DRAWING A LINE IN THE SAND – DEFINING BEACHFRONT SETBACKS BASED ON ACCEPTABLE RISK

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Introduction

A key function of local government is to assess development applications. For beachfront development, an important control to manage risk of damage to new structures is to apply a minimum setback such that development is located sufficiently landward of the beach. This setback distance should take account of beach erosion in a severe coastal storm and long term recession over a suitable planning period, as well as non-coastal engineering considerations such as view loss.

Coastline hazard lines have traditionally been used to define beachfront setbacks for development control. These lines have been defined for particular planning periods, eg at 50 and 100 years, or at 2050 and 2100. However, until recently, there has not been a rigorous consideration of whether new development setback to be landward of such hazard lines would be at acceptable risk. For instance, it could not be readily demonstrated that a selected setback was appropriate, with difficulties in choosing a single planning line from the multiple hazard lines with various planning periods, sea level rise scenarios and other nuances. Such nuances include the Nielsen et al (1992) zones, that is whether the landward edge of the Zone of Wave Impact (ZWI), Zone of Slope Adjustment (ZSA), or Zone of Reduced Foundation Capacity (ZRFC) should be used in hazard definition.

An example of various coastline hazard lines that can be defined at a location is provided in Figure 1, for several planning periods (Immediate, 2050, 2074 / 50 year, 2100, 2114 / 100 year) and zones (ZWI, ZSA or ZRFC). The myriad of potential setbacks is evident.

As part of the draft Collaroy-Narrabeen Beach and Fishermans Beach Coastal Zone Management Plan (CZMP), a methodology was developed by Haskoning Australia (a company of Royal HaskoningDHV) to define the appropriate setback for new beachfront development on the basis of “acceptable risk”, as reported in Warringah Council (2014). This was established on the premise that Warringah Council planners wanted a single well considered setback line, that is, only one line should apply to any one lot.

Ultimately, two setback positions for new development were defined at each lot as part of the risk assessment, depending on whether structures were to be founded on conventional foundations or on deep piles. The methodology also allowed for consideration of the effect of existing protective works (that may fail in a severe storm) in reducing storm erosion demand.

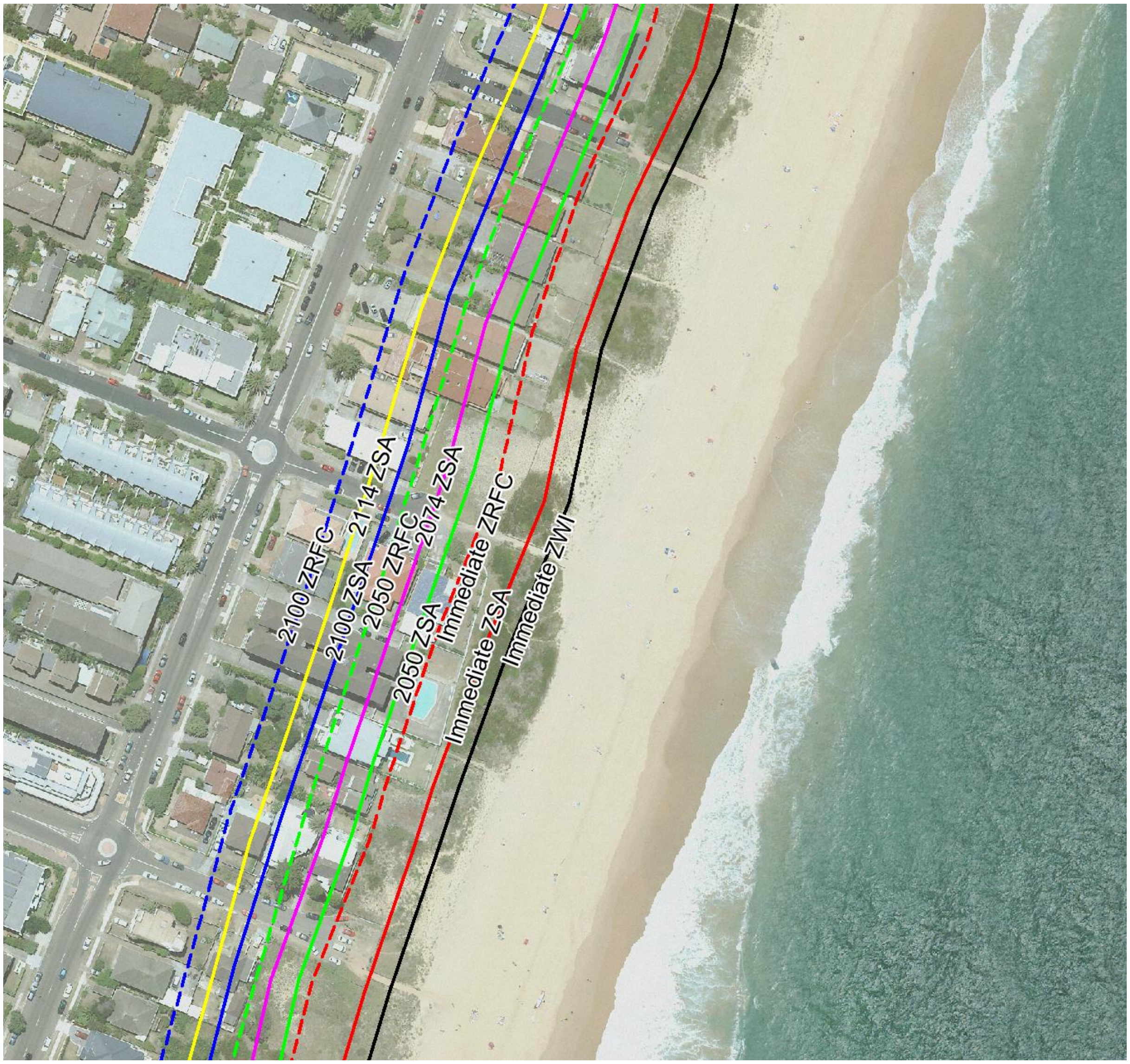

Figure 1: Example of various coastline hazard lines that can be defined at a location, demonstrating the multitude of choices of planning periods and zones that can apply

The framework of the adopted risk assessment methodology came from Australian Geomechanics Society (AGS) procedures for landslide risk management, which can also be applied to development on coastal cliffs and bluffs. These procedures were modified to be appropriate for "sandy beach" coastal hazards. The adopted methodology was peer reviewed by Mr Bruce Walker of JK Geotechnics, who was the Working Group Convenor when the AGS procedures for landslide risk management were published in 2007.

In the paper herein, the risk assessment methodology is described, including discussion on the AGS Framework, selection of design life, risk definition, likelihood, consequences, and definition of acceptable risk. Discussion on application of the risk assessment and comparison to the traditional hazard lines approach is also provided.

The views expressed in this paper are those of the authors and do not necessarily represent those of OEH.

Risk Assessment Methodology

AGS Framework

The AGS procedures for landslide risk management (AGS, 2007a, b) were developed over a period of more than a decade via a Working Group of experts, and have been widely applied in geotechnical engineering practice since 2000. The AGS procedures were also subject to peer review and discussion through the AGS Landslides Taskforce, with 23 members. That is, the AGS procedures can be considered to be an established, recognised and peer reviewed methodology for defining landslide risk for development assessment. With modification to be appropriate for "sandy beach" coastal hazards, it was considered that the same principles of the AGS procedures could be applied to define acceptable risk for beachfront development at Collaroy-Narrabeen Beach and Fishermans Beach and sandy beaches in general.

Note that only risk to property was evaluated. Risk to life related to development in the study area (adjacent to sandy beaches) was considered to be acceptably low as it is highly unlikely that a resident would be occupying a dwelling and would be unaware (or would not have been made aware) that this dwelling was at imminent threat of damage from coastal erosion. This would not be the case if the study area contained cliffs/bluffs.

Selection of Design Life

The first step in the risk assessment was to define the design life for building structures. Risks to structures were determined as being acceptable (or not) on the basis of the risk of damage to the structure at the end of the design life.

The design life of a structure should be related to the typical design life of its components, such as concrete, steel, masonry and timber. The design life used in various Australian Standards is as follows:

- AS 1170 (structural design): 50 years
- AS 2870 (residential slabs and footings): 50 years
- AS 3600 (concrete): 40 to 60 years
- AS 4678 (earth-retaining structures): 60 years
- AS 4997 (maritime structures): 50 years for a normal commercial structure

The cost of new residential development is amortised for tax purposes over 40 years based on Subdivision 43-25 of the *Income Tax Assessment Act 1997*.

In AGS (2007a, b) it is noted that:

- a design life of at least 50 years would be considered to be reasonable for permanent structures used by people; and
- there is a community expectation that a residential dwelling frequently, with appropriate maintenance, will have a functional life well in excess of 50 to 60 years.

Based on review of the above AGS comments, the various Australian Standards noted, and the *Income Tax Assessment Act 1997*, it was considered that a design life of 60 years for residential structures was reasonable. The design life was applied in 2014, and thus the year 2074 represented the end of the design life.

It should be noted that this design life was applied for residential development assessment purposes for new development in an already well developed area. For new subdivisions or important non-residential structures (such as medical emergency or emergency service facilities) for example, a longer design life may be appropriate.

Risk Definition

Risk is defined as the product of likelihood and consequences. The methodologies adopted for defining likelihood and consequences are described in subsequent sections.

Likelihood

AGS (2007a, b) used 6 likelihood descriptors, along with associated annual exceedance probabilities (AEPs), see Table 1. For a design life of 60 years, the cumulative probability of an event of that AEP occurring at least once over the design life can be determined, as also shown in Table 1.

Table 1: AGS (2007a, b) likelihood descriptors, associated annual exceedance probabilities, and cumulative probabilities of event occurring at least once over 60 years

Descriptor	Designated Annual Exceedance Probability	Designated cumulative probability of event occurring over design life of 60 years
Almost Certain	5%	95.4%
Likely	0.5%	26%
Possible	0.05%	3%
Unlikely	0.005%	0.3%
Rare	0.0005%	0.03%
Barely Credible	< 0.0005%	< 0.03%

It may seem counterintuitive that a seemingly low probability 0.5% AEP event is considered to be “likely”. However, when design life is taken into account, this “likely” event has a cumulative probability of 26% which is consistent with the descriptor.

To define the probability of occurrence of a particular coastal hazard line, probabilities (or probability distributions) need to be assigned to the various components used to define the line, including:

- storm demand (beach erosion);
- long term recession due to net sediment loss;
- long term recession due to sea level rise; and
- beach rotation (where applicable).

For example, the "unlikely" hazard line was delineated by components that had a combined probability of 0.3% over the design life.

One of the advantages of this approach was that there was no need to be constrained by the former *NSW Sea Level Rise Policy Statement* benchmarks for 2050 and 2100 (and arguments about their technical and legal applicability). The benchmarks were found to be close to upper limit projections based on the latest (5th assessment) Intergovernmental Panel on Climate Change (IPCC) reports. In the risk assessment, sea level rise values were assigned various probabilities.

That stated, it is recognised that IPCC projections are inherently based on assumptions regarding future greenhouse gas emissions for various scenarios, known as representative concentration pathways. These scenarios were assumed to be equally likely, but what is actually realised in the future will depend on various political and economic factors.

It was also possible to consider probabilities associated with Bruun Rule type recession by assigning different probabilities to different depths of closure.

A paper in itself could be written on defining coastline hazard lines probabilistically. The key points for the paper herein are that these probabilities were assigned on the basis of AGS (2007a, b) categories, and probabilistic lines enabled the hazard definition to be based (as it should) solely on a technical understanding of coastal processes. Further background on the methodology used to define probabilistic hazard lines is provided in Warringah Council (2014).

Consequences

AGS (2007a, b) used 5 consequence descriptors. These descriptors were related to the percentage of damage caused to a property due to a landslide event, relative to the market value of the property (land plus structures), as listed in Table 2.

Table 2: AGS (2007a, b) consequence descriptors and relationship to cost of damage

Descriptor	Approximate cost of damage	Description
Catastrophic	> 100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.
Major	40% to 100%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.
Medium	10% to 40%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage
Minor	1% to 10%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works
Insignificant	< 1%	Little damage

For development on conventional foundations, it was considered that the appropriate consequence descriptor for structures immediately landward of a slumped erosion escarpment (that is, a hazard line defined to be at the landward edge of the ZSA) was "minor". For development on appropriately engineered piled foundations, it was considered that the appropriate consequence descriptor for structures immediately landward of a slumped erosion escarpment was "insignificant" (although temporary loss of land around the structure would require additional considerations to ensure that access to the dwelling was possible when surrounding land had been eroded).

Definition of Acceptable Risk

A risk matrix has been developed by AGS (2007a, b), as shown in Table 3. For example, if the consequences of a particular "unlikely" event were "minor", then the risk would be considered "low".

Table 3: AGS (2007a, b) risk matrix

Likelihood	Consequence				
	Catastrophic	Major	Medium	Minor	Insignificant
Almost Certain	Very High	Very High	Very High	High	Medium
Likely	Very High	Very High	High	Medium	Low
Possible	Very High	High	Medium	Medium	Very Low
Unlikely	High	Medium	Low	Low	Very Low
Rare	Medium	Low	Low	Very Low	Very Low
Barely Credible	Low	Very Low	Very Low	Very Low	Very Low

A key aspect of the AGS (2007a, b) approach is that they defined the risk for new residential development as being acceptable if the risk level was "low" (or lesser, that is "very low") as per the matrix above in Table 3. This was based on review of literature, extensive discussion amongst the AGS Working Group, and consideration of the annualised cost of damage to property. This definition was adopted for the Collaroy-Narrabeen Beach and Fishermans Beach CZMP risk assessment.

Given that "low" risk can be considered acceptable for typical residential structures, it follows that:

- the "unlikely" likelihood line defines the acceptable risk setback for new development that is constructed on conventional foundations (since a slumped erosion escarpment at such a structure would have "minor" consequences); and
- the "likely" likelihood line defines the acceptable risk setback for new development that is constructed on piled foundations (since a slumped erosion escarpment at such a structure would have "insignificant" consequences).

Therefore, for example, to define the required setback for new development on conventional foundations, the "unlikely" line must be defined. As per Table 1, this line is defined as having a 0.3% cumulative probability of occurring over a design life of 60 years.

Note that for structures of Importance Level 4 in the Building Code of Australia (such as buildings and facilities designated as essential facilities or with special post-disaster functions, medical emergency or surgery facilities, emergency service facilities including fire, rescue, police etc.), the designated acceptable risk level is "very low".

Application of Risk Assessment

It is emphasised that the risk assessment approach should not operate in isolation from other planning considerations (such as view loss and privacy from neighbouring development, impacts on beach amenity from structures imposing on the beach outlook, and the practicality of maintaining access to dwellings as a beach recedes).

At Collaroy-Narrabeen Beach, existing protective works are present along most of the southern portion of the beach. However, these works are variable in standard, and they may be undersized and/or founded inadequately. Using the probabilistic risk assessment approach, it was possible to take account of the effect of these works in partially reducing storm demand. As a result, different likelihood lines were generated in areas with existing protective works at Collaroy-Narrabeen Beach.

To account for the fact that new development essentially (by default) has no time limit to a consent (compared to the finite design life of 60 years) and to allow for uncertainty, a Council or other regulator may wish to consider applying trigger conditions to development consents (for example that the consent lapses if an erosion escarpment progresses to within a certain distance of an approved dwelling). It must be recognised that any development landward of a particular “acceptable risk” line is not at zero risk, but at an “acceptably” low risk over a particular design life.

Although not applied at Collaroy-Narrabeen Beach, it can be noted that land use planning that stipulates that structures are to be relocatable can change the “consequence” considerations of the risk matrix. The acceptable risk approach has the flexibility to take account of such a planning control.

Comparison to Traditional Hazard Lines Approach

A summary of the key differences between the traditional hazard lines approach (historical practice) and acceptable risk approach outlined herein is provided in Table 4. It is considered that the acceptable risk approach has numerous advantages, in particular that a single probabilistic “acceptable risk” line for a fixed planning period is defined, rather than the application of multiple lines with varying planning periods and zones with undefined probabilities and hence unknown conservatism (or non-conservatism).

Table 4: Key differences between traditional hazard line definition and acceptable risk approach outlined herein

Parameter	Traditional Approach	Acceptable Risk Approach
Design life or planning period	50 and 100 years, but which should be chosen? More recently, at 2050 and 2100 (36 years and 86 years), but again which should be chosen?	60 years based on consideration of Australian Standards, community expectation and tax legislation.
Design event for storm demand	100 year ARI, but some practitioners have argued for use of rarer events, eg Nielsen and Adamantidis (2007) recommended that an encounter probability of 5% (equivalent to the probability of a 1,000 year ARI event occurring over a 50 year planning period) be used.	Define overall probability of line based on consideration of storm demand, long term recession and other factors, using specific AGS categories. For example, "unlikely" line has a 0.3% cumulative probability of occurring over a design life of 60 years.
Landward edge of zone to define hazard line	ZSA, but in recent years the ZRFC has been used (for example, Wyong Council used the ZRFC in its CZMP adopted in 2011, now under review). Use of ZRFC may have originated from Department of Planning (2010). ZWI used traditionally in Warringah from 1991 to recently.	ZSA, which is considered to be the appropriate position to define risk to a structure and to be landward of the key damaging coastal processes of wave impact and sand slumping.
Setback line	Any of the above planning periods, design events and zones, with subjectivity and inconsistency of application. Usually multiple lines are defined with uncertainty for planners as to which line should be adopted.	"Unlikely" line for development on conventional foundations, and "likely" line for development on piled foundations.
ZRFC	Always design for ZRFC (by requiring piled development) if using a ZSA hazard line, even if it would be overly conservative to do so	Distinguish between conventional and piled foundations and define need for ZRFC based on probability
Existing protective works	Ignore	Take account of reduced storm demand in probabilistic approach

Conclusions

As part of the Collaroy-Narrabeen Beach and Fishermans Beach CZMP, a methodology was developed by Haskoning Australia to define the appropriate setback for new beachfront development on the basis of "acceptable risk". The framework of the adopted risk assessment methodology came from Australian Geomechanics Society (AGS) procedures for landslide risk management, modified to be appropriate for "sandy beach" coastal hazards.

The first step in the risk assessment was to define the design life for building structures. Based on consideration of Australian Standards, community expectation and tax legislation, a design life of 60 years for residential structures was considered to be reasonable.

Risk is defined as the product of likelihood and consequences. AGS used 6 likelihood descriptors , with defined probabilities for each, and AGS used 5 consequence descriptors. A key aspect of the AGS approach is that they defined the risk for new residential development as being acceptable if the risk level was “low”. It followed that:

- the “unlikely” likelihood line (0.3% probability over 60 years) defined the acceptable risk setback for new development constructed on conventional foundations (since a slumped erosion escarpment at such a structure was considered to have “minor” consequences); and
- the “likely” likelihood line (26% probability over 60 years) defined the acceptable risk setback for new development constructed on piled foundations (since a slumped erosion escarpment at such a structure was considered to have “insignificant” consequences).

It is considered that the acceptable risk approach has numerous advantages over traditional hazard lines definition, in particular that a single probabilistic “acceptable risk” line for a fixed planning period is defined, rather than the application of multiple lines with varying planning periods and zones with undefined probabilities.

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