Deliberations on Private Property Coastal Hazard Line Assessments in NSW and Recent Experience including the Effects of Climate Change (Barlings Beach, Eurobodalla and Boomerang Beach, Great Lakes)

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1. Introduction

A standardised methodology is used for assessing coastal hazard lines (CHLs) in NSW. This involves investigation of existing beach condition, and design storm erosion and shoreline recession for a particular planning period, typically 50 or 100 years. More recently beach rotation has also been considered.

Sea level rise (SLR) due to climate change contributes to shoreline recession. The widely accepted and readily applicable tool for assessing SLR recession is the Bruun Rule. The interpretation of CHLs for building foundation requirements is obtained directly from the Wedge Failure Plane (WFP) model. Aspects of this model are canvassed and guidance offered as to level of geotechnical investigation to assist in describing slope instability hazard.

SLR benchmarks published by DECCW in 2009 significantly exceed SLR values used in coastal assessments in prior years. As a result, CHLs have moved landward by 20 m or more. Properties which previously were assessed to be not at threat, are now affected by CHLs. Thousands of coastal properties in NSW are now considered to be potentially at risk within planning time frames. It is appropriate that the methodology for assessment of CHLs and the implications for building foundations be reviewed and updated as required.

This paper outlines deliberations brought by gbaCOASTAL (GBAC) to private property CHL assessments in NSW. Two recent investigations are cited. Work at Barlings Beach, Batemans Bay, reviewed the methodology for incorporating shoreline recession to treat budget and SLR recession components into the future. The effect of beach rotation and climate change on storm intensities and erosion was also included. Work at Boomerang Beach involved similar considerations, and we briefly refer here to assessment of shoreline recession and the geotechnical investigation.

2. Climate Change Considerations and Erosion and Recession Hazard

The NSW Coastline Management Manual lists 8 coastline hazards to be considered in coastal hazard assessments as follows:

- Beach erosion hazard
- Shoreline recession hazard
- Coastal entrance hazard
- Sand drift hazard
- Coastal inundation hazard

- Slope and cliff instability hazard
- Stormwater erosion hazard
- Hazards of climate change

The procedures to assess these are well established. Its fair to say that while hazards of climate change are listed, the influence of climate on assessment of CHLs is often limited to SLR and Bruun Rule recession. Before the DECCW benchmarks were adopted, the SLR increments used in coastal assessments in NSW were approximately half the benchmark values. Equally important in locating the CHLs, the design life typically applied to individual residential developments was 50 years (eg Gosford, 1990) but more recently Council's are requiring 100 years (eg Pittwater, Eurobodalla and Gosford, 2010). The additional 50 years plus additional say 0.45 m of SLR (50% of the 2100 benchmark increment) has resulted in design CHLs shifting landward by some 20 to 30 m compared to where these may have been mapped less than 10 years ago. This is having a substantial impact on coastal planning and development controls in NSW coast (eg Shoalhaven draft DCP).

In the light of this change, it is of interest to reflect on methodologies applied to assess the key hazards of beach erosion and shoreline recession, checking that they remain consistent with the current state of knowledge and coastal engineering best-practice. Two hazards in particular may warrant a closer consideration:

- Beach erosion hazard
- Shoreline recession hazard

Beach Erosion Hazard

Design beach erosion hazard as it applies today is defined by beach surveys and photogrammetry. If required, adjustments for post-storm recovery are applied. Sometimes 2D beach erosion models are also used.

Gordon (1987) summarises design beach erosion hazard in terms of storm recurrence for different beach types in NSW. Although over 20 years old, this information still captures a large NSW dataset which remains useful and applicable.

With climate change, we learn that weather systems will move and resulting storm waves and storm wave directions will change. CSIRO have investigated the consequences of weather patterns on offshore wave climate, modified by climate change, for Wooli and Batemans Bay (McInnes et al., 2007), and these results can be used to gauge the influence on beach erosion hazard.

Shoreline Recession Hazard

The Bruun Rule is used almost exclusively to predict contribution of SLR to shoreline recession. It is simple, and while shortcomings are highlighted (Ranasinghe et al, 2007), no immediate acceptable alternatives are canvassed by the wider coastal engineering profession. Input parameters for Bruun are limited to SLR and slope of the active coastal profile.

Global sea levels have been rising for at least 140 years (DECCW, 2009). Relative SLR on the NSW coast over the last 100 years has been about 15 - 25 cm, depending on measurement method (You et al., 2009). According to Bruun and applying a typical active profile slope for the NSW coast of 1:50, we should have experienced recession of 7.5 to 15 m over the last 100 years. This may have occurred, but we do not attribute it to SLR recession but rather conventional recession due to sediment budget losses.

Notwithstanding the limitations of Bruun, if we are to apply the Bruun Rule going forward to predict SLR recession to develop CHLs, it is only reasonable that we make due allowance for any SLR recession that should have occurred in the past but has not been attributed to SLR. If we use photogrammetry to develop a finding that a beach is receding by x m/yr in the long term, we should then reduce this to account for the contribution of SLR recession over the period of assessment.

This idea is not new. Coastal engineers would have acknowledged that such a modification to long term recession was reasonable, but chose to neglect the effect and be conservative. This may have been appropriate previously for 50 year planning periods and/or when SLR predictions were substantially less then the current benchmarks. However, for assessments today, where Bruun is applied to predict future SLR recession, it would seem appropriate that the adjustment be included.

3. Slope Instability Hazard

The wedge failure plane (WFP) model, originally developed by Culmann (1866), was further developed and applied to describe slope instability hazard for Collaroy-Narrabeen Beach in 1991by Coffey Partners and Geomarine. Its general application to coastal hazard assessment was reported the following year (Nielsen et al, 1992). While the WFP model is not referenced specifically in the Coastline Management Manual (it was then only recently developed), its application today to coastal hazard assessments in NSW continues and is endorsed by DECCW.

The WFP model describes the various slope instability zones that apply at the back of the beach and into the dune. These include the Zone of Slope Adjustment (ZSA), Zone of Reduced Foundation Capacity (ZRFC) and Stable Foundation Zone (SFZ). The model assumes a homogenous sand profile extending down to at least 1 m below mean sea level (approximately RL -1 m AHD), the minimum level at which sand is assumed to scour or fluidise at the back of a beach berm in a severe storm event. Water table effects and surcharge loading at ground level are disregarded in the model. A Factor of Safety of 1.5 is applied to describe the landward extend of the ZRFC.

To apply the WFP model a judgement is made as to a suitable residual angle of friction for the sand. Typically values between 30 and 35 degrees are adopted in NSW.

It may be conservative to assume that the stratigraphic profile fully comprises beach and dune sand. If the sand is dense or if overconsolidated clay layers or bedrock occur, then the instability zones as described in the WFP model are likely to translate seaward. However, there is some effort involved in progressing from a direct application of the WFP model to a dedicated geotechnical investigation. At least one borehole would be required on or near the site to confirm the presence of bedrock. Less costly penetration tests would assist to describe a stratigraphic model, but without the same level of confidence. A typical cost for geotechnical site investigations covering a residential site might vary between say $5,000 and $20,000 depending on a number of factors including location, site size and access, scope of site investigations, laboratory testing and slope stability computer modelling.

If a site is significantly encumbered by slope instability hazard but bedrock protrudes nearby, then drilling a borehole may be justified. Geotechnical information from drilling will permit a refined foundation design, particularly if this involves deep foundations.

The following may be used to guide the appropriate level of geotechnical assessment for describing slope instability hazard:

1. In homogenous sands with no seepage of groundwater, slip circle slope stability computer modelling is not required. The minimum FOS for a failure surface through the toe of the slope will always be a linear filure plane (2D simulation) as defined in the wedge failure plane (WFP) model reported in Nielsen et al. (1992).

2. For a subsurface comprising stratified horizons of homogenous sands, the minimum FOS for a failure surface through the toe of the slope can be represented by a compilation of straight lines (2D simulation) as defined in the WFP Model.

3. Realistic assumptions can be made as to the angle of friction of the sands for use in the WFP Model.

4. A geotechnical investigation may be required to confirm the composition and homogeneity of the subsurface materials, and the groundwater conditions. This investigation is likely to include penetration testing (eg DCPs) and possibly test pits and boreholes.

5. Slope stability modelling should be carried out to define the slope instability zones where geotechnical investigations encounter subsurface materials other than homogenous sands. Such modelling should comprise both circular and non-circular failure surfaces.

6. A scour resistant horizon located above RL-1m AHD, landward of the toe of the slope, may result in a seaward translation of the Zone of Reduced Foundation Capacity. Confirmation of the location of any such scour resistant horizon is likely to require subsurface geotechnical investigation.

4. Case Studies

We cite two recent GBAC investigations which have involved some of the above concepts:

- Barlings Beach (Eurobodalla)
- Boomerang Beach (Great Lakes)

Barlings Beach (Eurobodalla)

Background

A residential subdivision is being developed at Barlings Beach, Batemans Bay on the NSW South Coast. Approximately 1 km in length, the beach faces S/SSE and enjoys protection by prominent headlands and an offshore reef (**Figure 1**). Initial coastal engineering assessments to describe the coastal hazard for the subdivision were undertaken in 2005 and 2009. In 2009, Eurobodalla Shire Council requested further information from the developer, particularly in relation to the effects of climate change. GBAC was retained to address the additional requirements and develop refined maps for the 2050 and 2100 CHLs.

Effect of Climate Change on Design Storm Erosion

Additional information was sought by Council on the effect of climate change on design storm erosion. To gauge this effect, erosion demand trends reported for the NSW coast by Gordon (1987) were extrapolated for predicted increases in offshore wave height.

McInnes et al (2007) reported that for storms from the S to SE at Batemans Bay, maximum Hs is predicted to increase by up to 11% by 2030 and up to 32% by 2070. Having regard to the broad trends indicated by these results and for the purposes of this advice, GBAC adopted increases in storm Hs of 20% by 2050 and 50% by 2100. The change in predicted storm recurrence associated with the increased Hs was then used to estimated increased erosion demand from Gordon's 1987 dataset (**Figure 2)**.

Assessment of Slope of Active Coastal Profile for application of Bruun Rule

As prescribed by Council, the DECCW SLR benchmarks were adopted. A combination of seabed profile survey and accepted analytical techniques (Hallermeier, 1978) were used to select closure depth to apply Bruun.

Figure 1 – Barlings Beach Study Area

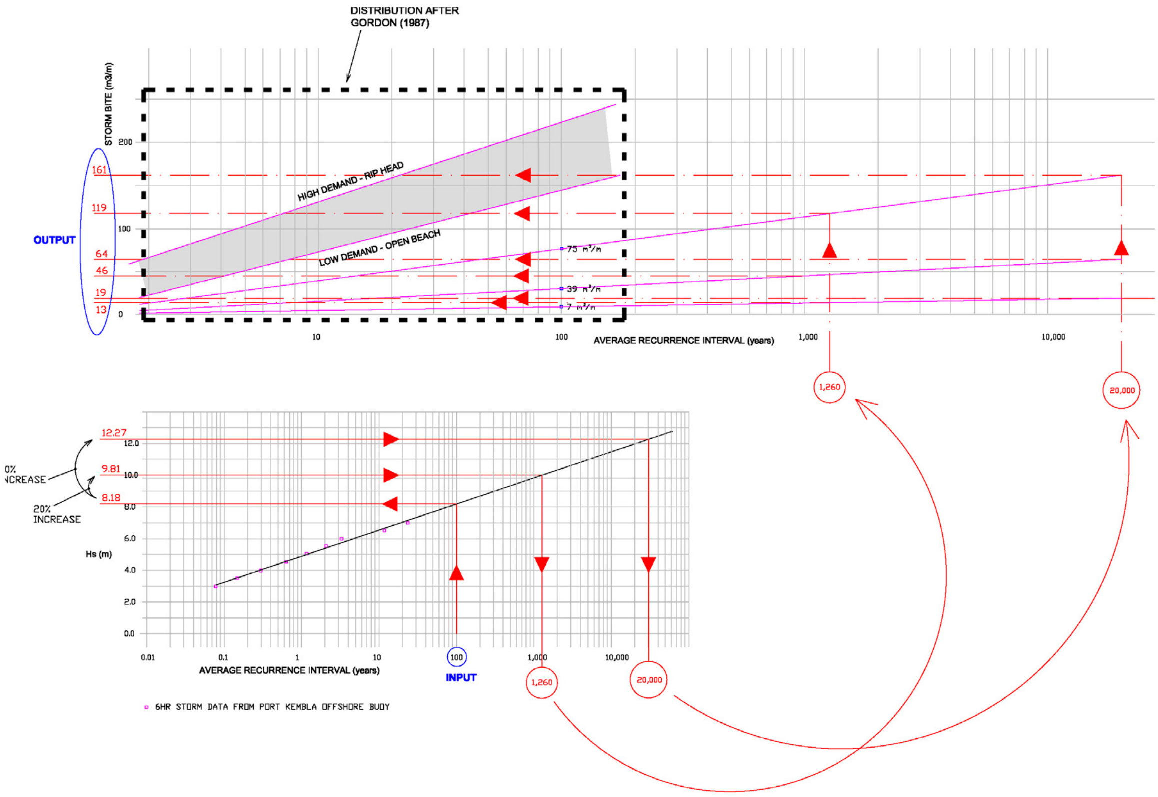

Figure 2 – Influence of Increased Hs on Storm Bite as a Consequence of Climate Change

A discontinuity in bed slope off Barlings Beach is evident from survey at a mean tide depth of between 5 and 8.5 m. This is interpreted as the nominal interface between the inner and outer nearshore zone. The annual depth of closure as defined by Hallermeier is 10.3 m below MSL. For want of a reasonable interpretation of these results, the depths from the two procedures were simply averaged yielding an active profile slope of 1:40 which was applied to the relevant western and central parts of the beach.

Base Date Correction for Design SLR

The base date for the CHL assessment was 2010. It followed then that design SLR recession values relative to 1990 needed to be reduced to account for the SLR that had taken place over the intervening 20 years. Having regard to recent analyses of long-term water level records for Sydney Harbour (You et al, 2009), 1 mm/yr was applied.

Correction of Sediment Budget Recession Rates Going Forward

When applying sediment budget recession rates going forward to generate future CHLs, it is appropriate to make a correction to account for the contribution of SLR recession to the calculation of sediment budget recession. If not done, then the SLR recession is effectively double-counted into the future. Accordingly, we find that Barlings Beach is not undergoing sediment budget recession, but rather is stable or accreting. This outcome is reasonably common for compartmentalised NSW beaches, many of which are found on the NSW South Coast.

Precautionary Allowance for Beach Rotation

A precautionary allowance for beach rotation was also adopted, based on NSW experience at other compartmentalised beaches.

Ranasinghe et al (2004), and Short and Trembanis (2004) have reported on a decadal scale pattern in beach rotation correlated to the Southern Oscillation Index (SOI). In simple terms, the beach alignment pendulates in response to slight changes in wave direction as a consequence of SOI shifts in the location of weather systems. Beach rotation manifests in alternating and opposite erosion / accretion cycles at the ends of the beach, with the centre of the beach acting as the fulcrum and remaining stable.

Based on available information for the NSW coast, a 9 m swing over a beach length of 1 km was adopted for Barlings Beach representing a rotation of 0.5 degree. We concede that the applicability of SOI rotation to Barlings Beach which faces SSE is uncertain but chose to include this nonetheless as a precaution. It is surmised that because the beach is well shielded from the ENE to NE waves that drive the El Nino component of the process, beach rotation may be largely irrelevant at this site.

Refined Assessment of CHLs

The refined but suitably conservative assessment confirmed and that the seaward boundary of the proposed subdivision was well landward of the 2100 ZRFC. At its most critical location, the subdivision was assessed to encroach no closer than 27 m from the 2100 ZRFC (**Figures 3** and **4**)

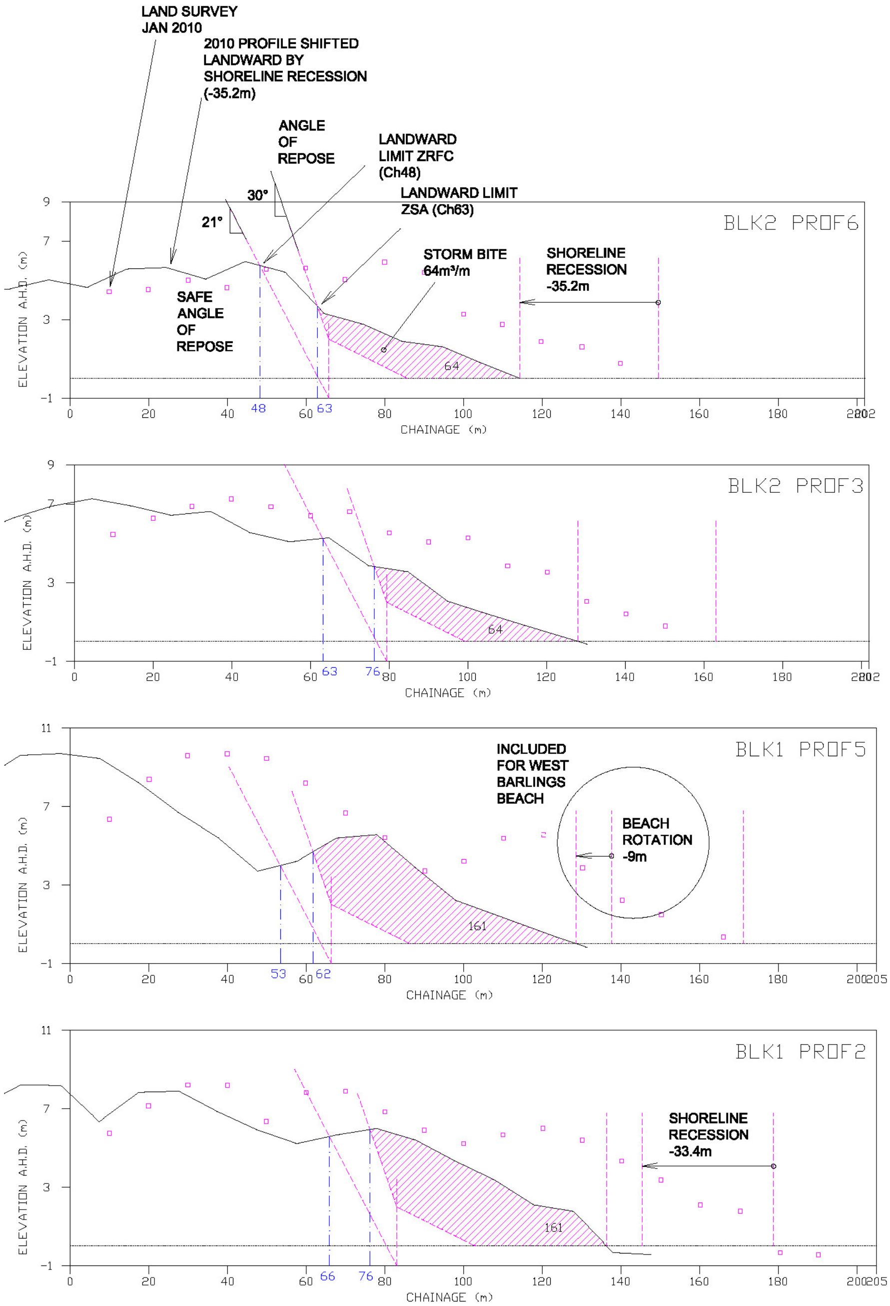

Figure 3 – 2100 Hazard Line Assessment

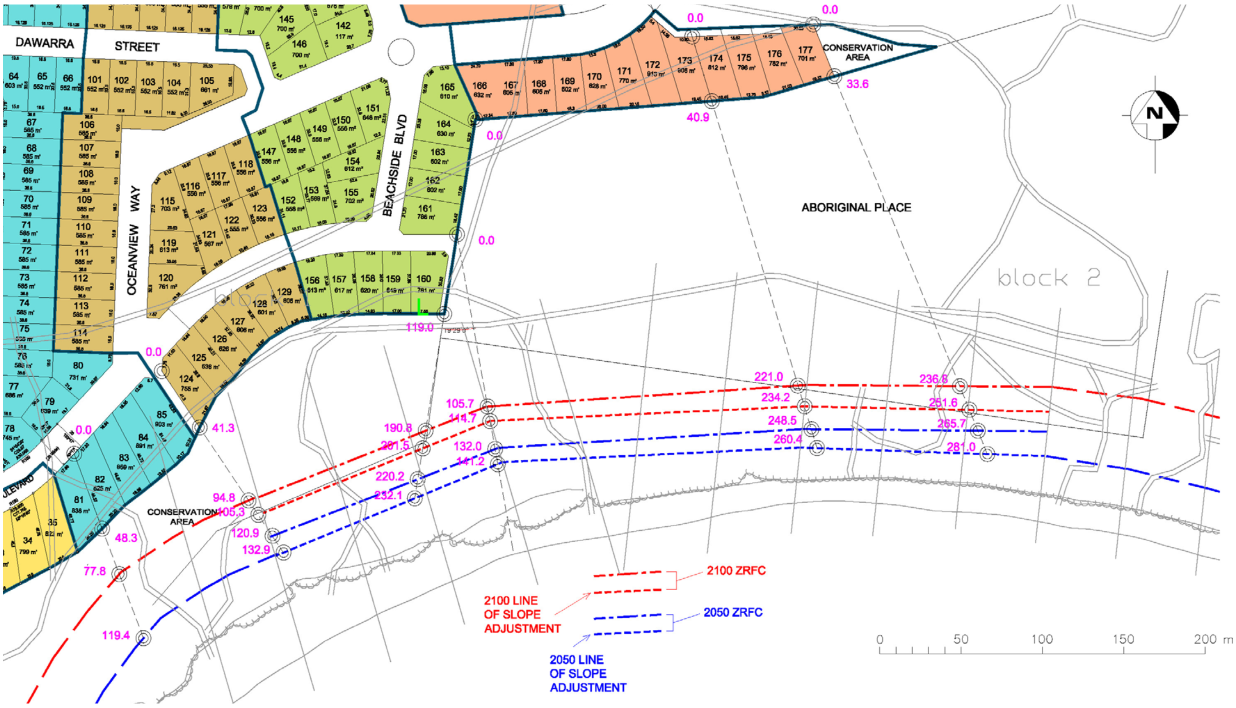

Figure 4 – Refined Assessment of CHLs, Barlings Beach

Boomerang Beach (Great Lakes)

Background

It was proposed to redevelop an existing private residential cottage at the southern end of Boomerang Beach, NSW Mid North Coast (**Figure 5**). The work was to entail extensive modifications to the building, plus a new two story addition on the landward side. To best take advantage of planning controls, the ground floor slab of the cottage was to be preserved. A coastal engineering assessment was required to address particular concerns raised by Great Lakes Council (GLC).

GBAC in association with Jeffery & Katauskas (J&K), Geotechnical Engineers, were retained by the property owner. A planning period of 50 years (planning date 2060) was prescribed by GLC and adopted for assessment. The assessment identified a range of relevant hazards for consideration including shoreline recession, slope instability, and hazards of climate change.

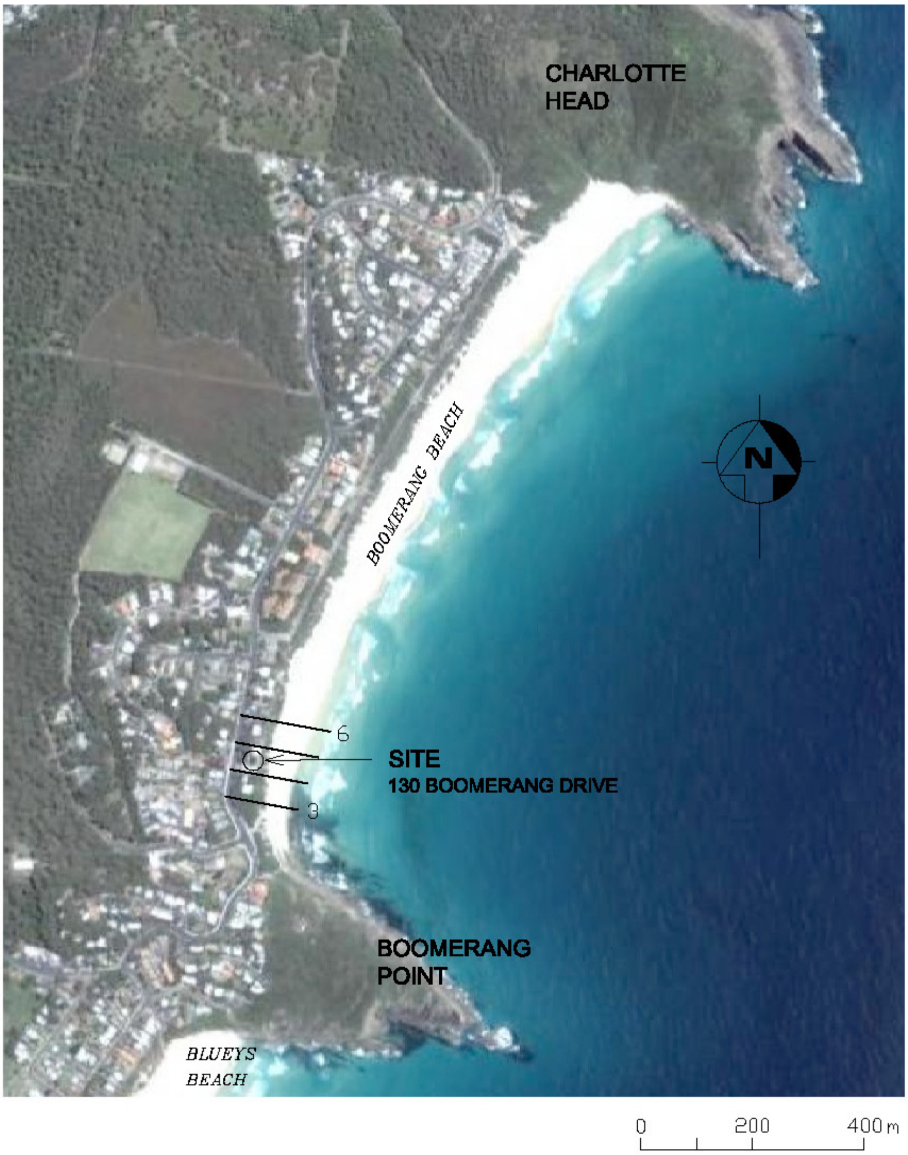

Figure 5 – Boomerang Beach Study Area

Shoreline Recession

Sediment Budget Recession

PWD (1985) adopted a long term recession rate of 0.3 m/yr for Boomerang Beach, based on aerial photogrammetry covering the period 1956 to 1981. However, no recession was discerned in the southern portion of the beach. This was relevant for the subject site. Updated photogrammetry provided by DECCW has confirmed that no long-term recession is occurring at the beach in the vicinity of the property (**Figures 5** and **6**).

The question was posed by Council as to whether previous sand mining activities may have influenced the longer term stability of southern Boomerang Beach: could it be that

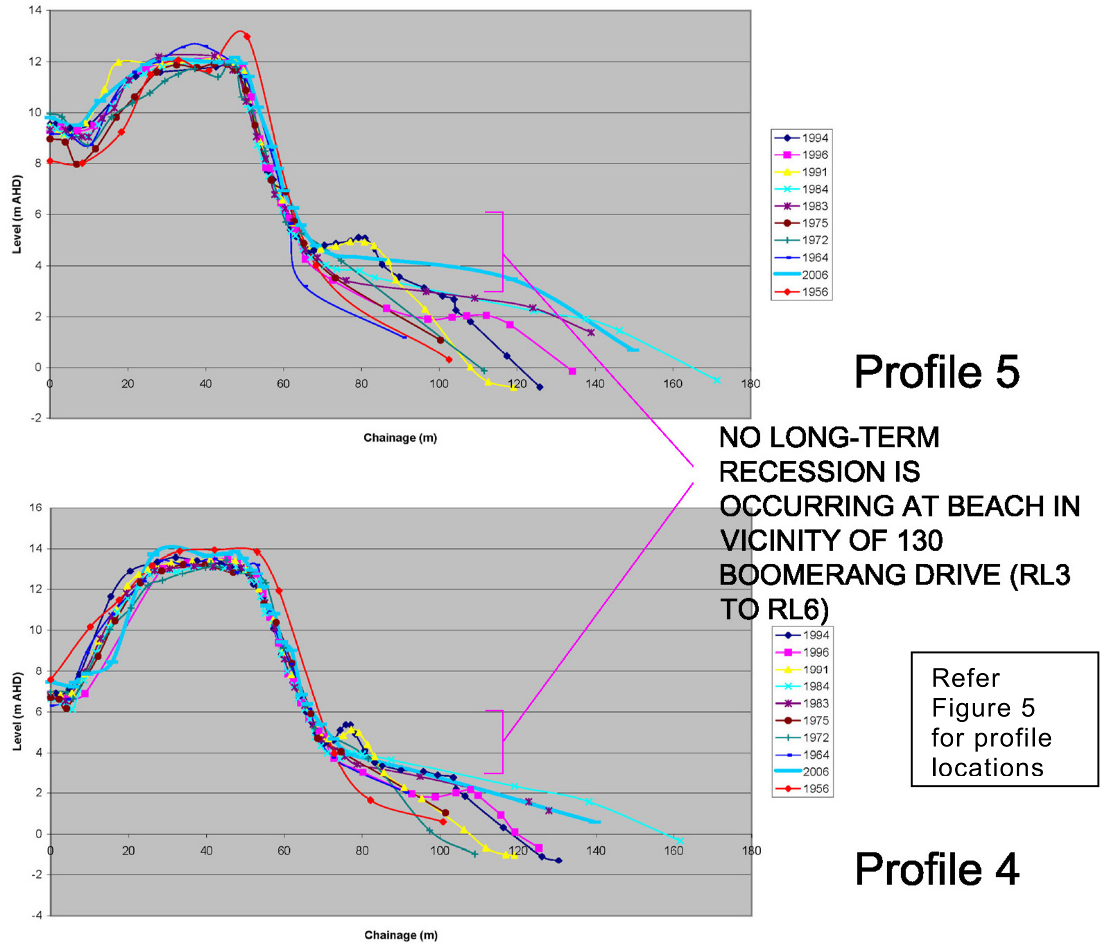

Figure 6 – Extract from Updated Photogrammetry, Source: DECCW

the beach here was not receding because sand has been removed by mining and natural recession processes were "still playing catch up"? (Geoff Dowling, GLC, pers comm).

We considered that this unlikely, for two reasons:

(i) Sand mining at Boomerang Beach commenced in July 1970 at the northern end of the beach and tracked southwards along the dune. The mining terminated in January 1972 some 300 m north of the subject property. While we accepted that beach profile readjustment would extend alongshore from the location of mining activities, the mining was nonetheless well removed from the site.

(ii) Only heavy minerals (rutile and zircon) were mined at Boomerang Beach. As this type of mining typically removes less than 1% by volume of the material within the dune, the sediment budget and morphological response would be insignificant.

For these reasons a zero long-term sediment budget recession rate was adopted for the site.

SLR Recession

The adopted design SLR was 0.50 m between 1990 and 2060. This is consistent with the DECCW SLR benchmark recommendations.

For the reasons described above, we gauged SLR recession as the difference between Gross SLR Recession and SLR Recession Adjustment.

(a) *Gross SLR Recession*

In accordance with Bruun, the predicted SLR recession for the site was 19.6 m (0.50 x 39). The calculation adopted a slope for the active coastal profile of 1:39 based on a seaward limit located at the interface between inner nearshore sands and outer nearshore sands, and a landward limit located at the crest of the dune.

(b) *SLR Recession Adjustment*

There is compelling evidence that the relative sea level has risen at Boomerang Beach over the past century, but shoreline recession is not observed in the vicinity of the site. It follows that if future shoreline recession due to SLR using Bruun is to be incorporated into an assessment of CHLs, this assessment should reasonably make allowance for the process(es) whereby the contemporary antecedent SLR has not led to recession.

The precise reason why we observe no recession is not clear. It could be that the beach is in fact accreting in the longer term and that the expected SLR recession not observed over the period of photogrammetry (60 years) is masked by this accretion. Alternatively, the temporal linkage between SLR and recession could be relatively slow compared to the nominal 50 to 100 year development planning periods being considered. Whatever the reason, it seems only fair and reasonable to be allowing for this outcome when prescribing SLR recession over comparable periods going forward.

The adopted SLR recession adjustment allowed for 84 mm of SLR over the period 1990 to 2060, equating to 3.3 m (0.084 x 39).

(c) *Net Design SLR Recession*

Net design SLR recession at the site was assessed as the gross SLR recession, less the SLR recession adjustment, ie 19.6 m less 3.3 m = 16.3 m.

Geotechnical Investigation and Foundation Design

The proximity of the dwelling to the crest of the dune and the requirements for foundation design were important for this site. A letter was provided from the then NSW Department of Natural Resources (DNR) to GLC in regard to another residential development at Boomerang Dive (August 2006). This letter indicated that application of the WFP Model may be regarded as a starting point to determine foundation design in active dunal systems, and may then be refined through site specific geotechnical studies. It was considered that the same approach would reasonably apply at the subject property.

Coastal process investigations reported in PWD (1985) included a photograph taken in June 1978 showing what appeared to be a lag deposit of cobble sized material towards the southern end of the beach. It was of interest to check whether this deposit may present as a scour resistant horizon beneath the site or its fronting dune and back beach (**Figure 7**).

Figure 7 – Storm erosion at Boomerang Beach (June 1978)
Source: PWD 1985

A single borehole was drilled at RL 13 m AHD to a depth of 17.5 m on the landward side of the existing cottage. SPT tests were included with the drilling, and five DCP tests to depths of 4 to 5 m were completed on the face of the dune and at the back of the beach.

The site investigation revealed a subsurface profile comprising wind blown sand and silty sand overlying sandy soils of increasing density with depth. Friction angles for the sands were interpreted to range between 29 degrees in the loose surface materials, to 35 degrees in the dense sands below RL -1.5. No scour resistant materials were found in the profile. Seepage in the borehole was noted at a depth of about 11.5 m, and the groundwater level was measured at RL 0.9 m AHD, 18 hrs after completion of drilling.

The geotechnical investigation included slip circle slope stability analyses, although in retrospect this may not have been necessary for this site.

It was found that the existing cottage was located in the Zone of Reduced Foundation Capacity (ZRFC) with the majority of the proposed additions in the Stable Foundation Zone (SFZ). While parts of the redevelopment were located in the SFZ, to limit differential settlements piled footings into the SFZ were recommended throughout.

5. Acknowledgements

gbaCOASTAL would like to acknowledge Mr Peter Wright from Jeffery & Katauskas and Mr Lex Nielsen from AECOM for their insights regarding slope instability hazard and the application of the WFP model.

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