Site-specific erosion hazard shoreline prediction for the Waikanae Estuary in the vicinity of the Kotuku Parks Ltd subdivision

A report prepared for the Kapiti Coast District Council

By Dr Roger D Shand

Following the October 2013 local body election, the Kapiti Coast Residents Group (CRU) dominated the council and had the words "This report cannot be relied upon" printed on CSL hazard assessments. This was baseless, motivated by self interest, and legally liable. CSL reports have always used current best practice, are peer reviewed and fit for purpose.

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1.0 BACKGROUND

The following site-specific shoreline prediction assessment was co-operatively carried out by Kapiti Coast District Council consultant Dr Roger Shand of Coastal Systems Ltd and the Kotuku Parks Ltd coastal consultant, Mr Angus Gordon, following receipt by the KCDC in March 2013 of Mr Gordon's report (2 April, 2013) which formed part of the Kotuku Parks Ltd (subdivision developers) submission for the District Plan review. This site-specific assessment uses the basic inlet assessment methodology of CSL 2008 and 2012, albeit more refined and coupled with some additional data. As with all the CSL assessments, it is carried out at the "potential" level for at least 100 yrs as required by the NZCPS 2010 (Policy 24) and as is applicable to a subdivision (Policy 25). Note that if an existing development had been involved, then the implementator's would need to convert the assessment's potential shoreline location predictions to "likely" predictions (Policy 27).

Dr Shand provided Mr Gordon with a draft response on 18th November, 2013. Email correspondences in late November are included as Appendix A. A meeting occurred on 6 December at the KCDC offices in Paraparaumu to establish final aspects of the site-specific approach and this set out in document, the outcome of which is acceptable to both consultants.

2.0 LONG-TERM SHORELINE CHANGE (LT)

Mr Gordon considered the use of a long-term shoreline change value of zero was reasonable (p20), but raised the possibility of future inlet infill associated with past management make this value conservative. New data presented in Figure 1, coupled with the regression analysis results in Table 1, show one (K_3) of the three transects fronting the Kotuku Parks site to have a statistically significant slope (high F-ratio). Given that this is in the vicinity of K_nth which is a significant positive slope associated with rivermouth change, the conservative approach is to assign a value of zero to the entire site shoreline. However, I accept Mr Gordon's systematic infill argument, and site inspection shows that the K_sth vegetation line may undergo a seaward excursion in the relatively near future. At a future (10 yr) review a seaward adjustment in the prediction shoreline may be warranted, but for now the apparent processes allow for the prudence required in an assessment.

3.0 INLET MIGRATION CURVE (IMC)

The reference shoreline for the inlet model is the inlet migration curve (IMC) rather than the current shoreline. When I originally located the IMC for the 2008 and 2012 Waikanae Inlet assessments, I smoothed along the landward extremes of the shoreline envelop (as the method allows). However, as part of the site-specific assessment, I have examined in much greater detail the shoreline history and in particular the large cross-shore

Table 1 Linear regression analysis output for the five shoreline time-series shown in Figure 1. The F-ratios and corresponding probabilities relate to whether the slopes are statistically significant, and the standard error of estimate is a measure of dispersion about the mean (regression model).

Transect (Fig 1)	Slope	F-ratio	p	SEE
K_STH	0.304	21.78	0.009	4.9
K_1	0.689	2.80	0.123	53.1
K_2	0.230	0.51	0.512	42.8
K_3	0.996	30.90	0.002	23.0
K_NTH	1.777	38.90	0.001	36.7

undulations contained within the shoreline envelop to the north of, and in the front centre, of Kotuku Park (see Figure 16 in CSL 2008, Part 2). I now consider these represent systematic variation as the inlet system adjusted to rivermouth modification rather than random channel migration. So in this case the landward envelop margin (i.e. the *landwardmost composite shoreline* in Fig 4.2, CSL 2012) can be taken to be the IMC. This results in the final plotted shoreline prediction lines being relocated further seaward in these areas for both scenarios in these areas.

4.0 RESPONSE TO SEA-LEVEL RISE (RSLR)

4.1 Introduction

Mr Gordons emailed comment on 24 November 2013 (Appendix A) to my draft response (18 November 2013), was that the "remaining area of major disagreement was in regard to conceptual modelling of the SLR response of the Waikanae Inlet". In Mr Gordon's subsequent email on 26 November 2013 (Appendix A) he noted that he was "not aware of any specific work that assists in resolving this situation" and he raised the possibility using local data. At our meeting on 6th December we discussed the use of available site profile data I had sourced, included was a new survey Mr Gordon had had his client commission (from Cardino). I subsequently carried out a slope analysis and associated profile translations, and these are now described.

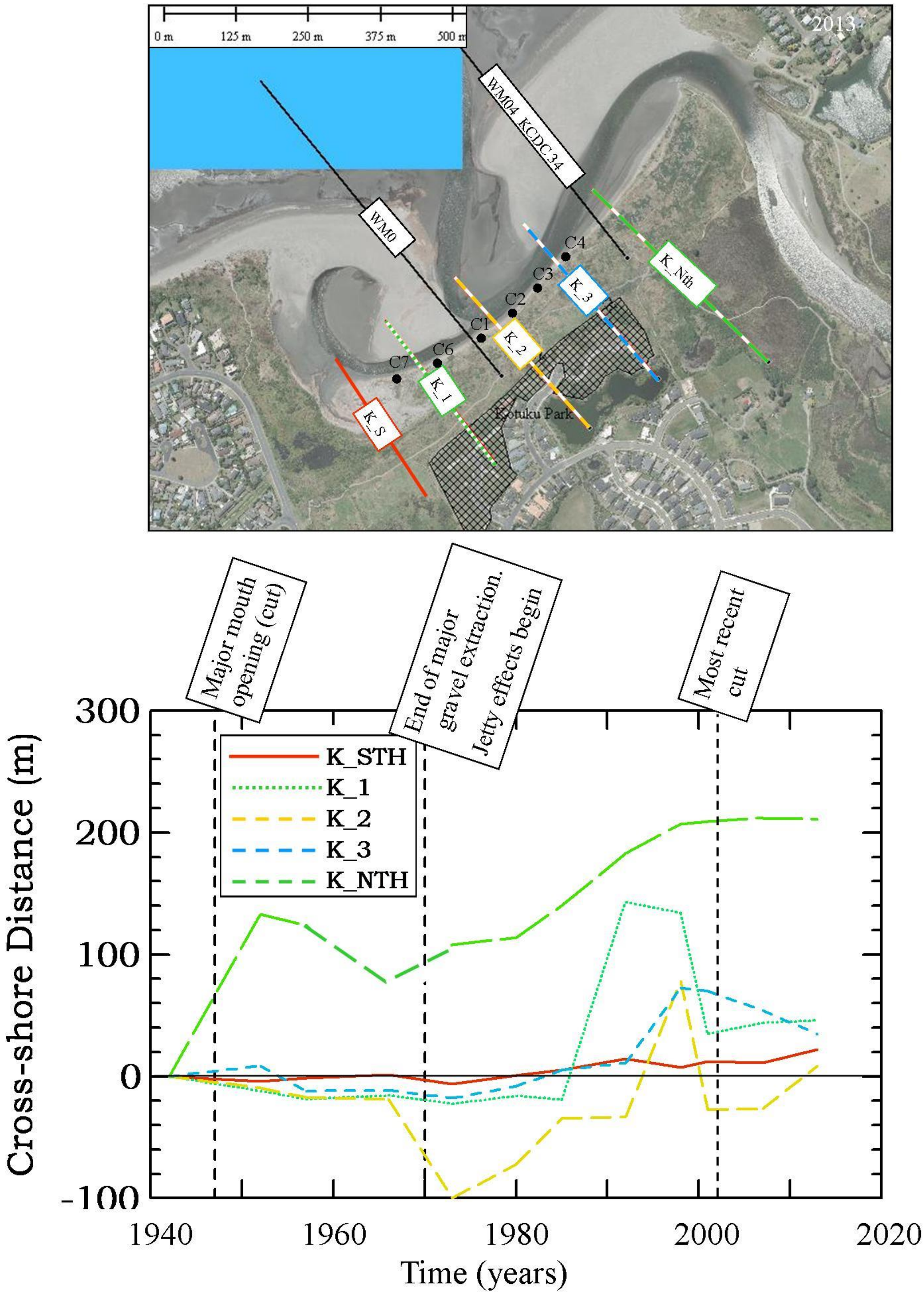

Figure 1 Waikanae Estuary shoreline time-series graphs for K-series transects as located on aerial photo. Time lines for 1947, 1970, 2001 demark potentially significant management practices for shoreline behaviour. K_Nth is in the vicinity of the 19th century rivermouth so early steepness relates to systematic infill while the later increase reflects systematic adjustment to the rivermouth groyne. An increase in sediment supply occurred during the late 1980s/early 1990s (evident in aerial photos) and this is reflected in seaward shoreline migration on most transect shorelines. The landward fluctuations for Transect K_2 result from scour associated with the outlet channel frequenting this location making the shoreline more erosion-prone by riverflow and also high tide storm-wave attack. The southernmost transect shoreline has remained relatively stable throughout the record. Since the last mouth cut in late 2001, all shorelines have been relatively stable.
Profile data referred to in the text is from the following transect locations: C1 to C6 are by Cardno, WM03 and WM04 are for GRWC transects and KCDC 34 are for Kaptiti Coast District Council.

4.2 Indicator slope

The mean slope between MSL and +1 m was used as the sea-level rise translation slope, as 1 m RL is the typically observed high tide, and the MSL inclusion in expected to coincide with some marine influence. Samples that did not intersect MSL in the vicinity of the vegetation-front typically had a shallow channel and then a sand bar separating the shore from the MSL. This added some 200 to 300 m to the horizontal distances, the slope calculation reduces considerably and this was unrealistic in terms of the expected inlet shoreline response to SLR.

4.3 Data sources (see Figure 1 for locations)

1) GWRC Profiles WM03 and WM04
Sampled 10 and 9 times respectively between Nov 2001 - Jan 2005

2) KCDC Profile 34 (same transects as WM 04)
Sampled June 2000, Nov 2005, Aug 2008, June 2011 and Jul 2013

3) Angus Gordon site visit April 2013
Direct measurement of upper beach (above MSL)

4) Kotuku Parks (Cardno) Dec 2013
6 profiles sites along eastern shore

4.4 Results

Mean slope computations are given in terms of Tan β, and
RSLR is for horizontal response of profile translation for SLR = 0.9 m

i) Profile WM03
Only 3 samples (27%) intersected MSL and limited temporal cover (4 yrs)

Mean slope = 0.11
RSLR = 8.2 m

ii) Profile WM04/KCDC34
All samples (n = 14) intersected MSL, and this data-set had longest temporal cover (13 yrs). To avoid over sampling the WM04 subset (2001 to 2004), the KCDC34 samples were used together with only two additional samples from WM04 (March 2002 and June 2003). This provided a uniform temporal coverage.

Mean slope 0.037 (0.024 to 0.07)
RSLR = 24.3 m (37.5 to 12.9 m)

iii) Angus Gordon slope measurements
Single temporal sampling, approx location of upper beach

Mean slope = 0.07 to 0.105 (4 to 6 degrees)
RSLR = 12.9 m to 8.6 m

iv) Kotuku Parks (Cardno)
Single temporal sampling. Only the four northern sites (C1 to C4 in Figure 1) intersected MSL

Mean slopes = 0.105 (0.08 to 0.127)
RSLR = 8.6 m (11.3 m to 7.1 m)

4.5 Conclusion

Slope and profile translation based on the WM04/KCDC34 data for the 100 yr shoreline prediction were used for the erosion prediction computation as these data had been collected over the longest period and provided the best MSL to +1m coverage. This RSLR output was also the most conservative, albeit still 60% less than the adjacent open coast value.

5.0 DUNE STABILITY ADJUSTMENT (DS)

Mr Gordon was satisfied (p20) that the dune stability (DS) model I had originally used would suffice and this has been reapplied for the revised shoreline predictions at 50 m intervals alongshore. The eastern shoreline and adjacent ground back to the Kotuku Park boundary comprises sand dunes ranging in height from 1.5 to 5 m (above MSL). As the revised shoreline prediction distances are less than the original 2008/2012 values, i.e. the resulting line is somewhat seaward where the dune heights are often less, the DS values are lower by some 1 to 2 m.

6.0 COMBINED UNCERTAINTY (CU)

At p 20 Mr Gordon also notes that the CU value should be reduced by the LT error (7.4 m for 100 yrs) as the actual LT value is zero. However, CU is a measurement error term and applies even if the value is zero as in this case. However, it is noted that even if removed in its entirety the CU value is reduced by 3.6 m not 7.4 m due to the dependency-based method of error term combination.

7.0 INLET EROSION PREDICTION LINE (IEPL)

The site-specific and initial generic inlet erosion prediction lines (IEPLs) fronting the Kotuku Parks subdivision are shown in Figure 2. Both the managed and unmanaged lines are now seaward of the Kotuku Parks boundary by about 40 m with the managed line adjustment increasing up to about 65 m in the northern sector.

Given the typically low lying nature of inlet surrounds (as low as 1.5 m RL in isolated places fronting the south Kotuku Parks subdivision) we must be particularly mindful of potential susceptibility to inundation and erosive processes under climate change predictions. However, Mr Gordon has provided substantial evidence based on his extensive experience of Australian inlets not unlike the Waikanae (Appendix A), that the

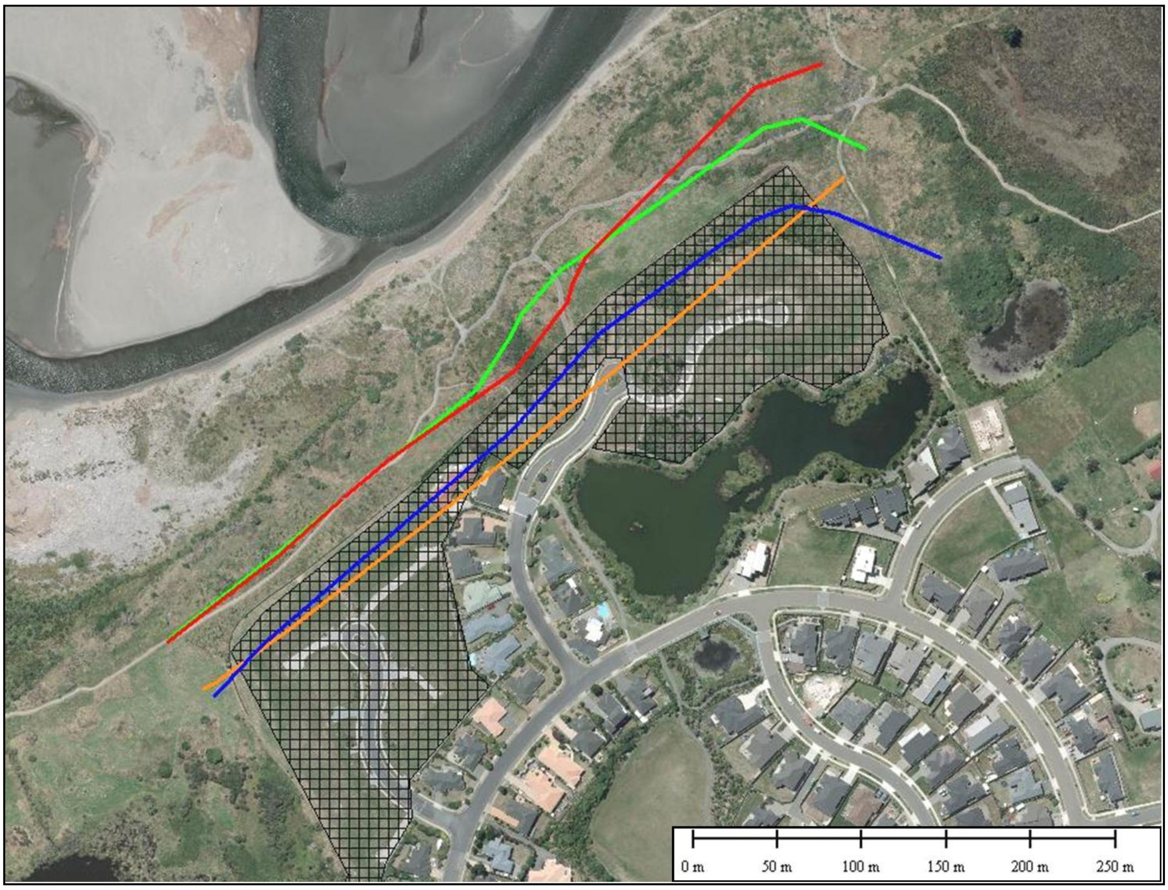

Figure 2 Revised 100 yr erosion prediction lines based on this site-specific assessment: Red = managed inlet, Green = unmanaged inlet. For comparison the 100 yr IEPLs from the 2012 generic assessment are shown in orange for the managed and blue for the unmanaged scenario.

particular characterisitics of this managed inlet will potentially counter low lying vulnerability. I accept the tenor of his testimony and hence submit the revised IEPLs fronting the Kotuku Parks subdivision.

8.0 GENERAL APPLICATION

There is potential for more general use of a co-efficient-based multiple of the adjacent open coast RSLR at inlets where inlet profile data is invariably not available, and where background dune heights exceed some pre-determined minimum and/or appropriate (jetty/guide wall) control structures occur.

APPENDIX A
Written correspondences between Roger Shand and Angus Gordon between 24 November 2013 and 27 November, 2013

On 27 Nov 2013, at 7:59 pm, Roger Shand wrote:
Hi Angus, I appreciate your comments regarding possible futures for the Waikanae estuary/mouth... as you say, they are favourable possibilities (insurance).
Regarding coming up with a rational and robust method for determining shoreline response to SLR using local Waikanae estuary data. I have now sourced some profile data for the estuary that the Regional Council collected several yrs ago. There is also LIDAR for the area and in places between the Kotuku embankment and the present shoreline the surface is pretty low lying ...1 to 2 m RL I recall. So that will need to be considered when developing a profile-based solution.

Such a Waikanae Beach/estuary profile analysis constitutes a site-specific approach, but it may still be useful in refining the general method I have used (i.e. using the open coast profile translation for the inlets), i.e. perhaps that can be related to its adjacent open coast profiles. My understanding is that there is only open coast profile data available for the other inlets.

Once I have the Kotuku surveyors estuary data, coupled with the council estuary data, I will define slopes, run profile translations and get back to you.
Roger

On 26 November 2013 at 08:06:53 Angus Gordon <sandgus@optusnet.com.au> wrote

Hi Roger
I will briefly elaborate on my interpretation of the behaviour of Waikanae Inlet and indicate a possible way forward, but please note that I am using a great deal of your own data, observations and interpretations so please don't think I am plagiarising your own work, rather I am simply reiterating it and then extending a possible way forward.

I am working from your 2008 Inlet Report and your 2012 Update Report. For my own convenience I am labelling the area "outside" the river mouth, but before the "open" coast the "estuary" and the area inside the river mouth the "river" because I find the term "Inlet", while technically correct, a bit inconvenient.

Your data and explanation clearly show that the size of the estuary is very much a function of how far the littoral drift spit on the northern side can "wander" southward before it is breached. I fully agree with this and it has certainly been my experience that this is the case with other unconstrained, or partially constrained river mouths/lagoons/estuaries. You point to the northerly relocation of the river mouth in the 19th century and that this had some understandable impact on generally reducing the limits of southern migration. You also note that mechanical intervention in the 1940s, possibly along with some other influences resulted in a substantial infill of the southern portion of the estuary which in turn created "new land" that was subsequently subdivided (Manly Street area). Since that time the river mouth was stabilised with what I will refer to as the Southern Training Wall (a term often used by engineers in regard to this type of structure that is not really a groyne, nor a breakwater). Further, an entrance "breakout" of the spit regime has been implemented as a mechanical intervention to both improve navigation (a bit tricky from my observations), to relieve flooding and to stop the entrance migrating too far.

Based on your data it would appear that, as a result of the training wall and the mechanical intervention the southern area of the estuary is continuing to accrete in the southern area, albeit at a far slower rate than the earlier "significant step" the data shows that created the Manly Street area. However, from time to time the estuary entrance to the sea still migrates a reasonable distance south and, depending on its location, exposes parts of the eastern shore (in the Kotuku area) to some of the impacts of the sea (albeit modified). Further the shoreline is also sculptured by the natural meander of the estuary as it heads south from the training wall before it turns at right angles to achieve its ocean mouth.

I believe that to this point we are in agreement. By this I am not suggesting that what I say next necessarily means we will be in disagreement but rather represents my thoughts on the possible, and I use the word "possible" future trend might be for the overall estuary.

The first thing is that if climate change brings more intense and/or regular rainfall (as seems to be predicted, and demonstrated as a criteria by the fact my engineering colleagues are being required to design their bridges to cope with significantly increased flow events) then, based on the current performance of the estuary and the river it could reasonably be expected that breakout through the spit (both mechanical and natural) will be more regular. The more regular, the less distance the estuary mouth has the opportunity to migrate between breakouts and hence the greater the infilling of the southern area of the estuary. To what degree? well clearly from past evidence this will depend on the frequency of breakouts. This has certainly been my experience with estuaries in both Australia and in other parts overseas where I have been involved in projects that included estuaries/lagoons/rivers/creeks.

Ultimately of course, if the southern training wall were extended to the open coast beach alignment, or the mechanical intervention rate significantly limited any meandering, the ability for the estuary to exist at all would be compromised and it would likely totally infill. How do I conclude this? Well, over many years I have studied the impacts of breakwater construction on adjacent shorelines. One project I had in the 1980s was to review the condition of all the breakwaters in NSW and to document their history including how, how much, and when the shorelines changed. The report was published in several large volumes! What this showed, and in many cases going back to the construction records, was that the shore parallel ebb and flood flows along the coast from the untrained entrances were cut off, and made shore normal, as the training walls/or breakwaters reached the general coastal alignment. Within a very short period of time the downdrift beach/estuary infilled and the shoreline followed the breakwater construction offshore.

Now if I can turn to the future. As ocean beach shoreline recession progresses as is expected under a rising seal-level, the training wall progressively becomes a more dominant feature, modifying the flows that currently sustain the dynamics of the estuary until eventually the end of the training wall penetrates the spit and the estuary totally infills as has been evidenced by the processes outlined above.

While all of this may take a long time the purpose of my discussion on the topic is to point out the potential implications of coastal recession on the estuary area. Obviously, greater intervention with mechanical breakouts and/or extension of the southern training wall will speed up the process. So strangely, long term coastal recession combined with changes in rainfall may well result in estuary infill and the estuary shoreline actually accreting somewhat. Please understand that I am not arguing that this is definitely "on the cards" within the proposed planning period but rather using experience from elsewhere where the hydrodynamic mechanisms are similar to seek to understand potential, overall future trends.

I agree with you that the very real difficult facing us right now is to come up with a rational and robust method for evaluating the likely changes at the Kotuku shoreline as a result of relative sea level rise. I am not aware of any specific work that assists us in resolving this dilemma. However, as I previously indicated, the assumption of recession based on a (open coast) wave created equilibrium profile that translates shoreward, is, in my opinion, likely to lead to an overestimation, all other things being equal. It is also my view that the bed of the estuary is likely to rise as sea level rises due to the dynamics of the estuary and its relation to the longshore drift supply. Hence, all other things being equal, and for the time being forgetting my arguments above, I would expect that for the immediate future the channel conveyancing of the estuary would remain similar to that of today. This is based on the fact that the depth of such estuary channels is determined by flow velocities of the tide and river and as long as there is sufficient sediment to allow infill to occur. Hence the relationship of the estuary characteristics should remain similar (recognising of course the dynamic nature of estuary characteristics from time to time due to variability of flows and sediment availability).

Regardless of my concerns that the direct application of open coast, wave induced equilibrium profile will produce an overestimate of recession, at this point of the discussion lets just say that the predicted recession by this approach represents an upper bound. The lower bound is of course obtained by the assumption that the shoreline of the estuary will behave the same as a river bank where there is no wave action. That is, apart from some minor localised slope adjustment a sea level rise of ,say, 1 metre will be simply reflected in the intersection of the new water level with the existing slope of the bank. I am of the opinion that the response at Kotuku will be somewhere between these two extremes.

To this end, and to assist both of us in further discussions I have requested that my client survey a number of cross-sections so we can look at the actual profile from the shoreline up to the property boundaries. I was advised yesterday afternoon that the surveyors have undertaken the work and are reducing their results. These profiles should be of assistance in applying either extreme.

It remains difficult to determine where between the extremes the actual response will be. As I previously indicated I feel that the “active" beach width provides an indication of the energy conditions and hence, a basis for determining what the actual response might be (sheltered areas of open coast beaches are narrower than exposed areas). So I would propose that we explore this approach further as being a way to “scale” the likely shoreline response at Kotuku. In saying this I recognise that my proposed methodology is not necessarily precise and hence it would be wise to take a conservative approach.

Thanks for your patience with this rather lengthy email. I hope it is of assistance as I do believe we can develop a methodology for examining the Waikanae inlet situation.

Kind regards
Angus Gordon

On 25 Nov 2013, at 9:35 am, Roger Shand <rshand@coastalsystems.co.nz> wrote:

Hi Angus,
Very helpful feedback.
I will have another look at my report and get back to you.
Regarding inlet shoreline response, what specific approach based on available data would you suggest for the Waikanae?

Roger Shand

On 24th November Angus Gordon wrote:

Hi Roger
Thanks for forwarding a copy of your review of my submission. I note that we are generally in agreement on most matters and in particular on the way forward. Over the many years I have been involved in the application of coastal zone management I have become increasingly concerned when coastal studies, such as yours that scope out the issues, are then applied by authorities, such as councils, to peoples properties when it is clear that more work is required before adversely impacting on communities. As the CEO of a council located on the coast I made considerable effort to advise people of potential risks but to not encumber property until we had a reasonable understanding of the likely impacts. The key words being "reasonable understanding" and "likely impacts".

Now to comment on your comments, where we do have some differences of opinion.

On re-reading my report I don't think I explained my thoughts and experience with slope slumping particularly well and hence accept your criticism. I happen to disagree with Lex Nielsen (a colleague of many years) as I think his approach, while theoretically neat, does not reflect what actually happens. My experience is that a near vertical erosion scarp can stand for a long time. Infill at the base can happen quite quickly after an erosion event due to beach recovery. This is then followed by incipient fore dune building. While there may be some slumping, depending on a number of factors, the actual height of the escarpment is reduced before this occurs. In some cases where there is good vegetative binding at the crest, a semi-slumped escarpment can persist for many years (I can still detect the remnants of some dune escarpments from the 1974 storms, at some locations). So, dune slumping is very dependent on a number of factors and is very site specific.

In regard to Bruun and Komar (translating the inter-tidal slope), both are dependent on the concepts of equilibrium profiles for wave dominated beaches. That is, open coast and no littoral drift. On the open coast at Kapiti, if we accept littoral drift, the rate of drift also contributes to the profile shape and hence both approaches will tend to overestimate erosion due to sea level rise as eroded material will be replaced through littoral drift (obviously the rates of both processes will determine the actual response). Both Bruun and Komar approaches have been increasingly criticised as being applicable to longshore drift coasts. Uni of NSW recently undertook a study for Geosciences Australia demonstrating the difference between shoreline movements for open and closed embayments (I had a small sub-consultancy on the project).

I am of the strong opinion that neither approach can be applied to the type of estuary shoreline in Waikanae Inlet as, not only is there longshore drift but also the "equilibrium profile" concept, without even longshore drift, is an inapplicable concept due to the immediate "offshore" region being an active estuary bed that provides considerable modification to any waves. Also I note that a key indicator of the energy being experienced by a coastline is in terms of its beach width and that the "beach" inside the Waikanae inlet is approximately a third of that of the adjacent open coast. You note that MfE (2008) suggests that rising sea levels will result in deeper water and hence larger waves, while this is true in some circumstances, an understanding of Bruun and Komar indicates that the profile simply moves shoreward and hence the wave height at the beach remains the same. Clearly in a situation such as Waikanae the approach is doubly flawed. As sea level rises the dynamic nature of the coastal system of the inlet will result in a rising bed level, to do anything else implies a change in the overall inlet dynamic processes and of the nearby coast. That is why other researches have noted increased erosion of adjacent open coast beaches, the sand flows in to offset the attempted changed water depths.

So, in summary, my major disagreement is in regard to your conceptual modelling of the reaction of Waikanane inlet. I am of the opinion that there is sufficient information, historical and present, to have a better understanding of the 3D response of the inlet over time and, based on experience elsewhere, a reasonable basis for projecting that conceptual model forward.

Finally I note that throughout your review you indicate that for a number of the matters I raised you feel that you needed to take a conservative approach based on the material available, but would appreciate further input from colleagues in regard to what might otherwise be applied. I fully support you in this and will encourage others to do likewise. Given the unknowns and uncertainties, I believe it is essential that a peer group provide guidance to what they consider is the best way to deal with situations such as at Kapiti and in particular provide council with a way forward that will appropriately risk manage the Kapiti coast.

Again, I reiterate my comments in my earlier report that I consider your work an very good and useful "scoping study" that clearly identifies what the issues are that require further examination.

By the way, and not being pedantic, I did have some trouble interpreting your figure 2 as it seemed to me the lines were the wrong way around but this could just be a feature of the transmission by email where all lines seem to be of the same colour. Further, on pp17 parr1 line 6 the word "unusually" seemed out of place, I assume you meant "usually".

Thanks again for forwarding your review to me.

Kind Regards

Angus Gordon