



Final Report

Killick Creek Entrance Management Plan

Kempsey Shire Council

3 March 2025



Document Status

Version	Doc type	Reviewed by	Approved by	Date issued
V01	Draft Report	ND	ND	08.12.2021
V02	Revised Drat	CB	CB	18.01.2022
V03	Final Draft	CJB	CJB	28.03.2022
V04	Final Report	CJB	CJB	03.03.2025

Project Details

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Document Number	21010360_R04_V04_Killick Creek_EMP



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1 INTRODUCTION

1.1 Background

Killick Creek is a small saline coastal lagoon and an intermediately closed estuary on the north coast of NSW adjacent to the town of Crescent Head. The entrance to the estuary naturally alternates between being open or closed to the ocean. These types of estuaries are referred to as Intermittently Closed and Open Lakes and Lagoons (ICOLLS).

Whilst the intermittent nature of the entrance condition is a natural process, sometimes the natural processes of ICOLLS can be at odds with nearby built environments and social and recreational amenity. ICOLLS share a set of common morphological and hydrological attributes which may vary greatly among systems making each system unique. The oscillation between the two states of the estuary is a natural process. But sediment accumulations (sand barrier or berms or forming shoals) at the entrance restricts the tidal-ocean exchange, often even resulting in closure of the entrance which can prevent tidal flushing completely.

Nearly 60% of NSW estuaries are classified as ICOLLS and urbanised areas along the NSW coasts are often situated around them. Thus, there is need for local councils to manage issues of flooding to protect infrastructure and water quality changes when there is no exchange of water or tidal flushing happening in the system.

Historically, these issues were addressed by manipulating ICOLL entrances with or without compliance to government legislation. Artificial alteration of the entrance opening can lead to a range of unintended negative impacts (such as fish kills, water quality impacts) and may have higher costs than expected benefits. Therefore, entrance management needs to be a tailored approach based on unique properties of each system.

An Entrance Management Plan (EMP) is required to outline to local councils and the community if, how and when the estuary entrance should be managed, or other works undertaken. Adoption of a flexible and adaptable 'best practice' EMP is crucial to ensure the environmental and social values of the estuary is protected. It provides specific focus on short term life frames (of around 10-15 years), whilst acknowledging potential future changes related to climate change and sea level rise impacts.

Adoption of a future-risk oriented (climate change, sea level rise, storms etc), integrated, and adaptable 'best practice' EMP is crucial to maintain, and where possible, enhance the environmental and social, cultural, values of the estuary system.

1.2 The Area to Which this Plan Applies

The site is located at the ocean entrance of Killick Creek estuary as it adjoins the ocean. The area covered by this EMP is shown in Figure 1-1. This EMP applies to the catchment of the estuary which comprises the waterway, foreshores and land adjacent to the estuary up to the tidal limit of the tributary creeks and the extent of the drainage catchment directly contributing to the estuary waterways. The area relevant to this EMP also includes the proposed access route for excavator access to the estuary entrance.



Figure 1-1 The area to which this plan applies

1.3 Objectives for Entrance Management

This EMP supports a minimum intervention approach for environmental sustainability of the estuary - with a preference for supporting a “natural as possible” breakout regime, and recommends a procedure for management that minimises the need for artificial opening to:

- Ensure that entrance opening is maintained follows a regime that minimises the constraints of property inundation and flooding; and
- Ensure that the water quality of the estuary is suitable for human contact activities, which includes swimming;
- Responsibly and practically mitigate the impacts of coastal and catchment flooding;
- Conserve the natural habitats and ecosystems within the estuary;
- Gain broad based community understanding and support for management of the lake entrance;
- Clarify responsibilities and accountabilities in relation to entrance management; and
- Document the protocols for entrance management that determines whether intervention is required.

1.4 Coastal Management Context

Kempsey Shire Council (Council) is preparing a Coastal Management Program (CMP) to provide a long term strategy for outcomes for its open coastline and estuary systems under the new NSW Coastal Reforms. A CMP initiates an integrated and coordinated estuary and catchment management approach that aims to



maintain and enhance the social, cultural, economic, and environmental values with coordination between local councils, state agencies and other relevant stakeholders.

Based on the recommendation of the Stage 1 Scoping Study (BMT WBM, 2020), Kempsey Shire Council with the support of Department of Climate Change, Energy, the Environment and Water (DCCEEW) has commissioned this CMP Stage 2 - entrance management study and plan.

The EMP will be included in the pending Kempsey LGA CMP, and implementation of recommended/supported entrance management actions will subsequently commence following Certification by the Minister and adoption of the CMP by Council.



2 STUDY AREA DESCRIPTION

Killick Creek is a small saline coastal lagoon, in the mid-north coast of NSW within the Kempsey Local Government Area (LGA). It is the main natural waterway that runs through the township of Crescent Head, about 20 km from Kempsey – see Figure 2-1.

The creek opens to the ocean through a narrow channel which extends from its entrance at the southern end of the Killick Beach to the tidal influence limit at the floodgates to Belmore Swamps. Down from the floodgates the creek has a catchment area of 5 km² and is approximately 2.75 km long. It has two major tributaries known as the Muddy Arm and the Flood Cutting.

Areas within the catchment are parts of the Hat Head National Park which supports several habitats and aquatic communities. It's protected water and natural environments make it a popular destination for recreational activities used by local community as well tourists. The creek entrance is located within the Crescent Head National Surfing Reserve, which stretches along 3.5 km of spectacular coastline either side of the Head.

Killick Creek is part of the Macleay Flood Mitigation Scheme wherein floodgates have been installed in the upper Connection Creek. The creek is connected to the Macleay River in the upper Belmore and the upper Maria River via Connection Creek. When the upper reaches of the river are inundated during severe flooding events, water is discharged into Killick Creek to mitigate flood risk and protect agricultural land.

Like most ICOLLs, this estuary goes through the cyclic process of its entrance opening and closing influenced by berm formation due to wave actions. In the case of Killick Creek to avoid flooding, the entrance has been artificially modified since 1950 with rock training wall works, but drier climatic condition have historically been known to result in entrance closures.

Prior to the 1950's the natural condition of the estuary entrance was significantly more mobile and dynamic than its present state. A historical aerial of the estuary from 1942 is provided in Figure 2-3, and depicts a wide and variable sand berm, and meandering entrance channel.

As part of the flood mitigation scheme works in the late 1950s, a number of major modifications to Killick Creek entrance took place – see Figure 2-4. The entrance to the estuary was stabilised and straightened by installing a 700 m long rock-armoured revetment along the southern foreshore. Land behind the rock wall was reclaimed and is now the site of the caravan park. To the north of the estuary entrance, the spit was extended southwards around 400 m (therefore constructing the width of the entrance), and then stabilised with dune vegetation. As a result, the estuary entrance is highly modified from its original condition prior to European settlement.

Killick Creek forms an integral component of the Lower Macleay River flood mitigation scheme. Along with Korogoro Creek and Ryans Cut, Killick Creek is used to mitigate major flooding by providing supplementary ocean discharges for floods within the Lower Macleay River, and the Upper Belmore River tributary in particular.



Figure 2-1 Killick Creek and Crescent Head (Source: DCCEEW, 2021)



Figure 2-2 Killick Creek entrance

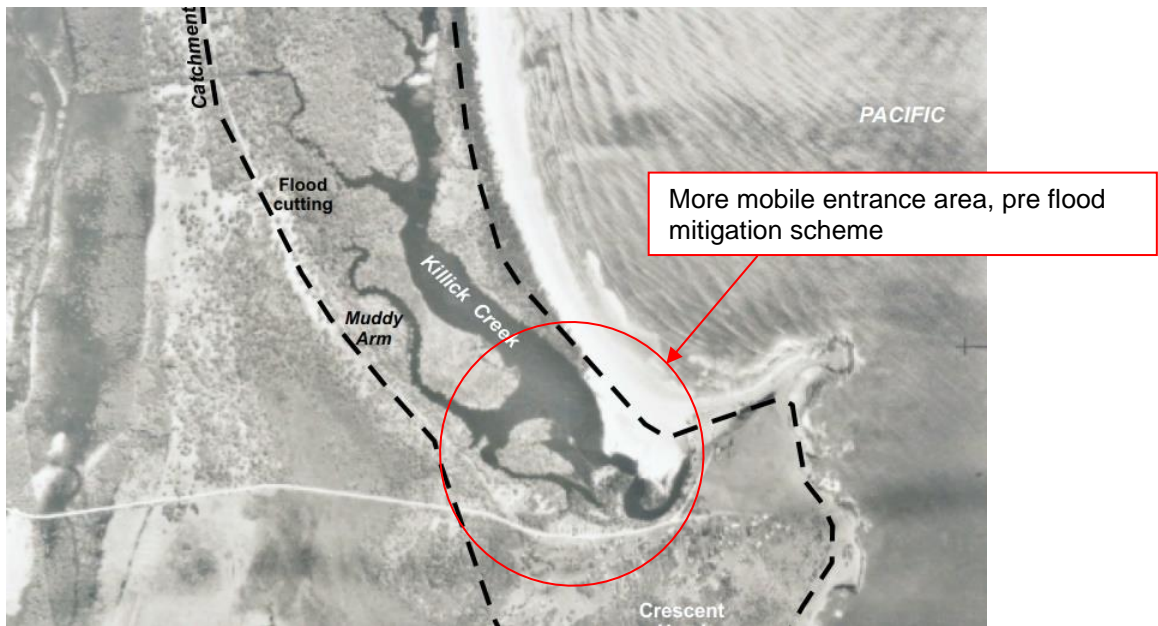


Figure 2-3 Killick Creek in an undisturbed state in 1942 (MHL, 2002)

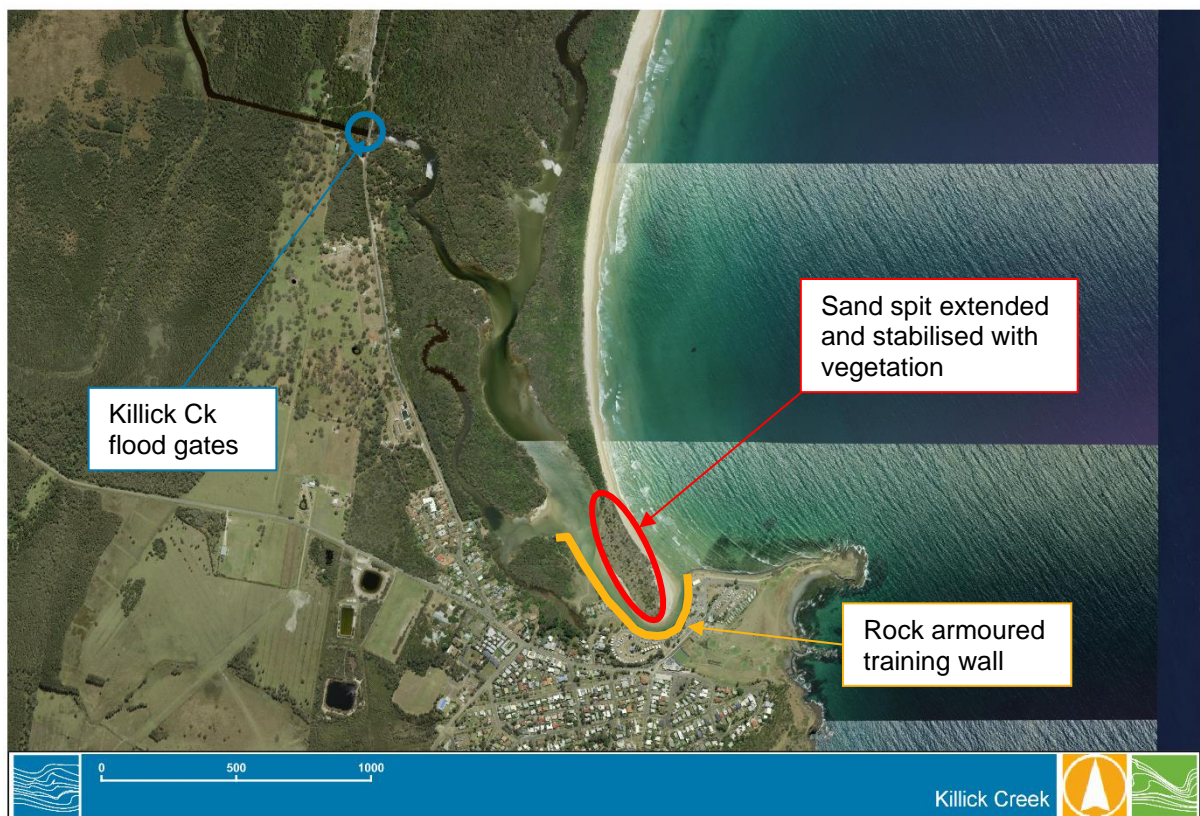


Figure 2-4 Killick Creek modifications from the flood mitigation scheme

3 GOVERNANCE CONTEXT

3.1 Overview

Responsibility for undertaking artificial openings of ICOLL entrances usually lies with the local council under its duty of care to the local community, to manage water quality and land subject to flooding.

However, any works within an ICOLL entrance may require approval depending on land tenure and the applicable planning framework. Artificial entrance management is generally assessed under Part 5 of the EP&A Act, where the determining authority (e.g., council or a public agency) is responsible for assessing the environmental impacts. Therefore, tenure needs to be clearly established to determine responsibility for entrance management and required approval processes (NSW DPI-Fisheries, 2020). A map of land tenure at the Killick Creek Entrance is provided in Figure 3-1, and it shows that:

- The estuary entrance and the entrance berm are located on Crown land waterway.
- The estuary entrance is bounded by Council-managed Crown land, and Hat Head National Park.



Figure 3-1 Land tenure at the Killick Creek entrance

3.2 Legislation

The following legislation has been considered in development of this EMP.



3.2.1 Local Government Act 1993

Under Division 2 (Section 35) of the *Local Government Act 1993* (LG Act), community land is required to be used and managed in accordance with the following:

- The plan of management applying to the land (which will only have relevance to activities on Council Managed Reserves); and
- Any law permitting the use of the land for a specified purpose or otherwise regulating the use of the land.

The relevant Plan of Management (PoM) for Killick Creek would likely be the Kempsey LGA CMP. This EMP forms part of the certified CMP.

3.2.2 Crown Land Management Act 2016

The Department of Planning, Housing and Infrastructure - Crown Lands (DPHI-Crown Lands) is responsible for the administration and/ or management of Crown land under the *Crown Land Management Act 2016* (CLM Act). Crown land includes submerged Crown land, seabed and subsoil to three nautical miles from the coastline of NSW that is within the limits of the coastal waters of the State. The CLM Act requires that environmental, social, cultural heritage and economic considerations be considered in decision-making about Crown land.

Council Managed Crown Land

Under the previous *Crown Lands Act 1989*, local councils proposing to remove gravel, sand or any other material (including by mechanical entrance management activities and/or maintenance dredging) on Crown land were required to obtain a licence from DPHI-Crown Lands under Part 4, Division 1 of the CLM Act.

However, under the new CLM Act (Specifically Division 3.4), for locations where a council has been appointed the Crown Land Manager of the subject Crown land, Council is authorised to manage the Crown land as if it were public land within the meaning of the LG Act. In the circumstances that a tenure from the Crown should no longer be required for the environmental management activity being undertaken by Council, the approval sections will therefore need to focus on the requirements of the LG Act

Crown Waterway

Where artificial entrance management works occur on Crown waterway or directly (Minister) managed Crown land, a PoM will have no effect, and a licence will be required under Section 1.15(1) the CLM Act.

3.2.3 Fisheries Management Act 1994

The objectives of the *Fisheries Management Act 1994* (FM Act) are to conserve, develop and share the fishery resources of the State for the benefit of present and future generations.

Under Part 7 Division 3 of the FM Act, any proposals to artificially open ICOLLs must be authorised by a permit from the Minister, or authorised by Department of Primary Industries and Rural Development (DPIRD) - Fisheries after consultation with the Minister - unless the work has already been authorised under the CLM Act. Otherwise, a dredging and reclamation permit is required as per Sections 198-202 of the FM Act.

The provisions of Division 3, Part 7 of the FM Act are likely to be relevant to any works associated with the works to the opening of Killick Creek. The provisions relate to the protection of aquatic habitat. Although flood mitigation works would be precluded from requiring consent under State Environmental Planning Policy (Infrastructure) 2007 (ISEPP), the provisions of the FM Act are still applicable and as part of the Review of Environmental Factors (REF) process concurrence from DPIRD-Fisheries may be required for certain activities. Table 3-1 outlines the relevant provisions of the Act that would apply to works to the opening of the estuary.



Table 3-1 Activities requiring concurrence under the Fisheries Management Act 1994

Section	Activities
198-202	Concurrence is required from the Minister, Department of Primary Industries (Fisheries) for dredge and reclamation works on defined water land. The nature of works to the opening would constitute dredge works and also potentially reclamation works in watered land. Hence a permit and concurrence may be required prior to commencement of any works.
219-220	Concurrence is required when barriers to the movement of fish including water course crossings are to be constructed or modified. Any proposed works to the opening is unlikely to create a barrier to the movement of fish. However, such specifics would need to be confirmed within the REF.
204-205	Any works to the opening would likely be restricted to the area of the sand berm. Any works must not affect mangroves or other protected marine vegetation. If marine vegetation would be harmed by flood mitigation works, a permit must be sought from the Minister before works commence. Clause 205 (2) states that <i>A person must not harm any such marine vegetation in a protected area, except under the authority of a permit issued by the Minister under this Part.</i> It is unlikely that any such vegetation would be affected by activities associated with the works to the opening of Killick Creek, however the REF must confirm this.
Schedule 4, 4A, 5 and 6	The REF prepared for works associated with works to the opening would need to consider any presence of local threatened aquatic habitat for flora or fauna. Key Threatening Processes (KTPs) would need to be considered in preparation of the REF.

3.2.4 Coastal Management Act 2016

The *Coastal Management Act 2016* (CM Act) establishes the framework and sets forth the objectives for coastal management in NSW. The purpose of the CM Act is to manage the use and development of the coastal environment in an ecologically sustainable way, for the social, cultural and economic well-being of the people of NSW (DPIE, 2019).

The CM Act defines the coastal zone, comprising four coastal management areas:

1. Coastal wetlands and littoral rainforests area
2. Coastal vulnerability area
3. Coastal environment area
4. Coastal use area.

The CM Act establishes management objectives specific to each of these management areas, reflecting their different values to coastal communities. These coastal management areas are mapped as part of the *State Environmental Planning Policy (Resilience and Hazards) 2021 (R&H SEPP)* – and is depicted in Figure 3-2. This shows that:

- A significant portion of the Killick Creek estuary waterway and its catchment are classified as Coastal Wetlands;
- A significant portion of the estuary waterway and foreshore are classified as Coastal Environment Area (CEA) and Coastal Use Area (CUA); and
- The estuary entrance falls within both the Coastal Use and Coastal Environment areas.



3.2.5 Marine Estate Management Act 2014

The *Marine Estate Management Act 2014* (MEM Act) forms part of the NSW Marine Estate Management Framework. The framework comprises statutory instruments, strategies, assessment, plans and policy settings, and is administered under the auspices of the Marine Estate Management Authority (MEMA).

The objective of the MEM Act is to provide for strategic and integrated management of the NSW marine estate, including the marine waters, coasts and estuaries (MEMA, 2018). The key legislative instruments under the act include:

- Marine Estate Management Regulation 2017;
- Marine Estate Management (Management Rules) Regulation 1999; and,
- Aquatic Reserves Notification 2015.

It should be noted that one of the objectives of the CM Act (and of the broader CMP process) is to support the objectives of the MEM Act.

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

Section 5.5 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) states that a determining authority (in this case, Kempsey Shire Council), in its consideration of an activity shall examine and take into account to the fullest extent possible all matters affecting or likely to affect the environment by reason of that activity.

Although flood mitigation works would be permitted without consent on any land (see Section 3.3.1), the requirements of Section 5 of the EP&A Act 1979 must be fulfilled.

As part of the licencing process under the CLM Act, a determined environmental assessment, undertaken in accordance with the EP&A Act, must be submitted with any Crown Land licence application. DPHI - Crown Lands strongly recommends that Council consult with relevant agencies, including DPIRD-Fisheries, as part of preparing these environmental assessments. Feedback from agencies should be considered and incorporated into the assessment, as appropriate. Noting that under s199 of the *Fisheries Management Act 1994*, Crown land licence applications that involve 'dredging and reclamation' must be referred to DPIRD-Fisheries for their consideration, and before a licence can be issued

The assessment should consider the impacts associated with repeat openings over a long period and under a range of conditions, rather than a single opening, so that it does not have to be reproduced each time an opening is necessary.

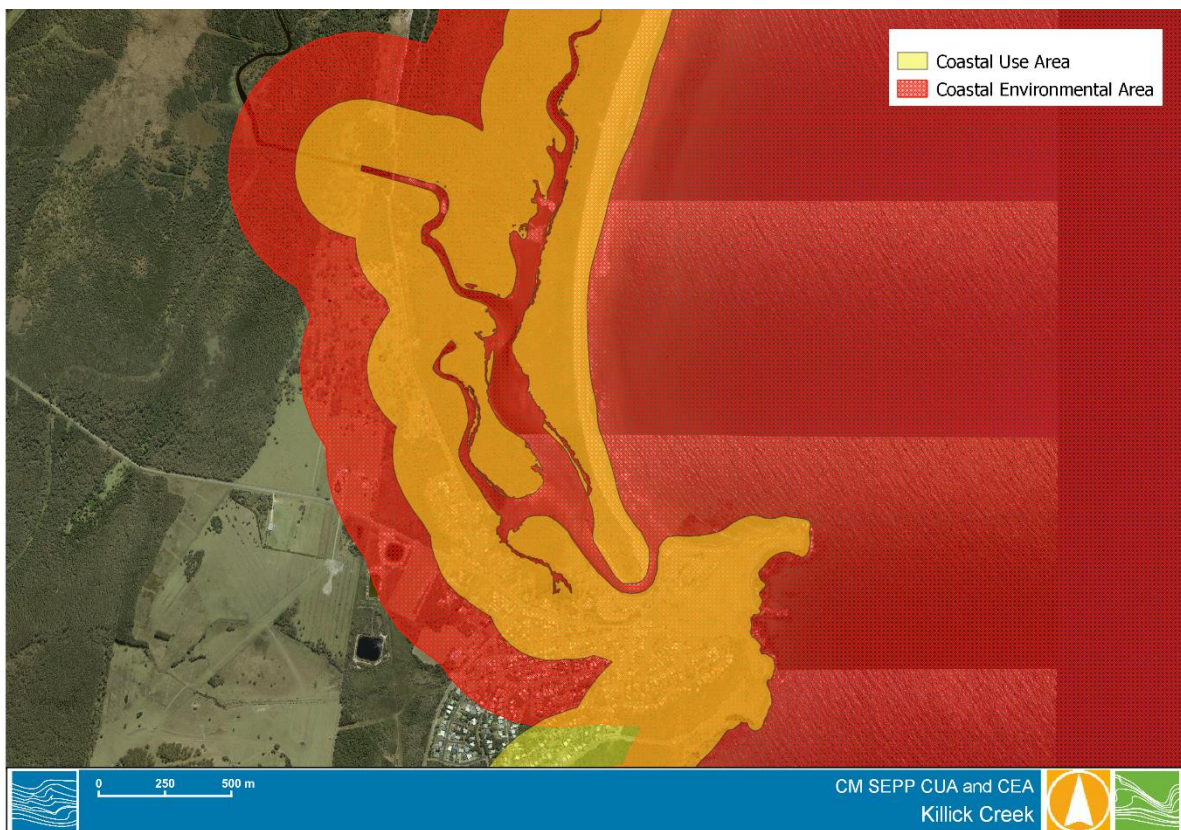


Figure 3-2 R&H SEPP mapping for Killick Creek



3.3 Policy Context

3.3.1 State Environmental Planning Policy (Infrastructure) 2007

The 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 development consent.

Kempsey Shire Council is proposing to use mechanical opening of the entrance of the estuary for flood mitigation purposes, and therefore the entrance management works would be defined as “infrastructure” works under Division 7, Clause 50 of the ISEPP.

Although flood mitigation works would be permitted without consent on any land, the requirements of Part 5 of the EP&A Act must be fulfilled, and Council would be required to prepare a REF for proposed works to open Killick Creek.

3.3.2 State Environmental Planning Policy (Resilience and Hazards) 2021

The R&H SEPP updates and consolidates into one integrated policy a series of previously enforced SEPPs, including: SEPP 14 (Coastal Wetlands), SEPP 26 (Littoral Rainforests) and SEPP 71 (Coastal Protection), including clause 5.5. of the Standard Instrument – Principal Local Environmental Plan.

The R&H SEPP commenced on 3 April 2018 and gives effect to the objectives of the CM Act from a land use planning perspective, by specifying how development proposals are to be assessed if they fall within the coastal zone.

The R&H SEPP streamlines coastal development assessment requirements, identifies development controls for consent authorities to apply to each coastal management area to achieve the objectives of the CM Act, and establishes the approval pathway for coastal protection works.

The estuary entrance falls within both the coastal environment and the coastal use areas. Therefore, clauses 2.10 to 2.15 list matters that must be considered prior to granting development consent on land within these coastal management areas respectively. However, as noted in Section 3.3.1, development consent would not be required for the proposed works.

3.3.3 NSW DPIRD Policy and Guidelines for ICOLL Entrance Management

The NSW DPIRD Policy and Guidelines for Fish Habitat Conservation and Management 2013 state the following (NSW DPI-Fisheries, 2013):

1. Any proposals to artificially open ICOLLs must be authorised by a permit from the Minister or authorised by NSW DPIRD or other public authority after consultation with the Minister under the FM Act.
2. NSW DPIRD supports minimal interference with ICOLL barriers and advocates natural processes being allowed to operate to the greatest extent possible.
3. NSW DPIRD does not support the artificial opening of an ICOLL unless the proponent can demonstrate that the social, environmental, and economic benefits greatly outweigh any potential adverse impacts.
4. NSW DPIRD supports using estuary management plans and environmental assessment processes to analyse the issues relating to opening a particular ICOLL, and to develop an EMP. Proposals for artificial openings which are to be carried out according to a formulated entrance management plan are more likely to be approved.

Furthermore, guidelines for mechanical opening from DPIRD include:



- The decision to open an ICOLL should be made on the basis of factual data on:
 - verified water levels and the nature and extent of associated flooding impacts - which should be referenced to a standard datum (e.g., Australian Height Datum) obtained from appropriately sited staff gauges, or automatic water level recorders, and
 - quantitative evidence of changes to relevant water quality parameters (especially nutrient and bacterial levels) produced by monitoring programs designed specifically to assess water quality pre- and post-opening.
- In the event that the criteria for an artificial opening are met, breaching should be conducted during a falling tide (if possible, around a spring tide) so that the potential for establishing an entrance channel long enough to flush the water body is achieved.
- In the long-term, local councils and government agencies should aim to reduce the need for artificial manipulation by taking active measures to remove, relocate or otherwise manage items of low-lying infrastructure that currently necessitate breaches below the natural breakout range, and adopting catchment management practices that:
 - reduce the inputs of nutrients and pollutants from point and diffuse sources,
 - prevent transfer of flood prone and riparian land on the margins of ICOLLs into private ownership,
 - prevent the future development or subdivision of flood-prone and riparian lands by adopting appropriate zonings and buffers in relevant land use planning instruments,
 - implement community awareness campaigns to gain broad based understanding and support for the environmentally responsible management of ICOLLs.
- NSW DPIRD will require proponents to carefully monitor the impacts of extraction activities including:
 - rates of sediment infilling post-works,
 - upstream and downstream impacts,
 - immediate habitat changes

3.4 Summary of Potential Approvals

- Works to the opening of the entrance for the purpose of flood mitigation are permitted without development consent under Clause 50 of the ISEPP.
- As the entrance management works are to occur on Crown waterway, an authorisation from DPHI-Crown Lands is required under Section 5.30 the CLM Act. As part of the DPHI-Crown Lands licence application process, the following would be required under the CLM Act:
 - A determined environmental assessment must be submitted with any Crown Land licence application. This assessment must also fulfill the requirements of Part 5 of the EP&A Act. Therefore, Council is required to prepare a REF for proposed works.
 - Furthermore, under s199 of the FM Act, Crown land licence applications that involve 'dredging and reclamation' must be referred to DPIRD-Fisheries for their consideration. As part of this process, Council would be required to consult with and consider any matters concerning the proposed work that are raised by DPIRD-Fisheries prior to DPHI-Crown Lands issuing a licence.
- It is recommended that an REF is prepared, and approvals obtained, on a rolling basis to allow a proactive planning approach to occur, rather than a reactive approach when water levels are rising.

It may be possible for Council to obtain a head licence that covers entrance management works across all of their ICOLL estuaries.



4 HISTORICAL MANAGEMENT ARRANGEMENTS

The Killick Creek Estuary Management Plan (WBM Oceanics, 2006) was developed in 2006 and sets out interim management protocols for the estuary. The protocols are based on the following objectives:

- Maintain high water quality within the estuary;
- Maintain high recreational opportunities within the estuary;
- Allow for opportunistic usage of the boat ramp within the entrance channel; and
- Ensure conservation of ecosystem values, within the natural variability expected of the estuary.

Killick Creek estuary entrance connection to the ocean waters has been artificially maintained since the 1950s, keeping it predominantly open. Historically, entrance closures have only occurred during extended dry weather periods such as droughts - notably several occasions from 2002 – 2008.

The opening of the entrance remains a contentious issue due to its complex impacts on water quality, recruitment and populations of fish and wetland bird species, biodiversity, local flooding, and recreational uses of the water body.

4.1 Trigger Conditions for Entrance Management

The 2009 Estuary Management Plan lays out the historical trigger conditions for entrance management.

4.1.1 Water Quality

The primary trigger for implementation of entrance management actions was estuarine water quality. The conditions related to waters behind the entrance berm when the estuary is closed, and are based on ANZECC (2000) guidelines established to protect estuarine environment for human health and safety for primary contact recreation.

The protocols state that water quality was to be determined with sampling - and averaging results across three sites located around 50 metres apart in the lower estuary, behind the entrance berm. The criteria were:

- Dissolved oxygen 4 mg/L (minimum)
- pH 6.0 (minimum)
- Temperature 35°C (maximum)
- Secchi depth 1.0 metres
- Secchi depth (non bathing period) 0.5 metres
- Faecal coliforms 600 counts/100mL (maximum) ⁽¹⁾
- Enterococci 60 counts/100mL (maximum) ⁽²⁾
- Odour Significant malodour generation ⁽³⁾

Note: (1) Alternative threshold is four (4) consecutive records greater than 150 counts/100mL

(2) Alternative threshold is four (4) consecutive records greater than 35 counts/100mL

(3) Although subjective, this threshold would be based, to some degree, on the impact any odour generation has on the patrons of the adjacent Caravan Park and other users of the estuary and its foreshores.

4.1.2 Entrance Condition

Meander Correction works

In the past, Council has carried out “meander correction” works - whereby the open entrance has been realigned during periods where it meanders northwards and results in severe erosion of the Killick Beach spit and the local dune system. An example of this meander is provided in Figure 4-1. The works have been historically justified by:

- The need to prevent potential erosion and undermining of the coastal foredune which provide a barrier to erosion and inundation of the Crescent Head township.
- If the channel meander migrates too far west, it can affect the foundations of the pedestrian footbridge.
- Loss of beach access: Killick Beach is a highly popular recreation area, and when the entrance meanders northwards it can at time cut off safe access to the beach from Crescent Head.

As part of the works, the entrance channel is realigned to a more typical north-easterly aspect - see Figure 4-1. The works are undertaken in order to realign the channel only, and not to increase the channel depth or width.



Figure 4-1 Killick Creek Entrance – northerly entrance meander (left), compared to a more typical north-easterly aligned channel (right)



Figure 4-2 Examples of erosion of the Killick beach spit and dunes caused by the entrance meander

It is understood that historically the entrance meander works have been undertaken through a licence from DPHI-Crown Lands, however a referral to DPIRD-Fisheries is sought before issuing a licence to Council. This



was the case during entrance meander correction works undertaken in September 2020, which was undertaken to protect the foundations of the pedestrian footbridge – see Figure 4-3.

4.2 Flood Mitigation

Interim protocols for the Killick Creek Floodgate Management Policy are provided in Appendix B of the Estuary Management Plan.

These protocols for the Killick Creek Floodgate Management allow for the unimpeded flow of floodwaters to Killick Creek during flood events, as well as intermittent releases of water from the upstream agricultural drainage system within Belmore Swamp and Connection Creek (which potentially has poor water quality). The protocols state that: *“Prior to the release of flood or drainage waters to Killick Creek, achieved by removing dropboards located on the upstream side of the floodgate structure, the entrance of Killick Creek must be open. Consequently, if removal of dropboards is proposed, in accordance with the Floodgate Management Policy, and the entrance to Killick Creek is closed, then the provision is given to artificially open the entrance”*.

It is understood that this trigger condition for entrance opening has not been met since the policy was developed (WBM Oceanics, 2006).

4.3 Historical Entrance Management Events

It is understood that around 12 artificial openings (and meander corrections) have been undertaken since the early 2000s, as listed in Table 4-1. The results show a high frequency of entrance openings in the early to mid-2000s, followed by a long period where no intervention was required in between 2007 and 2020. This demonstrates how the entrance condition is linked to rainfall and drought cycles - as discussed in Section 5.1.

Table 4-1 Entrance openings from 2000-2020

2000s		
October 2000	July 2001	January 2002
August 2002	February 2003	April 2003
April 2004	September 2006	March 2007
August 2007	September 2007	
2010s		
None		
2020s (up to December 2021)		
September 2020 (meander correction)		



Figure 4-3 Entrance meander correction in September 2020



5 MANAGEMENT ISSUES

5.1 ICOLL Entrance Dynamics

5.1.1 ICOLL Behaviour

Killick Creek is classified as an ICOLL - under the subtype of “lagoon” with intermediate age. This subtype is based on the ICOLL’s flushing times, freshwater inflow relative to ICOLL volume and water quality. These ICOLL subtypes have specific morphometric and hydrological characteristics that correspond to their stage of sedimentary infilling that has a range of implications for entrance dynamics, water quality, habitat distribution and ecological function (DPIE, 2021).

The natural dynamic connection and disconnection between the estuary and ocean is usually from the berm or sand barrier development formed at the final stages in an entrance closure. This is typically formed when sediment is deposited by waves, tides, flood flows and winds generally from the offshore to the entrance (DPIE, 2021). The estuary opens and closes to the ocean naturally in a constant but irregular cycle. Examples of open and (almost) closed entrance conditions are provided in Figure 5-1.



Figure 5-1 Entrance open (left) and almost closed with berm formation (right)

Generally, coastal process such as tides and waves tend to push sand from offshore into the entrance, which gradually closes the entrance. Conversely, when there is sufficient intensity and volume of catchment inflows into the lagoon (usually following heavy rainfall), water levels in the estuary rise in response as the estuary fills. Eventually the water in the ICOLL will spill over the entrance sand berm and drain to the ocean. The force of the backed-up water then quickly scours an entrance channel through the beach and reopens the ICOLL to the ocean (DPI, 2018).

Prior to being a completely closed system, the estuary experiences a significantly attenuated tide range (compared to the open ocean) due to hydraulic energy losses through the narrow and shallow estuary entrance – with the extent of the flood tide delta generally controlling the tide range within the estuary.

The estuary is generally shallow at the entrance where its tributaries meet and flow into the ocean, and increases in depth upstream near the flood cutting arm (MHL, 2002).

The exchange of water into the creek is generally inefficient. Every incoming tide rise brings in seawater resulting increasing the volume of water but not fully draining on each falling tide. This process builds up water levels and results in a higher mean water level inside the ICOLL compared to the mean sea level outside.

Higher waves could produce higher berms and keep the estuary entrance closed for longer which could be months or even years. On the other end of scale, if there is heavy flow (after a rainfall event), the catchment inflow increases the water level in the estuary and eventually the water in the ICOLLs rise and surge over the



entrance sand berm releasing water into the ocean connecting the two systems where there is daily tidal exchange of seawater.

The estuary entrance is generally located at a rock armoured training wall on the southern eastern side bank of the creek (Figure 5-1), however it can move depending on shoaling patterns. The Little Nobby headland immediately next to the estuary mouth interrupts the littoral and along shore sediment transport processes along the coast, and is considered to be a minor control point for the local coastal sediment transport regime.

History of Entrance Condition

Killick Creek entrance was kept almost permanently open from the 1950s to the late 1990s through a combination of training wall works, impacts of the flood mitigation scheme, and periodic sand clearance works for flood mitigation.

However, as discussed in Section 4, the estuary did become prone to closure for a seven-year period from 2000 to 2007. This period was heavily affected by drought and below average rainfalls – commonly referred to as the “Millennium Drought”, which officially ran from 2000 to 2009 and is considered to be one of the worst droughts recorded since European settlement. During this period, below average rainfall resulted in a significant reduction of catchment inflows – and a gradual net accumulation of marine sediment into the estuary by tides and waves. This is also evidenced in Figure 5-2 which depicts recorded water levels in the estuary – and demonstrates that the estuary entrance gradually constricted during this time period, and resulted in a corresponding reduction of the tide range. Figure 5-2 shows that a series of significant rainfall events occurred in 2009 that flushed out the entrance - where over 450 mm of rain was recorded in February, 250 mm in June, and 240 in November.

From the period 2009 to 2021 the entrance has remained open, with the only intervention in recent times occurring in September 2021 in the form of an entrance meander correction.

This history demonstrates that the entrance condition for Killick Creek is heavily linked to rainfall, and subsequently to medium term climatic drivers such as the El Niño-Southern Oscillation (ENSO). ENSO is the term used to describe the oscillation between the El Niño - which brings drier conditions to the east coast, and the La Niña, or opposite, phase – which brings above average rainfall. The entrance closures observed during the early 2000s corresponded with an extended El Niño period from 2001 to 2007. However, the entrance was not observed to close during the shorter duration El Niño period from 2015-2016.

During future period of extended dry conditions, the estuary may be expected to close again. This is considered to be a natural response of an ICOLL to broader climatic conditions.

5.1.2 Estuary Hydrodynamics

Water levels within the estuary are influenced by different processes which may act over time spans ranging from hours bases to several years such as astronomical tides, wind direction, rainwater inputs and floods, ocean storm surges, and sea level rise (MHL, 2002).

When the entrance is open, water levels in Killick Creek are controlled by tides, with seawater moving into and out of the estuary with the semi-diurnal tidal cycle. Killick Creek’s tidal limit is around 2 km upstream from the entrance, at the floodgates (MHL, 2002). Tidal planes for the estuary are provided in Table 5-1.

Water level records of the estuary from 2002 to 2021 are shown in Figure 5-2. These water levels have been recorded by a water level gauged operated by Manly Hydraulic Laboratory, located around 400 m upstream from the Killick Creek entrance. This data shows that when the estuary entrance is open, the tidal range within the estuary varies with the degree of ocean connectivity – but is generally between 0.5 m to 1.5 m. Figure 5-1 presents tidal planes for Killick Creek at both the downstream gauge, as well as from a temporarily gauged location around 300 m downstream from the flood gates.



The tidal prism, which is the volume of water in the estuary between High Water Solstice Springs and Indian Spring Low Water, in the whole estuary ranges between 90,000 – 130,000 m³ (MHL, 2002) . Most of tidal prism mixing occurs at the mouth, with very low mixing upstream.

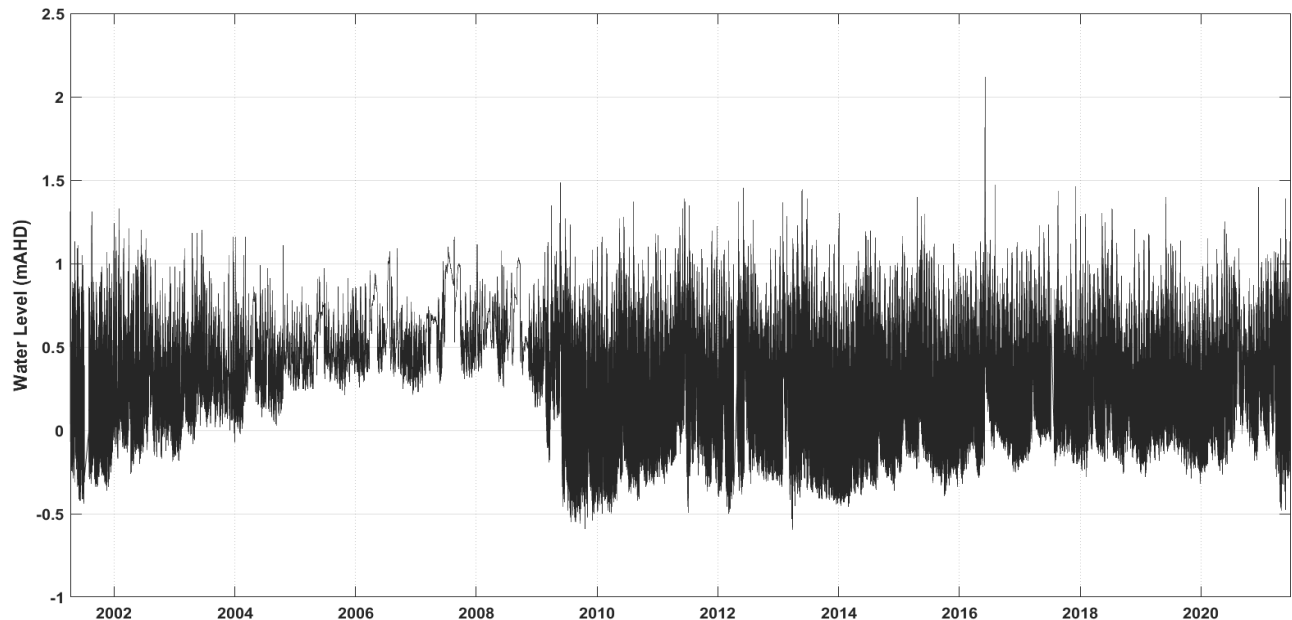


Figure 5-2 Estuary water levels from 2002 to 2021

Table 5-1 Tidal planes for South West Rocks and Hat Head in the vicinity of Killick Creek estuary (source: MHL, 2002), in mAHD

Tidal Plane	Ocean Tide at Crowdy Head	Killick Entrance	Killick Upstream
Higher High Water Spring Solstice (HHWSS)	1.14	0.98	0.77
Mean High Water Springs (MHWS)	0.69	0.61	0.57
Mean High Water Neaps (MHWN)	0.46	0.46	0.43
Mean Sea Level (MSL)	0.04	0.16	0.15
Mean Low Water Neaps (MLWN)	-0.39	-0.15	-0.12
Mean Low Water Springs (MLWS)	-0.62	-0.30	-0.26
Indian Spring Low Water (ISLW)	-0.94	-0.56	-0.52
Full Tidal Range (HHW to ISLW)	2.08	1.55	1.44
Mean Spring Range (MSR)	1.31	0.91	0.83
Mean Neap Range (MNR)	0.85	0.60	0.56

5.1.3 Natural Breakout Range

As there is little available recorded berm survey from historical entrance closures, there is a paucity of information available to determine the natural breakout range of the estuary when closed. The water level data depicted in Figure 5-1 depicts a range of breakout events from 2000 to 2007, however almost all of these opening events were artificial, which gives little indication of the range of natural breakout events.

Hanslow et al (2000) provides some guidance regarding potential berm level, and berm level variability for ICOLLs on the NSW coast. Generally speaking, berm height is related to wave height, beach slope, and grain size – and berms that are exposed to higher wave energy, steeper slopes and coarser sediment like to experience higher vertical berm growth. The findings of Hanslow suggest that, in lieu of more detailed berm survey, a natural breakout range for the estuary may be between 1.8 to 2.2 m AHD. However, such estimates are broad, and should be considered with caution. As Killick Creek entrance is provided significant wave sheltering from the Little Nobby Headland, it is possible the natural breakout range could be lower than these estimates, and closer to the natural breakout range of the nearby Saltwater Creek and Lagoon, which has a natural breakout range between 1.2 and 1.8 m AHD.

5.2 Estuarine Flooding

5.2.1 The Macleay Valley Flood Mitigation Scheme

Killick Creek estuary has been significantly modified by a history of flood mitigation works, which were mostly completed in 1968 – including the construction of drains, floodgates and levees as a part of the flood mitigation scheme. The Macleay Valley Flood Mitigation Scheme was designed to protect low-lying areas from flooding throughout the catchment.

The scheme includes the Killick Creek Floodgates which are used to reduce flooding on the Belmore River, including when Connection Creek joins the Belmore River (Connection Creek connects the Macleay and the Hastings River catchments in large floods). Killick Creek therefore provides an outlet for the water stored in the Belmore swamp areas (SES, 2017).



Figure 5-3 Killick Creek floodgates (WBM Oceanics, 2006)

Water levels in the agricultural drains upstream of the Killick Creek floodgates are controlled by the position of the dropboards. Higher water levels are retained in the drains at times to assist with acid sulfate soil management within the floodplain. During other times, maximum drainage from the floodplain is required, particularly during Macleay River and/or Maria-Hastings River flood events or significant local rainfall within the Belmore Swamp area. Post-flood drainage is also critical for removing floodwaters from productive agricultural lands and minimising pasture losses due to extended inundation (WBM Oceanics, 2006).

The upper Belmore catchment has an approximate area of 90 km² and the catchment of Connection Creek approximately 40 km². During severe flooding events, the local Killick Creek catchment (downstream of the floodgates) is affected by processes operating across these wider catchments, and can result in the discharge of water through the Killick floodgates and waters exit to the ocean via Killick Creek. During flood events (when flood gates are opened), agricultural drains can be a major source of pollutants for the estuary (BMT WBM, 2020).

The current floodgate management protocols (WBM Oceanics, 2006) stipulate that in “*To ensure minimum effect on the water quality and aquatic ecosystem of the Killick Creek estuary, discharges from the agricultural drains should only be permitted when the creek entrance is open, thus allowing tidal exchange of waters between the estuary and the ocean... If the entrance is closed and an intermittent ‘pulsed’ discharge of water agricultural waters (of poor water quality) is proposed, then the entrance of Killick Creek should be opened artificially in accordance with the provisions specified in the Killick Creek Entrance Management Policy*”.



5.2.2 Flood Behaviour Design Flood Levels

Crescent Head is affected by flooding from the Lower Macleay southern floodplain, on the western side of the village, in addition to flooding in Killick Creek which is influenced by flows from the southern floodplain into the creek combined with elevated ocean levels entering the creek entrance. The Lower Macleay Flood Study (Jacobs, 2019) was undertaken in 2019, and developed design flood levels for a range of Annual Exceedance Probabilities (AEPs) across the Lower Macleay Floodplain. Design flood levels for Crescent Head are depicted in Table 5-2 below.

The study shows that for more frequent “nuisance flooding events” – of around 0.2EY (~ 20% AEP) Killick Creek flooding is influenced mainly by high ocean tides with minor contribution of flows from the southern floodplain into the head of the creek. A number of properties along Willow Street experience shallow yard flooding.

In the 5% AEP event, floodplain inflows into Killick Creek increase and properties along the creek are flooded to depths of 0.5 – 1m. Flooding in the southern floodplain begins to encroach on the properties in the western side of town. This is also demonstrated spatially in the 5% AEP design flood level map in Figure 5-4. Inundation depths increase to 1 – 2m in the 1% AEP event along Killick Creek properties and up to 0.5m on western side properties. Floodwater begins to overflow from the southern floodplain to Killick Creek through properties (Jacobs, 2019).

Figure 5-4 indicates that during a design flood event, there exists a small but notable hydraulic gradient in flood levels between the estuary entrance and the low-lying residential properties on Willow Street. This is due to the relatively shallow and narrow state of the creek, which of itself acts as a form of constriction for the energetic conveyance of flood waters. Table 5-2 shows that for a 5% AEP event, flood heights at Willow Street may be up to 0.4 m higher than at the entrance opening. This steep hydraulic gradient needs to be appropriately considered when determining appropriate water level triggers for entrance management.

Notably, the downstream reaches of the estuary are also affected by oceanic inundation. Design storm tide levels from the Kempsey Coastal Hazard Study are provided in Table 5-2. It shows that design storm tide levels also have potential to overtop the local levee system. This is a significant consideration for entrance management – as it demonstrates that entrance management itself is limited in its ability to mitigate inundation.

However, it should be noted that shoreline wave set-up is likely lower at the Killick Creek entrance than the numbers reported in Table 5-2, due to the wave sheltering provided by Little Nobby Point. However, a more precise estimate cannot be determined without numerical modelling. Nonetheless, the table demonstrates that in inundation of the lower estuary, the entrance is affected by both catchment and coastal flooding – with a combination of coastal and catchment flooding dominating for lower AEPs, and catchment flooding generally dominated for AEPs of greater than 1% AEP.

Table 5-2 Design catchment flood levels in Killick Creek (Jacobs, 2019) at Crescent Head

Event	Catchment Flooding (Jacobs, 2019)	Ocean Storm Tide Levels, excl. wave set-up (BMT WBM, 2013)	Ocean Storm Tide Levels, incl. wave set-up (BMT WBM, 2013)
0.2 EY	1.3	N/A	N/A
5% AEP	2.2	1.43	2.5*
1% AEP	2.6	1.49	2.7*
0.2% AEP	3.3	1.52	2.9*
PMF	4.9	N/A	N/A



* wave set-up at the Killick Creek entrance is likely to be lower than for open coast locations exposed to easterly to south-easterly swells. Therefore, these total storm tide estimates are likely to be conservative at this location.

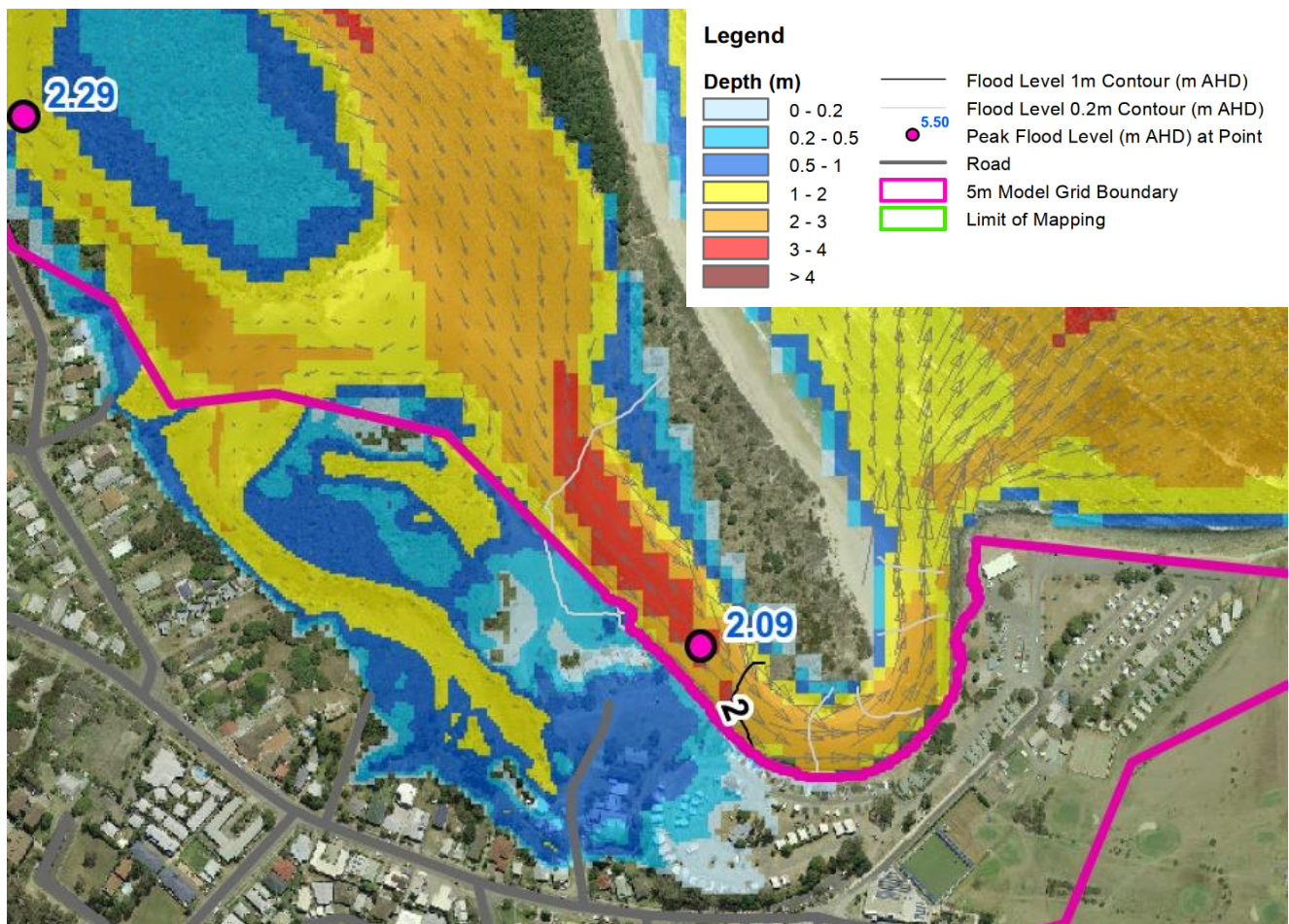


Figure 5-4 5% AEP flood levels and depths at Crescent Head (Jacobs, 2019)

5.2.3 Historical Flood Events

The Macleay region is periodically prone to flooding due to its exposure to storm activity originating in the sub-tropics of the north and the mid-latitudes of the south. To the north are tropical cyclones, which occur during the summer months with depressions developing into easterly troughs. Further south, low pressure systems such as cut-off lows, migratory lows and east coast lows are a major source of severe weather, particularly in the colder months. These systems are all capable of generating storm surges and elevated coastal storm tides, as well as intense rainfall and associated catchment flooding.

The worst recorded flooding in Kempsey Shire occurred during the winters of 1949 and 1950. The 1949 flood reached a level of 8.42 m AHD at Kempsey, which is approximately a 1% AEP event, while the 1950 flood reached a level of 8.27 m AHD at Kempsey, which is a 2% AEP event. These floods caused extensive inundation and damage throughout the catchment, and floodwaters drained from inland areas to the ocean via the creeks and artificial cuts (Brown, 2017).

Crescent Head was affected by a minor flooding event the June 2011 flood event. Whilst downstream water levels and inundation impacts were minor, flooding upstream was more severe, and the town was isolated from Kempsey for at least four days (SES, 2017).

The largest water levels recorded at the downstream gauge since 2002 were during the June 2016 east coast low event. During this event, a peak water level of 2.1 m AHD was recorded. This event was associated with over 250 mm+ of rainfall at the Kempsey Airport rain gauge in 48 hours, along with a storm tide level of +1.5 m AHD recorded at the Tweed Heads tide gauge (which excludes local wave set-up). This indicates that the observed water levels at the Killick gauge were the likely to be the result of combined coastal and catchment flooding.

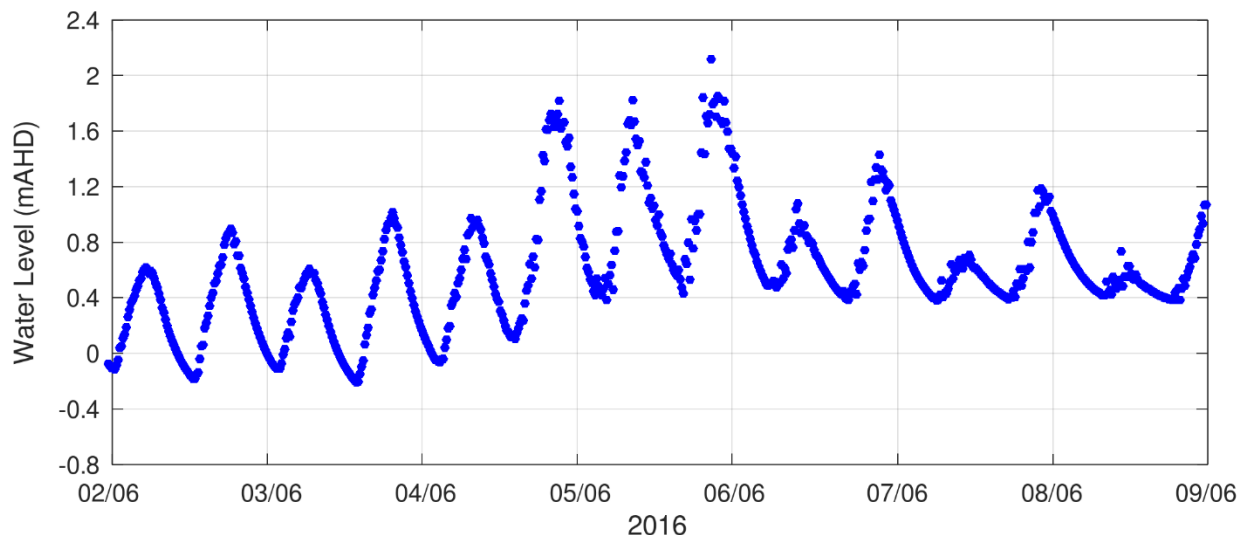


Figure 5-5 Recorded water levels during the June 2016 ECL event

5.2.4 Inundation of Assets

Topographic contours and wastewater infrastructure for the site are mapped in Figure 5-6. The levels at which infrastructure around the park become inundated are summarised in Table 5-3. It shows that the residential properties on Willow Street are particularly low lying – with many positioned at around 1.5 m AHD, the road itself at around 1.4 m AHD.

This is also demonstrated by the fact the properties on Willow Street are known to be impacted by periodic tidal inundation (“sunny day flooding”) and particularly coastal flooding from storm tide inundation. This requires consideration in determination of entrance management procedures.

With regards to catchment flooding, it is also prudent to consider the water level gradient in between the entrance opening and the Willow Street properties located around 400 m upstream. Flood modelling (Jacobs, 2019) indicates that for a 5% AEP event, water levels at Willow Street may be around 0.4 m higher than at the entrance.

Table 5-3 Inundation thresholds at Crescent Head

Level (mAHD)	Affected infrastructure
1.4	<ul style="list-style-type: none"> Willow St cul-de-sac road inundated in places (<0.1 m depth)
1.5	<ul style="list-style-type: none"> Willow St cul-de-sac road inundated and dangerous for driving (~0.2 m depth), and therefore considered to be cut-off. Nuisance backyard flooding of 10 properties on Willow St (<0.1 m depth)
1.6	<ul style="list-style-type: none"> Nuisance backyard flooding of 12 properties on Willow St Inundation of dwellings for 5 properties on Willow St

Level (mAHD)	Affected infrastructure
1.7	<ul style="list-style-type: none"> Nuisance flooding of 18 properties 6 Properties completely inundated including inundation of dwellings
1.8	<ul style="list-style-type: none"> Wastewater pump station C2 on Willow Street inundated

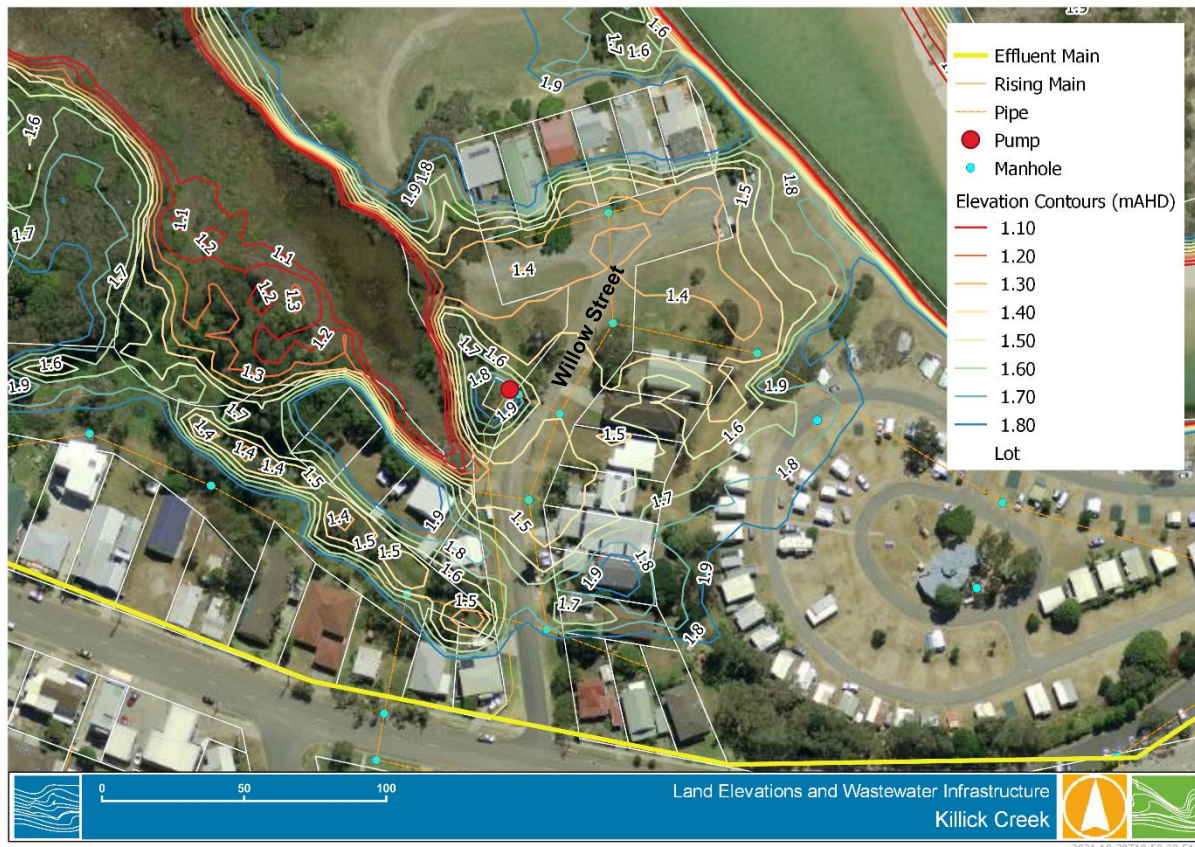


Figure 5-6 Local topographic contours and wastewater assets

5.3 Water Quality

5.3.1 Water Quality in the Estuary

ICOLLS are dynamic systems in terms of their water quality, much of this can be attributed to the estuary entrance status (open or closed), quality of catchment input and runoff, the vertical stratification of the waterbody itself (i.e., water separates from top layer has good water quality and the bottom layer has poor water quality) and the influence of groundwater inputs from surrounding low-lying catchments. While water quality variation may appear extreme relative to permanently open tidal systems, in many cases this variation should be considered natural and an integral part of the greater coastal ecosystem (DPIE, 2021).

Water within small ICOLLS systems like Killick Creek are commonly influenced by tannin-rich groundwater and wetland runoff inputs. Tannins are responsible for the 'tea-like' brown water appearing in these systems and should be regarded as a natural attribute of the system (DPIE, 2021).



Figure 5-7 Example of brown tannin rich water in the creek (Source KSC)

The 19th Century post-European hydrological manipulations have altered the Killick Creek water quality, which in the long term has significantly diverged from its pre-development conditions. The Killick Creek is an essential part of the Macleay River flood mitigation scheme and has been widened and deepened in the upper reaches of the creek to improve the flood drainage efficiency, while the lower reaches of the estuary entrance have been partially trained with a rock wall along the south/eastern entrance bank. All of these have implications for water quality within the system.

The creek receives agricultural outfall from the greater Macleay catchment and inflows from the urbanisation of the catchment from Crescent Head township. Urbanisation of the catchment has led to an increase in sediment and nutrient loads to the estuary. During rainfall events, pollutants are washed into the creek from diffuse sources such as Crescent Head urban area and rural areas. They may also be discharged directly into the creek from point sources such as stormwater within the catchment (MHL, 2002). The connection of Killick Creek to the flood mitigation scheme has also led to increased loads of sediments and nutrients, as well as other pollutants through the floodgates. This water had low oxygen, low pH, high nutrient, organics and silt. This, combined with the stormwater drains discharge from the Crescent Head area, multiplies the nutrients and pollutants.

Subsequently, the estuary receives high sediment and nutrient loads including pollutants (such as acid sulphate problems) that are of concern (WMA, 2004). When closed, the estuary acts as a sink - with the deeper waters upstream and the tidal exchange minimised, there is reduced mixing of water that can result in stratified waters with low dissolved oxygen near the bed.

The water at the lower reaches of the estuary has also been known to be affected by algal blooms – specifically from red algae (also known as Cornflake Weed). These events are typically precipitated by coastal upwelling events that bring nutrient rich waters from the ocean side during summers. These algae can be advected into the estuary, and when the algae eventually die, it can reduce the amount of oxygen in the water, sometimes causing fish kills and generating odours. Algal blooms and associated reduced oxygen levels can also cause adverse skin conditions in humans (BMT WBM, 2020). A series of notable algal bloom events occurred in December 2006, when a high volume of red algae was deposited onshore, see Figure 5-8.



Figure 5-8 Red Algae bloom at Killick Creek in December 2006

5.3.2 Water Quality and Impact on Biota

Good water quality is vital for healthy aquatic ecosystems. In natural flow regimes, temperature, oxygen, and Chlorophyll exert very little effect on the overlying waters. However, in small size estuaries like Killick Creek, during turbulent flows, the sediment water interface is disturbed causing resuspension. They release excessive organics that can cause eutrophication.

Eutrophication occurs in the creek and lagoon system when the water body is enriched with organic matter, leading to the depletion of dissolved oxygen. While high levels of chlorophyll can support larger fish populations, it can be problematic if sustained over long periods of time due to resulting noxious odours, overall poor water quality, fish kills, and human health issues upon contact with the water body (Roper, et al., 2011). These factors can also be associated with high turbidity caused by elevated suspended sediment load, which can smother or otherwise negatively impact benthic organisms and habitats within the estuary.

Fish Kills

During entrance breakout events, estuaries can experience a process whereby it is predominantly the surface water layer that drains, leaving behind hypoxic water trapped in deeper parts of the estuary basin. This process is commonly referred to as 'decanting' (Wiecek, 2001). Furthermore, the drawdown, or rush of water out of the estuary may cause a rapid decrease in oxygen in the water, by drawing the stagnant water out of the upper reaches of the estuary creeks and into the main basin. These processes result in a risk of fish kill events occurring, even in natural breakout situations. Deoxygenation of water stresses fishes and often cause them to come to the water surface gasping. Such short term low dissolved oxygen levels episodes and high organics are common in small sized estuaries such as Killick Creek but are also highly unpredictable.

In general, the occurrence of fish kills is highly unpredictable, however a significant mitigating factor is the size of the rainfall event (and hence the quantity of oxygenated freshwater inputs) that initiates breakout. Larger events will tend to cause greater flushing of hypoxic waters with overland runoff, and will also result in greater channel scour allowing fish easier passage to the ocean (DPIE, 2021).

Management approaches to reduce the likelihood fish kills include:

- Promotion of “natural openings” by scraping the beach berm prior to heavy rainfall – as opposed to “mechanical openings” where the entrance is directly opened by machinery; and
- Ensuring opening events coincide with rainfall (where possible).

It is important to note that while fish kills are often perceived to be the result of pollution or contamination of waters, there may also result from natural causes. NSW DPIRD maintains a database of fish kills in NSW. It contains over 1,400 records dating back to the early 1970s. The data suggests that on average 40 fish kills are reported to NSW DPIRD each year. Since many smaller kills go unnoticed and others remain unreported, the real number of kills is considered to be significantly larger (NSW DPI-Fisheries, 2013).

Fish kills have been recorded in Killick Creek since the late 1970s. Historical account from the Crescent Head Progress Association suggests there no evidence of fish kills occurring prior to 1975. The exact cause of each fish kill is unclear and may be due to either deoxygenation, acid sulphate soils, the toxic effects of aluminium or stranding of fish in swamp areas after flooding. However, most authors agree that deoxygenation has been the primary cause of fish kills in the Macleay River and Killick Creek to date (MHL, 2002).

In January of 2007, tens of thousands of Sea Hares (*Aplysia extraordinaria*) were stranded between January onshore along Killick Creek and Beach Killick beach Figure 5-9. The occurrence of Sea Hares was recorded after the Red Weed event, indicating a potential interrelation between the two events - however this needs further scientific investigation.

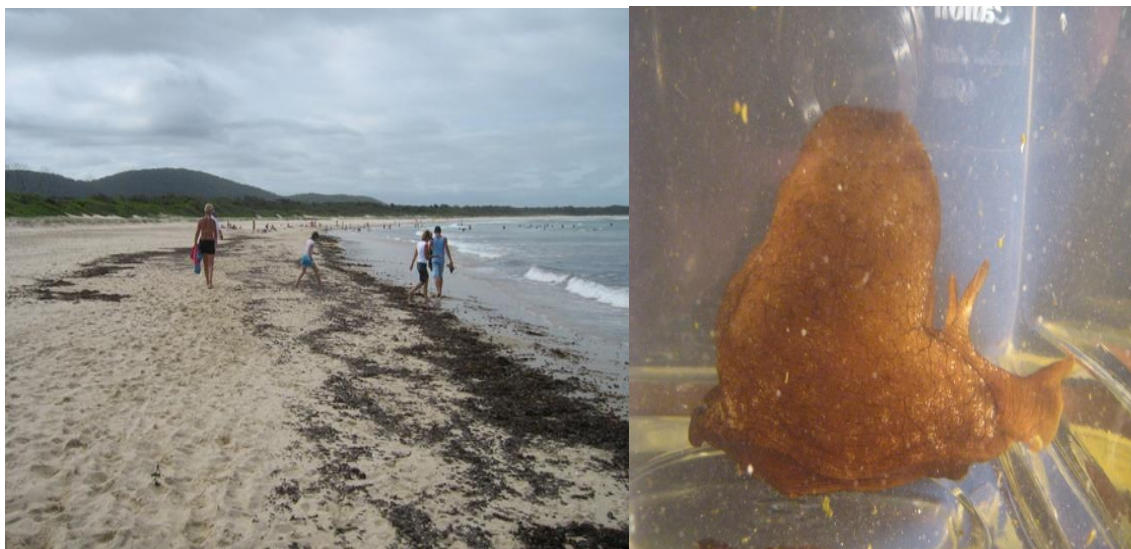


Figure 5-9 A) Sea Hares stranded onshore along Killick Beach. B) This Sea Hare specimen taken from Killick Beach was identified as *Aplysia extraordinaria*

5.3.3 Water Quality and Entrance Management

Artificially opening estuary entrances is often perceived as a ‘quick fix’ to redress water quality problems stemming from causes such as inadequate stormwater treatment from urban areas or inadequate erosion control measures in the catchment. Best practice for estuary management is based on addressing the source of the water quality issues rather than treating the symptoms by artificially opening entrances to ‘flush’ an estuary.

ICOLLS, more than any other estuary type, have a wide range of naturally occurring physical and chemical water quality conditions – and opening ICOLLS to improve water quality and estuary health is generally not recommended and could (despite best intentions) have undesired negative impacts on the estuary. Some



advice provided by DCCEEW in regard to artificially opening ICOLLs, and water quality impacts includes (DPIE, 2021):

- Opening at Lower Water Levels:
 - As outlined above, tidal prisms and exchange in the estuary is relatively low. Therefore, water quality in the estuary basin will not be significantly improved by dry weather opening. Low-level opening will only impact water quality in the lower estuary reach (around the flood-tide delta), and only during incoming tides. Sediment, nutrient, debris and faecal contamination will continue to enter the estuary from the catchment, and therefore opening of the entrance will not improve water quality while catchment sources remain active.
 - Opening at low water levels is generally not recommended as there is not enough of a hydraulic head differential between the estuary and the ocean to sufficiently scour the entrance. Under such conditions rapid entrance reclosure is common, and therefore any potential water quality benefits are also short term and temporary.
- Opening at High or Moderate Water Levels:
 - If estuary breakout and opening occurs in response to relatively small rainfall events, then there is an increased risk of decanting surface water without sufficient catchment inflow to flush hypoxic bottom waters from the system. This increases the likelihood of fish kills.

Therefore, there is no need for flushing of the estuary to improve water quality under 'normal' conditions. Nevertheless, there may be instances where artificial opening is justified to address extreme water quality issues in the waterway, particularly where water quality poses a threat to human health and safety for primary recreation.

5.4 Estuarine Ecology

Estuaries habitats are ideal spots that support many plant and animal species who often reside or migrate destination. The catchment supports tropical, subtropical and temperate terrestrial and marine ecosystems. The ecology and the ecological processes across the study area are well outlined in the following studies:

- UNE and SCU
- Killick Creek Estuary Process study (MHL, 2002)
- Killick Creek Estuary Management Study Plan (WBM Oceanics, 2006)
- Environmental Investigation Assessment of Strategy H (Ecological, 2008)

Killick Creek supports many types of flora and fauna and is surrounded by wetlands as designated as R&H SEPP Coastal Wetlands.

Flora

The main vegetation types within the study area comprise Eucalyptus, mangroves (Grey mangroves- *Avicennia marina* and river mangrove *Aegiceris corniculatum*) and seagrass (*Zosteraceae*). The coastal areas which were formerly covered with seagrass (*Zostera capricorni*) beds are now either very patchy or swapped by rushes (*Juncus* sp.) (MHL, 2002). A total of 23 plant species were recorded within the creek's vicinity, the common natives included *Acacia longifolia*, *Casuarina glauca*, *Juncus Kraussii*, *Spinifex sericeus* and *Chrysanthemoids monilifera*. The condition of mangroves within the creek was rated as poor.

Fauna

A total of 26 taxa was recorded within the entrance sandy flats of the Killick Creek near the entrance which include 16 aquatic taxa and 10 bird species. Many bird species have been recorded, including migratory birds



and their numbers increase during summer migration periods (Ecological, 2008). A previous study conducted in 1993 (UNE 1993), indicates the presence of 26 fish species (the yellowfin bream, tarwhine, sand whiting and others). Updated targeted information within the study site is missing and needs to be addressed. However, some studies have observed the presence of stingray feeding pits at the lower reaches of the estuary at low tide.

The presence of Sydney Rock Oyster (*Saccostrea commercialis*) and marine snail (*Bembicium nanum*) around the rock wall near the entrance is well documented in all previous studies, along with several sandy infauna such as beach worms (polychaetes), crabs, yabbies and bivalve species (UNE & SCU 1993).

Threatened species

A total of 64 species of threatened fauna are recorded within 10 kilometers of Killick Creek, among which are five threatened bird species (*Ephippiorhynchus asiaticus*, *Haematopus fuliginosus*, *Haematopus longirostris*, *Ixobrychus flavicollis*, *Pandion haliaetus*) (Ecological, 2008).

Several threatened or protected species including osprey, green and golden bell frog, black-necked stork, sooty and pied oystercatchers, comb-crested jacana, little tern, koala and the little bent-winged bat are found in the Killick catchment (MHL 2002).

Overall, there is relatively limited knowledge of the vegetation within the Killick catchment and this needs thorough investigation in the future for better management (BMT WBM, 2020). This should be addressed in the Kempsey Shire LGA CMP.

5.5 Social, Economic and Recreational Values

The Killick estuary contributes to the overall Kempsey region's economy through its environmental, cultural, social and economic resources. Killick Creek passes through the Crescent Head township, and thus provides a variety of recreational uses including swimming, fishing, canoeing and kayaking for locals, as well for tourists that flock during summer and other school holiday periods. Its shallow waters provide a safe location for primary contact recreation, especially at the entrance, making it an ideal location for such activities. The population within the town can increase four times and has considerable pressure on infrastructure and facilities in the coastal villages.

The creek is also used by the Caravan Park business located at Crescent Head, which is heavily reliant on the estuary to attract tourists to the area. In 2008, Crescent Head was classified as a Surf reserve, an iconic surf location recognised of significance - both nationally and internationally. This high level of touristic usage may further exacerbate pressures and risk to the estuary (BMT WBM, 2020).

The Killick catchment supports the economy via its agricultural sector, which accounts for 0.2% of MSW gross state product (GSP) (BMT 2020). The creek is used for discharging water from agricultural farmland through man-made drains that pour out in the low-lying swamps areas of the system. In addition, the creek obtains inputs from stormwater drains from the urbanised Crescent Head located at the entrance that flushes to the ocean.

5.6 Cultural Heritage Values

The Macleay Valley Region has a rich and continuing indigenous heritage, with cultural history extending more than 40,000 years (NPWS, 1998). Killick Creek estuary study area is located in the traditional lands of the Dunghutti nation. Extending from the eastern coast to the tablelands in the west, Dunghutti country encompasses Kempsey, Bellbrook, and the towns of the Macleay Valley Coast. The traditional Dunghutti people were hunters and gatherers, who lived in harmony with the land, and their pattern of life was governed by sacred laws, handed down through countless generations (MVC, 2020).

The traditional Aboriginal people depended on the large rich food resource (fish and shell-fish) from sea, estuaries, creeks, rivers and its associated habitats. In the Kempsey Region the river plains and coastal headlands were open grasslands maintained by fire and grazed by large numbers of macropods and smaller marsupials and integrated with the daily life of the Aboriginal people prior to European settlement. This is particularly seen in the many Aboriginal important sites in the Kempsey region.

An interrogation of the National Native Title Register (NNTR) found no existing or pending federal native title claims across the study area catchment. The extent of claims made under the *NSW Aboriginal Land Rights Act 1983* across the study area is not known at this time. In terms of the implementation phase of the EMP, where there are unresolved claims lodged on Crown land, any dealings/works on Crown land will generally require the consent of the relevant Local Aboriginal Land Council.

5.7 Potential Impacts of Climate Change on Entrance Management

Many impacts of climate change are currently being felt by NSW's estuaries. Killick Creek will experience both broader impacts and specific local impacts, which are often inter-related. Management of the estuary will require understanding and accommodation of the long-term impacts of climate change. These include the following (Haines & Thom, 2007):

- **Mean sea level rise**, will pose a serious risk to coastal communities due to inundation and erosion. Between 1993 and 2009, the rate of global sea-level rise was estimated to be 3.2 ± 0.4 mm/year (Church & White, 2011). Depending on future carbon emission pathways, as defined by the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (IPCC, 2020) sea levels around eastern Australia could rise between 0.63 to 1.10 m by 2100. In these circumstances, built infrastructure may be potentially at risk, including drainage pathways, abutments, and adjoining roadways. Undeveloped shorelines may be equally vulnerable, with potential significant ecological implications (Glamore, Rayner, & Rahman, 2016).
- **Entrance morphodynamics**: Disruptions from sea-level rise, littoral sand transport, and changes to rainfall and flooding behaviour are likely to result in an upward and landward shift in the beach profile, and potentially increased size, height and extent of the entrance berm (Hanslow, Davis, You, & Zastawny, 2000). This would then require higher water levels to precipitate a natural entrance breakout. As shown in Figure 5-10, an increase in mean sea level will result in an elevation of the base and maximum water levels, as well as the berm height within the ICOLL. This will cause inundation of additional properties in the low-lying areas adjacent to the lagoon and creek as the water level rises. It will likely require additional management of the ICOLL entrance to alleviate water level rise in the creek and lagoon due to prolonged entrance closure, as well as consideration of other measures to alleviate nuisance flooding including relocation or modification of built infrastructure.

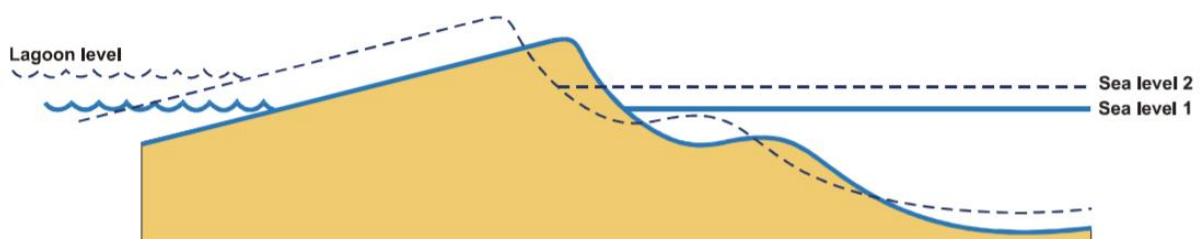


Figure 5-10 Upward and landward translation of an ICOLL berm under SLR (Hanslow, Davis, You, & Zastawny, 2000)

- **Tidal Inundation**: As sea level rise increases it is expected that the frequency and severity of tidal inundation (also referred to as “sunny day flooding”) will increase over time. This may lead to the progressive drowning of intertidal environments and freshwater habitats and increase the rate of landward displacement of estuarine shorelines and riparian ecosystems.



- **Estuarine Flooding:** With warmer weather, the storms and rainfall events are predicted to become increasingly intense in both the near and far future (IPCC, 2013). Combined with sea level rise, this will have major implications for the severity of flooding in the estuary. Typically, closed ICOLLs are predicted to have an increase in available water storage volume with the lagoon and creek as the berm height increases in response to sea level rise, increasing the potential for inundation of the estuary fringe as natural entrance breakouts are reduced.
- **Ocean and Estuarine Impacts:** In addition to sea level rise, climate change is expected to result in changes to the water quality (temperature, salinity, turbidity, suspended solids) and chemistry (oxygen, nutrients, pH and alkalinity, Chlorophyll-a) of coastal and estuarine systems. This will also effect estuarine heat budgets; hydrodynamic and mixing in particular after rainfall; and the effect on sediment dynamics. This includes ocean acidification and the impacts of warmer oceans on soft coral and fisheries (Adapt NSW, 2019).
- **Estuarine water temperatures:** A recent study has found that estuaries along the NSW coast are warming very rapidly, with average temperatures increasing more than 2 degrees over the past 12 years, which has been accompanied by acidification (Scanes, Scanes, & Ross, 2020). Coastal lagoons and creeks are acidifying and warming more rapidly compared to other estuary types. As Killick Creek lies at the boundary between temperate and tropical habitats, it is also expected to experience a tropicalisation of both marine and coastal environments, as the extent of flora and fauna extends south with the warming climate.
- **Biodiversity:** can be impacted by increasing air and ocean temperatures, rising sea level, changing in ocean chemistry (i.e., due to ocean acidification), and decreasing water quality. Coastal wetlands are particularly sensitive to climate change. These systems are usually unable to migrate inland as the shoreline recedes under sea level rise and are subject to threats caused by changes in the hydrologic and climate regimes.



6 STAKEHOLDER ENGAGEMENT

6.1 Community Engagement

Entrance management typically draws high levels of community interest and is often a controversial issue with a range of differing viewpoint across the community. The goal of the engagement with communities and other stakeholders is to obtain a high level of support for the EMP. Although it would be ideal to achieve total consensus in support, this is not always achievable with possible polarised and intransigent viewpoints that exist across the community.

To attempt to achieve a high level of community support, the project employed a three-step community engagement approach allied with engagement with public authority stakeholders. The three steps are provided in Figure 6-1, and described in detail below.

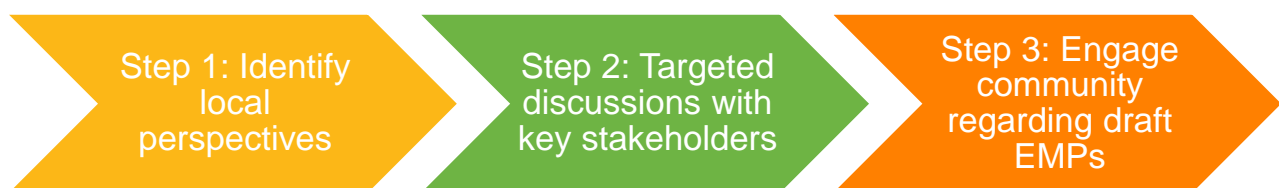


Figure 6-1 Community engagement process

In the first instance, Kempsey Shire Council developed a *Your Say Macleay* webpage for the project – in order to provide the local community with information about the project and how they can be involved. The webpage included:

- A project bulletin and a three-minute informative video about the project and the principles of entrance management;
- A series of Frequently Asked Questions (FAQs) regarding entrance management and the NSW State Government's Policies on ICOLL management; and
- Links to information about the wider Kempsey Shire LGA CMP.

6.1.1 Step 1: Identification of Community Perspectives

The first step in the community engagement process was to identify local viewpoints and perspectives. The original intention for the project was to undertake an in-person community information session and workshop. However, COVID-19 restrictions during this stage of the project prevented the possibility of face-to-face engagement methods. Therefore, an online community survey was utilised for this task.

The survey was open from 9 August to 31 August 2021 in order to ascertain local community viewpoints and attitudes towards entrance management. A total of 19 responses related to Killick Creek were received during the survey period, and answers to key questions regarding entrance management are provided in Table 6-1.

These results demonstrated the relatively polarised viewpoints within the community with regards to entrance management approaches. In particular, "[The Estuary] should be left to open / close naturally" received mostly high levels of "Strongly Agree" and "Strongly Disagree", with no recorded neutral responses.

In order to ascertain community priorities, respondents were asked to rank their biggest, or most prominent concern regarding entrance management. Responds ranked the various issues from (1) biggest concern, to (5) lowest concern.



Value judgements from the local community indicated that the highest priorities are towards “Maintaining good water quality”, which possessed an average score of 2.0, and “Maintaining natural ecosystems and environmental processes” (2.4) and “Minimising flooding” (2.6). Other issues such as “Maintaining safe vessel navigation” (3.6) and scored lower in terms of priority – as depicted in Figure 6-2.

Table 6-1 Community Survey Question 1: How strongly do you agree that the estuary should be managed in this way? [Total: 19 respondents]

Entrance Management Approach	Definitely agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree	Definitely disagree
It should be left to open / close naturally	7	3	0	1	8
Mechanical opening if/when properties surrounding the estuary are under threat of flooding	12	1	3	0	3
Mechanical opening if/when water quality in the estuary is degraded	13	2	0	2	2
Mechanical opening to allow recreational vessel navigation in and out of the estuary	8	1	3	1	6

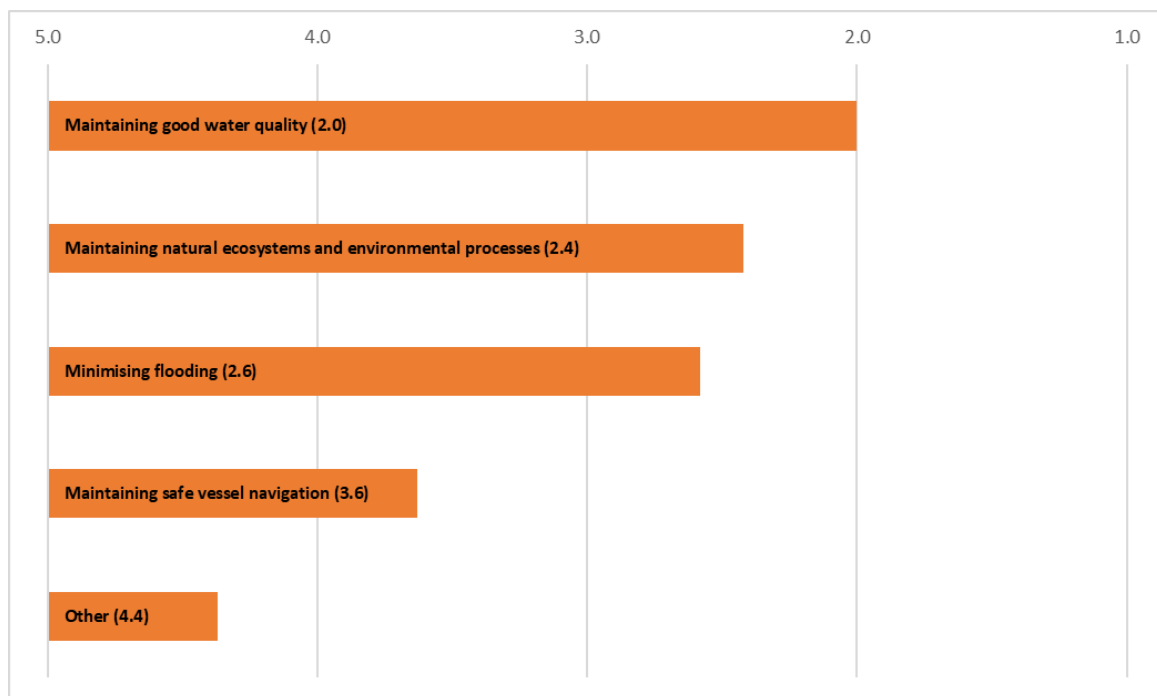


Figure 6-2 Community Survey Q4: Please rank your biggest concern regarding management of the entrance? (1 being the biggest concern)



6.1.2 Step 2: Targeted Community Discussions

The second step of the engagement process involved undertaking targeted community discussions. A community meeting was held on 3 November 2021 outside of the Crescent Head Surf Club, however only one community member attended. The main concern that was discussed pertained to water quality in the creek. The following were discussed:

- There is concern about stormwater drainage flowing directly into the creek, and possible pollution of animal faeces into the creek. It was noted that many children had ear infections after swimming in the creek during the March 2021 floods, even though the entrance was open at the time.
- There are concerns about flooding, and it was noted that during storms, the creek can flood due to storm surge and elevated ocean levels.
- There is a broader perception that the community is happy with how the meander correction has been managed by Council.

6.1.3 Step 3: Engage Community Regarding Draft EMPs

The final step in the engagement process will be to ascertain community feedback on the draft EMPs. The EMPs will be included as part of the wider Kempsey LGA Coastal Management Program. Feedback on the EMPs will therefore be garnered from the local community when the CMP goes to public exhibition.

6.2 Stakeholder Engagement with NSW Government Agencies

During development of the EMP, stakeholders were actively engaged from a range of relevant public authorities. A key component of this engagement was a stakeholder workshop, undertaken on 23 August 2021. Attendees of the workshop included representatives from Council, DCCEEW(BCS), DPIRD-Fisheries, DPHI-Crown Lands, and Transport for NSW. Representatives from National Parks and Wildlife Service (NPWS) were not available to attend but were engaged with separately. The key objectives of the workshop were to:

- Identify management roles and, responsibilities and legislation in relation to entrance management;
- Confirm details of historical entrance management arrangements, and the “on-the-ground” reality of how those arrangements have been practically implemented;
- Discuss historical barriers and constraints to effective management, and opportunities to respond and adapt to future challenges; and
- Identify relevant stakeholders for additional engagement.

The workshop was highly interactive and participatory. Follow-up with stakeholders was undertaken on a regular basis throughout development of this EMP.



7 ENTRANCE MANAGEMENT APPROACH

7.1 Overarching Approach

The overarching approach of this EMP is to advocate the general principle of minimal intervention. NSW DPIRD-Fisheries supports minimal interference with ICOLL barriers and advocates natural processes being allowed to operate to the greatest extent possible. This EMP therefore applies an approach of non-intervention - except where trigger conditions for intervention are reached.

Therefore, this EMP outlines the following:

- Decision making criteria for *if* and *when* entrance management intervention should occur; and
- Determining the most suitable method of *how* entrance management will be undertaken, namely:
 - Berm height management; or
 - Direct mechanical opening.

7.1.1 Decision Making Criteria (If and When)

Decision making in entrance management needs to consider environmental, social and economic factors including the range of viewpoints of the local community towards entrance opening. This EMP outlines guidance for entrance management based on the following matters of interest:

- Flood mitigation within the Crescent Head township – with consideration of the presence of both coastal and catchment flooding, as well as the impacts of the Macleay River Flood Mitigation network and Killick Creek floodgates.
- Water Quality within the estuary – under rare circumstances where water quality may affect human health and safety during peak usage periods. Artificial opening of the estuary for these purposes should only take place if agreement between relevant public authorities is reached.
- The entrance meander correction – in order to prevent potential erosion and undermining of the coastal foredune which provide a barrier to erosion and inundation of the Crescent Head township, protect the foundations of the pedestrian footbridge, and maintain recreational access to Killick Beach.

As discussed in Section 8.2, while the entrance management framework provided in this document provides a strong scientific basis for determining the most appropriate course of action – the decision of which approach to take will ultimately belong to Council, in conjunction with relevant public authority stakeholders (Section 8.3).

7.1.2 Entrance Management Methods (How)

Entrance management is complex, and a flexible approach is therefore beneficial. The final course of action may be one of three potential options for entrance management, listed below in order of low intervention (most preferred) to high intervention (least preferred):

Option 1: Do Nothing

The overarching approach of this EMP is to advocate the general principle of minimal intervention and allowing the estuary to operate naturally to the greatest extent possible. This EMP therefore applies an approach of non-intervention - except where trigger conditions for intervention are reached.

Option 2: Berm Height Management

This involves managing the height of the berm such that it does not exceed a pre-determined level, using mechanical equipment to implement a “dry notch” or “saddle point” in the entrance berm which the water can



then preferentially flow across. If maintained correctly, the notch would breach when the lake water level reaches the appropriate level during a runoff event.

This approach is intended to reduce the likelihood of fish kills through promotion of natural openings - by scraping the beach berm prior to heavy rainfall events, and allowing the opening events to coincide with rainfall and freshwater inflows. Selection of an appropriate berm height management level should be in consideration of:

- Adoption of a “minimal interference” approach by implementing a berm height management level within the natural breakout range, thereby allowing the natural processes to operate to the greatest extent possible; and
- Responsible and practical mitigation of flooding and inundation impacts across the estuary - by ensuring that the berm height management level (also referred to as the “berm saddle level”) also considers the levels and nature of fringing foreshore antistructure.

An added advantage of the berm height management approach is that - as it involves managing the berm prior to a storm event - it avoids Council having to activate machinery and conduct work at the berm during potentially dangerous conditions, such as heavy rainfall, energetic waves, and eroded beach states.

The approach of berm height management is strongly advocated by this EMP.

Option 3: Mechanical Opening

Direct mechanical opening has commonly been used in entrance management across NSW in recent decades, and has been used in rare circumstances historically at Killick Creek. As discussed in Section 5.3, direct mechanical opening can often be expedient, however it can also result in an increased risk of fish kills events. Therefore, there has been a recent shift in NSW towards managing ICOLL opening through berm height management – as opposed to direct mechanical opening.

However, historical entrance closure events at Killick Creek have often resulted in a relatively wide entrance berm – tens of metres wide, and sometimes extending upstream of the pedestrian footbridge. There are logistical limitations associated with getting safe machinery access upstream of the footbridge, and so in some circumstances, direct mechanical opening may be necessary or more appropriate. This may also include a rare circumstance where there is a need to act urgently – as assets around the estuary are particularly low-lying around Willow Street, and emergency situations are possible (when water levels have risen rapidly and urgent opening for flood relief is necessary).

Therefore, a flexible approach is required - and in the event of entrance closure, Council should liaise with relevant agencies listed in Section 8.3 in order to determine the most suitable opening method.

7.2 Entrance Management for Flood Mitigation

7.2.1 Purpose and Limitations

Killick Creek is considered to be an important ocean outlet for the Macleay Valley Flood Mitigation Scheme. Therefore, the primary purpose of entrance management in the event of a closure would be to ensure that flood impacts at Crescent Head are not exacerbated by a closed entrance condition.

However, it should be noted that entrance management is somewhat limited in its ability to mitigate rare and severe flooding (of around 1% AEP or more severe). Section 5.1.3 demonstrates that, as with many ICOLLs, the impact of the entrance condition on flood levels at Killick Creek diminishes with increasing flood severity. Furthermore, entrance opening does can exacerbate the impacts of ocean flooding from elevated storm tides.

Entrance management should therefore not be perceived or advertised as a “silver bullet” to alleviate all flooding within the estuary, and appropriate flood mitigation measures should consider the many components



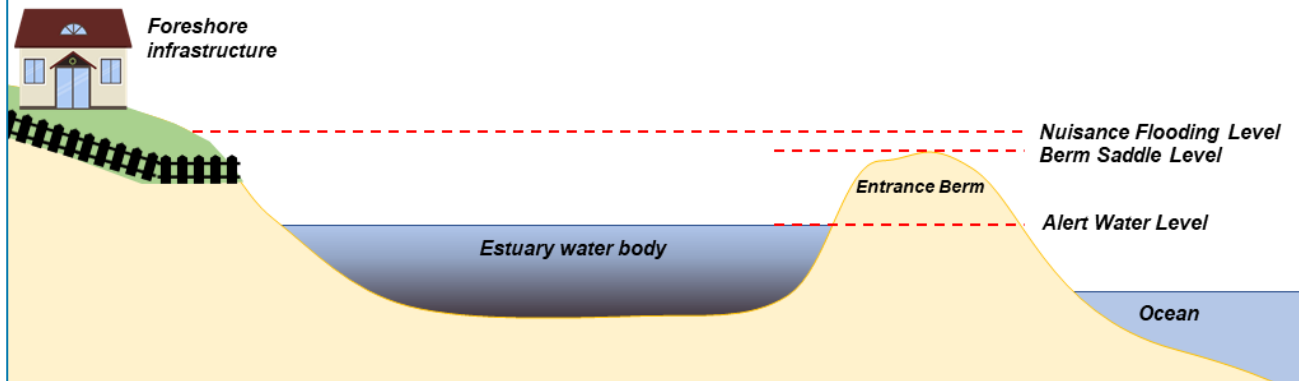
of the Macleay Valley Flood Mitigation Scheme. Rather, the process of entrance management is intended to mitigate the impacts of less severe inundation events – referred to as “nuisance flooding”. The approach of berm height management includes three main components:

- **The Alert Water Level:** When the estuary is closed, Council should immediately commence monitoring estuary water levels. When the recorded water level inside the closed estuary is high enough that the next major rainfall event could result in nuisance flooding – then the entrance management protocols should commence. Therefore, when the water levels reach the Alert Water Level, then Council should be on “alert” to start the entrance management process.
- **Berm Saddle Level:** If a significant rainfall event is forecast - 60+ mm event over the coming 72 hours - then Council should survey the level of the closed entrance berm. If the natural saddle point of the berm (i.e., the natural breakout level) is above this level – then the entrance berm is to be scraped so that it does not exceed this level. Later during a rainfall event, the estuary will overtop the entrance berm at this level and break out. This is intended to replicate the natural breakout process and reduce the risk of fish kill events.
- **The Nuisance Flooding Level:** This is the desired maximum level of nuisance inundation that scraping the entrance berm intends to minimise. The Berm Saddle Level and the Alert Water Level are essentially determined by working backwards from Nuisance Flooding Level.

These three components are described in the schematic in Figure 7-1. The specific levels for these triggers are provided in Table 7-1, along with justification for their adoption.



Prior to rainfall event: Once the Alert Water Level is reached, scrape the entrance berm to the Berm Saddle Level - to induce a natural opening later when rainfall occurs



During the rainfall event: Entrance berm naturally opens at the Berm Saddle Level with freshwater flows

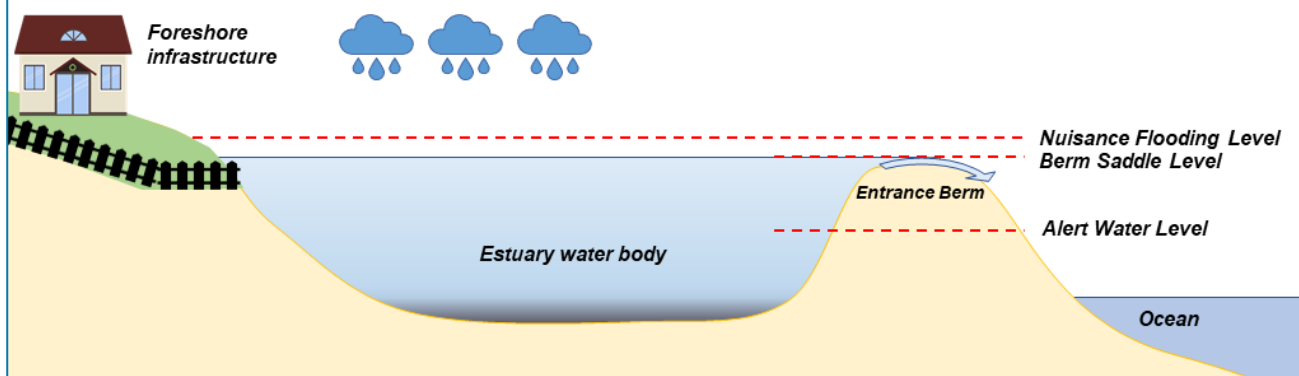


Figure 7-1 Berm height management - breakout process

Table 7-1 Flood mitigation trigger levels

Description and rationale		Level (mAHD)
Flooding Level	The desired level of nuisance flooding that scraping the entrance berm intends to prevent. In this instance, the intention is to where possible prevent inundation of properties on Willow Street, downstream near the estuary entrance. As discussed in Section 5.2.4, at a water level of 1.5 m AHD, the Willow St cul-de-sac road inundated and dangerous for driving (~0.2 m depth), and therefore considered to be cut-off. This water level also results in nuisance backyard flooding of 10 properties on Willow St (<0.1 m depth).	1.5
Berm Saddle Level	If a significant rainfall event is forecast – greater than a 60 mm event - then Council should survey the level of the closed entrance berm. If the natural saddle point (i.e., the breakout level) of the berm is above this level – then the entrance berm is to be scraped so that it does not exceed this level. Later during a rainfall event, the estuary will overtop the entrance berm at this level and break out with a	1.3



<i>Description and rationale</i>	<i>Level (mAHD)</i>
<p>freshwater flush. This is intended to replicate the natural breakout process and reduce the risk of fish kill events.</p> <p>Results of the Lower Macleay Flood Study indicate that during a 5% AEP flood event, a steep hydraulic gradient in water level of around 0.4 m may be present between the entrance and Willow Street properties during peak flood conditions. During the onset of entrance breakout, this gradient is likely to be lower, likely around 0.2 m. Therefore, in order to ensure that a level of 1.5 m AHD is not exceeded at the at Willow St, the berm saddle level should be set no higher than 1.3 m AHD.</p> <p>A berm saddle level that is higher than this may increase the risk of catchment flooding. Conversely, it should be noted that that if the berm saddle level is set much lower than this, then it will increase the likelihood of storm tides entering the estuary and putting infrastructure at risk.</p> <p>As there very little records of natural entrance breakouts, there is little information available to determine if this saddle level is within the natural breakout range of the estuary. However, given the likely infrequent requirement of entrance management – it is not expected that adoption of this level would significantly impact on long term estuary function.</p>	
<p>Alert Water Level</p> <p>When the estuary is closed, Council should commence monitoring estuary water levels. When the recorded water level reaches this trigger value, Council should be on “alert” to start the entrance management process described below.</p> <p>It should be noted that due to the potential for ocean tide ingress during high spring tides, the estuary would be unlikely to be “fully” closed at a level lower than around +0.7-1.0 m AHD.</p>	0.8



7.3 Approach to Managing Estuarine Water Quality

7.3.1 Overview

As discussed in Section 5.3, the most effective and sustainable way of managing ICOLL water quality is through improved management of catchment and floodplain runoff into the estuary. This will likely be addressed in the forthcoming Kempsey Shire Council CMP.

However, artificial opening may (in rare cases) be required to address extreme water quality issues where severe environmental and public health risks may be posed by poor water quality. exist. Killick Creek is highly valued and used by the local community for its safe primary contact recreational amenity opportunities, particularly during peak season.

It is often difficult to include triggers to address a broad range of potential water quality scenarios and associated uncertainties – and many EMPs do not include specific trigger values for opening estuaries based on water quality. A good example is the Woolgoolga Lake EMP (Coffs Harbour City Council, 2019b). A range of factors would need to be considered during a poor water quality event, such as:

- Environmental and public health risks posed by the water quality issue;
- The extent to which artificial opening will mitigate the water quality issue; and
- The consequent environmental and public health risks along the adjoining coastline following artificial opening of the estuary.

This EMP recommends that opening for water quality purposes should not be undertaken unless poor water quality can be evidenced through monitoring data. It is recommended that any water quality event is assessed on an individual basis and any decision to open should be made by Council with advice / approval from DCCEEW(BCS), DPHI-Crown Lands, DPIRD – Fisheries, and NPWS. Artificial opening of the estuary should only take place if agreement between relevant agencies is reached.

7.3.2 Guidance for Management Decisions

Recommendations are provided herein to guide discussions between stakeholders for a scenario where Council may consider opening the estuary on the grounds of water quality:

- Water quality conditions are more appropriate as a trigger for entrance management actions during high use periods when primary contact recreation is more prevalent - nominally for the period from September school holidays to Easter school holidays.
- Guidance is provided below in the form of ANZECC (2000) guidelines for primary contact recreation (such as such as swimming, bathing and other direct water-contact activities). The guidelines state that the estuary waters should generally be free from faecal contamination, pathogenic organisms and other hazards (e.g., toxic chemicals) to protect the health and safety of the users. Additional guidance is provided for protection of aquatic organisms, with regard to low dissolved oxygen and asphyxiation of aquatic organisms, particularly fish.

Table 7-2 ANZECC WQ guidelines

Water quality parameter	ANZECC (2000) Threshold Value	Monitoring Location(s)
Faecal coliforms	<ul style="list-style-type: none">▪ Median from 4 consecutive samples taken during closure > 150 organisms /100mL; or▪ Any one sample > 600 organisms/100mL	<ul style="list-style-type: none">▪ Downstream



Water quality parameter	ANZECC (2000) Threshold Value	Monitoring Location(s)
Enterococci	<ul style="list-style-type: none"> Median from 4 consecutive samples taken during closure > 35 organisms /100mL; or Any one sample >60 organisms/100mL 	<ul style="list-style-type: none"> Downstream
pH	<ul style="list-style-type: none"> < 5.0 	<ul style="list-style-type: none"> Upstream Downstream
Dissolved Oxygen	<ul style="list-style-type: none"> < 4 mg/L 	<ul style="list-style-type: none"> Upstream (bed and surface) Downstream (bed and surface)

If any of the above thresholds are exceeded, then any decision to open should be made by Council with advice / approval from DCCEEW(BCS), and DPIRD - Fisheries. With regards to the opening method, the following is noted:

- Monitoring for dissolved oxygen (DO) is to be undertaken in the water column at both the bed and the surface. If monitoring indicates that DO levels in the estuary are highly stratified – then direct mechanical opening may increase the likelihood of estuary “decanting” and associated fish kills. In this scenario, berm height management may be a more suitable opening method.
- If monitoring for faecal coliforms and enterococci indicates a significant risk to human health and safety for primary recreation, then direct mechanical opening may be a more suitable approach so that risks are mitigated more readily – rather than scraping the berm and waiting potentially weeks or months for sufficient rainfall to facilitate an opening. However, this approach would need to be discussed with DCCEEW(BCS), and DPIRD-Fisheries.



7.4 Entrance Meander Correction

As discussed in Section 4.1.2, the estuary meander correction works have been undertaken by Council for many years. However, the Estuary Management Study and Plan (WBM Oceanics, 2006) recommended discontinuation of meander correction:

“...until further investigation of potential threats to the dune system are identified”. However, the plan also stated that if “...following further investigations... indicates that sensitive or endangered habitat is at risk due to the erosion (as the dunes at risk on the northern side of the entrance are contained within Hat Head National Park), or if the erosion results in unfavourable tidal and wave penetration conditions within the estuary, or if there are significant access restrictions to the beach from the footbridge, then these protocols shall be amended to include [the] additional meander correction [trigger]”.

The Kempsey Coastal Hazard Study (BMT WBM, 2013), undertaken seven years later in 2013 indicated established the potential erosion threat facing the dunes (BMT WBM, 2013). Figure 7-2 depicts the erosion hazard lines developed in the hazard study. It indicates that under “rare” conditions the Killick Beach spit and the local dune system would incur significant erosion – in some cases resulting in the complete erosion of the spit. This analysis demonstrates that the spit provides a significant barrier to erosion and inundation of the Crescent Head township – and maintaining the condition of the entrance spit is therefore beneficial from a coastal hazard perspective. Subsequently, it is recommended that continuation of the entrance meander correction works is justified on this basis.

It should be noted that the continuation of the entrance meander correction works was discussed with relevant state agency stakeholders during development of this study (see Section 6.2), and no major objections were raised in regard to the works, as long as the REF showed that there were no major adverse environmental impacts. With regards to this, the following are noted:

- The purpose of the works would be to realign the channel – whilst maintaining the current level of ocean connectivity. Therefore, increasing the width or depth of the channel should not be part of the works. If this is adhered to, the occasional entrance realignment would not be expected to have a significant impact on hydrodynamic or ecological processes.
- The need for meander correction has been relatively infrequent in nature – noting that no such works were undertaken in between September 2007 and September 2020 (a period of 13 years). Therefore, the works are likely to be undertaken on a relatively rare and infrequent basis.

7.5 Procedures

- Procedures are provided in Section 8 for entrance opening – called Scenario 1.
- Procedures are provided in Section 9 for entrance meander correction – called Scenario 2.

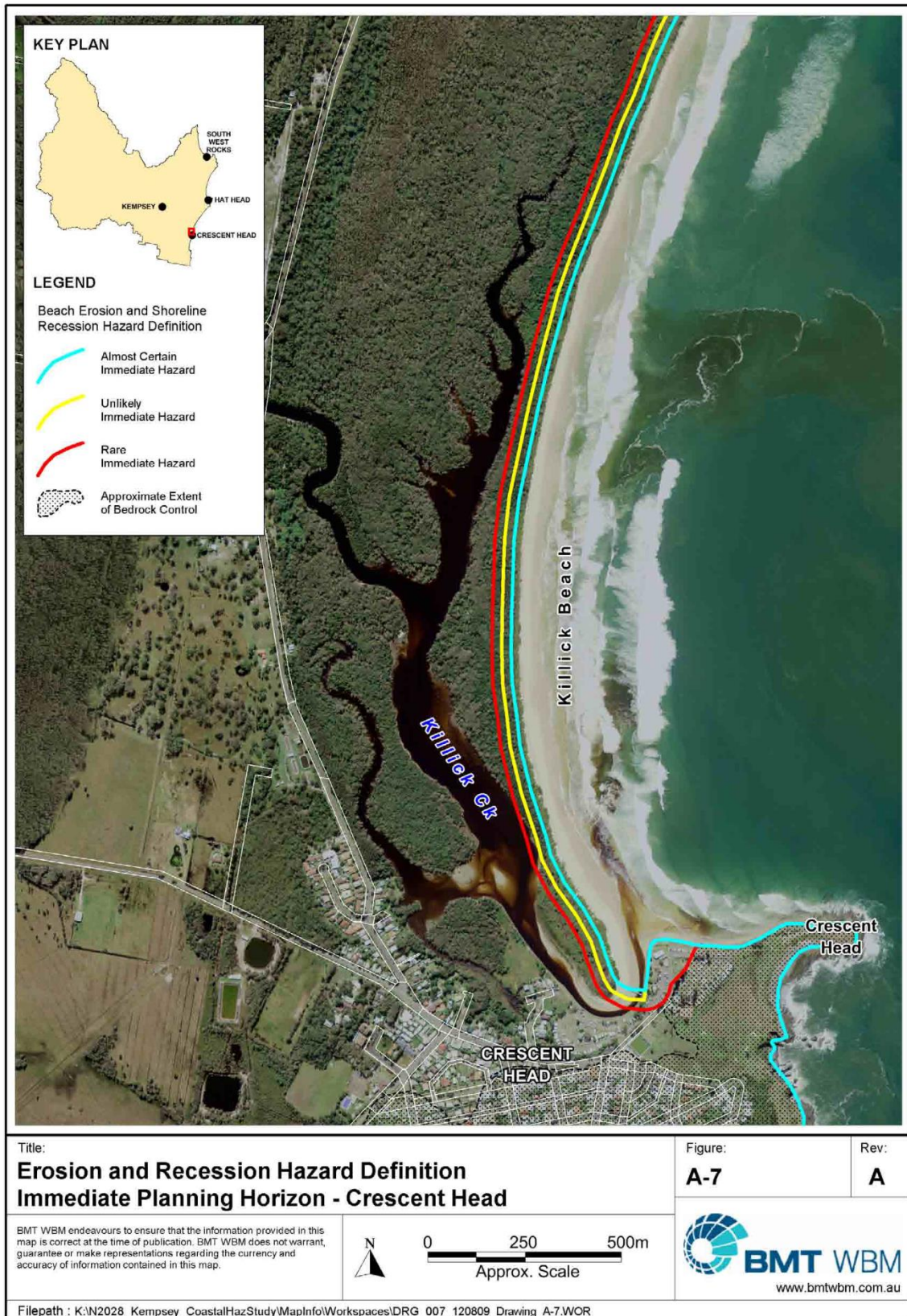


Figure 7-2 Immediate (Present Day) coastal erosion hazard lines for Crescent Head (BMT WBM, 2013)



8 ENTRANCE MANAGEMENT PROCEDURES - OPENING

8.1 Roles and Responsibilities

The primary responsibility for implementation of the entrance management protocols is with Kempsey Shire Council. These responsibilities include obtaining relevant licences and approvals, and direction and supervision of all works on site to ensure that they are carried out in accordance with these protocols and relevant standards and codes of practice.

8.2 Decision Making Framework

A summary of the decision-making framework is depicted in Figure 8-1. The framework is to be initiated, informed, and supported by monitoring of key environmental parameters. The decision needs to consider environmental, social and economic factors including the range of viewpoints of the local community towards entrance management.

The procedures for entrance management include the following:

- **Notify** relevant public authorities that the entrance is closed, and that the monitoring and decision-making process has commenced;
- **Monitor** key environmental and social parameters that affect decision making;
- **Assess** environmental and social parameters against guidance set out in the framework;
- **Decide** on the most appropriate course of action based on available data;
- **Communicate** the course of action with relevant public authorities and the Crescent Head community;
- **Act** based on an informed, consultative process; and
- **Reporting**: Monitoring and reporting are essential for informing future management and determining improvements to the procedure.

The framework in Figure 8-1 summaries a range of considerations, intended to provide guidance for the determination of eventual course of action. This is not intended as a rigid decision-making tool. Rather, flexibility is always beneficial, as “on the ground” conditions can change quickly, and a broad range of potential environmental, social and economic scenarios can exist in reality. Therefore, while the framework provides a strong scientific basis for determining the most appropriate course of action – the decision of which approach to take will ultimately belong to Council, in conjunction with public authority stakeholders (Section 8.3).

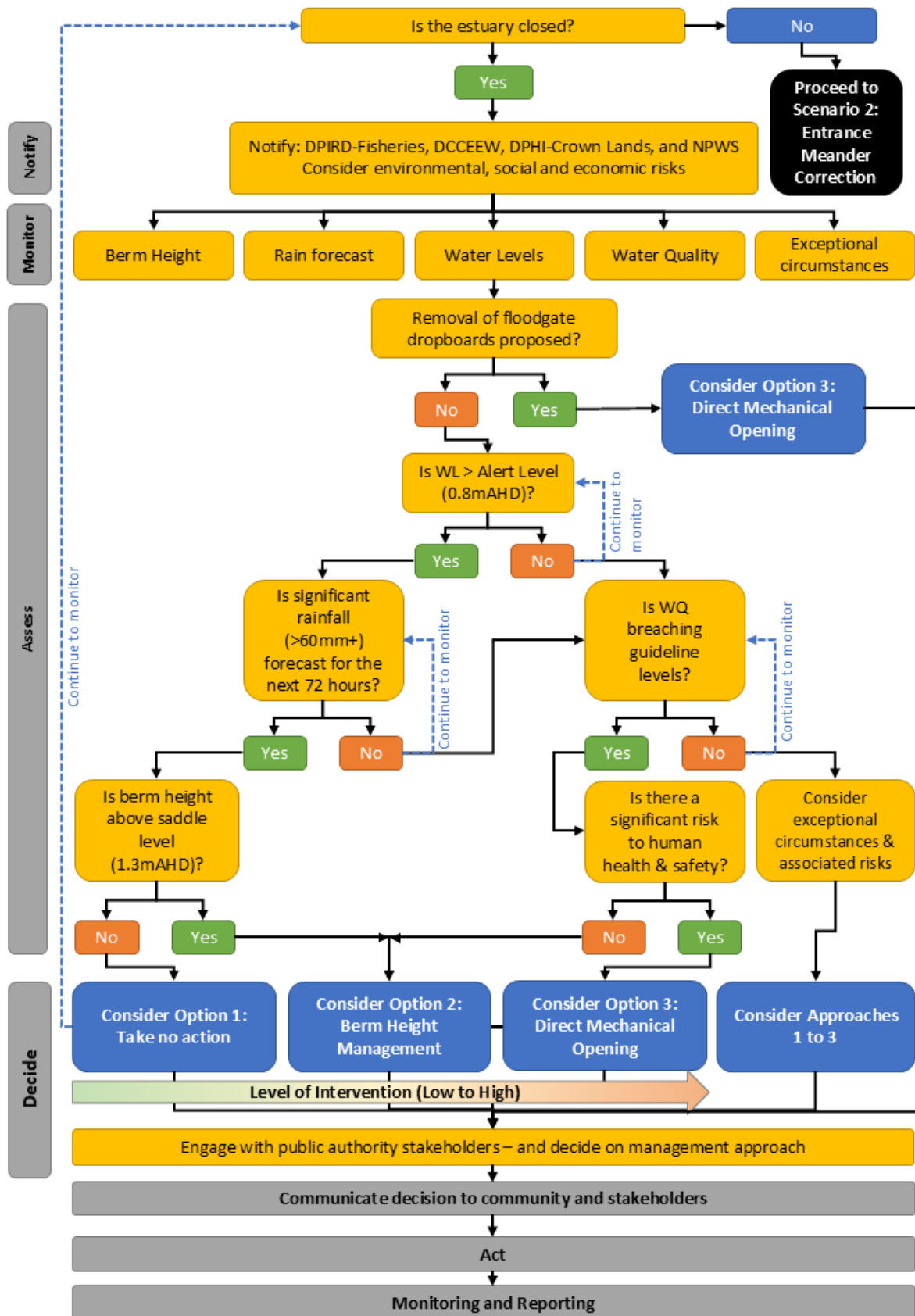


Figure 8-1 Overview of the entrance management decision-making framework: Scenario 1 (entrance closed)



8.3 Notify

In the event of entrance closure, the first step will be for Council to notify the following agencies:

- DCCEEW(BCS);
- DPHI-Crown Lands;
- DPIRD-Fisheries; and
- NPWS.

Council should inform these agencies that the entrance is closed and commence the entrance management decision making process. This process should consider the environmental and socio-economic parameters outlined in Section 8.4.

Whilst entrances closures are expected to be relatively rare events, it is important to acknowledge that there are strongly held and polarised views within the community with regards to entrance management. Therefore, a pragmatic and responsive approach to entrance closure is required.

8.4 Monitor

8.4.1 Water Levels

- When the estuary is closed, water levels should be monitored daily, with a focus on monitoring during and after rainfall events.
- **Estuary Water Levels:** Water levels in the estuary are automatically monitored and recorded by Manly Hydraulics Laboratory (MHL) - Crescent Head Station (ID: 207452) - and reported online. The water level recorder is located at the footbridge, approximately 400 m upstream of estuary entrance. The instrument records the water level every 15 minutes and is visible on the MHL website (<https://mhl.nsw.gov.au/>).
- **Ocean Water Levels:** The nearest ocean tide gauge is located at Port Macquarie (Station ID: 207420), around 25 km south of the estuary entrance. This location is sufficiently proximate to be representative of the coastal ocean tide levels at the estuary entrance. Predicted tides can be accessed via at the BOM at: http://www.bom.gov.au/oceanography/projects/ntc/nsw_tide_tables.shtml

8.4.2 Water Quality Monitoring

- Once the estuary closes, Council officers are to carry out periodic water quality monitoring of the estuary. Water quality monitoring should be carried out on a weekly basis, and immediately after significant rainfall events (> 60 mm in 24 hours).
- In order to inform decision making in entrance management, it is recommended that water quality monitoring is undertaken for the following parameters:
 - Dissolved oxygen
 - pH
 - Faecal coliforms
 - Enterococci
- A hand-held water quality multi-probe is to be used to determine results for dissolved oxygen and pH. With respect to faecal coliforms and enterococci, water samples are to be collected and provided to a suitable microbiological laboratory for analysis. Sampling procedures shall be followed in accordance with laboratory requirements, with samples delivered to the lab not less than 24 hours after collection. Samples are to be chilled during storage and transportation to the laboratory. With respect to bacteria, a combined sample using waters taken from all sampling sites (minimum of 3 within lower section of creek) should be provided to the laboratory for analysis.
- Water quality monitoring is recommended in two general areas:



- Downstream near the estuary entrance and footbridge and boat ramp; and
- Upstream near the Killick Creek floodgates (just downstream of the gates themselves, near the tidal limit).

8.4.3 Entrance Condition and Berm Height

- Once the estuary has closed, Council's designated officers should assess the site and observe relevant factors, including:
 - The condition and extent of sand berm
 - Survey equipment should be used to survey levels of the berm, and determine the level (in mAHD) of the natural "saddle point";
 - The best location on the berm to undertake any potential scraping or opening works. It should be noted that at Killick Creek, the flood tide delta can extend several hundred metres upstream, and depending on the shape and height of the berm, the task of scraping may be difficult or impractical; and
 - Safety and access arrangements.

8.5 Assess: Decision Making Guidance

The framework in Figure 8-1 summaries a range of decision making pathways, intended to provide guidance for the determination of eventual course of action. Based on the prevailing environmental and social conditions, the entrance management may be one of three potential options: (1) Do Nothing, (2) Berm Height Management, or (3) Direct Mechanical Opening.

The purpose of this section is to provide additional detail to support the framework in Figure 8-1.

Step 1: Floodgate Considerations

1. In the first instance, Council should consider whether or not there is any proposal for operation of the Killick Creek floodgates.
 - a. If removal of dropboards is proposed, in accordance with the Floodgate Management Policy, and the entrance to Killick Creek is closed, then consideration should be given to given to artificially opening the entrance prior to removing the drop boards. **Consider Option 3: Direction Mechanical Opening: Proceed to Section 8.8 for mechanical opening procedures. Proceed to Step 6.**
 - i. This is likely to occur during Macleay River and/or Maria-Hastings River flood events, or when significant local rainfall is received within the Belmore Swamp area, and a significant volume of water would be expected to be discharged during such an event.
 - b. If removal of dropboards is not proposed, the Council should proceed to monitor the estuary water levels. **Proceed to Step 2.**

Step 2 Water Level Monitoring

2. In the first instance, Council should monitor the water level of the estuary. The alert level of 0.8 m AHD will be based on water level data automatically monitored at 15-minute intervals by Manly Hydraulics Laboratory (MHL) at the Killick Creek gauge.
 - a. If the alert level of 0.8 m AHD is exceeded at the gauge, Council will monitor rainfall forecasts to predict if water levels are likely to rise significantly and pose a flood risk. **Proceed to Step 3.**
 - b. If the estuary water levels are below 0.8 m AHD at the gauge, then there is not considered to be an immediate nuisance flood risk.



- i. At this point, other criteria for entrance opening may be considered. **Proceed to Step 4.**

Step 3: Forecast Rainfall and Berm Height Monitoring

3. Council should monitor rainfall forecasts, to assess if there is increased risk of inundation.

- a. If a significant rainfall (>60mm+) is forecast for the next 72 hours, then:

- i. Council should proceed to undertake site assessment to survey the height of the entrance berm and determine if berm scraping is required (see Section 8.4.3).

- ii. If the lowest point in the berm (and thus the expected natural breakout level), is confirmed to be above the desired berm saddle level of 1.3 m AHD – **Consider Option 2: Berm Height Management: See Section 8.8 for berm scraping procedures. Proceed to Step 6.**

1. Note that if an elevated ocean tide above the berm saddle level of 1.3 m AHD is forecast, then reducing the berm height in this scenario may allow ocean inundation to enter the estuary - and place infrastructure at risk. In this scenario, an intact berm will act as a barrier providing the estuary with protection. Therefore, the works should be timed appropriately in order to manage the balance of forecast rainfall and ocean tides.

2. Council officers should also note the shape and extent of the entrance berm, in order to determine if scraping will be a practical opening method.

- iii. If the lowest point in the berm (and thus the expected natural breakout level), is confirmed to be below the desired berm saddle level of 1.3 m AHD, then no physical action is required. During the next major rainfall event, the berm will naturally overtop at a low level - **Consider Option 1: Take No Action. Proceed to Step 6.**

1. At this point, other criteria for entrance opening may be considered. **Proceed to Step 4.**

Step 4: Water Quality Monitoring

4. As outlined in Section 8.4.2, after the entrance closes, Council staff are to carry out water quality monitoring on a weekly basis, and immediately after significant rainfall events. Guidance is provided in Section 7.3 to help inform whether water quality parameters may precipitate an opening event.

- a. If any of the water quality parameters breach guideline levels, then a range of factors need to be considered, such as:

- i. Environmental and public health risks posed by the water quality issue;
- ii. The extent to which artificial opening will mitigate the water quality issue; and
- iii. The consequent environmental and public health risks along the adjoining coastline following artificial opening of the estuary.

Artificial opening of the estuary for water quality purposes should only take place if agreement between relevant agencies in Section 8.3 is reached.

The method of mechanical opening should consider potential ecological and human health risks. Some guidance is provided in Section 7.3 to inform decision making:



- iv. If monitoring for faecal coliforms and enterococci indicates a significant risk to human health and safety for primary recreation, then direct mechanical opening may be a more suitable approach. **Consider Option 3: Direction Mechanical Opening: Proceed to Section 8.8 for mechanical opening procedures. Proceed to Step 6.**
 - v. Otherwise, or if monitoring indicates that DO levels in the estuary are highly stratified, then berm height management is recommended for opening to reduce the potential for fish kills. **Consider Option 2: Berm Height Management: Proceed to Section 8.8 for berm scraping procedures. Proceed to Step 6.**
- b. If none of the water quality parameters breach guideline levels, then there is unlikely to be sufficient environment or a human health risk to warrant artificial opening – and no action is required (**Consider Option 1: Take No Action**).
 1. At this point, other criteria for entrance opening may be considered. **Proceed to Step 5.**

Step 4: Exceptional Circumstances

5. While the framework provides a strong scientific basis for determining the most appropriate course of action, the decision of which approach to take will ultimately rest with Council, in conjunction with key stakeholders.

Whilst the framework provides guidance for entrance management from flooding and water quality perspectives, entrance management decision making needs to also consider exceptional circumstances that may present a risk to the environmental, social, and cultural values of the estuary such as chemical/pollutant spills, fish kills, algal blooms, or infrastructure related issues. Any such issues identified through monitoring or community & stakeholder engagement will be highlighted and forwarded to relevant authorising agencies for consideration in the decision making process.

In the event of entrance closure, it will be important to be responsive and communicate clearly with the Crescent Head community (see Section 8.7).

Proceed to Step 6.

8.6 Decide

Step 6: Decide

6. The framework in Figure 8-1 summaries a range of considerations, intended to provide guidance for the determination of the eventual course of action. While the framework provides a strong scientific basis for determining the most appropriate course of action, the decision of which approach to take will ultimately belong to Council, in conjunction with public authority stakeholders (Section 8.3).

8.7 Communicate

Step 7: Communicate

7. Once decided, the course of action should be communicated to relevant stakeholders and the community – prior to undertaking any specific course of action.
 - DCCEEW(BCS): To provide technical advice and confirm agreement with the proposed approach. Council should also confirm whether shorebirds are known to be nesting in the vicinity of the Saltwater Creek entrance. If nesting shorebirds are found to be breeding at the entrance site, entrance management works should take this into consideration.



- DPHI-Crown Lands: As entrance berm and any proposed works would be undertaken on Crown land tenure.
 - DPIRD-Fisheries: To provide technical advice and confirm agreement with the proposed approach; and
 - NPWS: To provide technical advice and confirm agreement with the proposed approach.
- a. Any matters concerning the openings 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.
 - b. The decision should also clearly be communicated to the local community. Kempsey Shire Council should generate media release and social media communications to inform the community of the works.

Proceed to Step 8.

8.8 Act: Procedural Notes

Step 8: Act

This section provides procedural notes for entrance management options that require on-ground works:

- Option 2: Berm Height Management and
- Option 3: Direct Mechanical Opening.

8.8.1 Option 2: Berm Height Management

Once the decision has been made to adopt an approach of berm height management, the following procedure should be undertaken:

- When a decision to take action is made, Council's personnel and machinery will be deployed to the entrance if the site assessment considers it appropriate and safe.
- The recommended access point for the 4WD backhoe operator to access the beach is via the boat ramp. 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.
- Appropriate pedestrian safety measures are to be put in place during the works. This should take the form of either signage, or Council staff present on site to prevent pedestrian access within 20 m of machinery and the entrance.
- Survey equipment is to be used to survey levels of the berm and confirm a height above the nominated berm saddle level of 1.3 m AHD.
- The excavator / backhoe then proceeds to scrape the berm to the appropriate level while continually cross-referencing levels with survey equipment. The dry channel width should measure at least 5 m across. Figure 8-2 shows the recommended location of the works.
- Once the nominated berm saddle level is achieved, the operator is to smooth the dry channel batter slopes to make safe for pedestrian traffic.
- Although the volume of scraped sand is expected to be small, the excavated sand should be retained on the beach and not removed from the system. The sand should ideally be placed on Killick Beach and spread evenly across the beach foredune in such a manner that no vegetation is disturbed.
- After the scraping works, Council personnel and machinery are to remain on stand-by, until:
 - The forecast rain eventuates, and the estuary opens of its own accord; or



- The operation is cancelled by Council's designated officers.
- Decline in water quality at adjacent surf beaches may occur as a result of the estuary breakout. Council should consider the need to notify the community of this issue for at least the first 7 days after the opening has occurred.

8.8.2 Option 3: Direct Mechanical Opening

If the decision has been made to adopt an approach of direct mechanical opening, the following procedure should be undertaken:

- The mechanical opening is to be planned so that where possible the actual opening of the estuary occurs shortly after the tide turns from high to low, preferably for the lower of the two low tides of the day.
- The recommended access point for the 4WD backhoe operator to access the beach is via the boat ramp. 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.
- Appropriate pedestrian safety measures are to be in place during the works. This should take the form of either signage, or Council staff present on site to prevent pedestrian access within 20 m of machinery and the entrance.
- The channel should generally be positioned as close as practical to the natural flow path of the estuary when open – adjacent to the bedrock on the eastern bank but without interference to the rock.
- The opening should be deep enough for scouring flow to develop, 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 creek. 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 creek end) should be kept closed, and where possible, opened shortly after the next high turns from high to low tide (i.e., to the lower of the two low tides of the day). Figure 8-2 shows the recommended location of the works.
- 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 creek 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.
- Although the volume of scraped sand is expected to be small, the excavated sand should be retained on the beach and not removed from the system. The sand should ideally be placed on Killick Beach and spread evenly across the beach foredune in such a manner that no vegetation is disturbed.
- Decline in water quality at adjacent surf beaches may occur as a result of the estuary breakout. Council should consider the need to notify the community of this issue for at least the first 7 days after the opening has occurred.

8.9 Monitoring and Reporting

Monitoring and reporting are essential for informing future management and determining improvements to the procedure. At a minimum the following should be recorded:

- Water level of estuary prior to opening (obtain from MHL water level recorder);
- Date and time of opening;
- Location and dimensions of works (width, depth, length);



- Ocean swell conditions (wave height and direction)
- Preceding rainfall;
- Date of natural closure of the entrance;
- Digital photographs of the opening and breakout development.

The information is to be recorded on a standard monitoring sheet, provided in Appendix A.

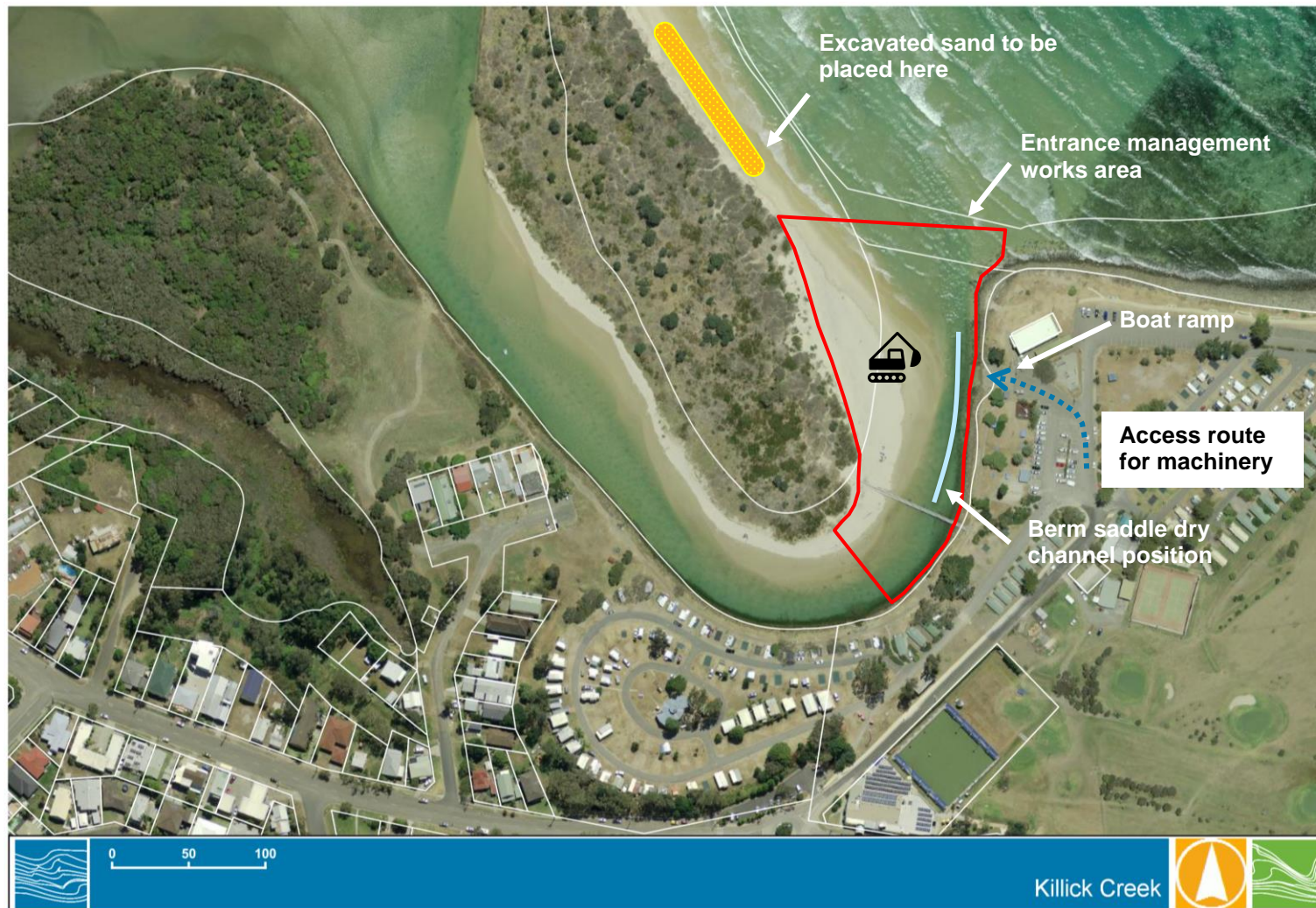


Figure 8-2 Entrance management schematic



9 MEANDER CORRECTION WORKS

9.1 Roles and Responsibilities

The primary responsibility for implementation of the entrance meander correction protocols is with Kempsey Shire Council. These responsibilities include direction and supervision of all works on site to ensure that they are carried out in accordance with these protocols and relevant standards and codes of practice.

9.2 Procedures

The operational procedures are summarised in Figure 9-1 with detailed steps provided below.

1. These operational procedures come into effect in the event that:
 - a. A pronounced entrance meander has been observed by a Council officer; or
 - b. A complaint is received by Council regarding the presence of a meander that has affected access to Killick Beach. In the event of a complaint, Council is to arrange a preliminary visual inspection to determine the legitimacy of the complaint.
 - i. If in the opinion of the Council officer, the complaint is not substantiated - then no action is to be taken.
 - ii. If the complaint is substantiated, then proceed to Step 2
2. In this event, Council is to notify DPHI-Crown Lands, DCCEEW(BCS), and DPIRD-Fisheries, and arrange a visit to the site to observe the nature and extent of the issue, and to work through the decision-making process outlined in Figure 9-1. Photographs should be taken for Council records. The decision-making process relates to the following issues:
 - a. The need to prevent undermining of the foundations of the pedestrian footbridge.
 - b. The desire to prevent potential erosion and undermining of the coastal dune at the entrance spit; and.
 - c. The desire to maintain pedestrian access from Crescent Head to Killick Beach during peak usage periods – that is, from 2 weeks prior to start of September School Holidays, to end of Easter School Holidays.
3. If the decision-making process indicates that works are required:
4. Council should seek a dredging and reclamation licence from DPHI-Crown Lands. It is likely that as part of this process, a referral to Fisheries is sought before a licence is issued to Council.
5. Once decided, the course of action should be communicated to relevant stakeholders and the community – prior to undertaking any specific course of action. Kempsey Shire Council should generate media release communications to inform the community of the works.
6. Council officers will arrange for appropriate earth moving equipment to be mobilised to Crescent Head. Council's personnel and machinery will be deployed to the entrance if the site assessment considers it appropriate and safe.
7. For each of works, entrance meander works should be timed to coincide an appropriate low spring tide period (the lowest tide available during the proposed scheduling of the works).



8. Appropriate actions should be carried out to ensure public health and safety during the operations.
9. The recommended access point for the 4WD backhoe operator to access the beach is via the boat ramp. 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.
10. Appropriate pedestrian safety measures are to be in place during the works. This should take the form of either signage, or Council staff present on site to prevent pedestrian access within 20 m of machinery and the entrance.
11. The works should ensure the existing level of entrance connectivity is maintained during the works. That is, that the channel is realigned only, and not deepened or widened.
12. Although the volume of scraped sand is expected to be small, the excavated sand should be retained on the beach and not removed from the system. The sand should ideally be placed on Killick Beach and spread evenly across the beach foredune in such a manner that no vegetation is disturbed.

9.3 Monitoring and Reporting

13. Council should maintain records of the entrance meander correction. At a minimum the following should be recorded:
 - Date and time of the works;
 - Location and dimensions of works (width, depth, length);
 - Tide and wave conditions;
 - Digital photographs of the entrance, before and after the works

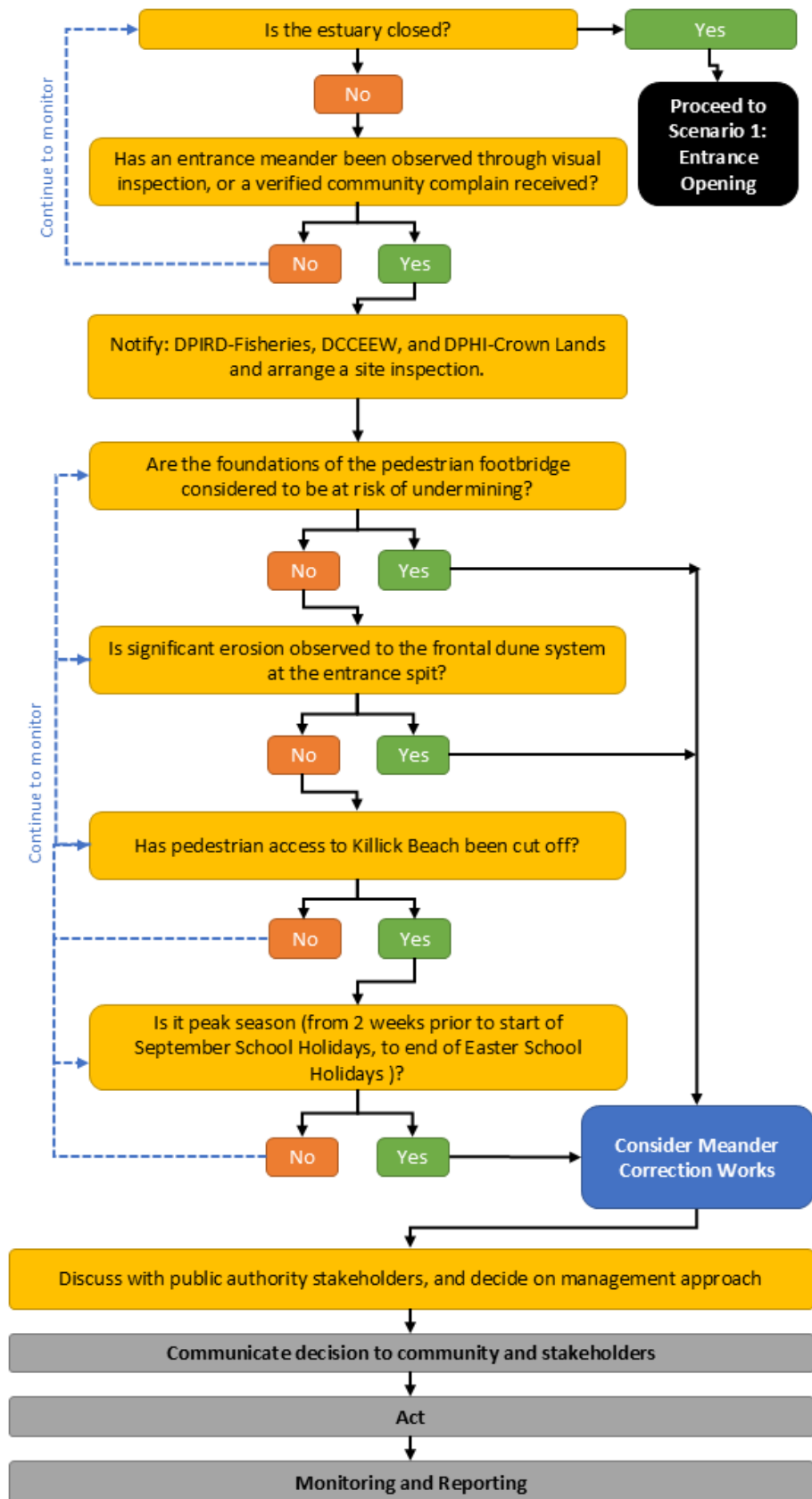


Figure 9-1 Overview of the decision-making framework: Scenario 2 (entrance open)



10 RECOMMENDATIONS

10.1 Review and Update of this Procedure

This EMP should be reviewed every ten years, or in response changes in the relevant legislation (as required). Review of the EMP procedure should include analysis of all monitoring data collected over that period to ensure that predictions and assumptions outlined in it are adequate.

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.

10.2 Long Term Management Approaches

Long term management of the entrance should also be considered in the context of findings and management actions the following major projects:

- Stage 2 and 3 of the Lower Macleay Floodplain Risk Management Study and Plan.
- The Kempsey Shire LGA CMP.

As per the advice of NSW DPIRD-Fisheries, the long-term approach of ICOLL management should be to reduce the need for artificial manipulation by taking active measures to remove, relocate or otherwise manage items of low-lying infrastructure that currently necessitate breaches below the natural breakout range, and adopting catchment management practices that:

- Reduce the inputs of nutrients and pollutants from point and diffuse sources,
- Prevent transfer of flood prone and riparian land on the margins of ICOLLs into private ownership,
- Prevent the future development or subdivision of flood-prone and riparian lands by adopting appropriate zonings and buffers in relevant land use planning instruments,
- Implement community awareness campaigns to gain broad based understanding and support for the environmentally responsible management of ICOLLs.

10.3 Other Recommendations

It is recommended that a permanent survey mark be installed at the estuary entrance, to more easily facilitate a rapid survey of the berm. A suitable location for a marker could in the vicinity of the boat ramp.



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APPENDIX A MONITORING FORM





Entrance Monitoring Form	
Opening date / time	
Natural opening, or Council initiated	
Berm Height Management, or direct mechanical opening?	
Opening Water Level (mAHD)	
Berm Height (mAHD)	
Summary of conditions (rainfall, swell etc)	
Type plant onsite & contractor	
Location of works	
Date / time works commenced	
Date / time works finished	
Date of subsequent closure	
Notes	

Melbourne

15 Business Park Drive
Notting Hill VIC 3168
Telephone (03) 8526 0800

Sydney

Suite 3, Level 1, 20 Wentworth Street
Parramatta NSW 2150
Telephone (02) 8080 7346

Brisbane

Level 5, 43 Peel Street
South Brisbane QLD 4101
Telephone (07) 3105 1460

Adelaide

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Eastwood SA 5063
Telephone (08) 8378 8000

Perth

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Subiaco WA 6008
Telephone (08) 6555 0105

New Zealand

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Cambridge New Zealand 3434
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Wangaratta

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Geelong

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Geelong VIC 3220
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Wimmera

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Gold Coast

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