2007) for design sketches and structural assessment.
- An intermittent rock revetment protecting a 330 m frontage along 25-37 Main Rd, Hector with some gabion sections (20 m). Representative rock diameter is 0.8-1.1 m. Note there are unprotected gaps of about 20 m at no. 29 Main Rd and 50 m at 25A Main Rd (e.g., Figure 3-15).

These recent revetment structures are all constructed similarly as linear rock-faced revetments. The face slope is typically 1:2 or 1:3 with evidence of geotextile underlay (at School, unknown for other structures), some gabions baskets (reasoning unknown, but present at Merrett's wall and the northern Hector revetments), and with vegetation planting on crest and backshore. The depth of toe embedment is unknown but appears to be 1-2 rock diameters below the current beach level (see DTEC 2007). Structure crest width is typically 1-2 rock diameters.

The main difference between these structures is the crest elevation above beach level (approximately >3 m at Granity School and stream banks of Morris Creek and Granity Stream and 1-1.5 m along parts of Hector). The higher crest typically indicates a more substantial structure (larger rock sizes) and affords greater protection from storm wave run-up, overtopping and erosion e.g., Granity School, 95-100 Torea St, Granity and Merrett's wall. Lower crests with fewer rocks to resist wave attack have a lower level of protection, however this is often justified as risk is reduced by the larger dwelling setback and slower historic rates of erosion, e.g., southern parts of the Hector structure.

These recent structures seem to have predominately adhered to the general guidelines of NIWA (2006, 2007) for appropriate coastal defences, apart from:

- The use of natural beach material as backfill beneath the revetments, which is not recommended as this reduces the available sediment on the active beach face. Where possible, new sediment should be brought in (with similar size grading and composition) to contribute to the beach sediment budget.
- The use of gabion baskets as a revetment where waves regularly reach them is not recommended. The sections of gabion baskets within the rock revetments (Merrett's wall and at 25-37 Main Rd, Hector) will act as a weak spot in future storms as they are more prone to failure of the basket structure, slumping with toe-scour and have less interlocking (i.e., more movement with waves) compared to rock-only revetments.

In general, these defences represent an appropriate design and afford a reasonable level of protection for the short-medium term lifetime expected for these structures of 10-20 years. The structures will provide some protection during mild storms, but they are likely to experience significant damage and are unlikely to prevent overtopping and inundation and continued erosion during more major events. Toe scour and crest damage will lead to a high maintenance commitment. It should be noted that these structures are fixed and therefore provide a reducing level of protection given the region-wide erosion trend. Further, on a retreating coastline such as this, the potential negative impacts (e.g., outflanking erosion, loss of natural beach building material) caused by the structure often increases with time.

Improvements which could extend the level of defence of these structures, such as increasing the crest level or re-armouring with larger rocks, are discussed below.

4.2 Future approaches to managing coastal change

4.2.1 Adaptation pathway for long-term

An adaptation pathway is a process of managing changing levels of risk, including minimising or reducing risk where possible, and managing any residual risk. It involves a process for achieving change over time to enable people and communities to adjust to changing conditions and to minimise of reduce the risk to themselves and to property from the effects of natural coastal hazards. In essence, an adaptation pathway is a journey which involves many steps towards a place where coastal communities are resilient i.e., to a place where communities have the capacity to adapt to climate change impacts. Adaptation is complex and often involves iterative steps over time to include and give effect to community needs, legislation and environmental change. An adaptation pathway is based on a mutual understanding of the issues relating to climate change, coastal hazards and risk, and the needs of different participants. Adaptation is a shared responsibility and partnerships are critical between the community and authorities (Britton et al. 2011)[1].

A schematic of the adaptation pathway for coastal change is illustrated in Figure 4-1 and Table 4-1.

Figure 4-1: Illustration of Pathways to Change – 4 steps on the coastal adaptation journey. From Britton et al. (2011, Figure 3.1).

[1] Britton et al. (2011) addresses coastal adaptation to climate change and provides guidance for a pathways to change for Councils and communities to follow when addressing and adapting to coastal erosion changes. Britton et al. (2011) refers to the national guidance manual titled *Coastal Hazards and Climate Change: A Guidance Manual for Local Government in New Zealand* (MfE, 2008) as the most comprehensive account for the establishing effects of climate change and sea-level rise on coastal areas of New Zealand, and as the fundamental basis for the adaptation pathway.

The Granity, Ngakawau and Hector sections of the West Coast are already on the adaptation to long-term coastal changes journey. The community are past Step 1 as they are aware of the coastal erosion issues and have begun to accept that future coastal changes will impact their coastal properties. They are also passing Step 2 as information has been gathered and assessed to inform the scope, scale and timeframes of the future coastal changes and risk being faced. They are now at Step 3 which is about planning what needs to happen to best adapt to coastal changes (although some areas have temporarily advanced to Step 4 with the construction of short-term defence structures).

Britton et al. (2011) states that:

> *"If you are at Step 3, you accept the need to address the potential impacts of climate change and have reasonable information about these impacts on your coastal community. Your focus is on considering adaptation options and working with key stakeholders and communities to make decisions on the best way forward in both the short and longer term"*

Any decisions, thresholds or milestones must be based on community established acceptable risks. This community involvement is crucial to a successful adaptation strategy; it is the community who occupy these dwellings and are vulnerable to the risks, and vulnerability is a subjective assessment.

When considering planning for an adaptation pathway at Granity, Ngakawau and Hector, the New Zealand Coastal Policy Statement (NZCPS) recommends promoting and identifying long-term sustainable risk reduction approaches including the relocation or removal of existing development or structures at risk (NZCPS 2010, Policy 27(1)(a)) and calls for focus on reducing the need for hard protection structures (i.e., rock revetments) and similar engineering interventions. (NZCPS 2010, Policy 27(2)(a)).

Table 4-1: The 4 step adaptation pathway. From Britton et al (2011, Table 3.1).

Step 1	**Awareness and Acceptance**	This step is about informing people within your council and your communities of the potential effects of climate change. It is also about accepting there's a problem and that further work is needed. • *Why do we need to be doing anything about coastal adaptation to climate change?* • *How much of a priority is it?* • *What are the levels of political and community awareness, and how could we enhance this awareness?* • *How are other councils addressing coastal adaptation to climate change?* • *Do we have general acceptance that we have a problem to address?*
Step 2	**Assessment**	This step is about gathering knowledge to be better informed on the scale and scope of potential effects of climate change • *What information do we need to assess how climate change might affect our local coastal communities?* • *What issues do we face?* • *Where are our most vulnerable locations?* • *What is the level of risk we are facing?*
Step 3	**Planning a way forward**	This step is about planning what needs to happen to achieve adaptation to climate change • *What is going to be our strategic and long-term approach to adaptation?* • *What are the steps required to move us in this strategic direction over time and thereby build community resilience?* • *How do we get buy-in from key stakeholders and communities?*
Step 4	**Implementation, Monitoring and Review**	This step is about undertaking the actions that have been set out in the adaptation plan developed in Step 3. It includes monitoring change over time of the environment, of information, of implementation progress and so on. The monitoring results then feed into regular reviews of the adaptation plan, in order to incrementally build community resilience to the increasing risks being faced. • *Is our plan for a strategic way forward being implemented effectively?* • *Are our communities becoming more resilient to climate change?* • *What do we need to monitor, and what are the triggers for reviewing our adaptation plan?*

At Granity, Ngakawau and Hector level of risk to the community over the long-term will be minimised best by considering a hierarchy of options for adaptation. Table 4-2 illustrates a simplified hierarchy of the level of protection or level of risk exposure to the community for adaptation options when considering a long-term timeframe. This illustrates that hard engineering structures located close to the beach face are less preferable from a risk management perspective, and that retreating or relocating are ultimately the best approaches to reducing risk to the community. On this long-term scale it is clear that structural interventions are only suitable as short-term or limited option to buy time while a long-term strategy is planned and agreed by the community.

Table 4-2: Simplified long-term adaptation hierarchy for Granity, Ngakawau and Hector.

Risk to community over long-term	Level of protection provided to community over long-term	Adaptation action
Lowest	Highest	Relocate buildings off site
↓	↑	Retreat buildings on existing property + buffer planting
		Retreat buildings on existing property (no buffer)
		Backstop defence + buffer planting
		Backstop defence (no buffer)
		Hard defence structure + buffer planting
		Hard defence structure (no buffer)
Highest	Lowest	Beach nourishment

This adaptation hierarchy is incorporated into specific guidance for coastal sections at Granity, Ngakawau and Hector below.

An adaptation plan should also be adaptive so it can be implemented in stages based on the erosion observed, community vulnerability and new information/assessments. It should also set out the overall context and strategic directions for managing coastal areas at a large scale and draw together community aspirations.

4.2.2 Monitoring and decision points

An observation-based monitoring programme for the coastline should be established in order to inform community decision making for appropriate coastal management options. This should include regular photographs (with date, time, location and photographer) from the road to the low-water level along the whole coastline and at properties with minimal setback from the beach face. Additional photographs should be collected which show the impact of extreme events with features such as erosion scarps, debris lines and the distance from high-water to dwellings (i.e., how close the water came to the houses). **This observational monitoring should be community led with property owners responsible for collecting and collating evidence to be delivered to WCRC periodically.**

The main outcomes of the monitoring is to establish local coastal retreat rates in relation to private property (i.e., quantify the position, elevation and changes to key beach features) and provide evidence of risk and vulnerability to private property. Features such as the gravel berm crest/toe, vegetation line and drain/lagoon should be identified where possible. The monitoring will also help to quantify risk and exposure to dwellings along coastal properties, which can be used to inform and prioritise decision making for the community and Councils and as information for coastal protection design (if that is the selected option).

When used for adaptation planning and decision making by the community and Councils, the monitoring will inform the setting of decision points for management of coastal sections related to both inundation events and erosion or retreat of the beach. Decision points or thresholds are central to coastal adaptation planning as they are a sensible pathway to agree on community actions for when the beach erodes to a certain point, but agreement is reached *before* the erosion reaches a critical stage. These points may not be a single milestone, but have several intermediate steps for consultation and planning before an action is implemented. Beginning the consultation process now (rather when the threshold is reached) is the most sensible pathway for coastal adaptation along these frontage sections. These decision points should be based on risk to property (i.e., how close the storm waves get) rather than retreat/migration of beach features (which are more difficult to quantify). Examples of decision points or milestone pathways include (note these options are not sequential and not specific to a West Coast location):

- When waves overtop (but do not substantially damage) an existing coastal defence twice in 12 months, prepare a plan to retrofit the defence. This should include cost estimates for the options. Retrofit options may include adding larger rocks to the toe or crest of the structure or increase planting density on the crest.
- If erosion is localised to a 200 m stretch and the beach toe erodes to within 40 m from a dwelling, the community will prepare and cost the relocation of at-risk dwellings landward on the property or off-site entirely.
- When an erosion scarp advances to within 20 m from a private dwelling the community and Council will aggressively manage vegetation (new planting, replanting) on the backshore behind the beach crest.
  - When this scarp position has been sustained for 2 years, the community agrees that affected properties will plan, cost and obtain resource consent for backstop gabion defences to be installed at property boundaries.
  - If the erosion continues to within 10 m and sustains this position for more than 2 years, the affected property owners will construct the backstop defences.
- The community agree to undertake action to relocate dwellings off-site when 2 inundation events (e.g., overtopping the beach crest with flooding into/beneath private dwellings) occur in any 12 month period AND an erosion scarp is within 10 m from of dwellings.

This type of adaptation strategy with decision points means that if the beach advances seaward (accreting sediment), the planning and preparation is not wasted, and may remain for when/if erosion affects properties again.

Note that in a setting such as Granity, Ngakawau and Hector where long-term coastal retreat has been recognised, any intervention measures (rock walls, gabions, vegetation planting) to reduce risk should be considered short to medium term options only to ‘buy some time’. The most effective long-term measure to reduce risk is to relocate buildings as far from the active beach face as possible, or to another property entirely.

4.2.3 General advice for coastal property

It is important that both Councils and landowners are aware that further residential construction seaward of SH67 along any part of the Granity-Hector frontages will be impacted by coastal erosion during the lifetime of the property. Avoiding any further new development or significant redevelopment along this section of coastline needs to be a priority.

Coastal defences such as seawalls or revetments built to ‘hold’ or ‘advance the line’ are often viewed as ‘solutions’ to coastal erosion problems. Unfortunately, such actions tend to be reactive and are rarely the most effective option in the long term. The construction of defences also leads to a false sense of security and often facilitates further development behind the structures. Ultimately, there is an expectation that such defences will be maintained *in-perpetuity* which leads to ever increasing financial commitment to upgrade and maintain the defences.

Coastal defences should only be used where a property is at direct risk from storm or erosion damage. Such defences should be considered 'transitionary' to 'buy some time' to permit a longer-term approach to reducing the property risk. Along the Granity, Ngakawau and Hector coastal frontage, in the long-term the relocation of existing buildings as far from the active beach face as possible, or to another property entirely will be required.

4.2.4 Large-scale engineering solutions

During discussions with local residents a number of other large-scale engineering solutions were mentioned and discussed. Among these were a groyne field along the Granity frontage, a groyne to Lovers Rock and artificial surfing reefs. These were discussed and discounted as feasible options in NIWA (2006); the reasoning for these exclusions remains, and the options are still not recommended. A groyne field can be a suitable option given the right coastal setting, but the circumstances at Granity, Ngakawau or Hector are not suitable and community investment in a groyne/groyne-field is environmentally and economically unwise.

Large-scale rock revetments are another an option for the coastline, but to be an effective engineering solution for the medium-long term they need to be on the scale as the recently constructed Punakaiki revetment (see Figure A-1, Appendix A). Such a structure along the Granity, Ngakawau and Hector frontage would be prohibitively expensive (construction and ongoing maintenance), and if constructed from Granity to Hector it would likely cause other adverse environmental impacts on adjacent sections of shoreline.

4.3 Appropriate defence design and typical cross sections

General guidelines for appropriate defences along the Granity, Ngakawau and Hector coastal settings were listed in NIWA (2006, 2007) and are extended and refined below. The options include vegetation buffer zones, back-stop gabion structures, revetment structures and beach nourishment.

The typical cross sections for hard defence options given below are indicative only; detailed design is recommended for full analysis of the structure dimensions, layout, materials and construction method. These cross sections are provided as realistically scaled examples for coastal defences along the Granity, Ngakawau and Hector frontage and should not be used elsewhere without consultation.

4.3.1 Buffer Zones

All back gardens need to be treated as buffer zones.

- A zone of at least 10 m width (the more the better) of natural coastal vegetation, such as flax or bamboo clumps as commonly found along the coastline of the West Coast, is recommended.
- Much of the benefit of such zones is lost if this vegetation is replaced by gardens or decking out to the coast. Similarly, the benefit is lost if wide gaps are cleared for coastal views or vehicular beach access which become conduits for overtopping and eroding flows.

- Buffer zones are still required if coastal defences have been built (as wave overtopping and occasional failure of such defences will still occur). Extending gardens or decks to the edge of the coastal defence will reduce much of the overall effectiveness.
- Where there is little space to accommodate a buffer zone between the coast and assets or dwellings, thicker vegetation, e.g., bamboo clumps, is recommended. This can be routinely trimmed to around a metre high to still remain effective but not spoil sea views.
- Creation of shore-parallel vegetation 'facines' to trap overwash sediment and wind-blown material will assist building the buffer zone (see NIWA 2007, Figure 10). An example of this type of fence-enhanced vegetation, driftwood and sediment capture can be seen in Ngakawau (section N3, see Figure 3-11).

4.3.2 Defence structures - gabion backstop

A typical gabion-basket backstop defence should be constructed within the private property boundary and landward of existing beach face and natural buffers (vegetation, swamp or berm) to provide a higher level of protection to a property for a longer length of time. Figure 4-2 illustrates the typical cross section of a gabion backstop defence suitable for Granity, Ngakawau or Hector frontages in settings with/without a backshore drain or swamp. Table 4-3 shows the estimated material volumes per metre length of the example defences. The following guidelines should also be considered in conjunction with the backstop defence design given below.

- Any further defences that are built still need to include as wide a vegetated buffer in front and behind them as possible. Topsoil and small grasses may be planted to cover the gabion structure but large trees are to be avoided due to basket damage by roots. This may require relocation of garden decking and sheds from immediately behind the coastline if there is insufficient space to accommodate an appropriate coastal defence seaward of the existing decking and shed.
- The backstops should be underlain by geotextile filter fabric.
- Gabion fill should be large gravel and cobbles (0.1 m to 0.3 m nominal diameter). These should be sourced from an external source and not taken from the surrounding beach or backshore deposits.
- The front face of all beach-facing gabion structures should ideally be sloping at 1:2 or 1:3 (less appropriate is a stepped profile) but not vertical.
- The ends of any structure need to curve back into the land behind, i.e., wing walls of gabions extending back landward perpendicular to the seaward face of the structure to prevent outflanking.
- Future beach nourishment or drain clearance deposits should be place on the beach face.

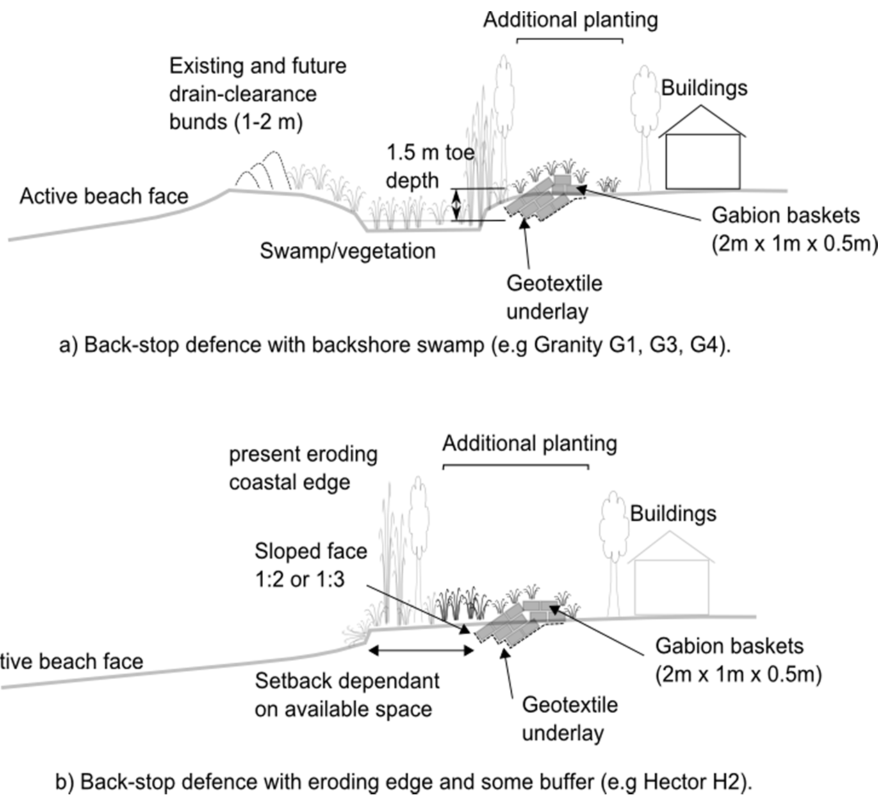


Figure 4-2: Schematic of gabion basket backstop defence along foreshore of typical coastal frontage at Granity, Ngakawau or Hector. Not to scale.

Approximate quantities per metre length for gabion-basket backstop defences are listed in Table 4-4 (see Appendix B for calculation).

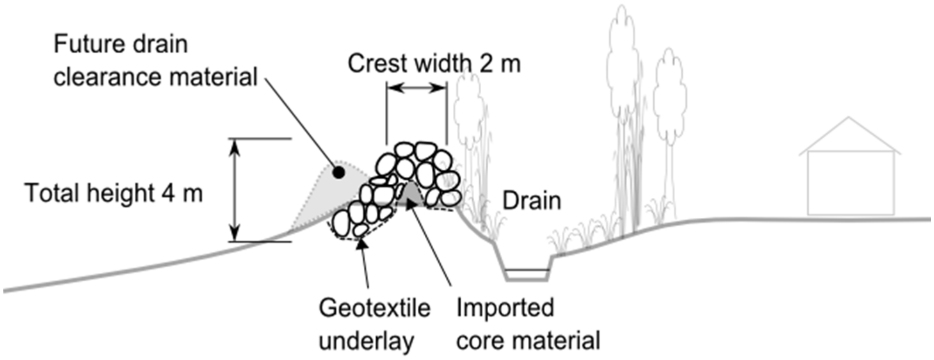
Table 4-3: Approximate volumes per metre length for gabion backstop defence. See Appendix B for calculations.

Component	Quantity per metre length of defence	Comments
Geotextile underlay	9 m^2	Area of geotextile underlay, note rolls usually 20 m x 100 m
Gabion basket fill (0.1-0.3 m nominal material diameter)	1.8 t	For single basket (i.e., 1 m^3=2 m x 1 m x 0.5 m)
	20 t	For 11 baskets (as diagram)
Vegetation planting	15 m^2	Area of additional/replacement planting after construction

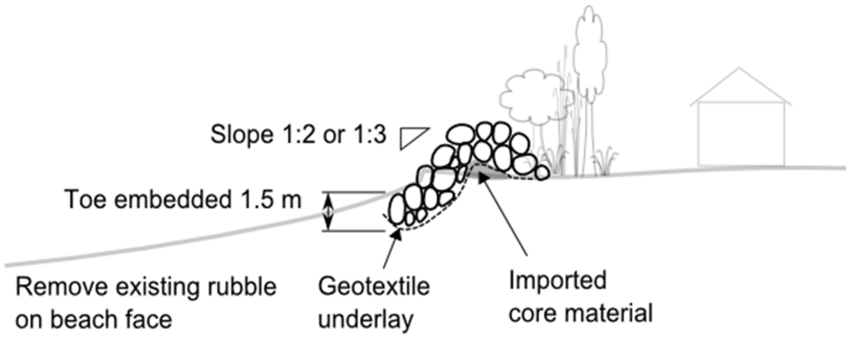
4.3.3 Defence structures - rock revetments

A typical rock revetment will emulate the structures recently constructed along the frontage, although larger armour stones than the school structure are recommended. Figure 4-3 illustrates the typical cross section of a rock revetment suitable for Granity, Ngakawau or Hector frontages in settings with/without a backshore drain or swamp. Table 4-4 shows the estimated material volumes per metre length of the example revetments. The following guidelines should also be considered for defence construction in conjunction with the revetment design given below:

- Where there is scope, i.e., more space between the coastline and any assets or dwellings, consideration should be given to a backstop defence rather than a defence located right behind the beach (e.g., gabion defences in Section 4.3.2 above). This will provide a higher level of protection to a property for a longer length of time.
- Any revetment structure should be located landward of the present active beach, with the interface of the beach and structure well above present high tide levels (i.e., the present beach is left in front of the defence where possible).
- Any further defences that are built still need to include as wide a vegetated buffer behind it as possible (as outlined above). This may require relocation of garden decking and sheds from immediately behind the coastline if there is insufficient space to accommodate an appropriate coastal defence seaward of the existing decking and shed.
- Where defences are planned along a number of sections, the location and profile of the defence should be consistent and continuous. New coastal defences should not be constructed for less than 100 m or 5 adjacent properties, and ideally a minimum of 200 m or 10 adjacent properties should have a single defence type protecting their properties.
- If there is a nearby or attached wall, then any new structures should tie-in to and present a single line of defence (e.g., section G2, between Granity School and Granity Stream and section H3 to infill gaps at 25A and 29 Main Rd, Hector).
- New defences should also include a wrap or tapering of the ends of the structure to minimise the effect of edge effects on adjacent properties, as often the properties immediately adjacent to hard protecting works are worst affected. Similarly, structures should wrap around stream-mouths with a consistent crest elevation to protect against outflanking and stream-bank erosion (e.g., section N2, Morris Creek entrance).
- Revetments should:
  - Consist of two layers of well placed (rather than dumped), evenly sized interlocking rock with a bedding layer (smaller rock/gravel) and with geotextile or an appropriate filter layer between the rock and the underlying substrata.
  - Be constructed such that the largest rock is placed at the toe of the structure, which should be at least 1.5 m below the level of the present beach.
  - Have a width at the crest of the revetment of at least three rocks wide to prevent scouring behind the crest due to run-up and overtopping.
- Core material should be imported fill and overlain by geotextile and armouring rock.
- Future beach nourishment or drain clearance deposits should be place on the seaward side of the structures.



a) with backshore drain (e.g G2, Granity School - Granity Stream).



b) without backshore drain (e.g. N2, Morris Creek - 19 Main Rd, Ngakawau)

Figure 4-3: Schematic of rock revetment defence structure along foreshore of typical coastal frontage at Granity, Ngakawau or Hector. Not to scale.

Approximate material quantities for these rock revetments are shown in Table 4-4 (see Appendix B for calculation). Although the designs differ slightly, the estimated material volume is the same for each design and represents an average value per metre length of defence.

Table 4-4: Approximate volumes per metre length for rock revetment protection structure. See Appendix B for calculations.

Component	Quantity per metre length of defence	Comments
Core material	4 t	Imported mixed sand/gravel. Not to be sourced from adjacent beach face or backshore. Assumed bulk density 1.8 t/m^3.
Geotextile underlay	14 m^2	Area of geotextile underlay per metre length of defence. Material is usually suppled as 20-25 m wide rolls.
Rock armour stone	32 t	Imported rock to be placed not dumped (nominally 0.7-0.9 m diameter or 0.6-1.4 t). Assumed density 2.7 t/m^3 and placed porosity 33%.
Vegetation planting	5 m^2	Area of additional/replacement planting after construction.

4.3.4 Beach nourishment

The placement of new gravel/cobble material along the beach front is an option to build up a more robust beach where the coastline is currently in deficit of sediment. However, beach nourishment is only a short-term measure to buy time or extend the life of a defence. The nourished material augments the natural beach sediment supply, and acts as a sacrificial erosion buffer in place of the natural beach material. Nourishment often involves a single large placement followed by top-up nourishment periodically (say, every 5-10 years) or after storm events depending on the rate of sediment loss. Any nourishment project would require further study to assess appropriate placement and scale, projected longevity and resulting distribution of wave-reworked nourishment material along the beach, and monitoring of the beach to quantify performance of the nourishment. Nourishment may only be suitable in short sections in and adjacent to the rock-outcrops at the northern end of Granity where the rocks form more an anchor to hold sediment on the beach. It is unclear whether there is a suitable gravel source close to Granity, Ngakawau and Hector as the source material should be sourced from a sustainable location not on the adjacent beach, backshore or lagoon.

The cross sections presented in Figure 4-4 for beach nourishment are indicative only, and the material volumes estimated assume a trapezoidal cross section of 2 m height, 10 m base width and 2 m crest width for a volume of 23 tonnes per metre length of nourishment. The following guidelines should also be considered in conjunction with the beach nourishment schematic given below:

- When appropriately designed, the nourished elevation should correspond to or slightly exceed the natural berm elevation.
- Nourishment is usually undertaken as one large volume to start with, with subsequent regular deposition at multi-year intervals, or after storm events as needed.
- Nourishment is most effective where source material is of similar size and composition to that on the shore to be nourished. The source location should have a significant excess of available material but should not be the adjacent active beach, backshore or lagoon. There are few on-shore locations on the West Coast which will meet this criteria, making this a costly option.

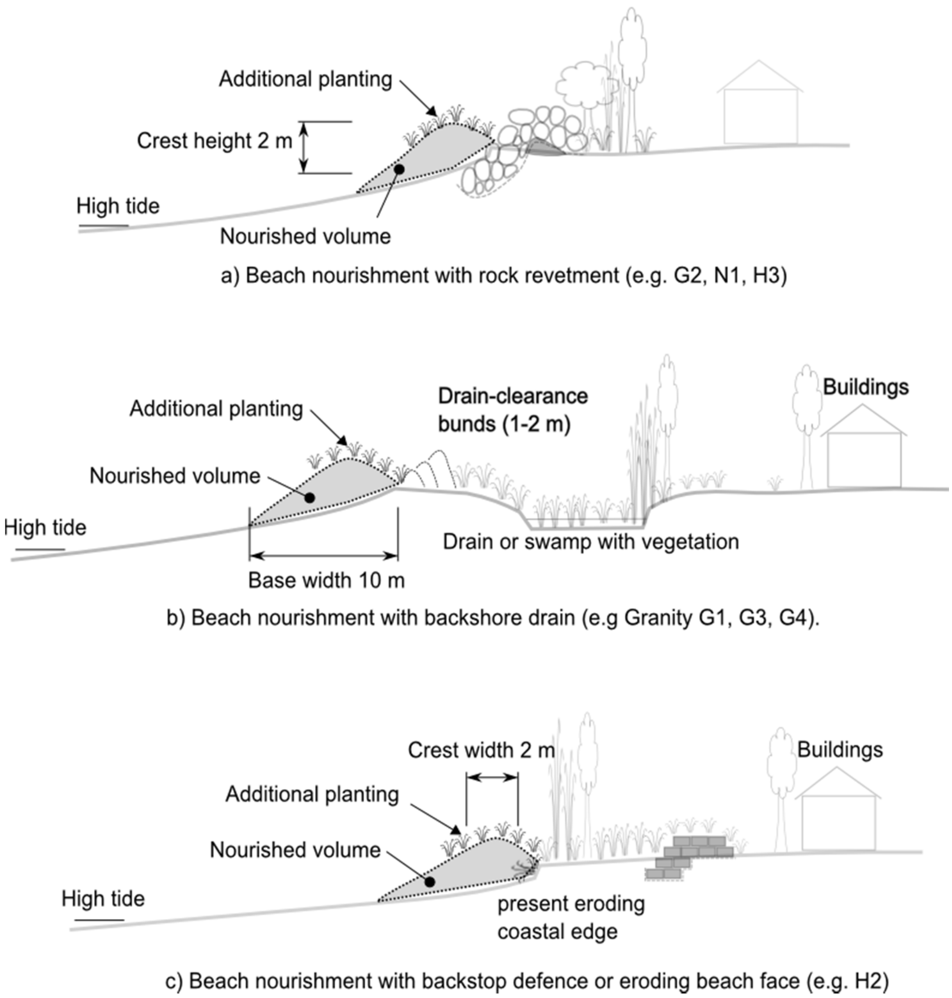


Figure 4-4: Schematic of example beach nourishment placement along Granity, Ngakawau and Hector coastline in various coastal settings. Not to scale.

Large scale beach nourishment is unlikely to be a realistic option for Granity, Ngakawau and Hector because of the large sediment migrations already occurring over the beach face. Any deposited material may only last in the deposited location for one storm event before being spread north and south over the wider beach. Further, the lack of an economically and environmentally viable sediment source limit the applicability of this option. However, it may be useful as a very-short term measure to buy time while resource consent or design/payment arrangements are made for an alternative coastal management option.

4.4 Site specific coastal adaptation recommendations

The 5 km Granity, Ngakawau and Hector coastal frontage was divided into twelve frontage sections roughly aligned with changes in coastal protection from existing defences, river/stream mouths and distinct features which influence coastal erosion (see Figure 3-1). Recommendations for coastal defence improvements at each frontage section are presented in Table 4-6. These were drawn from site observations, the current level of protection at each section (Section 3) combined with general defence designs and material estimates (Section 4), and considering a reasonable coastal adaptation pathway and hierarchy of actions.

Irrespective of the following section-specific recommendations:

- All community members should be involved with establishing an appropriate adaptation pathway for the long-term management of coastal changes.
- All frontage sections should monitor the coastal environment (photographs, surveys) at regular intervals and after storm events.
- All frontage sections should actively manage vegetation planting in/around their property and beach frontage (planting, replanting washed-out plants).

4.4.1 Site specific recommendations

These specific recommendations and options are presented as coastal management options for the short to medium term only, i.e., up to 20 years. They neither exclude nor reduce the need for a long-term strategy for community adaptation and resilience to coastal changes.

The specific interventions recommended for each frontage section are suggested with various timeframes based on the current risk profile of the properties. To interpret Table 4-6, use the following text definitions of actions and timeframes (Table 4-5):

Table 4-5: Definitions of recommended short-medium term coastal erosion management text and timeframes. See Table 4-6.

Text	Definition
Y	Currently an adequate level of protection unless a storm event triggers adverse conditions.
N	A possible action but not recommended at this stage.
N/A	Not applicable to this setting.
Implement	Put into place (design, consent) within a 0-2 year timeframe.
Prepare/Plan	Consider the design (location, length, height), fully scope the cost and resource consent, 2-5 years from now.
Consider	Beach nourishment may be an appropriate option to buy time before intervention or extend the life of existing defences and could be implemented soon (< 5 years) or in the future (> 5 years).
Monitor	Specific monitoring of the beach environment for changes to beach features is essential to informing future options for managing coastal erosion and will help establish effective risk reduction measures.

Table 4-6 illustrates the recommendations and options for short-medium term risk management for each frontage section. Summarising this:

- Three frontage sections (G5, N4, H1, see Figure 3-1) have no inhabited dwellings or are not backed by private property, and are <u>not at direct risk</u> so intervention is currently unnecessary.

- Several frontage sections with occupied dwellings currently have a satisfactory level of protection for now and currently require little or no intervention (G2, N1, N3, see Figure 3-1). However, this may change with storm events and long-term adaptation strategies should still be considered.
- Three frontage sections (G2, N1, H3, see Figure 3-1) have recently constructed rock revetment defences (total length 700 m) and intervention is mostly unnecessary except as a preventative measure to fill gaps in defences or as tie-ins to the natural beach berms. Future intervention may be necessary if the level of protection reduces and a long-term adaptation strategy should still be considered.
- Three frontage sections (G4, N2, H3, see Figure 3-1) should implement a hard defence option to fill gaps between existing rock revetments or a backstop gabion-basket wall. This is to improve the level of protection along those frontage sections while a long-term strategy is being developed.
- Five sections (G1, G2, G3, N3, H2, see Figure 3-1) should prepare/plan for hard defences as either upper-beach rock revetments or backstop defences. Property owners along these sections should closely monitor the beach face and consider establishing thresholds for when they will implement the hard defences. A long-term adaptation strategy should still be considered
- Beach nourishment is only likely to be effective at some locations and should be addressed on a case by case basis and with further monitoring and assessment.
- Most frontage sections have little or no room to relocate buildings away from the beach face, however sections G3, G4, N2 and N3 (see Figure 3-1) have room for movement which would reduce the risk over the short-medium term while a long-term adaptation strategy is developed.

To interpret the following table consider the example of frontage section N2 (Morris Creek to 19 Main Rd, Ngakawau). Here there is currently an ad-hoc rubble defence with insufficient buffer between buildings and the active beach face. It does not currently have an adequate level of protection, and there are actions to improve this level of protection over the short-medium timeframe. The recommended action is to implement a hard-defence structure in the short term, prepare to carry out beach nourishment in the future if monitoring suggests it is worthwhile, and where possible to relocate buildings landward within existing property boundaries. A backstop defence is not appropriate along this stretch due to minimal setbacks. Independent of the recommended outcomes or actions, a long-term strategy for adaptation should be considered and the frontage should be monitored (surveys, photographs) and have active vegetation management (planting, replanting washed out plants).

ID	Coastline section description	Length (m)	Setting	Fundamental ongoing actions for all sections	Satisfactory level of protection for now	Recommended actions over short - medium term			
						Hard defence structure	Backstop defence (at or within private boundary)	Beach nourishment	Relocate buildings within boundary
G1	South of Granity School	320	No hard defence. Sufficient buffer.	Develop long-term coastal adaptation pathway AND Shoreline monitoring - regular beach profiles or surveys - photographs of extreme events AND Active vegetation management - replanting die-back areas - in-filling gaps - planting backshore areas	-	Prepare 40 m tie-in to School structure	Prepare/Plan	N	N/A
G2	Granity School - Granity Stream	350	Hard defence for 230 / 350 m (120 m gap). Marginal buffer.		Y	Prepare to fill 120 m gap	N/A	Monitor/consider (future)	N/A
G3	Granity Stream - Chair Rock	500	No hard defence. Sufficient buffer.		-	N	Prepare/Plan	N	where possible
G4	Chair Rock - Lovers Rock	850	No hard defence. Marginal buffer.		-	N	Implement	Monitor/consider	where possible
G5	Lovers Rock - Merrett's wall	780	No defence. Backed by SH67. Marginal buffer.		Y	No intervention necessary			
N1	Merrett's wall - Morris Creek	180	Hard defensive structure. Marginal buffer.		Y	Existing	N/A	Monitor/consider (future)	N/A
N2	Morris Creek - 19 Main Rd, Ngakawau	100	Ad-hoc rubble defence. Insufficient buffer		-	Implement	N/A	Monitor and prepare/plan	where possible
N3	19 - 26 Main Rd, Ngakawau	200	No hard defence - vegetation trap only. Marginal buffer.		Y	Prepare/Plan	N/A	Monitor/consider (future)	where possible
N4	26 Main Rd - River mouth, Ngakawau	300	Backed by SH67 or abandoned property. Sufficient buffer.		Y	No intervention necessary			
H1	River mouth - Corbett St, Hector	320	No hard defence. Sufficient buffer.		Y	No intervention necessary			
H2	Corbett St - 25 Main Rd, Hector	550	No hard defence. Marginal to sufficient buffer.		-	N	Prepare/Plan	N	N/A
H3	25 - 37 Main Rd, Hector	350	Hard defence for 280 / 350 m (70 m gap). Marginal buffer.		-	Implement, fill 70 m gap	N	Monitor/consider (future)	N/A

Table 4-6: Summary of recommended short-medium or ongoing actions for coastal management along frontage at Granity, Ngakawau and Hector. Text definitions: Y - Currently an adequate level of protection unless an event triggers adverse conditions; N – a possible action but not recommended at this stage; N/A – not applicable to this setting; Implement - Put into place (design, consent) with 0-2 year timeframe; Prepare/Plan - consider the design (location, length, height), fully scope the cost and consent, 2-5 years from now; Consider – beach nourishment is an appropriate option to buy time before intervention or extend the life of existing defences and could be implemented soon (< 5 years) or in the future (> 5 years); Monitor – Specific monitoring of the beach environment to inform future options for managing coastal erosion and establish effective risk reduction measures.

4.4.2 Material Estimates

Extending the recommended management strategies to material volumes for cost estimation and decision making, Table 4-7 illustrates rough-order total material volume estimates for each recommended option. The estimates use the typical cross-section options and estimates for defences (Section 4.3) and the site-specific recommended management actions (Table 4-6). These typical designs do not constitute detailed design, err towards a conservative estimation and should be refined before construction. Estimates to not include excavation for structure foundations or any topsoil imported to support vegetation growth.

The unit length requirement for each improvement option is included for reference and to calculate additional volumes/costs for wrap-around walls (i.e., stream mouths) or where the structure is not required over the whole section length as indicated.

Table 4-7: Estimates of material volumes for coastal defence works at Granity, Ngakawau and Hector based on typical cross sections (Section 4.3) and recommended actions (Table 4-6). See Appendix B for calculations. Volumes are estimates only and represent improvements over the whole frontage section except where indicated.

Section ID	Total section length m	Hard defence					Backstop gabions				Beach nourishment	
		Defence length m	Fill: mixed sand/gravel t	Armour rock/stone t	Geotextile underlay m^2	Vegetation planting m^2	Defence length m	Gravel/cobble gabion fill t	Geotextile underlay m^2	Vegetation planting m^2	Defence length m	Mixed sand/gravel t
Unit length (1 m)		-	4.0	31.7	13.6	5.0	-	19.8	9.0	15.0	-	22.8
G1	320	40	200	1300	500	200	320	6300	2900	4800	-	-
G2	350	120	500	3800	1600	600	-	-	-	-	350	7980
G3	500	-	-	-	-	-	500	9900	4500	7500	-	-
G4	850	-	-	-	-	-	850	16800	7700	12800	850	19380
G5	780	-	-	-	-	-	-	-	-	-	-	-
N1	180	-	-	-	-	-	-	-	-	-	180	4104
N2	100	100	400	3200	1400	500	-	-	-	-	100	2280
N3	200	200	800	6300	2700	1000	-	-	-	-	200	4560
N4	300	-	-	-	-	-	-	-	-	-	-	-
H1	320	-	-	-	-	-	-	-	-	-	-	-
H2	550	-	-	-	-	-	550	10900	5000	8300	-	-
H3	350	70	300	2200	1000	400	-	-	-	-	350	7980

4.5 Further considerations and implementation

Outlined above are a number of observations and potential measures for reducing the rate of coastal retreat along the Granity, Ngakawau and Hector frontage in the short to medium term. They are based on site observations, brief discussions with community members and staff at the Regional and District Councils. Most options will require further discussion between residents, District and/or Regional Council as well as further investigation, i.e., monitoring, detailed design, cost estimation weighed-up with benefits.

Buller District Council should continue to clear the back-shore drains as this prevents ponding water from the stream discharge, helps drain any overwash flows, returns sediment to the active beach face and resists wave runup during minor storms.

None of the options presented will 'solve' the erosion problem, rather they are a way of adapting to and managing the erosion issues, and in many cases providing an increased level of protection to provide time to implement long-term plans for relocating buildings over the coming decades.

5 Summary of recommendations and conclusions

At Granity, Ngakawau and Hector, as in most coastal areas, the problem is not due to the ongoing changes in the coastline but rather that development historically (and ongoing) has been located too close to the sea to accommodate natural changes and trends in shoreline position. The ongoing coastal erosion and shoreline retreat is occurring because of a long-term, region-wide deficit in new sediment reaching and resupplying the beach face after erosion episodes or storm events.

The report outlines a number of potential measures, as a basis for future discussion between the Regional Council and residents, which could assist in reducing the impact and/or slowing down the rate of coastal retreat along the coastal frontage in the short-medium term and long-term time frames.

The 5 km coastal frontage of the villages was divided into 12 individual sections from observations about the current level of coastal protection and likely ongoing protection needs. Short to medium term coastal management actions have been recommended to improve the level of protection in each section. These actions are intended to 'buy some time' to permit development of a long-term strategy or adaptation pathway which addresses the coastal erosion and improves community resilience. The options reflect typical coastal defence designs suitable for this stretch of coastline and include recommendations of a timeframe for implementation. Large-scale engineering approaches, such as groynes, whole-coastline armouring or beach nourishment, remain unsuitable for this stretch of coastline.

Independent of the section-specific recommendations, the community should be involved with a developing a long-term adaptation strategy, should monitor the beach (surveys, photographs) and undertake active vegetation management (planting, replanting washed out plants).

The specific recommendations to implement or put into place (design, costing, consent, construction) over a short term (0-2 years) timeframe include:

- Gaps in the beachfront revetment at northern Hector should be filled (total length 70-80 m) to provide a continuous line of defence and eliminate out-flanking erosion within already defended sections.
- Tie-in or wrap-around walls are recommended for the southern edge of Granity school to reduce outflanking erosion and wash-around sediment deposition which is causing vegetation die-back and reducing the level of protection.
- Gabion- basket backstop defences and aggressive replanting along the private property boundaries of northern Granity frontage from Chair Rock to Lovers Rock are recommended to reduce the impact of storm washover events.
- While not a new task, the Buller District Council should continue to clear the back-shore drains and re-form the narrow beach berm to allow drainage of any overwash flows and allow sediment to reach the active beach face through stream flow.

The actions which should be prepared/planned by considering the design (location, length, height), fully scope the cost and resource consent, on a timeframe of 2-5 years from now include hard defences as either upper-beach rock revetments or backstop defences. This approach is recommended for the central and southern Granity frontages, northern Ngakawau and central

Hector. The frontages are recommended to begin this process as an adaptive management strategy by planning/preparing and agreeing on erosion thresholds for when action will be taken.

The actions to consider into the future for most coastal frontages into the future are beach nourishment and relocating of buildings within private property boundaries. These options should be considered for the future (5 years) at northern Granity and northern Ngakawau and at locations where monitoring indicates whether the actions are necessary.

Volumetric material estimates for a typical rock revetment, gabion backstop wall or beach nourishment defences relevant for each frontage section have been established to aid community/Council decision making through eventual cost-benefit analysis. All recommendations are subject to change when critical risks arise from coastal storm events which cause large or severe erosion, inundation and overtopping.

Development of a specific and long-term adaptation plan for the Granity, Ngakawau and Hector coastline is recommended. The adaptation pathway is process for achieving change over time to enable people and communities to adjust to changing conditions and to minimise of reduce the risk to themselves and to property from the effects of natural coastal hazards. An adaptation plan may be implemented in stages, but it should set out the overall context and strategic directions for managing coastal areas at a large scale, and draw together community aspirations.

The options presented here are actions to implement before the coastline becomes untenable and risk to property is critical. **The options and actions presented must not be considered long-term solutions and should be considered short-medium term options to 'buy some time' while planning for a long-term adaptation strategy or until the situation changes**. Ultimately, the lowest-risk long-term solution will be to retreat away from the coastline, either through moving houses inland within the property boundaries or relocation building off-site.

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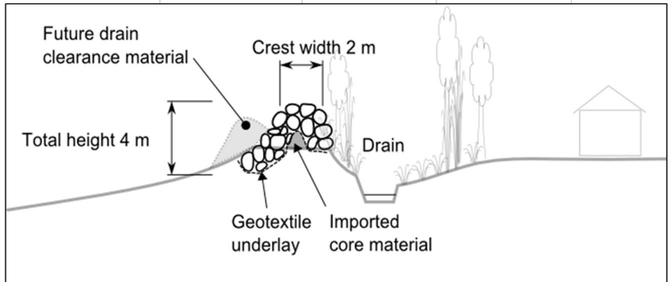
Appendix A Example coastal defence

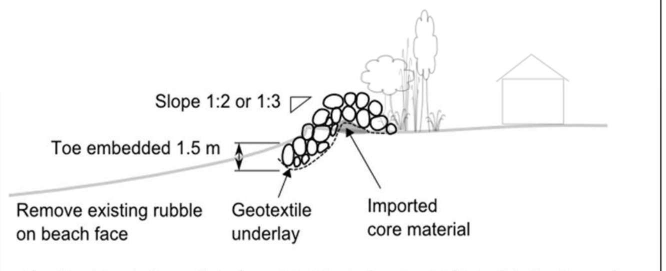
Figure A-1: Larger-scale rock revetment for coastal defence at Punakaiki. Defence constructed to protect both SH6 (visible centre right) and township. Photograph looking north towards Punakaiki township. [22 September 2015].

Appendix B Volumetric estimate calculations

1 Rock revetments (e.g. G2, N2)									
Step	*Component*	*Calculations*						*Estimate*	*Explanation*
Revetment (per metre length)									
	Core material	height (m) 1.5	width (m) 1.5	Cross sectional area (m^2) 1.125	Additional area for rock bedding (m2) 1	bulk density kg/m^3 1900	-	-	**4.0**	imported core material (t/m length) (mixed sand/gravel NOT from beach face)
	Revetment armour stone	Slope, i.e. 1:2 0.5	height (m) 4.00	Crest width (m) 2.5	Thickness (m) 1.4	Cross sectional area (m^2) 17.5	Rock density (kg/m^3) 2700	Placed rock porosity (%) 33%	**32**	new rock required (t/m length), (nominally 0.7-0.9m diameter, mass 0.6-1.4 t)
	Geotextile underlay	length (m) 12.1	Overlap/extra (m) 1.5	-	-	-	-	-	**14**	Geotextile underlay area (m2/m length)
Plant vegetation									
	planted surface area (tussock, flax, bamboo)	surface area (m2) 5	-	-	-	-	-	-	**5**	Surface area to plant (m2/m length)

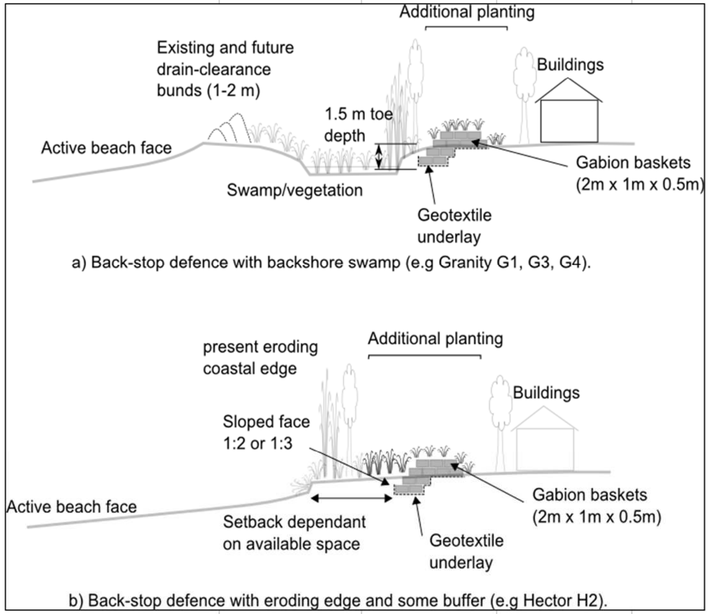


a) with backshore drain (e.g G2, Granity School - Granity Stream).



b) without backshore drain (e.g. N2, Morris Creek - 19 Main Rd, Ngakawau)

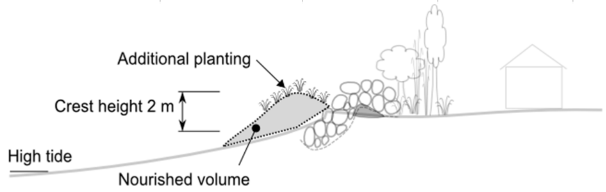
2 Gabion Basket back-stop defence (e.g. G1, H2)										
Step	***Component***		***Calculations***						***Estimate***	***Explanation***
Gabions										
	Geotextile underlay	length (m)	Overlap/extra (m)	-	-	-	-	-		
		8	1						**9**	Geotextile underlay area (m2/m length)
	Gabions	volume per basked	bulk density (kg/n	number of baskets						
		1	1800	11					**20**	Gravel gabion fill volume (t/m length) (Gravel size > 0.1 m diameter)
Plant vegetation										
	planted surface area (tussock, flax)	surface area (m2)	-	-	-	-	-	-		
		15							**15**	Surface area to plant (m2/m length)



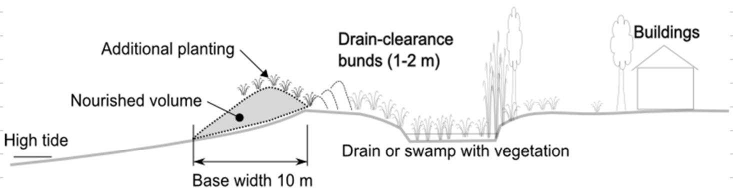
a) Back-stop defence with backshore swamp (e.g Granity G1, G3, G4).

b) Back-stop defence with eroding edge and some buffer (e.g Hector H2).

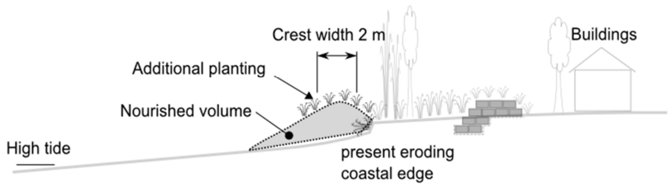
3 Beach nourishment to buy time or extend life of defence (e.g. G1, G4, N1, N2, N3, H3)									
Beach nourishment material	height (m)	width, base (m)	width, crest (m)	Cross sectional area (m2)	bulk density (kg/m3)				
	2	10	2	12	1900	-	-	**22.8**	Nourishment volume (m3/m length) (Well-sorted mixed sand/gravel with similar size grading and composition to beach material but NOT sourced from active beach face.)



a) Beach nourishment with rock revetment (e.g. G2, N1, H3)



b) Beach nourishment with backshore drain (e.g Granity G1, G3, G4).



c) Beach nourishment with backstop defence or eroding beach face (e.g. H2)