HCL
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Dear Peter

Review of coastal hazard reports by Tonkin & Taylor

I have reviewed the two reports prepared by Tonkin & Taylor (T&T) for Christchurch City Council (CCC) on coastal hazards. The stage one and stage two reports deal with identifying areas susceptible to inundation and erosion over both a 50 and 100 year planning timeframe for district planning purposes.

In summary, the methodologies used are appropriate, the assumptions made are good, the referencing to and interpretation of other similar research is appropriate in its application, the results are valid and the discussion of the results and the conclusions reached are valid. Overall the Stage One and Stage Two reports read well. However the Stage Two report has a number of typos and incorrect referencing of figures/tables that may result in a poor or potentially incorrect understanding of the science/technical matters being discussed. These errors should be corrected.

I am happy for my review comments to go to T&T.

Scope of Peer Review

Following your instruction of 29 April 2015 I reviewed the reports by T&T:

- Tonkin & Taylor (2015) Coastal hazard assessment stage one - review. Technical report prepared for Christchurch City Council. 22p + Appendices. February 2015.
- Tonkin & Taylor (2015) Coastal hazard assessment stage two. Technical report prepared for Christchurch City Council. 52p + Appendices. April 2015.

The terms and conditions of my peer review were:

1. Deliverable - a written review report by 5 June 2015.

2. The peer review is not to assess whether or not the consultant met the requirements of the brief. (Take it that the consultant has met the terms of the brief).

3. The peer review is not to edit typos, grammar, report structure etc necessarily, however, if you wish to highlight these that would be useful, and particularly where a typo or awkward grammar may result in a poor or potentially incorrect understanding of the science/technical matters being discussed.

4. The peer review will include, but not necessarily be limited to a critique of: 1) the appropriateness of the methodologies used, 2) the relevance/significance of any assumptions made, 3) the appropriateness of and referencing to and interpretation of other similar research and its application, 4) the validity of the results and 5) the adequacy of the discussion on the results and particularly with respect to the conclusions reached.

Coastal Hazard Assessment Stage One – Review

The stage one report was commissioned to review the existing coastal hazard zones for southern Pegasus Bay and to identify areas susceptible to coastal inundation around Lyttelton Harbour. The purpose of the T&T review is to provide CCC with supporting information for undertaking Stage Two of the CCC District Plan Review.

Southern Pegasus Bay

The review was required because the existing delineation of the CHZ for southern Pegasus Bay was completed prior to 2005 and there are now over 10 years of additional data that could be included in the assessment. Also the existing CHZ assessments did not incorporate the potential effects of sea level rise as required under both the NZPS (2010) and the Envirolink Guidelines (2012).

The report provides a clear and concise description of the methodologies used.

The hypothesis that T&T set out to test was sound, namely: reviewing the existing CHZ for southern Pegasus Bay due to sea level rise to test whether the long term rate of accretion exceeds the potential rate of shoreline retreat. If the historic accretion rate is greater, Council would consider maintaining the existing CHZ. Alternatively if the rate of potential shoreline retreat from sea level is greater, Council should consider revising the existing CHZ.

The timeframe of 100 years (baselined at 2015) is appropriate as this is required by the NZCPS (2010).

There is a good decadal-scale dataset on which to base the analysis, namely: 1) beach profiles surveyed twice yearly at eight sites from 1990 to current and 2) five historic photographs (1941 to 2011) and one GPS shoreline (2014) covering four 2 km-long sections along Pegasus Bay.

Understanding how sea level rise could potentially interact with the coastal sediment budget and particularly the sediment inputs from the Waimakiriri River is appropriate

The linear regression analysis of the beach profiles data is an appropriate method to use providing output values of rate of shoreline change over time and with the correlation coefficients providing the strength of the rate or trend. The results are well supported by the beach profile linear progression plots and the summary table. I didn't see a justification as to why the eights sites were grouped the way they were in Table 2-3 (e.g., North New Brighton, New Brighton etc), although this doesn't make any difference to the overall tend or rate of movements data. (I subsequently found an explanation of this in the Stage Two report). It was correct to exclude Tern Street data from the long-term analysis of shoreline movements as the site is very likely to be affected by processes at the Avon-Heathcote inlet. It was good to see consideration of the potential effects of the 2010 – 2011 Canterbury earthquakes on the beach profiles, and interesting that ECan have not noted a response in the beach profile record to date.

The analysis of the aerial photographs uses best practice and is sound. Using the dune toe line (as opposed to dune crest or edge of vegetation) as a reference is standard procedure. The historic shorelines were digitised from geo-referenced aerial photographs and this was verified against the source information by T&T, focussing on the accuracy of the shoreline proxy (the dune toe) including the position and frequency of the frequency of the polyline notes. The error analysis looks realistic and is probably on the conservative side due to the addition of the errors.

[redacted]

Importantly there is consistency in the results and rates of shoreline change determined from the beach profile and aerial photograph analysis.

The sediment budget (input to system) calculation is very general, but probably the best that can be achieved with the information used (the NIWA 1998 report). The estimate of input of fine sand and sand from the Waimakiriri River provides a useful check on the rate of accretion derived from the beach profile and aerial photograph analysis as it is of the same order of magnitude.

The summary of current state of scientific knowledge and best practice guidance on sea level rise projections (section 2.4.1.1) is good.

To estimate the shoreline response to sea level rise T&T appropriately use: 1) for historical rate of sea level rise the slightly higher rates of 1.9 + 0.6 mm/year reported for Christchurch by Hannah and Bell (2012) and 2) a range of sea level rise values of 0.7, 1.0 and 1.3 m which conform to guidance provided within MfE (2008) and also take into account new model results presented in the IPCC 5th Assessment Report (AR5; IPCC, 2014) (note this is referenced as 2013 in the text and 2014 in the references). The adjustment of these values by deducting the historic rate of sea level rise (of 1.9 mm/year) is appropriate.

The beach response to sea level rise is calculated by applying the Bruun Rule. This geometric response model is now more than 60 years old, however in that time, and despite its limitations (listed in the T&T report), we have seen no simple model to replace it, and hence it's continued use. T&T quite rightly point out that the national guidance in the form of the Envirolink best practice guidelines for defining coastal hazard zones in New Zealand state that the Bruun Rule is applicable to open coast sandy beaches (like Pegasus Bay) and that it provides an acceptable "order of magnitude" estimate of shoreline retreat distance due to a rise in sea level (Ramsay et al. 2012).

The method of Hallermeier (1983) for calculating closure depth (the outer limit of where profile adjustment can keep up with sea level change), is another simple model of long standing use, which too has limitations. The result is sensitive to the choice of wave parameters, which in this case is minimised as good wave climate data (a 14 year buoy record) was available to feed into the calculations. The resulting closure depth of 8.5 m below MLWS sounds reasonable from my knowledge of closure depth statistics on from other New Zealand beaches.

I agree with T&T's reasons and choice to use the aerial photograph dataset over the beach profile dataset to define long term trends along the Pegasus Bay shore.

I agree with the key points of the discussion of results and the conclusions reached, in particular:

- The summary of net shoreline change allowing for both long-term accretion and retreat due to sea level rise (Table 2-9).
- That the existing CHZ do not accurately identify areas susceptible to coastal hazards along southern Pegasus Bay and that the historic rate of accretion will not continue to offset any potential retreat due to sea level rise.
- The remaining CHZ distance after adding the net shoreline movement ranges between 3 m at New Brighton to 55 m at South New Brighton, averaging 28 m for the entire shore.
- The recommended allowance for storm cut of 15 m and dune stability of 7 m (total 22 m) to account for short-term erosion effects.
- The existing CHZ at both New Brighton and Southshore do not have the required distance to mitigate the potential effects of coastal hazards over the next 100 years.

There are no places in this report where typos may result in a poor or potentially incorrect understanding of the science/technical matter being discussed. Very minor issues that could be corrected if other corrections are being made (see later) are:

[redacted]

- Figure 2-2 caption - (red dotted line) and (blue dashed line) should be pluralised to lines?
- Page 8 section 2.4.1.1 para 3 - IPCC 5th Assessment Report (AR5; IPCC, 2014) this is referenced as 2013 in the text and 2014 in the references.
- Table 2-9 notes #3 – potential is misspelt.
- Page 19, section 41, first sentence – the time span of the aerial photographic analysis is 73 years (cf. page 12, the data used were aerial photographs spanning 1941-2011 and a GPS survey dated 2014).

Lyttelton Harbour Coastal Inundation Hazard

CCC required T&T to make an assessment of areas susceptible to coastal inundation within Lyttelton Harbour including both passive inundation and storm tide inundation over a 100 year planning timeframe. Passive (bathtub) inundation is defined as MHWS including and allowance for sea level rise. This is used to identify areas of land potentially susceptible to flooding due to sea level rise over the 100 year planning time frame (i.e., likely to become intertidal and therefore flooded daily by the tide). The storm tide inundation level is used to define areas of land potentially susceptible to flooding during the 1% Annual Exceedance Probability (AEP) storm surge event over the 100 year planning timeframe. The storm tide inundation level is defined as the 1% AEP storm tide plus wave set-up plus an allowance for sea level rise. Inundation mapping was undertaken for six low lying settlements (i.e., Lyttelton, Rapaki, Alandale, Teddington, Charteris Bay and Purau).

The report provides a clear and concise description of the methodologies used. The methodologies used to determine passive inundation and storm tide inundation over a 100 year planning timeframe are appropriate for the following reasons:

- The terrain GRID derived from LiDAR survey data, astronomic tide data from Lyttelton Harbour and 1% AEP storm tide data from Goring et al. (2009) provide an excellent database for the modelling.
- The choice of CRESS methodology for wave height prediction was made following a comparison of three methods.
- Wave set-up is predicted using a method described in the Coastal Engineering Manual.
- The reasons for excluding consideration of offshore swells and wave run-up are consist with this environment and the purpose of this study.
- Wind effects are included and calculated following a comparison of the CIRIA and CRESS methods
- Sea level rise uses the 1.9 mm/year (local) value for Christchurch and the SLR of 1.0 m by 2115 a recommended in national guidance provided in the Envirolink report.

There could have been a brief description of the reason for choosing to model passive (bathtub) inundation as opposed to a dynamic inundation model, or at least some statement saying that passive inundation will provide a maximum worst case scenarios/prediction of the area flooded (cf. the dynamic inundation which takes into account losses due friction, infiltration and tidal time lag effects which slows water down as it floods the land).

The storm tide inundation level is used to define areas of land potentially susceptible to flooding during the 1% Annual Exceedance Probability (AEP) storm surge event over the 100 year planning timeframe.

The maps in Appendix D provide a clear picture of areas susceptible to passive inundation and storm tide inundation over a 100 year planning timeframe.

I agree with the key points of the discussion of results and the conclusions reached.

[redacted]

On page 16 of this report there are places where typos may result in a poor or potentially incorrect understanding of the science/technical matter being discussed:

- Section 3.1 para 2 line 3 - "susceptible to erosion due to sea level rise" should read "susceptible to flooding due to sea level rise"
- Section 3.2 – bullets 5 and 6 should be part of bullet 4

Coastal Hazard Assessment Stage Two

The T&T review of the existing coastal hazard zones as presented in the Canterbury Regional Coastal Environment Plan recommended re-assessing the existing CHZ because they do not adequately incorporate the potential effects of sea level rise as required under the New Zealand Coastal Policy Statement (NZCPS, 2010). The CHZ also needed to be re-assessed to consider the coastal erosion hazard (CEHZ) over a 50 year planning timeframe (2065). The coastal inundation hazard (CIHZ) needed to be assessed for the open coast to identify low lying areas of land with coastal inundation pathways. The extent of the study includes the coastal settlements located on non-consolidated sand or gravel shorelines within the Council jurisdictional boundaries.

There are a number of places in the stage two where typos and incorrect referencing of figures/tables may result in a poor or potentially incorrect understanding of the science/technical matters being discussed and should be corrected (I have also identified minor typos which can be corrected as the more important changes are being made).

Section by section review

Section 2 - Overall a thorough methodology is employed with verification of data supplied by ECan and discussion of errors. The descriptions of coastal processes and choice of parameters are well reported. The selection of parameters relating to the rate of sea level rise and the RCP 8.5 (business as usual) scenario parameters are consistent with best practice and recommendations of MFE guidelines (2008) and Bell (2013).

Section 2.1.1 bullet 2 – identify should read identifies?

Need to check throughout report that wave set-up and wave run-up are always hyphenated. See inconsistencies on p 3 and 4

Section 2.3.1. There is inconsistency in the text (para 1) and Table 2-3 as to whether the aerial photograph record runs from 1941 or 1942 and therefore whether the record covers a 70 or 69 year period. Also I wondered why the 2014 GPS shoreline (reported in stage one) was not used? (however this does effect the results as reported).

Section 2.3.2 Para 1 last sentence - Appendix C the DSAS results – does not show the beach profile positions.

Section 3 – No issues

Section 4 p.12 Section 4.1.1 para 3, and also see p.20 and Figure 4-5 - Why was the deep water wave height and period of 5 m and 9 seconds chosen? (presumably from the 14 years of ECan buoy data?)

Section 4.1.1 para 4 – good to see the CIHZ computed values were verified against field data

Section 4.1.2 – very good to see the probabilistic projects approach being used by T&T and as recommended by the Envirolink guide to good practice (Ramsay et al. 2013).

Section 4.1.3 – para 1 line 2 – delete the word "in"

Section 4.1.3 – para 2 – should also reference that the cell divisions are shown in Appendix C (the DSAS maps).

[redacted]

Section 4.1.4.2 – para 1 line 3 – 'storms events' should read 'storm events'

Good description of the statistical methods.

p.16 para 3rd from bottom of page, While this analysis … last sentence delete word each in '… for the C0848 each profile site'.

p.16 - last 4 lines of the page are all part of the same paragraph and need to be connected. Also both references to Table 4-2 should read Table 4-4

p.19 para 1 - Table 4-2 should read Table 4-3, and Table 4-3 should read Table 4-4

p.19 - SBEACH is an appropriate tool to use for short term erosion rate and a good check against the short term erosion rate derived from the beach profile data. I agree with the interpretation that the SBEACH results for the HAT tide level are considered as a minimum value for the short-term component lower bound

p.21 first para, first sentence – Clarify by addition of the underlined ……..Numerical storm cut distances of 8 to 10 m were found for the HAT tide contour and 4 to 5 m for the dune toe contour for the 2 x 100 year storm.

p.21 para 3 – Needs some clarification as I found myself struggling to locate the data in the tables. Can be done easily by 1) changing the -20 m value to -19.5 m which is the exact value in the table (rather than the rounded value) and referencing Table 4-4, and 2) the sentence beginning "The maximum 2 x 100 years storm …." should reference Table 4-5.

p.21 last para – all good points to make

p.22 last para – 73 years? or should it be 69 or 70 years? Reconcile with p.8 data

section 4.1.4.5 adopted sea level values – all good choices

section 4.1.5, first para - 1) Table 4-6 should read Table 4-10 2) Table 4-11 doesn't seem to be referenced anywhere and 3) the first sentence could be improved to clarify by adding the underlined bits to read ………. For each coastal cell, the relevant theoretical hazard parameter bounds influencing the CEHZ have been defined according to the methods described above and as summarised in Table 4-10.

Figure 4-9 – The x-axis name/legend on the panels top row 1 and 3 should be SF (m) not ST (m). It's the same for all the diagrams in Appendix G. Probably a good idea to add to the caption of Figure 4-9 an explanation of the definitions. Maybe add …….. "Refer to Figure 4-1 for explanation of axis legends" or words to that effect

Figure 4.1.8 and 4.1.9 - I agree with the points made here

Section 4.2 para 1, first sentence – replace has with have

Section 4.2 – I agree with the choices of methodology and the descriptions

p.35 - No mention of Appendix D before Appendix E is cited?

p.38 – The heading **Sea level rise** should read **Sea level rise (SL)** to be consistent with the other headings

p.39 para 2 – Table references wrong and sentence needs reordering to read ……… "The calculated retreat values due to sea level rise based on the equilibrium profile method are presented in Table 4-17 and 4-18 for the 2065 and 2115 timeframes respectively."

Section 4.2.2 and Harbour coast CEHZ - I agree with the choices of methodology and the descriptions

[redacted]

Section 5.1 para 4 – first mention of Appendix D?

Section 5 - I agree with the choices of methodology and the descriptions

Sections – 7 and 8 – Discussion and summary and conclusions – all OK

Executive summary – all OK

<u>Summary</u>

I agree with the methodologies used and the assumptions made. The CEHZ methodology used combines standard and well-tested approaches for defining coastal erosion hazard zones by addition of component parameters. T&T refined the method for the open coast to include parameter bounds which are combined by stochastic simulation. The resulting distribution is a probabilistic forecast of potential hazard zone width, rather than including single values for each component and one overall factor for uncertainty. This approach, along with incorporating the potential effects of sea level rise as required under the NZPS (2010), is consistent with recommendations in the best practice Envirolink Guidelines (Ramsay et al. 2012). T&T wisely developed and implemented separate methodologies to assess coastal hazards for the open coast and the harbour coast sites due to the different processes in the two coastal environments namely: 1) the harbour coast CEHZ methodologies combine two approaches to account for the low-lying morphology typical of these sites in accordance with best practice guidelines, 2) The CIHZ was mapped using the connected "bath-tub" method for sites located within both the Lyttelton and Akaroa Harbours and the open coast, and appropriately the dynamic model method for wide flat areas of Avon-Heathcote Estuary, Brooklands Lagoon and Sumner and 3) consultation with Council to define the $P_{66\%}$ CEHZ value at 2065 and the $P_{5\%}$ CEHZ value at 2115 as likely and potential CEHZ values. The mapping results are well reported and displayed. I agree the conclusions reached, including T&T's recommendations: 1) to regularly monitor the shoreline position and inundation levels across the region to provide measured data, and 2) that the adopted baselines and both the CEHZ and CIHZ values are reassessed at least every 10 years or following significant changes in either legislation or best practice and technical guidance

Dr Terry M. Hume

Director

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