ICOLLS: CAN WE SAVE DEVELOPMENTS ALONG THEIR FORESHORES FROM SEA LEVEL RISE OR ARE THEY DOOMED?

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**ABSTRACT**

ICOLLS (Intermittently Closed and Open Lakes and Lagoons and some lakes that now have permanent entrances) are particularly vulnerable to climate induced sea level rise. Further, the low lying foreshores of many (Tuggerah Lakes, Terrigal Lagoon, Wallis Lake, Lake Macquarie) are densely populated. As a result, a large number of existing developments are already flood affected and many more have floor levels only slightly above flood levels. At most ICOLLS, a rise in sea level will translate into a similar rise in flood level. As a result there will be a significant increase in the number of buildings inundated and hence a substantial increase in flood damages.

This paper explores the feasibility of management measures to protect existing developments (levees, house raising, “Thames” style barriers). However, in some places redevelopment at a higher level or even the complete removal of existing developments may be the only viable solution. The latter will obviously cause significant social hardship but must be considered.

If the predicted sea level rates of rise occur (0.4m by 2050), Councils will have little time to plan suitable actions and enact long term strategies to ensure the safety of existing developments. Further, to be confident that future developments are adequately protected, Councils will need to ensure that all new developments are subject to flood related development controls in line with the recently released NSW Government Sea Level Rise Policy.

**1. INTRODUCTION**

There are around 70 ICOLLS (catchment area > 1 hectare) along the NSW coast. The ICOLL/lake with the largest waterway area is Lake Macquarie (110km\(^2\)) but other large water bodies include Lake Illawarra, Wallis Lake and Tuggerah Lakes. The foreshores of ICOLLS have long been popular development locations, initially for “holiday homes” but today there are all forms of residential developments (large homes, units, motels, resorts, caravan parks etc.). The attraction is the enviable aesthetic and recreational qualities of the foreshore. However, a shoreline location also often means that flooding is an inevitable hazard.

In NSW, all of the larger ICOLLS have a well established history of flooding. The relatively flat shorelines mean that large tracts of land (and hence developments) are inundated by ponded flood waters. For example, in June 2007 Lake Macquarie experienced a 30 year Average Recurrence Interval (ARI) flood event which inundated the majority of the Swansea peninsula (approximately 1m AHD ground level).
ICOLL flooding occurs due to a combination of intense rainfall over the catchment and/or an elevated ocean level. The contribution from each factor varies from ICOLL to ICOLL and event to event, and is highly dependant upon the status of the entrance (open, closed, will open naturally during flood, is artificially opened before or during an event). As a result, flood levels can vary substantially for similar rainfall events and different ICOLLS have very different 100 year ARI peak flood levels, as indicated in Table 1.

### Table 1: Existing 100 year ARI Flood Level

<table>
<thead>
<tr>
<th>ICOLL</th>
<th>Flood level (m AHD)</th>
<th>Floors inundated</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake Macquarie</td>
<td>1.38</td>
<td>670</td>
<td>Entrance permanently open</td>
</tr>
<tr>
<td>Tuggerah Lakes</td>
<td>2.23</td>
<td>1450</td>
<td>Intermittently open, entrance channel dredged by Council</td>
</tr>
<tr>
<td>Wallis Lake</td>
<td>1.95</td>
<td>420</td>
<td>Entrance permanently open</td>
</tr>
<tr>
<td>Smiths Lake</td>
<td>2.6</td>
<td>&lt;5</td>
<td>Intermittently open. Artificially opened by Council</td>
</tr>
<tr>
<td>Terrigal Lagoon</td>
<td>3.0</td>
<td>160</td>
<td>Intermittently open. Entrance berm permanently lowered by Council</td>
</tr>
<tr>
<td>Wamberal Lagoon</td>
<td>3.5</td>
<td>8</td>
<td>Intermittently open. Artificially opened by Council</td>
</tr>
<tr>
<td>Gt Mackerel Beach</td>
<td>2.4</td>
<td>22</td>
<td>Intermittently open. No entrance management</td>
</tr>
</tbody>
</table>

2. **WHY ARE ICOLLS SO VULNERABLE TO FLOODING AND A CLIMATE CHANGE INDUCED SEA LEVEL RISE?**

Most coastal properties are affected by flooding in some way. Climate change induced sea level rise will increase that vulnerability. However, properties surrounding ICOLLS are particularly vulnerable for the following reasons:

- For nearly all ICOLLS, large and small, sea level rise will increase design flood levels by approximately an equivalent amount. The mechanisms will be different but the effect on flood levels will be similar:
  - For predominantly open ICOLLS, such as Tuggerah Lakes or Lake Illawarra, sea level rise will raise the "normal" water level and hence flood levels by an equivalent amount,
  - For predominantly closed ICOLLS such as Lake Wandabyne it is expected that berm levels will increase approximately in line with sea level, resulting in initial ponding of a larger volume of water but also higher average breakout levels and hence flood levels,
  - For ICOLLS with managed entrances such Terrigal Lagoon or Smiths Lake, the artificial berm opening level may be retained at the existing designated level and hence flood levels would be similar to existing. However, retaining current levels without allowance for sea level rise will require far more and frequent artificial openings, an outcome that is contrary to NSW Government policy. For existing low level opening systems such as Terrigal Lagoon (1.2 m AHD),
retaining an entrance opening at a very low level would not be practical, so flood levels would have to increase,

- for permanently open river systems (i.e., not ICOLLs), where flood levels are largely determined by peak discharges, the effects of sea level rise will quickly dissipate away from the ocean. As a result, relatively few developments should be affected;

- The foreshores of most ICOLLs were formed by coastal and riverine processes since the last ice age and often have very flat grades. As a result, a small increase in water level equates to a large increase in inundated area. This also tends to make travel distances to high ground significant;

- Many existing developed areas have already experienced significant inundation (Tuggerah Lakes and Lake Macquarie in June 2007 and February 1990) and because many of the homes built in the last 30 years are at similar levels, a small sea level rise will significantly increase the number of floors inundated;

- Similarly, the infrastructure built to service these properties, roads, drainage, sewerage, water, telephone, etc., will be affected. For example, already at some locations the sewage system is turned off during flood events, creating a potential health risk. If roads are cut or services disrupted frequently, the “habitability” of the area will be affected, possibly rendering the area unsuitable for development;

- For the larger ICOLLs, where large volumes of water can be ponded, inundation may extend for up to 24 hours. As a result, residents face considerable hardship either having to live surrounded by floodwaters and with a failed sewerage system or be evacuated;

- For some ICOLLs, the entrance berm provides some protection against invading sea levels. However, if climate change affects the mechanisms that form the berm and this protection is lost, then the impacts of sea level rise may not be mitigated;

3. WHAT MANAGEMENT MEASURES ARE POSSIBLE TO PROTECT EXISTING DEVELOPMENTS?

There are three broad categories of possible measures (Flood Modification, Property Modification and Response Modification). In relation to Response Modification, it is unlikely that measures such as flood warning or evacuation procedures, etc., could be enhanced to the extent that they will provide a significant reduction in sea level rise hazard.
Flood Modification measures do provide some potential for actually reducing the increase in flood levels:

- **Flood mitigation dams, retarding basins or other peak flow reduction measures:** These will provide no significant benefit for ICOLLs because flood volume and entrance conditions are critical to determining ICOLL flood levels, not the flow rate.

- **Channel management measures (clearing, dredging):** For predominantly open ICOLLs these measures are unlikely to provide much benefit, as any entrance channel enhancement will also increase inflows from the ocean. However for some ICOLLs these measures may provide some reduction in flood height but could also cause environmental changes in the ICOLL.

- **Construction of Levees:** The construction of levees (earthen banks or concrete walls) has been used in NSW since the early 1800’s as a practical means of flood protection. The Entrance North levee at Tuggerah Lakes is a good example of an ICOLL flood levee. Existing levees could be raised or new ones constructed to prevent inundation by a sea level rise. However, there will be many issues to address.

    Probably the most obvious issue with levees is the resultant reduction in aesthetic quality and access to the water (boats, fishing). These amenity attributes are why residents live around ICOLLs and there is likely to be considerable adverse public feedback if these attributes are affected. However in existing (non-ICOLL) flood liable areas (Maitland, Lismore, Grafton etc.) levees are accepted as the only means of protection and the public accepts this drawback.

    From a hazard perspective levees represent a significant risk due to the likelihood of failure/overtopping. The most dramatic failure in recent times was in New Orleans (Hurricane Katrina, August 2005). The failure of the levee system caused enormous loss of life (1450), disruption to millions of inhabitants, a major health hazard, a several billion dollar damages bill and prompted a review of the design of levee systems. All levees have the potential to fail and the possible consequences of failure must be rigorously evaluated if such systems are to be implemented around ICOLLs.

    Levees are generally seen as a means of mitigating damages and hazards to existing developments but not as a means of promoting further development. Thus for new developments other measures are required.

    There are also many technical difficulties with levee construction on the shores of ICOLLs. These will vary depending upon locality but may include: internal drainage issues; ability to tie the levee into high ground; land requirements may mean the purchase of properties; pedestrian and vehicular access across the levee; maintenance, etc.

    In summary levees are probably viable in some areas but not in all areas.

- **“Thames” style tidal barrages:** This type of structure would be hugely expensive and would only be viable on the large ICOLLs with major flooding problems and “suitable” entrance conditions. A risk for many ICOLLs is that the sea and/or catchment runoff may initiate new entrances from the lake to the ocean. There are examples of these previous openings at many ICOLLS. A barrage would provide an effective barrier in an elevated ocean event (storm surge) but would also prevent
catchment runoff from exiting. Again a detailed investigation would be required to assess the viability of this measure.

In relation to Property Modification, the most obvious measure is house raising. This has had widespread use in many flood liable areas of NSW. However, it is only suitable for non-brick type construction and thus is not practical for the modern brick, slab-on-ground construction. Also increasingly it is more viable economically to demolish an older style home and rebuild a new home at the required level. Re-development is therefore a practical solution and incentives could be provided to encourage such activities. However, a house on fill or piers in an area that is frequently flooded is not attractive. Access to such properties would be difficult, particularly in emergencies, and the inundation would prevent the establishment of lawns and gardens, particularly if the flood waters were saline.

Other such measures are re-zoning or development controls but these will only benefit future not existing developments.

4. IS IT VIABLE OR PRACTICAL TO PROTECT ALL DEVELOPMENTS ON THE FORESHORES OF ICOLLS?

For many developments on the foreshores of ICOLLS it will be possible to construct levees. There will be significant social, economic, environmental and technical issues with their construction but it will be possible. “Thames” style barrages could be considered for the large heavily developed foreshores with a suitable entrance type but barrages are unlikely to be economically feasible. House raising may be appropriate for some older style homes but as an overall solution it will not be practical or economically viable. Furthermore, house raising will not prevent inundation of roads and the surrounding property, thus making the area unattractive for habitation.

Based on the above, it is likely that many existing developments on the foreshores of ICOLLS cannot be feasibly protected from sea level rise. This represents a significant challenge to Councils, as they have a duty of care to provide a safe and hospitable environment for habitation. If the sewerage system or the road network is constantly inundated, residents will be forced to move.

Filling of areas to provide high ground will be possible and new developments constructed on them. The areas where it is appropriate to fill will vary and need to be carefully evaluated to ensure that the flood hazard is minimised. Fill can be expensive and will reduce the floodplain storage but is inevitable for some foreshore areas.

For Councils the challenge is to initiate an investigation program that assesses the implication of sea level rise for every ICOLL in NSW that has potentially flood liable developments. In accordance with NSW Government policy, all new developments should be subject to flood related development controls that include potential sea level rise. This step should be taken now and it is noted that some Councils (Lake Macquarie) have already taken this step. A hard decision taken today will minimise the problem in the future.

Based on the results of this investigation program the ICOLLS should be categorised and initial steps taken to determine possible mitigation measures. For those that cannot be protected now is the time to develop a program to reduce the extent of existing development over time.
5. CONCLUSIONS

A climate change induced sea level rise is considered inevitable by many of the world’s scientists. Such a scenario will have significant implications for all flood liable development in NSW but particularly for those on the foreshores of ICOLLs. The viable measures to protect existing developments are limited to:

- Levees,
- “Thames” style barrage (possibly),
- Channel management measures (possibly),
- House raising (only for suitable houses),
- Demolition, land filling and redevelopment.

In the first instance flood related development controls that include potential sea level rise should be implemented and then a major investigation program to assess the viability of the above measures for each ICOLL. If these measures are not viable for economic, social, environmental or technical reasons then Councils must develop a program to reduce the extent of existing developments. It is better to act now rather than wait and have the problem exacerbated by continued development.