

Draft Flood Risk Management Guide:

**Incorporating sea level rise benchmarks
in flood risk assessments**

Department of
Environment, Climate Change and Water NSW



Submissions invited

Please send your submissions by email to coast.flood@environment.nsw.gov.au or posted to

Sea Level Rise Technical Guide Consultation
Urban and Coastal Water Reform Branch
Department of Environment, Climate Change and Water
PO Box A290
Sydney South, NSW 1232

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Department of Environment, Climate Change and Water NSW
59–61 Goulburn Street
PO Box A290
Sydney South 1232

Phone: (02) 9995 5000 (switchboard)

Phone: 131 555 (environment information and publications requests)

Phone: 1300 361 967 (national parks information and publications requests)

Fax: (02) 9995 5999

TTY: (02) 9211 4723

Email: info@environment.nsw.gov.au

Website: www.environment.nsw.gov.au

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1. Introduction

The NSW Government has adopted a Sea Level Rise Policy Statement (NSW Government 2009) to support adaptation to projected sea level rise impacts. The policy statement includes sea level rise planning benchmarks for use in assessing potential impacts of projected sea level rise in coastal areas, including flood risk and coastal hazard assessment.

These benchmarks are a projected rise in sea level (relative to 1990 mean sea level) of 0.4 m by 2050 and 0.9 m by 2100 (DECCW 2009). The projections were derived from sea level rise projections by the Intergovernmental Panel on Climate Change (IPCC) and the CSIRO. These benchmarks will be periodically reviewed.

This guide has been prepared to assist local councils, the development industry and consultants incorporate the sea level rise benchmarks in floodplain risk management planning and flood risk assessments for new development. The information in this guide updates the sea level rise information in *NSW Floodplain Development Manual* (NSW Government 2005) and can be used in the floodplain risk management planning process described in this manual. This guide also updates the sea level rise section of the *Floodplain Risk Management Guideline: Practical Consideration of Climate Change* (DECC 2007). The 2007 guideline provides additional advice on dealing with the impacts of climate change on existing development areas and discusses the consideration of potential changes to flood producing rainfall events caused by climate change.

2. The impacts of sea level rise on flooding

Sea levels can have a significant impact upon both the tidal range and flood levels in lower coastal waterways. Flood levels can be affected even where these may be generally separated from the ocean by outlet berms, such as intermittently closed and open lakes and lagoons (ICOLLs). The Appendix to this guide provides advice on the determination of ocean boundary conditions for hydraulic flood modelling in coastal waterways.

The degree of the impact of sea level rise will vary significantly with location and vulnerability and may lead to:

- an increase in the depth and areas affected by inundation due to normal tidal fluctuations and an increase in the frequency and duration of inundation in areas already affected by tides
- improved hydraulic efficiency of tidal entrance channels, increasing current tidal ranges in coastal waterways and associated geomorphic and environmental impacts
- an increase in the duration, frequency and magnitude of coastal flooding and the levels reached by flood waters during these events
- a reduction in the capacity of drainage systems discharging into tidal waters. This may lead to an increase in localised stormwater flooding and more water flowing overland to waterways rather than through drainage systems.



Flooding from the Hunter River at Morpeth, June 2007

3. Where is sea level rise likely to impact on flood levels?

This guide applies to areas where projected sea level rise is likely to have a discernable impact on predicted flood levels. This includes the NSW Coastal Zone and areas in the vicinity of lower coastal waterways, including rivers, creeks, estuaries and ICOLLs. In particular, this is likely to apply if the land is:

- likely to be inundated if water levels were 1.0 m above the upper limit of the current tidal range, generally defined by mean high water springs
- likely to be inundated if water levels were 1.0 m above the current flood planning level
- within 1.5 m of the maximum historic height of the entrance berm or the upper limit for management intervention identified in entrance management plans for any ocean entrance to the waterway which controls flooding (this commonly applies to ICOLLs)
- below 4 m AHD.

Major infrastructure crossings (road and rail bridges) often have a significant impact on flood levels and therefore may represent the upper limit of the likely area of influence of changes in sea level on flooding. This needs to be assessed on a case by case basis, as the impacts on flood levels (that is, backwater effects) will depend on the relative size of the crossing's waterway area.

4. Sea level rise planning areas

Flood behaviour may have been identified in a flood study prepared as part of the floodplain management planning process described in the *NSW Floodplain Development Manual* (NSW Government 2005) or carried out on behalf of a developer for new urban development areas. This may have involved the prediction of flood levels and mapping of flood extents, usually corresponding to the current 1-in-100 year average recurrence interval (ARI) flood. Additional mapping may have been prepared to define flood planning areas, which represent the extent of the flood planning level, being the extent of the design flood (e.g. 1-in-100 year ARI) plus an appropriate freeboard (e.g. 0.5 m) and the probable maximum flood (PMF).



Flooding from the Hunter River at Maitland, June 2007

Projected sea level rise will increase flood levels and flood extents in coastal waterways, with this effect generally diminishing with distance upstream from the coast. A sea level rise planning area applies between the:

- flood planning area (derived from a flood assessment excluding consideration of sea level rise) and
- predicted extent of the design 1-in-100 year ARI flood level incorporating the sea level rise benchmarks plus an appropriate freeboard (e.g. 0.5 m).

This is illustrated in Figures 1 and 2. Flood studies should use the 2100 sea level rise benchmark and may use the 2050 benchmark if information on the projected extent of flooding by 2050 is likely to be relevant for future decision-making.

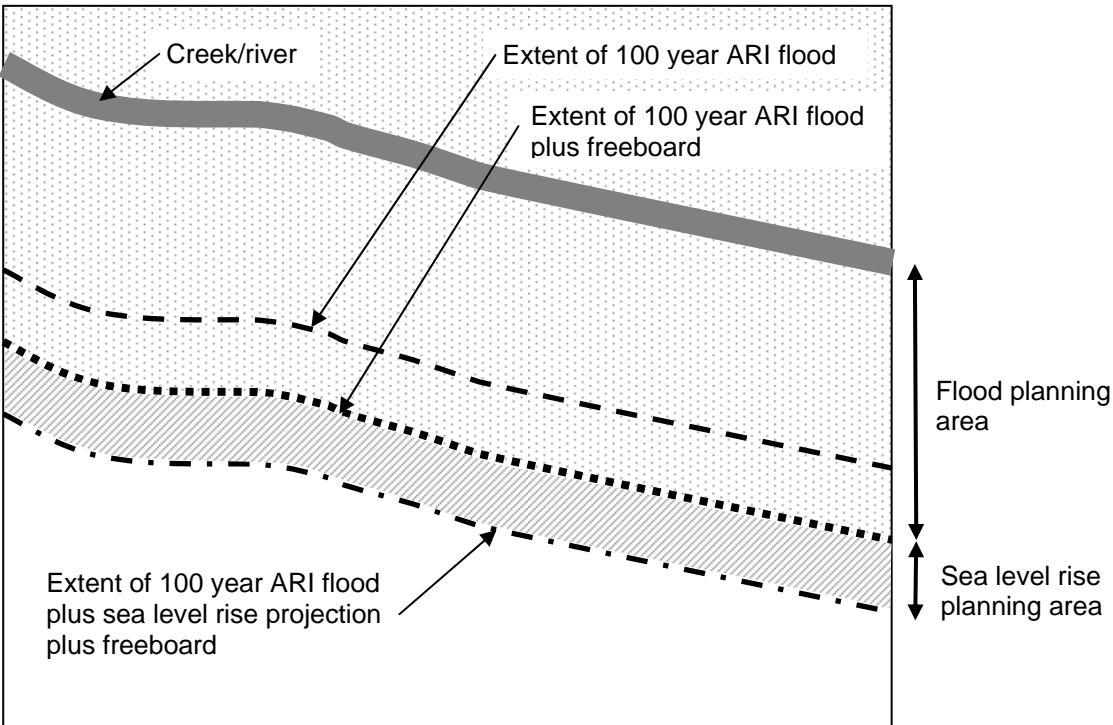


Figure 1 Flood extents and planning areas

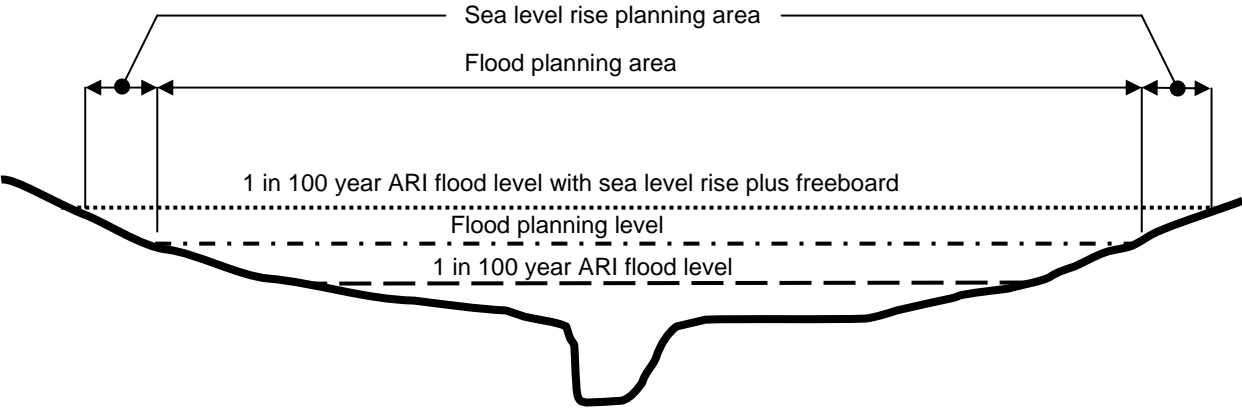


Figure 2 Flood levels and planning areas (cross-section view)

The *Draft NSW Coastal Planning Guideline – Adapting to Sea Level Rise* (DoP 2009) provides detail about the consideration of this information in land use planning and development assessment.

The 0.5-m freeboard outlined in the *NSW Floodplain Development Manual* (NSW Government 2005) for general residential development provides a factor of safety to ensure that the risk exposure selected is accommodated. This freeboard includes a component related to climate change impacts on flood levels in both coastal and non-coastal areas and for a wide variation in sensitivity of estimated design flood levels to flood flow. The freeboard provides only a relatively small allowance to accommodate some of the projected increases

in rainfall intensity of flood-producing storm events associated with climate change, which has currently not been accurately quantified. The manual's small allowance for climate change in the 0.5-m freeboard figure should be considered to only address some of the uncertainty associated with estimating climate change impacts. Freeboard should not therefore be used to allow for sea level rise impacts, which should be quantified and applied separately as shown in Figure 1.

The estimation of a sea level rise planning area will usually involve an extension to an existing floodplain risk management study and plan for a coastal area. This involves modelling changes, particularly increasing the ocean boundary conditions, whether static or dynamic, and initial water levels for dynamic hydraulic models by the sea level rise benchmark.

Specific local council requirements may apply to these flood studies, including:

- key parameters to be used in the study (such as downstream boundary conditions and initial water levels) that may be influenced by sea level rise
- the use of appropriate flood models used in previous studies
- the availability of improved land surface elevation data (e.g. aerial laser survey)
- the availability of any new flood information, and
- allowances for the potential impact of climate change on rainfall.

Flood levels in low-lying coastal areas are influenced by ocean and estuarine water levels. Flood studies therefore need to make appropriate assumptions about these downstream boundary conditions. The influence of sea levels on flood behaviour varies significantly with the location, the catchment, and the floodplain and the type of ocean–waterway interface. Flood planning levels therefore need to account for both the flooding by catchment rainfall in addition to elevated ocean levels. Given the complexity of the issue of combined probabilities of these two independent flood events occurring simultaneously, the Appendix has been provided to assist in estimating flood levels.

Australian Rainfall and Runoff (Engineers Australia 1999) is currently being updated and is expected to provide advice in relation to the coincidence of catchment and ocean flooding derived from the same storm cell, as a combination of these factors often control flood levels in lower coastal waterways. The Appendix to this guide provides interim advice on the assessment of these conditions for a variety of classes of entrances and conditions (excluding sea level rise considerations).

Where a flood investigation has been prepared, the modelling can be updated to include sea level rise projections or a conservative assumption can be made about sea level rise impacts. Where the site is below 4 m AHD, an appropriate conservative assumption to estimate the 1-in-100 year ARI flood level is to add the sea level rise benchmarks to the 1-in-100 year ARI flood level relevant to the site. Site-specific modelling can be undertaken to refine this approach where warranted. The additional extent of flooding beyond the flood planning area (the sea level rise planning area) can then be determined based on the flood level (derived from the sea level rise benchmarks) and freeboard.



Flooding from the Richmond River at Coraki, January 2008

In addition to the 1-in-100 year ARI flood, the PMF should also be modelled including the effects of sea level rise for emergency response planning purposes, critical infrastructure, such as emergency care hospitals and vulnerable developments, such as aged care homes facilities.

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Glossary

average recurrence interval (ARI)	The long-term average number of years between the occurrence of a flood as big as (or larger than) the selected event.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
flood planning level	The combinations of flood levels and freeboards selected for floodplain risk management purposes.
flood planning area	The area of land below the flood planning level.
Freeboard	A factor of safety typically used in relation to the setting of flood planning levels.
NSW Coastal Zone	Land identified in a series of gazetted maps under the <i>Coastal Protection Act 1979</i> .
ocean boundary conditions	The ocean water level used as the downstream boundary level for hydraulic modelling for a flood study.
PMF	The probable maximum flood.
sea level rise planning area	The area of land excluding the flood planning area which is below the 1-in-100 year ARI flood level plus freeboard plus projected sea level rise influence.

Appendix - Ocean boundary conditions for hydraulic flood modelling

A1 Introduction

Flooding in lower coastal waterways may occur due to a combination of ocean and catchment flooding driven by the same storm cell. The influence of flooding from these two sources on overall flood risk in these waterways varies with location, distance from the ocean, and the entrance conditions for discharge to or from the ocean.

The guidance in this Appendix provides interim advice on the consideration of the coincidence of flooding from these sources considering the variation of typical ocean boundary conditions and initial water level conditions in the waterway.

This information will be reviewed when Australian Rainfall and Runoff (Engineers Australia 1999) is updated to provide advice on the coincidence of catchment and ocean flooding or when improved interim advice is available.

A2 Envelope approach

Consideration of catchment and coastal flooding provides an envelope of effects which can be determined by considering scenarios such as the following:

- 1-in-100 year ARI ocean level (with the addition of wave setup and/or wave runup where relevant) with 1-in-20 year flooding from the catchment;
- 1-in-20 year ARI ocean level (with the addition of wave setup and/or wave runup where relevant) with 1-in-100 year flooding from the catchment.
- Neap tide cycle with 1-in-100 year ARI flooding from the catchment.

These scenarios assume that initial water levels within the coastal waterway are based upon the peak tidal water level in the waterway or the height of any controlling entrance outlet. They provide an envelope of peak impacts that can be used to determine the 1-in-100 year ARI flood affects in the lower coastal waterway. A sensitivity analysis of key parameters such as relative timing of peak catchment flooding and peak ocean levels should be carried out to enable Councils to make informed decisions about appropriate flood planning levels.

Any rise in sea level is expected to have a direct impact upon ocean boundary conditions and initial conditions in the coastal waterway and therefore the sea level rise benchmarks need to be added directly to these downstream ocean boundary conditions for the assessment of the impacts of the benchmarks outlined in the *NSW Government Sea Level Rise Policy Statement* (NSW Government 2009).

A3 Downstream ocean related boundary conditions

Downstream ocean boundary conditions can vary significantly with the class of entrance and the specifics of the location and can be costly to derive. Advice is provided on simplistic approaches that can be used to derive a conservative ocean boundary conditions in particular circumstances in lieu of more sophisticated site specific analysis. However, if the simplistic approach results in levels considered too conservative for the particular situation, a site specific coastal engineering assessment can be carried out.

A conservative assumption for an ocean boundary condition for a catchment that drains directly to the ocean (that is, does not drain into an ICOLL or coastal lake) is to adopt a 1-in-100 year ARI ocean level of 2.6 m AHD. This boundary level comprises components related to elevated ocean water level levels, tidal anomalies and wave setup. A more sophisticated approach would be to use the default dynamic open ocean boundary condition (Figure 3). Site-specific analysis would give a further degree of sophistication and potentially a lower, less conservative answer.

The sea level rise benchmarks would be added directly to the ocean related boundary conditions to obtain ocean boundary conditions under projected sea level rise conditions.

A4 Classes of entrances and their modelling

There are four general classes of entrances outlined below:

- Class 1 - Catchments that drain to a coastal lake (e.g. Lake Illawarra, Tuggerah Lakes);
- Class 2 - Catchments that drain direct to the ocean via trained or otherwise stable entrances;
- Class 3 - Catchments that drain direct to the ocean via shoaled entrances; or
- Class 4 - Catchments with normally closed or partially blocked entrances.

The method of deriving appropriate downstream starting water levels will vary for each class of entrance, as the downstream controls differ. Their determination and the required background data are discussed in Sections A4.1 with the analysis of entrance breakout discussed in Section A4.2.

A4.1 Downstream ocean related boundary conditions

Data for the following is needed for effective modelling of downstream ocean related boundary conditions.

1. The fixed or starting entrance geometry condition (for dynamic situations). This may be impacted upon by:
 - a any entrance management arrangements that control entrance conditions within set limits. For managed entrances, the case governing catchment flood levels will be the trigger for management intervention under the management policy, which should have regard to prevailing entrance conditions (that is, degree of choking/shoaling). The case governing upstream flow velocities in the post intervention geometry (that is, fully scoured opening) case also needs to be modelled.
 - b the dynamics of entrance conditions over time. This may be directly relevant for:
 - i a particular historical event. This may require alteration to the entrance configuration within realistic limits to match available calibration data; or
 - ii providing details on peak shoaled and scoured states over time. Peak shoaled condition will govern upstream catchment flood levels whereas peak scoured condition will govern coastal flow ingress.
 - c The geometry for current conditions would preferably be confirmed as part of the survey data collected for model development.
2. The limits of potential dynamics. These include limits to vertical and lateral scour, including any headlands, rock shelves or reefs known to exist in the locality is essential to appropriate modelling of the area rather than arbitrary limits.

3. The dynamics of entrance conditions during an event, particularly in relation to scour due to entrance management practices. Modelling of entrance breakout is discussed in detail in Section A4.2.

Modelling of ocean boundary conditions should involve a detailed understanding of the ocean boundary geometry, and in the case of entrance shoaling and scouring, their dynamics and physical limits, as discussed above. Modelling may generally be either: steady state; or unsteady state with either a built in dynamic scour model or with interface to a breach model to examine scouring.

The dynamics of the situation may be complex, involving flow, downstream ocean levels, and ocean boundary geometry. In addition, different conditions may dominate flooding at different times during an event and different starting conditions can govern peak flood levels (most restricted conditions) and flow velocities (most open conditions). This can make modelling complex, requiring a number of runs, and the development of upper boundary curves for flood level and flow velocities and limit the effective use of steady state modelling in these areas.

It is recommended that the elevated ocean levels presented in Figure 3 are used until significant advances in methods to predict elevated ocean levels produce more reliable estimates or further advice is provided through updates to *Australian Rainfall and Runoff*. The levels in Figure 3 include ocean anomaly and wave setup factors.

These estimates include wave setup and wave runup factors and are therefore conservative in some coastal waterways where these factors are negated by entrance conditions.

Site-specific or alternate analysis may provide advice more directly relevant to a particular entrance condition. Where this analysis is undertaken and relied upon to support the development it should be submitted to the consent authority for review.

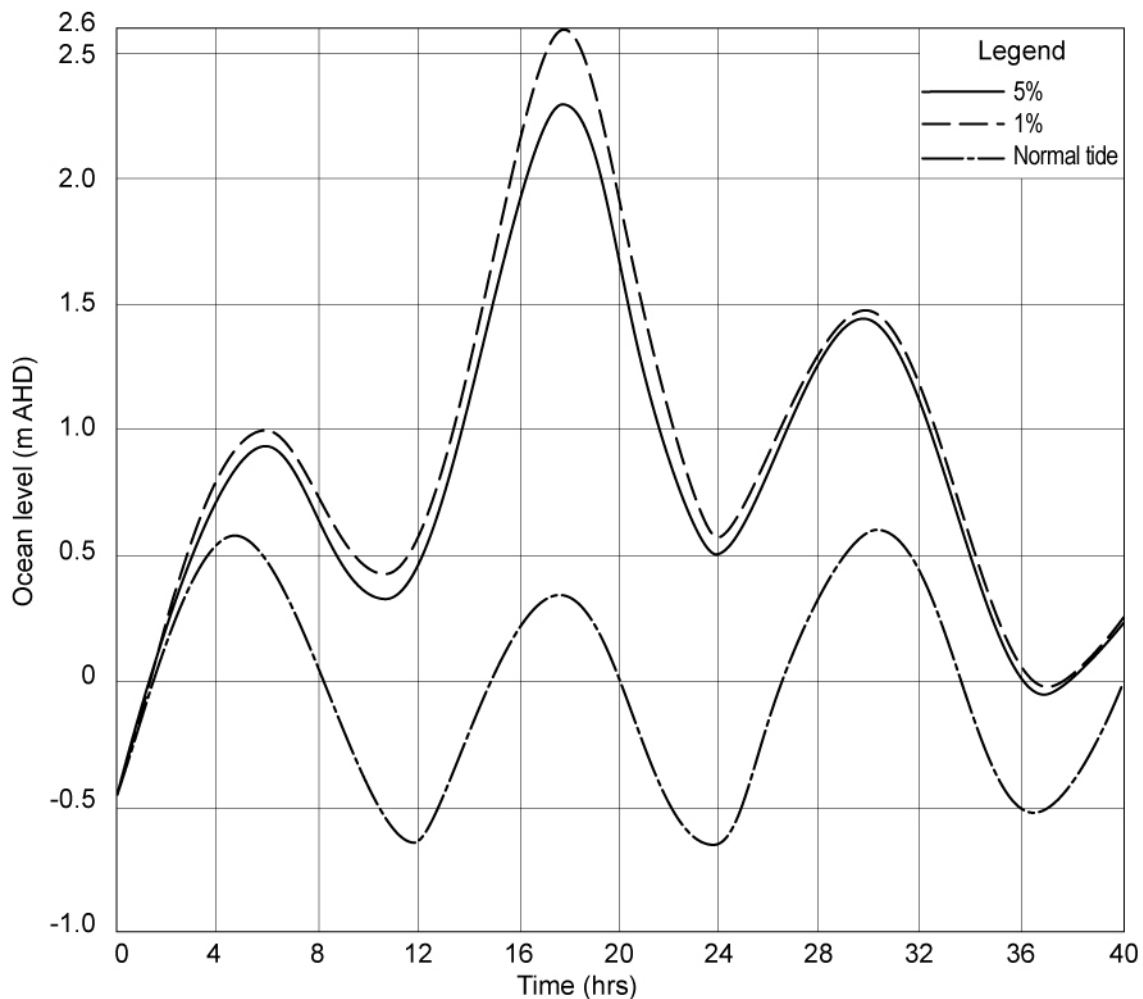
Consideration of the sea level rise benchmarks requires direct addition of the benchmark levels to both the fixed or varying ocean boundary conditions and the initial water level conditions in the waterway.

A4.2 Entrance breakout analysis

The appropriate approach to entrance breakout analysis depends upon the scale of the ramifications of the potential flooding on the community at the site in question. Where these ramifications are low a more simplistic conservative approach can be undertaken.

Sensitivity analyses should consider a range of ocean levels, and the upper limit for management intervention where management is undertaken or else a range of known historical configurations. Where the entrance is managed, management protocols should be available from the local council or other agency that may manage the entrance. Controlling historical entrance configurations can be assessed based upon the interpretation of historical aerial photos and other relevant information.

Use of the upper limit of management intervention or the range of known historic configurations is conservative as it assumes that the entrance configuration, including the beach bar, does not erode during the flood event. If the ramifications resulting from this sensitivity analysis are significant, then some form of analysis (e.g. Gordon 1990) or simplified modelling should be undertaken.



Note: 1% represents 1 in 100 year ARI and 5% represents 1 in 20 year ARI

Figure 3 Default open ocean boundary condition
 Note: 1% represents 1-in-100 year ARI and 5% represents 1-in-20 year ARI

The object of this analysis is to determine a conservative estimate of the erosion likely to occur during the rising limb of the flood event. This in turn allows an estimate of the height of the beach bar prior to the onset of the flood peak and in combination with the results of the sensitivity analysis yields the flood level profile. More detailed modelling of the breakout using an appropriate hydraulic model incorporating dynamic scour capabilities or by running interactively with a breach model may be worthwhile particularly if the ramifications are considerable and the approach outlined in the previous paragraph does not produce workable or satisfactory outcomes.

Sea level rise can be expected to alter entrance conditions directly relative to the change in the sea level rise benchmark. Table 1 provides a summary of typical ocean boundary conditions and modelling issues.

Table 1 - Summary of typical ocean boundary conditions and modelling issues

Class of entrance	Starting water level	Influence of sea level rise benchmarks	Modelling	Analysis method	Entrance breakout
Class 1 Coastal lakes	May be obtained from lake flood studies or else the lake should be modelled as part of this study. In the latter case refer to classes 2–4.	Should be assessed as changed ocean boundary and initial water level conditions as part of flood study for lake.	Use of steady and unsteady models may be suitable. Other consideration outside entrance conditions will determine the form of modelling	NA	Should be considered as part of lake flood study. If the lake is modelled as part of this study refer to classes 2–4.
Class 2 Trained or deep stable entrances	See Figure 3 * Note that the information in Figure 3 may be considered conservative for these entrances and could be refined by a site-specific analysis.	Should be assessed as changed ocean boundary conditions and initial water level in the waterway.	Use of steady and unsteady models may be suitable. Other considerations other than entrance conditions will determine the form of modelling	Develop an upper limit envelope curve for scenarios outlined in Section A.2.	Not applicable
Class 3 Shoaled entrances	See Figure 3 *	Should be considered as changed shoaled conditions and initial water level conditions for the waterway.	Use unsteady models.	Develop an upper limit envelope curve for scenarios outlined in Section A.2.	See Section A4.2
Class 4 Closed entrances	See Figure 3 *	Should be considered as changed entrance conditions and initial water level conditions for the waterway.	Use unsteady models.	Develop an upper limit envelope curve for scenarios outlined in Section A.2.	See Section A4.2

* Site-specific or alternate analysis may be undertaken by a suitably qualified specialist