Assessment of the Kapiti Coast Erosion Hazard Assessment Report 2008 and 2012 Update by Dr Roger Shand

Kotuku Park Ltd

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Shaping the Future

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Summary

The coast is a dynamic zone where shorelines have historically responded to natural coastal processes of erosion, accretion and storm wave attack. Yet, the coast is also the place where many people want to live, holiday and/or enjoy the environment.

At the very time governments are facing greater competing interests for ever decreasing available funds, there are increasing demands on all levels of government to allow coastal development, and to put in place coastal management of both private and public assets. To complicate matters there is the issue of climate change and its associated sea level rise, increases in storminess and in rainfall intensity and runoff. The result is that there is a growing need for detailed scientific information on coastal behaviour and the development of the tools necessary to enable informed management decisions. And this is at a time when the available funds for such work are a scarce resource.

Present day coastal studies are now typically only funded to the extent of less than of the value of one house and yet the findings of such studies may have adverse impacts on thousands of houses, the council rate bases and millions of dollars of public infrastructure, not to mention the economic impact on local businesses. Because of the lack of the funds necessary to undertake comprehensive studies, and time constraints imposed for councils to have Coastal Zone Management Plans in place, consultants often have no option but to adopt a generic, non site specific approach. However, because of the paucity of data and information such an approach must necessarily result in conservative answers. In some cases such conservatism can produce reasonable results however where there are high value properties or infrastructure or where the shoreline configuration is not a good fit to the assumptions contained in the generic approach, it is essential that future management decisions are based on a more detailed site specific assessment.

Kapiti Coast District Council (KCDC) engaged Coastal Systems (CS) to re-assess the existing information they had on the erosion hazard along 38km of the open coastal region administered by KCDC, to enable the KCDC to refine its coastal management strategies. The first report, in three sections was completed in 2008 (Shand, 2008) with a follow-up “Update” report in 2012 (Shand, 2012). The “Update” report included further information on sea level rise, the requirements of the second version of the Government’s Coastal Hazard and Climate Change Guidance Manual (2008), the New Zealand Coastal Policy Statement of 2010 and additional information available since 2008 regarding coastal behaviour in the Kapiti region.

It should be noted that the analyses that were undertaken were to determine where shorelines might be in 50 and 100 years with, and without, maintaining the traditional shoreline management structures. This is the lead-in to decisions on what shoreline management/asset planning measures will be implemented. While this is a separate exercise it is likely to have an impact on

the actual evolution of the shoreline and the management of the potentially threatened assets.

CS's Dr Shand clearly makes the point, in both the 2008 and 2012 reports that the generic approach adopted in CS's studies was "due to the extensive spatial coverage coupled with available time and funding" and that this inevitably led to some apparently inconsistent results, over-estimation of results and conservative assumptions. Dr Shand responsibly, and transparently, details the limitations and constraints throughout the reports (2008 and 2012). Significantly he also indicates that some refinement of his results can be achieved "using more localised site-specific assessments as these are carried out with greater detail".

The limitations of the conservative approach Dr Shand took because of lack of detailed information can be appreciated by examination of the assessment of future shoreline movements. For example, in some locations the historical evidence showed long-term shoreline accretion was occurring, however Dr Shand believed that due to the paucity of information he should assume that no such accretion would continue into the future. This was regardless of the fact that the historical evidence showed accretion had occurred during a period of available data when the region experienced a relative sea level (RSL) rise of between 1.7mm to 2mm per year, and hence significant erosion should have occurred over the past 100 years if there were not a mechanism of sediment feed to the coast. Dr Shand did recognise that the rivers and streams are present-day, and have historically been, contributing sediment to the coast however he felt it was necessary to make the assumption that this factor would not be included in the analysis due to the lack of information on the historical quantities and trends.

The assumption that historical accretional trends and sediment feed from the rivers and streams would not continue is noted in the reports as being a precautionary approach stemming from the lack of scientific information on the overall coastal processes of the region. Dr Shand has also pointed to the need to adopt a precautionary approach because of the difficulties of assessing the potential location of the 100 year hazard line due to the limited data, and the reliance on the IPCC acceleration projections (Shand, pers. comm.).

Hence the studies have been significantly constrained by the available information on the coastal process systems of the region, the likely RSL change (rather than the absolute, global, sea level rise projections) and the lack of information on other factors such as change in wave energy flux, and sediment sources and sinks for the sediment budget of the coast. The results of the studies must be viewed in this context.

Dr Shand's reports can be seen as providing very useful scoping information which points out the areas where further work is required before potential 50 and 100 year future shoreline positions can be projected. Given the conservative approach adopted, had Dr Shand's studies shown that no assets were threatened in the next 100 years, then the work would have been sufficient for Council's purposes. However, since the studies indicate potential impact on so many private and public assets, along with significant economic ramifications for Council, the community and businesses, a far more detailed analysis is warranted. Dr Shand kindly made himself available to openly and professionally discuss, and clarify detail, and to answer questions on the information contained within the reports. For this he is thanked.

The purpose of this submission is to highlight, apart from the overall limitations of the studies thus far, the unusual situation at the Waikanae Inlet, as detailed by Dr Shand. Also to point out that there appears to be an inconsistency between the calculated parameters for the eastern shore, and the actual plan locations of the 50 and 100 year hazard lines on the diagrams in the report.

It is believed there is a need for both a re-assessment of the transposition of the erosion hazard distances onto the plans/diagrams, and a detailed site-specific analysis of the factors effecting the set back distances on the eastern shore of the inlet, landward of which the Kotuku Park development is situated.

In short, it is felt that a further examination of the line positions, and a refinement of the calculations for the eastern shore region is likely to result in a seaward shift of the 50 and 100m projected IEPLs which would remove the current impediment imposed on the properties in the Kotuku development by the 100 year IEPL. The most seaward boundary of the most seaward allotments in the Kotuku enjoy a setback of over 400 m from the overall coastal alignment, between 100m and 150m from the current estuary shoreline and approximately 80 to 100m from the current estuary shoreline vegetation. Further, they are at an elevation of between 3 m and 4 m. Hence there is a significant buffer between the allotments and the estuary foreshore. Further the allotments are at a sufficient level to accommodate the projected sea level rise and other factors, given their relatively sheltered location.

1.0 Background Comment

Over the past few decades Governments, both in New Zealand and other countries such as Australia, have been progressively reducing their expenditures on coastal research and studies that provide important fundamental natural process information for investigation of current and future coastal hazards and built and natural asset management. At the same time governments have also reduced their investment in the necessary coastal data collection required to reasonably undertake those studies. While this has produced short-term savings it reflects a lack of understanding of the risk management consequences and costs to the overall society.

At the same time local Councils are being increasingly burdened with the responsibility to risk manage their coasts, without the resources, including additional funds, to do so. This places Councils in an unenviable position of having to adopt a precautionary approach by imposing conservative planning strictures on their communities without really being able to meaningfully assess the benefits and costs, social, environmental and economic, of their decisions. It can also place the Council body in conflict with its community.

Priorities for expenditure of limited ratepayer funds, and the many competing demands, provide a challenge for both the community and all levels of government. This challenge includes whether it is reasonable, and productive, to manage a coastal region based on studies where the funding available is a fraction of the value of a single property, when the adverse impacts affect thousands of properties and millions of dollars of public and private assets. That is, is it reasonable for the economic wellbeing of coastal communities to be determined by such low investment in hazard risk management?

A matter often overlooked by coastal managers is that if property is simply "zoned" as being potentially hazard affected it can decrease in value, thereby reducing the rates base and hence the ability to manage the future of that coast, including general infrastructure (roads, water, sewerage etc). If on the other hand a potential hazard is recognised and actively, appropriately managed, then property values and hence public rate based funds can be sustained. Further, if an active management option is to be adopted there is argument for consideration of some level of intensification in order to generate the funds required for on-going management of any intervention option. This may seem counter intuitive but, carefully thought through and with the appropriate use of building types and infrastructure, intensification can be achieved without necessarily increasing the value of asset potentially at risk.

The following assessment of the work by Dr Shand should not be seen as a criticism of the studies and reports rather it is intended to highlight the challenges faced by Dr Shand when working with limited funds and information on what is clearly a complex coastal system. It is noted that Dr Shand has responsibly, and transparently, chronicled the limitations of the available information, the process understanding and the conservative nature of the assumptions that were necessary to undertake the project.

2.0 The Kapiti Coast Erosion Assessment

2.1 Introduction

The coastal dynamics of the Kapiti coast are clearly complex. Kapiti Island has, and is continuing to act, like a large, natural, offshore breakwater. The shoreline in the vicinity of Paraparaumu (the "Foreshore") is typical of the incipient tombolo formation that could be expected to form behind such a breakwater. That is, the Island plays an important role in determining the overall coastal alignment, its vulnerability to change and the sediment (beach and near shore) system of the region.

Given the history of erosion threat to some properties, the overall value of the properties fronting the shoreline, the rating income from those properties, the public infrastructure involved, the commercial economic significance of the centres and the extent of ribbon coastal development, the future behaviour of this shoreline requires a detailed approach to investigation of future shoreline behaviour. This includes modelling of scenarios (with sensitivity testing) for littoral drift, sediment feed and future changes in sea level, wave climate and sediment supply to the coast.

The role that Kapiti Island plays should not be underestimated. This applies to both present and future coastal alignments and the sediment movements within the region.

Further, the behaviour of the inlet entrances also requires a detailed assessment of their past and likely future behaviour. In considering their future behaviour, particular attention needs to be given to scenarios of projected future increases in rainfall intensity and hence more regular and energetic breaching of the entrance bars/spits, and the impacts of future relative sea level rise/fall at the coast on stream energy slopes/tailwater conditions. It is vital to investigate the issue of a projected increased sediment delivery to the coast as this is/will be a key component of the coastal sediment budget and hence the future shoreline behaviour. The uncertainty as to rainfall intensity projections should be no impediment to sensitivity testing of a range of conceivable projections.

The Kapiti Coast Erosion Hazard Assessment 2008 and the 2012 Update prepared by Dr Roger Shand of Coastal Systems followed the New Zealand Coastal Guidance Manual (2008) and the dictates of the Government Coastal Policy Statement 2010. To Dr Shand's credit he has, in many places throughout his reports, pointed to the problems and the suboptimal results the approach produces for complex areas such as the Kapiti coast. In particular Dr Shand points to the "generic" rather than specific nature of his investigations due to the lack of time and funds to properly investigate issues, the fact that some of the key processes are not "fully understood", the "erratic" nature of some results, the need for further "detailed assessment", some hazard distances in his report being "overly cautious", the "regional nature" of the study as against the need for a more "site specific approach" with more detail, and so on and so on.

Dr Shand also makes reference to the uncertainty as to what climate change may bring. He indicates that the actual sea level rise that has occurred over the last few decades is well below that predicted, and further that there is uncertainty as to whether climate change may indeed increase sediment supply to the coast resulting in reduced erosion than predicted by the generic model, or even shoreline accretion. Further, questions need to be asked as to whether the sea level rise model he has used to project possible future shoreline recession is valid on a littoral drift coast.

It must be recognised that, particularly in regions that have extensively developed shorelines, potential shoreline trends are the end product of a detailed coastal sediment budget assessment. Decisions that impact on future coastal management actions, including drawing lines depicting possible present, and future, zones where assets may be at threat are an end product of further social, economic and environmental studies examining a range of management options, and their likely impacts.

This report is constructed in three sections and three appendices. The first part of the report examines the methodology the open coast shoreline projections, the second with the methodology of the Inlet shoreline projections and the third with issues specifically relating to the shoreline fronting the Kotuku Park development. Three appendices have been included to expand, and comment in detail on the specific relevant issues of sea level, sediments, and wave and longshore sediment movements, all of which really require further consideration.

2.2 Coastal Shoreline Movements

The natural process that formed, and continue to shape, the Kapiti coast are complex and very four-dimensional. They not only involve on-shore/offshore sediment movement processes, including river supply, and longshore transport of sediments but are also time dependent due to changes in the El Niño/La Nina, the Inter-decadal Pacific Oscillations (IPO) and a climate change. It should therefore come as no surprise that a simple one-dimensional application of the approach favoured in New Zealand of determining the cross-shore hazard distances (CEHD), has significant limitations on the Kapiti coast. It should be noted that the favoured approach can be undertaken using a four dimensional analysis of the components, however far more information is required than was available to Dr Shand and hence his approach has been limited to a one-dimensional, or pseudo two dimensional (time) analysis.

The favoured equation, which represents New Zealand "best practice" (Shand, 2012), is:

$$CEHD = LT + ST + SLR + DS + CU$$

Where:

LT = the long-term historical shoreline change. However this can only be properly determined by a detailed study of what has caused the change and how it may have altered over time. What are the sources and sinks for sediment? How have they changed, and how might they change into the future? What are the effects of Kapiti Island and how has its modification of wave patterns altered over time, and might alter into the future? What of the longshore transport mechanisms, the waves, the currents and the storms and in particular the sand "slug" (explained in detail in Appendix 3) feature and how it can create localised accretion and erosion episodes that mislead simple shoreline movement analysis using the vegetation lines on aerial photographs. What have been/will be the impact of changes in rainfall and catchment management practices and therefore changes of sediment supply to the coast? Hence the practice of using a simple approach of determining historical shoreline behaviour only using aerial photographs has significant limitations, as does the use of vegetation lines to represent the shoreline (experience indicates that a rapid accretion episode shortly before a photograph was taken can bury vegetation, leading to a conclusion that the shoreline has retreated because the vegetation line is further shoreward and therefor erosion has occurred, when in fact the actual situation is one of accretion). Dr Shand clearly recognises these limitations, and in the absence of the information necessary to fully interpret the shoreline movements, assumed that for shorelines that exhibit an erosional history, that erosion rate applies. However, for shorelines that exhibit an historical accretional trend, the shoreline movement is set at zero. This is clearly a conservative approach based on the one-dimensional analysis of the four-dimensional behaviour of the coastal processes of the region.

ST = the shorter-term shoreline fluctuation. Again, the significant limitations of information, as recognised by Dr Shand, have resulted in a conservative approximation by use of a statistical analysis of the variability of the normalised shoreline positions (taken as the vegetation lines, an approach that has its own limitations) given by the aerial photographs. Again Dr Shand recognises the weakness of the data he had to work with so uses a statistical function that is 3 times the "standard error of estimate". That is, his approach is totally reliant on the spread of the aerial photograph derived shorelines being representative of the statistical distribution of shoreline positions, and therefore a statistical error assessment can be used to predict the potential extremes (storm cut). This approach really requires far more data than was available to Dr Shand. Storm cut analysis is particularly sensitive to episodes of closely spaced storm events and their concurrence with elevated water levels due to tides and storm surge and therefore the approach adopted, out of necessity, by Dr Shand cannot be considered particularly robust. As Dr Shand points out, the existing seawalls and the river and stream mouths added to the degree of difficulty in obtaining meaningful results. Had more comprehensive wave information been available (actual or synthesised) than the 12 year record, it would have been possible to obtain far more confident results for the ST term. There are a range of well tried numerical modelling techniques that could be applied to even as complicated a coast as at Kapiti. In addition it was noted, on inspection, that the remnants of old erosion scarps could be seen in the vegetation at some locations and hence a more detailed examination of the sediment depositional features through the dunes would assist in obtaining a more robust value for the storm cut, and hence short term fluctuation term. Given that the ST term is a major factor in determining the CEHD, with the exception of where there are existing seawalls that are to be maintained into the future, there is a strong argument that it would be productive to focus on refinement of this factor. This particularly where the analysis has been clearly impacted (potentially inappropriately) by nearby inlet behaviour and open coast STs of up to 36m (2 to 3 times those elsewhere) has been applied. The results seem very inconsistent as compared to experience elsewhere, and what would be normally expected, which brings into question the reliability of the basic methodology.

SLR = the shoreline retreat due to sea level rise. Dr Shand has pointed to the difficulties in developing robust estimates of the sea level rise induced shoreline retreat. The Hazard Component Value tables contained in Appendix B of Dr Shand's 2012 report show that, with the exception of the southern section of the Kapiti coast, the SLR term is the largest component of the calculated CEHD distance. Hence this component has a significant impact on the end result, particularly for the 100 year projection, again because of the method Dr Shand has had to use. The issue of sea level rise is a complex one and hence is the subject of a more detailed comment later in this report (see Appendix 1). Suffice to say that the approach used by Dr Shand is considered conservative. He has highlighted difficulties with some of the available approaches, such as that of Bruun (1983) for the Kapiti coast where there is both onshore/offshore and longshore movements. Interestingly the reference used is a rather early presentation of the Bruun approach that Bruun and others developed further. In particular Dr Shand points to the unreliability of determining the "closure depth" for profiles. Experience elsewhere dictates that such issues can often be resolved by examination of offshore sediment distributions, emphasising the need for detailed offshore sediment sampling (see Appendix 2). Dr Shand has chosen to use the Komar et al (1999) approach, which is relatively simplistic as the predicted profile shift is just a function of the predicted rise in sea level and the average intertidal slope. As discussed in Appendix 1, dealing with sea level in this report, the 50 and 100 year projections should not necessarily be based on the IPCC values as the historical information suggests this would be very conservative. But of equal concern is the use of the present day intertidal slope, without consideration as to how that may change over time, nor the fact that the present day slopes are, to a degree, related to grain size. The grain size varies along the coast from cobbles to fine sand, with a mixture of both in many locations and hence the need for detailed longshore sediment distribution studies (see Appendix 2). If the Komar et al (1999) approach reasonably predicted the likely future shoreline behaviour the variation of grain size along the coast combined with the RSL rise over at least the past 100 years should have already resulted in altered shoreline alignments. The fact that this has not occurred is evidence that a simple application of the approach is not valid. That is, a more comprehensive approach combining sea level rise with longshore sediment transport is required and hence the need to adopt a study methodology as outlined in Section 2.3, and Appendix 3, of this report . Interestingly, the use of intertidal slope alone also produces the potentially anomalous result that protected shorelines with generally flatter intertidal slopes will apparently recede more than high-energy shorelines. Further, that this will occur regardless of what the landform is that is backing them. The impact of the SLR term is so significant on the ultimate determination of future shoreline positions that a far more sophisticated overall approach to coastal behaviour and the response to likely local RSL rise (rather than just a global sea level projection) is essential, including a risk analysis of the likelihood and consequences based on a statistical analysis of the likelihood of sea level rise scenarios.

DS = the retreat of the dune scarp due to natural slope adjustment. Dr Shand uses the approach of Clark and Small (1982) but makes the interesting comment that the equation assumes a 50 % recovery of the foredune toe. However this is not the case as it actually assumes that the slump of the top half of the escarpment produces an equal fillet in the bottom half. The significance being that incipient foredune formation due to independent beach recovery after a storm reduces the height of the escarpment, usually before slumping occurs. There are other factors as well that should be taken into consideration, as covered by Nielsen et al (1992). While the DS factor is potentially significant along the far southern Kapiti coast it does not contribute markedly to the CEHD of much of the region.

CU = a term to allow for a safety margin for the combined uncertainty of all the previous factors. The CU factor is generally in the vicinity of 6m with a couple of exceptions where it is 9m for the "seawalls repaired" option. The largest factors of the combined uncertainty component shown in the tables in Appendix B (Shand, 2012) are generated by the LT and the ST components. As previously indicated a more sophisticated analysis would reduce these. Interestingly a relatively small component is the SLR factor, which it is felt should actually produce the greatest uncertainty. But that uncertainty should be a +/- factor based on likelihood and consequence.

It is not intended to comment in detail on Dr Shand's derivation of the Coastal Erosion Hazard Lines as they are very dependent on the CEHD calculations. They are also dependent on the establishment of the origin from which they are offset. Dr Shand has used the 2008 shoreline position as the reference.

The main challenge with this technique is in the vicinity of the inlets, and for some distance either side where the shoreline position can be very variable as a result of local effects. The value of the depicted lines is really a function of how robust the calculations were for the CEHD, a matter of question given the limitations of the study.

Again the point is made that had the coastal erosion lines for the 50 and 100 year projections not impacted on significant public and private assets, the conservative approach adopted by Dr Shand should have provided a reasonable level of comfort to the Council and the community. However, given that they do have a significant impact, a more detailed approach to establishing the erosion hazard lines is warranted.

2.3 A More Detailed Coastal Process Understanding

The steps required for a more sophisticated and robust approach should include:

The development of a conceptual model of the overall coastal process system for the Kapiti coast. This would entail the establishment of the processes and mechanisms that have formed the coast (and coastal plain), currently shape the coast and, in the future, will alter the coast both in plan form, and in elevation (onshore, offshore and longshore as well as the inlets). It would provide a working model of how the coast can be expected to behave under different circumstances and identify why different regions of the coast are present day experiencing accretion while other parts are eroding. A conceptual model is also a "sanity check" on the following, more detailed, work as it is the foundation for the interrelationship of the various components. Further, it helps identify the relative importance of those components and hence dictates the areas of interest that need to be focused on; where the resources need to be applied for best outcomes.

Following on from the development of the conceptual model is the sediment budget analysis. This identifies and quantifies the sources and sinks of sediment involved in the overall coastal system, and how they may vary over time (short, medium and long-term). For example, the quantity of longshore transport of sand into the region from the coastline to the north, the amount of sediment being added to the coast from the rivers and streams within the region and where the sediment ends up. Basically if there is more sediment entering a coastal region then it is accretional whereas if more is leaving it is erosional. There is evidence that has been, and continues to be, a feed of sediment into the region, however there is shoreline recession in the southern part so either there is a differential shoreline response or there is a long-term sediment loss mechanism, or a combination of both. Dr Shand has indicated he believes their may be a long-term loss of sediment to the offshore region south of Kapiti Island and that this sediment may be finding its way to the deeper region of Cook Strait. Experience dictates that this is a plausible theory that could be readily tested by offshore sediment sampling and current and wave driven sediment transport. A better understanding of the sources and sinks for the Kapiti coast would significantly enhance the understanding of what the future may hold for the shoreline behaviour.

Finally, the development of linked numerical models of both longshore sand movement and onshore offshore movement as well as river and stream transport which are driven by wave, tide, current and stream flow data would enable the dynamics of the workings of the coastal processes of the Kapiti coast to be analysed in detail (see Appendix 3). The linked models would provide the "engine" to allow projection of likely shoreline behaviour to be generated for the entire region for a range of conditions, including an evaluation of both short term and long-term shoreline fluctuations. It would also enable sensitivity testing for various sea level rise/coastal subsidence scenarios to be evaluated, combined with the sediment budget analysis and the conceptual model an understanding of the range of coastal behaviours and how they may vary along different sections of the coast. Such a sophisticated tool is required given the public and private assets involved and the potential impact on the regional economy.

The overall outcome of the above approach would be to develop a sound basis for understanding and calculating where shorelines might be in the future, including the ability to do so incorporating a range of coastal management options. That is, the approach would produce the vehicle by which the impact of a range of management options would have on the coast, and at various locations along the coast. It would also provide a tool by which future empirical data on climate change could be input, that is, it would be an "alive" tool.

2.4 Inlet Shoreline Movements

The approach adopted by Dr Shand for the inlet shoreline projections, is similar to that of the coastal analysis, except that he has included an inlet migration term and has dropped the short-term shoreline fluctuation term. Again a generic approach has been taken however, just as there are differences between regions on the open coast, so are there differences between the inlet types, however these differences are even more marked. The actual inlet performances tend to be relatively individual, as demonstrated by the diagrams and treatments in the reports (Shand 2008, 2012). Hence while the generic description and values are a starting point, it is important to recognise that site specific interpretations for the different inlets are essential, particularly those with training walls.

Dr Shand points out that the regression based modelling he undertook for the open coast to define the longer-term shoreline trends or the shorter-term fluctuations, would not necessarily be appropriate, and hence he focuses on the shoreline envelopes of inlets in order to determine the future shoreline locations. While mentioning the issue of the training works and pointing out that they are unlikely to be abandoned in the future, he struggles to fit those inlets into the generic model.

The modified equation Dr Shand used to calculate the Inlet erosion hazard distance, which was the basis for the inlet hazard lines is:

$$IEHD = IM - (LT + SLR + DS + CU)$$

Where:

> IEHD = the inlet erosion distance. Dr Shand goes to considerable lengths to consider each inlet individually, which is testament to the fact that the generic model represented by the above equation should be viewed as a "first pass only" assessment.
>
> IM = the inlet migration. It should be noted that the model adopted by Dr Shand includes the inherent assumption that inlet migration is a continuous process "Sand-dominated inlets are typically characterized by frequent channel migration and changes in bar and spit morphology which often result in considerable shoreline change both within and between inlets" (Shand, 2012). However both experience and on-site evidence dictates that inlet entrances behave in a cyclic nature. That is, inlet channels migrate longshore during low flow stream and river conditions, depending on the prevailing longshore drift conditions at the time. Significant flood episodes provide the energy for rivers and streams to straighten their course near their entrances, taking the line of least resistance, and breaking through the migratory spit developments, thereby disconnecting the spit formations and recreating the entrances at the location directly downstream of their lower reaches, and hence re-establishing the cycle of migration. Both training works and amplified flows, as a result of climate change increased rainfall intensity, will limit the historical meandering of entrances, as break through of the spit is likely to be more frequent and occur at a particular location, immediately downstream of the lower reach of the river/stream.
>
> LT = the historical long-term shoreline change of the open coast. The use of the LT term in determining the inlet shoreline movements is fraught with problems. Not only is the LT term faced with the issues raised in the section on the open coast, but its use in defining estuary shoreline movements is difficult to reconcile as it required a wide range of assumptions on the river/stream dynamics and particularly how those dynamics will vary with a changing climate that may impact on both the wave conditions at the inlet entrance and the stream flow conditions due to changes in rainfall intensity and storm occurrence. Put simply the use of the open coast LT in this form presupposes that the entire inlet behaviour can be considered ambulatory in that it will be of the same form and dimensions, but simply regress landward as the open coast

shoreline erodes. Again there is no provision for the inlets, and open coast shorelines that have shown an accretionary trend over the period of record. Further there is no provision for the fundamental changes to inlet behaviour, shape and form that will occur as the coast retreats and the training works become more prominent by virtue of that retreat, nor the impact of increased "jetting" behaviour as a result of increased rainfall intensity.

SLR = the shoreline recession due to sea level. The use of the open coast SLR calculation in the inlet model is arguably inappropriate as, while there are issues relating to the open coast determination of the likely SLR distance, approaches such as those by Komar et al (1999) or Bruun (1983) were developed for shorelines where wave action is the determining factor, and were not intended to be applied to river bank shorelines. Bank response to sea level rise will be dominated by river, and riverbank processes. Equations developed for wave environments should not be used in river situations. Such use will lead to erroneous results and, depending on the backshore topography are likely to significantly overestimate shoreline recession due to sea level rise. Some work has been undertaken on estuary shorelines' response to sea level rise, such as presented by Stevens (2010) but even that work is of little value when applied to the rather unique challenges of the inlet shorelines as again the approaches depend heavily on wave action in estuaries as the driver for shoreline migration. The manner in which the SLR term is calculated needs a major re-think and, given it is a significant contributor to the landward establishment of the projected future shorelines, it is critical that the matter receive further detailed consideration.

DS = the dune scarp retreat. This is a strange term when applied to inlet banks as there is actually no dune, as there is on the open coast. However, the "DS response model" used on the open coast may well be appropriate as it is actually based on a simple bank collapse approach and is not altered by the manner in which the collapse is initiated (waves or inlet flows). However the reservation, raised previously, regarding the open coast response being potentially limited by incipient foredune growth as a result of beach recovery after storms, clearly does not apply to the inlet situation. The only issue is that the use of the bank collapse approach is likely to give a conservative result because, unlike the open coast, inlet bank vegetation is generally far denser and more erosion resistant, hence banks are often steeper, as evidenced on the Kapiti coast. It is recognised however that where inlets are particularly unstable there is less opportunity for vegetation to develop, and hence the equation used to calculate DS is appropriate.

Again the CU factor is an artifact of the conservative analysis based on limited information and description of the four-dimensional nature of the processes involved.

Rather than dissecting the approach in detail for each of the estuary inlets, this analysis focuses on the Waikanae Inlet that is of particular interest to Kotuku Park Ltd.

3.0 Waikanae Inlet

3.1 Background

The following is quoted directly from Dr Shand's 2008 report (Part 2 Inlets) as it clearly indicates the unusual situation and demonstrates that Waikanae Inlet cannot reasonably be analysed using the generic approach, and therefore requires a more detailed site specific analysis:

> "The historical shoreline record for the Waikanae River (Fig 15) has affected about 1700 m of coastal shoreline, of which approximately 400 m lies on the northern (Waikanae Beach) side and 1300 m on the southern (Paraparaumu) side. The back of the inlet, i.e. the eastern (Otaihanga) side, lies about 200 m landward of the coastal shoreline at its northern end (nearer the river), and about 400 m landward at its southern end (towards the residential area). In the early 20th century the inlet area was about 55 ha. The Waikanae River has the second largest catchment (147 km^2) and second largest mean annual flow (160 m^3/s) of all the Kapiti water courses (Jamieson, 1991). While river control works and current management practices have halved both the extent of the inlet's lateral migration and the inlet area, this inlet is still the largest and most dynamic on the Kapiti Coast. Before considering the historical geomorphological changes in greater detail, the history of river management will be described.
>
> The lower Waikanae River has undergone substantial change in terms of channelisation, bank protection and mouth control for the purposes of flood mitigation and erosion prevension. In addition, in 1921 the northern branch (the Waimeha Stream), was diverted directly to the sea (see Section 3.6) some 2.3 km to the north of the Waikanae Rivermouth. The Waimeha and Waimanu Lagoons formed in the seawardmost section of the original Waimea River channel.
>
> Both the Waikanae River Catchment Control Scheme, which was implemented between 1956 and 1964, and the intensive gravel extraction which occurred until the 1970s (Brougham and Gestro, 1986), could have affected the entrance hydrodynamics. Until the construction of a southern groyne in the mid 1960s, no structural control works occurred at the entrance to limit the southward migration of the channel. However, rivermouth cutting has occurred at 5 to 10 yearly intervals since the 1930s and the years such management were carried out are listed in Easther (1991). The following trigger conditions are contained within the Wellington Regional Coastal Plan: *when the channel outlet*

migrates either 500 m south or 200 m north of a projected line parallel to the centre line of the southern rivermouth groyne. These trigger lines are depicted in Fig 16. *Alternatively, mouth cutting occurs when the water level increases to 300 mm above normal at the Otaihanga footbridge*.

A range of river control structures were established during the late 1960s to early 1970s in association with residential development at Waikanae Beach and these are depicted in Fig 16. While these structures fix the location at which the upstream channel enteres the inlet, the mouth is still able to migrate laterally.

The historical shorelines show that while the northern side of the entrance has fluctuated laterally over a range of about 300 m, rivermouth structures and mouth cutting now limit the variation to about 20 m. It is noted that on the adjacent open coast the shoreline is slowly moving seaward at about 0.25 m/yr.

The southern side of the inlet has, in the past, extended some 700 m beyond its present location. The 1872 cadastral shoreline had an extreme southern mouth location, and this configuration also occurred during the 1940s and 1950s (Fig 15). Remnants of even more southerly inlet channel locations can be identified by stereographic analysis of aerial photos, and one such shoreline is included in Fig 15. The two dated episodes of spit extension suggest that the process may be quasi cyclic with a period of 50 to 60 yrs. Artificial mouth cuts have prevented any further episode(s) of significant southward inlet migration.

The occurrence of extreme southern inlet shorelines are a consequence of the channel being constrained and redirected by growth and extension of the northern spit. This situation is relieved by spit breaching which occurs either by natural or artificial (mouth cutting) near the Waikanae Beach end of the inlet. Sediment contained within the dissected north spit is then washed landward by wave action and merges with the southern side of the inlet. This process was particularly evident in the 1950s and 60s when about 20 ha of accretion occurred following the (artificial) spit breaching in 1947. Some 16 ha of this 'new land' was subsequently used for residential development in what is now the Manly Street North area. This particular episode of inlet sedimentation may have been exacerbated by construction of the entrance jetties (groynes) in the late 1960s and early 1970s and this is discussed further below.

The entrapment of north spit sediment within the southern part of the estuary in the 1950s and 60s appears to have affected the coastal sediment budget. In particular, the southern open coast shoreline changed from a state of long-term advance to one of stability or slight erosion as illustrated in Fig 3A of the Open Coast Erosion Hazard Assessment and on sheets C14-20 and x14-48 in the Erosion Hazard Data-Base. In addition, shorter-term fluctuations (10 – 20 yrs) are superimposed upon the longer-term shoreline trend and this may, in part, relate to the more frequent mouth-cutting regime.

> Along the landward (Otaihanga) side of the inlet, the shoreline has remained relatively stable apart from changes which have occurred closer to the groyne (on the southern side of the mouth). It is evident from Fig 15, that the southern riverbank in this area was about 200 m further south than the present bank in the 19th century. Infill of the old bed is evident in the early aerial record. In addition, the southern entrance groyne has further affected the sedimentation in this area with the shoreline reaching the end of the groyne by the 1990s. In total, the inlet area here has been reduced by some 9 ha."

Interestingly in his 2012 Update Dr Shand indicates that pre 1960s the Inlet area was 71 ha and is now 35 ha, as against the previously quoted area of the inlet originally being 55 ha. There are also a number of other inconsistencies in the 2012 description as can be shown by comparing the following quotation to the above (2008) description:

> "The natural Waikanae Inlet (pre-1960s) has a maximum area of 71 ha and alongshore length up to 1800 m. By contrast the present managed inlet (discussed below) has an area of 35 ha and alongshore length of 1000 m. The catchment area of the Waikanae River is 15,300 ha (153 km^2), and the mean annual flood flow is 148 m^3/s. The channel (both natural and managed) has a southerly offset. The Waikanae Inlet (both natural and managed) is the largest on the Kapiti Coast, and this relates to the size of the fluvial system coupled with fine sediment in its lower reach which facilitates channel migration. The adjacent northern (Waikanae Beach) open coast has a long-term shoreline progradation rate of 0.27 m/yr while the adjacent southern (Paraparaumu) coast has a long-term erosion rate of 0.28 m/yr. By contrast the rear shoreline of the inlet (Otaihanga side) is remarkably stable.
>
> Past shorelines and derived hazard characteristics are summarized in Figure 4.9. For reference the full set of aerial photo-based shorelines have been overlaid in Appendix F, Figure F7, and the shoreline dynamics are described in the 2008 Hazard Assessment.
>
> In early colonial times the Waikanae River bifurcated near Waikanae Township and followed two main courses - the northern Waimeha and the southern Waikanae. These branches reunited at the position of the present Waimanu Lagoon and their resultant southerly orientation may have contributed to the inlet's southerly offset. About 1890 the Waimeha bifurcate was cut-off, with the southern branch (present Waikanae River course) receiving the full flow. In the early 1920s, the present Waimeha channel was excavated and the remnant Waimeha further seaward forming the present Waimanu and Waimeha Lagoons.
>
> Over the past 60 yrs in particular, the lower Waikanae River and Inlet have undergone substantial change due to gravel extraction, channelisation, bank protection works and rivermouth control for the purposes of flood mitigation and erosion prevention associated with the

> Waikanae River Catchment Control Scheme. In addition, groynes were constructed at the Waikanae side of the inlet in the late 1960s to early 1970s as part of a residential development project and substantial reclamation carried out on the Paraparaumu side of the inlet in the late 1960s, also for residential development. Present management consists of mouth cutting. The various management works and practices have halved the inlet area and constrained the lateral extent of channel migration by almost a half. Further details on this inlet's history are described in the 2008 Hazard Assessment, Part 2, Section 3.7.
>
> The increase in management since the late 1960s provides the basis upon which to divide the shoreline data into earlier (natural) and later (managed) subsets. However, because the jetties at the northern end of the inlet and the subdivision earthworks at the southern end resulted in systematic shoreline adjustment, the 1966 to 1980 shorelines were classed as 'transitional' and not included in the analysis."

The point of highlighting these inconsistencies is simply to reinforce the need to undertake a more focused and detailed assessment of the Waikanae inlet, and in particular the shoreline of interest, referred to in the text as the "central (eastern) Otaihanga side". For the record it is also noted that the "managed shoreline" is actually landward of the "unmanaged shoreline," along part of the Otaihanga shoreline, demonstrating a further localized inconsistency.

3.2 Kotuku Park

In the 2012 Update Dr Shand recognizes both the massive amount of accretion that has occurred in the Inlet since the 1960s (possibly in the vicinity of 1M m^3, indicating the Inlet has been a major sediment "sink", and reinforcing the need for a detailed overall coastal process study), and the relative current, and likely future stability of the Otaihanga shoreline. He therefore has taken the approach of setting the LT term, in the equation, to zero. This is possibly reasonable under the circumstances however, further consideration of the infilling and the training wall constraints will most likely show it is conservative. Dr Shand continues to use the SLR factor as if the Otaihanga shoreline is open coast and the DS factor for the open coast, even though there are no foredunes as such, and the bank collapse is likely to be less than what will be experienced on the open coast. It is also curious that he retains the CU factor as applied to the open coast even though he has dropped the LT component from the equation. That is he has dropped the LT component but retained its uncertainty term. Of greater concern is that the calculated figures of an offset of 29.1m (SLR =20m, DS=3.1m, CU= 6m) for the 50 year period and 73.1m (SLR=60m, DS=3.1m, CU=10m) for the 100 year period produce hazard lines that, for the 100 year line, pass through some of the allotments of the Kotuku Park development when in fact the seaward side of those allotments are set back more than 73 m from the shoreline. That is, there appears to be an error in the location of the lines on the aerial photographs presented in the report, and hence possibly on the information being held by Council.

It is also interesting to examine Dr Shand's rational for determining the eastern (Otaihanga) shore. On the southern side of the Inlet he derives the 50 and 100 year shorelines by adjusting the IMC landward by 44.1m and 103.1m respectively, even though this area has a recent history of massive accretion. It would seem Dr Shand's view may have been influenced by the open coast situation to the southern side of the Inlet, however it is possible that the shoreline response in this region is, in part, an artifact of the infilling of the Inlet on the southern side. That is, some of the sand that in filled the Inlet may have come from the open coast beach as a result of gross (as compared with net) longshore sand transport. On the north side, where there has also been accretion, but not to the same extent, he adjusts the IMC landward by 24.2m and 58.3m respectively. This is compared to the 29.1m and 73.1m for the more sheltered eastern shore. In fact, the major difference in the figures is generated by the SLR component, which clearly means it requires significantly more refinement as it does not seem logical, nor reasonable that the SLR (RSLR) component for the 50 and 100 years IMC is 20m and 60m respectively for the eastern shore but only 15m and 45m for the northern shore.

It would seem that a closer examination of the Otaihanga shoreline and the setback of the Kotuku should remove the impediment placed by the 100 year line without even giving further consideration to the inclusion of the sea level rise components of 20m for the 50 year period and 60m for the 100 year period. It is however argued that a more comprehensive analysis of these SLR factors, and the recognition that the Komar et al (1999) approach used to obtain these figures, is intended for open coast wave conditions and could therefore be expected to overestimate the impact of RSL rise on the Otaihanga shoreline, even accepting the IPCC projections. It is also felt that the topography of the area between the allotments and the shoreline, and the three dimensional nature of the processes involved in forming future shorelines must be taken into account when calculating the likely setbacks required to accommodate the effects of sea level rise. Further it is argued that both the DS and CU allowances would likely be revised downward by a more detailed examination.

It is noted that, the comment included in the 2012 report by the reviewer, that the training walls may be outflanked in the future, is discounted by Dr Shand as being unlikely. This was reinforced by Dr Shand in discussions and, given the topography of the region, must be considered "barely credible" (a risk management term). It most likely reflects the reviewer's lack of detailed information on the present day topography of area in question.

4.0 Concluding Remarks

Dr Shand's report(s) can reasonably be described as a regional assessment, or scoping study, which recognises the issues that need further research and/or more detailed study. The reports also identify the gaps of knowledge and information that should be obtained before assessing potential property impacts and/or coastal management options. Dr Shand importantly makes the point that more detailed, site specific studies are required to refine the hazard lines. It is however also considered that a more detailed overview would provide a better context for determining future shoreline trends. Clearly, in their current form, caution should be exercised in using the results from the reports as the basis for determining the vulnerability of properties.

In regard to the Waikanae Inlet, and particularly the eastern shore fronting the Kotuku Park, a site-specific re-examination of the information is required. There would appear to be an inconsistency in the calculated IMC and the plotted position on the diagrams, given the actual size of the buffer between the shoreline and the Kotuku Park allotments. There is also an inconsistency in the calculation of the SLR (RSLR) term throughout the overall inlet. Further, the entire methodology of calculation of SLR for the inlet seems out of context and overly conservative as it utilises a methodology developed for an open coast wave environment, not a sheltered inlet situation.

Finally it is noted that Dr Shand has responsibly placed caveats throughout the report(s) and he has made careful distinctions between the outcomes of regional studies and those obtained from site-specific analysis. Further he has openly canvassed the limitations of the approaches he has adopted, including those applied to the internal regions of inlets.

5.0 Recommendations

The following actions are recommended:

1. A re-examination of the positions of the 50 and 100 year projected "Otaihanga shorelines" at Kotuku Park, as there appears to be an inconsistency between the calculated values and the plotted locations. Should that not remove the impediment to the allotments indicated by the 100 year projected shoreline, a more detailed, site specific examination be undertaken focussing on the way in which the SLR term is calculated on an inlet shoreline, particularly in respect to the Otaihanga shore and its adjacent back-of-bank topography, a re examination of the calculation and application of the DS term, and removal of the LT uncertainty from the CU figure.

2. The CS documents (Shand, 2008, 2012) be used as a starting point for a detailed coastal process study of the entire Kapiti coast. This study should include the development of an overall conceptual model of the coastal system and the interaction of its component parts. The conceptual model phase should be paralleled with data collection and synthesis to provide long-term wave, current and storm information, offshore/onshore and longshore sediment distributions and river and stream flow data. The development of an overall sediment budget identifying, and quantifying, the sources and sinks of the coastal sediments should follow the establishment of the conceptual model.

Finally the sediment budget phase should be followed by the establishment of a suite of interlinked numerical models that both quantify and explain the behaviour of the different regions of the Kapiti coast, and provide a vehicle by which future coastal trends can be examined and sensitivity tested. Such models will enable explanation and investigation of the shoreline movement trends, the offshore loss mechanism south of the forelands and include a detailed understanding of the longshore drift and the shoreline response to various sea level rise scenarios and the likely changing impacts of Kapiti Island on the shoreline processes.

3. It would also be useful to undertake an assessment of the development of the regional coastal plain through dating of sediments so as to ascertain the history and rate of progradation of the plain. This will assist in developing the overall conceptual model and in ascertaining how and when it was formed and whether it is still forming. The history of progradation would also provide helpful input for the sediment budget analysis.

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Appendix A - Sea Level Considerations

When considering long term shoreline movement trends it is vital to understand, and take into account any long term trends in the relative sea level change over the same period. The challenge is that global sea levels may alter due to both temperature changes in the oceans and due to alterations in the volumes of terrestrial ice; sea ice already displaces its weight and so does not change the volume of the oceans whether it grows or declines in volume.

The Intergovernmental Panel on Climate Change's most recent report indicates that the worldwide trend over the past 100 years has been an absolute rise in sea level of an average of 1.7mm/y, +/- 0.5mm/y. The IPCC also projected a global sea level rise for 2095, relative to the 1980-1999 baseline, of 0.18m to 0.59m but when including anticipated ice sheet loss the range could be 0.28m to 0.78m. It is important to note that these are "absolute sea level rises" that is, they are the rises measured from the centre of mass of the earth.

The important factor when analyzing a particular coastal region is to consider the actual sea level change at the site. This is known as the relative sea level (RSL) change. This depends not only on what the global sea levels are doing, but also on other factors such as tectonic movements and the long-term rebound of landmasses as a result of the change in glacial loadings; termed the GIA. Both of these factors are important in the New Zealand context.

Beavan and Litchfield (2012) indicate that the Kapiti coastal region has been experiencing a subsidence of between 2mm/y and 4mm/y over the historical period of interest and that this trend is likely to continue for the next 50 to 100 years. This is despite the fact that the GIA, which is being experienced, is 0.3 mm/y, that is, the coast is the rebound is a lifting of the landmass of 0.3mm/y. Hence the actual subsidence is between 2.3mm/y and 4.3mm/y. Bevan and Litchfield also note that over the past 125,000 years the coastal area has been rising at an average rate of 0 to 1mm/y, contrary to the current trend.

Based on the above information, and considering the period of record (last 50 to 100years), with the absolute global sea level rise during the past 100 years of approximately 1.7mm/y (+/- 0.5mm/y) combined with the subsidence of the Kapiti coast, it should be experiencing a RSL rise of between 3.2mm/y and 6.2mm/y. Hence the historical shoreline behaviour should reflect the impact of this relative sea level rise.

Interestingly however Bell and Ramsay (2011) and Bell and Hannah (2012) have undertaken detailed analyses of the New Zealand tide gauges, with particular emphasis on the Wellington region, in the latter report and have concluded that the RSL rise during the past 100 years has been 2.03mm/y. However, as they note, the subsidence in the region, during this period, has been 1.7 mm/y and hence the absolute sea level rise, also taking into account a 0.3mm/y GIA component has only been 0.33mm/y as compared with the world average of 1.7mm/y (+/- 0.5mm/y). That is, during the period of historical record there has been a RSL rise of 0.33mm/y that has impacted on coastal behaviour and, all other things being equal, should have caused an associated shoreline recession.

Of even greater significance however is the fact that all authors appear to be of the view that current trends will continue for the next 50 to 100 years but seem to fail to recognise that the historical absolute sea level trend for New Zealand is only approximately 20% of what has been the historical world trend. Yet, the same authors project forward sea level rise scenarios for New Zealand that are the same as the world averages given by the IPCC. Hence the projections are 5 times what a normalized trend would imply. Yet, it is the absolute global figures that are enshrined in the New Zealand Government documents and therefore have to be used by investigators such as Dr Shand.

Unfortunately the subsidence rate of the New Zealand coast is similar to the historical global sea level rise trend of 1.7mm/y. While this may, at first glance seems to be a self-equalizing factor, it in fact presents a major dilemma. While the subsidence is expected to not accelerate, the global sea level rise is projected to accelerate. There could therefore be an increasing disconnect between the absolute global figures, with a base of 1.7mm/y accelerating and the New Zealand absolute figure of 0.33mm/y accelerating but the subsidence rate for New Zealand remaining at 1.7mm/y. That is, from the available evidence the use of 50 year and 100 year sea level rise figures based on world averages will significantly overestimate the expected RSL in New Zealand. If the historical ration of 20% continues to apply, say a 1 m global sea level rise in 100 years will result in a 0.2m absolute rise in New Zealand, which, with a subsidence of 0.17m expected over the next 100 years, would only produce a 100 year RSL of 0.37m, not 1 m.

Interestingly Watson (2011) recently undertook detailed studies of the long-term tide gauges across Australasia, including New Zealand, and concluded the physical evidence showed that not only is the historical sea level trend not accelerating, as projected by the IPCC, but rather the evidence is that it is showing a slight deceleration trend. Watson's work is acknowledged in Bell and Hannah (2012) and other authors, worldwide, are starting to publish similar results. Further, Watson (pers. comm.) is of the view that the reliable absolute sea level rise information for the Australasian region demonstrates a far lower historical rise than the 1.7mm/y contained in the IPCC documents (eg, IPCC, 2007). This is in keeping with the Wellington region study by Bell and Hannah as discussed previously.

Appendix B – Sediment Issues

The sediment forming the beaches of the Kapiti coast varies from cobbles near the river mouths to fine sand. The sand is angular and contains a high percentage of lithic fragments as testament to its terrestrial origin. Given the lack of rounded particles, as would be expected from a sand exposed to marine processes for an extended period of time, it is considered the sand and gravel beaches are of relatively recent origin. This, combined with the sand and gravel bars in the rivers and streams, is believed to be indicative of a present-day active terrestrial supply of sediment to the coast; that is, the rivers and streams are an active source of sediment to the present-day coastal sediment budget.

It is understood that the climate change projections for the area include a potential significant increase in rainfall intensity and hence runoff. This in turn implies additional erosion of the hinterland and an increased capacity of the streams to transport sediment to the coast. As transport capacity is a non-linear function of velocity increase in stream flow, it could be anticipated that the projected changes in rainfall intensity could result in a disproportionally large increase in sediment supply to the coast.

It is noted that, although it is understood that rainfall intensity projections are being included in calculations for stormwater and bridge designs, the Coastal Hazards reports (2008, 2012) contain no assessment of the additional sediment source to the coastal budget. There is however a reference to the fact that climate change may increase terrestrial sediment supply to the coast, but no calculations to scope this aspect of the sediment budget.

It was also not possible to discover any information on dating of the coastal plain sediments. Dr Shand confirmed the lack of availability of such data and agreed with the view that such information could provide an important insight as to the rate and time of progradation/recession of the shoreline (Shand, pers. comm.).

The visual indicators are that this is a coast that has in the recent past, or currently is, undergoing accretion in the regions north of Paraparauma, regardless of the fact that the tide gauge information for Wellington and Auckland indicate a relatively steady RSL rise over the last century, which implies that, unless sediment is being supplied to the coast, present-day, the shoreline should be eroding.

A detailed study of the history of formation of the coastal plain of the Kapiti coast, particularly a study dating its recent behaviour, would prove most useful in determining the historical trend and be invaluable in projecting the likely trend forward 50 to 100 years. This would assist in determining the rate, and historical trends of sediment supply from the hinterland to the coast and hence the "feed" to the shoreline coastal process system. In turn this would assist in determining the potential vulnerability of private and public assets, even given a range of accelerated sea level rise scenarios.

Without access to such information Dr Shand felt he had little option but to assume a conservative position of no present-day supply to the coast (Shand, 2012). In part he has done so because of the changes in catchment management practices in the region. When first developed the catchment was somewhat denuded of vegetation, thereby potentially releasing more sediment down the rivers and streams to the coast, however in more recent times good catchment management has resulted in a restoration of vegetation in the catchment thereby potentially inhibiting the sediment flow (Shand, pers. comm.). This all points to the need to examine this important potential supply in far more detail and to consider the impacts of climate change. Greater rainfall will likely lead to an increase in catchment erosion, and certainly to more energetic stream flow, hence the potential to increase sediment supply to the coast from the hinterland in the future. This in turn means more sandy sediments in the coastal system.

A further important sediment issue is the potential offshore loss of sediments into the deep waters of Cook Strait, to the south of Kapiti Island. Examination of the offshore sediment characteristics and distribution would most likely assist in investigating this potential sink. Similarly, experience elsewhere indicates that investigation of the offshore sediment characteristics along the entire length of the region is likely to provide valuable information on the closure depth of the active coastal process profile and hence important boundary information for the conceptual model and the numerical modelling.

Appendix C - Wave and Longshore Sand Transport Studies

Inshore wave climate and longshore sand transport on the Kapiti coast is complicated by the effects of Kapiti Island, the many, and varied inlets and the present day supply of sediment to the coast both from the north and from the rivers and streams within the region. A further factor is the current regime through the channel between the Island and the mainland. This regime includes not only the tidal currents but also storm wave and surge induced currents.

The variability and trends of the annual net wave energy flux can significantly influence the areas that will be subject to coastal storm erosion and shoreline recession. The net wave energy flux is a function of the generating weather systems and is therefore subject to short term (2 to 5 years) variability factors associated with the El Niño/La Nina Southern Oscillation, medium term (50 to 60 years total cycle, 20 to 30 years in each phase) variability driven by the Interdecadal Pacific Oscillation (IPO) and long term climate change, which also implies a shift in the Latitudes of the weather systems as well as changes in intensity. In addition, the tidal and storm generated flows between the Island and the mainland evoke additional complexities. Interestingly Dr Shand notes a IPO length signal in the inlet behaviour (Shand, 2012) although does not refer to it as such.

The 2012 Update study utilised a 12 year hindcast of offshore wave conditions from 1998 to 2010 that was provided by MetOceans; this being the only wave information available for the region. It is understood that the offshore waves were transformed to the near shore zone using a nested SWAN model (Dr Shan, pers. comm.) so as to synthesise the wave climate at 16 inshore locations along the coast. The inshore wave conditions were then used to calculate the littoral drift (longshore sediment transport) by applying the Kamphius (2002) equation at each of the 16 locations.

Engineers Australia's publication regarding adaption to climate change and climate variability contains an appendix entitled "At What Price Data" (NCCOE, 2012). This clearly demonstrates the difficulties in using such a short wave record. Further, the wave climate defined by hindcast techniques, while being some times all that is available, must be used with caution as it is very dependent on the available meteorological information which can be notoriously unstable in areas such as the Tasman Sea where there are few recording stations ,and reliance on the satellite imagery is necessary. Another issue is that the period of hindcast was during a time of change of the phases of the IPO and therefore may not be representative, particularly in regard to wave direction. It is therefore believed that, if the only long term wave data available for the region must be generated using hindcast techniques, a far longer period of record would be necessary if that information is to be used for assessment of the shoreline processes.

The use of the SWAN model could not be assessed as it is not detailed in the report. It is understood others undertook this section of the work and simply provided the derived inshore wave conditions at the 16 points. Experience has indicated that a limitation of the SWAN model is its application to situations where there is strong wave diffraction, let alone possible current modification of wave lengths. Given that there is significant wave diffraction around both ends of Kapiti Island, and that this is likely to generate a state of wave crossings behind the island, with reduced energy areas, as demonstrated by the incipient tombolo shoreline shape, the output of the SWAN modelling should be viewed with caution. It is understood (Dr Shand, pers com) that some verification of the wave modelling has been undertaken using S4 meters. This information was not available for analysis, as it is understood it has been undertaken recently. It is generally necessary, particular with a complicated wave environment such as that shoreward of Kapiti Island, to not only have a period of record that spans a wide range of wave conditions, but also to collect that data over at a array of locations so that the model can be adequately verified.

The 12 years of hindecast wave data available to the CS study was clearly inadequate to enable assessment of the potential variability of the near shore wave climate and hence the gross and net longshore sediment transport along the coastline, and hence the shoreline response. With such a dominant coastal influence as Kapiti Island a far longer wave record needs to be synthesised.

The numerical wave model that should be used must also be capable of not only handling wave refraction and diffraction, but also the effects of differing currents conditions, particularly between the Island and the mainland, on wave steepness. The wave model then needs to be coupled to a continuous, rather than multi point, longshore sand transport model that provides both gross and net littoral drift information. Both forms of drift are required because from time to time the areas of accretion and erosion will vary along the coast, particularly at the inlets and in the regions sheltered, from time to time, by the Island.

At Kapiti where the river/stream entrance bars slowly build, and the river/stream mouths are deflected by the longshore drift impacts on the bars, then a flood event causes the river/stream to straighten its course and cut off the previously evolving bar, it is possible to get an unusual phenomenon referred to as sand “slugs”. The cut off bars, once disconnected from the processes that formed them, move off as “slugs” of sand. As the “slug” moves along the coast, the shoreline initially accretes, but as the “slug” moves on the shoreline erodes. The associated cycle can take months or even years depending on the size of the “slug” and the rate of net longshore transport. On a coast that can experience such sand “slug” behaviour, shorelines will fluctuate accordingly, quite independent of the storm erosion/beach-rebuilding short term fluctuations. Unless this process is understood shorelines behave somewhat erratically, apparently without explanation. The modelling needs to be capable of replicating this phenomenon.

Modelling needs to be versatile enough to test the sensitivity of the shoreline alignment for varying wave conditions including storms and medium and long-term changes in net wave energy flux, as well as changes to sediment supply from the north and from the rivers and streams. The modelling also needs to be capable of taking into account the likely differential changes in shoreline response due to the disproportional impacts of climate change, both sea level and storm intensity, as a result of the Islands changed "sheltering" characteristics. The requirement to include not only the 50 year projection but also the 100 year climate change projection makes this level of sophistication imperative due to the potential spread of results, and hence the need for a detailed statistical analysis and meaningful interpretation of that spread.

The New Zealand Naval Chart of the region provides some insight to the likely complexities of the offshore sediment transport and its inshore component. It shows very different offshore slopes off some of the river mouths, and a steepening of the immediate offshore zone off the mainland's incipient tombolo formation. The latter may be an indicator of the current regime through the passage that has implications for the longshore transport calculations in this region. Interestingly the offshore area to the south of this region suggests a possible depositional area, and hence a potential off shore sink for sediments. Dr Shand suggested there might be an offshore loss mechanism here, which sees the sediment diverted into the Cook Strait Canyon (Dr Shand, pers. Com.). This aspect clearly requires further investigation.

Longshore sediment transport formulae remain a developing science which is why it is important to undertake studies using sophisticated models that can be sensitivity tested and verified. The Kamphius longshore transport equation used by Dr Shand is as good as those currently available when applied to a series of points on a simple coast configuration. Unfortunately most formulae have their limitations when applied to a coast with the sort of complexities as exist at Kapiti, and therein lies the reason for a more sophisticated, integrated modelling approach that can be tuned to replicate coastal behaviour and provide sensitivity testing of various scenarios.

The approach used by Dr Shand should be seen as a scoping study, undertaken within a limited budget and with time constraints. His work has helped identify the need for a far more sophisticated, and accordingly expensive, approach to obtaining a sound basis for understanding both present and long term behaviour of the Kapiti coast. Given the value of both public and private assets potentially impacted, such an understanding is considered essential for development of informed management decisions.

It is not intended to critique Dr Shand's results in any detail because, as previously mentioned, they mainly serve to highlight the need for further work, something it is understood Dr Shand recognises (Dr Shand, pers. com.). The fact that in the northern region of the coast the results in the 2012 report suggest a south to north longshore sand drift, when all evidence points to drift in the opposite direction, along with the clear inconsistencies implied by the graph (Figure G5) on page 104 of his Update report (Shand, 2012) is a testament to the difficulties of applying simple techniques based on limited data to such a complex situation.

Appendix D – Authors Biography, Technical Experience and Papers.

Short Biography – Angus Gordon

Completing a Civil Engineering degree in 1969 Angus commenced work on water and coastal projects in 1970 at the Water Research Laboratory of the University of New South Wales (WRL). In 1973 he obtained a Master of Engineering Science and took up a position at the Manly Hydraulic Laboratory (MHL) and then in Coastal Branch of Public Works NSW. In 1986 he returned to MHL as Manager and in conjunction WRL established Australian Water and Coastal Studies Pty Ltd. For 40 years he has been involved in coastal engineering, coastal zone management and planning projects in all states of Australia and in Brunei, Dubai, Kuwait, Indonesia and Hong Kong. He has also been engaged by the UN as an international expert.

In 1976 he established the NSW Governments Beach Improvement Program and led the team that, in 1978 produced NSW's first comprehensive costal investigation and management study the "Byron Bay – Hastings Point Erosion Study". As a direct result of that study Angus then became involved in the drafting and implementation of the 1979 NSW Coastal Protection Act.

First becoming involved in the issue of climate change in 1976, he arranged a secondment to the Antarctic Division of the Department of Science for a 12 month period in order to investigate climate change as he was concern with the approach of simply using historical coastal recession data for prediction of future shoreline movements. In 1987 he published a paper as a chapter in the CSIRO's book "Greenhouse 87"; the paper linked sea level rise to coastal erosion at 32 locations in NSW where his team had undertaken studies over the preceding decade. He has published a number of papers on climate change and was the lead author of the Engineers Australia 1991 guidelines for adaption to climate change in the coastal zone. In 2010 he was a Keynote Speaker at the 1st Australian Conference on Practical Adaption to Climate Change.

For 9 years prior to his retirement Angus was CEO of Pittwater Council, a coastal council on Sydney's Northern Beaches. This provided an excellent opportunity to experience coastal management from the perspective of a community leader and regulator. In retirement he continues to indulge his passion for coastal zone issues such as adaptive coastal engineering solutions for an uncertain climatic future and is currently Chairman of the Industry Advisory Board to the University of NSW's Water Research Centre.

Angus has over 50 technical papers published nationally and internationally on coastal engineering and coastal zone management.

TECHNICAL EXPERIENCE: ANGUS DONALD GORDON

Special Fields of Competence: Problem solving and Multi Disciplinary Team Leadership in Coastal, Ocean and Environment; Engineering; Coastal Zone Management; Estuary and River Management; Sediment Transport; Sand Bypassing, Beach Nourishment; Oceanic Inundation; Numerical and Physical Model Studies; Wave Climate; Shelf Currents; Outfall Monitoring; Climatic Change and Sea Level rise.

Coastal/Environmental Engineering:

Coastal Zone Management

Byron Bay (NSW) - 1977-1979, 2000	Tweed Heads (NSW) - 1983-1989
New Brighton (NSW) - 1977-1979	Warringah Shire - 1982-1984
Tathra (NSW) - 1980	Cronulla (NSW) - 1977-Present
Hawks Nest (NSW) - 1982-1984	Sydney (NSW) - 1989
NSW Coastal Zone Management Policy - 1977-1986	Jerudong (Brunei) - 1992, 1993
Jakarta (Indonesia) 1994	Dubai (UAE) - 1995
Saibai Island (Torres Strait) – 2007 – 2008	Pittwater Coastal – 1996 – 2005

Estuary, River and Wetlands Management

Forster/Tuncurry (NSW) - 1979-Present	South West Rocks (NSW) - 1985
Warriewood (NSW) 1979-Present	Shuwalkh (Kuwait) - 1990
Lake Burrill (NSW) - 1972	North Jakarta (Indonesia) - 1994-1995
Shoalhaven (NSW) 1973-1995	Narrabeen Lagoon (NSW) – 1970 - Present
Dee Why (NSW) - 1977-1982	Swansea/Lake Macquarie (NSW) – 1986 - Present
Port Stephens – 1977 - 1985	Wagonga Inlet (NSW) – 1984 - Present

Sediment Transport

Coastal process studies, sand movement onshore/offshore, longshore and beach erosion

Newcastle Bight (NSW) - 1974-1977	Hawks Nest (NSW) - 1982
Wamberal (NSW) - 1978, 1984	Cronulla (NSW) - 1977-Present
Byron Bay (NSW) - 1977, 1978	Carama Inlet (NSW) - 1989
Tathra (NSW) - 1980	Fly Point (NSW) - 1989
Broken Bay (NSW) - 1981	Tweed Heads (NSW) - 1989
Burnie (Tas) - 1981	Somers (VIC) - 1991
Hawks Nest (NSW) - 1982	Belmont (NSW) - 1991
Sydney Shelf (NSW) - 1979	Jerudong (Brunei) - 1991

Wave Climate Studies

Bombo (NSW) - 1970	Pilot Bay (Tas) - 1971
NSW Coastal – 1986 - 1992	Brunei coast – 1991-1992

Breakwater/Seawall/Groynes

Banksmeadow Revetment -1970	Lord Howe Island Runway - 1985
Mascot Runway Seawall – 1970	Stockton Beach Revetment - 1989
Cockburn Sound (WA) – 1971	Basin Beach Revetment – 1991
Cape Jervis Ferry harbour (SA) – 1975	Port Kembla Eastern Breakwater - 1992
Port Kembla Coal Loader Revetment – 1977	RPYC Marina Seawall - 1992
Low Head Pilot Boat Harbour (TAS) – 1978	Brunei Seawalls, Islands and Harbour – 1987-1993
Port Macquarie North Wall – 1979	NSW Breakwaters Assessment -1992
Narooma Breakwaters – 1980	Kuwait Revetments and Seawalls - 1993
Mona Vale Seawall – 1983	Jakarta Bay Revetments - 1994
South West Rocks - 1985	Saibai (Torres Strait) Seawalls - 2007

Beach Nourishment

South Cronulla – 1978 – 1979	Brunei – 1992
Jimmy's beach (NSW) – 1984	Sydney Coast 1979 - 1989

Sand Bypassing Studies

Tweed Heads (NSW) - 1989, 1990	Shoalhaven (NSW) - 1974

Oceanic Inundation Studies
Batemans Bay (NSW) - 1987 Pittwater (NSW) - 1991

Shelf Currents Studies
Various Studies on NSW Shelf (Tweed, Coffs, Gosford, Sydney, Illawarra)

Outfall Monitoring/Studies
Sydney (North Head/Bondi/Malabar) (NSW) - 1987-1993
Illawarra (NSW) – 1991
Hong Kong - 1995

Climatic Change
Various research studies and papers on Climatic change;
sea level; coastal erosion; flooding) 1980-Present

Marina Studies
Southport Yacht Club (Qld) - 1991 Royal Prince Alfred YC (NSW)1992,1993, 2007

Water and Sewerage:

Water Supply Design
Nowra, Bomaderry, Greenwall Point, Culburra, Cambewarra, Berry, Jervis Bay (NSW) – 1973
Manly Hydraulics Laboratory (NSW) – 1974, 1987
Jakarta (Indonesia) – 1995

Sewerage Design
Nowra, Bomaderry – 1973
Brisbane Waters Outfall – 1973
Various NSW towns trouble shooting – 1986-1993
Sydney Outfall – 1986
Various NSW Outfalls – 1986-1993
Hong Kong Outfall – 1995-1996

Flood/River Studies
Kempsey (NSW) – 1973
Captains Flat (NSW) – 1974
Woden Valley (ACT) – 1975
Shoalhaven (NSW) – 1975
Narrabeen lakes (NSW) – 1986, 1989, 1991
Manning River (NSW) – 1989
Flood Control North Jakarta (Indonesia) – 1992

Hydraulic Structures
Toonanbar Dam (Iron Pot Creek, NSW) – 1968
Qantas 747 Hanger Fire Fighting Deluge System – 1971
Intake Conduits for Vales Point Extension (NSW) – 1972
Fire Control Valves – 1973
Flat Rock Creek Filtration Plant - 1973
Atomic Power Station Cooling Water Intakes (Jervis Bay NSW) – 1974
Major Stormwater Structure (Turramurra NSW) – 1975
Design and testing of road inlet pits – 1986-1989

Lecturing:

AWACS Short Courses
Climate Change, Coastal Management and Breakwater Design 1987-1993
University of New South Wales
Guest Lecturer Marine Sciences Institute – Coastal Zone Management 1988-1993
Full Time Lecturer School of Civil Engineering – Fluid Mechanics, Water Engineering and Systems Analysis – 1972
Macquarie University
Guest lecturer Climatic Impacts Centre – Climate Change 1990-1993

PUBLISHED PAPERS: ANGUS DONALD GORDON

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Gordon, A.D. (2003) How to Improperly Influence Public Officials, for Fun and Profit or, Towards Best Practice Management of Corruption risk in Local Government, Proceedings 10th Annual Government Fraud and Corruption Conference, Canberra February 2003

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