5 Flood Planning Review

5.1 Overview of Environmental Planning Instruments

Within the study area, development is largely controlled through the Eurobodalla Local Environment Plan (LEP) 2012 and a series of Development Control Plans (DCP). The LEP is an environmental planning instrument (EPI) which designates land uses and development in the study area, while the DCPs regulate development with specific guidelines and parameters. There are also a number of EPIs and related planning documents that can affect the development of property within the study area. These may be in the form of State Environmental Planning Policies (SEPP) which take precedence over the provisions of the LEP such as:

- SEPP Exempt and Complying Development Codes (2008)
- SEPP Educational Establishments and Child Care Facilities (2017)
- SEPP - Housing for Seniors and People with a Disability (2004)
- SEPP - Affordable Rental Housing (2009)
- SEPP 21 Caravan Parks
- SEPP 36 - Manufactured Home Estates
- SEPP 65—Design Quality of Residential Apartment Development
- SEPP - Primary Production and Rural Development (2019)
- SEPP Coastal Management (2018)
- SEPP Infrastructure (2007)
- SEPP No 33—Hazardous and Offensive Development
- Other SEPPs as relevant to land use and/or development type
- Other Council plans, policies, or other publications.

The review of SEPP provisions is relevant insofar as they relate to how they might inter-relate with local provisions are it is generally not possible for a SEPP to be modified as a recommendation of this review.

All relevant planning controls for individual land parcels are summarised in a Section 10.7 certificate (formerly a Section 149 certificate) issued under the Environmental Planning and Assessment Act, 1979.

A review of flood-related controls incorporated within the LEP, relevant DCPs, Council policies and plans has been completed. Recommendations for updates to improve the management of flood risk are provided in **Section 5.8**.

At the time of preparation of this report, the Department of Planning, Industry and Environment released a Draft Flood-prone Land Package for comment (over the period May-June 2020). The NSW Government has now finalised these reforms. As part of the Flood-prone Land Package, the wording of all NSW Councils flood planning clauses were updated on 14 July 2021. Under these changes the Council will need to nominate the FPL or levels that it wishes to define the FPA and make alternative arrangements for making flood planning maps publicly available.

Additionally, at the time of preparation of this report, Eurobodalla Shire Council released their Draft Local Strategic Planning Statement (LSPS, dated 11 May 2020) for comment (over the period May-June 2020). This draft package has been referred to in this review (**Section 5.3**). Reference is also made here to the relevant aspects of the Draft LSPS pertinent to flood risk management (**Section 5.4**).

This review does not specifically deal with matters related to building construction (such as the National Construction Code, which includes the Building Code of Australia (BCA), both of which are updated every three years by the Australian Building Codes Board). However, it is important to note that these types of controls are sometimes called or referenced in planning controls and therefore their content and direction are of relevance. In the regard, how they are applied is directed under the NSW Planning System via numerous mechanisms but primarily via Building System Circulars issued by the Department of Planning, Industry and Environment (DPIE). The most relevant circular is BS 13-004, dated 16 July 2013 entitled *The NSW Planning System and the Building Code of Australia 2013: Construction of Buildings in Flood Hazard Areas*. Importantly the BCA deals with the concept of the 'defined flood event' (DFE) and imposes minimum a construction standard across Australia for specified building classifications 'flood hazard areas' (FHA) up to the DFE. These requirements will be referenced when developing appropriate recommendations for policy and planning approaches within the study area.

5.2 Eurobodalla Local Environment Plan 2012

The Eurobodalla LEP 2012 commenced 20 July 2012. The LEP sets the direction for land use and development in the study area by establishing suitable land uses across the local government area (as 'zones') and defining where development consent is required. It determines what can be built, where it can be built and what uses or activities can occur on land.

The Eurobodalla LEP 2012 (ELEP) is based on a standard format used by all Councils in NSW and can be viewed on the NSW legislation website (www.legislation.nsw.gov.au).

5.2.1 Flood Planning Objectives and Controls

The objectives for land at or below the flood planning level (100 Year ARI event plus 0.5m freeboard) are outlined in Clause 6.5 of the ELEP. The objectives of this clause are:

- *to minimise the flood risk to life and property associated with the use of land;*
- *to allow development on land that is compatible with the flood function and behaviour on the land, taking into account projected changes as a result of climate change;*
- *to avoid adverse or cumulative impacts on flood behaviour and the environment; and,*
- *to enable the safe occupation and efficient evacuation of people in the event of a flood.*

It is stated that development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

- *is compatible with the flood hazard of the land, and*
- *is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and*
- *incorporates appropriate measures to manage risk to life from flood, and*
- *is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and*
- *is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.*

As a FPA is no longer defined with the LEP clause it is recommended prior to a FRMS&P that the FPA (as further discussed in **Section 5.8**) be defined at the 1%AEP plus 0.5m and climate change.

The LEP provides specific flood related considerations for development approval within the "Moruya Town Centre". While these considerations do not currently apply to the study area, they are relevant in the development of appropriate recommendations for policy and planning approaches within the study area.

The ELEP contains a clause (6.5(4)) that addresses properties that are affected by flooding and coastal processes and states:

Before determining a development application for development on land to which this clause applies, the consent authority must consider the potential to relocate, modify or remove the development if the land is affected by coastal processes, coastal hazards and sea level rise.

In this regard, the LEP Dictionary has the following definition:

- *coastal hazard has the same meaning as in the Coastal Management Act 2016, which is:*

(a) beach erosion,

(b) shoreline recession,

(c) coastal lake or watercourse entrance instability,

(d) coastal inundation,

(e) coastal cliff or slope instability,

(f) tidal inundation,

(g) erosion and inundation of foreshores caused by tidal waters and the action of waves, including the interaction of those waters with catchment floodwaters.

Coastal processes and sea level rise are undefined in both the ELEP and in the *Coastal Management Act, 2016*.

The Eurobodalla Interim Coastal Hazard Adaptation Code (ESC, 2017) applies to lands within the coastal zone or areas identified by Council as potentially at risk from coastal hazards out to a maximum planning period ending at the 2100 coastal hazard projections identified in the *Eurobodalla Coastal Hazard Assessment* (WRL, 2017 or area mapped within the Code as 'Eurobodalla Investigation Areas' (noting that no maps were incorporated in Appendix A at the time of this review).

The flooding associated with coastal inundation is one element of this study and could potentially be considered as flooding under the definitions of the State Flood Prone Land policy and in accordance with the NSW Floodplain Development Manual (2005) and/or could be considered under the provisions of the Coastal Management Act, 2016.

5.2.2 Flood Mitigation Works

The ELEP 2012 permits flood mitigation works with consent only in areas zoned RU5 Village. This is a relatively limited extent of where works can occur. However, it is noted that the provisions of SEPP (Infrastructure) 2007 allow for Council flood mitigation works without consent in any zone under Clause 50(1) which states:

Development for the purpose of flood mitigation work may be carried out by or on behalf of a public authority without consent on any land.

This includes construction, routine maintenance, and environmental management works.

5.2.3 Flood Mapping and Related Amendments

On 8 August 2017, Council endorsed a planning proposal to rezone certain flood prone land from E2 to an appropriate zone and to make related amendments. A Gateway Determination on this planning proposal was issued on 27 November 2017 and it was placed on public exhibition from 8 November 2017 to 2 February 2018.

5.3 Draft Flood Prone Land Package

In May 2020 the Department of Planning, Industry and Environment released a Draft Flood Prone Land Package which contains a series of documents that seek to update the manner in which local planning is conducted for flood prone lands. In summary, the key relevant aspect for strategic planning is the consideration of three types of flood prone areas:

- Flood Planning Area (FPA), which has commonalities with the flood planning level concept in the ELEP and seeks to ensure development is compatible with flood risks within the FPA (noting that there are some circumstances where no development is compatible with flood risks)
- Special Flood Considerations (SFC), which seeks to control certain types of vulnerable and hazardous development within the floodplain in its entirety (i.e. potentially up to the extent of the Probable Maximum Flood)
- Regional Evacuation Consideration Area (RECA), which seeks to ensure lands which are indirectly affected by flood behaviour with respect to being unable to evacuate due to flooding in adjacent areas and becoming isolated.

Whilst only being a draft package, consideration of the potential application of the draft from a strategic planning perspective has been made as part of this study. **Maps G905a – f** show the extent of a potential Flood Planning Area (FPA), **Section 9.1** provide more detail on the selection of the FPA. A Special Flood Consideration (SFC) area is also shown on these maps (which is the extent of the Probable Maximum Flood where it is greater than the 1%AEP plus 0.5 m).

5.4 Draft Local Strategic Planning Statement

The Draft Eurobodalla Local Strategic Planning Statement (LSPS, ESC, 2020) is a strategic document, setting out a 20-year vision for land use planning in the Shire. It outlines how growth and change will be managed to ensure high levels of liveability, prosperity and environmental protection are achieved in Eurobodalla. Once adopted, the LSPS will set the direction for the revision of the ELEP, 2012 and the update of the range of existing development control plans (Section 5.5).

With respect to flooding, the Draft LSPS states that:

- Planning Priority 3 is Consolidate development within town and village centres. In this regard the LSPS states that the region is subject to coastal inundation and erosion, and inland flooding which are threats that are predicted to increase over time. These threats are an ongoing threat to many residents living in the Shire. It is essential that hazards are identified, and mitigation measures are put in place to reduce the risk to loss of life or property in the future.
- Planning Priority 4 is Adapt to Natural Hazards. Specifically, Item 4.3 is to adopt the Batemans Bay Urban Creek Flood Study (this study) and Item 4.4 is to Develop a Flood Management Code across Eurobodalla.

5.5 Development Control Plans

5.5.1 Residential Zones DCP

The Residential Zones DCP was adopted by Eurobodalla Shire Council (Council) on 18 October 2011 and came into operation on 28 November 2011. The aim of this DCP is to further the aims of the ELEP 2012 and the particular objectives for the R2, R3, R5 and E4 zones as stated in the ELEP 2012.

Section 6.1 of the DCP outlines the Flood, Ocean Influences and Climate Change controls. However, the DCP simply states that "*all development within the area to which the Moruya Valley Floodplain Development Code applies must comply with that Code*". This would suggest that no flood related development controls are applied in R2, R3, R5 and E4 zones elsewhere, including the study area.

Some flooding considerations are included in Section 7.3, which requires a stormwater management plan be prepared to ensure stormwater management systems or other site works do not adversely impact on flooding.

5.5.2 Industrial Zones DCP

The Industrial Zones DCP was adopted by Eurobodalla Shire Council (Council) on 18 October 2011 and came into operation on 28 November 2011. The aim of this DCP is to further the aims of the Eurobodalla LEP 2012 and the particular objectives of the IN1 General Industrial Zone as stated in the LEP 2012.

Section 4.1 of the DCP outlines the Flood, Ocean Influences and Climate Change controls. However, the DCP simply states that "*all development within the area to which the Moruya Valley Floodplain Development Code applies must comply with that Code*". This would suggest that no flood related development controls are applied to IN1 zone elsewhere, including the study area.

Section 5.1 notes that a Master Plan must be prepared for subdivision of development within any identified Industrial Expansion Area. The Master Plan must consider the protection of the development from flood inundation and the impacts of sea level rise.

Section 7.3 requires a stormwater management plan be prepared to ensure stormwater management systems or other site works do not adversely impact on flooding.

5.5.3 Batemans Bay Regional Centre DCP

The Batemans Bay Regional Centre DCP was adopted by Eurobodalla Shire Council (Council) on 18 October 2011 and came into operation on 28 November 2011. The aim of this DCP is to further the aims of the Eurobodalla LEP 2012 and the particular objectives for the R3, B4 and B5 zones as stated in the LEP 2012.

Section 7.3 requires a stormwater management plan be prepared to ensure stormwater management systems or other site works do not adversely impact on flooding.

No other flood-related controls are specified in the DCP.

5.5.4 Neighbourhood Centres DCP

The Neighbourhood DCP was adopted by Eurobodalla Shire Council (Council) on 18 October 2011 and came into operation on 28 November 2011. The aim of this Plan is to further the aims of the Eurobodalla LEP 2012 and the particular objectives for the B1, B2 and R3 zones as stated in the LEP 2012 and the particular objectives for the Neighbourhood Centres as identified in the *Eurobodalla Settlement Strategy* (**Section 5.6.1**).

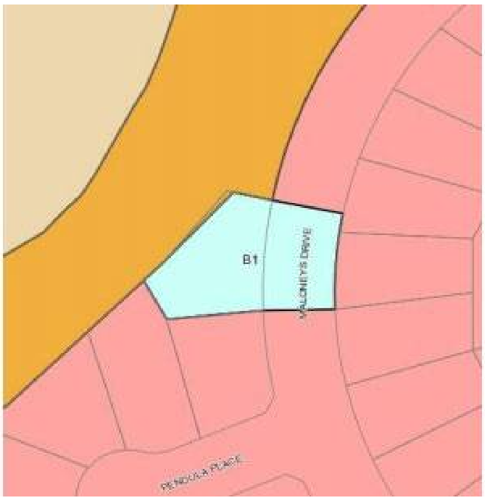
The DCP applies to the following neighbourhood centres as shown in the **Figures 5-1** to **5-5**:

- B1 in Longbeach
- B1 in Maloney's Beach
- B1 and R3 in Surfside & North Batemans Bay
- B2 and R3 in Batehaven
- B1 and R3 in Sunshine Bay.

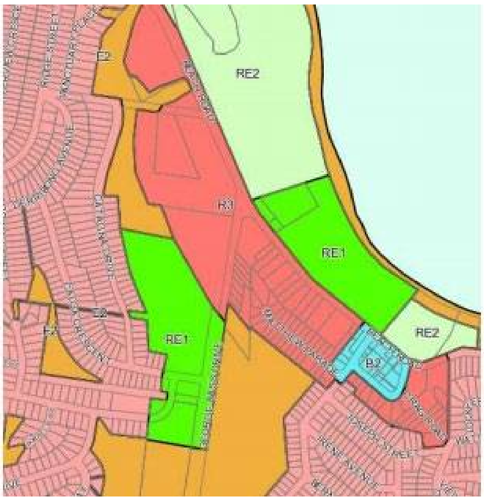
Section 7.3 requires a stormwater management plan be prepared to ensure stormwater management systems or other site works do not adversely impact on flooding. No other flood related controls are specific in the DCP.

B1 - Longbeach

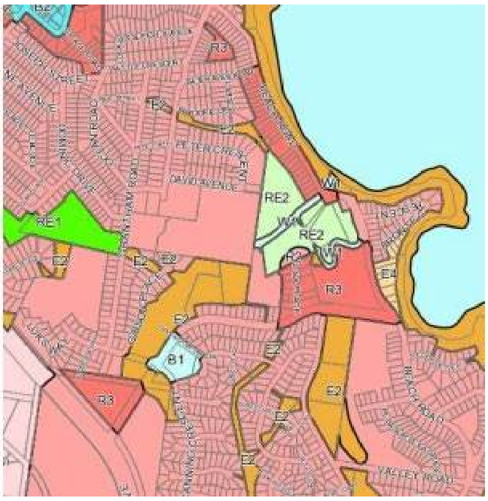
B1/R3 – Surfside/North Batemans Bay



B1 – Moloney's Beach



B2/R3 - Batehaven



B1/R3 – Sunshine Bay

Figures 5-1 to 5-5 Maps from Schedule 1 Neighbourhood Centres DCP

5.6 Other Policies, Plans and Codes

5.6.1 Eurobodalla Settlement Strategy 2006 – 2031

The aims of the *Eurobodalla Settlement Strategy 2006 - 2031* are to conserve biodiversity, respect our diverse cultural background, stimulate economic and community development, and provide efficient public services. The strategy reinforces and makes explicit the policy positionings of Council and the NSW Government which in turn are a response to contemporary local and wider community expectations. The Eurobodalla Settlement Strategy is aligned with the South Coast Regional Strategy 2007, prepared by the Department of Planning, Illawarra and South Coast Regional Office.

The Strategy makes reference to the fact that flood inundation has been mapped for most urban areas of the LGA and that restrictions are placed on building and construction on the extent of flooding that may result from a 1 in a 100 year event and, in some cases, from an extreme event. However, this is not supported by the relevant DCPs (**Section 5.5**).

The following actions are proposed in the Strategy:

- Undertake outstanding flood risk studies in areas that are potentially flood prone.
- Implement a management plan for flood liable land incorporating hazard and risk regimes, taking into account the potential effects of climate change, within which appropriate development is identified and restricted.
- Require applicants for new developments in potentially flood affected areas to carry out research to determine the extent of flood risk and potential impact of the development on flood behaviour and to submit this information to Council.

Preparing the Batemans Bay Urban Creeks Flood Study satisfies some of the proposal actions in the Strategy. However, to support the objectives of the Strategy, there needs to be better definition of flood-related controls for development in the floodplain.

5.6.2 South East and Tableland Regional Plan 2036

The *South East and Tableland Regional Plan 2036* (Department of Planning and Environment, 2017) guides the NSW Government's land use planning priorities and decisions over the next 20 years. Direction 16 of the Plan provides actions relating to the protection of the coast and increased resilience to natural hazards, such as flooding. The action relating to catchment flooding include:

- 16.1 – Locate development, including new urban release areas away from areas of flooding hazards and designated waterways to reduce the community's exposure to natural hazards
- 16.2 – Implement the requirements of the NSW Floodplain Development Manual by developing, updating, or implementing flood studies and floodplain risk management plans
- 16.4 – Incorporate the best available hazard information in local environmental plans consistent with current flood studies, flood planning levels, modelling, floodplain risk management plans and coastal zone management plans
- 16.6 – Manage risk associated with future urban growth in flood-prone areas as well as risks to existing communities.

5.6.3 Recreation and Open Space Strategy 2018

The *Eurobodalla Recreation and Open Space Strategy* (ESC, 2018) aims to provide the strategic framework for the management, provision and development of recreation and open space in the Eurobodalla LGA. The Strategy focuses on Council owned and/or managed public open space (community land, Crown land under

Council control and road reserves), including community halls and centres. Natural areas, including state-owned bushland reserves, have been considered for their role in providing for nature-based recreation.

The only mention of flooding within the strategy is with reference to the benefits of open space in reducing flood-related problems. This would suggest that the strategy would support the use of open space for the purpose of flood mitigation works as long as the other benefits and uses of open space are maintained.

There are 85 actions recommended in the strategy, none of these relate directly to flood risk management.

5.6.4 Moruya Floodplain Code 2012

The *Moruya Floodplain Code* (2012) is a development code that has been prepared in accordance with the principles of the *NSW Flood Prone Land Policy* and strategies contained in the *Moruya River Floodplain Management Plan (2004)* and the *NSW Floodplain Management Manual (2005)*.

The aim of this Code is to inform the community about Council's requirements in relation to the use and development of land potentially affected by floods.

The Code applies to all flood liable land up to and included the Probable Maximum Flood and some adjacent lands which become isolated during flooding of the Moruya River.

Development requirements are provided for various development types across four hazard categories. The development requirements do not differentiate between mainstream and overland flooding.

5.6.5 Eurobodalla Interim Coastal Hazard Adaptation Code 2017

The Eurobodalla Interim Coastal Hazard Adaptation Code (ESC, 2017) applies to lands within the coastal zone or areas identified by Council as potentially at risk from coastal hazards out to a maximum planning period ending at the 2100 coastal hazard projections identified in the *Eurobodalla Coastal Hazard Assessment* (WRL, 2017 or area mapped within the Code as 'Eurobodalla Investigation Areas' (noting that no maps were incorporated in Appendix A at the time of this review).

The development controls and strategies within this Code relate to coastal hazards and do not provide consideration of catchment flooding. However, the proposed strategies within the Code should be considered when developing floodplain risk management measures in the flood risk management study and plan phase. Further investigation should also be conducted as to how this Code applies in the context of the Coastal Management Act 2016 and the associated Coastal Management SEPP which came into force after the Code (in April 2018).

5.6.6 Eurobodalla Infrastructure Design Standards

This document provides design standards associated with the design of culverts, earthworks, drainage, and floor levels. This information will be considered in the preparation of recommended flood related planning controls as an outcome of the FRMSP.

5.6.7 Plans of Management

The following plans of management are within the study area and should be considered when identifying and assessing potential floodplain risk management measures as part of the future Floodplain Risk Management Study and Plan:

- Surfside Beach Foreshore Reserve Plan of Management
- Long Beach Foreshore and Wetlands Reserve Plan of Management
- Hanging Rock Recreational Reserve Plan of Management
- Catalina Reserves and the Hanging Rock Boat Ramp Car Park Reserve Plan of Management.

5.7 Implementation of Flood Planning Provisions and Development Controls – Summary of Current Practice and Desired Outcomes

A meeting was held in August 2019 to discuss Eurobodalla Shire Council's current flood planning processes. The meeting was attended by a range of Council staff across floodplain, planning and development assessment disciplines, as well as DPIE representatives. The key outcomes of the meeting were:

- LEP
  - Council's existing LEP Clause provides a good framework for applying flood related development controls.
  - The LEP Clause has recently been revised and makes reference to Council's adopted Sea Level Rise Policy.
  - Council is seeking direction on whether to include FPA maps within the LEP, the FRMPs or elsewhere. DPIE advised that as long as the FPL is clearly defined in the LEP then the mapping is not necessarily needed to accompany the LEP.
- DCP / Flood Code
  - The LEP Flood Clause (6.5) is not backed up by appropriate details in the DCP or a Code (with the exception of Moruya). Council is seeking guidance on the type of information and requirements within such a Code.
- Council's existing Section 10.7(5) certificates are used to clarify current and future risk; Section 10.7(2) are used to provide information about adopted studies, Public Works Department (PWD) advice from the 1980s, and easements identified by Council's stormwater engineers. A Section 10.7(2) certificate example was provided by Council.
- When development applications (DA's) are received by Council, Council's experience is that there is usually acceptance by the applicant that they have to apply flood related development controls and/or undertake site specific flood investigations, as long as it was already identified on the relevant Section 10.7 Planning Certificate. In some cases, Council identifies potential flood risk for a site that is not currently the subject of an adopted flood study when assessing the development application. The identification of flood-affected sites in this regard is based on the Council engineer's judgement. These are usually related to known overland flow issues or evidence of a low point.
- Development controls relating to overland flow are applied to DAs, however, Council does not have a standard set of controls for this purpose. Council often applies the advice provided by the consultant engaged by the applicant. The selection of an appropriate freeboard for overland flow was discussed, potentially <0.5m when depth of flow is <0.5m.
- Council currently requires flood impact assessments to show "no impact" on neighbouring and downstream properties. There was some discussion about quantifying acceptable impact, this can be discussed further as part of the planning review. If there are recommendations for broadscale filling to address sea level rise, some level of flood impacts may need to be tolerated in the short term (i.e. until neighbouring properties and roads are also filled).
- Both flood hazard and flood function should be considered in flood planning. The draft flood package covers both of these aspects of flooding (Section 5.3).

5.8 Flood Planning Recommendations

In considering the NSW flooding in land use planning guideline 2021 and Eurobodalla LEP 2012 It is recommended that an interim FPA be defined at the 1%AEP plus 0.5m. This is shown on **Map Series G901**.

Further consideration of flood function, flood hazard, flooding beyond the 1% AEP up to the PMF particularly with regard to risk to life and the implications of climate change should be a consideration of Council due to the risk associated with flooding presented in this study. It is likely these considerations will be reviewed as an outcome of the LSPS process (Section 5.4) and a future flood risk management study and plan for the study area.

Council's current DCPs (Section 5.5) do not currently contain comprehensive flood related controls for mainstream or overland flow flooding. Although it is also noted that Council does not currently have any specific overland flow studies completed. It is noted that the Draft LSPS makes reference to the introduction of a Council-wide Flood Management Code. Any such code would need to be consistent with the provisions of the LEP. The code would need to be consistent with the provisions of the Floodplain Development Manual (2005) or any updated Manual.

It is therefore recommended that:

- Council formally adopt this flood study and the associated maps and that all affected lots attract a Section 10.7(2) notation to indicate that flood-related development controls apply. In this regard, all flood-affected lots should become Flood Control Lots to ensure that exempt and complying development provisions under the State Environmental Planning Policy (Exempt and Complying Development Codes) 2008 do not apply to flood-affected lots.
- Council prepare a Flood Management Code to apply to various types of development within the floodplain. This should include:
    - How to determine whether the development is compatible with the flood function and the flood hazard of the land (as defined in the mapping in this study)
    - How to demonstrate the presence or absence of an adverse impact on flood behaviour on other properties or the alteration of flow distributions and velocities to the detriment of other properties or the environment of the floodplain
    - How to determine expectations for evacuation and whether there will be an adverse effect on the safe and efficient evacuation from the land or impact the capacity of existing evacuation routes for the surrounding area,
    - Council's expectations on appropriate measures to manage risk to life from flood,
    - How to determine that a site will not increase the potential for hazardous material to pollute the environment during flood events, and
    - What Flood-compatible building materials are considered acceptable (where some portion of the building is located below the flood planning level or the Probable Maximum Flood for Special Flood Considerations).
    - What Council's expectations are with regard to how climate change risk is addressed.
- Council adopt the interim FPA contained within this study based on the 1% AEP defined flood event, 0.5m freeboard and climate change as further described in Section 9.1.
- Council seek to add an additional clause to the ELEP to address Special Flood Considerations (which are not currently considered).
- Council consider whether there are existing land zonings that are incompatible with flood risk in the revision of the LEP and prepare a Planning Proposal for the alteration of the zone to a more flood-compatible zone.

The Moruya Floodplain Code (2012) provides a foundation for the LGA-wide Floodplain Code. However, contemporary flood risk management matters as listed above should be incorporated in the Code to ensure it is relevant for all floodplains across the LGA.

Any requirements contained within the LGA-wide Floodplain Code should be cross checked against the provisions of the National Construction Code (2019) to ensure that there are no gaps or inconsistencies. In some cases, consent conditions may need to be imposed where a specific provision should over-ride any standard provision in the NCC for conditions where a performance solution might be required (e.g. where flood depths are greater than 1.5m, being the limit of the provisions of the NCC, 2019).

6 Flood Modelling

6.1 Flood Modelling Approach

The approach to flood modelling for this project has been to develop site specific modelling approaches for each catchment considering the most appropriate methods of assessing hydrology, 1D / 2D hydraulics, ICOLL entrance behaviour, the influence of coastal processes and the impacts of hydraulic structures.

An integrated modelling system has been developed using TUFLOW as the 1D / 2D hydraulic modelling system for the representation of the hydraulics within the floodplains. The modelling approach for each catchment is provided in **Section 6.4**.

6.2 Hydrological Analysis

The hydrological modelling has been completed using the hydrological model in XP-RAFTS. Each of the catchments have been established as a separate model with the subcatchment delineation based on the supplied LiDAR information. The subcatchment delineation is shown in **Map G601**.

The hydrology has been based on Australian Rainfall and Runoff 2019 (ARR2019) with the parameters extracted from the ARR DataHub shown in **Table 6-1** (extracted 21 February 2020).

Inputs to the model and the data sources for those inputs are summarised in **Table 6-2**.

Table 6-1 ARR DataHub MetaData

Parameter	Value
Latitude	-35.697
Longitude	150.247
Storm Initial Losses (mm)	27
Storm Continuing Losses (mm/h)	6.9
River Region - Division	South East Coast (NSW)
River Region - Number	16
River Region	Clyde River-Jervis Bay
Point Temporal Pattern Code	SSmainland
Point Temporal Pattern Label	Southern Slopes (Vic/NSW)
Areal Temporal Pattern Code	SSmainland
Areal Temporal Pattern Label	Southern Slopes (Vic/NSW)
Version	2016_v2

Table 6-2 Hydrological Model Input Data

Parameter	Data Source
Sub-catchment area and slope	LiDAR data is available for full catchment.
Percentage impervious	Percentage impervious areas are largely a factor of development intensity and can be determined from aerial imagery. High resolution aerial imagery has been provided by Council and will be supplemented by freely available online imagery.
Roughness	Roughness parameters influence how quickly runoff occurs in a sub-catchment. Similar to the percentage impervious, the values have been determined from an examination of aerial imagery and have been largely dependent on land use. Delineation of roughness zones refer to Council's LEP mapping, particularly in areas that are undergoing development or redevelopment.
Runoff routing	Routing refers to the transfer of flows from one sub-catchment to another. This routing can be done in XP-RAFTS through either specifying a lag time between sub-catchments (10 minutes for example) or inputting a typical cross section, roughness and length and allowing XP-RAFTS to compute the lag time based on the flow volume. For this model, the cross section methodology has been adopted, with the sections being extracted from the available terrain and survey data.
Rainfall losses	Under the new methodology set out in ARR2019, rainfall parameters for hydrological modelling are all available from the ARR Data Hub. The parameters relevant to the modelling locations have been downloaded directly from this website. Data have been adopted and used in accordance with the DPIE Floodplain Risk Management Guide (2018).
Rainfall intensities	
Rainfall hyetograph	

6.2.1 Application of ARR2019

The new ARR2019 has a number of changes to the hydrological methods that have been traditionally employed. This includes updated design rainfall intensities, new ensemble storms and other catchment parameters such as losses.

One of the key challenges with the new approaches is the application of ensemble storms, with a number of storms to be run for each duration. This can result in challenges for large direct rainfall models, where it can be difficult to analyse all the temporal patterns due to the run times involved.

Our approach in the current study has been to run the full set of durations and temporal patterns through the XP-RAFTS model to determine the critical duration(s).

The critical duration(s) were then run through the hydraulic model for each of the 10 temporal patterns.

The results were then processed to:

- Extract the median plus one event from the 10 temporal patterns for each duration, and
- Extract the peak median from the set of durations.

6.3 DEM Development

A Digital Elevation Model (DEM) has been developed for input into the hydraulic models. This DEM is based on the survey data collected, including the LiDAR and ground survey. This DEM covers all the individual catchment areas.

One of the important components in the development of hydraulic models is to ensure that key hydraulic controls and features are defined appropriately within the DEM. This includes features such as embankment crest details, road levels where roads overtop etc. These have been incorporated where appropriate through the use of breaklines and other features, using the 12d ground modelling software.

6.4 Hydraulic Analysis

6.4.1 Hydraulic Model Areas

Based on a combination of preliminary 1% AEP rainfall on grid analysis, site inspections and discussions with the community, an 'area of interest' for each catchment has been identified. This represents the hydraulic modelling areas. This also represents the area within which catchment flooding may be significant and locations where flooding may pose risk to property and / or life. The hydraulic model areas are shown in **Map G602.**

6.4.2 Coastal Processes

Council recently completed a comprehensive coastal hazard assessment (WRL, 2017) that included the assessment of coastal water levels, waves, shoreline inundation and coastal erosion. This flood study leverages off the results of that study, specifically the coastal water levels inclusive of wind and wave setup, to define appropriate coastal boundary conditions consistent with guidance in the Floodplain Management Manual (NSW Government, 2005). Timeseries information of coastal water levels has been sourced from the Princess Jetty tide gauge to allow the consideration of tidal phasing with catchment flooding and define the High High Water Solstices Springs (HHWSS) up the reaches of each of the creeks.

6.4.3 Grid Cell Resolution

The urban areas of the study area will require a grid cell resolution fine enough to appropriately define flood risk. Based on site inspections and initial hydraulic model runs, a grid cell of 3 x 3 metres was adopted, which provided a reasonable balance in model run times and representation of flood behaviour.

6.4.4 1D Components

Stormwater infrastructure and culvert crossings within the study area has been included within the 1D portion of the model, with the floodplain defined in the 2D domain. Stormwater drainage, to a minimum pipe diameter of 600mm, has been included where it is available in Council's data sets and from the available survey data. Some smaller pipe reaches were included in order to extend the pipe network to road sag points, or where they provided a localised connection to an inlet pit.

Some regions of the pipe network had missing data for both inverts and pipe sizes. This data was infilled based on the following assumptions:

- 600mm cover of pipes and culverts, unless otherwise suggested by nearby survey.
- Missing pipe sizes were assumed to be the same as the largest of any upstream pipes.
- For a reach of pipes with missing data where sizes increased dramatically between known upstream and downstream sizes, a stepped increase was assumed through the missing reach.

6.4.5 Roughness

Roughness values extents were determined based on land use mapping and aerial photography, with reference made to ARR Project 15. The values adopted are summarised in **Table 6-3** and shown in **Map G603**.

Table 6-3 Adopted Roughness Values

Land Use	Manning's 'n'
Open space	0.035
Neighbourhood Centre (including building footprint)	0.250
Mixed Use (including building footprints)	0.200
Low Density Residential (including building footprints)	0.150
Recreation	0.040
Dense vegetation	0.080
Light vegetation	0.045
Medium Vegetation	0.060
Roads / Carparks	0.020

6.4.6 Buildings

There are several ways that buildings can be incorporated within a hydraulic model.

Buildings were typically incorporated using an increased lot roughness to account for the structures. The exception was the commercial buildings in the Water Gardens catchment.

Buildings within this region were incorporated as null objects, which effectively removes them from the model domain. The flowpaths were identified based on preliminary runs of the PMF event. Buildings were only nulled within the flood extents (refer **Map G602**).

6.4.7 Fences

There are numerous ways to incorporate fences within a 2D hydraulic model. While the techniques can be quite advanced, the reality is that the behaviour of fences in flooding can be quite uncertain and difficult to represent appropriately. Fences have been incorporated in the hydraulic model through a property averaged roughness value.

6.4.8 Downstream Boundary Conditions

Individual downstream water levels were determined for each catchment area, taking into account the offshore water level, wind setup, storm tide and wave set up. A full discussion on the derivation is provided in Appendix B.

Downstream water levels were prepared for the high high water springs solstice tide and the 5% AEP and 1% AEP ocean flood events. The HHWSS was constant at 0.91mAHD for all catchment areas. The derived entrance conditions and boundary levels are summarised below for the 5% AEP and 1% AEP ocean events in **Table 6-4**.

Details on how the ICOLL entrances scour during a flood event were modelled is provided in **Section 6.4.9.**

Table 6-4 Downstream Boundary Conditions

Location	Entrance Berm Height (mAHD)	5% AEP Ocean Level (mAHD)	1% AEP Ocean Level (mAHD)
Maloneys Beach	2.1	2.03	2.13
Long Beach	3.5	2.18	2.31
Surfside	1.5	1.96	2.03
Water Gardens	Permanently open	2.08	2.22
Catalina	Permanently open	2.09	2.21
Batehaven	2.3	1.72	1.82
Sunshine Bay	1.3	1.74	1.83

6.4.9 Modelling of the ICOLL Entrances

In modelling ICOLLs, it is possible to adopt a number of methodologies to represent the entrance, depending on how critical the entrance is to upstream behaviour, and how close development is to the entrance. In increasing order of accuracy, these options include:

- Option 1 - Modelling the entrance as fully closed and fully open in the hydraulic model and taking an envelope of these results. This precludes the need to determine how the entrance scours and is suitable for systems where development is away from the entrance, or the entrance has a minor impact on peak flood levels, regardless of its condition.
- Option 2 - Modelling the failure of the entrance using a terrain varying function or "dam break" style process in the hydraulic model. This approach simulates the scouring of the entrance. The breakout mechanism will be defined based on the geometry of the entrance (i.e. the lateral extent of the entrance), upstream flow regime and the experience of the project team with modelling ICOLL entrance breakout processes. This approach is generally suitable for small ICOLLs, or where development around the entrance is limited
- Option 3 - The most accurate (and resource intensive) method is to construct a hydrodynamic model of the ICOLL entrance, whereby the model determines the progression of the entrance failure based on flow conditions, and the material of the entrance. This level of accuracy may be warranted for large systems where significant development is located close to the entrance, and a detailed understanding of how the entrance behaves in flood events is required. Under this approach, the entrance breakout in TUFLOW will be defined as a "dam break" style process, but with the breakout timing defined based on a Delft3D model of the entrance. A localised Delft3D model of the creek entrance will be established, driven by upstream flows from the hydraulic flood model and by coastal water levels on the downstream boundary. The rate of entrance channel growth (i.e. entrance berm scour) will then be parametrised for input as a dam break in the TUFLOW model.

The approaches adopted for the specific entrances are discussed in **Table 6-5**.

Table 6-5 Modelling Approach

Catchment	Modelling Approach
Maloney's Beach (Maloney's Lagoon)	TUFLOW model covers the downstream catchment, incorporating the township and the entrance. The wider catchment is modelled in the hydrological model, with flow inputs applied at the extents of the hydraulic model. The entrance has been modelled using a dam break approach in TUFLOW (Option 2)
Long Beach Lagoon	TUFLOW model covers the lagoon and immediate foreshore areas. The topography rises steeply from the foreshore areas. The beachfront road and properties also included. The model assumes the lagoon starting level to be equal to the LiDAR level. The entrance has been modelled using a dam break approach in TUFLOW (Option 2)
Surfside Creek	TUFLOW model extends just upstream of Princes Highway on the main waterway but not on tributaries to the south west of the main waterway. The model assumes the lagoon to be full at the start of the storm. The outlet is unlikely to be all that sensitive to the berm due to the small pipes under the road. The entrance has been modelled using a dam break approach in TUFLOW (Option 2).
Water Gardens and Hanging Rock Creek	There are possible cross catchment flows so both Water Gardens and Hanging Rock Creek catchment areas are combined into one TUFLOW model. The model is extended to Princes Highway at the downstream end to better understand flooding in the CBD. Hanging Rock Creek entrance is modelled as an open entrance in TUFLOW (Option 1), this assumes the flood gates are open. Downstream of Water Gardens is controlled by a culvert outlet under the road which has been modelled in TUFLOW (Option 1).
Joes Creek	The entrance and lagoon breakout has been modelled in a dedicated hydrodynamic model. (refer **Section 6.4.9.1**)
Short Beach Creek	Given the short breakout distance required and the flow controls imposed by the bridge immediately upstream, a time varying terrain layer has been adopted to model the opening of this entrance (Option 2).

6.4.9.1 Hydrodynamic Modelling of Joes Lagoon Entrance

Hydrodynamic modelling of the Joes Lagoon entrance was undertaken using a Delft3D model, prepared by Baird.

Catchment inflows at the Beach Road bridge were extracted from the RAFTS model. This location acts as a culvert, channelling discharge into the ICOLL at a single location. The maximum discharge was aligned to the time of high coastal water level, the joint occurrence of which was determined using the guidelines provided by the former Office of Environment and Heritage (OEH, 2015), namely:

- For 5% AEP, 10% AEP and 20% AEP catchment flood events, the HHWSS tide for Batemans Bay was applied
- For 1% AEP and 2% AEP floods, a storm tide of 5% AEP was used
- For flood events 0.2% AEP, 0.5% AEP and PMF (nominally defined as 0.0001% AEP), a storm tide of 1% AEP was applied.

The Delft 3D-Flow model used 2018 LIDAR bathymetry of Joes Creek, and a berm height of 2.3 m AHD. An observation point, to obtain the downstream boundary conditions provided in this report, was placed in the lagoon landward of the entrance beach berm. The model was run for two days, ensuring maximum flooding levels were captured. Timesteps were set at 0.125s to accurately capture breakout over the berm and model maximum flooding.

The model was run for the full ensemble of storms, as per the ARR2019 guidance.

The levels reported from the Delft3D model were then incorporated in the TUFLOW model as downstream boundary levels.

7 Model Calibration, Validation and Sensitivity

7.1 Model Calibration / Validation

In a typical flood study, a calibration is undertaken by comparing observed flood behaviour, including recorded flood levels where available, against the flood behaviour determined from the flood model. This is done by obtaining or estimating the historical rainfall on the catchment for a particular historical flood event, and then reviewing the flood behaviour in the flood model to determine if it is consistent with observations. This provides greater confidence in the flood model results and assists in understanding the level of potential uncertainty.

In the Batemans Bay catchment areas, as identified in **Section 3.6**, there is a lack of historical pluviometers within the catchments. The nearest pluviometer gauge is located at Moruya Airport, approximately 20 kilometres from the catchment.

In addition to the rainfall data, many of the historical flood observations from the community (**Section 4**) were not specific to a particular date or flood event. In many cases, residents recalled a general period of time (for example, around 15 – 20 years ago), or a general frequency (for example, inundation of a particular area occurs every few years). This makes it difficult to assign a particular flood behaviour that was observed against a particular historical storm event.

Due to these challenges, it was agreed with Council that a full calibration against historical events would not be undertaken. Instead, an indirect validation was undertaken on the modelling. This validation has two key components:

- A review of the historical rainfall intensities – this provides an indication of the frequency and magnitude of historical events within the catchment (**Section 7.1.1**); and,
- A comparison of the modelled design events against the observations by the community (**Section 7.1.2**).

The outcomes of these analyses have been used to refine and confirm the various assumptions made within the model setup. It is noted however, that where ICOLL entrances have an impact on flood levels the historic entrance berm level may not be known.

7.1.1 Rainfall Intensity Assessment

An assessment of rainfall data can provide an indication of the magnitude of the rainfall events that may have been experienced within the catchment. The nearest rainfall gauge to the study area with pluviometer data available is the Moruya Airport gauge (refer to **Section 3.6** and **Map G303** for gauge details and location). This gauge is approximately 20 kilometres from the catchment areas to the south and an analysis of the rainfall may not necessarily represent local rainfall that falls on the catchment due to the variable nature of rainfall patterns in this area.

A common approach when there is no gauge within a catchment is to review surrounding rainfall gauges to understand how a storm event may have moved across the catchment and allow for an interpolation of the likely rainfall that fell on the catchment. Unfortunately, the next nearest pluviometer for the historical events that were identified was over 40 kilometres to the west, at the top of the ranges in Araluen. This makes it difficult to determine any localised movement of the rainfall during the period of a storm event.

An alternative is to use daily rainfall gauges. However, the Batemans Bay catchment areas typically respond to shorter duration rainfall events (i.e. up to 6-hour events). Understanding how these rainfall events move across a catchment is difficult to represent through a daily read rainfall gauge.

To provide an indication of the general magnitude of historical rainfall events that were identified by the community (**Section 4**), an analysis of the Moruya Airport gauge was undertaken. Design rainfalls for ARR2019 IFD data for design events was sourced from the BoM and are summarised on the log plot in **Figure 7-1**. Average rainfalls were determined for each of the historical events for durations ranging from 30 minutes to 6 hours. These historical events are the five largest storms recorded at the pluviostation, and all occurred within the last 20 years.

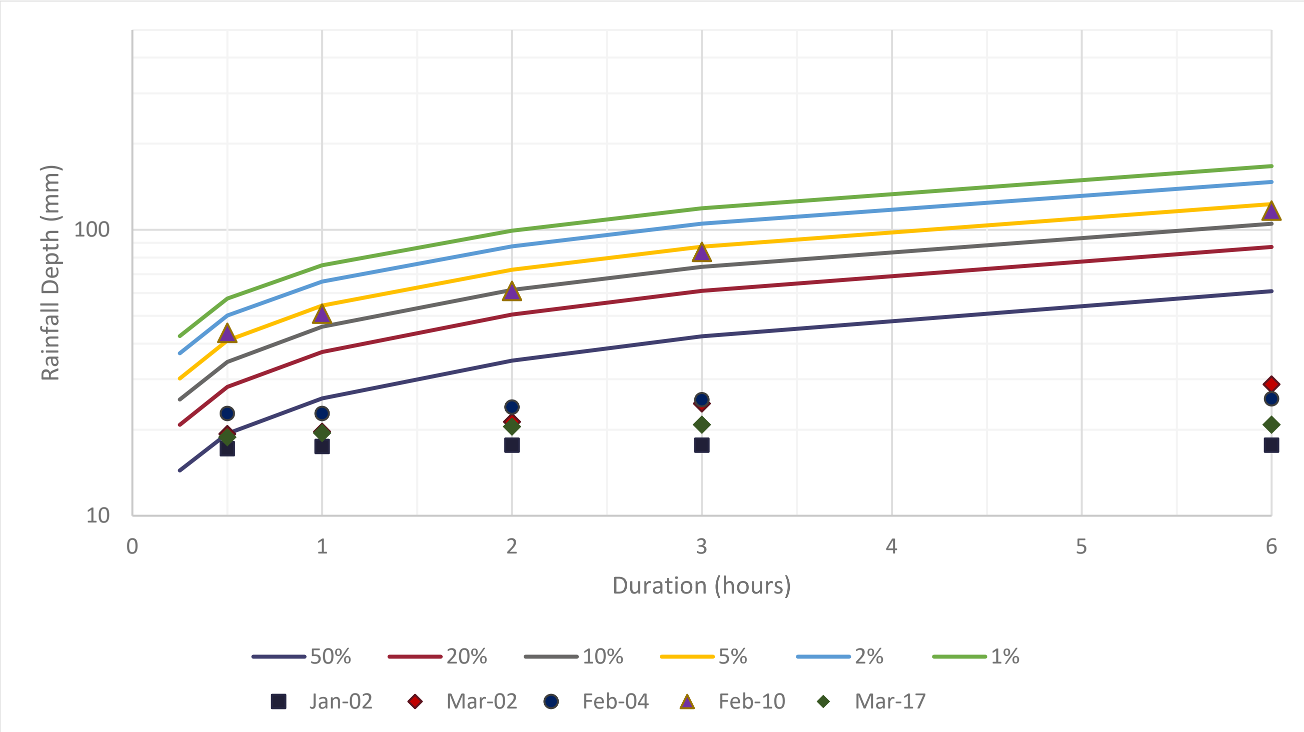


Figure 7-1 Moruya Airport Gauge Historical Event Intensity Compared to ARR2019 Intensity

The rainfall assessment showed that all of the events, save the February 2010 event, were very short duration storms, with rainfall being most critical for the 30 minute duration. All the short duration events were relatively small, in the order of a 50% to 20% AEP.

The February 2010 event was a larger event, with more sustained rainfall. The rainfall from the event was in the order of a 5% AEP event, for durations from 30 minutes to 6 hours.

A comparison of the largest rainfall events on record at the Moruya Airport gauge were also compared against the responses from the community collected as part of the mailout and community workshop (**Table 7-1**).

Table 7-1 Comparison of Gauge Record and Community Observations

Event	Approximate AEP	Mentioned by Community in Survey/ Door Knocking
January 2002	50% AEP	No
March 2002	50% AEP	No
February 2004	50% - 20% AEP	No
February 2010	5% AEP	No
March 2017	50% AEP	Yes

While the sizes of the rainfall events at the gauge are generally modest, it is of interest that only one of these events were identified or recollected by residents during the community survey. Conversely, a number of community responses noted a flood event in January 2014, which was not recorded as a significant event at the Moruya Airport gauge. This would suggest that there is variability in the local rainfall patterns particularly for short duration storms and, therefore, the rainfall at the Moruya Airport gauge is not always representative of the rainfall in the catchment and should be considered on a case by case basis in future studies.

7.1.2 Comparison with Community Survey Descriptions

As a part of the community survey and drop in sessions, there was information obtained on general flood behaviour (**Section 4**). This was not always specific to a particular event, or in many cases a general period was recalled. However, it provides useful information on the flood behaviour.

An indirect verification of the modelling was undertaken by comparing the flood behaviour in the model for the 1% AEP event against the observations from the community.

The generalised descriptions of flood behaviour, together with the modelled behaviour, is provided in **Map G701**. The map indicates a general level of consistency between the modelling and the observations from the community.

7.2 Sensitivity Analysis

Sensitivity analysis is a useful tool in understanding the potential variability of model results with different parameter assumptions. The following sensitivity analyses have been undertaken:

- Rainfall losses;
- Lag Time;
- Rainfall Intensity;
- Model roughness;
- Model inflows; and,
- Downstream boundary conditions.

7.2.1 Hydrological Sensitivities

The sensitivity of the modelling to rainfall losses, lag time and rainfall intensity were undertaken in the hydrological model. The testing was done on two catchment areas:

- Water Gardens (a small highly urban catchment)
- Batehaven (a larger catchment with large areas of open space and vegetation)

The results of the sensitivity testing are shown in **Table 7-2**.

Overall, the models were very insensitive to changes in lag time, and marginally more sensitive to changes in rainfall intensity than rainfall losses. The smaller Water Gardens catchment was more sensitive to all changes than the larger Batehaven catchment.

The insensitivity to the lag parameter is likely due to the fact that the models have relatively few subcatchment areas (around 10 to 15) so changes in timing are not given the opportunity to substantially affect outlet flows.

While a greater sensitivity was observed for both rainfall losses and rainfall intensity, neither resulted in substantially different peak flows given the scale of the parameter change. A 20% variation in both these parameters typically delivered a 15 – 25% change in peak flows.

Table 7-2 Hydrological Sensitivity

Parameter	Parameter Change	Peak Flow Rate Change
Water Gardens		
Rainfall Loss	+20%	+25.0%
	-20%	-15.9%
Lag Time	+20%	+10.4%
	-20%	-16.8%
Rainfall Intensity	+20%	+26.0%
	-20%	-25.3%
Batehaven		
Rainfall Loss	+20%	+18.2%
	-20%	-13.0%
Lag Time	+20%	+6.7%
	-20%	-4.9%
Rainfall Intensity	+20%	+23.8%
	-20%	-24.4%

7.2.2 Hydraulic Model Sensitivities

The sensitivity of the hydraulic model to inflows, roughness, downstream boundary and blockage conditions was assessed for the 1% AEP event. The results are shown in:

- Map Series G702 for a 20% increase in flows
- Map Series G703 for a 20% decrease in flows
- Map Series G704 for a 20% increase in roughness
- Map Series G705 for a 20% decrease in roughness
- Map Series G706 for a 20% increase in downstream levels
- Map Series G707 for a 20% decrease in downstream levels
- Mao G708 for a fully blocked culvert under Wharf Road at Surfside

The results show that the model is reasonably sensitive to flow increases and downstream boundary levels, marginally sensitive to flow decreases and blockage assumptions, and relatively insensitive to roughness changes.

As a result of a 20% increase in flows, increases in peak levels of 0.1 – 0.2 metres occurred in all catchment areas. Those regions with storage driven flood behaviour such as Maloneys Beach, Long Beach and Batehaven showed the most significant increases. While isolated pockets in the other catchments did show increases in the 0.1 – 0.2 metres range, typical changes in these non-storage driven systems were in the order of 0.05 – 0.1 metres.

Changes arising from a 20% reduction in flows were more modest, both in size and extent. Reductions were relatively constant across all catchment areas, in the order of 0.1 – 0.15 metres, and generally focused on areas of storage or local depressions.

The models were relatively sensitive to downstream boundary levels. Increases in the boundary levels resulted in water level increases propagating over 1.5km upstream of the shore in Surfside, Catalina and Batehaven. Impacts in catchments with more controlled entrance conditions such as Maloneys Beach and Long Beach were smaller for both increased and decreased downstream levels. The low lying areas of Surfside, Catalina and Batehaven were particularly sensitive to water level changes.

The model was relatively insensitive to changes in roughness values. The 20% change in roughness values typically resulted in in changes of less than 0.03m. Larger differences of +/- 0.05m were observed in the Maloneys Beach and Batehaven catchment areas.

The full blockage of the Surfside culvert under Wharf Road had a modest impact on peak levels in the region, similar to when the ocean levels are high. Levels immediately upstream of the culvert under the blocked sceario increased by 0.1m. Overtopping depths of Wharf Road increased by up to 0.1m at the low point to the east of the culvert. Increases of up to 0.09m occurred across residential properties along Timbara Crescent, Foam Street and Wallaringa Street also occured. Due to the terrain in the region, these increases did not result in any expansion in the flood extent and were already incorporated with the enveloped ocean boundary conditions further discussed in Section 8.

8 Understanding Flood Behaviour

8.1 Design Flood Behaviour

Peak flood depths (with water level contours) and velocities are provided in **Map Series G801** and **G802** respectively**.** Maps have been prepared for the 10% AEP, 1% AEP and PMF events.

The full set of data for all design events (PMF, 0.2% AEP, 0.5% AEP 1% AEP, 2% AEP, 5% AEP and 10% AEP events) has been provided to Council in a digital format.

Published maps are an envelope of a number of durations. The methodology for prepare the maps involved:

- The determination of the median event for each duration and recurrence interval.
- The determination of the maximum of the median values for each recurrence interval.

The 1% AEP has additional results included in the envelope, as per the guidance in the *Floodplain Risk Management Guide* (OEH, 2015), namely:

- Results from a 5% AEP catchment flood, coupled with a 1% AEP ocean surge which assessed flooding driven by ocean events; and,
- Results from a 1% catchment flood coupled with an Indian Spring Low Water (ISLW) tide to assess peak velocities at the entrances.

Both processed envelopes and raw results for all duration and recurrence interval combinations have been provided electronically to Council.

8.1.1 Maloneys Beach

As a result of the large storage provided by the lake upstream of the township, and the natural restriction at the lake outlet provided by the creek, flooding within the Maloneys Beach catchment is generally well contained within the creek system for events up to and including the 1% AEP.

The exception to this is at the bend in Maloneys Creek immediately upstream of the entrance, where some localised overbank flows commence in the 10% AEP. This results in inundation of properties at the western end of Pendula Place by 0.2m in the 10% AEP and up to 0.7m in the 1% AEP.

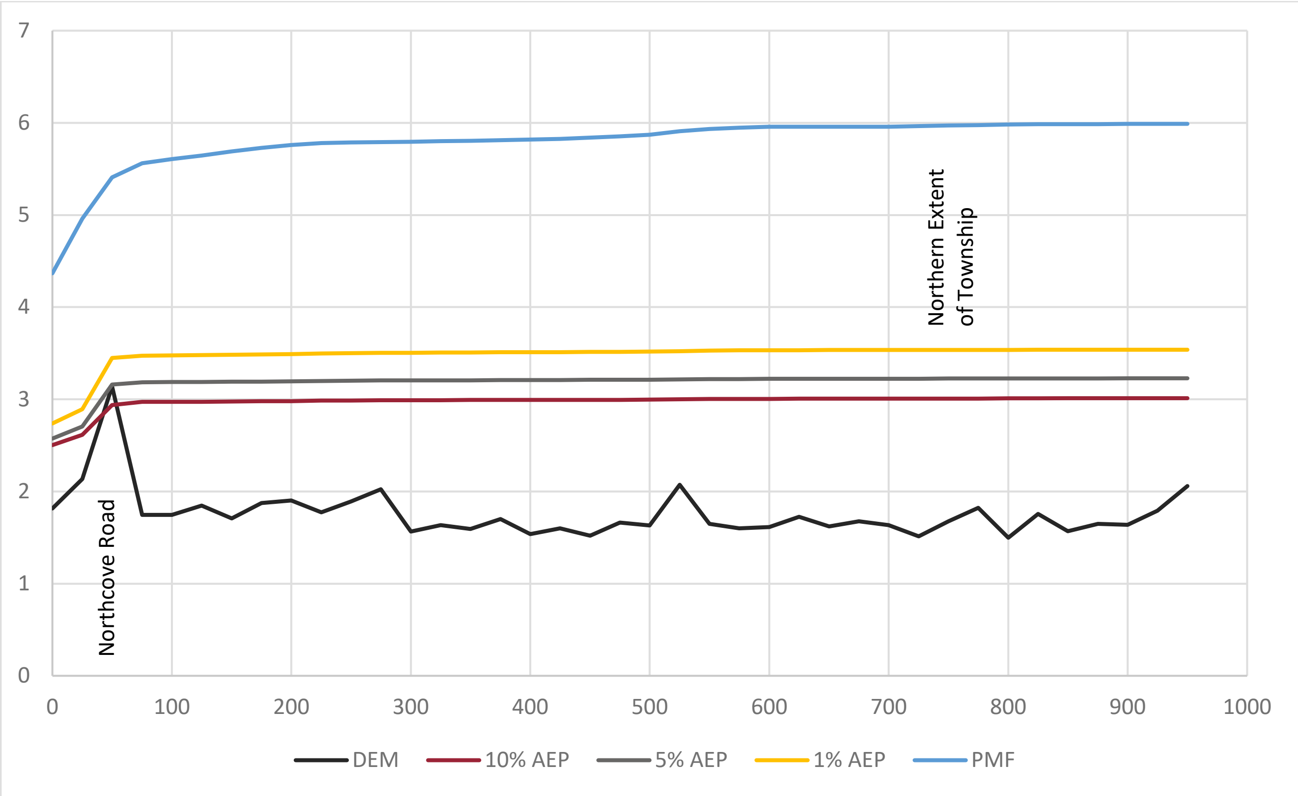
In the 1% AEP event overtopping of 0.6m occurs across Northcove Road at the creek crossing, isolating the township.

In the PMF, flow breaks out of both the lake and the adjacent creek to inundate the entirety of the township. Depths are most significant in the north, adjacent to the lake, with property flooding depths of up to 1.7m occurring in the PMF. Depths of over 1m occur across the majority of the township in the PMF, reducing to 0.2m Belbowie Parade as the terrain rises to the local high point at Maloneys Drive.

Velocities remain low across the catchment for all events. Even in the PMF, creek velocities do not exceed 1m/s. Velocities across the township are less than 0.5m/s in the PMF, although higher velocities of up to 0.8m/s occur within the road reserves.

The exception to this behaviour is the outlet, which sees velocities of 3.1, 2.3 and 4.3 in the 10% AEP, 1% AEP and PMF events, respectively. The velocities in the 10% AEP are higher at the entrance than the 1% AEP as a result of the lower ocean level when the entrance breaks out.

A long-section is shown in **Figure 8-1**.



7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800
900
1000
Northern Extent of Township
Northcove Road
DEM
10% AEP
5% AEP
1% AEP
PMF

Long-Section
1% AEP Depth (m)
0 - 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
>4
MALONEYS DRIVE
BOTTLEBRUSH PLACE
BLUE GUM PARADE
TRISTANIA PARADE
WILLOW COURT
EXCELSA COURT
EUGENIA PLACE
PENDULA PLACE
BELBOWRIE PARADE
CEDAR PARADE
NORTHCOVE ROAD

Figure 8-1 Maloneys Beach Long-Section

8.1.2 Long Beach

The flood affectation in Long Beach is minor, due to a combination of the relatively small catchment area, the large lake storage, and the substantial outlet control provided by the small outlet channel. These conditions result in no property flooding in events up to and including the 1% AEP event.

In the PMF event, some property flooding occurs as flow breaks out from the outlet channel at Sandy Place and from the lake directly at the intersection of Blairs Road and Sandy Place. Depths of up to 1.2m occur at properties adjacent to the outlet channel. Depths at the lake breakout are more modest, with property flooding depths of up to 0.5m occurring and 1.1m depths occurring across the intersection.

Velocities of up to 0.8 meters per second occur across properties adjacent to the outlet channel. As the flooding from the lake breakout is driven by lake flooding, and does not flow through to the bay, the velocities for properties affected by this flooding are very low, in the order of 0.1m/s.

A long-section is shown in **Figure 8-2**.

8.1.3 Surfside

The Surfside catchment has a number of locations that act, whether naturally or by design, as detention basins. The Princes Highway creates a large basin on the upstream side where the main channel crosses. Additional water bodies on the eastern and western sides of Batemans Bay Public School provide further storage, with their outlets controlled by small downstream watercourses.

In the 10% AEP event, flows are fully contained within the creek system.

In the 1% AEP, some properties experience flooding along Timbara Crescent due to elevated ocean levels. For the majority of these properties, flooding is confined to the rear of the lots, and does not impact dwellings. Immediately upstream of the Timbara Crescent and Wharf Road intersection, two properties are affected by flood depths of up to 0.5m in the 1% AEP.

Inundation also affects a number of properties on Foam Street, Wallaringa Street and Myamba Parade in the 1% AEP event, most significantly at the western ends around the intersections with Wimbarra Crescent. Local depressions adjacent to The Vista also result in ponding depths of up to 0.5m in the 1% AEP event.

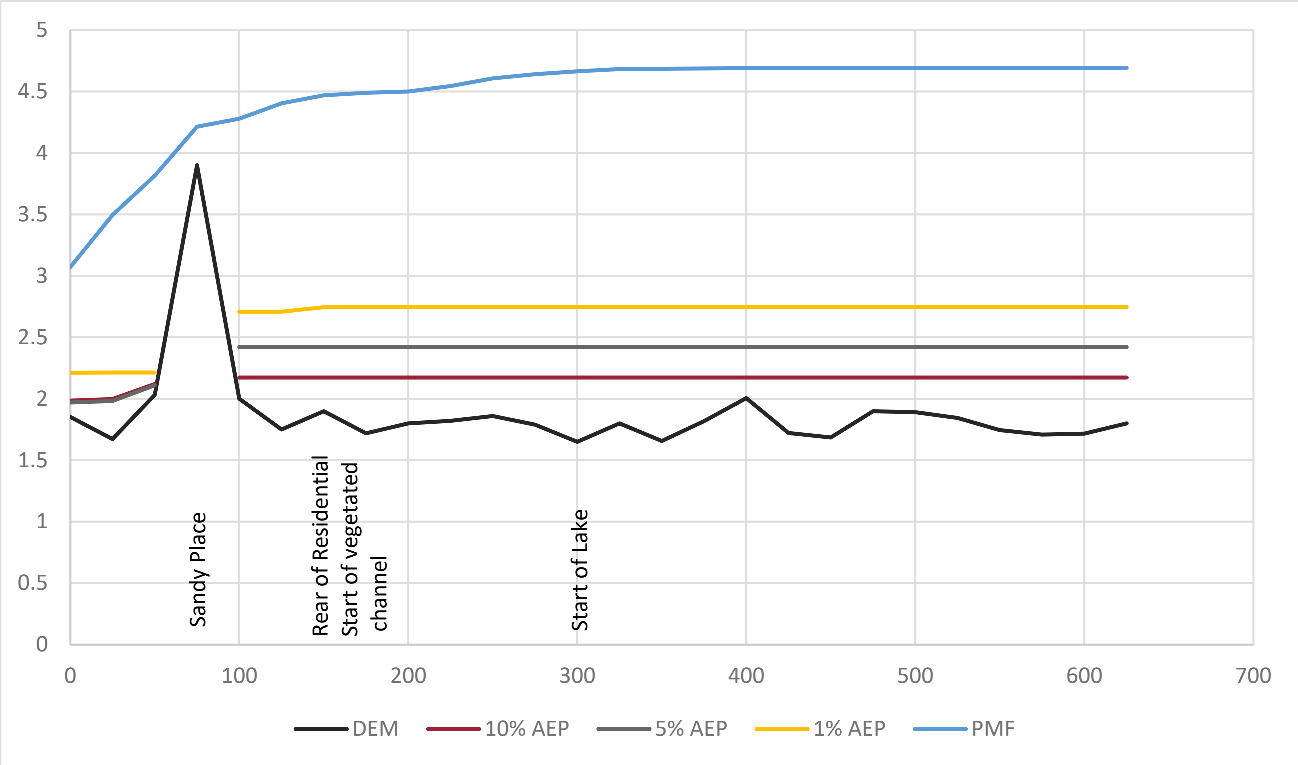
In the PMF event, elevated ocean levels result in widespread flooding across the region bound by Timbara Crescent by depths of up to 0.8m.

Batemans Bay Public School is also flooded by up to 0.3m across some buildings, 0.4m across the sports fields and up to 1.3m across the Mundarra Way access road.

Overtopping of the Princes Highway occurs in two locations in the PMF, with depths of 0.4m.

Velocities in the creek system are modest in the 1% AEP, with peaks up to 0.6 meters per second. These increase to 1.8m/s in the PMF. As residential flooding is largely driven by ocean levels, velocities across these regions remain below 0.5m up to and including the PMF, although higher velocities are observed within the road reserves.

A long-section is shown in **Figure 8-3**.


5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
100
200
300
400
500
600
700
Sandy Place
Rear of Residential
Start of vegetated channel
Start of Lake
DEM
10% AEP
5% AEP
1% AEP
PMF

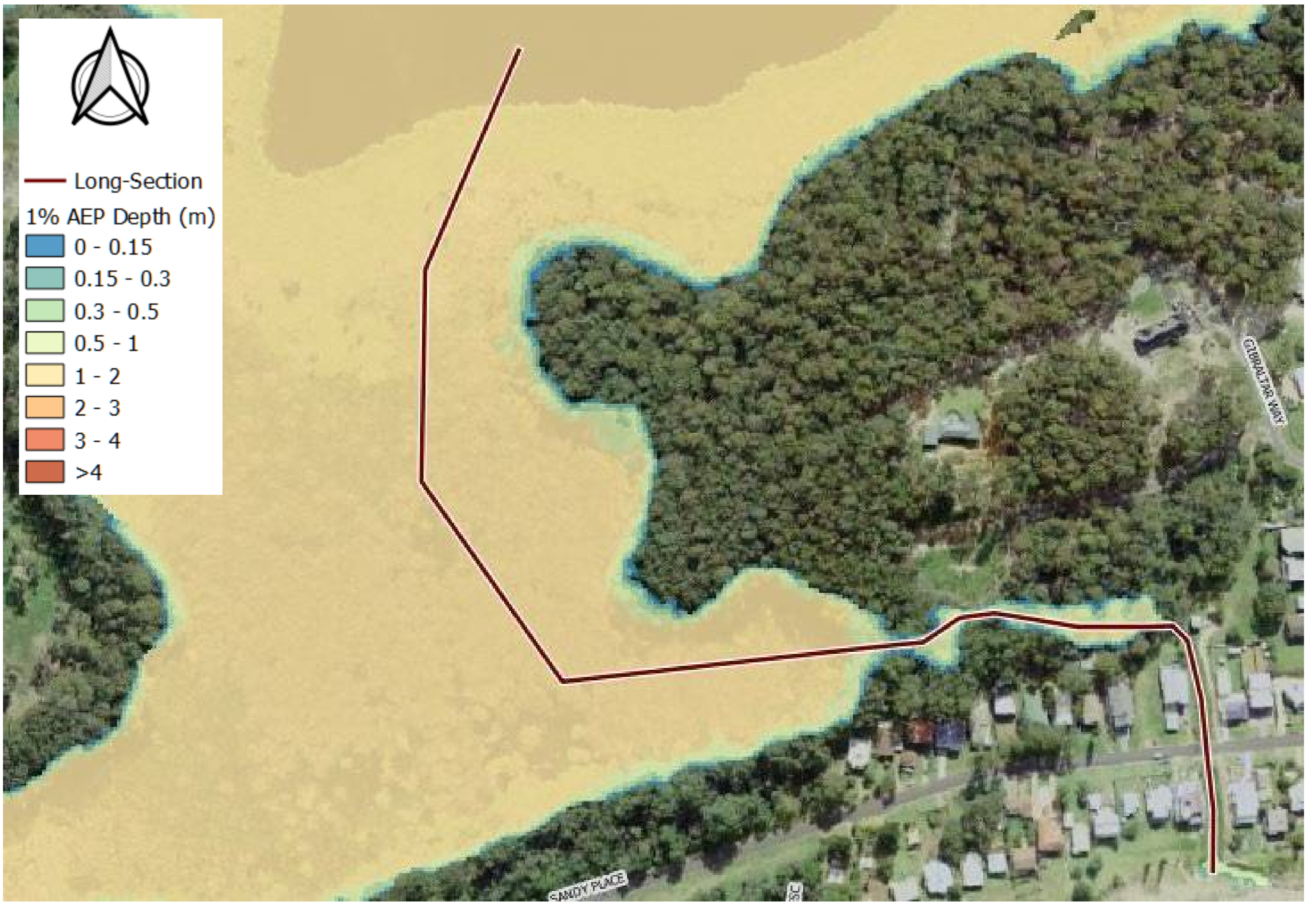

Long-Section
1% AEP Depth (m)
0 - 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
>4
SANDY PLACE
GIBRALTAR WAY

Figure 8-2 Long Beach Long-Section

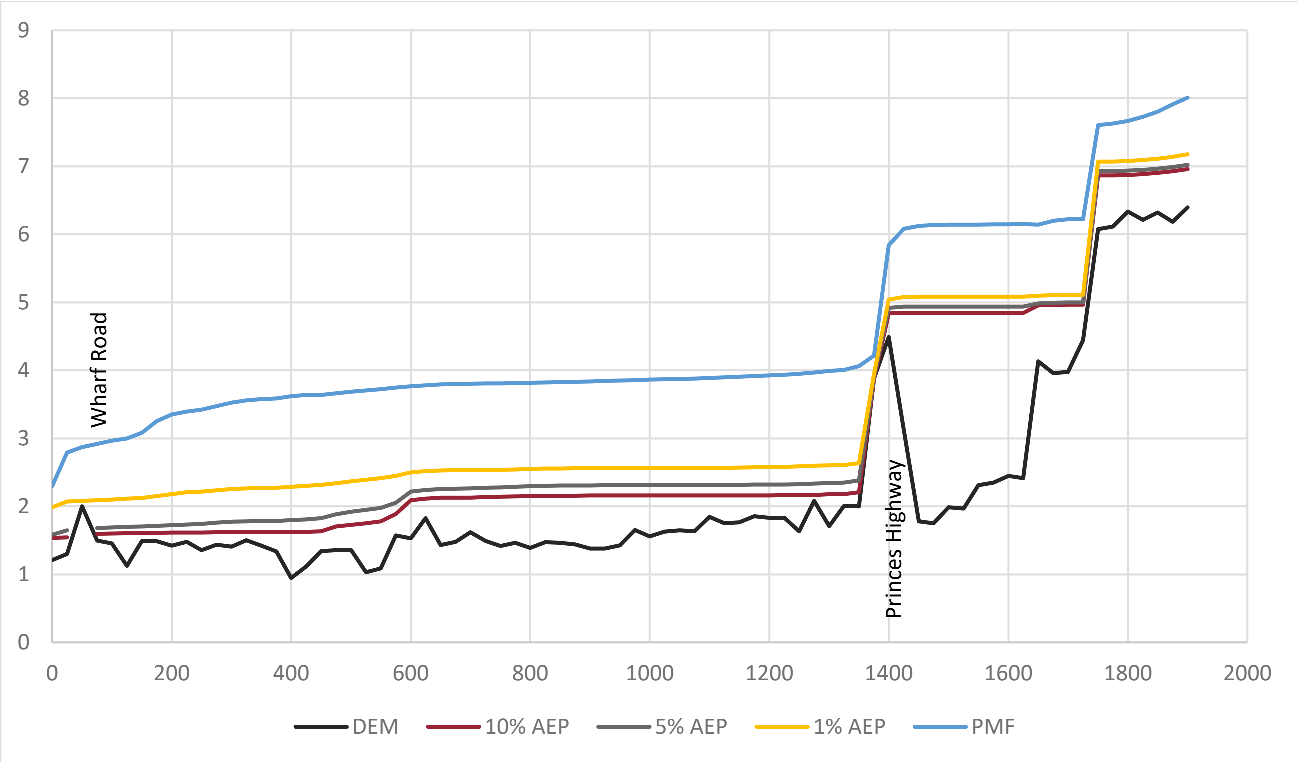


Figure 8-3 Surfside Long-Section

8.1.4 Water Gardens

Unlike the northern catchment areas, property flood affectation commences in more frequent events for the southern subcatchments. Water Gardens experiences property flooding in the 10% AEP, both within the CBD due to catchment flooding, as well as at the low point of Herarde Street and Beach Road. Depths in the CBD reach 0.3m at local low points, due to insufficient capacity in the drainage network. The regions of ponding are generally isolated. The property flooding on Herarde Street is a result of local catchment flows running down Heradale Parade, and then crossing Herarde Street properties and the Argyle Terrace Motor Inn, to discharge into the bay.

In the 1% AEP, flows within the CBD increase with local catchment flows draining out to the bay along the Old Princes Highway and Flora Crescent. The water body within Albert Ryan Park also overtops in the 1% AEP, breaking out through the park and the adjacent Medicare and Centrelink carparks. Flood affectation at the Herarde Street overland flowpath increases significantly in the 1% AEP. Driven by cross catchment flows from the neighbouring Catalina catchment, properties along Herarde Street and Heradale Parade experience depths of up to 0.8m.

The PMF events sees flood depths of up to 1.4m occurring on the Old Princes Highway and 1.2m along Flora Avenue and Beach Road. Flooding driven by elevated ocean levels impacts Clyde Street properties with depths occurring of up to 0.5m. The extent of flooding at the Herarde Street overland flowpath also increases to impact more properties and depths increase to 1.1m.

Velocities are typically low for all events, with velocities of less than 0.5m/s occurring across developed properties in the PMF event. Higher velocities are observed along the road reserves. They are generally less than 1m/s, although increase to 1.2m/s along the Old Princes Highway in the PMF event.

No long-section is shown for Water Gardens due to the highly developed nature of the catchment.

8.1.5 Catalina

The Catalina catchment is dominated by the golf course which covers much of the central region of the catchment, with residential zones located around the course, and between the course and the bay.

Upstream of Beach Road, flood affectation is relatively minor in the 10% AEP event. The golf course experiences widespread, shallow flow across the grounds, but otherwise the upper catchment flows are well contained within the creek corridor. Downstream of Beach Road, however, significant flooding occurs across residential zones located north of Caitlin Avenue (south of Caitlin Avenue is flood affected also but is located in the Batehaven catchment and is discussed below). This flooding arises due to the combined impacts of overbank flow from Hanging Rock Creek, elevated ocean levels, and cross catchment flows from Joes Creek in the Batehaven catchment. Depths of up to 1.2m occur in this region in the 10% AEP event.

In the 1% AEP, flow upstream of the golf course remains well contained. Downstream of the golf course, a wide flowpath inundates much of the region along Golf Links Drive, with depths of up to 0.7m. Flows from the golf course also break out to the north, contributing to the flooding observed along Herarde Street in the Water Gardens catchment (see above). The extent of flooding north of Caitlin Avenue does not increase in the 1% AEP, but the depths increase to up to 1.3m in some locations.

The PMF remains well contained within the upper catchment, although road access along Heron Road is lost. The golf course is fully inundated, as is all the low lying areas north of the golf course. In the PMF, this wide-scale flooding through the downstream region is driven by elevated lake levels. Depths of up to 1.2m and 1.8m occur along Golf Links Drive and Cailtin Avenue respectively.

As a result of the wide, shallow flow behaviour and the elevated lake levels, velocities remain typically low for all events. The 1% AEP event sees only isolated reaches exceed 1.0m/s, with the majority of the flow below 0.5m/s. This behaviour remains consistent in the PMF, save for where Hanging Rock Creeks breaks into the golf course. In the PMF event velocities of up to 2.4m/s were observed in this area.

A long-section is shown in **Figure 8-4**.

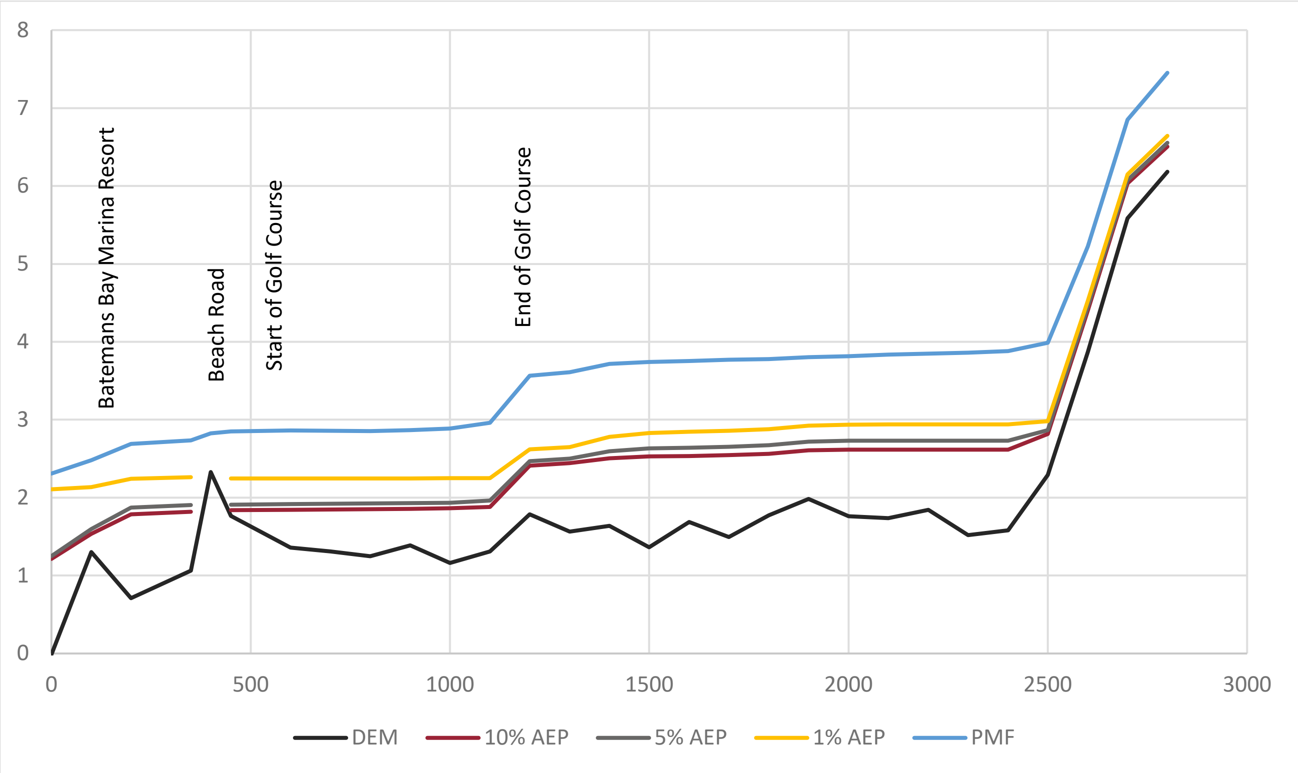


Figure 8-4 Catalina Long-Section

8.1.6 Batehaven

Joes Creek runs through the centre of the Batehaven catchment. In the 10% AEP event, there is no property flooding upstream of Beach Road, however road access is lost along George Bass Drive (0.45m), Calga Crescent (0.34m), Melaleuca Crescent (0.57m) and Glenella Road (0.21m). The region downstream of Beach Road is mostly inundated in the 10% AEP, by depths of 0.4 – 0.7m. This flooding is driven by breakout flow from Joes Creek at the entrance, and affects Clyde View Holiday Park, Big 4 Bay Beach Resort and the Batemans Bay basketball and tennis centre.

In the 1% AEP event, properties along are affected along Edward Avenue by depths of up to 0.78m, and Melaleuca Crescent by up to 0.27m. Downstream of Beach Road, the flood extent remains similar, but depths increase from 0.4 – 0.7m to 0.6 – 1.2m.

The PMF event results in significant break out flows from Joes Creek, inundating large numbers of properties along Melaleuca Crescent, Edward Avenue, Clara Crescent, Christopher Crescent, Matthew Parade and Beach Road. Downstream of Beach Road levels increase to 1.2 – 1.4m.

Velocities typically remain low in events up to the 1% AEP, with peaks of less than 1m/s across the catchment, save for the entrance and some road reserves. In the PMF, Joes Creek velocities increase to 2.5m/s in the upper catchment and 1.5 – 2m/s through the downstream reaches. Velocities remain less than 1m/s across residential and commercial areas in the PMF.

A long-section is shown in **Figure 8-5**.

8.1.7 Sunshine Bay

The Sunshine Bay catchment has two tourist parks in the lower reaches of the catchment, Caseys Holiday Park and Pleasurelea Tourist Resort. Both of these sites experience flooding in the 10% AEP event, with depths up to 0.7m in both locations. These depths increase to 1.1m in the 1% AEP and 2.2m in the PMF.

Velocities remain low at these locations for all modelled events, with peaks below 0.5m/s for all modelled events.

With the exception of these two locations, flows are generally well contained in the 10% AEP. There is some overtopping of John Street by up to 0.3m, but otherwise flow is fully contained within the creeks and channels.

In the 1% AEP event, the rear of properties along Beach Road are inundated, and overtopping occurs along Sunshine Road and Edward Road by 0.7m and 0.2m, respectively.

The PMF event results in increased affectation along Beach Road, as well as the inundation of St Bernard's Primary School. In the upstream reaches of the catchment, significant overtopping depths occur across Sunshine Road (2m), Edward Road (1.4m), George Bass Drive (0.9m) and Crosby Drive (0.9m) but no additional property affectation is observed.

Velocities remain low up to and including the 1% AEP for the majority of the catchment, the exceptions being the steeper vegetated reaches upstream of George Bass Drive and the entrance, which see velocities of up to 1.4 and 2.2m/s respectively.

In the PMF, velocities of 0.8 to 1.5m/s are observed through Short Beach Creek, and 4.1m/s at the entrance.

A long-section is shown in **Figure 8-6**.

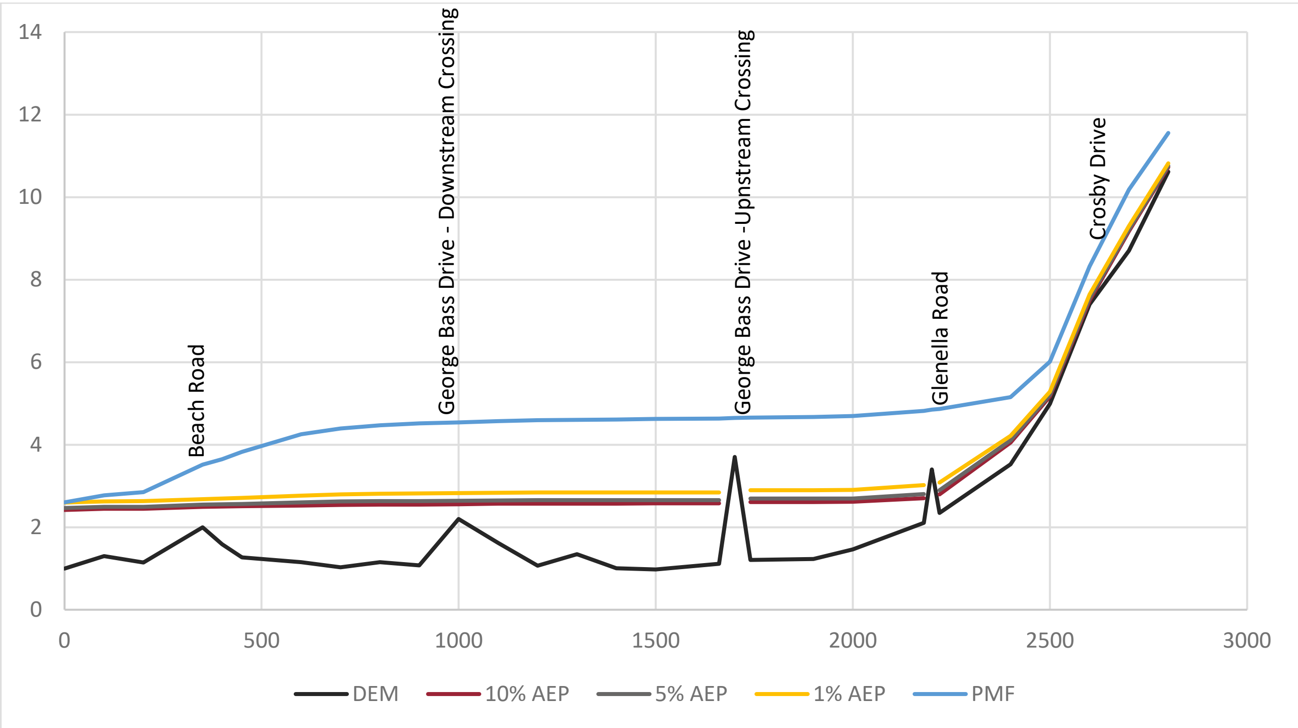


Figure 8-5 Batehaven Long-Section

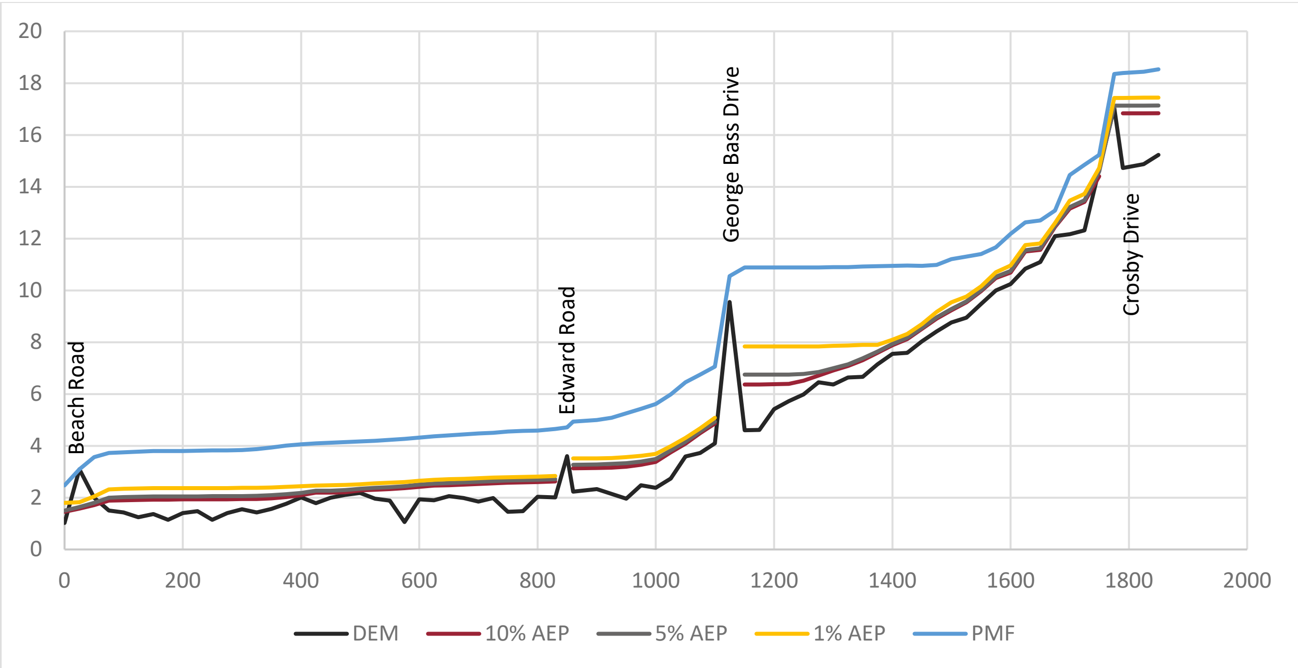


Figure 8-6 Sunshine Bay Long-Section

8.2 Flood Hazard

Flood hazard varies with flood severity (i.e. for the same location, the rarer the flood the more severe the hazard) and location within the floodplain for the same flood event. This also varies with both flood behaviour and in the interactions of the flood with the topography.

It is important to understand the varying degree of hazard and the drivers for the hazard, as these may require different management approaches. Food hazard can inform emergency and flood risk management for existing communities, and strategic and development scale planning for future areas.

The hazard categories mapped are summarised in **Table 8-1** and **Figure 8-7**. These are based on the categories as defined in the AIDR (2017) Guideline.

Table 8-1 Hazard Categories

Hazard Category	Description
H1	Generally safe for vehicles, people and buildings
H2	Unsafe for small vehicles
H3	Unsafe for vehicles, children and the elderly

H4	Unsafe for vehicles and people
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure

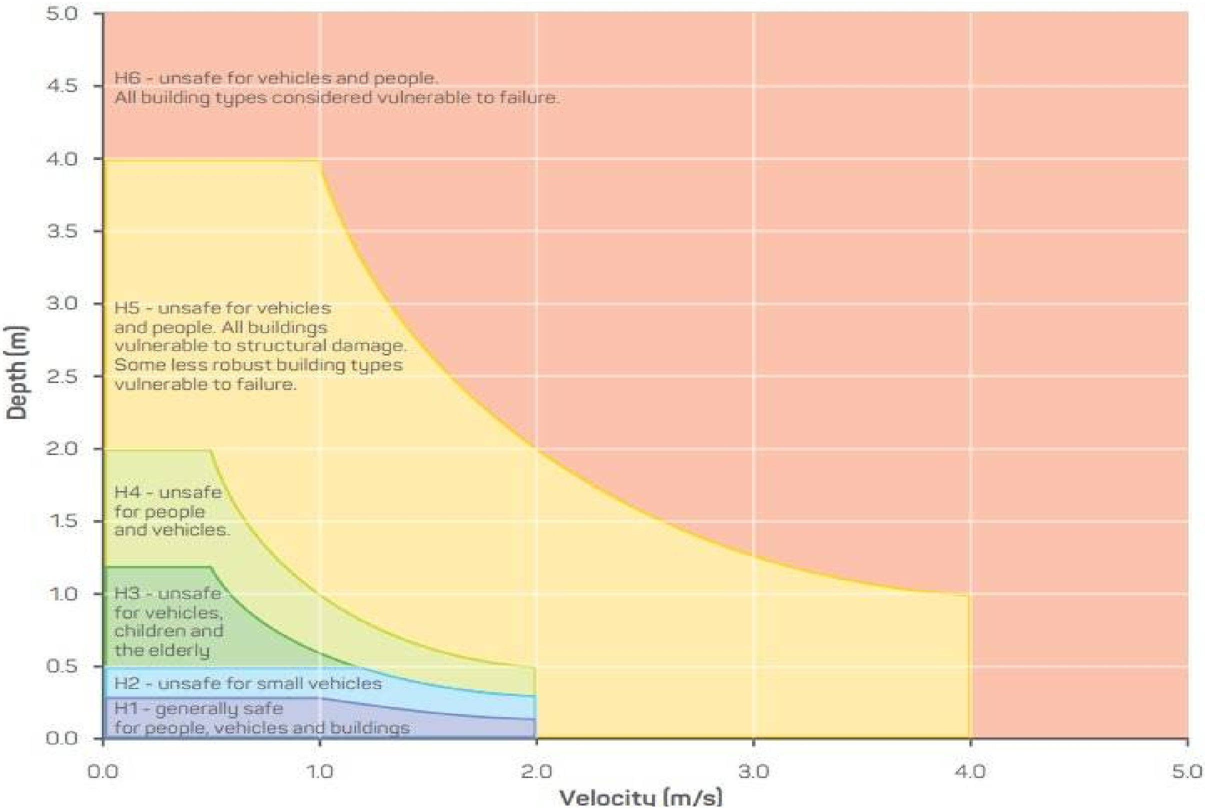


Figure 8-7 Flood Hazard Categories (AIDR, 2017)

Flood hazard mapping is provided for the 1% AEP and PMF events in **Map Series G803**. Hazard data for the full set of design events has been provided electronically to Council.

As a result of the generally low velocities present through the study area, hazard levels are typically driven more by depth than by velocity.

Hazard behaviour was largely similar through much of the study area. Creeks and channels remained relatively well contained in the 1% AEP, with hazard classes of H3 and H4. Hazard in the creeks increased to H5 and occasionally H6 in the PMF event.

Residential flooding was typically classed as H1 or H2 in the 1% AEP, increasing to H3 or H4 in the PMF, largely as a result of higher ocean levels increasing flood depth.

Exceptions to this typical behaviour were observed at some locations:

- Low lying residential regions of the Water Gardens, Catalina, Batehaven, and Sunshine Bay experienced H3 and occasionally H4 flood hazard in the 1% AEP.

- These hazard classifications remained largely consistent in the PMF, albeit with an increase of H4 affectation. However, the Pleasurelea Tourist Resort in Sunshine Bay experienced a marked increase in hazard in the PMF, with regions of the site classed as H5.

No H6 hazard was observed across residential areas in any of the modelled flood events.

8.3 Flood Function

Maintaining the flood function of the floodplain is a key objective of best practice in flood risk management in Australia, because it is essential to managing flood behaviour. The flood function of areas of the floodplain will vary with the magnitude in an event. An area which may be dry in small floods may be part of the flood fringe or flood storage in larger events and may become an active flow conveyance area in an extreme event. In general flood function is examined in the defined flood event (DFE), so it can be maintained in this event, and in the PMF so changes in function relative to the DFE can be considered in management.

The hydraulic categories (also known as flood function), as defined in the Floodplain Development Manual (2005), are:

- Floodway - Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.
- Flood Storage - Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges.
- Flood Fringe - Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

It is noted that there is no "one size fits all approach" to hydraulic category / flood function definition. Thomas & Golaszewski (2012) investigated a number of different approaches in some case study catchments. However, it was emphasised in this paper to test the underlying assumptions through methods such as "encroachment", testing the impact of reducing or increasing the floodway.

An initial categorisation (based on Thomas & Golaszewski, 2012) was undertaken based on the criteria below:

- Floodway – VelocityxDepth Product is greater than $0.5m^2/s$;
- Flood Storage – VelocityxDepth product is less than $0.5m^2/s$ and depth is greater than 0.5m; and
- Flood Fringe – areas in the flood extent outside of the above criteria.

Manual adjustments were then undertaken to ensure the continuity of floodways, and to remove isolated regions of storage within floodways and fringe within storage that occurred as a result of the automated process.

An encroachment test was then undertaken to assess the suitability of this categorisation. The model was run with:

- All flood fringe areas removed from the model extent; and,
- All storage areas revised to have a roughness of 1.

All floodway zones remained as per the design events.

These changes were made to determine if:

- Fringe areas are appropriately zoned and are not serving any conveyance or storge function during flood events;
- Storage zones are appropriately zoned, and not serving any conveyance function during flood events; and,
- Floodway zones are capable of conveying the active flow through the system.

The results indicated that peak levels changed by less than 0.1m across the study area as a result of these changes, indicating that the classifications are appropriate.

The flood function mapping is provided for the PMF and the 1% AEP events in **Map Series G804**.

In the 1% AEP, floodways are confined within the creeks and channels. Property affectation in the 1% AEP is typically classed as flood fringe, although in the low lying regions of the Water Gardens, Catalina and Batehaven catchments, some property flooding is classed as flood storage.

In the PMF event, the floodway extent increases substantially. While it is still typically contained within the overbank areas of the creeks and channels, some road flow becomes classed as floodway in the PMF. Some properties in the lower reaches of Batehaven and Sunshine Bay also fall within floodways in the PMF event, namely:

- Corrigans Cove Retreat in Batehaven;
- Matthew Parade, Batehaven;
- Caseys Beach Holiday Park; and,
- Sunshine Bay Public School.

8.4 Critical Durations

The critical durations for the PMF, 1% AEP and 10% AEP events are shown in **Map Series G807**.

A similar pattern is observed in all events, with shorter duration, higher intensity events dominating in the upper catchment regions, and longer duration, higher volume events dominating in the lower catchment regions.

The PMF event ha critical durations of 90 minutes and 120 minutes across the majority of developed regions within the study area, with the 60-minute event being critical for the steeper, upper reaches of the catchments. The exception to this was Maloneys Beach, which had peak levels occurring in the 180-minute event across both the creek and the township.

In the 1% AEP event, the 180-minute was the dominant event, governing flooding across the majority of the developed areas. The 60-minute event was critical for much of the road flooding within he Water Gardens catchment, as well as the upper reaches of Joes Creek and Short Beach Creek. Long Beach Lagoon experienced peak flood levels in the 120-minute event.

The 10% AEP was largely governed by the 120-minute event upstream and the 270-minute downstream. Notable exceptions were that the 90-minute event was critical at the downstream reach of the Surfside catchment, and the 120-minute event was critical for the full length of Short Beach Creek.

8.5 Tidal Inundation Extents

An assessment on tidal inundation was undertaken for the existing scenario and a 0.35m sea level rise scenario. The assessment was undertaken using the TUFLOW model, with the downstream boundary revised to a tidal time series based on the high high water solstice spring (HHWSS) tide. The series is shown in **Figure 8-8** and has a peak tidal level of 0.91mAHD and 1.26mAHD for existing and the sea level rise respectively.

The model was run assuming that all entrances were fully open. All the closed entrance levels would prohibit tidal inundation in both existing and sea level rise scenarios.

The tidal inundation extents for both scenarios are shown in **Map G808**.

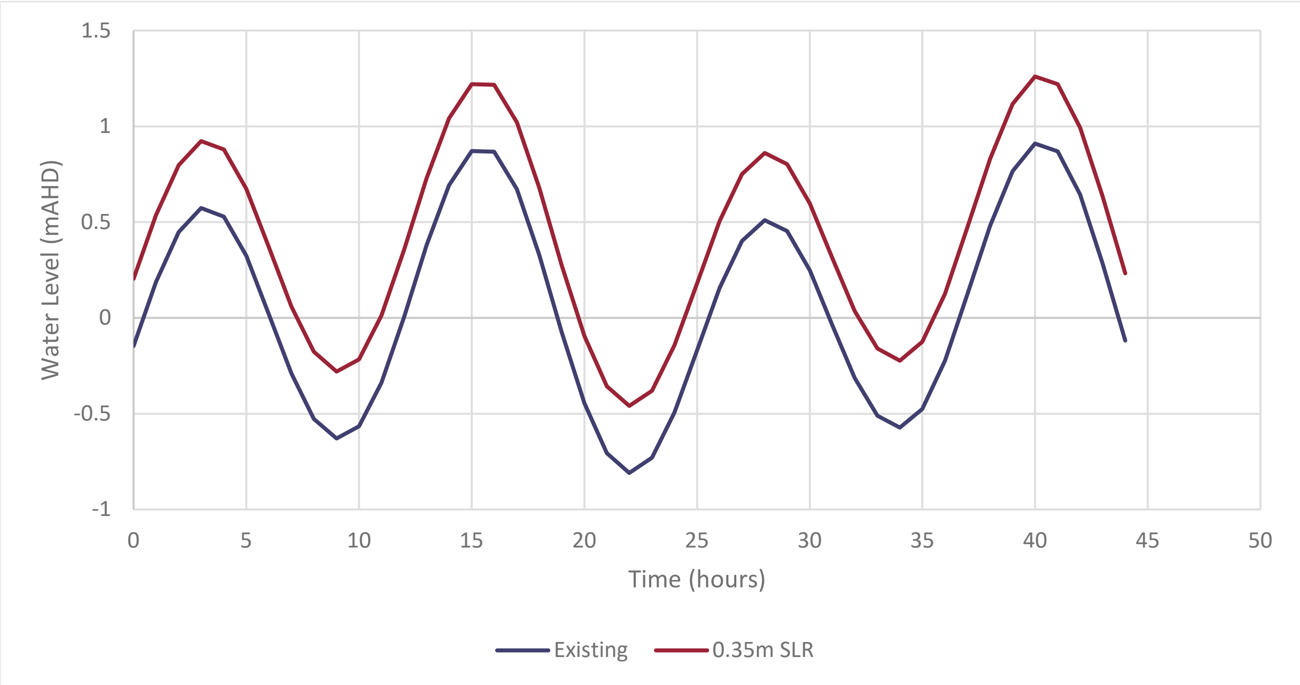


Figure 8-8 Tidal Inundation Downstream Boundary

The results show that 2050 sea levels have a relatively modest impact on tidal extents across the study area, with the 2100 levels exhibiting a greater impact, with the severity varying markedly between catchments. Increased high tide levels had no impact on developed regions in any catchment area in the 2050 scenario. However, some development was affected in the 2100 scenario.

At Maloneys Beach, the existing HHWSS tide did not progress past the Northcove Road crossing. With 2050 SLR, the tidal extent reached 1km upstream, and remained fully contained by the creek banks. The 2100 SLR tidal extent reached the model boundary, and also spread east around the top of the township. No development was impacted in either scenario at Maloneys Beach

The Long Beach catchment results showed that tidal impacts did not progress beyond the foreshore in either the existing scenario or the climate change scenarios.

At Surfside the tidal impacts were restricted to the foreshore in the existing scenario. With 2050 SLR, tidal impacts extended 250m upstream of Wharf Road, and remained fully contained within the creek banks. The 2100 tidal extents progressed further upstream, extending approximately 600m upstream of Wharf Road. The 2100 tide breaks out of the existing channel immediately upstream of Wharf Road, inundating the rear of some properties along Timbara Crescent.

The Watergardens foreshore remained above the peak tidal level for the 2050 scenario. In the 2100 scenario, the tide was observed to flood the low point of Beach Road at Herarde Street. The tidal extent in this region affected a number of properties.

There was very little difference between the existing and 2050 tidal extents in the Catalina catchment, with both scenarios having tidal limits that finished immediately downstream of Beach Road. In the 2100 scenario, while there was only a minor increase in the tidal extent upstream, there was a significant lateral expansion to the east, due to a breakout near the Batemans Bay Marina Resort. This expanded tidal area affected a large number of properties to the east of Hanging Rock Creek.

Differences between the existing and 2050 scenarios were most pronounced along Joes Creek in the Batehaven catchment. The existing tidal extent is fully contained within the creek and extends to immediately downstream of George Bass Drive. The 2050 SLR rise scenario however extended beyond George Bass Drive by 230m, and also resulted in water breaking out of the creek channel. It is noted that this breakout remained fully within the adjacent vegetated space and did not impact any developed areas. The 2100 scenario results in further lateral expansion of the tidal region but remains fully contained within the adjacent vegetated space upstream of Beach Road. Downstream of Beach Road, the 2100 scenario affects property within both the Big 4 Batemans Bay Beach Resort on the south bank of the creek, and Birdland Animal Park on the northern side.

Within the Sunshine Bay catchment, there was very little difference between the existing and 2050 scenarios, although the 2050 SLR tidal extents did begin to progress up two tributaries by a small amount (20 – 30m). In the 2100 scenario, there was a significant extension of the tidal area along minor flowpaths feeding into the creek, immediately upstream of Beach Road. Properties adjacent to the creek on both the north and south banks experienced property flooding in the 2100 scenario, although dwellings remained unaffected.

8.6 Climate Change Impacts

The impacts of future sea level rises on the study area was assessed in the model for:

- A 0.35m sea level rise, modelled for the 5% AEP and 1% AEP (nominally a 2050 scenario); and
- A 0.72m sea level rise, modelled for the 1% AEP (nominally a 2100 scenario).

For each event, the downstream boundary was increased by the nominated amount. The entrance berms were also assumed to increase in line with sea levels. All other model parameters remained as per the design runs.

The results for the 0.35m sea level rise are shown in **Map Series G805** and for the 0.72m sea level rise in **Map Series G806**.

In the 5% AEP, the 0.35m sea level rise had a modest impact in most catchment areas. Maloneys Beach, Long Beach and Water Gardens had no impacts arising from a 0.35m sea level rise in the 5% AEP. Impacts of 0.01m were observed in Surfside in the tributary running adjacent to Mundarra Way.

Flooding within the Catalina catchment showed flood level increases at Herarde Street of up to 0.07m, at Beach Street of up to 0.21m and at Golf Links Road of up to 0.12m. Impacts affected across the golf course, with increases of 0.12m, but did not extend further upstream.

Within the Joes Creek catchment, flood levels increased across the Big 4 Resort by 0.17m, and across the low point of Edward Street by 0.08m. Impacts extended to Glenella Road, but did not affect additional properties.

The impacts at Sunshine Bay were restricted to within approximately 350m of the entrance. Increases of 0.02m were observed across both Caseys Holiday Beach Park and Sunshine Bay Public School.

For the 1% AEP event, the 0.35m sea level rise had varied impacts across the study area.

Peak levels increased by a consistent 0.05m throughout the Maloneys Beach catchment. Increased levels did not impact any development and remained fully contained within the vegetated areas adjacent to the creek.

The Long Beach catchment showed negligible impacts from the 0.35m sea level rise, as a result of the relatively steep grade in the entrance channel. The observed impacts were fully contained within the entrance channel, and did not impact adjacent properties.

Impacts within the Surfside catchment extended as far upstream as the highway in the 1% AEP. While much of the increase was contained upstream, the downstream reaches, particularly the residential area between the beach and Timbara Crescent and Bayview Street, saw level increases of 0.27m and a significant expansion in flood affectation.

The North Street and Clyde Street intersection in the Watergardens catchment experienced flood level increases of 0.35m, and Beach Road (within the Water Gardens catchment) increases of 0.16m. Upstream of Museum Place, impacts were well contained and did not further impacts roads or properties.

Within the Catalina catchment, the low-lying areas around Herarde Street and Beach Road experienced a 0.32m increase. Increases of 0.24m were observed along Golf Links Road and the golf course. While impacts extended upstream beyond the golf course, they did not impact any further developed areas.

The Big 4 Resort in Batehaven was affected by increases of 0.17m due to increased sea levels. Impacts from sea level rise extended upstream as far as Glenella Road, but additional impacts on development were only observed at the low point on Edward Road, where levels increased by 0.1m.

Within the Sunshine Bay catchment, the 0.35m sea level rise resulted in increases across Caseys Holiday Beach Park and Pleasurelea Tourist Resort of 0.15m and 0.1m respectively. Levels also increased at Sunshine Bay Public School by up to 0.14m, and additional areas of the school became flood affected. Impacts extended up Short Beach Creek as far as Sturt Place but were fully contained within the vegetated overbank areas.

Similar to the 0.35m sea level rise impacts, the impacts in the 1% AEP of the 0.72m sea level rise varied substantially across the various catchments.

In the Maloneys Beach catchment, peak levels increased by a generally consistent 0.15m due to the restriction at the outlet stabilising upstream levels. Residential properties remained flood free, however, the intersection of Maloneys Drive and Blue Gum Parade was inundated by 0.15m depths.

At Long Beach, as a result of the relatively steep grade of the outlet channel, sea level rise impacts were confined to the channel downstream of the lake and did not influence lake levels at all. The increased sea levels did result in some additional flooding of low-lying properties adjacent to the outlet, due to coastal inundation.

Impacts at Surfside extended as far upstream as the highway and resulted in a significantly larger flood extent downstream. The school buildings remained flood free, however their grounds became inundated. A significant number of additional properties became flood affected between the beach and Timbara Crescent and Bayview Street, due to ocean flooding. A large number of these properties experienced flood depths in excess of 0.5m, and up to 0.8m in some locations.

Within the Water Gardens catchment, increases of 0.7m occurred at the intersection of North Street and Clyde Street, adjacent to the bay, and increases of 0.5m were observed along Beach Road and Flora Crescent. Due to the rising terrain within the catchment, increases did not extend beyond South Street, just beyond the central parklands.

Flood levels along Beach Road and Herarde Street in Catalina increased by 0.7m, further exacerbating flooding across these low-lying areas. Properties along Golf Links Road experienced increases of up to 0.6m. While increases extended a significant distance upstream, they were all contained within the golf course and vegetated areas and did not impact properties upstream.

Within Batehaven, levels across the Big 4 Resort increased by 0.32m. Impacts extended upstream as far as Glenella Road; however, impacts were modest, and largely restricted to properties along the creek side of Edward Avenue who experienced increases of 0.2m to 0.3m.

The impacts along the main reach of Short Beach Creek were fully contained within the creek reserve. The eastern tributary however saw impacts of 0.35m across Caseys Holiday Beach Park and the inundation of Sunshine Bay Public School by up to 0.2m of water. Increases of 0.25m also occurred across Pleasurelea Tourist Resort.

9 Understanding Flood Risk

9.1 Flood Planning Area

9.1.1 Flood Planning Area

In May 2020 the Department of Planning, Industry and Environment released a Draft Flood Prone Land Package which contains a series of documents that seek to update the manner in which local planning is conducted for flood prone lands. In summary, the key relevant aspect for strategic planning is the consideration of three types of flood prone areas:

- Flood Planning Area (FPA), which has commonalities with the flood planning level concept in the ELEP and seeks to ensure development is compatible with flood risks within the FPA (noting that there are some circumstances where no development is compatible with flood risks)
- Special Flood Considerations (SFC), which seeks to control certain types of vulnerable and hazardous development within the floodplain in its entirety (i.e. potentially up to the extent of the Probable Maximum Flood)
- Regional Evacuation Consideration Area (RECA), which seeks to ensure lands which are indirectly affected by flood behaviour with respect to being unable to evacuate due to flooding in adjacent areas and becoming isolated.

Mapping has been undertaken for the existing scenario, a 0.35m sea level rise scenario and a 0.72m sea level rise scenario, with the FPL set at the relevant 1% AEP flood level plus 0.5m.

The results of the analysis are provided in **Map Series G901**.

Flood risk precincts, incorporating the additional aspects of the Draft Flood Prone Land Package, are mapped in **Map G905**.

It is useful to note that the extent of the flood planning level mapping is generally similar to the extent of the Probable Maximum Flood, which is not uncommon for small coastal creeks where the catchments are not extensive and the variance in plan extent of flooding is not great between rare and extreme events.

9.2 Emergency Response Classification

Flood Emergency Response Classification aims to categorise the floodplain based upon differences in isolation due to the potential for entrapment of an area by floodwaters, potentially in combination with impassable terrain. It also considers the potential ramifications for an isolated area based upon its potential to be completely submerged in the probable maximum flood (PMF) or a similar extreme flood (AIDR, 2014).

Flood Emergency Response Classification mapping is a useful tool for emergency services and evacuation planning for a floodplain.

AIDR (2017) provides guidance on emergency response classification mapping, which is intended to be undertaken at the community or precinct scale (i.e. not at the lot scale). A summary of the classifications is provided in **Table 9-1**. These are presented in **Map Series G902**. It is noted that the Flood Free category was not shown on the map, and that ocean flooding has been removed, as emergency classification is not applicable to these regions.

Table 9-1 Emergency Response Classifications (AIDR, 2017)

Primary Classification	Description	Secondary Classification	Description	Tertiary Classification	Description
Flooded (F)	The area is flooded in the PMF	Isolated (I)	Areas that are isolated from community evacuation facilities (located on flood-free land) by floodwater and/or impassable terrain as waters rise during a flood event up to and including the PMF. These areas are likely to lose electricity, gas, water, sewerage, and telecommunications during a flood.	Submerged (FIS)	Where all the land in the isolated area will be fully submerged in a PMF after becoming isolated.
				Elevated (FIE)	Where there is a substantial amount of land in isolated areas elevated above the PMF.
		Exit Route (E)	Areas that are not isolated in the PMF and have an exit route to community evacuation facilities (located on flood-free land).	Overland Escape (FEO)	Evacuation from the area relies upon overland escape routes that rise out of the floodplain.
				Rising Road (FER)	Evacuation routes from the area follow roads that rise out of the floodplain.
Not Flooded (N)	The area is not flooded in the PMF			Indirect Consequence (NIC)	Areas that are not flooded but may lose electricity, gas, water, sewerage, telecommunications, and transport links due to flooding.
				Flood Free (NFA)	Areas that are not flood affected and are not affected by indirect consequences of flooding.

Across most study area, communities were typically classified as overland escape route (FEO) or rising road (FER). This is largely due to the nature of flooding, where flow emanates from a single waterway or rising ocean levels.

Some locations however had more significant response ratings:

- The entire Maloneys Creek community is classed as an elevated flood island (FIE) in the 1% AEP and a submerged flood island in the PMF, due to the only access road being cut in advance of property flooding in both events.
- Some rural lots in the upper Surfside catchment area are classed as elevated flood islands (FIE) for both events. They remain flood free in the PMF, but access is lost in both 1% AEP and PMF events.
- A region at the boundary of the Catalina and Batehaven catchments, covering parts of Golf Links Drive and Beach Road is classed as an elevated flood island (FIE) in the 1% AEP and a submerged flood island (FIS) in the PMF.
- In the PMF event, large regions across the Water Gardens, Catalina, Batehaven, and Sunshine Bay catchments are classed as elevated flood islands (FIE), as road access to these regions is lost.

9.3 Flood Impacts on Transport

There are a number of transportation routes through the study area, both major arterials (such as the Princes Highway and secondary roads providing access between the catchment areas. Understanding when these routes are overtopped by floodwaters and the duration in which they are flooded is useful, particularly for emergency response planning.

An analysis was undertaken on overtopping in the design events, with a road considered overtopped when flood depths exceeded 0.15m.

This information is presented in **Map Series G903**.

Roads throughout the study area are cut in events as small as the 20% AEP, including multiple locations along Beach Road in the southern catchment areas, multiple locations in the CBD within the Water Gardens catchment, and the Princes Highway in the Surfside catchment. Affectation increased in larger events, resulting in multiple isolated regions in both the 1% AEP and the PMF (see FERC mapping above).

The merits of increasing flood immunity of roads in the study area and regional access during a flood event should be investigated as part of the Floodplain Risk Management Study.

9.4 Flood Impacts on Infrastructure

The study area contains several developments that either accommodate or service higher risk groups, such as the elderly, children, or tourists (who are less likely to be aware of local flood conditions. A number of these locations are flood affected, to varying degrees.

The location of these sites is shown in **Map Series G904**. Note that no sites are found in Maloneys Beach or Long Beach, so these plots are not included in the Map Series. A summary of flood depths at these locations are summarised in **Table 9-2**.

Only a single health or aged care site, The Manor Retirement Village and Aged Care home, was impacted by flooding, and that only in the PMF, by flood depths of up to 0.71m. The site is located on Beach Road, immediately adjacent to Joes Creek, and is inundated in the PMF as a result of elevated ocean levels.

Both the Batemans Bay Hospital and the Catholic Healthcare Maranatha Lodge remained flood free in the PMF.

A number of large scale accommodation sites, such as motor inns and caravan parks, are located within the study area. The caravan parks in particular are vulnerable to flooding, with inundation commencing in the 20% AEP event. Significant depths occur across these sites in the 1% AEP, ranging from 0.5m to 1m, save for Corrigans Cove Resort which is only impacted in the PMF.

All education facilities within the study area remain flood free in the 1% AEP but are inundated in the PMF. Sunshine Bay Public School is the most affected, with depths of up to 1.23m occurring in the PMF. The Batemans Bay library is inundated by 0.76m in the 20% AEP, increasing to 1.36m in the PMF.

The Fire and Rescue NSW property in the Water Gardens catchment is inundated in the 1% AEP by 0.49m and the PMF by 0.91m.

The Batemans Bay SES property is located just south of the Water Gardens catchment boundary. While it is located on a rise that suggests it remains largely flood free, it is noted that access to the north along the Old Princes Highway is lost. As such, the unit will not be able to service the northern catchments during a flood event. The southern catchments will still be accessible, albeit via a long detour south.

The study areas contained multiple sewer pump stations that are affected by flooding to various degrees. These pump stations, and their level of flood affectation, is shown in **Map Series G905**. The majority of pump stations are either flood free or only affected by flooding in the PMF event. Stations in Maloneys Beach, and Water Gardens are affected in the 1% AEP event. The greatest flood affectation is for pump stations in the downstream regions of the Catalina and Batehaven catchments which are inundated in the 10% AEP event.

Table 9-2 Infrastructure Flooding

Location	Peak Flood Depth (m)				
	20% AEP	5% AEP	10% AEP	1% AEP	PMF
Health and Aged Care					
Batemans Bay Hospital	-	-	-	-	-
Catholic Healthcare Maranatha Lodge	-	-	-	-	-
The Manor Retirement Village and Aged Care	-	-	-	-	0.71
Accommodation					
Argyle Terrace Motor Inn	-	-	-	0.59	0.88
Big 4 Batemans Bay Beach Resort	0.32	0.42	0.38	0.55	0.96
Caseys Beach Holiday Park	0.23	0.57	0.45	0.90	2.31
Clyde View Holiday Park	-	0.34	0.30	0.48	0.95
Coachhouse Marina Resort	0.25	0.29	0.28	0.50	0.80
Corrigans Cove Resort	-	-	-	-	0.29
Pleasurelea Tourist Resort	0.33	0.62	0.51	0.98	2.30
Community					
Batemans Bay Library	0.76	0.88	0.85	1.03	1.36
Batemans Bay Public School	-	-	-	-	0.24
Catalina Country Club	-	-	-	-	0.51
SDN Batemans Bay Primary School	-	-	-	-	1.15
St Bernards Primary School	-	-	-	-	0.80
Sunshine Bay Public School	-	-	-	-	1.23
Emergency Response					
Fire and Rescue NSW Batemans Bay	-	-	-	0.49	0.91

10 Conclusions and Recommendations

The Batemans Bay Urban Creeks Flood Study has been prepared for Eurobodalla Shire Council to define the existing flood behaviour across these areas, and to establish the basis for subsequent floodplain management activities.

This project is a flood study, which is a comprehensive technical investigation of flood behaviour that provides the main technical foundation for the development of a robust floodplain risk management plan. It aims to provide a better understanding of the full range of flood behaviour and consequences. It involves consideration of the local flood history, available collected flood data, and the development of hydrologic and hydraulic models that are calibrated and verified, where possible, against historic flood events and extended, where appropriate, to determine the full range of flood behaviour.

Hydrological modelling was undertaken using XP-RAFTS. Hydraulic modelling was undertaken through a combination of TUFLOW and Delft3D for catchment and ocean flooding, respectively.

Validation was undertaken across the region through a comparison of historical community observations with design flood behaviour.

The hydrological and hydraulic models were analysed for the Probable Maximum Flood (PMF), 0.2%, 0.5%, 1%, 2%, 5%, 10% and 20% Annual Exceedance Probability (AEP) events. The models were analysed for storm durations from 60 minutes to 24 hours. Details and descriptions of the flood behaviour associated with these events has been provided.

In order to provide Council with an indication of future flood behaviour arising from climate change in the future, two climate change scenarios were modelled incorporating a 0.35m and 0.72m sea level rise.

From the results developed, planning and emergency response data has been prepared for use by Council and emergency services, including:

- Hazard mapping;
- Flood emergency response classification; and,
- Identification of road and crossing inundation and duration.

The assessment undertaken provides a thorough understanding of the existing flood behaviour and floodplain risks present in the study area.

Council's current DCPs (Section 5.5) do not currently contain comprehensive flood related controls for mainstream or overland flow flooding. Although it is also noted that Council does not currently have any specific overland flow studies completed. It is noted that the Draft LSPS makes reference to the introduction of a Council-wide Flood Management Code. Any such code would need to be consistent with the provisions of the LEP. The code would need to be consistent with the provisions of the Floodplain Development Manual (2005) or any updated Manual.

11 References

ARR2019 [Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors)], 2019, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia

Australian Institute for Disaster Resilience [AIDR] (2017). *Managing the Floodplain : A Guide to Best Practice in Flood Risk Management in Australia*, Handbook 7.

BMT WBM (2009) *Wharf Road Coastal Hazard Assessment and Hazard Management Plan*

Eurobodalla Shire Council (1997) *Wharf Road Drainage Report*

Eurobodalla Shire Council (2000) *Batemans Bay Primary School Relocation – Surfside: Stormwater Drainage Study*

Eurobodalla Shire Council (2017) *Wharf Road North Batemans Bay Coastal Zone Management Plan*

Land and Water Conservation NSW (1996) *Batemans Bay Vulnerability Study*

Lawson and Treloar (1987) *Batemans Bay Ocean Inundation Study*

Lawson and Treloar (1996) *Batemans Bay Vulnerability Study Wave Penetration and Run-up*

NSW Government (2005). *Floodplain Development Manual*.

NSW Public Works (1989) *Batemans Bay Oceanic Inundation Study*

OEH (2015). *Floodplain Risk Management Guide - Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways.* OEH 2015/0769, Office of Environment and Heritage, November 2015

SMEC (2010) *Eurobodalla Shire Coastal Hazards Scoping Study*

Storm Consulting (2009) *Existing catchment flood behaviour and impact of the proposed building for Batemans Bay Soldiers Club car park – Flood Assessment*

URS (2006) *Eurobodalla Flood Risk Assessment*

Water Research Lab UNSW (2017) *Eurobodalla Shire Coastal Hazard Assessment*

Water Research Laboratory (2012) *Coastal Zone Management Plan for Batemans Bay*

WBM Oceanics (1999) *Batemans Bay Estuary Processes Study*

WBM Oceanics (2004) *Batemans Bay & Clyde River Estuary Management Study*

Webb, McKeown and Associates (2006) *Batemans Bay Coastline Hazard Management Plan*

Willing and Partners (1984) *Batemans Bay Drainage Study*

Willing and Partners (1988) *Batemans Bay Inundation Study*

Willing and Partners (1989) *Joes Creek Flood Study*

Willing and Partners (1989) *Short Beach Creek Flood Study*

Willing and Partners (1991) *Reed Swamp – Long Beach Flood Study*

WMA (2005) *Batemans Bay Wharf Road Development – Soft Option Coastal Engineering Assessment and Addendum*

MAPS

engineering | environmental | economics | engagement

APPENDIX A

Community Engagement

Council Noticeboard

Next Council meeting

Ordinary Council meeting: Tuesday 8 June 2021.
Council meetings are held from 11am, with agendas available on Council's website the week prior at www.esc.nsw.gov.au/meetings

The public is welcome to attend or watch the meeting webcast.
To present to Council, please register at council.meetings@esc.nsw.gov.au or 4474 1358 by 12pm on the business day prior.

Current works

For all works visit www.esc.nsw.gov.au/currentworks

Shire-wide, maintenance
When: March 2021 until work in complete
Removing dangerous roadside trees.

Araluen Road, Deua River Valley
When: May to June 2021
Stabilising the roadside slopes.

Batehaven, George Bass Drive
When: May to June 2021
Widening the road shoulders.

Lilli Pilli, George Bass Drive
When: May to June 2021
Widening the road shoulder near Carramar Drive.

Lilli Pilli, George Bass Drive
When: April to October 2021
Realigning the road near Grandfathers Gully.

Malua Bay, Sylvan Street
When: May to June 2021
Building a shared pathway.

Moruya, North Head Drive
When: February to June 2021
Improving the road and widening Garlandtown Bridge.

Potato Point, Potato Point Road
When: October 2020 to August 2021
Installing water and sewer infrastructure.

Surf Beach footbridge, Beach Road
When: June 2021
Renewing the footbridge.

Surf Beach, Beach Road
When: April to August 2021
Renewing the toilets.

Surfside, Myamba Parade
When: June 2021
Building a shared pathway.

Tomakin, Sunpatch Parade
When: May to June 2021
Upgrading the playground at Jack Buckley Park.

Tuross Head, Hector McWilliam Drive
When: May to June 2021
Relocating the bus stop.

Roadwork sites have a 40km/h speed limit in place. Please drive safely and follow all traffic controls.

Temporary road closures

Araluen Road, Deua River Valley
Where: 3.5km north of Larrys Mountain Road
Please detour via the Kings Highway.

Eurobodalla Road, Cadgee
Where: at Murphy Bridge
Please detour via Nerrigundah Mountain Road.

North Head Drive, Moruya
Where: between the granite quarry and Bruce Cameron Drive (airport turnoff)
When: until 30 June 2021
Please detour via Broulee Road.

Temporary load limits

Araluen Road, 10-tonne load limit
Where: between the landslip at Knowles Creek to the Queanbeyan Palerang border.

Nerrigundah Mountain Road, 5-tonne load limit
Where: from Cadgee Mountain Road to the village of Nerrigundah.

EOI: Land for lease, Moruya Airport

Eurobodalla Council invites expressions of interest for land for land for lease at Moruya Airport. Ten commercial lots of varying sizes are available.

EOI documents: www.esc.nsw.gov.au/eoi
Ref: LI:40616 / RFT 2021-028
Closing: Wednesday 16 June 2021, 10am
Enquiries: Property Officer, Leah Mills, 4474 1034

Draft flood study on exhibition and drop-in session

A draft Batemans Bay Urban Creeks Flood Study is on public exhibition until Wednesday 30 June 2021.

View the draft: www.esc.nsw.gov.au/haveyoursay

The flood study is the first step in better understanding flood behaviour in seven urban creek catchments in the Batemans Bay area.

Council staff and consultants can answer questions and receive feedback regarding the draft study at a drop-in session.

Community drop-in session
When: Thursday 17 June 2021
Drop in: anytime from 12.30pm to 6.30pm
Where: Hanging Rock Function Centre, Batemans Bay

Don't bin household waste calendar

The Eurobodalla Household Waste and Recycling Calendar was delivered to local mailboxes last week.

The calendar lists hard waste and chemical collection dates, as well as a handy A to Z list of waste types and how to manage them.

If you missed a copy, or want to discuss waste and recycling, get in touch with Council's waste services.

Phone: 4474 1024
More: www.esc.nsw.gov.au/waste

Heritage grants available

Owners of heritage properties in Eurobodalla can now apply for grants to help them restore their pride and joy.

Council offers grants of up to $5,000 for projects that enhance individual places, buildings and/or historic streetscapes and promote the appreciation of Eurobodalla's history.

Grant recipients are required to contribute $1 for every grant dollar provided, and the restoration work must be complete by 22 April 2022.

Applications close: Friday 2 July 2021, 2pm
Details: www.esc.nsw.gov.au/grants
More info: 4474 1324

Sea Solutions on the Clyde (Bhundoo)

This unique event celebrating World Environment Day and World Oceans Day showcases local initiatives helping to reduce marine debris.

Find out what's lurking in our stormwater drains, learn more about Snapper Island's little penguin colony and see what school students are doing to protect the Clyde River (Bhundoo) and the ocean beyond.

When: Tuesday 8 June, 9.30am to 1pm
Where: Batemans Bay Clyde Street foreshore (near the toilet block).
More: www.esc.nsw.gov.au/events

Positions vacant

Council offers a range of career opportunities in local government. To find out more about a role:

- phone 4474 1016
- email positions@esc.nsw.gov.au
- visit www.esc.nsw.gov.au/jobs

Aquatic and Arts Contract Coordinator
Fixed term: until June 2024
Closing: Wednesday 9 June 2021
Appointment to this role is dependent on an assessment of the results of a criminal history record check.

Coastal and Flood Management Planner
Closing: Thursday 10 June 2021

Payroll Officer
Fixed term: until Friday 26 November 2021
Closing: Wednesday 16 June 2021
Appointment to this role is dependent on an assessment of the results of a criminal history record check.

Building Certification Coordinator
Closing: Tuesday 29 June 2021
Appointment to this role is dependent on an assessment of the results of a criminal history record check.

What's on in Eurobodalla

Check out whatson.eurobodalla.com.au, which brings together events listed on Facebook, the Australian Tourism Data Warehouse, and selected websites - all in the one place.

Users can sign up for alerts and newsletters, or upload their own events.

More: whatson.eurobodalla.com.au

Winter Lego club for kids

Eurobodalla libraries are hosting a weekly Lego play club for children aged six to 10, starting at Batemans Bay Library in June.

Lego club is free to attend, and all blocks are supplied. Kids can build their own creations and try the weekly challenge, and their builds will be on display at the library for the week.

Batemans Bay Library: Tuesdays in June, 3.30-4.30pm
Narooma Library: Wednesdays in July, 3.30-4.30pm
Moruya Library: Thursdays in August, 3.30-4.30pm
More info: www.esc.nsw.gov.au/libraries

Free tech training for seniors

Narooma Library is offering free sessions to help older people develop basic technology skills.

Held on Wednesdays in June, the sessions cover introductory and next level skills on different topics each week, including Android phones and tablets, iPhones and iPads, and an introduction to Microsoft Office. Similar sessions will run at Moruya Library in August. Participants can attend one, or all sessions.

Bookings are essential:

- phone 4476 1164
- email narooma.library@esc.nsw.gov.au

Want more news from Council?

Subscribe to our monthly email newsletter Council News to stay up-to-date on Council services, events and projects.

More: www.esc.nsw.gov.au/subscribe

89 Vulcan Street PO Box 99 Moruya NSW 2537
T 02 4474 1000 | F 02 4474 1234 |
E council@esc.nsw.gov.au | www.esc.nsw.gov.au

eurobodalla shire council

Batemans Bay creek study identifies flooding risk

2 June 2021

Eurobodalla Council has commissioned a technical study into the flooding behaviour of seven urban creek catchments in the greater Batemans Bay region.

Currently on public exhibition for community feedback, the draft Batemans Bay Urban Creeks Flood Study details the flooding risk of Maloneys Lagoon at Maloneys Beach, Long Beach Lagoon at Long Beach, Surfside Creek at Surfside, the Batemans Bay Water Garden, Hanging Rock Creek at Catalina, Joes Creek at Batehaven and Short Beach Creek at Sunshine Bay/Caseys Beach.

Residents – particularly in these areas – are being urged to take a look at the study and provide their feedback to Council. A drop-in session will be held Thursday 17 June, from 12.30pm to 6.30pm, at the Hanging Rock Function Centre, where Council staff and the consultants who prepared the study can answer any questions. No RSVP is required.

Council's flood planning officer Cameron Whiting said the study focused on flooding from rainfall events while taking into account projected sea-level rise impacts.

"This draft study is the first step in better understanding where there may be a flooding risk, giving Council the information needed to progress the next steps of the process, which is to look at mitigation options," he said.

"It also helps other agencies, like State Emergency Service, plan for the potential impacts of flooding on the community."

Councils are required by law to prepare for and manage the risk of flooding, as set out in the NSW Government's NSW Flood Prone Land Policy and Floodplain Development Manual 2005.

The draft Batemans Bay Urban Creeks Flood Study, prepared by Rhelm environmental consultants, was jointly funded by a NSW Government floodplain management grant and Council.

It is available to view on public exhibition until 4.30pm on Wednesday 30 June.

In this section

Eurobodalla Shire Council

Corner of Vulcan and Campbell streets, Moruya
PO Box 99 Moruya NSW 2537

T: 4474 1000
E: council@esc.nsw.gov.au

Batemans Bay Urban Creek Flood Study

eurobodalla shire council

Council is undertaking a Flood Study to understand the flooding from the creeks in the suburbs of Batemans Bay, Catalina, Batehaven, Sunshine Bay, Surf Side, Long Beach and Maloney's Beach. Council is inviting the community to share their experiences with flooding is these areas.

Previous studies have focused on ocean inundation rather than the effects of rain-fall on local creeks and lagoons.

Very little is known of past flooding events. This information is important for verifying flood modelling.

Past rainfall events have flooded houses, shops, roads and public spaces.

Council is asking the community to share their experiences with flooding and any concerns about flood risk.

At Eurobodalla Shire Council we know some parts of the Local Government Area (LGA) are more prone to flooding than others and we're committed to finding solutions to reduce the social and economic damages of flooding.

With the assistance of the State and Commonwealth Government we are currently preparing a flood study for the creeks draining the urban areas in and around Batemans Bay. The areas in green on the map will be the focus of the study.

The flood study will involve developing flood models to represent the flooding from catchment rainfall and ocean storms. The computer based models will be built using survey data to represent the landform of the catchments and creeks. Rainfall and ocean conditions from past flood events will be used to recreate these events and calibrate the results against flooding observed by the community.

Do you have any local knowledge of flooding in and around Batemans Bay?

Council would like to hear from you by email, phone or by filling in a brief survey (via Council's website or the reverse side of this page). Your responses will help us understand the local flooding problems in more detail. Local knowledge and personal experiences of flooding are an invaluable source of data.

You can also share you knowledge and thoughts with the project team at the community drop in sessions (see below).

Community drop in sessions will be held on Tuesday 20th November at Batemans Bay Community Centre, 3 Museum Place between:

- 10am - 2pm
- 3pm - 6pm

You are invited to come along to find out more about the study and to share with the project team your experiences and concerns about flooding in the local area.

Online: www.esc.nsw.gov.au (got to ' Have Your Say' link on main page

For more information phone: (02) 4474 1374

Email: council@esc.nsw.gov.au
Mail: PO Box 99, Moruya 2537

Submissions should be provided by 30th November 2018

Batemans Bay Urban Creeks Flood Study

eurobodalla shire council

Community Feedback Form

Contact Details (these details will be confidential):

Name ____

Address ____

Email ____

Contact Phone Number ____

How have you lived, worked or visited in and around Batemans Bay?

_______ Years

Are you aware of flooding in and around Batemans Bay? (please select one)

Aware

Some knowledge

Not aware

Have you seen in and around Batemans Bay?

Date and time (as best as can be remembered) ____________________________________

Location ____

Description of flooding (e.g. flooded the road outside my house or work, went into the house, went up to the front step, went part way up the yard, went into the garage) ___________________________

____

____

____

____

Do you have any photos of flooding in the catchment?

Yes, I have attached a copy to the survey

Yes, please contact me to obtain a copy

Yes, I will email a digital copy to council@esc.nsw.gov.au

No

Can Council or our consultant contact you for further information relating to your responses to this survey?

Yes / No

Please feel free to attach additional pages. This survey can also be completed online at Council's website.

Please provide your responses to the survey via email, mail, phone or online through Council's website

Online: www.esc.nsw.gov.au (got to ' Have Your Say' link on main page

For more information phone: (02) 4474 1374

Email: council@esc.nsw.gov.au
Mail: PO Box 99, Moruya 2537

Submissions should be provided by 30th November 2018 eurobodalla shire council

Our Reference: OP0046-S009

3 June 2021

Name
Address
Town

Dear Sir/Madam

Draft Batemans Bay Urban Creeks Flood Study

The Draft Bateman's Bay Urban Creeks Flood Study is currently on public exhibition until 30 June 2021. This flood study is the first step in better understanding flood behaviour in seven urban creek catchments in the Batemans Bay area. It does not include recommendations to manage flooding as these are investigated in later stages of the NSW Government's floodplain risk management process.

You are receiving this letter because the draft study provides new information about flood behavior in the Batemans Bay area and this information is relevant to you as a property owner. This does not necessarily mean that you will experience flooding, but it is important that you are aware what the study could mean for you.

The draft flood study can be viewed:

- On Council's website: www.esc.nsw.gov.au/haveyoursay and look for "Batemans Bay Urban Creeks Flood Study"
- At Council's Moruya administration centre, 89 Vulcan Street, Moruya

We welcome your attendance at a community drop-in session where project staff can answer questions and receive your feedback on the draft study's findings.

What: Community drop-in session - Draft Bateman's Bay Urban Creeks Flood Study
Date: Thursday 17 June 2021
Location: Batemans Bay Hanging Rock Function Centre
Time: 12:30pm – 6:30pm (drop-in at any time, no need to RSVP)

You can send us your feedback on the draft flood study via Councils website or by emailing council@esc.nsw.gov.au.

If you have any questions about the study, please contact our Coastal and Flood Officer on 4474 1374.

Yours sincerely

Cameron Whiting
Coast and Flood Officer

APPENDIX B

Technical Note on Downstream Boundaries

Baird.

Baird Australia Pty Ltd as Trustee for the Baird Australia Unit Trust
ACN 161 683 889 | ABN 92 798 128 010

Office | Suite 8, Level 22, 227 Elizabeth Street, Sydney, NSW 2000, Australia
Phone | +61 2 8278 7266 Email | sydney@baird.com

Memorandum

Reference # 13142.201.M1.RevA

Status: Draft

28 January 2020

Attention:	**Cameron Whiting (Eurobodalla Shire Council)**
CC:	Raymond Laine (NSW Department of Planning, Industry and Environment) Emma Maratea (Rhelm Pty Ltd)
From:	Sean Garber (Baird)

RE: Summary of Proposed Downstream Boundary Conditions to be Adopted for the Batemans Bay Urban Creeks Flood Study

The Eurobodalla Shire Council (Council) recently commissioned Rhelm Pty Ltd (Rhelm) to complete the Batemans Bay Urban Creeks Flood Study. Baird Australia Pty Ltd (Baird) are assisting Rhelm to establish accurate downstream boundary conditions to be applied for design flood scenario modelling based on an understanding of the coastal hazards within Batemans Bay.

This memo provides a summary of the available datasets, a review of each coastal entrance and the proposed downstream boundary conditions to be adopted for the flood study.

Study Area

The Batemans Bay Urban Creeks Flood Study will assess the flood behaviour and impacts at seven (7) catchments that connect to Batemans Bay, including:

- Maloneys Creek
- Long Beach Lagoon
- Surfside Creek
- Watergardens
- Hanging Rock Creek
- Joes Creek
- Short Beach Creek

The locality of each coastal entrance within Batemans Bay is presented in Figure 1.

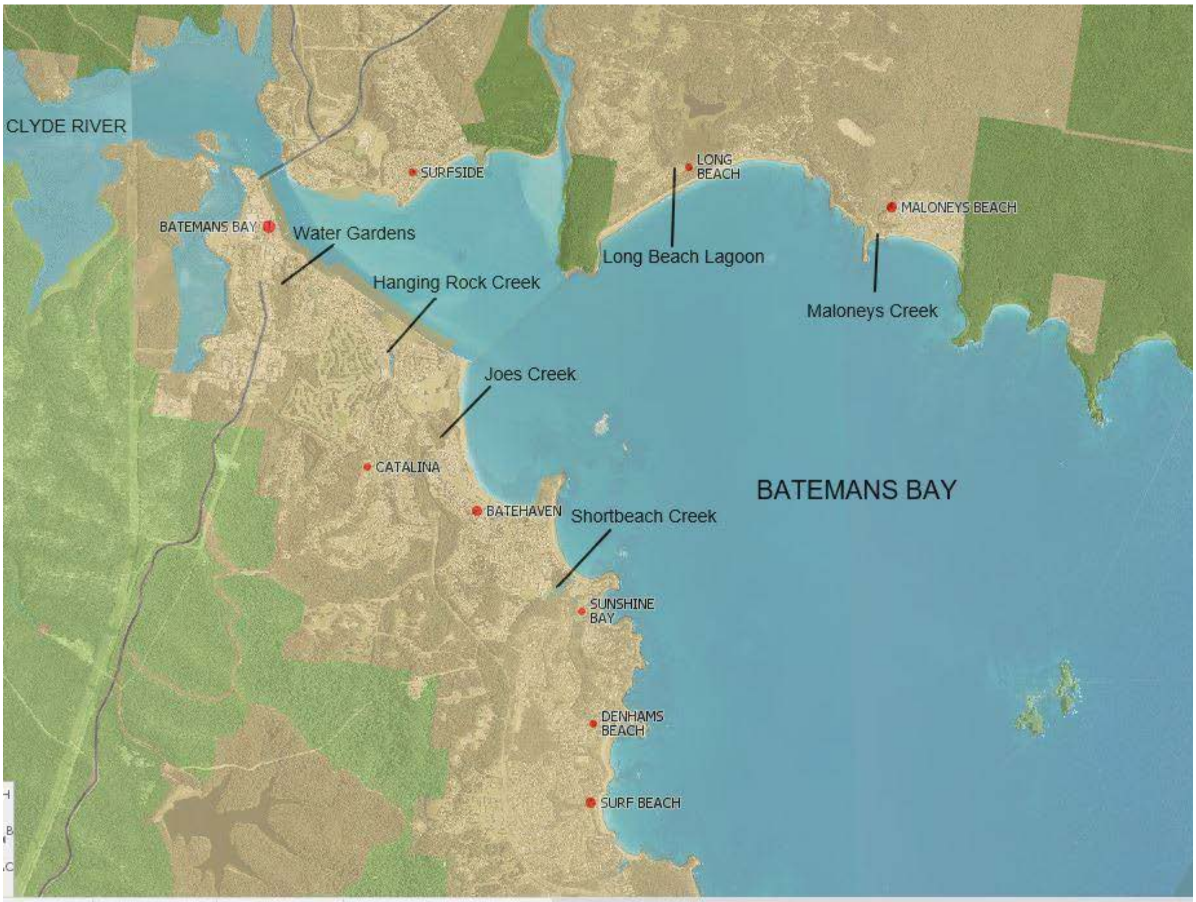


Figure 1: Creek Entrances within the Flood Study Area (from ESC, 2018)

The following sections provide a brief summary of each entrance, including the available topographic description. Topographic and bathymetric data for this study has been obtained from three sources, being:

- Ground Survey collected for the Flood Study in 2019. Data supplied as spot levels in dwg format (23762 SITE survey.dwg)
- NSW Marine LiDAR Topo-Bathy 2018 Dataset (DPIE, 2019)
- 1m Resolution Digital Elevation Model (DFSI, 2011)

The available data sets were in general agreement, where co-located data existed at the creek entrances. While some differences were identified between the 2018 and 2011 LiDAR datasets, berm levels extracted from the 2018 dataset were marginally higher. As a result, the 2018 NSW Marine LiDAR Topo-Bathy Dataset (DPIE, 2018) has been used to inform the adopted entrance conditions for this flood study.

Maloneys Creek

The entrance to Maloneys Creek is situated at the western end of Maloneys Beach, adjacent to a rock headland outcrop. Prior to reaching the entrance, creek waters flow through a culvert under Northcove Road that runs about 30m behind the back beach at this location. The entrance is generally closed but opens (breaks out) when water levels in the creek overtop the berm level, as such it is classed as an Intermittently Closed and Open Lake or Lagoon (ICOLL). The adjacent beach is a narrow (~10 m), moderately steep (1V:10H) and backed by a low foredune (WRL, 2017) typical of a stable barrier system. Recent photogrammetry indicating no net recession, but a possible counter-clockwise rotation of the shoreline (WRL, 2017).

Available topographic data indicates a berm crest level of between +2.05 and +2.45 mAHD (see Figure 2) when the entrance is closed, which is consistent with the berm levels further along the beach to the east. Council do not operate an entrance management policy at Maloneys Creek and the entrance is left to breakout naturally.

It is therefore feasible that prior to the onset of a design flood event that a berm level of +2.1 mAHD would have established. Further, from review of historical aerial imagery and cross checking with the available survey data a water level in creek of +1.8 mAHD may be present.

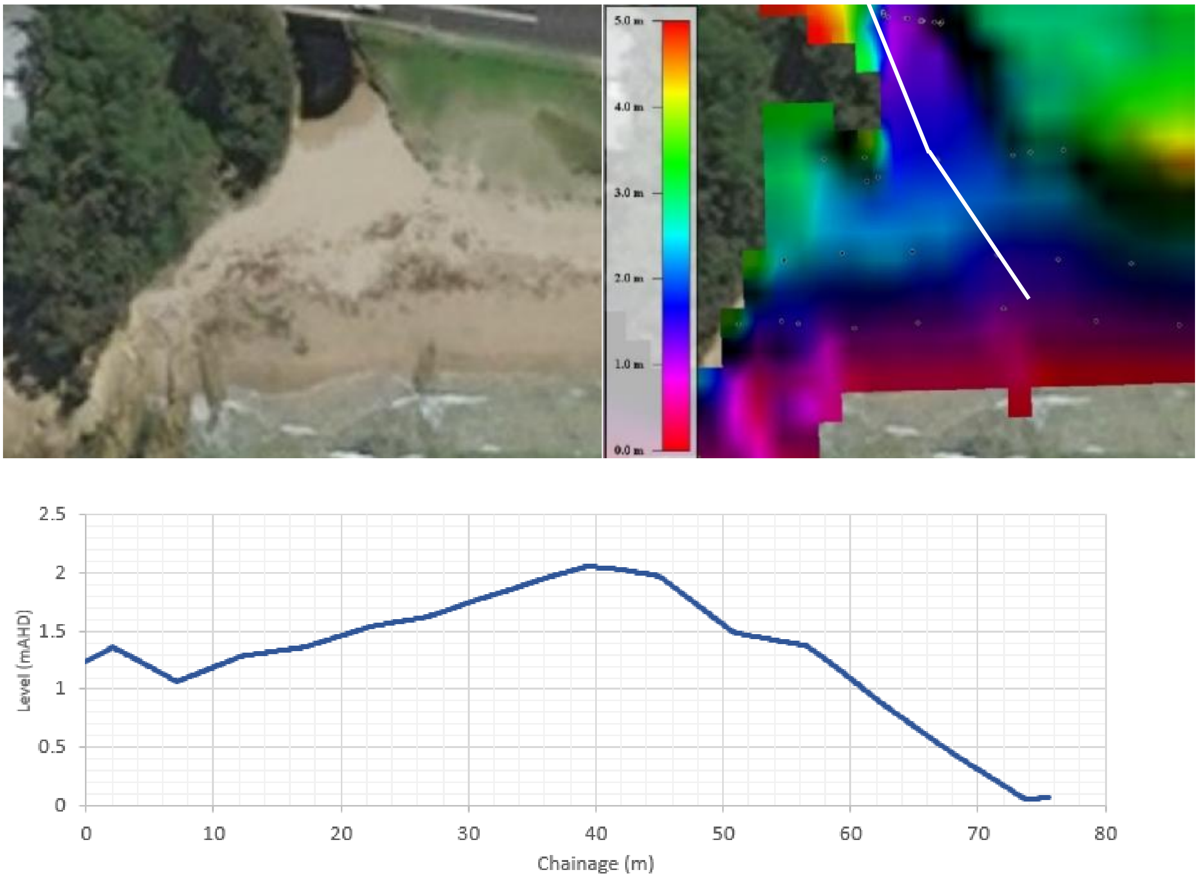


Figure 2: Maloneys Creek Entrance at the western end of Maloneys Beach. Top Left: An aerial view of the entrance. Top Right: Available topographic data of the entrance. Bottom: Transect Profile through the entrance indicating a berm level of +2.05mAHD.

Long Beach Lagoon

Long Beach Lagoon, located in the lee of the Long Beach barrier dune system, is a wetlands reserve that drains to the ocean via a small overland channel centrally located along the beach compartment. The entrance channel is approximately 300m in length between the lagoon and beach face and appears to typically remain dry outside of rainfall events. In this location the beach is relatively narrow (~20m) with a moderate beach slope (1V:9H-1V:18H) and experiences very little longshore transport (WRL, 2017). At the channel entrance, no trends in beach width are identifiable, although the beach compartment undergoes slight rotation in response to changes in wave direction (WRL, 2017).

Available topographic data indicates a lack of a classic entrance berm feature with the channel centreline profile starting at an elevation of +3.5 mAHD at the Lagoon and steadily dropping to +1.95m AHD through the beach dune (see Figure 3). Channel levels at the back beach are lower than the natural dune level of ~+3.0 mAHD to the east and west, indicating the potential for the channel entrance to further infill with sand during long periods of reduced rainfall. Council do not operate an entrance management policy at Long Beach Lagoon and the entrance is left to breakout naturally.

Given the elevation and length of the entrance channel, it is not expected to break-out and open like an ICOLL entrance, with no tidal exchange expected following the release of flood waters through the channel. As such, entrance channel levels from the 2018 LiDAR dataset (DPIE, 2018) will be adopted to describe the entrance condition in the flood models.

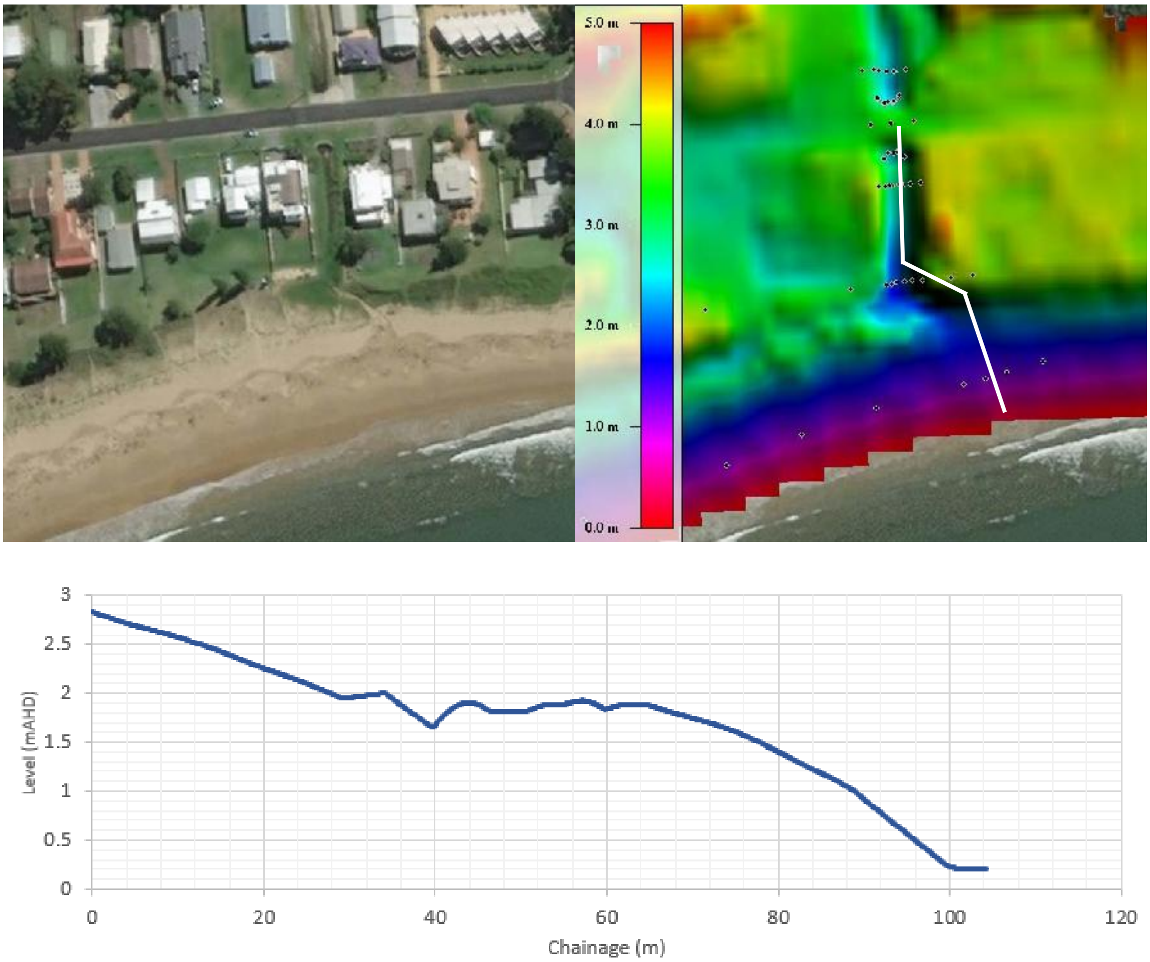


Figure 3: Long Beach Lagoon Entrance in the middle of Long Beach. Top Left: An aerial view of the entrance. Top Right: Available topographic data of the entrance. Bottom: Transect Profile through the entrance channel indicating a steady grade from lagoon to beach.

Surfside Creek

The entrance to Surfside creek is located at the western end of a small perched beach (Surfside Beach West) that marks the western side of a low regressive beach ridge plain (WRL, 2017). The entrance is an ICOLL, with sand closing over the entrance and infilling back to the culvert under McLeod Street during periods of limited rainfall. Council operate an entrance management policy at Surfside Creek entrance, whereby the entrance is mechanically opened if the water levels in the creek reach the trigger level of +1.5mAHD or when sand reaches the top of road culvert (ESC, 2019).

The shoreline along Surfside Beach (west) demonstrates a higher degree of oscillation owing to the impact of the migratory sand waves (WRL, 2017) and combined with the breakout process at the Surfside Creek entrance would likely lead to variable berms levels at the creek entrance. Available topographic data indicates a berm crest level of between +1.3 and +1.4mAHD (see Figure 4) when the entrance is closed, which is consistent with the entrance management policy (i.e. lower than the trigger level). It is therefore considered feasible that the berm level of +1.5 mAHD with a water level in the creek of +1.45 mAHD could occur prior to the onset of a design flood event.

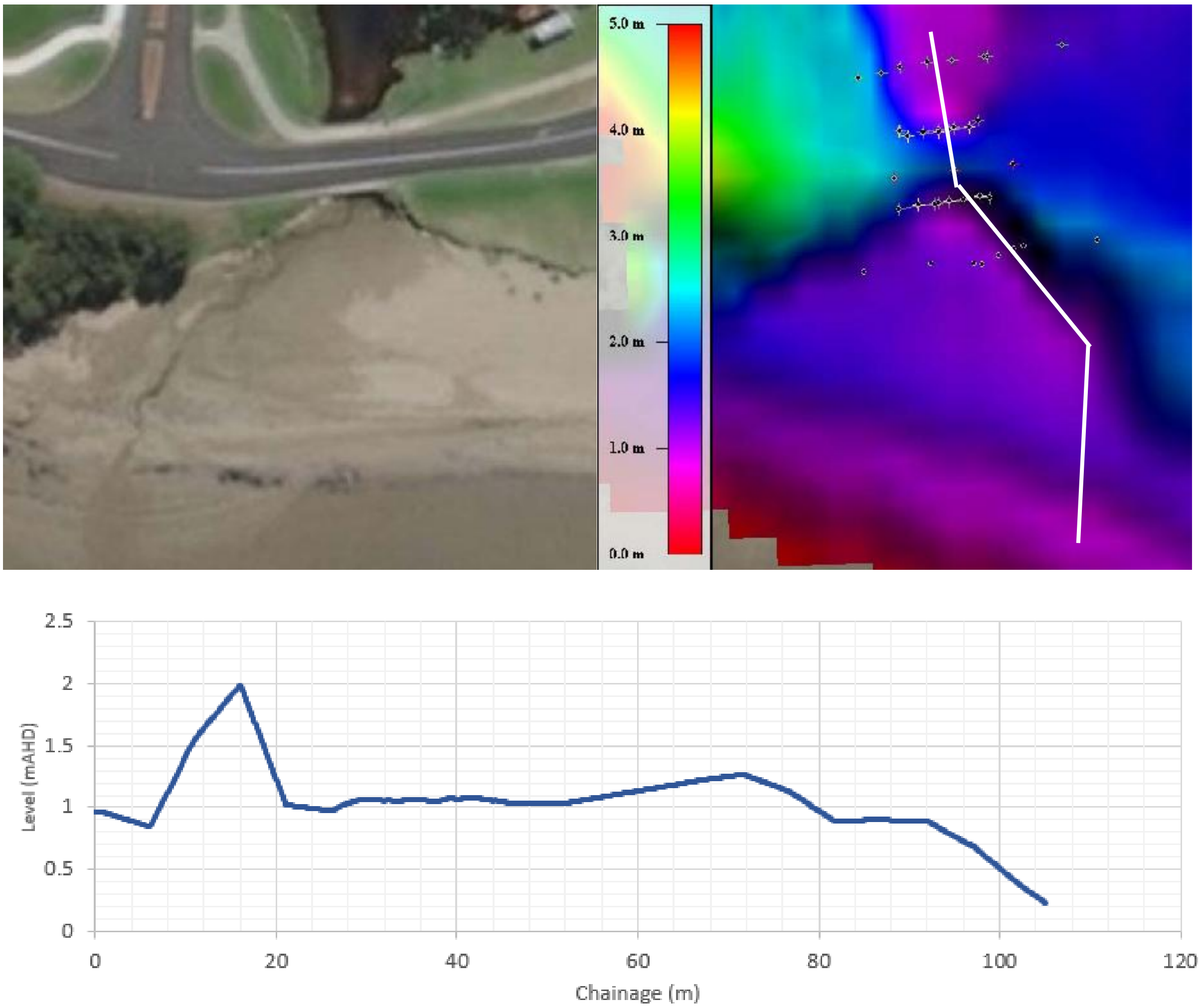


Figure 4: Surfside Creek Entrance at the Western end of Surfside Beach West. Top Left: An aerial view of the entrance. Top Right: Available topographic data of the entrance. Bottom: Transect Profile through the entrance indicating a berm level of +1.3mAHD.

Watergardens

The Water Gardens is a six-hectare wetland park close to the Batemans Bay town centre that is a natural drainage area that was once used for stock grazing (ESC, 2018). The wetlands drain to Batemans Bay via culverts under Beach Road to an engineered outlet. No data was available to ascertain the levels of the outlet however from site reconnaissance the outlet appears at or near mean sea level and would remain clear of sediment build up along the shoreline (see Figure 5). It could therefore be considered permanently open.

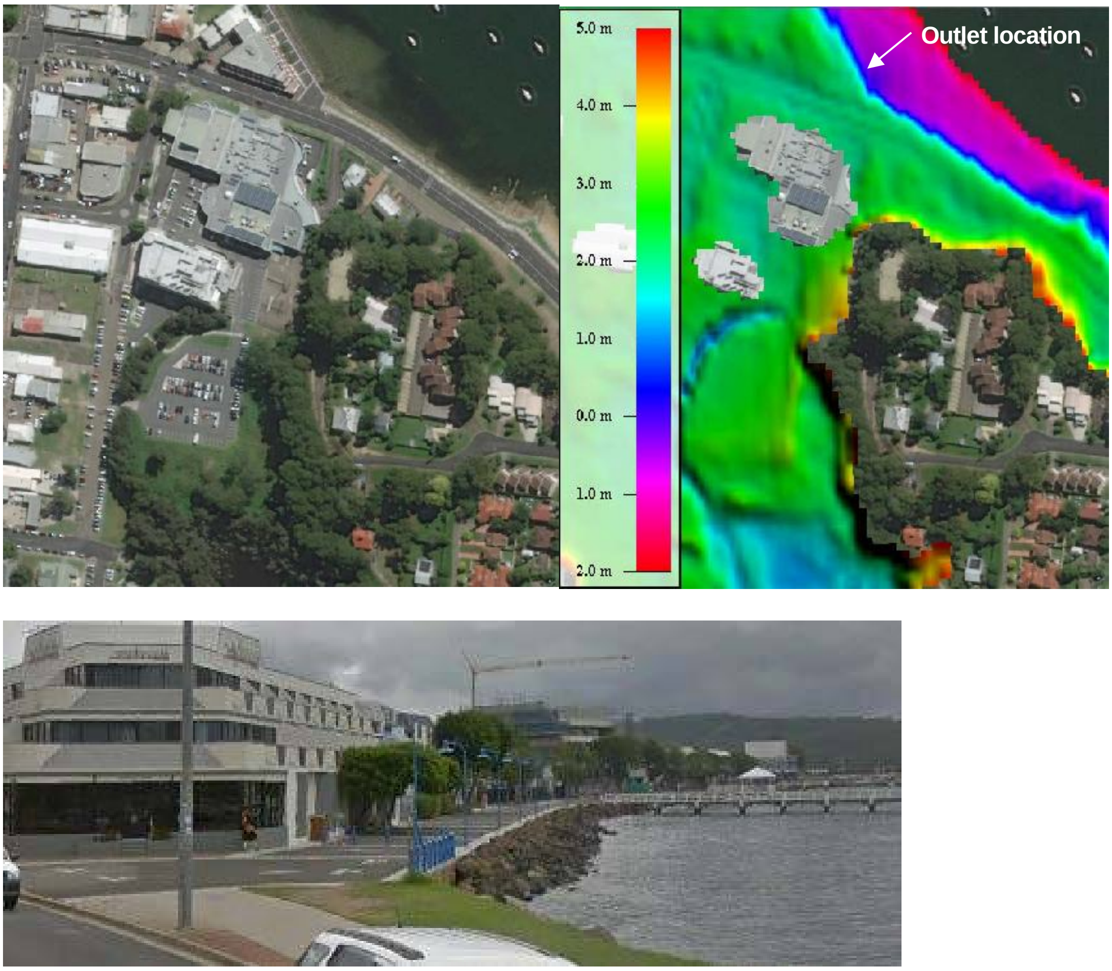


Figure 5: Watergardens Outlet. Top Left: An aerial view of the area. Top Right: Available topographic data of the area. Bottom: Google Street view image of the shoreline where the outlet is located.

Hanging Rock Creek

Hanging Rock Creek flows into the Batemans Bay marina precinct which is an 8-hectare water body that is enclosed by an 850m long breakwater structure (see Figure 6). Access from the basin to Batemans Bay is made via a 40m opening in the breakwater through which seabed levels are relatively deep (<-4.5mAHD). A large fluvial fan feature is present where the creek meets the enclosed water body with seabed levels of between -0.3 and +0.3 mAHD. Despite this shallow fluvial feature, the creek entrance remains permanently open.

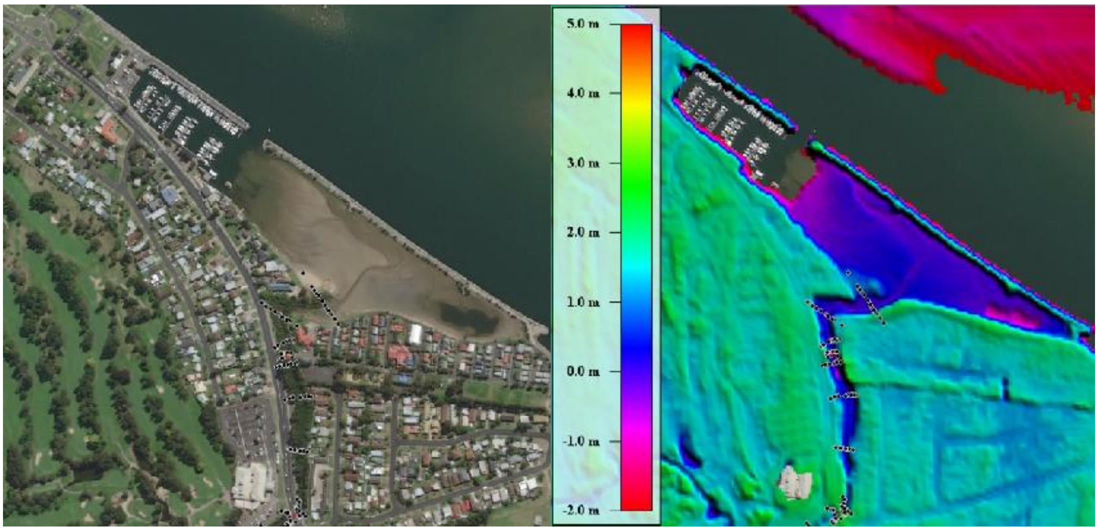


Figure 6: Hanging Rock Creek Entrance. Top Left: An aerial view of the entrance. Top Right: Available topographic data of the entrance indicating levels of 0mAHD (+/-0.3m) across the fluvial fan feature.

Joes Creek

The entrance to Joes Creek is centrally located along Corrigans Beach. The entrance is an ICOLL, with the beach berm closing over the entrance during periods of low rainfall following breakout events. Corrigans Beach has had recent nourishments from sediment dredged from the Clyde River entrance sand bar, in 2014 and 2016 (WRL, 2017), and has a beach width of 30 to 40m.

Available topographic data indicates a berm crest level of +1.81 mAHD (see Figure 7) when the entrance is closed, which is consistent with the beach berm levels both north and south of the entrance (between +1.75 and +1.90 mAHD). Council operate an entrance management policy at Joes Creek entrance, whereby the entrance is mechanically opened if the water levels at the cycle path bridge reach the trigger level of +1.4mAHD or +1.2mAHD if heavy rain is predicted (ESC, 2019).

It is therefore feasible that a berm level of up to +1.9 mAHD and a lake level of +1.4 mAHD could exist prior to the onset of a large design flood event.

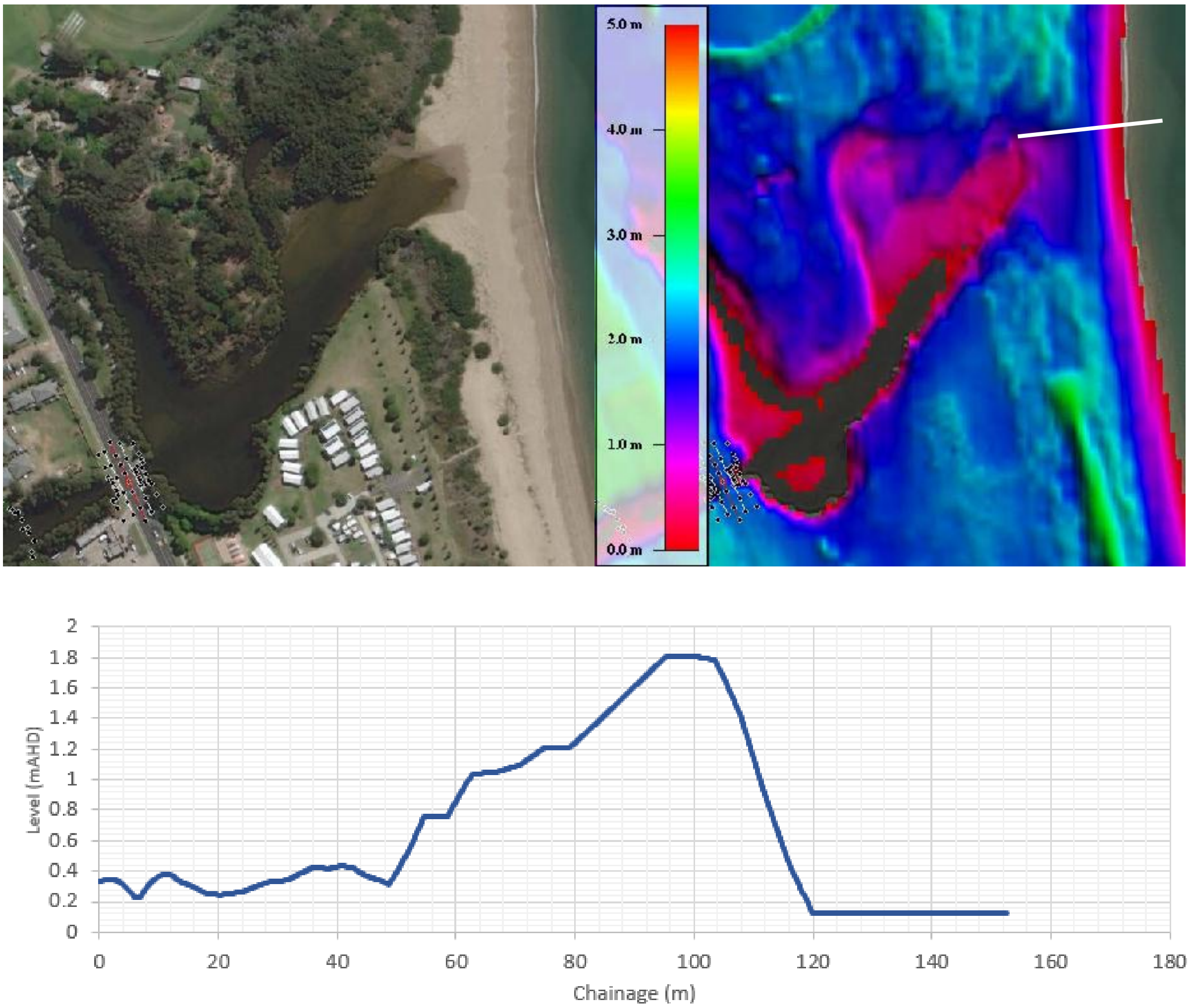


Figure 7: Joes Creek Entrance at Corrigans Beach. Top Left: An aerial view of the entrance. Top Right: Available topographic data of the entrance. Bottom: Transect Profile through the entrance indicating a berm level of +1.81mAHD.

Short Beach Creek

The entrance to Short Beach Creek is located towards the south end of Caseys Beach. The entrance is intermittently open and closed, where the beach berm builds up across the entrance between rainfall driven breakout events, and is intersected by the bridge along Beach Road. Caseys Beach is a relatively thin beach (~10-15m wide) in the vicinity of Short Beach Creek entrance, with the overall beach compartment displaying a recessional trend evidenced by the seawall constructed a long Beach Road.

Council operate an entrance management policy at Short Beach Creek entrance, whereby the entrance is mechanically opened if the water levels in the creek reach the trigger level of +1.3mAHD, however the entrance generally breaks out naturally (ESC, 2019). Available topographic data indicates a berm crest level of between +1.0 and +1.1 mAHD (see Figure 8) when the entrance is closed, which is consistent with the berm levels along the beach (+0.9 to +1.3 mAHD) and the entrance management trigger level.

Based on the available data and entrance management policy it is feasible that an entrance berm level of +1.3mAHD and creek water level of +1.1 mAHD could be present prior to the onset of design flood event.

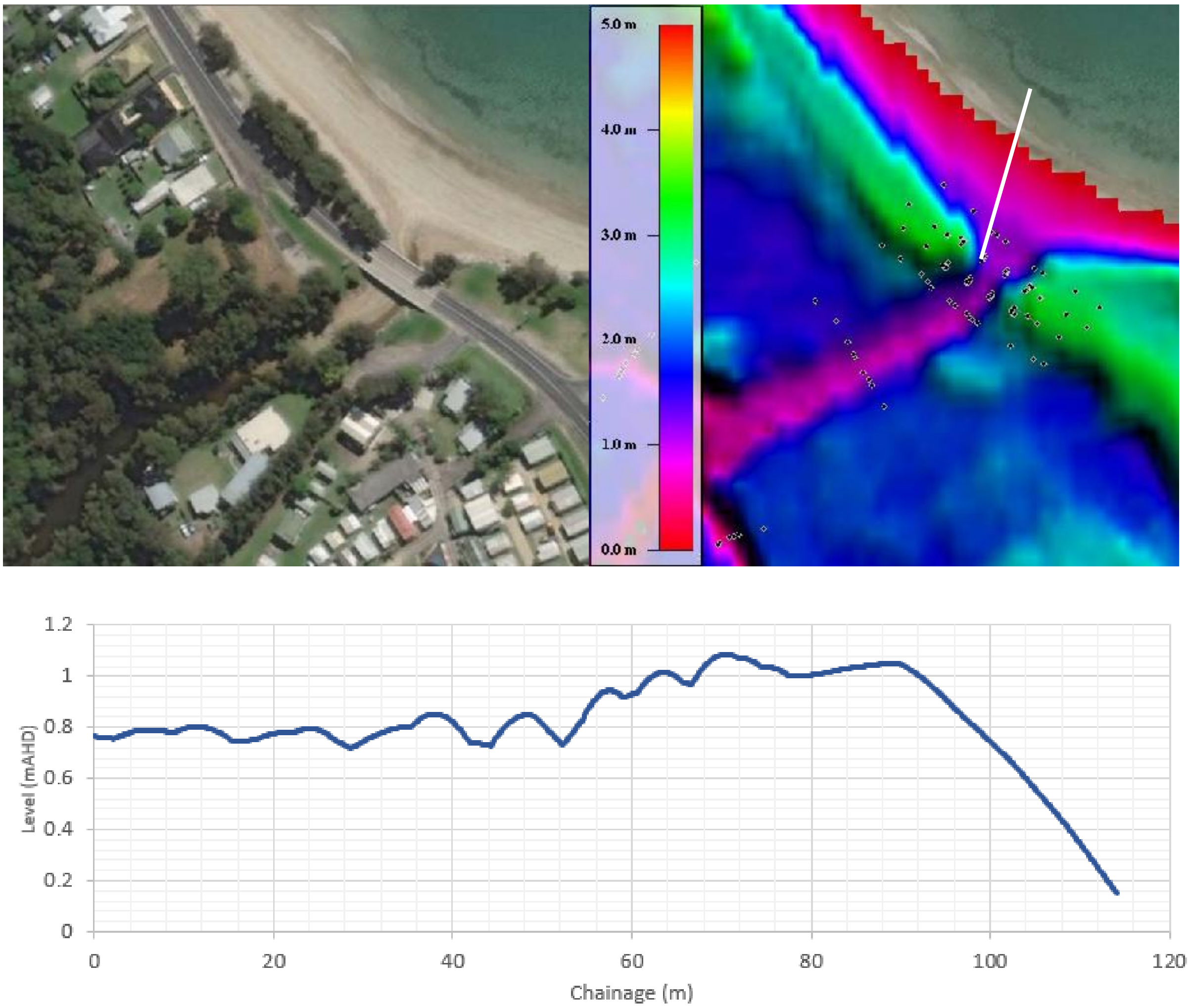


Figure 8: Short Beach Creek Entrance at Casseys Beach. Top Left: An aerial view of the entrance. Top Right: Available topographic data of the entrance. Bottom: Transect Profile through the entrance indicating a berm level of +1.10mAHD.

Tailwater Levels

On the NSW South coast, major flooding typically occurs coincident with costal storms and it is not unusual for flooding to occur on the spring tides during the East Coast Low season (ESC, 2018). Flood levels in the lower reaches of a catchment or waterway can therefore be exacerbated by the ocean conditions resulting in coincident ocean/catchment flooding. In 2017, Council completed the Eurobodalla Coastal Hazard Assessment (WRL, 2017), that quantified coastal hazards included extreme water levels at coastal locations.

For the determination of design flood levels, the *Floodplain Risk Management Guide - Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways* (OEH, 2015) provides guidance as to the combination of catchment flood scenarios and ocean water level boundary conditions. In summary Table 8.1 of OEH (2015) specifies the following:

- For catchment flood scenarios <2% AEP a downstream ocean water level of High High Water Springs (Solstice Spring) or HHWS(SS)should be used
- For catchment flood scenarios 1-2%AEP a downstream ocean water level of 5% AEP should be used
- For catchment flood scenarios <0.5%AEP a downstream ocean water level of 1% AEP should be used

For dynamic numerical modelling, a timeseries of the downstream ocean water level boundary condition must be developed. Such a timeseries can be synthetised as follows:

- Select a representative predicted spring tide based on the measured water levels at the Princess Jetty tide gauge
- A design peak storm surge is then selected for the desired ARI (see sections below)
- The selected peak storm surge is then added to the predicted tide, scaling up and down over a 96-hour period. This is consistent with the guidance in OEH (2015) that applied a similar method using a scaled May 1974 event.

An example of a synthesised ocean water level timeseries in presented in Figure 9. The relative timing of catchment flooding and ocean water levels is then adjusted such that the peak of the storm tide timeseries is aligned with the peak in the flood discharge event.

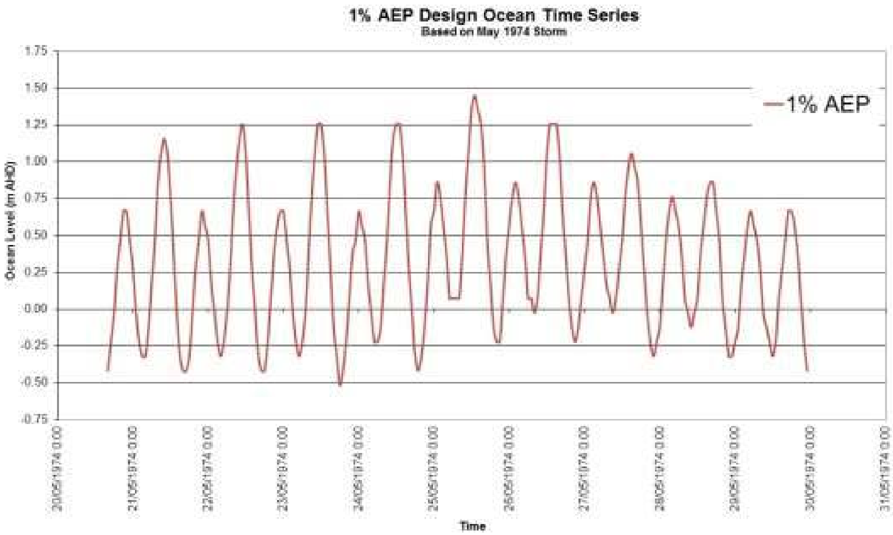


Figure 9: Example Timeseries of a downstream ocean water level peaking at +1.45mAHD (from OEH, 2015)

Eurobodalla Coastal Hazard Assessment

The Eurobodalla Coastal Hazard Assessment (WRL, 2017) provides a comprehensive analysis and quantification of coastal hazards at key locations around Batemans Bay, including extreme water levels, nearshore waves, wave runup and beach erosion. For consistency between floodplain and coastal management, it is proposed that the coastal water levels from the Coastal Hazard Assessment be adopted.

Within Batemans Bay, coastal water levels have the potential to be higher than offshore due to wind setup over the shallow bathymetry and inland flood events from the Clyde River. Fresh water floods are not expected to cause significant increase in ocean inundation levels in most of the study area. However, in inner Batemans Bay, flooding from the Clyde River may increase peak coastal inundation levels by up to 0.16 m. Therefore, water level defined in the Coastal Hazard Assessment made an allowance for an increase in inundation levels due to flooding from the Clyde River. The flood contribution levels adopted for this study are provided in Table 1.

Table 1: Summary of Design Total Still Water Levels at the Creek Entrances extracted from the Eurobodalla Coastal Hazard Assessment (WRL, 2017)

Location (Coastal Hazard Assessment ID)	ARI (Years)	Offshore WL (mAHD)	Wind Setup (m)	Storm Tide (mAHD, excl Wave setup and Flood)	Flood Contribution (m)	Wave Setup (m)	Total SWL (mAHD)
Maloneys Creek (CHA: Western End)	20	1.37	0.11	1.48	0.00	0.55	2.03
	100	1.43	0.13	1.56	0.00	0.57	2.13
Long Beach (CHA: Central)	20	1.37	0.18	1.55	0.00	0.63	2.18
	100	1.43	0.22	1.65	0.00	0.66	2.31
Surfside Creek (CHA: Surfside W)	20	1.37	0.10	1.47	0.04	0.45	1.96
	100	1.43	0.13	1.56	0.07	0.43	2.06
Watergardens (CHA: CBS E)	20	1.37	0.12	1.49	0.03	0.54	2.08
	100	1.43	0.15	1.58	0.05	0.56	2.22
Hanging Rock Creek (CHA: Boat Harbour)	20	1.37	0.08	1.45	0.03	0.61	2.09
	100	1.43	0.10	1.53	0.06	0.61	2.21
Joes Creek (CHA: Corrigans S)	20	1.37	0.08	1.45	0.00	0.27	1.72
	100	1.43	0.10	1.53	0.00	0.28	1.82
Short Beach Creek (CHA: Caseys S)	20	1.37	0.07	1.44	0.00	0.30	1.74
	100	1.43	0.10	1.53	0.00	0.30	1.83

Baird's Monte Carlo dataset

Baird have an established 1,000-year Monte Carlo synthetic East Coast Low (ECL) event set that includes maximum event impact footprints for coastal inundation as well as wind and rainfall, as presented in Taylor et. al. (2017). The dataset has been developed from a detailed library of hindcast data for 1,119 ECL events between 1970 and 2016 (46-years) and a novel synthetic track and intensity ECL model. The sequence applied to develop the data set is presented in Figure 10. The coastal inundation data set defines elevations for total peak steady water level (tide + residual + wave-setup) and maximum wave run-

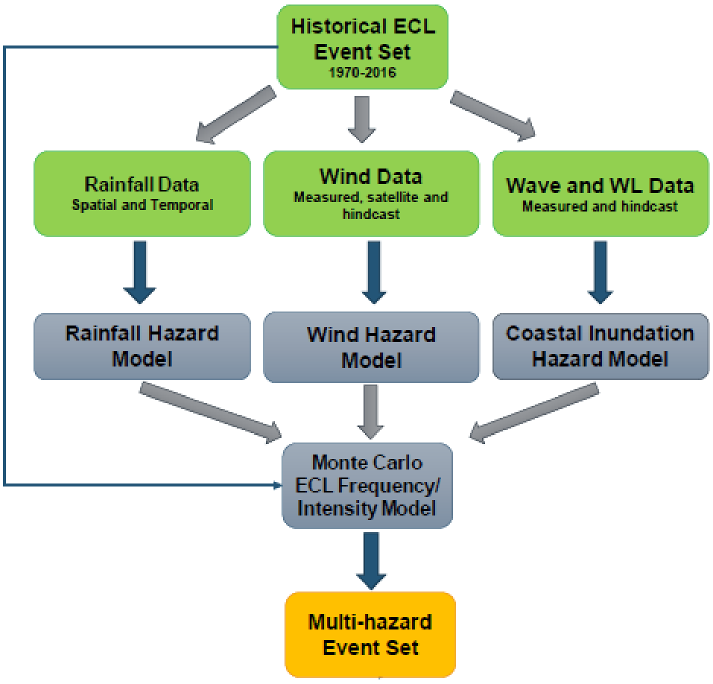


Figure 10: Method flow chart for Baird Australia's multihazard ECL Event Set

For the total peak steady water levels, a number of factors contribute to the observed water at the shoreline during ECL events. The factors contributing to total water level include:

1. Astronomical tide;
2. Surge from wind and pressure forcing along the coast;
3. Residual water levels from other oceanographic and meteorological forcing, including coastal trapped waves; and
4. Wave setup inshore of the surf zone.

The water levels included in the data set account for the above four components in the assessment of coastal water levels and wave run-up levels. Astronomical tide was based on a 19-year hindcast of astronomical tide along the NSW coast and covers an entire solar and lunar astronomical tide cycle which is applied in a continuous cycle over the 1,000 year data set period.

A comparison of the extreme Total Still Water Levels, excluding wave setup and flood contribution, at the Princess Street Jetty from Baird's Monte Carlo dataset and the Eurobodalla Coastal Hazard Assessment (WRL, 2017) is presented in Table 2. The comparison indicates Baird's ECL dataset is around 0.1m lower than that Eurobodalla Coastal Hazard Assessment. This is expected as the Coastal Hazard Assessment adopts a somewhat conservative method of combining extreme offshore water level and wind setup from the most severe direction at the same ARI, whereas Baird's ECL dataset makes consideration of the true joint occurrence of offshore water levels and local wind setup. Give the comparison, and for consistency with the Coastal Hazard Assessment it is recommended that Flood Study adopt Storm Tide levels from the Eurobodalla Coastal Hazard Assessment

Table 2: Comparison of Extreme Still Water Levels excluding wave setup and flood contribution at the Princes Street Jetty from the Eurobodalla Coastal Hazard Assessment (WRL, 2017) and Baird's Monte Carlo ECL dataset.

Location	ARI (Years)	Eurobodalla Coastal Hazard Assessment	Baird's ECL Dataset (mAHD)
Princes Street Jetty	20	1.48	1.39
	100	1.56	1.45

Entrance Condition

In addition to the consideration of ocean water levels for downstream boundary conditions, the condition of the creek entrance needs to be specified. Four of the seven creeks being investigated for this flood study are small coastal lagoons with intermittently open and closed entrances (ICOLLs). Consistent with requirements of *Floodplain Risk Management Guide - Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways* (OEH, 2015) for Group 4 Waterway Entrance Type (ICOLLs) consideration of dynamic morphology of the ICOLL entrances is important in establishing accurate flood levels in downstream areas of the catchment.

This requires an assumption as the entrance condition prior to the onset of the flood scenario and is a site-specific consideration of the following (OEH, 2015):

- Peak shoaled entrance condition from previous estuary/coastal study or historical analysis
- Current entrance geometry (confirmed by survey)
- Whether there is a trigger level for mechanical intervention under entrance management policy
- Dynamic morphology of entrance

A summary of each entrance to be considered in this flood study, included in previous sections, provides the extent of information available for this study. For the ICOLLs, a closed entrance condition will be adopted, noting that there is a high likelihood of the entrance being closed prior to a large flood event and it being a conservative position for flooding of the downstream areas of the catchment. The assumed closed entrance condition for each ICOLL has been based on the entrance berm level obtained from the available survey (ensuring consistency with the adjacent beach berm levels) or the entrance management trigger level, where available, as discussed in the previous sections.

Table 3 provides a summary of the berm levels to be adopted for the ICOLL entrances.

Table 3: Summary of Adopted Berm Level and Water Level for modelling of ICOLL entrances

ICOLL	Adopted Berm Level (mAHD)	Adopted Creek WL (mAHD)	Source
Maloneys Creek	+2.1	+1.8	Nearshore LiDAR Survey Data (OEH, 2018)
Surfside Creek	+1.50	+1.45	Entrance Management Trigger Level (ESC, 2019)
Joes Creek	+1.90	+1.4	Nearshore LiDAR Survey Data (OEH, 2018)
Short Beach Creek	+1.30	+1.10	Entrance Management Trigger Level (ESC, 2019)

Summary Adopted Downstream Boundary Conditions

Based on the information and data provided above, Table 4 provides a summary of the downstream boundary conditions to be adopted for the Batemans Bay Urban Creeks Flood Study.

Table 4: Summary of the Downstream Boundary Conditions for the Batemans Bay Urban Creeks Flood Study

Location	Entrance Type	Entrance Condition	Adopted Berm Level (mAHD)	Creek / Lagoon WL (mAHD)	20 yr Peak Total SWL (mAHD)	100 yr Peak Total SWL (mAHD)
Maloneys Creek	ICOLL	Closed	+2.10	+1.80	2.03	2.13
Long Beach Lagoon	Overland Channel	Closed	+3.5 - 2	TBA	2.18	2.31
Surfside Creek	ICOLL	Closed	+1.50	+1.50	1.96	2.06
Watergardens	Engineered Outlet	Open	N/A	N/A	2.08	2.22
Hanging Rock Creek	Navigable Entrance	Open	N/A	N/A	2.09	2.21
Joes Creek	ICOLL	Closed	+1.85	+1.40	1.72	1.82
Short Beach Creek	ICOLL	Closed	+1.30	+1.30	1.74	1.83

Concluding Remarks

This memo provides a summary of the rationale and assumptions that have informed the proposed downstream boundary conditions to be adopted for the Batemans Bay Urban Creeks Flood Study. The memo is submitted for review and feedback from Council and DPIE prior to the commencement of design flood simulations.

Should you have any queries or require clarification as the information presented herein, please do not hesitate to contact Rhelm (Emma Maratea) or Baird (Sean Garber) to discuss.

References

DPIE (2019). NSW Marine LiDAR Topo-Bathy 2018 Dataset. NSW Department of Planning, Industry and Environment. Accessed via the Geoscience Australia Elevation Information System (ELVIS), January 2020.

DFSI (2011). 1m Resolution Digital Elevation Model. Spatial Services, a unit of Department Finance, Services and Innovation. Accessed via the Geoscience Australia Elevation Information System (ELVIS), January 2020.

ESC (2018). Technical project brief for Batemans Bay Urban Creeks Flood Study. Commissioned by Eurobodalla Shire Council.

OEH (2015). Floodplain Risk Management Guide - Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways. OEH 2015/0769. Office of Environment and Heritage. November 2015.

Taylor D.R., Burston J.M., Dent J.M., Garber S.J. (2017). East Coast Lows: A Wind, Rainfall and Inundation Hazard Database Showing Locations Most at Risk. NSW Coastal Conference, Port Stephens, November 2017.

WRL (2017). Eurobodalla Coastal Hazard Assessment. WRL Technical Report 2017/09, October 2017.

Baird Australia Pty Ltd as Trustee for the Baird Australia Unit Trust
ACN 161 683 889 | ABN 92 798 128 010

Office | Suite 8, Level 22, 227 Elizabeth Street, Sydney, NSW 2000, Australia
Phone | +61 2 8278 7266 Email | sydney@baird.com

Emma Maratea
Director | Rhelm
50 Yeo Street
Neutral Bay, NSW 2089

Status: Final
11 March 2020

Dear Emma,

Reference # 13142.201.L1.Rev0

RE: BATEMANS BAY COASTAL TAILWATER CONDITIONS FOR DESIGN FLOOD EVENT MODELLING

As part of the Batemans Bay Urban Creeks Flood Study, Baird has completed an assessment of coastal water levels during storm tide conditions at seven locations within Batemans Bay (Figure 1). These water levels are provided for use as downstream boundary conditions (tailwater levels) for flood simulations to be undertaken by Rhelm.

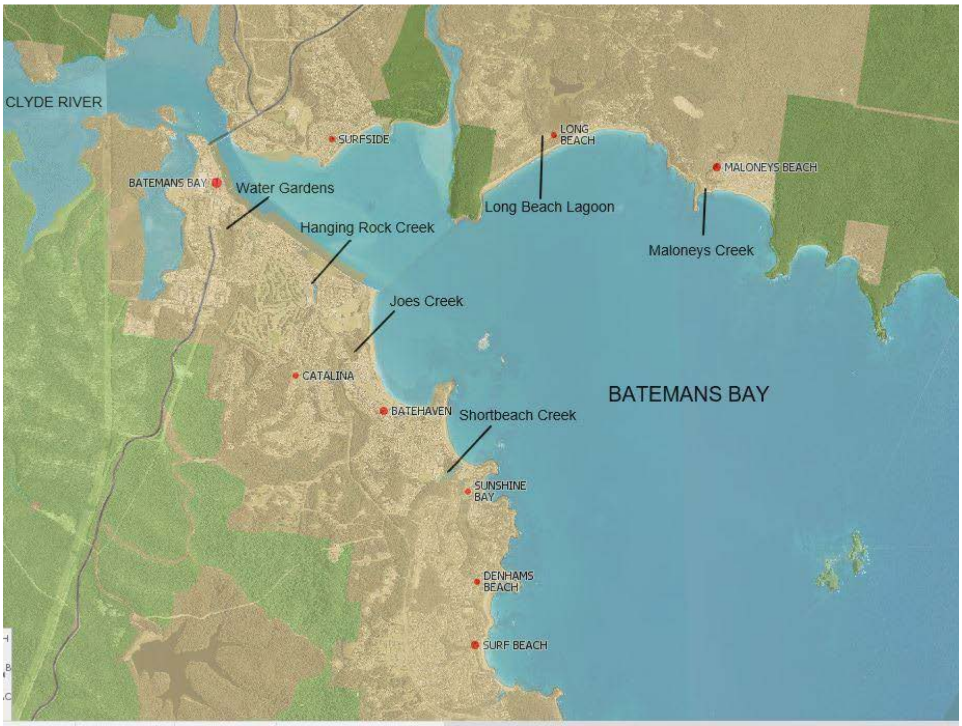


Figure 1: Creek Entrances within the Flood Study Area (from ESC, 2018)

Tailwater Levels for Flood Event Modelling

On the NSW South coast, major flooding typically occurs coincident with coastal storms and it is not unusual for flooding to occur on the spring tides during the East Coast Low season (ESC, 2018). Flood levels in the lower reaches of a catchment or waterway can therefore be exacerbated by the ocean conditions resulting in coincident ocean/catchment flooding. In 2017, Council completed the Eurobodalla Coastal Hazard Assessment (WRL, 2017), that quantified coastal hazards included extreme water levels at coastal locations.

For the determination of design flood levels, the *Floodplain Risk Management Guide - Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways* (OEH, 2015) provides guidance as to the combination of catchment flood scenarios and ocean water level boundary conditions.

For dynamic numerical modelling, a timeseries of the downstream ocean water level boundary condition must be developed. Such a timeseries can be synthetised as follows:

- Select a representative predicted spring tide based on the measured water levels at the Princess Jetty tide gauge
- A design peak storm surge is then selected for the desired ARI
- The selected peak storm surge is then added to the predicted tide, scaling up and down over a 48-hour period.

The joint occurrence of catchment flooding and peak coastal water levels is also specified in OEH (2015) as follows:

- For catchment flood scenarios >2% AEP a downstream ocean water level of High High Water Springs (Solstice Spring) or HHWS(SS) should be used
- For catchment flood scenarios 1-2%AEP a downstream ocean water level of 5% AEP should be used
- For catchment flood scenarios <0.5%AEP a downstream ocean water level of 1% AEP should be used

Water Level Datasets

1. Measured Water Levels at Batemans Bay

Measured water levels from the tide gauge at the Princess Jetty (Batemans Bay) serviced by MHL (Manly Hydraulics Laboratory) were sourced for this study.

To develop the design ocean water level timeseries, a tide record spanning two days over a representative spring tide were extracted from the Princes Jetty measured data (25/09/2000 19:00 - 27/09/2000 19:00). The peak of this timeseries at 0.71mAHD, is above the Mean High Water Spring (MHWS) tidal plane level of, as defined in MHL (2012).

The HHWS(SS) level at Princess Jetty is defined as 0.92m (MHL, 2012), based on 19 years of measured data. A two day spring tide period representative of the HHWS(SS) level at its peak was extracted from the Princes Jetty dataset for use as a downstream boundary condition for catchment flood scenarios >2% AEP. This timeseries can be used for all catchments being assessed in this study.

2. Eurobodalla Coastal Hazard Assessment

The Eurobodalla Coastal Hazard Assessment (WRL, 2017) provides a comprehensive analysis and quantification of coastal hazards at key locations around Batemans Bay, including extreme water levels, nearshore waves, wave runup and beach erosion. For consistency between floodplain and coastal management, the coastal water levels from the Coastal Hazard Assessment were adopted. The Average

Return Interval (ARI) still water levels were calculated in this assessment for 20 year and 100 year ARI, for each of the seven locations.

Within Batemans Bay, coastal water levels have the potential to be higher than offshore due to wind setup over the shallow bathymetry and inland flood events from the Clyde River. Fresh water floods are not expected to cause significant increase in ocean inundation levels in most of the study area. However, in inner Batemans Bay, flooding from the Clyde River may increase peak coastal inundation levels by up to 0.16 m. Therefore, water level defined in the Coastal Hazard Assessment made an allowance for an increase in inundation levels due to flooding from the Clyde River. The flood contribution levels adopted for this study are provided in Table 1.

Table 1: Summary of Design Total Still Water Levels at the Creek Entrances extracted from the Eurobodalla Coastal Hazard Assessment (WRL, 2017)

Location (Coastal Hazard Assessment ID)	ARI (yrs)	Offshore WL (mAHD)	Wind Setup (m)	Storm Tide (mAHD, ex Wave setup and Flood)	Flood Contrib. (m)	Wave Setup (m)	Total SWL (mAHD)
Maloneys Creek (CHA: Western End)	20	1.37	0.11	1.48	0.00	0.55	2.03
	100	1.43	0.13	1.56	0.00	0.57	2.13
Long Beach (CHA: Central)	20	1.37	0.18	1.55	0.00	0.63	2.18
	100	1.43	0.22	1.65	0.00	0.66	2.31
Surfside Creek (CHA: Surfside W)	20	1.37	0.10	1.47	0.04	0.45	1.96
	100	1.43	0.13	1.56	0.07	0.43	2.06
Watergardens (CHA: CBS E)	20	1.37	0.12	1.49	0.03	0.54	2.08
	100	1.43	0.15	1.58	0.05	0.56	2.22
Hanging Rock Creek (CHA: Boat Harbour)	20	1.37	0.08	1.45	0.03	0.61	2.09
	100	1.43	0.10	1.53	0.06	0.61	2.21
Joes Creek (CHA: Corrigans S)	20	1.37	0.08	1.45	0.00	0.27	1.72
	100	1.43	0.10	1.53	0.00	0.28	1.82
Short Beach Creek (CHA: Caseys S)	20	1.37	0.07	1.44	0.00	0.30	1.74
	100	1.43	0.10	1.53	0.00	0.30	1.83

Boundary Condition Timeseries

As per the methodology for synthesising a downstream ocean water level boundary condition described above, water level timeseries representing the 20- and 100- year ARI levels were developed for each catchment. The design storm surge component was calculated as the difference between the Total Still Water Level (from the Coastal Hazard Assessment) and the peak of the two day representative spring tide signal. This storm surge value was then scaled up and down from zero over a total 48 hour period and added to the tidal signal (aligning the peak storm surge value at the peak of the tide signal) to derive a boundary condition timeseries that peaks at the design Total Still Water level, as shown in Figures 2 and 3.

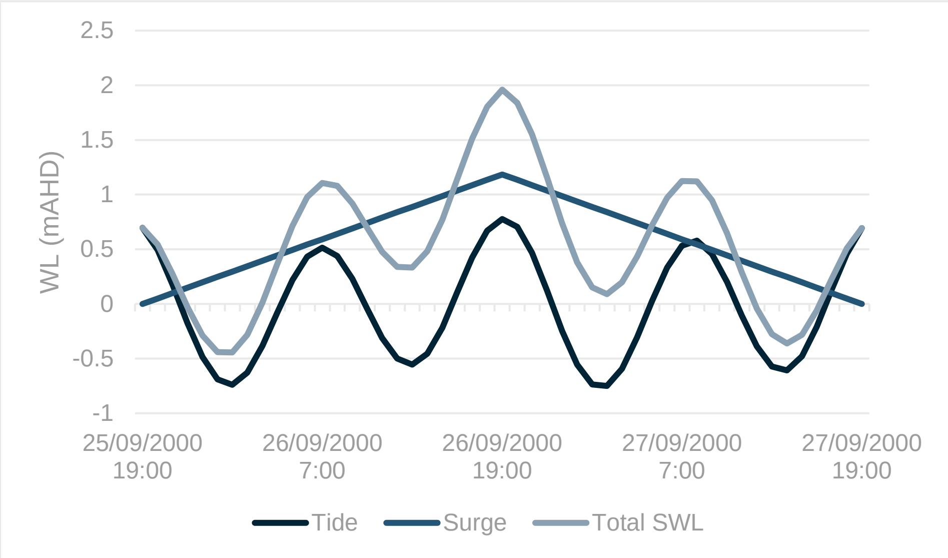


Figure 2: Surfside 20-year ARI. Peak Total SWL of 1.96mAHD

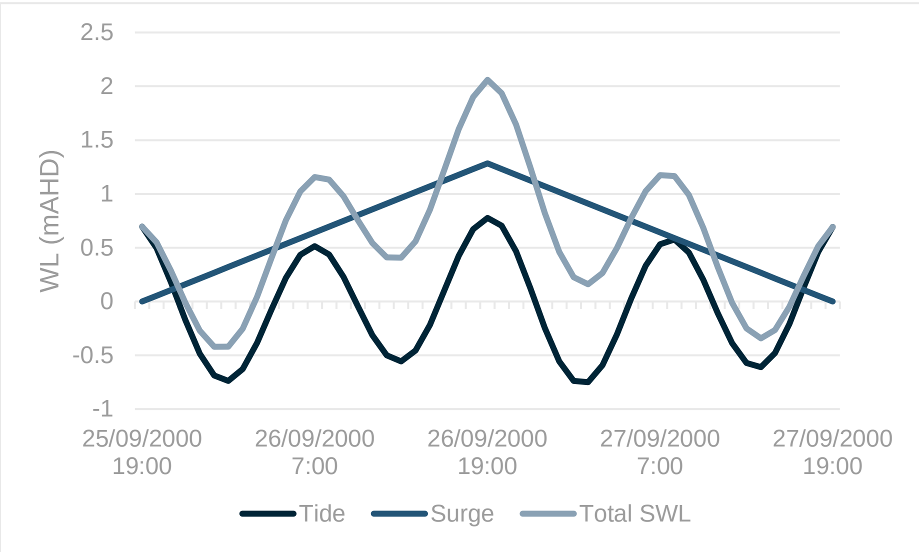


Figure 3: Surfside 100-year ARI. Peak Total SWL of 2.06mAHD

Data Transmittal

The boundary timeseries are being transmitted as CSV files for each location and ARI, with the following specification:

- Column 1: hour (from a nominal zero hour). The peak Total Still Water Level occurs at hour 24 of the timeseries.
- Column 2: Total Still Water Level referenced to mAHD.

File naming follows the following convention:

*CATCHMENT_ARIYEAR*yr_ARI.csv

I trust that these files provide you with the required boundary conditions to commence design flood simulations. Should you have any questions regarding the data files, please let me know.

With thanks,

Sean Garber | Associate Principal
Baird Australia
E: sgarber@baird.com
M: 0404 203 74

References

ESC (2018). Technical project brief for Batemans Bay Urban Creeks Flood Study. Commissioned by Eurobodalla Shire Council.

MHL (2012). OEH NSW Tidal Plane Analysis - 1990-2010 Harmonic Analysis. MHL Report 2053. Report Prepared for NSW Office of Environment and Heritage. October 2012.

OEH (2015). Floodplain Risk Management Guide - Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways. OEH 2015/0769. Office of Environment and Heritage. November 2015.

WRL (2017). Eurobodalla Coastal Hazard Assessment. WRL Technical Report 2017/09, October 2017.

Attachments

13142.201_BatemansFloodStudy_CoastalWLs.zip

Document Approval and Revision History

Revision	Status	Comments	Prepared	Reviewed	Approved
0	Final	Transmittal of Data	CLS	SJG	SJG

Baird Australia Pty Ltd as Trustee for the Baird Australia Unit Trust
ACN 161 683 889 | ABN 92 798 128 010

Office | Suite 8, Level 22, 227 Elizabeth Street, Sydney, NSW 2000, Australia
Phone | +61 2 8278 7266 Email | sydney@baird.com

Emma Maratea
Director | Rhelm
50 Yeo Street
Neutral Bay, NSW 2089

Status: Final
28 April 2020

Dear Emma,

Reference # 13142.201.L2.Rev0

RE: Downstream Boundary Conditions for the Batemans Bay Urban Creeks Flood Study

The Eurobodalla Shire Council (Council) recently commissioned Rhelm Pty Ltd (Rhelm) to complete the Batemans Bay Urban Creeks Flood Study. Baird Australia Pty Ltd (Baird) are assisting Rhelm to establish accurate downstream boundary conditions to be applied for design flood scenario modelling based on an understanding of the coastal hazards within Batemans Bay. Downstream coastal water levels have previously been delivered to Rhelm for seven urban creeks (Baird, 2020a). This memorandum outlines the further analysis performed by Baird for Joes Creek, an Intermittently Closed and Open Lake or Lagoon (ICOLL). Baird has created a hydrodynamic model for Joes Creek using Delft 3D-Flow, with sediment transport and morphology, to determine the downstream water levels in the Joes Creek lagoon for a range of flooding scenarios as provided by Rhelm.

Model Setup

Rhelm provided Baird with numerical catchment inflows at the Beach Road bridge which acts as a culvert, channelling discharge into the ICOLL at a single location. Maximum discharge was aligned to the time of high coastal water level, the joint occurrence of which was determined using the guidelines provided by the Office of Environment and Heritage (OEH, 2015). For 5, 10 and 20 % Average Exceedance Probability (AEP) catchment flood events, the High High Water Springs (Solstice Spring) tide for Batemans Bay was applied. For 1 and 2 % AEP floods, a storm tide of 5% AEP was used, whilst for flood events 0.2% AEP, 0.5% AEP and PMF (nominally defined as 0.0001% AEP), a storm tide of 1% AEP was applied.

The Delft 3D-Flow model used 2018 LIDAR bathymetry of Joes Creek, and a berm height of 2.3 m AHD, as previously reported in Baird (2020b). An observation point to obtain the downstream boundary conditions provided in this report was placed in the lagoon landward of the entrance beach berm. The model was run for two days, ensuring maximum flooding levels were captured. Timesteps were set at 0.125 s to accurately capture breakout over the berm and model maximum flooding, with results captured every 5 minutes.

Model Results

In total 264 models were run, for AEPs ranging from PMF to 20 % AEP, each with up to 4 storm durations and 10 temporal patterns.

An indicative water level timeseries from the 1%AEP event is presented in Figure 1. This shows that lagoon water level responds very quickly to the catchment inflow with little lag.

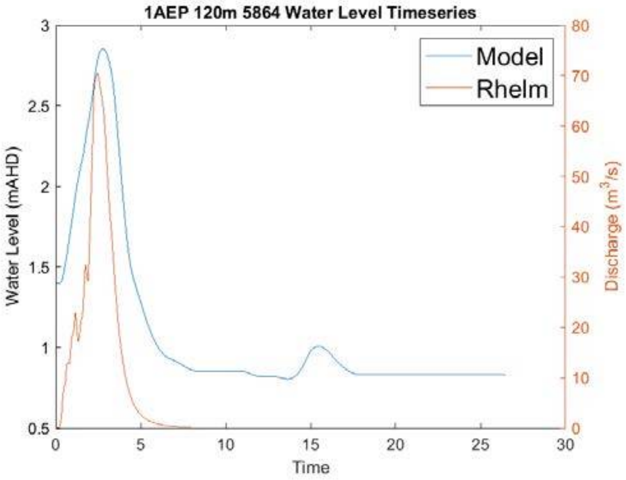


Figure 1 Timeseries of 1%AEP, 120min duration event (ID 5864) discharge rate provided by Rhelm and resultant flooding in the Delft 3D model. Time in hours.

A summary of the maximum water level results from all flood scenarios run in the Delft3D model is presented in Figure 2. This demonstrates that longer duration events govern the peak flood levels at each AEP.

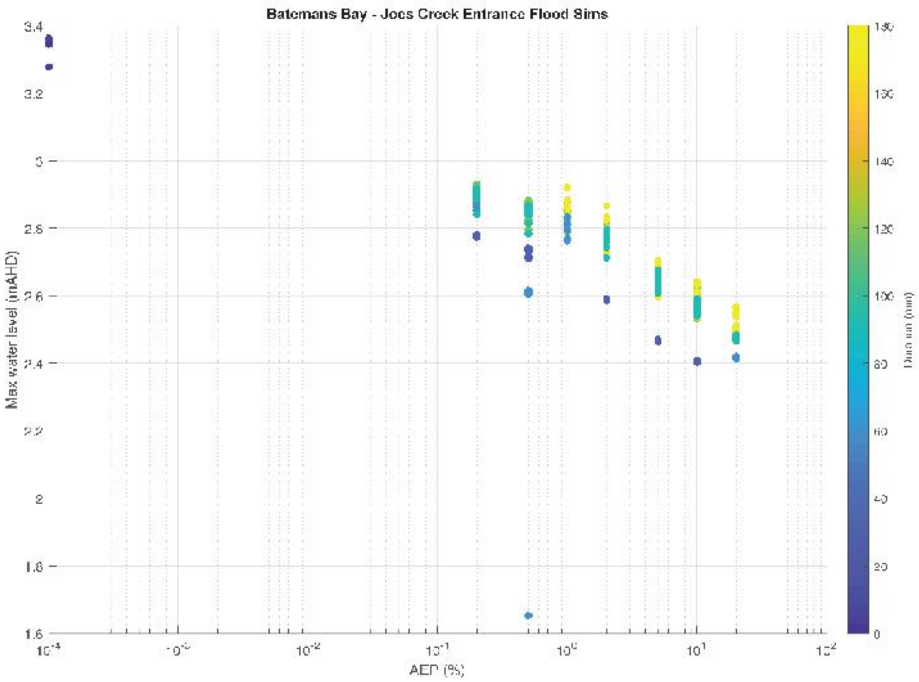


Figure 2 Comparison of maximum Water Level results all Joes Creek Lagoon Entrance Flood Simulations

Data Transmittal

Water level timeseries to be used for further modelling by Rhelm as the downstream boundary condition to the overland flow models are being transmitted as CSV files for each of the 264 flood events, with the following specification:

- Column 1: hour (from a nominal zero hour that aligns with the catchment inflow data files provided by Rhelm).
- Column 2: Lagoon Flood level referenced to mAHD.

File naming follows the following convention:

- *catchmentAEP*_duration_eventID.csv

The eventID is defined based on the catchment flow data provided by Rhelm.

I trust that these files provide you with the required downstream boundary conditions to commence design flood simulations for Joes Creek. Should you have any questions regarding the data files, please let me know.

With thanks,

Sean Garber | Associate Principal
Baird Australia
E: sgarber@baird.com
M: 0404 203 74

References

Baird (2020a). Batemans Bay Coastal Tailwater Conditions for Design Flood Event Modelling. 13142.201.L1.Rev0, March 2020.

Baird (2020b). Summary of Proposed Downstream Boundary Conditions to be Adopted for the Batemans Bay Urban Creeks Flood Study 13142.201.M1.Rev0. February 2020.

OEH (2015). Floodplain Risk Management Guide - Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways. OEH 2015/0769. Office of Environment and Heritage. November 2015.

Attachments

13142.201_JoesCk_Timeseries_csv.zip
13142.201_JoesCk_Timeseries_Figures.zip

Document Approval and Revision History

Revision	Status	Comments	Prepared	Reviewed	Approved
0	Final	Transmittal of Data	CLS	SJG	SJG

Rhelm

engineering | environmental | economics | engagement

Rhelm Pty Ltd

ABN 55 616 964 517

ACN 616 964 517

Head Office

Level 1, 50 Yeo Street

Neutral Bay NSW 2089

contact@rhelm.com.au

+61 2 9098 6998

www.rhelm.com.au