FLOODPLAIN MANAGEMENT IN NSW – ADAPTING FOR SEA LEVEL RISE

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Abstract

Sea level rise due to climate change has the potential to significantly influence floodplain management in NSW. This paper provides a description of the likely effects of a sea level rise of up to 1 m on urban developments. This is followed with a preliminary quantitative assessment of the increase in number of building floors inundated, frequency of inundation and magnitude of flood damages for several case studies.

Adaptive strategies to manage the potential problem for both existing and future developments are then discussed. These strategies include amendments to Flood Planning Levels to account for the rise in design flood levels, planned retreat from an area, levee construction, raising buildings and constructing new buildings to accommodate a sea level rise.

Key Words: Flooding, Floodplain Management, Case Studies, Adaptive Strategies, Sea Level Rise, Flood Planning Levels, Planned Retreat.

Introduction

Since the mid 1990's floodplain managers have been aware of the potential impacts of a climate change sea (ocean) level rise on existing and future urban developments on the floodplain. Subsequently, the 2007 Intergovernmental Panel on Climate Change (IPCC) meeting has provided some guidance on the magnitude and timeframe of the ocean level rise. Climate change has the potential to affect the flood regime in four broad ways:

? an increase in ocean level,
? an increase in design rainfalls,
? a change in the erosional/sedimentation regime that may affect the channel capacity or in the case of coastal lagoons, the entrance channel,
? a change in wind/wave activity during a flood that may influence the extent of wave inundation, particularly in large coastal lakes/lagoons or at coastal properties.

This paper is concerned with the first of the above and thus only includes those floodplains along the coastal fringe of NSW. An increase in design rainfalls will affect all floodplains in Australia and thus may have greater implications for flooding than an ocean level rise. A change in the erosional/ sedimentation regime may affect all channels but will be of great significance for ICOLLs (Intermittently Closed and Open Lakes and Lagoons) as will a change in wind/wave activity.

There is no definitive data on the magnitude and timeframe for an ocean level rise along the coast of Australia. This paper has focused solely on the impacts on urban developments within the floodplain along the NSW coast. The analysis assumes the following possible ocean level rises by the year 2090:

? 0.18 m – Low scenario,
? 0.55 m – Medium scenario,
? 0.91 m – High scenario.

These scenarios are taken from the DRAFT NSW Department of Environment and Climate Change Floodplain Risk Management Guideline "*Practical Consideration of Climate Change*", October 2007 and are recommended for use in Flood Studies undertaken in NSW.

BACKGROUND ON OCEAN LEVELS

Flood studies for NSW catchments draining to the Pacific Ocean must consider the impact of high ocean levels on flooding. With hydraulic (computer) models of river systems it is possible to simulate the effect of various ocean level scenarios on flood levels. In some studies a constant ocean level is included but for major river systems a tidally varying ocean level is included.

Table 1 lists typical peak ocean levels along the NSW coast. All levels are to Australian Height Datum (AHD) with 0 mAHD approximating mean ocean level.

Table 1: Typical Ocean Levels along the NSW Coast

Scenario	Level mAHD
Mean Ocean Level	0 m
Low Tide	-0.4 m
High Tide	0.6 m
Highest Tide in a Year	1.1 m
20 year Flood Level at Fort Denison	1.43 m
50 year Flood Level at Fort Denison	1.47 m
100 year Flood Level at Fort Denison	1.50 m
20 year Coastal Ocean Level	2.2 m
50 year Coastal Ocean Level	2.4 m
100 year Coastal Ocean Level	2.6 m

The design ocean levels at Fort Denison are based on approximately 100 years of tidal records in Sydney Harbour. These levels are greater than the highest astronomical tide due to storm surge effects, predominantly caused by atmospheric depressions which can raise ocean levels by typically 0.6 m in the 100y ARI event (less in a more frequent event). Along the coast, wave setup effects can raise the local ocean level by up to 1.6 m, depending on the nature of the estuary. A climate change induced ocean level rise will result in all the levels in Table 1 increasing by approximately the same amount.

INCREASE IN OCEAN LEVELS

As a general guide the mouths of rivers restrict the entry of high ocean levels. Thus the peak water level upstream of the mouth may not reach the same level as the peak ocean level (assuming nil runoff) as there is insufficient time for the two systems to balance. When the high ocean level is combined with high runoff the peak ocean level has even less effect, as the river flood level is dominated by the high flow in the river. The effect of ocean level rise will therefore vary between catchments depending on the peak flow in the river and the entrance conditions.

The specific impacts for each river can be estimated by adjusting the downstream boundary of the hydraulic model used to determine design flood levels. The following are some general comments on the likely range of impacts of ocean level rise.

Small (2.4km^2) Urban Catchment - Rushcutters Bay, Woollahra – The upstream channel is concrete lined but the culverts under New South Head Road severely restrict the flows (Figure 1). For this reason any increase in flood levels due to ocean level rise is largely confined to the 250 m reach downstream of the culverts which is predominantly open space. Thus there is little impact on the urban community.

Figure 1: Rushcutters Bay

Medium (50km^2) Rural/Urban Catchment – Boambee/Newports Creek, Coffs Harbour – The lower reaches are estuarine in nature with sparse urban development (Figure 2). Thus it is only at the upper limits of the estuarine reach where ocean level rise will have a significant impact on existing urban developments.

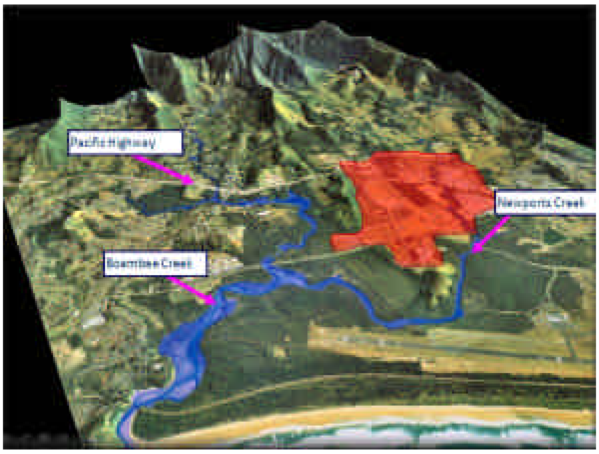

Figure 2: Boambee/Newports Creek

Large (20,000km^2) Catchment – Clarence River – The entrance of the Clarence River is some 300 m wide and is therefore subject to the full effects of an ocean level rise. The urban centres of Iluka (north bank) and Yamba (south bank) would both be directly affected (Figure 3).

Figure 3: Clarence River

Managed ICOLLs – Smiths Lake, Terrigal Lagoon, Wamberal Lagoon, Lake Cathie, Dee Why Lagoon – A large number of ICOLLs are "managed" by the Council who "open" them when a critical level is reached using an excavator (Figure 4). For these systems an ocean level rise may not have a significant impact on flood levels upstream, as long as the same management process is retained. Of greater concern is any change in the wind wave effects on the ocean side affecting the height of the beach berm.

Figure 4: Smiths Lake

Lakes - Lake Macquarie, Wallis Lake, Lake Illawarra - These lakes only have permanent open entrances due to significant dredging and training works (Figure 5 - Lake Macquarie). Any ocean level rise will further restrict the entrance capacity to discharge floodwaters, thus increasing flood levels upstream. These systems are some of the most sensitive to an ocean level rise due to the large number of buildings with floors only just above the normal lake level (typically around 0.1 mAHD with little tidal variation). A period of high ocean levels will "pump" up the lake level to say 0.5 mAHD. A general ocean level rise will therefore increase the "normal" lake level as well as the flood level.

Figure 5: Lake Macquarie

Estuaries – Port Stephens, the Hawkesbury, Sydney Harbour - The impact of ocean level rise depends on the existing and potential land use and the topography of the land on the perimeter. Around Sydney Harbour, the land rises fairly steeply (Figure 6) and thus only the foreshore properties will be affected to any significant extent. At Port Stephens and on the Hawkesbury the impact will include more properties as the foreshore is much flatter and thus an ocean level rise will extend further inland.

Figure 6: Sydney Harbour

CASE STUDIES

The effects of ocean level rise on flooding will be reflected by an increase in:

- the number of building floors inundated in a design flood event,
- the flood damages in a design flood event and over the life of a structure,
- the frequency of inundation (as flood levels rise, land once inundated say on average every 5 years may now be inundated on average every 2 years),
- the extent of inundation. The increase in lateral extent of inundation depends on the perimeter slope of the floodplain. In flat areas there will be a greater increase than in steeper areas,
- the duration of inundation. This impact will generally not be significant as it is typically the initial wetting that causes the damage and not the duration of inundation. The duration is of greater importance for agricultural damages (crop loss, etc.).

Examples of these effects are provided in the following.

Boambee and Newports Creek, Coffs Harbour has a $50km^2$ catchment area and is enclosed by heavily vegetated hills. The upper slopes are steep and predominantly used for agricultural (banana) activities whilst the middle reaches are where significant urban development has recently occurred. The lower reaches are predominantly estuarine with low-lying areas subject to both tidal and flood inundation. The impacts of ocean level rise are shown on Figure 7 and are largely confined to the lower reaches with the increase attenuating further upstream from the ocean (as expected). Importantly for the low-lying areas, ocean level rise will increase the frequency of inundation and thus could affect the types of future development as well as the ecological regime.

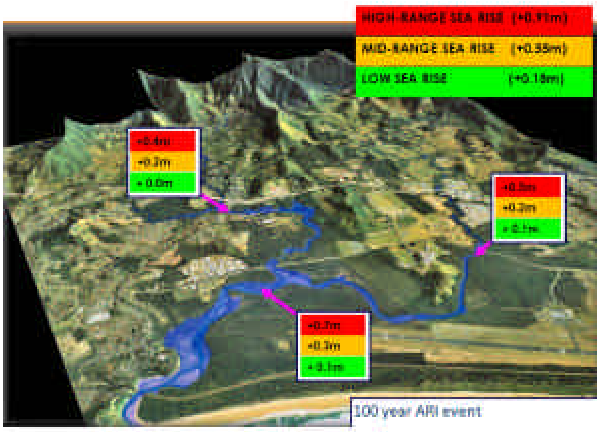

Figure 7: Ocean Level Rise – Boambee Creek

The Lower Macleay River on the mid-north coast has a catchment area of $11,500km^2$. Downstream of Kempsey the floodplain is predominantly used for rural activities. Significant flood mitigation works, including levees, drains and control structures, have been constructed to reduce flooding. Some 400+ rural residential properties occupy the floodplain and the increase in number of building floor levels and consequent increase in flood damages for ocean level rises are shown on Figures 8 to 10.

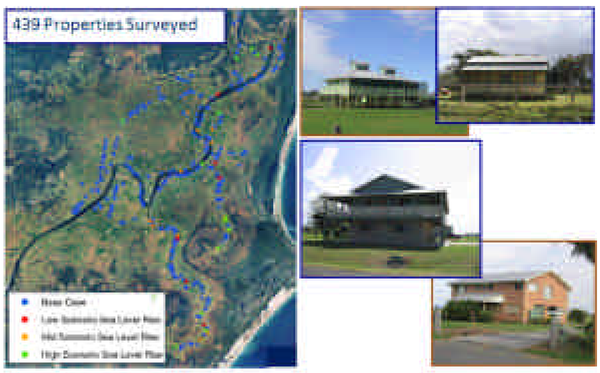

Figure 8: Lower Macleay River – Rural Residential Properties

Ocean Level Rise Scenario	Flood Event			
	5 y	10 y	20 y	100 y
Existing Conditions	52	74	118	224
Low Rise (+0.18m)	+3	+2	+1	+6
Midrange Rise (+0.55m)	+18	+11	+8	+3
High Rise (+0.91m)	+29	+26	+15	+23

Figure 9: Macleay: Number of Buildings Inundated

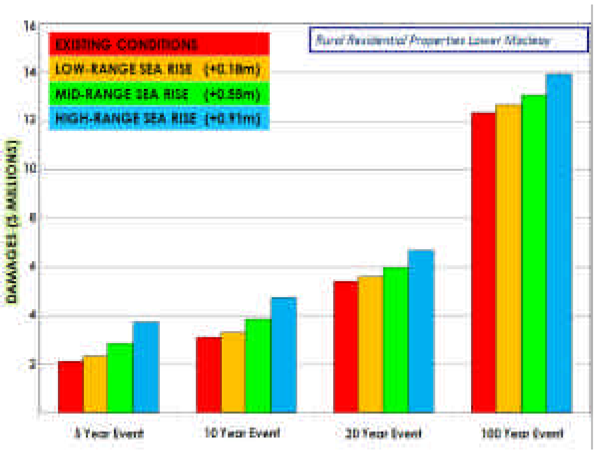

Figure 10: Macleay: Flood Damages

Lake Macquarie is the largest coastal lake in eastern Australia and is surrounded by extensive urban developments (largely residential – refer Figure 11). Parts of the foreshore are below 1 mAHD (<0.9 m above normal water level) and were inundated in the June 2007 and February 1990 floods. Flood levels for these events reached approximately 1.1 mAHD (refer to Figure 12). Figure 13 shows the impacts of ocean rise on the number of buildings inundated.

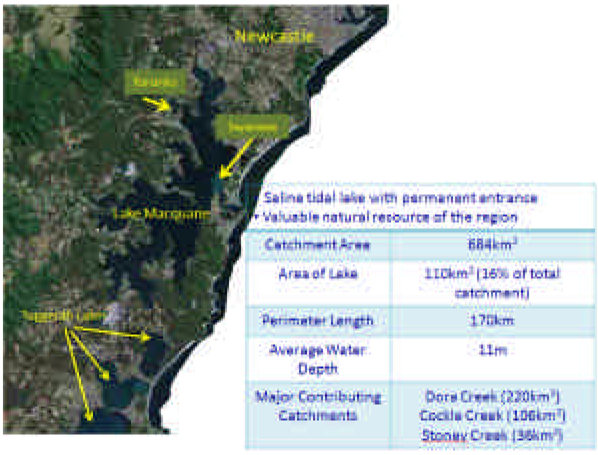

Figure 11: Lake Macquarie

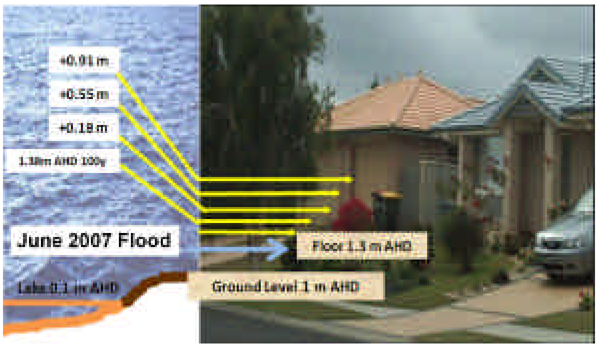

Figure 12: Swansea: Typical Building

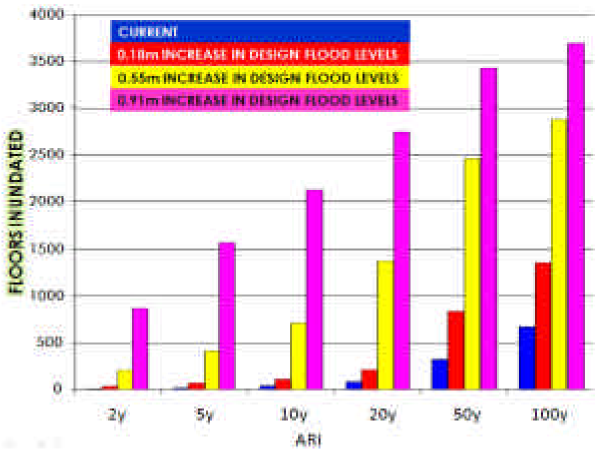

Figure 13: Lake Macquarie: Buildings Inundated

Figure 14 indicates the percentage of buildings inundated at Swansea located on the eastern shore of Lake Macquarie. Any rise in ocean level has a significant impact on the frequency of inundation. Figure 15 indicates that the existing 100y ARI flood level will be reached on average every 5 years with a 0.91 m ocean level rise. A consequence of this is the dramatic rise in Average Annual Damages (Figure 16).

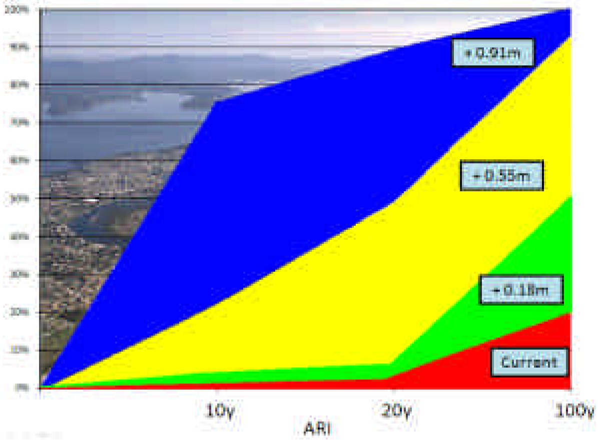

Figure 14: Swansea: % Buildings Inundated

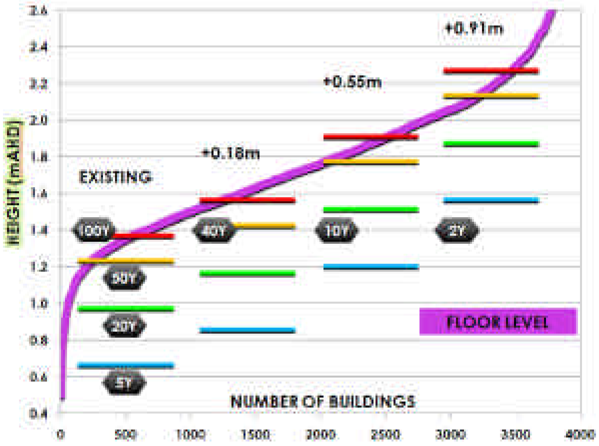

Figure 15: Lake Macquarie: Frequency of Inundation

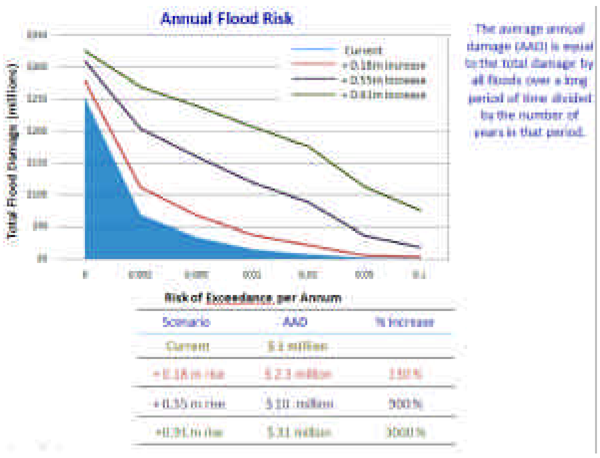

Figure 16: Lake Macquarie: Average Annual Damages

Great Mackerel Beach on the western foreshore of Pittwater on the Hawkesbury River is only accessible by water (Figure 17). Some of the 50+ houses are located on land below 1.75 mAHD. There is a narrow entrance to the creek/lagoon system and the resulting 100y ARI flood levels is around 2.4 mAHD. Figure 18 indicates that raised ocean levels of up to 0.91 m only result in a maximum 0.2 m increase in the 100y and 5y ARI flood levels.

Figure 17: Great Mackerel Beach

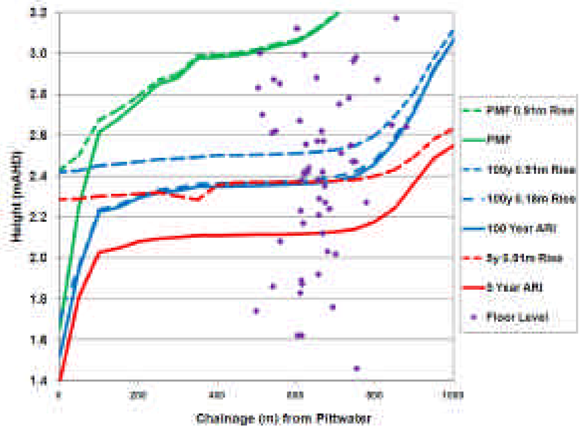

Figure 18: Great Mackerel Beach: Flood Profiles

ADAPTIVE STRATEGIES

There is sufficient advice available that local and state governments must formulate adaptive strategies for the management of the impacts of ocean level rise on flooding. To “Do Nothing” is not an option.

An obvious strategy is construction of a tidal barrier (Thames River, London – Figure 19 or proposed for Venice). These have been tested (rubber pneumatic barrage) on the Macleay River and are worthy of consideration. However for the majority of rivers this type of measure is not viable.

Figure 19: Thames Barrier

For existing development, potential mitigation measures include house raising or the construction of levees (high banks to prevent inundation). House raising (Figure 20) is only viable for non-brick single storey houses on piers and thus is suitable for the Lower Macleay River rural residential properties but not for more modern brick slab-on-ground constructions.

Figure 20: House Raising

At a number of coastal locations where there is an existing levee (Iluka - Figure 21, The Entrance North, Tuggerah Lakes) these could be raised as long as visual and landtake issues can be resolved. At some other locations new levees could be constructed whereas at other sites (e.g. foreshore of Sydney Harbour) they are impractical.

Figure 21: Iluka Levee

Apart from visual impacts there are a number of technical issues with levees, including the risk of failure and resolving internal drainage. Levees also tend to promote a false sense of security which may induce further inappropriate developments within the leveed area.

For new developments there is a wider range of strategies available. The most obvious is to change the potential use of the land to one that is less susceptible to an increase in flood level due to climate change. This may include changing residential to parkland, industrial or tourist and recreational usage. Another approach is termed "planned retreat" where the development would only be approved on the basis that the infrastructure could be altered to maintain the existing level of flood risk. Examples of this are tourist or low cost houses which typically have a short lifespan (say 20 years) or commercial/ industrial developments which can make investment decisions based on an agreed rate of abandonment or include a "sacrificial" part of the development.

To ensure new developments do not incur a higher level of flood risk the Flood Planning Levels (FPL) can be modified to include the progressive increase in flood levels. Thus a house with a life span of 70 years would have a FPL based on the flood level estimated to be applicable in 70 years time.

There are also measures that can be accommodated within the design of new buildings to minimise the increase in flood damages due to ocean level rise. Examples include "flood proofing" of the ground floor, designing for planned retreat of the ground floor or designing for the retro-fitting of barriers such as "pop up" flood gates or construction of future levees.

CONCLUSIONS

A 1 m ocean level rise will have significant consequences for floodplain management in NSW. The impacts will vary depending upon the type and size of the river system. For some catchments the effects will be minor but for others there will be a significant impact which may render part of the land unsuitable for many activities.

There are only limited adaptive strategies to protective existing developments but with good design and foresight the damage to future developments can be reduced to an acceptable level.