NIWA

Taihoro Nukurangi

Climate, Freshwater & Ocean Science

[Coastal climate services in New Zealand – Scott Stephens] [14 November 2019 Orleans France]

What happens when king tides and storms coincide?
2017–18 the "summer of storms", NZ

JAMIEE THOMSEN/SUPPLIED

The Thames Coast Road has been washed out.

BRADEN FASTIER/STUFF

Firefighters helped evacuate people from homes in flooded Tait St at Ruby Bay on February 1 as ex-Tropical Cyclone Fehi hit the Nelson-Tasman region.

EMELYN MCHARDY/STUFF

The Sunset Motel near Thames has been evacuated as flood waters arrive.

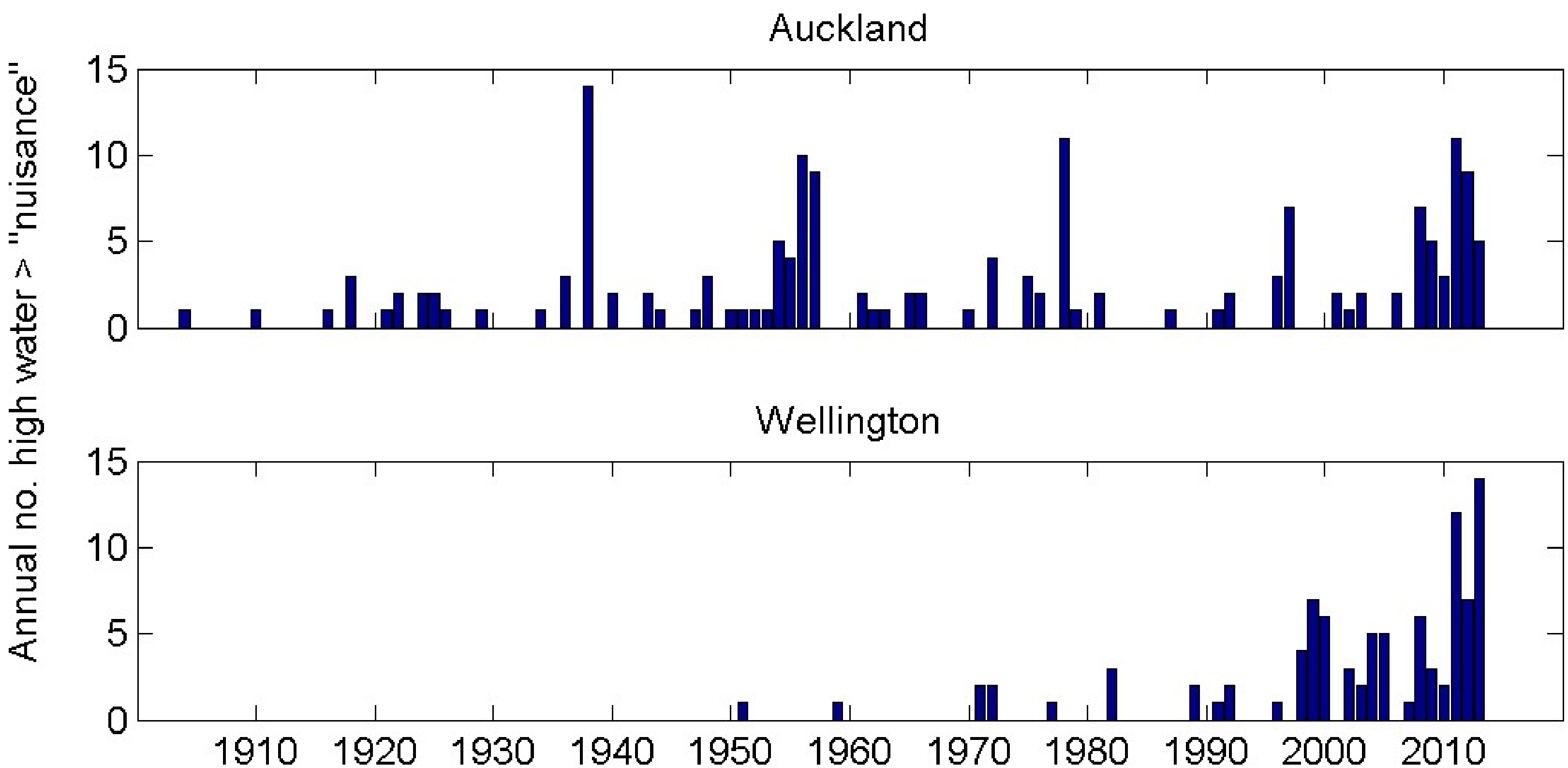
Coastal Flooding Examples – What we are Trying to Map

http://auckland.kingtides.org.nz/

https://www.stuff.co.nz/national/100346389/evacuation-warnings-and-rocks-on-the-road-in-firth-of-thames

Annual number of sea-level > “nuisance”

“nuisance” = MHWS tide + 45 cm (1–2 ft)



NZ SLR scenarios – moved away from a #, no stopping …

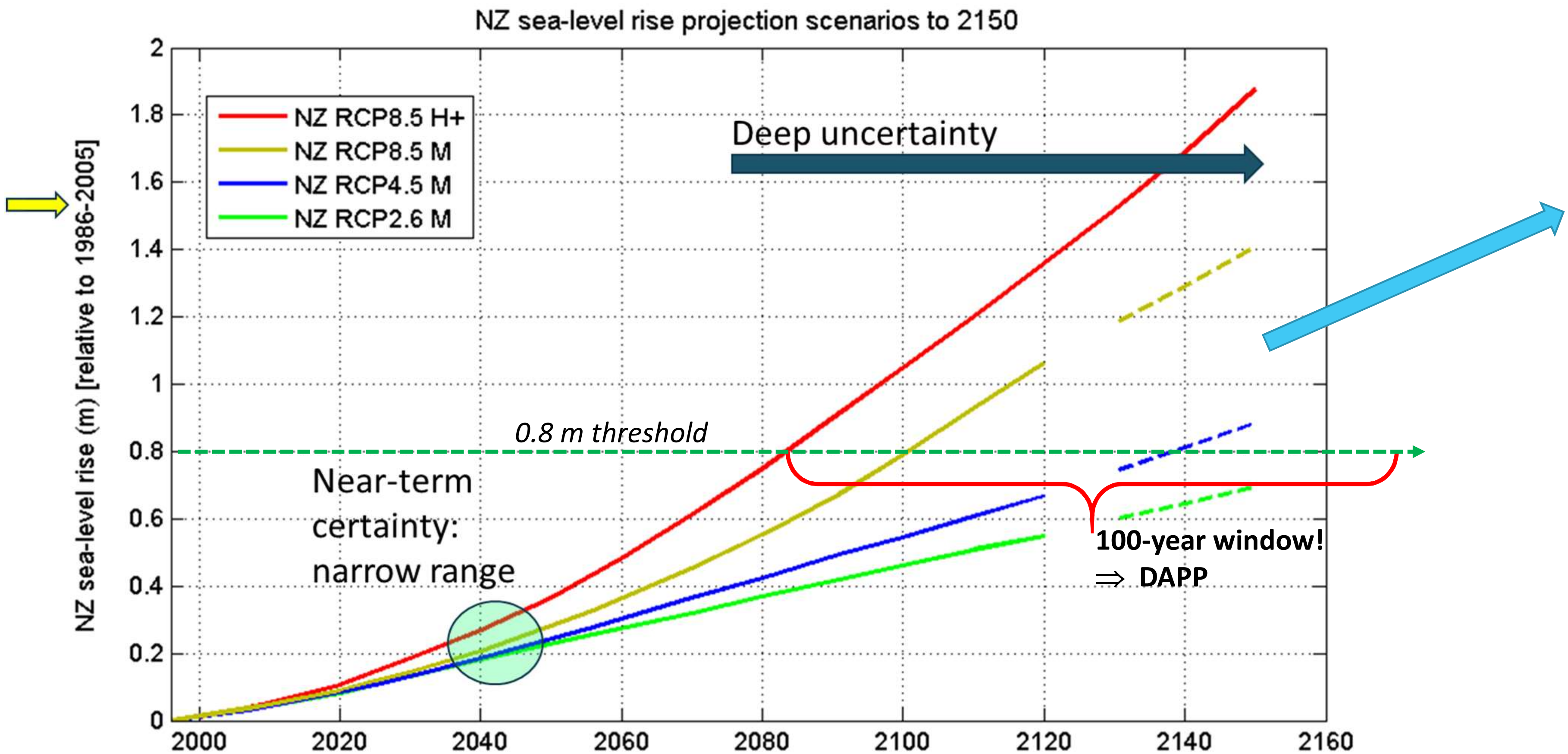
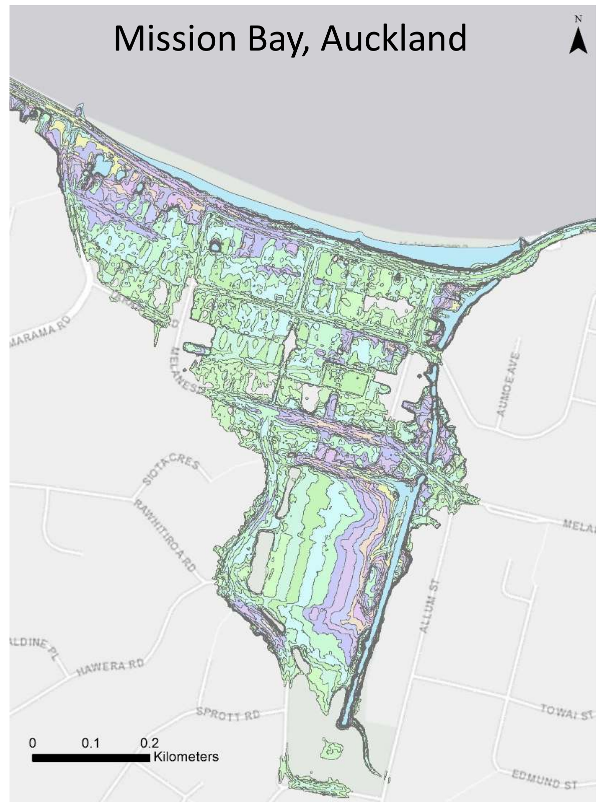


Figure 27: MfE Coastal Hazards & Climate Change

Elements at Risk

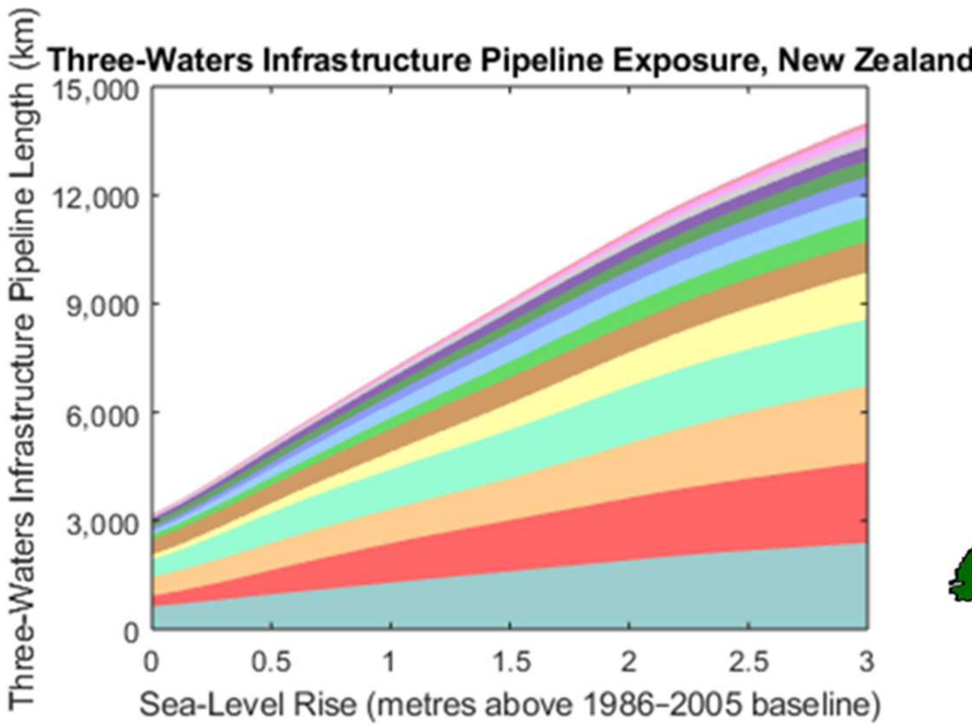
- Population (2013 Census)
- Buildings (No.; Replacement Value -$2016 NZD)
- Transport (Roads, Railway, Airports)
- Electricity (National Grid – Lines, Structures, Sites)
- Three-waters (Potable, Waste and Storm water nodes and pipes)
- Land cover (Built, Production, Natural/Undeveloped)

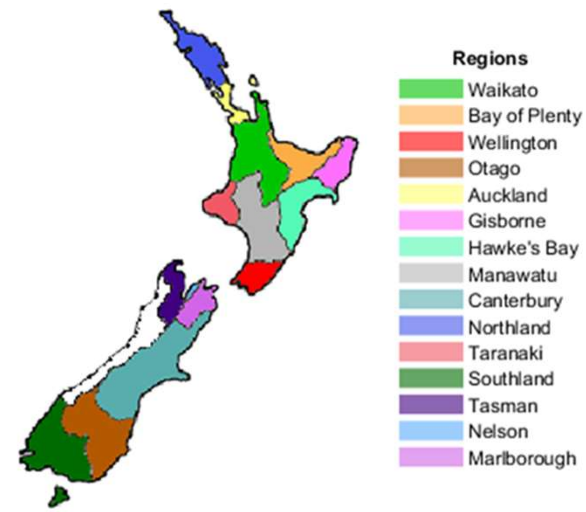


National and Regional Coastal Flood Exposure – 3-Waters

- Node and pipeline exposure ↑ 7,937 & 361 km for every + 0.1m SLR on average.

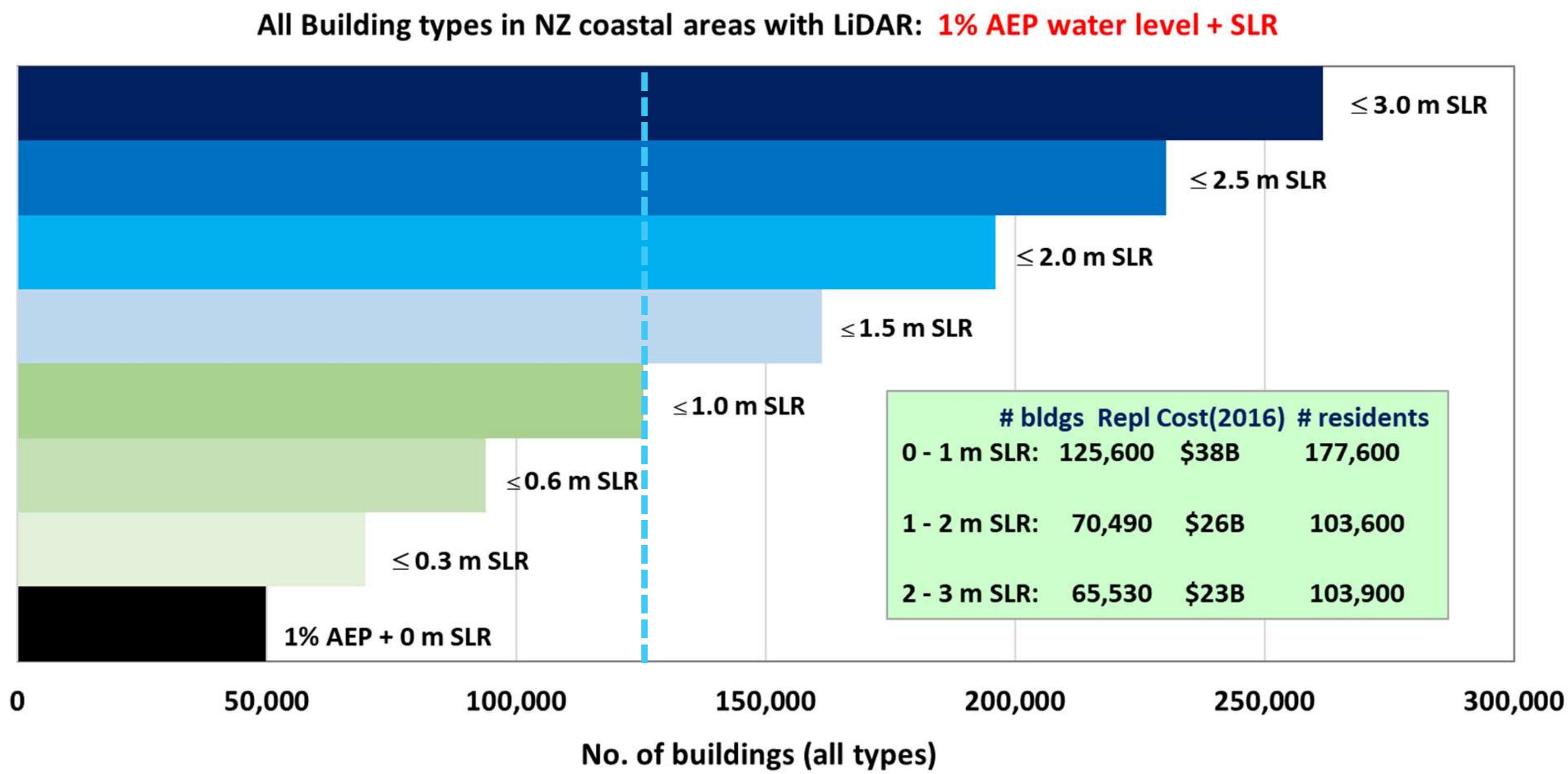
- Node and pipeline exposure exceeds by 130,000 and 5,500 km at 0.6 m SLR.





NIWA
Taihoro Nukurangi

Latest coastal risk exposure “census” – Deep South Challenge



~50% of exposure for < 3 m SLR is in the first 0–1 m band of SLR

Highest exposure: Canterbury, H-B, BoP, Waikato

So adaptation work to do “early on” for exposure in next few decades

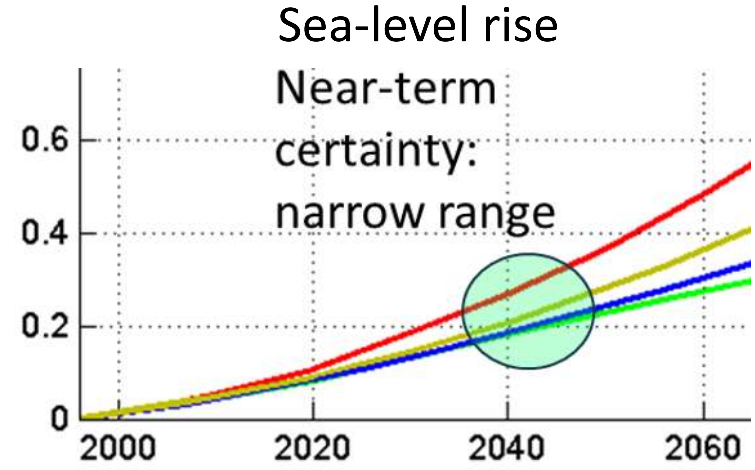
National Science Challenges THE DEEP SOUTH Te Kōmata o Te Tonga

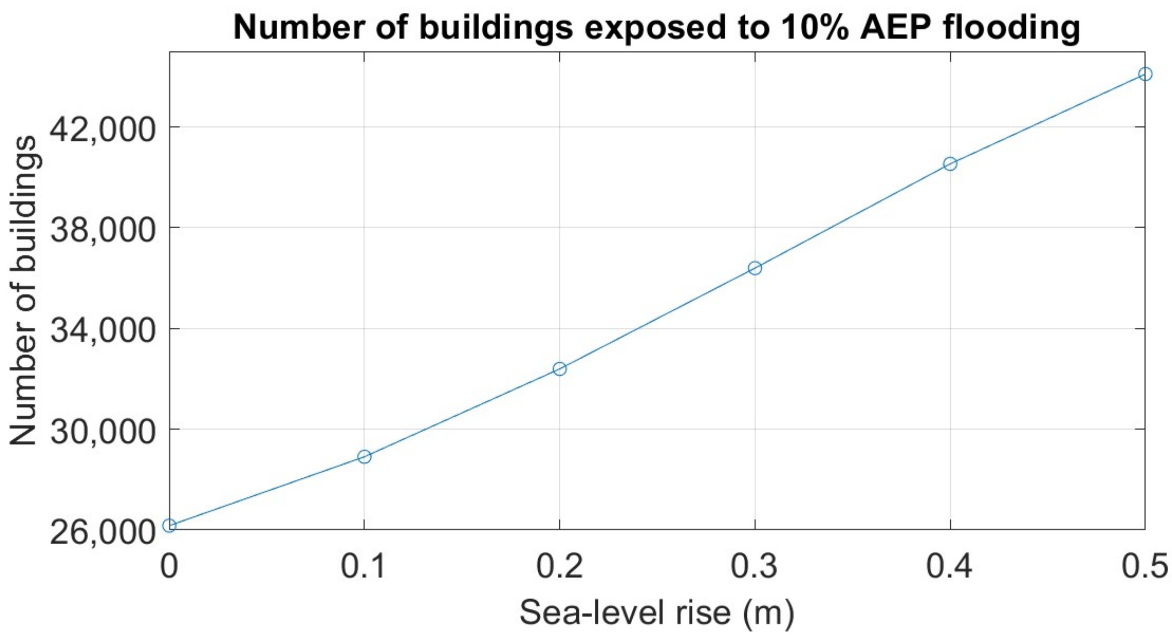
Source: Paulik et al. (2019)

NIWA Taihoro Nukurangi

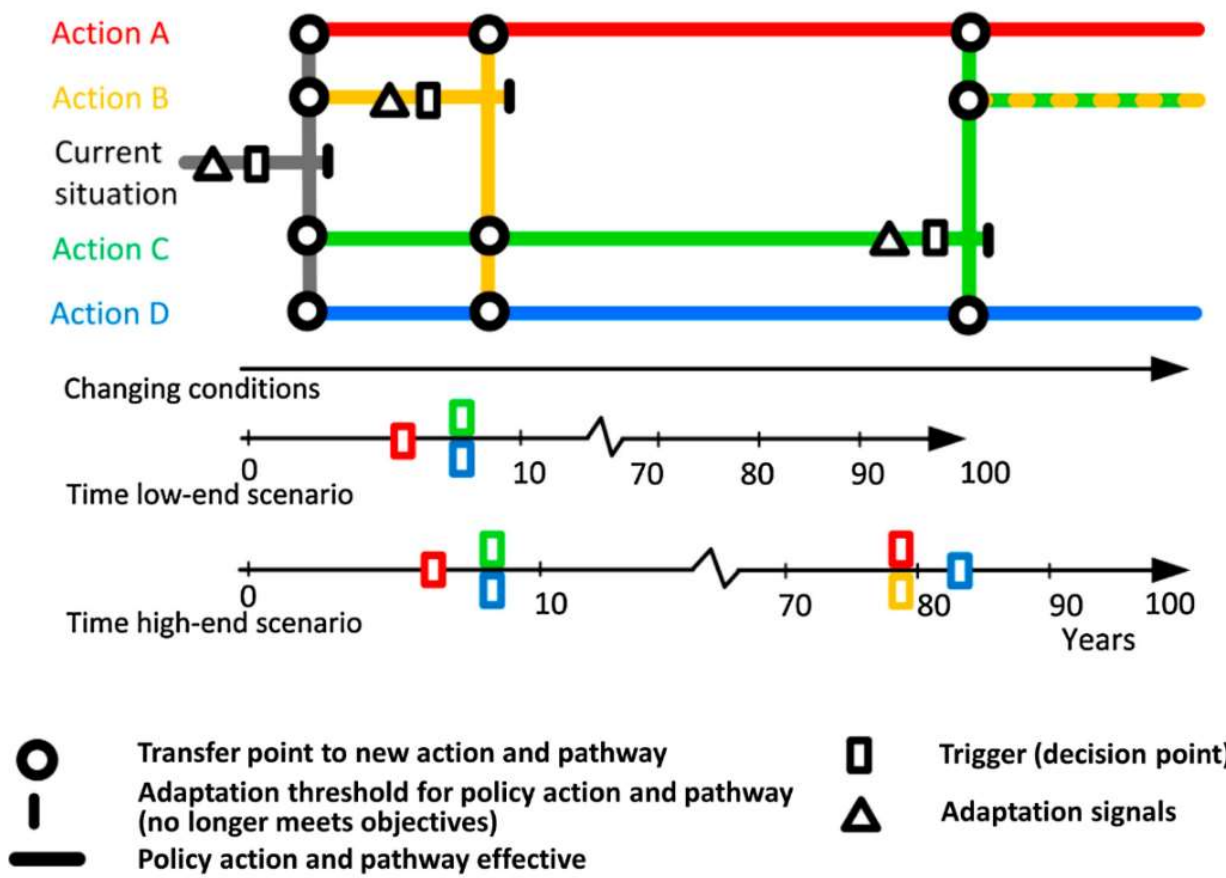
Banking sector: higher-frequency events

- Information requests from the banking sectors
- 10% annual exceedance probability, 1 in 10-years
- Sea-level rise out to year 2050, 0 – 0.3 m
- Insurance sector also short-term focus



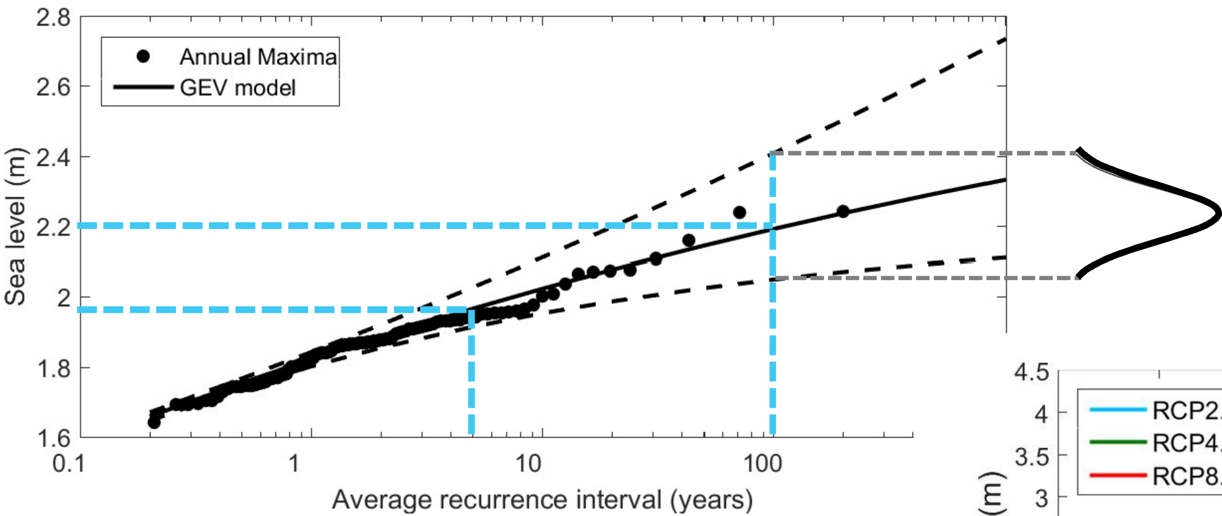


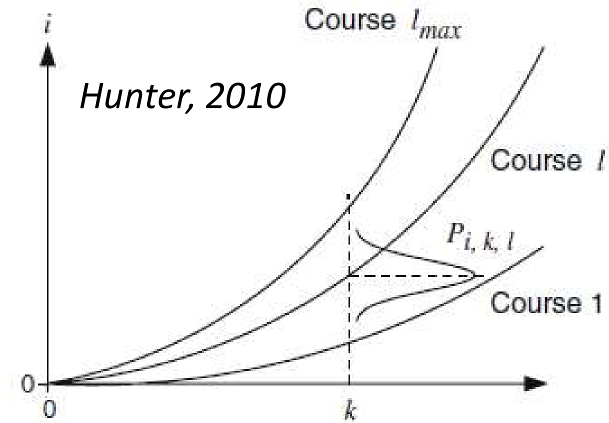
Signals and triggers for DAPP

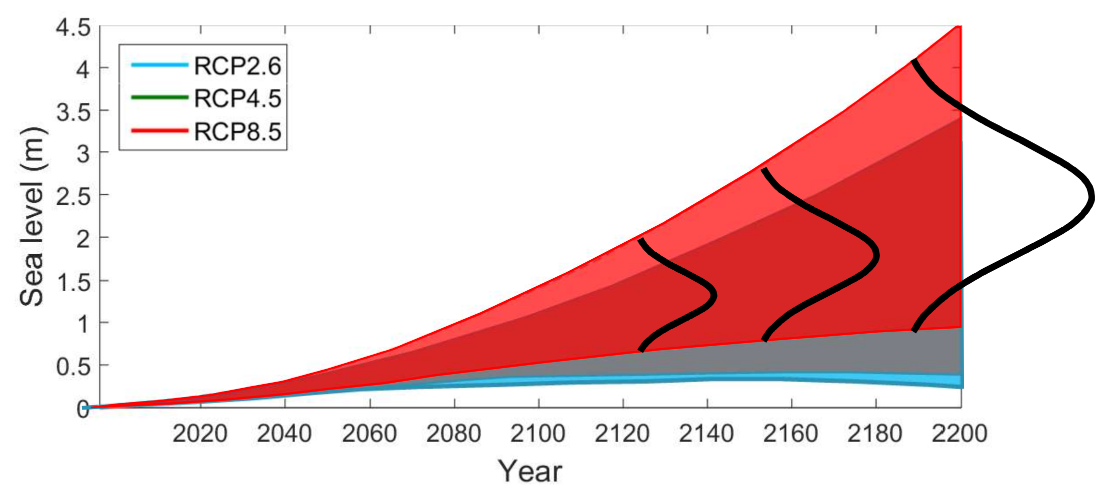


After Haasnoot et al. (2013), Hermans et al. (2017)

Uncertainty in timing of adaptation thresholds, signals and triggers

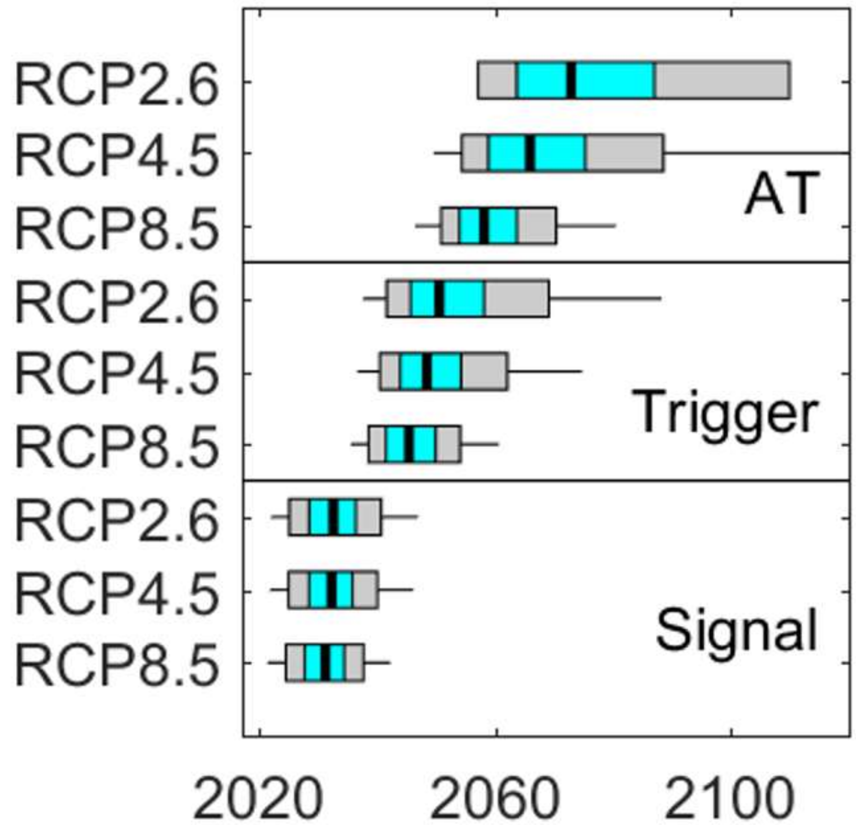






Designing signals and triggers for storm-tide sea levels

- Probable timing of several events reaching a specific height threshold within a set monitoring period (10-year monitoring)
- Uncertain timing
- Adaptation threshold: 1% AEP → 50% AEP
- Trigger: 5 x 5% AEP in 10-year period
- Signal: 5 x 20% AEP in 10-year period



Red-alert tide calendar – in demand

Very high tide dates (red-alert) with increased coastal inundation potential
and carefree low high-tide dates generally for New Zealand (local dates will vary within the bands)

2019

January

Mo	Tu	We	Th	Fr	Sa	Su
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	**22**	**23**	**24**	**25**	**26**	**27**
28	29	30	31			

February

Mo	Tu	We	Th	Fr	Sa	Su
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	**19**	**20**	**21**	**22**	**23**	**24**
25	26	27	28			

March

Mo	Tu	We	Th	Fr	Sa	Su
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	**19**	**20**	**21**	**22**	**23**	**24**
25	26	27	28	*29*	*30*	*31*

April

Mo	Tu	We	Th	Fr	Sa	Su
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	**18**	**19**	**20**	**21**
22	23	24	25	*26*	*27*	*28*
29	*30*					

May

Mo	Tu	We	Th	Fr	Sa	Su
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	*26*
27	*28*	*29*	30	31		

June

Mo	Tu	We	Th	Fr	Sa	Su
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	*25*	*26*	*27*	*28*	29	30

July

Mo	Tu	We	Th	Fr	Sa	Su
1	2	3	**4**	**5**	**6**	**7**
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

August

Mo	Tu	We	Th	Fr	Sa	Su
			1	**2**	**3**	**4**
5	**6**	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	**30**	**31**	

September

Mo	Tu	We	Th	Fr	Sa	Su
						1
2	**3**	**4**	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	**27**	**28**	**29**
30						

October

Mo	Tu	We	Th	Fr	Sa	Su
	1	**2**	**3**	**4**	5	6
7	*8*	*9*	*10*	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	**27**
28	**29**	**30**	**31**			

November

Mo	Tu	We	Th	Fr	Sa	Su
				1	2	3
4	*5*	*6*	*7*	*8*	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	**26**	**27**	**28**	**29**	30	

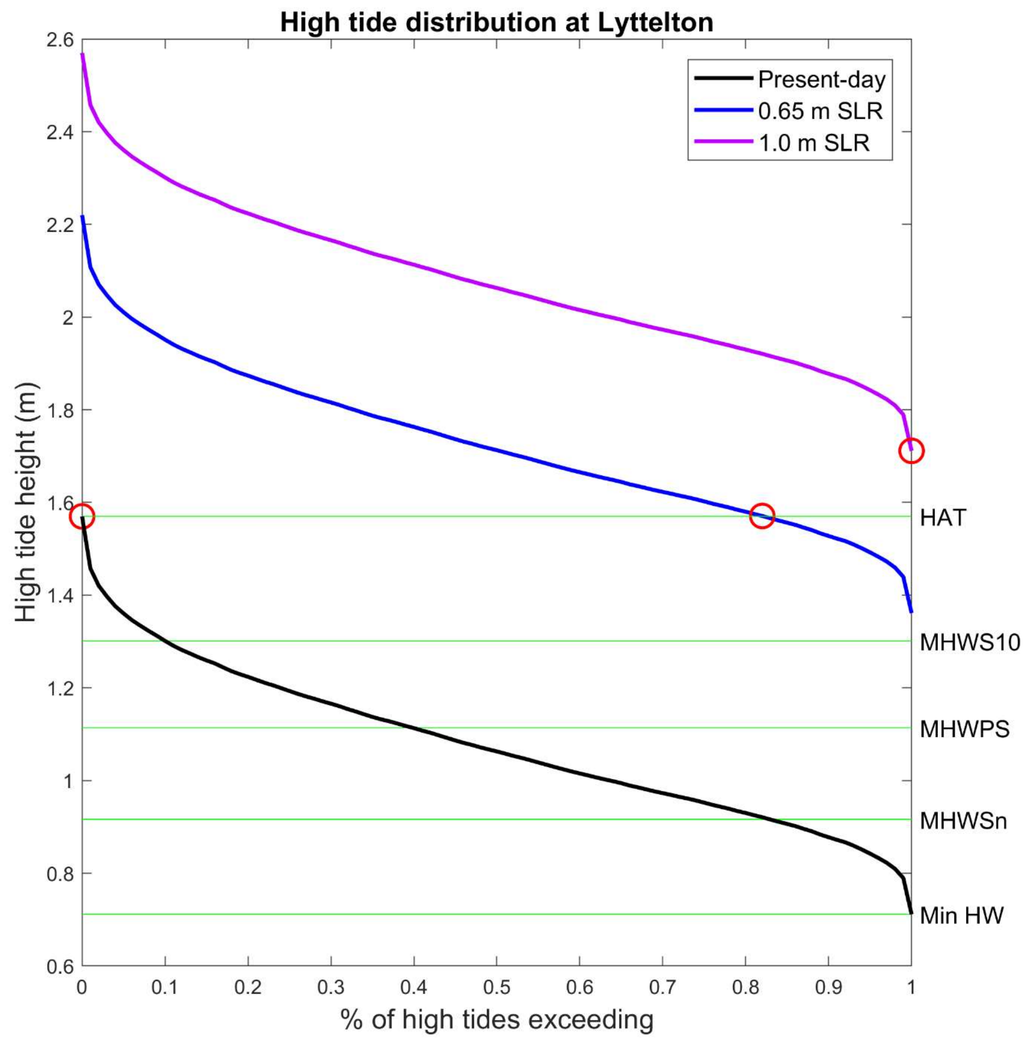
December

Mo	Tu	We	Th	Fr	Sa	Su
						1
2	3	4	*5*	*6*	*7*	*8*
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

= red alert tide dates (highest perigean-spring high tides)
= carefree tide dates (lowest neap high tides)

Sea-level exceedance curves

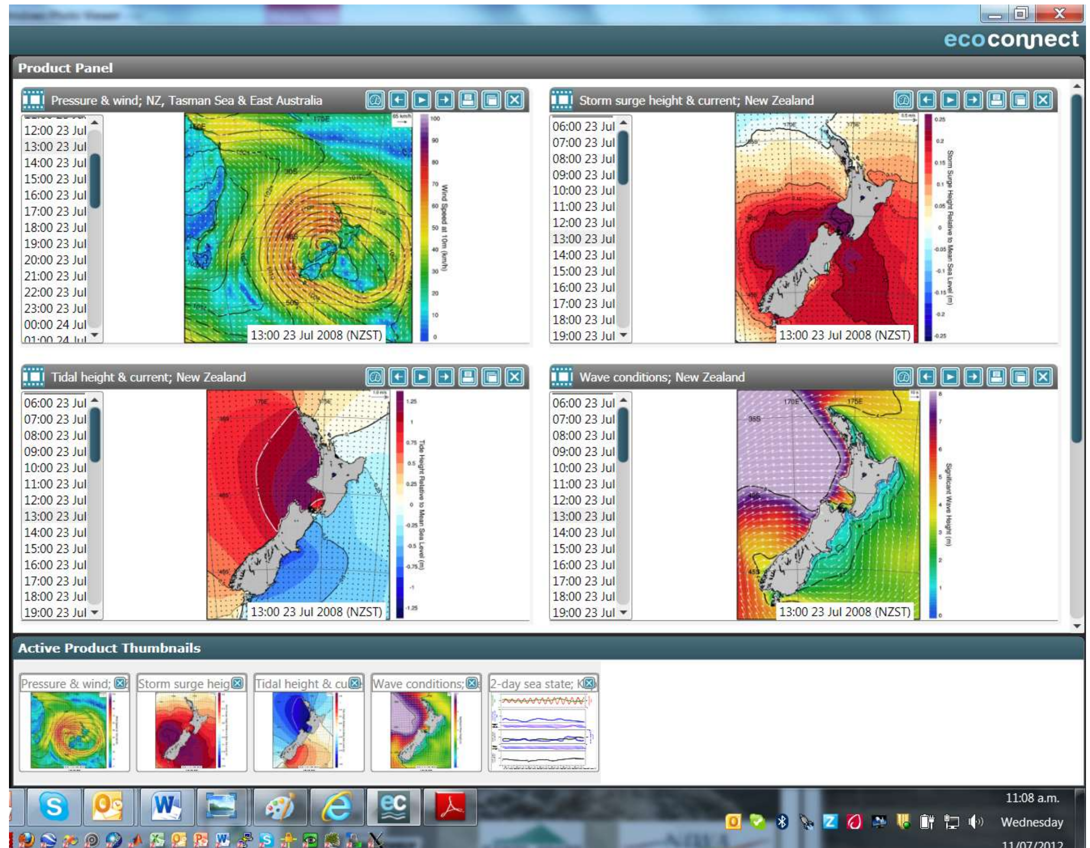
- Simple
- Tell a story
- In demand by Councils
- Allows them to communicate with communities



EcoConnect Multi-Hazards Forecasting System

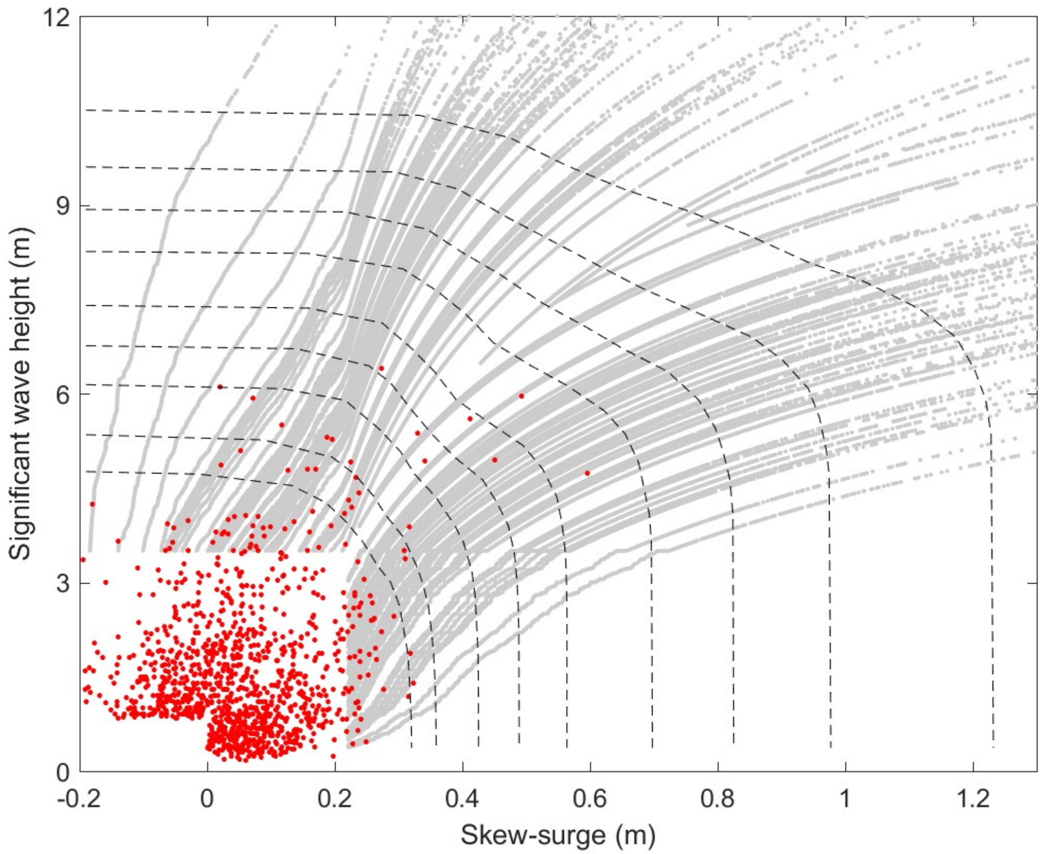
- Weather
- Marine operational forecasting
- Storm surge
- Waves
- River floods under development

- WASP – Waves and Storm-surge Projections + hindcast



Joint probability

- Model dependence between extreme values – multiple variables
- Heffernan & Tawn (2004)

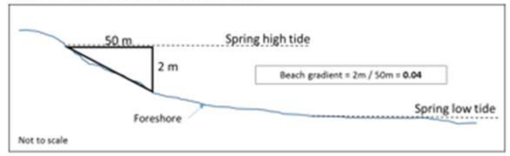


Site Information

Site	Wainui Beach
Beach gradient	0.150
	(Please enter beach gradient)

Coastal Calculator

How to calculate beach gradient



Note: many beaches have a composite slope with smaller slopes at lower tide mark and steeper slopes at high-tide mark – in this case we recommend use of the steepest beach slope (as shown in figure), as this will conservatively return a higher wave setup and run-up value.

The Coastal Calculator uses the Stockdon et al. (2006) wave setup and run-up formula, developed for sandy beaches. This formula employs a constant beach slope, so does not consider any natural features (e.g., dunes) or human modifications (e.g., sea-walls) to the upper foreshore that could affect wave setup and run-up. In such situations the user may wish to consider alternative wave setup and run-up formulae such as van Rijn, 2010 (http://www.conscience-eu.net/documents/deliverable13b-modelling.pdf), EurOtop, 2007 (http://www.overtopping-manual.com/manual.html) or HR Wallingford online calculator (http://www.overtopping-manual.com/calculation_tool.html).

Equation 2-1: Empirical wave setup formula (Stockdon et al. 2006).

Wave setup (m) = $0.35\beta_s(H_0L_0)^{\frac{1}{2}}$

where
- H_0 = Deep-water wave height (m)
- L_0 = Deep-water wave length (m) = $\frac{gT_0^2}{2\pi}$ = $\frac{H_0}{0.021}$ (for Poverty Bay)
- T_0 = Deep-water wave period (s), g = 9.81 m s^{-2}
- β_s = Beach slope (dimensionless)

Equation 2-2: Empirical formula for 2% exceedance value of runup peaks on natural beaches (Stockdon et al. 2006).

Note: this wave runup formula <u>includes the wave setup</u> component (Equation 2-1).

Wave runup (m) = $1.1\left(0.35\beta_s(H_0L_0)^{\frac{1}{2}} + \frac{[H_0L_0(0.563\beta_s^2+0.004)]^{\frac{1}{2}}}{2}\right)$

Disclaimer: This spreadsheet calculator has been developed for use by Gisborne District Council for the purpose of calculating the frequency and magnitude of coastal inundation levels. This calculator should only be used with a full understanding of the work conducted as part of the 2014 "Extreme sea levels along the Gisborne District coastline" project, and a full understanding of the methods and their associated limitations contained within the calculator. The calculator is supplied on an "as is" basis and NIWA makes no representations or warranties regarding the accuracy of the calculator, the use to which the calculator may be put, the results to be obtained from the use of the calculator or its fitness for any particular purpose. Accordingly, the user agrees that NIWA shall not be liable for any loss, damage or cost howsoever caused (whether direct or indirect) incurred by any person through the use or reliance of the calculator. Supporting documentation for this spreadsheet calculator can be found in Robinson, B.; Stephens, S. A. ; Gorman, R. M. 2014: Extreme sea-level elevations from storm-tides and waves along the Gisborne District coastline. NIWA Client Report to Gisborne District Council, HAM2014-052.

Mean High Water Spring elevation
Wainui Beach

Relative to GVD-26 including +0.21 m offset for baseline MSL (2004-2012 average)

MHWS* elevation:	1.00 (m)
MHWS* elevation +1.0m sea level rise	2.00 (m)

*Based on an elevation exceeded by the highest 10% of all high tides

Ways to describe extreme value likelihood

Annual Exceedance Probability (AEP) (%)	63	39	18	10	5	2	1	0.5
Average Recurrence Interval (ARI) (years)	1	2	5	10	20	50	100	200
Asset lifetime exceedance calculator								
Asset planning life time (years)	100	(Please select)						
Likelihood of at least one exceedance in life time (%)	100	100	100	100	99	86	63	39
Expected **average** number of exceedances in life time	100	50	20	10	5	2	1	

Worked example (for selected AEP)

Joint AEP % (for worked examp: 1 (please select)

For the selected AEP the highest joint storm tide and wave setup elevation is:

4.66 meters above NVD-55

which comprises of:

0.62	Storm tide elevation (m)
2.83	wave setup* (m)
0.21	datum offset (2004-2012 average) (m)
1.00	sea level rise (m)

The highest joint storm tide and wave runup elevation is:

8.86 meters above NVD-55

0.49	Storm tide elevation (m)
7.16	wave runup* (m)
0.21	datum offset (2004-2012 average) (m)
1.00	sea level rise (m)

* Calculated using Stockdon et al. (2006) formula with a beach gradient of 0.150

Wave setup and runup from equations 2.1 and 2.2

Storm tide (m)	Wave heigh (m)	Wave lengt (m)	Wave run up (including setup)	Wave setup (m)	Storm tide + wave setup	Storm tide + wave runup
0.00	8.22	391	7.30	2.98	2.98	7.30
0.31	8.16	388	7.25	2.95	3.27	7.56
0.49	8.05	384	7.16	2.92	3.41	7.65
0.62	7.82	372	6.95	2.83	3.46	7.57
0.72	7.45	355	6.62	2.70	3.42	7.35
0.81	7.07	337	6.28	2.56	3.37	7.09
0.87	6.61	315	5.87	2.39	3.27	6.75
0.93	6.04	288	5.37	2.19	3.12	6.30
0.99	5.48	261	4.87	1.99	2.97	5.86
1.04	4.90	233	4.35	1.77	2.81	5.39
1.08	4.24	202	3.77	1.54	2.61	4.85
1.12	3.50	167	3.11	1.27	2.39	4.23
1.15	2.58	123	2.29	0.93	2.09	3.44
1.19	1.67	79	1.48	0.60	1.79	2.67
1.22	0.00	0	0.00	0.00	1.22	1.22

Highlighted rows illustrate the maximum combined storm tide plus wave setup or runup elevations.

Maximum combined storm tide + wave setup elevations

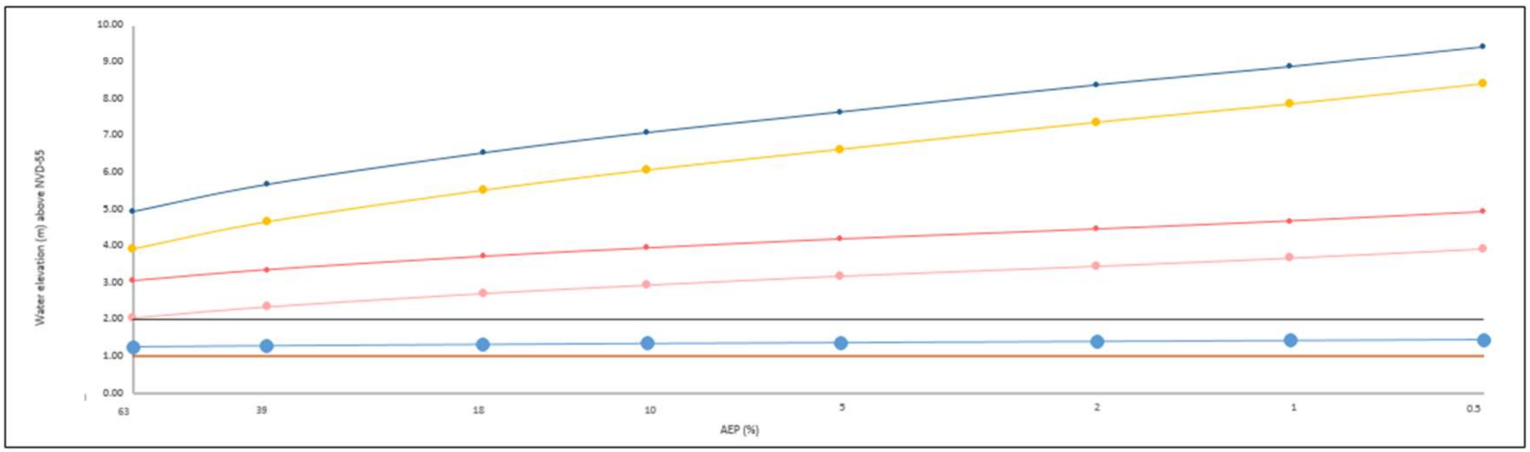
AEP (%)	**63**	**39**	**18**	**10**	**5**	**2**	**1**	**0.5**
ARI (years)	**1**	**2**	**5**	**10**	**20**	**50**	**100**	**200**
Maximum combined storm-tide + wave setup elevation (m)	2.05	2.35	2.71	2.94	3.18	3.45	3.66	3.91
Maximum combined storm-tide + wave setup + 1.0 m sea level rise	3.05	3.35	3.71	3.94	4.18	4.45	4.66	4.91
Maximum combined storm-tide + wave runup elevation (m)	3.92	4.66	5.51	6.07	6.63	7.36	7.86	8.41
Maximum combined storm-tide + wave runup + 1.0 m sea level rise	4.92	5.66	6.51	7.07	7.63	8.36	8.86	9.41

Graph

Relative to GVD-26 including +0.21 m offset for baseline MSL (2004-2012 average)

Wainui Beach

Beach gradient used to calculate wave setup and run up is 0.150



Summary

- Historic sea-level rise is already causing problems in NZ
- NZ will experience impacts in the near decades from modest SLR
- Banking and insurance sectors are concerned with the short–medium term (present to 2050)
- Uncertainties and constraints for near-term decision-making are socio-economic, not physical
- Simple coastal climate services are in demand – understandable, applicable

Thank you

Scott Stephens (PhD)
+64 7 856 1745
scott.stephens@niwa.co.nz