Tabourie Lake

Entrance Management Policy

59917098

Prepared for
Shoalhaven City Council

22 October 2019

Shoalhaven City Council

Cardno
Shaping the Future

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Executive Summary

Cardno was engaged by Shoalhaven City Council (Council) to review the existing Entrance Management Policy (EMP) for Tabourie Lake. Tabourie Lake is a small coastal lake located in the Shoalhaven Local Government Area (LGA) (refer **Figure 1-1**). It is what is referred to as an Intermittently Closed and Open Lake or Lagoon (ICOLL), and has periods during which the entrance is closed off from the ocean by the formation of berm. The study area for this EMP comprises the tidal waterway of Tabourie Lake, its foreshores, and the adjacent lands.

Background

A *Draft Entrance Management Policy and Review of Environmental Factors* was developed for Tabourie Lake by Peter Spurway & Associates in 2005. This existing EMP has been used since that time by Council to guide the management of the entrance of Tabourie Lake for flood mitigation purposes (refer **Section 2**). Under the Draft EMP the entrance is mechanically opened by Council when:

> Lake water levels are equal to, or in excess of, 1.17 m AHD initiates an immediate entrance opening; or
> Lake water levels stabilise after rainfall at a level between 1.00 m and 1.17 mAHD and a period of over two months has elapsed since attaining that level, resulting in below floor level flooding of foreshore land.

Peter Spurway & Associates (2005) recommends that the assumptions of the Draft EMP and the management framework contained therein be reviewed following adoption of the Tabourie Lake Floodplain Risk Management Study and Plan (FRMS&P). The FRMS&P was completed in 2016, and one of the recommended actions in the FRMS&P was to review the Draft EMP in light of the improved understanding of flood behaviour.

Given the significant amount of time that has passed since the Draft EMP was prepared, and acknowledging the changes in the catchment and improved understanding of flood behaviour, Council determined to proceed with a review of the Draft EMP and preparation of a final EMP.

Review of Existing Information

There is a range of existing information for Tabourie Lake that is of relevance to understanding the need and context for the EMP. ICOLL behaviour, entrance behaviour and flooding processes (refer **Sections 3.3-3.5**) are important determinants of the level of risk to low-lying development from inundation, and aid in determining potential entrance management options. The statutory and policy context (refer **Sections 3.1-3.2**), and environmental and social values of Tabourie Lake (**Section 3.6**), are important in assessing the appropriateness and acceptability of these different options from both regulatory and stakeholder perspectives.

Review of Entrance Management Options

Based on the review of existing information presented in **Section 3**, six potential entrance management options were developed for assessment:

> Option 1: A "Do Nothing" option. Under this scenario, there is no active management of the lake entrance. For the 'do nothing' option the entrance berm would be overtopped when water levels rise during a rainfall event and the entrance breaks out naturally without any intervention.

> Option 2: The continuation of the existing management approach, comprising mechanical entrance opening when lake water levels reach the trigger level of 1.17 m AHD.

> Option 3: Raising the trigger Level to 1.3 m AHD. This would lead to fewer mechanical openings of the entrance of Lake Tabourie, thereby reducing the environmental impact of the current practices on the Lake.

> Option 4: Berm height management. This involves managing the entrance berm height (when closed) such that it does not exceed a pre-determined level; this is known as maintaining a 'dry notch', which is a low or 'saddle' point in the entrance berm which the water can preferentially flow across. The purpose of the notch is to dispense with the need to mechanically open the lake when a flood occurs.

> Option 5: Construction of a permanently open entrance, through the use of rock armoured training walls.

> Option 6: Implementation of a pilot channel - a mechanical excavation of sand from the entrance berm 1-3 days before a large storm is scheduled to arrive, by digging a pilot channel starting from the ocean. The exercise is intended to reduce the volume of sand required to be removed to instigate a lake breakout, thereby inducing an earlier breakout and reducing flood levels within the lake.

These options, and their relative pros and cons, are discussed in **Section 4**.

Assessment of Entrance Management Options

In order to identify a preferred option for entrance management, the potential options were assessed using a multi-criteria analysis informed by:

> Stakeholder and community feedback (refer **Section 5.2**);

> Hydrodynamic and morphological computer-based modelling of a sub-set of options in order to determine the impacts of each option on flood levels and the duration of inundation in the lake (refer **Section 5.3**); and

> A semi-quantitative triple-bottom line assessment, including consideration of the cost of implementation of each option (refer **Section 5.4**).

The six management options were then ranked on the basis of the Adjusted Benefit Index. The results of the options assessment are provided in **Table 5-5**.

The highest ranked option was Option 3 (raising the trigger level). Options 2 (existing approach) and 4 (pilot channel) were the second highest ranked options, followed by Option 6 (pilot channel). The lowest ranking options were Option 5 (permanently open entrance) and Option 1 (do nothing).

Based on the options assessment outcomes, the preferred option is Option 3 - which comprises the raising of the existing trigger level to 1.30 m AHD.

The Entrance Management Policy

Section 6 of this report contains the updated, final EMP. The aim of the policy is to address the following issues:

> The rear yards and below-floor areas of at least four houses along the Princes Highway are inundated by lake levels as low as 1.0 m AHD. Although not resulting in direct damage as such, saturated soil can cause odours from rotting vegetation and limit access to outbuildings if sustained for lengthy periods;

> Garages and outbuildings such as laundries and sheds in this location can flood if the lake reaches a level of around 1.3 to 1.4 m AHD; and

> The lowest house floor level is 2.0 m AHD.

> In the 20% AEP flood event, two properties experience over floor flooding and 21 properties have flooding below floor level (refer **Section 2.2**).

The EMP clearly sets out the procedure by which Council will make a decision to open the entrance of Tabourie Lake for flood mitigation purposes (refer **Section 6.2**), whether in response to a flood event or to alleviate below floor level inundation of foreshore land. It includes:

> Consultation and communication protocols (**Section 6.3**) for notification of agencies and other stakeholders,

> Roles and responsibilities for implementing the EMP (**Section 6.4**);

> The procedure or methodology by which the entrance should be mechanically opened (**Section 6.5**) and how the entrance should be monitored following a natural or mechanical opening and up until it closes again (**Section 6.6**); and

> Advice on how the works should be managed with respect to safety and environmental impacts (**Sections 6.5 and 6.8**).

It is recommended that Council adopt the final EMP and undertake the necessary environmental approvals pathway to enable practical implementation. **Section 7** contains some additional recommendations for Council's consideration.

Glossary and Abbreviations

Term / Abbreviation	Explanation
Annual Exceedence Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage; e.g. for a 5% AEP flood event, there is a 5% chance (that is a one-in-20 chance) that this sized flood event or larger occurring in any one year.
AHIMS	Aboriginal Heritage Information Management System.
ASS	Acid Sulfate Soils
Australian Height Datum (AHD)	A common national surface level datum appropriately corresponding to mean sea level.
CAMBA	China-Australia Migratory Bird Agreement.
Catchment	The area of land that drains to a common location or watercourse. This always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Coastal Inundation	A natural process whereby elevated ocean water levels combined with wave run-up result in seawater overtopping coastal and estuarine foreshores during storm events. This process is generally rare and episodic, occurring principally around the peak of a high tide, creating a hazard particularly in areas below about 5 m AHD.
CLM Act	NSW *Contaminated Land Management Act 1995.*
CSIRO	Commonwealth Scientific and Industrial Research Organisation.
DPI	NSW Department of Primary Industries
EEC	Endangered Ecological Community as identified under the TSC Act
EMP	Entrance Management Policy
EPA	Environmental Protection Authority
EP&A Act	NSW *Environmental Planning and Assessment Act 1979.*
EPBC	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999.*
Fluvial	Relating to, or inhabiting a river or stream.
FM Act	NSW *Fisheries Management Act 1994.*
Foreshore	The area of land at the land-water interface that is likely to be affected by coastal and catchment processes.
FRMS&P	Floodplain Risk Management Study and Plan.
Highest Astronomical Tide (HAT)	A highest level of water which can be predicted to occur under average meterological conditions any combination of aastronomical conditions over 18 years (however water levels can often exceed HAT values because of the influence of wind and waves)
Hs	Significant Wave Height. The average height of the one-third highest waves of a given wave group.
IBE	Inverse Barometer Effect
ICOLL	Intermittently Closed and Open Lake or Lagoon.
Inundation	Flooding, by the rise and spread of water, of a land surface that is not normally submerged.
ISEPP	NSW State Environmental Planning Policy 2007.
JAMBA	Japan-Australia Migratory Bird Agreement
LALC	Local Aboriginal Land Council
LEP	Local Environmental Plan
LGA	Local Government Area
m AHD	Elevation in metres with respect to the Australian Height Datum.
MWL	Mean water level

Term / Abbreviation	Explanation
NSW	New South Wales
PoEO Act	NSW *Protection of the Environment Operations Act 1997*.
REF	Review of Environmental Factors
ROKAMBA	Republic of Korea-Australia Migratory Bird Agreement.
Run-off	That proportion of rainfall that drains off the lands surface.
SCC	Shoalhaven City Council, or referred to as 'Council'
SEPP	State Environmental Planning Policy.
SEPP 14	State Environmental Planning Policy No. 14 – Coastal Wetlands.
Still Water Level (SWL)	Average water-surface elevation at any instant including the effects of tides and storm surge, but excluding local variation due to wind and waves.
Storm Surge	The increase in coastal water level caused by the effects of storms. Storm surge consists of three components: the increase in water level caused by the reduction in barometric pressure (barometric set-up or IBE), the increase in water level caused by the action of wind blowing over the sea surface (wind set-up), and the increase in water level caused by the piling up of waves against the coast (wave set-up).
Storm Tide	Storm tide is different from storm surge in that it includes all the elements of storm surge (IBE, wave set-up and wind set-up) as well as the astronomical tidal level.
TSC Act	NSW *Threatened Species Conservation Act 1995*
Wave Run-up	The vertical distance above mean water level reached by the uprush of water from waves across a beach or up a structure.
Wave Set-up	The increase in water level within the surf zone above mean still water level caused by the breaking action of waves.

Table of Contents

Appendices

Tables

Figures

1 Introduction

Cardno was engaged by Shoalhaven City Council (Council) to review the existing Entrance Management Policy (EMP) for Tabourie Lake.

1.1 Area to Which the Policy Applies

Tabourie Lake is a small coastal lake located in the Shoalhaven Local Government Area (LGA) (refer **Figure 1-1**). It is what is referred to as an Intermittently Closed and Open Lake or Lagoon (ICOLL), and has periods during which the entrance is closed off from the ocean by the formation of berm. The study area for this EMP comprises the tidal waterway of Tabourie Lake (also referred to as Tabourie Creek or Tabourie Lagoon), its foreshores, and the adjacent lands up to 2 m Australian Height Datum (AHD). This is considered to be the maximum height that the berm could reach (Wainwright and Baldock, 2010), and therefore includes all potentially affected lands.

Tabourie Lake is located on the NSW South Coast, south of Ulladulla. The township of Lake Tabourie is the only settlement in the study area. The majority of residences in the township straddle Lemon Tree Creek. On the northern side of Tabourie Lake where it meets the Tasman Sea is the Lake Tabourie Tourist Park. There are also 12 low-lying residences along Princes Highway.

The village of Tabourie Lake is low-lying with an elevation of around 2 m AHD and as a result low level persistent flooding is common. The Tabourie Lake study area has experienced major flooding in the past due to a number of contributing factors. The entrance (i.e. where Tabourie Creek discharges to the ocean) has the capacity to close due to formation of a sand berm which can lead to water levels rising throughout the floodplain. High antecedent lake conditions, coupled with large rainfall events, have cause major flooding in the past, including in 1971, 1975 and 1988. For this reason, the entrance is managed by Council, whereby it is broken open (if required) during a flood event to minimise the risk to property. Flooding has also occurred due to elevated ocean levels rather than catchment flooding, as was the case in 1974.

1.2 Objectives for Entrance Management

Council, in conjunction with the NSW Government, is responsible for managing the entrance of Tabourie Lake for the purpose of below floor level flood mitigation. Due to the historical development of the catchment and development of the floodplain, low-lying properties are at risk of flooding under certain rainfall and entrance conditions.

The specific objectives of the Tabourie Lake EMP, as articulated in (Peter Spurway & Assoc., 2005), are to:

> Implement a management regime which is consistent with the principles of ecologically sustainable development;

> Ensure that entrance opening follows as natural a regime as possible within the constraints of property inundation and flooding;

> Gain broad based community understanding and support for management of the lake entrance;

> Deter unauthorised opening of the lake;

> Streamline the decision-making and approvals process in relation to artificial opening events;

> Provide a mechanism for review and update of the EMP;

> Ensure the appropriate level of environmental assessment and consultation are undertaken before the lake is artificially opened;

> Clarify responsibilities and accountabilities in relation to artificially opening the lake;

> Clarify when, where and how the lake is artificially opened;

> Detail the procedure for monitoring the lake entrance after it has been opened; and

> To identify and implement actions that allow for the progressive increase of the opening trigger level with sea level rise.

1.3 The Tabourie Lake Floodplain Risk Management Study and Plan

It should be noted that Shoalhaven City Council have recently developed a Floodplain Risk Management Study (FRMS), and Floodplain Risk Management Plan (FRMP) for the Lake Tabourie Township and its surrounds. The FRMS investigated what could be done to reduce or manage the effects of flooding in the catchment, and recommended a mix of strategies and options to manage the risks of flooding. These options included:

> Flood modification measures;

> Property modification measures; and

> Emergency response measures.

Those options selected for inclusion in the FRMP were based upon both their likely benefit and the funding available from Council and the State Government. These options included structural options aimed at preventing, avoiding or reducing the likelihood of flood risks – including the construction of levees behind properties and raising roads in specific locations.

It is anticipated the implementation of the measures outlined in the FRMP would, in the future, likely remove the need to undertake entrance management and mechanical lake opening as a means of mitigating below floor level flooding. Therefore, it is intended that this Entrance Management Plan should be adopted as an "interim" policy, until the measure outlined in the FRMP have been fully funded and implemented.

Figure 1-1 Tabourie Lake Study Area

1.4 Definition of Terms

Figures 1-2 and 1-3 explain the key features of the Lake entrance, as discussed in this report.

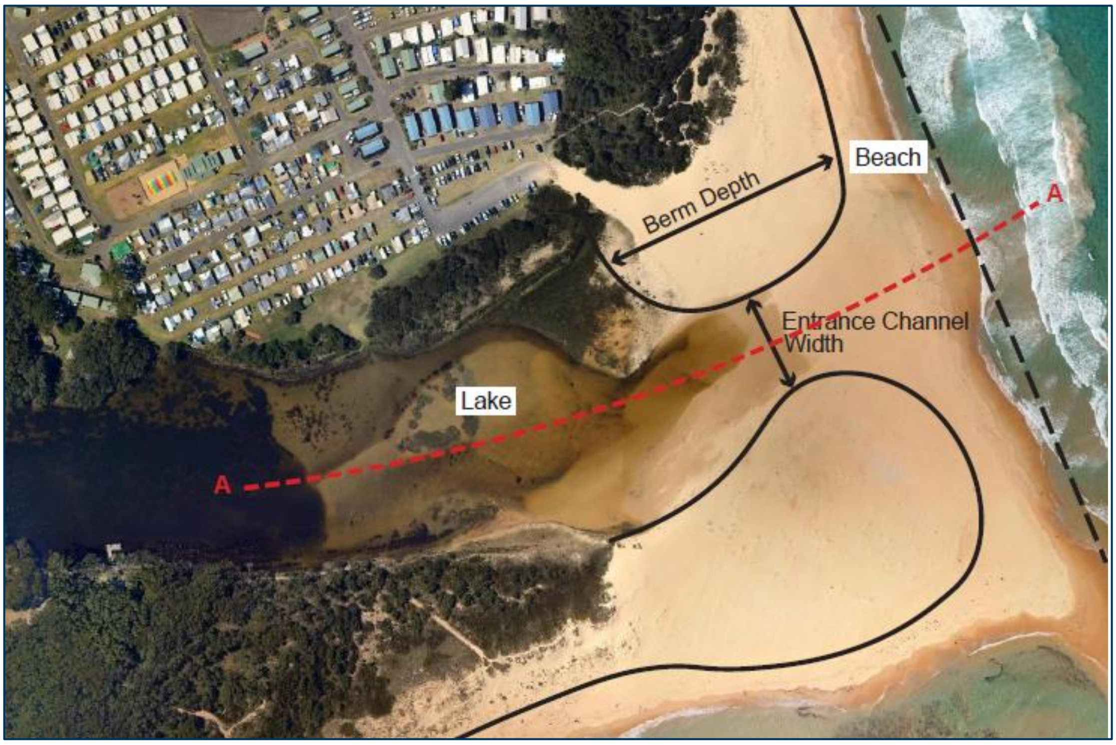


Figure 1-2 Plan View of Lake Entrance

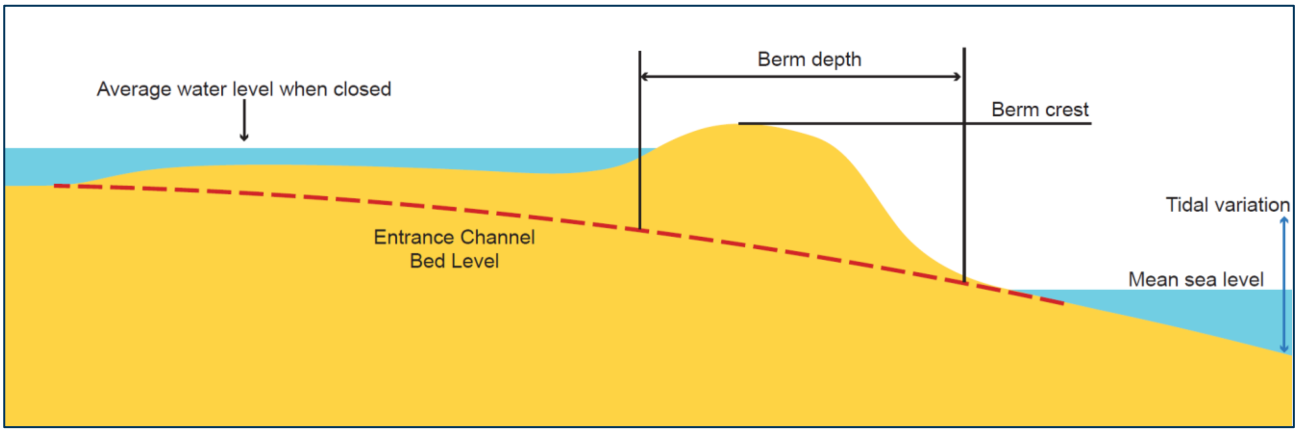


Figure 1-3 Conceptual Cross Section of Lake Entrance

1.5 Policy Statement

The Tabourie Lake EMP seeks to provide Council and the community with a detailed procedure for the short and long-term management of the Tabourie Lake entrance.

This policy will be implemented by Shoalhaven City Council in consultation with the appropriate State Government Agencies.

2 Background

2.1 Existing Draft Entrance Management Policy

A *Draft Entrance Management Policy and Review of Environmental Factors* was developed for Tabourie Lake by Peter Spurway & Associates in 2005. This existing EMP has been used since that time by Council to guide the management of the entrance of Tabourie Lake for flood mitigation purposes.

It includes:

> Purpose and policy context for the Draft EMP;

> Aims and objectives;

> Description of the existing environment and management issues;

> A review of the management context for the lake, including statutory context and the Tabourie Lake Estuary Management Plan (SCC, 2012);

> The procedures for opening the lake and required monitoring;

> Recommendations for management; and

> A Review of Environmental Factors (REF) for the entrance management prepared in accordance with Part 5 of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

At the time it was prepared, the Draft EMP (Peter Spurway & Assoc., 2005) addresses the particular flooding issues as follows:

> Inundation of yards of at least four properties along the Princes Highway when lake water levels are as low as 1.0 m AHD;

> Inundation of garages and other ancillary buildings in this area when lake water levels reach 1.3-1.4 m AHD; and

> Above floor level flooding of houses, which occurs when lake water levels are 1.83 m AHD or more.

Peter Spurway & Associates (2005) established in the Draft EMP essential conditions under which the entrance can be breached, as follows:

1. Lake water level equal to, or in excess of, 1.17 m AHD initiates an immediate entrance opening;

OR

2. Lake water level stabilises after rainfall at a level between 1.00 m and 1.17 mAHD and a period of over two months has elapsed since attaining that level;

AND

3. Non-breeding season for threatened shorebirds, or clearance from NPWS has been obtained.

The Draft EMP lists the following conditions as desirable (but not essential) to a successful opening:

> Continuing moderate to heavy rainfall;

> Relatively large ocean tidal range (greater than 1.0 m) with opening to coincide with a falling tide; and

> Relatively low wave action at opening location north of tombolo.

If the above essential condition 1 is not met for an immediate entrance opening, the Draft EMP requires that a 28 day consultation period apply after the lake attains a level at or above 1.0 m AHD.

Peter Spurway & Associates (2005) specify the location of opening as being north of Crampton Island (refer **Figure 1-1**), which was identified as being the most frequently occurring entrance channel location determined from historical observations and aerial photography analysis. The channel is to be excavated with a width of around 2 m, starting from the ocean and working back towards the lake entrance.

It is understood that due to the difficulty of safely excavating the channel during adverse weather conditions, Council often commence the channel excavation and leave a “notch” or plug of sand at the lake edge until such time as the trigger level is reached.

It is understood that access by machinery is via the Lake Tabourie Holiday Park carpark.

Peter Spurway & Associates (2005) recommends that the assumptions of the Draft EMP and the accompanying REF be reviewed following adoption of the Tabourie Lake Floodplain Risk Management Study and Plan (FRMS&P). Failing preparation of the FRMSP, the Policy should be reviewed in 2010.

2.2 Tabourie Lake Floodplain Risk Management Study and Plan

A FRMS&P (Cardno, 2016) was recently completed for Tabourie Lake by Council in accordance with the requirements of the *NSW Floodplain Development Manual* (NSW Government, 2005) and with support from the NSW Office of Environment and Heritage (OEH).

The FRMS&P defined and assessed flood risks in the Tabourie Lake catchment. The 20% Annual Exceedance Probability (AEP) and 1% AEP flood extents are mapped in **Figure 2-2**. It should be noted that %AEP refers to the probability of exceedance of a particular discharge (and associated peak level) each and every year, irrespective of the time since the last occurrence. Floor level survey was undertaken to inform the assessment of economic damages from flooding presented in the FRMS&P, identified that:

> In the 20% AEP flood event, with a peak flood level at the Tabourie Creek gauge of 2.0 m AHD, two properties experience over floor flooding and 21 properties have flooding below floor level; and

> In the 1% AEP event, , with a peak flood level at the Tabourie Creek gauge of 2.66 m AHD, 42 properties have over floor flooding and 121 have flooding below floor level.

The floor level for the lowest-lying property in the floodplain 2.0 m AHD, not 1.83 m AHD as stated in Peter Spurway & Associates (2005). This is thought to be due to the recent re-development of two lots. Inundation of lots tends to occur at lake water levels of around 1.0 m AHD.

Details of the flood behaviour of the study area are provided in **Section 3.4**.

In accordance with the requirements of the Floodplain Development Manual (NSW Government, 2005) a range of structural, property modification (e.g. planning controls), emergency response modification and other options were subjected to a cost-benefit analysis to shortlist of recommended actions for implementation by Council.

One of the recommended actions in the FRMS&P was to review the Draft EMP in light of the improved understanding of flood behaviour.

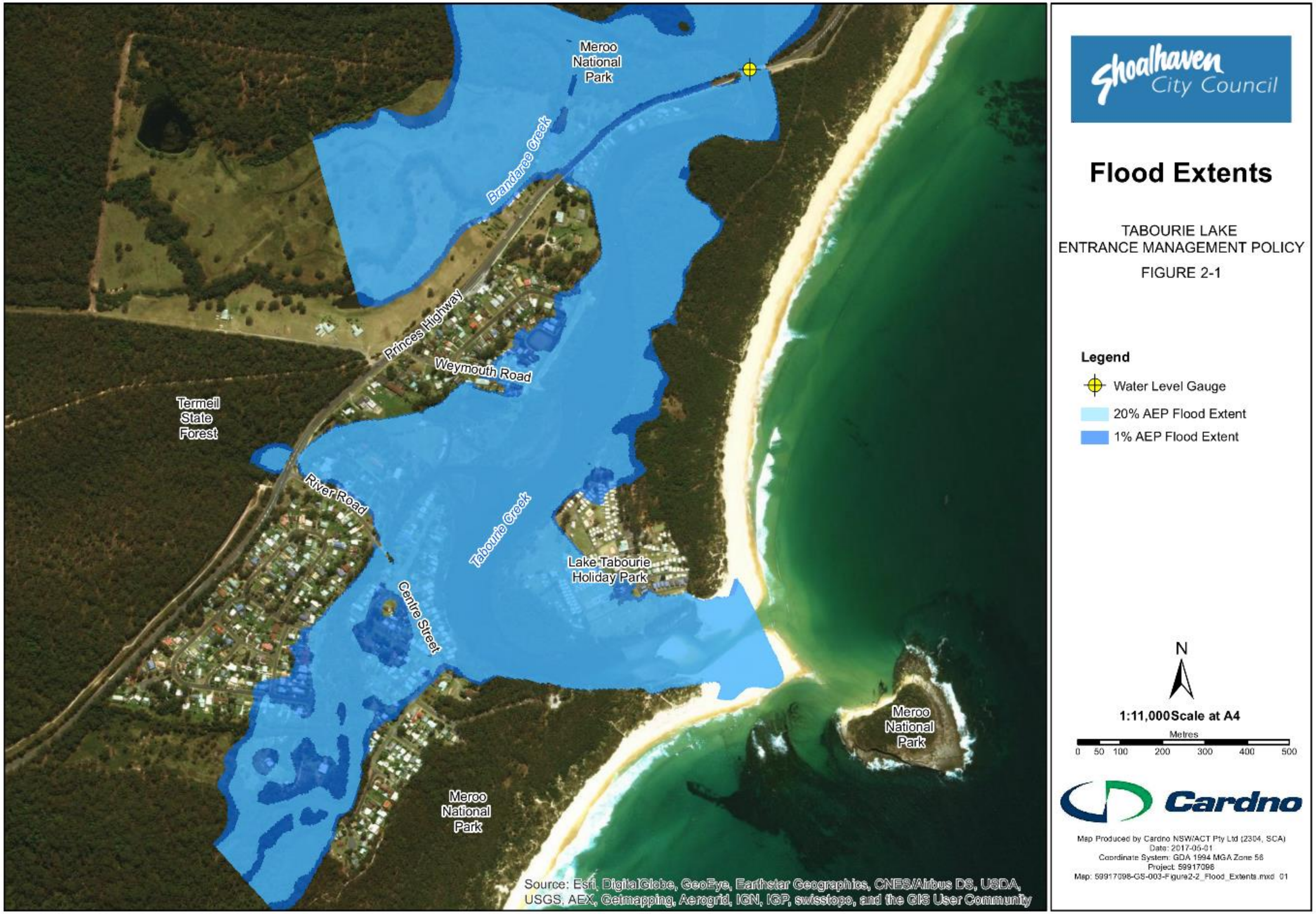


Figure 2-1 20% and 1% AEP Flood Extents for Tabourie Lake

3 Review of Existing Information

This section presents a review of existing information of relevance to entrance management. It includes:

> A review of the statutory and policy context (**Sections 3.1 and 3.2**);

> A description if ICOLL behaviour (**Section 3.3**)

> A description of flood behaviour (**Section 3.4**);

> A description of entrance behaviour (**Section 3.5**);

> A description of the environmental and social values of the Lake. (**Section 3.6**); and

> An assessment on the potential impacts of climate change on entrance management (**Section 3.7**).

It concludes with a statement on the ongoing need for entrance management based on the findings of the review.

3.1 Policy Context

3.1.1 State Rivers and Estuaries Policy

There are a number of State Government Policies and Guidelines supporting the management of estuaries in a manner that promotes the maintenance of natural processes. The objective of the NSW State Rivers and Estuaries Policy is to manage the rivers and estuaries of NSW in ways which:

> Slow, halt or reverse the overall rate of degradation in their systems;

> Ensure the long term sustainability of their essential biophysical functions; and

> Maintain the beneficial use of these resources.

The Policy aims to phase out degrading, non-sustainable uses of estuaries. Under the Policy, there is an intent to reduce or avoid entrance management for Tabourie Lake.

3.1.2 State ICOLL Management Policy

The NSW Department of Industry (The Department) management policies and guidelines for the management of ICOLLs are:

1. Any proposals for artificial opening of ICOLLs must seek the approval or concurrence of The Department under the *Fisheries Management Act 1994*.
2. The Department supports minimal interference with ICOLL entrance barriers and advocates natural processes being allowed to operate to the greatest extent possible.
3. The Department does not support the artificial opening of an ICOLL unless the proponent (i.e. Council or other agency) can demonstrate that the social, environmental and economic benefits greatly outweigh any potential adverse impacts.
4. The Department supports using estuary management plans and environmental assessment processes to analyse the issues relating to opening a particular ICOLL, and to develop an entrance management plan or entrance management policy. Proposals for artificial openings which are to be carried out according to a formulated entrance management plan or policy are more likely to be approved by I&I NSW.

In the long-term, The Department objective is that local councils and government agencies should aim to reduce the need for artificial manipulation of ICOLL entrances by taking active measures to remove, relocate or otherwise manage items of low-lying infrastructure that currently necessitate breaches below the natural breakout range.

3.1.3 Flood Prone Land Policy

The primary objective of the NSW Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners of property, and to reduce public and private losses from floods, using ecologically positive methods, wherever possible. The EMP aims to achieve this objective for the community of Tabourie Lake.

The Policy espouses a merit based approach to decision making, taking into account social, economic and ecological factors, as well as flooding considerations. This principle is applicable to this EMP review.

3.2 Statutory Context

3.2.1 Environmental Planning and Assessment (EP&A) Act 1979

Part 5, Section 111 of the EP&A Act requires that a public authority by or on whose behalf an activity is to be carried out (in this case Shoalhaven City Council) has a duty to examine and take into account to the fullest extent possible all matters affecting or likely to affect the environment. Furthermore, this duty to consider environmental impacts extends to any public authority whose approval is required for the activity (in this case Department of Lands).

Section 112 of the EP&A Act requires that if any of the above authorities considers that there is likely to be a significant effect on the environment then an Environmental Impact Statement must be prepared.

Once the preferred entrance management option is selected, it will be necessary to confirm the approvals pathway and ensure these requirements are addressed in the environmental impact assessment for the ongoing entrance management.

3.2.2 State Environmental Planning Policy (Infrastructure) 2007

The State Environmental Planning Policy (Infrastructure) 2007 (ISEPP) aims to facilitate the effective delivery of infrastructure across the state. Division 7, Clause 50 of ISEPP permits development on any land for the purpose of flood mitigation work to be carried out by, or on behalf of, a public authority without consent.

Shoalhaven City Council is proposing to clear the entrance of Tabourie Lake for flood mitigation purposes, and therefore the entrance management works would be defined as “infrastructure” works under Division 7, Clause 50 of the ISEPP.

3.2.3 State Environmental Planning Policy (Coastal Management) 2018

The aim of the SEPP is to promote an integrated and co-ordinated approach to land use planning in the coastal zone in a manner consistent with the objects of the *Coastal Management Act 2016.* The SEPP applies to land defined under the *Coastal Management Act 2016* as the “coastal zone”, which is comprised of land mapped as:

- Coastal wetlands and littoral rainforests area;
- Coastal vulnerability area;
- Coastal environment area; and/or
- Coastal use area.

The Lake Tabourie entrance falls within both the coastal environment and the coastal use areas. Clauses 13 and 14 list matters that must be considered prior to granting development consent on land within these two coastal management areas respectively. However, as noted in **Section 3.2.2**, consent would not be required for the proposed works.

3.3 ICOLL Behaviour

ICOLLs are common along the southeast of the NSW coastline. In terms of physical processes, the key driver of the ICOLL system is the entrance condition. The entrance berm is the sand bar that separates the lagoon from the ocean during periods when the entrance is closed. When the entrance is closed, both catchment inputs and in-lake processes are the key influences on factors such as circulation and water quality.

Rainfall events lead to stormwater runoff that flows into the lake raising water levels. Following inflow events water levels gradually decrease due to evaporation from the water surface and seepage through the berm, particularly at higher lake water levels. Successive inflows will eventually cause the water levels to rise above the berm crest height and overtop the berm initiating scouring of the berm sands to form a channel connecting the lake to the ocean. During this breakout process, significant volumes of water can flow out of the lake over a period of hours. The frequency with which the entrance breaks out is therefore determined by rainfall patterns in the catchment and the volume or capacity of the lake that is in turn determined by the berm height prior to break out.

When the entrance is open, coastal processes play a more significant role in the hydrodynamics of the lagoons. Tidal processes influence lake water levels and exchange of lake and ocean waters, thereby influencing water quality and circulation patterns in the lake. During this time, however, the action of coastal waves and currents that drive littoral sediment transport will also gradually begin to fill in the entrance channel and re-build the berm. The sand that previously formed the entrance berm gets deposited in the nearshore zone as an ebb tide delta during the entrance breakout event. During flood tides both cross-shore and long-shore currents transport this sand from this nearshore area into the open lake entrance channel, where the lower energy environment leads to deposition and formation of a flood tide delta. In this manner, more and more sand is deposited back into the entrance and the berm re-builds. The duration of entrance open conditions is determined by these coastal processes, and in high energy coastal environments such as those occurring in the study area, the lake entrance will typically close over a period of days to weeks. As the channel accretion process progresses, the magnitude of tidal exchange gradually decreases, until the berm crest exceeds ocean high tide and blocks the ocean waters from entering the lake. **Figure 3-1** depicts a closed entrance condition at the lake.

The entrance condition reflects a balance between these two sediment transport forces: catchment inflows and coastal processes. The natural balance between these competing processes is interrupted by mechanical opening of the lake before/during heavy rainfall events. Past land use and development in low-lying areas around the foreshore of the lake has resulted in a practice of entrance management for flood mitigation.

Figure 3-1 Lake Tabourie Entrance Circa 2001 (image courtesy of OEH, 2012)

Due to its relatively small waterway area (1.4 km^2) and catchment size (46 km^2) (OEH, 2012), Tabourie Lake is a wave dominated estuary. This means that the wave action is at times so dominant that entrance closure occurs on an intermittent basis, and may thereafter persist for extended periods of time.

3.4 Flood Behaviour

Flood behaviour for the study area was defined in the Tabourie Lake FRMS&P (Cardno, 2016). A comprehensive description of the flood behaviour of the study area is provided in that report, and is summarised below.

3.4.1 Flood Mechanisms

The Tabourie Lake community is subject to flooding from three primary mechanisms:

> Flooding of Tabourie Creek arising from catchment rainfall;

> Flooding of Tabourie Creek from elevated ocean water levels (e.g. storm surge); and

> Slow build-up of water levels in Tabourie Creek (below floor level flooding) when the estuary entrance is closed.

The entrance condition plays a role in each of these flooding mechanisms.

Catchment rainfall results in the worst case flooding scenario for the study area, resulting in inundation of the Pacific Highway and of key access roads along Lemon Tree Creek. For catchment flooding events, the entrance plays little role in influencing flood behaviour. This is due to relatively small volume of the lake relative to the catchment size, and the berm quickly overtops and is naturally broken open in advance of the flood peak.

Elevated ocean water levels affects those properties closest to the entrance, with the impact reducing for properties further upstream. The entrance, if closed, provides protection against smaller ocean events and provides some buffering in larger events.

The occurrence of low level, persistent flooding is wholly driven by the entrance condition. When open, water is allowed to drain to the ocean and lake water levels do not become high enough to inundate foreshore properties. As the entrance closes and the berm crest level gradually gets higher, the lake water levels tend to increase due to periodic catchment inflows. If the entrance is closed for long enough, and the catchment inflows exceed evaporation, the water levels in the lake will continue to gradually rise and impact low-lying land. This issue will persist until the entrance is opened, either naturally or mechanically.

3.4.2 Rate of Rise

The typical rate of rise for the study area in a 1% AEP catchment rainfall event is shown in **Figure 3-2.** The rate of rise quickly increases from 0.1 m per hour to 0.4 m per hour, illustrating the fast response time of the lake to catchment rainfall. The rate of rise increases to 0.55 m per hour, before beginning to fall off as the flood reaches its peak. There is a three hour period up until the peak flood level where the average rate of rise is over 0.4 m per hour. This poses a significant hazard to residents, as access to and from properties and along local roads is quickly inundated, with little or no warning.

There is around three hours between the time when the lake water level reaches the trigger level for opening (1.17 m AHD; refer **Figure 3-2**) and when the 1% AEP peak flood level occurs. There is very little time between reaching the trigger level for opening and until lake water levels reach 2.0 m AHD and the lowest-lying property is subject to over floor flooding.

The typical rate of rise for a 20% AEP event is shown in **Figure 3-3**. The rate of rise quickly increases for this event, increasing to 0.3 m per hour before falling off as the flood reaches its peak. There is a three hour period up until the peak flood level where the average rate of rise is over 0.3 m per hour.

Analysis of the flood model results for different design events presented in the FRMS&P (Cardno, 2016) indicates that the rate of rise of lake water levels from the 1.17 m AHD trigger levels are:

> 45 to 60 minutes to reach 1.50 m AHD;

> 60 to 90 minutes to reach 1.80 m AHD; and

> 90 to 120 minutes to reach 2.0 m AHD.

There is around 45 to 120 minutes between the time lake water levels reach 1.50 m AHD and the time they reach 2.0 m AHD.

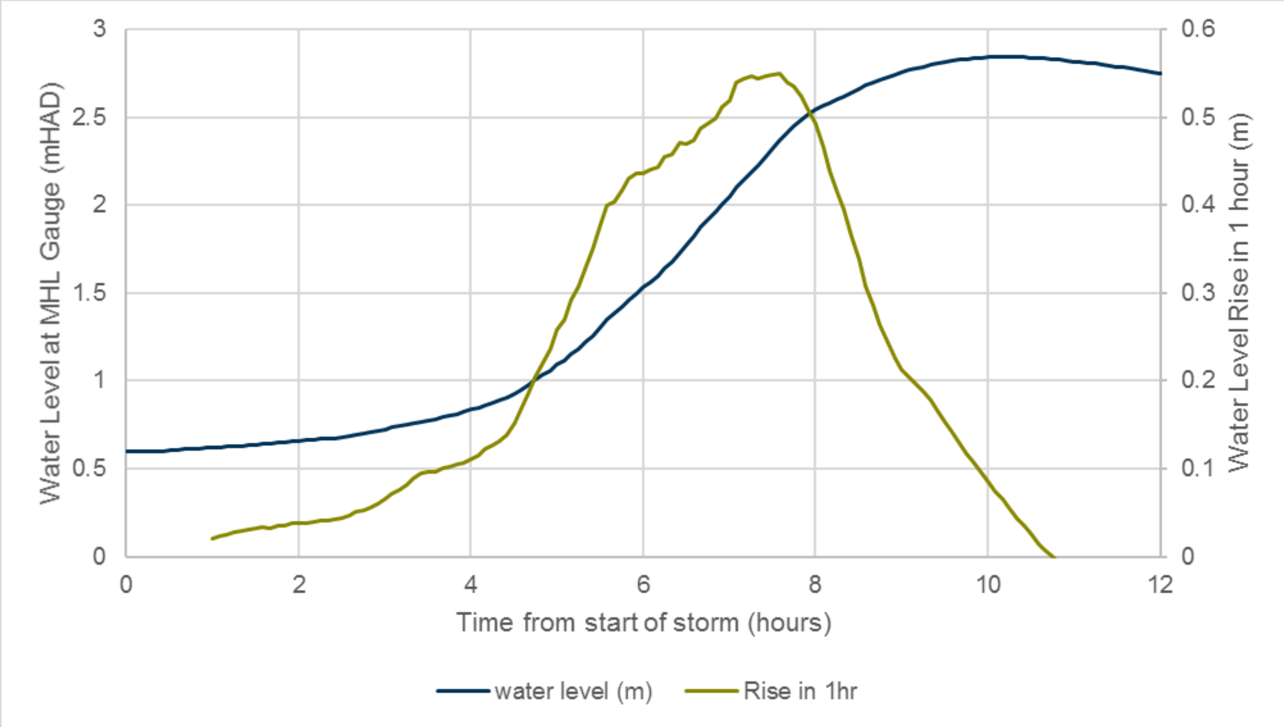


Figure 3-2 Rate of Rise for the 1% AEP Flood Event

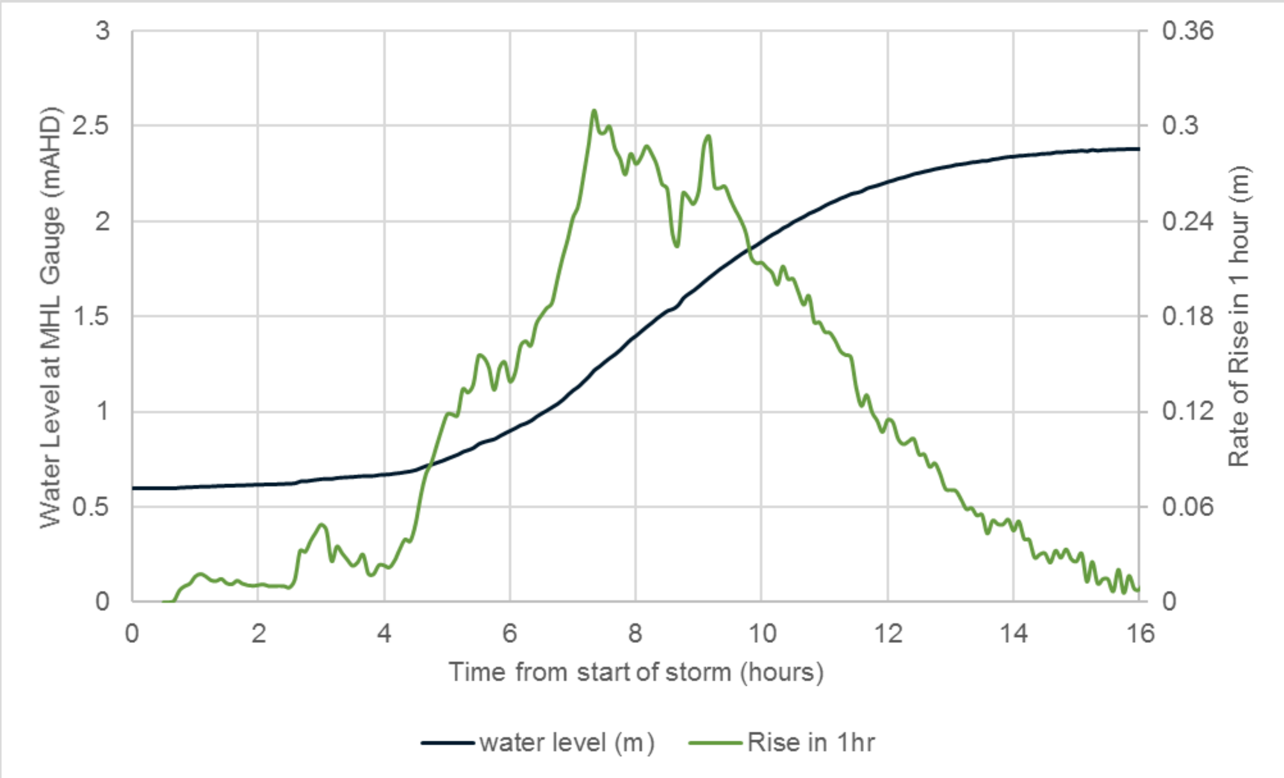


Figure 3-3 Rate of Rise for the 20% AEP Flood Event

3.4.3 Flood Emergency Response Planning Classifications of Communities

The FRMS&P included mapping of Flood Emergency Response Planning Classifications across the study area (refer **Figure 3-4**). This mapping is an important tool for the initial planning of emergency response, and highlights which areas of the community are most at risk in flood events.

The mapping identifies two regions of low flood islands where access roads are inundated. This represents a significant hazard to residents, as by the time they become aware of flooding on their land, their chance to evacuate may already have been lost.

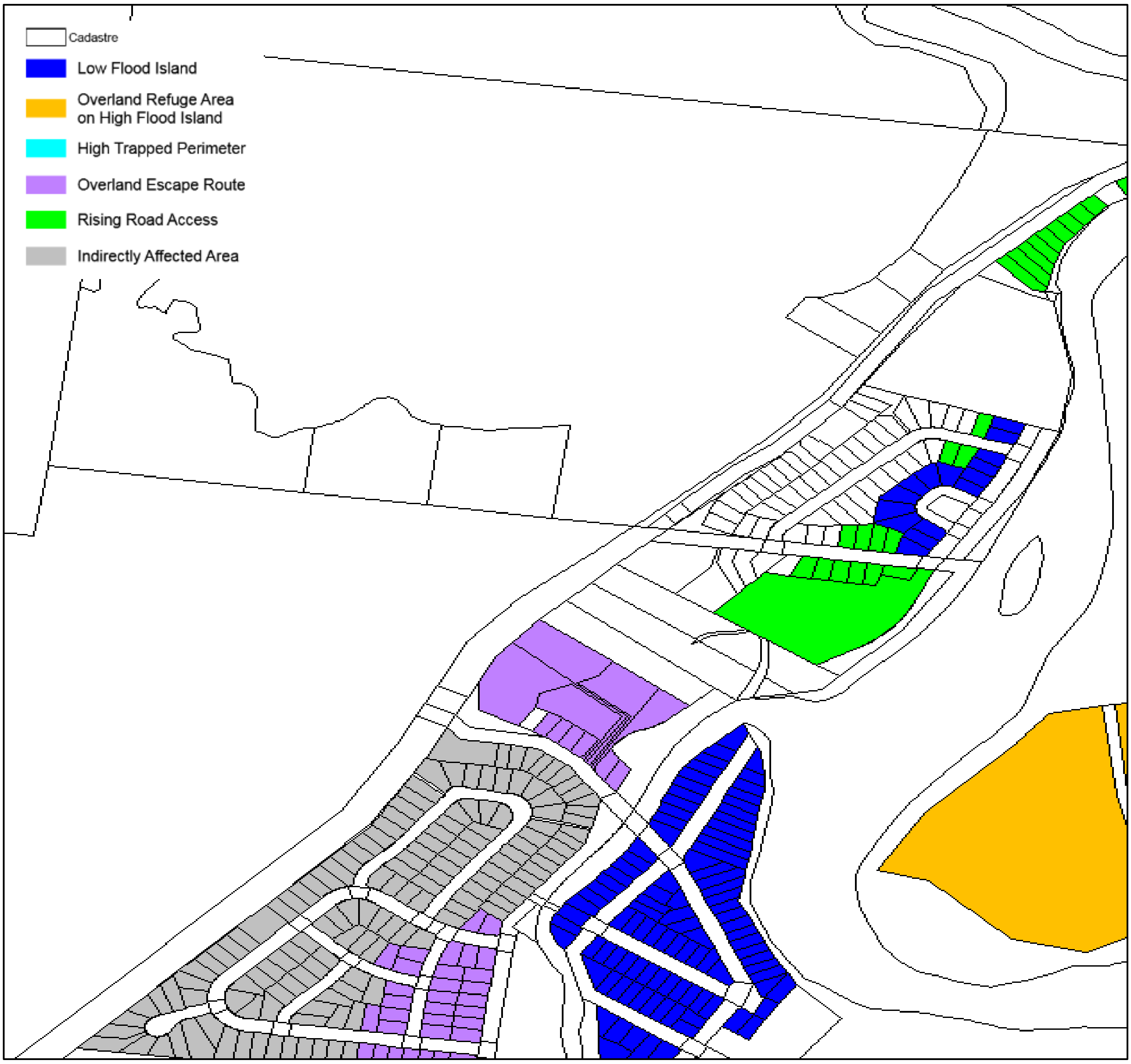


Figure 3-4 Flood Emergency Classifications for Tabourie Lake

3.4.4 Inundation of Assets

The terrain surrounding Tabourie Lake is relatively flat immediately adjacent to the creek, with sharper rises in terrain occurring to the north and west. Much of the development in the area has been undertaken on this flat region adjacent to the lake. As such, many of the built assets of the town are affected by flooding.

Key assets located on this low-lying land are:

> *Residential properties* – a number of residential properties are affected by flooding. The FRMS&P (Cardno, 2016) reports that:

- 21 properties experience flooding of their land in the 20% AEP, and two properties experience over floor flooding, and
- Flood level rise quickly in larger events, and in the 1% AEP 121 properties experience flooding of their land and 42 properties experience over floor flooding. Most of these properties are single storey, increasing the flood risk to residents;

> *Lake Tabourie Holiday Park* – located immediately north of the entrance, the caravan park is built on low-lying flood-prone land. Of particular concern for the caravan park, flooding first affects the access road, resulting in the site quickly becoming isolated during flood events. The high proportion of tourists that visit the site, particularly in the summer, further increases the risk profile of the site, as tourists are unlikely to be familiar with the flood behaviour and flood risk ;

> *Tabourie Child Care Centre* – The Tabourie Child Care Centre is located on River Road, adjacent to an unnamed tributary of Tabourie Creek. The site experiences flooding in minor events from both catchment and ocean backwater flooding;

> *Bridges and Roads* – There are two major bridge crossings in the study area, the Princes Highway crossing of Tabourie Creek, and the Centre Street crossing of Lemon Tree Creek. Both these bridges are affected by flooding in events as small as the 5% AEP event;

> *Rural Fire Service* – There is a Rural Fire Service building and equipment storage shed at the end of Bridge Road. The site is flood free, even in the PMF, and was suggested as an emergency evacuation site for nearby residents during large flood events; and

> *Petrol Station and Tabourie Lake Motor Inn* – Located on the Princes Highway, these premises are outside of the floodplain. However, access along the Princes Highway is lost both north and south from these sites, preventing access to and egress from these sites during large flood events.

3.5 Entrance Behaviour

3.5.1 Berm Behaviour

Tabourie Lake has a relatively small estuary area (1.4 km^2) and large catchment size (46 km^2) and, like most ICOLLs along the NSW coast, is a wave dominated estuary. This means that the wave action is at times so dominant that entrance closure occurs on an intermittent basis, and may thereafter persist for extended periods of time. Analysis by Peter Spurway & Associates (2005) found that from 1987-2005, the lake was open approximately 47% of the time. Analysis of lake water level data extending from 1992 to 2017 shows that the lake was open approximately 32% of the time during that period.

While entrance opening occurs naturally during flood events, the entrance is opened more often artificially using mechanical equipment for the purpose of mitigating below floor level flooding. The Flood Study (BMT WBM, 2010) and FSRMP (Cardno, 2016) showed that mechanical opening does little to reduce peak flood levels during rarer, more severe catchment flooding events. Peter Spurway & Associates (2005) found that from 1987 to 2005, the lake was mechanically opened 24 times, and only opened naturally twice. It is therefore reasonable to assume that the Lake is open much more frequently than would naturally be the case.

As discussed in **Section 3.3**, the formation of the entrance berm closes off the lake from the ocean. Many studies have investigated the models of berm development in ICOLLs. Weir *et al.* (2006) proposed two different modes of berm development:

1. Vertical growth of a principal berm at higher due to substantial swash overtopping; and
2. Horizontal progradation at lower tides through the formation of a secondary berm located lower, and further seaward of the principal berm.

The maximum height of the berm will depend upon vertical extent of wave run-up. This means that, generally speaking, the berm will continue to grow until the berm crest reaches the maximum the level of day to day wave run-up experienced at the site. The height of wave run-up is a product of incident wave conditions (wave height and period) and beach slope. Beaches exposed to higher incident waves tend to have higher wave run-up and could therefore be expected to have higher (on average) berm levels. Beach slope is related to sediment grain size, with coarse grained beaches exhibiting steeper slopes than fine grained beaches. Steeper beaches also tend to have higher run-up, and as such steeper, coarse grained beaches could also be expected to experience higher (on average) berm levels (Hanslow *et al*., 2000). It should be noted that in some instances the berm may continue to grow higher than the maximum wave run-up level due to aeolian (wind-blown) sediment transport, which may blow sand higher up the beach during extended periods of onshore winds.

Some information regarding historical berm levels for Tabourie Lake was available from Peter Spurway & Associates (2005), reproduced in **Table 3-1**.

Table 3-1 Recorded Berm Levels at Tabourie Lake

Date	Beach Berm Level (mAHD)	Comment	Time Since Entrance Closure (months)
1978	2.0	Maximum berm level reported in EMP	Not known
21 April 1986	1.6	Aerial photogrammetry DIPNR*	Not known
14 May 1993	1.4	Aerial photogrammetry DIPNR	Approx. 2 months
1 February 2005	1.5	Aerial photogrammetry DIPNR	Approx. 2 months
June 2005	1.7 to 1.8	Survey by Council	Approx. 5 months

*DIPNR = Department of Infrastructure, Planning and Natural Resources, now OEH.

The data in **Table 3-1** suggests that the maximum level that the lake would attain prior to commencement of natural breakout would only rarely exceed 2.0 m AHD. Wainwright and Baldock (2010) estimated exceedance probabilities for the berm height at Tabourie Lake based on analysis of ocean water levels (i.e. wave run-up levels) (refer **Table 3-2**). The data supports the review by Peter Spurway & Associates (2005), indicating that the berm crest level would exceed 2.0 m AHD around 5% of the time.

Table 3-2 Estimated Berm Elevation Exceedances for Tabourie Lake

% of Time Exceeded	Present Day (m AHD)	2050 (m AHD)
80	1.80	2.22
50	1.91	2.33
20	1.99	2.41
10	2.03	2.45
5	2.06	2.48
1	2.10	2.52

Given the lack of data on the berm behaviour at Tabourie Lake, an analysis of lake water level data from 1992 to present was undertaken as a proxy for berm height. The analysis is presented in **Figure 3-5**. Water level data was provided by Council for the water level gauge situated inside approximately 200 m upstream from the entrance (refer **Figure 2-2**).

The water level data was investigated to identify three different entrance conditions:

> <u>Entrance Open</u>: When the entrance is open, semi-diurnal tidal variations (that is, two high tides, and two low tides per day) are visible in the water level data, with daily variations in the order of 0.2 – 0.5 m. These continue after a breakout, and the daily variations gradually reduce as the entrance infills, until they are no longer visible when the entrance closes;

> <u>Entrance Closed or Very Weakly Open</u>: When the entrance is closed, no semi-diurnal tidal variations are visible in the water level data. Some variations during entrance closure still occur due to rainfall and evaporation, however these are easily distinguishable from the semi-diurnal tide; and

> <u>Entrance Opening and Breakout</u>: These were identified by a significant and rapid drop in water levels inside the lake, that are generally (but not always) preceded by a rapid rise in levels due to rainfall.

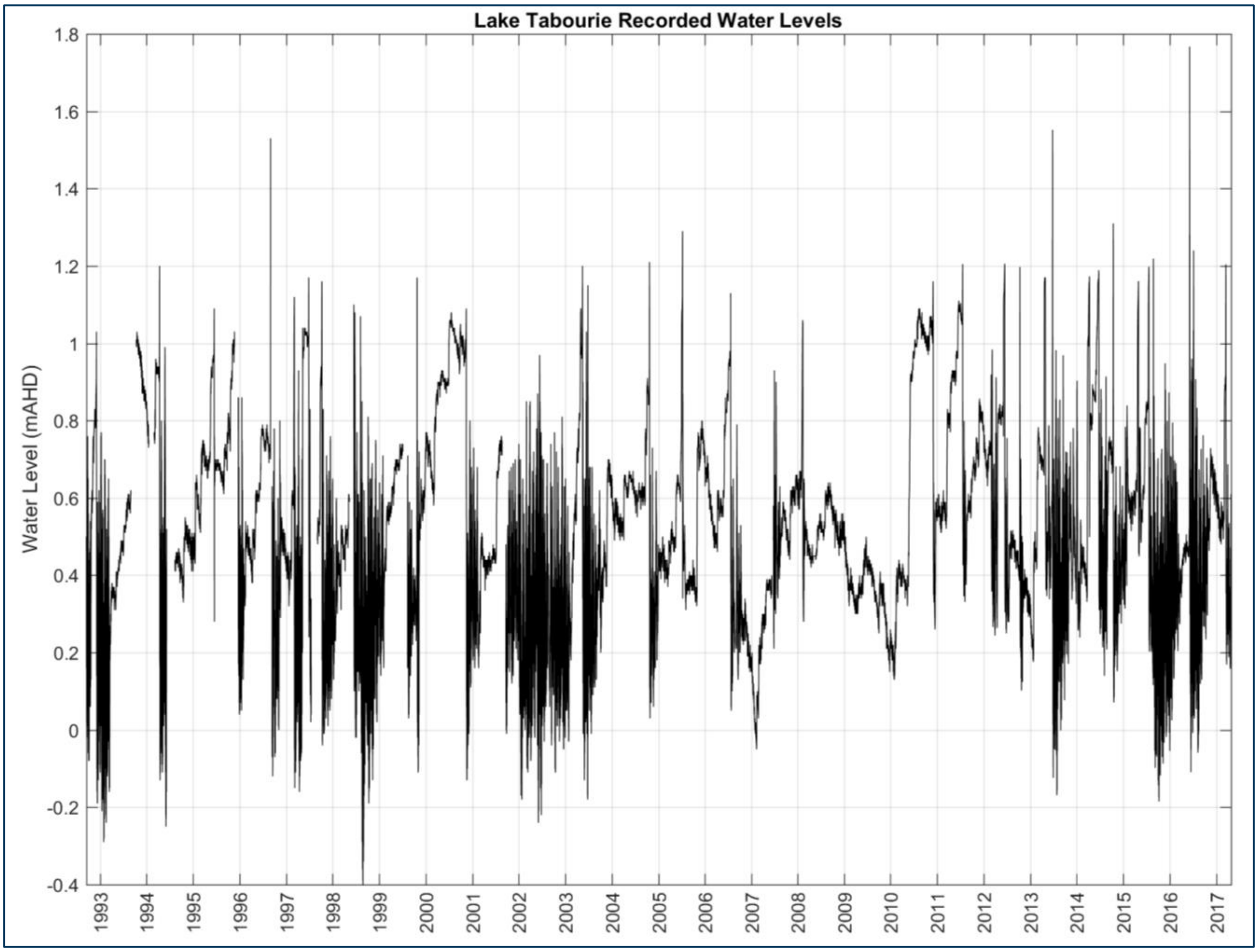


Figure 3-5 Lake Tabourie Recorded Water Levels 1992-2017

Figure 3-6 shows an example of the various entrance conditions and their effect on lake water levels. The figure depicts Tabourie Lake water level data for October 2014 to March 2017 against the corresponding daily rainfall data from the Bureau of Meteorology rainfall gauge at Ulladulla, approximately 10 km to the north of Tabourie Lake. **Figure 3-6** depicts a somewhat typical cycle of entrance openings and closure, and demonstrates the close correlation between entrance openings and rainfall events. The figure also depicts typical durations of the open entrance condition that follows a breakout event and the gradual reduction in tidal range within the lake as the entrance slowly re-closes.

Councils EMP (Peter Spurway & Assoc., 2005) has as its trigger for mechanical opening of the entrance when water levels inside the lake reach 1.17 m AHD. This level was selected to prevent or minimise the flooding of a number of low-lying properties around the estuary foreshore, although it is noted that the floor level of lowest-lying property is now 2.0 m AHD (refer **Section 2.2**).

Analysis of recorded lake water levels indicates that over the period 1992 to 2017, entrance openings (mechanical or otherwise) occurred at an average frequency of 1.5 times per year, or every 258 days (see **Table 3-3** and **Figure 3-5**). The average duration of the open entrance condition was 77 days, though some individual open periods lasted significantly longer, such as between September 2001 and August 2002, where a series of rainfall events kept the entrance open for 351 days. Conversely, average duration of the closed entrance condition was 171 days, with the longest duration event lasting over 1000 days between February 2008 and December 2010.

Table 3-3 shows that the average peak water level immediately prior to entrance opening events is 1.19 m AHD, which is in close keeping with Council's trigger level of 1.17 m AHD. However, some events show significantly higher peak water levels, such as the opening event in June 2016, where peak water levels reach 1.79 m AHD prior to entrance opening (see **Figure 3-5**). This is likely due to the fact that that lake is very small in size compared to its catchment, and so has limited capacity for flood storage. This means that water levels in the lake are highly responsive to rainfall, and heavy rainfall events can result in rapid water level rises. Consequently, during severe rainfall events, lake water levels can exceed the mechanical opening threshold before Council has a chance to respond and mechanically open the lake.

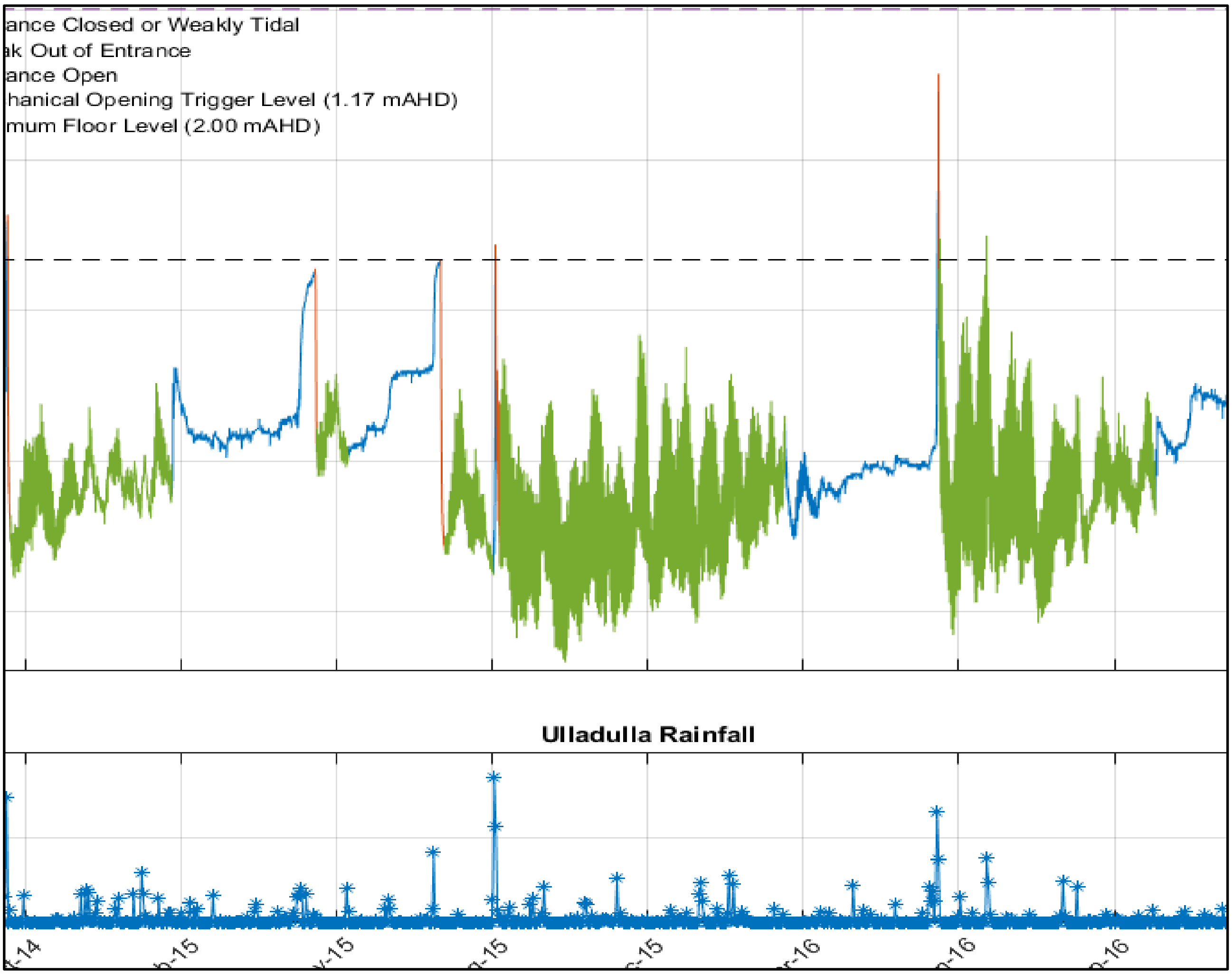


Figure 3-6 Lake Tabourie Berm Status, Water Levels and Rainfall

Table 3-3 Lake Tabourie Berm Status and Rainfall Statistics

Total Openings	36
Average Openings Per Year	1.5
Average Duration Open	77 days
Average Duration Closed	171 days
Average Time Between Openings	248 days
Average Peak Water Level At Opening	1.19 m AHD

Figure 3-7 shows an entrance opening event during July 2015. This figure shows the evolution of the entrance condition (from closed, to breakout, to open) that occurred over a period of months during a significant rainfall event.

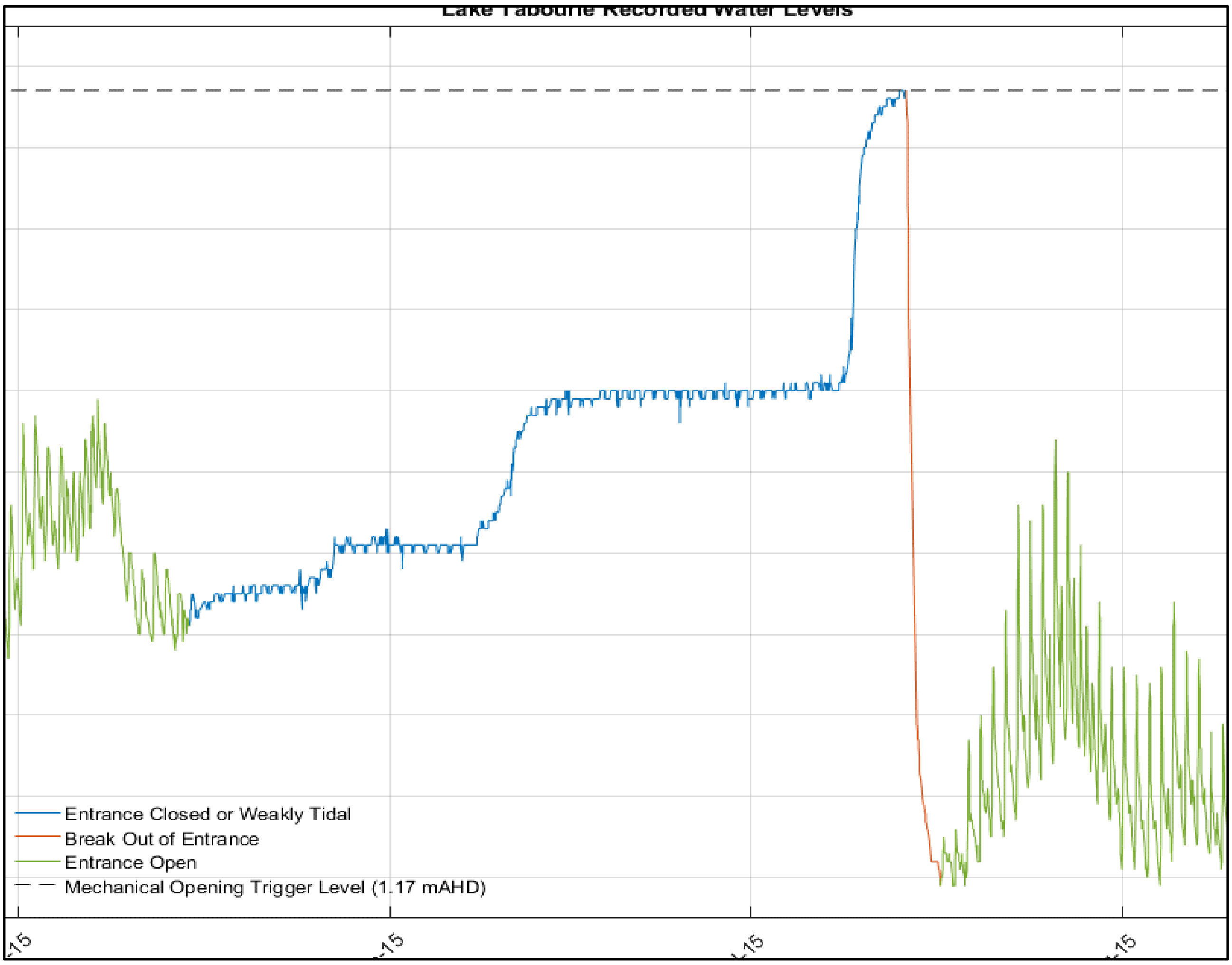


Figure 3-7 Zoomed Lake Tabourie Berm Status and Water Levels: May – June 2015

3.5.2 Ocean Inundation

While catchment flooding is the predominant flooding mechanism in the lake (refer to **Section 3.4.1**), ocean inundation of foreshore land may also occur if large spring tides (such as king tides) or storm tides occur while the entrance is still open in the weeks / months following a breakout.

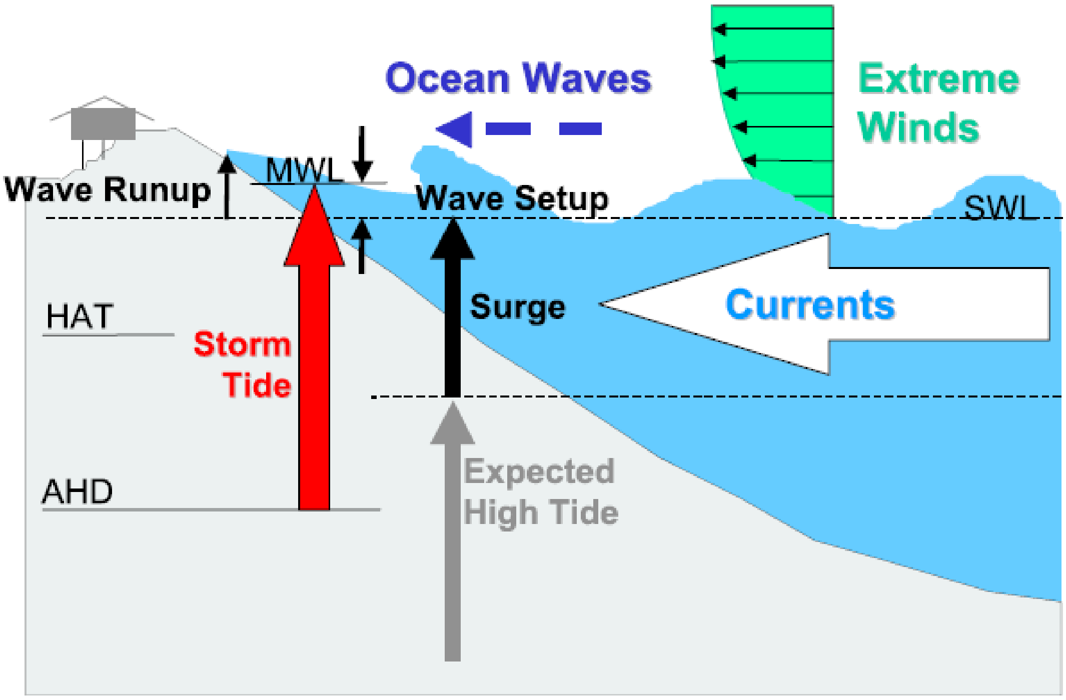
During an open entrance condition, high spring tides or storm tides may propagate into the estuary. There is some attenuation of the tide (or storm tide) as it travels upstream due to the bed form of the estuary, however it is possible that the full spring or storm tide levels would be observable as far upstream as the Princes Highway bridge. Large astronomical spring tides occur several times a year and are the result of the gravitational attraction of the moon and the sun.

Storm tides can significantly exceed the astronomical tide level, and are the result of significant short duration variation from the predicted astronomical tide referred to as storm surge. The physical processes that contribute to storm surge are depicted in **Figure 3-8**, and include:

> Wind Set-up – the increase in water level that results from strong onshore winds piling water up against the shoreline;

> The Inverse Barometer Effect – the resultant increase in sea level associated with a decrease in barometric pressure; and

> Wave Set-up – the elevation of the still water level that can be considered as a piling up of water against the shoreline that is caused by breaking waves.



*HAT = highest astronomical tide, MWL = mean water level, SWL = still water level.

Figure 3-8 Storm Surge Conceptualisation

The Tabourie Lake Flood Study (BMT WBM, 2010) included detailed hydrodynamic modelling of both catchment & ocean derived storm surge design events. As part of that study, the 1% AEP ocean storm tide level was determines as 2.51 m AHD at the entrance, & 2.57 m AHD inside the lake body (it assumed a fully scoured entrance as the starting condition for ocean inundation events).

A supplementary review of existing information was undertaken to provide a simplistic assessment of *potential* ocean inundation inside Tabourie Lake based on potential design still water levels and wave set-up (i.e. storm tide). Offshore design still water levels recommended by OEH (2015) for the NSW coast south of Crowdy Head are presented in **Table 3-4**. Design significant wave heights (Hs) have been taken from Cardno (2012), which presents the Extreme Value Analysis of Hs for the Batemans Bay waverider buoy data from 1998 – 2009. **Table 3-4** provides a preliminary estimate of the total design still water level including wave set-up, for Tabourie Lake, assuming that wave set-up is approximate to 12% of the offshore wave height (OEH, 2015).

Based on the data presented in **Table 3-4**, it is reasonable to assume that the berm height, and therefore the lake water levels, could be as high as 2.4 m AHD if the berm were allowed to keep on building. The data also indicates that, if the entrance is open during a coastal storm, there is potential for ocean inundation of foreshore properties. The estimated 100% AEP storm tide level, which has potential to occur once every year, is 1.9 m AHD, well above the trigger level of 1.17 m AHD and close to the floor level of 2.0 m AHD of the lowest lying property.

Table 3-4 Design Still Water Levels

AEP	Design Still Water Level (m AHD) – Excl. Wave Set-up (OEH, 2015)	Design Significant Wave Height at Batemans Bay (m)	Potential Storm Tide Level at Lake Entrance (m AHD) (Incl. Wave Set-up)
1%	1.45	7.9	**2.4**
2%	1.40	7.5	**2.3**
5%	1.37	7.0	**2.2**
10%	1.35	6.6	**2.1**
100%	1.25	5.1	**1.9**
HAT	1.10	-	**-**

It should be noted that these storm surge levels are likely to be conservative as in reality there is likely to be some attenuation of incident wave energy provided by Crampton Island that would reduce the overall wave energy (and hence total wave set-up) at the shoreline.

3.5.3 Inundation of Assets

The entrance behaviour will affect the inundation of properties and other assets in two distinct ways.

> A closed entrance condition may result in inundation of low-lying assets due to catchment flooding (see **Section 3.4**); and

> An open entrance condition may result in inundation of low-lying assets due to ocean inundation.

The Lake Tabourie Flood Study (BMT, WBM, 2010) found that the flooding behaviour within the study area was only somewhat sensitive to the berm conditions at the onset of flooding. This sensitivity was most pronounced in smaller flood events. In larger (rarer) flood events, where the entrance is quickly overtopped, entrance conditions had a smaller influence on peak flood levels. These differences were largely restricted to the creek and overbank areas.

During more severe flood events the entrance quickly breaks out and washes away due to the rapid rise of lake water levels, and that this overtopping occurs in advance of the peak flood. Therefore, it is not practically feasible to manage the entrance (i.e. break it open) to mitigate flood risk from a 1% AEP event.

3.5.4 Entrance Management Policy

The current Tabourie Lake Draft EMP (Peter Spurway & Associates, 2005) stipulates the conditions under which mechanical opening is to occur (refer **Section 2.1**). The current trigger level of 1.17 m AHD appears to be relatively effective for mitigation of below floor level flooding of properties; **Figure 3-5** shows that lake levels have only exceeded 1.3 m AHD four times between 1993 and 2017 (approximately every six years). This would suggest that the current opening level generally allows enough time for council entrance opening to take place before over floor flooding of properties can occur.

The desired condition for mechanical opening of the entrance is for a large ocean tidal range (greater than 1.0 m) with opening to coincide with a falling tide is considered appropriate. The policy states that the mechanical opening is to be planned so that, where possible, the actual opening of the lake occurs shortly after the tide turns from high to low, ideally within 30 minutes of the published high tide time. This will normally require mobilisation of the digger and commencement of excavation just after the low tide, as a total of four to six hours excavation across the beach would commonly be necessary according to Peter Spurway & Associates (2005). The idea is that there would be sufficient time to undertake the entrance opening so that there is a large head difference between the lake and ocean water levels. The greater this head difference, the more rapidly the lake will drain and the more sand will be scoured out of the entrance, hopefully leading to longer opening duration. While these are the preferred conditions and procedure for commencement of mechanical opening of the entrance, they may not always be achievable.

It should be noted that opening the lake during a spring tide may result in tidal inundation of foreshore lands on subsequent high tides following the initial opening. It may therefore be appropriate to consider an additional “desirable condition” for entrance opening that it should not coincide with a spring tide. A reasonable guideline for this condition would be that it is preferable that predicted high tides in the week following breakout not exceed 0.8 m AHD, although this may not be feasible given the requirement to respond to lake water levels.

The potential impacts of climate change may also a review of entrance management policy in the future. **Section 3.5.4** discusses the potential impacts of climate change on entrance management.

3.6 Environmental and Social Values

A desktop review of publically available information on the existing social and environmental constraints was carried out on 11 April 2017. Further consideration of these issues was undertaken during the options assessment, and any impacts formally assessed in an environmental impact assessment for the preferred option in the Entrance Management Policy (refer **Section 6**).

3.6.1 Aboriginal Cultural Heritage

The traditional custodians of the land which is the subject of the EMP are the Budawang people. The study area falls within the boundary of the Ulladulla Local Aboriginal Land Council (LALC), which was confirmed in consultation with the Ulladulla LALC Chief Executive Officer (pers. comm, T. Mackenzie, Cardno – S. Carriage, LALC, 21/04/2017).

A number of archaeological and other sites of Aboriginal cultural heritage significance protected under the *National Parks and Wildlife Act 1974* were identified through a detailed search of the Australian Heritage Information Management System (AHIMS). A total of five sites were identified based on a search adopting a buffer of 1 km around the lake entrance. These sites comprise:

- An isolated find and midden; and
- Four midden sites.

Of the five sites, none are located in the area that would be subject to direct impact due to the entrance management works; however, this should be reviewed during the options assessment phase.

There is potential for Aboriginal sites or artefacts to exist in the study area that may not have been recorded in the AHIMS database, and thus not formally recorded. It is, however, unlikely that any such artefacts exist in the area that would be disturbed by the works due to the highly active nature of the beach, particularly where it breaks out and can be subject to significant scouring.

3.6.2 Non-Aboriginal Heritage

Non-Aboriginal heritage (or European heritage) is classified into three statutory listings, namely Commonwealth, State and local.

A desktop assessment of the following data bases was undertaken for the Shoalhaven LGA on 11 April 2017 to identify any non-Aboriginal heritage sites in the study area:

- Australian Heritage database which incorporates the World Heritage List, National Heritage List, Commonwealth Heritage List and includes sites and relics protected under the EPBC Act;
- State Heritage Register, established under the NSW *Heritage Act 1977*; and
- Local heritage sites as listed on the *Shoalhaven Local Environmental Plan 2011* (LEP).

There were no records of sites or relics in Australian Heritage Database or the State Heritage Register in the study area or surrounds.

As discussed above with reference to Aboriginal cultural heritage, there is also a risk of uncovering previously unidentified sites or relics of non-Aboriginal cultural heritage significance, although this is considered unlikely due to the dynamic nature of the lake entrance and beach.

3.6.3 Topography and Soils

Sourcing information from the 1:100,000 map sheet (Geoscience Australia, 2008), the soil type is identified as sulfidic extratidal hydrosol and neutral peat soil (OEH, 2016).

The LEP indicates the presence of Acid Sulfate Soils (ASS) in the study area, primarily class 1 and 3 near the entrance (on a scale of 1 to 5, 1 being the most extreme acidic conditions). However, as discussed in Peter Spurway & Associates (2005) there is no evidence of ASS in the entrance area, and the lithology of the Tabourie Lake entrance is primarily coarse, poorly graded marine sands. Given the dynamic nature of the entrance channel and adjacent beach, it is considered reasonable to assume that the entrance channel comprises marine sand and is free of ASS.

3.6.4 Contaminated Land

Contaminated land refers to land that contains, within their soils or otherwise, concentrations of contaminants that pose a risk to environmental or human health. Contaminated land is managed under the NSW *Contaminated Land Management Act 1997* (CLM Act).

The OEH regulates contaminated land, maintaining records of written notices issued by the Environmental Protection Authority (EPA) in relation to the investigation and/or remediation of contamination. A search of the OEH Contaminated land register conducted on 11 April 2017 for the Shoalhaven LGA returned records of two sites in Nowra, some distance from the study area. There were no records of any contaminated lands in the study area. It is important to note that there are limitations to the registers and some contaminated sites may yet to be reported or investigated by the EPA, as such, may not be recorded on the register. Noting, however, the presence of clean marine sand in the entrance area (refer **Section 3.5.3**) and dynamic nature of the environment in this area, it is considered unlikely that any contaminated material would be encountered in the entrance area.

A search of the licensed premises public register on 21 March 2017, identified one premises in the study area that have a current Environment Protection Licence for pollution discharges. Lake Tabourie Tourist Park holds an Environment Protection Licence issues under the *Protection of Environment Operations Act 1997* (PoEO Act) for the operation of a sewage treatment and exfiltration plant. The licence permits discharges to waters at any time of between 20 – 100 ML.

3.6.5 Flora and Fauna

Meroo National Park intersects the study area, spaning from Ulladulla in the north to Termeil to the south of Tabourie Lake and including Crampton Island (refer **Figure 3-9**). It borders the north-western shores of Tabourie Lake upstream of the Princes Highway, but otherwise does not interact with the study area for the EMP. The Termeil State Forest is located southwest of Tabourie Lake.

Figure 3-9 presents mapping of Endangered Ecological Communities (EEC) and SEPP 14 Wetlands in the study area. The EECs comprise:

> Bangalay Sand Forest;

> Coastal Saltmarsh;

> Swamp Oak Floodplain Forest; and

> Swamp Sclerophyll Forest on Coastal Floodplains.

All four communities are listed under the *Biodiversity Conservation Act, 2016* (BCA Act). There were six Threatened Ecological Communities (TECs) as listed under the EPBC Act returned on the Protected Matters Search Tool with potential to occur in the study area, although only the Coastal Saltmarsh is confirmed from the study area.

Mapping of estuarine macrophytes prepared by DPI (Fisheries) has also been included in **Figure 3-9**, and shows the extent of seagrasses and saltmarshes in the study area. The seagrasses are mapped as Zostera and a mixed bed of Zostera and Halophila. Shoalhaven Council's Tabourie Lake Estuary Health Report Card showed that seagrasses in Lake Tabourie Lake decreased by 82% between 1985 and 2006, though this was attributed to largely due to natural processes associated with fluctuating water levels and associated changes in Salinity.

Searches of the following databases were conducted on 11 April 2017, adopting a 10 km by 10 km search area, to investigate the potential occurrence of threatened species in the study area:

> EPBC Protected Matters Search Tool for species listed under the EPBC Act. The Tool also includes records of migratory birds protected under the Japan-Australia Migratory Bird Agreement (JAMBA), China-Australia Migratory Bird Agreement (CAMBA) and Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA);

> OEH BioNet Atlas for species listed under the BCA Act; and

> Department of Primary Industries (Fisheries) threatened species distribution mapping for species listed under the *Fisheries Management Act 1994.*

There were not threatened fish species records for Tabourie Lake.

There are a number of records of threatened species listed under the BCA Act and/or the EPBC Act, as shown in **Table 3-5**. The BioNet database results for species listed under the BCA Act is based on actual observations of species in the search area, noting that some records may be from a number of years ago, or may represent a single occurrence of the species in the search area (i.e. as opposed to a resident species or population).

The Protected Matters Search tool results for EPBC Act listed species are less reliable as they are based on the species distributions and potential occurrence, as well as species records. Similarly, the species records may be from migratory species or those transiting the area, as well as resident species.

The three bird species with records immediately around the entrance include:

> Sooty Oystercatcher – wader bird with potential to forage in and/or around the lake, the last sighting is from the 1990's; and

> Little Tern – potential to nest on the sand, although there are no records since 1950.

The assessment of the preferred option should consider the potential impacts on biodiversity, and these threatened species in particular. In the event any significant impacts on threatened species are identified, this may trigger the requirement for a Species Impact Statement.

Table 3-5 Threatened Species Records for the Study Area

Species Name	Common Name	BCA Act Listing*	EPBC Act Listing^
Amphibia			
Litoria aurea	Green and Golden Bell Frog	E1,P	V
Heleioporus australiacus	Giant Burrowing Frog		V
Litoria Littlejohni	Littlejohn's Tree Frog		V
Mixophyes balbus	Stuttering Frog		V
Reptiles			
Caretta	Loggerhead Turtle		E
Dermochelys coriacea	Leatherback Turtle		E
Eretmochelys imbricata	Hawksbill Turtle		V
Natator depressus	Flatback Turtle		V
Chelonia mydas	Green Turtle	V,P	V
Hoplocephalus bungaroides	Broad-headed Snake		V
Aves			
Stictonetta naevosa	Freckled Duck	V,P	
Thalassarche cauta	Shy Albatross	V,P	V
Thalassarche cauta steadi	White-capped Albatross		V
Thalassarche melanophris	***Black-browed Albatross***	**V,P**	**V**
Diomedea antipodensis	Antipodean Albatross		V
Diomedea antipodensis gibsoni	Gibson's Albatross		V

Species Name	Common Name	BCA Act Listing*	EPBC Act Listing^
Diomedea epomophora	Southern Royal Albatross		V
Diomedea exulans	Wandering Albatross		V
Diomedea sanfordi	Northern Royal Albatross		E
Phoebetria fusca	Sooty Albatross		V
Thalassarche bulleri	Buller's Albatross		V
Thalassarche bulleri platei	Northern Buller's Albatross		V
Thalassarche eremita	Chatham Albatross		E
Thalassarche impavida	Campbell Albatross		V
Thalassarche salvini	Salvin's Albatross		V
Macronectes giganteus	Southern Giant Petrel	E1,P	E
Macronectes halli	Northern Giant Petrel		V
Gregetta grallaria	Storm Petrel		V
Pterofroma leucoptera	Gould's Petrel		E
Pterofroma neglecta	Kermadec Petrel		V
Haliaeetus leucogaster	***White-bellied Sea-Eagle***	**V,P**	**C**
Hieraaetus morphnoides	Little Eagle	V,P	
Pandion cristatus	***Eastern Osprey***	**V,P**	
Esacus magnirostris	Beach Stone-curlew	E4A,P	
Haematopus fuliginosus	***Sooty Oystercatcher***	**V,P**	
Thinornis rubricollis	Hooded Plover	E4A,P	V
Limosa lapponica baueri	Bar-tailed Godwit	P	V,C,J,K
Limosa lapponica mensbieri	Bar-tailed Godwit		CE
Rostratula australis	Australian Painted Snipe		E
Numenius madagascariensis	Eastern Curlew	P	CE,C,J,K
Calidris ferruginea	Curlew Sandpiper		CE
Sternula albifrons	***Little Tern***	**E1,P**	**C,J,K**
Callocephalon fimbriatum	Gang-gang Cockatoo	V,P	
Calyptorhynchus lathami	Glossy Black-Cockatoo	V,P	
Pezoporus wallicus	Eastern Ground Parrot	V,P	
Lathamus discolour	Swift Parrot		CE
Neophema chrysogaster	Orange-bellied Parrot		CE
Ninox strenua	Powerful Owl	V,P	
Tyto novaehollandiae	Masked Owl	V,P	
Tyto tenebricosa	Sooty Owl	V,P	
Anthochaera phrygia	Regent Honeyeater	E4A,P	CE
Grantiella picta	Painted Honeyeater		V
Botaurus poiciloptilus	Australian Bittern		E
Dasyornis brachypterus	Eastern Bristlebird		E
Daphoenositta chrysoptera	Varied Sittella	V,P	
Pachyptila turtur subantarctica	Fairy Prion (southern)		V
Artamus cyanopterus	Dusky Woodswallow	V,P	
Petroica phoenicea	***Flame Robin***	**V,P**	

Species Name	Common Name	BCA Act Listing*	EPBC Act Listing^
Fish			
Epinephalus daemelii	Black Rockcod		V
Prototroctes marena	Australian Grayling		V
Sharks			
Charcharias Taurus	Grey Nurse Shark		CE
Carcharodon carcharias	White Shark		V
Rhincodon typus	Whale Shark		V
Mammalia			
Balaenoptera borealis	Sei Whale		V
Balaenoptera musculus	Blue Whale		E
Balaenoptera physalus	Fin Whale		V
Eubalaena australis	Southern Right Whale		E
Megaptera novaewangliae	Humpback Whale		V
Isoodon obesulus	Southern Brown Bandicoot		E
Dasyurus maculatus	Spotted-tailed Quoll	V,P	E
Sminthopsis leucopus	White-footed Dunnart	V,P	
Cercartetus nanus	Eastern Pygmy-possum	V,P	
Petaurus australis	Yellow-bellied Glider	V,P	
Petaurus norfolcensis	Squirrel Glider	V,P	
Petauroides volans	Greater Glider	P	V
Petrogale penicillata	Brush-tailed Rock-wallaby		V
Phascolarctos cinereus	Koala		V
Potorous tridactylus	Long-nosed Potoroo		V
Psuedomys fumeus	Smoky Mouse		E
Psudomys novaehollandiae	New Holland Mouse		V
Pteropus poliocephalus	Grey-headed Flying-fox	V,P	V
Mormopterus norfolkensis	***Eastern Freetail-bat***	**V,P**	
Chalinolobus dwyeri	Large-eared Pied Bat	V,P	V
Kerivoula papuensis	Golden-tipped Bat	V,P	
Myotis macropus	***Southern Myotis***	**V,P**	
Scoteanax rueppellii	Greater Broad-nosed Bat	V,P	
Vespadelus troughtoni	***Eastern Cave Bat***	**V,P**	
Flora			
Cryptostylis hunteriana	Leafless Tongue Orchid	V,P	V
Galium australe	Tangled Bedstraw	E1,P	
Boronia deanei	Deane's Boronia		V
Bundawangs gnidioides	Budawangs Cliff-heath		V
Caladenia tessellate	Thick-lipped Spider-orchid,		V
Correa baeuerlenii	Chef's Cap		V
Euclyptus aggregate	Black Gum		V
Genoplesium baueri	Yellow Gnat-orchid		E
Genoplesium vernale	East Lynne Midge-orchid		V

Species Name	Common Name	BCA Act Listing*	EPBC Act Listing^
Haloragis exalata subsp. exalata	Wingless Raspwort		V
Leptospermum thompsonii	Monga Tea-tree		V
Leucopogon exolasius	Woronora Beard-heath		V
Melaleuca biconvexa	Biconvex Paperbark		V
Periscaria elatior	Knotweed		V
Pterostylis gibbosa	Illawarra Greenhood		E
Pultenaea baeuerlenii	Budawangs Bush-pea		V
Syzygium paniculatum	Magenta Lilly Pilly		V
Thesium australe	Austral Toadflax		V
Triplarina nowraensis	Nowra Heath-myrtle		E
Zieria tuberculate	Warty Zieria		V

*Key: P = Protected, V = Vulnerable, E1 = Endangered, E4A = Critically Endangered.
^Key: V = Vulnerable, E = Endangered, CE = Critically Endangered, C = CAMBA, J = JAMBA, K = ROKAMBA

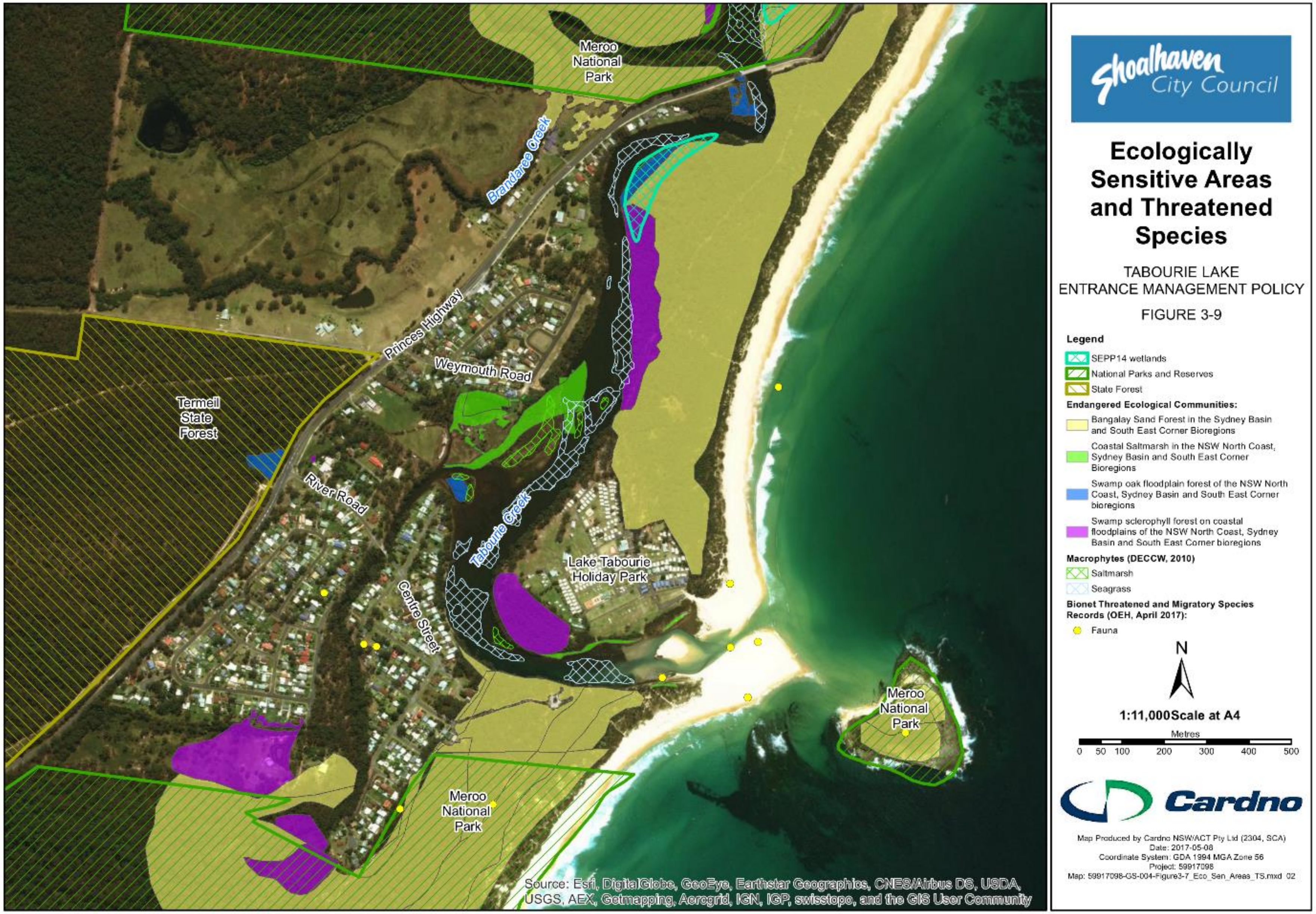


Figure 3-9 Mapping of Endangered Ecological Communities (EEC) and SEPP 14 Wetlands in the study area

3.6.6 Water Quality

Tabourie Lake is defined as an ICOLL (refer **Section 3.3**). Both natural and mechanical openings of the lake have an impact on water quality. While the entrance is closed, any pollutants residing within the lake system will be trapped and remain until the entrance is either naturally or artificially open (though some will also be assimilated within the system). Given the average depth of 0.8 m (estimated by Roper *et al.,* 2011), it is assumed that while closed, mixing primarily occurs via wind forces and catchment inflows (Peter Spurway & Assoc., 2005). The water quality processes in the estuary will are very complex, and highly variable at any given time based on the balance of environmental forcing. It is not the intent of this report to document this in detail.

A number of physical changes to the characteristics of water are expected to change dramatically with the mechanical opening of the entrance. Peter Spurway & Associates (2005) report that during quarterly monitoring salinity concentrations have consistently been recorded as 35 to 36 ppt (parts per thousand), which is equivalent to that of seawater. Ocean flushing is likely to result in higher than normal turbidity conditions, temperature fluctuations (introduction of typically warmer ocean water) and dissolved oxygen fluctuations (with the influx of less oxygen dense ocean water).

Council has monitored water quality regularly since 1989 across 19 sites, of which nine are currently inactive (SCC, 2012). Council uses a Water Quality Index to rate sites on a scale from 'very poor' to 'excellent'. The 2008 – 2010 sampling period indicated the lake to fluctuate between 'medium' and 'good' water quality (SCC, 2012).

It is noted that the properties in the study area are now connected to the reticulated sewage system, and therefore there is now low risk of overflows from on-site sewage systems negatively impacting on the lake.

3.6.7 Potential Approvals Pathway for the EMP

The environmental and social values to be considered for the updated entrance management policy of Tabourie Lake include:

> Provided no significant impacts are identified during the assessment of the preferred option, and assuming also that the review of the EMP confirms the need for entrance opening, it is likely that the ongoing entrance management works would be defined as infrastructure works under the ISEPP and would fall under Part 5 of the EP&A Act;

> A number of threatened species and EECs/TECs were identified within Tabourie Lake and the wider study area. The potential impacts on these species and communities will require careful consideration in the impact assessment;

> The potential impacts of the works on the AHIMS sites in the entrance area will also require careful consideration, and may require further assessment under the *National Parks and Wildlife Act 1979*; and

> The works will likely also require other approvals, permits and licences, including (but not necessarily limited to) landowner access under the *Crown Land Management Act 2016* and a Fisheries Permit under the FM Act.

3.7 Potential Impacts of Climate Change on Entrance Management

As the morphology of the entrance berm is a product of the interaction between fluvial, tidal and wave processes, any impact on these processes associated with climate change may also affect the entrance behaviour, resulting in a new 'dynamic equilibrium'.

Specifically, climate change is expected to result in changes to the Tabourie Lake entrance behaviour due to the following processes, as outlined by Haines *et al.* (2007):

> Mean sea level rise;

> Changes in offshore wave climate; and

> Changes in rainfall behaviour.

3.7.1 Mean Sea Level Rise

It is generally considered that mean sea level rise is likely to result in an accompanying shoreline recession. For a lake entrance, this recession would also be accompanied by a landwards and upwards translation of the entrance berm (Hanslow, 2010), as seen in **Figure 3-10**. This shift in berm position would result in higher maximum lagoon water levels and a higher associated flood risk. The magnitude of the upwards movement of the entrance berm will be governed by the magnitude of the corresponding mean sea level rise. As berm height is controlled by wave run-up processes, any increase in mean sea level will likely result in an equal increase in berm level.

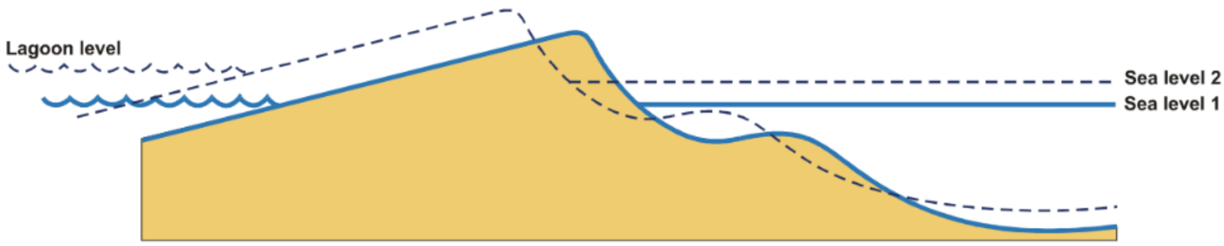


Figure 3-10 Upward and Landward Translation of the Berm Crest due to Mean Sea Level Rise (after Hanslow, 2010)

3.7.2 Offshore Wave Direction

In addition to changes in sea level, climate change may also lead to changes in the direction of wave approach. Hennessy *et al*. (2004) posits that this may result in the prevalent offshore wave conditions shifting to slightly a more southerly direction. This change in wave direction may result in an increase in the south to north longshore sediment transport, and an overall 'rotation' of the beach compartment. At Tabourie Lake, this may result in an increase in the amount of sand washed into the estuary during an open entrance condition. This would increase the speed at which the entrance closes after an opening event, and hence decrease the average amount of time the entrance is open.

It should be noted that there is still a reasonable degree of uncertainty associated with the likelihood changes in wave height and direction, and the magnitude is presently difficult to quantify without detailed numerical modelling.

3.7.3 Rainfall Behaviour

The frequency of flooding and breakout events in an ICOLL are dependent on the total rainfall occurring within the catchment. Therefore, changes to both average annual rainfall and rainfall intensity and frequency will affect the frequency of opening events. CSIRO and Bureau of Meteorology (2015) indicate that over the 21st century mean annual rainfall is likely to decrease in southern Australia, and that extreme rainfall events may become less frequent, but more severe. As a result, it is possible that the frequency of entrance opening may decrease (though this would be offset somewhat be the increase in average lake level due to mean sea level rise), while the magnitude of scour of the entrance during severe rainfall events may increase. However, this impact may be mediated by other factors that affect amount of entrance scour during opening events, such as the presence of underlying bedrock.

It should be noted that there is presently considerable uncertainty regarding climate change projections for changes in rainfall, compared to effects on temperature and mean sea level, of which there is relatively high confidence.

3.7.4 Implications for Entrance Management

As stated in the Lake Tabourie FRMS&P (Cardno, 2016), the potential increase in entrance berm level does not necessitate a change in entrance management, and the trigger level would likely still need to be set with a view to preventing over floor flooding of properties. However, maintaining the existing trigger level does have some consequences:

> The entrance will require more frequent openings, as an increase in mean lake water level means that the trigger level would be reached more frequently;

> There will be a reduced head difference between lake water levels and ocean water levels at the time of breakout, which will result in a less efficient breakout process and less sand being scoured from the entrance; and

> The entrance will be more difficult to keep open as a result of the reduced scour.

If it is elected to increase the trigger level in line with projected sea level rise:

> There will be a greater risk of inundation of foreshore development (although it is noted that there will be a greater risk of inundation regardless of entrance trigger level, as mean water levels approach the current trigger level over time);

> The capacity of the estuary (storage volume) would increase, which may reduce the frequency of breakouts.

The relative levels of the lake, entrance and ocean would remain similar, so opening behaviour and duration should remain closer to the current regime.

3.8 Review of the Need for Entrance Management

The assessment is the FRMS&P (Cardno, 2016) found that entrance management is not an effective flood management strategy, even in small events. In the 20% AEP, for example, if the entrance is closed and is allowed to break open naturally, peak flood levels still exceed 2.0 m AHD and over floor flooding would affect at least one property. There may be some reduction in flood levels for this event if the entrance is open prior to the flood event, whether achieved naturally or mechanically. However, when the entrance is open, there is risk of storm tide inundation of foreshore properties, with the 100% AEP storm tide level being 2.4 m AHD. There is, therefore, a trade-off between risk of catchment flooding and storm tide inundation of properties. If the catchment flood event coincides with an ocean storm, it may not be practical to open the entrance. Hence, the management procedure may require review to take into account these processes.

It is noted that at the time the Draft EMP was prepared, only Council was able to access the lake water level data (with a password). This is now publicly available in real time, and there may be no need for to provide an additional gauge to make reading water levels easier.

4 Alternatives for Entrance Management

4.1 Option 1 - 'Do Nothing' Option

Under this scenario, there is no active management of the lake entrance. For the 'do nothing' option the entrance berm would be overtopped when water levels rise during a rainfall event and the entrance breaks out naturally without any intervention. Under this management approach, the water levels in the lake would be governed by the amount of rainfall over a given time period, the height of the entrance berm, and the rate of entrance scour during the breakout event.

Table 3-2 provides estimated probability of exceedances for berm heights at Lake Tabourie, noting that 80% of the time the berm height exceeds 1.80 m AHD. This means that flood levels within the lake body would likely exceed this level at least 80% of the time, resulting in more frequent and longer inundation of foreshore lands. While this is a natural process, the historic development of the lake foreshores has resulted in a risk to public and private property due to flooding.

This approach is keeping with the NSW DPI policy on ICOLL management, which supports minimal interference with ICOLL entrance barriers, and advocates natural processes being allowed to operate to the greatest extent possible (unless the social, environmental and economic benefits of artificial opening outweigh any potential adverse impacts).

4.2 Option 2 - Continue Existing Approach

Option 2 provides for the continuation of the existing management approach. As stated in **Section 3.5.4**, the current management practice of mechanical entrance opening has proved to be a relatively effective approach for the mitigation of below floor level flooding of properties (noting that there is little benefit in terms of mitigation of more extreme flood events). The trigger level of 1.17 m AHD for mobilisation to open the lagoon generally allows sufficient time for Council to open the entrance before over-floor flooding of properties can occur.

The current approach does, however, significantly increase the amount of times the Lake entrance is opened and the duration of opening beyond that which would naturally occur, leading to environmental impacts.

4.3 Option 3 - Raise Trigger Level

Option 3 proposes continuing the existing management approach, but with a higher mechanical opening trigger level of **1.30 m AHD**. As for Option 2, this option would predominantly serve to address below floor level flooding. The main benefit of this option is that it would lead to fewer mechanical openings of the entrance of Lake Tabourie, thereby reducing the environmental impact of the current practices on the Lake. This option is more in keeping with the minimal interference policy of NSW DPI.

However, there are also several potential negative consequences. Raising the level would result in less reaction time for Council to mobilise and open the lake before lake levels rose high enough to cause below floor level flooding.

4.4 Option 4 - Berm Height Management

When the lake entrance is closed, the berm height plays a very important role in determining the maximum water level that may be reached in Tabourie Lake. The berm height can be managed such that it does not exceed a pre-determined level; this is known as maintaining a 'dry notch', which is a low or 'saddle' point in the entrance berm which the water can preferentially flow across. The purpose of the notch is to dispense with the need to mechanically open the lake when a flood occurs.

If maintained correctly, the notch would breach when the lake water level reaches the appropriate level without requiring Council to mobilise excavators during the event. Option 4, berm height management, would require more frequent mobilisation of an excavator to the beach in order to maintain the notch level, and therefore has potential to result in increased risk to the public and more regular impact on the environment where the excavator accesses the beach.

The setting of the level of the notch needs to consider both its effectiveness in mitigating flooding and the practicality maintaining the notch. If the notch level is set too high, then it is essentially rendered ineffective for below floor level flooding mitigation purposes. However, the level of the notch also needs to be set high enough so that it is not affected by normal coastal processes such as tides and wave run-up. If the notch is set too low, then it may begin to be filled in by sand transported by waves or the wind. This would compromise the maintenance life of the notch to the point where it may become impractical to maintain.

Other ICOLLs that have successfully implemented dry notches (such as Shoalhaven River) are generally in locations where beach berms are naturally higher, and so notches can be set at levels that are less affected by coastal processes. In order to make the dry notch more effective than the present mechanical opening approach for Tabourie Lake, the dry notch level would need to be set lower than the present mechanical opening trigger level of 1.17 m AHD, to say 1 m AHD or possibly lower. Wainwright (2010) estimated that the berm level naturally ranges from 1.8 m AHD (exceeded 80% of the time) to 2.1 m AHD (exceeded 1% of the time).

Therefore, the dry notch is considered to be impractical at Tabourie Lake for two reasons:

> This naturally low berm level means that the notch would likely be affected by the local coastal processes, and would likely fill-in frequently enough that maintenance would be less practical than the current mechanical opening approach; and

> If the notch was set back far enough to be less frequently affected by wave-over wash, then the notch itself would be so small that it would be rendered only minimally effective.

For these reasons, Option 4 has not been subjected to detailed assessment via computer modelling.

4.5 Option 5 - Construct a Permanently Open Entrance

Option 5 proposes constructing a permanently open entrance through the use of rock armoured training walls. A permanently open entrance would, in theory, lower peak catchment flood levels within the lake by facilitating a more rapid release of flood waters to the ocean. Training walls have been successfully implemented at a number of other ICOLLs along the NSW coastline, such as at Lake Illawarra and the Shoalhaven River. In these instances, training walls have managed to maintain a permanently open estuary and reduce extreme catchment flooding. However, the implementation of training walls at these locations have also led to a number of other physical and environmental impacts.

There are, however, several issues associated with Option 5. From a flooding perspective, the main issue is that a permanently open entrance would allow high spring tides (which occur several times a year) and storm tides to propagate up the estuary and flood low lying properties (as discussed in **Section 3.5.2**). The estimated 100% AEP storm tide level, which has potential to occur once every year, is 1.9 m AHD (refer **Section 3.5.2**), close to the 2.0 m AHD floor level of the lowest lying property. Over time, sea level rise due to climate change would increase the incidence of elevated lake water levels due to coastal processes.

Another issue associated with the trained entrance is the significant cost involved. Rock armoured coastal structures can come with significant costs associated with the design, sourcing and transporting of suitable rock material for construction, and for the ongoing maintenance of the structure. Previous experience in design and cost of such structures indicates that the cost for the required training walls (two walls of 400-500 m length) could be of the order of millions, to tens of millions, of dollars.

Other issues to consider include the visual impact and loss of beach amenity, as well as the disruption to the local community associated with the construction phase.

There is also the impact on the local terrestrial and aquatic ecology, due to the significant alteration of the tidal regime inside the lake. Once constructed, the altered tidal regime within the lake could have impacts on:

> Entrance morphology - The increased tidal prism and tidal velocities would likely change the pattern and scale of shoaling and scouring in the entrance channel, and may also lead to erosion around the lake foreshore. This has potential to negatively impact assets and important ecological areas, such as the dunes and areas used by birds. It would likely also prevent public access for people walking along the beach and may under certain conditions make swimming in the estuary more hazardous;

> Water quality and ecology – It is possible that the increased tidal exchange may improve flushing of the estuary, though detailed studies on the impacts of training walls at nearby Lake Illawarra have not observed such improvements to water quality subsequent to training wall implementation. It would, however, make more of the estuary more saline than is currently the case, with potential to significantly alter the distribution and occurrence of flora and fauna species. This could impact estuarine vegetation such as saltmarsh and seagrass, and increase the occurrence of mangroves, with flow on effects for fauna. Furthermore, the impacts of training walls on water levels within the lake system would also adversely affect estuarine vegetation such as seagrass.

4.6 Option 6 - Pilot Channel

Option 6 involves a mechanical excavation of sand from the entrance berm 1-3 days before a large storm is scheduled to arrive, by digging a pilot channel starting from the ocean. The channel is then progressed lake-wards, with a small width of berm left in place so as not to induce entrance breakout (at least initially). The exercise is intended to reduce the volume of sand required to be removed to instigate a lake breakout, thereby inducing an earlier breakout and reducing flood levels (and possibly duration) within the lake. This would reduce risk to personnel, who often have to excavate the entrance during a storm event under the current management practice.

Figure 4-1 Excavation of the Pilot Channel on 17 March 2017

The option would be undertaken as an additional component to Council's current entrance management policy of opening the lake once trigger levels reach 1.17 m AHD. The potential benefits of this option are:

> The mobilisation of personnel and machinery to the mechanically open the lake is a faster and safer process, as most of the required excavation has already been undertaken;

> If the storm is particularly severe, then the lake may open naturally before Council has time to mobilise following the trigger level exceedance, and this natural opening would occur earlier than would otherwise be the case, thereby lowering flood levels; and

> If the forecasted lake water level does not arrive, or turns out to be less severe than anticipated, then the pilot channel may remain effective for a brief period of time (before coastal processes re-fill the channel) should a subsequent severe storm arrive with little warning.

This option is theoretically effective; however, there are some issues to consider. The first is that if the pilot channel is excavated too early, then coastal processes will begin to re-fill the channel before the storm arrives, thereby reducing its effectiveness. If the channel is excavated too late, then Council may as well remain on-site to open the lake, as returning several hours later to open the lake may be impractical.

While this option may theoretically have positive flooding implications, it is also dependant on storm forecasts, which may not be sufficiently accurate or available far enough ahead of time in order to properly implement. Therefore, it could only ever be considered as an option that supplements Council's current management policy, rather than a replacement.

Another consideration is that excavation of the initial pilot channel would make easier for members of the public to undertake unauthorised opening of the entrance - with a shovel for instance. Such openings are illegal, and may result in the lake opening prior to the optimal time in terms of tidal driven head difference.

5 Assessment of Management Options

5.1 Options Assessment Methodology

In order to identify a preferred option for entrance management, the potential options outlined in **Section 4** were assessed using a multi-criteria analysis informed by:

> Stakeholder and community consultation feedback (refer **Section 5.2**);

> Hydrodynamic and morphological computer-based modelling of a sub-set of options in order to determine the impacts of each option on flood levels and the duration of inundation in the lake (refer **Section 5.3**); and

> A semi-quantitative triple-bottom line assessment, including consideration of the cost of implementation of each option (refer **Section 5.4**).

5.2 Stakeholder and Community Consultation

A community workshop was held in Lake Tabourie on the 9 August 2017 to present the initial findings of this entrance management policy review, including the results presented in **Sections 1 to 3** of this report. The six options discussed in **Section 4** were also presented and discussed with the community.

Following the workshop, a survey was released to enable the community to rank each of the six options and identify their preferred option, or to suggest an alternative option for consideration. Over 90 responses were received.

The following questions were asked in the survey:

> Q1 **-** We may wish to discuss your responses with you, and would be grateful if you could please provide your contact details below. Please be assured your contact details will remain confidential.

> Q2 **-** We appreciate that, as a member of the Lake Tabourie community, you will have a view on how the entrance should be managed into the future. We have prepared six management options for your consideration. Please rank the options from 1 (most preferred) to 6 (least preferred).

> Q3 **-** Do you feel there are any other entrance management options that have not been considered? If so, please provide further information below.

Table 5-1 and **Figure 5-1** show the options ranking results, including an indication of how respondents ranked each option. An average score is also provided, whereby each respondent ranked their most preferred option ‘1’ and their least preferred option ‘6’. The survey results were inconclusive, with no clear preference indicated by the community. The ‘most preferred’ options were Options 3 (Raise trigger level) and 4 (Dry notch) with an average score of 3.1 out of 6, followed closely by Option 2 (Existing approach) with a score of 3.2.

The least preferred options were Option 1 (Do nothing), which would allow flooding to occur with no intervention. Option 6 (Construction of a permanently open entrance) appeared to be a fairly polarising option, being scored as the most preferred option by 38.8% of respondents, and least popular by 30.6% of respondents.

Table 5-1 Question 2 - Preferred Management Options Scores

Entrance Management Option	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Average Score
Option 1 – Do nothing	6.7%	4.4%	10.0%	6.7%	20.0%	52.2%	**4.9**
Option 2 - Current approach	20.0%	13.3%	17.8%	33.3%	8.9%	6.7%	**3.2**
Option 3 – Raise trigger level	17.8%	24.4%	13.3%	22.2%	18.9%	3.3%	**3.1**
Option 4 – Berm height management	12.0%	27.2%	25.0%	14.1%	19.6%	2.2%	**3.1**

Entrance Management Option	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Average Score
Option 5 - Permanently open entrance	38.8%	7.1%	5.1%	3.1%	15.3%	30.6%	**3.4**
Option 6 - Pilot channel	5.3%	22.3%	30.9%	18.1%	18.1%	5.3%	**3.4**

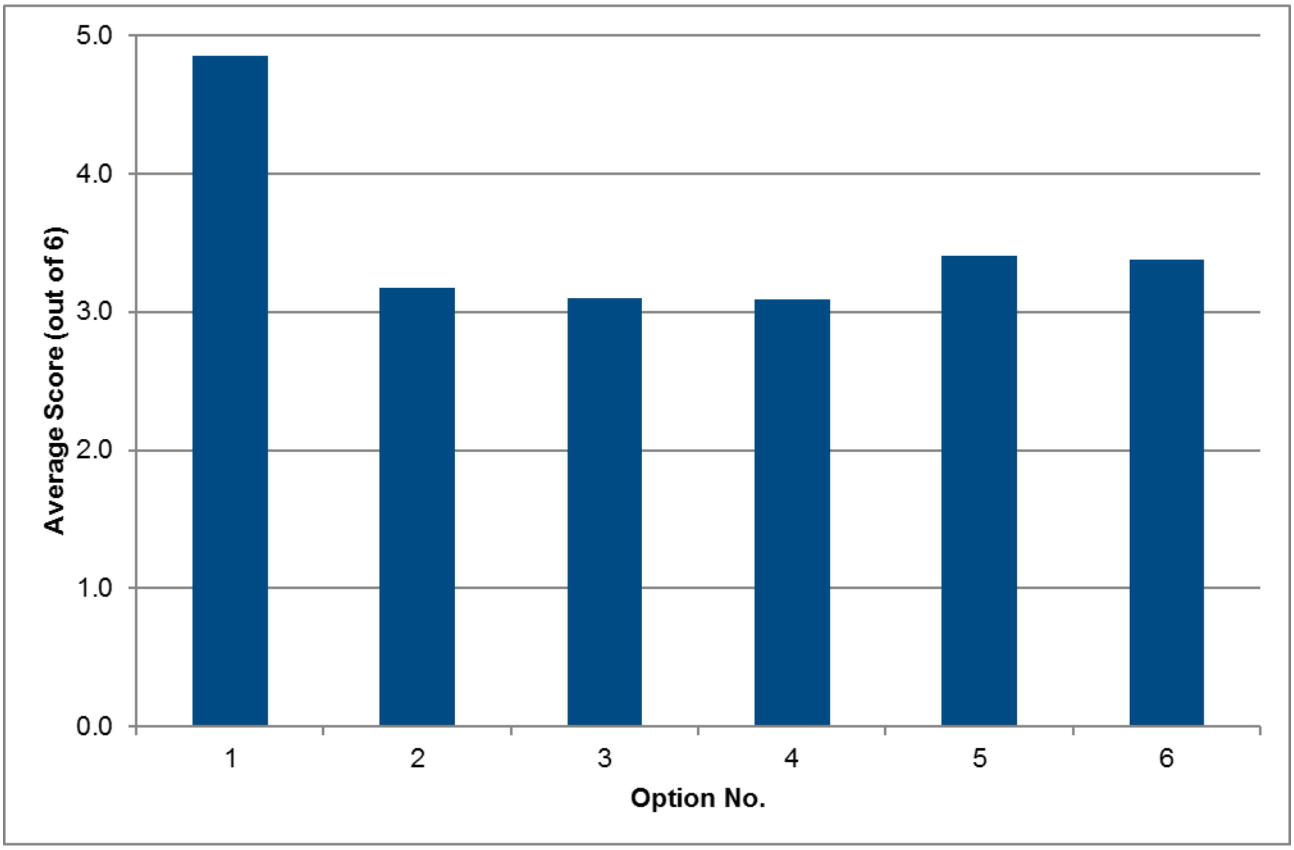


Figure 5-1 Options Ranking by the Community (lower scores indicate the preferred options)

The options are ranked based on community feedback alone in **Table 5-2**. The community feedback was incorporated directly into the multi-criteria options assessment matrix (refer to **Section 5.4**).

Table 5-2 Options Ranking Based on Community Feedback

Management Option	Rank
Options 3 and 4	1
Option 2	3
Options 5 and 6	4
Option 1	6

5.3 Options Modelling

5.3.1 Modelling Methodology

Computer-based numerical modelling of various a sub-set of the entrance management options was undertaken using the Delft3D hydrodynamic and morphological model of the Tabourie Lake Estuary, which was established during the Tabourie Lake FRMS&P (Cardno, 2016). It used the same model set-up and catchment inflow data used in that study.

Numerical modelling was undertaken to assess the impact of three of the potential management options on peak flood levels and durations for the more regularly occurring flood event of a 20% AEP event (5 years ARI). It is noted that the 1% AEP flood event occurs so rapidly that entrance management is not feasible for purposes of flood mitigation; hence it was not considered in the options assessment.

Option 1 was not modelled as it was lowest ranking and was considered unacceptable to the community. Option 5 was not modelled as it was considered unacceptable due to its lower ranking, high cost of implementation and risk of coastal inundation (refer **Section 4.5**). Option 4 was not modelled due it's higher cost and the fact that it's technical feasibility was questionable (refer **Section 4.4**).

The remaining three options modelled included:

> **Option 2:** Existing approach with trigger level of 1.17 m AHD;
> **Option 3:** Raising the trigger level to 1.30 m AHD; and
> **Option 6:** Incorporation of a pilot channel (in conjunction with the existing trigger level).

Each of the three options was modelled under five discrete conditions, summing to a total of 15 model simulations:

> **Condition A:** High High Water Springs (HHWS; plus wave set up) and initial berm height of 2.1 m (i.e. 1% berm height, refer **Table 3-2**);
> **Condition B:** HHWS (plus wave set up) and initial berm height of 1.8 m (i.e. 80% berm height, refer **Table 3-2**);
> **Condition C:** 1% AEP ocean level (plus wave set up) and initial berm height of 2.1 m (i.e. 1% berm height, refer **Table 3-2**);
> **Condition D:** 1% AEP ocean level (plus wave set up) and initial berm height of 1.8 m (i.e. 80% berm height, refer **Table 3-2**);
> **Condition E:** HHWS + 0.4 m sea level rise (plus present day wave set up) and initial berm height of 2.2 m (i.e. 80% berm height under sea level rise conditions, refer **Table 3-2**).

The model results are discussed in **Section 5.3.2** and were used to inform the multi-criteria matrix-based options assessment (refer **Section 5.4**).

5.3.2 Results

Peak water levels at the MHL gauge located on the east of the lake near the caravan park are provided for the full suite of simulations are provided in **Table 5-3**. There was very little spatial variation across the study area where properties may be affected, and so the peak water levels can be considered representative for purposes of assessing the potential flood impacts of each option. The results have generally been compared back to the existing management approach (i.e. Option 2).

Results have been presented for Conditions A, C and E in **Figures 5-2**, **5-3** and **5-4** respectively.

Figure 5-2 Peak Water Levels for Each Option for Each of Model Run

Option	Condition A	Condition B	Condition C	Condition D	Condition E
Option 2	1.86	1.86	2.52	2.53	1.86
Option 3	1.93	1.93	2.52	2.53	1.93
Option 6	1.76	1.76	2.52	2.52	1.77

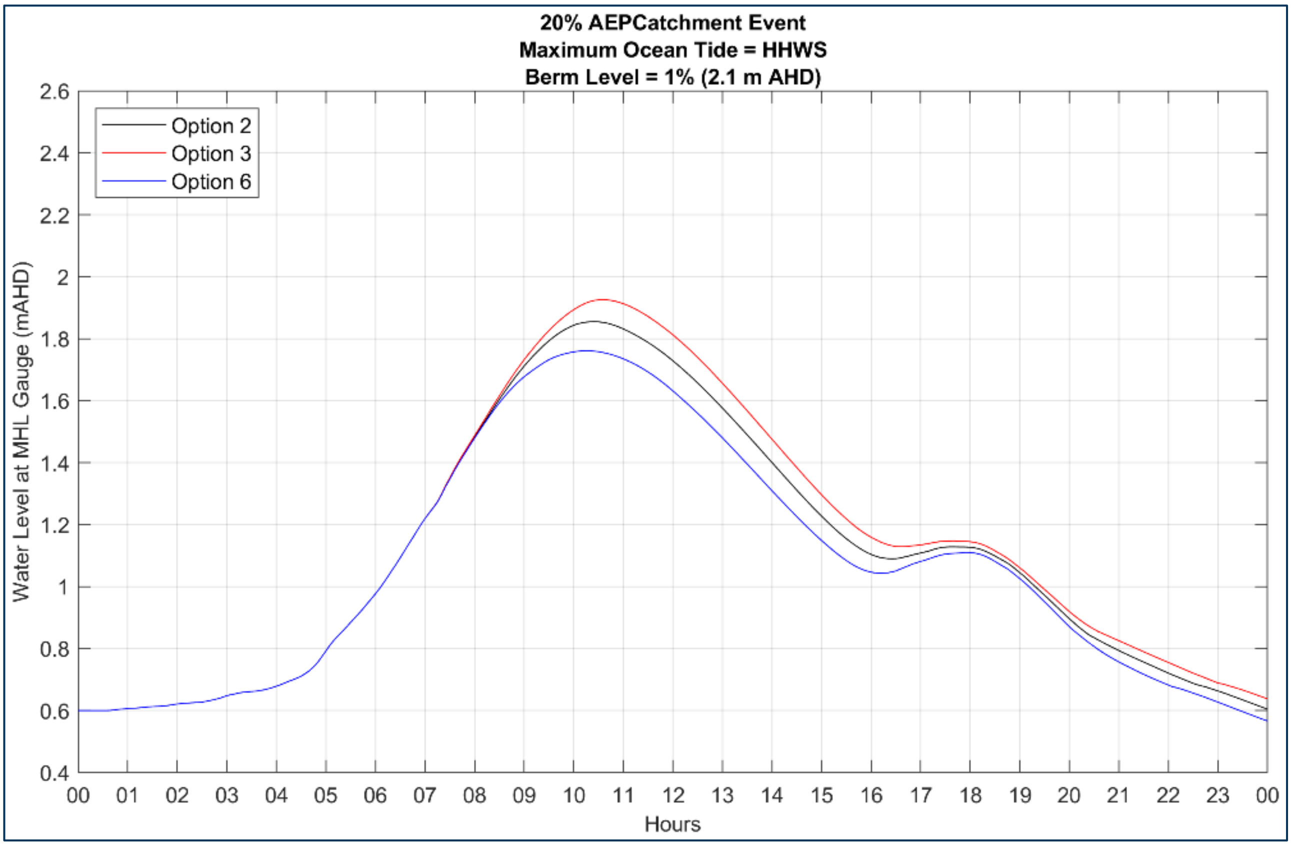


Figure 5-3 Results for Condition A

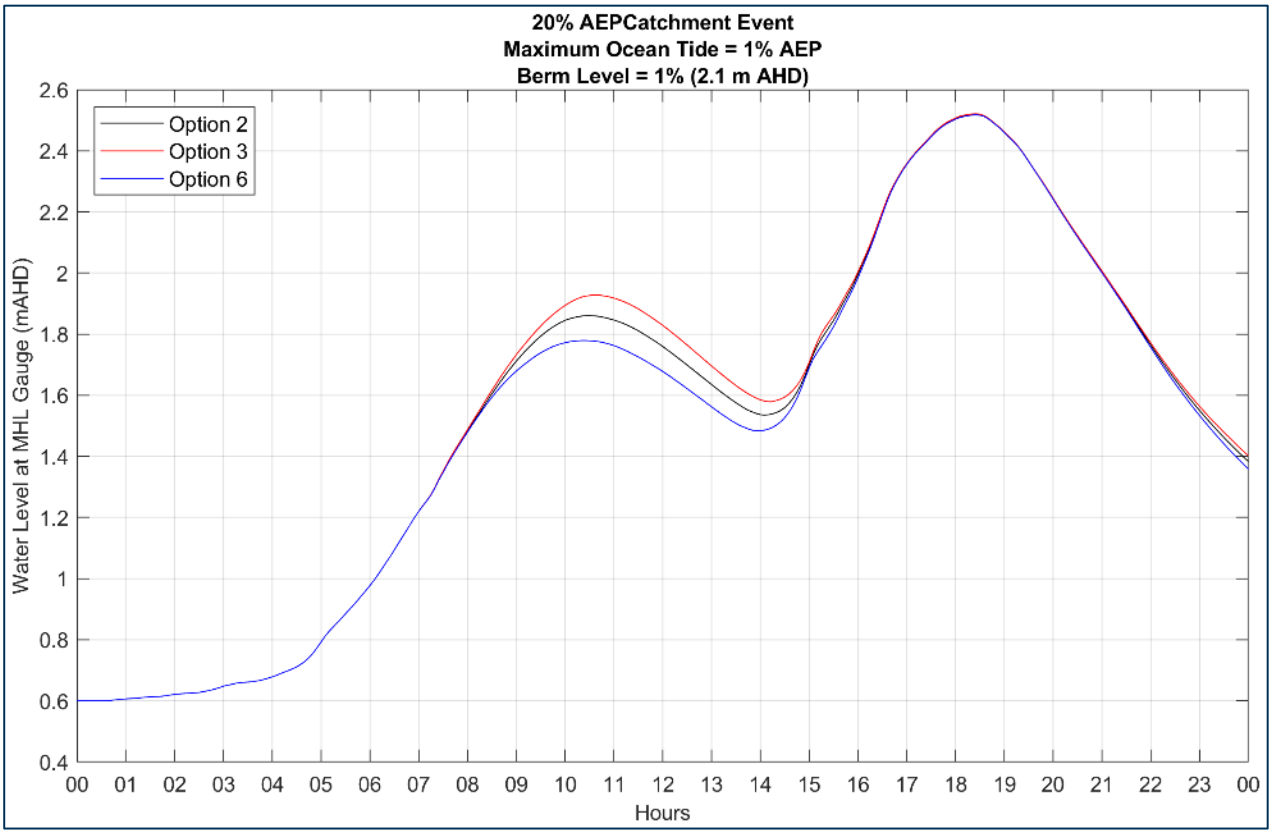


Figure 5-4 Results for Condition C

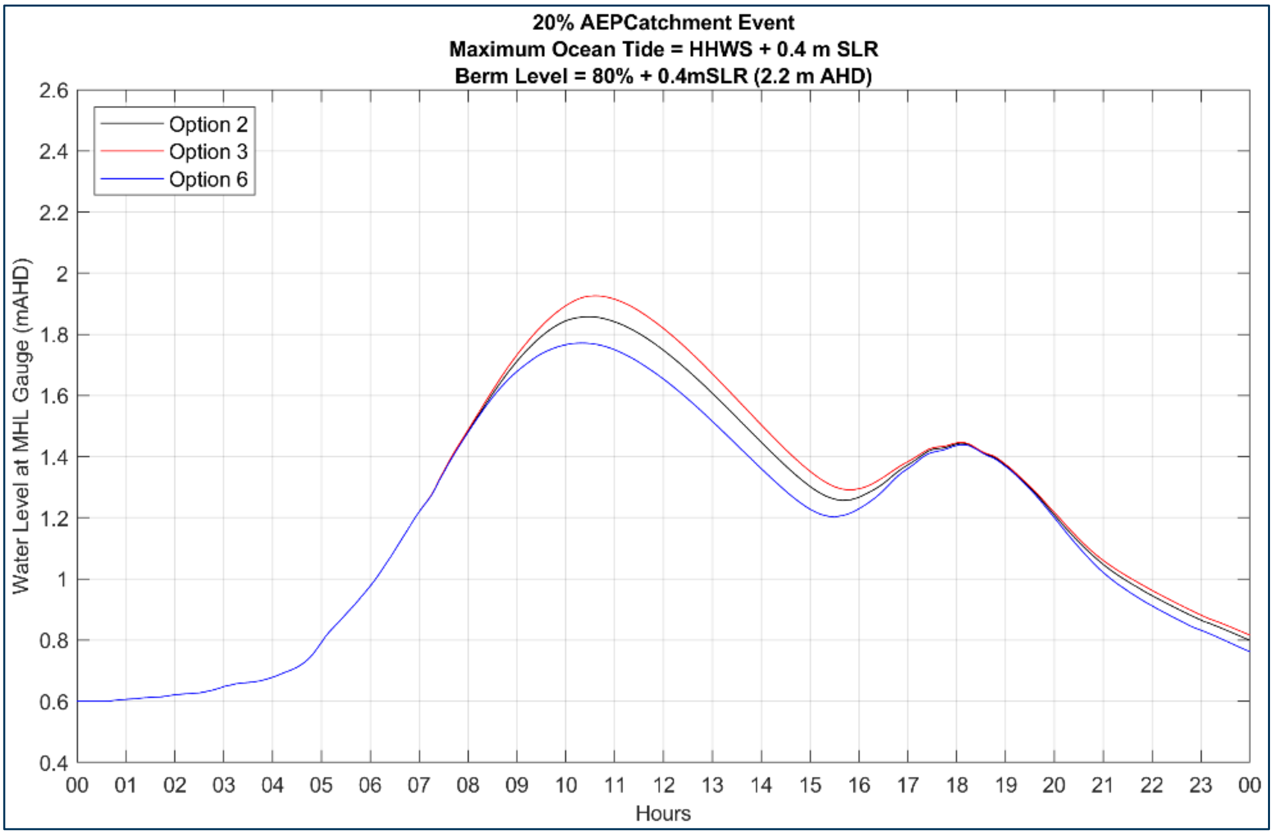


Figure 5-5 Results for Condition E

Impact of Berm Height

The initial berm height did not appear to have a significant impact on flood impacts.

The results for the Conditions A and B simulations show minimal difference in terms of peak flood level, and hence the rate of drainage of flood waters from the lake. This indicates that for more a frequent flood events like the 20% AEP, the water levels at the entrance aren't high enough to overtop the berm completely. While the maximum water levels at the location of the MHL water level gauges are slightly different at around 1.86 m AHD and 1.93 m AHD, being higher than the 1.80 m AHD berm level), the water surface slopes downward getting closer to the entrance, until it is lower than 1.80 m AHD berm at the entrance. Therefore, for more frequent flood events, the height of the berm is less important, and each option will produce more or less the same flood mitigation result regardless of the berm height at the time of implementation. The height of the berm would likely effect flood levels for more severe, rarer events, such as those of magnitude 10% AEP or larger.

For Conditions C and D, the results show that the height of the berm (and the degree of entrance scour after catchment flooding) has minimal impact on the tidal inundation during a 1% AEP tide (including wave set-up).

Comparison of Condition E with Conditions A and B shows that each option will keep the same level of efficacy under a 0.4 m sea level rise condition. That is, the higher ocean tides, and resulting loss of head between the lake and ocean has only minimal impact for the 20% AEP event.

Option 3: Raise the Trigger Level

Comparison of results for Options 2 and 3 shows that raising the trigger level from 1.17 m AHD to 1.30 m AHD (an increase of 13 cm) would result in an increase in the maximum flood level. However, the increase in flood level is not one for one, and flood levels only increase for Option 3 by around 7 cm (from 1.86 to 1.93 m AHD) for conditions A and B. The increase is non-linear due to the fact that as flood level increases, so too does the available flood storage. Additionally, the flood levels are likely heavily influenced by the geometry of the entrance channel, which constricts the rate of lagoon outflow.

The results also indicate show the same level of storm tide inundation for Options 2 and 3. This would suggest that Options 2 and 3 result in a comparable level of entrance scour, and therefore allow ingress of the storm tide to the same degree.

Option 6: The Pilot Channel

For Option 6 (pilot channel plus existing trigger level) does have a quantifiable flood benefit. The results for the Conditions A and B simulations show that the addition of a pilot channel results in a reduction of peak flood levels of around 10 cm when compared to Option 2 (existing approach). The pilot channel facilitates more rapid entrance breakout by reducing the volume of sand to be scoured out during the flood event. Option 6 also has potential to reduce flood duration (i.e. time spent above 1.2 m AHD) by about an hour. It should be noted that this modelling assumes no channel infilling in between the excavation of the channel and the entrance break out during the flood event. As discussed in **Section 4.6**, in reality the pilot channel may be infilled by coastal waves during the time between its excavation and the entrance breakout, such as during an east coast low when heavy rainfall and high wave conditions tend to occur at the same time.

The results also indicate show the same level of storm tide inundation for Options 2 and 6. This would suggest that Options 2 and 6 result in a comparable level of entrance scour, and therefore allow storm tide ingress to the same degree.

5.4 Multi-criteria Options Assessment

Each management option was assessed using a multi-criteria matrix based framework that acts as a decision-support tool. The multi-criteria matrix incorporates the calculation of a cost-benefit index based on a quadruple bottom line assessment in accordance with the requirements of the NSW Government's Estuary Management Policy.

Each option was scored against the following social, environmental and governance criteria:

> Environmental criteria:
  – Impact on natural physical processes,
  – Impact on ecological processes,
  – Sustainability under a climate change (sea level rise) scenario (informed to some extent by the modelling results);
> Social criteria:
  – Level of risk to infrastructure and property (e.g. from flooding; informed by modelling results),
  – Impact on recreational amenity, public access and public safety,
  – Level of community support, based on the community survey results (refer **Section 5.2**); and
> Governance criterion:
  – Compatibility with the policy and legislative framework.

Scores ranging from -3 (strongly negative impact) to 0 (neutral or no impact) and +3 (strongly positive impact) were allocated for the environmental, social and governance criteria as described in **Table 5-4**. The scores for each of these criteria were summed to calculate the raw benefit index.

The economic impact of each option was assessed by calculating the Net Present Value of Implementation of each option, which was based on a function of any capital and ongoing costs of implementation over a ten year period of implementation, adopting a 7% discount rate. The cost estimates are preliminary in nature, and have been based on information provided by Council on their current entrance management costs.

Finally, a cost:benefit index is calculated based on a function of the net present value (cost of implementation) and the raw benefit index. The cost:benefit index can then be used to rank the options against each other.

Table 5-3 Options Scoring Descriptors

Criteria	Score						
	-3	-2	-1	0	+1	+2	+3
Impact on natural physical processes	Significant change to natural tidal processes, beach morphology, estuarine water levels, estuarine water quality and entrance behaviour.	Moderate or occasional change to natural tidal processes, beach morphology, estuarine water levels, estuarine water quality and entrance behaviour.	Negligible change to natural tidal processes, beach morphology, estuarine water levels, estuarine water quality and entrance behaviour.	No impact on natural hydraulic processes.	N/A	N/A	N/A
Impact on estuarine ecology	Permanent change in estuarine ecology (e.g. shift in ecosystems).	Moderate and/or longer-term negative impact on estuarine ecology. May be restored.	Minor, short-term negative impact on estuarine ecology. Natural recovery likely.	No impact on estuarine ecology.	N/A	N/A	N/A
Sustainability under climate change scenario	N/A	Not sustainable in the long term (e.g. up to 0.9 m sea level rise).	Not sustainable in the short term (e.g. up to 0.4 m sea level rise).	N/A	Sustainable in the short term (e.g. up to 0.4 m sea level rise).	Sustainable in the long term (e.g. up to 0.9 m sea level rise).	N/A
Level of risk to infrastructure and properties from inundation	Significant increase in risk to property and people.	Moderate increase in risk to property and people.	Minor increase in risk property and people.	No change in level of risk from flooding or coastal processes under "do nothing" approach.	Minor reduction in risk property and people.	Moderate reduction in risk to property and people.	Significant reduction in risk to property and people.
Impact on recreational amenity, access and public safety	Long-term or permanent reduction in recreational amenity and/or access. Increased risk to public safety.	Impact on recreational amenity, public access and/or public safety that requires active management.	Minor, short-term impact on recreational amenity, public access and/or public safety during the works.	No impact on recreational amenity, access or public safety.	Provides short-term improvement recreational amenity (e.g. via improved water quality for primary and secondary recreation).	Provides medium-term improvement recreational amenity, access or public safety.	Provides long-term improvement recreational amenity, access or public safety.
Likely level of community support	N/A	Unacceptable to community and/or highly divergent range of views with potential for conflict amongst community members.	Not supported by community.	N/A	Supported by small number of community members.	Supported by a large number of community members.	N/A

Criteria	Score						
	-3	-2	-1	0	+1	+2	+3
Compatibility with statutory and policy context	N/A	N/A	Not likely to be supported.	N/A	Compatible. Requires environmental approvals.	Preferred. May or may not require environmental approvals.	N/A

The full list of management options was ranked on the basis of the Adjusted Benefit Index. The results of the options assessment are provided in **Table 5-5**.

The highest ranked option was Option 3, which provides for the raising of the existing trigger level to 1.30 m AHD. Options 2 (existing approach) and 4 (pilot channel) were the second highest ranked options, followed by Option 6 (pilot channel). The lowest ranking options were Option 5 (permanently open entrance) and Option 1 (do nothing).

Based on the options assessment outcomes, the preferred option is Option 3.

5.5 Community Consultation on the Draft Policy

The outcome of the options assessment and the draft EMP were subject to public exhibition by Council between 21 January 2019 and 22 March 2019. As part of this public exhibition, the Draft EMP was presented to the local community on 20 February 2019 at a Community Workshop at the Tabourie Lake Rural Fire Service (RFS) Shed. More than 30 community members attended this workshop.

In total 12 online submissions have been received, of which seven submissions were in support of the draft EMP, one was neutral, and four were against. Of the submissions that were not in favour of the Draft EMP, one submission was made by ten residents.

Table 5-4 Multi-Criteria Options Assessment Results

Option Description	Impact on natural physical processes	Impact on estuarine ecology	Sustainability under climate change scenario	Level of risk to infrastructure & properties	Impact on recreational amenity, access & public safety	Likely level of community support	Compatibility with statutory & policy context	Raw Benefit Index	Preliminary Estimate of Capital Cost	Preliminary Estimate of Annually Recurrent Cost	10 Year Net Present Value	Benefit Cost Index	Rank
Option 1 – Do nothing.	0	0	-1	-3	-2	-2	-1	-9	$ -	$ -	$ 0	-1.7	5
Option 2 - Current approach (open at 1.17 m AHD).	-1	-1	-2	2	0	1.5	1	0	$ -	$ 7,500	$ 52,677	0.1	2
Option 3 – Raise trigger level (open at 1.30 m AHD).	-1	-1	-1	2	0	2	2	3	$ -	$ 5,000	$ 35,118	0.7	1
Option 4 – Dry notch.	-1	-1	-2	1	0	2	1	0	$ -	$ 15,000	$ 105,354	0.0	3
Option 5 - Permanently open entrance.	-3	-3	-3	-2	-2	0	-1	-14	$ 5,000,000	$ 5,000	$ 5,035,118	-9.4	6
Option 6 - Pilot channel.	-2	-1	-2	3	-1	1	1	-1	$ -	$ 10,500	$ 73,748	-0.2	4

6 Entrance Management Policy

6.1 Entrance Management Policy

The logic behind this policy relates to the threat of flooding of private property and public assets situated on low lying areas around the lake foreshore. The aim of the policy is to address the following issues in particular:

> The rear yards and below-floor areas of at least four houses along the Princes Highway are inundated by lake levels as low as 1.0 m AHD. Although not resulting in direct damage as such, saturated soil can cause odours from rotting vegetation and limit access to outbuildings if sustained for lengthy periods;

> Garages and outbuildings such as laundries and sheds in this location can flood if the lake reaches a level of around 1.3 to 1.4 m AHD; and

> The lowest house floor level is 2.0 m AHD.

> As discussed in **Section 2.2**, the FRMS&P, identified that in the 20% AEP flood event, two properties experience over floor flooding and 21 properties have flooding below floor level.

The entrance management policy contains the following appendices and attachments:

> **Appendix A:** Includes a flowchart of outlines the decision making process;

> **Appendix B:** A list of relevant contacts;

> **Appendix C:** A map of the entrance and preferred location and orientation of the channel for a mechanical opening; and

> **Appendix D:** A copy of the entrance monitoring sheet.

6.2 Decision Making Framework

There is a need to address extended elevated lake levels due to the impact over time on flooded yards. This policy addresses this issue by considering a lake opening if lake water levels have been at an elevated level (defined as being **above 1.0 m AHD**) for a continuous period of two months. The requisite is that after two months, lake opening can take place only in a non-breeding season for threatened shorebirds or if clearance from NPWS for the excavation has been obtained.

The policy also allows for the mechanical opening of the entrance when lake water levels are elevated and heavy rain is predicted such that lake water levels are likely to exceed 1.3 m AHD overnight. This provision is required because, even for more frequent events (such as the 20% AEP), the rate of rise of lake water levels can be as high as 0.3 m per hour (see **Section 3.4.2**). Due to these high rates of rise, when lake water levels exceed 1.0 m AHD it may be necessary to proactively open the entrance to prevent overnight flooding where heavy rain is forecast overnight. Forecasts of heavy rain are typically provided 24 to 48 hours in advance.

Appendix A (attached to this policy) outlines the decision making process to be followed before a mechanical entrance opening is undertaken. The following summarises conditions under which the lake entrance can be mechanically opened:

1. If the lake water level at or exceeding 1.3 m AHD - then the lake shall be mechanically opened as soon as conditions permit (see **Section 6.4** for a description of those conditions);
2. If the lake water level stabilises after rainfall at a level between 1.0 m and 1.3 m AHD, then
    a. If heavy rain is predicted and lake water levels are likely to exceed 1.3 m AHD overnight;

    OR

    b. If a period of over two months has elapsed since attaining a level of 1.0 m AHD;

    AND

c. If it is non-breeding season for threatened shorebirds, or clearance from NPWS has been obtained (the breeding period typically extends from late August to March in any year).

Additionally, the following conditions are desirable to enable a successful opening, but are not essential:

> Continuing moderate to heavy rainfall, to allow a greater degree of entrance channel scour;

> Relatively large ocean tidal range (greater than 1.0 m), with opening to coincide with a falling tide. Preference should be given to undertaking the works during a spring tide, but since these only occur for a few days every fortnight this is not always possible. Nonetheless, the mechanical opening should only be undertaken when high tides are predicted to be lower than the pre-opening lake levels; and

> Relatively low wave action at opening location north of Crampton Island – for safety reasons.

6.2.1 Monitoring of Conditions and Forecasts

At levels below 1.3 m AHD, there is better opportunity to plan an opening. Once water levels reach 1.0 m AHD and rainfall is predicted, monitoring of water levels is to be undertaken so that an opening can be planned for in the event of water levels reaching 1.3 m AHD.

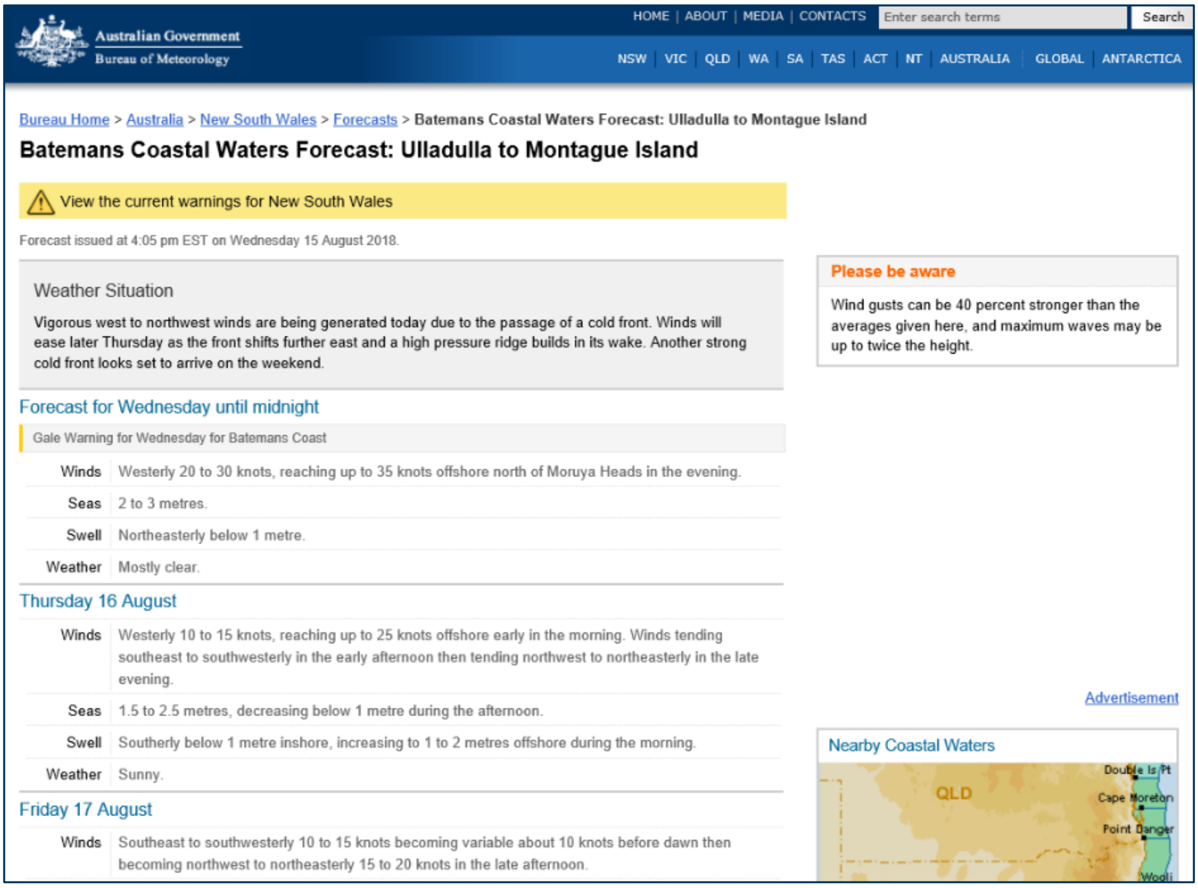
The water level in the lake is to be monitored at 15 minute intervals at the MHL gauge located on the east of the lake near the caravan park, which is reported via: https://mhl.nsw.gov.au/Site-216440

It is important to note that while the data is regularly logged, the information on this webpage may not necessarily be available in real time.

Rainfall in the locality can also be monitored via routine checks of the nearby MHL rainfall gauge at Conjola Lake, which is reported via: https://mhl.nsw.gov.au/Site-216420D

Predicted rainfall and other weather forecasts can be accessed via the following Bureau of Meteorology (BOM) web pages:

> South East Districts Forecast: - http://www.bom.gov.au/products/IDN10061.shtml#ILL



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Bureau Home > Australia > New South Wales > Forecasts > Batemans Coastal Waters Forecast: Ulladulla to Montague Island

Batemans Coastal Waters Forecast: Ulladulla to Montague Island

View the current warnings for New South Wales

Forecast issued at 4:05 pm EST on Wednesday 15 August 2018.

Weather Situation

Vigorous west to northwest winds are being generated today due to the passage of a cold front. Winds will ease later Thursday as the front shifts further east and a high pressure ridge builds in its wake. Another strong cold front looks set to arrive on the weekend.

Please be aware

Wind gusts can be 40 percent stronger than the averages given here, and maximum waves may be up to twice the height.

Forecast for Wednesday until midnight

Gale Warning for Wednesday for Batemans Coast

Winds	Westerly 20 to 30 knots, reaching up to 35 knots offshore north of Moruya Heads in the evening.
Seas	2 to 3 metres.
Swell	Northeasterly below 1 metre.
Weather	Mostly clear.

Thursday 16 August

Winds	Westerly 10 to 15 knots, reaching up to 25 knots offshore early in the morning. Winds tending southeast to southwesterly in the early afternoon then tending northwest to northeasterly in the late evening.
Seas	1.5 to 2.5 metres, decreasing below 1 metre during the afternoon.
Swell	Southerly below 1 metre inshore, increasing to 1 to 2 metres offshore during the morning.
Weather	Sunny.

Friday 17 August

Winds	Southeast to southwesterly 10 to 15 knots becoming variable about 10 knots before dawn then becoming northwest to northeasterly 15 to 20 knots in the late afternoon.

Advertisement

Nearby Coastal Waters

Figure 6-1 Example Screenshot Showing South East Districts Weather Forecast

> 128 km Canberra Radar - http://www.bom.gov.au/products/IDR403.loop.shtml#skip

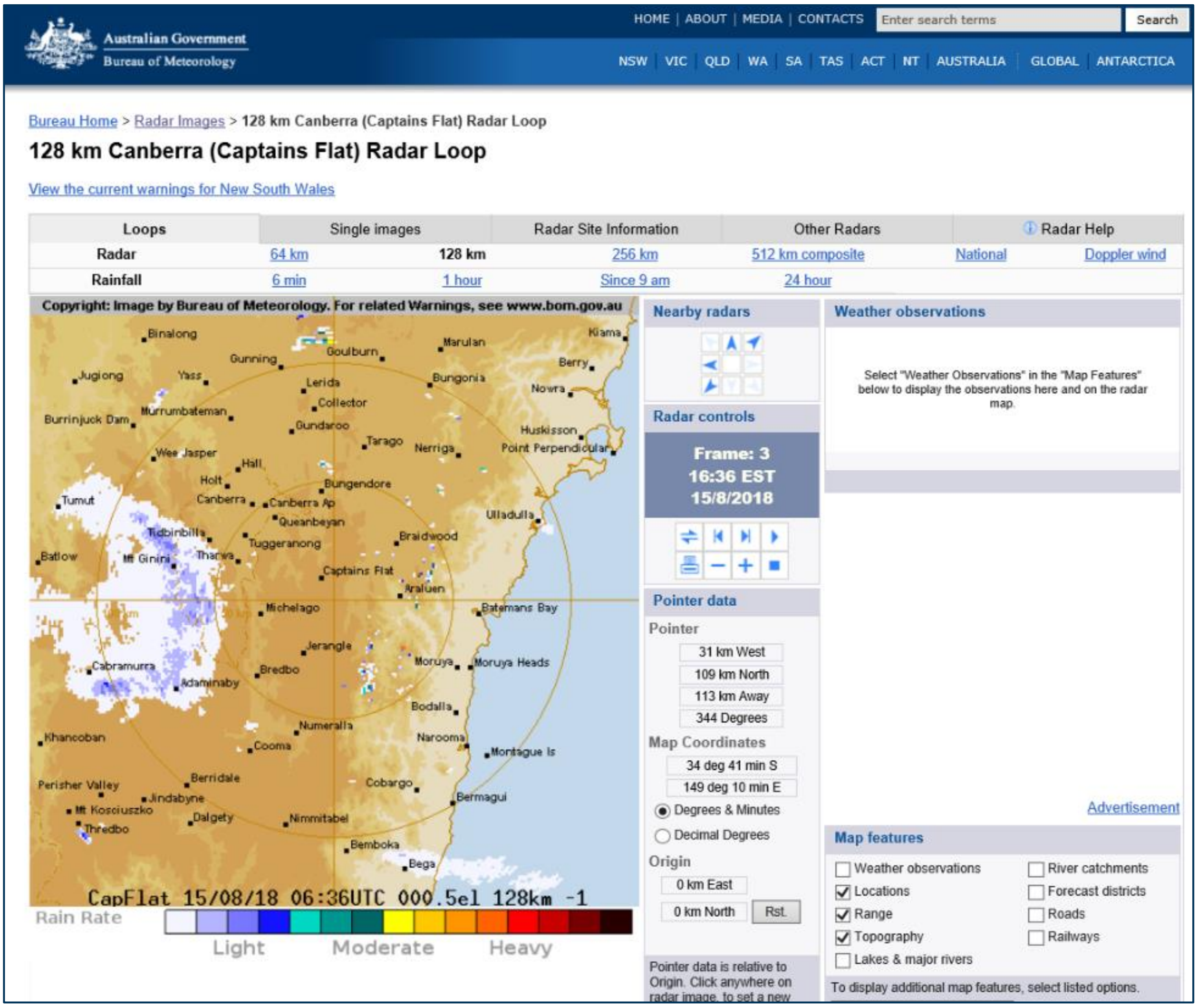

Figure 6-2 Example Screenshot Showing Canberra Region Rainfall Forecast

6.3 Consultation and Communication Protocols

Once a decision has been made to undertake a mechanical breakout, consultation with the following agencies must be undertaken to advise of the planned mechanical breakout:

> The NSW DPI - Fisheries,

> The NSW OEH; and

> The NSW NPWS.

These agencies should be provided with the following information:

> Proposed time of opening;

> Purported reason(s) for opening; and

> Potential health impacts on recreational swimmers on the adjacent beach areas for the following three days.

Failure to notify the public about the health and safety hazards could result in Council being liable for any incidents. Therefore, a press release is necessary.

A list of contacts is provided in **Appendix B**.

Any matters concerning the opening that are raised by the above agencies should (where reasonable and feasible) be satisfactorily addressed by Council prior to the commencement of entrance opening works. Assets around Tabourie Lake are particularly low-lying, and emergency situations are common (when water levels have risen rapidly and urgent opening for flood relief is necessary). Therefore this policy proposes that notification to the above bodies is required, although a three-day consultation period would not be feasible. This policy is subject to council satisfying itself that the accompanying REF is a suitable level of environmental impact assessment for each particular opening event.

6.4 Roles and Responsibilities

Shoalhaven City Council is responsible for entrance opening, should intervention be necessary. The responsible officer in respect to sanctioning mechanical intervention is Shoalhaven City Council Director Assets and Works or their appointed delegate.

The responsible officer in managing the mechanical opening and monitoring process shall be the Shoalhaven City Council City Services Works and Services Manager. The Works and Services Manager would normally delegate responsibility for emergency openings in accordance with this plan, to officers in Council's Natural Resources and Floodplain Management Unit ("Flood Engineers"). The site works would normally be delegated to Council's District Engineer – Southern, who will assign the task to the "Site Supervisor."

The Works and Services Manager will also nominate an officer to liaise with other groups as required. These would include Council's Rangers, Council's Liaison Officer at the Emergency Operations Centre, the State Emergency Service, and NSW Government agencies such as OEH, NPWS and DPI - Fisheries.

The NPWS Area Manager, Shoalhaven Area, is the officer that will arrange for Shoalhaven City Council City Services to be informed whether shorebirds are known to be nesting in the vicinity of the Lake Tabourie entrance.

Details of essential emergency communications are set out in the "Procedures" attachments to this plan.

6.5 Entrance Opening Procedure

Once the decision has been made to undertake a mechanical opening in accordance with the framework in **Section 6.2**, the following breakout procedure should be undertaken:

1. The mechanical opening is to be planned so that where possible the actual opening of the lake occurs shortly after the tide turns from high to low, preferably for the lower of the two high tides of the day;
2. Opening should not be undertaken if wave conditions are dangerous (i.e. if Hs is greater than 4 m):
    a. Predicted offshore wave heights from the BOM can be accessed at: http://www.bom.gov.au/marine/waves.shtml
    b. Real-time offshore wave-rider buoy measurements can be obtained from the MHL at: https://mhl.nsw.gov.au/
3. A mechanical opening should only be undertaken when high tides are predicted to be lower than the pre-opening lake levels:
    a. Predicted tides can be accessed via at the BOM at: http://www.bom.gov.au/oceanography/projects/ntc/nsw_tide_tables.shtml. Tide data is provided for Port Kembla, and this can be considered applicable at Lake Tabourie in this instance. Note that the datum for these predictions are Lowest Astronomical Tide (LAT) - not AHD. At Lake Tabourie AHD ≈ LAT - 0.9 m
4. The recommended access point for the 4WD backhoe operator to access the beach is provided in the figure in **Appendix C**. The machine will access the site as much as possible via the established roads and access ways. Particular care should be taken to avoid damage to or disturbance of vegetated areas of sand dunes;
5. The figure provided in **Appendix C** shows the recommended position and orientation of the excavated channel. The channel should be located to the north of Crampton Island, such that the

lake will drain to the north of Crampton Island, a location that is more sheltered from offshore waves;

6. The opening should be deep enough for scouring flow to develop (i.e. with a flow velocity of greater than 0.4 m/s), at least 1 m. The 4WD backhoe operator is to dig a ‘pilot’ excavation channel starting at the ocean end of the berm and moving progressively towards the lake. The pilot channel is to be around one bucket-width (commonly 2 m or less) and the bed should be graded down to the ocean. The last section of the channel (at the lake end) should be kept closed, and where possible, opened shortly after the next high tide (i.e. the highest possible tide of the day) turns from high to low.

7. In terms of timing, ideally the initial breaching should occur 30 minutes after the published high tide time (adjusted for daylight saving time when appropriate). Initiation of a breakout at this time is likely to result in the most effective and sustained mechanical breakout due to the increasing hydraulic head difference between the water in the lake and the ocean through the progression of the breakout. This will normally require commencement of excavation just after the preceding low tide, allowing for a total of 4 to 6 hours excavation time across the beach;

8. Where access to the internet is not available (due to loss of power during a storm), checking of a water level marker (a ‘tide board’) at a location visible from the Beach St wharf (to be installed at the landward side of the wharf at the approximate location depicted in **Appendix C**) should be undertaken.

9. The volume of sand to be excavated for the breakout channel is expected to be small. This sand is to be retained on the beach, and should be placed to one or both sides of the excavated channel. It may be washed into the channel as it expands laterally. The location for placement of the excavated sand is shown on the Figure in **Appendix C**. *Excavated sand is not to be removed from the beach area*.

10. Appropriate action should be taken to protect public health and safety at the site while excavation equipment is operating and the entrance breakout event is underway. Signage should be erected warning the public of the safety hazards a mechanical opening. There is considerable danger to members of the public that might choose to be at the site during excavation. The potential hazards include being hit by large machinery or being swept to sea by the river as the banks of the scouring entrance channel collapse. To help reduce such risks, Council’s Rangers will provide crowd control when an opening is taking place.

11. Compliance with the occupational health and safety legislation and Council’s health and safety systems is required for the works. The activity requires a clear Safe Work Method Statement. Given the nature of the work and likely hazards, a clear description of operation would address issues such as induction of operators, the use of public access barriers, temporary signage, and hazards management.

12. Declines in water quality, including at adjacent surf beaches, may occur as a result of the lake emptying. Council should consider the need to notify the community of this issue for at least the first 7 days after the opening has occurred.

6.6 Entrance Monitoring

6.6.1 Mechanical Entrance Openings

When mechanical openings have been carried out, monitoring of the entrance should be undertaken to determine the efficiency of the opening and for use in a possible future flood study. Council’s Natural Resources and Floodplain Manager will be responsible for this monitoring function.

For each opening attempt, the following data will be recorded:

> Level of lake prior to opening;

> Date and time of opening;

> Location and length of excavation;

> Approximate width and depth of channel;

> Ocean swell conditions (wave height and direction)

> Rainfall in the preceding 48 hours;

> Date of natural closure of the entrance and cause (if evident); and

> Digital photographs of the opening and breakout development.

The information is to be recorded on a standard monitoring sheet (**Appendix D**).

If possible, an estimate of depth and peak flow velocity should be made coincident with ocean low tide, as well as photographs of the water surface at each time interval. Comment should be made on apparent depth, velocity and width variations along the channel. Tides and prevailing winds should also be recorded.

Once the breach is completed and water starts flowing outwards, the data listed above should be recorded at hourly intervals (at least). Once the lake has emptied to tidal conditions, record keeping can revert to being undertaken on a daily basis. The intent of the data collection is to record the event in such a way that the scouring process can be studied/assessed after each event and so that opportunities to progressively improve the process are identified.

6.6.2 Unassisted Entrance Openings

Monitoring should also include unassisted breakouts, where possible, recording the prior lake level, time and date of opening, the date of lake closure, and any other relevant comments. The monitoring is to be carried out by Council.

The information is to be recorded on a standard monitoring sheet (**Appendix D**), which is to be completed for every entrance opening, whether mechanical or unassisted.

6.7 Entrance Berm Clearance

The berm height and depth (refer **Section 1.3** for defined terms) at Lake Tabourie entrance may build up to such a volume that a mechanical breakout would be difficult, and the length of time it would take to open the entrance would increase substantially. Due to the relatively fast rate of rise of Lake water levels, the increased time required to undertake a mechanical opening under these conditions may result in inundation of low-lying assets around the Lake.

Therefore, it may be necessary on an infrequent basis to undertake an entrance berm clearance. Entrance berm clearance would involve the redistribution of built up sand from the entrance berm to the surrounding beach area. This would increase the likelihood of an unassisted breakout and reduce the amount of time required to undertake a mechanical breakout.

The decision to undertake a major entrance berm clearance project will be undertaken by Council’s Natural Resources and Floodplain Manager after conferring with:

> The NSW DPI – Fisheries;

> The NSW OEH; and

> The NSW NPWS.

This decision will only be made after reference to information provided through the lagoon monitoring system, and by acquisition of berm and bathymetric survey.

Entrance berm clearance operations are a major capital project cost to Shoalhaven City Council and require inclusion in a Capital Works Budget prior to the consideration of such operations.

The essential consideration prior to the initiation of an entrance berm clearance operation is whether the lake berm volume (i.e. depth and/or height) is considered of sufficient size such that the corresponding time required to undertake natural or mechanical breaching of the entrance berm is high that the additional risk to low lying assets is considered unacceptably high.

The following conditions are desirable to enable a successful entrance berm clearance operation:

> Mechanical closure of the entrance may be required if a breakout occurs during a berm clearance operation;

> The entrance berm clearance operations should ideally be conducted in the winter months to minimise disruption to the recreational users of the lake, lake entrance and beach areas.

A separate REF and relevant consultation would be required if entrance berm clearance works are to be undertaken.

6.8 Management of Environmental Impacts

Any mechanical entrance openings conducted under this Policy are subject to the:

> Environmental management and mitigation measures listed in the accompanying environmental impact assessment prepared under the EP&A Act; and

> Requirements of any associated permits or licences obtained for the works.

7 Recommendations

7.1 Adoption of the EMP

It is recommended that Council adopt Option 3 (raising trigger level to 1.3 m AHD) as the Tabourie Lake EMP, as described in Chapter 6. This recommendation is based on the technical assessment presented in Section 5.4, which included a triple bottom line cost-benefit assessment. The assessment resulted in highest score for Option 3 out of the six options considered.

Appendices A, B, C and D are to be used for implementing the Policy.

This document comprises the Entrance Management Plan for Tabourie Lake, and henceforth supersedes the previous Peter Spurway & Associates (2005) EMP. This EMP sets out the procedure by which Council will make a decision to open the entrance of Tabourie Lake for flood mitigation purposes, whether in response to a flood event or to alleviate below floor level inundation of foreshore land.

It should be noted that Shoalhaven City Council have developed a FRMS&P for the Lake Tabourie Township and its surrounds. The options selected for inclusion in the FRMP were based upon both their likely flood mitigation benefit and the funding available from Council and the State Government. These options included structural options aimed at preventing, avoiding or reducing the likelihood of flood risks – including the construction of levees behind properties and raising roads in specific locations.

It is anticipated the implementation of the measures outlined in the FRMP would, in the future, likely remove the need to undertake entrance management and mechanical lake opening as a means of mitigating below floor level flooding. Therefore, it is intended that the EMP be adopted as an “interim” policy, until the relevant measures outlined in the FRMP have been fully funded and implemented.

7.2 Infrastructure and Monitoring Systems

The following infrastructure and monitoring systems should be implemented as part of this Policy:

> A water level marker should be placed at the Beach Street wharf, in the location identified in **Appendix C**. This will assist with determining water levels in the event of a mechanical breakout if access to the internet is lost. The water level marker should be accompanied by clear signage which outlines this Policy and the marker should have a clear mark at 1.3 m AHD (the trigger level). This will inform residents of the Policy and the level at which Council will undertake a mechanical breakout.

7.3 Review and Update of This Policy

This policy and the associated environmental impact assessment should be reviewed every five years, or in response changes in the relevant legislation (as required). Review of the policy should include analysis of all monitoring data collected over that period to ensure that predictions and assumptions outlined in the policy and the environmental impact assessment are correct.

A review of the trigger level should also be in relation to the latest floor level data and levels of any other infrastructure on low lying land at risk of inundation from floodwaters. If any of the low-lying assets listed in this policy are removed or modified, the trigger level should be subject to review and the policy updated as required.

8 Limitations

Opening of the entrance of the Lagoon will not prevent flooding of property and dwellings in many circumstances. For example, even if the entrance is fully open at the start of a large flood (i.e. it has recently been scoured by a preceding flood event) there are existing dwellings that would be expected to be affected by flooding. The Policy aims to reduce (where possible) but not eliminate the impacts of catchment flooding. Further, there may be circumstances (e.g. closed access roads, night, or dangerous sea conditions) where, despite its best endeavours, Council cannot act to mechanically open the entrance of the lake at the levels indicated in this Policy.

The opening of the entrance during times of flood is only one of a range of floodplain management measures discussed in the FRMS&P (Cardno, 2016). It should not be considered in isolation as the overall solution to the flood problem.

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Entrance Management Policy

APPENDIX A

MECHANICAL OPENING DECISION FRAMEWORK

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APPENDIX

B

EMP CONTACT LIST

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APPENDIX C

MECHANICAL ENTRANCE OPENING SCHEMATIC

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APPENDIX

D

ENTRANCE BREAKOUT MONITORING SHEET

About Cardno

Cardno is a professional infrastructure and environmental services company, with expertise in the development and improvement of physical and social infrastructure for communities around the world. Cardno's team includes leading professionals who plan, design, manage and deliver sustainable projects and community programs. Cardno is an international company listed on the Australian Securities Exchange [ASX:CDD].

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