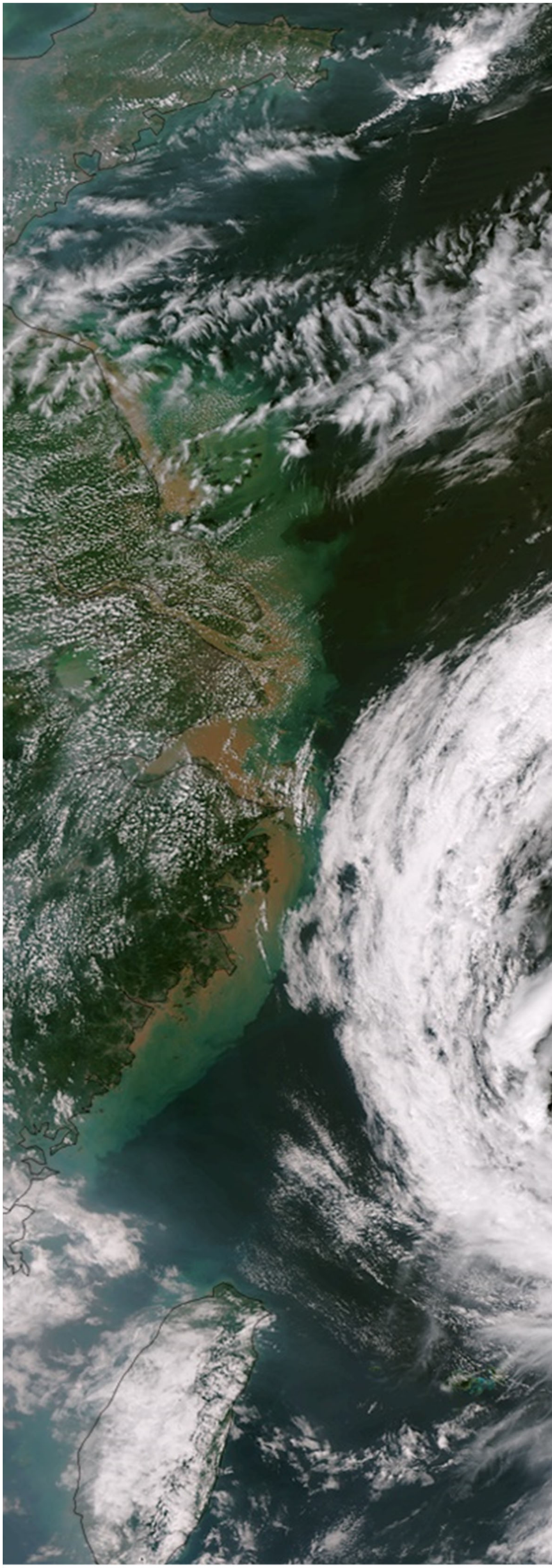

JBP scientists and engineers

Coastal vulnerability maps and associated

Data Compilation Report

Final Report

14 May 2020

KEMPSEY Shire Council

JBP Project Manager

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Revision History

Revision Ref / Date Issued	Amendments	Issued to
1.0 (Draft) / 28 Apr 2020		RK, ND
2.0 (Final) / 14 May 2020		RK, ND

Contract

This report describes work commissioned by Ron Kemsley on behalf of Kempsey Shire Council. Daniel Rodger, Barney Bedford and Ellie Vahidi of JBP carried out this work.

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Purpose

This document has been prepared as a Final Report for Kempsey Shire Council. JBP accepts no responsibility or liability for any use that is made of this document other than by the Client for the purposes for which it was originally commissioned and prepared.

JBP has no liability regarding the use of this report except to Kempsey Shire Council.

Acknowledgements

Kempsey Shire Council has prepared this document with financial assistance from NSW Government through the Department Planning, Industry & Environment. This document does not necessarily represent the opinions of the NSW Government or the Department Planning, Industry & Environment.

JBP would like to acknowledge the support from Nicholas Denshire from the NSW Department of Planning, Industry and Environment, and the work by Clyde Treadwell and Keelan Birch from RDM.

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Executive Summary

JBPacific were commissioned by Kempsey Shire Council to undertake tidal inundation modelling and mapping and to develop a Coastal Vulnerability Area (CVA) map for the Kempsey Local Government Area (LGA). The CVA mapping will be the key output of Stage 2 of the Coastal Management Program (CMP) development for Council, in compliance with the Coastal Management Act 2016 and the State Environmental Planning Policy (Coastal Management) 2018.

This Data Compilation Report included a comprehensive review of all available studies, data and models to undertake the development of the Coastal Vulnerability Area (CVA) mapping, which forms a part of the Coastal Management framework for land use planning within the coastal zone. The CVA mapping will be developed considering the seven coastal hazard mapping components:

1. Beach erosion
2. Shoreline recession
3. Coastal lake or watercourse entrance instability
4. Coastal inundation
5. Coastal cliff or slope instability
6. Tidal inundation
7. Erosion and inundation of foreshores caused by tidal waters and the action of waves, including the interaction of those waters with catchment floodwaters.

To support the development of the CVA map, this project will undertake new tidal inundation modelling to address Hazard 6: Tidal inundation. The Lower Macleay River flood study and associated hydrodynamic modelling, adopted in 2019, was reviewed and considered to provide a sound basis for the tidal inundation modelling. Some modification of the flood study model is necessary to address tidal inundation, as opposed to flood inundation. The tidal inundation modelling and mapping will be delivered by this project and incorporated into the development of the CVA mapping.

Of the remaining six hazards, this Data Compilation Report has identified that suitable information to support the development of the CVA mapping is available (or readily derivable) based on data within the Kempsey Coastal Processes and Hazard Definition Study (2013) for:

- Hazard 1: Beach erosion
- Hazard 2: Shoreline recession
- Hazard 4: Coastal inundation

Three hazards require additional consideration before inclusion within the CVA map.

- Hazard 3: Coastal lake or watercourse entrance instability
- The mapping of beach erosion and shoreline recession within the Kempsey Coastal Processes and Hazard Definition Study is based on the existing entrance position of all creeks in the study area. While the creek entrances are generally stable, there are locations, such as Killick Creek, where future changes to the entrance geometry could occur.

  The potential entrance instability is recommended to be included within the mapping. A simplified approach is proposed.

  - For waterways with an approved training wall or revetment (e.g. Macleay River and South West Rocks Creek) or bedrock feature (e.g. southern side of Killick Creek) a landward buffer is created, e.g. 10m.
  - For waterways with a sandy spit that may be subject to a future breakthrough (e.g. Saltwater Creek and northern side of Killick Creek) the land between the coastline and the creek is included in the hazard map.
  - For areas where watercourse entrance instability may be a hazard to infrastructure or land use planning (e.g. Korogoro Creek) a historic aerial review is undertaken, and the maximum envelope of historic entrance positions are mapped.

  This is recommended for further discussion with NSW Department of Planning, Industry and Environment (DPIE).

- Hazard 5: Coastal cliff or slope instability.

  A goal of the Kempsey Coastal Processes and Hazard Definition Study (2013) was to identify areas that may be subject to cliff instability for further investigation. No significant cliff instability areas were identified within the document. Given these results, the hazard associated with coastal cliff or slope instability is considered to be minor. It is proposed that no mapping will be undertaken for this coastal hazard. This is recommended for further discussion with NSW Department of Planning, Industry and Environment (DPIE).

- Hazard 7: Erosion and inundation of foreshores caused by tidal waters and the action of waves, including the interaction of those waters with catchment floodwaters.

  Mapping is proposed to be based on a combined flood and tide scenario from the Lower Macleay Flood Study (2019). This would represent the following definition:

  Inundation caused by tidal waters, including the interaction of those waters with catchment floodwaters.

  A number of coincident flood and tidal scenarios have been mapped, typically with flood-dominated conditions due to the fluvial nature of the study. A flood with a 1% Annual Exceedance Probability (AEP) (100-year return period) inflow occurring with a coincident Higher High Water Spring (HHWS) tidal boundary is proposed for use within the CVA mapping. These flood maps are available for present day, 2050 and 2100.

  A review of the Lower Macleay Flood Study Model has found that model is fit for purpose for the joint fluvial-tidal flooding for which it was designed. The model appropriately includes a number of flood gates and flood control structures, as well as levees that control some fluvial flood events along the Lower Macleay. Fluvial-tidal interaction is handled at the downstream extents of the modelled creeks with tidal signatures which provides a realistic oscillation in flood levels in the foreshore.

  The limitations of this approach are:

  - This mapping will not consider 'erosion'. This will instead be mapped in Hazard 1 as beach erosion.
  - This mapping will not consider 'waves'. This will instead be mapped in Hazard 4 as wave runup levels.
  - The model simulation will extend throughout the floodplain and won't just consider the 'foreshore'. It is unsure if the intention of Hazard 7 is to limit mapping to just the foreshore, which is defined in the Coastal Management Act as ‘the area of land between highest astronomical tide and the lowest astronomical tide', but typically includes land up to the maximum extent of wave uprush. This area will already be mapped through Hazard 6: Tidal inundation and Hazard 4: coastal inundation.

  This is recommended for further discussion with NSW Department of Planning, Industry and Environment (DPIE).

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Abbreviations

CMP .... Coastal Management Program

CVA................................ Coastal Vulnerability Area

LGA................................ Local Government Area

SEPP .... State Environmental Planning Policy (Coastal Management) 2018

Definitions

Definitions used in this document are as per the NSW Coastal Management Manual and NSW Coastal Management Glossary.

1 Introduction

JBPacific were commissioned by Kempsey Shire Council (KSC) to undertake new tidal inundation mapping and to develop a Coastal Vulnerability Area map for the Kempsey Local Government Area (LGA). This is to be developed in accordance with the *State Environmental Planning Policy (Coastal Management) 2018*, as a part of the NSW government coastal planning reforms.

This project focusses on Coastal Vulnerability Area mapping, which forms a part of the Coastal Management framework for land use planning within the coastal zone. The overall framework includes four coastal management areas:

- Coastal wetlands and littoral rainforests
- Coastal Vulnerability Area (CVA)
- Coastal environment area
- Coastal use area.

The development of the CVA map has included new tidal inundation modelling, which has been included within seven coastal hazard mapping components:

1. Beach erosion
2. Shoreline recession
3. Coastal lake or watercourse entrance instability
4. Coastal inundation
5. Coastal cliff or slope instability
6. Tidal inundation
7. Erosion and inundation under tides, waves, and catchment floodwaters.

In addition to this introductory chapter, this report contains the following:

- **Section 2:** Statutory context and CVA map
- **Section 3:** Approach to CVA mapping
- **Section 4:** Data review
- **Section 5:** Approach to Tidal Inundation Mapping

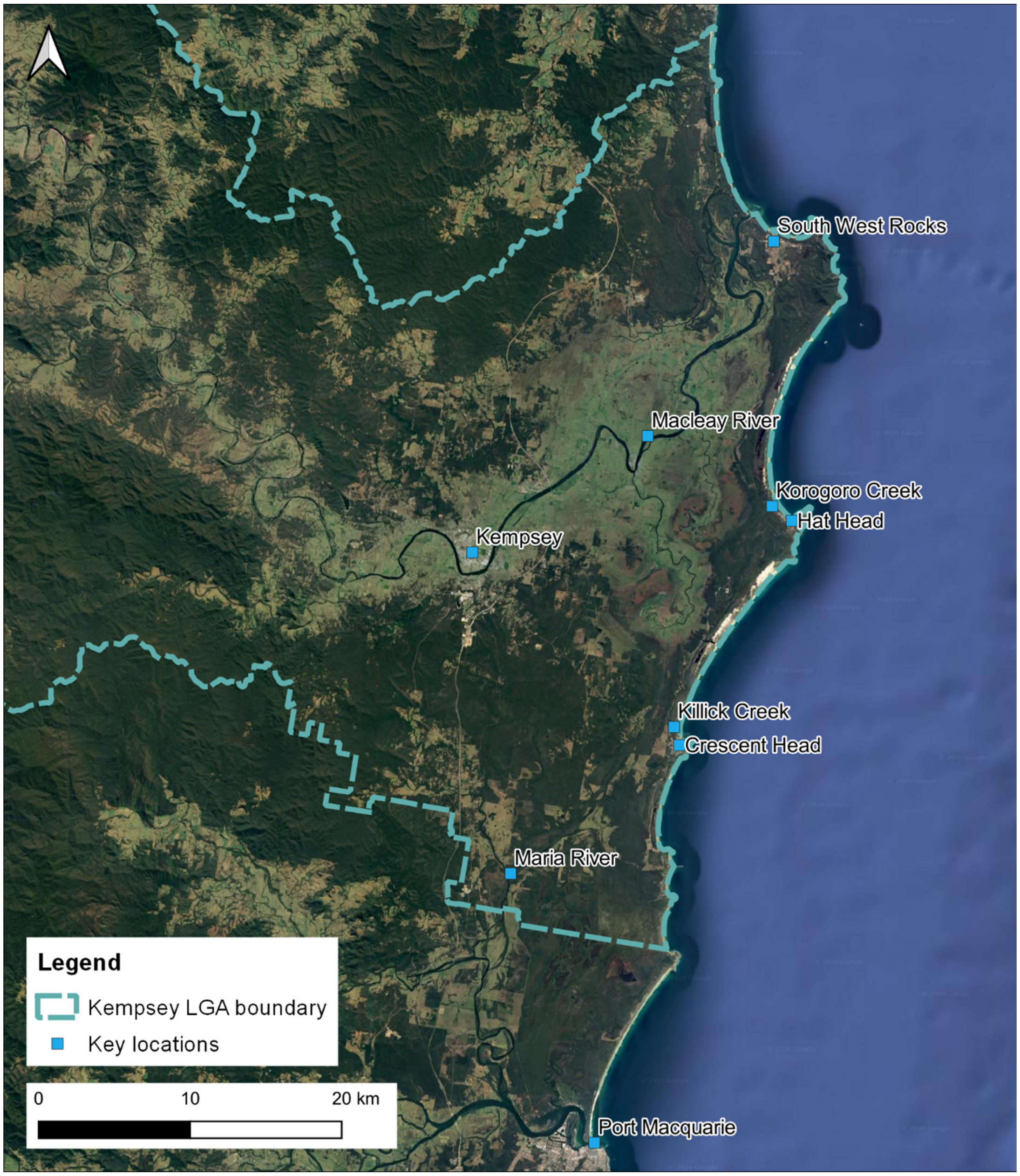


Figure 1-1: Study area and key locations

2 Statutory context

The Coastal Vulnerability Area (CVA) mapping is subject to the NSW legislative reforms undertaken since 2014. These include the *Coastal Management Act 2016*, Coastal Management Programs, State Environmental Planning Policy and the *Marina Estate Management Act 2014*. This legislation now considers seven separate coastal hazards, which will form the basis of the CVA Map.

2.1 Legislation and Policy

2.1.1 Coastal Management Act 2016

The *Coastal Management Act 2016* establishes a framework for strategic management of coastal areas within NSW. It establishes essential and mandatory requirements of Coastal Management Programs. The Coastal Management Act 2016 repeals the previous *Coastal Protection Act 1979*.

2.1.2 Coastal Management Program (CMP)

Coastal management programs (CMPs) set the long-term strategy for the coordinated management of the coast, with a focus on achieving the objects and objectives of the *Coastal Management Act, 2016*. CMPs identify coastal management issues and the actions required to address these issues in a strategic and integrated way.

CMPs detail how and when those actions are to be implemented, their costs and proposed cost-sharing arrangements and other viable funding mechanisms.

The *Coastal Management Act, 2016* (and other relevant legislation) establishes specific roles and responsibilities for relevant Ministers, the NSW Coastal Council, public authorities and local councils, as well as providing opportunities for communities to participate when preparing and implementing a CMP.

2.1.3 Coastal Management Manual

The Coastal Management Manual sets out a five-stage process by which CMP's are prepared:

- Stage 1: Scoping Study
- Stage 2: Detailed studies of vulnerabilities and opportunities
- Stage 3: Response identification and evaluation
- Stage 4: Finalise, exhibit, certify and adopt the CMP
- Stage 5: Implementation, monitoring and reporting.

The preparation of the CVA mapping is undertaken in Stage 2 of this process, as it draws together maps of seven coastal hazards that are typically prepared within a Coastal Management Program. These include the results of a Tidal Inundation Study and Coastal Hazard Mapping.

2.1.4 State Environmental Planning Policy (Coastal Management) 2018

The State Environmental Planning Policy (Coastal Management) 2018 gives effect to the objectives of the *Coastal Management Act 2016* from a land use planning perspective by specifying how development proposals are to be assessed if they fall within the coastal zone.

2.1.5 Marine Estate Management Act 2014

The *Marine Estate Management Act, 2014* was developed to support the management of the marine estate of NSW in a manner consistent with the principles of ecologically sustainable development. The development of a CVA map is considered to satisfy the objectives of the Act, in that it will allow the identification of coastal areas, allowing co-ordination by public authorities for the management of marine parks and aquatic reserves.

2.2 Coastal Zone

The coastal zone is defined in the *Coastal Management Act 2016* as being the area of land comprised of one of the four coastal management areas. These are:

- Coastal wetlands and littoral rainforests.

  These are areas that have distinctive hydrological and ecological characteristics of a coastal wetland and littoral rainforest and includes their surrounding proximity areas to manage the impacts of adjacent development.

- Coastal vulnerability areas (CVA)

  The *Coastal Management Act 2016* outlines seven (7) different coastal hazards in the coastal vulnerability area:

  - Beach erosion
  - Shoreline recession
  - Coastal lake or watercourse entrance instability
  - Coastal inundation
  - Coastal cliff or slope instability
  - Tidal inundation
  - Erosion and inundation of foreshores caused by tidal waters and the action of waves, including the interaction of those waters with catchment floodwaters.

- Coastal environment areas

  The coastal environment area identifies the environmental features of the coastal zones, such as state water, estuaries, coastal lakes and coastal lagoons as well as land adjoining those features including beaches, dunes, coastal headlands and rock platforms.

- Coastal use areas

  The coastal use area is land adjacent to coastal waters, estuaries, coastal lakes and lagoon where development is or may be carried out and impacts of development on scenic and cultural values and use and enjoyment of the beaches, foreshores, dunes, headlands, rock platforms, estuaries, lakes and the ocean need to be considered

2.2.1 Application of the coastal management areas

The State Environmental Planning Policy (Coastal Management) 2018, requires Councils to prepare maps of the four coastal management areas throughout their Local Government Area (LGA), which will be used to flag areas for development controls. Maps of the Kempsey LGA coastal wetland and littoral rainforest, coastal environment area, and coastal use area are publicity available to view on the NSW ePlanning Spatial Viewer. The development of new CVA maps will complete the mapping of the four coastal management areas. These maps will be able to be used to identify areas that may be vulnerable to coastal processes now or in the future.

The NSW Depart of Planning Circular 19-006 outlines that no CVA map has yet been adopted in NSW, and no coastal vulnerability areas have been formally identified for any local government area. As such, this project will be one of the first to interpret the requirements of the State Environmental Planning Policy (Coastal Management) 2018, and to develop a combined CVA map for seven coastal hazards.

3 CVA mapping

3.1 Formatting

There are currently no available examples of Coastal Vulnerability Area (CVA) mapping, developed under the State Environmental Planning Policy (Coastal Management) 2018. Guidance was sort from the Department of Planning, Industry and the Environment, however the only feedback related to the technical GIS specification. In summary the mapping deliverables will comply with the following:

- Datasets must comply with the Department's Standard Technical Requirements for Spatial Datasets and Maps
- Datasets should be projected in Geocentric Datum of Australia 1994 (GDA94)
- Datasets should be in either Geodatabase (.gdb) or Shapefile (.shp) formats.
- Datasets will use polygon format.
- Metadata should make clear what the polygons measure or represent particularly in relation to risk scenarios and time horizons.

3.2 Components

The Coastal Vulnerability Area (CVA) maps will be based on current and future coastal hazards.

Three CVA maps will be produced, representing three planning horizons:

- Present day
- 2050
- 2100

A combined CVA map will show an amalgamation of all seven hazards. Each CVA map will also be able to be split into its seven hazard components:

1. beach erosion,
2. shoreline recession,
3. coastal lake or watercourse entrance instability,
4. coastal inundation,
5. coastal cliff or slope instability,
6. tidal inundation,
7. erosion and inundation of foreshores caused by tidal waters and the action of waves, including the interaction of those waters with catchment floodwaters.

All hazards have been considered in terms of their definition under the NSW Coastal Management Manual and NSW Coastal Management Glossary[1]. The approach used to select hazard maps is described in the following sections.

1 OEH (2018) "Coastal Management Glossary", State of NSW and Office of Environment and Heritage

3.3 Beach erosion

Beach erosion is defined as:

"the landward movement of the shoreline and/or a reduction in beach volume, usually associated with storm events or a series of events, which occurs within the beach fluctuation zone. Beach erosion occurs due to one or more process drivers; wind, waves, tides, currents, ocean water level, and downslope movement of material due to gravity."

Coastlines naturally erode and accrete over time, driven by variations in sediment supply and climate patterns. This hazard relates to the landward movement of the shoreline during a storm over a short-term timescale. When a beach is stable, the sand moved offshore during a storm will eventually move back onto the beach, over timeframes of months to years. However, any development, buildings, foundations or structures located within the eroded land may be damaged during this process.

Figure 3-1: Erosion at Hat Head[2]

3.3.1 Available data for CVA mapping

- Identified dataset: 'unlikely' beach erosion extents
- Probability: Labelled an 'unlikely' event. Considered the best estimate of erosion.
- Source: Kempsey Coastal Processes and Hazard Definition Study (2013)
- Status: Adopted study by KSC

Beach erosion mapping has been completed within the Kempsey Coastal Processes and Hazard Definition Study (2013)[3]. This mapping has used an evidence base to understand past erosion events and their potential to occur again in the future. Beach erosion extents have been defined based upon analysis of the most eroded profiles recorded in the historic photogrammetric data. Three beach erosion likelihoods were produced; reflecting ‘almost certain’, 'unlikely' and ‘rare’ extents. These were based on different analysis of the photogrammetric data.

The 'unlikely' beach erosion extents are considered the best estimate of an extreme erosion event, and are proposed for use within the CVA map. These estimates are based on the maximum

2 The Macleay Argus (2018) "Hat Head 4WD beach access closed". Accessed on 16 Apr 2020 from: https://www.macleayargus.com.au/story/5326111/hat-head-4wd-beach-access-closed/

3 Kempsey Coastal Processes and Hazards Definition Study (2013) BMT WBM for Kempsey Shire Council

observed erosion along any part of a beach, which was then projected along the entire beach. This encompasses the possibility that rips (and their associated erosion scarps) may form at any location along a beach, that waves may affect any section of the beach, and that differentials in longshore sediment transport may propagate up- or down-coast depending on the short and medium term wave climate.

The 'unlikely' beach erosion extents are available for a present-day coastline. They have also been mapped for future planning horizons by being combined with shoreline recession (See Section 3.4). For these future planning scenarios, the present-day beach erosion estimates have been at the estimated 2050 and 2100 shoreline positions, as there is currently no reliable or reasonable data that would justify assuming a different beach erosion magnitude in the future.

An example of an 'unlikely' beach erosion map is shown in Figure 3-2.

Figure 3-2: Present day 'unlikely' beach erosion extents at Hat Head

3.4 Shoreline recession

Shoreline recession is defined as:

"the continuing landward movement of the shoreline, that is, a net landward movement of the shoreline, generally assessed over a period of several years. As shoreline recession occurs the beach fluctuation zone is translated landward."

Along many coastlines, due to changing sediment supply or climate conditions, the beach may not have sufficient capacity to rebuild between storm events. In the absence of intervention, these long-term trends will result in the continued landward movement of the shoreline. The net loss in sediment supply may be caused by shoreline structures such as river training walls or groynes that interrupt or block the natural transport of sediment between embayments or a natural alongshore gradient in the longshore sand transport. At other locations the coastal processess or new structures may cause a net increase in sediment, and beach accretion. Analysis of reliable photogrammetry between approximately 1967 to present indicates the Kempsey coastline has been relatively stable, with no significant recession, with areas such as Trial Bay experiencing long term accretion due to the breakwater.

Figure 3-3: Long-term changes in beach width near the Trial bay Gaol.

3.4.1 Available data for CVA mapping

- Identified dataset: Coastline recession calculations. Presented as recession plus beach erosion.
- Probability: No likelihood assigned to coastal recession. Considered the best estimate of erosion.
- Source: Kempsey Coastal Processes and Hazard Definition Study (2013)
- Status: Adopted study by KSC

Shoreline recession mapping has been completed within the Kempsey Coastal Processes and Hazard Definition Study (2013). The rate of historic long-term recession was measured from photogrammetric data. Analysis of reliable photogrammetry between approximately 1967 to present day indicates the Kempsey coastline has been relatively stable, with no significant recession, with areas such as Trial Bay experiencing long term accretion. However, future coastal recession is expected under the influence of climate change.

Future recession due to climate change has been assessed using the Shoreline Evolution Model (SEM), which simulated the response of the shoreline to sea level change, and structural changes such as the introduction of harbour breakwaters or groynes to the coastal system. The SEM simulated the coastline under a range of scenarios; including past, present and future coastlines, present day climate conditions, and future sea level rise cases. For the latter, the long term simulation kept sea level rise constant until the year 1990, after which a rise of 0.06 m to 2010, followed by a linear rise to 0.4 m by 2050, and to 0.9 m by 2100.

The shoreline position were extracted from the model at 2050 and 2100 planning horizons. At each horizon, the long-term recession rates have been combined with the 'unlikely' beach erosion hazard extents to derive the 2050 and 2100 hazard probability zones.

Figure 3-4: Combined coastal recession and beach erosion under a 2100 scenario at Crescent Head

3.5 Coastal lake or watercourse entrance instability

Coastal lake or watercourse entrance instability is described as:

" the variety of potential hazards and risks associated with the dynamic nature of both natural and trained entrances. Coastal lake and watercourse entrances are highly active environments with their shape constantly changing in response to processes such as alongshore sediment transport, tidal flows, storms and catchment flooding."

At many untrained coastal estuaries and rivers, there is inherent variability of the coastal entrance position. While some estuary channels and entrances are relatively stable through time and are held by natural geomorphic features (e.g. Korogoro Creek), others have historically broken through at various positions along the coast. Other causes for entrance instability can be artificial openings or new engineered structures being introduced into the coastal system, such as the large-scale changes made to the Macleay River. Figure 3-5 shows the changes to waterway position over the 1900s[4].

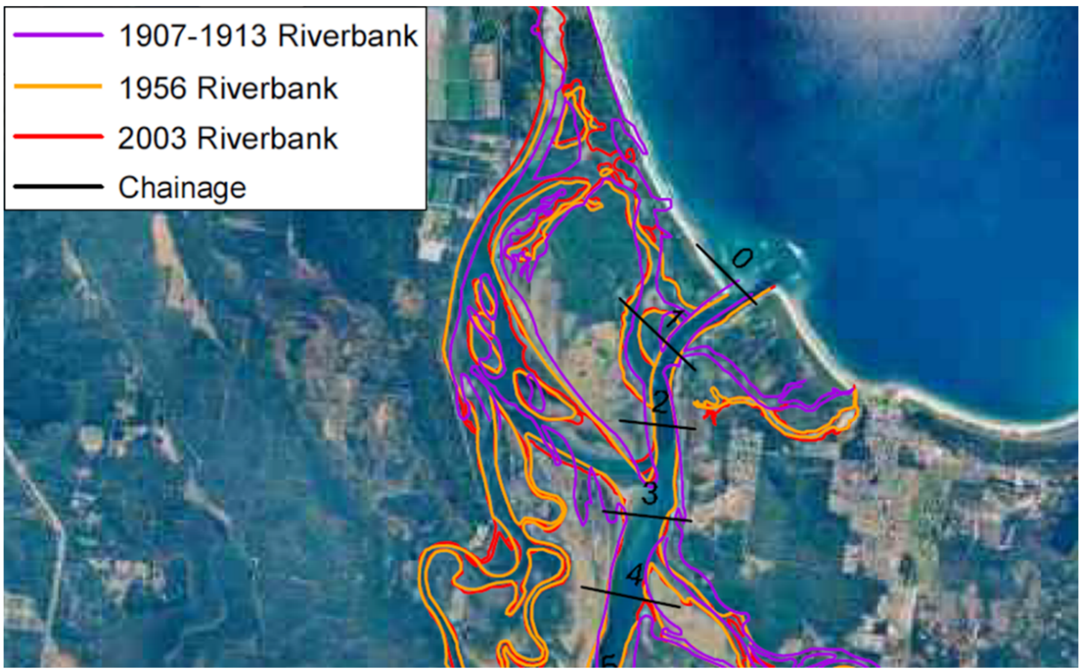


Figure 3-5: Changes to waterway position of the Macleay River

3.5.1 Available data for CVA mapping

- Identified dataset: No dataset provided

The mapping of beach erosion and shoreline recession within the Kempsey Coastal Processes and Hazard Definition Study (see Section 3.3 and 3.4) has covered the Kempsey creek mouths. However, the origin line from which beach erosion extents were measured was taken on the landward side of the creek entrance berms and drainage lines. In all cases, and as confirmed by the photogrammetric data, the entrance berms have been eroded away frequently in the past (such as at Saltwater Creek). The Hazard Definition Study states that it is reasonable to assume that the entire berm would potentially be eroded in the future, however this process is not included in maps.

In discussion with Council regarding the potential hazard associated with coastal lake or watercourse entrance instability, Council highlighted that the Macleay River, South West Rocks Creek and Killick Creek were both trained and considered relatively stable. Council was also not aware of historical entrance instability at the Korogoro Creek - which they observed was likely because of the protection offered by the Hat Head headland. Instability at the entrance to Saltwater

4 WMA Water (2009) Macleay River Estuary Processes Study (2009)

Creek has been investigated and is shown to have the potential for influences on important processes including water levels, water quality and ecological processes.

Other CVA projects are undertaking specific assessments of coastal lake instability. The coastal hazard study for Bega Valley[5], has based new mapping on empirical calculations and historical photogrammetric data, with the creek entrance instability hazard estimated and added to the short-term erosion hazard.

On review of the potential risk for this hazard, the potential entrance instability is recommended to be included within the mapping. A simplified approach is proposed.

- For waterways with an approved training wall or revetment (e.g. Macleay River) or bedrock feature (e.g. southern side of Killick Creek) a landward buffer is created, e.g. 10m.
- For waterways with a sandy spit that may be subject to a future breakthrough (e.g northern side of Killick Creek) the land between the coastline and the creek is included in the hazard map.
- For areas where watercourse entrance instability may be a hazard to infrastructure or land use planning (e.g. Korogoro Creek) a historic aerial review is undertaken, and the maximum envelope of historic entrance positions are mapped.

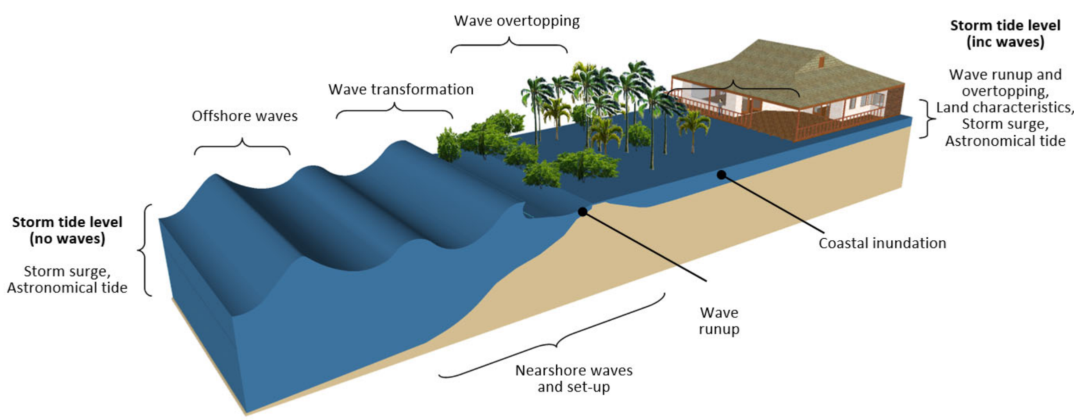
This is recommended for further discussion with NSW Department of Planning, Industry and Environment (DPIE).

3.6 Coastal inundation

Coastal inundation is described as occurring when:

" a combination of marine and atmospheric processes raises the water level at the coast above normal elevations, causing land that is usually 'dry' to become inundated by sea water. Alternatively, the elevated water level may result in wave run-up and overtopping of natural or built shoreline structures (e.g. dunes, seawalls."

Coastal flooding is a complicated process, effected by several dependent and independent variables, as shown in Figure 3-6. The storm tide level is comprised of the underlying astronomical tide and a storm surge component, including local wave effects. These components determine the resulting sea-level for a specific location at a given time.



5 BVSC (2017) "Coastal Management Programme - Coastal Hazards". Bega Valley Shire Council. Accessed on 24 April 2020 from: http://begavalley.wrl.unsw.edu.au/wp-content/uploads/2018/03/20171222-Coastal-Processes-and-Hazards-Draft.pdf

Figure 3-6: Coastal risk drivers

3.6.1 Available data for CVA mapping

- Identified dataset: 'unlikely' coastal inundation extents
- Probability: Labelled an 'unlikely' event, which reflects a 1 in 100-year Annual Recurrence Interval (ARI)
- Source: Kempsey Coastal Processes and Hazard Definition Study (2013)
- Status: Adopted study by KSC

The Kempsey Coastal Processes and Hazard Definition Study (2013)[3] defined coastal inundation extents using a 'bath-tub' modelling approach. This approach takes an estimate of the maximum wave runup possible during a high storm tide and applies that water level across the model domain. This results in flooding anywhere that the land is lower than this predicted water level, regardless of its connection to the ocean. It provides a conservative estimate of inundation by coastal waters. Mapping is available under multiple probabilities, and three planning horizons. The 'unlikely' coastal inundation extents are considered the best estimate of an extreme coastal inundation event, and are proposed for use within the CVA map. An example of an 'unlikely' present day coastal inundation map is shown in Figure 3-7.

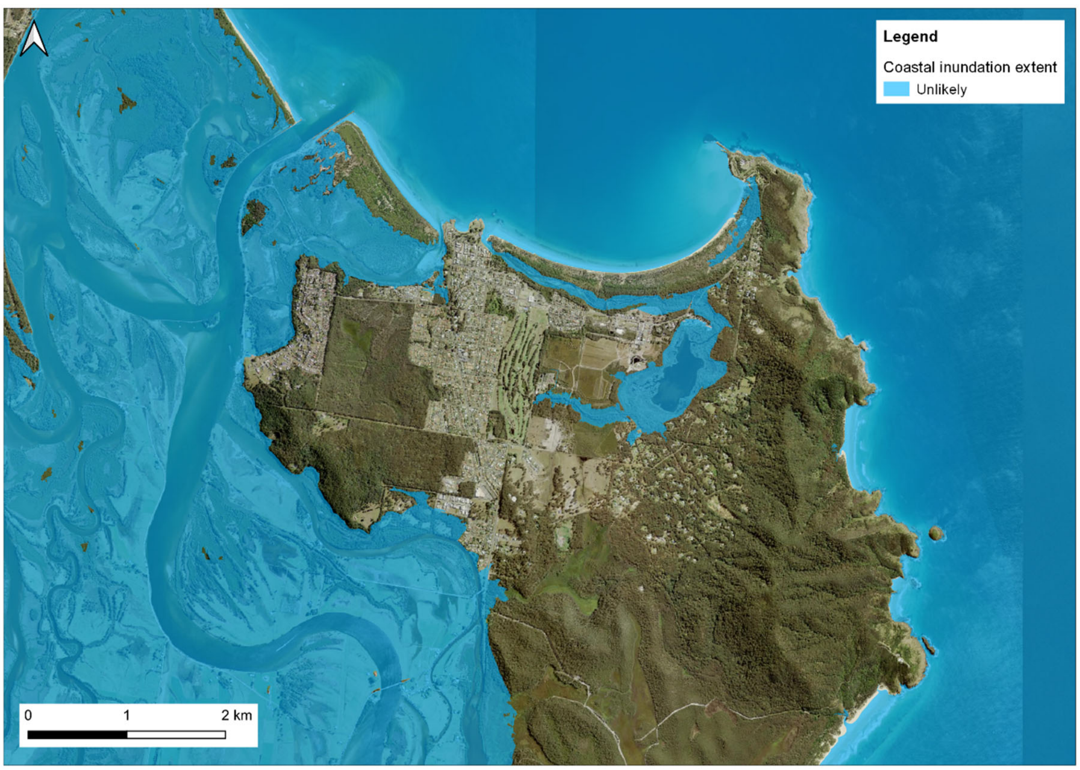


Figure 3-7: Present day 'unlikely' coastal inundation throughout the Kempsey LGA

3.7 Coastal cliff or slope instability

No definition of this hazard is provided in the NSW CMG but the NSW Coastal Management Manual[6] relates instability to risk to life and property, e.g. from "catastrophic failure of cliffs and headlands and hazards associated with rock platforms".

Cliff and slope instabilities are geotechnical hazards. They are heavily dependent on the geology (stratigraphy, geochemistry and structure) of the underlying bedrock. An instability may lead to a failure of the cliff or slope, which may naturally result in a shallower slope angle. The cause of instability in a coastal environment is typically marine action of waves on the foot of cliffs and slopes that undercut or over-steepen cliffs and slopes to a point that the composing materials have insufficient internal strength to maintain.

The Kempsey coastline can be broadly described as a set of rocky headlines joined by wide east-facing beaches that feature shallow dunes formations. Most dwellings are located behind these dunes rather than on the more stable headlands. Unlike some areas, the Kempsey coastline has not historically recorded any cliff instabilities or failures that has affected public or private infrastructure. The predominantly rocky coastline is resilient to everyday wave action and thus does not change as rapidly as softer areas of coastal frontage.

3.7.1 Available data for CVA mapping

- Identified dataset: No dataset provided

The NSW Coastal Management Manual suggests detailed geotechnical studies may be required when the Stage 1 scoping study indicates complex interactions between geotechnical hazards and coastal assets or public access.

An aim of the Kempsey Coastal Processes and Hazard Definition Study (2013)[3] was to identify areas that may be subject to cliff instability for further investigation. No areas have been identified within the document yet it was recommended that following storm events dune slopes near recreation areas should be subject to geotechnical investigation to identify any zones of increased risk that can therefore be assessed on a case-by-case basis.

It is proposed that no mapping will be undertaken for this coastal hazard; however a summary of the Hazard Definition Study will be included within the CVA summary report to justify the absence of spatial extents related to coastal cliff instability. This is recommended for further discussion with NSW Department of Planning, Industry and Environment (DPIE).

3.8 Tidal inundation

Tidal inundation is defined as:

" the inundation of land by tidal action under average meteorological conditions and the incursion of sea water onto low lying land that is not normally inundated, during a high sea level event such as a king tide or due to longer-term sea level rise."

Tides are a regular, periodic variation within the ocean and estuaries due to the gravitational effects of the moon and sun. The tide cycle can be separated into two general types by the level that is reached at high and low tide; referred as 'spring' (also referred informally as a king tide) and 'neap' tides. Spring tides are characterised by larger tides than the neap tides. Information on large "king tides" is increasingly being recorded through citizen science, through sites such as the Witness King Tides Project[7]. Here, images such as Figure 3-8 are being recorded, to understand the magnitude of flooding associated with an increased tidal range due to sea level rise.

6 'NSW Coastal Management Manual Part B: Stage 1 – Identify the scope of a coastal management program' (2018) Office of Environment and Heritage, State of New South Wales.

7 Website available at http://www.witnesskingtides.org/

Figure 3-8: Images of tidal inundation during a "king tide" in the South West Rocks Creek (Witness King Tides Project).

3.8.1 Available data for CVA mapping

- Identified dataset: To be delivered as part of this project.
- Probability: Highest Astronomical Tide (HAT) level.

The Highest Astronomical Tide (HAT) has been identified as the planning level for the Tidal Inundation hazard. The HAT is the highest expected tide level due to astronomical processes (i.e. not including the effects of weather). It occurs once each 18.6 year period, although at some sites high tide levels similar to HAT may occur several times per year during peak tidal conditions.

Other tidal levels were considered for this hazard map. Typically, tidal levels along the NSW coastline are regular in shape (approaching sinusoidal shape) and do not vary significantly. However, the tides within the Kempsey LGA have a pronounced diurnal inequality, where subsequent tides have a significant change in water levels. Within the study site can be observed as consecutive tides showing a "higher" and then "lower" high water level. The Higher High Water Level is a common reporting level within Kempsey tidal handbooks. However, for consistency with other hazard mapping, the HAT is proposed to be adopted.

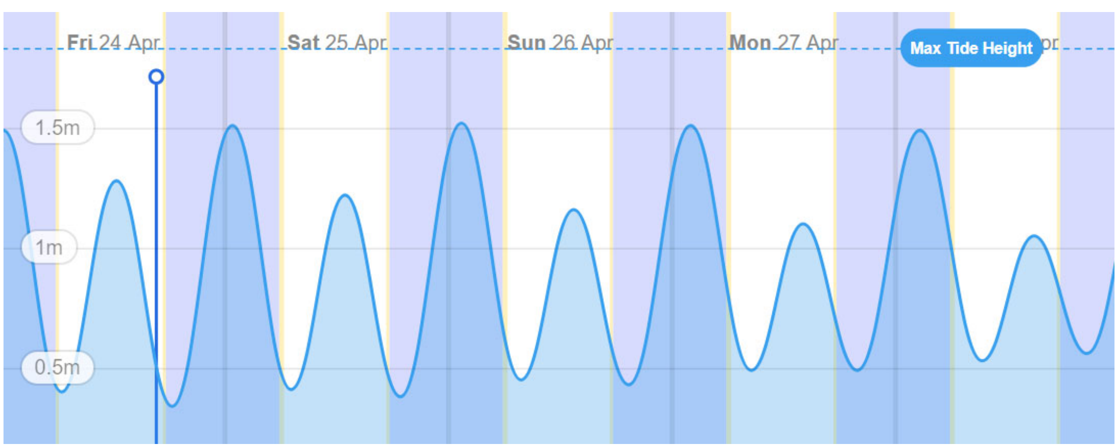


Figure 3-9: Diurnal inequality within the Kempsey tidal pattern

3.9 Erosion and inundation of foreshores under tides, waves, and catchment floodwaters.

This hazard does not have a formal definition within the NSW Coastal Management Glossary.

This hazard encapsulates all foreshore areas that could be affected by erosion or inundation from all coastal and fluvial processes. The NSW Coastal Management Manual[6] states that the impacts of this hazard may include:

- loss of foreshore vegetation and degradation of coastal habitats
- land tenure issues where foreshore property boundaries are ambulatory
- damage to residential or commercial buildings
- damage to public and private infrastructure
- disruption of services and facilities
- loss of public access and public safety issues.

It is unknown if the intention of Hazard 7 is to limit mapping to just the foreshore, or if it would extend further inland. The foreshore is defined in the Coastal Management Act as 'the area of land between highest astronomical tide and the lowest astronomical tide', but typically includes land up to the maximum extent of wave uprush. This area will already be mapped through Hazard 6: Tidal inundation, and Hazard 4: Coastal inundation.

Foreshores can be comprised of unconsolidated material deposited during estuary evolution, as well as dunes which are equally susceptible to erosion. There can be many drivers of erosion and accretion that affect these sediments such as fluctuating water levels (tides), wind waves, boat wash, tidal and/or wind-induced currents or catchment flooding. A return to present day conditions may be impossible after a large inundation event that results in erosion of a portion of the unconsolidated material. Erosion events may result in instability and ongoing recession or bank erosion. The Coastal Management Manual[6] states that erosion of estuary foreshores may also be associated with the long-term evolution of the estuary due to geomorphic processes.

As described in Section 3.3, coastlines naturally erode and accrete over time, driven by variations in sediment supply and climate patterns. Similarly, inundation around estuaries can occur due to coastal or catchment flooding, acting either independently or together.

3.9.1 Available data for CVA mapping

- Identified dataset: There is no single dataset available that covers each of the processes named. However, a combined flood and tidal inundation scenario from the Lower Macleay Flood Study (2019) is considered relevant. This would represent the following definition:
    - Inundation caused by tidal waters, including the interaction of those waters with catchment floodwaters.
- Probability: A number of coincident flood and tidal scenarios have been mapped in the Lower Macleay Flood Study, typically with flood-dominated conditions due to the fluvial nature of the study. To create a larger emphasis on coastal processes, a moderate flood with a 5% Annual Exceedance Probability (AEP) (20-year return period) inflow occurring with a coincident Higher High Water Spring (HHWS) tidal boundary is proposed for use within the CVA mapping.
- Source: Kempsey Coastal Processes and Hazard Definition Study (2013), Lower Macleay Flood Study (2019) and tidal inundation extents from this study.
- Status: Adopted by KSC.

The limitations of this approach are:

- This mapping will not consider 'erosion'. This will instead be mapped in Hazard 1 as beach erosion.
- This mapping will not consider 'waves'. This will instead be mapped in Hazard 4 as wave runup levels.
- The model simulation will extend throughout the floodplain and won't just consider the 'foreshore'.

4 Data Compilation Report

The development of the CVA map requires information on seven coastal hazards. A review of available coastal and flood information was completed to assess the availability hazard mapping components and suitability of information to be used for this project. This data has principally considered elevation (bathymetry, ground level, defence crest and profile), tide and wave data, flow conditions for available water level gauging, stormwater asset data, flood models, background reports and historical storm and coastal event information. Table 4-3 and Table 4-4 present the datasets, documentation and available flood modelling supplied for this project, and provides an assessment of their appropriateness or relevance to this study. Data gaps and limitations are presented, providing information on additional data required to meet the objectives of the study.

4.1 Past studies

A range of coastal, estuary and flood studies have been conducted within the Kempsey LGA and the Lower Macleay River. A range of coastal information is contained within estuary processes studies and the coastal hazard definition study, which include the following:

- DIPNR Macleay River Estuary Tidal Data Collection (MHL Sept 2004)
- Macleay River Estuary Processes Study (WMAWater Jan 2009)
- Coastal Lake Assessment and Management (CLAM) Back Creek South West Rocks Sustainability Assessment Report (Jun 2007)
- Macleay River Estuary Coastal Zone Management Plan (GeoLINK 2012)
- Kempsey Coastal Processes and Hazard Definition Study (BMT WBM 2013)
- Kempsey Coastal Zone Management Study (BMT WBM 2014)
- Kempsey Coastal Zone Management Plan (BMT WBM 2015)
- Macleay River Estuary Coastal Management Program Scoping Study – Draft (WBM 2019)
- Killick Creek Estuary Coastal Management Program Scoping Study – Draft (2019)
- Korogoro Creek Estuary Coastal Management Program Scoping Study – Draft (2019).

The Coastal Process and Hazard Definition Study (2013) includes a robust assessment of coastal hazard elements. This includes beach erosion hazard extents based on beach profile analysis, and long-term coastal recession estimates based on new numerical modelling of shoreline evolution. These are considered appropriate to meet the three of the coastal seven hazards required under the CVA map. The impact of the coastal inundation hazard has also been investigated within the Kempsey Coastal Processes and Hazard Definition Study (2013). The adopted inundation levels for the immediate, 2050 and 2100 timeframe have been defined.

The seventh coastal hazard of the CVA map is *"Erosion and inundation of foreshores caused by tidal waters and the action of waves, including the interaction of those waters with catchment floodwaters".* This is interpreted as areas that may be subject to combined tides and flood waters and requires the review of catchment flood studies, as shown in Table 4-1. The most relevant is the Lower Macleay Flood Study (Jacobs, 2019[8]) which assessed the flood behaviour in the broader Lower Macleay floodplain including villages and urban areas. This study has used hydraulic modelling, and considered both design flood conditions and downstream tidal conditions. Whilst it does not include wave inputs, it is considered an appropriate source of combined flood and tidal hazards to meet the CVA mapping requirements.

8 Jacobs (2019) Lower Macleay Flood Study. Prepared for the Kempsey Shire Council.

Table 4-1: Previous studies

Previous Studies/Reports	Organisation/Date	Description
Kempsey CBD Floodplain Risk Management Study and Plan	WMAwater, 2017	Builds on the flood study documented in Kempsey Hydraulic Model TUFLOW Update Final Report (WMAwater, 2016). Outlines the existing flooding problem in Kempsey CBD to Frederickton area including hydraulic and hazard characterisation, flood damages, flood planning level; the catchment context and assesses a number of floodplain management measures.
Kempsey Shire Flood Emergency Sub Plan	NSW SES, 2017	The flood emergency sub plan cover preparedness measures, the conduct of response operations and the coordination of immediate recovery measures from flooding within the Kempsey Shire area. They cover operations for all levels of flooding within the council area.
Kempsey Hydraulic Model TUFLOW Update Final Report	WMAwater, 2016	This report discusses the development of a TUFLOW model for the Kempsey CBD Floodplain Risk Management Study and Plan. The TUFLOW model was updated with more recent LiDAR data.
Flood Levee Audit Reports	Kempsey Shire Council, 2015/2016	The reports indicate the surveyed crest levels and condition of the levee banks which can be used to verify the LiDAR data along the levees, or to help to accurately define the crest levels in the hydraulic modelling.
Kempsey Flood Study Hydraulic Modelling Report	WMA, 2009	Discusses the calibration and verification of the WBNM and RUBICON models from Webb McKeown and Associates (1997) to the March 2001 flood event and conversion of modelling to a 2D SOBEK model for the Macleay River from Belgrave Falls to Frederickton.
Kempsey Levee Sensitivity Assessment	Webb McKeown & Associates, 2008	Assessment of the sensitivity of constructed levees in the Kempsey area to variations in flood gradient including the frequency of overtopping of each levee.
Saltwater Creek Flood Study Final Report	WBM Oceanics Australia, 2006	This study discusses the predicted flood behaviour in Saltwater Creek, noting that the sand berm initial level has an influence on upstream flood levels, however the influence declines significantly upstream of the German Bridge on Philip Drive. The main feature controlling flood levels in Saltwater Lagoon is the German Bridge on Phillip Drive and flood levels in floodplain upstream of it, are almost similar due to the proportionally wide conveyance for the flood flows.
Lower Macleay Floodplain Management Plan, Supplementary Report covering the Floodplain between Kempsey and Frederickton – Final	Webb McKeown & Associates, 2004a	This study updated the RUBICON model from Webb McKeown & Associates (1997) with survey along No. 1 Floodway in Kempsey and cross section data of the main river between Aldavilla and Frederickton.
Lower Macleay Floodplain management Study	Webb McKeown & Associates, 1997	This study investigates the flooding issues in the Lower Macleay floodplain at that time and presents options to improve the performance of the area during and after flooding and in non-flood periods.
Kinchela Flood Channel EIS Stage 1 Report	Webb McKeown & Associates, 1994	The report describes the capacity of the Kinchela floodway as being in the range of 41 to 47m3/s in a design flood of 2500 m3/s at Fredrickton, depending on whether the flood lift gates are in place or removed, based on modelling in RUBICON.

Previous Studies/Reports	Organisation/Date	Description
Macleay River Flood Study April	Webb McKeown and Associates/NSW Public Works, 1989	This flood study estimated flood behaviour for the 5%, 2%, 1% AEP events and an extreme event for the floodplain downstream of Aldavilla and flood outlets at Ryan's Cut, Korogoro Creek, South West Rocks Creek and Killick Creek. The report also describes that the river entrance at its current location was significantly scoured out in the 1949 flood, as was outlets at Korogoro Creek.

4.2 GIS data

Council provided asset location and specification data which was assessed for its relevance to the tidal inundation modelling study. The coverage of these datasets is summarised in Table 4-2.

Table 4-2: Council GIS data provided

Type	Appropriateness
Flood bank or rock protection - 62 total	Found along the majority of the banks of the Macleay river downstream of Kempsey. The data features a condition grade for each structure. This information will not be important for the inundation modelling.
Levees - 18 total	Found along the banks of the Macleay River downstream of Kempsey. The data includes lengths but not peak or average water levels. This information is instead included in the Kempsey Flood Levee Audit Reports which were reviewed as part of the flood study. Appropriate crest levels for levees are therefore already included in the TUFLOW model and will be considered accurate, although a sensibility check will be performed during model development.
Flood gates - 177 total	These are located alongside all of the major watercourses in the study area as well as smaller drains. Some include invert levels and dimensions but the topographic survey will add further value to this information by visiting as many gates as possible that lie within the coastal inundation extents since these may be relevant to tidal inundation.
Drains and channels	Highly appropriate for the present study. These data alone are not enough to incorporate into the model without further topographic data but the presence of a great number of drains in the model already is likely to avoid this being an issue. Topographic survey will assist with any missing information.
Culverts and surface water networks	A large number of culverts are included in the dataset but many are missing dimensions and invert levels to allow integration in the model. This was considered in the flood study and 'key' structures were included in the model. These will be kept for the present study and additional culverts may be included if deemed relevant after initial simulations are performed.
Timber overbridges on floodplain drains	These minor bridges are located on small channels and drains away from the main rivers and creeks. No topographic data is included in the asset GIS files. During initial model development the locations of any important missing structures will be assessed, and survey may be targeted at some of these structures to gather missing topographic data.
House levels and flood levels	No relevant to the present study
Flood planning level/area	No relevant to the present study
Properties marked as affected in the March 2001 flood event	No relevant to the present study

The data cover a wide range of asset types and locations across the Kempsey LGA as shown in Figure 4-1 and Figure 4-2. The key coastal outlets, such as those shown in the north of Figure 4-2, will be important in determining accurate tidal inundation extents. Some of the detail from these datasets will be incorporated into the model where the assets could provide flood pathways or obstructions to tidal flows that would not otherwise exist in the DEM. Initial model simulations will help identify the key areas of missing data.

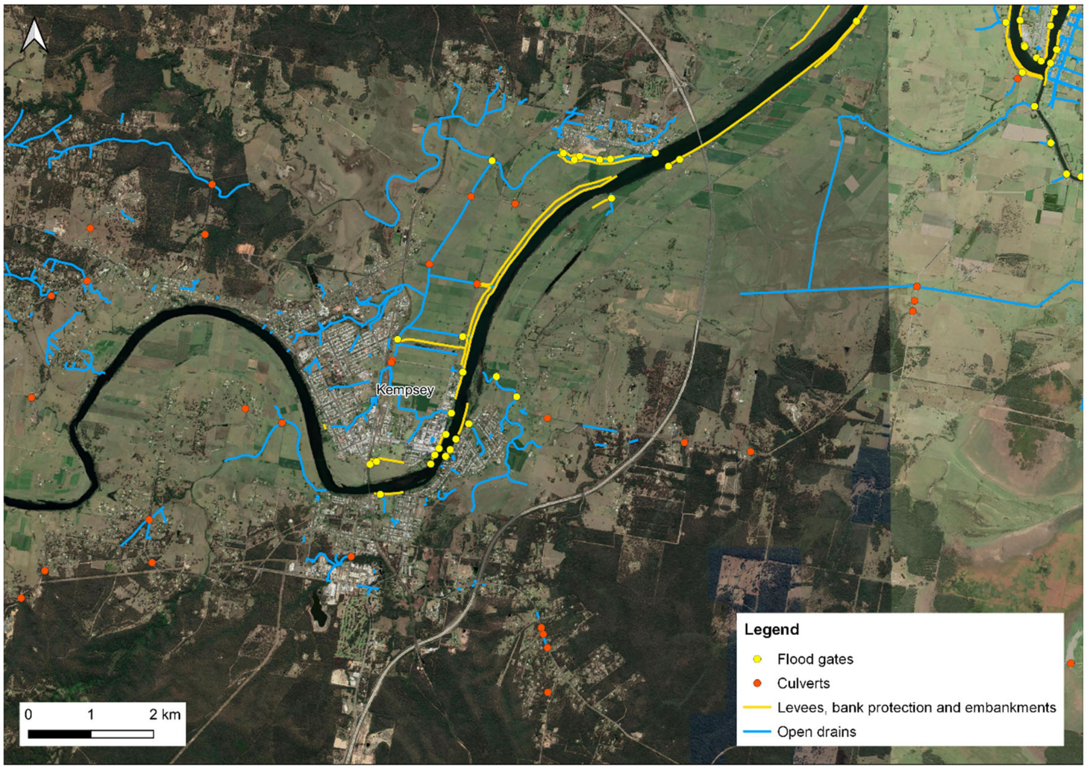


Figure 4-1: Council surface GIS data

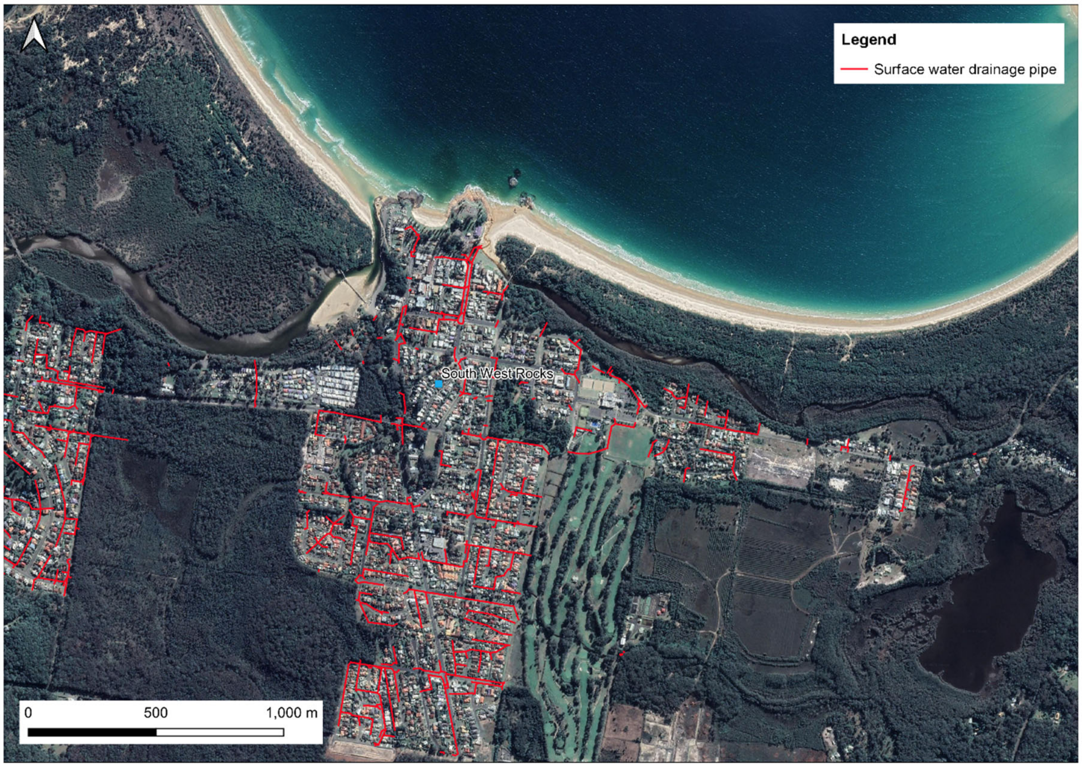


Figure 4-2: Council subsurface drainage GIS data

4.3 Hydrodynamic model data

The adopted Lower Macleay Flood Study[8] included an in-depth review of the collated data used in the study. The model data review will not be repeated here due to the short time that has elapsed since the flood study was completed - the data is considered up-to-date and appropriate for use in the tidal inundation model. The main data sources used in the flood study are listed in Table 4-3.

Table 4-3: Flood study data sources

Type	Source	Appropriateness
LiDAR (DEM)	1m LiDAR (2009-2016) provided by Council.	This is the latest information available.
Creek bathymetry	OEH bathymetry datasets available for all three catchments (1-2m resolution) and manually modified by Jacobs (2019) to incorporate recent geomorphological changes to main river sedimentation.	No further requirements. Modified dataset will be checked prior to modelling and is already incorporated into TUFLOW model so expected to be no further changes necessary.
Flood control structures	Council database.	
Drainage structures	Council database and inferred from LiDAR or topographic survey.	An appropriate focus on structures impacting flood flows.
Topographic features	Road network data and inferred from LiDAR.	Appropriate use of the available data. Some additional data will be considered for the tidal inundation model to ensure coastal infrastructure is fully captured.

Type	Source	Appropriateness
Hydraulic model files	Historic models dating from 2010 to 2017.	The data within a number of historic models covering areas including Kempsey CBD, Frederickton and a portion of the Pacific Highway upgrade route was reviewed and updated where necessary. Structures from each model were carried to the final model and Council's asset GIS data were used to add additional structures to the model where necessary. The final extents of the flood study model were significantly larger than the combined extents of these previous models. With the flood study now adopted we are confident that the model is a suitable starting point for tidal inundation modelling.

4.3.1 Model summary

The TUFLOW model was based on a 20 m grid of the broader floodplain (Lower Macleay Flood Study, 2019), while, the design flood levels in and around Kempsey CBD were analysed in greater detail in the Kempsey CBD Floodplain Risk Management Study (WMAwater, 2017b) using a 10m model resolution. Based on hydrologic study of Lower Macleay Flood Study (Jacob, 2019), Inflows in the Macleay River into the model for design events are adopted from previous and recent flood study undertaken for Kempsey CBD. Additional inflows in tributary catchments into the Lower Macleay and on local catchments within the floodplain were estimated with DRAINS/RAFTS hydrologic modelling (design flood conditions for the 0.2EY, 5%, 1% and 0.2% AEP and PMF were estimated). The outcome of the study was the flood mapping, included peak flood extents & levels, depths and velocities for all modelled events. Sensitivity assessment of modelling assumptions and parameters, removal of the flood mitigation scheme works from the study area and climate change impacts on flooding were also undertaken. Some other previous flood studies were extracted from Lower Macleay Flood Study (2019) report and briefly summarised in Table 3-1.

4.3.2 Modelled structures

The structures included in the final flood study model appropriately include assets across the study area which are equally important to the modelling of tidal inundation. Figure 4-3 shows the main features represented in the model including channels, culverts, embankments, levees, dunes and training walls.

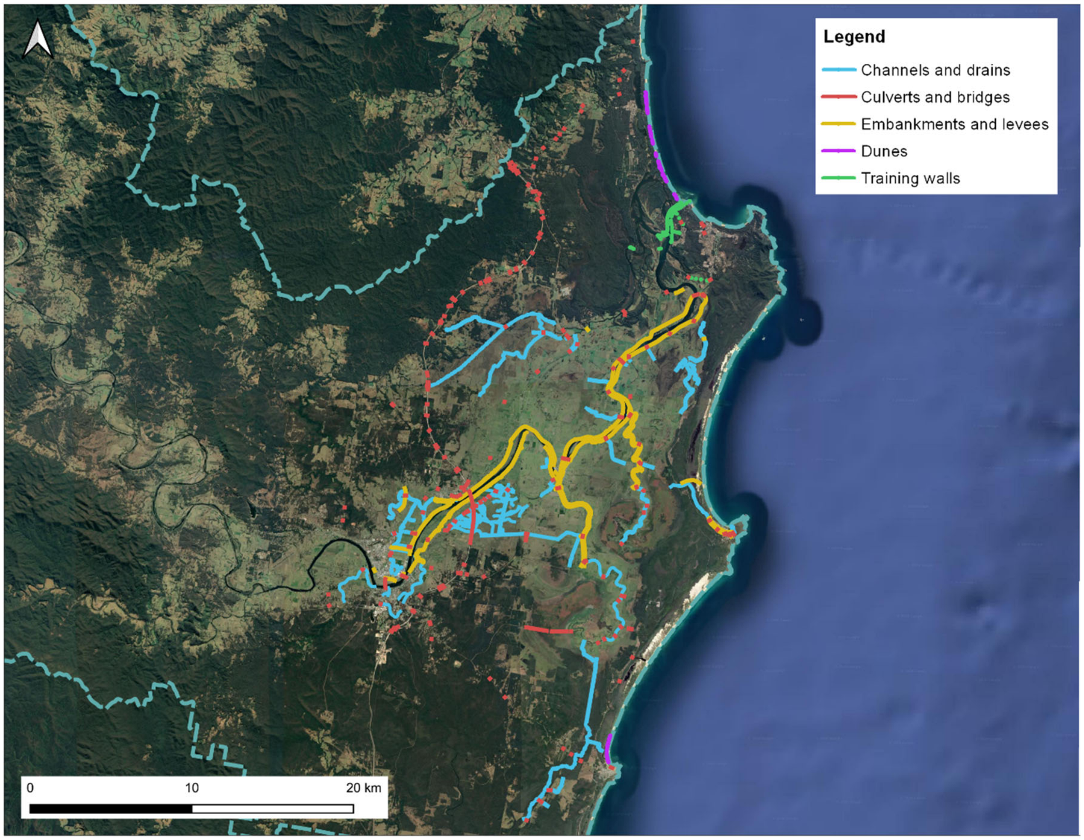


Figure 4-3: Features included in the flood study model

The structures with capacity to carry water include primary creek channels and agricultural drains as well as bridges and major culverts. In general, the subsurface drainage networks within built up areas are not included.

There are a number of modelled structures that form obstructions to surface waters such as levees, sand dunes and the training walls at the mouth of the Macleay River. These structures are relevant to the current study and will remain in the model.

A number of the floodgates in the study area are included in the model, as shown in Figure 4-4. However, compared to the small area shown in Figure 4-1, it is evident a number of floodgates are not included in the current modelled. This is not unexpected, given the scope of the Lower Macleay Flood Study was on fluvial flooding.

The focus of the next phase of survey and modelling will ensure relevant coastal features are captured within the model. These floodgates will be reviewed and included in the tidal inundation model where relevant.

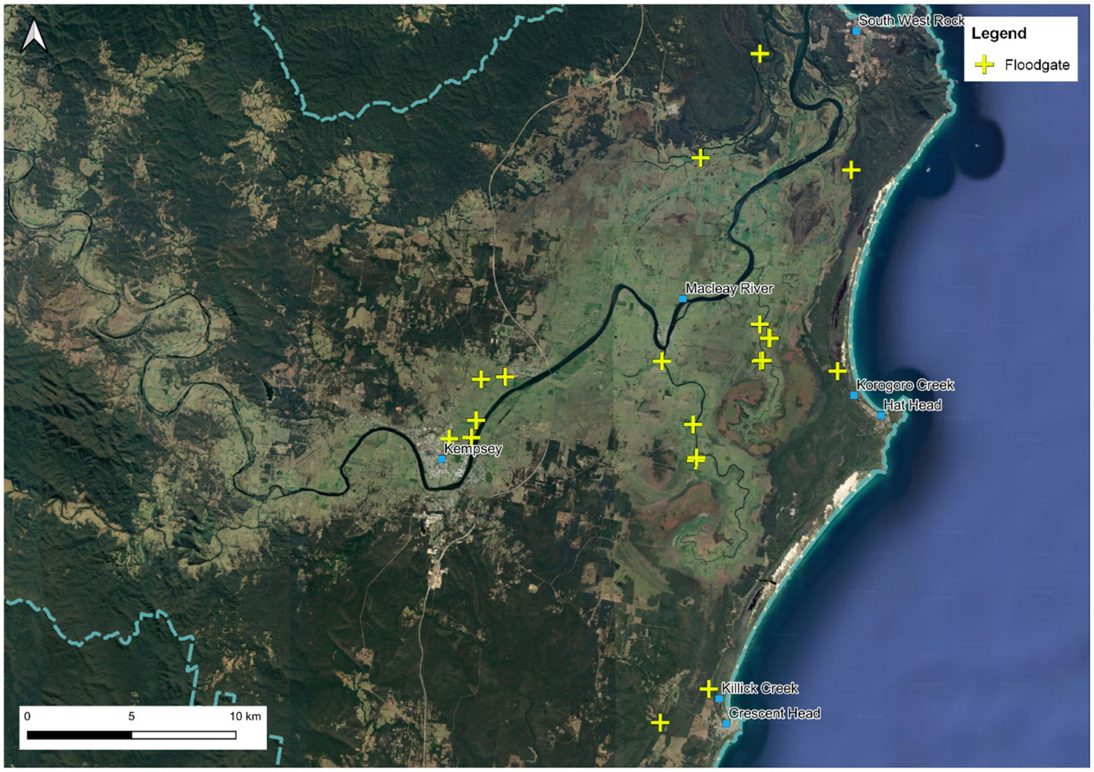


Figure 4-4: Modelled floodgates

4.3.3 Data for model updates

The existing model and available data has been reviewed to identify any areas within the coastal zone of the Kempsey LGA where additional, more detailed survey would benefit the tidal inundation study. The main focus of this data collection will be along the coast and connections to surface watercourses which could connect the highest tides to inland areas.

The TUFLOW model itself has been provided in its entirety and the flood study simulations run as expected. A number of minor changes need to be carried out to adjust its purpose to suit tidal inundation modelling. Primarily, the changes will allow the model to be extended along the full coastal extents of the Kempsey LGA and an accurate tidal signature to be applied offshore. The data required to make these changes are detailed in Table 4-4.

Table 4-4: Additional data for model updates

Type	Availability	Use
LiDAR	1m LiDAR (2009-2016) provided by Council.	Extension of the model along full coastal frontage.
Offshore bathymetry	Available from nautical charts and Geoscience Australia Australian Bathymetry projects.	Topography on which offshore tidal boundaries will be applied.
Nearshore bathymetry	Data available in coastal charts online	Connection between offshore bathymetry and onshore LiDAR DEM's
Coastal asset and defence information	Provided by Council. Any missing topographic detail for relevant assets will be collected by RDM in a field survey.	To be included in the model where appropriate to ensure all realistic tidal water flow pathways are resolved. Particularly important are the locations of any two-way stormwater outlets along the coast that could allow tidal water ingress.

Type	Availability	Use
Hydrology estimates	Available through studies of Australian Rainfall and Runoff with particular reference to Chapter 5 of ARR2019 which addresses catchments discharging to the coast.	The Regional Flood Frequency Estimation Model is appropriate for all but the Macleay River which is too large and will necessitate use of a hydrological model.
Tidal planes	MHL data for Coffs Harbour and Port Macquarie.	Estimate of HAT (peak water level) along the Kempsey coast. Used in estimation of tidal signatures.
Tidal signatures	Available via combination of MHL analysis, existing reports and TXPO tidal harmonic model. Final data developed in UTide software based on MHL tidal planes data.	Oscillating tidal data to be used directly in the model as the offshore tidal boundary for the present day.
Climate change estimates	Available from NSW government	Estimates of future HAT levels to be used for 2050 and 2100 climate change model simulations.
Recorded tide levels	MHL (2004) Tidal Data Collection Report available.	Calibration data for tidal inundation model.

4.4 Boundary data

The flood study model incorporated tidal boundaries along the coastal outlets of the main rivers and creeks, inflow boundaries along the upstream river extents and in regions representing each sub-catchment of the hydrological model across the model domain. These are shown in Figure 4-5.

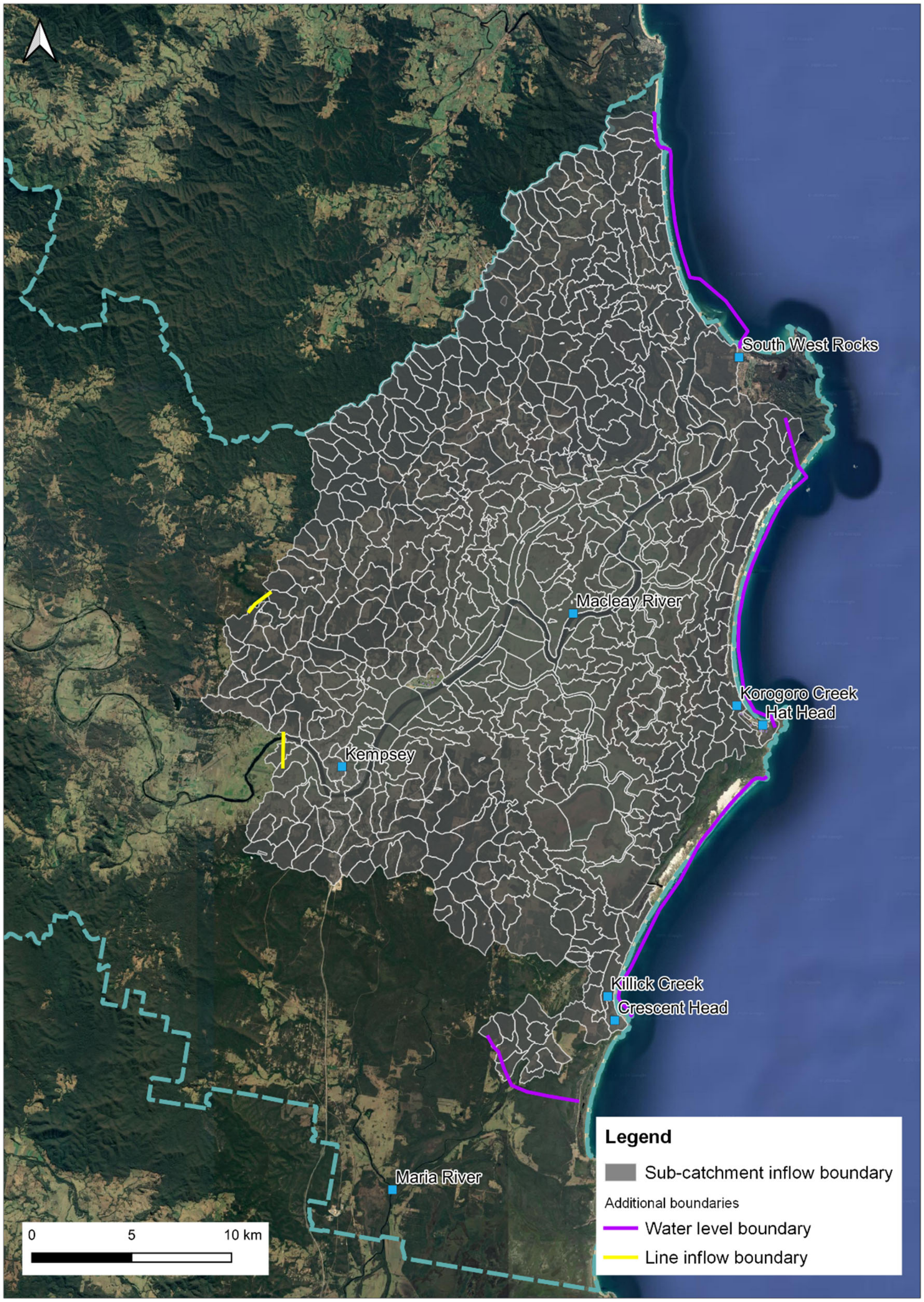


Figure 4-5: Flood study model boundaries

4.4.1 Tidal data

In the flood study model tidal signatures were taken from the MHL Coffs Harbour tide gauge. These tailwater levels were adopted as the tailwater boundary in the vicinity of the Macleay River entrance (and north to Grassy Head), Korogoro Creek, Killick Creek and Ryans Cut entrances.

Recorded water levels at Green Valley on the Maria River were adopted as the water level boundary on Connection Creek. The table below is taken from the flood study (Jacobs, 2019) to show tailwater levels used for each design flood event.

Table 4-5: Summary of tailwater levels adopted in Lower Macleay flood model (Extracted 'Table 7-7 Adopted Design Joint Flood Scenarios' from the Lower Macleay Flood Study, 2019.

Design Flood Envelope AEP	Dominant Flood Mechanism	Flood Event AEP			
		Macleay River	Local Catchment	Maria River	Ocean
0.2EY (i.e. 1 in 5)	Macleay River	0.2EY	0.2EY	0.2EY	HHWS(SS) 1.25m AHD
	Maria River	N/A. Incorporated into Macleay River flood run.			
	Ocean	N/A. HHWS(SS) is highest recommended TWL.			
5%	Macleay River	5%	5%	5%	HHWS(SS) 1.25m AHD
	Maria River	N/A. Incorporated into Macleay River flood run.			
	Ocean	N/A. HHWS(SS) is highest recommended TWL.			
1%	Macleay River	1%	1%	5%	5% Type B. TWL 2.0m AHD Type C. TWL 2.45m AHD
	Macleay River (Low Ocean Tide Level)	1%	1%	5%	ISLW. TWL -0.84m AHD Same tidal pattern as HHWS(SS) except the low tide coincides with catchment flooding.
	Maria River	5%	5%	1%	5% Type B. TWL 2.0m AHD Type C. TWL 2.45m AHD
	Ocean	5%	5%	5%	1% Type B. TWL 2.1m AHD Type C. TWL 2.65m AHD
0.2%	Macleay River	0.2%	1%	1%	1% Type B. TWL 2.1m AHD Type C. TWL 2.65m AHD
	Maria River	1%	1%	0.2%	5% Type B. TWL 2.0m AHD Type C. TWL 2.45m AHD
	Ocean	N/A. 1% AEP is highest recommended TWL.			
PMF	Macleay River	PMF	1%	1%	1% Type B. TWL 2.1m AHD Type C. TWL 2.65m AHD
	Maria River	1%	1%	PMF	5% Type B. TWL 2.0m AHD Type C. TWL 2.45m AHD
	Ocean	N/A. 1% AEP is highest recommended TWL.			

Abbreviations: "TWL" = Tailwater Level. "HHWS(SS)" = High High Water Spring (Solstice Spring) tide. "ISLW" = Indian Spring Low Water.

4.4.2 Fluvial inflows

The flood study generated hydrographs that reflect rare storm conditions rather than everyday conditions. The available flow data from the flood study hydrological analyses are as follows.

Table 4-6: Flow data available

AEP	ARI (years)
0.2EY	5
5%	20
1%	100
0.2%	500
PMF	PMF

These storm events are not reflective of fluvial conditions expected during flooding solely from high tides and therefore they will not be used in the current study. Instead we will adopt a baseflow condition that reflects everyday flow conditions on a 'dry day'. A baseflow condition in the Macleay River will be dominated by tidal conditions as necessary in tidal inundation modelling.

As shown in Figure 4-5 the model uses inflow boundaries spread across the catchment. These will be removed from the model leaving only the tidal boundaries located off the coast and an inflow at the models' upstream extent of the Macleay River. Smaller creeks are considered small enough to be fully tidally dependent, or else are connected to the Macleay River, and thus will not have individual inflow boundaries applied. The approximate location of these is shown in the figure below.

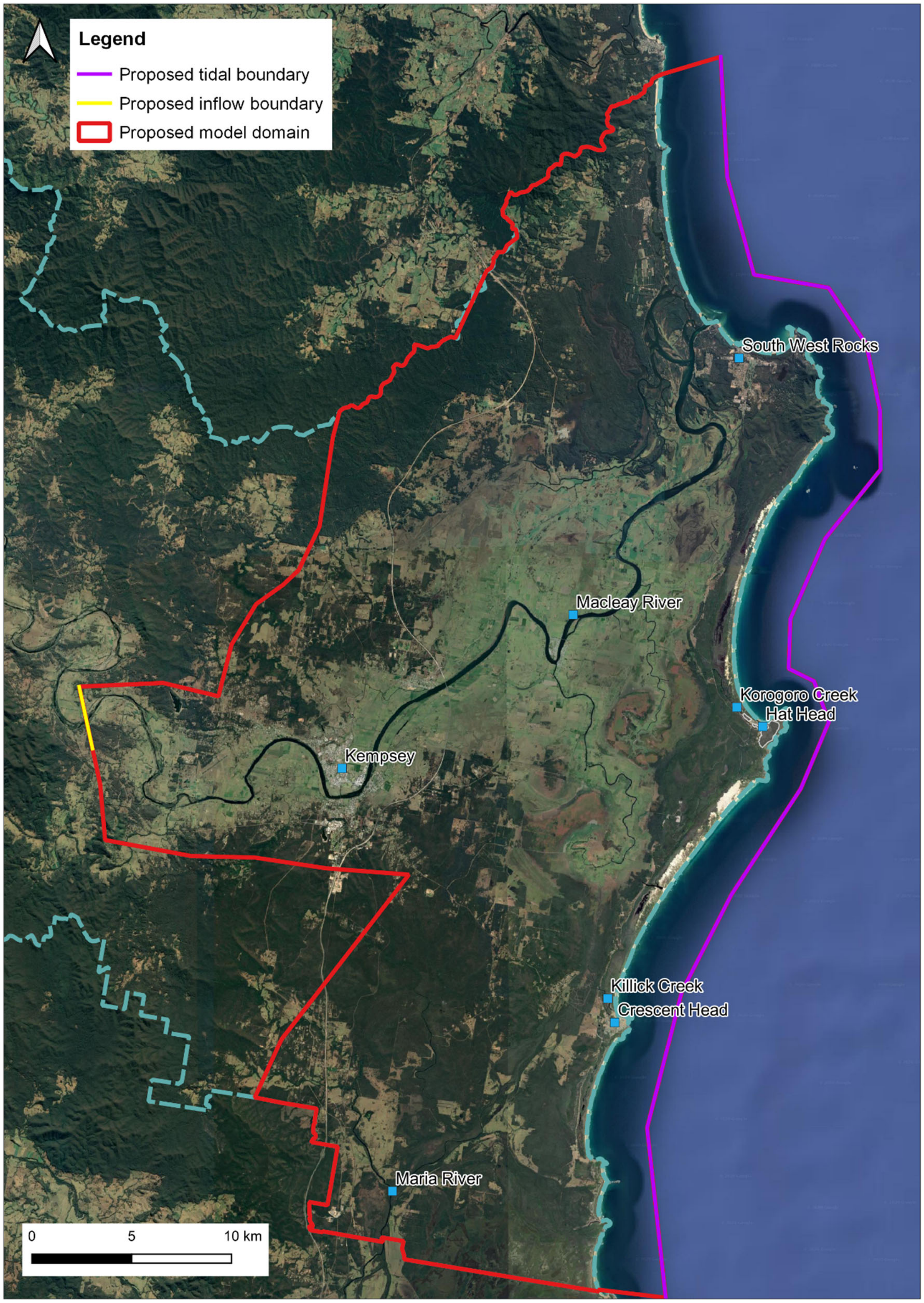


Figure 4-6: Tidal inundation model boundaries

5 Tidal inundation modelling

5.1 Source of existing models

The model will be derived from the Lower Macleay Flood Study (2019). The Lower Macleay River has an upstream catchment area of 11,500km² and also has several secondary outlets to the ocean at Hat Head, Crescent Head, Ryans Cut and South West Rocks and a hydraulic link to the Maria River and Hastings River to the south, all owing to improved channel linkages constructed during historic flood mitigation schemes.

The supporting documentation from flood study shows that an extensive package of work was carried out for the study that brought the modelling up to date. Calibration to two well-documented events, one in 2001 and one in 2013, showed that the model is capable of adeptly reproducing flood levels across the current study area.

Previous uses of the model and its constituent sub-models were the determination of flood extents during extreme events and thus some changes will be required to ensure it meets the current scope. Nevertheless, these changes are few relative to the modelling that has already been done.

5.2 Modelling package

The tidal inundation model will utilise the industry-standard 1D-2D hydrodynamic modelling package, TUFLOW - to keep the existing model in the same format. The same version of TUFLOW (2018-03-AB double precision) will be used for consistency.

5.3 Model layout

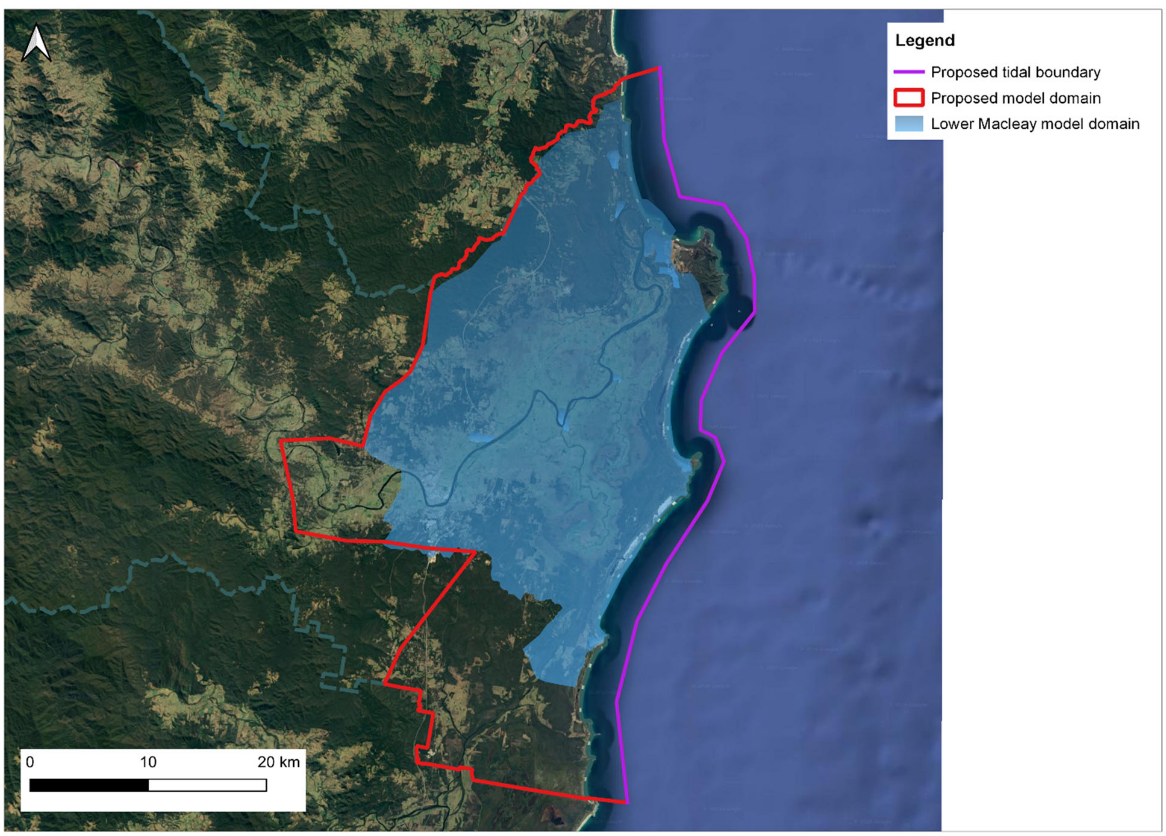


Figure 5-1: Tidal inundation model schematic

The existing model covers the Lower Macleay River up to Euroka. The effects of the tide are marginal in this area but initial simulations will be used to determine whether a small extension of the 2D domain is required to move the upper extents closer to Sherwood. Tidal inundation extents should be smaller than the coastal inundation extents produced in the Kempsey Coastal Processes and Hazard Definition Study[3] due to the latter using a "bath-tub" modelling approach, but this will be reviewed once the model is operational.

Similarly, the model domain will be extended to the south to ensure the full extents of the Kempsey LGA coastal frontage are included.

5.4 Boundaries

A nearshore tidal boundary will be applied along the full extents of the Kempsey LGA coastal frontage. This boundary will be split into sections to enable us to apply a tidal curve that varies in scale from north to south to make best use of the tidal gauge data available for Manly Hydraulics Lab (MHL) gauges at Coffs Harbour and Port Macquarie. The Coffs Harbour gauge is a representative ocean site whereas Port Macquarie is subject to influence from the Hastings River. As in the flood study, preference will therefore be given to Coffs Harbour data where a HAT level of 1.24mAHD was calculated from the MHL observed dataset. The flood study used only a few tidal boundaries at the entrance to the major creeks. The nearshore boundary approach that will be used for tidal inundation mapping enables high tidal water levels to impact anywhere along the coastal frontage rather than solely at creek outlets. This will enforce very similar boundary conditions to the flood study but is more appropriate to the modelling of tidal inundation.

Dynamic tidal series for the Highest Astronomical Tides (HAT) will be applied along the nearshore boundary, starting several tidal cycles earlier than the peak of the HAT and ending several cycles later. This allows water levels in the creeks to equalise prior to the highest tide level and ensures the maximum inundation extent is recorded in the outputs.

5.5 Topographic adjustments

The flood study found the Lower Macleay River to be sensitive to entrance conditions and a scoured bed condition was incorporated into the TUFLOW model to reflect historic opening of the estuary. This ensured accurate model reproduction of historic storm events. Since the model now needs to reproduce everyday conditions rather than storm conditions this bathymetric adjustment at the entrance will be modified to reflect normal conditions like during tidal inundation.

5.6 Structures

Additional structure detail will be added to the model based on the GIS data supplied by Council and the additional survey work to be carried out by RDM. Particular focus will be paid to flood protection assets and any structures capable of conveying tidal waters inland.

The Belmore and Kinchela floodways will remain shut for all tidal inundation events. It is understood that they are ordinarily opened to mitigate against flooding on the Macleay River which is not expected in the baseline tidal inundation scenario being modelled. The Yarrahapinni flood gates will be removed from the model to reflect their current state.

5.7 Grid resolution and timestep

The Lower Macleay River TUFLOW model uses a 20m grid with 9 nested 2D domains using 5m grids to increase resolution in urban areas. The main channels were modelled in 2D with large hydraulic structures modelled in 2D and smaller structures in 1D. This setup will be maintained in order to make best use of the data incorporated into the flood study. Following initial model runs the resolution may be increased dependent on model run times.

5.8 Calibration

The Lower Macleay River model has been calibrated to two historic events:

- March 2001 flood event: 13 year average recurrence interval (ARI) or 8% AEP event
- February 2013 flood event: 7 year ARI or 14% AEP event.

The model performed well in its reproduction of peak water levels, particularly along the main river reaches. Whilst there was some variation in timing of the peak this should not impact the models' proficiency in accurately estimating peak tidal levels in the tidal inundation study.

Once adapted for tidal inundation modelling further calibration will be carried out against the recorded tidal data reported by Manly Hydraulics Laboratory (2004) for a period of time in early 2003, as well as data observed from January to March 2020.

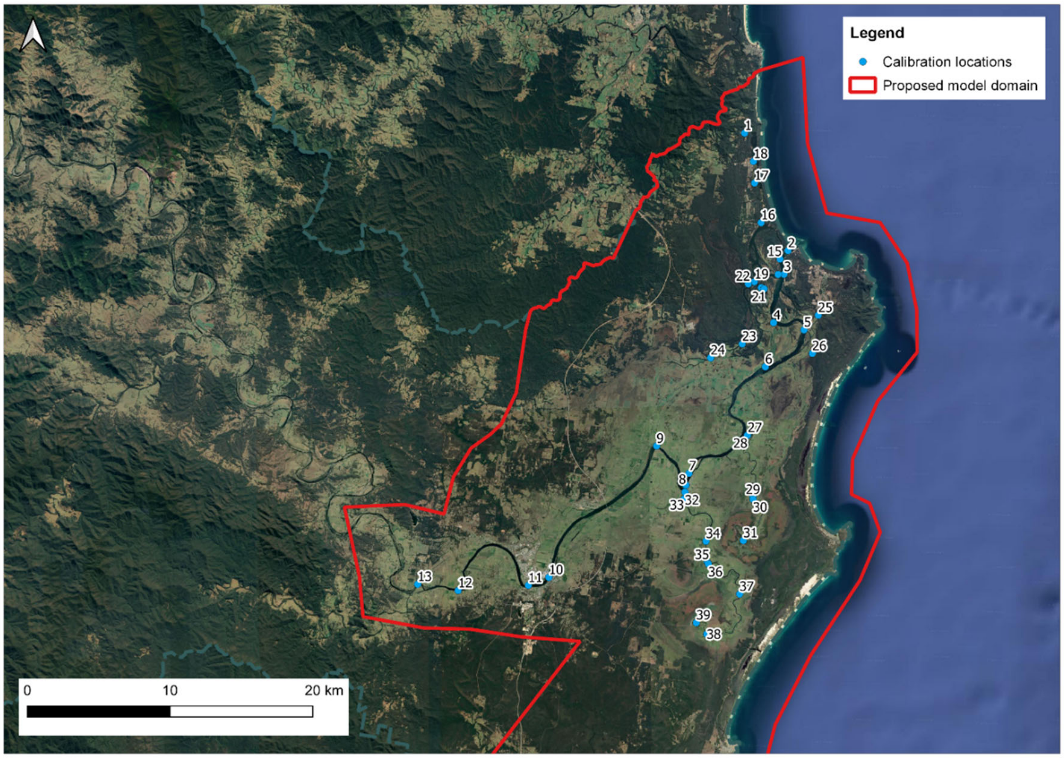


Figure 5-2: Calibration locations from 2004 MHL Report

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