TAMING AND DEVELOPING THE COASTAL MARGINS OF AOTEAROA

LESSONS TO BE LEARNT

April 2022

engineering new zealand
te ao rangahau

CONTENTS

This document summarises the webinar by Dr Rob Bell FEngNZ CPEng in conjunction with the New Zealand Coastal Society.

Rob is Managing Director of his own consultancy, Bell Adapt, a Teaching Fellow in the Environmental Planning Programme at Waikato University, and formerly with NIWA.

Rob started his career with the Ministry of Works & Development, Water and Soil Division – which included working on coastal land margins and water quality around Aotearoa New Zealand.

1: INTRODUCTION

Aotearoa New Zealand has one of the longest and most diverse coastlines in the world. It ranks ninth longest in the world - greater than 15,000 kilometres.

The Anglo-Saxon proverb 'time and tide wait for no man' recognises that no human can control the tides. This applies to the new challenge we are facing with a rising of sea levels.

This webinar looks at significant coastal floods and coastal erosion events in our country and examines how these have helped shape current thinking on how we approach the management and planning of our coastal areas.

Ōhiwa Spit. Photo courtesy of Bay of Plenty Regional Council

ACKNOWLEDGEMENT

Dr Rob Bell wants to acknowledge the following groups of people for their perspective and work on managing coasts.

- Iwi and hapū for their inter-generational mātauranga and kaitiakitanga of Aotearoa's takutai (moana, environs and attributes). We have a lot to learn about how they have adapted and changed as the coasts changed.
- Our 'coastal pioneers' in engineering and physical processes (especially in the 1960-90s), and those practitioners who helped create the cross-discipline of coastal science and engineering.

2: COASTAL FLOODS

Let's look at coastal floods first. There have been a series of coastal flooding events that have influenced our learning on this topic.

EARLY EUROPEAN SETTLER PHASE

While the early European settlers developed a working knowledge of tides, they lacked understanding of what was happening in terms of storms, waves, and erosion. This is evident by their sand mining or gravel mining and removal of the materials from the coast.

For example, on Ponui Island, near Waiheke, wheelbarrows were used to harvest beach materials that were put on to scows to take to Auckland.

Source unknown, Ponui Island

KOHIMARAMARA COASTAL FLOOD EVENT (1936)

EFFECTS OF THE CYCLONIC STORM : EXTENSIVE DAMAGE ON AUCKLAND WATERFRONT

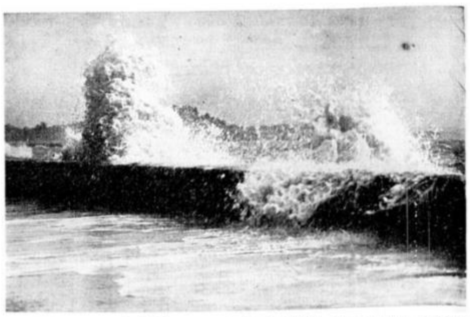
AUCKLAND DISTRICT SWEPT BY FIERCE GALE YESTERDAY: ABNORMAL TIDE AND FIERCE WIND RESULTS IN EXTENSIVE SEA ENCROACHMENT ON FORESHORE PROPERTIES

In 1936 a large strong tide event caused coastal flooding at Kohimarama in Auckland. It flooded the Parnell Baths and across the waterfront and caused extensive damage.

What was significant about this flooding event was that it:

- was perceived as an 'abnormal tide' - people were quite surprised by the coastal flooding which occurred (actually a combination of a high spring tide, storm surge and wave overtopping); and
- was the highest storm tide experienced by Auckland until over seventy years later (in 2011).

Parnell Baths – Judges Bay (2 ft above baths)



A typical scene on the Kohimarama waterfront at high tide yesterday morning.

NZ Herald 27 March 1936

HAURAKI PLAINS COASTAL FLOOD EVENT (1938)

Just over two years later in 1938, a large part of the Hauraki Plains was flooded at night on a high tide. This was caused by a combination of:

- a perigean spring tide (some people call them king tides),
- north easterly gales coming down the Firth of Thames, plus
- waves and rain.

Sixteen hundred hectares of the plains were flooded, at depths of 0.5 -1.3 metres. The flooding also overtopped coastal and Piako River stopbanks, and the outflow of the water breached sizeable sections of the road (caused by the combined force of the land drainage and outflowing at the same time as the tide dropping).

This event led to raising of the coastal stop bank.

Source: RNZAF photo

Ohinemuri Regional History Journal 53, 2009

LEARNINGS FROM HISTORIC EVENTS

Some learnings were from my time at the National Institute of Water and Atmospheric Research (NIWA), where we unpacked the combinations that cause coastal flooding, such as storm tides (high tide + storm surge), waves and rainfall. While storm surge heights of around 1 metre that we get on open coasts in Aotearoa are not as high as other parts of the world that experience hurricanes or tropical cyclones, with the wind set-up, storm surges can rise to 1.3 to 1.5 metres in some harbours.

Coastal flooding events primarily occur in Aotearoa on high spring tides. That's why NIWA has developed Red Alert Tide Days[1], which are published every year. It warns when these highest tides might be expected, so to look out for weather with low pressure and wind.

We've also learnt that wave overtopping of stop banks and sea walls can be accompanied by long wave surges – which are a bit like a tsunami wave but at shorter one-to-two-minute periods.

Now Aotearoa faces gradually rising sea levels. In the last hundred years, the sea level has risen 0.2 m, which is starting to increase the frequency of coastal flooding events. This is not surprising as the 0.2 m rise is the equivalent of a fifth of the maximum storm surge for Aotearoa on the open coast (1 m).

[1] https://niwa.co.nz/our-science/coasts/tools-and-resources/tide-resources

COASTAL FLOODING IN AUCKLAND (23 JANUARY 2011)

On 23 January 2011, Auckland experienced its highest storm tide. State Highway 16 Waterview Causeway had to shut for three hours until debris was cleared. The following factors were found to have contributed to the flooding of the Waterview Causeway:

- the ongoing subsidence of the marine muds on which the motorway sits;
- the low rock wall which was overtopped by small waves;
- sea-level rise (SLR); and
- a high spring tide and storm surge from a low-pressure system.

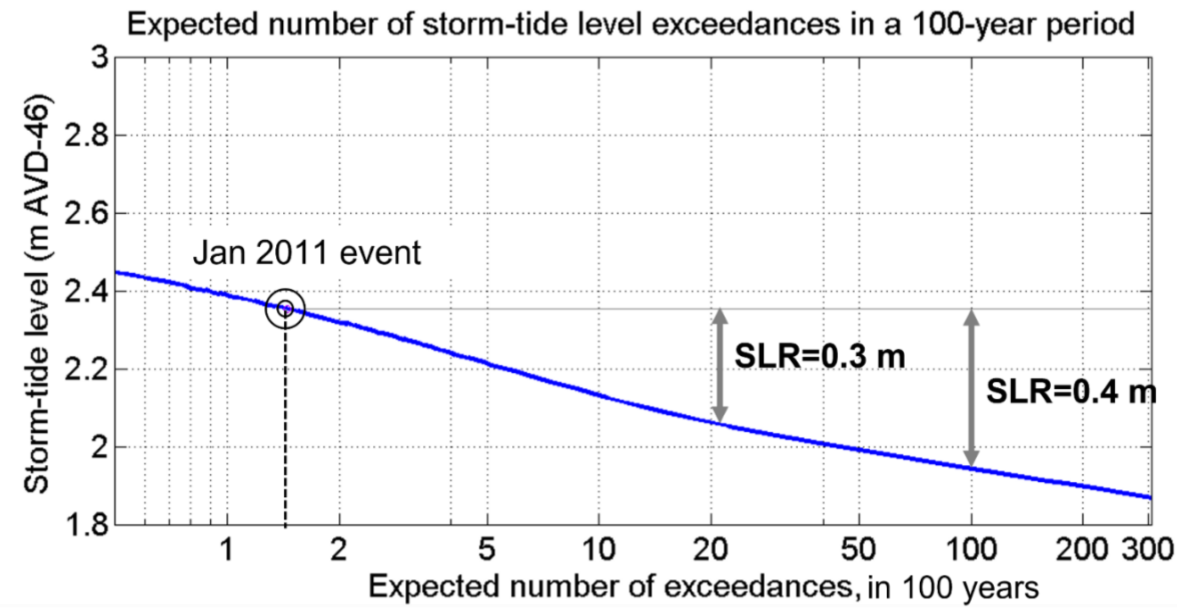
As a result of a New Zealand Transport Agency (Waka Kotahi) funded project, the causeway was widened and raised factoring in an allowance for sea-level rise of 0.8 m, with sufficient footprint and ground treatment to enable a further half metre rise in the road elevation (if required).

Bucklands Beach: Peter Heyes

SH16 Waterview Causeway (NZTA/AMA)

LEARNINGS FROM THIS EVENT

This graph shows the historic extreme distribution of storm tide levels for Tāmaki Makarau in terms of the number exceedances of coastal floods for different storm tide levels over a 100-year period. Note: this would be a similar pattern for other parts of the country.



While the 2011 coastal flooding was approximately a 1:100-year event, from now on (taking into account SLR) the same flooding would happen with smaller and smaller storm tide levels. By the time there is a 0.4 m SLR in Auckland, there will be:

- around 100 **extreme** storm occurrences like the 2011 event. This equates to one a year on average.
- many more **moderate** nuisance flooding events.

3: COASTAL EROSION

Let's look at coastal erosion now. Controversy and public discussion inevitably follow severe erosion events. When erosion events occur, it can be from either individual storms or gradually as part of a multi-decade cycle of erosion and accretion, or both.

ABOUT COASTAL MARGINS AND BUFFERS

Firstly, sedimentary coasts and coastal margins, including dunes, are nature's mechanism to buffer storms and waves. They do this by resisting the waves forces by moving sand.

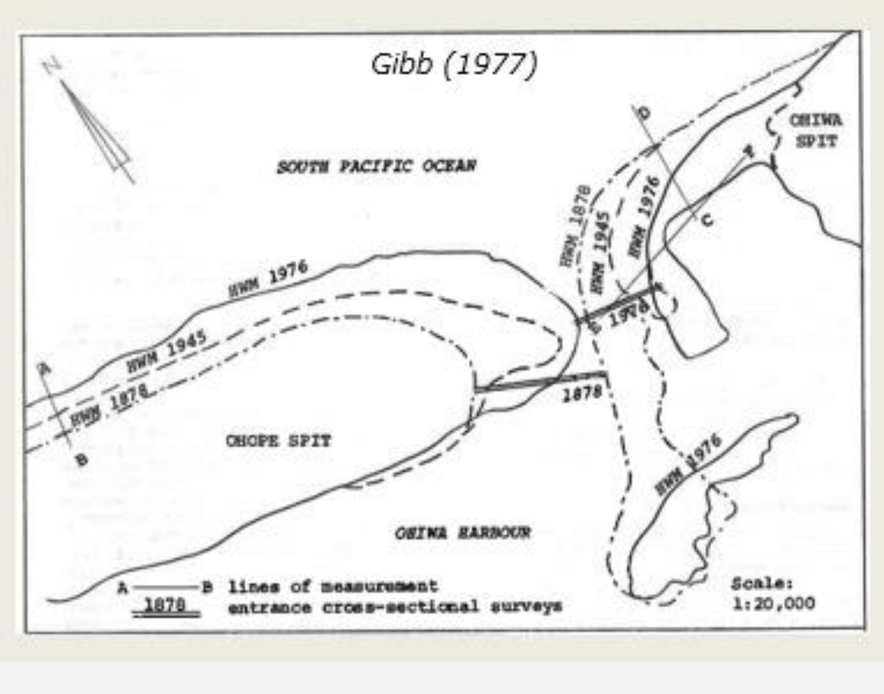
Imposing hard defences (such as rocks) in the buffer zone invariably breaks that buffering action, so we need to be ultra-careful when we're putting structures within this active buffer zone. But:

- the words *shoreline* and *coastline* inadvertently create perceptions of relative stability, and that once nature goes beyond that line, we need to defend that line.
- *Coastal cliffs* are a one-way erosion process. They don't accrete (grow). They are frequently regarded as being 'rock solid' but if the cliffs are unconsolidated or partially consolidated, they will continue to erode. This can also be compounded by storm water runoff and activities and buildings at the top of the cliff if not managed carefully.

It's important to start to think about these coastal margins and coastal buffers now as we face ongoing SLR.

Source: R Bell

PORT ŌHIWA COASTAL EROSION CYCLES



Port Ōhiwa is a sandspit that has changed remarkably over the last century or more:

- around 1878, the spit was much larger, and Ōhope on the other side was much further back (the entrance has moved a lot).
- during the early 1880s to 1900s, Ōhiwa Harbour was the most used harbour in the eastern Bay of Plenty, as the neighbouring harbours were much harder to navigate.

In 1873 approval was given to build a hotel in the middle of the sandspit and this became the nucleus of the Ōhiwa township. It is noteworthy that the local Māori people settled on the hill and used the coast, but Europeans settled on this very highly fragile spit system [Johnston, 2003].

Johnston (2003) Ohiwa Harbour – Report to Waitangi Tribunal

At this stage the area had not been surveyed, but in:

- 1879 a survey was completed, and sections were offered for sale; and in
- 1896 the wharf was built.

The erosion of the spit in the early decades of the 1900s doomed the settlement and gradually houses were removed one by one. And the spit itself was washed away during the storms in the 1930s, so completely disappeared!

But in the 1950s the erosion abated, and people began to build holiday homes on Ōhiwa Spit. The current operative district plans and planning maps still show land parcels from the original settlement.

In the late 1950s and early 1960s, the Department of Lands and Survey subdivided the remaining land on the spit, but by 1965 the rate of erosion from the eastern end of the spit had increased to 6 m per year. This increased through the 1970s to 56 m in 1978. Attempts to save the land (for example laying down rail irons and cars were used to defend the shoreline) failed and dwellings on part of the spit were again abandoned.

Substantial accretion in last few decades has reinstated extensive foreshore. A holiday home was even allowed to be built about a decade ago on land that was previously in the sea in the 1970s). **But** there is growing evidence that it is now on an eroding phase.

There's a pattern here that building on highly dynamic sand spits is to be avoided.

Source: Bay of Plenty Regional Councill

SERIOUS LESSONS FROM OMAHA

In Omaha from 1942-1963, the ebb tide delta was sand mined. The ebb tide delta is the bulge of sand that forms at the seaward mouth of tidal inlets as a result of interaction between tidal currents and waves on sediments.

The sand mining stopped after the owner of the farm on the sandspit took the dredging company to court about the emerging erosion he witnessed.

In the late 1960s Broadland Properties wanted to create a residential subdivision in the central quarter of the Omaha sandspit. In 1970 they built a 1 km timber retaining wall to retain sand behind the wall, with the boards down to mean high water springs (MHWS). This was pre- Resource Management Act (RMA) days.

Through the 1970s (until 1976) 13 m of erosion occurred behind, what was called at the time, the 'Useless Wall'.

- It resulted in a 1976 court case that went on between the developer and Rodney District Council for a few years.
- Meanwhile the erosion continued. The erosion was exacerbated not just by the presence of the timber wall, but also the dune lowering for the subdivision, reducing the sand buffer. This highlighted the importance to retain the precious resource of sand within the sand buffer and not erecting walls on the active beach.
- The stalemate continued until the wall was completely obliterated in the July 1978 storm
- Emergency remedial work was completed from 1979 to 1980. This included installing two offshore groynes (a training wall at the end of the spit and some renourishment). This has facilitated the seaward growth of the shoreline and the protection has stabilised the spit.

Further residential development in the area occurred in 2015, and in line with learnings from the past, at an increased setback from the coast this time round.

LEARNINGS FROM ŌHIWA AND OMAHA

Some learnings from Brookes & Riley (2000) and my observations

- Observe nature and the established geomorphology – the body of sand or beach being formed, and how is it responding. Then analyse what has changed to offset that quasi-equilibrium.
- Recognise that nature and coastal areas are never in total equilibrium, and they come and go in cycles. Management of our coastal areas need coastal experts, monitoring, and geomorphic data to understand the natural and geomorphic response. 'Holocene sand deposits' are finite and practices such as dune shaving, dredging, sand mining and seawalls often deplete those deposits that sustain that coastal buffer.

- Closely examine the variability (including trends in SLR) in coastal situations before setting property/subdivision boundaries or hazard setbacks, such as in Omaha South where, (post RMA) this setback zone safeguarded the dune buffer there.
- Be cognisant of the *develop-defend-feel secure* cycle. While a setback zone may look to be sustainable, this won't be the case forever, particularly with rising sea levels.
- Realise that storms usually magnify the effects of the other causes of erosion and the hidden 'costs' of interventions. Storms are not always the cause of the erosion, but they can exacerbate the underlying changes in sand budgets (that we don't see from day to day).
- Consider the possibility of interdecadal climate shifts such as at Ōhiwa where spits come and go over a 40-to-50-year cycle, and the sand buffer moves from one side of the harbour to the other.

PAUANUI COASTAL HAZARD SET-BACK ZONE

The Ministry of Works' Water and Soil Division assisted councils with technical support for coastal areas including groundwork studies and surveys of the Pauanui spit in Coromandel Peninsula [Gibb & Aburn (1986)]. While working for the Water and Soil Division, I was involved in undertaking oceanographic and survey measurements. The purpose was to create the first coastal hazard zone determination in New Zealand (1986) incorporating an allowance for SLR, that could be used to set the seaward boundary of development of the spit.

NIWA

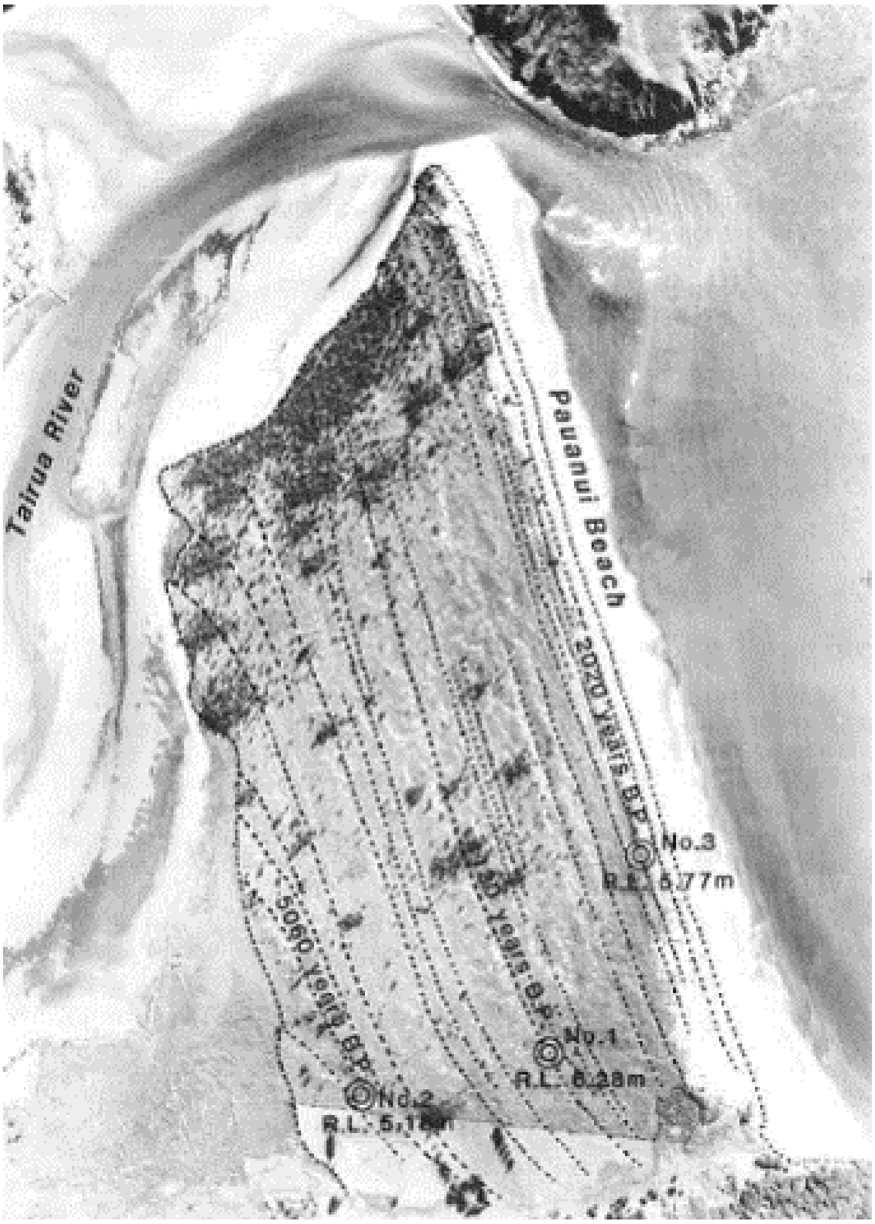
Source: NIWA CamEra web page

As a result, a SLR allowance of 0.7 metre was built into a set back zone for the Pauanui development. At the time it was estimated that this would last from 1983 to 2080 (a hundred-year period).

- This SLR estimate used, still matches the latest IPCC projections for 2080.
- The Bruun Rule was used but was informed by very extensive geomorphic and beach surveys and historic data/aerials.

For the developer, inclusion of a SLR estimate meant that the planned front-row property plan couldn't go ahead. Instead, it has resulted in a much-used recreational asset and a coastal-hazard buffer has been put in place.

A more recent re-assessment of the coastal hazard set-back zone by the Waikato Regional Council confirmed that the zone largely aligns with modern practice.



WATER & SOIL TECHNICAL PUBLICATION NO. 27
WELLINGTON 1986

Shoreline fluctuations and an assessment of a Coastal Hazard Zone along Pauanui Beach, Eastern Coromandel Peninsula, New Zealand

Jeremy G. Gibb and John H. Aburn

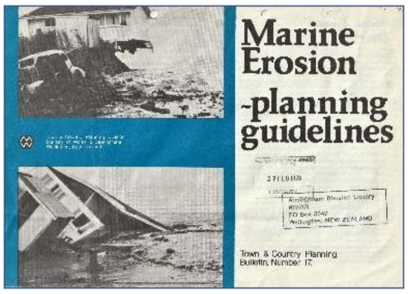
Water and Soil Directorate, Ministry of Works and Development, P.O. Box 12-041, Wellington North

Ministry of Works and Development, Private Bag, Hamilton

4: LESSONS TO BE LEARNT

"The number one problem is not marine erosion (a natural process) – it's the lack of foresight and bad land-use planning by both central and local government." [*1978 Marine Erosion – Planning Guidelines by Ministry of Works and Development (MWD), Town & Country Planning Division*]

MWD Marine Erosion planning guidelines 1978



In cleaning out my office at NIWA, I stumbled upon these erosion guidelines produced 44 years ago by the Town & Contry Planning Division of the then MWD. These offer some clear insights on planning and developing at the coast to reduce the risk of erosion, which we still continue to learn over again.

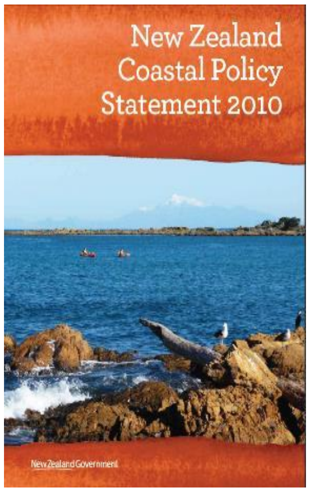
Some examples of this early directive planning guidance:

- it's essential we learn from our past mistakes.
- local authorities should recognise the *dynamic nature* of the coastline.
- it's dangerous to assume that accretion will continue indefinitely – reversals can occur (*e.g., the Ohiwa Spit example I presented*).
- foredunes and spits should never be built on.
- development should be located behind the buffer zone.

It seems we have to keep learning some of these lessons.

NZCPS: 2010

More recently, the mandatory New Zealand Coastal Policy Statement 2010 provides some clear directives for managing coastal hazards and climate change. It:



- talks about avoiding increasing the risk of social, environment and economic harm from coastal hazards.
- directs coastal **risk assessment** and **planning** for at least 100 years, and requires taking into account national guidance and the best available information, including climate change and SLR.
- promotes strategies for existing development including **identifying and planning for transition mechanisms and timeframes for moving to more sustainable approaches.**

But there is still work to be done. For example:

Source: R Bell

- The present RMA reform process needs to address the issue of existing use rights to 're-possess' land parcels after accretion or continue living on land subject to frequent coastal hazard impacts. For example, on Ōhiwa spit:
  - in the late 1970's, several responses were applied (railway irons, car bodies and other objects) to halt the erosion, which were all unsuccessful at the time.
  - since that period, the spit moved into an accretion phase building out nearly 200 m seaward.
  - a holiday home was built on accreted land with the owners re-possessing the existing use rights. Although the new holiday home dwelling is removable and subject to an erosion trigger, all the coastal experts involved in consenting agreed that it had a limited 'tenure' of decades.

Source: R Bell

- For existing development, in terms of adaptation, we need to start identifying and planning for transition mechanisms and timeframes for moving to more sustainable approaches. (This is what dynamic adaptive pathways planning (DAPP) framework, in the 2017 national guidance on coast hazards and climate change by the Ministry for the Environment, is attempting to do).

The management challenges from 'hold the line' approaches

Another aspect to learn from is the proliferation of ad hoc or informal coastal defence measures used to tame the sea. We've seen wool bales, tanalised timber poles, wooden "fences", car bodies, car tyres and railway irons - all futile in most cases, especially when placed in the active coastal buffer. This community default option to 'hold the line' with rocks, walls, or renourishment (or all three) is continuing despite the adverse effects and failures we've seen around New Zealand and the directive of the New Zealand Coastal Policy Statement (NZCPS) 2012 to discourage hard structural defences.

Increasingly, the wider community and recreational users are contesting the public funding that is going towards management of coastal shorelines to benefit private 'good'.

There are varying council responses to coastal management of existing vulnerable dwellings, some are very active, and some quite permissive. Looking ahead, the resource management reforms should bring more consistency in managing these issues, although the present NZCPS provides considerable direction.

The importance of coastal engineering and management, including the role of coastal experts

Although there are coastal processes and science courses at most universities in New Zealand, there is no formal coastal engineering degree in New Zealand. Most of our coastal engineers have studied in the Netherlands, Australia, United States, or the United Kingdom, or have taken courses or subjects as part of a civil engineering degree or are self-taught.

Given that many district and city plans with a coastal hazard overlay require coastal hazard experts to support consenting, planning, assessments, and approvals (for example the Auckland Unitary Plan E36.9), I think there is a need to formalise:

- who can be a coastal hazard expert or coastal engineer, and
- the peer review process, particularly in the case of sole-practice engineers.

We need experts who explicitly consider uncertainties and stress test options, designs, and plans. We need to also move past our fixation with setback 'lines'. The coasts are natural buffers, and we also have the compounding impacts of climate change and SLR to consider.

Finally, in terms of ethics, we need to be particularly mindful when working on coastal projects. The Code of Ethical Conduct (Section 2) for members of Engineering New Zealand and Chartered Professional Engineers states that we must have *regard to reasonably foreseeable effects on the environment …* [2(i)] and *have regard to the need for sustainable management of the environment* [2(ii)].

5: IMPLICATIONS FOR PRACTICE

There is ongoing change ahead for our coastal margins. We need a new way of managing the ongoing and increasing risk that we are facing from rising sea level. Although we can learn lessons from the past, we can no longer rely on past practice data and knowledge to adapt.

We need to start asking ourselves these questions in every coastal situation.

- "Do we continually react, recover and stay put as we see more coastal flooding and coastal erosion?" **Or**
- "Do we protect assets and hunker down? And for how long might that occur?" **Or**
- "Do we anticipate, adapt, and reduce or avoid the rising risk?"

We now have these emerging coastal hazards from the rising base sea level. Mean sea level is now ~0.2 m higher than the 1920s.

The most obvious effects will be the following (which can all compound together at various times):

- more frequent flooding
- sunny-day flooding (king tides)
- nuisance flooding

- extreme events
- compound flood hazards:
    - intense rainfall
    - river flow
    - high tides and storm surge
    - groundwater rise and ponding
- increasing coastal and cliff erosion, which is going to be complex because climate change will affect all the sediment processes that play out at coastal buffers.

SUMMARY

In summary, here are the key points covered.

Sediment coasts buffer stormy seas by expanding energy and shifting sediment, and our interventions invariably have repercussions. So don't extract and take away sand or gravel. This is a coastal buffer. It's a finite resource which needs to stay on the beach.

Hard defences that are ill positioned on the shoreface, invariably create adverse effects on coasts, and these structures can be undermined, overtopped, or outflanked.

With climate change **coastal flooding will become the dominant coastal hazard as sea levels rise** (compared with more localised coastal erosion impacts). The risk (magnitude and extent) will become far greater than coastal erosion, so we need to turn our focus towards adapting to coastal flooding.

There will be **increasing frequency of compound flooding,** both from the land side, from fluvial sources, but also from the sea. With only modest rises in sea level of 0.3–0.45 m, what was once a 100-year event will become something that is an annual event.

We need to recognise that most **existing revetments/sea walls around Aotearoa are not designed for flood protection**, either because they are too short and they have ends, or they are porous (they are made of rocks, or not high enough).

While we have good coastal policy in New Zealand, there is inconsistent local and regional application. Local councils are under immense pressure from developers and vested interest from property owners.

The Resource Management reforms should improve statutory outcomes, particularly around dealing with existing use rights, funding adaptation, and setting some ground rules.

Finally, coastal experts are a small group in Aotearoa. We need to be wary of employing engineers and planners with limited coastal experience to sign off or to develop options for the coast. **Geomorphic scientific advice, field data and an understanding of climate-change impacts are important for any project involving the coast**.

6: Q&A

What about the new enabling housing supply in the National Policy Statement – Urban Development, which requires councils to allow three by three storey buildings on every lot across our cities. Should this outcome be avoided in coastal hazard zones, or can we rely on the building act to mitigate for building design, relocatable and/or land protection?"

It's hard without the Spatial Planning Act in place. A number of councils are starting to do some ad-hoc spatial planning within their coastal hazard zones, or their flood hazard zones or risk assessment findings to try to inform where housing intensification or housing re-development should take place.

Do you have any opinions on using the concrete Dolosse used in South Africa?

Dolosse or tetra pods, which are heavy precast concrete units, have only been used in a few places (it is quite expensive) in New Zealand, mainly for breakwaters for ports and airports e.g., the seaward facing revetment at the southern end of the Wellington Airport runway

According to the Ministry of Works planning guidelines foredunes and spits should never be built on. Are you aware of coastal erosion issues at Port Waikato foredunes and the houses, car park and surf club that had been built there historically? If so, can you comment on the erosion occurring there and past developments suitability for that area? Is that typical of other New Zealand areas and communities?

In the Port Waikato situation, there are long cycles of erosion and accretion. When building on those foredunes we need to understand the geomorphology and get a longer view of those cycles instead of just going ahead and building on those dynamically active systems (that can have over 40- or 50-year cycles).

Can legislation and policy play a greater role regarding coastline or shoreline? For example, the definitions of the New South Wales Coastal Management Act 2016 No 20, defines the 'beach fluctuation zone ambulates as the coastline or estuary or coastal lake foreshore experiences net long-term recession or accretion due to changes in their sediment budgets'?

There needs to be a formal way of considering requirements of what an active beach buffering zone or coastal fluctuation zone is. Setback hazard zones being done by a number of consulting engineers and NIWA and others have considered those fluctuations, but there are other areas where some of that groundwork hasn't been done.

Coastal engineering is one topic covered by a course at the University of Canterbury. Do you think our universities should be doing more to prepare students and offer more coastal courses?

A lot can be learnt a lot on the job in terms of observing, measuring, doing research, monitoring, beach profiles, and how the coast operates. But with New Zealand's challenge with climate change, where coastal engineering is going to take on a whole new dimension, we need to do more to prepare our students and develop that capability.

Does the new coastal policy take account of seismic risks such as tsunami or the seismic stability of stop banks?

The New Zealand Coastal Policy Statement does include some measures around planning for tsunami, but not seismic. It doesn't specifically mention liquefaction, but again that's another hazard that we're going to see in terms of compound effects from sea level rise and rising groundwater in our coastal lowlands

Have you any comment on the use of geo bags to stabilize coastal areas, sea walls, and coastal reefs?

A number of these structures, whether they're geo textile or another material, are being damaged and needing replacement. They are only a temporary measure, and we need to ask the critical question, are we holding the line? For how long can we do that?

Do you think that involving mātauranga in the decision making for coastal development would be beneficial?

The mātauranga know how our wetlands and marshes is much needed, as they have become damaged, drained, or reduced habitats. I'm part of research being coordinated by NIWA called Future Coast Aotearoa, looking specifically at coastal lowlands – marshes and wetlands, which will incorporate mātauranga perspectives. One measure is managed realignment of the shoreline further inland to enhance and reduce the coastal squeeze of wetland and estuarine habitats that we see from sea walls, embankments, causeways and stop banks.

7: REFERENCES

Brookes, H.; Riley, P. (2000). Omaha Beach – A brief background, and, Omaha Beach: Erosion and repairs 1970-84. NZ Coastal Society Annual Conference, Auckland, 2000.

Gibb, J.G. (1977). Late Quaternary sedimentary processes at Ohiwa Harbour Eastern Bay of Plenty with specific reference to property loss on Ohiwa Spit. Water & Soil Technical Publication No. 5, Ministry of Works & Development. 16 p.

Gibb, J.G.; Aburn, J.H. (1986). Shoreline fluctuations and an assessment of a Coastal Hazard Zone along Pauanui Beach, Eastern Coromandel Peninsula, New Zealand. Water & Soil Technical Publication No. 27, Ministry of Works & Development.

Johnston, E. (2003). Ohiwa Harbour. A report commissioned by the Waitangi Tribunal. 337 p.

Ministry of Works and Development, Town & Country Planning Division. Marine Erosion – Planning guidelines, 1978

New Zealand Coastal Policy Statement (NZCPS) 2010

New South Wales Coastal Management Act 2016 No 20

Watton, G.; Scott, N. (2009). Coastal plains inundated by tidal flood. Ohinemuri Regional History Journal 53, September 2009. **http://www.ohinemuri.org.nz/journals/81-journal-53-september-2009/1818-coastal-plains-inundated-by-tidal-flood**