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Coastal Engineering Advice on Intermittently Closed and Open Lake and Lagoon (ICOLL) near Proposed Subdivision at Inyadda Drive and Sunset Strip Manyana

1. INTRODUCTION AND BACKGROUND

A Development Application (DA), SF10921, for a 100 Lot Torrens Title residential subdivision at Inyadda Drive and Sunset Strip Manyana (covering Lot 106 DP 755923, Lot 2 DP 1121854 and Lot 2 DP 1161638) was refused by Shoalhaven City Council on 24 February 2023. This is now being considered by the Land and Environment Court, and an amendment to the DA is being prepared which will, amongst other things, alter the subdivision to be for 65 lots. The amended DA to be submitted to Council is to respond to issues previously raised with the development as originally lodged, including the following:

> "Having regard to the proposed fill on the site, the development application has the potential to change the opening and closing regime of the intermittently closing and opening lake/lagoon (ICOLL) that the site drains to and the ecology of that system by virtue of the water balance on the site changing. Changes to the ICOLL behaviour also have potential implications for Aboriginal cultural heritage in the vicinity of where the ICOLL opens and closes to the sea. Insufficient information has been provided in relation to this concern to enable a proper assessment. The Court would not be satisfied that Section 2.10 'Development on land within the coastal area' (in particular section 2.10(1) and (2)) of SEPP (RH) has been addressed in relation to the application".

Coastal engineering aspects of the above are addressed herein.

The report author is Peter Horton [BE (Hons 1) MEngSc MIEAust CPEng NER]. Peter has postgraduate qualifications in coastal engineering and 31 years of coastal engineering experience, including numerous studies in the Shoalhaven area. He is a Member of Engineers Australia and Chartered Professional Engineer (CPEng) registered on the National Engineering Register. Peter is also a member of the National Committee on Coastal and Ocean Engineering (NCCOE) and NSW Coastal, Ocean and Port Engineering Panel (COPEP) of Engineers Australia. He undertook a specific inspection of the site on 25 March 2023.

All levels given herein are to Australian Height Datum (AHD). Zero metres AHD is approximately equal to mean sea level at present in the ocean immediately adjacent to the NSW mainland.

2. EXISTING SITE DESCRIPTION

The site drains to an unnamed creek that discharges to Inyadda Beach. For convenience, this creek is denoted as Inyadda Creek herein. Inyadda Creek is also known as an Intermittently Closed and Open Lake and Lagoon (ICOLL). Inyadda Beach is about 1.6km long and extends between a headland forming the southern edge of One Tree Beach in the north, and Inyadda Point in the south. The beach is backed by an extensive vegetated dune. Inyadda Creek is located about 400m from the southern end of the beach.

A broad aerial view of the proposed development site, hereafter denoted as the 'site', is in Figure 1. The Manyana township is located south of the site. The site has been cleared of most vegetation except groundcovers in the past, with a 1970 aerial view of the same extent as Figure 1 depicted in Figure 2. The site remained mostly cleared of vegetation until at least 1987, and even at 1997 (Figure 3) had much sparser vegetation coverage compared to the present.

An oblique aerial view of the ICOLL entrance is provided in Figure 4, with photographs taken during the 25 March 2023 site inspection provided in Figure 5 and Figure 6.

Based on NSW Government LiDAR data collected in 2018, elevations over the site and surrounds are depicted in Figure 7. There are two creek branches that feed Inyadda Creek, denoted as 'A' and 'B' in Figure 7. Elevations generally increase moving west over the site, and the elevated dune seaward of the site is also evident in Figure 7.

Figure 1: Broad aerial view of site (approximate red outline) on 27 May 2023

Figure 2: Broad aerial view of site (approximate red outline) on 23 May 1970

Figure 3: Broad aerial view of site (approximate red outline) on 5 January 1997

Figure 4: Oblique aerial view of the Inyadda Creek entrance on 27 May 2023

Figure 5: View of Inyadda Creek entrance on 25 May 2023, facing NNW

Figure 6: View of Inyadda Creek entrance on 25 May 2023, facing south

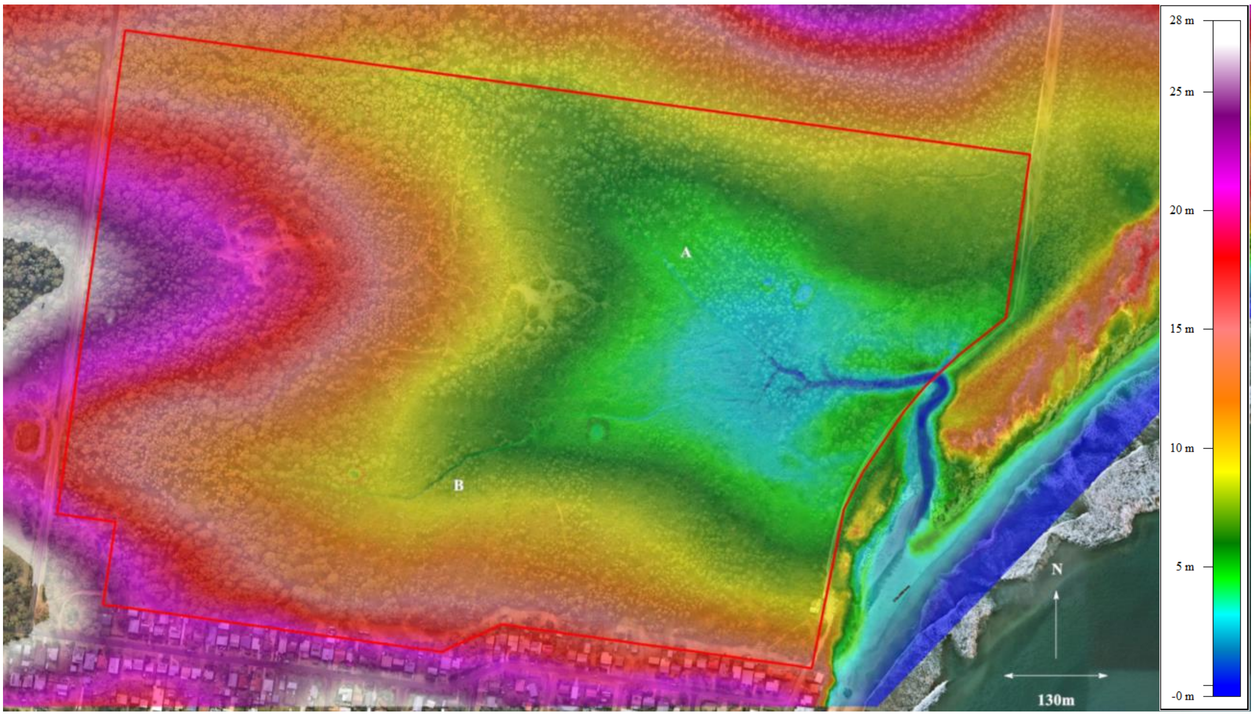

Figure 7: Elevations over site and surrounds to AHD from 2018 LiDAR data

The DEA Coastlines (part of the Geoscience Australia Landsat Coastlines Collection 3) data set, which has the median annual position of the shoreline at 0m AHD from 1988 to 2022, would suggest that Inyadda Beach has not been subject to significant long term recession over this historical record. However, it is expected that the beach will recede (move landward and upward) as a result of projected sea level rise, unrelated to the proposed development. There is also significant variability in beach width and level in response to wave climate and ocean water levels, with a 40m distance between the most seaward and most landward median annual shorelines over this 35 year period.

3. REVIEW OF AERIAL PHOTOGRAPHY

From review of aerial photography (5 dates in the NSW Government Historical Imagery viewer from 1970 to 1997, 18 dates in Google Earth from 2004 to 2022, 11 dates in Nearmap from 2012 to 2023, and one date in NSW Government Spatial Services in 2014), the Inyadda Creek entrance is almost always closed by sand. Out of these 35 dates, the entrance was open (only just) on one occasion.

There are three different entrance states that can be discerned from the historical record:

1. closed, and with sand choking the entrance to around the southern tip of the vegetated dune, as may occur in a low rainfall period (see example in Figure 8);
2. closed, but where the creek has formed a path to the SW of the entrance, that can vary in distance from 30m to about 200m, as may occur after a rainfall event when there is insufficient discharge to breakout the entrance, or when the entrance quickly closes after the breakout (see example in Figure 9); and
3. open briefly after a rainfall event, with the one instance observed in the historical record having a narrow entrance about 200m south of the vegetated dune (Figure 10).

Note that the site boundary depicted in Figure 8, Figure 9 and Figure 10 is only approximate, and is not intended to imply that public pathways are on private land.

Figure 8: Inyadda Creek entrance state 1, closed and choked with sand on 31 January 2020

Figure 9: Inyadda Creek entrance state 2, closed and creek extending SW along beach on 27 May 2023

Figure 10: Inyadda Creek entrance state 3, briefly open on 20 March 2022

4. ICOLL ENTRANCE PROCESSES

ICOLLs such as Inyadda Creek are separated from the ocean by a sand beach barrier or berm. This entrance barrier forms and breaks down depending on the movement and redistribution of sand and sediments by waves, tides, flood flows and winds (Department of Primary Industries [DPI], 2023).

There are limited observations of the berm level at Inyadda Creek. From 2011 LiDAR data, it was 2.33m AHD, and from 2018 LiDAR data it was 2.65m AHD. This is within the typical range of berm levels on NSW beaches of 2m to 3m AHD (Hanslow et al, 2000).

As outlined in Department of Planning, Industry and Environment [DPIE] (2021), the dynamics of ICOLL entrances such as Inyadda Creek (ie the proportion of time that systems remain closed and the frequency with which they may open and close) are determined by the interactions between the opposing forces of catchment and ocean processes on the movement and accumulation of sand at the flood-tide delta, entrance berm and nearshore.

In simple terms, the Inyadda Creek entrance can only potentially open in rainfall events that generate sufficient runoff for the creek to overtop and flow over the berm. Whether breakout then occurs depends on a number of factors, including the head and duration of water level above the berm, berm width, and wave conditions at the time. Once a breakout occurs, wave processes then act to close the entrance relatively quickly, with larger waves tending to accelerate closure.

As noted by Calibre Professional Services (2022), the catchment draining to Inyadda Creek is only 75.6ha, or 0.76km^2. Based on DPIE (2021), ICOLL entrances are generally closed around 90% of the time for catchments of about 10km^2, due to the limited freshwater inflow to cause breakout of the entrance. The order of magnitude smaller 0.76km^2 catchment at Inyadda Creek is the main reason that is it closed almost all of the time, as it does not generate sufficient freshwater inflows to regularly open the entrance or keep it open when it does breakout.

The proposed development would not affect one of the main factors influencing entrance behaviour, namely sand levels on the beach (ie, the berm level and geometry) which are controlled by wave conditions and wind. However, the proposed development may potentially affect freshwater inflows reaching the entrance, and thus influence how often breakouts occur and their duration. To assess this, numerical flood model simulations have been undertaken as described in Section 5.

5. NUMERICAL MODELLING OF PRE AND POST DEVELOPMENT ENTRANCE PROCESSES

Various pre and post development flood model simulations were undertaken by Egis as outlined in Table 1. These were selected to cover a wide range of events, namely 4 Exceedances per Year (EY), 63% Annual Exceedance Probability (AEP), 18% AEP, 5% AEP, 1% AEP and the Probable Maximum Flood (PMF). Some events were also simulated considering potential future increases in berm levels to sea level rise (with 0.5m of sea level rise considered, leading to an equivalent increase in berm level) as per Office of Environment and Heritage [OEH] (2015). Horton Coastal Engineering estimated the berm levels to be simulated by Egis.

Table 1: Pre and post development flood model simulations undertaken by Egis

Event	Equivalent to[1]	Planning Period	Adopted berm level (m AHD)
4 EY	98.2% AEP	Present	2.3
4 EY	98.2% AEP	Future	2.8
63% AEP	1 year ARI	Present	2.5
18% AEP	5 year ARI	Present	2.7
5% AEP	20 year ARI	Present	2.9
1% AEP	100 year ARI	Present	3.0
1% AEP	100 year ARI	Future	3.5
PMF	-	Present	3.0

The model results for flow at the bridge near the creek entrance, which is representative of the freshwater inflow governing breakout, are depicted in Figure 11. It is evident that pre and post development flowrates are similar. For all the simulations from 18% AEP and rarer, the post-development peak flow was within 1.0% of the pre-development peak flow. For all the simulations from 5% AEP and rarer, the post-development event volume was within 2.2% of the pre-development event volume. For the more frequent events, there was tendency for the peak flow and event volume to be slightly lower post-development (about a 5% to 11% reduction in peak flow, and a 3% to 9% reduction in volume). Egis considered that this reduction in peak flow and peak volume was potentially due to:

- modelling approximations, for example the developed pit and pipe network was not simulated, which may lead to some trapped low points in the model that cause an artificial reduction in peak flow and event volume; and

[1] Note that ARI refers to Average Recurrence Interval.

- the development causing a slight change in the distribution of flow between Creek A and Creek B in Figure 7, which may be partly related to changes to the culverts under Inyadda Drive entering the site so that they can convey the 1% AEP event under the road, which were simulated.

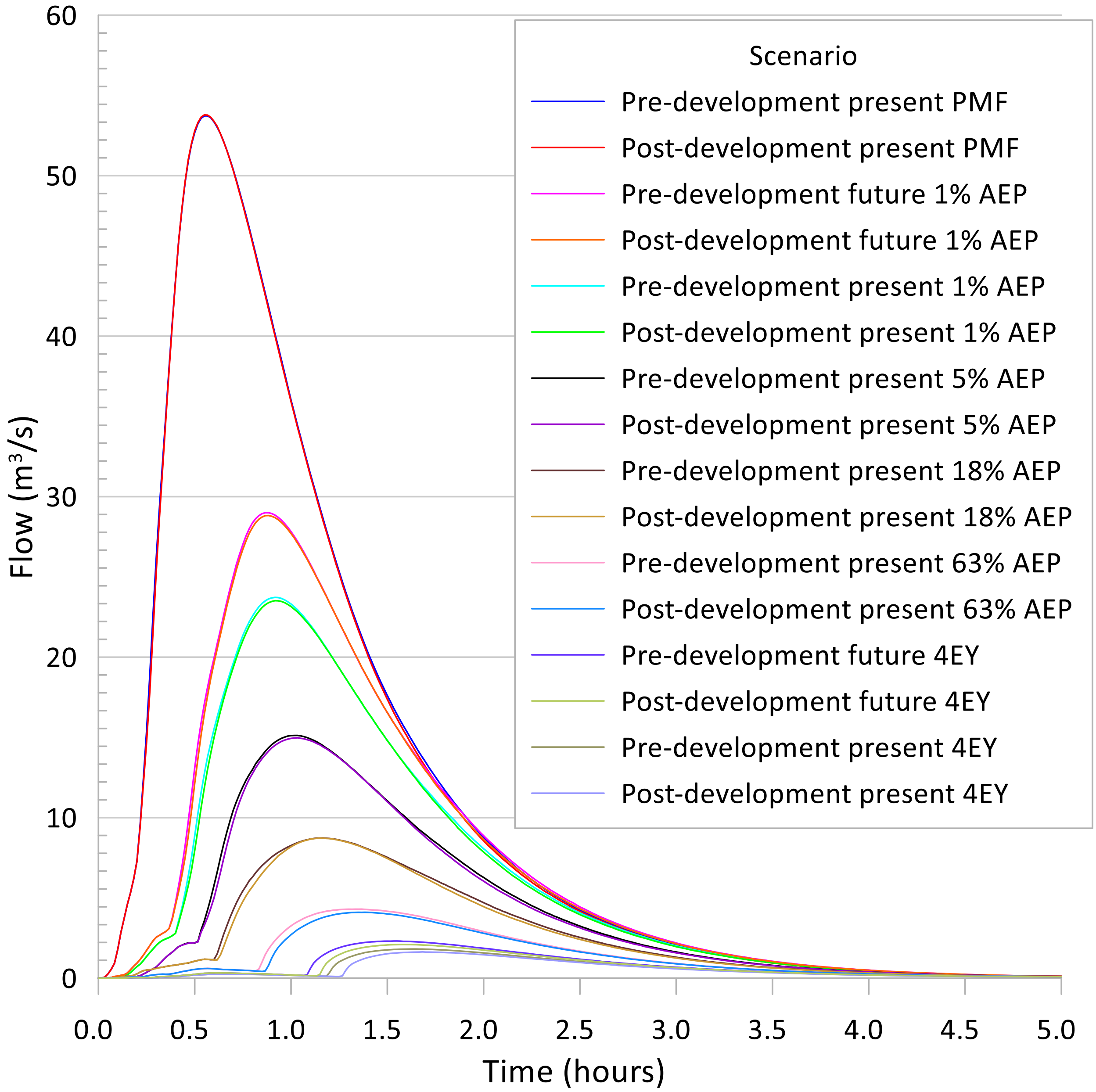

Figure 11: Pre and post development flood model results for flow into entrance area

Also note that the berm was not simulated as erodible, ie able to breakout. This is not considered to be a significant limitation to the modelling, given that the flowrate and flow volume entering the entrance governs the breakout process, and flows have been assessed herein.

If the slight reduction in post-development peak flows and event volumes is genuine, ie not a modelling artefact, this is not considered to be of a magnitude to significantly alter the behaviour of the creek entrance as a result of the development. In the future, the entrance will continue to be closed almost all of the time, and similar probability rainfall events will cause the berm to be overtopped and potentially breakout as at present. If a breakout occurs, the entrance will continue to close quickly under wave action, and the development would not alter that process. If berm levels increase under projected sea level rise over the long term, which is unrelated to the proposed development, then this would have more impact on entrance behaviour than any potential slight reduction in peak flows and event volumes (note also that climate change could potentially alter peak flows, eg by increasing rainfall intensities).

In summary, the proposed development would not be expected to significantly affect freshwater inflows reaching the entrance, and thus would not significantly affect how often breakouts occur and their duration. The opening and closing regime of the ICOLL would thus not be expected to change as a result of the proposed development. Inyadda Creek would be expected to continue to have an entrance that is closed almost all of the time, and even more so than at present if sea level rise causes the entrance berm to increase in level.

Any approximations related to the numerical model simulations that have been undertaken are not considered to influence the above findings. It can be robustly asserted that the proposed development would not be expected to affect the opening and closing regime of the ICOLL.

6. CONCLUSIONS

The potential impacts of a proposed subdivision at Inyadda Drive and Sunset Strip Manyana on the opening and closing regime of a creek and ICOLL entrance downstream of the site on Inyadda Beach has been assessed herein.

Review of 35 dates of aerial photography from 1970 to 2023 revealed that the ICOLL entrance is almost always closed. In simple terms, the entrance can only potentially open in rainfall events that generate sufficient runoff for the creek to overtop and flow over the beach berm. Once a breakout occurs, wave processes then act to close the entrance, with larger waves tending to accelerate closure. The entrance is usually closed as only a small catchment drains to the entrance, which does not generate sufficient freshwater inflows to regularly open the entrance or keep it open when it does breakout.

The proposed development would not affect sand levels on the beach, which are controlled by wave conditions and wind. However, the proposed development may potentially affect freshwater inflows reaching the entrance, and thus influence how often breakouts occur and their duration. To assess this, numerical flood model simulations have been undertaken.

Various pre and post development flood model simulations were undertaken to cover a wide range of events from 4EY to the PMF, and also including consideration of potential increases in the berm level due to sea level rise. As evident in Figure 11, simulated pre and post development peak flowrates and event volumes are similar. For the more frequent events, there was tendency for the peak flow and event volume to be slightly lower post-development (in the range from 3% to 11%) but this may be a modelling artefact, or potentially due to an altered distribution of flow through the site with two culverts entering the site now able to convey the 1% AEP flow.

If the slight reduction in post-development peak flows and event volumes is genuine, this is not considered to be of a magnitude to significantly alter the behaviour of the creek entrance as a result of the development. In the future, the entrance will continue to be closed almost all of the time, and similar probability rainfall events will cause the berm to be overtopped and potentially breakout as at present. If a breakout occurs, the entrance will continue to close quickly under wave action, and the development would not alter that process. If berm levels increase under projected sea level rise or rainfall intensities increase due to climate change (both unrelated to the proposed development), then this would have more impact on entrance behaviour than the potential slight reduction in peak flows and event volumes caused by the development.

It can be concluded that the proposed development would not be expected to significantly affect freshwater inflows reaching the entrance, and thus would not significantly affect how often breakouts occur and their duration. The opening and closing regime of the ICOLL would thus not be expected to change as a result of the proposed development. The creek would be expected to continue to have an entrance that is closed almost all of the time, and even more so than at present if sea level rise causes the entrance berm to increase in level.

7. REFERENCES

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8. SALUTATION

If you have any further queries, please do not hesitate to contact Peter Horton via email at peter@hortoncoastal.com.au or via mobile on 0407 012 538.

Yours faithfully
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