The National climate change risk assessment: A case of science denial?

June 2021

tailrisk economics
te maha hoki o nga pihikete

About Tailrisk economics

Tailrisk economics is a Wellington economics consultancy. It specialises in the economics of low probability, high impact events including financial crises and natural disasters. Tailrisk economics also provides consulting services on:

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Summary report

In August 2020 the Ministry for the Environment (MfE) released the first National Climate Change Risk Assessment (NCCRA). The purpose of the assessment was to provide the 'best available evidence, information and assessment of risks' to inform the development of a National Adaptation Plan (NAP) that will set out what will be done to respond to climate change risks.

The central message in the assessment is that the climate change risks are very serious, even in the relatively near term. Eight of the 43 sectoral risk assessments found that the consequences of climate change would be extreme by 2050. It is also argued that many risks need to be addressed urgently if the costs are to be mitigated, and that substantial resources need to be made available for additional adaptation research.

Our review of the NCCRA found that for the most part, the assessements were not based on the 'best available evidence' and often consisted of little more than a recitation of the 'five horsemen of the apocalypse': more extreme weather events, more drought, more river flooding, higher sea levels, and more wildfires, followed by unsubstantiated claims that they will have either major or extreme consequences.

Contrary to the picture painted in the assessment the science does not show that wind speeds will increase significantly, and river flood risk might actually fall overall. Droughts are likely to become more likely in drought prone areas, and there might be a few more wildfires, but these effects are likely to be outweighed by the positive impacts of climate change, including warmer weather and more fine days in summer, and the impact of carbon fertilisation on primary sector productivity. Sea level rise is a real issue but here the impacts in the NCCRA are overstated.

Our full review of the hundreds of references cited to support the NCCRA conclusions found that many were irrelevant or did not support the arguments. Critical research reports that did not support a 'catastrophist' narrative were often ignored. In some cases steps were taken to cover up 'inconvenient' evidence.

Structure of the NCCRA

There are four documents in the NCCRA reporting suite:

- A summary report that identifies the ten most significant risks that require urgent action in the next six years to reduce their impacts.
- The Main report.

- The Technical report that provides the full detail on the individual assessments.
- A Methods report that addresses some more technical detail.

The key output of the assessment are 43 individual risk assesssments that are divided into five domains:

- Natural Environment
- Human
- Economy
- Built Environment
- Governance

The central message

The purported seriousness of the adaptation risks is captured in table one, which is a summary of the consequence assessments report. Thirteen of the 43 risks reviewed are classified as 'extreme' by 2100. Even for 2050 there are 10 extreme assessments. Of the eight human, economic, built environment and governance risks reported in the summary report, seven were classified as extreme.

The NCCRA also assessed the urgency of taking action to address each risk (with an 'adaptation urgency' score), to determine the degree to which further action is recommended in the next six years. A significant number require early action.

Table one: Consequence assessments

	insignificant	**Minor**	**Moderate**	**Major**	**Extreme**
Now	2	19	8	14	
2050			22	11	10
2100				30	13

At first sight many of the risk assessments appear to be overblown, and in some cases rather hysterical. For example, taking the first of the human domain assessments: the risk to social cohension, we are told that the consequences by 2050 will be extreme. An extreme human domain outcome is described in the Methods report as follows:

Health, safety and wellbeing significantly compromised across whole of society. The happiness and satisfaction of hapū and iwi are severely affected. Permanent disruption to education, employment and community services. Patterns of daily activity and behaviour unable to continue. Coping range of all communities exceeded

All of this is expected to occur in thirty years when temperatures are expected to have increased by less than one degree; when the sea level has risen by perhaps 15 centimetres; and there has been a very limited increase, if any, in 'extreme' climate events.

When we read the social cohesion assessment we did not see the analysis or evidence that would support the extreme outcome assessment. There were several refences that purported to support the link between the changing climate and social cohesion. They were:

- A paper that discussed a large Canterbury wildfire. It found that the wildfire was discussed by people in the local pub and that there was a barbeque for the firefighters.
- A paper on disaster induce migration in developing countries.
- A UK paper on the attitudes of people towards the community when people moving out of immigrant enclaves. It found that moving from a homogeneous to a more diverse community had no impact on attitudes.
- A paper on building 'community resilience' in Trinidad Tobago.
- Two papers on the implications of climate change for small Pacific Islands.
- A UK paper on the coping capacity of the elderly in extreme events. It found that extreme cold was a bigger problem than floods.
- A paper that described the experience of people that had to relocate from a small Nre Zealand community due to flood risk. It found that despite plans to keep in touch, many people did not do so.

This evidence base is not even suggestive of the nationwide impacts implied by the extreme risk assessment.

Commonsense would suggest that such an extreme outcome is not credible. Auckland's mean temperature is four degrees higher than Invercargill's, without any apparent ill effects, and many cities, such as Wellington, are subject to more 'extreme' weather events than others, without falling to pieces.

Assessing the NCCRA evidence base

However, one exaggerated or sloppy assessment does not necessarily condemn the whole report. To assess the report as a whole we reviewed each risk assessment individually. We reviewed all of the supporting references and commented on the NCCRA arguments. We did not assess the natural domain assesements because that is not our field. Nor did we review the Maori risk assessments or all of the assessments covered by the Government's Three Waters programme.

Each cited reference was scored on a 0 to 10 scale in terms of the of the evidential strength it provides to support the NCRRA argument. This is the evidence quality score (EQS). Considerations in our scoring included: relevance; rationality of the argument; and quantification of the effects. The latter is given the highest weighting because simply describing a possible relationship often does not help the reader assess its significance. An example of one of our assessment is a reference to a report on Tuvalu to support an argument about risks to political stability in New Zealand. This was rated at zero because it lacked relevance to the New Zealand situation.

The average EQS for each assessment was calculated and is reported in table five . Table two below provides an overall summary. The overall EQS is 3.09.

Table two: Evidence Quality Scores by grade

Grade	Number of assessments
Very poor < 3	17
Poor 3 < 5	3
Adequate 5 < 7	3
Good 7+	0

Note some risk assessments were not graded because there was a insufficient number of references to assign a fair score.

We also made our own assessment of the consequences of climate change based on the NCRRA's evidence and our knowledge of the relevant literature.

Our assessment

Our assessment of the NCCRA report is that it lacks sound analytical foundations and is largely a highly subjective, and some times a dishonest exercise that systematically exaggerates the risks. Contrary to the risk assessment title of the report it is not a risk assessment at all. Risk requires a consideration of both consequences of an event and the probability that the event will occur. The NCCRA simply leaves out the probability assessement and presents a series of more or less extreme scenarios with likelihoods ranging from just possible to very remote, as being 'plausible'.

Our review of the individual assessments found that:

- Critical documents that did not support a 'catastrophist' narrative were often ignored or key results were not reported. In some cases steps were taken to cover up 'inconvenient' evidence.

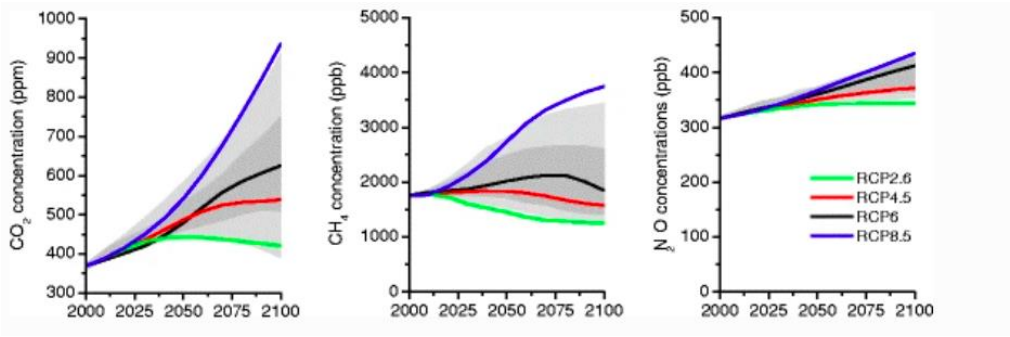
- The consequence assessments were almost never supported by a reasoned discussion with reference to the actual climate change evidence.
- Many of the references were irrelevant or did not support the narrative.
- Many of the consequence assessments relied on little more than a recitation of the 'five horsemen of the apocalypse': more extreme weather events,more drought, flooding, sea-level rise and wildfires.

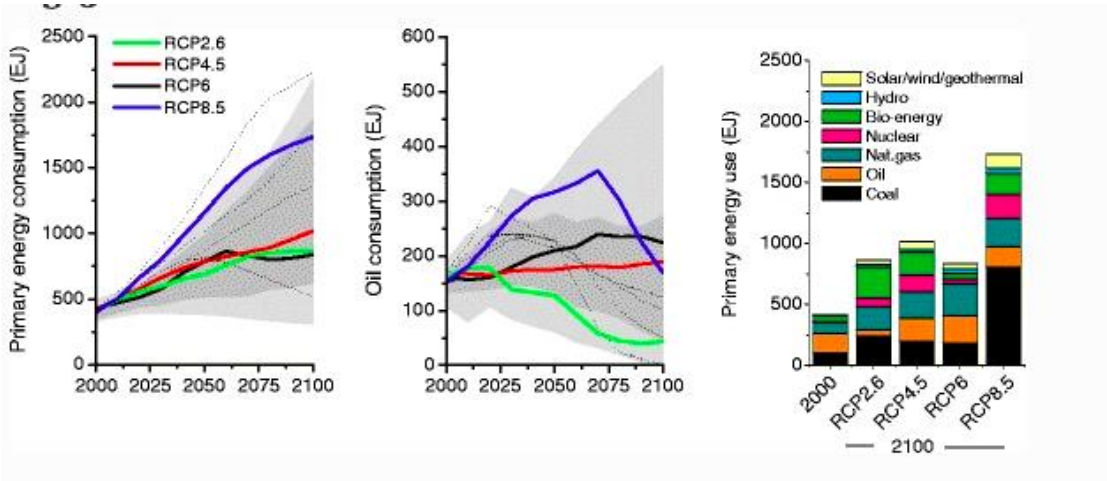
What climate changes are we talking about?

The starting point of the NCCRA is to describe climate changes in two Representative Concentration Paths (RCPs), RCP 4.5 and RCP 8.5. Concentration pathways represent what will happen with different levels of greenhouse emission concentrations reflecting emmissions paths over time driven by different economic, political and technical developments, RCP 8.5 is represented by the blue line in figure one. RCP 4.5 is the red line.

RCP 8.5 is a worst case scenario. The Paris Accord is assumed to fail completely and the world reverts to behaviours before climate change became an issue. Coal becomes the fuel of choice, with usuage increasing by 6.5 times by 2100. The energy intensity of economies increase and technological progress is slow. Emissions do not top out until beyond 2100 when accessible carbon fuel sources start to run out.

Figure one: Emmissions and energy use and sources under RCPs





RCP 8.5 was generally described, in the NCCRA documentation, as a scenario where global emissions would continue at a 'high level', which suggests contining at the current levels (not that emissions would increase very substantially from their current levels). This was misleading. RCP 8.5 is also often described as a 'business as usual' scenario, which can also be misleading. For most people business as usual is more likely to be interpreted as something like the current level of emmissions not a strong growth in emmissions.

The probability that we will get a particular RCP outcome is a matter of judgment and will depend on, amongst other things, assumptions about the contribution of technological change, and the extent that governments will deliver on Paris Agreement commitments. The discussion in the literature (around 2010) suggests a probability of an RCP 8.5 outcome at between two and ten percent, but a pessimistic view on international co-operation and in particular sceptiscm about India and China's efforts could generate a higher probability.

On the other hand there is possibly more room for optimism on the technological front than ten years ago. Electric vehicles are not now just an enthusiast's toy. An electric car revolution is underway which should see most of the developed world's transport fleet go electric in thirty to fifty years. In ten years electric cars will be the vehicle of choice because they will be cheaper and better than internal combustion engine cars. Solar power is now the cheapest form of power generation in some locations, unimaginable fifteen years ago. The coming decades are likely to generate further positive 'surprises'.

Under RCP 4.5 countries still fail to meet their Paris commitment to a 0.5 temperature increase[1] but CO2 levels top out before 2070. In terms of the associated climate

[1] The 0.5 degree increase is from current temperatures

changes there is not much between RCP 8.5 and RCP 4.5 by 2050, but by 2100 the differences become material.

Table three: Temperature and sea level rises

	Temperature increase ^{o} C		Sea level rise m.	
	2050	**2090**	**2050**	**2100**
RCP 4.5	0.7	1.3	0.18	0.5
RCP 8.5	1.0	2.8	0.25	0.8

Source: NIWA estimates[2]

In our view an RCP of 4.5, rather than 8.5, is the more natural baseline scenario for a climate change adaptation risk assessment. However, the choice of RCP scenario would not matter if both scenarios were assessed. Policymakers and the public could form their own view on the probabilities. But despite claims in the NCCRA that assessments were made under both RCPs this was not the case.

Rather the consequence assessments were entirely based on the RCP 8.5 scenario. In the Methods Report it was just stated:

RCP4.5 This scenario presents a lower level of warming, but the changes will still create risks that need early action.

There was not a single piece of analysis in all of the risk assessments to support this claim. In some assessments it was simply said that the consequence would be less under RCP 4.5 than RCP 8.5. On many occassions the reviewers neglected to even go through that perfunctory reference to the lower impacts of the RCP 4.5 scenario.

In most of the RCP 8.5 assessments there was no reference to any specific climate change outcomes in making the consequence assessment. It was simply assumed that the familiar litany:more floods, high winds, drought, wild fires and sea level rise would generate the assessed consequence.

We do know that there will be gradual climate changes. Temperatures will increase and that sea levels will rise, but the evidence on the extreme climate events is that the impacts will mostly be small. Certainly there is nothing relating to extreme events that requires a large and early adaptation effort.

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[2] Note the NIWA estimates use a baseline centred on 1995. On figures make an approximate adjustment for changes from 1995 to 2020

Floods, high winds, droughts and wildfires

The NCCRA paints a picture that is represented as generating very significant adverse effects.

- *Extreme weather events such as storms, heatwaves and heavy rainfall are likely to be more frequent and intense. Large increases in extreme rainfall are expected everywhere in the country, particularly in Northland due to a projected increase in ex-tropical cyclones.*

- *Drought is predicted to increase in frequency and severity, particularly along the eastern side of the Southern Alps*.

- *Wildfire risk is predicted to increase in many areas towards the end of the century, due to higher temperatures and wind speeds, and decreased rainfall and relative humidity.*

However, when we look at the scientific evidence for the extreme weather claims, a rather different picture emerges.

River Flooding

The primary scientific basis for the increase in river flooding risk is a 2019 NIWA report by Paulik and others. It produced two sets of estimates. The first was an assessment of the number of people and assests currently 'exposed' to flooding risk.

One statistic that was frequently used in the NCCRA report and that has caught the media's attention, is that 675000 people are currently exposed to flooding risk. However, the NIWA data is not very informative because, effectively, all it does is identify people and assets located on historical floodplains. It does not take account of flood protection measures or make any assessment of the probability of flooding. An area with a risk of flooding of 1:1000 (the target for the Hutt valley CBD, for example) is treated the same as one with a a 1:20 risk. From a risk assessent perspective this is an almost useless document. Its apparent role was to provide a pumped up perception of risk for public consumption.

The second piece of analysis was an assessment of the impact of climate change on flooding risk. Changes in the mean annual flood (MAF) was the proxy for flooding risk, in line with industry practice. A summary of the changes in risks to buildings for RCPs 2.6 and 8.5 is presented in table four and the regional data is presented in table five for RCP 8.5.

The top line in table four, for example, shows that in the RCP 2.6 scenario, buildings with a replacement cost $1220 million will have an increase in their flood risk of more

than twenty percent by 2036 -2056, and $22965 million will have an increase of between zero and twenty percent. But for buildings worth $15326 million the risk will fall by up to twenty percent, and buildlings worth $949 million will have a risk reduction of more than twenty percent.

The outcomes, for the RCP 8.5 scenario, which is the focus of the NCCRA assessments, is that properties worth just $5 million in 2036-56 and $475 million in 2086-89 will have a risk increase of more than 20 percent. By contrast buildings valued at $7750 and $3544 million wlll experience a risk decline of over 20 percent.

Table four: Summary of changes in flooding risk value of buildings $m

	>20%	0 to 20%	0 to -20%	<-20 %
RCP 2.6 2036-56	1220	22965	15326	949
RCP 2.6 2086-99	37	17828	28862	3129
RCP 8.5 2036-56	5	10361	30282	7750
RCP 8.5 2086-99	475	8944	30964	3544

On a regional basis only Hawkes Bay and Nelson could be described as facing increased flooding risk by 2090 and even then the relative increases are not dramatic. The absolute levels of risk might be very small, because, as discussed above the NIWA assessments do not take account of any flood protections.

Table five: Flooding risk to buildings by region under RCP 8.5, 2086-99. $m

Region	2036-2056				2086-2099			
	>20%	0-20%	-20-0%	>-20%	>20%	0-20%	-20-0%	>-20%
Auckland	0	6	3,466	1,701	0	83	3,958	720
Bay of Plenty	0	493	1,867	8	0	192	2,153	22
Canterbury	3	1,141	3,990	859	217	124	3,174	1,886
Gisborne	0	0	2,173	28	0	139	2,047	16
Hawkes Bay	0	184	2,392	16	0	1,998	1,327	8
Manawatu-Whanganui	0	541	2,644	95	1	1,301	1,838	79
Marlborough	0	9	805	171	0	60	909	16
Nelson	0	0	1,190	623	141	1,019	646	8
Northland	0	0	2,096	431	0	512	1,796	219
Otago	1	4,046	2,578	2	1	565	3,426	2
Southland	0	1,419	2,787	0	0	4	2,110	174
Taranaki	0	1	406	0	2	73	332	0
Tasman	1	233	1,386	1,151	66	1,141	1,184	381
Waikato	0	2,214	1,773	2,633	0	382	2,509	2,084
Wellington	0	0	3,009	14	0	739	2,740	6
West Coast	0	752	720	18	47	612	815	15

Clearly, based on this evidence, claims that buildings and people will be generally subject to large increases in flooding risk are misleading. The NCCRA report authors were aware of the NIWA report because they cited it on numerous occsassions, but they never disclosed the results. This was at the least misleading, and arguably, dishonest.

Obviously these flood risk results pose a challenge to the standard mantra. NIWA responded to this 'problem' by covering up the the study results. In its press release[3] on the flooding paper NIWA claimed that there was no assessment of the effect of climate change:

With climate change, more extreme rainfall events are expected to occur – but weren't covered in this report.

This was false. The climate change result were in the report but NIWA obviously did not want to share the 'good news' with the public.

About the same time NIWA was producing a report for Horizons (Manawatu/ Whanganui) Regional Council. It was explained (deep in the appendix of a lengthy report) that the Mean Annual Flood represented a relatively small flood, and that, despite it being an industry standard metric for assessing the likelihood of larger more consequential floods, it should not be used alone to infer changes in flood hazards which involves large floods.

Changes in MAF alone cannot be used to infer changes in flood hazard. For this, research would need to address the more extreme floods, in terms of both size and frequency, and both discharge and inundation extent. Translating the hazard into a risk would require the further consideration of social, cultural, economic, and environmental vulnerability of flood-prone areas.

Because there was no such assessment on this (impossibly complex) basis, the MAF analysis that had been done was 'not relevant' and NIWA could ignore the inconvenient, positive results. In the body of report they simply repeated the standard mantra of increasing flooding risk without any supporting evidence. Apparently a very high evidence standard is required to say that there will be an decrease in flooding risk, but no evidence at all is required to say that the risk is increasing.

[3] https://niwa.co.nz/news/new-reports-highlight-flood-risk-under-climate-change

Surface flooding

It is generally expected that there will be more heavy rainfall events, because the atmosphere can hold about 6-7 percent more water per degree of temperature rise. This could result in more flash floods if stormwater systems are overwhelmed. Many councils are renewing old stormwater systems and no doubt are putting in the larger pipes that will help mitigate this risks. The marginal cost of the larger pipes is probably quite low.

However, the theoretical presumption that there will be an increase in heavy rainfall events is not actually supported by the New Zealand empirical evidence. Two NIWA studies found no increase in intense rainfall events since 1930 and 1960 respectively, despite the temperature increases over their data periods.

High winds

High winds are expected to increase in frequency in winter and decrease in summer. But these changes are not expected to be large. The New Zealand empirical evidence is that there has been a slight decrease in windspeeds as temperatures have increased.

Wildfire risk

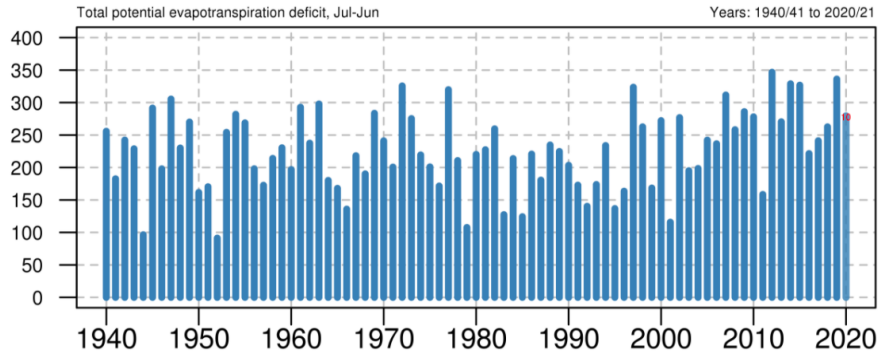
The NIWA study[4] on fire risk showed that most regions would show an increase in fire risk, but often this was from a low base. Two of the regions most prone to fire risk, Canterbury and the East Coast, were not expected to experience a large increase in their risk. So the overall risk may not increase as much as is commonly supposed. Possibly the average increase in at risk days will be around 40 percent by the 2080s. As wildfires do not have material economic consequences on a national basis changes in this risk can be safely ignored in most consequence assessments. Insurance payments for large wildfire events have totalled $57 million this century.

Droughts

The main evidence here is based on a projected increase in rainfree days of about 10 days a year. This could increase the risk of drought particularly in areas that are already prone to drought. The NIWA historical record of their drought indicator over 1940-2020 (with a temperature increase of nearly 1 degree C) suggests only a moderately positive relationship between temperature and the likelihood of droughts.

[4] Pearce et al 2012

Figure two: Historical drought indicator



Extreme weather

There is a suggestion that there will be more ex-tropical cyclones as there appears to have been a southward movement in their tracks in recent years. It is not clear whether this southward trend will continue in the future.

Gradual changes

Sea level rise

Some sea level rise is inevitable and will have material consequences. The primary evidence on the risks this poses is a 2019 NIWA study that quantitfied the number of people and property currently at risk from storm surges an dhigh tides and how this would increase as sea levels rise. 72000 people and 50,000 buildings are estimated to be currently 'at risk' that the property would be at least reached by sea waters once every 100 years, or once in 36,500 days.

With a sea level rise of 0.5 metres the number of people and buildings at risk would increase to 133,000 and 93,000 respectively.

The study's methologogy overstates the risk by a large margin. First, it does not take account of the extent to which buildings are elevated from the ground. A house that is elevated by piles by say 0.6 metres would mostly escape damage from a 0.5 metre flood, but would be still recorded as being inundated in the modelling results.

Second, and most importantly, the study used what is know as the 'bathtub' method to assess inundation risk. This assumes that low lying land is instantly inundated by the combination of a high tide and a storm surge, with the flooding rising to the peak sea level. It does not take account of protective mechanisms such as sea walls and stopbanks. Further, the instanteous inundation assumption does not take account of

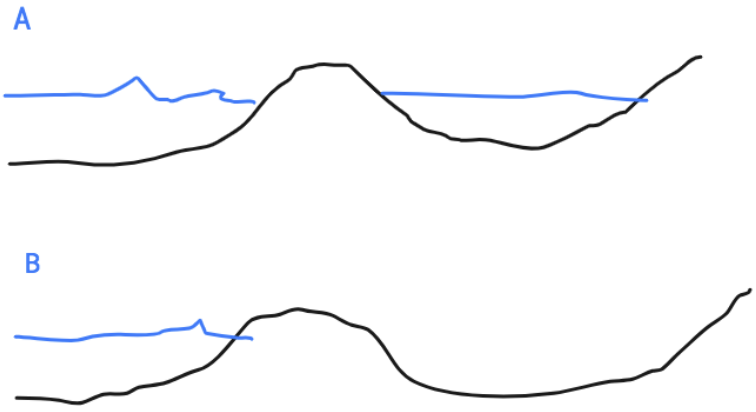
the duration of the combination of a storm surge and spring tide that increases the sea level, which might only be one to three hours. Over this period not enough water

can flow into a low lying area with constrained access to the sea, to create the calculated sea level rise.

The alterative dynamic method that takes account these factors would have generated much lower at risk numbers. The difference between the two methodologies is illustrated in figure three. A is the dynamic assessment. The low lying area behind a large elevated dune is not inundated. B is the bathtub assessment. The low lying area is inundated to the level of the sea and any buildings in the area would be at risk.

A large proportion of the Dutch population would currently be designated as being at risk (applying the 1:100 risk metric) using the bathtub method, but none would be using the dynamic method.

Figure three: Inundation with bathtub and dynamic assessments.



Closer to home figure four shows the elevations for Dunedin. Large parts of South Dunedin are only slightly above sea level but are surrounded by higher areas. Using the bathtub method all of these low lying areas would currently be at risk. A more detailed study by the Otago Regional Council using dynamic methods shows, in figure five, only very limited exposures, due to ponding, with a 0.28 sea level rise.

Because the bathtub and dynamic methods can yield such dramatically different results NIWA should not have released it results without using dynamic method results where appropriate.

Figure four: Dunedin South elevations

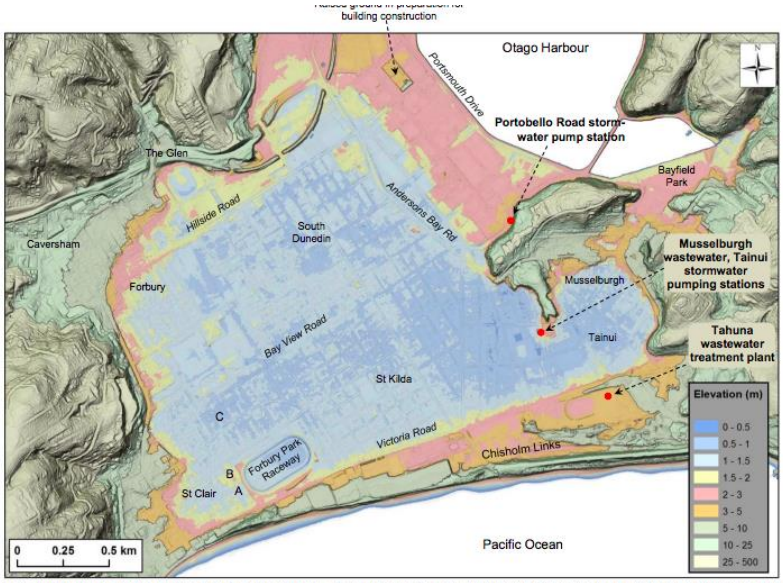


Figure 3. Topography and localities on the South Dunedin plain. Topographic features labelled A-C are shown in Figure 20. Background image is Dunedin City LiDAR, flown 2009, and coloured according to elevation. Elevation is in metres above MSL (mean sea level).

Figure five: Otago Regional Council Sea level impacts

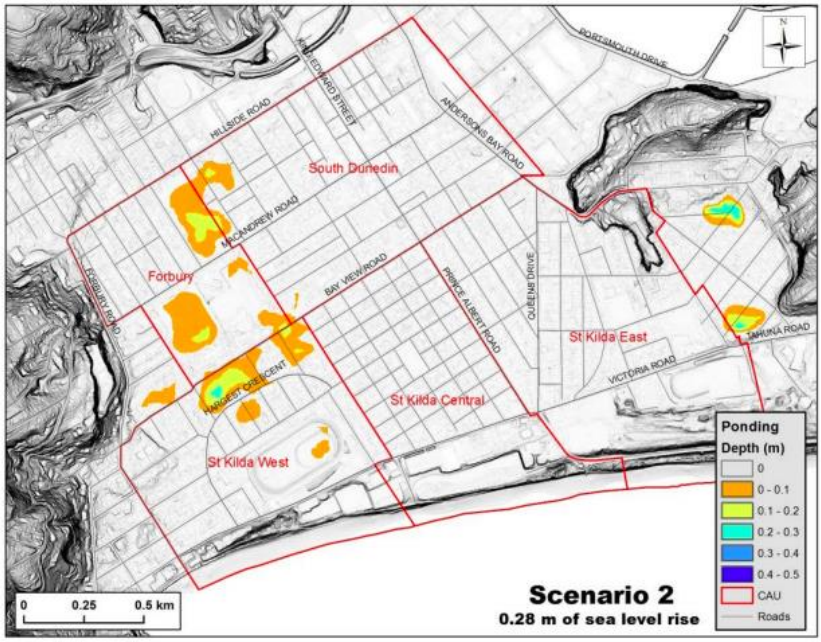


Figure 41. Above-ground ponding for 0.28 m of mean sea level rise, relative to the 2003-2015 average

Summary of climate risks

Table six provides a quick summary of the climate risks out to 2100.

Table six: Climate change risk summary

Event	Climate Change
River flooding	Fall in risk in most areas
Surface flooding	Expected to increase but mitigated by drainage improvemnts
Wildfires	Moderate increase from low base
Droughts	Moderate increase
Highwinds	No increase
Sea level rise	Impact less that reported

Consequences

As we have reviewed 28 assessments it is not possible to capture all of our analysis and conclusions in this summary. Instead we focus here on the eight assessments that had extreme outcomes by 2050, and some of the economic assessments . A summary table of all our assessments is presented in table seven.

Risks to social cohesion and community wellbeing from displacement of individuals, families and communities due to climate change impacts

Implicit in this assessment is that some form of large scale managed retreat will be imposed by central government and this will be socially disruptive to large communities. In our view the managed retreat philosophy propoted in the NCCRA is economically flawed and will be politically unacceptable. If early and widespread managed retreat does not occur there will not be material risks to social cohesion by 2050 or by 2100.

Risks of exacerbating existing inequities and creating new and additional inequities due to differential distribution of climate change impacts

The consequence assessment did not define what was meant by inequities and the discussion never rose much beyond annecdotes that some disadvanatged people might be disproportionately affected. For example, it was suggested that handicapped people could find it more difficult to deal with floods. There was no understanding that river flood risk is more likely to be reduced not increased. Possibly the only widespread wealth impact will be on homeowners with waterfront properties, but they tend to be the better-off.

Risk to potable water supplies (availability and quality) due to changes in rainfall, temperature, drought, extreme weather events and ongoing sea-level rise.
As the risk to water supplies will be managed as part of the Government's three waters strategy the marginal risks that might unfold by 2050 should be addressed through this process. The key issue is how much this will cost and who will bear those costs.

Risks to buildlngs due to extreme weather events, drought, increased fire weather and ongoing sea-level rise
A relatively small number of buildings will be at material physical risk from sea level rise if sensible measures to mitigate those risks are taken. The risks from flooding could fall slightly. As noted above the bigger risk is the managed retreat philosophy that could see buildings unnecessarily or prematurely abandoned. There is a risk from insurance withdrawal and a paper[5] addressing the issue was finally released in December 2020, which argued that insurance retreat would begin as soon as 2030 in New Zealand's major cities and that at least 10,000 properties would be affected. The paper was hurridly drafted and did not provide adequate information on the modelling methodolgy. However, it appears that it mistakenly used the bathtub rather than the dynamic model for assessing flooding risk and consequently overstated the extent of the problem by a wide margin. In most cases where large numbers of buildings are affected it will be economic to protect the buildings with hardened defences against sea level rise.

Risks to stormwater and waste water
The primary risk is to gravity based systems that will have to be augmented by pumps. This should be managed by the Three Waters programme.

Risk of maladaptation across all domains due to practices, processes and tools that do not account for uncertainty and change over long timeframes.
This is basically the risk that policy makers and markets do not adapt in the way that the writers of the NCCRA would like. In many cases this will be a good thing. The incongruity here is that the NCCRA methodology is almost the antitheses of good process and practice. For example the real options analysis approach that considers a range of possibiliies and adapts the strategy as new information on climate change comes to hand is promoted as good practice. And it is. In the NCCRA, on the other hand, the focus is on worst case scenarios to the exclusion of all the other possibilties and on early action regardless of the loss of time value and the loss of option value from premature decision making.

[5] Storey et al 2020

Risk of institutions not being fit

This is largely another case of the risk that policy makers and markets will not do what the authors of the NCRRA think best.

Risk of not getting parliamentary agreement

This is a rather transparent attempt to railroad Parliament into locking in the kind of policy responses promoted in the report. The risk that there will be inadequate funding for climate change adaptation research was assessed as having a major impact by 2100. This was an obvious and shameless pitch for more funding for the consultants who wrote the NCCRA.

The economy risks

On the economy assessments the tendency to a catastrophist narrative contrasts with the more sober perspective in the 10th chapter of the Fifth IPCC report:

For most economic sectors, the impact of climate change will be small relative to the impacts of other drivers (medium evidence, high agreement). Changes in population, age, income, technology, relative prices, lifestyle, regulation, governance, and many other aspects of socioeconomic development will have an impact on the supply and demand of economic goods and services that is large relative to the impact of climate change.

Well-functioning markets provide an additional mechanism for adaptation and thus tend to reduce negative impacts and increase positive ones for any specific sector or country (medium evidence, high agreement).

Risks to governments from economic costs associated with lost productivity, disaster relief expenditure and unfunded contingent liabilities due to extreme events and ongoing, gradual changes.

The NCCRA assessment was largely based on two main presumptions. First, there will be a negative impact on GDP, which will impact on tax revenue, and second there will additional expendures as central and local governments pick up the tab for both extreme events and adaptation capital costs.

The problem with the taxarion argument is that there is no NCCRA analysis of the impact on GDP. The international literature suggests that some temperate countries will be little affected by climate change by 2100, or even come out slightly ahead. The limited New Zealand modelling on the issue (which was ignored) suggests a small positive impact. Instead the NCCRA seems to have selected a negative GDP impact of three percent by 2100 because that was the international consensus for the world economy. Even if this was applicable to New Zealand it would not be consequential for the central government's long term fiscal position. Assuming an average annual

GDP growth rate of, say, 2.5 percent, GDP will be 7.2 times higher than 2020 by 2100. A three percent decline reduces this to 7.17 times. This is not an extreme impact.

The reason why New Zealand is likely to be less affected than the world average is that the two main export industries, land based industries and tourism, should be positively impacted. Land based industries will benefit from carbon fertilisation and, generally, from longer growing seasons, offsetting some negative effects. There is a New Zealand literature, mainly coming out of the Ministry for Primary industry that supports this.

However, climate change is assessed as having a **major** negative impact on the landbased sector. The NCCRA achieved this by assessing only the negative impacts on the sector in its consequence assessement. The positive impacts, which were admitted only grudgingly, were discussed in a separate assessment that was not given a consequence assessment.

This approach is obviously misleading, and was designed to cover up any suggestion that climate change could have a positive outcome. The costs and benefis should have been considered together in the same consequence assessment.

Tourism is also assigned a major negative consequence assessment based mainly on the impact on the skiing industry and on the standard presumption that storms, flooding and so on would have a strong negative impact. The supporting literature was little more than a couple of academic papers that suggested the glacier towns could be negatively affected when the glaciers retreat, and a suggestion that Queenstown could be affected by a decline in the skiing industry.

However, an industry/NIWA study that showed that the skiing industry could be sustained by snow making to the end of the century and that it could benefit from the earlier demise of the Australian skiing industry, was ignored. Similarly, the international literature that tourism in temperate countries could benefit, as tourism is diverted from hot weather countries was also ignored. The science on the climate changes also suggests that there will be a positive rather than a negative impact. Higher temperatures and fewer wet and windy days in summer (the main tourism season) would help mitigate New Zealand's reputation for being cold and wet.

On the expenditure side there is an assumption that expenditures will be large, implicitly assuming widespread 'managed retreat' due to sea level rise and increased flooding risk. But the alternative of defending New Zealand's cities against sea level rise would be much less expensive. There has been limited analysis of the overall cost of defending against sea level rises but a 2014 Beca study for Dunedin put the capital

cost at $75 million. A Hawkes Bay Regional Council study put the present value of the costs at a little over $100 million. On the other hand preliminary assessments of flood gates and stopbanks for Christchurch suggest a cost of up to one billion dollars. But this would be a small price to pay to avoid a retreat that could cost more than $10 billion.

It is noteworthy that despite the significance of the issue, and the large amount of money spent on research there has never been an analysis that provides even some ballpark assessmemt of the national sea level rise defence costs.

Risks to the financial system from instability due to extreme weather events and ongoing, gradual changes.

The assessment that climate change poses a major risk to financial stsbility is wildly overblown. The insurance industry is not at risk even if there were a pronounced increase in the incidence of extreme climatic events, as these events are individually small relative to the industry's capacity to absorb losses. If climate risks increase excessively then insurers can readily withdraw insurance cover from affected areas.

In the banking sector the largest exposures are to the housing and farming sectors. The Reserve Bank of New Zealand has examined climate risks to farming and concluded that the sector did not pose a systemic risk.

On housing lending the argument is that insurance companies will withdraw from areas threatened by rising seawater and that banks will follow them because they do not wish to lend on uninsured houses. This could have two effect. First, the value of 'redlined' houses could drop decreasing the owners' equity and hence the banks' risk. Second, unlike insurance companies, banks cannot easily withdraw from the lending relationship. Technically banks could foreclose on properties without insurance, but in practice would be reluctant to do so. This would mean that banks would be exposed to possible losses if there was a flooding event.

While this is possible in particular cases there was no examination of its quantitative significance in the NCCRA, which is necessary to form any view on whether the risk is systemic or not. Looking at the numbers we found it extremely difficult to develop a plausible scenario in which climate change related losses could have a material impact on banks' profits, let alone eat into capital.

To illustrate, even if there were an average of, say, 1000 climate related housing loan loss events every year and the average bank loss was $200,000, the aggregate loss would be $200 million, or about 3 percent of bank profits.

But even this is a very pessimistic view. Currently there might be perhaps 10,000 houses genuinely at risk of a 1:100 event and this might double over time. This would be less than one percent of the housing stock. Now assume there is a sudden realisation that there is a climate change risk and that the price of affected houses fall by 40 percent (a fairly extreme assumption). A relatively small proportion of the homeowners, say, 10 percent[6] would be in a negative equity position. But this would not mean that banks would automatically lose money. That would only occur if the homeowner was unable to service the loan, most likely because they lost their job in a recession. Assuming a 10 percent default rate only 200 loans would be affected, and then in a recession.

The other risk is that banks will lose money if uninsured houses are damaged in a seafront storm surge event. But as the risk that will happen are low (the loss falls initially on the homeowner) and diversified (storms do not impact on all of New Zealand at once) the losses in any one year will be small.

Table seven: Summary of NCRRA and Tailrisk results

Risk	Adaptation urgency	More action needed	Impact now	Impact 2050	Impact 2100	Tailrisk Impact 2100	Evidence quality score
H1 Risk to social cohension	88	70	Minor	Extreme	Extreme	Minor	2.64
H2 risk of exacerbating inequities	85	60	major	Extreme	Extreme	Insignificant	3.28
H3 risks to health	83	50	Minor	Moderate	Major	Insignificant	3.44
H4 risk of conflict, disruption	83	50	Moderate	Major	Major	Minor	2.25
H7 risk to mental health	80	50	Major	Major	Major	Minor	2.33
H01 reduction of cold weather mortality	45	0	Minor	Moderate	Mod.	Minor	NA
E1 risks to governments from economic costs	90	70	Minor	Major	Extreme	Minor	2.5
E2 risks to financial system	83	40	Minor	Moderate	Major	Minor	1.76
E3 risks to landbased sector	81	50	Minor	Moderate	Major	Minor	4
E4 Risks to tourism	80	40	Minor	Moderate	Major	Insignifican	1.63

6 Note that many homeowners either do not have a mortgage or only have a small mortgage. Possibly the proportion of owners of beachfront properties in this position is higher than average.

						t	
E5 Risks to fisheries	80	40	Minor	Moderate	Major	Minor	NA
E6 risks to insurability of assets	75	40	Insignificant	Moderate	Major	Minor	5.40
E7 Risks to supply chains	68	20	Minor	Moderte	Major	Minor	2.57
B1 Risk potable water supply	93	70	Major	Extreme	Extreme	Moderate	NA
B2 Risks to buildings	90	60	major	Extreme	Extreme	Moderate	2.44
B3 risks to landfils	85	40	Moderate	Major	major	Moderate	5.2
B4 risk to waste and stormwaters	85	50	Major	Extreme	Extreme	Moderate	2.0
B5 risk to ports	70	10	Minor	Moderate	Major	Minor	2.25
B6 risk to linear transport	60	20	Major	Major	Extreme	Minor	2.67
B7 Risk to airports	55		Major	Major	Extreme	Moderate	2.75
B8 Risk to electrcity infrastructure	55	-	Moderate	Moderate	Majoe	Moderate	NA
G1 Risks of maladatation	83	60	Major	Extreme	Extreme	Moderate	5.77
G2 institutions not fit	80	60	Major	Extreme	Extreme	Moderate	NA
G3 Risk to govt busimess of litigation	78	50	Moderate	Major	Major	Minor	2.0
G5 Risk of knowledge gaps	75	50	Moderate	Moderate	Major	Minor	2.0
G6 risk to emergency services	70	40	Major	Major	Major	Minor	1.88
G7 Risk of not getting parliamnetary agreement	68	40	Major	Extreme	Extreme	Minor	0.6
G8 risk to democratic institutiosns	53	10	Moderate	Major	Major	Minor	0.5

Why the gross exaggeration of the risks?

There are a number of reasons why there is a systematic overstatement of climate change risks in the NCCRA.

False connection with climate change mitigation

Some analysts and institutions might believe that it is necessary to paint an exaggerted picture of climate change impacts to buttress support for measures to mitigate climate change risk. If the impact of climate change will be relatively benign in New Zealand, at least over this century, then why would anyone sign up to ambitious and expensive emmision reduction goals?

In our view there are three reasons to support a rational least cost approach to emmission reductions. First, climate change is an international problem and as a good international citizen New Zealand should do its fair share, even if, as a temperate country, we will not directly benefit in the medium term. Some poor countries could be severly affected and we should not be a party to that.

Second, from a self interested perspective unrestrained emmissions growth poses a real risk, to New Zealand's wellbeing over longer (more than one hundred years) time horizons.

Third, if New Zealand were to stand aside from the international consensus on emmissions reductions then there is a real risk of trade retaliation. Our agricultural exports could be subject to tariffs or excluded altogether. Out tourism brand could be sullied.

These arguments should suffice. It should not be necessary to invent stories about impeding doom to encourage New Zealanders to do the right thing.

An echo chamber effect

So many people and institutions in the climate change industry have been repeating the mantra of markedly increased risks and from floods, sea level rise, wildfires and stronger winds, that it is now regarded almost as an immutable truth. Any push back on this story is not likely to be well received. It risks being labelled as climate change denial, or at least evidence that the person just doesn't get it. If anyone has misgivings it is easier to keep quiet.

It also becomes necessary to protect the received wisdom. Earlier research that doesn't suit the narrative is ignored, or misrepresented.

Sheer repetition of a catastophist narrative, unsupported by the science, has an effect. Trump did not win the U.S. presidential election but many people believe he did because the lie has been repeated so many times.

Limited economic understanding

It is apparent from the assessments that the authors had a limited economics understanding of the economics of climate change.

A centralist perspective

There is a strong preference for centralised planning solutions rather than leaving many of the adaptations to markets and communities.

Financial and other incentives

The climate change industry is now a good sized business and consultants and academics will follow the money. A balanced or skeptical perspective could put that funding at risk. This is not to say that all funding recipients are cynically dressing their research to deliver the 'right' results. It is just that priors will tend to change to be consistent with the financially rewarding outcomes. People like to truly believe in what is making them rich or is protecting their jobs. Normally this process is subtle but the NCCRA is more tranparent about the pursuit of financial advantage for many of the report's authors and other participants in the process. An entire risk assessment is directed to obtaining more funding and another to getting bipartisan agreement to a strong and early adaptation agenda that will be a consultant's paradise.

Lack of consequences

Unethical and/or imcompetent behaviour is unlikely to have negative consequences. New Zealand has a small analytical community so the risks of being found out are relatively small. And as most of the 'experts' are in on the game they can circle the wagons to protect the narrative, isolating any dissent.

Main report

Introduction

The first National Climate Change Risk Assessment (NCCRA) for New Zealand was released in August 2020. It focuses just on the risks caused or influenced by the physical impacts of climate change. It does not include the risks of transitioning to a low carbon economy. The report was delivered to government from September 2019 to May 2020.

The NCCRA was delivered by a consortium led by AECOM (an international consultancy with an arm that focusses on climate change adaptation), with support from Tonkin and Taylor, NIWA, Latitude, Victoria University of Wellington, Lincoln University and several independent consultants. However, it is Ministry for the Environment (MfE) document and they presumably agree with and are responsible for the content.

The assessment had the following objectives:

- Provide a national overview of how New Zealand may be affected by various hazards and threats that are caused, exacerbated or influenced by climate change, and the risks and opportunities this brings as well as any gaps in evidence for further consideration.
- Support decision-makers to better understand the wide range of risks that New Zealand will face due to climate change, and which risks need to be addressed most urgently.
- Provide the best available evidence, information and assessment of risks to directly inform the development of a National Adaptation Plan (NAP).

The key output of the assessment are 43 risk assesssments divided into five domains:

- Natural Environment
- Human
- Economy
- Built Environment
- Governance

Four areas where climate change can have a positive impact are also discussed.

For each of the 43 risks there is a written assessment backed by references to supporting documents. The conclusions are summarised in a table. Figure six, which is an assessmentof the risks to social cohesion, is an example.

Figure six: NCCRA outputs example

H1 Risks to social cohesion and community wellbeing from displacement of individuals, families and communities: Urgency profile						
Urgency category	**Proportion of urgency**		**Description of actions**			
More action needed	70		Action needed on how communities might relocate away from risk areas in an agreed and fair way. Policy and funding need to be considered first.			
Research priority	20		Understand how to successfully retreat affected individuals and communities.			
Sustain current action	0					
Watching brief	10		Need to establish a monitoring process to ensure actions are effective.			
Adaptation urgency	88		**Confidence**	High agreement, moderate evidence		
Consequence	**Now**	Minor	**2050**	Extreme	**2100**	Extreme

The key outputs are:

- A measure of adaptation urgency captured by a summary index number.
- Consequence assessments for now/2050/3200 expressed qualitatively (i.e. minor/major/ extreme) but purportedly based on some quantitative assessment criteria.

There is also a Confidence assessment expressed in terms of the level of agreement amongst the reviewers and the quality of the supporting evidence.

The central message

The central message of the review is that adaptation risks are very serious; that many need to be addressed urgently if the risks are to be mitigated; and that substantial resources need to be made available to the kinds of consultants who contributed to the NCCRA assessment.

The purported seriousness of the situation is captured in table eight, which is a summary of the consequence assessments. Thirteen of the risks reviewed in this report are classified as extreme by 2100. Even for 2050 there are 10 extreme assessments. Of the eight human, economic, built environment and governance risks in the summary report, which got a wider distribution, seven were classified as extreme.

The NCCRA also assessed the urgency of taking action to address each risk (the 'adaptation urgency'), to determine the degree to which further action is recommended in the next six years.

Table eight: Consequence assessments summary

	insignificant	Minor	Moderate	Major	Extreme
Now	2	19	8	14	
2050			22	11	10
2100				30	13

The assessments are driven by this picture of adverse climatic developments:

- *. If global emissions **remain high,** temperatures will increase by a further 1.0°C by 2040 and 3.0°C by 2090.*

- ***If global emissions remain** high, sea levels will increase by a further 0.21 m by 2040 and 0.67 m by 2090.*

- *Extreme weather events such as storms, heatwaves and heavy rainfall are likely to be more frequent and intense. Large increases in extreme rainfall are expected everywhere in the country, particularly in Northland due to a projected increase in ex-tropical cyclones.*

- *Drought is predicted to increase in frequency and severity, particularly along the eastern side of the Southern Alps*.

- *Wildfire risk is predicted to increase in many areas towards the end of the century, due to higher temperatures and wind speeds, and decreased rainfall and relative humidity.*

*Although there is inherent uncertainty associated with these projections, particularly towards the end of the century, they provide **plausible futures** resulting from climate change.*

Media attention

This picture of extreme consequences and urgency has been picked up by the media. James Morton reported this (and more) in the NZ Herald on 3 August 2020.

New Zealand's buildings, water supplies and population in general have been deemed at "extreme risk" of climate change impacts this century, which could come with 3C of temperature rise and seas nearly 70cm higher.

Among 10 urgent areas, the assessment – based on emissions rising at the current rate and resulting in a projected 67cm of sea level rise and 3C of temperature increase by 2090 – found ourselves to be at "extreme" risk, with threats of people and communities being displaced, and inequities widening.

About 675,500 Kiwis lived in areas already prone to flooding, with a further 72,065 living in the firing line of where some of the most dramatic effects of sea level rise could hit.

People being forced to shift came with more pressure on social services, labour and housing markets, along with broken social bonds and shrunken communities losing essential services.

Much of this is exaggerated or misleading. For example most the 675,000 people in areas 'already prone to flooding' are protected by flood protection schemes that already reduce the risks to acceptable levels, or will do some when planned protection schemes are complete. The assessements were not based on global emissions rising at their current rate but rather on a worst case scenario where international mitigation efforts fail almost completely.

The fault was not with the journalist but rather with misleading and sometimes false narratives in the NCCRA and associated promotional material.

Our assessment

Our assessment of the NCCRA report is that it lacks sound analytical foundations and is a subjective and sometimes dishonest exercise that systematically exaggerates the risks and consequences. Contrary to the risk assessment title it is not a risk assessment at all. Risk requires a consideration of both consequences of an event and the probability that the event will occur. The NCCRA simply leaves out the probability assessement and presents a series of more or less extreme scenarios, with degrees likelihood ranging from the just possible to very remote, as being plausible and in the minds of the average reader, the most likely outcomes.

Our review of the individual assessments found that:

- Critical documents that did not support a 'catastrophist' narrative were often ignored or the results were not reported.
- The consequence assessments were almost never supported by a reasoned discussion with reference to the evidence.
- Many of the references were irrelevant or did not support the narrative.
- Many of the consequence assessments simply relied on little more than a recitation of the five horsemen of the apocalypse – more extreme weather, drought, flooding, sea-level rise and wildfires.

Our Review framework

Our approach in this review is as follows:

We first review the overall methodology, the explicit and implied assumptions and key issues that cut across multiple risk assessments. The topics covered are*:*

1. The risk definition
2. Choice of climate change path
3. Projected climate changes
4. Flooding risk analysis
5. Consequence assessment metrics
6. Managed retreat
7. Cascading effects
8. Insurance withdrawal

We then review the risk assessments individually. We did not review the natural environment assessments, because that is not our field, the specifically Maori assessments, and the risks to all of the 'three waters' because they will be managed by a centralised government process.

For each assessment we assess the evidence base and consequence claims by reviewing the supporting references and commenting on the arguments. Each reference is graded from 0 to 10 in terms of the of evidential strength it provides to support the arguments. Considerations in our scoring include: relevance; rationality of the argument; and quantification of effects. The latter is given a high weighting because simply describing a possible relationship often does not help the reader assess its significance. An example of an assessment is a reference to a report on Tuvalu to support an argument about risks to political stability in New Zealand. This was rated at zero because it lacked relevance to the New Zealand situation.

An average score is calculated for each risk assessment (see table nine). The overall average is 3.09, which is a poor score. If references were genuinely used to support the arguments we would expect an average score of at least five or six.

The NCCRA risk assessments are normally presented mostly in their entirety, except where there is repetiton, to fairly present the MfE analysis and to spare the reader the inconvience of referring back to the NCCRA documents. This has resulted in a lengthy document beyond most reader's tolerances, but it is still useful to dip into a few of the assessments to get a better feel for the quality of the NCCRA analysis.

A summary of the NCCRA outputs together with our consequence assessments and average reference scores is presented in table nine.

Table nine: Summary of ouputs

Risk	Adaptation urgency	More action needed	Impact now	Impact 2050	Impact 2100	Tailrisk Impact 2100	Reference quality sco
H1 Risk to social cohension	88	70	Minor	Extreme	Extreme	Minor	2.64
H2 risk of exacerbating inequities	85	60	major	Extreme	Extreme	Insignificant	3.28
H3 risks to health	83	50	Minor	Moderate	Major	Insignificant	3.44
H4 risk of conflict, disruption	83	50	Moderate	Major	Major	Minor	2.25
H7 risk to mental health	80	50	Major	Major	Major	Minor	2.33
H01 reduction of cold weather mortality	45	0	Minor	Moderate	Mod.	Minor	NA
E1 risks to governments from economic costs	90	70	Minor	Major	Extreme	Minor	2.5
E2 risks to financial system	83	40	Minor	Moderate	Major	Minor	1.76
E3 risks to landbased sector	81	50	Minor	Moderate	Major	Minor	4
E4 Risks to tourism	80	40	Minor	Moderate	Major	Insignificant	1.63
E5 Risks to fisheries	80	40	Minor	Moderate	Major	Minor	NA
E6 risks to insurability of assets	75	40	Insignificant	Moderate	Major	Minor	5.40
E7 Risks to supply chains	68	20	Minor	Moderte	Major	Minor	2.57
B1 Risk potable water supply	93	70	Major	Extreme	Extreme	Moderate	NA
B2 Risks to buildings	90	60	major	Extreme	Extreme	Moderate	2.44
B3 risks to landfils	85	40	Moderate	Major	major	Moderate	5.2
B4 risk to waste and stormwaters	85	50	Major	Extreme	Extreme	Moderate	2.0
B5 risk to ports	70	10	Minor	Moderate	Major	Minor	2.25
B6 risk to linear transport	60	20	Major	Major	Extreme	Minor	2.67
B7 Risk to airports	55		Major	Major	Extreme	Moderate	2.75
B8 Risk to electrcity infrastructure	55	-	Moderate	Moderate	Majoe	Moderate	NA
G1 Risks of maladatation	83	60	Major	Extreme	Extreme	Moderate	5.77

G2 institutions not fit	80	60	Major	Extreme	Extreme	Moderate	NA
G3 Risk to govt busimess of litigation	78	50	Moderate	Major	Major	Minor	2.0
G5 Risk of knowledge gaps	75	50	Moderate	Moderate	Major	Minor	2.0
G6 risk to emergency services	70	40	Major	Major	Major	Minor	1.88
G7 Risk of not getting parliamnetary agreement	68	40	Major	Extreme	Extreme	Minor	0.6
G8 risk to democratic institutiosns	53	10	Moderate	Major	Major	Minor	0.5

Assessment framework issues

1. The definition of risk

In the Method report risk is defined as follows:

In this framework, risk is a function of climate hazards, the degree to which assets and values are exposed to the hazard, and their vulnerability to its effects. Rating risks with this framework relies mainly on assessing and rating the magnitude of the consequences from the interaction of hazards, vulnerability and exposure.

This is distinct from the industry standards for assessing risks (ISO 31000:2010 and AS/NZ4553), which use both the magnitude and likelihood of consequences.

The NCCRA approach is also distinct from common and wider professional understandings of risk. In the NCCRA framework a risk event with loss of $1 million, but a probabilty of occurance of 1:1000, giving an expected loss of $1000 is regarded as more risky than an event with a loss of $500,000, but a probabilty of occurance of 1:5 with an expected loss $100,000. This does't make sense.

The definition of 'risk' that is used in the assessments can give users a very misleading and exaggerated picture of the overall challenges facing New Zealand. Worst case

scenarios can, and are, presented as almost likely, because few readers will have read the methodology report and understood its significance.

The arguments for using their (worst case) risk definition was as follows.

This is because climate change creates cascading and ongoing changes when an ongoing trend such as sea-level rise, atmospheric temperature rise or ocean acidification, among other environmental changes, reaches various thresholds within a given system. The associated risks at a national level are not event-based, ***so it is not useful to estimate the likelihood of an event as a major component of the risk*** (our emphasis***)****. The changing risk environment requires more emphasis on consequences.*

To put it bluntly it is useful to estimate the likelihood of an event. It matters whether there is a 1:2 chance of occurance or 1:1000. The claim that 'cascading and ongoing changes' creates a situation where outcomes cannot be assessed in probabilistic terms is simply wrong. There is nothing new or special about cascading effects. Economists have been estimating the consequential (or cascading) impacts of initial economic shocks for decades.

Because of the apparent reliance on cascading events to justify a purely consequence based definition of risk we discuss cascading events in more detail in part 6.

2. Choice of climate change path

Two climate change Representative Concentration Paths (RCPs)[7]; RCP 4.5 and RCP 8.5 were selected as the benchmarks for analysis. The process was described as:

Stage 1 of this NCCRA used projections based on RCP8.5, a high greenhouse gas emissions scenario. This is assumed to be a plausible upper level of risk. It supports the identification of the most significant climate-related risks, analysed in Stage 2 of the assessment

Stage 2 also used RCP4.5, a relatively lower greenhouse gas emissions scenario. It was used to consider climate risks associated with trajectories involving greater mitigation of emissions. This involves a sharp reduction in emissions in the second half of the century, but importantly it does not achieve the Paris Agreement goal of limiting warming to 2°C

The RCP 8.5 was generally described in the documentation as a scenario where global emissions would continue at their present high level, and sometimes was described as a 'busines as usual' scenario.

[7] A Representative Concentration Pathway (RCP) is a greenhouse gas concentration trajectory adopted by the IPCC.

Description of RCP 8.5 misleading

The inference that RCP 8.5 represents a scenario where emissions continue at their present level is somewhat misleading. It gives the impression that global emissions will top out near their current levels.

However, RCP 8.5 assumes a much worse outcome than that. The Paris Accord is assumed to fail completely and the world revert to a pre-climate change awareness 'business as usual'. Coal increasingly becomes the fuel of choice, with usuage increasing by 6.5 times by 2100; the energy intensity of economies increase and technological progress is slow. Emissions do not top out until beyond 2100 when accessible carbon fuel sources start to run out.

The structure and outputs of the RCP system are explained in a 2011 article 'The representative concentration pathways:An overview' by Van Vuuren and others. Some key model inputs and outputs for RCPs 2.6, 4.5, 6 and 8.5 are shown in the figures below. The left-hand of Figure seven shows that C02 concentration for RCP 8.5 is substantially higher than for the lower RCPs. The reason, as shown in the left-hand of figure eight is that primary energy consumption is much higher. The right-hand graph shows the composition of the energy consumption by 2100 where coal dominates the energy mix.

Since the RCP's were devised there has been substantial progress to a lower emissions energy use profile. There is a real chance that transport emissions will fall sharply over the coming decades and substantial improvements in the economics of wind and solar power will give them a much more important role than thought possible back in 2010. The RCP8.5 is increasingly looking like a very extreme outcome.

Figure seven: Greenhouse gas emissions by RCP

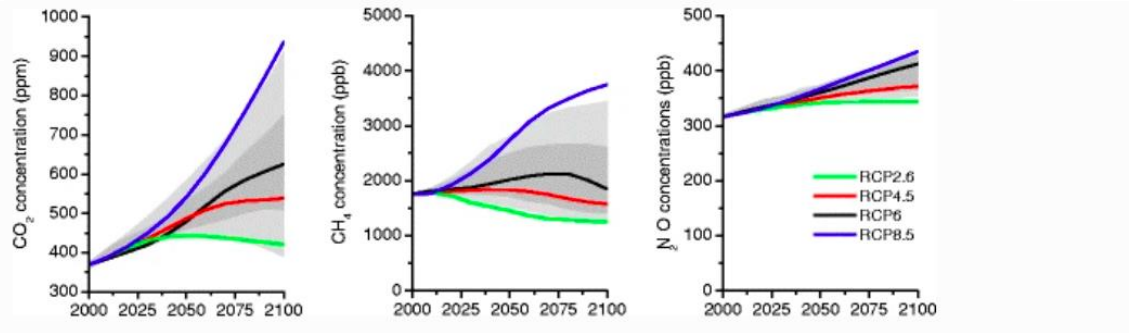
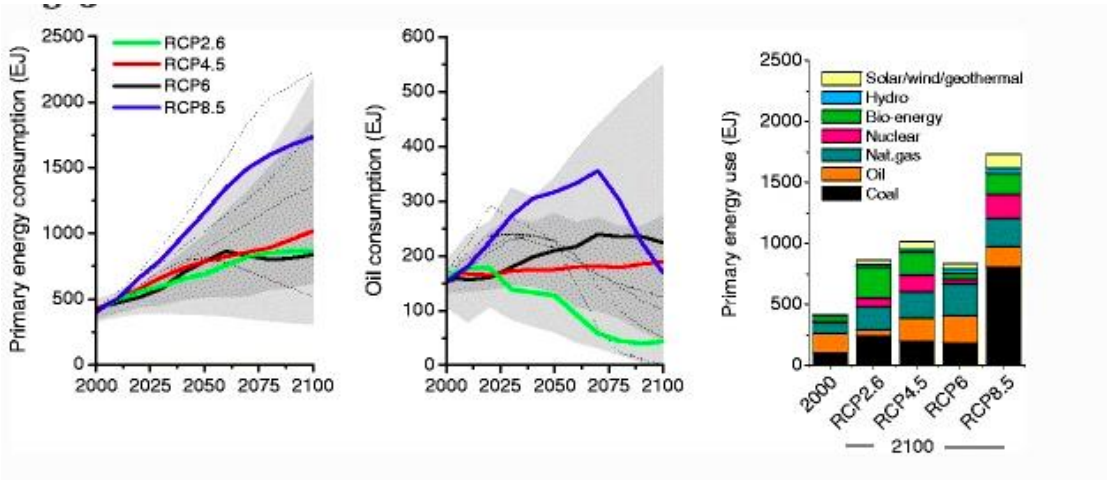


Figure eight: Energy consumption by RCP



Only one scenario considered

The social and economic factors that drive the RCPs are, of course, uncertain and it might be appropriate to consider both the worse case and a more plausible RCP outcomes in making the risk assessments. However, despite the claim noted above that both RCP 8.5 and RCP 4.5 were to be considered, in practice the consequence assessmenst were based on just the RCP 8.5 scenario.

In almost every case the only 'analysis' of RCP 4.5 was a statement that the risks are less under RCP4.5 than under RCP 8.5. In the Methods report it was stated:

RCP4.5 This scenario presents a lower level of warming, but the changes will still create risks that need early action.

There is not a single piece of analysis in all of the risk assessments to support the claim that early action was still required under RCP 4.5.

3. Projected climate changes

For many of the risk assesssments there is a standard 'mantra' that flooding, and 'extreme weather can result in extreme outcomes, without any reference to the actual climate changes underpinning the assessments. The evidence on flooding is discussed in section 4 below. On the other extreme weather events even a casual reading of the projected changes shows that weather patterns in most of the country will not fundamantally change and the risks should not be materially different. The only significant difference is a possible increase in the frequency of former tropical cyclones. The climate change assessments in the NCCRA are presented in table ten.

Table ten: NIWA climate changes

RCP	4.5	6.0	8.5
Temperature			
increase 2040	0.8	0.8	1.0
increase 2080	1.4	1.8	3.0
Hot days >25c			
Auckland 2040	36	35	39
2080	48	59	90
Wellington 2040	29	28	31
2080	35	41	61
Overall precipitation	Very small (0-5%) changes in most places		
Dry days	Increases in most places average around 10 days – but variable		
Droughts	Drought was only reported for RCPs 2.6 and 8.5. In general the risk of drought are higher in already drought prone areas.		
Moderately extreme daily precipitation (Determined from the 99th percentile on wet days),	Increases over most of the country except for parts of Northland and Hawke's Bay. Increases are small for the remainder of the North Island, larger for the South Island, and largest of all (20 per cent or more) in the south of the South Island.		
Very extreme precipitation (Very Extreme precipatation is expressed as the percentage increase per degree increase in temperature)	Percentage increases in the incidence of extreme precipitation falls events fall with the duration of events from about 13 percent for 1 hour to about 6-7 percent for longer duration per degree of trmperature increase		
Storms	Limited information. There may be a minor increase.		
Highwinds	An increased incidence of up to 10 percent or more in parts of the country		

One point to note is that there is limited statistical support for the relationship between increasing extreme precipitation and increasing temperatures in New Zealand. Two NIWA studies [8] found no overall upward trend in extreme precipitaion

[8] Griffiths, G.M. (2005). Changes in New Zealand daily rainfall extremes 1930-2004. *Weather and Climate 26:* 30–46.
Griffiths Weather and Climate, 33, 76-88 76 New Zealand six main centre extreme rainfall trends 1962-2011

events over 1930 and 2004 and 1960 -2011 respectively, despite the significant temperature increase over those periods.

For extreme winds there will not be much change**.** The following is the summary from the NIWA report on the issue (Mullan 2011).

The principle finding of this study … are that the frequency of extreme winds over the century is likely to increase in almost all regions in winter and decline in summer especially in the Wellington region and the South island. However ***the magnitude of the increase in the extreme wind speed is not that large only a few percent by the end of the century under the middle-of-the - range emission scenario (***our emphasis).

Fire risk

The best analysis on the relationship between fire risk and climate change is presented in a paper by MAF and Scion (2011)[9]. Table eleven shows the number of days with very high or extreme fire risk danger for 1990 and 2080 by region. The average increase, from 1990 to 2080 is 55 percent. As some of that increase has already occurred the future increase might be around 40 percent. Wildfires have resulted in $57 million in insurance claims this century so an increase of 40 percent in that level would not amount to much from a national perspective.

Some locations are predicted to have very high increases but this is generally from low bases. The two areas currently most at risk, Canterbury and the East Cape, are forecast to have only a moderate increase in risk. Note that these assessments assumed emission concentraions roughly equivalent to RCP 4.5.

Table eleven: Fire risk changes by region

	Days at risk /yr Base 1990	**Days at risk/yr. 2080**	**Change %**
Kaitaia	5.9	8.1	37.3
Dargaville	2.2	3.2	45.4
Coromandel	1.5	2.2	46.7
Auckland	8.3	12.4	49.4
Tauranga	7.7	10.2	32.5
Rotorua	1.5	2.7	80.0
East Coast	34.1	43.7	28.1
Taupo	2.2	3.7	68.2
New Plymouth	1.1	1.5	36.4
Wanganui	2.6	5.5	111.5
Kapiti	2.0	4.6	130.0

[9] Improved estimates of the effect of climate change on NZ fire danger MAF Technical Paper No: 2011/13

Wellington	16.0	32.7	104.4
Nelson	8.9	12.5	47.0
Westport	0	0	0
Hokatika	0	0	0
Kaikoura	6.3	14.1	123.8
Christchurch	39.7	48.1	21.2
Queenstown	5.8	8.5	46.6
Dunedin	5.7	21.0	268.4
Invercargill	0.4	1.2	200.0
Average	7.6	11.8	55.3

4. Flooding risk analysis

The primary research on flooding risk is a 2019 NIWA document by Paulik and others on fluvial flooding risk. It produced two sets of estimates. The first was an assessment of the number of people and assets currently 'exposed' to flooding risk.

One statistic from the NIWA report that was cited repeatedly in the NCCRA report, and has caught the media's attention, is that 675000 people are currently exposed to flooding risk. However, the NIWA data is not very informative because, effectively, all it does is identify people and assets located on historical floodplains. It does not take account of any flood protection measures or make any assessment of the probability of flooding. An area with a risk of flooding of 1:1000 (the target for the Hutt valley CBD, for example) is treated the same as one with a a 1:20 risk. From a risk assessent perspective this is an almost useless document. Its apparent role was to provide a pumped up perception of risk for public consumption.

The second piece of analysis was an assessment of the impact of climate change on flooding risk. Changes in the mean annual flood (MAF) was the proxy for flooding risk, in line with industry practice. A summary of the changes in risks to buildings for RCPs 2.6 and 8.5 is presented in table nine .

The top line in the table, for example, shows that in the RCP 2.6 scenario buildings with a replacement cost $1220 million will have an increase in their flood risk of more than twenty percent by 2036 -2056, and $22965 million will have an increase of between zero and twenty percent. But for buildings worth $15326 million the risk will fall by up to twenty percent and buildings worth $949 million will have a risk reduction of more than twenty percent.

The outcomes, for the RCP 8.5 scenario, which is the focus of the NCCRA assessments is that properties worth just $5 million in 2036-56 and $475 million in 2086-89 will have a risk increase of more than 20 percent. By contrast buildings valued at $7750 and $3544 million wlll experience a risk decline of over 20 percent.

Table twelve: Summary of changes in flooding risk by value of buildings $m

	>20%	**0 to 20%**	**0 to -20%**	**<-20 %**
RCP 2.6 2036-56	1220	22965	15326	949
RCP 2.6 2086-99	37	17828	28862	3129
RCP 8.5 2036-56	5	10361	30282	7750
RCP 8.5 2086-99	475	8944	30964	3544

Clearly, based on this evidence, claims that buildings and people will generally be subject to larges increases flooding risk is misleading. The NCCRA report authors were aware of the report because they cited it on numerous occsassions, but they never disclosed the results. This was deliberately deceptive.

Obviously the results pose a challenge to the standard mantra. NIWA responded to this 'problem' by covering up the the study results. In its press release[10] on the flooding results NIWA claimed that there was no assessment of the effect climate change on flooding.

With climate change, more extreme rainfall events are expected to occur – but weren't covered in this report.

This was obviously misleading. The work had been done (see the screen shot in figure nine) suggesting no cause for alarm on a nationwide basis (although things will deteriorate in a few places, including the West Coast), but NIWA obviously did not want to share the 'good news' with the public.

[10] niwa.co.nz/news/new-reports-highlight-flood-risk-under-climate-change

Figure nine: Screen shot from the NIWA report

About the same time NIWA was producing a report for Horizon (Manawatu/ Whanganui) Regional Council. It was explained (deep in the appendix of a lengthy report) that the Mean Annual Flood represented a relatively small flood, and that, despite it being an industry standard metric for assessing the likelihood of larger consequential floods, it should not be used alone to infer changes in flood hazards that involves large floods.

Changes in MAF alone cannot be used to infer changes in flood hazard. For this, research would need to address the more extreme floods, in terms of both size and frequency, and both discharge and inundation extent. Translating the hazard into a risk would require the further consideration of social, cultural, economic, and environmental vulnerability of flood-prone areas.

Because there was no such assessment on this (impossibly complex) basis, the MAF analysis that had been done was not considered 'relevant' and NIWA could ignore the inconvenient, positive results. In the body of report they simply repeated the standard mantra of increasing flooding risk without any supporting evidence. Apparently a very high evidential standard is required to report a fall in flooding risk, but no evidence at all is required to report an increase.

5. Consequence assessments

The consequence assessments are described as being based on:

'Qualitative analysis led by domain leads drawing from literature and data reviews, expert elicitation and focus stakeholder consultation'.

If that were all there was was to it most of the assessments could be dismissed as purely subjective exercises designed to attract attention rather than a reasoned assessment based on the available evidence.

But there was also, purportedly, a more objective, quantitative element to it. The Methods paper sets out a set of criteria for applying the qualitative assessments, which we set out in table thirteen.

Table thirteen: Consequence assessment criteria

Domain	Minor	Moderate	Major	Extreme
Overll	Some minor impacts at the national scale that could be addressed through local or regional management and adaptation processes	Significant impacts at the national scale, of interest to national agencies to address adaptation, or a major impact for 1–2 sub-national climate zone	Major impacts at the national scale, of high interest to national agencies to quickly address adaptation, or an extreme impact for 1 sub-national climate zone	Extreme impacts at the national scale (or even in a few sub-national climate zones), of heightened interest to national agencies to urgently address adaptation. May be of interest to international partners or financial or insurance institutions
Human	Minor impact on physical health, physical safety or mental health Happiness and satisfaction of whānau in some communities are mildly affected Isolated and short-term disruption to education employment and community services Minor impact on patterns of daily activity and behaviour	Moderate lasting impacts on physical health, physical safety or mental health Happiness and satisfaction of hapū and iwi in some communities are moderately affected Moderate disruption to education, employment and community services Moderate impacts on patterns of daily activity and behaviour Coping capacity of many communities exceeded	Physical health, physical safety and wellbeing significantly compromised in many communities The happiness and satisfaction of hapū and iwi are affected in a major way Prolonged disruption to education, employment and community services Major impacts on patterns of daily activity and behaviour Coping range of most communities exceeded	Health, safety and wellbeing significantly compromised across whole of society The happiness and satisfaction of hapū and iwi are severely affected Permanent disruption to education, employment and community services Patterns of daily activity and behaviour unable to continue Coping range of all communities exceeded
Economy	Financial losses equivalent to 1% of gross regional product (GRP) Limited impacts on businesses, livelihoods and consumer behaviour Temporary increase in unemployment within one sector Short-term/minor increase in local and central government costs, minimal loss of assets	Financial losses equivalent to 2–4% of GRP Ongoing losses equivalent to 0.5% of GRP Temporary impacts on businesses, livelihoods and consumer behaviour Temporary increase in unemployment in many sectors Medium-term increase in local and central government costs	Financial losses equivalent to >5% of GRP or 1–2% of gross domestic product (GDP) Ongoing losses equivalent to 1% of GRP Sustained impacts on businesses, livelihoods and consumer behaviour Sustained increase in unemployment in many sectors Long-term increases in local and central government costs and some loss of assets	Financial losses equivalent to >3% of GDP Ongoing losses equivalent to >0.5% reduction of GDP Sustained increase in unemployment across most sectors. Long-term costs for local and central government increase, and significant loss of assets
Built environment	Isolated and short-term infrastructure service disruption; no permanent damage;	Many short-term infrastructure service disruptions; damage recoverable by	Widespread short-to-medium term disruptions to infrastructure service;	Widespread, long-term service disruption; significant permanent damage to and/or

	some minor restoration work required Early renewal of infrastructure by 10–20%; need for new or modified ancillary equipment or design standards Increasing temporary or recoverable damage to buildings Planning for future relocation required Some damage to a small number of Māori cultural assets	maintenance and minor repair Early renewal of infrastructure by 21–50% Moderate damage to 10–100 dwellings; some require immediate relocation Between 5–20 commercial and public buildings require assessment; some require temporary relocation Moderate, reparable damage to Māori cultural asset	extensive infrastructure damage requiring major repair Major loss of infrastructure service Early renewal of infrastructure by 51–90% Major damage to 100–1000 dwellings; significant numbers need to be immediately relocated Costs exceed insured value Between 20 and 100 commercial and public buildings require assessment; many need to be permanently relocated Major, widespread damage to Māori cultural assets	complete loss of infrastructure and its service. Loss of infrastructure support and translocation of service to other sites; early renewal of infrastructure by more than 90% More than 1000 dwellings require assessments for immediate relocation More than 100 commercial buildings and more than 100 government and non-commercial buildings require assessment for permanent relocation options. Is Costs significantly exceed insured value Damage to more than 75% of Māori cultural assets
Governance	Some minor impacts at the local level, leading to tensions between levels of government Disruption to some local governance and decisionmaking functions (eg, temporary limited access to local services) Some negative impacts on perceived reputation Minimal effects on Te Tiriti o Waitangi rights	Moderate localised impacts on decision-making functions, service delivery and community resilience Rising community unrest and litigation Moderate impacts on perceived reputation requiring specialised management to restore Some Te Tiriti o Waitangi rights temporarily eroded or damaged	Major multifunctional impacts on decision-making and service delivery at local and national levels Policy and legislation cannot cope with the impacts, eg, funding, planning practice, emergency services Inequitable outcomes lead to loss of trust and reputation, and greater community unrest and litigation Major erosion of Te Tiriti o Waitangi rights	Extreme multifunctional, cascading and compounding impacts lead to inability at all levels of government to govern and provide services in an equitable and just manner Extreme community disruption (eg, loss of place and community cohesion) Significant damage to perceived reputation of and trust in institutions Te Tiriti o Waitangi rights overridden

The human and goverance domains descriptions are entirely descriptive and at the extreme criteria level overblown. Are we seriously expected to believe, for example, in the human domain that there will be ' *Permanent disruption to education, employment and community services Patterns of daily activity and behaviour unable to continue Coping range of all communities exceeded*'? all because temperatures have increased by less than one degree and there might be some more surface flooding and a few more wildfires. The impacts can't be due to sea level rise because these effects will be localised. The consequence assessments are meant to be New Zealand wide.

There is an attempt at more objectivity with the economic and built environment domains but the criteria are unclear. The quantitative test for major economic criteria which applies to five of the six economy risks is as follows:

Financial losses equivalent to >5% of GRP or 1–2% of gross domestic product (GDP) Ongoing losses equivalent to 1% of GRP

What are these financial losses that are greater than 1-2 percent of GDP? Are they the capital losses of buildings and infrastructure per year or over some longer time period? Are they cummulative across the six economic risks or do they relate to each economic risk? With five major and one extreme outcomes the losses accumulate to at least 10 percent of GDP if the latter approach was intended.

The criterion that we do agree with is that local and central government expenses will increase, but as no attempt has been made to even approximately quantify this effect throughout the NCCRA assessment, this does not mean very much. We have no idea whether the financial impact will be a minor, moderate, major or extreme.

With the built environmen the key criterion is that more than one thousand houses, presumably per year, will require assessment for relocation. As the building risk will be extreme by 2050 this suggests that ay least 50,000 homes and conceivably many more will be lost to managed retreat. Again there is no analysis anywhere in the NCCRA to support these calculations.

In our view the NCCRA assessment criteria are a mess and a muddle. There were tractable alternatives that would have added more transperancy and clarity to the exercise. An example is the United States Environment Protection Agency's[11] climate change economic cost assessment, which is set out below. The data is for the North Western US. Note that the numbers tend to be well overstated because they do not take full account of sensible and natural adaptations, and in some cases have not used credible cost inputs. The main value of the exercise is that the modelling is explicit and freely available. It could have been readily adapted to generate a New Zealand estimate of the costs.

[11] Multi-Model Framework for Quantitative Sectoral Impacts Analysis A Technical Report for the Fourth National Climate Assessment EPA May 2017

Table fourteen: EPA climate costs assessents for NW Costs per year $'m

	2050			2090		
	RCP8.5	RCP4.5	Benefit	RCP8.5	RCP4.5	Benefit
HEALTH						
Air Quality	$240 ($22 to $690)	$65 ($5.8 to $180)	$180 (NA)	$1,400 ($130 to $4,000)	$450 ($40 to $1,300)	$950 (NA)
Extreme Temperature Mortality	$41 (-$7.2 to $150)	$14 (-$13 to $46)	$27 (-$21 to $160)	-$5.8 (-$16 to $14)	$46 ($10 to $120)	-$52 (-$100 to -$19)
Labor	$350 ($170 to $790)	$220 ($87 to $440)	$130 ($41 to $340)	$1,900 ($1,000 to $3,300)	$730 ($260 to $1,800)	$1,200 ($750 to $1,500)
Harmful Algal Blooms	$0.18 (-$0.050 to $0.69)	$0.22 (-$0.069 to $0.73)	-$0.033 (-$0.18 to $0.061)	$3.5 (-$0.19 to $16)	$0.15 (-$0.10 to $0.61)	$3.4 (-$0.12 to $16)
West Nile Virus	$5.5 ($5.3 to $5.6)	$5.4 ($5.2 to $5.5)	$0.090 ($0.045 to $0.13)	$11 ($11 to $12)	$11 ($10 to $11)	$0.50 ($0.38 to $0.62)
INFRASTRUCTURE						
Roads	$360 ($200 to $500)	$210 ($90 to $320)	$150 ($71 to $280)	$950 ($580 to $1,400)	$300 ($160 to $450)	$660 ($310 to $960)
Bridges	$83 ($48 to $130)	$71 ($56 to $86)	$13 (-$7.9 to $42)	$31 ($18 to $51)	$22 ($2.6 to $42)	$9.1 (-$11 to $30)
Rail	$45 ($33 to $63)	$36 ($24 to $57)	$8.7 ($5.7 to $11)	$160 ($96 to $230)	$89 ($42 to $130)	$75 ($54 to $110)
Urban Drainage	$84 ($46 to $130)	$70 ($45 to $93)	$14 (-$47 to $71)	$84 ($61 to $120)	$75 ($65 to $83)	$8.7 (-$22 to $47)
Coastal Property	$250 (NA)	$240 (NA)	$11 (NA)	$250 (NA)	$220 (NA)	$28 (NA)

	2050			2090		
	RCP8.5	RCP4.5	Benefit	RCP8.5	RCP4.5	Benefit
ELECTRICITY						
Electricity Demand and Supply	$160 ($98 to $240)	$100 ($54 to $150)	$57 ($25 to $94)	$550 ($270 to $880)	$180 ($87 to $280)	$370 ($190 to $610)
WATER RESOURCES						
Municipal and Industrial Water Supply	-$0.44 (-$0.52 to -$0.37)	-$0.40 (-$0.52 to -$0.26)	-$0.039 (-$0.16 to $0.15)	-$0.27 (-$0.61 to $0.46)	-$0.33 (-$0.63 to $0.32)	$0.069 (-$0.60 to $0.57)
Inland Flooding	$100 (NA)	$130 (NA)	-$21 (NA)	$280 (NA)	$170 (NA)	$100 (NA)
Water Quality	$58 ($18 to $96)	$45 (-$5.4 to $80)	$13 ($1.8 to $24)	$140 ($60 to $210)	$90 ($9.7 to $150)	$47 ($27 to $69)
Winter Recreation	$110 (-$57 to $220)	-$44 (-$120 to $34)	$160 (-$91 to $290)	$260 ($27 to $400)	$76 (-$150 to $240)	$190 ($160 to $220)
ECOSYSTEMS						
Freshwater Fish	-$42 (-$84 to -$8.6)	-$59 (-$100 to -$24)	$17 (-$17 to $37)	$34 (-$34 to $120)	-$56 (-$100 to -$2.9)	$90 (-$31 to $180)
Wildfire	$22 (-$20 to $110)	$7.8 (-$16 to $35)	$15 (-$18 to $71)	-$15 (-$63 to $19)	-$29 (-$61 to $22)	$14 (-$7.4 to $44)

Notes:

6. Managed retreat

The logic for the managed retreat strategy is that it wil reduce costs in the long term but this argument is never spelt out or demonstrated by its proponents. The closest to a discussion of the issue referenced in the NCCRA is in Boston and Lawrence J. 2018. 'Funding climate change adaptation: The case for a new policy framework.

This paper tries to make the case that current planning, regulatory and funding frameworks are ill equiped to handle climate change because they will not deal with large scale managed retreat well. Early action is required to address these shortcomings.

However, there is no credible analysis of the scale and timing of the problem. The only discussion on the evidence for 'strong early action' is:

Significantly, Local Government New Zealand estimates that $1 spent on risk reduction saves at least $3 in future disaster costs by avoiding losses and disruption (Deloitte Access Economics, 2013).

The Deloitte report looked at the benefit/cost ratios for three disaster risk mitigation measures in Australia. One proposal, to increase a dam's hight to reduce flood risk, had a high payoff. Notably the option to retreat from the flood risk was not considered. The benefit/cost ratio for buildling houses that were more resilient to bushfires was marginal, and in general reducing cyclone risk for new housing in Queensland did not pay. Obviously this study did not, and could not, prove that all proposals to reduce disaster risk everywhere are desirable.

There is a box on managed retreat in the Boston and Lawrence paper that makes the following points:

Technically, 'managed retreat' has been defined in a coastal setting as 'the application of coastal zone management and mitigation tools designed to move existing and planned development out of the path of eroding coastlines and coastal hazards' (quoted in Hino, Field and Mach, 2017, p.1). It is deliberate, coordinated and planned. The aim is to reduce natural hazard risk permanently, rather than temporarily.

Whether or not managed retreat is a 'permanent' solution is an open question. If sea levels rise by, say, 30 metres in 300 years then most managed retreat 'solutions' will not be permanent.

Understandably, managed retreat is often viewed as complex and controversial, partly because of the financial costs, but also because of the more intangible costs – the loss of 'place', the social, emotional and psychological challenges of displacing people from their homes, the disruption to community life, and the loss of buildings or land of architectural, aesthetic or spiritual value. However, managed retreat can be implemented in a staged and progressive manner, as 'managed' suggests, preferably through community engagement processes that can address the sense of loss of place and value.

Two examples of managed retreat in two coastal locations in New Zealand were cited. The Matata case in the Bay of Plenty was not due to sea level rise. It was a response to a perceivd life safety risk from river flooding. For reasons that are not altogther obvious a managed retreat option that cost around $18 million was preferred to an earlier enginneering option estimated to cost $6 million.

The second case was the inclusion of managed retreat as an option in the Hawkes Bay Coastal Hazards strategy. The outcome of that exercise was that early managed retreat was not favoured. A real options costing put the present value of the costs of a managed retrat option at $230 million compare to $110 million for a staged menu of other responses.

The paper further makes the point that new developments were increasing risks.

… notwithstanding their responsibilities to mitigate long-term risks, many local authorities, often under pressure from property developers, have been approving major new subdivisions and other developments in areas that are likely to be vulnerable to rising seas later in the century (see, for example, Gibson and Mason, 2017).

The Gibson and Mason reference was completely misleading. it related to a case in Thames where the Council approved a new high rise building in a retirement village on the condition that the ground floor was left open for parking. There was no large scale development, no developer pressure, and the risk of inundation damage to the building had been substantially mitigated.

But on this almost non existent evidence base it was concluded.

the existing policy arrangements focus too much on post-event responses (e.g. post-disaster assistance and recovery) and too little on pre-event responses – that is, public funding designed to enhance societal resilience, minimise risk, and enable cost-effective adjustments and transitions.

It is further argued that there is a bias in the political processes to inaction.

Public expenditure on pre-event risk reduction is much harder to 'sell' politically than the funding of post-disaster recovery. Voters, it seems, reward governments that spend money on disaster relief, but not those investing in prevention and preparedness (ibid.). This phenomenon is common across advanced democracies. It reflects humanity's cognitive biases, including myopia: citizens tend to value post-event cures over preventative interventions (Boston, 2017a, 2017b; White and Haughton, 2017). Finding ways to counter such propensities will be crucial over the coming decades. Otherwise, there will be many sub-optimal policy decisions – ones that increase and entrench risk exposure, thereby placing additional burdens on future generations. This works in the opposite direction to what effective adaptation requires, namely to reduce risk now and for the future.

This argument just assumes that risk reduction is always desirable regardless of cost. But voters may be actually be acting rationally than when they eskew expensive risk reduction proposals often driven by ill informed academics and self interested professionals. Post-event cures might be more economically rational then pre-emptive interventions.

The discussion also assumes that governments will make rational risk reduction decisions. This ignores the evidence that governments will often force overinvestment in 'safety' and will ignore rational cost benefit analysis once an issue assumes a high public profile. For example:

- Earthquake strengthening: Benefits are probably less than 5 percent of the costs.
- Drinking water: In response to the Havelock North drinking water disease outbreak, (a rare large scale event that cost $17 million), the Government is compelling councils to spend many billions that will have a low payoff.
- Worksafety: The working from heights campaign benefits are less that ten percent of costs.

The problem with the preemptive managed retreat philosophy is that it tends to ignore the actual risks, focusing on worst case scenarios, and the value of time. Going for a final early solution can risk adaptation spending that turn out to be unnecessary, and ignores the use value of buildings in the time up to the point that retreat becomes genuinely necessary. These points can be illustrated by a simplified example.

It is assumed that there are two sea level rise possibilties that are equally likely. Sea level increases by 0.3 metres by 2050 and by 1.2 metres by 2100 under the high sea level rise scenario; and by 0.2 metres and 0.6 metres under the moderate scenario. Note that the equal probabilities are for illustrative purposes only. The 1.2 metre rise has a realworld probability of less than five percent.

There is a choice between managed retreat in 2030 costing $1000 million and a defend strategy that involves spending $50 million in 2050 and $200 million in 2050. Under the high sea level scenario retreat becomes technically necessary in 2100 and costs $1000 million. There is a 80 year decision horizon. The discount rate is 3 percent, which captures the net value of services from the buildings. Table fifteen shows the costs under the managed retreat and 'defend' policy options.

If the focus is just on the total undiscounted financial costs in the worst case scenario then managed retreat appears to be the best option with a total cost of $1000 million compared to $1250 million to defend. But from an economic perspective it is clearly the wrong decision with a present value cost of $746 million compared to $167 million for the defence option.

Notably neither of the two sea level adaptaion exercises that have been conducted for the Hawkes bay Regional Council, and in a small way for Makara Beach in Wellington, having favoured managed retreat.

Table fifteen: Managed retreat and defend costs

	Cost 2020	Cost 2030 $m	Cost 2050 $m	Cost 2100 $m	Total costs $m
Managed retreat	0	1000			1000
Defend scenario oucome one	0	50	200	1000	1250
Defend scenario outcome two	0	50	200	0	250
Present value of costs					
Managed retreat Preseny value					746
Defend Present value (Average over both outcomes)		32	87	47	167

The National Coastal Policy Statement

Buttressing the managed retreat philosphy is the National Coastal Policy Statement, which can be intrepreted as making a strong preseumption in favour of managed retreat. The relevant (lengthy) parts are presented below.

Objective 5: To ensure that coastal hazard risks taking account of climate change, are managed by:

- *locating new development away from areas prone to such risks;*
- *considering responses, including managed retreat, for existing development in this situation; and*
- *protecting or restoring natural defences to coastal hazard*

Policy 3 Precautionary approach

(1) Adopt a precautionary approach towards proposed activities whose effects on the coastal environment are uncertain, unknown, or little understood, but potentially significantly adverse.

(2) In particular, adopt a precautionary approach to use and management of coastal resources potentially vulnerable to effects from climate change, so that:

(a) avoidable social and economic loss and harm to communities does not occur;

(b) natural adjustments for coastal processes, natural defences, ecosystems, habitat and species are allowed to occur; and

(c) the natural character, public access, amenity and other values of the coastal environment meet the needs of future generations.

Policy 25 Subdivision, use, and development in areas of coastal hazard risk In areas potentially affected by coastal hazards over at least the next 100 years:
(a) avoid increasing the risk10 of social, environmental and economic harm from coastal hazards;
(b) avoid redevelopment, or change in land use, that would increase the risk of adverse effects from coastal hazards;
(c) encourage redevelopment, or change in land use, where that would reduce the risk of adverse effects from coastal hazards, including managed retreat by relocation or removal of existing structures or their abandonment in extreme circumstances, and designing for relocatability or recoverability from hazard events;
(d) encourage the location of infrastructure away from areas of hazard risk where practicable;
(e) ***discourage hard protection*** *structures and promote the use of alternatives to them, including natural defences; and*
(f) consider the potential effects of tsunami and how to avoid or mitigate them

Policy 27 Strategies for protecting significant existing development from coastal hazard risk
(1) In areas of significant existing development likely to be affected by coastal hazards, the range of options for reducing coastal hazard risk that should be assessed includes:
(a) promoting and identifying long-term sustainable risk reduction approaches including the relocation or removal of existing development or structures at risk;
(b) identifying the consequences of potential strategic options relative to the option of 'do-nothing';
(c) recognising that hard protection structures may be the only practical means to protect existing infrastructure of national or regional importance, to sustain the potential of built physical resources to meet the reasonably foreseeable needs of future generations;
(d) recognising and considering the environmental and social costs of permitting hard protection structures to protect private property; and
(e) identifying and planning for transition mechanisms and timeframes for moving to more sustainable approaches.

(2) In evaluating options under (1):
(a) focus on approaches to risk management that reduce the need for hard protection structures and similar engineering interventions;
(b) take into account the nature of the coastal hazard risk and how it might change over at least a 100-year timeframe, including the expected effects of climate change; and
(c) evaluate the likely costs and benefits of any proposed coastal hazard risk reduction options.

(3) Where hard protection structures are considered to be necessary, ensure that the form and location of any structures are designed to minimise adverse effects on the coastal environment.

(4) Hard protection structures, where considered necessary to protect private assets, should not be located on public land if there is no significant public or environmental benefit in doing so.

The National Policy Statement can be intrepreted in ways that allow local authorities to adopt a hard defence strategy if they wish. Managed retreat only has to be considered. 27(c) explicitly recognises this. If the statement is being interpreted in ways that are not productive it can always be rewritten. It is not holy writ.

7. The Cascading effect

The premise behind the cascading effects argument is that climate change events expose a range of interconnections and dependencies that amplify the effects of specific shocks. As the NCCRA risk assessments were based on specific shocks it is argued that the aggregate of these assessments will understate the overall effects of climate change.

As this idea seems to have had a significant effect on NCCRA thinking about the seriousness of climate change, we review the primary New Zealand research on the subject *'*Cascading impacts and implications for Aotearoa New Zealand' *(*Lawrence et al.). The paper presents the result of a Deep south funded project that had a budget of $291,800 and took three years to complete

The purpose and content of the report was described as follows:

We were funded by the New Zealand Deep South National Science Challenge Impacts and Implications programme to explore cascading impacts of climate change and their implications, and, in particular, to examine how the impacts might cascade within, between, and across areas such as urban systems (including the underlying support systems that enable the provision of services and exchange for urban populations), the delivery of water services (stormwater, wastewater, and water supply), and the financial services sector (insurance and banking). This report examines cascading impacts of climate change from a conceptual, methodological, and grounded position using examples from urban systems, delivery of water services, and the financial services sector.

The process was described as:

- *Develop a framework (*drawing on two workshops*) for thinking about cascades of impacts how impacts interact, who is affected, where interdependencies and co-dependencies occur, and how far impacts and implications might extend across multiple geographic locations, scales, and sectors.*
- *Conducted three work shops, mostly attended by; local authority officials based around two narratives and two cascade diagrams*
- *To identify the impacts across the domains of interest, the participants at the Hamilton and Christchurch workshops attached sticky notes to an aerial photograph of the geographic area at possible impact locations.*

- *Developed system maps in brain storming sessions with workshop participants*
- *Six targeted interviews conducted with selected workshop participants. A systems map was used to guide interviewees, was used to guide interviewees through 'the conceptual and empirical framing of cascades'.*

And the outputs were:

- A set of narratives that are 'plausible stories' that in 'in some cases have occurred'. There were six such narratives that ran to a about a page each.
- Cascading loops that 'can help decision makers think about the implicatios of cascades'.
- CIrcle tool outputs that provided further evidence of connections and interdependencies beyond that described in the narratives and stimulated thinking about critical dependencies.

An example of a narrative is the 'Water supply drought Wellington' which we have reproduced below to give the reader a sense of what we think is the triviality of much of the exercise.

Wellington City Council documents show a "record-breaking" 2140 leaks were reported in drinking-water pipes across the region in December – 762 more than in the same month the previous year. The council's quarterly report, ending December 31, states old and brittle drinking water pipes were particularly vulnerable to cracking as the ground around them dried out.

Residents faced delays of several days or longer before repairs could be undertaken, resulting in extra crews being brought on and more late-night repair work. One Evans Bay Parade resident was furious when a crew turned up to repair a leaking pipe at 10.30pm – five days after the leak was reported. …….

The council's target for responding to non-urgent calls was 36 hours, but in the December quarter this stretched out to about 45 hours. ……. "Across the region, somewhere in the order of $300,000 could be attributed to leak responses, and it's more a case of prioritising our responses rather than additional cost pressures." Heat and a lack of rainfall can cause a loss of infrastructure service, decreasing satisfaction with services, which results in a further demand for repairs.

The council prioritises the work, using additional staff and contractors to keep up with the backlog. Staff work nights (which is not normal), placing strain on their families. This affects community functionality and residents get disgruntled. Maintenance costs increase, which may mean another service is reduced or another revenue stream is needed to continue the same level of service across all sectors.

Long hot dry summers will combine with greater frequency of higher intensity rainfall events, creating compounded impacts that will also flow on to the ability of the maintenance teams

to keep up. As a consequence, the planning for new infrastructure will be affected. This will also accelerate the demand for new design standards and approaches with institutional flow-on effects.

None of this, even taken together, seems to be the stuff of disaster. $300,000 is not an impossibly large cost for the Wellington Council to bear from time to time, and if an Evans Bay resident gets furious and there is a nine hour longer delay in getting the Council's attention, then this should be treated as part of normal life.

Circle derivided dependancies

One of the key outcome from the process were two 'circle derived dependancies ' between impact categories. The one from the Hamilton exercise and the system mapping are shown below.

Figure nine: Circle derived depenancies

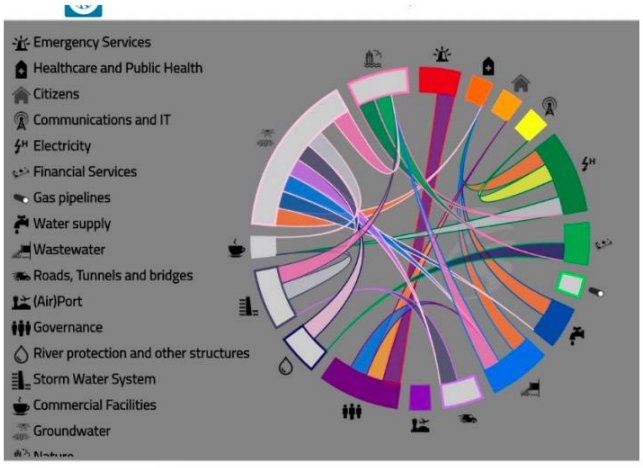
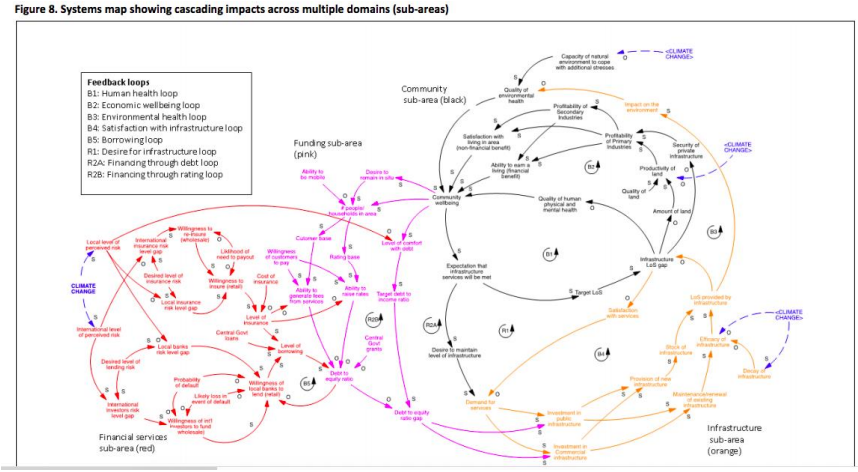


Figure ten: System mapping of cascading impacts



The interviews

The narratives, systems map and circles were used to underpin interviews with key informants. They were shown the systems map and narratives, which formed the basis of discussion of 'the consequent implications of the cascades' for their domain of interest.

The interviews descriptions extended to just over one page for urban systems and infrastructure, and three pages for financial services. There was little content in the one page urban design report. The financial services summary, focused on insurance company 'red lining '. The opinion from a banker was that if insurance was withdrawn it was likely that they would withdraw from lending. There was an acknowledgement that this could be a tricky problem but there was no discussion of its quantitative significance. The discussion would probably have been just as productive without the narratives and systems mappings. Indeed it appears that there was no reference to them in the discussion.

The paper concluded that the exercise demonstrated the advantages of a system based approach. In substance there is nothing very new or useful (other than as a kind of initial brainstorming tool) about this approach. NIWA has already built a model for estimating the full costs of flood events. It allows the user to calculate a range of expected costs for different events, which, in our view, is more useful than drawing lines on a circle.

The significance of the cascading effect is overblown. Practically every major social, economic or physical shock has flow on effects, which can be accounted for in a good impact analysis. For example, an economic analysis of the effects of a terms of a trade shock will take into account flow-on effects as well as the initial income impact effect on exporters. There is nothing special about climate events.

In our own field three economists could produce insights just as useful as those produced in this cascading effects exercise, in a day, though it would take longer to produce the 'artwork'. A system map of such an exercise for the Great Depression is shown below.

Figure eleven: Systems map for the Great Depression

8. Sea level rise and insurance withdrawal

In December 2020 a report: 'Insurance Retreat: Sea level rise and the withdrawal of residential insurance'[12] was released. It was funded by a Deep South Challenge grant of $110,000. It made some striking claims. Insurance premiums for 10,000 homes would rise by a factor of four in Auckland, Wellington Christchurch and Dunedin, with sea level rises of just 12 to 15 centimetres. Insurance companies would start partially withdrawing insurance cover by 2030 in Wellington and cover would be fully withdrawn in the 2040s. The 10,000 affected houses was just part of the problem. These were just the homes within one kilometer of the sea and there are many more further inland that would be similarly affected.

The report also made a strong pitch for managed retreat rather than hardening defences to manage the emerging sea level rise risks.

The report was widely reported in the media and raised obvious concerns amongst homeowners.

Review of the report

One problem with the report was that it wasn't really a final report at all, despite being described as such. Rather it just presented some key results backed by about two pages of analysis that didn't make it clear how the results were produced.

There is a reference to a further report by the authors that purported to present more detail. When we asked for a copy the request was refused. We were told that the paper is a draft journal article, currently being peer reviewed, that won't be available for about a year.

Thank you for your interest in our report. The paper referenced in the report is being submitted for peer review. Until that process is completed we're not in a position to release the paper. I can ask my team to put you on the distribution list to notify you once the paper is published. The review time for economics papers can be long (i.e. more than 12 months). When the paper is published the citation year will be updated in on line versions of our report.

This was obviously an evasion. Authors can make available drafts of papers under consideration for publication if they chose to do so.

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[12] Authors: Belinda Storey, Climate Sigma; Sally Owen, Te Herenga Waka-Victoria University of Wellington; Ilan Noy, Te Herenga Waka-Victoria University of Wellington; and Christian Zammit, NIWA.

Lacking the detail we have had to piece together some of the fragments and clues in the 'Final' report to assess the analysis and conclusions.

The paper

Data

Our Insurance Retreat empirical study relies on the following data sets:

• property data from RiskScape ,

• elevation data from the New Zealand School of Surveying (NZSoS) ,

• tide gauge, coastline and land district data from Land Information New Zealand (LINZ),

• and extreme sea level extent modelling from the National Institute of Water and Atmospheric Research (NIWA).

The summary table for housing data is presented below.

Table sixteen: Insurance retreat data

	Coastal houses in ESL1 zone (n)	Construction year (median)	Floor type 1=wood 2=concrete (mean)	Floor height (median)	Replacement cost (median)
Auckland	540	1970	1.20	63 cm	$314,000
Wellington	1,740	1955	1.17	63 cm	$273,000
Christchurch	4,850	1970	1.65	40 cm	$239,000
Dunedin	3,100	1925	1.15	63 cm	$248,000

Table 1: Summary statistics of residential properties located within 1% AEP coastal inundation extents (ESL1), as modelled by NIWA. Note this only includes properties within 1km from the coast.

An important piece of information provided is the floor level hight data. The effect of increased floor hight is analytically equivalent to a reduction in the sea level and a floor hight of 0.63 can substantially reduce the probability of damaging inundation. A risk of 1:100 could well become a risk of 1:500. The problem is that the paper does not say whether there was an an adjustment for floor hight in their estimates of the number of houses affected.

The estimates of the number of properties currently in the 1:100 risk zone (their ESL1) is lower than the NIWA estimates that does not account for elevated elevated floor hights (see table fourteen), but there are other factors other than floor hight that could account for this. The NIWA data includes non-residential buildings and all buildings, not just those within one kilometre of the sea

Table seventeen: NIWA estimates of properties at risk

	Number of buildings AEP 1%
Auckland	1790
Wellington	4084
Canterbury	9506
Otago	5506

Source*:* NiWA 2019

Bathtub vs dynamic inundation modelling

The bigger problem is that Storey almost certainly uses the bathtub method for identifying buildings at risk of a 1:100 year inundation. As explained above the bathtub method assumes that the indundation is determined solely by hight above sea level, regardless of the possibility of whether buildings will be inundated. We showed that using the example of Dunedin that bathtub and dynamic methods can yield very different results. Storey estimates that 3100 houses will be affected in Dunedin. The true figure might be just a few, at least in South Dunedin.

The situation with Wellington is similar to Dunedin. Most of the 'vulnerable' houses will be in the low lying area of Petone and Kilburnie that have limited access to the sea. Christchurch is more complicated being driven by flooding in the Avon and Heathcoate rivers and estuaries.

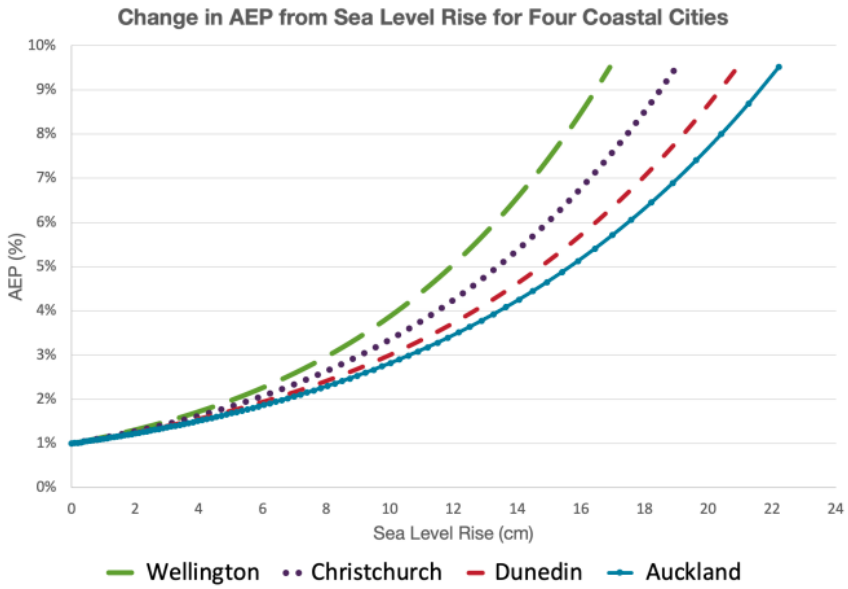
Process

The process is described as follows:

We fit a three parameter Generalized Extreme Value (GEV) distribution to the annual maximum value sea level series from four cities to model the relationship between each cm of sea level rise and how much more frequent a 1% AEP (1 in 100 year) event is likely to become. For properties already within the 1% AEP (1 in 100 year) inundation zone, we estimate the water height per property to estimate damage incurred (di) and then calculate the hazard specific risk-adjusted premium.

The results for the relationship between sea level rise and the annual excedence probabilites are shown in figure fourteen. This basically just replicates the work by Hunter for the Parliamentary Commissioner for the Environment published in 2015. The results appear to be identical.

Figure twelve: Relationship between sea level rise and AEP



From this figure the following probabilty of exceedance numbers are calculated:

Table eighteen: Probability of exceedence by sealevel rise

Sea level rise	Auckland	Wellington	Christchurch	Dunedin
0	1:100	1:100	1:100	1:100
10 cm	1:35	!:20	1:22	1:29
20 cm	1:12	1:4	1:5	1:9
30cm	!: 4	1:1	1:1	1:2

Calculating insurance premiums

Given the relationship between sea level rise and the probability of exceedance the connection to insurance premiums and to insurance retreat is a relatively straight forward exercise.

The premiums were calculated by mutiplying an inundation damage function by the value of the building times the probability of inundation. This figure in turn was multiplied by a factor of 1.3 to account for administrative costs and the insurer's profit margin. The damage function was described as follows;

Our analysis assumes that a property incurs 50 percent damage if the water reaches over 1 metre above the floorboards, 30 percent damage if the floor is of timber construction and the flooding rises above the ground level floorboards (but less than one metre deep) and 10 percent if the floor is concrete and the flood rises up to 1 metre above the floorboards.

For example with an annual probabilty of excedance of 1 percent; a home valuation of $300,000; and expected damage of 50 percent the premium will be $300,000 x 0.5 x .01 x 1.3 =$2015.

The estimated insurance premiums are shown in table nineteen.

Table nineteen: Impact on estimted insurance premiums

	Currrent modelled premium			**Sea level rise to reach 5% AEP threshold**	**Expected premium at 5% AEP**
	Median	Mean	St dev		Median
Auckland	2000	2600	4227	15 cm	10000
Wellington	1800	1700	1624	12cm	8700
Christchurch	1600	2100	2997	13 cm	7600
Dunedin	1600	1800	779	14 cm	7900

Partial insurance retreat was predicted once the probabilty of inundation exceeded two percent based on annecdotal evidence.

Insurance premiums overstated

The modelled current insurance premiums appear to be overstated. When we checked an online price for a Dunedin South property we found that the premium for a $300,000 property, including fire and other risks (including flooding from rainfall events) was less than $900. Storey's estimated premium for just the sea flooding risk was $1800. Hopefully this suggests that insurers are taking note of the Otago regional council modelling that shows there is currently almost no sea inundation risk, and are not using a simplistic bathtub model.

But there are risks in the Storey report for insurance premiums and coverage. Insurance companies will charge whatever they can get away with in a competitive market. If the idea that insurance premium increases are a justifiable and almost virtuous response to sea level rise risks gains currency, then we could see premium increases driven by the Storey analysis regardless of the evolution of the real underlying risks.

Insurance retreat

The obvious response to threat of (justified) insurance retreat in denser urban areas is to build defences such as flood gates and sea walls to reduce the risk. However much of the effort in this report was directed against this option.

In the discussion section there is a focus on the relative merits of managed retreat and hardening defences. It consisted of little more than a string of often sweeping assertions.

Any response to insurance retreat should attempt to reduce the underlying risk instead of simply delaying the risk or shifting responsibilities for insurance.

Some of the most obvious responses may lock in maladaptive paths that increase risk in the long term. With sea level rise and storm surge incursion, there may be a temptation to harden our coasts to defend property from inundation.

Hardening defences might allow us to maintain insurance temporarily, but it only extends the deadline rather than eliminates it.

Extending the 'deadline by many decades has real economic value. In some cases, depending on the final increase in sealevel rise, and the hight of the protection, the defence might be a 'final' solution.

Engineering responses like sea walls, stop banks and levees can create a false sense of security. People living in areas 'protected' by a stop bank, levee or sea wall perceive - and often are told - they are safe from future floods and storms. As a result, there is increased economic development in these areas and property owners see little need to invest in other kinds of defensive measures.

They are not told they are absolutely safe. There is always a residual risk. The Dutch build their protections to a 1:2000 standard and there is much development behind that protection. The residual risk is not insured but the Dutch get on with their lives on the assumption that the government will compensate them if the worst happens.

Storey engaged with the Dutch issue in a youtube presentation of the insurance retreat paper. Her argumentt was that the Netherlands has a relatively short shoreline and a large economy. New Zealand has a longer shoreline and a smaller economy so our shore line/GDP ratio is 46 times bigger than the Dutch ratio. Hence it is suggested the Dutch experience may not applicable to new Zealand because they have so much more resources. This is a silly argument. No one is suggesting that the entire New Zealand coastline should be protected. Probably there might be an eventual need to harden a few hundred kilometres.

constructing something to defend an at-risk low-lying area from flooding might induce property owners to invest more in their property or build more dwellings, increasing the potential damages should the stop bank breach. When a stop bank, sea wall or levee is overtopped or fails, the resulting losses can be catastrophic.

This argument doesn't necessarily follow. Many councils have banned new developments in hazard areas. Alternatively conditions such as using the ground floor of a multifloor building for garaging or elevating the building platform can be imposed. Sea rise defences might also be built so they can be topped up at a future point if sea levels continue to rise.

In addition, most engineering solutions defend the land immediately behind them, but can make flooding worse in other areas by creating a traffic-jam or ripple effect that forces water higher elsewhere. So, paradoxically, what is seen as a solution may increase overall flood risk.

This is an argument for sound engineering design not an argument against all engineering solutions. The real point here is that there are no univeral prescription for (or against) managed retreat. Everything depends on the local circumstances. What is appropriate for a city like Christchurch[13], which according to the NIWA modelling currently has close to 10,000 properties 'at risk' may not be right for a seaside community with 50 properties. A Christchurch retreat could well cost in excess of $20 billion compared to under $1 billion for a defence strategy.

The value of the report

While we have misgivings about the report it does send a valuable message that insurance risk brings forward the day of reckoning for councils on the sea level rise issue. They need to develop plans on whether they will defend or retreat from particular areas, and if they are going to defend what level of protection will be offered. If it is to a 1:100 standard then this will only provide a bare margin over insurers' risk tolerances and a higher standard could be required. Insurance, defence and retreat are intertwined and communities need to understand the trade-offs between higher capital costs and lower insurance premiums.

[13] Christchurch has been looking at defense including fllodgates across the estuary for some time. The cost could well run to $600-800 million. But this would be preferable to abandoning properties worth in excess of $10 billion. NIWA Avon-Heathcote Tidal Barrier Pre-Feasibility Study Contract Number: 14/15 – 185 Prepared for: Christchurch City Council July 2015

The Risk assessments

Assessment framework

Our reviews of the individual NCCRA risk assessments follow a common framework.

We present:

- The NCCRA consequences assessments and urgency scores.
- The Tailrisk: summary, consequence assessments and evidence quality scores.
- A review of the NCRRA analysis.
- Reviews of cited references and evidence quality scores.

Where cited documents are reviewed this discussion is delineated by a dashed line: -------. When the discussion reverts back to the NCCRA analysis a further dashed line identifies the transition.

Our discussion is presented in normal script.

Excerpts from the NCCRA are presented in italics. i.e.

Extreme events such as flash floods, more frequent coastal flooding, and erosion or landslides,

Excerpts from papers cited in the NCCRA discussion are presented in a blue script i.e..

Risk exposure (replacement value of buildings only) around the New Zealand coast has been estimated at $3 billion and $19 billion (2011 NZ$) for coastal land elevations within 0.5 and 1.5 m respectively of spring high tide mark – based on ~85% of developed areas (Bell et al., 2015

Human Domain

The consequence descriptions for the human domain are as follows. Readers can make their own judgment on whether the evidence and analysis supports the NCCRA consequence assessments.

Moderate	Major	Extreme
Moderate lasting impacts on physical health, physical safety or mental health Happiness and satisfaction of hapū and iwi in some communities are moderately affected Moderate disruption to education, employment and community services Moderate impacts on patterns of daily activity and behaviour Coping capacity of many communities exceeded	Physical health, physical safety and wellbeing significantly compromised in many communities The happiness and satisfaction of hapū and iwi are affected in a major way Prolonged disruption to education, employment and community services Major impacts on patterns of daily activity and behaviour Coping range of most communities exceeded	Health, safety and wellbeing significantly compromised across whole of society The happiness and satisfaction of hapū and iwi are severely affected Permanent disruption to education, employment and community services Patterns of daily activity and behaviour unable to continue Coping range of all communities exceeded

H1 RIsks to social cohesion and community wellbeing

NCCRA Consequence assessments
Now: Minor
2050: Extreme
2100: Extreme

Urgency score: 88

Tailrisk summary

The NCCRA provides almost no evidence to support its assessement that there will be extreme risks to social cohesion and stability by 2050, beyond a sprinkling of papers that are of only tangental relevance. The possible argument that a managed reteat response to sea level rise could result in widespread dislocation of populations was not developed but seems to be implicit in the assessment.

The reality is that New Zealand has a highly mobile population and communities and always evolving and adapting to changing circumstances. Beyond a few local exceptions, there will not be widespread damaging disruptions to communities if sea level rise risk is handled sensibly.

Tailrisk consequence assessment: Minor

Evidence quality score: 2.64

NCCRA discussion

Risk summary

Extreme events such as flash floods, more frequent coastal flooding, and erosion or landslides, or a series of ongoing, gradual changes that accumulate over time, particularly ongoing sealevel rise, may result in some currently inhabited locations becoming uninhabitable.

It is unlikely that extreme weather events, in themselves, will result in many locations becoming uninhabitable. The substantive risk 'uninhabitability due to sea level rise, and this will not become material until the latter part of the century.

This risk has two sides: first, the impact on those who move away; and second, the impacts on the community left behind. When people are displaced or mobilised, they can suffer trauma from leaving familiar surroundings, the breaking of social and cultural bonds, and the challenges of resettlement. …….. Those who remain behind may experience a sense of loss and abandonment as the community diminishes, and similar trauma due to the breaking of family, social and cultural bonds. As a community reduces in size, essential services, such as education facilities, job opportunities or community services, may be eroded. This has been reported in rural New Zealand communities over the last 30 years, as a result of government reform in the mid-1980s. These risks to social cohesion and community wellbeing increase over time and are greater under representative concentration pathway (RCP) 8.5 than RCP 4.5.

Exposure

New Zealand's low-lying coastal areas are exposed to ongoing sea-level rise and associated pressures such as groundwater rise and salinisation, and extreme events. Development intensification along coastal areas, and concentration of population through urbanisation, are increasing the number of people exposed to extreme weather events, landslides and coastal inundation (Glavovic et al, 2010)

Glavovic BC, Saunders WS, Becker JS. 2010. Land-use planning for natural hazards in New Zealand: The setting, barriers, 'burning issues' and priority actions. Natural Hazards 54: 679–706.

This is a review article of climate adaptation issues from a land use planning perspective. There is no attempt to quantify any of the effects. Later papers that do make some attempt at quantification (albeit in many cases flawed and misleading) should have been cited.

Score: 3

About 675,500 people live in areas currently prone to flooding. A further 72,065 people live in areas that are currently subject to 1 per cent annual exceedance probability (AEP) of extreme sea-level elevation (Paulik et al, 2019b).

Paulik et al, 2019b

As noted above there are two Paulik studies. The one on river flooding shows that there will not be an overall increase in the incidence of river flooding with climate change. The reference to 'prone to flooding' is misleading because the Paulik study is really just a measure of the number of people who live in historical flood plains. It does not account of current flood protection measures or provide any assessment of the risk of being flooded. The second paper, on sea level rise, overstates the current level of risk and does not tell us about the population that would still be 'at risk' after sensible economic protective measures are taken.

Score: 3

Inland communities are exposed to extreme events and ongoing, gradual changes that may alter the viability of economic enterprises crucial to sustaining an area.

This pure assertion, which is not linked to the climate change projections or backed by any analysis.

Sea levels are projected to increase by up to 0.9 metres by 2100 under RCP8.5 for all zones, leading to coastal inundation and salinisation of groundwater (Ministry for the Environment, 2017b).

Changes under RCP 4.5 and for 2050 are not mentioned.

Extreme storm tides, winds and rainfall are also projected to increase in frequency and magnitude in all regions for both 2050 and 2100 under RCP8.5. The intensity of tropical cyclones in the North Island and northern South Island is also projected to increase (Pearce et al) This will result in flooding, landslides and erosion that can have immediate and long-term implications due to damage to belongings and households, displacement and trauma (Stephenson et al, 2018).

Pearce P, Bell R, Bostock H, Carey-Smith T, Collins D, Fedaeff N, … Woolley JM. 2018. Auckland Region Climate Change Projections and Impacts. Auckland: Auckland Council.

This paper is discussed above under the climate change projections. There is a suggestion that there could be an increase in the frequency of former tropical cyclones.

Score: 7

Stephenson J, Barber J, Barth J, Bond S, Diprose G, Heyd C, … Vincent N. 2019. Community Developmentfor Adaptation (CD4A): Council-community engagement for a climate-impacted future. Wellington: Deep South National Science Challenge.
This paper primarily dealt with council/community engagements. There is no quantitative or analytical support for the argument that there will be material climate impacts on affected communities.

Score: 5

Some areas are already highly exposed to flooding. For example, 4.3 per cent of Westport will be inundated by a 1-in-50-year flood. By 2080 this could rise to 80 per cent (IPCC, 2007a).

IPCC 2007 Impacts adjustments and vulnerabilities
It is not clear why, what is now a very dated IPCC report was cited here. The example of a single small town does not tell us about the risks on a New Zealand wide basis. In any event there was no reference to Westport in chapter 11 of the IPCC report which covered Australia and New Zealand impacts. If Westport was to be used then more up to date information should have been used. Westport has been reviewing its flood protection options which will take climate change into account. [14] The West Coast Regional Council's Westport 2100 report[15] did raise the possibility that relocating the town in 50 to 100 or more years could be a possibility.

Score: 0

Sensitivity
Networks and relationships are particularly important in communities prior to, during and in the recovery process after extreme events and disasters (Jakes and Langer, 2012).

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[14] Keenan and Oldfield: Climate change & flood adaptation Weather and Climate, 32(2), 40-61 40 The Urban Impacts Toolbox: An initial assessment of climate change flood adaptation options for Westport N J Keenan1 , S G Oldfield2

[15] Report to Council Recommendations of the Westport Working Group

Jakes PJ, Langer LE. 2012. The adaptive capacity of New Zealand communities to wildfire. International Journal of Wildland Fire 21: 764–772.
This was a study of the effects of a large wildfire on a South island community. It found that residents went to the pub to talk about the fire and had a barbeque for the firemen. The only substantial losses were to farmers' livestock. There was no community support to make good these loses.

Score: 2

As a result, erosion of these networks as a community shrinks can increase the sensitivity, and decrease the ability, of the community to respond to future events. The communities that are most likely to be sensitive to this risk include those with livelihoods that depend on the natural environment. For example, farming communities are highly sensitive to events that disrupt farming practices, which lead to financial losses and have impacts on mental health, social cohesion and community wellbeing (Krishnamurthy, 2012). This risk may cascade through the natural environment and economic domains rather than resulting directly from exposure to a hazard.

Krishnamurthy PK. 2012. Disaster-induced migration: Assessing the impact of extreme weather events on livelihoods. Environmental Hazards 11(2): 96–111.
This is a general review on an international scale mostly focusing on developing countries. It has limited relevance to New Zealand.

Score: 3

Communities that are most likely to be exposed to this risk:

1. *communities in low-lying areas facing the impacts of coastal erosion and ongoing sea-level rise. These hazards increase the risk of disruption to livelihoods and communities in both the short and long term (Stephenson et al, 2018* **See above***). As the frequency of disruption increases, so does the likelihood that those who can move will move. (Lawrence et al, 2018).*

Lawrence J, Bell R, Blackett P, Stephens S, Allan S. 2018. National guidance for adapting to coastal hazards and sea-level rise: Anticipating change, when and how to change pathway. Environmental Science and Policy 82: 100–107
This paper referenced sea level rise exposures estimates from an earlier paper prepared for the Parliamentary Commissioner for the Environment. The Paulik study should have been referenced with appropriate caveats with respect to the methodology.

Risk exposure (replacement value of buildings only) around the New Zealand coast has been estimated at $3 billion and $19 billion (2011 NZ$) for coastal land elevations within 0.5 and 1.5 m respectively of spring high tide mark – based on ~85% of developed areas (Bell et al., 2015).

Score: 5

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2. *communities on floodplains, or in areas potentially affected by waterlogging (due to groundwater changes), which may cause parts or all of the community to be relocated.*

3. *Ethnically and culturally homogeneous communities, who generally experience a decline in social cohesion as diversity increases (Laurence and Bentley, 2016)*

Laurence J, Bentley L. 2016. Does ethnic diversity have a negative effect on attitudes towards the community? A longitudinal analysis of the causal claims within the ethnic diversity and social cohesion debate. European Sociological Review 32(1): 54–67.

What the NCCRA authors probably had in mind here are small relatively isolated Maori communities. The cited study by Laurence and Bentley was actually about the behaviour of immigrant communities to the UK as they begin to voluntarily move from immigrant enclaves to the wider community. Contrary to what is implied by the reference to the paper, its conclusion does not support the loss of social cohesion argument.

This article performs the first longitudinal test of the impact of diversity, applying fixed-effects modelling methods to three waves of panel data from the British Household Panel Survey, spanning a period of 18 years. ….the findings suggest that changes in community diversity do lead to changes in attitudes towards the community. However, this effect differs by whether the change in diversity stems from a community increasing in diversity around individuals who do not move (stayers) or individuals moving into more or less diverse communities (movers). Increasing diversity undermines attitudes among stayers. Individuals who move from a diverse to a homogeneous community report improved attitudes. **However, there is no effect among individuals who move from a homogeneous to a diverse community**.

Score: 1

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4. *Individuals who rely on strong social networks for support (for example, the elderly) are more sensitive to loss of social cohesion (Wistow et al, 2015) and connectedness.*

Wistow J, Dominelli L, Oven K, Dunn C, Curtis S. 2015. The role of formal and informal networks in supporting older people's care during extreme weather events. Policy and Politics 43(1): 119–135.

This paper is a rather thin attempt to argue that the elderly will be disproportionately affected by climate change because, for example, they are heavy user of health systems that coud be disrupted by climate events. It was based on case examples of two villages with a high proportion of the elderly and caregivers. They were resilent to flooding events but less so to freezing weather and snow, which presumably will become less of a problem with climate change.

the communities were quite resilient in general to short run weather related events, such as occasion when the local area flooded following an extended period of heavy rain in September 2008, closing the bridge over the river to the south of the villages. Whilst the effects of the flooding were severe, they were short lived, for most residents.

For most of those we interviewed, regardless of whether they were receiving or delivering care services, a prolonged period of freezing weather with snow in the winter of 2009/10 was most disruptive to both villages because local roads and pathways were blocked for much longer than during the floods.

Community connections, along with many other factors, were generally identified as contributing to resilience.

Score: 2

Adaptive capacity

A sense of community, social cohesion and community wellbeing is vital for resilience and adaptive capacity (Jakes and Langer, 2012 **(See above)** *; Tompkins and Adger, 2004). The importance of this outlook is shown in community responses to historical events. When Mt Ruapehu erupted in 1995/96, a sense of community and self-efficacy was an important predictor of people's resilience and the capacity to respond (Tompkins and Adger, 2004). The ability of this community to cope would have been compromised without such connections and cohesion.*

Tompkins E, Adger N. 2004. Does adaptive management of natural resources enhance resilience to climate change? Resilience Alliance Inc 9(2): art. no. 10.

This paper focused on 'community resilience building' in a coastal community in Trinidad Tobago. There was, however, a short reference to New Zealand.

In New Zealand, for example, after the volcanic eruption of Mt. Ruapehu, it was found that self-efficacy and a sense of community were good predictors of community resilience and

increased community capacity to respond to sudden changes (Paton et al. 2001). Most importantly, Paton and colleagues recognize the importance of the nature of social relationships as a factor that can enhance resilience.

Score: 3

Maintaining social cohesion and community wellbeing through displacement and movement of people requires a recognition that adaptation in other domains will affect this risk. For example, good governance and inclusive decision-making processes are needed to develop adaptation options that will be acceptable to communities, and minimise risks to cohesion and wellbeing.

Anticipatory governance and effective decision-making through uncertainty is needed to reduce exposure to this risk, by ensuring communities do not become established in areas prone to climate change hazards that may lead to displacement.

The Jakes and Langer paper (see above) shows that social cohension and adaptive capacity did not help the farmers who were worst affected. Rather, insurance and government support are generally the vital components for community resilence and recovery in New Zealand. 'Urgency' in building social cohesion for events that might become a little more serious fifty years or more in the future is an obvious overreaction.

Consequence
Populations displaced by disasters and climate change will change the composition of communities, impact on housing and labour markets, require adjustment to regional development planning, and alter the level and pattern of demand for social services. Displaced people may also lose their local support networks, and communities receiving them might be unwelcoming of new and different community members, contributing to or causing tension and conflict (Boege, 2018; Campbell, 2019)

Campbell JR. 2019. Climate Change, Migration and Land in Oceania Tokyo: Toda Peace Institute.
This report discusses climate change in Pacific Islands.

Rating: 0

Boege V. 2018. Climate Change and Conflict in Oceania: Challenges, Responses, and Suggestions for a Policy-Relevant Research Agenda. Tokyo: Toda Peace Institute.
This report also relates just to Pacific Islands.

Rating: 0

In New Zealand, for example, Kelso was a small town of 200 residents that experienced severe floods in 1978 and then again 15 months later. Flood mitigation works to increase protection were considered unaffordable, and residents relocated on an individual basis, dependent on the level of perceived risk to households (Glavovic et al, 2010). This led to the closure of community amenities and the eventual relocation of remaining residents to neighbouring towns (Glavovic et al, 2010). The townspeople have held reunions since then, but the social bonds in the community were ultimately broken.

Glavovic BC, Saunders WS, Becker JS. 2010. Land-use planning for natural hazards in New Zealand: The setting, barriers, 'burning issues' and priority actions. Natural Hazards 54: 679–706.

As noted above this paper is a general discussion of the relationship between land use planning and natural hazards with the objective of reducing hazards. There was no discussion of the costs of reducing those hazards. It had this to say on the Kelso experience:

Residents subsequently held reunions. But this longstanding, close-knit community could not sustain community ties once they relocated.

More focused analysis of the social impacts of alternatives, an inclusive and collaborative planning process and dedicated governmental support, may have enabled the residents to relocate in a way that sustained community ties.

The possiblity that residents were not particularly bothered by the 'loss of community' was not condidered. New Zealand is a highly mobile society and large numbers of people move from local communities without obvious consequences for social stability.

Score: 4

Interacting risks

No additional information.

Confidence: High agreement, moderate evidence

Almost all of the assessments had a high level agreement on the assessments. This just reflects the level of group think amongst relatively small groups of the NCRRA assessment participants.

Adaptation

Neither the literature review nor the consultation process identified any adaptation actions for this risk.

This should not be a surprise. There is no evidence in the assessment of any adaptation measures that would address a real issue.

H2: Risks of exacerbating existing inequities and creating new and additional inequities due to differential distribution of climate change impacts

Consequence assessments
Now: Major
2050: Extreme
2100: Extreme

Urgency score: 85

Tailrisk summary

There is no credible evidence that climate change will increase inequality in a material way. If there is an adverse effect it is probably the impact on wealthier people who own beachfront property and are more likely to be affected by sea level rise.

The assessment is based on the largely false premise that there will be a large increase in extreme weather events and lower income people will fare worse in these events.

It is claimed that climate change is already having a major effect on inequality but there is no discussion of the impact of historical climate change anywhere in the assessment.

Tailrisk consequence assessment: Negligible

Evidence quality score: 3.28

NCCRA discussion

Risk summary

Exposure to extreme weather events such as flooding or heatwaves, or to ongoing, gradual changes such as inundation of low-lying areas, will be the same for communities and individuals in affected areas. However, the ability to respond or adapt to or cope with these risks is uneven, due to existing inequalities (Ellis, 2018).

Ellis L. 2018. How Should the Risks of Sea Level Rise be Shared? Discussion document for Deep South National Science Challenge. Wellington: NIWA.

The focus of this paper was on the potential local government liabilities. A key issue is the extent that local councils and their residents bear the cost of seafront protection. The closest the report came to an inequality focus is an observation that:

because of its size, local government is reportedly particularly vulnerable to being captured, or at least heavily influenced, by well-organised property lobbies.

As a majority of residents in most communities are property owners it should not be a surprise that they are influencial, nor should their influence be regarded as a bad thing In a democratic society.

Score: 3

Those experiencing marginalisation due to demographic factors such as age, race, ethnicity, socio-economic status, gender, literacy or health may be unable to access resources to respond to climate risks (Ton et al, 2019). An inability to convert resources to action can also create and exacerbate existing inequities (Ton et al, 2019).

Ton KT, Gaillard JC, Adamson CE, Akgungor C, Ho HT. 2019. Expanding the capabilities of people with disabilities in disaster risk reduction. International Journal of Disaster Risk Reduction 34: 11–17.

The focus of this paper is on disabled people in developing countries where the risks are higher and the capacity of the state to assist much lower, than in New Zealand. Obviously people with disabilities will be at a relative disadvantage compared to the able bodied in an extreme weather event. Given the low number of serious climate disasters in New Zealand, and the small (if any) increase in their frequency, there is unlikely to be a material increase in risk to disadvantaged people from these events.

Score: 4

New inequities may emerge, especially with respect to slowly emerging risks such as sea-level rise. Exacerbation of existing inequalities and creation of new ones can have cascading impacts on livelihoods and wellbeing.

This is unsupported conjecture.

Exposure

Extreme events and ongoing, gradual changes will be spread across all regions of New Zealand and may intersect with existing sources and experiences of social vulnerability and inequality. For example, flooding and waterlogging hazards often occur in the low-lying areas of South Dunedin. A significant proportion of this community has socio-economic deprivation scores of between 8 and 10 (Stephenson et al, 2018).

Stephenson J, Orchiston C, Saunders W, Kerr S, MacMillan A, McKenzie L, … Willis S. 2018. Communities and Climate Change: Vulnerability to Rising Sea and More Frequent Flooding. Wellington: Motu

This paper starts with the example of flooding in South Dunedin, which is a lower income area, that leads on to a more general argument:

All of these impacts have financial implications for people who own property as well as those who rent, but will affect them differently. Owners of houses and businesses may find the value of their assets declining and at the same time may need to undertake unanticipated repairs or alterations. More well-off people will be in a position to buy elsewhere, but less wealthy people may find this challenging. If they seek to sell their property they are likely to find that its value has declined. In some cases they may be unable to afford the repairs and end up living in substandard housing.

If the affected houses experience proportionate declines in value then there will be a proportionate impact on the wealth of the owners. As beachfront properties tend to be owned by the better off, climate change may have an equalizing effect on wealth inequality overall. It the value of a property has declined then this will not affect the owner-occupier's capacity to make repairs as the decline in value will not affect their income.

Tenants may find themselves living in increasingly substandard conditions if landlords see little value in investing in maintenance or upgrades due to the declining value of their asset (Barnett et al., 2015). There is a risk that tenants with little economic power will either stay on as the properties decline in quality, or move in because they are attracted by low rents, thereby increasing the stratification of neighbourhoods.

Lower income tenants are more likely to be advantaged than disadvantaged unless there is a forced evacuation. An increase in the supply of cheaper, lower quality

rental houses, which lower income people will disproportionately rent, will lower rents.

None of this is evidence that lower income people will be disproportionately affected than higher income people.

Score: 5

Conversely, changing exposure may create new inequities as the hazards increase and impact on new groups of people and communities.

This is conjecture without any argument or evidence.

Exposure to this risk will be greater under RCP8.5 than RCP4.5 and will increase over time, potentially compounded by factors of inequality spreading from other domains.

Which is not saying very much.

Sensitivity

Sensitivity is influenced by social, cultural, political and economic processes (Adger et al, 2004). Sensitivity and adaptive capacity are place-dependent; they differ depending on the climate hazard and vary over time (Cutter and Finch, 2008).

New indicators of vulnerability and adaptive capacity W Neil Adger, Nick Brooks, Graham Bentham, Maureen Agnew and Siri Eriksen January 2004

This paper developed a conceptual framework for measuring vulnerability to climate change. It does not tell us anything about the direction and extent of any impact. The Cutter and Finch paper similarly does not get into specifics.

Score: 3

For example, the Intergovernmental Panel Change's (IPCC's) Climate Change 2014: Impacts, Adaptation, and Vulnerability (2014) differentiates between vulnerability before a crisis or disaster (for example, drought or flood) and subsequent vulnerability in the post-disaster and recovery processes. The following characteristics are understood to be key sources of sensitivity to extreme events associated with climate change.

- *Socio-economic disparities: The socio-economic disparities between Māori and non-Māori communities mean that sensitivity to climate change impacts and risks are higher for Māori society (Manning et al, 2015).*

Manning M, Lawrence J, King DN, Chapman R. 2015. Dealing with changing risks: A New Zealand perspective on climate change adaptation. Regional Environmental Change 15(4): 581–594.
The full publication was not freely available so we relied on the abstract. There did not appear to be any discussion of inequality impacts beyond the following:

Ongoing socioeconomic changes in New Zealand also raise the risk of structural effects caused by climate change impacts becoming unevenly distributed across society.

Score: 2

• *Socio-economic status: In general, people living in poverty are more sensitive to the impacts of climate change hazards (Fothergill and Peek, 2004).*

Fothergill A, Peek L. 2004. Poverty and disasters in the United States: A review of recent sociological findings. Natural Hazards 32(1): 89–110.
This review paper had a limited discussion on climate disasters.

Mobile homes, also most often occupied by lower and working class groups, are the most dangerous types of buildings in a tornado. In 1994, almost 40% of all tornado fatalities occurred in mobile homes (U.S. Department of Commerce, 1995). While Bolin and Bolton (1986) acknowledged that living in beachfront property exposes all residents, regardless of SES, to the risks of hurricanes,

New Zealand does not have many mobile homes and tornados.

In South Carolina, 60,000 people, many of whom were low-income and ethnic minority residents, were reported to have become homeless as a result of Hurricane Hugo (Federal Emergency Management Agency, 1990). Aguirre (1988), in his study of a 1987 Texas tornado, found that less powerful groups, such as the poor, faced higher disaster impacts, such as injury and death.

In the Midwest heat disaster in 1980, there were 148 heat related deaths and most of the victims were from the inner-city, elderly, and from a low socioeconomic bracket (U.S. House of Representatives Testimony, 1980). measures (p. 3). In another heat wave disaster in Chicago in July 1995, 739 people died, the majority of whom were low-income (Klinenberg, 2002)

Score: 3

Ethnicity: Ethnic communities are often geographically and economically isolated from jobs, services and institutions.

In New Zealand all ethnic groups are heavily urbanised and not isolated except for relatively small groups.

Discrimination also plays a major role in increasing the sensitivity of ethnic minorities (Fothergill et al, 1999).

Fothergill A, Maestras E, Darlington J. 1999. Race, ethnicity, and disasters in the United States: A review of the literature. Disasters 23(2): 156–173.
This literature compilation reported:

We show that studies have important findings, many illustrating that racial and ethnic communities in the US are more vulnerable to natural disasters, due to factors such as language, housing patterns, building construction, community isolation and cultural insensitivities.

As this was just a compilation we were unable to assess the merits of the arguments. We are unaware of any literature that has demonstrated thatethnic minorities have been discriminated against in New Zealand natural disasters. There may have been instances of positive discrimination.Uninsured homeowners were biled out after the Edgecumbe flood. Forty-six percent of the popultion identify as Maori.

Score: 2

Where minorities are immigrants from non-English-speaking countries, language barriers can greatly increase vulnerability to a disaster (Trujillo-Pagan, 2007).

Trujillo-Pagan N. 2007. Katrina's Latinos: Vulnerability and disasters in relief and recovery. In: KA Bates, RS Swan (eds) Through the Eye of Katrina: Social Justice in the United States. Durham, NC: Carolina Academic Press. pp 147–168.

The New Orleans experience with hurricane Katrina does not have any obvious and clear implications for New Zealand. New Zealand does not have any cities that are currrently below sea level and there is a vanishingly small probability that New Zealand will experience the Katrina storm surge of 8 metres. The highest recorded surge experienced in New Zealand is about 0.8 metres.

Score: 2

Gender: Following disasters, women and children are often vulnerable. Evidence indicates that lower-income women experience and navigate ongoing job and house displacement,

increased domestic violence, and reduced access to children's education and to childcare after extreme events (Freudenburg et al, 2008).

Freudenburg W, Gramling R, Laska S, Erikson KT. 2008. Organising hazards, engineering disasters? Improving the recognition of political-economic factors in the creation of disasters. Social Forces 87(2): 1015–1038.

According to the abstract this paper focused on the causes of the flooding disasters in the upper Mississippi River Valley and the Katrina-related devastation of New Orleans.

In the former case, damage was caused in part by building the very kinds of higher and stronger floodwalls that were shown to be inadequate in the latter. In the New Orleans case, a more important factor in the death and destruction was the excavation of a transportation canal. In both cases, and many more, the underlying causes of damage to humans as well as to the environment has involved a three-part pattern, supported by the political system--spreading the costs, concentrating the economic benefits and hiding the real risks. In very real senses, these have been floods of folly, created not just by extreme weather events, but by deadly and avoidable patterns of political-economic choices.

The paper didn't appear to have to much to do with post disaster consequences.

Score: 0

Unequal participation in labour markets and decision-making processes compound inequalities (Enarson, 2007).

Enarson E. 2007. Chapter 13: Identifying and addressing social vulnerabilities. In: WL Waugh, K Tierney (eds) Emergency Management: Principles and Practices for Local Government (2nd ed.). Washington, DC: ICMA Press. pp 257–278.

Not available.

Research also shows that the incidence of domestic violence increases following extreme events, such as fires (Parkinson and Zara, 2013).

Parkinson D, Zara C. 2013. The hidden disaster: Domestic violence in the aftermath of natural disaster.

This was a report on research by Women's Health Goulburn North East following a bushfire disaster.

Interviews with 30 women and 47 workers in Victoria after the 2009 Black Saturday bushfires provided evidence of increased domestic violence, even in the absence of sound quantitative data and in a context that silenced women. Community members, police, case managers, trauma psychologists and family violence workers empathised with traumatised and suffering men-men who may have been heroes in the fires-and encouraged women to wait it out. These responses compromise the principle that women and children always have the right to live free from violence.

Score: 5

- *Age: Disruptions created by a disaster can have significant psychological and physical impacts on children. The elderly are likely to suffer health problems and experience a slower recovery, and tend to be more reluctant to evacuate their homes in a disaster (Ton et al, 2019.* See above *).*

- *Disability: People living with mental or physical disabilities are less able to respond effectively to disasters, and require additional assistance in preparing for and recovering from disasters (McGuire et al, 2007).*

This seems obvious.

- *Other factors such as perceived risk, previous experiences and trauma, social networks and informed climate change knowledge all influence sensitivity to risks (Freudenburg et al, 2008* (See above).

Sensitivity associated with ongoing, gradual change is less well known, but it is becoming apparent that the distribution of climate change risk is changing across society. For example, wealthy asset owners of coastal properties, who may have significant mortgages, could enter more precarious situations if they experience insurance retreat and are impacted by an extreme event.

This suggests that 'inequality' will reduce with sea level rise.

Adaptive capacity

Inequity and adaptive capacity are related; inequity can hinder adaptive capacity and a lack of adaptive capacity can intensify social vulnerability (Fisher, 2011).

Fisher B. 2011. Climate change and human security in Tuvalu. Global Change, Peace and Security 23(3): 293–313.

This is a paper on Tuvalu, which is very vulnerable to sea level rise, and is not helpful for understanding of the New Zealand situation.

Score: 0

Those community members most likely to be affected are simultaneously the least empowered or accustomed to contributing to decision-making processes (Barnett and O'Neill, 2010). Decisions can lead to inequitable outcomes or maladaptation that further entrenches inequity (Barnett and O'Neill, 2010; Guerin, 2007).

Barnett J, O'Neill S. 2010. Maladaptation. Global Environmental Change – Human and Policy Dimensions 20: 211–213.

This was a discussion of a project to increase Melbourne's water supply. The 'maladaptation' was that the 11 percent increased cost of water would fall disproportionately on lower income households.

These costs will impact disproportionately on poorer households, who pay a higher share of their incomes on water and power, and who do not have the same opportunities to reduce water use that wealthier households have for reasons of income and land tenure (Lee, 2007).

Score: 5

Socio-economic conditions such as age, gender, social networks and social capital – in conjunction with past experiences, perceived risk and informed knowledge – impact on the ability to adapt. Limited knowledge or understanding of climate change risks, which can be a consequence of lack of access to information, can result in maladaptation and path dependency and constrain adaptive capacity, further exacerbating inequity. For example, development of coastal areas and low-lying land that is exposed to inundation and flooding, or reliance on hard protection measures such as structural flood controls to mitigate risk, can lead communities to perceive that they are protected (Manning et al, 2015 (See above).

Inclusive decision-making and adaptation strategies that help increase self-efficacy and empower individuals to participate may help to address existing inequities and limit future ones from arising (Stephenson et al, 2018 -See above), *(Tompkins and Adger,* 2004 (See above).

Consequence

The ability to access resources to meet individual, family and community wants and needs is already unequally distributed across society, with some groups experiencing marginalisation and poor social outcomes (for example, in health, employment, access to education or welfare and support services) compared with others.

Climate change is likely to exacerbate these existing inequities and generate additional and new inequities as communities experience climate change-related impacts.

There is no substantive evidence to support these assertions in the above discussion.

One question is who will fund the response to climate hazards, particularly managed retreat (Boston and Lawrence, 2018). Financial assistance to affected communities and households after natural disasters is currently ad hoc (Boston and Lawrence, 2018). For example, the Government announced after severe flooding of Edgecumbe in 2017 that it would be responsible for the clean-up and repair of all affected properties, including the uninsured and those unable to afford repairs (Boston and Lawrence, 2018). However, many other communities affected by similar extensive flooding have not received such funding.

Boston J, Lawrence J. 2018. Funding climate change adaptation: The case for a new policy framework. Policy Quarterly 14(2): 40–49.

This paper was discussed in part 6. Above.

The Edgecumbe bailout probably disproportionately benefited lower income people and there is no reason to expect that this political propensity will change. 100 properties that were uninsured were bailed out. Well-off owners of beachfront properties, who neglect to insure will probably not be treated as sympathetically.

Score: 7

Interacting risks

No additional information.

Confidence: High agreement, medium evidence

Adaptation

Although efforts to address social inequities in a more general sense are under way, few have a component concerned with climate change adaptation

This is not a surprise given the paucity of the evidence that climate change will impact on inequality.

H3: Risks to physical health from exposure to storm events, heatwaves, vector-borne and zoonotic diseases, water availability and resource quality and accessibility due to changes in temperature, rainfall and extreme weather events

NCCRA consequence assessments

Now: Minor
2050: Moderate
2100: Major

Urgency: 83

Tailrisk summary

The health risk assessments are mostly based on assertions and conjectures. The fiscal impact, if there is one, should be trivial. The only substantive piece of evidence related to increased heat stress deaths. However, this was based on an outdated study, that measured the impact on the fragile elderly and cannot be applied to the wider population. Later evidence suggests that populations adapt to gradual increases in average temperatures so no significant impacts can be expected as the climate gradually warms. The main impact will probably be a reduction in cold weather related deaths.

There is no evidence of temperature related differences in health outcomes across New Zealand despite average temperature differences of 5 degrees centigrade from north to south.

Tailrisk consequency assessment: Negligible

Evidence quality score: 3.44

NCCRA Discussion

Risk summary

New Zealanders are already experiencing physical health impacts from climate hazards such as wildfire, floods, heatwaves, droughts and storms (Jones et al, 2014b).

Jones R, Keating G, Hales S. 2014b. Health and equity impacts of climate change in Aotearoa-New Zealand, and health gains from climate action. New Zealand Medical Journal 127(1406): 16–31.

This paper did not present any evidence of the current impact of climate change on health. It just stated the following:

New Zealand is already affected by a range of diseases that are sensitive to climatic factors,26–29 and climate trends may well be affecting New Zealanders' health and wellbeing, although such effects are not yet well quantified.

Score: 0

These hazards are projected to increase in frequency and severity. New Zealanders will also become exposed to zoonotic and water-borne diseases, which result from changes in the distribution of species, and changes in hydrological systems (Cann et al, 2013;

Cann KF, Thomas DR, Salmon RL, Wyn-Jones AP, Kay D. 2013. Extreme water-related weather events and waterborne disease. Epidemiology and Infection 141(4), 671–686.

This paper was an international literature search on waterborne disease outbreaks following climate events. Between 1910 and 2010 87 events were identified. The paper did not distinguish between outbreaks in modern developed temperate countries and outbreaks in developing countries. It did not identify trends in the frequency and severity of these events.

Score: 3

Human health will also be impacted indirectly from the influence of drought and heavy rainfall events on water availability and quality (McBride et al, 2014; Woodward et al, 2001).

McBride G, Tait A, Slaney D. 2014. Projected changes in reported campylobacteriosis and cryptosporidiosis rates as a function of climate change: A New Zealand study. Stochastic Environmental Research and Risk Assessment 28(8): 2133–2147

This paper assessed the impact of climate change on the reported incidence rates for two pathogens: the bacterium *Campylobacter* and the protozoanoo cyst *Cryptosporidium*. Unfortunately the full study was not freely available on line and we had to rely on the abstract, which does not describe what is driving the modelling. The only reported result was that:

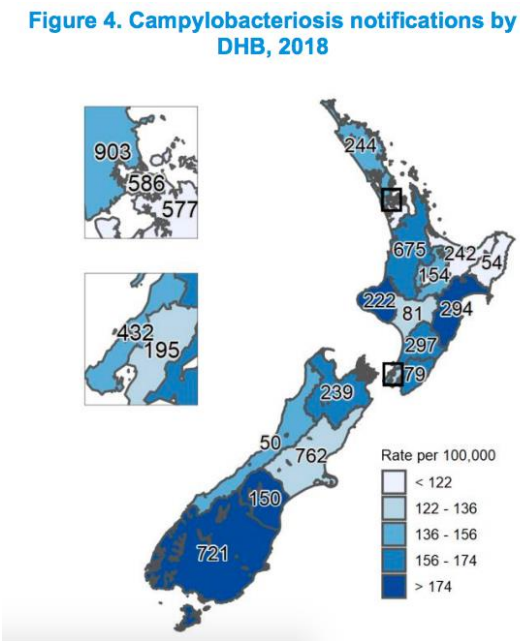
reported campylobacteriosis are predicted to rise by as much as 20 % and by 36 % for cryptosporidiosis (children, A2 scenario, 2090).

The reporting of the result for children suggests that the increases for the general population would be smaller than twenty and thirty six percent. In terms of the impact on the health system, the impact, if there is one, will be small. Campylobacteriosis infections are mostly relatively innocuous and most are not reported. The economic cost is under $1000 per infection with a possible cost of $ 35 million per year (Tailrisk 2020, Sapere 2016), which could be doubled to account for all entric illnesses. An increase of, say, 10 percent would impose a $7 million health burden. There are currently about 500 hospitalisation for campylobacteriosis each year so there might be another 50 admissions at a total cost of around $500,000 (cost per hospitalisation from Sapere).

The McBride analysis does not take account of adaptation to increased temperatures. As temperatures increase people may become more concious of the need to be more careful with food preparation and change their behaviour accordingly.

A line of enquiry that has not been pursued is the relationship between infections and average temperature in different New Zealand regions. Below is a figure for campylobacteriosis infections rates by region in 2018. There is no obvious positive relationship between the number of infections and north south geography – which roughly equates to temperature differences. Indeed the opposite appears to hold. Obviously year to year figures will be affected by region specific events and the north/south locations are an imperfect proxy for summer temperatures so a systematic study may reveal a different pattern.

Figure thirteen: Campylobacteriosis notification rates by DHBs



Score: 8 As the overall increase in notifications was not reported it is not possible to fully assess the significance of this result.

Woodward A, Hales S, de Wet N. 2001. Climate Change: Potential Effects on Human Health in New Zealand. Wellington: Ministry for the Environment.
On heavy rainfall this paper reported the following:

Approximately **one** drowning a year is recorded by the New Zealand Health Information Service as due to "floods and civil emergencies" (Margaret Warner, personal communication), but this is almost certainly an under-estimate of the number of deaths in which extreme weather conditions are a contributing element.

On the impact of floods and drought on the quality of water there was the following:

Droughts add to the pressures on drinking water supplies, jeopardising both the quantity of flows and their quality. Heavy rainfall events may also be associated with outbreaks of waterborne infections. For example, research in the United States has shown an association between intense rainfall events and outbreaks of campylobacteriosis (Rose et al., 2001). One explanation for this finding is that heavy run-off may cause animal wastes to be washed into reservoirs in sufficient quantities to overwhelm treatment processes. Similar studies have not been carried out in this country. However, the high density of farm animals in many parts of the country, the fact that many communities rely on ground water sources, and the variable level of monitoring and treatment of drinking water supplies mean that New Zealand may be equally susceptible.

No assessment was made in the NCCRA on whether New Zealand water sources are in fact being overwhelmed by run-offs from farm animals. This is unlikely because water supplies are typically kept separate from farming (with the exception of Havelock North). In any event this problem will be addressed by ungrades under the three waters programme.

Score: 3

Further, climate change will alter the quality and access of resources that support human health and wellbeing, such as food, water, outside space and clean air (Royal Society | Te Apārangi, 2017). These climate change impacts will affect the physical health, safety and wellbeing of New Zealanders.

We have reviewed the full Royal Society report. There was no evidential support for the claim that there will be negative impacts on the 'quality and access' of resources that support human health and wellbeing.

Exposure

Extreme weather events that have direct impacts on health, safety and wellbeing, particularly heatwaves, wildfire and flooding, are projected to increase in frequency, intensity and spatial extent (see section 2).

Heat mortality and other heat-related illnesses are likely to be exacerbated by the urban heat island effect. Urbanisation results in the replacement of natural vegetation with non-permeable materials; these materials store heat during the day and release it at night, exacerbating heat mortality and heat-related illnesses in urban areas (Oleson et al, 2015).

Oleson KW, Monaghan A, Wilhelmi O, Barlage M, Brunsell N, Feddema J, ... Steinhoff DF. 2015. Interactions between urbanization, heat stress, and climate change. Climatic Change 129(3–4): 525–541

This is an empirical paper showing the extent that large urban areas applified temperature increases in four large North American cities..

Heat island effects are likely to be less pronounced in New Zealand because we do not have large densely populated conurbations. The heat island effect will already be implicitly captured in studies of the overall impact of heatwaves so mentioning the effect does not add to the risk assessment.

Score: 5

Increased heat, particularly in urban areas, has also been shown to interact with and worsen air pollution (Xu et al, 2014).

Xu L, Yin H, Xie X. 2014. Health risk assessment of inhalable particulate matter in Beijing based on the thermal environment. International Journal of Environmental Research and Public Health 11(12): 12368– 12388.

A study of Beijing's air pollution has next to nothing to say about New Zealand risks.

Score: 0

Wildfires, as well as posing direct risks to life and health, can produce smoke that significantly impacts air quality, both locally and in other regions of New Zealand.

There is no assessment of the direct life and injury risk of wildfires in New Zealand or how these risks would evolve with climate change. And there is no analysis of the extent to which wildfires affect average air quality.

We were able to recover the following information on injuries and deaths from vegetation fires provided by Fire and Emergency New Zealand in response to an OIA request in 2017. The average number of injuries per year was 5 and the number of deaths was 0.6. Even if there was a material increase in the incidence of wildwifes in future the death and injury rate will still be inconsequential from a national health risk perspective. Note that not all vegetation fires would qualify as wildfires.

Table twenty: Vegetation fires deaths and injuries

Year	Deliberately lit	Total fires	Injuries	Deaths
2006/7	3336	5668	6	0
2007/8	3848	6416	5	0
2008/9	3181	5037	5	2
2009/10	2952	4859	4	1
2010/11	2748	4674	7	0
2011/12	1715	2809	2	0
2012/13	3047	5403	7	1
Total			36	4

Although New Zealand is still relatively free of exotic vectors that transmit introduced parasites and pathogens to humans, an increase in average temperatures will extend the suitability of climate for exotic vectors, encouraging their migration and subsequent transmission of disease (Derraik and Slaney, 2007).

Derraik JGB, Slaney D. 2007. Anthropogenic environmental change, mosquito-borne diseases and human health in New Zealand. EcoHealth 4(1): 72–81.

This paper concludes that there is an increased likelihood of mosqitos, that could be a vector for disease transmission, becoming established in New Zealand. There is no attempt to assess the increase in this likelihood at various temperature increases or to discuss its consequences. There is no discussion of the risks and managment of these risks in relevant warmer (by 2 or 3 degrees) developed country environments. Note that the WHO assessed the number of deaths in New Zealand from these diseases in 2090 at zero.

World Health Organization. 2014. Quantitative Risk Assessment of the Effects of Climate Change on Selected Causes of Death, 2030s and 2050s. Geneva: World Health Organization.

The WHO impact assessments for Australasia, were as follows:

Table twenty one WHO climate change assessments for Australasia

Heath risk	Deaths
Undernutrion	0
Malaria	0
Dengue	0
Diarrohal disease	0
Heat	236
Coastal flooding mortality	0

The heat death estimate is probably heavily dominated by Australia.

Score: 2

Limited information is available on the exposure to vector-borne diseases; however, it is likely that exposure will increase under RCP8.5 (McBride et al, 2014).

As noted above we did not review the full McBride paper. However, as vector-borne diseases was not the subject of this paper it is likely that the reference, if there was one, was just an aside.

Score: 1

Jones R, Bennett H, Keating G, Blaiklock A. 2014a. Climate change and the right to health for Māori in Aotearoa/New Zealand. Health and Human Rights 16(1): 54–68.
The tone of this paper is captured by this part of the abstract.

Climate change is widely regarded as one of the most serious global health threats of the 21st century. Its impacts will be disproportionately borne by the most disadvantaged populations, including indigenous peoples. For Māori in Aotearoa/New Zealand, as with other indigenous peoples worldwide, colonization has led to dispossession of land, destabilization of cultural foundations, and social, economic, and political marginalization. Climate change threatens to exacerbate these processes, adding future insult to historical and contemporary injury. Yet the challenges posed by climate change are accompanied by considerable opportunities to advance indigenous rights and reduce health disparities. In this paper, we examine issues related to climate change and Māori health using a right to health analytical framework, which identifies obligations for the New Zealand government.

The physical and mental impacts were set out in a table below. The overall impacts were taken from a literature review and analysis in the New Zealand Colledge of Public Health Medicine's 2013 Policy statement on climate change. A Maori overlay

assessement was then added. The assessments in the right hand colouns are ours. We have read the College of Public Health Medincine's report. There was no relevant evidence to support its conjectures and assertions.

Expected health impact on New Zealand	**Implications for maori health**	**Assessment**
Food security and nutrition Increase global food prices may exacerbate food insecurity and therefore compromise nutrition for some group	The higher burden of food insecurity for Maori compared to non-maori is likely to be exaccerbated	The implications for food prices are uncertain but unlikely to be material in most budgets. .As disproportioantely rural Maori would benfit from better incomes and emplyment opportunities and as farmers.
Mental health and suicide Assumes catrosphic climate change change	Loss of coastal land ,uropt, marae and other sites of coastal significance will add to the existing higher rates of suicidal behaviour experience by Maori	The physical impacts on land etc. are not assessed butare likely to be minor.
Immigration consequences Arrival of migrants and refuges may exacerbate housing shortage immigrants	Maori disproportionately experience insufficient afforable housing resulting in household overcrowding and crowding related infectious diseases. This may be exacerbated as people migrating because of climate change may also seek affordable housing	High immigation numbers combined with controls on building additional housing does increase house prices and rents. However immigration numbers can be controlled.
Injuries and illnesses from extreme weather events (eg flooding landslides , storm surges , drought.	Though most Maori now live in cities and towns many maori communities are situated in coastal areas and many maori cultural ,social , economic and recreation activities take place in coastal environments vulnerable to sea level rise, erosion storms and landslides and sea level rise. Many Maori rural and remote settlements have vulnerable infrastructure and lack of resilence to cope with and recover from extreme events. Maori also have a highe rburden of chronic disease and less access to health services and greater risk of indirect health impacts after extreme events	The number of physical injuries from climate events is very small and is unlikely to change/ Flooding is likley to decrease.
Heat related deaths and injuries: increase in heat relted deaths and injuries paricularly for those with chronic disease and for those over	Higher burden of chronic disease for Maori thus greater risk of heat related deaths. Though there are relatively small numbers of Maori over	Heat stress is only an issue for the elderly. Outside workers are unlikely to be affected materially

	65. Maori over 50 have poorer health outcomes and a higher burden of cronic disease than Maori of the same age. Maori are also overrepresented insemi-skilled or unskilled workforces and may be more likely to be employed in hevy outdoor labour and exposed to workplace heat stress.	
Vector-born and zoonotic disease	The Maori population is concentrated in the north island with many comunities situated near the coast. Thes areas are at higher risk for establishment of mosquito vectors of public health concern	This risk is very small.
Food and water born disease	A higher burden for Maori is expected given the existing higher rates of entteric infections for Maori (despite the more usual higher rates of those diseases in the elderly, among whom Maori are underrepresented, the role of Kaimoana as a regular part of maori diet and the fact that some parts of new Zealand with high Maori populations and many rural maree have unreticulated water supplies	More care may be required in summer
Ultravilet radiation Climate change may delay recovery of atmospheric ozone. Warmer weathe rmay increased or decreased outdoor time	The Maori population has a lower burden of melonoma skin cancer and non-melanoma skin cancer but higher burden of eye disease . if there is a trend to increased exxposure to solar radiation for Maori (from more time outdoors this could increase vitamen d levels which could positively impact Maori health chronic diseas burden.	Not obvious there is an issue here
Physical activity warmer temperatures may increase or decrease outdoor time may impacct on physical activity	Changes on physical activity levels would affect the burden of chronic dease for maori	Not obvious there is an issue here
Cardiovascular disease from airpoulution. Higher temperatures may exacerbate the photochemical air pollution with impacts on respiratory health. Hot dry conditions increase potentaal for bushfires where smake impacts people with cardiospirtory diseas	Maori have a higher respiratory and cardiovasclar diseas burden so the impact of increased pollution would fall more heavily on Maori. Maori mortality may be more sensitive to airpollution than non-Maori	Air polution is a relatively minor issue in New Zealand (WHO) Mitigation efforts should see internnal combustion engines off the road well before 2100
Allegic disease: possible	Greater health impacts on	Difficult to assess

imapcts on asthma an dother allegic conditions	maori population who have a higher burden of asthma and eczema than non maori	
Climate change may affect the healthiness of indoor environment	Greater health impacts on maori are expected given that the Maori population is overepresentd in vulnerable housing	Not clear why the healthiness of indoor environment would be affected and how significant this would be .

Score 4

Newcombe E, Smith H, Poutama M, Clark D, Spinks A, Ellis J, Sinner J. 2014. Faecal Contamination of Shellfish on the Horowhenua Coast. Wellington: Manaaki Taha Moana Research Team.
There is no reference in this paper to any relationship between temperature and the rate of faecal contamination.

Score: 0

These areas are most at risk from the establishment of vector-borne diseases (Jones et al, 2014a). Warmer temperatures and changes in rainfall can impact on water quality and availability, causing contamination or shortages, and heavy rainfall events can cause animal excrement and other pollutants to run off into water sources, contaminating them (Royal Society | Te Apārangi, 2017).

Royal Society | Te Paring. 2017. Human Health Impacts of Climate Change for New Zealand: Evidence Summary. Wellington: Royal Society | Te Apārangi.
There is no relevant evidence on rainfall affecting water quality in the Royal Society paper.

Higher temperatures can lead to the growth of bacteria, such as campylobacter and cryptosporidium, which thrive in a warmer climate (McBride et al, 2014 See above*) . Drought places pressure on water sources, potentially reducing the supply of water needed for maintaining hygiene* (Woodward et al, 2001 See above)

Eutrophication is likely to increase from persistent low-flow periods, or sequences of dry spells punctuated by intense rainfall – which could increase exposure to cyanobacteria and toxic algae (Hughes et al, 2019).

Hughes J, Cowper-Heays K, Olesson E, Bell R, Stroombergen A. 2019. Stormwater, Wastewater and Climate Change: Impacts on Our Economy, Culture and Society. Wellington: Deep South National Science Challenge.

The reference is to a section in the report that discusses the impacts of both reduced rainfall and higher temperatures on vegetated stormwater treatment devices, particuarly in wetlands. This is very unlikely to have implications for human health because humans do not typically access these areas. Most have a keepout sign.

Score: 2

A combination of changing weather patterns and ongoing sea-level rise may reduce the supply of healthy fresh food, leading to nutrition-related risks to human health (Royal Society | Te Apārangi, 2017).

The reference in the Royal Society document is to the results of a study by Springmann et al [16] that reports the outputs of a world climate/ag/cultural model, which was applied to individual countries, including New Zealand. It is predicted that:

In 2050, there are predicted to be an additional 140 climate-related deaths per annum in New Zealand as a result of changes (reductions) in fruit, vegetable, and red meat consumption, and bodyweight-related risk factors (increase in underweight) (including coronary heart disease, stroke, and cancer) in the adult population.

This paper does not provide a plausible picture of the effect of climate change on New Zealand and should be ignored. There is no plausible scenario where climate change will lead to a substantial reduction in fruit, vegetable and meat consumption and underweight becoming a serious risk factor.

Score: 0

Sensitivity

Vulnerable populations (H2) are particularly sensitive to the health impacts of climate change.

For example, adverse impacts on health are exacerbated by economic disadvantage and the existence of pre-existing health conditions (Jones et al, 2014b See above *). Māori in particular are sensitive to physical risks from climate change, due to the disproportionate number of Māori living in deprived circumstances, and experiencing higher rates of most major diseases than non-Māori (Jones et al, 2014b). The elderly, infants, and people with pre-existing*

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[16] Springmann, M., et al., Global and regional health effects of future food production under climate change: a modelling study. The Lancet, 2016. 387(10031): p. 1937-1946.

medicalconditions are sensitive to changes in maximum daily temperatures; age is the greatest risk factor for heat-related mortality (Wilson et al, 2011).

Wilson L, Black D, Veitch C. 2011. Heatwaves and the elderly: The role of the GP in reducing morbidity. Australian Family Physician 40(8): 637–640.
This three page paper defines a heatwave and explains why the elderly are more vulnerable to heatwaves.

Score: 5

Consequence
It is highly likely that climate change-related hazards will result in additional deaths, injury and illness. Climate change undermines many of the building blocks of good health, including clean air, plentiful safe drinking water, economic stability, and autonomy.

The health effects of climate change will not be spread evenly across the population and will exacerbate existing health inequalities. It is difficult, however, to measure and predict these changes. Data on how climate change related hazards affect health are sparse.

This is just a set of assertions. The only evidence that is provided relates to heat stress, which is discussed below.

Some deaths can be attributed to extreme weather events or climate change hazards. In Auckland and Christchurch, an average of 14 heat-related deaths occur each year among people aged over 65 years. This total may rise to 88 deaths with 3 degrees Celsius of warming, as is projected in New Zealand by 2090 under RCP8.5 ((Joynt and Golubiewski, 2019;

Joynt JLR, Golubiewski NE. 2019. Development of the Auckland Heat Vulnerability Index. Auckland: Auckland Council Research and Evaluation Unit.
Joynt JLR, Golubiewski referenced the Royal Society 2017 paper as the source of the heat-related death information. The Royal Society paper in turn referenced the underlying study by McMichael et al, which is discussed below.

Joynt JLR, Golubiewski also had a useful discussion on what causes heat related deaths.

It is the relative change of heat and the duration that defines an extreme heat event or hot day. The effects of heat exposure on individuals vary relative to the normal range of temperatures to which the population is acclimatised (Hajat & Kosatky, 2010). For example, it was the 11-12°C difference from the seasonal norm, raising

the temperature above 30°C for 10 consecutive days, that caused the 15,000 excess deaths in France in 2003 (Fouillet et al., 2006). This heat event, although extreme for France, would not be expected to cause the same impact in a city such as Dubai, where average temperatures exceed 30°C for six months of the year and the population and built environment are adapted to cope (World Weather Online, 2018). The World Health Organisation reports that temperate cities have higher rates of heat-related deaths than tropical cities (Berry, 2013; Johnson et al., 2012).

This discussion has important implications for understanding the impact of gradual increases in temperature due to climate change. People will become habituated to the higher average temperatures, and as long as the incidence of sharp and sustained increases over the heat stress threshold values does not change, then climate change should have a limited impact on heat related deaths. New Zealand's changeable climate should mean that there will be fewer instances of sustained high temperature episodes than in, say, Europe.

Score: 7

McMichael, A., R. Woodruff, P. Whetton, K. Hennessy, N. Nicholls, S. Hales, A. Woodward and T. Kjellstrom, 2003: *Human Health and Climate Change in Oceania: A Risk Assessment 2002*. Commonwealth Department of Health and Ageing
This paper analysed the relationship between daily all-cause mortality of people aged 65 and over and temperatures recorded two days before, and on the day of the death. Temperature attributable mortality started at 28 °C and increased by 3 percent per degree beyond that.

The problem with this analysis is that by only measuring temperature changes shortly before and on the day of the death it risked capturing just a 'harvesting' effect. The temperature increase accelerates the deaths of the fragile elderly who were close to death and only needed a slight trigger event to 'cause' the death. It is now recognised that this methodology substantially overstates the impact of gradual temperature increases for the reasons discussed above. In addition it is likely that over the next 80 years airconditioning will be increasingly used to mitgate the risk to the elderly.

A further problem is that the statistical analysis supporting the estimates does not appear to have been published. The upshot is that claims about increased heat stress deaths rest on a very thin evidential base.

Score: 5

Interacting risks
Health costs will increase fiscal need (E1) and are likely to entrench disadvantage (H2), erode trust in government, and lead to increased conflict (H4). In addition, physical health and mental health are strongly related: poor physical health can worsen mental health and vice versa (Ohrnberger et al, 2017).

As noted above the fiscal cost should be trivial.

Ohrnberger J, Fichera E, Sutton M. 2017. The relationship between physical and mental health: A mediation analysis. Social Science and Medicine 195 (November), 42–49.

This paper reported on an empircal study of the relationship between physical and mental health in the UK. It found indirect effects explaining 10 percent of the effect of past mental health on physical health and 8 percent of the effect of past physical health on mental health.

Score: 7

Confidence: High agreement, low evidence

Adaptation
Adaptation actions in the human domain and across other domains reduce this risk, but there are no common goals for climate change adaptation, or health sector plans for it. The Ministry of Health (Minister of Health, 2016) acknowledges that climate change has health and social consequences, but provides limited additional information.

District health boards are, in general, in their infancy in understanding the implications of climate change, but are starting to incorporate climate change into their plans. Some public health units also have institutional knowledge about climate change.

If District Health Boards understood the risks they would put off thinking about them for at least 10 years. They probably do understand that climate change related deaths are irrelevant over their planning horizons but may be reluctant to say so lest they be branded as 'deniers'.

H4: Risks of conflict, disruption and loss of trust in government from changing patterns in the value of assets and competition for access to scarce resources primarily due to extreme weather events and ongoing sea-level rise

NCCRA Consequence assessments
Now: Moderate
2050: Major
2100: Major

Urgency score : 83

Tailrisk summary

The major source of political tension is likely to be the debate about the need for managed retreat. This will be exacerbated by the kind of poorly evidenced and ideological policy responses that might be encouraged by this NCCRA. The need to respond to sea level rise will generate the ususual debates about what should be spent and who should pay. As the costs should not be prohibative and will extend over long time periods it should not put the political system under undue stress. To put the matter in proportion the review of sea level responses in Hawkes Ba lead to a proposals to impse a $60 a household levy to fund the response. Most of the evidence bought to bear on this issue in the NCCR is misleading, irrelevant or overblown.

Tailrisk consequences assessment: Moderate

Evidence quality score: 2.25

NCCRA discussion

Risk summary

Climate change is likely to exacerbate the existing stressors that give rise to conflict and disruption, particularly as the value of assets changes and competition for resources intensifies. Ongoing, gradual change, and the increase in magnitude and frequency of extreme events, are likely to affect the value of existing assets and decrease the availability of some resources (for example, land, water and safe building sites) while also increasing demand for the resources and the value of other unaffected assets. Conflict is therefore likely to arise as people compete for increasingly scarce resources such as water and arable land, and are relocated and displaced (Boege, 2018).

As noted above the Boege paper relates to Pacific islands not to New Zealand.

Score: 0

Ongoing, gradual changes may aggravate existing environmental, economic and social stressors such as water supply and food security, resulting in increased tension (Weir and Virani, 2011), and may also exacerbate existing socio-economic vulnerability.

Weir T, Virani Z. 2011. Three linked risks for development in the Pacific Islands: Climate change, disasters and conflict. Climate and Development 3(3): 193–208.
This paper is also based on the Pacific Islands with little relevance to New Zealand.

Score: 0

New tensions may also emerge if previously powerful groups in society have their interests affected and their wealth reduced due to the way climate change risks are distributed. Perceptions of unfairness and opacity in processes could also lead to tensions, particularly for adaptation funding. Competition for adaptation resources is likely to emerge rapidly, and conflict may arise from land-use changes driven by climate events such as coastal inundation, but also in response to changes in regulations and financial priorities. In addition, inadequate government response or maladaptation pathways may increase tension and reduce trust in governments.

Debates about the need for managed retreat in particular are likely to generate. tensions. This is is likely to be exacerbated by the kind of poorly evidenced and ideological policy responses that are encouraged by this NCCRA.

Exposure
As this report discusses, New Zealand's assets and resources, including buildings and transport infrastructure, cultural sites, natural ecosystems and economic sectors, are highly exposed to climate change hazards.

The view that New Zealand's economic assets are 'highly exposed ' to climate change drives the narrative about political risks. It is an exaggerted perspective. Once a realistic assessment is made on this point, most of the political concerns should be more muted.

These changes will alter the established, and sometimes contested, patterns of access to natural, economic, social and political resources. Further pressures and constraints on resource access may lead to conflict and disruption. The issue of water illustrates how New Zealand is potentially exposed to these risks. Water is a shared natural resource that is used

for community water supplies, irrigation, energy and industry (IPCC, 2007a). Changing hydrological regimes may impact on drinking water availability, particularly for rural communities that may be dependent on non-reticulated water resources (Climate Change Adaptation Technical Working Group, 2017).

This discussion mimics IPCC discussions that are relevant to some developing countries, that will be seriously affected by climate change, but are not so relelvant to New Zealand. New Zealand is not Niger. There is no evidence that climate change will impact on drinking water availability in New Zealand in a way that can not be readily addressed.

Irrigation has increased by about 55 per cent each decade since the 1960s, driving increased water demand in New Zealand (IPCC, 2007a). As early as 2007, Guerin concluded that: "New Zealand is now, however, reaching the limits of its ability to expand commercial and recreational use of natural resources (eg, freshwater and coastal space) in some regions without significant levels of direct conflict between competing users and interests." (p 7) When these pressures are combined with changing rainfall regimes (see section 2), the many users of this valuable and scarce resource may come into conflict. Other factors related to human activity, such as current land-use practices, may increase the potential for conflict by putting extra pressures on land and water resources (Boege, 2018). Population growth, agricultural intensification and social expectations each pose a challenge for managing natural resources (Guerin, 2007).

Guerin K. 2007. Adaptive Governance and Evolving Solutions to Natural Resource Conflicts. Wellington: New Zealand Treasury.

We were unable to recover this document but it is highly unlikely that the issues posed will put New Zealand political and social systems at risk in any fundamental sense. The extent to which, at the margin, climate change will exacerbate tensions about water use is the relevant issue.

Not assessed

Sensitivity

Little evidence is available on how sensitive New Zealand is to this risk. However, some early anecdotal signs are emerging from debates over the fairness of water allocation in drought-prone regions. Existing inequities and social tensions (H2) and real or perceived unfairness increase the sensitivity of relevant parties to conflict. Trusted institutions are needed to mediate the competing interests of stakeholders and help reduce this sensitivity (Boege, 2018).

On the evidence of this NCCRA and its other work ,the Ministry for the Environment is not a 'trusted institution'. We have been caught them out fabricating and misrepresenting evidence multiple times.[17]

Adaptive capacity

The ability to adapt to this challenge depends on governance processes that can actively manage stakeholder conflicts, identify future pressures, and are resilient and flexible enough to change with a changing climate (Guerin, 2007). The Resource Management Act 1991 is the core legislation for natural resource management, but has drawbacks in managing long-term resource allocations in a changing climate (Guerin, 2007). A key challenge will be finding a balance between providing certainty, being flexible and ensuring fairness so that trust can be maintained (Guerin, 2007). Wide engagement and representation of stakeholders can improve information flow, encourage buy-in to adaptation processes, and grow the trust necessary for building adaptive capacity (Guerin, 2007).

Consequence

Changing values of assets, particularly coastal assets, and competition over increasingly scarce and valuable resources such as water may contribute to conflicts between different parts of society. Conflicts over resource access can be expected, especially when actions or decisions benefit one section of society over another or are perceived as unfair. Water is a potential source of conflict. Farmers are generally concerned about water supply changes and increases in severe droughts (Niles et al, 2016).

Niles MT, Brown M, Dynes R. 2016. Farmer's intended and actual adoption of climate change mitigation and adaptation strategies. Climatic Change 135: 277–295.
The purpose of this paper was to report on a study that compared farmers' subjective norms with their intention to change their practices, and whether they had actually made changes.' There was no relationship. Farmers would make changes when they had capacity and they thought the changes would work.

Score: 7

In Australia, a history of overallocation of water in the Murray-Darling Basin has heightened the effects of prolonged droughts and led to significant conflict between irrigators, environmentalists and other water users (Connell, 2007).

Connell D. 2007. Water Politics in the Murray-Darling Basin. Alexandria, NSW: Federation Press.

[17] See Tairisk.co.nz/documents

This water allocation history in the Murray-Darling basin is of limited relevance. There are plenty of New Zealand examples that could have been used.

Score: 2

Consultation for the National Climate Change Risk Assessment for Aotearoa New Zealand also noted that some medical practices, such as renal services, consume significant amounts of water, and raised concerns about the potential for competition over scarce water in times of drought.

This is a silly concern. The amount of water consumed by medical practices will be trivial. The reference to it is indicative of the lack of perspective in the NCCRA.

Changing land use may also have implications for conflict and governance. Between 1990 and 2008, 28 per cent of high-quality land that would be suitable for many uses was converted to urban development, concentrated predominantly in Canterbury and Auckland (Ministry for the Environment and Stats NZ, 2018). Loss of land that is considered highly productive for agricultural use is occurring at the same time as pressure on food production systems is increasing (Ministry for the Environment and Stats NZ, 2018).

The amount of land that has been converted to more productive urban uses has not had a material impact on agricultural production in New Zealand. It has changed its location to some degree as market gardens have shifted in response to urban expansions. In any event the issue is to what extent climate change will exacerbate this tension. The answer is probably not very much.

In the absence of adaptive capacity, conflict and distrust in governance structures may arise over competing interests for land use. Additionally, land and infrastructure assets in low-lying areas and coastal regions are likely to become increasingly devalued, leading to social disruption and conflict, particularly in wealthy enclaves (Bengtsson et al, 2007). Competition for homes in 'safe' areas may also exacerbate other social and ethnic tensions (Bengtsson et al, 2007).

Bengtsson J, Bennett J, McKernon S, Mullan B, Page I. 2007. Climate Change Impacts in New Zealand: a cross-disciplinary assessment of the need to adapt buildings, with focus on housing. Porirua: BRANZ Ltd.

This document could not be recovered but the 'safe building' supply conclusion looks to be overblown. Very few homes are in genuinely 'unsafe' areas. The prospect that a building might be flooded once in a hundred years does not make it unsafe in the ordinary sense of the word and these buildings can be made safe by flood protection schemes. In any event, in principle, more houses can be built in 'safe' areas so the

stock adjustment over long the long time period involved will offset the demand effect. If there is a problem it will lie with the unwillingness of local authorities to allow land to be used so the market can adjust.

Score: Not assessed

Interacting risks
No new information.

Confidence: Moderate agreement, limited evidence

Adaptation
Neither the literature search nor the consultation process identified any adaptation actions for this risk.

H7: Risks to mental health, identity, autonomy and sense of belonging and wellbeing from trauma due to ongoing sea-level rise, extreme weather events and drought

NCCRA Consequence assessments

Now: Major
2050: Major
2100: Major

Urgency score: 80

Tailrisk summary

The assessment that mental health issues due to climate change is currently exceeding the coping range of most communities (this is the definition of a major consequence) is an obvious nonsense. However, a large number of people have concerns about the future. They genuinely believe that their lives could be at risk not too many decades away. The best response is to ensure that they are given accurate and balanced information.

Tailrisk consequence assessment: Minor

Evidence quality score: 2.33

NCCRA discussion

Risk summary

Climate change has several implications for the mental health and well being of New Zealanders, as the harm experienced or witnessed when exposed to extreme events can result in mental trauma (Berry et al, 2010).

Berry HL, Bowen K, Kjellstrom T. 2010. Climate change and mental health: A causal pathways framework. International Journal of Public Health 55(2): 123–132.

This is a discussion of possible pathways between climate change and mental health. It does not identify, empirically or analytically, actual relationships.

Score: 4

Mental health risks from exposure to climate hazards range from minor stress and distress through to clinically recognised disorders such as anxiety and post-traumatic stress disorders (Royal Society | Te Apārangi, 2017).

Communities may also experience disruptions to environmental and social determinants of health; disruptions to an individual's relationship with their environment can cause risks to mental health (Royal Society | Te Apārangi, 2017), as can the loss of livelihood, poverty and displacement (Berry and Welsh, 2010).

Royal Society 2017

The Royal Society paper's mental health assessment is as follows:

Mental health and well-being

As mentioned above, increased temperatures, extreme weather events, and displacement of people from homes and communities will all have significant mental health and well-being consequences [99, 100]. These range from minimal stress and distress symptoms to clinical disorders such as anxiety, depression, post-traumatic stress and suicidal thoughts [101-103]. Other consequences include effects on everyday life, perceptions, and experiences of individuals and communities attempting to understand and respond appropriately to climate change and its implications [104].

None of the references provided evidence to support the claim that the impacts will be material in an advanced country where displacement from homes will not be widespread if sensible measures are taken to protect them.

Environmental change

Degradation of a familiar environment can cause distress [105]. Research in Australia during the decade-long drought which officially ended in 2012 revealed an increase in anxiety, depression, and possibly suicide in rural populations. In these communities, concerns about financial and work-related issues were compounded by loss of hope for the future and by a sense of powerlessness or lack of control [105, 106]. For New Zealanders, the natural environment is at the heart of the nation's identity, particularly for Māori, shaping the economy, lifestyles and culture [107]. Disruption of cherished bonds between individuals and their environment, such as during the managed retreat of threatened coastal communities [108], can cause grief, loss, and anxiety.

Again, more assertions by the Society without much substance and mostly lacking relevance. Decade long droughts, whose main consequences are economic, are not predicted for New Zealand.

Threat of climate change as a stressor

Routine exposure to images, headlines, and risk messages about the threat of current and projected climate change provide a powerful and on-going stress-inducing aspect of an individual's everyday environment [109]. Between 2005 and 2016, there were on average 422 articles published per month mentioning climate change or global warming in print and online media in the New Zealand region, according to the global media database Factiva (vii). In the US, psychological responses to such stress have been shown to include heightened risk perceptions, general anxiety, pessimism, helplessness, eroded sense of self and collective control, stress, distress, sadness, loss, and guilt [109, 110].

The Royal Society may have a point here. A deluge of unfounded or exaggerated stories of impending catastrophe may have an impact on peoples' sense of wellbeing and security. A short Swedish teenager appears to have been severely affected. The solution is that bodies like the Society be more measured and responsible in their assessments and in publicising those assessments.

Score: 4

Berry HL, Welsh JA. 2010. Social capital and health in Australia: An overview from the household, income and labour dynamics in Australia survey. Social Science and Medicine 70(4): 588–596.

The relevant part of this report is:

Loss of autonomy and feelings of helplessness from being unable to stop the beach in front of your property eroding, for example, can also impact mental health. Finally, fear and grief associated with climate change and expected loss itself can cause trauma (Cunsolo and Ellis, 2018; Jones et al, 2014a).

This issue will be exacerbated if there is widespread forced managed retreat.
The trauma identified can be real but it will affect only a relatively small number of people. The trauma will be exacerbated if authorities do not allow people to protect their homes. This risks is also exacerbated by the National Coastal Policy Statement that can make it difficult for property owners to protect their proporties.

Score: 5

Exposure
Mental disorders are common in New Zealand…..
Exposure to environmental hazards is also a source of mental distress (World Health Organization, 2019). For example, mental trauma can be caused by the harm experienced or witnessed during an extreme weather event, as well as from the economic implications of damage to communities and property (Berry et al, 2010 See above *). Extreme weather events are projected to increase in frequency and intensity across all of New Zealand, and will interact with these risk factors.*

World Health Organization. 2019. Mental disorders
It was not clear what WHO document was referenced.

Score: Not scored

Adams H. 2016. Why populations persist: Mobility, place attachment and climate change. Population and Environment 37(4): 429–448.
This paper uses survey data from Peru to explore why populations experiencing environmental degradation do not move.

Analysis of these data reveals three reasons for nonmigration: high levels of satisfaction, resource barriers and low mobility potential. Immobility in dissatisfied people is more likely to be caused by attachment to place than resource constraints.

Peru is not New Zealand**.** New Zealand is a highly mobile population that generally is not highly attached to small communities where they and their ancestors have lived for hundreds of years. The communities most at risk are relatively recent beachfront settlements.

Score: 0

Disruption to the relationship between individuals and their environment, as a result of changes to that environment or moving away from a place, can cause risks to mental health (Royal Society | Te Apārangi, 2017 See above *). Trauma can also come from relocation or loss of valued places when the ability to emotionally and physical connect with a place is lost. Impacts on place attachment may occur across all of New Zealand as environments change. Grief and anxiety linked to the anticipation of future losses are likely to be prevalent among children and youth (Cunsolo and Ellis, 2018 See above). New Zealanders may also experience a loss of autonomy – the ability to affect an outcome – due to climate change.*

Royal Society 2017

There does not appear to be any such statement in the relevant section of the Royal society paper.

Score: 0

Cunsolo A, Ellis N. 2018. Ecological grief as a mental health response to climate change-related loss. Nature Climate Change 8: 275–281.

The evidence referenced in the paper is on the loss of farms in Australia due to drought and the story of a single Inuit adult subject to change. It is not clear that this had anything to do with impacts on children and youth.

Score: 0

Sensitivity

Many factors influence individuals' sensitivity to mental health issues, loss of identity, autonomy, wellbeing and sense of identity. These relate closely to factors detailed in risk H3 .

Key influences of sensitivity are reiterated below.

 Māori and Pacific people, in general, experience greater psychological distress and psychological or psychiatric disability, and have higher suicide rates than the general population (Mental Health Foundation, 2014). Māori, in general, are particularly sensitive to mental health risks from climate change, because of their strong historical and present day cultural connections with land and waterways (Jones et al, 2014a (See above)

Mental Health Foundation. 2014. Quick Facts and Stats 2014.

The relevant data is:

In the 2012/13 New Zealand Health Survey, rates of psychological distress in the last four weeks were significantly higher amongst Māori adults (10%) and Pacific adults (9%) than in

the general population (6%). Māori adults were 1.7 times as likely, and Pacific adults 1.4 times as likely, to have experienced psychological distress as non-Māori and non-Pacific adults, respectively (after adjusting for age and sex differences). People experiencing psychological distress are highly likely to have an anxiety or depressive disorder.

In the same survey, however, a similar percentage of Māori adults had been diagnosed with a common mental disorder (depression, bipolar disorder and/or anxiety disorder) at some time in their lives as for the general population (16%), while rates amongst Pacific adults are considerably lower (4%). Rates were also lower amongst Asian adults (6%).

However, rates of mental health service use by Māori are rising. The latest figures from the Ministry of Health show that in 2010/11 Māori had the highest rate of mental health and addiction service use (4938 people seen for every 100,000 Māori) and Asian people the lowest (911 people per 100,000), when compared with Pacific people and other ethnicities. The rate of Māori seen by DHBs also has risen at a faster rate in the last ten years (33.4% rise) than for non- Māori (18.5%).

There is no evidence of a higher Maori sensitivity to climate related mental health risks in Jones.

Score: 5

Women across all age groups are more likely to have been diagnosed with a common mental disorder than men; however, men are at higher risk of suicide (Mental Health Foundation, 2014).
 People living in socio-economically deprived areas have poorer mental health, and higher levels of unmet need for health care. Adults living in the most deprived areas have a higher incidence of common mental disorders and psychological distress than the general population (Mental Health Foundation, 2014).
 People in rural and remote settings have heightened sensitivity to mental health risks from extreme weather events (Royal Australian and New Zealand College of Psychiatrists, 2020). Because of their geographical isolation, they can also face increased exposure to trauma, as they typically have delayed access to support services.

Royal Australian and New Zealand College of Psychiatrists. 2020. Addressing the mental health impacts of natural disasters and climate change-related weather events.

There was no evidence in this paper that extreme weather events had a material impact on mental health but it could be true when farmers incur substantial economic losses.

Score: 3

Young people in particular are more sensitive to anxiety about the impacts of climate change (Jones et al, 2014b).

There is no evidence to support this in Jones but it may well be true. Young people may be more sensitive to a constant stream of catastrophist narratives.

Score: 0

Adaptive capacity

Adaptive capacity at the individual level is likely to depend on a mix of personal characteristics and an individual's social, economic and cultural context. Economically disadvantaged individuals often live in areas that are most at risk of environmental degradation and have less adaptive capacity as they lack the financial capital to migrate away from these regions (Adams, 2016 See above *).*

To reinterate, New Zealand is not Peru.

As a result, they face increased mental health risks. Individual adaptation actions are also impacted by institutional arrangements (Adger et al, 2005). For example, risks to mental health will worsen if emergency management responses are delayed or if efforts to reduce risk exposure are not transparent or seen as fair. There is limited investment in knowledge about the impacts of climate change on mental health, which will limit adaptation efforts.

Adger WN, Brooks N, Bentham G, Agnew M. 2004. New Indicators of Vulnerability and Adaptive Capacity: Final Project Report. Norwich: Tyndall Centre for Climate Change Research, University of East Anglia.

This is a review of indices for assessing vulnerabilities mainly of relevance to developing countries. We saw no reference to mental health as a vulnerability indicator.

Score: 0

Consequence

It is clear that New Zealanders' exposure to extreme weather events and ecosystem change will increase, increasing the impacts on mental health and wellbeing.

As the weather gets warmer and we have more stable and sunny summers wellbeing may well improve.

Increased risks to mental health are likely to lead to an increasing incidence of mental health problems and may increase the likelihood of suicide mortality (Berry et al, 2010 See above*). In New Zealand, depression and anxiety are experienced by about 13 per cent of the population (World Health Organization, 2017). Further increases in mental illness will put pressure on individuals, families, communities, and New Zealand's health system and economy. Limited research in this area makes it difficult to assess to what extent consequences are being felt in the present day and will be felt in the future.*

It is not clear that there not be a large increase in extreme weather events in New Zealand (see the changes assessment in part three) and no evidence has been produced to demonstrate that their will be material mental health impacts.

If it is '*difficult to assess to what extent consequences are being felt in the present day',* it is more difficult to see how it was concluded that communities are presently exceeding their 'coping range'. It is of course absurb to ascribe current mental health issues to the one degree of warming that has occurred over the last century.

Interacting risks
No new information.

Confidence: High agreement, limited evidence

Adaptation
There are limited targeted adaptation actions under way to address this risk in a holistic, forward-looking and integrated manner.

HO1: Opportunity for reduction in cold weather-related mortality due to warmer temperatures

In New Zealand, about 1600 more deaths occur in winter than in summer (Davie et al, 2007). New Zealand homes are, on average, colder than the World Health Organization's (WHO) recommended minimum of 18 degrees Celsius. Data collected for housing in Wellington in 2015, for example, found that the mean indoor temperature was around 15 degrees (Rangiwhetu et al, 2018). Many factors influence mortality rates, including temperature, influenza, household crowding, moisture levels and the thermal performance of buildings (Davie et al, 2007).

The World Health Organisation has never recommended a minimum temperature of 18 degrees. They said there was insufficient information to set a standard.

Rising temperatures in New Zealand may reduce winter mortality rates through impacts on household temperatures, crowding and moisture levels, but reductions in cold weather-related mortality are likely to be offset by increased heat-related illness and mortality (H3). Very little research is available to confirm this opportunity.

The evidence that cold weather deaths will be reduced is a lot more compelling than the evidence that there will be more heat related deaths. The NCCRA has simply chosen not to examine it. The evidence supporting the Warmup New Zealand campaign relied heavily on such arguments.

The relative savings and costs from less spending on heating in winter and more spending on air conditioning in summer were not considered. Our guess is that the winter savings will be substantially higher than the summer costs.

Economy domain

Consequence criteria for the Economy domain

Medium
Financial losses equivalent to 2–4% of GRP
Ongoing losses equivalent to 0.5% of GRP. Temporary impacts on businesses, livelihoods and consumer behaviour. Temporary increase in unemployment in many sectors Medium-term increase in local and central government costs

Major
Financial losses equivalent to 2–4% of GRP. Ongoing losses equivalent to 0.5% of GRP Temporary impacts on businesses, livelihoods and consumer behaviour Temporary increase in unemployment in many sectors. Medium-term increase in local and central government costs

Extreme
Financial losses equivalent to > 3 percent of GRP 1-2 percent of GDP.
Ongoing losses equivalent to 1% of GDP. Sustained impact on businesses, livelyhoods and consumer behavior.
Sustained increase in unemployment in many sectors
Longterm increase in central government costs, some loss of assets

IPCC Fifth report on economic impacts

Before addressing the indIvidual economy risk assessments is useful to read the more sober perspective in the 10th chapter of the Fifth IPCC report on Climate Change.

For most economic sectors, the impact of climate change will be small relative to the impacts of other drivers (medium evidence, high agreement). Changes in population, age, income, technology, relative prices, lifestyle, regulation, governance, and many other aspects of socioeconomic development will have an impact on the supply and demand of economic goods and services that is large relative to the impact of climate change.

Well-functioning markets provide an additional mechanism for adaptation and thus tend to reduce negative impacts and increase positive ones for any specific sector or country (medium evidence, high agreement). The impacts of climate on one sector of the economy of one country in turn affect other sectors and other countries though product and input markets. Markets increase overall welfare, but not necessarily welfare in every sector and country.

E1: Risks to governments from economic costs associated with lost productivity, disaster relief expenditure and unfunded contingent liabilities due to extreme events and ongoing, gradual changes

NCCRA Consequence assessments
Now: Minor
2050: Major
2100: Extreme

Urgency score: 90

Tailrisk assessment summary

The most serious ommission from this assessement is any modelling of the impact on the economy, which will have the most significant impact on the Government's fiscal position. This has been done elsewhere. For example 2016 OECD modelling showed a minor negative impact on Australiasia by 2060. Infometrics modelling in 2011 showed a positive impact on GDP. Generally international modelling shows that in temperate countries the negative impacts are small and can even be postive.

Added to the revenue impacts are the costs relating to climate events. The specific impacts are likely to be:
Health: Close to nil
Extreme events: Expected cost not much greater than present.
Infrastructure: Still material if economiclly rational but will depend on the overreaction effect.
Cost of funding the 'adaptation industry': Not immaterial.

Tailrisk consequence assessment: Moderate

Evidence quality score: **2.5**

NCCRA discussion

Risk summary

The costs of climate change in New Zealand are already significant (Frame et al, 2018) and will only increase over time. Almost all risks detailed in this report impact the economy and the Government's fiscal position, whether by causing a loss in revenue or by requiring additional expenditure to adapt infrastructure, respond to health needs or recover from extreme events. The damages from and costs of adapting to climate change are expected to

be a significant and growing financial burden on public authorities, who will be tasked with funding investments in adaptation, providing post-event relief and responding to health impacts.

Frame 2018

The Frame model tries to be able to segment the climate change and non-climate change components of particular climate events, including droughts, which cause the largest losses. The cost assessment was largely based on apportioning a single drought event between the costs that would have normally occurred and the extent it was exacerbated by higher temperatures.. The Frame model put the climate change cost of the 2007-8 and 2012-13 droughts at $720 million but they did not assess the likelihood of these events. If they were 1:20 year events then the annual cost would have been $36 million. The New Zealand historical evidence (NIWA) does show a small upward trend in drought conditions as the average temperature has increased by 1^{o} C, which suggests the drought events in future will further increase in their likelihood or intensity but the impact will probably be moderate.

Score: 6

Exposure

The fiscal position of the public sector and Government is exposed to the consequences of climate change across the domains. The damage caused by climate change-related hazards will impose a growing financial burden on citizens, businesses and public authorities. Central and local government, on behalf of communities, are responsible for managing risks to public goods and assets (including the environment) and creating an institutional, market and regulatory environment that promotes resilience and action (Ministry for the Environment, 2017c).

Ministry for the Environment. 2017c. Adapting to Climate Change: Stocktake Report from the Climate Change Adaptation Technical Working Group. Wellington: Ministry for the Environment.

There is no assessment of the fiscal cost of climate change in this report.

Score: 0

Research by Frame et al (2018) investigated the scale of the economic impact of climate change-related floods and drought in New Zealand between mid-2007 and mid-2017. They conservatively estimate that flood and drought costs attributable to the influence of human activities on climate are already somewhere around $120 million per decade for insured

damages from floods, and $720 million per decade for economic losses associated with droughts. They warn that these costs will "almost certainly" (Frame et al, 2018, p 9) increase over time.

As noted above the Frame modelling is somewhat problematic, but even if the results are accepted the expected annual costs are still low. The flooding loses are mostly carried by insurers and as these are mostly foreign owned this reduces the immediate impact on New Zealanders. The government's share of those loses, through the loss of taxation revenues and increased expenditure would be lower again. Even if the drought and flood loses were to double they would likely be be outweighed by the positive impact of carbon fertisation on primary sector output.

Already the annual cost of repairing land transport networks damaged by weather-related events (B6) has more than quadrupled over the past decade (Boston and Lawrence, 2018).

Boston J, Lawrence J. 2018. Funding climate change adaptation: The case for a new policy framework. Policy Quarterly 14(2): 40–49.

Boston and Lawrence referenced a discredited claim made by the MfE in the Zero Carbon consultation paper that was reviewed in 'A question of trust' 2019. This review commented as follows:

The source of the $20 to $90 million increase in costs to the transport network was a 2017 MfE report[18]. That document in turn referenced a Ministry of Transport report as the source. That document was written in 2009, so it did not and could not provide evidence on the costs over the last 10 years.

Score: 0

The Government may be exposed to compensation for homeowners and commercial buildings in the event of managed retreat from areas exposed to landslides and coastal or river floods.

This will no doubt be an issue. The extent of the cost will depend on the managed retreat philosophy. If this is favoured over other more economic options and pulled forward in time then it could be very expensive.

The New Zealand Treasury also warns that "[i]n the future, we may also see threats to our natural resources (eg, climate change, water quality and natural disasters) as a fiscal pressure" (New Zealand Treasury, 2016, p 6).

New Zealand Treasury. 2016. New Zealand Economic and Financial Overview 2016. Wellington: New Zealand

We were unable to find the referenced statement in the document.

Score: Not scored

Ecosystem services provided by the natural environment are significant, and in some cases irreplaceable. Examples of these services include nutrient cycling, soil provision, water and air purification, carbon sequestration, food and resource provision, and cultural services and experiences. Their loss, as well as diminishing the welfare of all New Zealanders, may burden the Government by affecting key sectors of the economy, such as primary industries (E3, E5) and tourism (E4).

This is speculation, without any substance as to what services might be affected and their quantitative signficance. The argument that the loss of these services this will burden the government is grossly exaggerated. For an example of how the MfE has grossly exaggerated the value of ecosystem services see 'False and misleading?[19]'. The MfE claimed that each hectare of wetland generated $50,000 of ecoservice value a year. If that were true New Zealand could become rich simply by converting as much farmland as possible to wetland.

The impacts of climate change on people also manifest in the economy through declining productivity in hot weather, the direct health risks stemming from disease and exposure to extreme events (H3), and the indirect costs associated with trauma (H1) and exacerbation of persistent inequities (H2).

An average temperture increase of two or three degrees is unlikely to have a material impact on labour productivity particuarly as workers and businesses are likely to adapt to working in slightly higher temperatures. Workers in Invercargill are not more productive than Auckland but Invercargill is on average four degrees cooler. As noted above there is no evidence that small increases in temperatures will have health effects, there will be no increased 'trauma' and no obvious impacts on inequality.

Again this is a case of more unanchored speculation. A proper economic assessment as noted would have forced the more material of the claimed impacts to be quantified. A number of studies suggest that the net effect in temperate countries is small and would have no noticeable fiscal impact.

19 Tailriskeconomics.co.nz/documents

Sensitivity

New Zealand governments are sensitive to the financial risks from climate change. Already local governments are struggling to finance infrastructure for housing, tourism and regional development, provide safe drinking water and develop infrastructure that is resilient to climate hazards (Department of Internal Affairs, 2017). Some councils are also experiencing constraints on their ability to finance further investment because they are approaching covenanted debt limits (New Zealand Productivity Commission, 2019).

This is not evidence of the effect of climate change. Nevetheless there will be pressure on some local authorities due to the need to respond to sea level rises. The serious hole in the climate change analysis is the failure to quantify these possible effects. Even a broad order of magnitude estimate would help put the issue in persective.

Local government relies on rates for more than 50 per cent of their income, which are generally based on the land, capital or rental value of property in the local government area (Local Government New Zealand, 2019). This situation increases the sensitivity of local governments to climate change-related impacts that influence property values, for example insurance sector retreat (E6). Additionally, rates that are linked to land, capital or rental values may fail to keep pace with the expenditure required to adapt to climate change, particularly those projected to occur under representative concentration pathway (RCP) 8.5.

Falling relative property values in affected areas will impact on the distribution of the rates burden between proporty owners but will not affect the total tax take. Councils work out their expenditure budget and then use property valuations to distribute the burden between ratepayers.

At central government level, finances are relatively strong but fiscal pressures are projected to increase as an ageing population slows revenue growth and increases expenses (New Zealand Treasury, 2019a).

It is likely that a proper assesssemnt of climate change expenditure effects will show that these are not as large as implied, particularly as the expenditures can be spread over many decades. For example, the Hawkes Bay assessment put the present value of the costs at a little over $100 million. The bigger fiscal risk might be unnecessary and uneconomic spending on climate change mitigation. For example Norway has spent billions heavily subsidising electric vehicles that will become obsolete and be scrapped well before their zero carbon target date.

Adaptive capacity

Local governments currently have varying, but generally limited, adaptive capacity to respond to economic risks. Some councils have indicated that they could meet additional costs through general or targeted rates (James et al, 2019). However, on average, growth in council rates

has outstripped common economic indicators, and continuing rates increases may challenge the future affordability of council rates for households (Department of Internal Affairs, 2017). Other councils have disaster relief funds or have already budgeted for increased infrastructure costs. Many councils remain unsure of what the costs would be and how they would meet those costs (James et al, 2019). Central government has a greater ability to adapt to this risk by preparing for a changed climatic future and funding adaptation efforts to ensure New Zealanders can continue to prosper socially, economically and culturally.

James V, Gerard P, Iorns C. 2019. Sea-level rise and local government: Policy gaps and opportunities. Wellington: Deep South National Science Challenge.

This paper presented the results of a survey of local authorities on matters relating to sea level rise. The results were mixed and the issues thorny. It did not in itself add much to an understanding of the likely burden for local and central government over long time horizons.

One piece of useful information is the proposal by the Hawkes Bay local authorities to levy households $60 a year for an adaptation fund. This was a proportionate and affordable response to the risks that they have identified.

Score: 6

Central government sets the domestic regulatory framework in which adaptation is currently considered. Among other roles, it is also responsible for providing robust information on how New Zealand's environment may change and making this information accessible to other sectors (Ministry for the Environment, 2017c).

Consequence

There have been numerous attempts to calculate the economic cost of climate change. Notably the Stern Review (Stern, 2006) estimated that, without action, climate change may lead to losses equivalent to at least 5 per cent of global gross domestic product (GDP) each year.

The Economics of climate change: The Stern review 2006

The reference to the Stern report is misleading. These cost estimates are weighted well into the future (c2200) and they are almost entirely undiscounted. The analysis was widely discredited at the time. It assumed that costs would grow by 2 percent a year and would be discounted at only 0.1 percent. Over hundreds of years this can generate a very high cost burden. There have been numerous reviews that show limited economic costs by 2100. Many reports suggest small benefits over this century for cold and temperate climate countries.

Score: 2

More recently, Hinkel et al (2014) have estimated that if the sea level rises by 1.23 metres by 2100, frequent floods alone would cause losses of over 9 per cent of global GDP each year. A decline in economic output of this magnitude would have significant consequences for the New Zealand Government's ability to deliver services to support communities.

Hinkel J, Lincke D, Vafeidis A, Perrette M, Nicholls RJ, Tol RSJ, … Levermann A. 2014. Future coastal flood damage and adaptation costs. Proceedings of the National Academy of Sciences 111(9): 3292–3297.
The following is taken from the abstract:

Without adaptation, 0.2–4.6% of global population is expected to be flooded annually in 2100 under 25–123 cm of global mean sea-level rise, with expected annual losses of 0.3–9.3% of global gross domestic product. Damages of this magnitude are very unlikely to be tolerated by society and adaptation will be widespread. The global costs of protecting the coast with dikes are significant with annual investment and maintenance costs of US$ 12–71 billion in 2100, but much smaller than the global cost of avoided damages even without accounting for indirect costs of damage to regional production supply.

The modelling of the largest impacts assumes: the most extreme sealevel rise 1.23 m compared to the median modelled RCP 8.5 rise of 0.74m; that the at risk areas will expand at the same rate as the national economy despite the growing risk (in some cases it is assumed that building will continue on sites that are already underwater) ; and there is no attempt at all to reduce the risk with flood protection. This produces deliberately high figures for a shock effect.

The analysis does show that the costs of flood protection to mitiagate the costs is relatively small. Assuming world GDP of $900 trillion by 2100 then the annual costs of flood protection would be .008 of one percent of GDP. 0.008 percent of New Zealand's current GDP would be $25 million, rising to, perhaps. $100 million by 2100. We wouldn't suggest using the Hinkel figures on the costs of protection for New Zealand as they are too broad brush and probably overly optimistic, but they do put the fiscal burden into the right sort of scale.

It was irresponsible and dishonest to withhold the flood control cost information while using the 9 percent of GDP flooding cost estimate to suggest that flooding costs would put the New Zealand at an extreme financial risk.

Score: 2 The low score is due to the misleading presentation of the results.

Confidence: High agreement, medium evidence

Robust evidence shows the economic costs of climate change in other global regions, but very little research has explored this risk in the New Zealand context.

As noted most of the global models show minimal costs for temperate areas
This lack of evidence for New Zeaiand is the fault of the MfE, which has only been interested in negative stories. However, there is some evidence. A 2011 Infometrics study[20] found largely positive effects.

Under some scenarios the wider economic effects are negative, but most results show a positive effect. Changes in real gross national disposable income range from -0.2% to 1.8% and changes in gross domestic product vary between -0.4% and 3.9% (by 2100)– all relative to a situation of no climate change. Changes in agricultural and forestry output are an order of magnitude larger, with Horticultural output showing the most sensitivity to climate change.

As noted above the 2016 OECD study showed that the impact for Australasia was small negative by 2060. If the OECD model was applied just to New Zealand there probably woud have been a positive result.

A review of recent research related to climate change risks in New Zealand by McKim identified only two pieces of (grey) literature relating to finance (including banking and insurance) and climate change, and concluded that "a general lack of published research in this area, at least in the New Zealand context, is evident" (McKim, 2016, p15).

Climate Change Impacts and Implications for New Zealand to 2100 A systematic review of recent research Implications for policy and management, and tools to support adaptation decision making in New Zealand Laura McKim. Prepared for the New Zealand Climate Change Research Institute, Victoria University of Wellington.
This report missed the Infometrics study but the report was otherwise useful as a source of information.

Score: 4

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[20] The Economic Implications of Climate-Induced Changes in Agricultural Production Stroombergen 2011

Adaptation

All levels of government are undertaking actions that indirectly manage public sector fiscal risk.. These efforts are not necessarily targeted directly at climate risks, but all the same may serve to reduce associated risks

E2: Risk to the financial system

NCCRA consequences assessments

Now: Minor
2050: Major
2100: Major

Urgency score: 83

Tailrisk summary

The NCCRA conclusion that physical climate change '*presents a systemic risk to the financial system, with severe impacts on the real economy*' is not supported by relevant evidence or by serious analysis. For the most part the supporting evidence consists of little more that general suppositions or references to some flawed foreign modelling. There is a risk that the financial system could work less efficiently if the there is excessive insurance withdrawal and banks use this as a guide to their own red-lining of unacceptable risk. However, this does not mean that there is a risk to financial stability.

There appears to be is a complete lack of understanding of the scale of the events that are required to pose a systemic threat. It is not enough to surmise that climate change might result in some losses. It has to be shown that they are large enough to have a material impact on bank balance sheets.

The analysis focuses on climate 'catastrophes' like flooding that might at worst amount to losses in the hundreds of millions of dollars, but ignores the experience of the Canterbury earthquake that cost tens of billions without the banking sustem coming under stress or even losing much money. And as most flooding loses are insured the risks to the banking system will be minimal.

Evidence quality score: 1.76

NCCRA discussion

Risk summary

Financial instability affects livelihoods, socio-economic inequality and the economy. The fundamental changes projected for the climate system are likely to have severe implications for the stability of the global financial system (Dafermos, Nikolaidi and Galanis, 2018).

The Dafermos, Nikolaidi and Galanis paper is reviewed in the consequenses section below.

New Zealand is exposed to climate change impacts in financial markets globally as well as locally. Climate-related hazards could severely and abruptly damage the balance sheets of households, corporations, banks and insurers, triggering financial and macroeconomic instability (Batten, Sowerbutts and Tanaka, 2016).

Batten S, Sowerbutts R, Tanaka M. 2016. Let's Talk about the Weather: The Impact of Climate Change on Central Banks. Bank of England Staff Working Paper 603. London: Bank of England.

This paper sets out a framework for thinking about the ways climate change could impact on a central banks' responsibilties and talks about possible sources of risk. However, there is no quantification of the possible risks and there is nothing in the paper that could lead to a conclusion that there would be a material risk to the UK financial system, other than the obvious risks to some international insureres with exposures in offshore hurricane zones. There is nothing in the paper on the New Zealand economy and financial system, which is very different from the UK system. New Zealand is not an international financial centre.

Score: 3

Exposure

New Zealand's financial system is highly exposed to climate change through local changes and international markets. The global financial system is an extremely complex network of tightly linked financial institutions and markets. As the global fallout from the implosion of the United States' sub-prime mortgage market in 2008 showed, this complexity and interconnectedness can transmit and amplify disruption across the globe.

The stability of New Zealand's financial system is therefore influenced by climate-related hazards occurring globally, as well as the behaviour of foreign governments, regulatory bodies and financial institutions (Batten, Sowerbutts and Tanaka, 2016 See above *).*

The interconnection with the international system might mean that the pricing and availalblity of reinsurance could be affected by offshore events climate events. This could mean that lending markets could be less efficient for a period, if banks will not lend when insurance is not available, but it does not mean that banks will be exposed to a material increase in their credit risk. Notably, while liquidy in the New Zealand banking system was eventually affected by the implosion of the US sub-prime financial system it was easily managed by Reserve Bank interventions.

The system could be affected by any single acute event or a series of events – such as hurricanes or cyclones, fires or floods – that precipitate rapid reappraisals of asset values in major financial hubs such as New York, Tokyo, Shanghai, Shenzhen, Hong Kong or London. The pricing of ongoing, gradual events – particularly sea-level rise – could also trigger rapid reappraisal and disruption. Vulnerability of supply and distribution systems (E7) may also expose the financial system to disruption (Hong, Li and Xu, 2019).

This 'rapid reappraisal of asset values' seems far fetched. There have been many spates of large climate catastrophy events historically without a single shock to the world financial systems. Rapid changes in asset values occur frequently without wider ill-effects. Three hundred bilion dolllars were wiped off the value of the climate adaptation champion Tesla over a few days.

Hong H, Li FW, Xu J. 2019. Climate risks and market efficiency. Journal of Econometrics 208(1): 265–281.

The Hong Li paper reference is misplaced. That paper is about pricing efficiency in equity markets in response to information about future droughts. It has nothing to say about the vulnerabily of physical distribution systems to climate events.

Using data from thirty-one countries with publicly-traded food companies, we ranked these countries each year based on their long-term trends toward droughts using the Palmer Drought Severity Index. A poor trend ranking for a country forecasts relatively poor profit growth for food companies in that country. It also forecasts relatively poor food stock returns in that country. This return predictability is consistent with food stock prices underreacting to climate change risks.

The finding that food company returns are not reacting contemporaneously to information about droughts does not logically lead to a conclusion that the markets are not somehow properly embedding very uncertain information about how droughts might increase decades into the future. There are many rational reasons

why food company returns do not react to droughts. Droughts will at most have a relatively minor impact on the present value of a food companies returns and with international trade localised drougts are unlikely to impact materially on their input fprices. If food prices do go up this will not impact on processing companies if they can shift the costs to consumers.

Score: 0

Small and medium enterprises (SMEs), which account for 97 per cent of all New Zealand businesses and 29 per cent of employment (New Zealand Foreign Affairs and Trade, nd), are particularly sensitive to such disruption, and could function as a source of financial system instability.

There is no evidence that SMEs are particularly vulnerable to supply disruptions and there is no evidence that this vulnerbility will change over time as the climate warms. In any event SME lending is a very small part of banks' lending portfolios.

Extreme events and ongoing gradual changes could contribute to this financial instability in New Zealand. Sea-level rise, or change in climatic means, could over the long-term stress businesses, governments, bank balance sheets, and economic activity. Extreme events in areas where valuable assets are concentrated, such as cities, could also lead to disproportionate instability.

There is no evidence to support these sweeping conclusions for New Zealand.

Sensitivity

New Zealand's financial system is resilient to a broad range of economic risks (Reserve Bank of New Zealand, 2019). Many factors affect its sensitivity to climate change, including debt, capitalisation and the ability to price risk. New Zealand's AAA credit rating is justified by its 'very high economic resilience', a strong fiscal position and effective institutions and policies, which mitigate our vulnerability to financial shocks (Fyers, 2016).

This is basically refutes most of the sweeping claims made in the exposure section.

However, a large external or domestic shock, such as a natural disaster, could result in a credit downgrade, which would undermine the banking system by raising the cost of funding (Moody's, 2017). This would be particularly severe if some of New Zealand's many highly indebted households and dairy farms had to default (Reserve Bank of New Zealand, 2019). The Reserve Bank of New Zealand has recognised the costs of bank failures are higher than previously understood. It has proposed to reduce the sensitivity of the banking system by gradually raising bank capital requirements. However, some insurers and non-bank deposit takers have capital buffers that would absorb only relatively small losses, rendering them sensitive to disruption (Reserve Bank of New Zealand, 2019).

Moody's. 2017. Moody's affirms New Zealand's Aaa issuer rating; maintains stable outlook.
We do not have access to the full Moody's report but the public press release was glowing in terms of the fiscal position. There would have been the normal cavets in the report about future shocks that could lead to a credit downgrade, but almost certainly this was a reference to economic shocks and large catastrophes such as another large earthquake. If would not have been a reference to a New Zealand climate event.

A (foreign currency) rating downgrade would not undermine the banking system as the banks operate in New Zealand dollars. They have able to maintain their lending margins after previous downgrades.

Score: 0

Reserve Bank of New Zealand. 2019. Financial Stability Report May 2019. Wellington: Reserve Bank of New Zealand.
The Reserve Bank was considering the hypothetical situation of what might happen if there were high levels of default in the the household and dairy sectors, not what would happen if there was some kind of 'climate event'.

The Reserve Bank has reviewed what would happen to the dairy sector elsewhere and concluded that there was not a material risk.

Score: 0

The insurance sector is highly sensitive to changes in climate hazards and may be underestimating the impact of climate change on catastrophe risks. For example, reinsurers could be underestimating their exposure to 1-in-10-year and 1-in-250-year catastrophe losses by an average of about 50 per cent (Standard and Poor's, 2014). Catastrophe models, used by insurers, reinsurers, governments, capital markets and other financial entities, also tend to rely on historical data and do not necessarily incorporate climate change trends (Lloyd's, 2014).

The New Zealand insurance sector is not highly sensitive to changes in climatic hazards in the sense that it is put at risk of failure. Insurance companies work on one year contracts so they can readily reprice or drop their insurance coverage.

Lloyd's. 2014. Catastrophe Modelling and Climate Change. London: Lloyd's.
Exactly where in the large Lloyds report, which reviewed a host of complex models, the claim that insurance companies are irrationally backward looking is not clear. The NCCRA authors would not know because they simply uplifted the claim from the Batten paper.

An interesting piece of information in the Lloyds report was an estimate from the UK Environmental Agency that the cost of improving flood defences in the UK to maintain a constant flooding risk state would be stg. 20 million a year.

Score: 0

Adaptive capacity
The Reserve Bank of New Zealand Climate Change Strategy acknowledges the need to consider climate change risk in setting monetary policy (which controls either monetary supply or the interest rate payable on short-term borrowing), monitoring financial stability risks and financial markets, and identifying appropriate prudential requirements (Reserve Bank of New Zealand, 2020). However, historically low interest rates limit the ability to stimulate the economy in the event of a demand-side shock (Reserve Bank of New Zealand, 2019). Monetary policy instruments are also limited in addressing supply-side shocks.

As the risks of a material demand side shock from physical climate changes are close to nil in the near future the Reserve Bank's current limited capacity to respond to demand side shocks is irrelevant. Over coming decades we would expect interest rates to rise to normal levels and for the Bank's capacity to repond to be restored. It is not the Reserve Bank's role to address supply side shocks.

Actions by the financial sector influence the size and allocation of damages from a hazard (Batten, Sowerbutts, and Tanaka, 2016). For example, the amount of insurance and credit available for construction in flood-prone areas will determine the size of the eventual financial losses from flooding in these areas, as well as the allocation of these losses. The inherent uncertainty in future concentrations of greenhouse gas, corresponding climate change, and the reactions of humans hinder accurate and efficient pricing of risk (Aglietta and Espanage, 2016). Importantly, the 'long tails' of probability distributions (unlikely but extreme events) that grow 'thicker' (ie, more likely) with climate change inaction cannot be ruled out as they are crucial for accurate pricing of uncertainty (Weitzman, 2009).

Aglietta M, Espagne E. 2016. Climate and Finance Systemic Risks, More Than an Analogy? The Climate Fragility Hypothesis. CEPII Working Paper. Paris:
The Aglietta Espaghe paper attempts to demonstrate how climate change and financial fragility are interrelated. We found it to be an impossibly muddled and

speculative theoretical exposition, with no current relevance to an assessment of the New Zealand financial system. There are simpler ways to think about the issues it engages with.

Score: 3

Weitzman ML. 2009. On modelling and interpreting the economics of catastrophe Review of Economics and Statistics 91(1): 1–19.

The Weitzman paper was part of the debate on how to assess the costs and benefits of climate change when the costs are weighted well into the future (over 100 years) and the cost distribution includes potentially catastrophic events. It is not really relevant to pricing in financial markets where value is determined by events over the next 50 years at most.

Score: 3

There is an international movement towards disclosure of climate change risks such as the Carbon Standards Disclosure Board, the UN Principles for Responsible Investment, the Task Force on Climate-related Financial Disclosures, and the Network for Greening the Financial System, of which New Zealand is a member. The intention is to mobilise mainstream financial flows towards investments that are not exposed to climate risk. Thus far, disclosure by the Task Force on Climate-related Financial Disclosure (TCFD) is minimal, and capital flows generally still fail to consider climate risk. The market, in general, under-reacts to many types of value-relevant information (Weitzman, 2009) such as industry news, demographic shifts and upstream-downstream relationships (Hong, Torous and Valkanov, 2007; Cohen and Frazzini, 2008).

Papers that claim that markets are underreacting to climate change are a dime a dozen. And there are as many that come to an opposite conclusion. Whether there is a real problem here and whether climate change disclosures will make a material difference to climate change adjustment costs is unlikely. But it is certainly become the fashion to claim that it will. If the claim is to be made then it would be better to reference more up to date papers. A lot has happened since 2007-8.

Research also suggests that stock markets are inefficient in responding to information about drought trends (Hong, Li and Xu, 2019 See above *). The reasons require further research but may include inattention, home country equity bias, or other institutional investor frictions. Whatever the reason, the inability to price climate change risk adequately reduces adaptive capacity (Hong, Li and Xu, 2019* See above *). Government proposals to introduce TCFD-aligned disclosures may help reduce sensitivity to this risk by enabling more accurate pricing.*

Consequence

Climate change presents a systemic risk to the financial system, with severe impacts on the real economy. Extreme events, such as flooding or fire, along with ongoing gradual changes, like soil erosion or sea-level rise, can have several impacts. These could be intensified through interactions between the financial system and other parts of the economy as well as government policies and regulations. Financial instability could have a range of economic effects, including greater income inequality (Domanski and Zabai, 2016) and reinforcing the adverse effects of climate change on economic activity (Dafermos, Nikolaidi and Galanis, 2018).

These claims that climate change presents a systemic risk to the financial system are assertions entirely detatched from any empirical reality or solid reasoning. If you want to make the claim it is necessary to at least understnd the structure of the New Zealand banking system and preferably conduct a relevant stress test.

Dafermos Y, Nikolaidi M, Galanis G. 2018. Climate change, financial stability and monetary policy. Ecological Economics 152: 219–234.

A theoretical case for the intensification of the effects of climate change though the financial system is made in the Dafermos, Nikolaidi and Galanis paper. This presents the results of a longrun model (100 years) that assumes that climate change will have a damaging effect on firms' capital. It is further assumed that these effects are very large (50 percent of capital lost each year with a 6 degree temperature rise) and much larger than is credibly claimed in the literature for any country let alone advanced countries. The empirical evidence suggests current climate event damage figures are about 0.1 percent of GDP in developed countries.

The critical error in the model is that it is assumed that, over decades, firms do not recover these exaggerated climate damage costs (which are equivalent to accelerated depreciation), so the costs fall entirely on capital not on labour. Further it seems to be implicitly assumed that firms do not adjust their dividend payouts to reflect their lower profits. Because firms to not react to their increased costs, given enough time and sufficiently high climate damages they will always fail. As the firms are leveraged with bank borrowings, they take the banks down with them. Similary banks do not respond to the initial deterioration in firms financial positions by requiring them to inject more capital or reduce their dividends.

We found this paper to be a nonsense which generates its results from entirely unrealistic assumptions and a lack of understanding of basic facts about finance.

Score: 2

Climate change poses a potential risk to financial systems by disrupting both supply and demand. Demand-side disruptions affect consumption, investment and international trade. Climate change-induced losses could reduce household wealth and therefore private consumption. Business investments could be reduced by uncertainty and damage to physical and financial assets. Climate hazards can also have significant effects on domestic and international trade (Gassenher, Keck and The, 2010; Oh and Reuveny, 2010)

Gassenher M, Keck A, The R. 2010. Shaken, not stirred: The impact of disasters on international trade. Review of International Economics 18(2): 351–368.

The Gassenber paper examined the impact of major disasters on import and export flows using a gravity model (170 countries, 1962–2004). All large disasters, not just climate disasters are considered. An additional disaster reduces imports on average by 0.2% and exports by 0.1%. Changes of 0.1 and 0.2 percent are obviously not significant.

Score: 1

Oh C, Reuveny R. 2010. Climatic natural disasters, political risk, and international trade. Global Environmental Change 20(2): 243–254.

The Oh and Reuveny paper expores the interactions between political and climatic natural diasters using a large panel of countries and years. The more stable the country the less the effect of climatic disasters. For countries like New Zealand the disaster effect is trivial.

Score: 3

Supply-side disruptions affect productive capacity. These disruptions could include loss in worker productivity in hot weather, impacts on production facilities and the transport networks, or shortages in commodities reducing the supply of goods.

Climate change could cause permanent or long-term damage to capital and land (Stern, 2013), and increase the rate of capital depreciation (Fankhauser and Tol, 2005). Both can reduce profitability and gradually diminish the liquidity of firms. Extreme events undermine the financial robustness of banks (Klomp, 2014). In extreme cases, capital reserves become too low to cover regulatory requirements, necessitating a government response, which may include a bailout. This would adversely affect the public debt-to-output ratio (Dafermos, Nikolaidi and Galanis, 2018 See above *).*

The Stern citation is not in the list of references but obviously flooding can damage buildings. The issue is whether the impact is consequential for financial institutions.

Climate damage is equivalent to accelerated depreciation but with a cash effect. Accelerated depreciation, as a matter of accounting logic, will reduce profitability, but it does not gradually reduce liquidity. That is a separable business decision. Over time if profits fall, dividends fall leaving liquidity unchanged.

Fankhauser S, Tol RSJ. 2005. On climate change and economic growth. Resource and Energy Economics27: 1–17.

This is a theoretical paper that raises the possibility that damage caused by climate change could reduce growth rates. Its conclusions are preliminary and debatable, but are only likely to be relevant to developing countries. There is no reference to liquidity in the model.

Score: 3

Clomp J. 2014. Financial fragility and natural disasters: An empirical analysis. Journal of Financial Stability 13: 180–192.

We were not able to fully review the full Klomp paper because it is not freely availalable on line. The abstract says:

Using data for more than 160 countries in the period 1997–2010, we explore the impact of large-scale natural disasters on the distance-to-default of commercial banks. More precisely, we conclude that geophysical and meteorological disasters reduce the distance-to-default the most due to their widespread damage caused. In addition, the impact of a natural disaster depends on the size and scope of the catastrophe, the rigorousness of financial regulation and supervision, and the level of financial and economic development of a particular country.

Like a lot of this cross country literature the conclusions were probably mainly driven by underdeveloped countries with little or no application to developed countries.

Not scored

If banks suffer losses on their capital because of a climate hazard and cannot raise new capital immediately, they may reduce lending to both affected and unaffected areas to improve their regulatory capital ratios. The resulting reduction in credit supply could in turn exacerbate a fall in the value of assets used to secure loans, and further affect the balance sheets of households and businesses, potentially deepening the inevitable economic downturn (Batten, Sowerbutts and Tanaka, 2016).

This is just a further recitation of some Batten, Sowerbutts and Tanaka (Bank of England) suppositions. As far as we are aware there is no record of a large developed

country bank ever suffering a loss of capital due to a weather event. The losses, such as they were, would have been absorbed by provisions and current profits.

An extreme event could also undermine business confidence and trigger a sharp sell-off in financial markets. This could result in an increase in the cost of funding new investments and thus reduce investment demand. Climate change may also influence how households allocate capital. In response to declining corporate profitability and increases in risk, households may reallocate financial wealth from corporate bonds towards term deposits and government securities, which are perceived to be less risky. This reallocation of investment portfolios can cause a gradual decline in the price of corporate bonds, which would reduce economic growth from wealth-related consumption and firms' ability to fund investment, thereby constraining economic growth (Dafermos, Nikolaidi and Galanis, 2018). These impacts are expected to become more severe if global warming passes a 2.5°C threshold (Dafermos, Nikolaidi and Galanis, 2018).

This assessment is just a cut and paste from the Dafermos, Nikolaidi and Galanis model assumptions. As explained above the conclusions from this paper should not be taken seriously.

Climate change can also affect the stability of the financial system through the insurance sector. Increasingly frequent and severe extreme events, such as fires, floods and storm surges, could have a direct effect on the insurers that cover them. If insured losses from an event or a series of events are sufficiently large and concentrated, they could lead to distress or failure of insurance companies. This, in turn, could affect financial stability if it disrupted critical insurance services and systemically important financial markets, such as securities lending and funding transactions (French, Vital and Minot, 2015).

French A, Vital M, Minot D. 2015. Insurance and financial stability. Bank of England Quarterly Bulletin Q3: 242–258.

The French, Vital and Minot article is a general Bank of England review of risks in the insurance sector. There is no mention of climate change in the paper. The UK insurance market is much larger and more complex than the New Zealand market so the article should not be applied directly to New Zealand. Some of the risks relevant to the UK market may not exist here, at least to the same extent. The general view is that the loss of insurance coverage may make markets less efficient with attendant welfare losses. This might possibly justify government intervention in the insurance market to socialise uninsurable losses. The ECQ in New Zealand and the flood insurance scheme in the UK are examples.

Score: 3

Large-scale fire sales of assets by distressed insurers could reduce asset prices, which could adversely affect the balance sheets of other financial institutions like banks. If these risks are uninsured, the deterioration of the balance sheets of affected households and corporates could lead to losses for their lender banks (Campiglio et al, 2018).

New Zealand insurers have relativity small balance sheets (investment assets of $14b for both life and general insurers - RBNZ). So even if several general insurers had to run their portfolios down it would not be consequential for markets. Payouts after a climate event can take time so the effect would be even more muted.

Campiglio E, Dafermos Y, Monnin P, Ryan-Collins J, Schotten G, Tanaka M. 2018. Climate change challenges for central banks and financial regulators. Nature Climate Change 8: 462–468.

This is a short general discussion with no information on the magnitude of the risks. There is no direct information on the risks to the New Zealand financial system.

Score: 3

Interacting risks

Financial system instability will affect the Government's fiscal position (E1), other economic sectors (E3, E4 and E5) and the ability to fund adaptation (G2). Emergency government responses may occur in the context of a major financial system disruption, posing risks to democratic decision-making (G8). Financial crises also tend to exacerbate inequities (H2) and cause health problems (H3).

Confidence: high agreement, medium evidence

There is a reasonably high degree of agreement on the impacts of climate change on financial system stability, and a large, growing body of academic and grey literature to substantiate this *consensus. However, this research area is in its infancy, and there is little data for the New Zealand context.*

We have critiqued the cited literature both here and in a forthcoming paper on the Governor of the Reserve Bank's claim that climate change is a systemic risk. None of literature came to much.

Adaptation

Some adaptation efforts, both planned and under way, explicitly target financial system stability in the context of climate change. The Reserve Bank of New Zealand (RBNZ) has developed a climate change strategy and takes other regulatory actions to support financial system stability. The finance and insurance sectors are working with governments on policy frameworks to enable proactive risk reduction, and some banks are starting to factor climate

change risk into lending decisions. Adaptation to address other risks in New Zealand will also contribute to reducing this risk.

As noted above we have reviewed the Reserve Bank' analysis of climate change risks to the financial sector.

E3: Risks to land-based primary sector productivity and output due to changing precipitation and water availability, temperature, seasonality, climate extremes and the distribution of invasive species

NCCRA consequence assessments
Now: Minor
2050: Moderate
2100: Major

Urgency score: 81

Tailrisk summary

The approach taken for the land-based primary sector was to onsider all of the negative consequences and make the assessment on just those factors. The larger positive factors are considered, rather begrudglingly, in a different section. There was no assessment of the magnitude of these postive impacts but the literature suggests that these could be material. The effect of spliting the postive and negative impacts turned a positive story into a negative one.

We think this approach was misleading. The positive and neagtive impacts should have been considered together.

Before we proceed with the assessment of the NCCRA discussion we present the results of a study on the impact the landbased primary industries. It was mentioned in the 'postive' assessment but only in the context of trying to highlight a negative impact.

Climate Changes, Impacts and Implications
The "Climate Changes, Impacts and Implications" (CCII) was a four-year project (October 2012 – September 2016) designed to address the following question: What

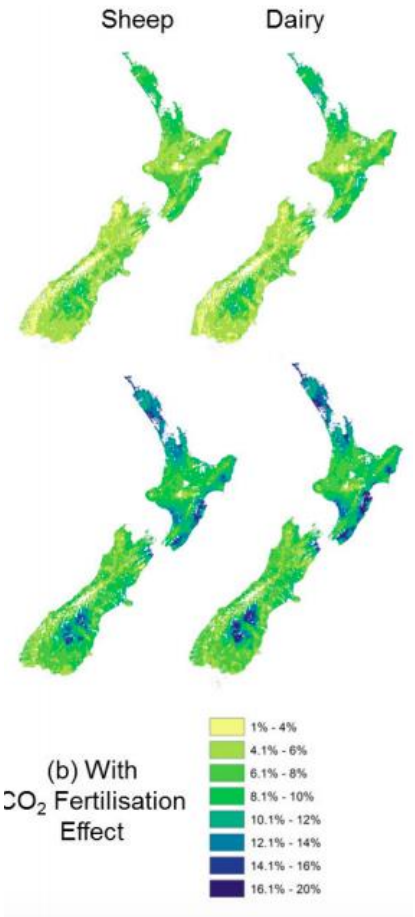
are the predicted climatic conditions and assessed/ potential impacts and implications of climate variability and trends on New Zealand and its regional biophysical environment, the economy and society, at projected critical temporal steps up to 2100?

It was a complex modeling exercise that employed many models with many scenarios. However on primary production the results were clear.

Pinus radiata yields to 2100 increase with higher concentration pathways because of positive effects from CO2 fertilisation outweighed negative effects of higher temperatures. The increase in productivity was 40 percent

Sheep & beef and dairy mean annual pasture productivity increased 1–10% (see figure fourteen) across scenarios in most locations, although changes in seasonal trends might cause larger summer feed gaps.

Figure fourteen: Climate change productivity increases sheep and dairy



The NCCRA also ignored other important documents that were inconvenient to the narrative. For example, in 2012 the Ministry for Primary Industries produced a comprehensive (over 300 pages) report Clark et al. 'Impacts of Climate Change on Land-based Sectors and Adaptation Options' that was on balance positive. And in 2009 Stroombergen explored the positive effect on agricultural commodity prices[21].

NCCRA discussion

Risk summary

The primary sector faces risks from both extreme events and ongoing, gradual changes. Climate change will directly impact the quality and quantity of output across many areas, including horticulture (Cradock-Henry, 2017), viticulture (Sturman et al, 2017), and agriculture and forestry (Ausseil et al, 2019; Lake et al, nd; Wakelin et al, 2018). Changes in temperature and seasonality influence maturation (Salinger et al, 2019), length of growing season and the quality (size, shape, taste) of horticulture products (Cradock-Henry, 2017; Salinger, 1987), the distribution of pests and diseases (Wakelin et al, 2018; Watt et al, 2019) and the efficacy of some pest control agents (Gerard et al, 2013).

The amount of land suitable for primary industries will decrease as sea levels rise, low-lying coastal areas become inundated, and groundwater is salinised (Lake et al, nd).

Cradock-Henry NA. 2017. New Zealand kiwifruit growers' vulnerability to climate and other stressors. Regional Environmental Change 17: 245–259.

This paper reported on the results of research based on semi-structured interviews with existing kiwifruit growers and orchard managers workshops and on secondary data that developed a 'bottom-up contextual assessment of vulnerability'. It concluded:

The paper demonstrates the need to move beyond outcome-oriented and model-based vulnerability assessments in New Zealand, to consider the broad range of the factors that contribute to vulnerability in the nation's agricultural sectors. It provides a basis for further consideration of multiple exogenous impacts in the industry and confirms the critical importance of qualitatively vulnerability assessments to determine spatially specific outcomes.

The paper had limited relevance to an assessment of sector wide adaptation issues.

Score: 3

[21] Stroombergen (2009): The International Effects of Climate Change on Agricultural Commodity Prices, and the Wider Effects on New Zealand. Infometrics report to Motu.

Sturman A, Zawar-Reza P, Soltanzadeh I, Katurji M, Bonnardot V, Parker AK, … Schulmann T. 2017. The application of high-resolution atmospheric modelling to weather and climate variability in vineyard regions. OENO One 51(2): 99–105.
This paper discussed the value of more precise knowledge of micro variations in climate. It does not address the cost of climate change for the sector.

Improved knowledge of spatial and temporal variations in climate and their impact on grapevine response allows better decision-making to help maintain a sustainable wine industry in the context of medium to long term climate change. This paper describes recent research into the application of mesoscale weather and climate models that aims to improve our understanding of climate variability at high spatial (1 km and less) and temporal (hourly) resolution within vineyard regions

Score: 3

Wakelin A, Gomez-Gallego M, Jones E, Smaill S, Lear G, Lambie S. 2018. Climate change induced drought impacts on plant diseases in New Zealand. Australasian Plant Pathology 47(101): 101–114.
This is another technical paper which doesn't make a strong case for an increase in risk. Droughts are only expected to increase materially in already drough prone areas.

We undertook analyses of potential drought impacts on several diseases of plants important to New Zealand: pea root rot (caused by *Aphanomyces euteiches*), onion white rot (*Sclerotium cepivorum*), wheat take-all (*Gaeumannomyces graminis* var. *tritici*), wheat crown rot (*Fusarium* spp.), brassica black leg (*Leptosphaeria maculans*), grapevine black foot (*Ilyonectria/Dactylonectria* spp.), kiwifruit sclerotinia rot *(Sclerotinia sclerotiorum*), and radiata pine red needle cast (*Phytophthora pluvialis*). For most pathosystems, increased drought is expected to increase disease expression. However, drought may reduce the severity of some diseases, such as Scelerotina rot of kiwifruit and red needle cast of radiata pine.

We recommend that land-based productive sectors need to better prepare for the deleterious impacts or beneficial opportunities of increased drought for plant diseases in New Zealand.

Score: 6

Watt MS, Kirschbaum MUF, Moore JR, Pearce HG, Bulman LS, Brockerhoff EG, Melia N. 2019. Assessment of multiple climate change effects of plantation forests in New Zealand. Forestry: An International Journal of Forest Research 92(1): 10–15.
This paper demonstrated that climate change would be a net positive for the forestry sector. While wind risk increases mostly this is from a low base and the most vulnerable areas can be avoided. Similarly with fire risk.

including photosynthetic effects from increasing CO_2, productivity gains across New Zealand averaged 19 per cent by 2040 and 37 per cent by 2090. This increased productivity results in marked increases in wind risk due to trees becoming taller and more slender. The average season length with 'very high and extreme' climatic fire risk increases by 71 per cent up to 2040 and by 83 per cent up to 2090. Currently, the most significant biotic disturbances in New Zealand plantations come from two needle cast diseases, for which climate projections show slight increases or decreases depending on the disease and region. Although insect pests currently cause little damage to New Zealand plantations, damage may increase in the future with projected increases in population and host susceptibility

Score: 2 The score is lower because of the misleading representation of its content

Salinger MJ. 1987. Impact of climatic warming on the New Zealand growing season. The Royal Society of New Zealand 17(4): 363–371.

The results reported in this study look positive.

The impact on agriculture depends on the magnitude of warming. Increases of 1, 2, and 5°C in mean annual temperatures are considered. A temperature increase of 1 °C would open a large area of land at higher elevations for pastoralism, and allow the introduction of many warm temperate crops into the South Island. A 2°C warming would extend the range of citrus and subtropical crops into the northern South Island. The results show the sensitivity of New Zealand horticultural, arable and pastoral farming activities to small changes in mean annual temperatures.

Score: 6

Gerard PJ, Barringer JR, Charles JG, Fowler SV, Kean JM, Phillips CB, … Walker GP. 2013. Potential effects of climate change on biological control systems: Case studies from New Zealand. BioControl 58(149): 149–162

it was concluded that most natural enemies will track the changing distributions of their hosts. The key climate change challenges identified were:disparities in natural enemy capability to change distribution, lack of frosts leading to emergence of new pests and additional pest generations, non-target impacts from range and temperature changes, increased disruptions caused by extreme weather events, disruption of host-natural enemy synchrony, and insufficient genetic diversity to allow evolutionary adaptation.

Score: 6

The amount of land suitable for primary industries will decrease as sea levels rise, low-lying coastal areas become inundated, and groundwater is salinised (Lake et al, nd).

Lake R, Bolton A, Brightwell G, Cookson A, Benschop J, Burgess S, Tait A. nd. Adapting to Climate Change: Information for the New Zealand Food System. Wellington: Ministry for Primary Industries

This paper was primarily about food safety. We did not spot any reference to land loss in this 133 page paper. If it was mentioned there was no substantive discussion.

There is no analysis anywhere of the amount of land that might be lost, and when, to sea level rise. This information may emerge as more local authorities conduct risk assessments and identify areas that might be protected economically. The Paulik paper on sea level rise suggests that at worst a few thousand hectares of land are at risk of being inundated at least once every hundred years. This would have only a small impact on average productivity.

Score: 0

The impacts of climate change will increase over time and be greater under RCP8.5 than RCP4.5. Some of these impacts are already being felt by the sector – for example, pressure on the availability of water (Frame et al, 2020).

Frame DJ, Rosier SM, Noy I, Harrington LJ, Carey-Smith T, Sparrow SN, Stone DA, Dean SM. 2020. Climate change attribution and the economic costs of extreme weather events. Climatic Change May.

This paper was a later version of the 2018 paper discussed above. It did not discuss water availability issues.

Score: 3

Exposure

The primary sector is highly exposed to climate change, as most activities depend on climate conditions. Many agricultural, horticultural and forestry varieties grow in narrow climate ranges, and current production distribution reflects historical climate suitability. The magnitude of the primary sector's exposure to climate change is affected by two main processes: the changing climate and associated hazards; and the changes made in the primary sector for non-climatic reasons that may increase or decrease its exposure to climate hazards.

Areas of New Zealand that have historically been suitable for certain types of production may become less suitable over this century (Ausseil et al, 2019). The mean air temperature in New Zealand has increased by 1 degree Celsius since 1909 and is projected to increase by a further 0.8 to 1.1 degrees by 2050 under RCP8.5. This may have spatial implications for growing seasons and harvesting, shifting the locality of certain crops (Salinger, 1987). Fewer frost days can also lead to pest outbreaks (Gerard et al, 2013). Changes in seasonality,

trending towards longer summers and shorter winters, will aggravate this.

Ausseil AGE, Van der Weerden TJ, Beare MH, Texeira E, Baisden T, Lieffering M, … Noble A. 2019. Climate Impacts on Land Use Suitability. Wellington: Deep South National Science Challenge.

This project explored the likely impact of climate on the spatial suitability of some primary production activities. It covered:

- pastoral farming – Higher yield with increasing RCP trajectory (3 locations). in Hawkes Bay reduced yield in summer in some locations. Higher risk of heat stress for animals.
- maize and catch crop wheat – earlier sowing of maize leading to higher catch crop yields.
- Wine and Kiwifruit - earlier flowering leading to higher risk on wine quality

Score: 4 The score relates to the way the results were represented not to the quality of the report.

Precipitation is another key factor for primary production. Under warming of about 2 degrees Celsius from pre-industrial temperatures, a 1-in-20-year drought could occur at least twice as often in eastern parts of New Zealand (New Zealand Climate Change Centre, 2010). Annual precipitation is projected to increase in the west and south of New Zealand and decrease in the north and east by 2050 under RCP8.5 (Ministry for the Environment, 2018). In 2100 under both RCP4.5 and RCP8.5, the largest changes in rainfall will be spatially and seasonally specific. Intense rainfall events can contribute to erosion and the loss of topsoil, so pose an irreversible risk to productivity. Sea-level rise is projected to be 0.79 metres under RCP8.5 by 2100, and coastal flooding exposes low-lying primary sector land to salinisation and inundation (Ministry for the Environment, 2017b).

New Zealand Climate Change Centre. 2010. Climate Change Adaptation in New Zealand: Future Scenarios and Some Sectoral Perspectives. Wellington: New Zealand Climate Change Centre.

This paper was discussed above. It is mispresented as showing negative effects when the overall effects were clearly positive.

Score: 4

As well as changes to mean climate variables, which put ongoing stress on primary sector industries, climate extremes can cause significant short-term disruption to production. In 1998, Cyclone Bola resulted in farming and horticulture losses equivalent to $170 million (Ministry for the Environment and Stats NZ, 2018).

New Zealand has always has had extreme climate events that have disrupted primary production in the short run.

Land-use decisions in the primary sector are based on many factors (Journeaux et al, 2017), and the composition of the sector is relatively dynamic. Between 2002 and 2016, for example, the dairying area has increased by 22.6 per cent and the area used for horticultural crops by almost 30 per cent (Stats NZ, 2018). Figure 17 shows the area changes for different land uses between 2002 and 2016.

This says nothing about future vulnerablity to climate change. It just means that the sector responds to market forces.

Climate change is also likely to increase the distribution of pests and diseases in New Zealand (Wakelin et al, 2018; Watt et al, 2019 – see above *), posing risks to primary production. If New Zealand's pastoral sector becomes more reliant on importing feeds or seeds, then it is likely that it will become more exposed to novel pathogens and invasive species.*

Sensitivity
Within the diverse and dynamic primary sector, areas differ significantly in their sensitivity. Horticulture, for example, is very sensitive to water availability at critical times of the growing season (B1), or to intense rain or hail. Pastoral systems are less sensitive to the timing of precipitation, but are sensitive to changes in precipitation (Ausseil et al, 2019) and temperature. In the arable sector, the sensitivity varies between locations and types of crops. Catch crops may be less sensitive due to their growth during late autumn and winter (Ausseil et al, 2019) when rainfall is usually higher, but changing seasonality may affect this. Like most of the primary sector, forestry is sensitive to pests and diseases (Watt et al, 2019), as well as windthrow and fire.

This gives the impression that farming and forestry will be 'losers', whereas the evidence is that there will be significant gains due to carbon fertilisation.

Sensitivity also varies with location (characteristics including soil type and topography) (Ausseil et al, 2019; Cradock-Henry, 2017) and the type of production in each sub-sector. For example, intensive livestock systems may be more susceptible to certain risks, including disease and heat stress, than more extensive systems (Ministry for the Environment and Stats NZ, 2018; Wreford and Topp, 2020

Wreford A, Topp CFE. 2020. Impacts of climate change on livestock and possible adaptations: A case study of the United Kingdom. Agricultural Systems 178: 102737.
This is a study of UK livestock farming. New Zealand studies obviously would have been more relevant.

Score: 4

Higher temperatures can increase the severity and range of disease and pathogens, reduce the efficacy of biological control agents and reduce yields. Dairy cattle are also sensitive to changes in temperature, which can lead to heat stress, facial eczema, mycotoxins, flies, ultra-violet (UV) damage to udder and teats, and eye cancer (Verkerk et al, nd).

Current land-use practices may amplify and perpetuate the impacts of climate change. Changes in the extent and intensity of agricultural practices, for example, result in compaction of soil, decreasing soil productivity, restricting plant growth and impeding water drainage. Conversely, reforestation and efforts to limit erosion can reduce climate change impacts. Beyond climate change, primary land-based economic activities are exposed to risks posed by legislative changes, input and output prices, credit markets, land valuation and operating costs (Cradock-Henry, 2017- See above*).*

Adaptive capacity

The primary sector in New Zealand as a whole has relatively high adaptive capacity, but this differs between individual farms, locations and sectors. The primary sector is dynamic, and adaptation may mean transformative shifts between production types and locations, so that in the longer term, the sector may look quite different from today (Cradock-Henry et al, 2020).

Primary sector industries are already adopting or considering adaptive measures such as water storage to improve reliability of supply and allow more efficient use, management of soil fertility and grazing, pasture diversity and infrastructure that will withstand climate extremes (New Zealand Climate Change Centre, 2010).

Despite this adaptive capacity there is an extensive discussion on ' how we can help'.

Consequence

The land-based primary sector contributed almost 4 per cent of New Zealand's GDP and just over half of the country's export earnings in 2016 (New Zealand Treasury, 2016). Māori GDP is still dominated by the primary sector, contributing $1.8 billion in 2013 (Ministry for the Environment and Stats NZ, 2018).

Climate change threatens the viability of parts of this industry, with major disruptions to production across the agricultural, horticultural and forestry sectors.

The evidence presented simply does not support this sweeping conclusion.

Extreme weather events, such as flooding or wildfire, can cause extensive damage and disrupt market access (E7), while changing seasonality and climate suitability will require farmers to adopt new management practices. Consequences will vary across production type and region but, without effective adaptation, are likely to involve considerable disruption and economic losses. Interdependencies in the primary sector value chains increase the risks of adverse consequence.

The wider New Zealand economy has already experienced the effects of climate change. Drought costs attributable to anthropogenic influence on climate have been estimated at $720 million (Frame et al, 2020). A Reserve Bank study reports that the 2013 drought reduced GDP by 0.3 to 0.6 per cent, increased world dairy prices by 10 per cent, and lowered the exchange rate by 3 per cent (Kamber et al, 2013). In a future where droughts are more frequent and intense, and combined with interacting hazards, these costs will become more significant.

Kamber G, McDonald C, Price G. 2013. Drying Out: Investigating the Economic Effects of Drought in New Zealand. Reserve Bank of New Zealand Analytical Note series. Wellington: Reserve Bank of New Zealand.

The 2013 drought was one of the worst, from a economic perspective, to strike New Zealand in many decades. Despite this there was only a moderate impact on GDP (-0.6 percent of GDP). The consequent positive impact on dairy prices helped mitigate the effects. The impact on GDP was unusually large (0.3 percent is the normal impact for a drought of this severity) because it was worse in dairying areas that are not normally drought prone. The climate science suggests that future droughts will impact on already drought prone areas that are not highly productive so the economic impact of climate change driven droughts should be muted.

Score: 8

A changed climate may increase the geographic ranges of pests and weeds already established in New Zealand, and make the environment more suitable for incursions of organisms not currently present. Nimmo-Bell (2009) estimated that plant and animal pests cost New Zealand's primary industries over $2.5 billion per annum in productivity losses and pest management activities. As an example to illustrate the costs involved, invertebrate pests are estimated to cost the pastoral sector between $1.7 and $2.3 billion each year currently (Ferguson et al, 2019) and climate change is likely to increase this. Climate change may also impact the ecology of existing biological control agents used to supress pests and weeds in New Zealand, reducing their efficacy and contributing to loss of production.

Nimmo-Bell. 2009. Economic Costs of Pests to New Zealand. MAF Biosecurity New Zealand Technical Paper No: 2009/31. Wellington: Ministry of Agriculture and Forestry.

Not recovered.

Ferguson C, Barratt B, Bell N, Goldson S, Hardwick S, Jackson M, … Wilson M. 2019 Quantifying the economic cost of invertebrate pests to New Zealand's pastoral industry. New Zealand Journal of Agricultural Research 62(3): 255–315.
This paper did not investgate the impact of climate change on its cost estimates.

Score: 3

Changes in weather systems, including temperature conditions and water availability, will affect plant growth and have implications for yields in primary productivity such as pastures and horticulture (Ministry for the Environment and Stats NZ, 2018).

The inference is that productivity will be reduced simply ignores the carbon fertilisation effect noted in several papers. The effects of climate change can be negative and positive.
Productivity may be further undermined by erosion and the attendant loss of soil. For example, the rapid erosion of low hill country after a drought or fire, followed by extreme rainfall, could permanently impact the landscape's ability to support primary industries.

*In addition, the risks to forests from climate change (Watt et al, 2019 (*See above *) may directly undermine New Zealand's ability to meet its international emissions reduction obligations under the Paris Agreement, as well as its domestic targets under the Climate Change Response (Zero Carbon) Amendment Act 2019.*

The Watts paper showed that exotic forest growth would significanly benefit from warmer temperatures and greenhouse gas fertilisation.

Interacting risks
No additional information

Confidence: High agreement, medium evidence

EO1: Opportunities for increased productivity in some primary sectors due to warmer temperatures

The positive story, impact which was based on information in the 2004 IPCC report on New Zealand, is as follows:

Initial benefits to agriculture and forestry are predicted in the western and southern parts of New Zealand and in areas close to major rivers due to a longer growing season, less frost and increased rainfall. The following are some specific opportunities NIWA (2007) has identified.
Kiwifruit: Warmer summer temperatures are likely to result in more areas of the South Island becoming suitable for kiwifruit cultivation, although this is likely to be offset by some existing areas becoming less productive.
Apples: Apples are likely to flower and reach maturity earlier, with increased fruit size, especially after 2050.
Grapes: Central Otago is currently the southern margin for cool-climate wine production in New Zealand. Wine grapes in this region will benefit greatly from warmer, drier conditions (Ministry for Primary Industries, 2018).
Horticulture: In general, new species may become viable.
Plantation forestry: Growth rates (mainly pine, Pinus radiata) are likely to increase inresponse to elevated carbon dioxide levels and wetter conditions in the south and west of New Zealand.

This discussion begs the question of why more up to date and authorative assessments than the 2004 IPCC report were not used.

NIWA. 2007. IPPC identifies climate change impacts and vulnerability for New Zealand.

This NIWA report was just a description of the IPCC 4 report on New Zealand.

Score: 3

Opportunities will depend on water availability, skills extension, adoption of new technologies, and biosecurity practices. Production yields may increase for certain species due to better growing environments. Higher average temperatures are associated with faster maturation, leading to an earlier harvest; higher carbon dioxide concentrations will also increase crop growth rates (Reisinger et al, 2010).

Reisinger A, Mullan B, Manning M, Wratt D, Nottage R. 2010. Global and local climate change scenarios to support adaptation in New Zealand. In: R Nottage, D Wratt, J Bornman, K Jones (eds) Climate Change Adaptation in New Zealand: Future

Scenarios and Some Sectoral Perspectives. Wellington: New Zealand Climate Change Centre. pp 26–43.
This paper compared high and low emission scenarios for climate variables for New Zealand. It did not specifically address agriculture. It noted Australia's problems in a fast warming world could give New Zealand a comparative advantage in agriculture and tourism.

Score: 5

However, these scenarios assume a system where nutrients and water supply are not limited, so do not consider complicating factors such as pests, extreme events and competition for dwindling resources (Wreford et al, 2010). Increasing crop yields would involve an increased demand for water supply, creating a greater reliance on irrigation systems. A change in mean average temperature may also allow the range of existing species to extend, and the introduction of new types of crops. As noted for kiwifruit above, this expansion may be offset by some existing areas becoming less productive. There may also be an opportunity for diversification into new areas or species of mahinga kai (food provisioning). Further research is needed to better understand the relationships between temperature, water availability and carbon dioxide fertilisation.

Wreford A, Moran D, Adger N. 2010. Climate Change and Agriculture: Impacts, Adaptation and Mitigation. Paris: OECD.
The paper did say, more or less in passing, that:

An increase of C02 in isolation from other factors is shown to increase crop growth and productivity. These effects will often be countered in relality by other factors in the system.

But this was more in a developing country context were there are more likely to be constraints on other inputs.

There was no mention of New Zealand agriculture in the report.

Score: 2

E4: Risks to tourism from changes to landscapes and ecosystems and impacts on lifeline infrastructure due to extreme weather events and ongoing, gradual changes

NCCRA consequence assessmenst

Now: Minor
2050: Moderate
2100: Major

Urgency score: 80

Tailrisk summary

The evidence base was restricted to a few academic papers on localised impacts that had almost nothing useful to say about the New Zealand wide impacts of climate change. Beyond that there was little more than the standard mantra of the disruptive effect of 'extreme' weather events. The international literature that suggests that tourism in temperate countries could actually benefit was ignored, as was an industry study that painted a reasonablely positive future for the skiing industry.

Tailrisk assessment: Minor

Evidence quality score: 1.63

NCCRA discussion

Risk summary

Natural environments have supported New Zealand's tourism industry but these environments, and the infrastructure that allows us to access and enjoy them, are at risk from climate change hazards. Changes to the number of snow days and peak snow elevation may impact skiing and snow activities (Hopkins, 2013), and, along with warmer temperatures, may result in glacier retreat (Espiner and Becken, 2014*).*

Hopkins D. 2013. 'The Social Phenomenon of Climate Change: Contextual Vulnerability, Risk Perception and Adaptation in the Ski Industry of Queenstown, New Zealand'. PhD thesis, University of Otago, Dunedin

This exerpt from the introduction is indicative of the value of this paper. It had little to say about the future prospects for the ski industry.

This thesis presents an empirical study of the ski industry in Queenstown, New Zealand, a popular international, bi-modal tourism destination. It employs a contextual vulnerability frame (O'Brien et al., 2007), whereby vulnerability is not the outcome of climate change alone but an on-going fluctuating state resulting from highly context specific factors. A social constructionist research paradigm was adopted, which aligns with a qualitative methodology.

Score: 3

The NCCRA missed, or ignored, the relevant NIWA[22] report that suggests the skiing industry will not be badly affected. It may actually benefit from more skiers from Australia, which will be more affected by temperature increases.

NIWA snow and ice scientist Dr Jordy Hendrikx says the new modelling confirms results from similar international studies.

"From these results we expect to see a gradual change in snow levels but **fortunately for New Zealand, we are unlikely to see the more extreme impacts predicted in Europe and Australia.** Our modelling shows that the loss may actually be less than originally anticipated and we should be able to continue to make snow, even under a more extreme climate scenario, right out to the 2090s.

Ski Areas Association of New Zealand executive director Miles Davison said:

"We are quite optimistic about these results. The sort of average percentage change predicted by 2040 under a mid-range scenario is actually much less than the current inter-annual variability in natural snow fall. We manage to deal with this annual variability now so we expect to comfortably deal with the average years of the 2040's with snow making systems which have greater capacity, and from expected improvements in snow making technology which will provide for more efficient conversion of water to snow."

Espiner S, Becken S. 2014. Tourist towns on the edge: Conceptualising vulnerability and resilience in a protected area tourism system. Journal of Sustainable Tourism 22(4): 646–665.
This was a study of the glacier towns of Fox and Franz Joseph.

Using 24 stakeholder interviews, this study evaluates susceptibility to change at multiple scales which could undermine the economic and social longevity of this iconic destination. Adopting a human–environment systems perspective, it utilises the concepts of vulnerability and resilience to examine dimensions of change and response that have shaped the community, conservation and tourism in this peripheral region.

[22] **NIWA** New Zealand snow areas confident they will adapt to any risks from climate change Recoverd 2/1/2021

Whatever the merits and use of this kind of study it has little to say about the threat climate change poses to the wider tourist industry. Perhaps fewer tourists will be inclined to stay in Fox and Franz Joseph but more will be inclined to stay in other towns. The paper doesn't address the main issue of whether fewer tourists will visit New Zealand in 80 years time because the natural environent has changed somewhat.

Score: 2

Ongoing sea-level rise and other climate hazards may cause damage to infrastructure including rail, roads and airports that provide accessibility for tourism (Paulik et al, 2019b).

The Paulik report was limited to identifying the 1:100 risk zones and the assets within them with different sea level rises. It said nothing about accessibility for tourism. There is no reason to expect that this will present a material problem for the tourist industry. Being cut off for a day or two once every hundred years is not the end of the world even if the incidence of these events increases somewhat. Vulnerable high value access routes can be repositioned or protected.

Furthermore, an increase in sea level can alter coastal ecosystems that attract visitors. Because many tourist activities are affected by weather, climate change that exacerbates precipitation, wind and other extreme weather events has the potential for negative impact.

There is no mention of what iconic tourist sights will be threatned by sea level rise. Perhaps hot water beach will be less of a draw. As summers will become drier and more settled the risk of adverse climate events in the peak tourist season may well fall.

There is an international literature that temperate countries may well benefit at the expense of hot countries that might become too hot. The fifth IPCC report concluded:

The economic implications of climate change-induced changes in tourism demand and supply entail gains for countries closer to the poles and higher up the mountains and losses for other countries.

An interplay of climate factors that degrade wildlife ecosystems may disrupt tourism ventures that centre on wildlife activities such as birdwatching tours (Kutzner, 2019). Changes in climate pose a risk to present-day tourism activities such as skiing and snow activities, and access to iconic destinations. The risk to the tourism industry is expected to intensify over time in the projected climate scenarios.

Kutzner D. 2019. Environmental change, resilience, and adaptation in nature-based tourism: Conceptualising the social-ecological resilience of birdwatching tour operations. Journal of Sustainable Tourism 27(8): 1142– 1166.

This paper presents empirical research into the 'social-ecological resilience' of tour operators using the case study destination of the Otago Peninsula. It introduced a 'conceptual framework' which highlights the tour operators' main coping strategies in response to key perceived social-ecological system (SES) drivers of change.

Climate change issues did not make the abstract so presumably the operators were not too concerned about it.

Score: 0

Exposure

Natural attractions in New Zealand are central to the tourism sector (Orchiston and Espiner, 2017). As a result, the tourism sector is exposed to a range of extreme events as well as ongoing, gradual changes, particularly related to changes in natural snow coverage (Hopkins, 2013 (See above*), extreme weather events and sea-level rise, as described in more detail below (see also section 2).*

Orchiston C, Espiner S. 2017. Fast and slow resilience in the New Zealand tourism industry. In: AA Lew, J Cheer. Understanding Tourism Resilience: Adapting to Environmental Change.

This paper focussed on case studies of the Fox and Franz Joseph townships and Christchurch after the earthquake. The former is a general discussion of changes and responses without a tight focus on particular climate change impacts. Post earthquake Christchurch is not relevant to climate change tourist issues.

Score: 3

- *Snow: Projected changes under RCP8.5 indicate that by 2090, snow days per year are expected to reduce by 30 days or more, with the largest reductions in the South Island high country (higher altitudes) and inland basins (Ministry for the Environment, 2018). Although not analysed for an RCP8.5 pathway, snow duration is negatively correlated with elevation for RCP4.5, where a decrease in snow duration and peak snow elevation is anticipated. This could negatively impact the ski industry, particularly for ski fields at lower elevations, such as Queenstown (Hopkins, 2013).*

This conclusion that skiing could be badly affected is not supported by the NIWA /industry study that suggests that improved snow making will offset decreases in natural snow falls.

• *Extreme weather events: An increase in extreme wind in the South Island and in the southern half of the North Island is projected for both 2050 and 2100 under RCP8.5. An increase in rainfall is projected for all zones, but is greatest for zones 1, 3 and 6. In addition, the intensity of tropical cyclones is projected to increase, as well as extreme rainfall events in zones 1–4 (Pearce et al, 2018). T*

The climate change projections show that the changes in weather events are not substantial.

In December 2019 slips and washouts to road infrastructure due to heavy rainfall and extreme winds (B6) resulted in the isolation of every major settlement along the West Coast between Hokitika and Haast, reducing tourism to this region during peak tourist season.

This illustrates that extreme weather has always been a risk in this location.

• *Sea-level rise: Under RCP8.5, by 2100 the greatest sea-level rise expected is 0.79 metres, which can result in salinisation of coastal wetlands and groundwater (Ministry for the Environment, 2017a) (N1). For all regions, exposure to extreme storm tides may also increase. Coastal flooding exposes key infrastructure such as rail, roads and airports to disruption (B6). Thirteen airports have been identified as exposed (B7), including Auckland and Wellington, which provide key international links for the tourism sector (Paulik et al, 2019b*).

These airports will be protected. The issue is the cost, which should not be massive relative to the value of the assets. The airports will not be abandoned.

Sensitivity

Tourism activities related to natural attractions employ about 300,000 people directly and generate a direct contribution to GDP of 5.8 per cent and an additional 4.0 per cent coming through industries supporting tourism (Stats NZ, 2019b). These activities are sensitive to extreme weather events, such as intense snowfall, wind and rainfall. These extreme events can be problematic for transport accessibility, as well as resulting in activity cancellation, closure of walking and access tracks, and damage to infrastructure such as accommodation and the electricity grid (Espiner and Becken, 2014).

The Espiner and Becken study did not consider risks to the wider tourist sector.

Weather-related damage can pose a significant cost to tourism providers both directly and indirectly through, for example, insurance costs (Becken et al, 2010). The direct dependence on the environment, combined with the relationship of exposures, heightens the sensitivity of New Zealand's tourism sector to climate change impacts.

Becken S, Wilson J, Reisinger A. 2010. Weather, Climate and Tourism: A New Zealand Perspective. Canterbury: Lincoln University.

In the summer of 2009/10 Lincoln University researchers surveyed 436 international tourists to find out how the weather and climate affects their travel in New Zealand. The survey showed that tourists were expecting warm and sunny weather. They found it to be rainier and colder than they expected. With the warming of the climate they should be happier.

There was no mention of insurance costs in this report.

Score: 0

Adaptive capacity

Does not add to the localised studies reviewed above.

Consequence

Climate change is expected to have negative implications for tourism and recreation, particularly operations that depend on natural assets. As described above, reductions in snowfall or the ability to operate snowmaking equipment could reduce the net number of days suitable for skiing.

This is not what the industry was saying.

Coastal erosion and ongoing sea-level rise could impact the viability of some coastal tourism,

Where, when and by how much was not discussed.

and extreme events could increase the risk of damage to important tourism infrastructure such as huts and tracks, as well as isolating key tourist destinations through disruptions to roads (B6). Changes to natural ecosystems such as the extinction of species may impact wildlife tourism ventures (see section 3 on the natural environment domain). The effects of climate change are already being realised in the tourism industry, although direct correlation is not always acknowledged (Hopkins, 2013 See above*). The cost to tourism of climate change impacts is likely to be high. It is estimated that billions of dollars of assets will be affected by ongoing sea-level rise, while the cost of extreme weather events to the land transport network alone in the past 10 years has increased from $20 million to $90 million per year (Ministry for the Environment, 2017c).*

The billions of dollars of assets that might be affected by sea level rise mostly have little to do with the tourist industry. The roading cost argument has already been discredited.

These costs may be compounded by the impacts on tourism that relies on the transport network and infrastructure assets, highlighting the interdependencies across domains. It is likely that with an increase in frequency and intensity of extreme weather events, cumulative costs will increase, challenging coping capacity.

Interacting risks

No additional information.

Confidence: High agreement, medium evidence

E5: Risks to fisheries from changes in the characteristics, productivity and spatial distribution of fish stocks due to changes in ocean temperature and acidification

NCCRA consequence assessments

Now: Minor
2050: Moderate
2100: Major

Urgency score: 80

Tailrisk Review summary

We have not reviewed the scientific papers in this assessment though it appears that the evidence that fisheries will be negatively affected is mixed.

The evidence on the economic impacts is based of conjectures or possibilities with no quantitaive information. There but nothing that would lead to a judgment that the national economic impacts will be 'major' by 2100. The judgment that an industry that accounts for 0.7 percent of GDP could have a 'major' impact on the New Zealand economy by 2100 does not make sense.

Tailrisk consequence assessment: Minor

Evidence quality score: Not assessed

NCRRA discussion

Exposure

Changes in habitat will lead to a change in the distribution of species, and this has already been observed in New Zealand's marine systems (Law et al, 2017b). and an increasing dominance of warm-water species (Ficke et al, 2007; Law et al, 2017b). The effects of ocean acidification on primary productivity, nutrient availability and chlorophyll, as well as on fish behaviour and calcifying species, are uncertain. Evidence is mixed, and varies between species (Avignon et al, 2020; Chan et al, 2016; Cross et al, 2016; Hildebrandt et al, 2016; Law et al, 2017a; Long et al, 2017; Parsons et al, 2014). Projections indicate that surface pH will continue a gradual decline across New Zealand's marine environment under RCP8.5 (Law et al, 2017a).

Sensitivity

The vulnerability of fisheries, and of the ecosystems that support them, will be determined by their tolerance to changes in sea surface temperatures and ocean acidification. How increasing temperatures impact on growth, metabolism and reproductive success will depend on the thermal tolerance of individual species, so it is difficult to determine just how vulnerable New Zealand fisheries are (Beentjes and Renwick, 2001). et al, 2017a).

Adaptive capacity

Adaptive capacity at the individual level and the ability of the industry to modify its practices and investments in part depend on governance frameworks and regulation (Royal Society | Te Apārangi, 2016). The quota management system (QMS) provides the framework for maintaining fisheries at a sustainable level within the exclusive economic zone (EEZ) and territorial sea, and New Zealand's fisheries management system allows for flexibility in responding to the changes.

Consequence

Commercial fisheries contribute about 0.7 per cent to New Zealand's GDP, produce the fifth largest export commodity by value, and are responsible for 0.7 per cent of New Zealand employment (Williams et al, 2017). By 2100, net primary productivity is projected to decline by 1.2 per cent under RCP4.5 and by 4.5 per cent under RCP8.5 (Tait et al, 2016).

Tait A, Rutledge DT, Frame B, Frame D, Lawrence J, McBride G, … Reisinger A. 2016. Climate Changes, Impacts and Implications for New Zealand to 2100. Synthesis Report. Wellington: Ministry of Business, Innovation and Employment

The reference to primary production in this paper is to land based production not to fishing. There was no discussion of fishing in the document. It is difficult to see how the NCCRA could have mistaken landbased primary production with fishing. As noted in the agriculture discussion this paper showed an increase in primary productivity. We were unable to find any reference to 1.2 or 4.5 percent falls in net primary productivity.

Score: 0

Ocean warming will affect fish stock productivity and species distribution, impacting on fish stock abundance in New Zealand's EEZ. The effect of ocean acidification on finfish species is unconfirmed, but could be significant. Two examples of species at risk from ocean acidification include the snapper and the greenlipped mussel. The snapper has been a food source for Māori, provides significant value to commercial fisheries and is highly sought-after among recreational fishers (Parsons et al, 2014). Increased acidity has been demonstrated to alter behaviour of larval fish and decrease survival, reducing future recruitment (Parsons et al, 2014). The green-lipped mussel, which is a significant export, is also highly sensitive to increasing acidification due to its shell composition (Law et al, 2017a)

Law CS, Rickard GJ, Mikaloff-Fletcher SE, Pinkerton MH, Gorman R, Behrens E, … Currie K. 2016. Climate Changes, Impacts and Implications (CCII) for New Zealand to 2100: Synthesis Report RA2, Marine Case Study – The New Zealand EEZ and South West Pacific. Wellington: NIWA.

This paper made no assessment of the impact of climate change on green-lipped mussels. It discussed cold water corals and the impact of warming on nutrients available to different species.

Score: 0

The decline of these and other species would have a negative effect on the economy and the marine ecosystem. Māori ownership, management and use of commercial and non-commercial fisheries in New Zealand is significant, accounting for almost 50 per cent of the national fisheries quota. Reductions in revenue from quota leasing would decrease the ability of Māori to fund social and cultural development initiatives.

Confidence: High agreement, limited evidence

E6: Risks to the insurability of assets due to ongoing sealevel rise and extreme weather events

NCCRA consequence assessment

Now: Minor
2050: Moderate
2100: Major

Urgency score: 75

Tailrisk review summary

There is a reasonable discussion of the high level issues relating to insurance withdrawal. What is lacking is any attempt to quantify, even in broad terms, those impacts. It matters whether 5,000 household could be affected or 500,000.

Tailrisk consequence assessment: Moderate

Evidence quality score: 5.4

NCCRA discussion

Risk summary

Projected changes in the frequency and intensity of the acute hazards people and organisations insure against, such as flood, fire, storm-surge, landslide, hailstorm and tsunami, are causing the insurance industry to change premiums, develop new insurance offerings and adjust availability. These changes are likely to affect many insurance markets; most significantly, the home insurance market. Changes to insurance offerings could result in additional hardship following extreme events and have significant flow-on effects for New Zealand society including loss of peace of mind, displacement of communities, changes in business investment and household consumption, fiscal risks to the Government, and financial system instability.

Exposure

Mainstream insurers increasingly see climate change as a material risk to their business. Through their pricing and terms and conditions, they play a key role in communicating and raising awareness about climate change risks and help society spread the cost of losses; however, they cannot be expected to insure all risks (Mills, 2009).

Mills E. 2009. A global review of insurance industry responses to climate change. The Geneva Papers on Risk and Insurance – Issues and Practice 34: 323–359.

This paper reported on a survey on how overseas insurance companies were responding to climate change risks. It did state that insurers can not be expected to insure all risks.

Score: 8

The insurance sector is intrinsically vulnerable to climate change; when a risk becomes uneconomic or sufficiently probable, as in the case of coastal, flood and fire risks, the insurer can decide that an area is 'uninsurable' and withdraw insurance altogether (Storey et al, 2015).

The insurance industry is **not** intrinsically vulnerable because it can closely manage its exposures. The possibility of insurance withdrawal or partial withdrawal is well known.

Storey B, Noy I, Townsend W, Kerr S, Salmon R, Filippova O, James V. 2015. Insurance, housing and climate adaptation: Current knowledge and future research. Motu Note 27. Wellington: Motu Economic and Public Policy Research.

This is a note on the risks to coastal housing from sea level rise. It is a short, fairly high-level discussion of institutional factors and some of the risk issues. The possibility that the risk of insurance retreat can be mitigated by protective measures was not mentioned.

Score: 6

Insurers may retreat from an area of New Zealand following a climate event, either in that location or in another New Zealand location. Because most of New Zealand's insurance providers are international, retreat may also be hastened by another country's experiences, which convince them that risk profiles have changed because of sea-level rise or other climatic changes (Storey et al, 2015).

Climate hazards such as drought, fire, flooding and ongoing sea-level rise have the potential to expose asset holders to insurance withdrawal. Most of New Zealand is projected to experience an increase of more than 150 per cent in very high or extreme fire days by 2100 under RCP8.5 (Ministry for the Environment, 2018). This increase may change insurance costs for assets located in rural areas or in the rural–urban interface, which are relatively more exposed to fire risk (Australian Financial Review, 2020; Shrimali, 2019).

We could not find a reference to the 150 percent increase in fire days in the Ministry document, but an increase in fire risk days is to be expected. The paper on the issue, discussed in the climate change section of this paper, suggests an increased risk of

around 40 percent. Wild fire risk to property in New Zealand is low so even with an apparently high proportionate increase the absolute impact will still be low.

Australian Financial Review January 13 2020
This story reported that insurance premiums in cyclone prone Northern Queensland were 2.7 times higher than in the rest of the state. There was conjecture that premiums would rise in bushfire prone areas. However the Insurance Council of Australia said:

insurance premiums across Australia are "unlikely to be significantly impacted" as a result of the current bushfire situation.

Score: 3

Shrimali G. 2019. In fire-prone California, many residents can't afford wildfire insurance.
This was an article in the Conversation that reported that fire insurance had been withdrawn from 340,000 Californian households and discussed insurance pricing issues.

Score: 3

The risks in bushfire prone areas in Australia and California are an order of magnitude higher than in New Zealand so the insurance consequences might be quite different.

Much of New Zealand's population lives in coastal areas, as reflected in a coastal bias in claims under the Earthquake Commission (Fleming et al, nd). Analysis indicates that the Northland, Bay of Plenty, Nelson and Tasman regions have the highest proportions of people and properties affected by extreme weather, and that, as well as coastal bias, properties on steeper land are more likely to be associated with landslip, flood and storm claims than properties on flatter land (Fleming et al, nd). Urban sprawl and population growth in areas of high exposure, such as along the coast, on floodplains and on the fringes of forestland, expose many more people and assets to climate change risks. The exposure of asset holders to this risk is greater under RCP8.5 than RCP4.5, and is likely to increase over the century.

Fleming DA, Noy I, Pastor-Paz J, Owen S. nd. Past Trends in Weather-related Insurance in New Zealand. Wellington: Motu Economic and Public Policy Research.

The focus of this paper is on the number and composition of weather-related events—landslips, storms, and floods EQC claims. There were than 26,000 weather related claims lodged between 2000 and 2017 and total payouts were $300 million. The outcome of this research was:

We **find no clear upward trend yet emerging in the number of claims or their value.** We find that the northern regions of both islands are the source of most claims, that only a handful of weather events caused a large proportion of EQC's weather-related pay-outs, that the average property lodging a weather-related claim is located twice as close to the coast as the national average, and that properties with claims usually are cited on much steeper land than the typical property in New Zealand. We also explore the relationship between claims and socio-economic characteristics, finding that higher income neighbourhoods appear to be those most benefiting from the EQC coverage for weather events.

We note that the most important result, that there was no upward trend in the number of claims was not mentioned in the NCCRA discussion.

Score: 8

Sensitivity

Some asset classes and population groups are more sensitive to insurance sector responses to climate change. Long-lived assets in areas of known exposure will be highly sensitive, as they will continue to be exposed to repeated events over the asset's useful life and unable to use insurance to help recover following events.

Owners and managers of heritage sites are also likely to be sensitive to insurance sector responses, which will compound challenges with securing insurance they already face. Profitable businesses and wealthy asset owners will be able to absorb higher insurance premiums, but lower-income asset owners and small businesses will be sensitive to changes in these premiums.

Adaptive capacity

Changes to market signals through insurance costs may encourage autonomous adaptation, and households and businesses may change behaviour in response. Businesses, for example, may choose to mitigate risks on site through elevating buildings or moving assets to lower risk locations; but such actions may be unaffordable for smaller businesses. Some households may be able to relocate to a less risky zone, but others be unable to move for diverse reasons (see, for example, Māori concerns related to place-based attachment and identity (H5) in section 4.4.5). These households may be unable to secure adequate insurance for their properties. Property developers and existing homeowners may also seek to block information about risk being shared with potential homebuyers, locking in future exposure.

The information about sea level rise is in the public domain. Property developers and existing homeowners cannot block this information. Banks should also know about it and the issue could come up if there is a mortgage application.

The current flat-rate Earthquake Commission premium nationwide helps spread the risk of more hazardous locations across all policyholders, supporting insurance penetration and affordability. However, it mutes the price signal, which can be an effective motivator of autonomous adaptation (Storey et al, 2015).

As climate projections become more granular, insurers will be able to price insurance at a finer scale (recognising that greater granularity does not decrease uncertainty). This may minimise the risk of broad swathes of communities being priced in the same way, or support development of new insurance products. It is unlikely that new entrants will come into the insurance market, as the highly detailed information needed to accurately price risk acts as a barrier to entry, particularly in small markets (White, 2011).

White E. 2011. Flood insurance: Lessons from the private markets. In: Proceedings of the ASEAN Disaster Risk Financing & Insurance Forum, Jakarta, November 2011.
This was a short discussion for an Asean meeting that would not be so relevant for New Zealand.

Score: 6

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*Reducing this risk (*what risk not clearly explained*) is critically dependent on governance arrangements, such as tools that support decision-making under uncertainty (G1), coordination among decision-makers (G1) and the ability for the central government to compensate property owners who are forced to relocate (G2). Alternative structures, such as multi-sector partnerships between the public, private and civic sectors, are increasingly seen as critical initiatives to improve risk management (Crick et al, 2018). An example in practice is the United Kingdom's Flood Re scheme, between the government and private insurers, which aims to make flood cover more available and affordable (Flood Re, 2020)*

Crick F, Jenkins K, Surminski S. 2018. Strengthening insurance partnerships in the face of climate change: Insights from an agent-based model of flood insurance in the UK. Science of the Total Environment 636: 192–204.
This is largely a review and critique (negative) of the UK Flood –Re public-private insurance partnership.

Score: 7

Flood Re. 2020. Flood Re: About us.
Flood Re was seen as a transitional arrangement towards a fully risk based system. It is due to expire in 2039 so it is odd that it was presented as a climate change risk solution.

Score: 5

Consequence
Insurance is a risk transfer tool used to improve adverse financial consequences that follow on from unlikely disasters. If an insurer retreats from an area where assets and asset owners are still exposed to the risk, recovery will be delayed and hugely costly for asset owners. The reduced insurance coverage could in turn reduce asset values in affected areas (and potentially also unaffected areas that face similar risks), which could tighten the borrowing constraints of households and corporates.

Even if losses are largely insured and financing for reconstruction is immediately available, a severe weather-related catastrophe could affect the banking sector and the real economy (flow of goods and services) in the medium term (Batten et al, 2016).

Batten was reviewd above. There is no substantial risk to the banking sector in New Zealand. Earthquakes catastrophes can be much larger than climate related events in New Zealand (100 times larger than the biggest climate event) but the Christchurch earthquake did not have a material impact on the banking industry.

Insurance contracts are generally renewed on an annual basis. Because insurance is a requirement for residential mortgages in New Zealand, and failing to maintain insurance can trigger default, insurance withdrawal could cause home loan defaults because of the maturity mismatches between residential insurance and mortgages. Lenders may be left in technical default, experience material losses, or change behaviour to require more equity and higher interest rates for properties at risk of insurance retreat (Lawrence et al, 2016). ----

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Lawrence J, Blackett P, Cradock-Henry NA, Flood S, Greenaway A, Dunningham A. 2016. Climate Change Impacts and Implications for New Zealand to 2100 Synthesis Report: RA4 Enhancing capacity and increasing coordination to support decision making. Wellington: Deep South National Science Challenge.

There did not appear to be a discussion of insurance issues in this paper.

Score: 0
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The main issue here is what banks should do if there is insurance retreat and banks have an uninsured risk. This happens from time to time at present when homeowners fail to renew their insurance. Banks have made conscious decisions not to check that insurance premiums have been paid because their overall losses, when there have been fire or flood events, are very small and would not justify the expense of checking whether insurance is current. It may become more difficult to turn a blind eye when there are well publicised cases of insurance retreat, but forcing a sale at significant loss to the homeowner who cannot get insurance is likely to be seen as oppressive. The most logical thing for the bank to do is accept the higher risk, which might be quite small, and could be compensated by a higher interest rate.

Local authorities and their insurers could find themselves holding unexpected liabilities if future courts rule that councils are liable for resource consents provided to homes threatened by climate change.

This is always a possibility of an adverse court decision but there are several mitigants. Strengthened legislation could ensure that the risk stays with the homeowner.

Interacting risks

Very human risks relate to insurance retreat. Insurance contributes to peace of mind and plays a key role in helping policyholders recover from losses (Mills, 2005). Loss of insurance could therefore impact on mental health and wellbeing (H7). Even for those who are insured, the processes following an event, such as managing insurance claims, can be a further source of trauma (Ohl and Tapsell, 2000; Thrush et al, 2005).

Mills E. 2005. Insurance in a climate of change. Science 39: 1040–1044

This short and dated general discussion of insurance that does not add much to the New Zealand discussion.

Score: 5

Ohl C, Tapsell S. 2000. Flooding and human health: The dangers posed are not always obvious. BMJ 321(7270): 1167–1168.

This is a short piece that cites a few studies on the health after effects of flood events. Dealing with insurance issues is mentioned as being stressful.

Score: 6

Thrush D, Burningham K, Fielding J. 2005. Exploring Flood-related Vulnerability: A Qualitative Study. Bristol: Environment Agency.

Not recovered.

If loss of insurance does not allow the policyholder to recover following a hazard event or encourages them to move away from the area prior to an event, many people will have the negative experiences associated with loss of place and community cohesion (H1).

The loss of insurance is more likely to trap homeowners in place. The value of their home will have fallen and they will be unable to afford an equivalent home elsewhere. The best financial decision will often be to stay on an uninsured basis.

Unavailability or unaffordability of insurance cover will reshape the distribution of vulnerable groups, exacerbating existing inequities or creating new ones (H2)

This is conjecture unsupported by analysis.

Confidence: High agreement, low evidence
There is a high degree of agreement that climate change will change asset insurability. Target research on asset insurability in New Zealand has been limited, although the international body of literature and attention to the topic are growing.

Adaptation
A number of adaptation efforts are under way or planned. These are currently directed at increasing knowledge about this risk. In particular, research is directed towards determining liability for costs in the instance of insurance retreat. Efforts to reduce the risk, through land-use planning that accounts for dynamism and sea-level rise, are being made in some regions of New Zealand

E7: Risks to businesses and public organisations from supply chain and distribution network disruptions due to extreme weather events and ongoing, gradual changes

NCCRA consequence assessment

Now: Minor
2050: Moderate
2100: Major

Urgency score: 68

Tailrisk review summary

The NCCRA assessment is based on the assumption that there will be large increases in disruptive weather events that will disrupt supply chains. As that assumption is not true the assessments flounder. Even if it were true the extent of any disruptions would be small from a national economic perspective.

Tailrisk consequence assessment: Negligble

Evidence quality score: 2.57

NCCRA discussion

Risk summary

Supply chains comprise local and global networks of infrastructure, people, information, materials and capital, so are subject to climate change-related disruption at a number of scales and in many geographies. Local, regional, national and international supply chains are likely to be adversely impacted by acute hazards such as flooding, fire or landslides, and gradual changes such as sea-level rise, changes in seasonality, drought and erosion. Adverse weather and transport network disruption (B6) are increasingly cited as reasons for supply chain disruption (Business Continuity Institute, 2019).

Business Continuity Institute. 2019. BCI Supply Chain Resilience Report 2018. Caversham: Business Continuity Institute.

This report provided information on supply change disruptions experienced by members of an UK industry group. 35.1 percent reported a weather cause, accounting for about 12 percent of all disruptions. About 80 percent of disruptions cost less than $500,000.

Score: 8

Due to its geographical separation from global markets, New Zealand is particularly prone to supply and distribution disruption (Basnet et al, 2006). Supply chain disruptions can lead to losses in productivity, share price movements, damage to brand and reputation, loss of customers and increased regulatory scrutiny. The sensitivity and vulnerability of supply chains are influenced by many factors, including the resilience of key physical infrastructures, industry profitability, the material characteristics of products, and regulatory frameworks. Because of this, their sensitivity and vulnerability differ between geographies, economic sectors and the actors in each sector. Supply chains are already vulnerable to climate change-related hazards, and exposure of supply chains to hazards is likely to be greater under RCP8.5 than RCP4.5, and to increase over time.

Basnet C, Childerhouse P, Foulds LR, Martin V. 2006. Sustaining supply chain management in New Zealand. International Journal of Logistics Systems and Management 2(3): 217–229.

This is an exploratory survey of supply chain management practices in New Zealand. There was no mention of climate events or climate change.

Score: 0

Exposure

The geographical reach and complexity of production and consumption systems create different degrees of exposure to climate change-related hazards occurring locally, regionally or internationally. Organisations with localised supply chains may be unaffected by events occurring in other regions, while other organisations are exposed to disruption from international events. For example, Woolworths, which operates Countdown supermarkets and is New Zealand's largest private sector employer, has noted the "devastating effects" that climate change is having on farmers in New Zealand, and the disruption caused by the floods in Townsville in 2019 (Woolworths Group, 2019). Supply chains can therefore be considered highly exposed to climate change-related disruption, although exposure will differ on a caseby-case basis.

Woolworths Group. 2019. Better for Everyone: 2019 Sustainability Report. Bella Vista, NSW: Woolworths Group.

The above reference is to the following in the Chief Executive's message.

Through our extensive agricultural supply chain we have observed the devastating effects that climate change is having on our farmers in Australia and New Zealand.

The Chief Executive was probably thinking that New Zealand was having an Australian style drought. We doubt that he knew much about climate change in New Zealand. There is no mention in the report about the effect of the climate on New Zealand supply chains. However, there was an Australian report that suggested more New Zealand supplies might be required as Australian supply regions get too hot.

Score: 0

Supply chains for all sectors are likely to be affected; the mining sector, as one example, is vulnerable and exposed to changing precipitation patterns and water availability. Water scarcity may increase operational costs, reduce output or lead to increased competition for water between local communities and the operation's sites (B1), while heavy rains over shorter periods could cause flooding of sites (B2). These same floods or flooding in a different

area could affect transport infrastructures, delaying or increasing the costs of product delivery (B6).

New Zealand's small pharmaceuticals sector may be affected by loss of biodiversity, an input to production, which is projected to decline in diversity and abundance as a result of long-term changes to climate (N7). Many other sectors, such as the industrial sector, are vulnerable to extreme weather events and rising sea levels, which could cause production facilities to shut down and increase the cost of raw materials (B2). Supply chains and distribution networks are already exposed to adverse weather. Exposure will increase under both RCP4.5 and RCP8.5.

This is all speculation without evidence as to the magnitude and probaility of possible effects.

Sensitivity
Trends in the global economy have increased the sensitivity of supply chains to climate change-related disruptions. For example, the centralisation of inventories over the past 40 years has increased the sensitivity of supply chains to extreme weather events in that location, such as flooding or storms (Dasaklis and Pappis, 2013). Supply chains have also, in general, become leaner, longer and more complex in response to technological change, globalisation and market competition, which can increase exposure and sensitivity to climate change hazards; although complexity can also enhance resilience (Lim-Camacho et al, 2017). The inventories that once buffered supply chain shocks have disappeared, making them more fragile and prone to disruption by acute events. Due to its geographic separation from global markets, New Zealand is particularly prone to supply and distribution disruption (Dasaklis and Pappis, 2013).

Dasaklis T, Pappis C. 2013. Supply chain management in view of climate change: An overview of possible impacts and the road ahead. Journal of Industrial Engineering and Management. 6(4).
This is a high level survey article on possible supply chain effects with no quantification and no reference to New Zealand.

Score: 3

Lim-Camacho L, Plagányi ÉE, Crimp S, Hodgkinson JH, Hobday AJ, Howden SM, Loechel B. 2017. Complex resource supply chains display higher resilience to simulated climate shocks. Global Environmental Change 46: 126–138.
The conclusion in in this report that diversified supply chains are more resilient would seem to be self-evident.

We use a network-based simulation approach to estimate the resilience of supply chains, particularly to disruption experienced during climate-related extreme events. We consider supply chain examples from three Australian resource industries - fisheries, agriculture and mining - that have experienced climate shocks in recent years. we show that complex supply chains with a large number of nodes and links are more resilient to disruption..

This highlights the importance of considering the broader economic benefits of diversified chains, leading to risk reduction and improved design post-disruption.

Score: 5

Many factors influence a sector or industry's sensitivity to supply chain disruption. These include industry profitability, access to alternative markets and suppliers, the material characteristics of products, and regulatory frameworks. A highly profitable industry is more likely to survive disruption, and alternative markets and suppliers can ensure that production processes can continue, and buyers can be reached. The case study below (box 7) highlights how alternative markets and material characteristics (in this instance, perishability) influence the sensitivity of a sector to supply chain disruption in a distant but important market.

Box 7 demonstrated how New Zealand business coped with disruptions to exports to China with covid-19. These disruptions were an order of magnitude larger than those from weather related delays in New Zealand.

Adaptive capacity

The resilience of infrastructure networks, such as roads, rail, airports and ports, influence supply chain vulnerability. Complex supply chains that have a lot of nodes and links are more resilient to disruption (Lim-Camacho et al, 2017). It is possible for individual businesses and organisations to manage the risk of disruption to their supply chain through:

- *design of new supply chain networks, which could consider facility location, product design, sourcing, transportation, and distribution and network configuration*
- *routing and scheduling programmes, inventory planning and control, material requirements planning, and production scheduling (Dasaklis and Pappis, 2013* See above *).*

However, it is challenging for many businesses to build detailed information on how supply chains and distribution channels may be affected by climate change-related disruptions. While empirical research on supply chain management in New Zealand is scarce, information sharing appears to be reactive rather than planned and is seen as an exchange of 'basic information' rather than an 'exchange of knowledge'. Developments are somewhat encouraging, with 88 per cent of respondents in a recent survey by Donovan et al (2017) stating that they regularly solve problems jointly with their suppliers. However, only 58 per cent of respondents include key suppliers in their strategic planning or goal-setting activities (Donovan et al, 2017). This suggests that while organisations set up contracts with their strategic partners, they do not integrate them into the organisation's strategic planning, nor do they include those partners in long-term planning. Research suggests that several factors influence information sharing in supply chains, including the:

- *number of buyers requesting information*
- *commitment of buyers to use information in their future procurement decisions*
- *profitability of an industry*
- *existence of greenhouse gas emissions regulations (Jira and Toffel, 2013).*

Donovan J, Castka P, Hanna M. 2017. Supply Chain Management in New Zealand: Practices, Strategy and Performance. Christchurch: University of Canterbury.
This paper reported the results of a questionaire on some aspects of supply chain management in New Zealand. There was no information on supply chain disruption.

Score: 0

Jira C, Toffel M. 2013. Engaging supply chains in climate change. Manufacturing and Service Operations Management 15(4): 1–19.
This paper was mainly about supply chain participants willingness to share greenhouse emission information. It had nothing to do with supply chain disruptions.

Score: 3

Resilient infrastructure is crucial in enabling businesses to minimise climate change disruptions to their operations. Some organisations (generally larger businesses) have a higher capacity to understand and manage risks from climate change, such as through collaborating with their suppliers. The actions these organisations take can have positive wider effects, by building capacity and increasing the resilience of supply chain partners. Further research is needed to identify and assess climate change risks to key nodes in the supply and distribution network (G5), and additional funding is needed to future-proof existing infrastructure (G2).

Consequence
Supply chain disruptions can lead to losses in productivity, share price movements, damage to brand and reputation, loss of customers, and increased regulatory scrutiny. For businesses, these changes are likely to result in unfulfilled orders and breach of delivery contracts, in turn leading to loss of revenue and reputational damage. Climate change also adds uncertainty to supply chain networks, especially for globalised ones operating across continents. Supply chains are also likely to incur higher insurance costs due to their exposure to climate change.

No evidence was been presented on how climate change outcomes will exacerbate these negative outcomes.

Confidence: High agreement, medium evidence

Adaptation
Managing supply chain risks requires adaptation action by governments, which can address market failures, and by organisations and businesses, which have a strong internal incentive to manage this risk. The New Zealand Transport Agency has a number of actions in progress, including a resilience project to ensure the highway network can withstand disruption, and it is developing guidelines to assess coastal risks. The Ministry for Primary Industries is also

working with the Rural Support Trust to support impacted rural communities. It is likely that major companies have their own supply chain risk management strategies; however, many private sector organisations have not yet considered changing climate change risk profiles.

There is no evidence that supply chain mangement in New Zealand suffers from market failutes or that they will emerge in the future as the climate changes.

Built environment domain

The consequence descriptions for the built environment domain are as follows;

Moderate	**Major**	**Extreme**
Many short-term infrastructure service disruptions; damage recoverable by maintenance and minor repair Early renewal of infrastructure by 21–50% Moderate damage to 10–100 dwellings; some require immediate relocation Between 5–20 commercial and public buildings require assessment; some require temporary relocation Moderate, reparable damage to Māori cultural asset	Widespread short-to-medium term disruptions to infrastructure service; extensive infrastructure damage requiring major repair Major loss of infrastructure service Early renewal of infrastructure by 51–90% Major damage to 100–1000 dwellings; significant numbers need to be immediately relocated Costs exceed insured value Between 20 and 100 commercial and public buildings require assessment; many need to be permanently relocated Major, widespread damage to Māori cultural assets	Widespread, long-term service disruption; significant permanent damage to and/or complete loss of infrastructure and its service. Loss of infrastructure support and translocation of service to other sites; early renewal of infrastructure by more than 90% More than 1000 dwellings require assessments for immediate relocation More than 100 commercial buildings and more than 100 government and non-commercial buildings require assessment for permanent relocation options. Is Costs significantly exceed insured value Damage to more than 75% of Māori cultural assets

B1: Risk to potable water supplies (availability and quality) due to changes in rainfall, temperature, drought, extreme weather events and ongoing sea-level rise

NCCRA Consequence assessments

Now: Major
2050: Extreme
2100: Extreme

Urgency score: 93

Tailrisk review summary

The Government's three waters proposals probably means that many of the issues raised in this NCCRA assessment will be dealt with centrally though a major upgrade programme that presumably will address many of the climate change vulnerabilities. As the decision has been made to manage these risk centrally this risk is not discussed. The key issue is the marginal cost climate change will add to changes that will occur regardless of climate change.

Evidence quality score: NA

B2: Risks to buildings due to extreme weather events, drought, increased fire weather and ongoing sea-level rise

NCCRA consequence assessments

Now: Major
2050: Extreme
2100: Extreme

Urgency score: 90

Tailrisk review summary:

As discussed elsewhere in this review paper the material issue is the risks due to sea level rises and the extent to which these are mitigated by coastal protection works.

Increases in risks due to 'extreme' weather events, drought and increased fire weather will be manageable.

Tailrisk consequence assessment: Moderate

Evidence quality score: 3.44

NCCRA discussion

The NCRRA discussion was somewhat repetitious with several historical event descriptions and purely technical and factual statements about buildings. We have focused on the more substantive points.

Exposure

In New Zealand many communities live on the coast, and buildings face significant exposure to coastal flooding and erosion, which will be exacerbated by sea-level rise. Currently over 72,000 people and 49,700 buildings are exposed to coastal flooding.

Under RCP8.5, by 2100 about 117,900 buildings across New Zealand are projected to be exposed to coastal flooding (Paulik et al, 2019b).

It is important to recall the critique of these exposure measures. First the exposures were calculated using the bathtub methodology, that overstates the risk very substantially in major urban areas.

Second, it takes no account of protective structures being installed or improved that could substantially reduce the number of buildings exposed. Many of the buildings are in urban areas where protection against sea level rise will be economic.

For example, in 2014 Beca Ltd. did a broadbrush assessment of the costs of dealing with a sea level rise of 0.8 metres for the Dunedin City Council (2014). The capital cost was $75 million and the annual running costs were $3.5 million.

Exposure to inland flooding is high at present, with about 675,000 people across New Zealand living in flood hazard areas and an estimated 411,500 buildings already exposed to inland flooding. Overtopping and breaching of stopbanks and flood defences, and failure of pumped stormwater systems, are already resulting in significant exposure.

Recall, from part two, that the Paulik study suggested fewer buildings will be subject to increased risk with climate change. Not discussing the results for building risk was, in our view, deceptive. What was presented was some technical information in a footnote that would not have been meaningful to the reader.

The data on insurance payments from severe weather events show the magnitude of loss from storms in New Zealand has increased over the past decade (Insurance Council of New Zealand, 2020).

Insurance Council of New Zealand 2020

Appendix one shows the insurance Council's data on insurance losses over the last 50 years. There has been an upward trend. To some extent this will be due to an upwards increase in assets at risk and bad luck, but there might be some suggestion of an underlying increase.

Score : 8

Groundwater rise is poorly understood in New Zealand. However, it is recognised as an emerging issue in many coastal communities

Climate change may accelerate the processes causing erosion, through extreme rainfall and sea-level rise, resulting in increased exposure of buildings (Basher et al, 2012; Rosser et al, 2017). Buildings may also be increasingly exposed to soils with higher liquefaction susceptibility, because of groundwater rise in coastal plains and reclaimed areas (Ministry for the Environment, 2017b; Quilter et al, 2015). Drought may increasingly affect expansive soils, which can cause soils to dry and shrink (BRANZ, 2008).

Basher L, Elliot S, Hughes A, Tait A, Page M, Rosser B, … Jones H. 2012. Impacts of Climate Change on Erosion and Erosion Control Methods – A critical review (MPI Technical Paper No. 2012/45). Wellington: Ministry of Primary Industries.

This was a lengthy review that could only make some qualitative assessments because of the technical difficulties in modeling the impact of climate change on erosion.

Areas most susceptible to increased landsliding include the soft rock hill country of Taranaki, southern Waikato, Manawatu-Wanganui west of the Ruahine Range, Otago, South Canterbury and inland Marlborough. Many of the areas of the South Island with the highest projected increase in rainfall and high potential for landslide erosion are steep forested mountains in national parks.

Many areas in both islands with highest potential for landslide erosion (erodible soft rock hill country of eastern North Island, Bay of Plenty, northern Waikato, Auckland, Northland, North Canterbury and Marlborough) are projected to have a decrease in mean annual rainfall and the impact of climate change will depend on changes to extreme rainfall and extra-tropical cyclone activity.

Generally landslides occur in areas where there are few people and buildings. The risk of a substantial amount of damage to the building stock is low. The more populated areas are projected to have lower rainfall and hence a lower risk.

Score: 3. This was a high quality paper but its use in the assessment was misleading.

Rosser B, Dellow S, Haubrock S, Glassey P. 2017. New Zealand's national landslide database. Landslides 14: 1949–1959.
This paper describes a landslide database contains information on landslide locations and where available: 1) the timing of landslides and the events that may have triggered them; 2) the type of landslide movement; 3) the volume and area; 4) the source and debris tail; and 5) the impacts caused by the landslide.

There was discussion of the nature damage to buildings but the paper provides no information on the quantum of the damage.

Score: 0

BRANZ. 2008. Soil Expansivity in the Auckland Region. Addendum Study Report No. 120A. Porirua: BRANZ.
Not recovered.

Quilter P, van Ballegooy S, Reinen-Hamill R. 2015. The effect of sea level rise on liquefaction vulnerability: A case study for consideration of development on coastal plains and reclamations. In: Proceedings of the Australasian Coasts and Ports Conference 2015. Auckland: Engineers Australia and IPENZ
This paper discussed the effect of sea level rise in increasing vulnerability to Earthquakes in Canterbury. It shows that liquefaction risk is increased even in relatively moderate earthquakes.

Score: 9

New Zealand has a history of wildfires, and exposure is projected to increase due to climate change (Pearce et al, 2018). Buildings will be exposed to wildfire through direct impacts on structures, as well as because of the characteristics of vegetation surrounding buildings., it is likely that exposure to wildfire, particularly in rural areas, will increase throughout this century (Pearce et al, 2018).

Pearce et al. Auckland Region climate change projections and impacts 2018
The reference to the Auckland report did not make much sense, when a New Zealand wide assessment[23] was available. Auckland will have only a moderate increase in fire risk.

Score: 2 The low score is for not using the most appropriate paper.

Sensitivity
Sensitivity to climate and natural hazards is driven by a range of factors including the design, age and condition of buildings.

New Zealand's building stock is largely made up of wooden and masonry houses, and houses with reinforced concrete frames (Uma et al, 2008). The average age of residential dwellings in New Zealand is about 50 years (Jaques et al, 2015). Dwelling condition is directly related to dwelling age, and therefore informs sensitivity to damage, with older buildings (including cultural heritage buildings) likely to experience a greater level of damage (Buckett et al, 2010).

Many buildings in New Zealand are sensitive to floods, which can result in structural damage, particularly where inundation reaches or exceeds the elevation of the floor (Reese and Ramsay, 2010).

Groundwater rise could also impact on buildings, which would lead to the risk of rising damp and impaired stormwater drainage (Tauranga City Council, 2019). Buildings in areas of high groundwater may have prolonged exposure to floodwaters, with resulting higher levels of damage.

Historically, extreme weather events have caused significant damage, disruption and financial cost throughout New Zealand (Cenek et al, 2019)

Reese S, Ramsay D. 2010. RiskScape: Flood Fragility Methodology. Wellington: NIWA.
This report summarises the development of the methodologies and current approaches incorporated within the NIWA RiskScape model to calculate damage to property, infrastructure and people due to flood inundation events.

Damage curves by flood depth for various loss types were presented but there was no overall summary measures that would allow a comparison, for example, of the ratio of building damage to overall costs. Our reading of the discussion was that it

[23] Pearce HG, Kerr J, Clark A, Mullan B, Ackerley D, Carey-Smith T, Yang E. 2012. Improved Estimates of the Effect of Climate Change on NZ Fire Danger. Christchurch: Scion, Rural Fire Research Group.

suggests that, generally, indirect losses would be a relatively small part of total costs. For example:

The post-event survey following the 2004 Manawatu / Hutt Valley floods contains information concerning business disruption. The average duration of business disruption was 2.9 days.

Score: 5

Tauranga City Council. 2019. Flooding from rising groundwater
The Tauranga City council monitors ground water levels to assist its planning and permitting processes. This reference is to the 2019 Tonkin and Taylor report on the statistical information on this process. There was no specific discussion of rising damp and impaired stormwater drainage.

Score: 5

Cenek P, Turner R, Flay R, Pirooz AS, Jamieson N, Carpenter P. 2019. Tools and Knowledge to Improve New Zealand's Long-term Resilience to Wind Storms: Final Research Report. Wellington: WSP OPUS.
This paper was largely concerned with updating windspeed data for building design standards. The section on climate change reviewed the international literature that found that wind speeds had generally **dropped**.

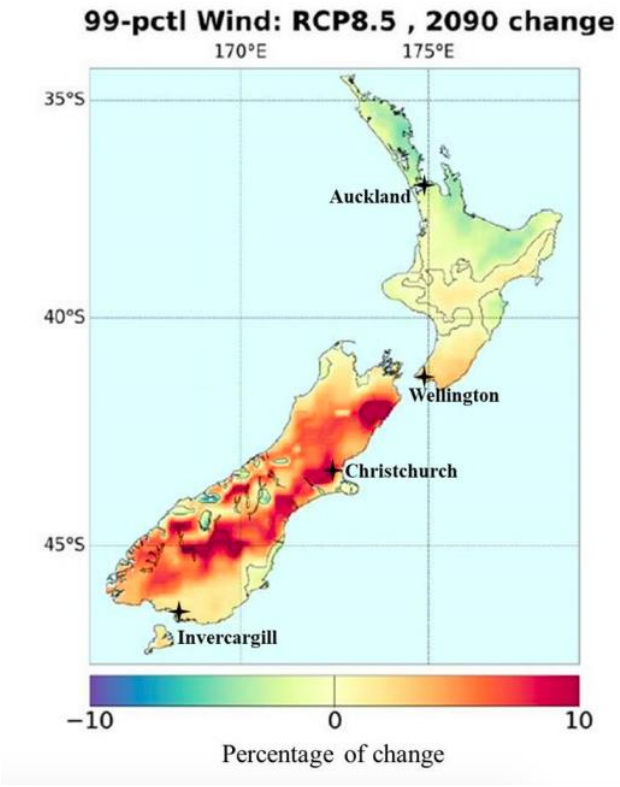
Their analysis for New Zealand for 1972-2017 found:

Generally, a **decreasing trend** is observed in the maximum seasonal gust speeds, except at Auckland and Christchurch stations in spring, and at Wellington station in summer. Autumn and winter had the strongest decreasing trends at the four selected stations. Annually, all the stations experienced a decreasing trend, and the strongest trends are observed at Invercargill ($p < 0.05$) and Christchurch ($p < 0.10$).

The 99th percentile of the maximum daily gusts correspond to the more extreme gust speeds that are recorded. Trends in the number of days where the gusts exceed the 99th percentile values are negative or show no change.

The paper also reported wind speed projections prepared for the Ministry for the Environment (2018) using the Regional Climate Model and NIWA's Virtual Climate Station. The figure shows the percentage changes in the magnitude of 99th percentile of daily-mean wind speed under RCP8.5, by year 2090, relative to the daily 99th percentile in the baseline 1986–2005 period.

Figure fifteen: Windspeed changes by 2090



Score: 0 Low score for the misleading use of the paper.

Prolonged periods of extreme rain can also damage buildings through increased moisture penetration in walls and damper conditions indoors, degrading building interiors (Department of Building and Housing, 2006). This has been associated with health consequences for building occupants (Department of Building and Housing, 2006).

The climate change evidence is that there will only be relatively moderate increases in prolonged rainfall episodes.

Extreme wind can exacerbate the impact of rainfall on buildings by increasing moisture penetration and can result in destruction of buildings, including roofing being blown off, broken windows, and other flying debris (Department of Building and Housing, 2006).

The evidence suggests (see above) that there will only a limited, or no increase, in wind speeds, particularly in the more populated regions

Knowledge of stopbank design, age and condition (which informs sensitivity to damage from flood events) remains sparse across New Zealand. This is compounded by a lack of consistency

between formal and informal stopbanks (Crawford-Flett et al, 2018), which reduces the effectiveness of monitoring and maintenance.

Crawford-Flett K, Blake D, Pascoal E, Wallace T. 2018. New Zealand Stopbank Networks: Understanding Resiliency Challenges. Christchurch: University of Canterbury.

This was a one page online 'poster'. It reports on efforts to compile a nationally consistent stopbank inventory.

Score: 5

Many types of buildings in New Zealand are also sensitive to wildfires. The level of sensitivity depends on a number of factors, which include the:

- *density per hectare of buildings*
- *size and shape of groups of buildings*
- *type and amount of vegetation close by*
- *distance between structures*
- *width and layout of roads and reserves*
- *climate zone*
- *materials used in structures (Opie et al, 2014).*

Opie K, March A, Leonard J, Newnham G. 2014. Indicators of Fire Vulnerability: Risk Factors in Victorian Settlements. Melbourne: CSIRO.

This was a detailed case study of the impact of a bushfire on a Bendigo Victoria suburb. It did not discuss the materials used in structures. It does not convey any useful information about the vulnerability of New Zealand suburbs to wildfires .

Score: 0

Buildings are sensitive to landslides, which are caused by a number of factors including rainfall, soil stability, structural building type (including foundations) and intensity of land development (Guillard-Goncalves et al, 2016; Lin et al, 2017).

They are also sensitive to drought-induced soil movements, which can cause certain types of soil to dry and shrink (Corti et al, 2011). As buildings shift and subside, this can result in structural damage to foundations and cracked walls and ceilings (Kovats and Osborn, 2016)

A listing of possible sensitivities is not very helpful in making a quantitaive assessment.

Lin Q, Wang Y, Liu T, Zhu Y, Sui Q. 2017. The vulnerability of people to landslides: A case study on the relationship between the casualties and volume of landslides in China. International Journal of Environmental Research and Public Health 14(2).
A Chinese study on casualties caused by landslides is not very relevant to New Zealand, particulary as there is only a small population exposed to increased landslide risk due climate change.

Score: 0

Guillard-Goncalves C, Pereira S, Garcia R, Zezere J. 2016. Assessment of physical vulnerability of buildings and analysis of landslide risk at the municipal scale: Application to the Loures municipality, Portugal. Natural Hazards and Earth Systems 16: 311–331.
Similarly for this Portuguese report.

Score: 0

Corti T, Wüest M, Bresch D, Seneviratne S. 2011. Drought-induced building damages from simulations at regional scale. Natural Hazards and Earth System Sciences 11: 3335–3342.
This paper compared modelled with actual drought damages in French Departments. The best costs estimate for France during the 2003 drought was 890 milllion euros. It is not clear how this estimate would translate to New Zealand. The New Zealand building stock is different; the population exposed to a higher risk of drought is not large and New Zealand would be unlikely to experience a drought of the severity that France experienced in 2003, purely because of climate change.

Score: 7

Kovats S, Osborn D. 2016. Chapter 5: People and the built environment. In: UK Climate Change Risk Assessment 2017: Evidence Report. London: Committee on Climate Change.
The only reference to structural damage in this paper was:

5.3.7 Structural stability of buildings
Along with the saturation of the soil by increased rainfall during winter periods, projected hot summers will likely lead to drying out of the subsoil with slopes and retaining structures becoming unstable. Fluctuating rainfall patterns may lead to increased shrinkage of clay soils (or clay heave), which could lead to subsidence and structural damage requiring underpinning or in worse cases demolition. Underground pipework may suffer damage. Subsidence risk is covered in more detail in Chapter 4.

Score: 3

Adaptive capacity

Existing residential and commercial buildings inherently have a low level of adaptive capacity.

This leaves out completely the most important adaptive defences against sea-level rise and associated flooding risk: coastal protection works. This should substantially mitigate the risk where the exposures are large.

Consequence

Climate change impacts on buildings will have significant economic, social, cultural and public health consequences. Major floods can have financial impacts on individuals and households, such as potentially reducing house and land prices. These impacts could be compounded by insurance retreat from high-risk areas in New Zealand.

This string of assertions on the impact on buildings was not backed by much solid evidence or analysis.

The consequences for coastal communities, such as Haumoana, Granity, Waitara and Urenui, which currently have homes that are being undermined or swamped by wave action, will increase due to climate change. Other low-lying settlements in New Zealand could also face increased social and economic impacts; for example, South Dunedin, Edgecumbe, Lower Hutt and Petone are already prone to major flooding (Stephenson et al, 2018 see above*). These consequences are far reaching across all domains.*

Not many people live in the exposed parts Haumoana, Granity, Waitara and Urenui,

Increased moisture in buildings due to extreme weather events and flooding could also result in poor public health outcomes, and have a range of economic and social consequences. At present, mould is visible to some extent in an estimated half of all houses in New Zealand, with a slightly higher prevalence in rental properties (White et al, 2017a). Mould is a key indicator of overall indoor air quality and is potentially harmful to the health of household occupants (Chang-Richards et al, 2018).

The failure of flood management and protection schemes could also lead to extreme consequences, given the large number of people living in areas where flood management schemes are in place.

There is no evidence here that mould in houses will increase with climate change. Extreme weather events are by definition relatively rare and should not cause chronic mould problems. Flooded houses will have to be repaired before they are reinhabited.

White V, Jones M, Cowan V, Chun S. 2017a. BRANZ 2015: House Condition Survey: Comparison of House Condition by Tenure. Porirua: BRANZ.

5 percent of owner occupied and 9 percent of rental houses had large patches of mould. 1 percent had extensive blacked areas. Mould is not a major problem in New Zealand houses. Many houses might have a patch in the bathroom of laundry but there is no evidence that this poses a significant health risk. Generally mould issues can be addressed with ventilation and cleaning.

Score: 3

Chang-Richards A, I-Kai Wang K, Fakhruddin B. 2018. Climate, Housing and Health Profiling: Promoting housing quality to improve health and wellbeing. Auckland: University of Auckland.

This paper reported on a study of thermal comfort that showed that thermal comfort was not achieved most of the time in unheated houses in Auckland.

Relative humidity was not significant, so lack of a heating system and the structural insulation method in the house seem to be the main reasons for the thermal discomfort.

The study demonstrated that people without heating will be better off with climate change.

Score: 0

Interacting risks

No new information

Confidence: High agreement, medium evidence

B3: Risks to landfills and contaminated sites due to extreme weather events and ongoing sea-level rise

NCCRA consequence assessment

Now: Moderate
2050: Major
2100: Major

Urgency score: 85

Tailrisk review summary

An assessment of the consequences of the legacy landfill problem should await the official review of the problem. However, almost certainly, the consequences will not rise to the level of a major national issue with financial costs of several percent of GDP. To put some of kind of scale on the problem, assume that 30 of the 100 legacy landfills should be removed to a safer site or protected over 50 years at a cost of $5 million each. That would be a cost of $3 million per year.

Tailrisk consequence assessment: Minor

Evidence quality score: 5.2

NCCRA discussion

Risk summary

Active and closed landfills and contaminated sites across New Zealand are currently at risk from extreme weather events and sea-level rise, and from the associated coastal and inland flooding, erosion and rising groundwater. All these hazards are projected to increase in frequency and severity over time due to climate change.

Exposure

While no detailed analysis has been undertaken, councils around New Zealand have reported that exposure of landfills to climate hazards is a major issue (Beehive, 2019). Landfills are likely to be exposed to extreme weather events and sea-level rise, along with associated coastal and inland flooding, erosion and rising groundwater. This exposure is projected to increase with climate change. Determining the specific exposure of landfill sites to climate hazards is hindered by a lack of information on the location of numerous closed landfills and contaminated sites (Beehive, 2019).

Beehive. 2019. Minister announces multi-agency response to identify risks from legacy landfills.

A Beehive announcement that there will be an investigation into the extent of the problem is not evidence of the extent of the problem. There was no statement from councils in this announcement that they considered legacy landfills to be a major problem.

Score: 4

In general, climate change will increase the exposure of landfills and contaminated sites to inland flooding across New Zealand).

This is not true in general because inland flooding is not expected to increase (Paulik 2019). Increased flooding risk may be the case in some areas but not in most areas.

Many landfills and contaminated sites are also likely to be exposed to sea-level rise. High-level analysis suggests that about 112 active and closed landfills are located around New Zealand, within 0.5 metres of the mean high water spring (MHWS) level (Local Government Zealand, 2019b).

Local Government New Zealand. 2019b. Vulnerable: The Quantum of Local Government Infrastructure Exposed to Sea Level Rise. Wellington: Local Government New Zealand.

88 of 110 closed landfills are in the Auckland region. 2 operating landfills are below 0.5 meters)

It is clear from the data that this is basically a closed landfill problem.

Score: 8

Sensitivity

Detailed investigations have not yet been done to understand the current sensitivity of landfills and contaminated sites to climate change in New Zealand.

Adaptive capacity

The adaptive capacity of landfills and contaminated sites is generally low, given that they are located in ground, with limited ability to relocate.

This is not necessarily true. It may be possible to remove the landfill from more vulnerable legacy sites to safer sites. The issue is the cost. It may cost less to shift the most vulnerable landfills than waiting for an event and then paying for the cleanup costs.

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Consequence

In New Zealand, recent events at the Hector landfill near Fox Glacier on the West Coast of the South Island demonstrate the potential environmental and economic consequences of landfill and contaminated site failure (Stuff, 2019b).

The Stuff piece mentioned that the cleanup had taken several months and cost several million dollars.

Score: 5

The failure of landfills and contaminated sites across New Zealand may mobilise pollutants (such as dissolved nitrogen and heavy metals) and solid waste, including glass, metal, plastics and asbestos (Brand et al, 2018). The consequences of this mobilisation could be substantial, possibly including impacts on sensitive ecosystems, groundwater and surface water contamination, reputational damage, declining health outcomes, and negative impacts on economic sectors such as tourism (Brand et al, 2018). These events can take significant time and cost to clean up.

Brand J, Spencer K, O'Shea F, Lindsay J. 2018. Potential pollution risks of historic landfills on low-lying coasts and estuaries. WIREs Water

This paper discussed possible effects of rising sea levels on low lying historical landfills in England. The conclusion was that little is known about the environmental impact of these risks. The paper did not say that the consequences could be substantial.

Score: 4

Interacting risks

Another risk is that adaptation actions are inadequately financed, which could increase the public sector financial burden due to climate change impacts (E1). Potential human risks could include impacts on public health from water contamination and exposure to pollutants, such as asbestos (H3). Further impacts could be on social wellbeing from contamination of recreational sites

There is no evidence that historical landfills pose a material risk to health that will be exacerbated by climate change.

Confidence: High agreement, low evidence

Adaptation

A nationwide assessment, implemented by the Department of Conservation, the Ministry for the Environment and local authorities, is identifying landfills and contaminated sites vulnerable to the impacts of floods and climate change. Assessments are also being carried out at the regional level to identify at-risk landfills and contaminated sites.

B4: Risk to wastewater and stormwater systems (and levels of service) due to extreme weather events and ongoing sea level rise

NCRRA consequence assessments

Now: Major
2050: Extreme
2100: Extreme

Urgency score: 85

Tailrisk review summary

This assessment largely consists of a recitation of the ways changing climate could impact on wastewater and stormwater systems. The conclusion that the impacts will be extreme by 2050 was not supported by the referenced paper (Hughes) that reviewed the risks and said that the risks were not understood. Nevertheless the NCCRA said in the confidence assessment that there was high agreement and moderate evidnce.

We don't yet know how climate change will impact our critical stormwater and wastewater infrastructure. We also don't know the extent to which climate change-induced damage to this infrastructure might directly, or indirectly, impact our economy, environment, culture and society.

The assessment has been largely superceded by government proposals on water services. The reported cost of tens of billions over several decades should include an allowance for climate change adaptation measures. The proposed new authority should be able to do its own research and analysis without the assistance of a central climate change authority.

A shorter version of the NCCRA discussion is presented here for completeness. It is largely based on two references. The short earlier Motu paper (White) has been superceded by the lengthy Hughes paper mentioned above. Only that paper has been reviewed.

NCCRA discussion

Exposure

Wastewater and stormwater systems in New Zealand are exposed to extreme weather events, sea-level rise and drought, and this is projected to increase this century under both RCP4.5

and RCP8.5. These climate hazards can lead to inland and coastal flooding, as well as coastal erosion. At present, over 12,600 kilometres of wastewater and stormwater pipes are estimated to be exposed to inland flooding throughout New Zealand, with approximately 6912 kilometres of wastewater pipes and 5720 kilometres of stormwater pipes also exposed (Paulik et al, 2019a). The exposure of wastewater and stormwater pipes to inland flooding may not necessarily imply damage or reduction in levels of service

The last point is worth emhasising. As discussed there is not expected to be a material increase in risk to these assets.

. Significant lengths of wastewater and stormwater infrastructure are also exposed to coastal flooding across a number of regions (Paulik et al, 2019b). At present-day mean sea level, 760 kilometres of stormwater pipes and 1020 kilometres of wastewater pipes are exposed to a 1 per cent annual exceedance probability (AEP) coastal flood (Paulik et al, 2019b).

Under RCP8.5 at 2100, about 1632 kilometres of stormwater pipes and 2431 kilometres of wastewater pipes are projected to be exposed (Paulik et al, 2019b). In areas where groundwater is tidally influenced, stormwater and wastewater systems will be exposed to ongoing sea-level rise. Groundwater levels are poorly understood in New Zealand, as few data are available; however, a number of areas are known to have high groundwater levels, including Tauranga, Christchurch and Dunedin (Tauranga City Council, 2019).

There are a number of low-lying wastewater treatment plants around New Zealand. These will be significantly exposed to coastal flooding (due to sea-level rise and storm surges), coastal erosion and rising groundwater. Many of the country's largest treatment plants (by treatment volume) are close to the coast and discharge to riverine, coastal or harbour rnvironments (Hughes et.al 2019)

Wastewater and stormwater infrastructure is exposed to extreme weather events and associated heavy rainfall. In general, stormwater infrastructure is not designed for the projected increase in flows and volumes due to climate change (White et al, 2017b). In addition, extreme rainfall can infiltrate wastewater systems and result in wastewater overflows entering receiving environments. This occurs regularly in a number of cities and towns, including Auckland, where wastewater discharges to Auckland beaches in storm events (White et al, 2017b).

At present, New Zealand is yet to experience drought that is long enough to impact wastewater and stormwater systems (White et al, 2017b). Drought severity is projected to increase due to climate change under both RCP4.5 and RCP8.5, and so exposure of these systems is also likely to increase.

There is no evidence that droughts of sufficient length will increase in the most populated areas. It this does occur then the probability of occuarnce will still be low.

Sensitivity

Most urban areas in New Zealand have ageing networks that need significant investment to continue to provide acceptable levels of service (National Infrastructure Unit, 2015). Older infrastructure is more sensitive to climate change impacts, in terms of both physical damage and operational performance (White et al, 2017b).

The infiltration of groundwater into storm and wastewater systems due to sea-level rise will lead to increased flow volumes and salinity, which has potential to affect the performance of wastewater and stormwater systems. Saltwater can accelerate corrosion of pipe, pump and treatment systems, and potentially reduce treatment plant performance (Hughes et al, 2019).

Severe droughts can impact buried pipelines through land subsidence and cracking. Droughts can also impact wastewater systems by reducing inflows (intensified by potential water restrictions), resulting in solids building up in pipes, and more concentrated wastewater flows. This results in oxygen-poor environments that encourage the growth of anaerobic bacteria in wastewater systems, leading to deterioration of concrete and steel pipes (Chappelle et al, 2019).

Often the discharge points of stormwater and wastewater systems are at the lowest elevation of populated areas, making them particularly sensitive to coastal erosion and inundation (White et al, 2017b).

The nature of the system will also determine its ability to cope with and adapt to climate change. Smaller systems, especially in densely populated areas, will be more sensitive to increased rainfall and extreme weather compared with larger systems with spare treatment capacity (Hughes et al, 2019).

Adaptive capacity

In general, the adaptive capacity of wastewater and stormwater systems is considered low. Most towns have ageing networks that are in poor condition and undersized compared with required design standards (for example, to cope with increasing rainfall). Although retrofit is possible, this will be costly and many councils are financially constrained.

Retrofita are possible and will happen. The issue is the cost and who will pay.

Consequence

Significant lengths of wastewater and stormwater networks across New Zealand are exposed and sensitive to climate hazards. This could result in significant disruptions and cascading consequences to communities, which will increase over time (Paulik et al, 2019a, 2019b).

Paulik did not discuss disruptions and casacading consequences.

Inland and coastal flooding will lead to increases in inflow and infiltration of surface and groundwater into wastewater systems and treatment plants. This will increase the frequency of uncontrolled wastewater discharges, and instances of untreated human and industrial waste, toxic material and debris being discharged into receiving environments (American

Progress, 2014; Watercare, 2020). Communities located near enclosed harbours or estuaries will potentially be at the highest risk from public health impacts and loss of amenity value (Hughes et al, 2019). As wastewater treatment plants are not designed to remove high concentrations of salts, salinity impacts from rising groundwater may require more advanced treatment processes (Chappelle et al, 2019; Lechevallier, 2014).

Similarly, the increased frequency and magnitude of flood events associated with climate change could have significant impacts on stormwater systems. As well as the physical damage, the capacity of systems could be overwhelmed, resulting in reduced levels of service, disruption to communities, and the mobilisation of contaminants into receiving environments (Hughes et al, 2019). Further, the failure of stormwater systems could have further flooding impacts, including on transportation infrastructure (White et al, 2017b). The consequences will be worse in low-lying areas with low-gradient systems. Sea-level rise and associated groundwater rise could more severely impact these systems, exacerbating flooding within communities.

Severe drought can have a range of physical and operational impacts on wastewater and stormwater pipelines. Wastewater impacts can adversely affect the receiving environment through poorly treated wastewater being discharged, with significant consequences for ecosystems and communities that rely on those environments. With increasing frequency and severity of droughts, there may be cracking and ground subsidence, along with other operational impacts, resulting in the need for extra maintenance to protect service levels (White et al, 2017b).

Confidence: High agreement, medium evidence

Hughes J, Cowper-Heays K, Olesson E, Bell R, Stroombergen A. 2019. Stormwater, Wastewater and Climate Change: Impacts on Our Economy, Culture and Society. Wellington: Deep South National Science Challenge.
The conclusion of this paper is that:

We don't yet know how climate change will impact our critical stormwater and wastewater infrastructure. We also don't know the extent to which climate change-induced damage to this infrastructure might directly, or indirectly, impact our economy, environment, culture and society.

This assessment obviousy begs the question of how the NCCRA came to the view that the effects would be extreme by 2050.

The Hughes report is basically a complilation of possible and likely impacts of different climate change effects. There were a number of case examples which pointed to local

issues but this is not evidence of an extreme or major risk situation from a national perspective.

Score: 2 This paper is scored at two because the NCCRA completely misrepresented the state of knowledge on this risk. It is not possible to read the Hughes report and then honestly claim that there is high agreement on the evidence.

B5: Risks to ports and associated infrastructure due to extreme weather events and ongoing sea-level rise

NCRRA consequence assessment

Now: Minor
2050: Moderate
2100: Major

Urgency score: 70

Tailrisk review summary

There is little evidence that port operations will be materialy affected by climate change. Ports are incentivised to deal with impacts if and when they arise. There is no evidence that ports are concerned about climate change issues over relevant planning horizons.

Tailrisk consequence assessment: Minor

Evidence quality score: 2.25

NCCRA discussion

Exposure

Ports and associated infrastructure are likely to be exposed to future extreme weather events (including strong winds, storms and ex-tropical cyclones), sea-level rise, and associated coastal and inland flooding. Quantitative data on specific port exposure around New Zealand are limited, and further assessments are needed to better understand the exposure of ports

and infrastructure both current and under RCP4.5 and RCP8.5 projections (Local Government New Zealand, 2019).

Local Government New Zealand. 2019a. Exposed: Climate Change and Infrastructure. Wellington: Local Government New Zealand.

Local Government New Zealand. 2019b. Vulnerable: The Quantum of Local Government Infrastructure Exposed to Sea Level Rise. Wellington: Local Government New Zealand.

The reports are assessments of exposure to sea level rise using the Paulik model results.

Score: 6

Exposure will differ for each port, and be influenced by factors such as geographic setting, wharf heights, tidal ranges, channel depths, and operating ranges for cranes and machinery. For ports in low-lying areas (such as Greymouth, Westport, Whanganui and possibly Gisborne), sea-level rise may result in permanent inundation over time, (Gardiner et al, 2008); further detailed analysis is required to better understand this.

These ports are economically irrelevant from a national perspective.

Gardiner L, Firestone D, Waibl G, Mistal N, Van Reenan K, Hynes D, … Clark A. 2008. Climate Change Effects on the Land Transport Network. Volume One: Literature Review and Gap Analysis. Wellington: New Zealand Transport Agency.
This risk assessment was almost entirely drawn from a report to NZTA from NIWA and MWH New Zealand Ltd. on risks to land transport. There was a short section on ports that reviewed a survey of the port managements' perceptions of the risk. Only five of 15 ports responded to the survey, probably reflecting a perception that climate change was not a risk within their planning horizons. Only one of the five reported an issue with sea-level rise and none pointed to operational issues.

Yes - corrosion of wharf decking components, stormwater backflow through sumps, reclamation, and coastal protection.

The report went through its own qualitative review of possible risks that could lead to a deterioration in service, but these assessments were not connected to actual sea level rises and the dates that these would occur.

Jetties or breakwaters protecting the port will be less efficient as peak tides rise, and may need raising and strengthening. The alternative is for the port to accept an increased risk of overtopping during storm surge and therefore a higher risk of damage. An increasing sea level will also result in a larger tidal prism (volume of tidal water entering/leaving the harbour) resulting in increased scour of foundations of marine structures. On the positive side, a rise in sea level will provide opportunities for ports to accommodate deeper draught vessels and undertake less dredging to maintain required channel depths (a positive aspect cited by Port B).

Despite the thin evidence base in Gardiner it was used to support multiple claims of elevated risk in the rest of this NCCRA assessment.

Score: 3

Sensitivity

Sea-level rise under RCP4.5 or RCP8.5 could result in extreme storm tides (including higher storm surges), exceeding wharf levels. This would affect operation of berth facilities, particularly impacting roll-on roll-off vessels such as the Cook Strait ferries (Gardiner et al, 2008).

There was no support for this risk in Gardiner.

Flooding could potentially impact on the ability of New Zealand ports to operate (Gardiner et al, 2008). Vessel navigation may be interrupted and delayed during flood conditions, especially for ports near rivers, due to debris being carried in flood waters causing damage to vessels and port infrastructure (Gardiner et al, 2008). Surface flooding could damage port buildings, roads and railways, affecting access and the transfer of cargo (Gardiner et al, 2008).

This is just a recitation of the possible risks in Gardiner, which as noted above were not backed by any assessment of their significance.

The operation of ports could also be sensitive to extreme weather events and associated strong winds and heavy rainfall. Strong winds can damage port buildings, crane infrastructure, containers, and associated equipment, and could cause operational delays due to ship handling difficulties and impacts on manoeuvring, berthing and loading operations (Gardiner et al, 2008; Astariotis, 2018; Scott et al, 2013)

There was no support in for these contentions in Gardiner. As noted elsewhere there is no evidence that there will be a material increase in strong winds in New Zealand.

Astariotis R. 2018. Sustainable freight transport in support of the 2030 Agenda for Sustainable Development: Sustainable transport and SIDS – some key considerations. Geneva: UNCTAD

This was a supporting document for a UNCTAD meeting on maritime transport achieving a sustainable development path. Because it was a general study there was little in it that would assist an understanding the impact of climate change on New Zealand ports. It did reference other documents that could be more useful, but they were not used in this NCCRA assessment.

Score: 0

Scott H, McEvoy D, Chhetri P, Basic F, Mullett J. 2013. Climate Change Adaptation Guidelines for Ports: Enhancing the Resilience of Seaports to a Changing Climate Report Series. Gold Coast: National Climate Change Adaptation Research Facility.
This was a generic paper on how to identify and evaluate climate change risks. The obvious question – when should adaptation measures be taken was not discussed. It adds no value to an assessment of how New Zealand ports will be impacted by particular dates.

Score: 0

More significant weather events could damage navigational infrastructure, such as aids to navigation (ATONs), and increase the risk of serious maritime incidents. This increases the risk of vessel casualties, impacting marine pollution and the need for vessel salvage (Gardiner et al, 2008).

Heavy rainfall could directly affect port operations through reduced navigation visibility and surface water flooding (Gardiner et al, 2008).

Storm surges may also cause overtopping and damage of breakwaters, and additional wave penetration and seiching are likely to cause excessive ship movement at berth, and possibly damage ship and wharf structures and interrupt loading operations (Gardiner et al, 2008).

This was mentioned by the consultants but did not reflect what the ports thought.

Internationally, ports and associated infrastructure (such as connecting coastal roads and rail lines) have been found to be sensitive to the impacts of transient or permanent flooding from sea-level rise, storm surges and waves (Astariotis, 2018). While the operational capability of ports is predicted to be adversely impacted in most cases, sea-level rise may provide opportunities for ports to berth ships with deeper draught.

Associated infrastructure, such as petroleum storage infrastructure, can also be affected by flooding. Large storage tanks can 'float', creating the potential for hazardous spills and contamination of surrounding environments (United States Department of Energy, 2015).

Associated infrastructure can, obviously be affected by flooding, but this tells us nothing about increased New Zealand risk.

Adaptive capacity

The adaptive capacity of port infrastructure will vary considerably around New Zealand. Climate change impacts and rising sea levels are unlikely to require existing ports to be totally relocated.

Assets likely to be affected by climate change include port facilities such as cranes and gantries, which will need to be assessed for changing operational requirements. Storage facilities may need to be changed or upgraded to accommodate more extreme events and changes in temperature, and changes made to drainage to manage increased flooding of the facilities. On the marine side, modifications or enhancement to existing breakwater systems will need to be considered, as well as upgrades of wharves and berths to cater for expected sea-level rise projections, and any increase in exposure to extreme events.

There is no evidence to support these claims.

Consequence

Ports are critical infrastructure. They facilitate billions of dollars of trade both internationally and nationally, and act as vital lifelines in a natural hazard event (New Zealand Lifelines Council, 2017)

Associated infrastructure is often critical at a regional or national level. For example, New Zealand is highly reliant on petroleum infrastructure at ports for the storage and distribution of petroleum around New Zealand. This directly supports economic activity, public service delivery, and transportation. By mid-century, the impact of climate change on associated petroleum infrastructure may be of less importance, as New Zealand may be less reliant on petroleum as an energy source, through increased electrification of transport systems and industry.

Information on the impact of climate change on ports and associated infrastructure is limited for New Zealand. However, given the importance of this infrastructure and locational constraints, the risk to ports and infrastructure from climate change will increase over time.

There is nothing here and in the preceeding discussions to support the assessment that the consequences will be moderate by 2050, and major by 2100.

Interacting risks

No material new information.

Confidence: High agreement, low evidence

Adaptation

Ports of Auckland have conducted assessments of climate risk. However, engagement undertaken for the National Climate Change Risk Assessment for Aotearoa New Zealand (NCCRA) revealed no further information on adaptation actions planned or under way in relation to this risk.

It might have been useful if the assessment had been shared. Perhaps they had nothing dramatic to say.

Example of another climate change risk assessment

In 2015 the Port of Dover released its second climate change adaptation reports as it was legally obliged to do. In a more than 100 page report (which strained to find problems) this was all it had to to say on sea level rise.

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6.4.2 The potential effects of rising sea level

As sea level is expected to rise, the duration of berth closures would increase over the high water but decrease over the low water. However, link spans and passenger access ramps only have a 30 year life span and so will be replaced with spans and ramps that could cope with the new tidal range as part of the normal replacement programme which is already underway.

This suggests that the risk to the Cook Strait ferry link mentioned in the NCCRA is not really an issue.

B6: Risks to linear transport networks due to changes in temperature, extreme weather events and ongoing sea-level rise

NCRRA consequence assessment

Now: Major
2050: Major
2100: Extreme

Urgency score: 60

Tailrisk review summary:

This is another risk assessment that mostly relies on the assumption that there will be substantial increases in extreme weather events. The report was deliberately deceptive on flooding risks, which will decrease rather than increase as claimed. The risk of increased rail buckling with higher temperatures and the cost of redirection of road and rail are legitimate concerns but these can be managed by NZ Rail. No attempt was made to assessment the magnitude of these problems or whether they are alrady being addressed.

Tailrisk consequence assessment: Minor

Reference quality score: 2.67

NCCRA discussion

Exposure

Transport networks are exposed to increases in temperature (heatwaves, hot days and drought), extreme weather events (heavy rainfall, storm events) and ongoing sea-level rise (exacerbating coastal flooding and erosion).

At present, more than 19,000 km of road, or about 20 per cent of New Zealand's road network, is located in inland flood hazard areas (Paulik et al, 2019a). Over 1500 kilometres of railway is currently exposed to inland flood hazards around New Zealand (Paulik et al, 2019a). Exposure of transport networks to flooding is likely to increase under both RCP4.5 and RCP8.5, although only limited assessments of future flood risk due to climate change have been done.

As noted above all the Paulik report is showing is the infrastructure located on historical flood plains. It does not reflect the risk to these assets. It looks impressive (see figure sixteen) but is not meaningful from a risk management.

As also discussed the modelling showed that the risk is likely to decrease not increase.

The Paulik study provided some more detailed information on lengths of exposed roads and rail at different dates and RCPs for some regions that points to an overall decrease in risk. Under RCP 8.5 the hightened risk to the most exposed region Canterbury almost disappears by 2086-2099.

How someone could have read the Paulik report and then still opinned at length on how flood risk to roading will increase is beyond us.

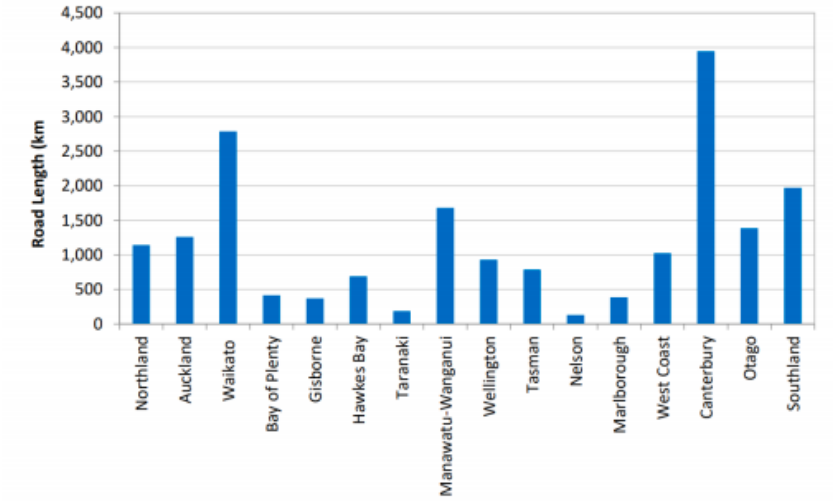
Roads

Marlborough (147 km) and Canterbury (112 km) regions have the highest FLHA road exposure in catchments that could experience >20% MAF increase in RCP 2.6 2036-2056. In these regions, road exposure reduces to almost **zero** for these catchments in RCP 2.6 2086-2099.

In RCP 8.5 2036-2056, Canterbury also has the highest FLHA road network (163 km) in catchments with a >20% MAF increase. The regions FLHA roads in these catchments with this MAF change increases slightly (175 km) by 2086-2099, while Otago's FLHA roads increase by almost 100 km. In other regions, FLHA roads in Auckland, Waikato and Manawatu-Whanganui each exceed 500 km catchments with an estimated >20% MAF decrease.

Figure sixteen: Road network expoures to flooding

Figure 18: Regional-level road network exposure to inland flood hazard (Paulik et al, 2019a)



Railway

New Zealand's FLHA railway network has 21.9 km in catchments where a >20% MAF increase is estimated in RCP 2.6 2036-2056, reducing to less than 10 km by 2086-2099. Canterbury is the only region with FLHA railway (20 km) in catchments with an estimated >20% MAF increase in RCP 8.5 2036-2056. The regions FLHA railway exposure decreases 50% for this MAF change by 2086-2099. For this period, 90 km of West Coast FLHA railway is in catchments with an estimated >20% MAF increase.

Score: 0 For not honestly presenting the Paulik results.

Road and rail networks are also highly exposed to coastal flooding (Paulik et al, 2019b). New Zealand has about 1400 kilometres of roads currently exposed to coastal flooding. About 87 kilometres of rail networks are exposed at present. Exposure of transport networks to coastal flooding is projected to increase under both RCP4.5 and RCP8.5. Under RCP8.5 at 2100, about

2710 kilometres of roads and 180 kilometres of rail networks are projected to be exposed (Paulik et al, 2019b).

Note, as discussed above that these estimates are based on the 'bathtub' methodology, which overstates the exposure. Note also that the exposure test is one ar least inundation every 100 years. That is the road or will be unuable once every 36500 days, and then possibly for a few hours, though this frequency will increase as sea levels rise.

Road and rail networks around New Zealand are potentially exposed to higher temperatures and drought – leading to potential land subsidence, degradation of asphalt and buckling of rail lines. Between 2004 and 2008, Gardiner et al (2009) recorded 78 events throughout the national rail network of tracks buckling due to heat. Road and rail networks in the north are at greater risk from climate change, as temperatures and hot days are projected to be higher in these locations. Exposure to higher temperatures will increase under both RCP4.5 and RCP8.5, with higher exposure projected under RCP8.5.

Groundwater rise is poorly understood in New Zealand. However, it is recognised as an emerging issue in a number of coastal areas, and as having potential to particularly impact on roads.

Gardiner L, Firestone D, Osborne A, Kouvelis B, Clark A, Tait A. 2009. Climate Change Effects on the Land Transport Network Volume Two: Approach to Risk Management. Wellington: NZ Transport Agency.

This report developed a risk assessment methodology to identify and prioritise dominant risks to road, rail, ports and coastal shipping. The analysis does not address basic questions such as how much will road maintenance and road outage costs increase due to extreme weather. Transit (Kinsella & Mcguire 2005)[24] found that its current design practices to be flexible enough to adapt to future changes in climate**.**

Score: 6

Sensitivity

The sensitivity of linear transport networks to extreme weather events depends on the physical condition of the assets, local ground conditions, and design of the infrastructure itself (Gardiner et al, 2009). Transport networks are sensitive to frequent inland or coastal flood events. These events can result in short-term disruption and closure while the road or rail route is impassable, and larger events can lead to damage (for example, scour, erosion or washout) (New Zealand Lifelines Council, 2017). Large rainfall events can also lead to

[24] Kinsella, Y., McGuire, F. 2005. Climate change uncertainty and the state highway network: a moving target. Transit New Zealand Conference Paper.

landslides. Recent events have demonstrated they can cause substantial damage to road and rail networks.

New Zealand Life Lines Infrastructure: Vulnerability Assessment
New Zealand Lifelines Council, 2017

This report devoted one page to weather disruptions to lifelines. The entire discussion on climate change was as follows;

The impacts of climate change are expected to be increased intensity storms (both wind speeds and rainfall intensity) and increased droughts.

Score: 2

The transport network is currently sensitive to these hazards, as numerous examples of road and rail disruption, damage and closure demonstrate. The 2019 Canterbury floods resulted in damage and closures to state highways connecting North and South Canterbury after the Rangitata River burst its banks. King tide flooding of State Highway 1 north of the Auckland Harbour Bridge has occurred a number of times in the past five years, resulting in inundation and lane closures (Auckland Transport, 2018). The sensitivity of the rail and road networks to inland flooding is partly related to inadequacies in culverts and drainage systems (Rushbrook and Wilson, 2007).

A recitation of possible risks and recounting recent events has limited value in assessing the possible increases in risk due to climate change.

Increased temperatures can cause damage and disruption to both the rail and road network, with extreme heat causing buckling of rail lines and degradation of asphalt road surfaces. All railway networks are sensitive to increased air temperature, which can buckle tracks and cause signalling system overheating and outages (Gardiner et al, 2009). These impacts already occur regularly.

High groundwater can damage road formations, lead to shrink–swell issues when combined with drought conditions, and increase liquefaction susceptibility.

Adaptive capacity

Many factors affect the adaptive capacity of linear transport infrastructure, including availability of funding, asset renewal cycles, and the fragmentation of ownership (across the New Zealand Transport Authority, KiwiRail and territorial authorities). Because of this wide range of influences, adaptive capacity varies considerably.
The length of road available per person in New Zealand is one of the highest in the world, which could constrain funding. Because local government is responsible for maintaining local

roads, regions could differ in their adaptive capacity because of funding constraints faced by territorial authorities and regional councils.

Transport assets also have long life cycles. It is easier to adapt assets for climate change when they are scheduled for renewal; in contrast, recently constructed infrastructure that does not already consider climate change will be more costly to adapt.

Another issue is the lack of consistent approaches (such as design standards and decision support tools) to account for climate change. This inconsistency reduces the adaptive capacity of the road and rail systems. Adoption of improved, consistent methods and approaches will improve risk reduction for transport infrastructure, through appropriate siting of infrastructure, using suitable standards and designing for uncertainty, redundancy and flexibility.

Consequence

Extreme weather events, ongoing sea-level rise and increased temperatures could damage and disrupt linear transport networks. These networks provide a critical service to all communities in New Zealand and are essential to the economy.

Road networks provide critical access to lifeline utilities (power, water, gas, telecommunications, health care) and other essential services. Any disruption to transport can lead to significant cascading consequences.

None of this says anything about the increase in risk and leads to the conclusion that these risks become extreme by 2100. Almost certainly they will not.

The New Zealand Transport Authority has assessed the resilience of the transport network, including weighting for suitable detour routes given their importance of overall resilience. For example, the West Coast highway in the South Island (State Highway 6) has no alternative route along much of its length. Climate change hazards and associated flooding and erosion could lead to widespread, and potentially long-term, service disruption.

The West Coart highway is the most vulnerable in New Zealand and will become more vulnerable. Notably there is no discussion of the resilence of other routes, which are much more economically significant.

Interacting risks

No significant new information

Confidence: High agreement, medium evidence

B7: Risk to airports due to changes in temperature, wind, extreme weather events and ongoing sea-level rise

NCCRA consequence assessment

Now: Major
2050: Major
2100: Extreme

Urgency score: 55

Tailrisk review summary

This risk assessment mainly consisted of a recitation of the possible ways climate change could affect airports taken from generic foreign reviews. There is almost no evidence from the airport companies and airlines who would be best equipped to assess the risks. These companies will have the knowledge and incentives to adjust in an optimal manner without assistance of a national adaptation plan. The extreme risk assessment seems to be based on the assumption that airport companies would make no effort to protect their investment from sea level rise. Of course they would.

Tailrisk consequence assessment 2100: Moderate

Evidence quality score: 2.75

NCCRA discussion

The following captures most of what was said.

Airports are exposed to increases in temperature, wind, extreme weather events (heavy rainfall leading to inland flooding) and ongoing sea-level rise (exacerbating coastal flooding and erosion). The airport components exposed are the airfield (including the runway, taxiway and apron), terminals, navigation and ground equipment, and airport and aircraft operations (including aircraft take-off and landing, loading and unloading). Exposure of all components is likely to increase by 2050 and 2100 under both RCP4.5 and RCP8.5.

And

Operational impacts of flooding on airports can include flight delays, temporary apron or runway closure, and reduced access to airports (National Academies of Sciences, Engineering, and Medicine, 2012, 2019). This is a nationally significant risk, as airports are central to the movement of people and goods and support the functioning of New Zealand's economy; they are gateways for tourism, commerce and business.

Airports have always been, and will be, subject to weather delays. These delays are not really national systemic risks. The substantive longrun risk is sea level rise with the more existential risk relating to changes out to 2050. This is the entirety of what was said on this issue.

Airports are also exposed to sea-level rise and associated coastal flooding. At present-day mean sea level, there are 13 airports with land exposed to coastal flooding (Paulik et al, 2019b). This includes Auckland and Wellington international airports, and major domestic airports in Tauranga, Hawke's Bay, Nelson and Dunedin (Paulik et al, 2019b). Coastal erosion, exacerbated by sea-level rise and extreme weather events, has been raised as an issue by representatives from major airports in New Zealand during consultation for the NCCRA. Exposure of airports to coastal flooding is likely to increase at 2050 and 2100 under RCP4.5 and RCP8.5, with an estimated 14 airports exposed in 2100 under RCP8.5 (Paulik et al, 2019b).

This overstates the risk. Paulik often does not take account of existing stopbanks designed to protect airport from flooding risk and there is no discussion of the measures that airport companies will take to protect their assets.

There were some somewhat desperates attempts to talk up the risks. For example:

Regional airports service much of New Zealand and can have national significance in an emergency (G6). For example, Hokitika Airport could become critical as a transport link for the West Coast if the region is isolated by road (New Zealand Lifelines Council, 2017).

Higher temperatures can also affect airport operations by impacting on aircraft take-off performance (Coffel et al, 2017). Take-off performance is particularly affected in airports with short runways and high temperatures, or those at high elevations (Coffel et al, 2017).

Coffel ED, Thompson TR, Horton RM. 2017. The impacts of rising temperatures on aircraft take-off performance. Climatic Change 144: 381–388.

The full study was not freely available. The following is from the abstract.

We construct performance models for five common commercial aircraft and 19 major airports around the world and use projections of daily temperatures from the CMIP5 model suite under the RCP 4.5 and RCP 8.5 emissions scenarios to calculate required hourly weight restriction. We find that on average, 10-30% of annual flights departing at the time of daily maximum temperature may require some weight restriction below their maximum takeoff weights, with mean restrictions ranging from 0.5 to 4% of total aircraft payload and fuel capacity by mid- to late century.

Both mid-sized and large aircraft are affected, and airports with short runways and high temperatures, or those at high elevations, will see the largest impacts. Our results suggest

that weight restriction may impose a non-trivial cost on airlines and impact aviation operations around the world and that adaptation may be required in aircraft design, airline schedules, and/or runway lengths.

The discussion woud have been more useful if the NCCRA writers had approached Air New Zealand to get information on whether higher temperatures would have a material impact on operations in New Zealand conditions. As Air New Zealand does not fly from short or high altitude airports, and will not be subject to temperatures that are substantially higher than present levels, probably the answer would be – not very much.

Score : 2

National Academies of Sciences, Engineering, and Medicine. 2012. Airport Climate Adaptation and Resilience. Washington, DC: The National Academies Press.
This is a detailed compliation of possible risks and adaptation measures, which does not allow any conclusions to be drawn about New Zealand.

Score: 3

National Academies of Sciences, Engineering, and Medicine. 2019. Climate Resilience and Benefit Cost Analysis: A Handbook for Airports. Washington, DC: The National Academies Press.
This is a 'how to' book for cost benefit analysis for airports. It would be useful for an airport company. Two main relevant risks are identified. The increase in very hot days, which is not relevant for New Zealand airports because we wil not get hot enough, and sea level rise which will eventually impact on several airports.

Score: 3

Burbidge R. 2016. Adapting European airports to a changing climate. Transportation Research Procedia 14: 14–23.
This paper Identifies key questions to be asked when initiating a climate change risk assessment at an airport. It presents the outcome of a workshop that identifies four key priorities for action. It highlights identifying knowledge gaps; raising and promoting collaboration and awareness. Again there is nothing specific that points to the risk for New Zealand airports.

Score: 3

There was no attempt to quantify the significance of any climate change Impacts . Nevertheless it was concluded that the consequences would be major by 2050 and extreme by 2100.

In making these assessments it must have been implicitly assumed that airports would not make any effort to protect the airport form rising sea levels, even if this were inexpensive relative to the value of the airport.

B8: Risks to electricity infrastructure due to changes in temperature, rainfall, snow, extreme weather events, wind and increased fire weather

NCCRA Consequence assessments
Now: Moderate
2050: Moderate
2100: Major

Urgency score: 55

Tailrisk review summary

This risk assessment is little more that a necessary true claim that the electricity system is affected by climate and a string of mostly unsupported assertions that climate changes will make this worse at least for the transmission and distribution infrastructure. There is almost no connection of these claims with actual predicted changes in climate changes.

Evidence quality score: Not assessed. There were no papers that supported a consequence assessment.

NCCRA Discussion

Risk summary

Climate change presents a range of risks for electricity infrastructure in New Zealand. These risks are predominantly associated with changes in temperature, rainfall, snow, extreme weather events, wind and fire weather. Electricity infrastructure is also at risk from natural hazards such as inland and coastal flooding.

For generation infrastructure, present-day risks are low, with limited changes in risk projected into the future. New Zealand's heavy reliance on renewable electricity sources (particularly hydro and wind) means it has significant exposure to climate variability. Specific risks include potential changes in water flows (resulting from changes in rainfall and snowmelt) and in wind patterns, affecting security of supply and associated generation capacity. Climate change could also affect demand for electricity through increased cooling demand in summer and reduced heating demand in winter. This will cascade impacts into physical infrastructure, which could require upgrades to adjust for changing demand peaks.

Transmission and distribution infrastructure is currently at risk of disruption and damage from climate change hazards, including extreme weather and fire weather, and this risk will increase into the future. Climate change risks to electricity transmission and distribution infrastructure could have significant potential consequences for New Zealand's energy security if they are not well managed.

Electricity generation in New Zealand has a moderate level of adaptive capacity, as diverse distributed generation sources are connected to the national grid. A number of electricity generation companies are actively assessing, modelling and planning for risks associated with a changing climate. The results of this work should provide for more informed decisions that account for uncertainty wherever possible, enhancing adaptive capacity.

Transmission and distribution infrastructure has a lower level of adaptive capacity, given that many of the networks are already operating at capacity.

Māori face potential flow-on effects from increased electricity demand in summer at the expense of ecological or cultural values (Interim Climate Change Committee, 2019).

Exposure

Elements of New Zealand's electricity generation, transmission and distribution network are exposed to changes in temperature, rainfall, snow, extreme weather events, wind and fire weather. Exposure is expected to increase under both RCP4.5 and RCP8.5 over this century.

Electricity generation

New Zealand's generation infrastructure is exposed to changes in rainfall and snowmelt, which will affect inflows to dams supplying hydro-electric generators, reducing generating capacity. Similarly, changing wind patterns will affect generation from wind sources. Managing volatility in both water inflows and wind patterns is already a key challenge for New Zealand's electricity providers (Meridian Energy Limited, 2019).

This does not tell us whether these changes will be positive or negative.

Water storage for hydro-electric power generation is dominated by a few key reservoirs in the South Island and Lake Taupō in the North Island (Renwick et al, 2010). Generation is driven by a combination of rainfall and snowmelt, with snowmelt providing on average 50 per cent of

spring and summer inflows into New Zealand's main hydro-electric storage reservoir in the Waitaki catchment (McKerchar et al, 1998). Modelling has indicated little change in total yearly inflow to hydro lakes by 2050, but seasonal changes are projected for the South Island, with summer inflows reducing and winter inflows increasing (Interim Climate Change Committee, 2019). North Island inflows are not expected to change by 2050 (Interim Climate Change Committee, 2019).

New Zealand's current wind energy resource is predominantly from westerly winds. Climate change could increase these westerly wind flows, particularly during winter and spring (Electricity Authority, 2018), potentially increasing generation capacity.

This is a positive if it occurs.

Generation infrastructure is also exposed to potential changes in electricity demand from climate change (for example, warmer winters meaning less demand for heating, or warmer summers meaning increased demand for cooling) (Interim Climate Change Committee, 2019; Meridian Energy Limited, 2019; Ministry of Business, Innovation and Employment, 2019).

Again it is not clear whether this is a positive or negative.

Transmission and distribution infrastructure

Transmission and distribution infrastructure around New Zealand is exposed to extreme weather events, wildfire and associated natural hazards including inland and coastal flooding.

Extreme weather events, including extreme wind and rain, and coastal flooding from storm events and ex-tropical cyclones, currently affect the electricity network throughout New Zealand (Orion New Zealand Limited, 2019; Paulik et al, 2019b). Over the long term, the exposure of electricity networks to extreme weather events is likely to increase under both RCP4.5 and RCP8.5 (Ministry for the Environment, 2018).

This is just a recitation of the mantra. The MfE is not a source of original analysis and is prone just to recite mantras.

Transmission and distribution infrastructure is currently exposed to wildfire in hotspots throughout New Zealand, and exposure is projected to increase this century (Pearce, 2019; Pearce et al, 2018). Fire exposure could also increase due to wildfires starting from electricity networks, particularly in rural areas. With more uncertainty over projected fire weather, it is difficult to identify the changing level of exposure between RCP4.5 and RCP8.5 out to 2100.

There is no assessment here on the extent to which electricity transmission has created wildfires. There is also no evidence on the extent to which transmission has been disrupted by wildfires.

In terms of inland flood exposure, at present there are about 3400 kilometres of transmission lines and 5800 structures in inland flood hazard areas (Paulik et al, 2019a). Canterbury, Waikato and Manawatu–Whanganui have the highest transmission line exposure in these areas (Paulik et al, 2019a). Over the past decade, flooding has affected the electricity network (including pylons and substations) on numerous occasions across New Zealand (Powerco, 2017; Transpower, 2019; Vector Limited, 2017). Inland flood exposure is likely to increase under RCP4.5 and RCP8.5.

As discussed in the issues section the Paulik study does not provide a risk assessment. Because transmission structures and lines are elevated above flood levels the risk of damage from exposures from floods will generally be lower than other structures affected by floods.

Transmission infrastructure is also exposed to coastal flooding at present, including around 120 kilometres of transmission lines, 180 support structures and two substation sites (Paulik et al, 2019b). Exposure of transmission networks to coastal flooding is projected to increase under both RCP4.5 and RCP8.5. Under RCP8.5 at 2100, about 187 kilometres of transmission lines and 305 support structures are projected to be exposed (Paulik et al, 2019b).

As discussed previously the exposure threshhold level is once every 36500 days.

Sensitivity

Wind and hydro-electric generators are sensitive to changing water inflows, wind patterns and demand profiles due to climate change. Transmission and distribution infrastructure sensitivity is driven by the age, condition and design of structures.

Generation infrastructure

The sensitivity of generation infrastructure depends on inflows of water into reservoirs and the capacity of the network to respond to changes in demand for electricity (Climate Change Adaptation Technical Working Group, 2017). Although hydro-electricity stations are inherently sensitive to changes in rainfall and snowmelt, at present this is considered a manageable impact and does not pose a significant risk over the short term (Meridian Energy Limited, 2019).

The generation capacity of existing wind farms should increase as a result of climate change, but strong winds could also result in more instances where turbines need to be shut down to avoid damage from strong winds (Electricity Authority, 2018).

Overall there is not expected to be a major increase in strong winds, although there will some increase in the eat of the South Island.

Generation infrastructure could also be sensitive to increases in demand and the potential flattening of the annual demand profile (due to increased demand for summertime cooling and irrigation and reduced wintertime heating requirements), although not all studies have

reached these conclusions (BusinessNZ Energy Council, 2019; Climate Change Adaptation Technical Working Group, 2017; Electricity Authority, 2018; Transpower, 2018). While it is understood that energy generation is not overly sensitive to changes in peak demand, the electricity grid is vulnerable to increasing demand (Transpower, 2018), as discussed below.

Transmission and distribution infrastructure

Transmission and distribution infrastructure is currently sensitive to extreme weather events, fire weather and associated coastal and inland flooding (Climate Change Adaptation Technical Working Group, 2017).

Extreme weather events can damage the network and interrupt power supply throughout New Zealand (Orion New Zealand Limited, 2019). Transmission and distribution lines can be damaged by wind, including from falling trees and other windborne debris, and lightning (Burillo, 2018; Orion New Zealand Limited, 2019). Heavy rainfall can lead to flooding, landslides, and erosion, which can also damage the electricity network (Burillo, 2018; New Zealand Lifelines Council, 2017; Orion New Zealand Limited, 2019). Landslides can cause damage to overhead lines, and critical transmission lines pass through many areas of slip-prone terrain (New Zealand Lifelines Council, 2017). A recent example comes from the South Island floods in December 2019, when pylons were damaged due to river flooding, causing power outages (Transpower, 2019).

These are all possibilities but there is no quantification of the nationwide impact.

Underground cables tend to be more resilient to flood impacts, but floodwaters can scour bridges and attached cables (New Zealand Lifelines Council, 2017). Widespread flooding can also affect lower-level electrical generating equipment, such as substations, causing extended business interruption losses, although these are subject to high design standards (Burillo, 2018; Lawrence et al, 2016; New Zealand Lifelines Council, 2017).

Rural electricity networks are sensitive to fire weather in New Zealand. Wildfires can damage electricity network infrastructure and render power lines inoperable due to ionised air (Burillo, 2018). Networks are also potentially a source of ignition for fires (Burillo, 2018; Otago Daily Times, 2019b; Stuff, 2020). Ignitions can occur from the failure of distribution and transmission network components (Mitchell, 2013). This includes ignitions from an asset failure, such as transformer or substation failure, and those caused by a contact event, such as trees contacting powerlines (Caine, 2019).

Adaptive capacity

Electricity generation in New Zealand has a moderate level of adaptive capacity, given there are diverse distributed generation sources connected to the national grid. A number of electricity generation companies are actively assessing, modelling and planning for risks associated with a changing climate. The results of this work should provide for more informed decisions, accounting for uncertainty wherever possible and enhancing adaptive capacity.

Transmission and distribution infrastructure has a lower level of adaptive capacity, given that many of the networks are already operating at capacity, fixed in location and controlled by population locations. Additionally, as distribution infrastructure is managed by numerous individual businesses that make their own investment decisions about resilience levels, and less funding is available, distribution infrastructure is likely to have lower adaptive capacity than transmission infrastructure (Climate Change Adaptation Technical Working Group, 2017).

Consequence

The electricity network is nationally significant infrastructure, needed for powering homes and businesses and delivering public services (Lawrence et al, 2016; New Zealand Lifelines Council, 2017). Failures of generation, transmission or distribution elements can have widespread, severe consequences across all sectors of New Zealand's economy and society.

The most critical components of the transmission and distribution network are those that transmit the largest volume of electricity, have limited redundancy, and supply critical customers. Businesses, public services, and critical national infrastructure rely on a functioning electricity network, and unmanaged climate change impacts could result in increased cost and reduced reliability (New Zealand Lifelines Council, 2017). While impacts on transmission and distribution infrastructure are manageable at present, climate change is set to increase risks over this century, and this could present significant consequences to New Zealand if not well managed and planned for.

The claim that climate change is set to increase risk (by implication materially) is not supported by reference to actual changes.

If electricity demand increases significantly, additional infrastructure will be required to provide for this increased demand, with long lead times and much investment needed (Interim Climate Change Committee, 2019; Meridian Energy Limited, 2020; BusinessNZ Energy Council, 2019). Increasing proportions of renewable generation (particularly wind and solar) could result in increasing intermittency in supply, especially when the levels of dams supplying hydro-electric generators are low during dry years (Transpower, 2018; Meridian Energy Limited, 2020).

This is a matter for careful design of the generaion system, and design of the pricing system.

Interacting risks

Risks to the electricity network will interact with a range of risks in the built environment, economy, natural environment, and human domains. Climate hazards, and associated impacts, could result in power interruptions leading to cascading risks to supply chains and business continuity (E7), the delivery of public services (including emergency services) (G6), and electrified transport systems (B3). The risk of electricity networks igniting fires will have cascading risks across domains, including risks to buildings and people (B2), human health and

wellbeing (H3), and terrestrial ecosystems (N7). If demand for electricity increases, there could be increased investment in renewable energy projects. This could result in environmental risks and Māori-specific impacts in relation to ecological or cultural values (H5) (Interim Climate Change Committee, 2019).

Confidence: High agreement, medium evidence

There is high agreement that electricity infrastructure is exposed and sensitive to climate change impacts, with potentially high consequences. There is a strong understanding of the exposure and sensitivity of electricity infrastructure to climate change at present, but further research is needed to build an evidence base for long-term exposure under RCP4.5 and RCP8.5.

Adaptation

Most electricity generation companies are assessing future climate change risks and scenarios to understand potential future demand and how to plan and adapt to potential changes. Transpower are understood to be assessing climate change risk to transmission assets, such as substations, and are also looking at future demand scenarios and management options. Engagement for the NCCRA revealed limited information on adaptation actions planned or underway for distribution infrastructure in relation to this risk.

Transpower has a sustainability framework that just says that they ensure that the grid is resilient to climate change.

Governance domain

Consequence assessment criteria

The following are the consequence assessment criteria for the governance domain.

Major

Major multifunctional impacts on decision-making and service delivery at local and national levels Policy and legislation cannot cope with the impacts, eg, funding, planning practice, emergency services Inequitable outcomes lead to loss of trust and reputation, and greater community unrest and litigation Major erosion of Te Tiriti o Waitangi rights

Extreme

Extreme multifunctional, cascading and compounding impacts lead to inability at all levels of government to govern and provide services in an equitable and just manner. Extreme community disruption (eg, loss of place and community cohesion). Significant damage to perceived reputation of and trust in institutions. Te Tiriti o Waitangi rights overridden

G1: Risk of maladaptation across all domains due to the application of practices, processes and tools that do not account for uncertainty and change over long timeframes

NCCRA consequence assessment

Now: Major
2050: Extreme
2100: Extreme

Urgency score: 83

Tailrisk review summary

Despite the inference that G1 covers all of the domains affected by climate change it is almost entirely directed to the impact and management of risks to the buiit environment sector from the rise in sea level. The focus is on decision making techniques to optimaly respond to these risks. It is argued that many decision making tools are suboptimal and that better approaches that better balance over and underreactions to climate changes are available. The issue of the optimal analytical tools for climate change adaptation is debateable but the conclusion that making the 'wrong' choice will lead to *Extreme multifunctional,' cascading and compounding impacts*

lead to inability at all levels of government to govern and provide services in an equitable and just manner' is obviously overblown.

Tailrisk consequence assessment: Minor (if commonsense and sound analytical decision making prevails).

Evidence quality score: 5.77

NCCRA discussion

Risk summary
Climate change adds to the uncertainties already faced by decision-makers (Beck, 2009; Scoones, 2019; Weitzman, 2011).

There is no dispuite that climate change adds to uncertainties facing decision makers but that does not tell us very much.

Where decision-makers rely on practices that embed processes and tools that do not account for uncertainty and change over long timeframes, the likelihood of maladaptation across all domains will increase.

Risk description
The future contains inherent uncertainty.

Failure to account for uncertainty in decision-making processes increases the likelihood that an action will be maladaptive. That is, the action is more likely to have a high opportunity cost, reduce incentives to adapt, disproportionality burden the most vulnerable, close off other adaptation options for the future, or increase greenhouse gas emissions (Barnett and O'Neill, 2010).

Barnett J, O'Neill S. 2010. Maladaptation. Global Environmental Change – Human and Policy Dimensions 20: 211–213.
This is a short paper that identifies five 'key dimensions' of 'maladaption' illustrated by the example of a proposal to ease Melbourne's water shortage with a desalination plant. Maladaption is defined as action taken to avoid or reduce vulnerability to climate change that impacts on or increases the vulnerabity of other systems, sectors or social groups. As virtially every adaptation will have some adverse consequences nearly all can be called maladaptive by someone who doesn't like a particular project.

Score: 2

Decision-makers need to act, even when there is significant uncertainty. For example, today's researchers are confident that the frequency and intensity of heavy rainfall events will increase, but do not know how frequent or how intense those events will be or exactly when these conditions will occur. Researchers are also confident of the rate and magnitude of sealevel rise out to 2050, but beyond that the certainty range is wider (see section 2). Planners and engineers are making decisions about the location and design of infrastructure and housing that will be in place for more than 100 years, within which time frame climate change impacts will worsen (Lawrence, 2016).

This is self evident.

If decision-makers do not provide for uncertainties when locating and designing developments, these structures will be increasingly exposed to flood risk and incur high damage costs. On the other hand, if they plan and design for the most extreme events, they may incur the opportunity cost of not being able to use the land, or overdesign infrastructure that is costly and becomes redundant. Either way, there can be maladaptation. This suggests that tools and processes are needed that can inform flexible planning and design of infrastructure that can be changed and shifted before damage occurs (Mastrandrea and Luers, 2012).

Mastrandrea M, Luers A. 2012. Climate change in California: Scenarios and approaches for adaptation. Climate Change 111: 5–16.

This paper argues the need for adaptation policies for California focusing on mid-century outcomes because these results are relatively certain. This is the opposite of the point that the assessment was making about decision making under uncertainty.

Score: 0

Government decision-making frameworks and well-established practices in disciplines including law, economics, engineering and planning continue to use practices, processes and tools that rely on static assumptions of risk, and historical parameters of climatic conditions (Lawrence and Manning, 2012; Lawrence et al, 2019a; Manning et al, 2015; Weitzman, 2011).

For example, the use of single flood standards (such as a 1-in-100-year event) to plan land use and design infrastructure results in path-dependent decisions that are inflexible to changing flood risk (Lawrence et al, 2013). These measures can also create a false sense of security for those just outside the zones (Lawrence et al, 2013). Other static measures that are used routinely in planning, such as minimum flood levels, also create a false sense of security in the face of ongoing sea-level rise, increasing heavy rainfall and coastal storms. White (2019) argues that dominant institutional practices, and cultures that overwhelmingly focus on data, modelling and certainty, discourage adopting new or alternative approaches to urban planning that may better support liveability or sustainability.

White I. 2019. Rigour and rigour mortis? Planning, calculative rationality, and forces of stability and change. Urban Studies 1–16
This is a general discussion of how planning decision support tools can 'selectively open up or foreclose discourse and play important political roles relating to ordering complexity and mitigating professional risk'.

This no doubt true but not very helpful in addressing climate change adaptation consequence issues in New Zealand.

Score: 4

It is widely recognised that decision-makers must move beyond such approaches, particularly for flood risk, drought and coastal management strategies (Climate Change Adaptation Technical Working Group, 2017, 2018; Gersonius et al, 2012; Kundzewicz et al, 2008; Lawrence and Haasnoot, 2017; Lawrence et al, 2019a).

This does not make it very clear what the offending approaches are; how prevalent they are; what exactly are the prefered approaches;and what, quantitatively, are the implications of not adopting the preferred approaches.

Our understanding of one aspect of the argument is that a cost benefit analysis that assesses costs and benefits based on a single current assessment of the mean expectation of sea level rise can deliver inferior results compared to a technique such as real options analysis that considers multiple pathways and can adapt to new information. That is now widely accepted, and will increasing be used. So it is difficult to see how the choice of decision technique can be identified as a major governance risk.

Zeitoun et al (2016) also state that prevailing approaches to water security do not consider uncertainty, diversity and politics in society, limiting policy-makers to rigid and inflexible interventions that may reproduce inequalities.

Zeitoun M, Lankford B, Krueger T, Forsyth T, Carter R, Hoekstra AY, … Matthews N. 2016. Reductionist and integrative research approaches to complex water security policy challenges. Global Environmental Change 39: 143–154.
This paper is an academic literature review of water security papers that separates the papers into the prevailing 'reductionist' and 'inclusive' approaches.
The article, which is part of an ideological debate in the water security academica, is supportive of what appears to be the NCCRA author's 'inclusive' approach

Score: 3

In New Zealand, the use of cost–benefit analysis disproportionately burdens more vulnerable residents. The reliance on cost–benefit analysis to prioritise flood protection has led to faster implementation in higher socio-economic areas, as higher land and asset values generate higher benefit-to-cost ratios (Manning et al, 2015)

Manning M, Lawrence J, King DN, Chapman R. 2015. Dealing with changing risks: A New Zealand perspective on climate change adaptation. Regional Environmental Change 15(4): 581–594.).

Only the abstract of this paper was freely available. The closest support for the above claim was:

Ongoing socioeconomic changes in New Zealand also raise the risk of structural effects caused by climate change impacts becoming unevenly distributed across society.

We do not know whether this equity claim was evidenced based or just an assertion.

Score: not assessed

Various processes and tools available for adaptation decision-making under conditions of uncertainty. Examples include robust decision-making (Dittrich et al, 2016), real options analysis (Buurman and Babovic, 2016), and dynamic adaptive pathways planning (Haasnoot et al, 2013; Lawrence and Haasnoot, 2017; Lawrence et al, 2019).

Buurman J, Babovic V. 2016. Adaptation pathways and real options Analysis: An approach to deep uncertainty in climate change adaptation policies. Policy and Society 35(2): 137–150.

A reasonably useful review article with a Singaporean example.

Score: 8

Dittrich R, Wreford A, Moran D. 2016. A survey of decision-making approaches for climate change adaptation: Are robust methods the way forward? Ecological Economics 122: 79–89.

The full article was not recoverable. From the abstract this is another review article that concludes that what is described as robust decision making approaches appear to be best.

Score: 8 On the basis it lives up to the abstract.

Haasnoot M, Kwakkel JH, Walker WE, ter Maat J. 2013. Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. Global Environmental Change 23(2): 485–498.
This paper explains adaptive policy making and adaptive pathway techniques.

Score: 9

Such processes and tools are being applied in a growing number of locations in New Zealand, including the Hutt River (Greater Wellington Regional Council, 2015), Hawke's Bay (Bendall, 2018), and Petone (Kool) 2020) but wider uptake has generally been slow (Lawrence and Manning, 2012; Lawrence et al, 2019b). This is due to factors such as resourcing for capacity building, and the necessary engagement processes and caution about using new and unfamiliar processes in settings that 'demand' certainty (Lawrence and Haasnoot, 2017; White, 2019).

Flood Protection: Option Flexibility and its Value for Greater Wellington Regional Council 2015
This paper was an assessment of Hutt Valley flood protection strategies.

In broad terms the results show that a flexible investment strategy that enables a change of course in the future is more likely to deliver a lower cost outcome than pursuing a single option, unless the probability of a climate change induced change in flood frequency and its associated economic loss is almost certain. This holds true regardless of whether the outcome is based on Multi-Criteria Analysis or on minimising the expected total cost (cost of flood protection investment plus the residual risk of property loss in the event of a flood) of each option.

The message seems to be that the exact methodology does not matter too much as long as it is flexible.

Score: 9

Clifton to Tangoio Coastal Hazards Strategy 2120 REPORT OF THE NORTHERN AND SOUTHERN CELL ASSESSMENT PANELS FINAL REPORT 14 February 2018
This report used a combination of community driven and real options analysis to identify preferred responses to sea level rise. Using real options analysis analysis it showed that retreat was generally the least preferred option. There was a two stage process. Preferred approaches tended to favour retreat when more qualitative assessments of the benefits were used. When the participants were shown the real options analysis quantitative results they changed their minds and preferred defence after a consideration of both costs and benefits.

Table twenty two: Results from Hawkes Bay coastal hazards strategy

Zone	Retreat $m PV	Defence $m PV
Ahuriri	15.3	8.9
Pandora	12.6	9.0 Seawall 20yrs
Westshore	91.6	25.2
Bayview	21.3	11.1 Seawall
Whirinaki	32.3	15.8
Clifton	12.2	7.7
Te Awanga	24.1	16.8
Haumoana	24.2	14.9 Retreat the line
Total	233.6	109.4

Score: 10

Kool R. 2020. Preparing for Sea Level Rise: An Adaptive Managed Retreat Case Study. Danish Technical Institute and Victoria University of Wellington.
This paper identified retreat dates for Petone based purely on the time when existing gravity based stormwater and waste water systems will become less functional with rising sea levels. The retreat dates are from 2050. The obvious flaw in the paper is that it did not assess the option of upgrading these systems to cope with higher sea levels, and almost certainly gave economically inefficient and politically unacceptable advice.

Score: 3

The national Coastal Hazards and Climate Change Guidance (Ministry for the Environment, 2017b) sets out how to use some of these processes and tools, including the use of the dynamic adaptive pathways planning approach.

Ministry for the Environment. 2017b. Coastal Hazards and Climate Change: Guidance for Local Government. Wellington: Ministry for the Environment
This is a lengthy document with plenty of discussion information and guidance mostly without being overly prescriptive. The most significant short coming, discussed above, is that it might be interpreted as establishing a strong presumption in favour of managed retreat.

Score: 8

Case studies such as Corbett and Bendall (2019) demonstrate practical application in New Zealand.

A critique by Lawrence et al (2019b) and a practice brief (Lawrence et al, 2019a) also share lessons learned for mainstreaming these processes and tools. Further guidance is needed, however, to address the constraints of planning processes and improve understanding of the dynamic nature of climate change impacts (Lawrence, 2018).

Corbett, E., Bendall, S. (2019). Clifton to Tangoio Coastal Hazards Strategy 2120, Hawke's Bay, New Zealand. In: Responding to rising seas: OECD country approaches to tackling coastal risks, Chapter 6, p. 137–154, OECD Publishing, Paris.
This paper was not recovered but it appears to be a versionof the Hawkes Bay coast hazards strategy report**.**

Score: Not assessed

Lawrence J, Bell R, Blackett P, Stephens S, Allan S. 2018. National guidance for adapting to coastal hazards and sea-level rise: Anticipating change, when and how to change pathway. Environmental Science and Policy 82: 100–107
This paper is largely concerned with a discussion of the National Coastal Guidance document with a focus on councils' reluctance to promote planned retreat. There is a presumption that managed withdraw is the optimal policy response and there is a focus is on reasons why this is difficult to achieve because of 'flaws' in planning and political systems. These presumptions are not backed by any robust analysis.

In the New Zealand context, development of regional rules has been limited as regional councils are naturally reluctant to start discussions with district/city councils on withdrawal from the coastal margins. Where they have done so, they have received opprobrium, but if they delay, the risk will escalate as further investment at the coast takes place.

Consequently, the planning and emergency management activities are not well integrated. If the planning system is unable to reduce ongoing exposure to SLR, coastal erosion and inundation, then the growing burden is shifted to the emergency management system to deal with increasing frequency of inundation events and other ongoing impacts of rising seas (e.g., rising groundwater and reduced drainage capacity).

While the NZCPS requires consideration of managed retreat for existing development when planning adaptation, there are practical issues as yet unresolved for implementing pathways planning for this outcome.

These include property-owner acceptance of the need to eventually transition inland; equity for some groups in society including who pays and when; and how and to where communities might retreat.

Score: 5

Lawrence J, Bell R, Stroombergen A. 2019a. A hybrid process to address uncertainty and changing climate risk in coastal areas using Dynamic adaptive pathways planning, multi-criteria decision analysis and Real options analysis: A New Zealand application. Sustainability 11(2): 1–18.

This paper critiques the Hawkes Bay assessments (above) and tries to suggest that the processes biased the results away from their preferred retreat option. The presumption, as in the above paper, is that managed retreat is the best option and that if the Hawkes Bay community, after considering the cost and benefit evidence has not gone for managed retreat, then there is must have been something wrong with the modelling or the process.

An adaptive plan is ineffective unless it reduces coastal hazard risk over the long term, thereby giving effect to the NZCPS.

This is a misrepresentatioin of the NZCPS.

Score: 6

Lawrence J, Haasnoot M, McKim L, Atapattu D, Campbell G, Stroombergen A. 2019b. From theory to practice: A timeline of interventions by a change agent with the developers and users of Dynamic Adaptive Policy Pathways (DAPP). In: V Marchau, W Walker, P Bloeman (eds) Decision making under Deep Uncertainty: From Theory to Practice. Amsterdam: Springer International Publishing.

Not recoverable.

Consequence

Applying processes and tools that characterise risks as static and rely on historical parameters that do not account for uncertainty and changing risk profiles increases the risk of maladaptation. Maladaptation may limit the choices available to future generations, increase the vulnerability of other systems, sectors or groups to climate change impacts, and increase the costs of climate change. Maladaptive actions may also disproportionately burden New Zealand's most vulnerable people and communities, and entrench socioeconomic inequity. The consequences of maladaptation are most likely to be borne by future generations.

This discussion is based on assertions with almost no reference back to the previous discussion, which suggests that some councils are aware of better risk assessment techniques. There is no discussion of the likelihood that other Councils will not become aware of the processes over relevant time horizons. There is nothing in the

analysis or references to support the conclusions that genuime ‘maladaptions’ will be a significant issue.

Certainly there is nothing in the above discussions that justify the extreme consequence assessment.

Confidence: High agreement, robust evidence

Adaptation
Work is being carried out at the local government level with support from the Ministry for the Environment. This work includes National Science Challenges (Resilience to Nature’s Challenges and the Deep South National Science Challenges). Methods being deployed include:
- *dynamic adaptive pathways planning*
- *coastal adaptation and associated vulnerability, and economic assessment methodologies and engagement practices*
- *local government pilot projects under the Government’s Community Resilience Group.*

The planned national adaptation plan (NAP) will take a cross-government approach to address climate change risk in a more comprehensive manner.

G2: Risk that climate change impacts across all domains will be exacerbated because current institutional arrangements are not fit for climate change adaptation. Institutional arrangements include legislative and decision-making frameworks, coordination within and across levels of government and funding mechanisms

NCCRA consequence assessment

Now: Major
2050: Extreme
2100: Extreme

Urgency score: 80

Tailrisk review summary

This risk mainly focusses on centralised legal and other structures to support (ultimately forced) managed retreat. It relys on several of the Lawrence papers (who

was the lead author of the governance domain). The message is that unless her version of the 'appropriate mechanisim, or something close to it, is adopted then there will be 'extreme' consequences. This conclusion is not supported by any quantitative analysis. There is just an assertion that the economic and social costs will be high.

Tailrisk consequence assessment: Moderate

Evidence quality score: Not assessed

NCCRA discussion

Risk summary

Adapting to the diverse impacts of climate change at a variety of scales requires statutory and policy alignment, coordination across levels of government and with different sectors, and significant ongoing funding (Climate Change Adaptation Technical Working Group, 2018). These enablers for anticipatory adaptation have been repeatedly identified as barriers to effective adaptation to climate change (Boston and Lawrence, 2018; Hanna et al, 2018 Lawrence et al, 2013). If national and regional governments fail to plan and invest in anticipatory risk reduction measures and effective adaptation initiatives, the economic, social and cultural costs of climate change will be higher (Boston and Lawrence, 2018). Adaptive capacity across all domains is likely to be challenged unless there is strong alignment of relevant statutes, and coordination of actors and funding mechanisms to support adaptation.

As noted alsewhere in this report, Boston and Lawrence do not provide any evidence that later adaption measures will inevitably increase social and economic costs.

Hanna C, White I, Glavovic B. 2018. Managed Retreat Governance: Insights from Matatā, New Zealand. Report for the National Science Challenge: Resilience to Nature's Challenges. Hamilton: University of Waikato.

This report investigated the role of environmental planning in enabling managed retreat in New Zealand including an overview of the decisions that led to managed retreat in Matatā. Matata is a small Bay of Plenty town that experienced a potentially life threatening debris flood, followed by a long saga on what to do about it. The managed retreat option eventually chosen cost three times more than an engineering option rejected as too expensive earlier in the process. The retreat option was chosen because there was an 'unacceptable' life safety risk. It is not altogether clear where this unacceptable assessment came from, but it appears to have been a consultant enginner's assessment. It was not shared by many of the affected parties who continued to live in their homes.

The Matata experience does not readily translate into the sea level rise response issue. The response was primarily driven by life safety issues which are generally not material with sea level rise.

The report did not consider whether managed retreat was the best option. That was regarded as almost axiomatically true.

Score: 6

Risk description

The Climate Change Adaptation Technical Working Group (2018) recommended several governance-related actions to the Government. These include:

- *establishing governance arrangements that support long-term adaptation action (Action 5)*
- *reviewing existing legislation and policy to integrate and align climate change adaptation considerations (Action 7)*
- *defining funding arrangements for climate change adaptation (Action 16).*

While Action 5 has been partially implemented through this National Climate Change Risk Assessment for Aotearoa New Zealand, local government mandates linked to the national governance arrangements and the other critical supporting recommendations have yet to be actioned. In a review of the current governance arrangements relating to climate change adaptation in New Zealand, Boston and Lawrence (2018) conclude that existing institutional and funding arrangements are not fit for purpose and lack the capacity to ensure sound anticipatory governance and the ability to deliver equitable outcomes.
The authors note that: "without appropriate reforms, existing policy frameworks are destined to increase rather than reduce risk exposure, exacerbate future adaptation costs, and contribute to multiple inequities. In the interests of sound anticipatory governance, a better framework is required." (Boston and Lawrence, 2018, p 44)

Statutory and policy alignment

New Zealand's numerous laws and policies have inconsistencies and competing objectives related to climate change adaptation (Blackett and Hume, 2011; Lawrence et al, 2019a). For example, the Housing Accords and Special Housing Areas Act 2013 puts housing supply ahead of natural hazards provisions, increasing the risk that new housing is in unsuitable areas. Lawrence and Manning (2012) also note that misalignment between various Acts can result in short-term decisions that exacerbate risk. For example, the Soil Conservation and Rivers Control Act 1941 has a focus on protection works that give rise to static responses; the Resource Management Act 1991 has a precautionary focus; and the Building Act 2004 is the Act to default to in the absence of regional or district rules. At the national level, many sectors operate within regulatory frameworks and policies that are not well aligned with climate change adaptation (Climate Change Adaptation Technical Working Group, 2018).

Local council functions relating to climate change impacts are spread across a number of statutes. These functions include flood management, water and stormwater management, land-use controls, emergency management and the management of assets including infrastructure (Manning et al, 2015).

Coordination

To be effective, climate change adaptation practices must be coordinated across different levels of government, geographical regions, technical and disciplinary areas, and administrative boundaries, as well as between government and non-governmental institutions (Lawrence et al, 2018). New Zealand's national institutional framework, centred on the Resource Management Act 1991 (RMA), influences adaptation practice and, along with the Local Government Act 2002, determines the relationships between national, regional and district scales of government. However, these two statutes do not clearly mandate climate change risk management or adaptation, nor the coordination of related roles, responsibilities and actions across these levels of government. The framework empowers local government to make decisions on landuse activities, natural hazard management, infrastructure and urban development (Lawrence et al, 2013) and allows for central government to provide consistent overarching directions and guidance through national policy statements and national environmental standards (Lawrence et al, 2012).

This coordination architecture is currently under-used due to lack of a clear mandate (Climate Change Adaptation Technical Working Group, 2018; Lawrence et al, 2012), leaving local councils to individually design their responses.

The substance of the argument is that responses at the local level are suboptimal.

This fragmented effort increases the exposure of decisions to challenge in the courts, which may delay action (G3) (Lawrence et al, 2013). It also leads to resource inefficiencies and a poor understanding of climate change risks among decision-makers and community members (Lawrence et al, 2013

The opposing arguments is that local decsion making will better reflect the preferences of local communities than decsion making being substantially in the hands of distant politically and ideologically driven bureancrats and their consultants.

Funding

Currently no dedicated funds are available for adaptation to reduce exposure to climate change-related risks. However, funding is available for recovery from hazard events, including the Natural Disaster Fund and Adverse Events Fund for the primary production sector (Boston and Lawrence, 2018). Reallocating funding towards risk reduction measures would be more cost-efficient (Deloitte Access Economics, 2013).

We noted above that the Deloitte paper did not support the argument that risk reduction measures would always be more efficient.

Significant and ongoing funding is needed to implement adaptation actions in response to climate change. Some of the most pressing adaptation needs in New Zealand relate to the impacts of ongoing sea-level rise, which include rising groundwater and salinisation, erosion and more damaging storm surges (B2). One metre of sea-level rise from the present day, which may be experienced by 2100 under representative concentration pathway (RCP) 8.5 H+ (see table 19), will expose more than 49,000 buildings to a 100-year extreme sea-level flood event. These buildings have a replacement value of about $12.4 billion (Paulik et al, 2019b). In cases where managed retreat is the only option, significant investment will be needed to support these communities.

This 'analysis' is wrong. The cited numbers are the figures for the current exposure to the 'risk'. If sea level rises by 1 metre then the number of buildings at that risk increases.

The biggest gap in the MfE's research programme is its failure to make even a ball park assessment of the costs of dealing with predicted rising sea levels. It is obviously important to understand whether the costs are more likely around $10 billion or $100 billion, to be able to discuss the consequences for the country and to government expenditure risks.

The following are other areas where adaptation funding arrangements are either highly limited or absent.

- *Compensation: Governments are likely to face litigation (G3) seeking compensation for loss or damage due to climate change, or conversely due to the loss of existing use rights due to adaptation measures (Grace et al, 2019; Winkelmann et al, unpublished).*

Grace ES, France-Hudson BT, Klivington MJ. 2019. Reducing Risk through the Management of Existing Uses: Tensions under the RMA. Lower Hutt : GNS Science.
This is a discussion of the use of the RMA to reduce risks. The main issue discussed is the capacity to prohibit existing uses under RMA. s.85 states that no interest in land will be taken or injuriously affected as a result of a provision of a plan.

Score: 8

- *Research: There is a critical under-investment in research to support climate change adaptation (G5) relating to biophysical and ecological changes, biosecurity, changes in the hydrological cycle influencing fluvial and pluvial flooding, and the implications of climate change for human systems such as the economy, health and health services (Climate Change Adaptation Technical Working Group, 2018).*

• Developing new and future-proofing existing infrastructure: Investment will be required to redesign, reposition and future-proof public infrastructure (B2), especially transport networks (B6) and three waters services (B1, B4) (Boston and Lawrence, 2018).
• Capacity building: Adopting new tools and processes (G1) for decision-making in the context of uncertainty requires organisational change and capacity building at all levels of government.
• Participation and engagement: Extended engagement processes are needed to establish a shared understanding of climate change risks, and to avoid a breach of Treaty of Waitangi obligations (G4). Engagement processes are currently constrained by lack of resourcing (Stephenson et al, 2020).
• Mātauranga Māori: Indigenous knowledge is critical in developing culturally appropriate adaptation responses. Funding is required to make effective use of mātauranga Māori in adaptation.
• Protecting taonga and the natural environment: New Zealand's unique ecosystems and biodiversity are poorly understood (IPCC, 2014a) and are under stress from changing and intensive land uses, localised pollution, and pressures associated with tourism. The ability to fund climate change adaptation will depend in part on bipartisan political agreement on climate change adaptation (G7), which will drive the fiscal capacity and economic position (E1) of New Zealand as a nation.

Consequence
The impacts of climate change will be greater if policy and legislation remain unaligned, actors uncoordinated, and funding for adaptation limited. Failure to plan and invest in anticipatory risk reduction measures and effective adaptation initiatives will increase the risk of maladaptation, expose governments to litigation risk, decrease trust in government and increase the likelihood of inequitable distribution of harm.

This is just sloganeering.

Confidence: High agreement, robust evidence

Adaptation
Coordination within and across levels of government, alignment of statutes, and adaptation finance are being partly addressed through the Climate Change Response (Zero Carbon) Amendment Act 2019, the review of the RMA that is under way and the Government's Community Resilience Group work programme. Some local councils are developing adaptation plans and working together at a regional level to coordinate adaptation efforts. The planned NAP will take a cross-government approach to address climate risk in a comprehensive manner.

G3: Risks to governments and businesses from climate change related litigation, due to inadequate or mistimed climate change adaptation

NCCRA consequence assessments

Now: Moderate
2050: Major
2100: Major

Urgency score: 78

Tailrisk review summary

It is argued that central government and local authorities may face litigation risk if they take pre-emptive action, or if they do not. The discussion is mostly about legal challenges to 'inadequate' climate change mitigation responses. Little attention was paid to legal risks arising from excessive adaptation actions. Most of the risk discussion is a rerun of the issues raised in G.2

Evidence quality score: 2

NCCRA discussion

Risk summary

Governments and businesses face potential legal liability due to climate change. Plaintiffs may turn to the courts to seek compensation for loss suffered due to inadequate climate change action. Governments could be liable for a range of matters, including failing to adapt public infrastructure, planning decisions that increase exposure to coastal hazards, and failing to reduce greenhouse gas emissions (Iorns, 2019; Iorns et al, 2017).

Iorns C. 2019. Treaty of Waitangi Duties Relevant to Adaptation to Coastal Hazards from Sea-level Rise. Wellington: Deep South National Science Challenge.
Not reviewed.

Iorns C, James V, Stuart T. 2017. Courts as decision-makers on sea level rise adaptation measures: Lessons from New Zealand. In: W Leal Filho (ed.) Climate Change Impacts
The chapter was not available online. From the abstract It adopted a case study approach, discussing four decisions in cases where a precautionary sea level rise adaptation measure taken by a territorial authority was challenged by a holder of property rights in the coastal area.

Score: Not scored

The private sector may face litigation for failing to adapt to climate change, and for damages caused by historical greenhouse gas emissions.

There is not too much to be done to stop court action against private parties. The failure to reduce greenhouse emissions is not an adaptaion issue.

The threat of litigation against governments who are taking action to adapt to climate change is also, perversely, delaying adaptation (Lawrence et al, 2013; Manning et al, 2015). If litigation results in delays to adaptation, it is likely to increase the costs of climate change, thereby exposing the Government and businesses to further liability.

Again these are conjectures based on the unsubstantiated assertion that delay will be costly.

Risk description
Over the past decade, litigation related to greenhouse gas emissions has increased markedly (Setzer and Byrnes, 2019). Seeking damages due to a failure to adapt to climate change, or a failure to prepare for foreseeable events such as floods, is an emerging area of litigation but is likely to become increasingly significant (Marjanac et al, 2017). Setzer and Byrnes (2019) emphasise that both cases relating to enforcement of existing mitigation goals and those concerning adaptation obligations are expected to increase.

Setzer J, Byrnes R. 2019. Global Trends in Climate Change Litigation: 2019 Snapshot. London: Grantham Research Institute on Climate Change and the Environment.
International actions relating to reponsibility for greenhouse gas omissions have little relevance to actions in New Zealand relating to adaptation issues.

Score: 2

Marjanac S, Patton L, Thornton J. 2017. Acts of God, human influence and litigation. Nature Geoscience 10(19): 616–619.

Developments in attribution science are improving our ability to detect human influence on extreme weather events. By implication, the legal duties of government, business and others to manage foreseeable harms are broadening, and may lead to more climate change litigation.

The international literature that attributes specific extreme weather events to climate change can be dubious. What this analysis does not do is attribute the

responsibilty to particular emmitters. In terms of responsibility virtually everyone who has consumed something with embedded emissions can be held to be 'responsible'.

Score: 2

Claims may be brought against governments for failing to adapt to climate change. Governments plan for, own and manage a wide range of public infrastructure and assets, many of which will now need to be adapted to climate change. In the United States, lawsuits have already been filed against federal and municipal defendants by members of the public seeking damages for failures to adapt to climate change (Marjanac et al, 2017). Insurers have also brought claims highlighting government failure to adequately prepare for foreseeable flood events (Marjanac et al, 2017). Local governments have a range of options available under the RMA to prevent and control developments in hazard-prone areas, including areas affected by climate change (Hodder, unpublished). The New Zealand Coastal Policy Statement, which must be given effect to by local government, foreshadows managed retreat (Ministry for the Environment, 2017b)

This seems to be suggesting that local authorities that don't implement a managed retreat could be expossed to liability. This could be the case in some circumstances. Some property owners might be very willing to retreat if their compensation is more than the market value of their property. On the otherhand efforts to enforce managed retreat will certainly generate litigation.

However, some land-use provisions in the RMA are a barrier to implementing managed retreat. Existing land-use provisions can only be removed by regional government, which is reluctant to do so. The devolution of climate change adaptation responsibility to the local level, together with the lack of guidance for responding to flooding and other climate change hazards, is leading councils to address climate change separately and differently from each other.

As local circumstances are different management at the local level may be optimal.

Under this arrangement, councils are exposed to legal liability for both adaptation action and inaction (Lawrence et al, 2013; Manning et al, 2015). Businesses are also likely to become subject to more climate change-related litigation. For instance, private professionals and companies that design, construct, manage or maintain public assets are likely to become liable for responding to the risks posed to these assets by climate change. Cases in this area are limited, however Marjanac et al (2017) suggest that liability may arise from the application of codes and standards that have not been updated based on the best available climate science.

This is all conjecture.

Recently, many public nuisance suits against major fossil fuel emitters have been lodged seeking emissions reductions and damages potentially amounting to billions of dollars to cover the cost of adaptation (Setzer and Byrnes, 2019). While these cases have been largely unsuccessful to date, developments in climate change attribution science are likely to provide better evidence of the link between emissions from private sector actors and their consequences (Marjanac et al, 2017; Winkelmann et al, unpublished).

It is anticipated that this area of litigation will increase in the future (Winkelmann et al, unpublished). Plaintiffs are also making cases that governments are breaching duties and obligations to citizens by inaction on emissions reductions.

The Waitangi Tribunal has already heard claimants asserting that insufficient action by the Crown on climate change. mitigation is in breach of Treaty obligations (see G4). The case, Thomson v Minister for Climate Change Issues 2017, which challenged the New Zealand Government's responses to climate change, was unsuccessful, but demonstrates the willingness of the High Court to adjudicate on climate change issues (Winkelmann et al, unpublished). Although much climate change-related litigation in the past has been unsuccessful, Douglas Kysar of Yale Law School argues that tort law principles must adapt to deal with the complexities of climate change litigation or become irrelevant, and that judges in tort cases might soon choose adaptation over irrelevance (Kysar, 2011). Winkelmann et al (unpublished) also anticipate that parties will increasingly resort to public law remedies, holding governments and local authorities to commitments in domestic legislation interpreted in light of international treaties and agreements.

Again litigation relating to action or inaction on reducing emissions is not an adaption issue

The processes set out in the Climate Change Response (Zero Carbon) Amendment Act 2019 also create an accountability mechanism through Parliament for adaptation plans. 16 A case is currently in progress to extinguish land titles on land rendered unusable by a large debris flow (Hanna and White, 2020). Attribution science attempts to attribute specific climate change- related events to particular emitters of greenhouse gases.

The last point is a nonsense in a scienific sense. As noted all that can be said that most people on the planet have directly or indirectly been responsible for greenhouse gas emissions.

Consequence

The consequences of climate change litigation will be significant. Local councils are particularly exposed; if the Government fails to provide national direction to local councils, it is likely that individuals and communities will bring private claims to address inaction, with local councils being a key defendant (Hodder, unpublished).

It is not explained why it is likely that such actions will be taken as It appears that there have been no such actions to date. Individuals who are nervous about climate change impacts can always retreat by selling their house.

There is a risk that decision-makers will fail to act pre-emptively because of the fear of litigation, particularly around land-use planning and funding of adaptation. This could increase the likelihood of decisions that lock in exposure to future risks, such as granting planning consents in floodplains and areas exposed to ongoing sea-level rise and coastal erosion, exacerbating risks such as B1, B2 and E7.

Delays to decision-making will contribute to higher adjustment and adaptation costs (Boston and Lawrence, 2018 (See above *).*

This will require additional adaptation funding (G1) and could impact on the Government's fiscal position (E1).

As noted elsewhere Lawrence and Boston, and Lawrence in her various papers, do not provide any evidence for this.

Confidence: High agreement, robust evidence
There is a high level of agreement and robust evidence that this risk will increase over time.

Adaptation
Limited adaptation action is under way or planned in relation to this risk. However, stakeholders note that other processes could address aspects of this risk, including the review of the RMA, efforts being undertaken by the Community Resilience Group and the establishment of the Climate Change Commission. A growing body of researchers and legal scholars is investigating this risk, including adjudication by Supreme Court judges that may lead to new jurisprudence.

G5: Risk of delayed adaptation and maladaptation due to knowledge gaps resulting from under-investment in climate change adaptation research and capacity building

NCCRA consequence assessments

Now: Moderate
2050: Moderate
2100: Major

Urgency score: 75

Tailrisk review summary

This risk assessment is a rather shameless pitch for more money by the report writers who most stand to benefit from it. In our view the problem is not so much the lack of funding but that some of it has been wasted on ideologically driven and self interested analysis. Past research that undermines the preferred 'catastrphist' narrative has often been hiddened or misrepresented. This behaviour should not be rewarded.

As funding will always be more limited than researchers ambitions the NCCRA would have been more helpful if it had focussed its demands rather than declaring almost everything to be important.

Evidence quality score: 2

NCCRA discussion

Risk summary

Under-investment in research and capacity building to inform understanding of climate change risks and impacts is undermining New Zealand's ability to develop evidence-based adaptation policy. These research gaps are a critical barrier to informed decision-making. While these gaps remain, maladaptive actions are a key risk.

Risk description

Managing climate change risks requires knowledge-intensive adaptation action and policymaking. Table 70 (see below) provides an overview of key knowledge gaps identified by this risk assessment.

It is a long wish list.

Ideally these knowledge gaps should be addressed through coordinated and multidisciplinary processes. The co-production of knowledge and information by many stakeholders using different disciplines (science, policy and social science) enhances the usability of knowledge (Lemos and Morehouse, 2005). It also better enables communication and transparency, and builds trust among decision-makers (Cradock-Henry et al, 2020; Howarth and Monasterolo, 2017; Stephenson et al, 2020).

Score: 0

Craddock- Henry, Blacket 2020 Climate adaptation pathways for agriculture: Insights from a participatory process Environmental Science & Policy

This paper reported on a pathway approach to supporting regional adaptation planning in Hawkes Bay. It makes positive statements about the contribution of the process.

Score: 3

Figure seventeen: NCCRA research wishlist

Area of knowledge	Research gaps
	• Species traits that determine tolerance to various environmental conditions.
Economy	• The economic cost of inaction on climate change at different scales and across sectors (Climate Change Adaptation Technical Working Group, 2018). • How climate change impacts may flow into and through New Zealand's financial system (A Wreford, Lincoln University, pers. comm., 28 March 2020). • How climate change will impact on the banking and insurance sectors.
People and culture	• How to identify, assess and track the structural causes and expressions of social vulnerability in New Zealand, and how these may change in the future (P Blackett, NIWA, pers. comm., 23 March 2020). • The interactions between cultural values, biophysical sciences and adaptive capacity (IPCC, 2014a). • The impacts of climate change on human health and demand for health services (Climate Change Adaptation Technical Working Group, 2018), particularly in relation to potential diseases.
Built environment	• How built environment assets, particularly landfills, cultural sites and indigenous built structures, are exposed and vulnerable to climate change. • How exposure to natural hazards, such as flooding from rivers and surface waters, differs across New Zealand. • How impacts on built environment assets will flow through to other domains.
Cascading risks	• How risks cascade and feed back over time (Lawrence et al, 2018, 2020) and between different geographies (IPCC, 2014a). • How uses of land and water may be impacted by the compounding effects of climate change (Climate Change Adaptation Technical Working Group, 2018). • The implications of cascading consequences for the governance of social and ecological systems (Lawrence et al, 2018, 2020).
Governance	• The socio-cultural, technological and disciplinary barriers to adaptation actions at multiple scales (IPCC, 2014a). • How adaptation planning can better engage communities. • How central and local government coordination can be empowered to undertake adaptation action through changes to laws. • Developing locally relevant decision triggers and planning approaches for managed retreat. • Legal issues that may arise from compensation for harm to, or loss or extinguishing of, existing use rights. • The implications of international and national climate change-related court cases for New Zealand. • How parliamentary mechanisms can be deployed to support funding and implementation of climate change adaptation. • Understanding how adaptation tools are used and misused, and the barriers to uptake. • How past events can inform climate change risk management, such as the Canterbury and Kaikōura earthquakes, pandemics and biosecurity incursions.

Fi

However, resourcing knowledge co-production has proved challenging to date (Lemos and Morehouse, 2005)

Targeted and timely funding (G2) will be critical to addressing knowledge gaps to support decision-making processes. Understanding the barriers to uptake of best-practice decision support tools, practices and processes (G1) will reduce the risk of maladaptation. Mātauranga Māori encompasses a wealth of unique knowledge that can inform climate change science, policy -making and management; however, this knowledge can only be accessed with trust and good relations between Treaty partners (G4).

Lemos M. Morehouse B. 2005 The co-production of science and policy in integrated climate assessments

This paper examined:

the use of interactive models of research in the US regional integrated scientific assessments (RISAS), using as a case study the climate assessment of the Southwest (CLIMAS.

The paper had nothing to do with the adequacy of climate change research funding in New Zealand.

Consequence

Ongoing research is critical for informing adequate climate change risk assessment and adaptation action. Based on the current level of knowledge, particularly for compounding and cascading events, there is a risk of significantly underestimating climate change risks, intervening at the wrong points in the system and taking maladaptive actions. Lack of knowledge may be used to justify inaction (Hulme, 2009). For example, in the natural environment domain, a lack of consistent data is hindering conservation efforts even before climate change is considered

.

As we discussed above the cascading and compounding effect is nothing new and does not require more research. The results so far suggests the funding was wasted.

NIWA has a model that is designed to quantify flooding imapcts across a range of costs.

Hulme M. 2009. Why We Disagree about Climate Change: Understanding Controversy, Inaction and Opportunity. Cambridge UK: Cambridge University Press.

This UK book has little to do with adaptation research funding in New Zealand

Score: 3

Confidence: High agreement, robust evidence
There is a high level of agreement and a robust body of evidence to demonstrate underinvestment in relevant and targeted research to inform climate change adaptation in New Zealand.

They would say that. We would argue that much research funding is being misdirected.

Adaptation
Some research is under way that supports understanding of climate change impacts and adaptation. Efforts to date include research funded through:
- *Deep South National Science Challenge*
- *Resilience to Nature's Challenges National Science Challenge*
- *Sustainable Land Management and Climate Change Fund*
- *Climate Change Adaptation Technical Working Group.*

The amounts, that are not trivial, were not disclosed.

G6: Risks to the ability of the emergency management system to respond to an increasing frequency and scale of compounding and cascading climate change impacts in New Zealand and the Pacific region

NCCRA consequence assessments

Now: Major
2050: Major
2100: Major

Urgency score: 70

Tailrisk review summary

There is no discussion of the current cost of emergency responses to climate events and how this is amount is to likely to change with climate change. The analysis relies on assertions that there will significant increases in hazard events, which is not supported by the science. The assessment that climate change is already having major impacts on emergency services is unsubstantiated and exaggerated.

Tailrisk consequence assessment: Minor

Evidence quality score: 1.88

NCRRA discussion

Risk summary

Climate change will increase the frequency, severity and spatial extent of natural hazard events, and create new hazards that need emergency management responses.
This increased demand for emergency management services may be compounded by damaged infrastructure critical to delivery of those services. Infrastructure can be affected by extreme events such as floods, fires or landslides, as well as by gradual, ongoing impacts such as sea-level rise and coastal inundation that degrade critical infrastructure. The cascading effects of these increasing natural hazards across systems could also lead to coordination challenges, including lack of clarity about responsibility for risk management.

There is no attempt to quantify these demands on emergency services. For example a back of the envelop estimate could have been made of the expense of responses to extreme weather events in recent years and an assessment made of the increases by 2050 and 2100 to assess the increased burden.

Risk description

New Zealand faces significant natural hazard risks, many of which could be exacerbated by climate change due to increased frequency, severity and complexity of extreme weather, combined with ongoing hazards such as sea-level rise (IPCC, 2012). This will lead to a range of challenges for the emergency management sector (Ministry of Civil Defence and Emergency Management, 2019).

Ministry of Civil Defence and Emergency Management. 2019. National Disaster Resilience Strategy. Wellington: Ministry of Civil Defence and Emergency Managemen

The only reference to climate change in this document was the following:

In assessing our risks, we can learn from past events and emergencies, but we also need to consider broader and longer-term societal trends. Trends such as these have the potential to be a source of both risk and opportunity, sometimes in equal measure.

They include: Climate change and environmental degradation, which could impact on, or accelerate, a wide range of our risks owing to their effects on sea level rise, the frequency and severity of natural hazards and extreme weather, biodiversity, biosecurity, and the availability and quality of ecosystems and their services.

Climate change was hardly front of mind.

Score: 3

These challenges include:

- *the intersection of these impacts with other stressors, such as health and safety risks, that require joint agency planning and interoperability.*
- *supply chain vulnerabilities (New Zealand Lifelines Council, 2017)*
- *the need to revise building codes (New Zealand Lifelines Council, 2017)*
- *the need to adapt land-use planning to changing circumstances (Saunders et al, 2013).*

New Zealand Lifelines Council. 2017. New Zealand Lifelines Infrastructure Vulnerability Assessment: 1. New Zealand Lifelines Council

This assessment did mention severe weather events as a risk but did not mention climate change. It stated:

Regional lifelines studies have not identified any nationally significant infrastructure vulnerable to floods. The low-lying Dunedin CBD area does contain a number of regionally important infrastructure sites.

Score: 0

As events become increasingly complex, a multi-hazards approach to organising the emergency management sector is likely to be needed (Lawrence and Saunders, 2017).

Lawrence J, Saunders W. 2017. The planning nexus between disaster risk reduction and climate change adaptation. In: I Kelman, J Mercer, JC Gaillard (eds) The Routledge Handbook of Disaster Risk Reduction Including Climate Change Adaptation. London: Routledge.

From the abstract this paper makes a pitch for integration between climate change adaptation and disaster risk reduction. It does not appear to explain why a reduction in risk is critical and efficient. It is based on the premise that disaster risk reduction is always desirable regardless of cost.

Score: 3

If extreme events increase, so will the demands on full-time and volunteer emergency service personnel and non-government organisations. Meeting this demands would require increased resourcing, including volunteer support, and partnership between the public and private

sectors to meet critical infrastructure needs (Handmer et al, 2012; Mitchell et al, 2010; Ozanne and Ozanne, 2013).

Handmer J, McKellar R, McLennan B, Whittaker J, Towers B, Duggie J, Woolf M. 2013. National Climate Change Adaptation Research Plan: Emergency Management – Revised 2012 Edition.

This is an Australian paper with no direct relevance to New Zealand climate change issues.

Score: 0

Mitchell A, Glavovic B, Hutchinson B, MacDonald G, Roberts M, Goodland J. 2010. Community-based civil defence emergency management planning in Northland, New Zealand. Australasian Journal of Disaster and Trauma studies

This paper was about involving the community in emergency management. There was no reference to climate change.

Score: 0

Ozanne L, Ozanne J. 2013. Developing Local Partners in Emergency Planning and Management: Lyttelton Time Bank as a Builder and Mobiliser of Resources during the Canterbury Earthquakes. Wellington: Ministry of Civil Defence and Emergency Management.

This paper examined a 'partner' in emergency management—a local community time bank (a grass roots labour exchange system) following the Christchurch earthquake. It is difficult to see what relevance it has to the need for more civil defence resources for climate related events.

Score: 1

These additional responses required by the emergency management system may affect the health, safety and emotional wellbeing of emergency management workers. Cascading and concurrent events are likely to increase with climate change, stretching the capacity of the sector to respond (Australasian Fire and Emergency Service Authorities Council, 2018). New Zealand has already experienced concurrent and cascading severe and extreme events. For example, in 2017 a series of ex-tropical cyclones and storm events caused significant damage across parts of New Zealand. In March 2017, the 'Tasman Tempest' caused heavy rainfall and flooding in the upper North Island, floods and landslides in southeast Auckland and Coromandel, and restricted water supply in Auckland due to siltation of reservoirs in the Hunua Ranges.

There was no attempt to assess the pressure placed on emergency services from these 'concurrent and cascading 'events.

Australasian Fire and Emergency Service Authorities Council. 2018. Discussion paper on Climate Change and the Emergency Management Sector. Melbourne: Australasian Fire and Emergency Service Authorities Council.

This paper was entirely focussed on Australia. The only mention of New Zealand was:

The allocation of effort and resources to confront the climate change continues to increase. This challenge is exacerbated by the lack of a standardised approach in Australia and New Zealand to guide exposure assessment and vulnerabilities to climate change and disaster risks.

Score: 3

In April 2017, ex-Tropical Cyclone Debbie brought significant rainfall to the upper North Island, particularly the Bay of Plenty, where failure of a stopbank on the Rangitāiki River flooded Edgecumbe (Coomer et al, 2018). Shortly after this, ex-Tropical Cyclone Cook brought extensive rain and high winds to the upper and eastern North Island. In July 2017, heavy rain and high tides led to hundreds of homes being evacuated and a state of emergency in Waitakere, Dunedin, Christchurch, Selwyn, Timaru and eventually the entire Otago region, as floodwaters inundated parts of the eastern coast of the South Island (Coomer et al, 2018).

New Zealand has always experienced extreme weather events. The issue that is not seriously addressed is whether and what extent these events will increase to the extent that emergency management resources will be increased and over what time horizon. There is no evidence that these named events adversely affected the emergency workers involved.

Coomer M, Rogers A, Pinal C. 2018. Natural Hazards 2017. Lower Hutt: GNS Science.
This is an annual review of all of New Zealand's natural hazards. There was a section on ex-tropical cyclones impacting on New Zealand which looked at the historical record that showed 3 ex tropical cyclones was unusual compared to the average of under one a year. The decade showed an increase from historical levels though there is significant decade to decade variability. There was no mention of the impact on emergency services.

Score: 5

In addition to concurrent domestic events, extra demand is likely to be placed on New Zealand's capacity to provide emergency response services to its regional neighbours, and vice versa. New Zealand provides humanitarian aid, including disaster assistance, to the broader Asia-Pacific region. New Zealand shares close cultural political, and social links with the Pacific region and is considered a trusted partner that can respond quickly to support Pacific governments when a disaster occurs.

The expected increase in concurrent and coincident events may also limit New Zealand's ability to draw support from other states in the region during a crisis. For instance, equipment and personnel sharing arrangements with Australia and the United States may be jeopardised by the increasing overlap of fire seasons (Australasian Fire and Emergency Service Authorities Council, 2018).

Consequence
Climate change affects the emergency management sector's capacity to support preparedness, response and recovery efforts. This is likely to increase the consequences of climate hazards for communities. In particular, rural populations, which include a high representation of Māori communities, are usually dispersed across less accessible landscapes, which can leave them more exposed to the impacts of hazards.

There was no discussion or evidence on the extent to which the weather events placed a strain on emergency services.

Confidence: Medium agreement, limited evidence.
There is agreement that increasingly frequent and severe extreme events will place strain on emergency management capability. However, only a limited number of studies have directly explored the various impacts of coincident, cascading and compound hazard events on the integrity of emergency management systems.

Adaptation
Adaptation efforts relating to climate change and emergency management in New Zealand are at an early stage. The Hazard Risk Board, composed of chief executives of Government departments and ministries, is responsible for the cross-government strategic governance of natural hazard events. The National Emergency Management Agency and the National Disaster Resilience Strategy are taking steps to ensure the continuity of emergency management services in a changing climatic future.

G7: Risk that effective climate change adaptation policy will not be implemented and sustained due to a failure to secure sufficient parliamentary agreement

NCCRA consequence assessment

Now: Major
2050: Extreme
2100: Extreme

Urgency score: 68

Tailrisk summary

The thrust of this risk assesment is that a sustained bipartisan approach to a broad suite of climate change adaptation policies is required. We have not seen much analysis that supports this.

In our view it is essential that there is room for scutiny and debate at the political level. If one government is captured by the adaptation industry then successor governments should not be locked into a particular approach. Climate change mitigation and adaptation are two different things and bipartisan commitment to mitigation does not imply commitment to an excessive adaptation response. In our view this report goes beyond its mandate in pressing for structural political responses.

Tailrisk consequence assessment: Minor

Evidence quality score: 0.6

NCCRA discussion

Risk summary

To minimise future damages from climate change, pre-emptive and sustained action by the Government is needed.

It is necessary for successive governments to have a strong political mandate for and commitment to climate change adaptation. The structure of New Zealand's political system, together with an economy characterised by dominant sectors that have politicised climate change, has hindered meaningful action on both emissions reduction and climate change adaptation.

This argument is based on the premise that the authors of the NCCRA are right and that any dissenting opinion is dirty politics.

The recent passing of the Climate Change Response (Zero Carbon) Amendment Act 2019 with bipartisan support is a positive development. An ongoing spirit of bipartisanship will be critical to enabling necessary climate action.

Risk description

Climate change has been described as a 'super wicked problem' (Lazarus, 2009; Levin et al, 2012) that requires successive governments to commit to policy reform, confronting vested and special interests, and to take actions now to avoid future harm (Boston, 2016). Bipartisan alignment on issues and solutions is generally recognised as contributing to better policy development (Harbridge, 2015). Bipartisanship supports long-term policy development, which is necessary for large-scale coordinated climate change mitigation and adaptation efforts. It allows for consistent government guidance and ongoing funding commitments to reduce climate change risk. It also provides the certainty that institutions, planners and industries need to effectively respond to climate change.

Lazarus RJ. 2009. Super wicked problems and climate change: Restraining the present to liberate the future. Cornell Law Review 94(5): 1153–1233.

This paper makes the case for precommittment to climate change mitigation policies in the US context, which is very different to New Zealand. It has nothing to say about political precommitment to adaptation policies.

Score: 0

Levin K, Cashore B, Bernstein S, Auld G. 2012. Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate global climate change. Policy Sciences 45: 123–152.

This is also a discussion of mitigation in an international context, not adaptation.

Score: 0

Boston J. 2016. Anticipatory governance: How well is New Zealand safeguarding the future? Policy Quarterly 12(3): 11–24.

This paper sets out several attributes of 'sound anticipatory government' One attribute is 'assessing the long-term consequences of today's decisions and events, seeking wherever possible to minimise future harms'. This is not obviously a good idea. It implies that futher risk reduction will always be pursued regardless of costs. The paper concludes that New Zealand does not perform well on anticipatory governance measures and suggests some reforms. There is no specific discussion of climate change adaptation.

Score: 0

Harbridge L. 2015. Is Bipartisanship Dead? Policy Agreement and Agenda-Setting in the House of Representatives. Cambridge: Cambridge University Press.

This is a discussion of the US politcal system.

Score: 0

The challenge faced by elected representatives to address the trade-off between the cost of responding to climate risks and the benefits to future generations is compounded by New Zealand's short electoral cycle (Jacobs, 2011). The triennial electoral cycle concentrates decision-making on the short term and often leads to the postponement of policies that may be effective but politically unpopular (Palmer, 2015).

The cost of adaptation to safeguard future wellbeing sits in dramatic contrast to its uncertain and indirect future benefits, which makes it difficult for governments to justify this cost to the public (Boston and Lawrence, 2018 - See above *).*

The 'problem' can often be that the benefits are not only uncertain but that they are small. The public often suspects this and are reluctant to be pressured into accepting present costs.

To take preventative steps requires the government to make 'hard calls' that are potentially politically unpopular, and governments are unable to bind their successor to such a policy, who may just as easily reverse it. The history of market-based greenhouse gas mitigation policies in New Zealand illustrates this challenge: governments delayed enacting policies to reduce emissions and, when policies were implemented, they were either overturned or significantly diluted by new governments (Chapman, 2015). Lobbying is an important element of political participation. It involves efforts by individuals or collectives to directly influence decisions of legislators and public officials (Chapple and Anderson, 2018). New Zealand has a long history of lobby groups exerting influence on public policy. Much of this has been for the benefit of the public.

However, lobbying can also represent the narrow interests of specific groups; for example, property developers who lobby local authorities to approve subdivisions and other developments in areas likely to be vulnerable to ongoing sealevel rise (Boston and Lawrence, 2018).

Chapman R. 2015. Time of Useful Consciousness: Acting Urgently on Climate Change. Wellington: Bridget Williams Books.

Not reviewed but the proposition that early New Zealand action is inherently desireable in an international context is not self evident. We would have had almost had no impact on worldwide emissions at a potentially substantial economic cost.

Chapple S, Anderson T. 2018. Grease or sand in the wheels of democracy? Policy Quarterly 14(2): 10–17.

This paper was an article about 'professional' lobbying rather than lobbying more generally. It makes a case for light handed regulation to primarily to shed more light on what is happening in the industry which is currently unknown.

Score: 0

Boston and Lawrene

The Boston and Lawrence reference to lobbying efforts was inaccurate and quite misleading. They state:

Second, notwithstanding their responsibilities to mitigate long-term risks, many local authorities, often under pressure from property developers, have been approving major new subdivisions and other developments in areas that are likely to be vulnerable to rising seas later in the century (see, for example, Gibson and Mason, 2017).

The reference to Gibson, E. and C. Mason (2017) 'Drowning dreams: apartment block where the waters meet' was to a Newsroom story that made the following points:

- The council approved an apartment block development in a retirement community in Thames on the condition that the ground floor was 4.1 metres above sea level, so any flood would flow under the building. The building was also protected by a seawall.
- In its decision the council cited a 2001 Tonkin and Taylor report that put the 2100 sea level rise at 0.49 m
- A Thames lawyer was 'concerned' about floodind risk and wrote to the Council to reconsider.

This was not a case of developer lobbying pressure. The developers simply applied for a consent and complied with the Council's requirements. It was more of a case of busybody meddling in a process he didn't understand.

Score: 0

As another example, Barnett (2017) describes lobbying by landowners, particularly in major coastal cities, to fortify coastlines with sea walls that are often maladaptive.

Barnett J. 2017. Submission to Inquiry into Current and Future Impacts of Climate Change On Housing, Buildings and Infrastructure. Canberra: Parliament of Australia.

This is a 222 page report by the Australian Senate covering all aspects of climate change and the institutional environment. The relevant part, we think is seven pages on challenges local governments face responding to climate change. Concerns were

expressed by councils over potential costs and legal risk. Legal risks included the risk of litigation for refusing development applications. There was no discussion of lobbying in this section of the report but there could be elsewhere.

Chapter 4 on coastal land use planning is also relevant. There was no mention of lobbying there.

Score: 3

Lobbying is unregulated in New Zealand. Further, despite investigation by Chapple and Anderson (2018, p 16), "it is still unclear who lobbyists work for and how they act, with little hard evidence available to illuminate the true nature of the industry". This lack of clarity about the degree to which unregulated lobbying is influencing the policy-making and decisionmaking necessary for climate change adaptation is concerning (Boston, 2016).

Lobbying is a necessary part of the political process. It can bring different and sometimes better perspectives than that of supposedly expert and disinterested academics.

Consequence

Because central government actions are needed for large-scale and coordinated adaptation responses, a failure to sustain bipartisan agreement on climate change would pose a barrier to adaptation efforts. For instance, local governments, to which much adaptation responsibility is devolved, would not be adequately funded (G5), and action would be less coordinated between and across levels of government (G1), which would increase litigation-related risks (G3). Without consistent bipartisan alignment, actions across all domains are less likely to be taken in a timely and cost-effective manner, and the actions that are taken have a higher chance of being maladaptive.

Central government involvement may be sometimes optimal but sometimes local government and decentralised businesses will do a better job.

Confidence: Moderate agreement, medium evidence

There is a high degree of consensus and robust evidence about the need for central government action and the consequences of inaction. There is less evidence, and more divided opinion, about the causes of inadequate central government action.

Adaptation

The recent establishment of the independent Climate Change Commission, along with crossparty working groups on climate change, has created mechanisms that encourage long-term bipartisan decision-making.

G8: Risk to the ability of democratic institutions to follow due democratic decision-making processes under pressure from an increasing frequency and scale of compounding and cascading climate change impacts

NCCRA Consequence assessments

Now: Moderate
2050: Major
2100: Major

Urgency score: 53

Tailrisk review summary

The risk that democratic processes will breakdown under the pressure of unanticipated extreme events is overblown at least for many decades and probably to the end of the century. Climate emergency events are very small (historically with maximum costs of a few hundred million) compared to events such as pandemics and earthquakes.

Tailrisk 2100 consequence assessment: Minor

Evidence quality score: 0.5

NCCRA discussion

Risk summary

Climate change may also pose a risk to democratic decision-making processes, particularly in the aftermath of an intense, unanticipated extreme event. The risks to due process resulting from urgent responses to extreme events are likely to increase as hazards increase in frequency, intensity and spatial scale.

Risk description

Democracies depend on an informed and engaged citizenry that can hold elected officials accountable for effective policy-, law- and decision-making to ensure, among other things, equity and justice (Morlino, 2004). To enable citizens to play this role, governments need to engage, share information and be transparent. While research into how climate change might affect democratic functioning is scarce, the 10 principles of law-making, outlined by Geiringer et al (2011), provide guidance for evaluating the quality of governance in a changed climate future.

Morlino L. 2004. What is a "good" democracy? Democratization 11(5): 10–32.
This sets out general principles for good democracy. These are uncontroversial but do not contribute to the discussion.

Score: 0

Geiringer C, Higbee P, McLeay E. 2011. What's the Hurry? Urgency in the New Zealand Legislative Process 1987–2010
This set out 10 principles for good law making. Again this does not contribute to the discussion.

Score: 0

More severe and frequent extreme events, and ongoing changes in climate change impacts like sea-level rise, have implications for the ability of governments to consistently meet some of these principles. It is foreseeable that frequent, cascading and compound hazards, such as coastal and riverine flooding, could create situations that bypass standard consultative processes and curtail public involvement, potentially violating principles 1, 2 3, 4 and 6 outlined in box 12.

This is overblown. Sea level rise is gradual allowing plenty of time for careful deliberative law making. Extreme climate events are an order of magnitude lower than events such as earthquakes. New Zealand already has legislation dealing with natural disasters which is very flexible and can be potentially draconian. It was incumbent on the writers to demonstrate how excessive use of these powers under climate change would futher impingment on democratic processes.

For example, in response to the first earthquake in the Canterbury sequence, Parliament passed the Canterbury Earthquake Response and Recovery Act 2010 in a single day of sitting, despite serious constitutional concerns expressed in the House (Hansard Parliamentary Debates, 2010). According to constitutional scholar Dean Knight (2010), this Act, hurried through Parliament to enable recovery processes, gave "ministers vast and untrammelled power to change laws in the name of earthquake recovery – without adequate checks and balances" and, in doing so, the legislation "violat[ed] basic principles within our constitution and upset our democratic infrastructure" (para 2). Knight was not alone in his concern; the Law Society's Rule of Law committee expressed concerns about the structure of the legislation, specifically its "potential interference with existing court proceedings and removal of the right of access to the courts, along with reliance on restraint from government and public officials in the exercise of very broad powers of law" (New Zealand Law Society, 2010, para 8).

This criticism was recognised: the Act was repealed six months after it was passed, and replaced by the Canterbury Earthquake Recovery Act 2011

To reduce the trauma associated with managed retreat, there must be a strong element of trust supported by democratic accountability (Warren, 2018).

Warren M. 2018. Trust and democracy. In: E Uslaner (ed.) The Oxford Handbook of Social and Political Trust. Oxford: Oxford University Press.

This is a generic discussion of the foundations of political trust. It had nothing to say about climate change and managed retreat.

Score: 0

Decision-makers in New Zealand are faced with the challenge of anticipating the consequences of a rapidly changing set of risk profiles and how best to respond (Boston, 2016). The Christchurch earthquakes demonstrated that extreme, unexpected and ongoing impacts have the potential to disrupt even a robust and well-functioning democracy like New Zealand's (Hayward, 2013).

Hayward B. 2013. Rethinking resilience: Reflections on the earthquakes in Christchurch, New Zealand, 2010 and 2011. Ecology and Society 18

This is a personal reflection on the Christchurch earthquake with a somewhat distant relevance to this risk discussion. From the abstract:

Resilience is both a refreshing and a problematic concept. It is refreshing in that it creates new opportunities for interdisciplinary research and vividly reminds us that the material world matters in our social lives, political economy, and urban planning. However, the concept of resilience is also problematic. Widespread, uncritical calls for greater resilience in response to environmental, economic, and social challenges often obscure significant questions of political power.

Score: 2

It will be incumbent on governments to provide nuanced and democratically consistent responses that respond to immediate needs and respect constitutional norms. The Canterbury Earthquake Recovery Act 2011 demonstrates how a truncated parliamentary process can be rectified in a later amendment (Gobbi et al, 2011). Responding to the needs of New Zealanders need not compromise due process (Knight, 2010). The capacity to sustain trust and accountability in government and other institutions as climate change impacts worsen will also depend on collaboration between levels of government and with communities, the judiciary, the civil sector and the media. Trust in government (G3) is an essential prerequisite

for democratic decision-making processes and can be enhanced by these same processes. Avoiding breaches of Treaty of Waitangi obligations (G4) will also be necessary to ensure that Māori are willing and able to engage in policy- and decision-making.

Consequence

The consequences of breaches in due democratic process are major and equally significant across all timeframes. Democratic institutions and processes are critical for building adaptive capacity to climate change across all domains

Confidence: Medium agreement, limited evidence

Evidence of risks to democratic processes in the context of climate change is an emerging field of research. There is a medium level of agreement, but no primary evidence to suggest that the New Zealand Government will respond to climate hazards in an undemocratic manner.

This was one of the few assesments where there was less than high agreement or at least mdeium evidence. Given the paucity of the evidence it is not clear how they could decide that the 2100 consequences were major.

However historical events such as the Canterbury earthquakes provide a valuable case study to infer potential responses under a changed climate future. Adaptation Limited adaptation action is under way or planned. However stakeholders note that such action is implicit in other processes such as the review of the RMA, and in the remit of the independent Climate Change Commission.

Adaptation

Limited adaptation action is under way or planned. However stakeholders note that such action is implicit in other processes such as the review of the RMA, and in the remit of the independent Climate Change Commission.

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Appendix one

Cost of weather related disasters: Insurance claims

Year	Total Cost inflation adjusted $m	Largest single event $'m	Fire losses $'m
2020	141	44 (upper north island flooding	35
2019	206	171 Timaru hail storm	4
2018	217	74 Severe weather	
2017	243	91 Cyclone reminants	18
2016	53	31	
2015	118	42	
2014	165	55	
2013	182	77	
2012	9	9	
2011	53	21	
2010	76	55	
2009	5	3	
2008	99	53	
2007	114	73	
2006	61	52	
2005	62	37	
2004	192	148	
2003	33	29	
2002	35	29	
2001	4	2	
2000	31	13	
1999	78	68	
1998	37	17	
1997	21	6	
1996	17	12	
1995	20	7	
1994	29	17	
1993	12	12	
1992	13	12	
1991	5		
1984	148 Southland floods		
1968	301	234 Wahine storm	

Appendix two:
Bath tub and dynamic inundation Poverty Bay