Review of
Draft Great Lakes CZMP
and
Risk of Sea Level Rise upon Dune Stability and the surrounding Hinterland at Boomerang and Blueys Beaches, Pacific Palms, NSW

For

Boomerang & Blueys Residents Group Inc.

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1.0 Introduction

Great Lakes Council is seeking public review and comments for the draft Coastal Zone Management Plans (CZMP) for all the beaches under Council care and control.

This report has been prepared as an independent expert review in the field of coastal management to assist the Boomerang & Blueys Residents Group Inc. and is a technical review of the science underpinning the draft Great Lakes CZMP and supporting documents.

The comments are based on my experience of over 30yrs practicing as a coastal engineer with specific experience relevant to this review:

- Preparation and implementation of Coastal Zone Management Plans
- Developing and implementing site specific options and integrated strategies for beach and beachfront property protection.
- Developing sea level mitigation and adaption strategies (since mid-1980s).

My comments on the draft Coastal Zone Management Plans (CZMP) and supporting documents are detailed in sections 2 and 3 of this report.

In summary, from the data available in the draft CZMP and supporting documents with more recent regional sea level rise projections and photogrammetry, I cannot support the hazard assessments applied to Boomerang and Blueys Beaches in the draft CZMP and assess the situation as follows:

- Boomerang and Blueys Beaches are embayed beaches supplied with sand from updrift beaches located between large rock headlands backed by high dunes that have been slowly accreting despite sea level rise to date and the recent stormy period.

- Updating the Hazard Definition Study (WP 2011) calculations with more recent regional sea level data and up to date site data indicates that these beaches have a more than adequate buffer seaward of all properties and roads to accommodate the design storm cut and estimated recession due to sea level rise in the planning period to 2060 (and beyond).

- In the long term, the embayment, sand inflow and high dunes of these beaches provide model beaches for a range of mitigation measures that can be applied to protect them into the future against sea level rise.

- A CZMP is an important long term planning document based on a sequential process that relies on a number of technical and other studies. Each study is a critical component and needs to be based on adequate data to produce results that are supported by adequate evidence to achieve acceptance by the public through adequate public information, education and consultation. Unfortunately, the process has been compromised by a lack of critical data as identified in the 2011 Hazard Definition Study that was not obtained before proceeding with the subsequent options study and the draft CZMP. Further, the base data used in the Hazard Definition Study was not updated to 2015. A critical score card of key issues indicates issues that still need to be resolved (Table 1).

Table 1 CZMP scorecard

Component	Critical Assessment	Comments
Public Consultation	Inadequate / fast tracked	Some comments have been addressed from previous public consultation but they are important and complex documents that need a high level of public comprehension and support. The consultation timeframes and overlaps due to fast tracking have made effective public comprehension and response difficult.
Critical data	Inadequate and not up to date	The additional critical data recommended in the 2011 Hazard Definition Study was not obtained and / or used. The latest photogrammetry has not been used The lateset SLR data and studies have not been used.
Methodology	Over pre-cautionary	Very cautious assumptions have been applied to each of key inputs into hazard evaluation resulting in a cumulative exageration of the potential hazard levels. Key inputs and assumptions: - past accretionary trend with past SLR; discounted - potential storm cut; set at max level - sea level rise projections; much higher than other councils & latest studies would support .
Flexibility to adjust to changes	Needs improvement	Some improvement from original draft and regular updates have been specified

- The Hazard Definition Study needs to be updated with more data before the subsequent steps of hazard line plotting, options studies, LEP updates, DCP revisions and trigger levels can be undertaken. Given the low hazards on evaluation of present evidence there is time for data collection and monitoring programmes to be implemented with community involvement and education to provide a more adequate data base to update the Hazard Definition Study. A preliminary CZMP can be implemented that focuses on monitoring and data collection to update the coastal processes and hazard evaluations.

2.0 General Comments on draft CZMP for Boomerang and Blueys Beaches

My general concerns with the present CZMP and supporting documents are:

- This draft CZMP report (WBM 2015) has combined a number of steps in the NSW CZMP process. This has fast tracked the process without some critical data and full community input.

- The Hazard Definition Study (WP 2011) identified gaps in the data and recommended collation of additional data that was considered critical for informed decisions. The hazard lines from this study were modified at the ends of each embayment at the rocky headlands using additional geotechnical data (WBM 2014) but otherwise the draft CZMP remains reliant on an inadequate data base and very cautious assumptions. Recommended extra data collation in the Hazard Definition Study included the following (none of which has been used to update the 2011 study):
    - Directional wave data at Crowdy Head.
    - Repeat bathymetric surveys of the surf zone of Boomerang Beach and Blueys Beach.
    - Ongoing aerial photography and subsequent photogrammetry profiling and analysis.

- Beach profiles used in the Hazard Identification Study are from photogrammetry of the upper beach above 0m only. This data does not show the full sediment budget in the active beach profile that extends seaward to at least -15m and hence the recommendation in the Hazard Definition Study to obtain "*repeat bathymetric surveys of the surf zone".*

- Beach profiles used in the Hazard Identification Study do not include profiles after 2006.

- The assumption in the Hazard Identification Study of no accretion is over- precautionary. The data from 2006 to 2013 records continues to show an ongoing trend of volume and shoreline position progradation from both the 1954 and 1975 baseline positions despite erosion conditions and ongoing sea level rises during this period.

- Long term accretionary trend is evident even using the when using the arbitrarily and conservative upper limit of the +3m contour. The photogrammetry profiles indicate that a higher contour than the 3m contour would be more appropriate and, if a higher contour is used, a much stronger accretionary trend is evident by both volumetric and position analysis.

- The estimates of sea level rise (SLR) in the Hazard Identification Study are global predictions not evidence based regional SLR data.

- The draft Management Options Study (WBM 2015a) is inadequate for fully informed decision making of any future works as:

    - It is based on the Hazard Definition Study that requires review and in turn the options study will require review. After review it will need to investigate mitigation and adaption strategies involving various elements.
    - It has not investigated site specific solutions as did the separate CZMP for Jimmys Beach (SMEC, 2013)
    - It has not been subjected to a separate public consultation process.
    - Financial costings used have been very general and not site specific. Maintenance costs appear very high compared to experience.
    - The evaluation of the options has not included a quantitative benefit – cost analysis.

- Re actions arising from trigger points; Page v notes that "*Further discussion with the community (both foreshore residents and the wider population) is needed before an appropriate approach*

can be decided." However, the draft DCP also on display for public consultation allows for conditions to be set for removal of dwellings if a trigger point is reached. At this stage, without adequate and up to date data, trigger points cannot be set.

- Re community involvement; the process is outlined on Pages iii, viii and 13 but the process has not allowed adequate time for community understanding of complicated issues and the online surveys have not been tied well to the study.

3.0 Specific comments on draft CZMP for Boomerang and Blueys Beaches

Hazards: The draft CZMP identifies the southernmost 11 lots at south Boomerang Beach as being Extreme or High Erosion / Recession Risk at present and a further 2 more lots at south Boomerang and 9 lots on Blueys by 2060. There is no record in any reports of any historical threat to houses or property along Blueys or Boomerang Beaches and there is no evidence in the photogrammetry records 1956 to 2013 (57 years). Thus, the hazard assessment appears very conservative and is contra-indicated by the long term past health and stability of these beaches that are embayed between two large headlands with high dunes providing buffer and elevation to the properties (Figure 1). The adequate buffer to storm cut was evidenced during the recent April 2015 storms that did not cause any significant erosion to Blueys or Boomerang Beaches with the storm cut accommodated seaward of the dune vegetation (Figure 2).

Figure 1; Blueys Beach and Boomerang Beach embayments

Figure 2; Blueys Beach (L) and Boomerang Beach (R) on 21/4/2015. Wave run up to dunes but no significant storm cut.

Hazard lines; The hazard lines used in the draft CZMP were determined in the Hazard Definition Study. The hazards examined in that report are generally those set out in the NSW Government's Coastline Management Manual (1990), as listed below:

- beach erosion;
- shoreline recession;
  - sediment loss
  - sea level rise
- sand drift;
- coastal inundation;
- stormwater erosion;
- slope instability; and
- climate change.

The hazard lines were estimated by adding the immediate beach erosion hazard extent (storm cut) to the shoreline recession / accretion allowances (long term sediment loss / gain and SLR impacts). For any hazard lines to be reasonable, all these components need to be estimated as accurately as possible with adequate data.

The Hazard Definition Study (2011) estimated a 22m recession due to SLR on top of the 250m^3/m storm cut from the mean profile by 2060. The methodology used for the sea level rise impacts assessment was very precautionary in each step, resulting in an extremely conservative assessment of the potential hazard lines. Without understating the long term risks of sea level rise but given that sea levels and their impacts will be gradual and that more data and mitigation strategies will become available and that the CZMP will be updated regularly, a more pragmatic scientific approach that uses more site specific analysis for the south Boomerang and south Blueys is considered reasonable. Gordon (2014) addressed the complexity of the problem and the pitfalls of being over-precautionary for each individual component of calculating impacts:

> "*Coastal shorelines are naturally ambulatory; an uncertain future climate only adds complexity. Development involving public and private assets and infrastructure should be risk managed to accommodate the ambulatory nature of the coast yet balance it against the communities desire to "enjoy" usage and beneficial occupation of areas of the coast that may be under present and/or future threats.*
> *Historically the approach taken to obtain "coastal hazard lines" has been scientifically conservative, arguably too conservative because of the tendency for direct addition of individual components which, in themselves, have each been conservatively assessed using the more extreme values of threat.*

This has been driven by the traditionally approach to coastal zone management that has tended to focus mainly on risk avoidance of natural processes and their associated threats.
However the coastal region involves complex interactions, leading to contradictions regarding outcome objectives for natural systems and processes, communities' desires, economic drivers and State strategic planning. Hence the traditional approach has tended to generate outcomes that are not economically palatable nor socially or politically acceptable. This has frustrated many attempts to develop and implement coastal zone management plans. A more sophisticated approach of a layered risk management matrix is required in order to allow all the elements of the decision making process to be expressed and considered in a structured manner.
What is required is a pragmatic approach to planning and management of coastal regions that balances the potential vulnerability of an area against socio-economic and environmental outcome objectives and recognises that "legacy" areas need to be treated differently from "green field" sites. To be workable the outcome also must be a product that is useful and meaningful to planners, regulators and the community and is in keeping with the long-term strategic objectives of the State."

Immediate beach erosion hazard extent (storm cut); A theoretical storm cut of 250m^3/m was used for the <u>whole lengths</u> of Boomerang and Blueys beaches. From the photogrammetry profiles, this is very high for the southern sections of Boomerang and Blueys beaches. The 250m^3/m was based on analysis of the impacts of the 1974 storms along the NSW coast (Gordon 1987). The 1975 profiles clearly show the 1974 erosion scarp as a severe event and it is considered that it would be more appropriate to use the actual 1974 scarp location as the evidence based design erosion event than a theoretical 250m^3/m from the mean of all the profiles. The 1956 cut appears that it may have been slightly worse but the accuracy of the older photogrammetry is not considered accurate and the use of the 1974 scarp is reasonable given the accretionary trend identified in the Hazard Identification Study..

Using the 1974 storm cut as the immediate hazard moves the immediate storm hazard zone to seaward of residential properties. This was also of the finding of Blumberg (2010) in a published conference technical paper reporting on detailed site specific investigations of a dwelling at south Boomerang beach.

Long term net sediment loss / gain; The draft CZMP relied on analysis in the Hazard Definition Study of the upper beach profiles above 0.0m from photogrammetry 1956 – 2006. The Hazard Definition Study found accretionary trends using 2 methods, upper beach volume and dune position, for both Boomerang and Blueys beaches but as a "precautionary approach" assumed these beaches to be stable.

Comments on methodology in the Hazard Definition Study:

- 0.0m was used as the base only because this is the lower limit of the photogrammetry.
- 3m was chosen as a certain "cut" level through the foredune as the upper limit of calculations without clear technical reasoning
- The 2006 data used was 9 years old.

The volumes changes above 0.0m are not a very accurate method of determining long-term changes as large volumes of sand move from the upper beach to nearshore bars during erosion events and return in mild weather, not being lost from the active system. Without full profiles across the active zone, dune position changes are a better indicator of shoreline change over the long period of photogrammetry records and other historical erosion event data including the recent April 2015 erosion event.

The draft CZMP has not added the latest 2013 photogrammetry available. Adding the 2013 profiles adds "eroded condition" data points after the stormy period 2006 – 2013. The total upper beach volumes above 0.0m are reduced but the trend lines (volume and dune position) are still accretionary. Even if the beaches are considered conservatively to be "stable" this indicates that there still has been an accretionary trend sufficient to offset SLR to date. Given the complexity and limited time, we have focused on South Boomerang Beach as an example as this area was designated as high immediate risk

in the draft CZMP. Looking at the 2013 photogrammetry for this area there has still been a volume increase since both 1956 (first record) and 1975 (post sand mining) baselines. More significantly, as volumes above 0.0m only tell a part of the story, the +3m contour along South Boomerang Beach in 2013 has moved about 10m seaward using both baselines. If we take a higher contour, about 4 to 5m, as I believe is appropriate, the long term accretionary gains are even more evident.

Sea Level Rise; The assumptions for sea level rises are critical inputs in the hazard assessment process [WP2011 4.9.1 and 7]. SLR at a global level is a complex issue and even more complex at a regional levels where regional sea level dynamics and relative land movements modify the global averages.

The draft CZMP (1.5.1.1) states that:

"The NSW Sea Level Rise Policy Statement 2009 was repealed in September 2012. This means that prescribed state-wide sea level rise benchmarks no longer apply to coastal hazard assessments, such as this CZMP. The NSW Government indicated that local councils "have the flexibility to determine their own sea level rise projections to suit their local conditions" (NSW Environment and Heritage, 2012), although it is unclear if or how local councils may be equipped to do this. In lieu of prescriptive sea level rise benchmarks, the Office of Environment and Heritage (OEH) suggest that councils should adopt sea level rise values that are "widely accepted by competent scientific opinion" (OEH, 2013).

At the time of preparation of the hazards studies for this CZMP, the sea level rise projections that were 'widely accepted by competent scientific opinion' were that given by the former Sea Level Rise Policy Statement, being 0.4 m and 0.9 m rise above 1990 mean sea level by 2050 and 2100, respectively. These projections were based upon the latest reports by the IPCC (2007) and CSIRO (2007) available at that time. The NSW Chief Scientist and Engineer (2012) assessed the former NSW Sea Level Rise Policy Statement levels and advised that the science informing the policy levels was adequate. In 2010, Council adopted the Sea Level Rise Policy Statement benchmarks of 0.4 m and 0.9 m rise above 1990 mean sea level by 2050 and 2100, respectively.

The global projections for sea level rise are largely unchanged between the IPCC (2007) and the most recent IPCC report in 2014. The CSIRO also released new regional projections for Australia in 2015, including the east coast. These projections suggest a 'likely' range for sea level rise of 0.45 to 0.88m by 2090 for the highest emission scenario (and along which sea level rise is currently tracking). The minor discrepancy between the sea level rise projections adopted in the hazard studies supporting this CZMP and the latest projections is unlikely to substantially affect the actions prescribed in this CZMP for the next 5-10 years. At the next update for this CZMP, any revisions to sea level rise projections will be incorporated into the hazard estimates at that time."

2014 IPCC Assessment Report (AR5) had improved treatment of regional information and atlas of Global and Regional Climate Projections. There is no single prediction of SLR and AR5 made extensive use of model projections based on four greenhouse gas representative concentration pathways (RCPs) intended to span a broad range of plausible future greenhouse gas scenarios with RCP2.6 designed to meet goal of less than 2°C warming from pre-industrial by 2100. Looking at the projections in the AR5 the 0.4m value for 2050 seems too high (Figure 2).

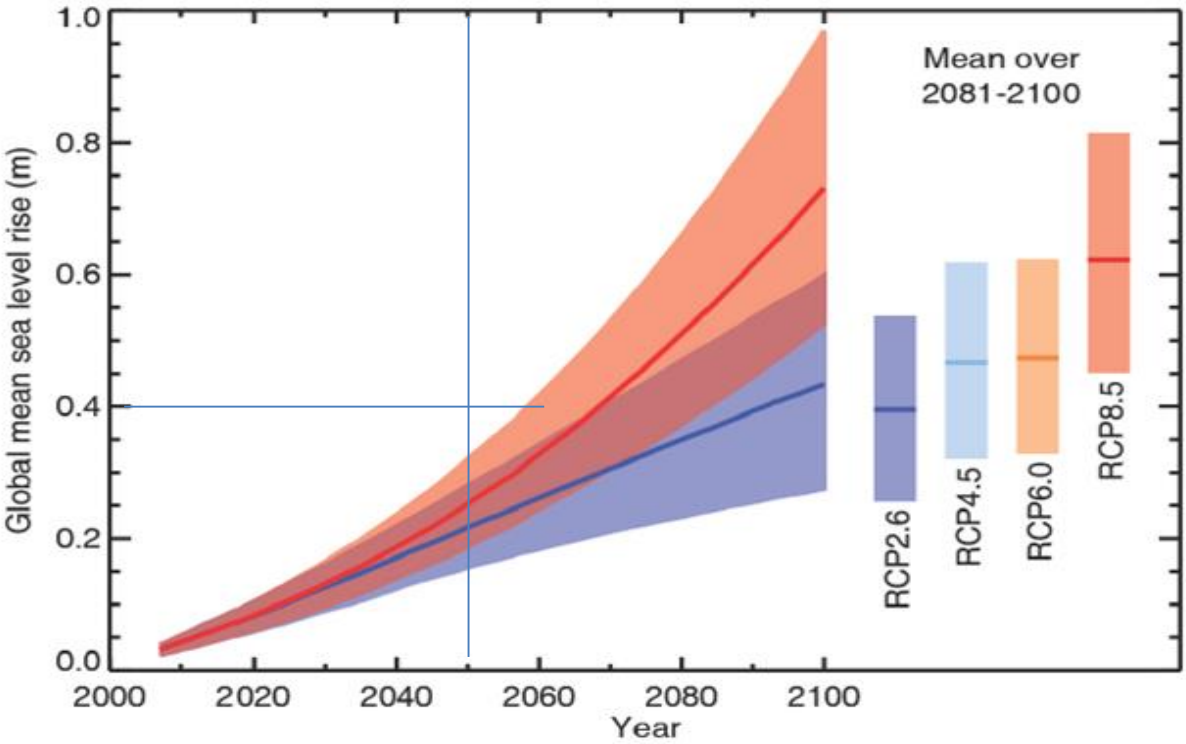

Figure 2 Global SLR projections from IPCC AR5 with 2050 / 0.4m superimposed.

The NSW approach is difficult for Councils to develop their own SLR projections widely accepted by competent scientific opinion and in 2014 Shoalhaven City Council and Eurobodalla Shire Council commissioned a joint study to develop a consistent planning framework for sea level rise (Whitehead and Assoc. October 2014). This lead to adoption by the Councils of the SLR estimates for 2015 - 2050 of 0.23m, the upper values of RCP6.0 as per Figure 3. Gosford has adopted the median value of RCP8.5 giving a similar, but slightly lower value of 0.2m.

SLR and its impacts will be very slow. In order to successfully implement a SLR policy, a reasonable level needs to be adopted that does not prematurely or unnecessarily stifle the use of coastal land. After the adoption of its SLR levels by Shoalhaven City Council, a Councillor was reported as saying that *"the higher level you adopt, the more properties become impacted and the higher potential (there is), upon sale of their property, to have their certificate notated 'subject to tidal inundation', which would eventually have an impact on both insurability and valuation,*" and that "*the seven-year revision clause was crucial*". This approach has enabled adoption of a SLR planning policy that will be revised on at least a 7 yearly basis.

SHOALHAVEN **EUROBODALLA** **GOSFORD**

Year	RCP2.6			RCP4.5			RCP6.0			RCP8.5		
	Low	Middle	High	Low	Middle	High	Low	Middle	High	Low	Middle	High
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	0.02	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.03
2030	0.05	0.07	0.10	0.05	0.07	0.10	0.05	0.06	0.10	0.06	0.07	0.10
2040	0.10	0.12	0.16	0.09	0.12	0.16	0.08	0.12	0.15	0.11	0.14	0.17
2050	0.13	0.17	0.23	0.14	0.18	0.24	0.13	0.17	0.23	0.16	0.20	0.26
2060	0.15	0.21	0.30	0.18	0.24	0.32	0.16	0.22	0.30	0.21	0.29	0.37
2070	0.18	0.27	0.37	0.22	0.31	0.41	0.21	0.29	0.39	0.29	0.39	0.50
2080	0.21	0.31	0.44	0.25	0.38	0.51	0.25	0.36	0.50	0.35	0.49	0.64
2090	0.23	0.36	0.51	0.30	0.44	0.60	0.31	0.44	0.61	0.44	0.61	0.79
2100	0.25	0.41	0.58	0.34	0.50	0.69	0.36	0.53	0.72	0.53	0.74	0.98

[1]Derived by adjusting the Global Projections from Table 3 for regional effects from 2015

Figure 3 Locally adjusted projections of SLR adopted for 3 NSW Councils (from NSW Coastal Alliance)
http://www.nswcoastalalliance.org/wp-content/uploads/2015/04/IPCC-090415.pdf

This study was presented at the 23rd NSW Coastal conference in late 2014 (before the draft CZMP) in a paper aptly entitled "***Widely Accepted by Competent Scientific Opinion" Sea Level Projections for the Shoalhaven and Eurobodalla Coast*** authored by D Wainwright, D Lord, P Watson, N Lenehan and I Ghetti.

This paper was based on various regional studies and included the following graph for regionally adjusted NSW South Coast Sea Level Rise Projection "High" Lines for AR5 RCP's and a 2015 base.

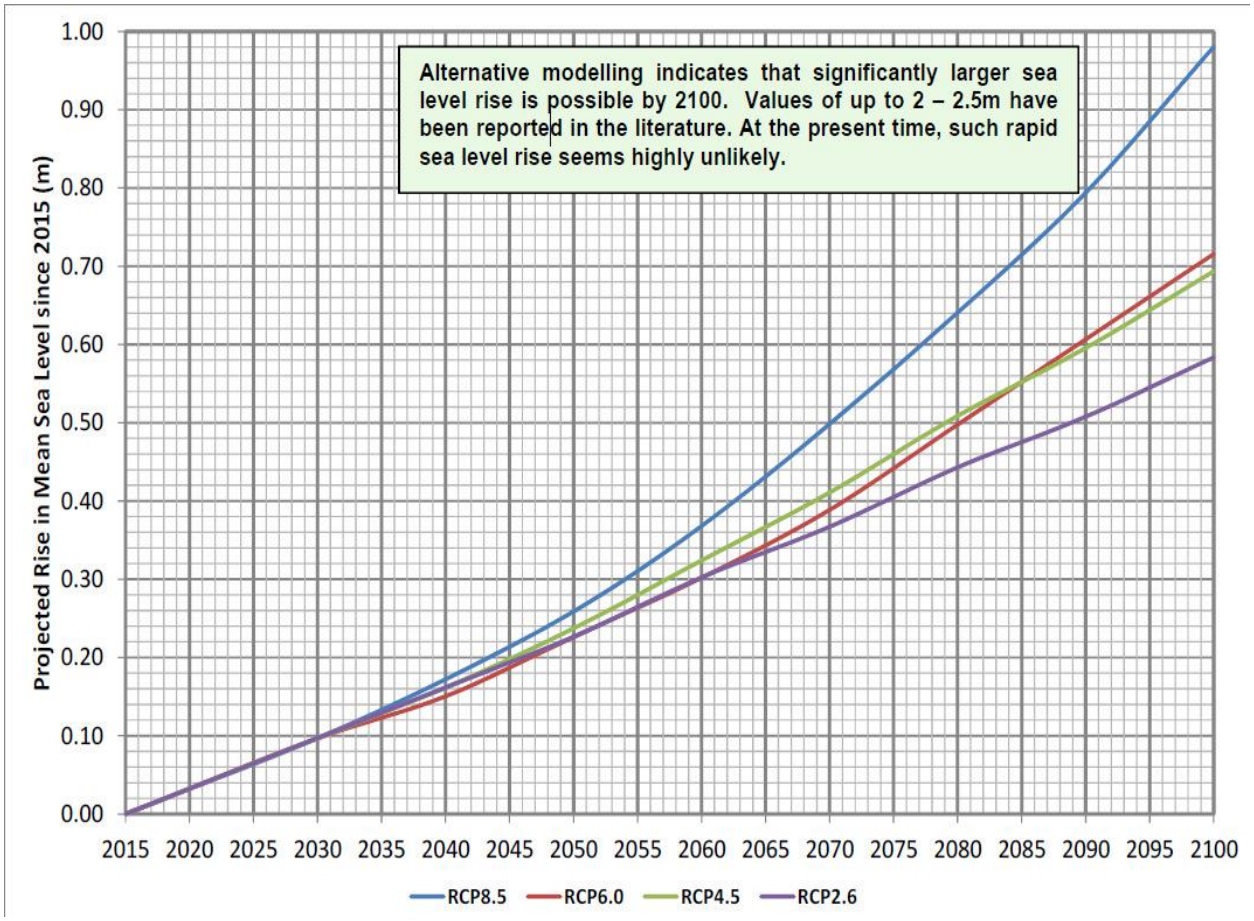

Figure 4 Regionally adjusted NSW South Coast Sea Level Rise Projection "High" Lines for AR5 RCP's.

The paper noted that the *"challenge is to try and ensure that the planning strategies implemented now are not an overreaction that unnecessarily stifles the use of coastal land."* and concluded: "*In summary, selection of the most fossil fuel intensive projection (RCP8.5) is guided by present legislation, legal advice and the planning documentation. Selection of the "high" line of uncertainty representing the AR5 model results spread is a function of good cautious engineering and planning practice which aims to defend development against failure during its design life. These two selections are different, and we suggest that selection of the projection is the aspect over which some decision makers may exercise discretion. However, on the basis of legal advice, the existing planning framework, the responsibilities of councils in New South Wales and recent information which indicates that the world is closely tracking RCP8.5 in terms of carbon emissions, we have recommended that RCP8.5 be adopted as the basis for sea-level rise planning by Shoalhaven City Council and Eurobodalla Shire Council at the present time."*

This paper also noted that there are potential for negative consequences from adopting a projection that is either too low or too high.

For 2015-2060 using the upper limit of RCP8.5 would result in a SLR of 0.36m as a cautious estimate. Using the more pragmatic approach of the Shoalhaven City Council and Eurobodalla Shire Councils, a slightly lower SLR of 0.3m would be a reasonable and still cautious estimate for 2015-2060 given that the estimates are to be reviewed and updated regularly.

The most up to date projections for the NSW coastline have been published recently CSIRO; "Climate Change in Australia Technical Report 2015. The estimates for Sydney and Newcastle are as per Table 2 below:

Table 2 Median values and likely ranges for projections of regional sea level rise (in metres) relative to 1986 to 2005 from CSIRO (2015)

SCENARIO	2030	2050	2070	2090
RCP2.6	0.13 (0.09- 0.18)	0.22 (0.14- 0.29)	0.30 (0.19- 0.42)	0.38 (0.22- 0.54)
RCP4.5	0.13 (0.09- 0.18)	0.24 (0.16- 0.31)	0.35 (0.24- 0.48)	0.47 (0.30- 0.65)
RCP6.0	0.13 (0.08- 0.17)	0.22 (0.15- 0.30)	0.34 (0.23- 0.46)	0.48 (0.32- 0.65)
RCP8.5	0.14 (0.10- 0.19)	0.27 (0.19- 0.36)	0.44 (0.31- 0.59)	0.66 (0.45- 0.88)

From the 2015 CSIRO projections, the extrapolated 2060 estimates with 2015 baseline would be:

Table 3 Median values of SLR 2015-2050 and 2015-2060 for Sydney and Newcastle from CSIRO (2015)

SCENARIO	2015 - 2050	2015 - 2060
RCP2.6	0.15	0.19
RCP4.5	0.17	0.23
RCP6.0	0.15	0.21
RCP8.5	0.20	0.29

Using the medium value of RCP8.5 of 0.3m (rounded) projected SLR for the Sydney region from the 2015 CSIRO Report seems a reasonable and cautious approach that, with regular updates as recommended in the draft CZMP, is consistent with the approach of the Shoalhaven City Council and Eurobodalla Shire Councils and that does not unnecessarily stifle the use of coastal land.

Predicting future sea level rise impacts is difficult and, as is common practice, Brunn's Rule (Figure 5) was used in the draft CZMP to estimate recession due to sea level rise. Bruun's Rule is very simple – it is a simple 2D cut and fill calculation of the sand needed to be eroded from the upper beach to move the simplified equilibrium profile up by the sea level rise. Thus, the original profile is moved up by sea level rise and then translated shoreward until the cut and fill balance out to the depth of closure. Bruun's Rule is best applied to straight coastlines.

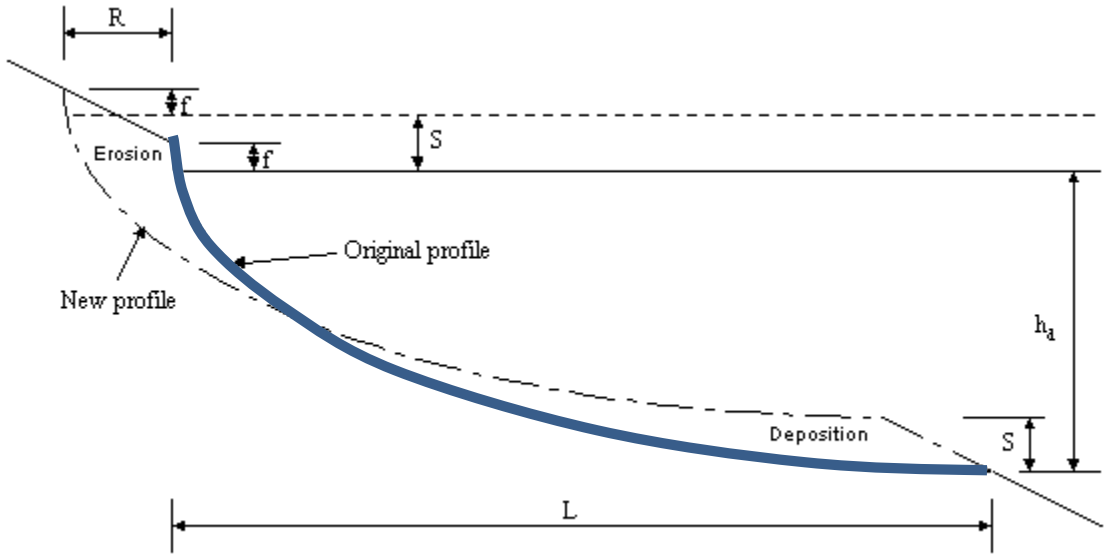

Figure 5 Bruun's Rule where R = SL/(h_d+f), Where S is the amount of sea level rise, L is the active length of the profile, h_d is the closure depth, and f is the freeboard. http://www.cmar.csiro.au/sealevel/sl_drives_short.html

It should be noted that in the Coffs Harbour Coastal Processes and Hazards Definition Study (WBM 2010) it was argued by WBM that their Shoreline Evolution Model (SEM) presents a considerable advance on the nearly 50 year old Bruun's Rule (1962), by accounting for the three-dimensional nature of the shoreline. The SEM also indicates clearly the headlands become increasingly effective at trapping sand (groyne effect) as sea levels rise mitigating the impacts.

Bluey and Boomerang Beaches differ from other beaches in Great Lakes area as they have high dunes and are located between substantial rock headlands that embay and compartmentise these beaches. Such embayed beaches are the most stable and the easiest to protect from SLR as the headlands become increasingly effective as natural groyne type structures with increased water levels, as demonstrated by the SEM. Nourishment placed will be stabilised by the headlands retained without large losses downdrift. If required, the headland effect can be enhanced further by extending the headlands seaward with groynes, either emerged, semi-emergent or submerged. The comment in the options study that groynes and artificial headlands are not an appropriate option for these beaches is not considered accurate.

Past SLR helps to understand the impact of SLR to date and an indication of how Bluey and Boomerang Beaches will respond in the future. The calculation of future recession due to SLR needs to be adjusted for the accretionary trend that has occurred with past SLR. Even if, very conservatively, the beaches are considered as being stable there has been an accretionary trend that has offset, at least, SLR recession to date. Accurate data of past SLR over the last century is available for the NSW coastline from the tide gauge network. The use of four regional databases of SLR in Oceania (Fort Denison Sydney, Freemantle, Auckland and Newcastle) has been used by Australian researchers to determine the rate of SLR pertinent to the East Coast of Australia. This data shows lower rates than the global IPCC data and a recent study (Is There Evidence Yet of Acceleration in Mean Sea Level Rise around Mainland Australia? P Watson JCR 2011) concluded that there was deceleration of SLR at all four sites and that " *Further research is required to rationalise the difference between the acceleration trend evident in the global sea level time-series reconstructions and the relatively consistent deceleration trend evident in the long-term Australasian tide gauge records. These differences are likely to have a significant bearing on the global average and "regional" projections for sea level rise into the future."* This deceleration supports using less than the max of the RCP8.5, at least at present. From Watson (Figure 6) there has been a SLR of about 30 – 35mm since 1956 (the start of the photogrammetry) during which there has been an accretionary trend at Blueys and Boomerang Beaches.

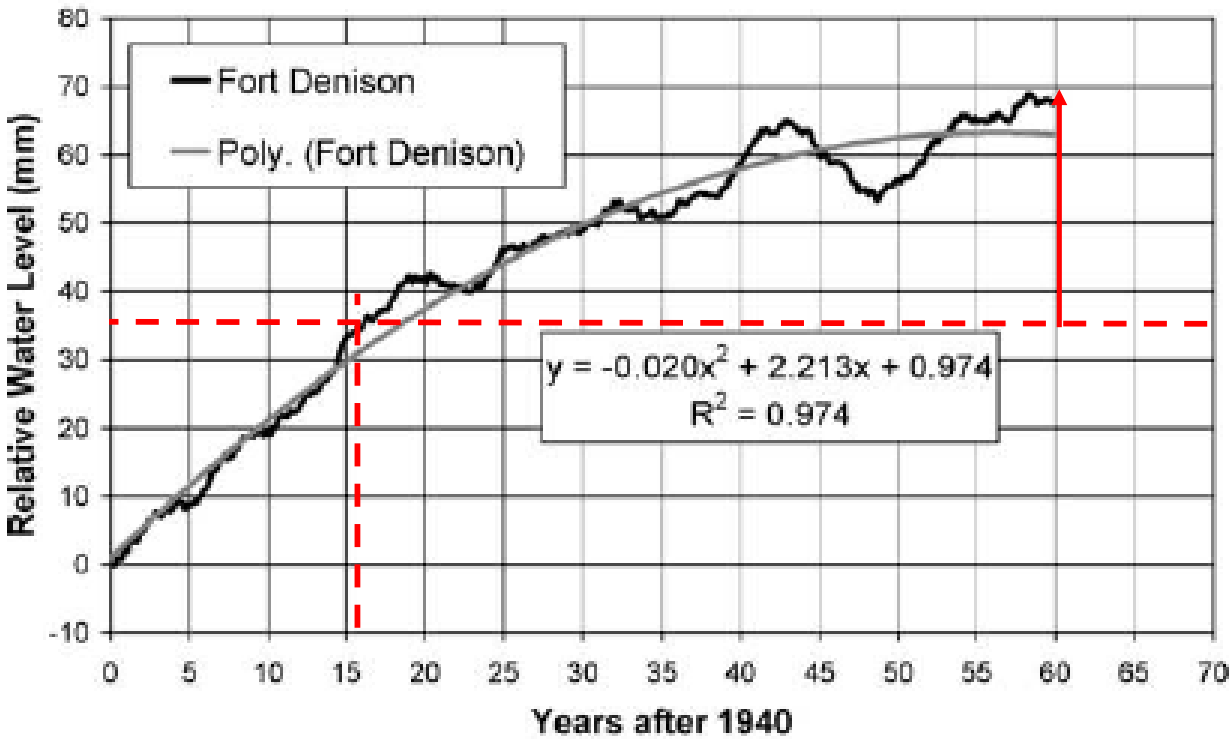

Figure 6 Past SLR at Fort Denison from 1940 to 2000 from Watson (2011).

The work by Wainwright et al (2014) extended the analysis and showed an increase to about 75mm from 1956 to 2014 (Figure 7) being an average 1.3mm/yr. This is lower than some other estimates but still higher than the rate used in the Hazard Definition Study where past sea level was taken as 0.86 mm/year from 1965 to 2006 and no consideration was applied to evaluations of beach stability for past SLR – *"Given the predicted low rate of recession due to historical sea level rise, together with the uncertainties in the Bruun analysis, no increase of measured progradation, to account for sea level influences, is considered warranted."*

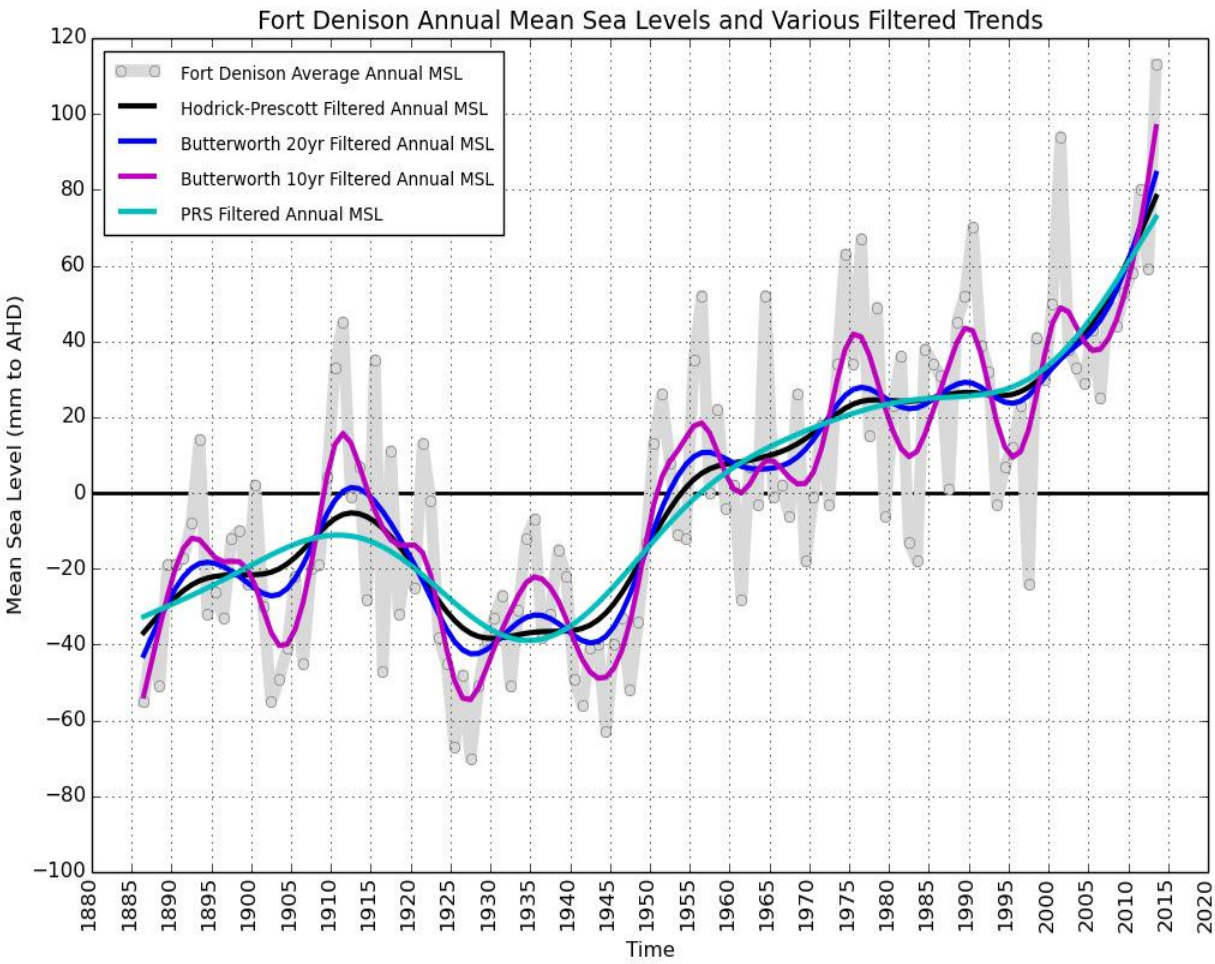

Figure 7 Past SLR from Wainwright et al (2014)

Assuming, the very conservative case used in the Hazard Definition Study that the beaches have been merely stable with past SLR, I have applied Brunn's Rule to south Boomerang beach with updated data as this area has been identified in the draft CZMP as having a high immediate threat. Using updated and site specific inputs, Table 4 compares the very precautionary values used in the Hazard Definition Study adopted by the draft CZMP (highlighted) against more up to date SLR values derived specifically for south Boomerang beach (not general values applied to the whole stretch of beach). The reductions in predicted hazards using site specific and more up to date data is significant.

As the nearest property at South Boomerang Beach is well landward of the 1975 scarp (the design storm cut) with a large dune there is no immediate threat predicted. With the accretionary trend, the 1975 scarp location (40 years ago) as the design storm cut becomes increasingly conservative with time. From the photogrammetry there is sufficient buffer to accommodate the 10m recession predicted by Bruun's Rule (without modification for headland effects) from the 1975 scarp for the planning period to 2060. This significant reduction in predicted recession from the Hazard Definition Study using up to date data would apply similarly to south Blueys Beach, the next area considered at potential risk.

Table 4 Comparisons of SLR impacts to 2060 from various sources.

source	date	storm cut	section of beach	1990-2060			
				SLR estimate 1990 - 2060	Gross SLR predicted recession (Bruun's rule) 1990 - 2060	adjust for reccession / accretion 1990 - 2015	Predicted recession 2015 - 2060
		m3/m		m	m	m	m
PWD	1985	200	all of Boomerang Beach				
Blumberg	2010	200m3 from 2009 profile	Sth Boomerang beach	0.5*	19.6**	-3.3***	16.3
WP	2011	250m3 from mean profile (1996)	all of Boomerang Beach	0.5*	22**	0***	22
WBM	2015						

source	date	storm cut	section of beach	2015-2060			
				SLR estimate 2015 - 2060	Gross SLR predicted recession (Bruun's rule) 2015 - 2060	adjust for reccession / accretion 2015 - 2060	Predicted recession 2015 - 2060
Jackson	2015	use 1975 scarp as design storm cut	Sth Boomerang beach	0.3*	12**	-2***	10

Notes:

*	0.5m SLR 1990-2060 used by Blumberg (2010) and WP(2011) are from the NSW Sea Level Rise Policy Statement 2009 that was repealed in 2012. 0.3m SLR 2015-2060 used by Jackson (2015) are regional values from CSIRO (2015)
**	19.6m recession 1990-2060 of Blumberg (2010) reflects the use of the site specific slope at south end of beach of 1:39 from PWD 1985. 22m recession 1990-2060 of WP (2011) is based on the more general 1:50 regional value. 12m recession 2015-2060 of Jackson (2015) is based on 1: 39 slope.
***	the 3.3m ajustment 1990 to 2060 by Blumberg (2010) is based on 1.2mm/yr from Church and White (2006) the zero adjustment 1990 to 2060 by WP (2011) is based on 0.86 mm/year from Church et al. (2001) that was then discounted as being negligable. the 2m adjustment 2015-2060 by Jackson (2015) is based on 1.3 mm/year from Wainwright et al. (2014)

For this area Bruun's Rule is likely to be over predicting recession as it assumes only slow 2D cross shore transport changes on long linear beaches due to erosion of the upper beach filling the offshore profile. Coastal processes are complex with the profiles in a constant state of change due to changes in wave driven longshore and cross shore transport as well as headland trapping and bypassing. SLR is gradual and is background to much larger changes in the profile out to the depth of closure due to high energy storm events that result in very large longshore and cross shore transport rates. As there is longshore transport and the headland trapping effect at the northern end of the beaches will increase with SLR (as the headland effect is virtually transposed further seaward into deeper water) then Bruun's Rule will overestimate the recession for Boomerang and Blueys Beaches (Figure 8). With the short length of Boomerang and Blueys Beaches the headland effect will translate to the south sections of the beach. The positive impacts of the headland effects is in agreement to the observed behavior of the beaches to date – despite SLR the beaches have been, at worst, "stable" and from the photogrammetry data, accreting. It is possible that the increased headland effect could continue to offset future SLR recession as has been predicted for beaches south of headlands by the modelling for Coffs Harbour coastline (WBM 2010). This resilience to SLR is evident in the past accretionary behavior of Boomerang and Blueys Beaches.

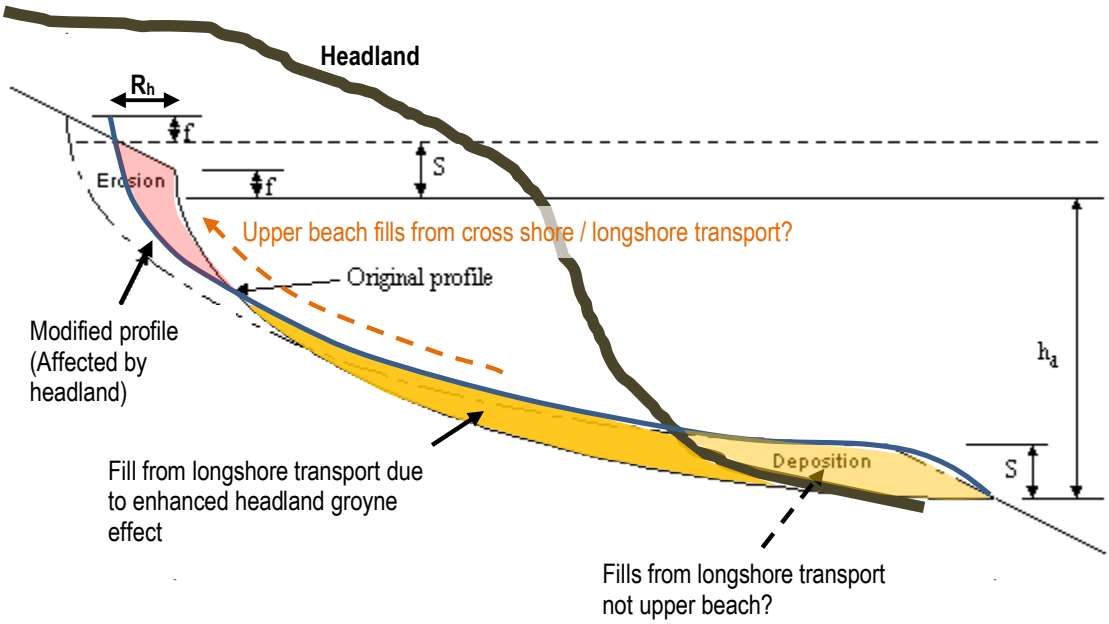

Figure 8 Bruun's Rule modified by headland

Thus, using up to date SLR values for the region with site specific data (even discounting the past accretionary trends) it can be concluded that:

- there is no immediate hazard predicted to properties
- the predicted recession to 2060 due to SLR will be well seaward of all properties.

Obviously, using high storm cut estimates for all of the beach length and making no allowance for past sea levels rises, as per the precautionary draft CZMP methodology, greatly increased the predicted impacts and hazards.

At this stage the supporting documents have insufficient up to date data to establish hazard lines and trigger points to a reasonable level of confidence. Additional data collection and regular monitoring over at least the next 5 years, as recommended in the draft CZMP and supporting documents, will provide up the date data required to replace assumptions reducing uncertainties and enabling future behavior and hazards due to SLR and climate change to be better predicted.

Options: Adoption of reduced recession rates and hazards with more data would considerably reduce the potential extent and cost of long term protection options. In the long term, the embayment and high dunes of these beaches provides model beaches for a range of mitigation measures that can be applied to protect them into the future against sea level rise. The Options Study needs to be up dated after additional data is obtained.

LEP updates, DCP revisions and Trigger levels: These all need to be considered after the hazards are reviewed with additional up to date data.

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3/6/15

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