Te Hunga Takutai o Aotearoa
NEW ZEALAND COASTAL SOCIETY

Coastal News

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Fehi storm surge in Ruby Bay near Nelson, 1 February, 2018 (Photo: Tasman District Council).

Summer of storms

The summer of 2017/2018 was notable for unusual – and destructive – weather, as the country was subjected to a series of powerful storms and very high spring tides. In this issue we look at both the reasons behind this unusual weather and the significant impacts it had on New Zealand.

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Word from the Chair

Tom Shand

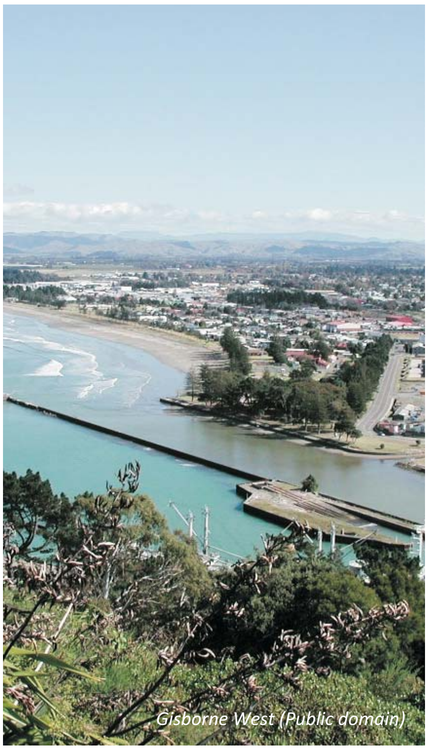
Kia ora koutou

Summer seems like a long time gone, but in many parts of the country work is still underway repairing damage caused by a series of intense storms. These storms tracked onto New Zealand further west than usual, descending via the Tasman Sea and down the west coast, before crossing the country. This brought strong northerly winds, driving large waves and storm surges onto northern and western coasts. Several of these systems also coincided with particularly high tides, further exacerbating their potential to cause damage, but also giving us some insight into life at higher sea levels. With this in mind, this issue of *Coastal New*s has focussed on this *Summer of Storms* – the meteorology driving the events, the statistical probabilities, and the impacts as observed on the ground.

From the sea to the land; our third special publication, *Shaky shores*, was formally launched in Christchurch on Friday 8 June. This publication examined the coastal impacts and responses to the Kaikōura earthquakes and was authored by some of New Zealand's leading scientists, engineers, coastal and emergency managers. It is hoped this publication helps to share some of the lessons learnt to support preparing for and responding to similar disasters in the future and we thank the authors for their efforts in sharing their knowledge.

This is my first Chair's message since taking over the role from Hugh Leersnyder at the beginning of the year. Hugh has done a fantastic job steadying the Coastal Society waka during quite a critical growth period and we thank him for his efforts and are grateful to still have his experience within the committee. We also have a returning committee member in Amy Robinson and have had Natasha Carpenter come on board. Thank you to our regional coordinators who continue to play a critical role in getting things happening on the ground. These have had an injection of new talent and enthusiasm over the last couple of years and together with the experienced existing hands, we've seen lots more events being held and news coming out from the regions. Check it out in this issue and get in touch if you'd like to get involved.

The Ministry for the Environment has been touring New Zealand presenting new science and key information from the updated Coastal Hazards and Climate Change guidance document in a series of one day workshops. The NZCS has been supporting this by holding evening summary sessions for our members, other practitioners, and the general public. These have been held at 12 locations around the country with good attendance and high levels of engagement.


Gisborne West (Public domain)

And finally, preparation for the NZCS annual conference in Gisborne is well underway by co-chairs Murry Cave and Sam Morgan and the local organising committee. The conference theme of *Crossing the Water – Whiti i te Wai* will commemorate a meeting of peoples and our connections to land and water. Get your abstract in and look forward to seeing you there.

For further information on the 2018 Conference, see page 20 or check out the conference page on the NZCS website at www.coastalsociety.org.nz/conferences/nzcs-2018. Copies of 'Shaky shores' can be downloaded from the NZCS website www.coastalsociety.org.nz (under the 'Publications' tab); if you would like a hard copy, email your request to the NZCS Adminstrator, or email the Coastal News Editor if you would like a high-resolution pdf (contact details are on page 20).

The hottest ever summer of storms

Mike Green[1]

The first three months of 2018 was the warmest start to any year on record, and followed on from the second warmest ever October to December period. These warm conditions combined with a series of storm systems crossing New Zealand from the Tasman Sea, including two direct hits of ex-tropical cyclones, Fehi and Gita. Also, the remnants of Cyclone Hola clipped the north of the country. On average, one ex-tropical cyclone affects New Zealand each season, but in a six-week period during February and March, three ex-tropical cyclones impacted on the country.

While this article focuses on ex-tropical cyclones, it is worth noting one other significant storm that affected New Zealand during the summer months. This storm developed in the North Tasman Sea from 3 January and rapidly intensified as it crossed the central North Island on 5 January, with a central pressure around 980 hPa. Ahead of the low, strong northerly winds, heavy rain, and large waves caused damage for many northern parts of the North Island. Due to the path and intensity of this storm system, and coinciding with high tide levels, it caused more coastal impacts in the Auckland and Bay of Plenty regions than any of the ex-tropical storms. This emphasises that 'regular' mid-latitude storms can also be impacting events.

The big picture

Before looking at these storms, there are some important background conditions to consider.

First was the weak La Niña through the later part of 2017 that lasted into April 2018. During a La Niña event, warm sea surface temperatures (SST) of the tropical Pacific Ocean are pushed further west than normal. This results in relatively lower air pressure than normal in the tropics to the north and northwest of New Zealand, and this in turn pushes the the high pressure zone in New Zealand's latitudes further south.

So, what typically occurs with tropical cyclone activity in La Niña years? The warmer SST in the west tropical Pacific increases the risk of tropical cyclones in the Vanuatu, New Caledonia, and Coral Sea areas, but with lesser risk for island groups east of Tonga. For New Zealand, a La Niña increases the risk of ex-tropical cyclones (storms originating from the tropics), especially for northern parts of the country. In October 2017, NIWA issued a warning that northern New Zealand should 'remain vigilant' with the risk that at least two ex-tropical cyclones could make landfall during the 2017-2018 season – which was an accurate prediction.

Figure 1 shows the path and intensity of all named tropical storms for the 2017-2018 season. A named tropical storm has a central pressure below 1000 hPa, and at least gale force winds extending all the way around its centre. As expected for a La Niña year, most storm activity was in western parts of the tropical South Pacific Ocean. Of the six named storms that developed, three of these ended up having some effect on New Zealand.

The second background feature was the extraordinary warm SST in the Tasman Sea. This 'marine heat wave' was caused by persistent high pressure over the Tasman Sea during November and early December, and this prevented the mixing of cool deeper ocean water to the surface. La Niña was also likely a contributing factor to this warm SST phenomenon.

Figure 1: Summary graphic of tropical cyclones in the South Pacific Ocean for the 2017-2018 season (NOAA).

The third factor was persistent high pressure to the east of New Zealand during the early part of 2018, for which La Niña was also likely a contributing factor. This high pressure area guided warm northerly air down its western flank and over New Zealand.

The end results of these three interconnected factors, La Niña, the 'marine heat wave' and persistent warm northerly winds, was a nation-wide average temperature for summer 2017-18 of 18.8°C, which was 2.1°C above the 1981-2010 summer average from NIWA's seven station temperature series which began in 1909. The warmer SST also likely help develop and/or maintain the intensity of storms in the Tasman Sea.

Cyclones and ex-tropical cyclones

Storms affecting New Zealand that have originated from the tropics are often incorrectly referred to as cyclones. While these storms can remain intense, when close to New Zealand they have already transformed into a mid-latitude weather system, rather than having the eye structure and consolidated strong wind and intense rain area around the eye when in the tropics. The descending air in a tropical cyclone eye makes these storms known as 'warm cored'. Storms in the mid-latitudes (even those originating from the topics) have the lowest temperatures over its centre, referred to as a 'cold cored' storm.

Fehi, Gita and Hola were often referred to as cyclones (Cyclone Fehi for example, when approaching or affecting New Zealand), but the correct name is ex-tropical cyclone. Keeping this in mind, these storms will be referred simply as Fehi, Gita and Hola for the remainder of this article.

Fehi

Cyclone Fehi became a named storm on the 28 January 2018 to the west of Vanuatu and was a Category 1 cyclone as it passed just west of New Caledonia and into the North Tasman Sea. Active remnants of Fehi crossed the South Island from about Haast to Dunedin on 1 February with central pressure still around 970 hPa (Figure 2).

Most of the South Island was impacted in some way by Fehi. The most significant damage was on the north side of the storm

(1) Engineering Meteorologist, Meteorology Solutions Limited.

Ex-cycleway and seaward dunes on Rabbit Island, Nelson, post-Fehi (Photo: TDC).

in places exposed to the north, including much of the West Coast and Nelson, with damaging wind gusts, heavy rain, and storm surge. On the south side of the storm, eastern areas about and south of Dunedin were also exposed to the force of Fehi with strong wind gusts, heavy rain and coastal flooding. For Canterbury impacts were diverse, including strong dry winds that fanned numerous fires, to coastal flooding caused by low air pressure and high tide levels.

The impacts from Fehi were enhanced by the contribution of king tide levels. The 'low air pressure effect' of lifting the sea and king tide alone would have raised the sea level around 1 m higher than normal in some places. Adding the effects from waves/swell generated by Fehi resulted in coastal inundation for some West Coast and Nelson locations.

A remnant low pressure area that was left behind from Fehi off the West Coast made its way slowly northeast off the coast, and then crossed the Auckland area on the afternoon of 3 February causing heavy rain and flash flooding in the Waitakere Ranges.

Gita

Tropical Cyclone Gita was the only Category 5 storm in the South Pacific Ocean for the 2017-2018 season. At its most severe, the lowest central pressure was estimated to be 927 hPa with a mean wind speed of around 205 km/h. Gita roamed around the tropical south Pacific as a named storm for nearly two weeks before moving in to the North Tasman Sea. It impacted on many island groups including Wallis and Futuna, Fiji, Samoa, Niue, Tonga and New Caledonia. Gita was the strongest tropical cyclone to affect Tonga since records began. Figure 3 shows the path of Gita for its lifetime, from being named in the tropics to its final gale force intensity location southeast of New Zealand.

As a side note, tropical cyclones move out of the Fiji Meteorological Service area of responsibility and into the New Zealand MetService area when they move south of 25S. The Bureau of Meteorology (Australia) is responsible for storms west of 160E, both to the north and south of 25S.

Gita moved east across New Zealand from about Westport to Kaikoura late on 20 February and caused significant weather conditions for much of New Zealand from Auckland to Otago. Figure 4 shows Gita as it approached Westport, with a central pressure around 975 hPa. The most significant impacts were in areas exposed to northerly winds on the north side of the storm, and areas exposed to the east of the south side of the storm.

Damage to SH1 north of Wellington after ex-cyclone Gita (Photo: WSP Opus).

Widespread flooding occurred across central parts of the country. The Nelson and Tasman regions were particularly hard hit due to the exposure to the strong northerly winds and active rain bands.

Along the Kaikoura Coast, significant damage occurred to the road and rail network, including to earthquake repair work. Some places along the Kaikoura Coast and Nelson reported the highest one-day rainfall totals since records began before 1900. Rosy Morn, an Environment Canterbury (ECan) rainfall site located just inland along the south Kaikoura Coast, recorded 302 mm in a 24-hour period, with 269 mm in 12 hours, estimated to be a once in 200-year event.

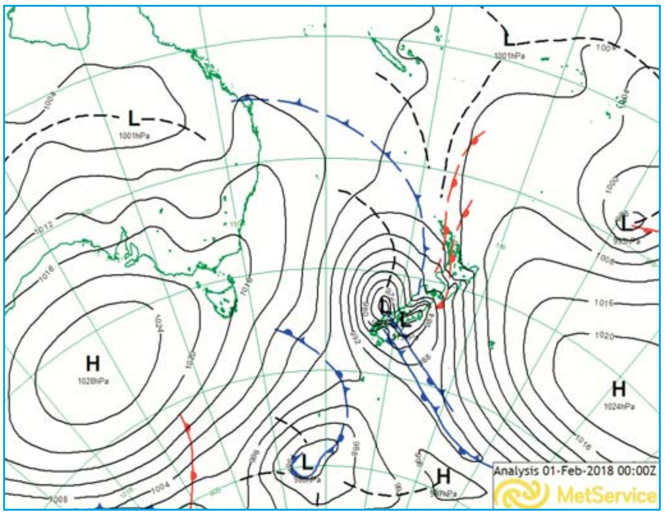


Figure 2: Surface pressure analysis at midday 1 February 2018 around the time Fehi was crossing the South Island (MetService).

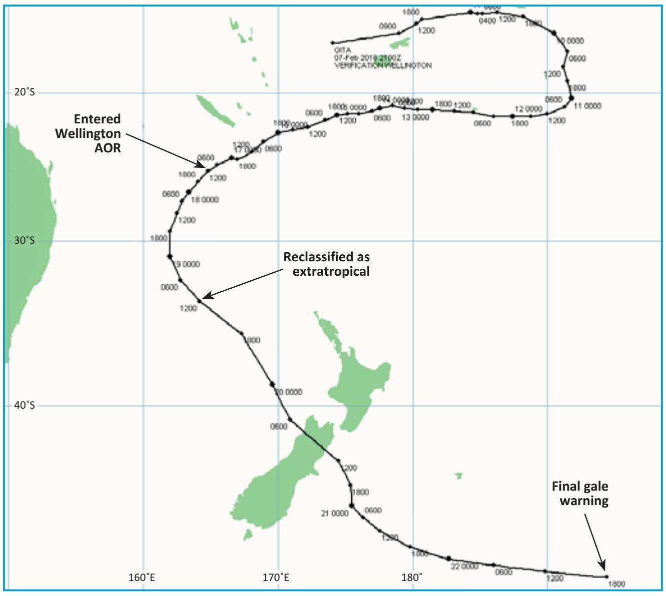


Figure 3: The track of Gita from the northwest of Fiji to the southeast of New Zealand. Date/time are shown in UTC (MetService).

Strong winds caused power outages and damage to trees and property along the West Coast, and in Taranaki power was cut to 23,000 properties.

Hola

Hola was the last tropical cyclone that moved out of the tropics towards New Zealand. Hola formed in the Vanuatu area, was named on 3 March, and then classified as a severe Category 4 tropical cyclone on 7 March while in the Coral Sea. Hola then moved between New Caledonia and Vanuatu, and into the area north of New Zealand. Over the cooler ocean and with vertical wind shear, Cyclone Hola weakened quickly as it moved southeast.

On 12 March, remnants of Hola passed by to the north of the North Island. Heavy rain fell in eastern Northland, and around 100 mm of rain was recorded in parts of Coromandel and East Cape (Figure 5).

The question would have been asked many times – did global warming play any role on the active weather in the early part of 2018? It is well researched that global warning will have a role in increasing the intensity of tropical cyclones, but for the 2017-2018 season it will difficult to quantify the global warming contribution amongst the other background influences of La Niña, the marine heat wave, and persistent high pressure to the east of New Zealand during that period.

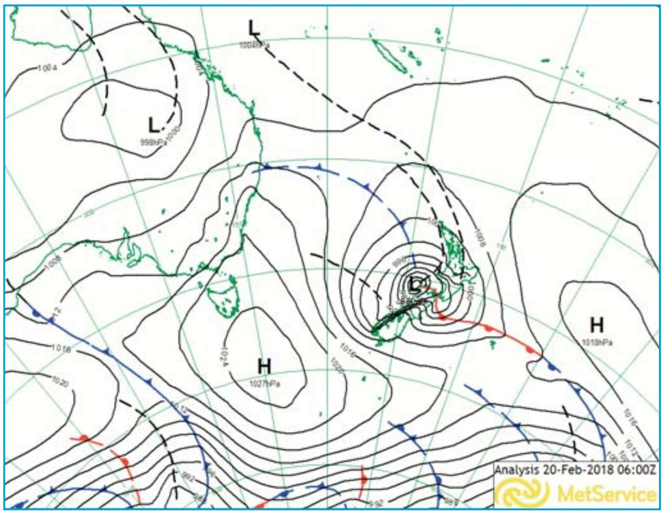


Figure 4 : Surface pressure analysis at 6 pm 20 February 2018 (MetService).

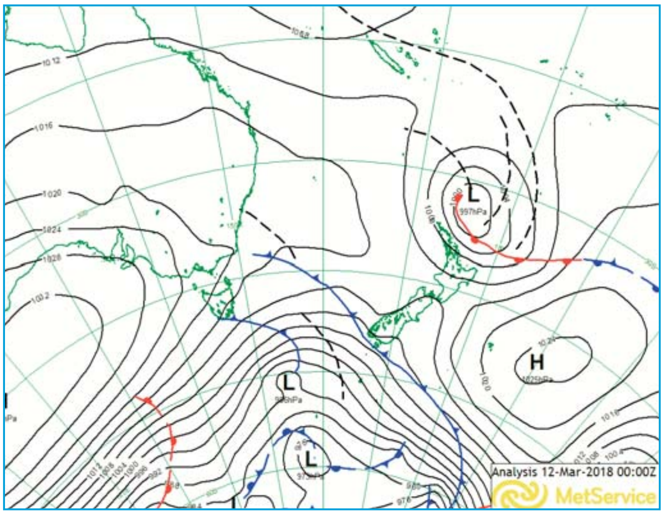


Figure 5: Surface pressure analysis at midday 12 March 2018 (MetService).

NZCS Regional Representatives

Every region has a NZCS Regional Representative who is available to help you with any queries about NZCS activities or coastal issues in your local area. If you are interested in becoming involved as a regional representative, please get in touch with Paul Klinac (paul.klinac@aucklandcouncil.govt.nz).

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The summer of storms – a rare combination of coastal hazard drivers

Scott Stephens, NIWA

During the spring and summer of 2017 and 2018, several large storms struck New Zealand, and coincidentally (also unusually), most of them coincided with very high predicted tides (red-alert tide days[1]). The storms occurred on 8 November, 5-6 January, 1 February (ex-tropical cyclone Fehi), 20-21 February (Gita), and 12 March (Hola). Some of the flooding and erosion impacts are described within this issue of *Coastal News*.

Questions that naturally arise after such a damaging sequence of storm events might include: Are we seeing the effects of climate change? Was this a rare combination of events? Could it occur again very soon? Answers to these questions would be helpful for decision making, such as whether to repair or realign (or close) a damaged road, estimate ongoing maintenance costs, or setting minimum building development conditions, for example.

In this article we address the likelihood of the damaging combinations of tide, surge, waves and mean sea level, evaluate the recent sequence of storms, and how the storm-tide hazard could change in the future.

It all adds up to trouble

Global sea levels began to rise in the late 1800s, due mainly to anthropogenic greenhouse gas emissions. Some parts of the world, like Florida, are now experiencing 'sunny day' flooding, when high tides overflow the streets[2]. In Nelson NZ, some car parks flood with seawater during high spring tides. However, the worst coastal flooding in NZ occurs when storms and high tides combine. Storms cause a temporary surge in water level, and whip up large waves to erode the coast or overtop barriers. When the tide is high, the combined tide + surge (= storm-tide) allows waves to approach closer and release more energy at the shore (Figure 1). Ongoing and accelerating sea-level rise (SLR) will compound the issue by further elevating the sea level, and vertical land movement can exacerbate the effects of relative SLR in places where the land is subsiding, such as in Wellington and Thames.

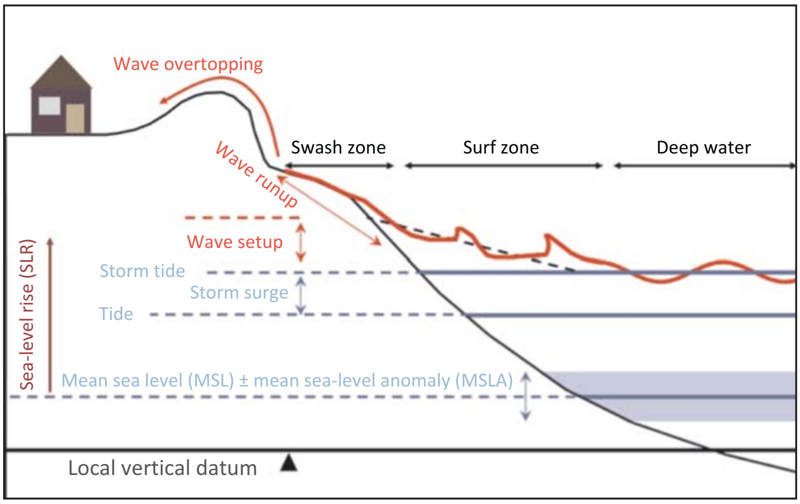

Figure 1: Schematic illustrating the various processes that contribute to coastal inundation.

How likely is it?

Coastal inundation, or other hazards such as erosion or structural damage to coastal defences, roads or buildings, is worse when high storm-tides and large waves occur together. We use the Heffernan and Tawn (2004) method to calculate the joint probability of extreme wave height and sea level (Figure 2). The objective is to extrapolate the joint-probability density of the wave height and sea-level variables to extreme values, with appropriate consideration of the dependence structure between surge and waves. The methodology compromises:

1. De-cluster the wave height and sea-level time series data into unique storm peaks.
2. Fit statistical models to the marginals (individual wave and surge components) and dependence (joint-probability) of the de-clustered data.
3. Simulate a large sample (equivalent of 10,000 years) of data from the fitted models to generate simulated data more extreme than those occurring in the relatively short measurement period, but with the same statistical properties, i.e., the same marginal extreme-value distributions and preserving the dependence structure between variables. The simulated data provides input to engineering design to assist planning.
4. Simulate tides and add the simulated surge to obtain the storm-tide sea level.
5. Fit joint-probability contours to the simulated data. The joint-probability is specified in terms of its annual exceedance probability (AEP), or its average recurrence interval (ARI).

Since the high tide is a major control on the total water level at the coast, the joint-probability analysis is based on data sub-sampled at high tide. This involves identifying the high-tide times, and sampling the tidal elevation, skew-surge and wave heights at high tide. Skew-surge is the difference between the high-water level and the nearest predicted tide.

Figure 2 shows a joint-probability analysis of skew-surge and wave height at Nelson. The measured data (red dots, Figure 2) shows there is a naturally strong dependence between wave height and skew-surge at Nelson, with a tendency for large skew-surge to occur at the same time as large wave height[3]. This dependence is reproduced by the joint-probability model and is built into

1 https://www.niwa.co.nz/natural-hazards/physical-hazards-affecting-coastal-margins-and-the-continental-shelf/storm-tide-red-alert-days-2018/High-tide-red-alert-calendar

2 https://www.businessinsider.com/sea-level-rise-high-tides-sunny-day-flooding-coastal-cities-2018-4/?r=AU&IR=T

3 Geographically the southern and western coasts of NZ are exposed to large swell waves that can travel long distances from the Southern Ocean, hence the local sea conditions may be unrelated to local weather systems. However, on the east coast of the North Island and in Tasman and Golden Bay,

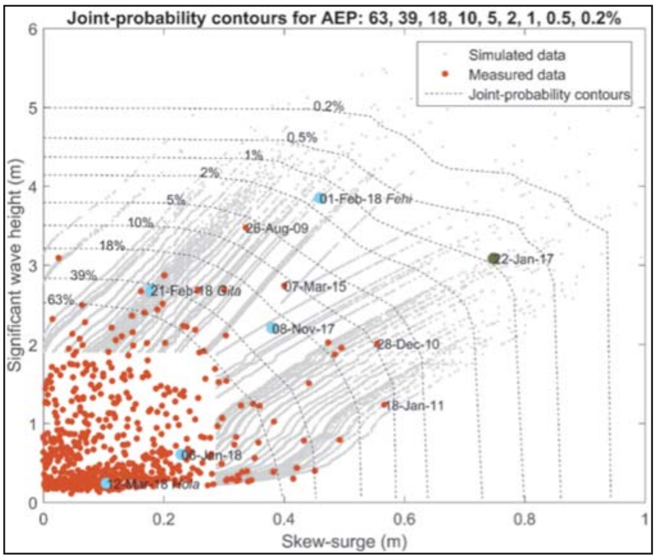

Figure 2: Joint-probability analysis of Nelson Wharf skew-surge and Nelson Fairway significant wave height (Stephens et al., 2018). Red dots represent measured data; grey dots represent data 10,000-years of simulated data, and dashed lines represent joint-probability contours for 63, 39, 18, 10, 5, 2, 1, 0.5 and 0.2%, from largest (most frequent) AEP on the inside to smallest (least frequent) AEP on the outside. There is a naturally-strong dependence between skew-surge and wave height observed in both the measured and simulated data – both tend to grow extreme together. Selected events with joint-probability of <18% (>5-year ARI) are dated, and five storm events from the 2017-18 summer are coloured light-blue, plus the 22 January 2017 'weather-bomb' event marked green.

the 10,000-years of simulated data (grey dots, Figure 2), which also show the skew-surge and wave height increasing systematically. Accounting for this dependence is important. For the example of a 10% AEP wave height and a 10% AEP skew-surge; if these two events are assumed to be entirely dependent then their joint-probability AEP is 10%, but if assumed to be entirely independent then their joint-probability AEP is only 1% (i.e. 10% x 10% = 1%). Using the Heffernan and Tawn (2004) code to account for the dependence allows the true AEP to be estimated and to be included into engineering design.

The probabilistic analyses shown are data driven – they pick up the correlations in the data over the overlapping (10-year) measurement period, and assume that those correlations are representative of the climate. However, a different measurement period, a longer or shorter record, would likely have returned a somewhat (maybe subtly) different correlation. The analyses do not account for climate variability (e.g., ex-tropical cyclones are more common in La Niña years), climate change or SLR (as any trend in the datasets has been removed for the analysis).

The events during the 2017-18 summer of storms are identified on the Nelson joint-probability plot (Figure 2). The skew-surge and wave height combination during extra-tropical cyclone Fehi, which caused the most damage in Nelson, had a low AEP of 1.4% (a large, rare event, expected about every 70 years on average). The unnamed storm of 8 November, which also did much damage in the Tasman Bay area, and Gita, were also quite rare events – Nelson could expect events like these about every 2-5 years. The skew-surge and wave conditions experienced at Nelson during Hola and the unnamed storm of 5-6 January, are relatively common – the 5-6 January event did little damage at Nelson, but caused widespread coastal flooding and erosion in Thames and Tauranga.

However, despite the extensive damage, Fehi was not the rarest (and by implication largest) wave-surge combination in Nelson, which instead occurred during the powerful 'weather-bomb' on 22 January 2017 (see Figure 2). Yet the January 2017 weather bomb did little coastal damage in Nelson. The key difference was that the high tide on 22 January 2017 was very small (2nd percentile, 0.74 m), but the high tide during Fehi on 1 February 2018 was very high (98th percentile, 2.06 m), a difference in high-tide height of 1.32 m.

Swim with the tide

In many NZ locations, and in many locations worldwide, the tide is the main control on the exposure to coastal hazards. At low tide there is little chance of waves and surge reaching damaging levels. But most weather events take several hours to pass, and will intersect with a high tide at some stage during the storm. The tides result from the gravitational pull of the Earth's moon and the sun, which move in and out of phase with each other. During spring tides, the moon and sun pull together, so the high tides are much higher than during neap tides, when the moon and sun pull at a right angle to each other. So, the level of impact for any event depends on the timing between storms and tides. Hence, NIWA's 'red-alert' tide calendar provides dates that Emergency Managers and Coastal Hazard Managers should keep an eye on for adverse weather (low barometric pressure, onshore winds), river levels and sea conditions (waves and swell), and also provides 'carefree' dates.

If every time we got a big tide, we also got a big surge and wave event, that would be bad. But, fortunately, there is no dependence between tide and storms, nor between tide and skew-surge or wave height when sampled at high tide. So, the fact that we had several large storms that coincided with very high tides is unusually bad luck. Had the storms all occurred one week earlier or later, then the resulting coastal flooding, erosion and wave impact would have been much less, or nonexistent.

Whereas Figure 2 showed the joint-probability of skew-surge and wave height, Figure 3 shows the joint-probability of the storm-tide and wave height. Once the tide is accounted for (i.e. storm-tide = tide + skew-surge), we see why the 8 November 2017 and Fehi storms were so damaging at Nelson – both had relatively large waves superimposed on unusually high storm-tide sea levels. In Fehi's case, conditions were very rare at 0.33% AEP or expected once every 300 years on average. The 22 January 2017 weather-bomb event had a relatively rare combination of storm-tide and waves (18% AEP or ARI of ~5 years), but is less-threatening (from a coastal-hazard perspective) once the tide is accounted for, because exposure to wave impact was limited through combination with a lower and relatively-common sea level.

The likelihood of Fehi's combination of tide, surge and wave height was only 0.33% per year at the offshore evaluation location. However, the level of hazard at the shoreline depends on how those offshore tide, surge and wave conditions are transformed over the near-shore, beach or seawall, into a total

the largest waves and surges tend to be driven by local weather events like ex-tropical cyclones, which means that surge and waves are often highly correlated, as shown in Figure 2.

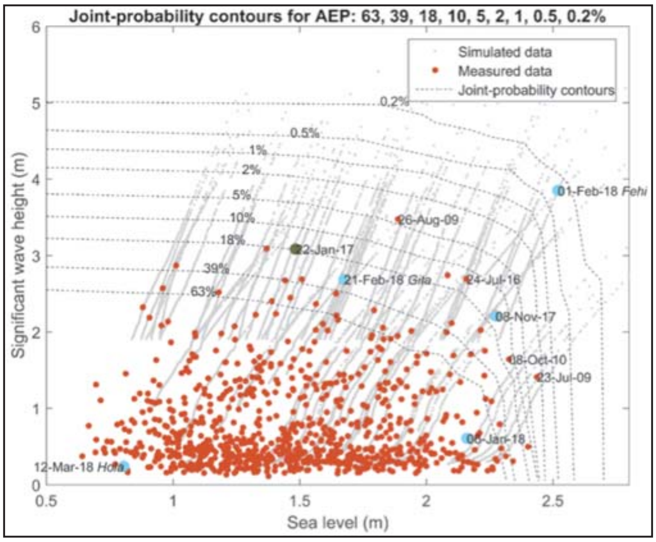

Figure 3: Joint-probability analysis of sea-level measured at Nelson Wharf and wave-height measured at Nelson-Fairway gauge (Stephens et al., 2018). Dashed lines represent joint-probability contours for AEP = 63, 39, 18, 10, 5, 2, 1, 0.5 and 0.2%, from largest (most frequent) AEP on the inside to smallest (least frequent) AEP on the outside. Measured peaks are plotted in red. Events with joint-probability of <18% (>5-year ARI) are dated, and five ex-tropical cyclone events from the 2017-18 summer are coloured light-blue, plus the 22 January 2017 'weather-bomb' event is marked green.

water level that includes wave setup and runup (Figure 1). The 10,000 years of simulated joint-probability conditions (grey dots, Figure 3), were used to evaluate the total water level from tide + skew-surge + wave setup and runup (using the Stockdon et al. (2006) formulae), and calculated for several beach slopes. For a relatively steep beach with slope 1:10, the total storm-tide + wave setup during Fehi would have a 0.6% AEP (ARI of ~170 years) at present-day MSL, which is more likely than the 0.33% AEP joint-probability of the offshore forcing, but still rare.

It could be worse

Damaging coastal flood events in recent years have resulted from a very high tide combining with moderately large surge and waves. Examples are the 23 January 2011 storm-tide flooding in Auckland, which closed the northern motorway, and the 5 January 2018 coastal erosion and flooding in the southern Firth of Thames and Tauranga Harbour, which both occurred during red-alert tides 3. However, similar or higher sea-levels were reached in these places during the great extra-tropical cyclone of 1936, during extra-tropical cyclone Gisele (the *Wahine* storm) in 1968, and the May 1938 inundation of the Hauraki Plains, even though both the mean sea level and the high-tide levels were lower during these events. In other words, the surges in these historical events were larger than we have seen in recent decades. The Auckland sea-level record shows that the north-east coast of NZ experienced considerably more large surge events in the first half of the 20th century than has occurred since; it is possible that modern sea-level (and other environmental) records could under-represent the long-term probability of intense storm effects on coastal hazards. Even now, before future SLR, the potential exists for a very high tide and a very intense storm to drive water levels to unprecedented heights.

The rising menace

Sea level in NZ has risen by an average of 2.0 mm yr^{-1} over the last century (MfE, 2017), so it is about 0.2 m higher than it was a century ago, when development in many of our coastal cities was intensifying. While 0.2 m doesn't sound much, thresholds are now being reached where coastal flooding is becoming increasingly frequent, such as along Tamaki Drive in Auckland. Even a few more centimetres makes a big difference to the frequency and depth of flooding once these thresholds are reached.

A future SLR of about 0.3 m would cause a 100-year return period sea-level (at present-day MSL) to be reached about every year in many NZ locations (Stephens, 2015), resulting in frequent flooding and erosion. This can be expected to happen sometime between the years 2045-2070, depending on the rate of future climate change (Stephens et al., 2017).

Returning to Nelson's total storm-tide + wave-setup during Fehi, which was estimated to have 0.6% AEP (170-year ARI) at present-day MSL. After SLR of 0.3 m, the AEP for events that reach the same total water level would rise to 5% (18-year ARI), and after 0.5 m would rise to 86% AEP (< 0.5-year ARI). Therefore, the water levels and wave impacts reached in this event, which could be considered very high and rare at present-day MSL, will become relatively common after modest SLR. In addition to SLR, more intense wind and rainfall due to climate change (Tait et al., 2016), could also increase the frequency and magnitude of coastal hazards.

The 2017-2018 summer of storms was unusual because the several storms that swept through coincided with unusually high tides. This resulted in several closely spaced events with large and rare combinations of tide, surge and waves. Although the summer of storms was unusual, the probability of the impacts of such events will continue to increase in the next few decades as seas continue to rise, with coastal flooding events becoming much more frequent.

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Cyclone Fehi impacts on the South Island West Coast

Don Neale, NZCS West Coast Regional Coordinator

The Wild Wild West

The West Coast felt the full force of the weather when ex-Cyclone Fehi made its way down through the Tasman Sea. In one of the biggest coastal storms I've seen in my 30 years living in Hokitika, Fehi produced a string of erosion and inundation events all the way down the region's 600 kilometre length.

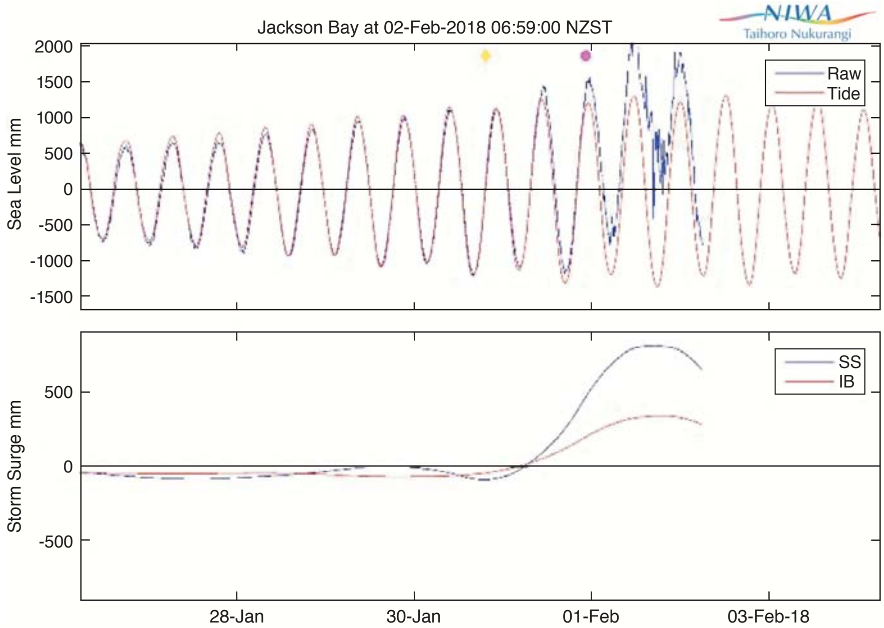

Figure 1: The NIWA tide gauge at Jackson Bay showed the 1 February 2018 sea level disruptions (blue) overlying the predicted tidal cycles (upper plot), and the components of storm surge (bottom plot) caused by inverted barometer effect (IB, red) and storm surge (SS, blue). Source: Jackson Bay tide gauge plots for Jan-Feb 2018, NIWA (NZ) & BoM (Australia).

Anatomy of the storm surge

Fehi's impact was accentuated on the West Coast by the combined effects of several meteorological events that produced something approaching a 'perfect storm'. For interested people like myself, these effects could be picked out as they happened (or soon after), from publicly available information on a selection of websites, such as NIWA.co.nz, metocean.co.nz, Marineweather.co.nz and stuff.co.nz.

Four main influencing factors interacted as the storm passed overhead.

- Tides – The two high tides that coincided with the arrival of the storm on 1 February were among the highest predicted tides of the year. The LINZ tide tables for Westport predicted high tides at 3.5 m above chart datum, or 1.75 m above mean sea level (and 0.3 m above MHWS).
- Waves – A major component of the storm's sea level effects was the wave heights, with significant heights that were modelled by marineweather.co.nz and other websites to be over 5 m, and up to at least 10 m as the storm approached the West Coast (Figure 1). These waves were built up over a period of about four days of persistent northerly winds aiming directly at New Zealand's western shores. This occurred as the cyclonic weather system made its way down the Tasman Sea from north-west of New Caledonia. With the height of waves directly related to the strength and fetch (effective distance/duration of wave formation) of their formative winds, the storm was able to build a southward-moving assemblage of unusually high waves.
- Storm surge – On top of the tides and waves, Fehi's storm surge effects also came into play. The 'inverse barometer effect' of low pressure weather systems causes the sea level to rise by 1 cm for every 1 hPa drop in air pressure, while the forcing of water onto a windward shore also leads to a localised rise in the sea level. The NIWA tide gauge at Jackson Bay showed a storm surge elevation of about one metre, comprising an inverse barometer (IB) effect of about 30 cm and storm surge (SS) component of about 70 cm. The storm surge effect was felt all the way along the West Coast (Figure 2).
- Wave setup – On the most exposed shores of the West Coast, the large waves would have added an amount of wave setup. No specific measure of this component is available, but this extra elevation of the sea level inside the surf zone is proportional to the wave height at the shore and so would have contributed to the storm surge effect.

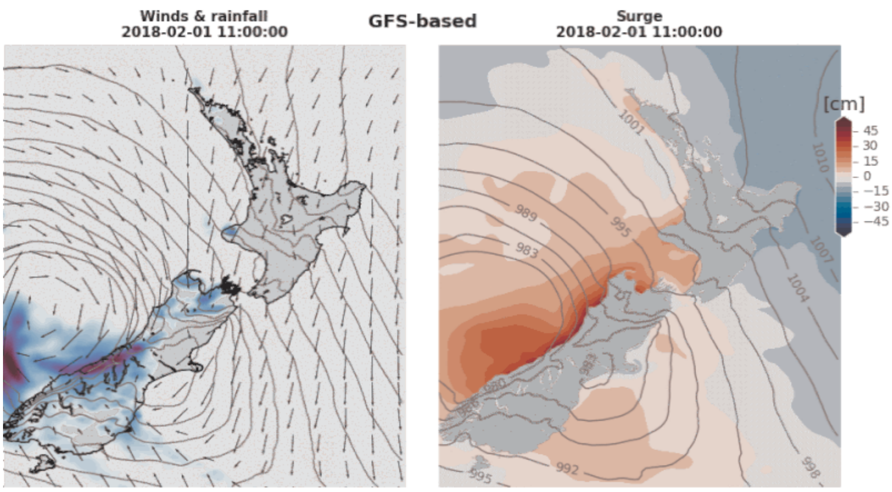

Figure 2: The storm surge effect of ex-cyclone Fehi was felt all the way along the South Island's West Coast. Source: MetOcean Solutions, part of the MetService of New Zealand.

Impact and responses on the West Coast

Any of the factors of tide, waves and storm surge on their own can be repelled by the coastal defences provided by beaches, dunes and rock walls. But their formidable combined effects on 1 February 2018 were too much to bear for many such locations, and the storm that hit the West Coast was well armed to do significant damage to the coastline.

As would be expected, beaches with good frontal dune formations and wide beaches were certainly hit by the storm waves, but they avoided the problems of overtopping and inundation. At Gillespie Beach near Fox Glacier, the 3-4 m high pingao- and scrub-covered dunes fended off the most damaging waves. Other places were not so fortunate.

Perhaps predictably, places that have a history of erosion and coastal flooding were among the areas worst hit by the storm. Granity-Ngakawau, Carters Beach and Rapahoe were buffeted by waves that crashed over the top of beaches already weakened by ongoing trends of coastal erosion. At Rapahoe, the shorefront roadway was covered by a sheet of beach cobbles thrown high by the waves (Figure 3), and the old Greymouth rubbish dump at Cobden – closed in the 1990s – was cut into, requiring costly repairs using plenty of rock and machinery.

Figure 3: Rapahoe Beach before (top) and after (bottom) Fehi went through (Photo: P Birchfield, WCRC).

State Highway 6 was badly hit in at least two places, at Punakaiki and 17 Mile, which six months later remain as single lane roadways as they get sturdy rockwork installed beneath them to replace the land lost to the sea. The road to Jackson Bay was also cut away by northerly storm waves that found their way into the usually well-protected South Westland fishing port.

As well as damage from storm waves, the elevated sea levels caused flooding problems at some river mouths, most notably at the Orowaiti Lagoon, which backed up and caused flooding as deep as one metre over parts of Westport's residential area (Figure 4). Similar flooding of houses also happened at the lagoon-side village of Okarito and in parts of Greymouth. It wasn't only people that were disturbed by the storm – natural habitats and native species were also badly hit. A small area of coastal dune farmland near Hokitika that was inundated by waves is the only known habitat of the already critically endangered Chesterfield skink. The storm event sparked a rescue effort by DOC to catch most of the remaining lizards for captive rearing, to better secure the species' survival. The Department now has the task of restoring the lizards to their natural home, in conjunction with the adjoining land owner and others.

Artificial rock seawalls should always be considered as only one option among many for managing coastal hazards, but when they are selected as the best option, there is definite value in ensuring that they are constructed to high standards. Such was the case in Hokitika, where the carefully-built 2013 seawall mostly withstood the storm's attack, despite some wave overtopping that caused a limited amount of damage to beachfront properties (and to the driftwood art created the week before in an annual community event! (Figure 5)).

A regional Civil Defence response attended to the main problems caused by widespread floods and slips, and helped communities to remain safe and restore order. The official CD response was strongly boosted by each community's own efforts to help those people who were worst affected (Figure 6).

Among that support was active assistance from Ngāi Tahu whanui to attend to problems at Hunts Beach – a vitally important turangawaewae of South Westland hapū – where a house was moved off its foundations by waves that crashed into the north-facing elbow of Makawhio Point.

The West Coast Regional Council is producing a comprehensive report that will review the Fehi event and its effects on the region's communities and infrastructure. The report will serve as a salient reminder to us all about the types of coastal hazards that might return in the future and for which we need to prepare.

Figure 4: The Orowaiti Lagoon backed up, flooding roads and paddocks near Westport (Photo: Howie Wilson).

Figure 5: Hokitika's driftwood art took a tumble as waves broke over the seawall (Photo: Don Neale).

Figure 6: Waves inundated houses near Granity and elsewhere (Photo: Howie Wilson).

January 2018 storm impacts on the Auckland coastline

Matthew McNeil and Tom FitzGerald, Auckland Council

The 5 January 2018 storm event resulted in extensive impacts along exposed stretches of Auckland's coastline. In excess of 50 different coastal locations were damaged, forcing emergency repairs to ensure public safety and protection of assets. The storm, Auckland's vulnerabilities, and the resulting response generated significant public, media and political interest. Figure 1 identifies coastal locations where Auckland Council maintained assets were impacted by the storm.

Damage caused by the storm highlighted underinvestment in some coastal assets. However, this presented an opportunity to not necessarily replace or repair like-for-like; in some cases it also provided Council with an opportunity to achieve improved coastal management outcomes and upgrade or realign management approaches.

Council's recently adopted 10-year budget includes $90 million over the next ten years for coastal asset renewals in a changing climate, as well as setting aside $20 million for a 'Climate Change Response Fund' to help in times of climate-related emergency. Funding has also been set aside to develop a suite of coastal compartment plans that will seek to manage the coast based on a natural systems approach and discussions around risk.

The following series of photographs are visual examples of sites affected by the storm, and a description of response works undertaken at Stanmore Bay.

Cockle Bay, Howick

Rock revetment end effects resulted in significant erosion of the reserve edge, leaving a narrow reserve buffer between the beach and adjacent road (Figure 2).

Clarks Beach, Manukau Harbour

Due to fetch exposure, storm conditions resulted in significant overtopping of an existing timber seawall. Resulting scour behind the seawall caused failure and collapse of the structure. The seawall is to be rebuilt and realigned further landward (Figure 3).

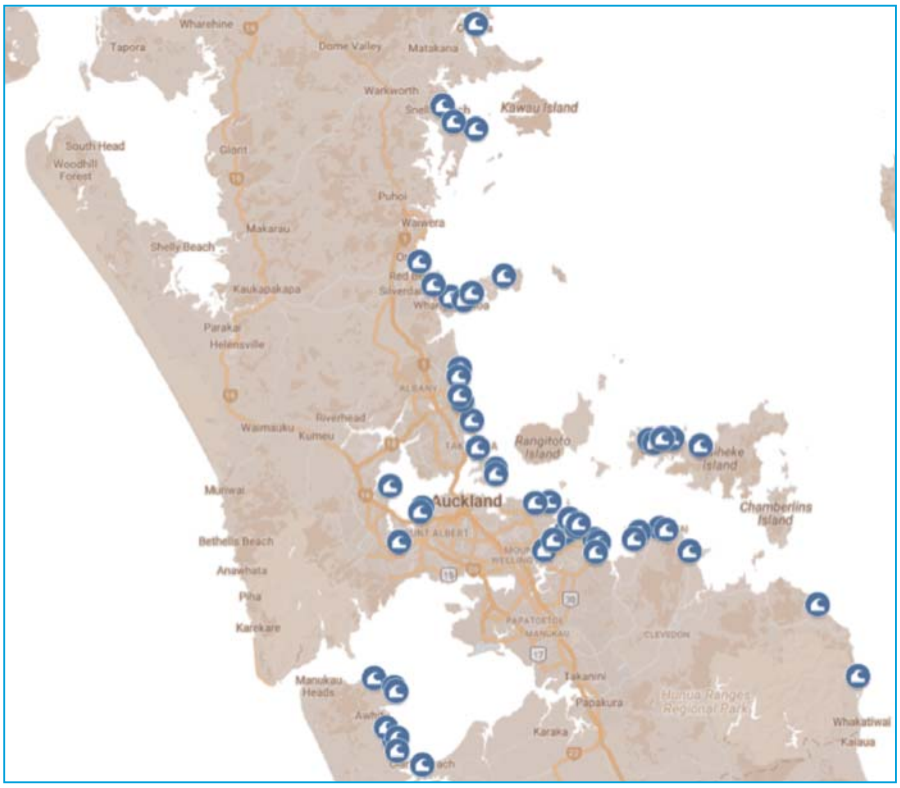

Figure 1: Coastal locations around Auckland that caused damage to Council maintained infrastructure and assets.

Scandrett Regional Park

Significant damage to the road that provided access to bach accommodation on the park (Figure 4). The road is to be relocated to a landward position, and the coastal edge restored.

Mairangi Bay

Significant seawall overtopping resulting in scour behind the wall, and lowered sand levels resulting in structure undermining (Figures 5 and 6).

Stanmore Bay, Whangaparaoa

Stanmore Bay is a relatively flat dissipative sandy beach, located on the northern coastline of the Whangaparaoa Peninsula. A large esplanade reserve backs onto the eastern end of the beach. Prior to the storm, the reserve edge was armoured by informal rock armouring positioned landward of the typical mean high water springs line. The January storm event generated significant wave energies and elevated water levels at Stanmore Bay. This resulted in erosion of the esplanade reserve edge by between 1 to 4 m, leaving a scarp of up to 2 m in height, and the rock armouring sitting proud on the beach face (Figure 7).

Following the storm, Auckland Council undertook emergency works that involved:

- Reconstruction of an approximately 35 m length of rock revetment adjacent to an existing toilet block, beginning at an existing boat ramp at the western end, with an improved return at the eastern end (Figures 8 and 9).
- Removal of the outflanked rock, and re-profiling of the further approximately 140 m length of reserve edge scarp. Material contained in the reserve edge was predominantly sand, which enabled such to be placed on the beach at the reshaped slope toe (Figure 10).
- Spinifex backed by muehlenbeckia is to be planted on the reshaped sandy reserve edge, and associated dune fencing installed.

Pressure to construct a seawall was resisted in favour of retreat and naturalisation of the reserve edge.

(L) Figure 2: Cockle Bay, Howick, 7 January 2018 (Photo: Jo Morriss, Auckland Council).

(R) Figure 3: Clarks Beach, Manukau Harbour, 7 January 2018 (Photo: Jo Morriss, Auckland Council).

(L) Figure 5: Mairangi Bay, 5 January 2018 (Photo: Matthew McNeil, Auckland Council).

(Below) Figure 6: Mairangi Bay, 5 January 2018, scour behind seawall (Photo: Matthew McNeil, Auckland Council).

(L) Figure 4: Scandrett Regional Park, 5 January 2018 (Photo: Beckie Trigg, Auckland Council).

(L) Figure 7: Stanmore Bay, outflanked rock armouring and eroded reserve edge, 5 January 2018 (Photos: Paul Klinac, Auckland Council).

(R) Figure 8: Removal of rock armouring (Photo: Natasha Carpenter, Auckland Council).

(L) Figure 9: Re-shaped reserve edge showing area to be replanted (Photo: Matthew McNeil, Auckland Council).

(R) Figure 10: Reconstructed rock revetment in front of toilet block (Photo: Matthew McNeil, Auckland Council).

Improving infrastructure resilience in the coastal zone: Fehi and Gita response reflections

Ana Serrano and Matt Balkham, WSP Opus

The State Highway Network in New Zealand is the backbone of our economic success. The highways continue to help connect people in isolated communities as well as to get goods and services to markets. The Ministry of Transport[1] identifies the following:

- The State Highway Network is 'the means by which most New Zealanders get about by car, bus or bicycle and connect with family, friends and employment' and it caters for '84% of personal daily journeys', servicing 'the needs of our international tourists'.
- 'The roading network is responsible for moving 70% of freight tonne-kilometres within New Zealand' providing 'access to and from our air and sea ports for the majority of exports and imports'.

In February 2018, the national roading infrastructure was severely affected by ex-tropical cyclones Fehi and Gita. The consequences of these events included traffic hazards, road closures, utilities damage, and the loss of cycleways, footpaths and road lanes. Despite the seriousness of the damage, thankfully there were no injuries.

These events highlight that essential components of the New Zealand transport system are vulnerable to natural hazards, especially erosion and inundation during storm events.

WSP Opus assisted with the immediate inspection, clean-up, and urgent works to restore the network's performance and manage the future erosion risk. Our involvement has principally been at two sections of the state highways that sustained significant damage: the Coast Road section of State Highway 1 (SH1) north of Wellington, and State Highway 6 (SH6) on the West Coast. Action was taken immediately at both sites to minimise network disruption, but different approaches to long-term risk management have been adopted by the New Zealand Transport Agency (NZTA).

1 https://www.transport.govt.nz/multi-modal/keystrategiesandplans/connectingnewzealand/cnzstateofinfrastructure/#roading

The solution to address the increased hazard presented by the damaged infrastructure at SH1 consisted of clearance of a significant volume of debris, and the placement of approximately 900 tonnes of rock rip-rap at a number of exposed erosion sites. Rock was sourced from a nearby NZTA construction site and placed on the exposed road embankment, providing immediate erosion risk management to minimise the risk of further erosion due to wave attack during the next high tide. This rapid repair allowed the highway to be reopened to full capacity the same day.

At SH6 sites, an initial stability assessment allowed the road to be re-opened to traffic under a one lane restriction (this was necessary to move live loading away from the seaward edge of the highway). Subsequent short-term stabilisation was provided by the importation and placement of fill seaward of the damaged section of the revetment. The long-term risk management approach comprises an engineered erosion risk management solution to protect the road pavement from damage in a similar magnitude future storm event. Due to the low traffic volumes on the road, NZTA

Figure 1: Debris from the sea that overtopped the Coast Road (SH1) north of Wellington after ex-cyclone Gita (Photo: WSP Opus).

Figure 2: Damage to road infrastructure on the Coast Road (SH1) north of Wellington after ex-cyclone Gita (Photo: WSP Opus).

determined that temporary closure of the highway would be tolerable and the solution does not need to provide a higher level of service to prevent inundation. To provide increased certainty in the performance of the new revetment WSP Opus has been working on its detailed design, adopting and applying international best practice to the design and specifications of the new works.

Although the storm event resulted in similar disruption and damage to the sites at both SH1 and SH6, the solutions developed in response to the damage were different. Given the traffic volume of SH1, a rapid erosion risk management solution was adopted. At SH6 the proximity of the road to the shoreline meant that a rapid rock placement was not practical, and an alternative design was required. The reasoning behind these decisions considers the coastal processes and risk at each site, the traffic volumes, the level of service required from the coastal infrastructure, and ease of access for future maintenance of that infrastructure.

Figure 3: Drone footage of the Coast Road (SH1) during emergency works – only one lane is operative (Photo: WSP Opus).

Figure 4: Punakaiki section (SH6) damaged after ex-tropical cyclone Fehi (Photo: WSP Opus).

Figure 5: Punakaiki section (SH6) damaged after ex-tropical cyclone Fehi (Photo: WSP Opus).

The events in February 2018 are not unique and we can expect to experience similar erosion and inundation of our state highway network in the future. As we near completion of the works to recover from ex-tropical cyclones Fehi and Gita, we take time to reflect and ask ourselves:

- What lessons have we learned from these events?
- What would we do differently next time?
- Can we do more to prepare for future events?

The emergency response took hard work from a large number of people from the emergency services, NZTA, consultant and contractor organisations. The teams worked long hours in difficult conditions to get the roads open and minimise disruption to the network. We now have an opportunity to plan for future events and improve the resilience of our critical infrastructure.

We suggest that the future risk to our infrastructure can be assessed and, where justified, proactive works can be undertaken to reduce the likelihood and severity of damage to our transportation infrastructure. Implementation of risk management works can also be timed to maximise the return on previous investment in coastal infrastructure (for example, by 'sweating the assets'). Now there is an opportunity to continue this open discussion, agree appropriate levels of service, and to undertake the design of new protective infrastructure before damage to the existing assets.

Consideration of the performance of existing coastal infrastructure can provide a better understanding of the residual risk and improve decision making around the operation of those assets. Furthermore, this improved understanding of performance and risk can provide significant public safety benefits.

Development of a simple tool for predicting extreme water levels in Tauranga Harbour

Rebekah Haughey[1], Paul Baunton[2], Tom Shand[1], Reuben Hansen[1]

The storm event of 5 January 2018 resulted in some of the highest recorded water levels around Tauranga Harbour since Cyclones Drena and Fergus in 1996-97. Significant overtopping and flooding occurred around low-lying, north facing shorelines (Figures 1 and 2) with some damage occurring to structures, including undermining of footpaths and scour around structures.

A combination of strong northerly winds around 70 km/hr with gusts up to 98 km/hr, a low barometric pressure of 990 hPa, and a very high spring tide (1.14 m above Moturiki Vertical Datum 1953), resulted in storm tide levels of 1.64 m MVD at the Tug Berth (0.5 m above usual MHWS). Following the storm event Tauranga City Council (TCC) and Tonkin + Taylor (T+T) surveyed the location and elevation of debris lines, representing the maximum level reached by the storm tide and any wave action present, at 29 locations around Tauranga City (Figure 3).

Inundation levels of up to 2.3 m MVD were found (1.2 m above usual MHWS). These levels were often sufficient to overtop coastal berms and flood backshore areas. The majority of the highest inundation levels were observed along north-facing shorelines that were exposed directly to the northerly wind and subsequently to wave effects. The debris elevations collected in 1996/97 following Cyclones Fergus and Drena by Gibb (1997) showed similar patterns to the 5 January debris lines, although the latter storm tide appeared to be on average 0.2 m higher.

With more high spring tides predicted over coming weeks TCC sought a robust and rapid method of forecasting of future storm tide inundation around the harbour to assist with emergency planning. T+T developed an empirical-based prediction tool to estimate extreme water levels based on readily available weather forecast information and calibrated using observed extreme water levels.

The prediction tool considers the three main components that contribute to storm tide inundation within an enclosed harbour: 1) astronomical tide, 2) barometric pressure, and 3) wind effects. Wind effects considered include both regional and local wind set-up, plus wind-wave setup and run-up. The combination of components contributing to extreme water levels will vary depending on exposure and orientation.

Figure 1: Flooding along Beach Road, Tauranga.

Figure 2: Wave overtopping near Kulim Park, Tauranga.

The tool estimates the contribution to water level elevation for each component based on a combination of empirical formula and/or observations for the 5 January event, and combines the components to obtain a total water level. The resultant extreme water levels are highly dependent on the direction of wind and hence vary dependent on shoreline orientation and location. For example, during the 5 January event, the exposed windward, north-facing shorelines were influenced by local wind setup (i.e. tilting of the water surface within the harbour) and additionally by wind-induced wave setup and wave run-up, whereas in sheltered, southern parts of the harbour there were no wave effects, but the local wind setup elevated water levels above the recorded storm tide. In leeward shorelines along the northern parts of the harbour the inundation level was driven entirely by the storm tide level. Based on these differences in the driving components, the extreme water level can be estimated for three different shorelines orientations, leeward, windward (sheltered), and windward (wave-exposed), as shown in Figure 4.

Figure 3: Location and elevation of debris lines recorded after the 5 January 2018 event.

(1) Tonkin + Taylor Ltd; (2) Tauranga City Council.

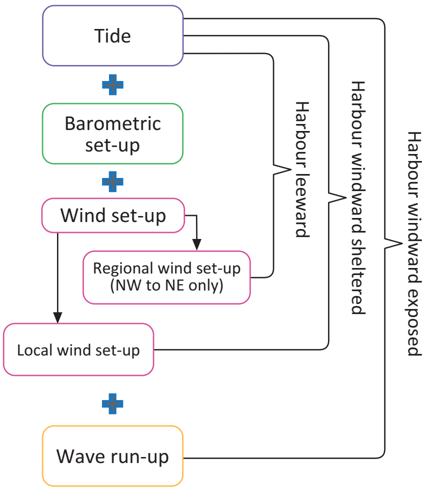

Figure 4: Schematic diagram of the parameters used to predict extreme water levels for different locations.

Inputs for the tool were kept simple, including predicted high tide elevations, forecast wind speed, and barometric pressure levels. Leading up to storm events, forecasts for these variables can change continually due to the nature of weather events. Sometimes this variability makes it difficult to determine when watch/warning/threat status should be implemented. However, the prediction tool is user-friendly, allowing input variables to be easily updated and multiple scenarios to be evaluated. The forecast data are available from a number of different services, each with different benefits to suit the user's requirement.

Outputs from the tool include a predicted water level over the specified timeframe of interest, allowing not only a peak water level to be estimated, but also an estimated time of peak water level (Figure 5). This output assisted TCC with preparation around storm events by determining when appropriate watches and warnings should be put in place.

Since the initial development of the tool following the 5 January storm, it has been successfully used to assist with forecasting extreme water levels leading up to Cyclones Geta and Fehi. Additionally, observational data from these events were used to further refine and calibrate the tool.

Development of the extreme water level prediction tool demonstrates how observational data, such as debris line elevations, provide not only useful information for increasing our understanding of individual events, but also can help with preparing for future events. Extreme water

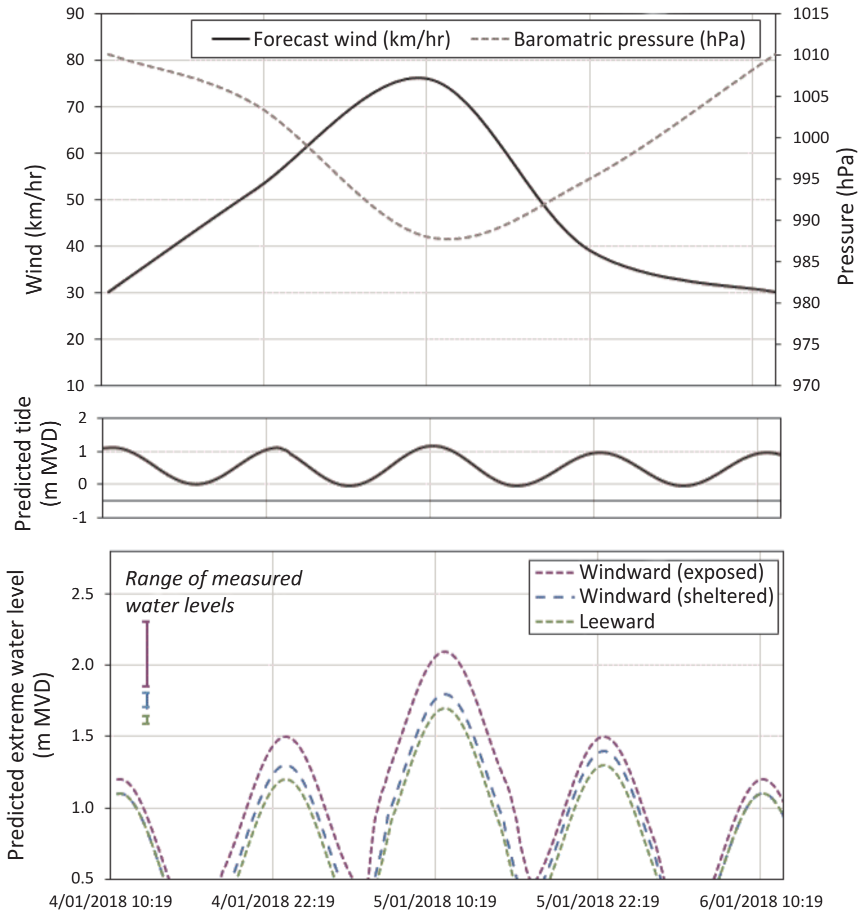

Figure 5: Example of extreme water level prediction tool. (Top) Input forecast data for 4th to 6th January 2018. (Bottom) Output of predicted water levels over time for three different shoreline orientations.

level estimates can also be combined with LiDAR and used to map the extent of likely inundation (Figure 6). Although it is a simple method of bathtub inundation mapping, this can be a useful way to identify which areas are at most risk of inundation. Simple, empirical-based tools can be developed very rapidly and, with good input and calibration data, can provide useful information far more quickly than complex numerical simulation.

Figure 6: Example of bathtub inundation using extreme water level predictions (2.1 m MVD) and 2015 LiDAR.

News from the regions

Northland

Laura Shaft and Michael Day, Regional Representatives

Ruakaka Estuary aerial imaging

Northland Regional Council's Coastal Monitoring team has undertaken a project to collect aerial images of the Ruakaka Estuary using a Phantom 3 Advanced Remotely Piloted Aircraft System (RPAS). A total of 12 flights were flown and 1545 images captured; 64 ground control points were also surveyed using an RTK GNSS survey. The images and ground control points have been processed to produce a high quality image that will be used to map the different habitats in the estuary. The resolution and the accuracy were much higher than existing aerial images of the area. The images have also been processed to create an elevation model; the vertical error of the elevation model was just 23 mm. Council is investigating using this technology to assess estuary-wide sediment patterns over long time periods.

Marsden Point resource consents

Independent commissioners have granted Marsden Point oil refinery operator Refining NZ (RNZ) a raft of resource consents to deepen and realign Whangarei Harbour's entrance and its approaches to better accommodate larger, new-generation tankers. For more information see: https://www.nrc.govt.nz/News/news-2018/july/refinery-operator-granted-harbour-entrance-dredging-consents

Proposed Regional Plan hearings

Hearings for the Proposed Regional Plan will commence in late August 2018. Regional council staff have prepared s42A reports to respond to submissions and these reports, as well as the staff recommendations version of the Proposed Plan, are available at: https://www.nrc.govt.nz/Your-Council/Council-Projects/New-Regional-Plan

Waikato

Christin Atchinson and Jacqui Bell, Regional Representatives

Preparing Coromandel communities for coastal hazards – TCDC update

Covering 400 kilometres, our Coromandel district has one of the largest coastlines in the country. Coastal living, here and in many other parts of New Zealand, involves being prepared for the natural processes slowly changing our coastline, and the hazards that can arise unexpectedly. This is something that has been front-of-mind for our Council, and we have been working on a coastal management strategy to help our communities be better prepared for the changes we face.

Last month Council approved a budget of nearly $2.6 million over the next three years to fund community-based resilience coastal hazard response planning and to draft a shoreline management plan. This is a significant commitment, which sees us lead the way in New Zealand towards building 'resilient' coastal communities. It ties in with the implementation of our Coastal Management Strategy (CMS), adopted in June alongside the LTP. We have also hired a coastal engineer who has been meeting with our communities to understand the different challenges faced across the district.

Bay of Plenty

Jonathan Clarke and Kieran Miller, Regional Representatives

Asian paddle crabs invade Tauranga

A summer marine pest survey conducted by MPI has discovered Asian paddle crab (*Charybdis japonica*) in Tauranga Harbour. While well established in the Hauraki Gulf and Northland, this is the first time they have been found in the Bay of Plenty. The Bay of Plenty Regional Council have been notified and will lead the response.

Biosecurity officer Hamish Lass said they're not sure how they got here, but the discovery was devastating. "We're not 100% sure but it's most likely that larvae floated here or hitched a ride on a fouled hull or in ballast water from another part of the country. It's also possible they naturally migrated here as they are very capable swimmers." Lass said *Charybdis japonica* is an extremely aggressive crab and an added threat to an already vulnerable ecosystem. "These crabs are extremely invasive. Not only do they compete with our native crabs, but they also feed on shell fish such as pipi, tua tua and cockles." Lass said that a response team, lead by the Regional Council and University of Waikato, is investigating the level of infestation in Tauranga Harbour and will also be setting up surveillance in the Maketu Estuary and Ōhiwa harbour. However, he warns, the outcome could be grim: "Surveillance will help us determine the extent of incursion and what, if anything, we can do. If it shows they have established, they will be very difficult to contain as current control methods are limited in their effectiveness."

The Bay of Plenty Regional Council asks people to keep an eye out for Asian paddle crabs and to remember that it is illegal to move living pest crabs. They encourage people to kill them if they find any and report it to The Bay of Plenty Regional Council on 0800 STOP PESTS (0800 786 773).

Orange peels and practice oil spill

An oil spill exercise took place at New Zealand's busiest port in late February. While the risk of a marine oil spill is extremely low, for the group tasked with responding to these events along the Bay of Plenty coastline, 12 nautical miles out to sea, it's important to be prepared. As well as Regional Council staff, those present represented the oil industry, Port of Tauranga, Maritime New Zealand, emergency services, and the Department of Conservation.

Regional On Scene Commander for the day, Adrian Heays, says Bay of Plenty is unique in its collaborative approach to oil spill response. "Because every spill is different and conditions and tides are never the same our approach in responding always varies too ... these exercises enable us to test that capability on the fly and feel comfortable with the procedures and equipment. This exercise in particular had a bigger focus on industry's rapid response capability. We had people responsible for transferring oil at the Port of Tauranga there and together we tested an upgraded capability. Orange peels were used to simulate the oil slick. All of the components came together and it felt like we had full control of the situation. It actually worked better than I expected, but that's what these things are about. We still have heaps of leanings to take away for next time."

All orange peels were recovered as part of this operation.

NZ first tsunami high ground

Tauranga City Council has made history with the official opening of the first purpose-built tsunami high ground in Australasia by the Minister of Civil Defence, Kris Faafoi. “This tsunami high ground is the culmination of years of ground-breaking research and investment that has allowed us to understand how a tsunami might affect our coastline”, says Deputy Mayor, Kelvin Clout. The high ground has been engineered to withstand a major earthquake, the scouring effects of tsunami water, and can take the combined weight of 4000 people. “Six years ago we were only beginning to understand the specific tsunami risk to our city ... most people assumed that the only place to be safe from a tsunami would be the top of the Papamoa hills and, of course, that everyone would have to drive there.”

Modelling shows that if everyone tried to evacuate the coastal areas in their cars, it would take up to eight hours to get everyone out – on a good day with no disaster or panic. Kris Faafoi said Tauranga City Council had worked to keep its community safe. “I was pleased to hear that the need was identified by the community who are preparing themselves for an emergency, and that Council have seen the benefit and progressed this high ground. Timely evacuation for school children and others with low mobility is vital in an emergency, and to have both community and Council get prepared is really outstanding.”

Council has a good understanding of local tsunami risks, knowing where the flooding is likely to go and how fast it is likely to be moving. The tsunami most likely to overtop our dune system would be triggered by a massive seismic event along the Kermadec Trench. It would be felt here, possibly the biggest earthquake felt in Tauranga in living memory. The resulting tsunami would reach this coastline after about 60 minutes.

Council has identified safe areas all along the coastline and has created a network of evacuation routes for people to reach them, on foot, within about 40 minutes, invested in an earthquake-proof evacuation bridge over the Wairakei Stream, and built the high ground at Gordon Spratt Reserve, the first of its type in Australasia, and the first of several planned for our coastline. Now that we have evacuation routes, we can start thinking about ways to add technology solutions to our suite of warning systems. We have a proposal in our Long Term Plan for tsunami alerting systems, options including outdoor public address speakers and 26,000 in-home warning devices for the most at-risk properties. This would be supplemented by the national alerting system.

Collaborative approach to Whakatāne commercial wharf and waterfront development

Te Rūnanga o Ngāti Awa, Ngāti Awa Group Holdings Limited, and the Whakatāne District Council have agreed to a collaborative approach to redeveloping the Whakatāne commercial wharf and its facilities. All three organisations will be represented on a governance group that will oversee the redevelopment proposal and, potentially, any projects that flow from it. The combined approach recognises the parties’ significant interests in the Whakatāne waterfront area and the need to consider cultural, historic, and commercial imperatives in any development plans.

Mayor Tony Bonne says the Eastern Bay of Plenty Visitor Economy Strategy identifies Whakatāne harbour and wharf development, along with a land-based White Island/ Whakaari experience centre, as one of the region’s biggest and most unique tourism opportunities. “Our ageing commercial wharf has to be replaced in the next few years,” he says. “Given the 50-100 year lifespan of any new waterfront assets, it’s important that we find a collaborative approach which both recognises the immense cultural significance of the area to iwi and hapū, and provides for current and future needs.”

Te Rūnanga o Ngāti Awa and Ngāti Awa Group Holdings are significant property and tourism stakeholders in the immediate vicinity of the commercial wharf and waterfront, making them obvious partners for Council to progress the commercial wharf development for Whakatāne and its communities.

Leonie Simpson, CEO of Te Rūnanga o Ngāti Awa, says that the collaboration is a positive step forward to support sustainable development for Whakatāne that embraces the social, cultural and commercial interests of the iwi. “Te Rūnanga o Ngāti Awa is pleased to participate in a collaborative approach with Council to imbed our cultural, social and commercial aspirations at the design, development and implementation phases. We are interested in positive, long-term intergenerational outcomes for Ngāti Awa, because, ultimately, positive outcomes for Ngāti Awa will also benefit Whakatāne.”

The Council has set aside $6 million for wharf replacement, on a like-for-like basis, in its 2018-28 Long Term Plan. Depending on the scale and nature of any final waterfront development proposal, it’s likely that a venture funding application will be made to the Government’s Tuawhenua Provincial Growth Fund, which has $1 billion a year available to promote regional growth.

Ohope harbourside trail opens

The Whakatāne District’s latest walking and cycling asset was officially opened in March, completing a long-held dream of making the estuarine beauty of the Ōhiwa Harbour more accessible to the community. The Ōhope Harbourside Trail is an initiative by the Rotary Club of Whakatāne, which raised more than $200,000 to develop a 2.9-kilometre, shared-use pathway along the harbour edge, from Waterways Drive to Port Ōhope Wharf.

Club spokesman Don Lewell says “Ōhiwa Harbour is one of New Zealand’s most unspoiled estuaries. It holds immense cultural significance to tangata whenua and is home to multitudes of birds, shellfish and fish species. Our vision throughout this project has been to provide locals and visitors with an opportunity to appreciate the taonga we have on our doorstep.”

Mr Lewell says it was also important that it serve as an ‘outdoor classroom’ to promote a love of nature and environmental consciousness. “With the improved access we now have to this section of the harbour edge, we can look to further enhance the estuary environment and a care group is being formed to lead those activities.”

He acknowledges the crucial role of the project sponsors. “Without the significant grants provided by the Lion Foundation, Southern Trust, Grassroots, the Whakatāne-Ōhope Community Board and Walking Access NZ, we would have struggled to get this off the ground. The support of the Whakatāne District Council and its staff has been hugely helpful and Tim Senior and the Bay of Plenty Regional Council have also contributed significantly. I think the Harbourside Trail shows just how much can be achieved when community groups like Rotary, funding agencies and local councils get together for a common purpose.”

University update

Waikato University

Karin Bryan

Submarine groundwater discharge into Tauranga Harbour

Benjamin Stewart, a PhD student at the Coastal Marine Group, University of Waikato (as part of the Inter-coast program between NZ and Germany), is in his final year of research and has been investigating Submarine Groundwater Discharge (SGD) into Tauranga Harbour, New Zealand, which is funded by the Bay of Plenty Regional Council. This project estimates the amount of groundwater and related nutrient inputs at the land/sea interface using radium isotopes (a naturally occurring geochemical tracer). These estimates were made at the harbour scale and were found to be comparable to surface water inputs from rivers and creeks. Hydrodynamic modelling (Delft 3D) has also been used to investigate the salinity and transport patterns within the harbour and coastal shelf.

This project suggests that SGD is a major driver of nutrient dynamics in coastal systems, which is currently unaccounted for along New Zealand coasts. This is important given the high nutrient loadings occurring across our catchments and the steep and permeable landscapes. Further information, including published results, is available upon request. Karin Bryan (NZ – chief supervisor), Conrad Pilditch (NZ), Christian Winter (Germany) and Isaac Santos (Australia) are supervising this work.

Spatial and temporal variations of turbidity

Mariana Coppede Cussioli, a PhD student at the Coastal Marine Group, University of Waikato (as part of the Intercoast research group, a collaboration between the University of Waikato (NZ) and University of Bremen (Germany)), undertook research (funded by the Port of Tauranga) to provide a multidisciplinary understanding of the spatial and temporal variations of turbidity, particularly during dredging, in Tauranga Harbour. The research was supervised by Karyn Bryan (chief supervisor, NZ), Conrad Pilditch (NZ), Willem de Lange (NZ), and Kai Bischof (Germany).

Increased levels of turbidity in coastal areas is an issue gaining more attention with enlargements of ports and harbours and future changes in land use practices. Specifically, Mariana investigated the effects of turbidity variations on underwater light quantity, quality and the health of shellfish. Through field campaign and numerical modelling (Delft3D) they developed an index of plume symmetry that contributed to identifying sensitive areas around dredging activities. The aim of the study was to predict whether negative impacts of a turbidity event on key species (seagrass *Zostera muelleri* and shellfish bivalve *Paphies australis*) are likely to occur. Therefore, they developed a relationship between underwater light attenuation and turbidity, which is an important controlling factor for primary production. They modelled feeding and digestion rates of *P. australis*, which can indicate potential effects of increased turbidity on their health. The key findings of this study will help manage conditions for dredging or any other port-related activity with monitoring and threshold suggestions.

Stability of cohesive sediments from the Firth of Thames

The habitat created by intertidal soft-sediments is very common on Earth, supplying the base of the food chain and influencing biogeochemical cycling. Intertidal areas are often characterised by fringing vegetation such as salt marsh and mangrove forests, which play a role in mediating sediment erosion and accretion, and ultimately the elevation of intertidal areas. With rising sea levels and predictions of increased storminess, intertidal areas are likely to experience increased inundation unless they can retain new sediments to build the seabed upward. Therefore, understanding the stability of coastal sediments is critical to predicting coastal resilience to future environmental stresses.

Hieu Nguyen Manh, a University of Waikato doctoral student, is studying the stability of cohesive sediments from the Firth of Thames, New Zealand. Continuous changes in wet and drained states of intertidal sediments may have a strong effect on the erosion properties of the intertidal area. The water content of exposed sediment is strongly mediated by air temperature. Hieu has conducted controlled experiments using the EROMES erosion device and varying temperature of exposed sediments to show that a change in temperature of the air can cause a doubling of the erosion thresholds, depending on the grain size and organic content of sediments. Hieu tested both the critical erosion threshold, which is the point where sediment transport is initiated, and the erosion rate, or the rate of loss of sediment after the initial transport occurs.

The results highlight that erosion properties of cohesive sediments in intertidal flats should be separately considered during flooding and ebbing tides, because sediment becomes more stable when exposed to the air during low tides. Hieu comes from Vietnam and his research project is being supervised by Prof. Karin Bryan, Prof. Conrad Pilditch and Dr. Vicki Moon.

Contributing to *Coastal News*

We welcome contributions for forthcoming issues of *Coastal News*. Please contact the Editor, Charles Hendtlass, at cellwairmonk@gmail.com if you'd like to submit an article, contribute a news item, have content suggestions or a photo to share, or if you would like a contributor's guide.

The submission deadline for the next issue is 30 September 2018.

Back issues of Coastal News (from 1996 onwards), plus a newly-added author and article index up to issue 65, are available to download from the Society's website at www.coastalsociety.org.nz (under the 'Publications' tab).

NZCS Conference 2018 – 20-23 November 2018, Gisborne

Registrations and abstract submission for the 2018 NZCS Conference 'Crossing the Water' are now open. We are looking for a diverse group of presentations and posters that delve into issues related to our changing coasts and the understanding of the important relationships between the land and the sea. Go to https://www.coastalsociety.org.nz/conferences/nzcs-2018 for all the conference information, including registration and abstract submission.

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