PLANNING FOR THE IMPACTS OF CLIMATE CHANGE ON THE LAKE ILLAWARRA FLOODPLAIN

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Abstract

The Lake Illawarra Floodplain Risk Management Study and Plan (FRMS&P) was commenced in 2001. Since the commencement of the project the need to quantify the risks associated with climate change on the floodplain and provide a management framework to deal with these risks into the future has become increasingly important. As such, a detailed climate change assessment has subsequently been incorporated into the FRMS. The objective of the climate change assessment was to assess the impacts of climate change on flooding in the floodplain and to make recommendations with regards to appropriate planning approaches to manage the risk.

The following tasks have been undertaken as part of the climate change assessment:

- Hydraulic modelling of four climate change scenarios (based on IPCC predictions and DECCW recommendations);
- Mapping of 100 Year ARI flood extents for the four climate change scenarios;
- An analysis of the properties impacted by flooding under the various climate change scenarios;
- An assessment of the consequences of adopting each of the four scenarios as part of the relevant planning provisions (LEP and DCP); and
- Recommendations for planning provisions to be adopted by Council.

The results of the hydraulic modelling showed that the flood levels around the foreshore increased by approximately 70 to 95 percent of the increase in sea levels due to climate change (depending on the climate change scenario). The results also show that a 20 percent increase in rainfall generally resulted in an increase in flood levels of 0.25m for the majority of the lake's foreshore.

Recommendations have been made to incorporate medium and high level sea level rise into the flood risk precinct mapping and flood planning levels for concessional and non-concessional development respectively. It was also recommended to include 0.25m into the freeboard on all flood planning levels to allow for a possible 20 percent increase in rainfall.

It should be noted that the climate change assessment described in this paper was completed before the release of the NSW Government's *Sea Level Rise Policy Statement* (DECCW, 2009) (and related guidelines and technical notes). The adopted methodology and benchmarks were based on best available information at the time (2008) and differ slightly from those now recommended by the NSW Government.

Introduction

Lake Illawarra is a shallow coastal lagoon located about eight kilometres south of Wollongong on the south coast of New South Wales. The Lake is located on the undulating coastal plain between the ocean and the cliffs of the Illawarra Escarpment. The Lake is an important recreational asset for the Illawarra Region, and also provides an important habitat for wildlife and acts as a valuable commercial and recreational fishing ground.

In the past, flooding of the Lake Illawarra foreshore has caused property damage, restricted property access and has been a general inconvenience to residents and tourists. These flooding issues, combined with considerable development pressure along the Lake foreshore, have prompted the Lake Illawarra Authority and Wollongong and Shellharbour City Councils, through the Lake Illawarra Floodplain Management Committee to prepare a Floodplain Risk Management Plan (FRMP) for the Lake Illawarra foreshore area.

As part of the flood analysis being undertaken in developing the FRMP, the impact of climate change on flooding was assessed for four climate change scenarios. The hydraulic model results for the scenarios were utilised in undertaking a property and planning impact assessment, which identified the numbers and types of properties impacted by the various climate change scenarios and the implications associated with adopting climate change into local government planning provisions.

Study area

The Lake catchment is approximately 27,000 hectares and is characterised by a low coastal plain, dominated by the western backdrop of the Illawarra Escarpment. The escarpment rises to a height in the catchment of 760m at Mount Murray, but more impressive is the slope of the escarpment, which rises over 400m over a horizontal distance of approximately 3km. The study area is shown in **Figure 1**.

Generally, elevated areas of the catchment closer to the escarpment are rural or forested in character and slope steeply while the lower areas closer to the Lake are flatter and have a mixture of residential, commercial and heavy industrial development. Two major transport links, the F6 freeway and the Illawarra railway line traverse the catchment from north to south.

The hydrological investigations for the assessment covered the whole of the Lake Illawarra catchment. Hydraulic modelling was limited to cover the Lake Illawarra foreshore area, which was defined as the area inundated by floodwaters rising from within the Lake body only. Flood liable areas affected by flows from waterways entering the Lake were not included in the model domain.

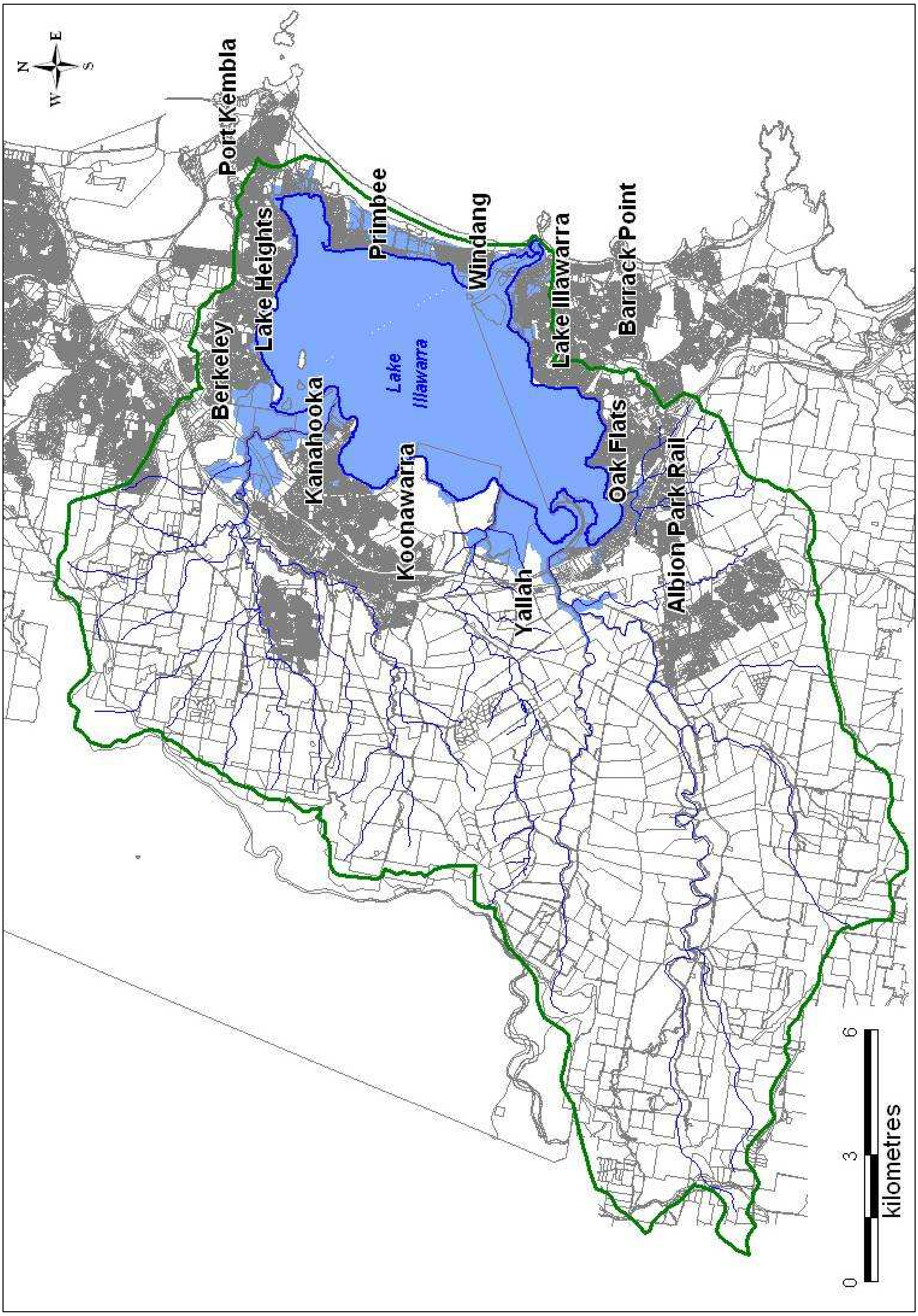

Figure 1: Lake Illawarra Catchment and Floodplain

Climate change assessment

The Inter-governmental Panel on Climate Change (IPCC) Assessment Report 2007 (Known as 'Climate Change 2007') concludes that climate change and sea level rise are inevitable. The *Floodplain Development Manual* (NSW Government, 2005) requires that Flood Studies and Floodplain Risk Management Plans consider the impacts of climate change and sea level rise on flood behaviour.

The following tasks were undertaken within the Lake Illawarra FRMS&P to address the issue of climate change:

- Hydraulic modelling of four climate change scenarios (based on IPCC predictions and recommendations made by the NSW Department of Environment and Climate Change (DECC) in 2007);
- Mapping of 100 Year ARI flood extents for the four climate change scenarios;
- An analysis of the properties impacted by flooding under the various climate change scenarios;
- An assessment of the consequences of adopting each of the four scenarios as part of the relevant planning provisions (Local Environment Plan (LEP) and Development Control Plan (DCP)) and exploration of different approaches to address this issue; and
- Recommendations for planning provisions to be included in the FRMP.

Adopted climate change scenarios

The Floodplain Risk Management Guideline (DECC, 2007) provided the most recent predictions of ocean level rise in NSW at the time that this assessment was undertaken and also discussed the potential increase in peak rainfall intensities as a result of climate change. The guideline provided predictions for three climate change scenarios:

- Low Level Rise (Low Greenhouse Gas Emissions Scenario);
- Medium Level Rise (Medium Greenhouse Gas Emissions Scenario); and
- High Level Rise (High Greenhouse Gas Emissions Scenario).

The assessments undertaken for the Lake Illawarra floodplain adopted the following climate change scenarios, which are based on the IPCC predictions and the Department of Environment and Climate Change (DECC) (2007) recommendations:

1. LCC: Low level ocean rise (0.18m), no change in rainfall intensity.
2. MCC: Medium level ocean rise (0.55m), no change in rainfall intensity.
3. HCC: High level ocean rise (0.91m), no change in rainfall intensity.
4. MCC + 20%: Medium level ocean rise (0.55m), medium level increase in rainfall intensity (20%).

Since the preparation of the DECC (now Department of Environment, Climate Change and Water DECCW) Floodplain Risk Management Guideline (2007) and the modelling undertaken for the FRMS&P, the NSW Government has adopted a sea level rise prediction for 2050 of 0.4m and 0.9m for 2100 (DECCW, 2010). These values are not significantly different from the values adopted for the Lake Illawarra assessment.

Modelling methodology

Climate change modelling of the four climate change scenarios was undertaken to investigate the potential impacts on flood levels within Lake Illawarra as a result of climate change. The modelling was undertaken using a full-process Delft3D model of Lake Illawarra. The model included catchment flows as well as realistic ocean boundary conditions, for example, tides, waves and storm surge. The model included sediment transport calculations and morphological change so that the scouring of the entrance during a flood is realistically simulated.

The following boundary conditions were applied to the model:

- Catchment inflows were applied for the 36 hour, 100 year ARI event from hydrological modelling. For the 20% increase in rainfall scenario, it was assumed that the runoff volume increases by 20%, although the basic hydrograph form remains the same.
- Bathymetry: A recent (2008) hydro-survey provided much of the detail for the model. Available survey and airborne laser survey (ALS) data supplied by Shellharbour and Wollongong City Councils was used to define the Lake floodplain. Data compiled in previous entrance modelling (Lawson & Treloar, 2004) was used to define the offshore bathymetry. The critical flood conditions at Lake Illawarra may occur when the entrance is initially closed. It was therefore conservatively assumed that the entrance is initially closed. Based on historical data, the level of the entrance berm when the entrance is closed is typically 1.5m AHD. This berm level has been adopted for the 'present' condition. Under climate change scenarios, it is not unreasonable to assume that, provided there is sufficient sand within the system, the level of the berm may increase by the same magnitude as the rise in mean sea level (MSL). Therefore, for each sea level rise (SLR) scenario, the berm level was adjusted according to the increase in MSL.
- The initial Lake level has been obtained from 28-day simulations of the Delft3D model with a surveyed (open) entrance condition (March 2008) to obtain the average water level within the Lake. The initial Lake level derived from these simulations and then applied to the Delft3D flood simulations were:
    - Existing Condition: 0.13m AHD;
    - Low-Level Climate Change Scenario: 0.29m AHD;
    - Mid-Level Climate Change Scenario: 0.66m AHD; and
    - High-Level Climate Change Scenario: 1.00m AHD.
- The 20 year ARI ocean storm conditions were adopted as the downstream boundary condition. The total 20 year ARI storm tide for the present sea-level was adopted as 1.41m AHD (McInnes et al, 2007). This level was then adjusted by the rise in MSL for each climate change scenario. The 20 year ARI offshore wave conditions were adopted based on long-term wave data from the Botany Bay wave rider buoy (to the north of the Lake).
- The peak ocean storm conditions were conservatively assumed to coincide with the peak catchment inflows into the Lake.

Results and mapping analysis

Table 1 presents peak water levels for the existing condition and the specified climate change scenarios. In general, it can be seen that the increase in flood levels for the majority of the lake's foreshore as a result of climate change ranges between 70 and 95 percent of the increase in ocean levels. In addition, a comparison of the results from Scenario 2 and 4, show that a 20 percent increase in rainfall generally results in an increase in flood levels of 0.25m for the majority of the Lake's foreshore.

Table 1: 100 Year ARI Existing and Climate Change Flood Levels

	100-year ARI Flood Levels (m AHD)				
		Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Existing	Low-level - SLR +0.18m	Mid-level - SLR +0.55m	High-level - SLR +0.91m	Mid-level - SLR +0.55m +20% rainfall
Griffins Bay	2.24	2.41	2.63	3.04	2.88
Tallawarra Power Station	2.24	2.41	2.63	3.04	2.88
Horsley Inlet	2.24	2.41	2.63	3.04	2.88
Cudgeree	2.24	2.41	2.64	3.04	2.88
Windang Bridge	2.15	2.35	2.55	3.01	2.77
Entrance Channel	1.71	1.89	2.25	2.32	2.25

The flood extents under the four climate change scenarios are shown as overlays (including the existing 100 Year ARI extent from the Delft3D model) in **Figure 2**.

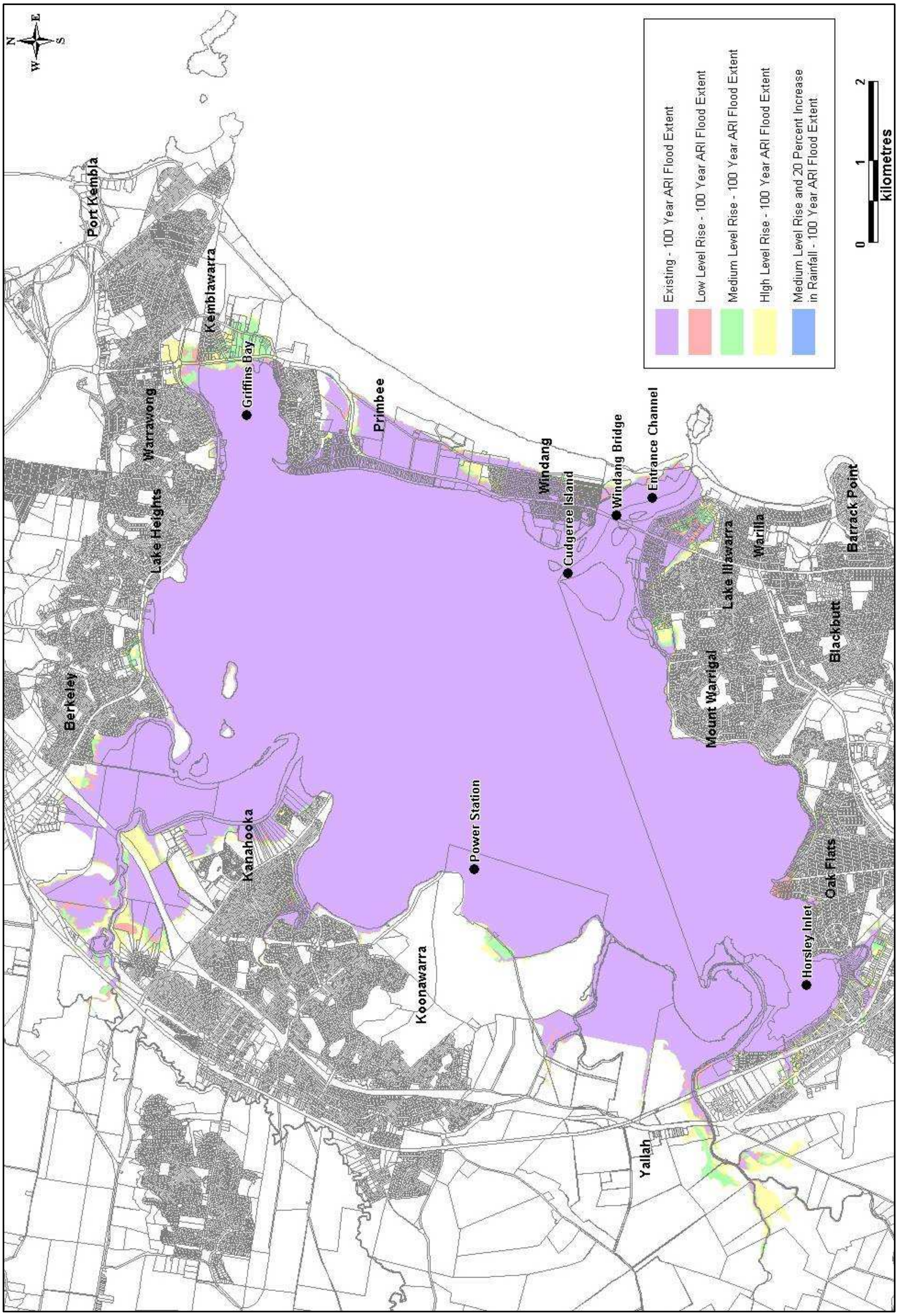

Figure 2: 100 Year ARI Flood Extents

Utilising geographic information system (GIS) data for the floodplain, the property impacts resulting from the various climate change scenarios were determined in terms of number of cadastral lots and LEP zoning areas affected. The results are provided in tabular form below in **Table 2**.

Table 2: Total Cadastral Lots affected under the 100 Year ARI Flood and Various Climate Change Scenarios

Climate Change Scenario	Number of cadastral lots affected	Average lot size (sq m)	Number of cadastral lots (<2000 sq m)	Increase over current	Average lot size (sq m) (<2000 sq m)
Current (No SLR)	2,621	10,855	2,287	0	754
LCC	3,155	9,295	2,758	534	744
MCC	3,492	8,637	3,030	871	759
MCC with +20% rainfall increase	3,814	8,182	3,278	1,193	771
HCC	4,007	8,238	3,432	1,386	768

The change reported in **Table 2** represents an increase of 120 to 150 % in cadastral lots between the current and the high climate change (HCC) scenarios.

A summary of the key findings of the assessment is provided below:

- There would be an increase in inundation of an additional 1,386 cadastral lots under the High Climate Change Scenario when compared to the existing 100 Year ARI extent. The majority of these additional lots are zoned as residential (low and medium density).
- Residential properties represent 7.14% and 11.17% of the existing Wollongong and Shellharbour flood affected land within the Lake Illawarra floodplain respectively. Under HCC the number of residential properties affected by 100 Year ARI flooding will increase by 459 and 668 in Wollongong and Shellharbour and under HCC the proportion of flood affected land that is residential will also increase (8.06% and 15.6% respectively).
- Environmental Protection Zones are currently located in areas which are likely to be flooded by a 100 Year ARI event, and are the dominant land zones affected. This is maintained under all climate change scenarios. However, their proportionate area of inundated land is decreased due to the increase in inundation of other land uses under the various climate change scenarios.
- Within Shellharbour, the inundated Rural 1A Zone area increases under all climate change scenarios. However, it should be recognised that there are only 32 Rural 1A Zone lots within the Shellharbour LGA and the reported proportions are affected by the substantial lot sizes within this zone (i.e. a small number of lots comprise the majority of the flooded area).

Planning implications

Council's in NSW use flood information presented in a Flood Study or Floodplain Risk Management Plan to identify flood affected properties and to set development controls related to flood risks. Wollongong and Shellharbour City Councils are considering adopting climate change flood related impacts into the planning considerations associated with flooding.

A Ministerial Direction (PS 07-003, issued 31 January 2007 under Section 117 of the NSW *Environmental Planning and Assessment Act*, 1979) advised in general terms that only the 100 Year ARI flood extent is to be considered with regards to flood-related development controls (unless in exceptional circumstances, which Wollongong City Council was awarded). The consideration of the climate change assessment was therefore only undertaken by considering the 100 Year ARI flood extent under the four climate change scenarios with respect to potential development controls.

The consequences of adopting the 100 Year ARI flood for each of the four climate change scenarios for planning purposes are discussed below with regard to Wollongong and Shellharbour's relevant DCPs and LEPs. The relevant planning documents are:

- Wollongong LEP 1990 (now superseded by a 2010 version);
- Shellharbour LEP 2000;
- Wollongong DCP 2009; and
- Floodplain Risk Management Development Control Plan (Shellharbour).

To manage risks associated with redevelopment or new development, a draft development control matrix to be inserted into the DCP of each Council for the Lake Illawarra floodplain has been prepared as part of the Floodplain Risk Management Plan. Each Council utilises the 'matrix' approach for the purposes of development control. These controls are proposed to be implemented as part of both of the Council's DCPs upon adoption of the Floodplain Risk Management Plan. The climate change scenarios have direct implications for the proposed DCP matrix.

The matrix approach relies on the mapping of risk 'precincts' for spatial application of controls. The risk precincts referred to in both Wollongong and Shellharbour's DCPs are defined by the 100 Year ARI 'true' high hazard (High Risk Precinct), Flood Planning Level (FPL) extent (Medium Risk Precinct) and the PMF extent (Low Risk Precinct). Climate change modelling and mapping of some of these conditions (i.e. true hazard and PMF under climate change) is not available for these events and as such the likely planning consequences discussed below are based on the 100 Year ARI results only.

It is important to note that at the time of preparation of this paper that the draft matrix had not yet been released for comment by the community and had not been adopted, or recommended for adoption by either Councils. The discussion below outlines the implications of adopting any one of the climate change scenarios evaluated.

Table 3 summarises the increase in lots affected for each of the climate change scenarios for the development types identified in Councils' DCPs.

Table 3 Increase in Lots Affected by 100 Year ARI Flooding

Type of Development	No. of Lots Affected	Increase in Number of Lots Affected (compared to existing)							
	Existing	LCC		MCC		MCC+20		HCC	
Residential	2,008	25%	2,508	39%	2,784	49%	2,998	56%	3,135
Commercial & Industrial	50	20%	60	84%	91	241%	178	324%	222
Tourism	44	16%	51	32%	58	50%	66	50%	66
Recreational and Non Urban	268	4%	280	13%	302	18%	315	21%	324
Total (of these land zones)	2,370	22%	2,899	36%	3,235	49%	3,557	57%	3,747

Note: *This table only addresses the main land use types that are listed in the draft DCP matrix and it should be noted that there are other lot types in the LEP (such as environmental protection zones and reservation areas). It should also be noted that a large proportion of the floodplain is zoned 'Special Uses' - this has not been included in the planning assessment below.*

Low Level Rise Climate Change (LCC)

If it is assumed that the increase in 100 Year ARI extent (**Figure 2**) would be similar to the increase in the current high risk precinct extent, the following comments on adopting the Low Level Rise Climate Change scenario for planning purposes can be made:

- For all types of development (except for *Recreational and Non-Urban* and *Concessional Development*) there would be a moderate increase (16 to 25 percent) in the number of properties that would no longer be developable under the proposed development control matrix (i.e. their classification would change in the draft DCP matrix from medium to high risk and the land would be considered unsuitable for that use).
- There would be only a small increase in the number of *Recreational and Non-Urban* lots that would trigger planning controls.
- Overall, the Low Level Rise Climate Change scenario could be adopted for planning purposes without a significant impact on development within the floodplain.

Medium Level Rise Climate Change (MCC)

If it is assumed that the increase in 100 Year ARI extent (**Figure 2**) would be similar to the increase in the current high risk precinct extent, the following comments on adopting the Medium Level Rise Climate Change scenario for planning purposes can be made:

- There would be a significant increase in the number of *Commercial and Industrial* lots (84 percent) that would no longer be developable (i.e. the land would be considered unsuitable for that use). The additional properties are primarily located in Kemblawarra, Lake Illawarra, Albion Park Rail and Oak Flats.

- Approximately two fifths of all developable lots (albeit with floodplain controls) within the floodplain would no longer be developable under the draft development control matrix.
- It should be noted that, whilst the increase in residential lots impacted by 100 Year ARI flooding is only 40 percent, this relates to an increase of 500 lots in the floodplain.

Medium Level Rise Climate Change plus 20% Increased Rainfall (MCC + 20%)

If it is assumed that the increase in 100 Year ARI extent (**Figure 2**) would be similar to the increase in the current high risk precinct extent, the following comments on adopting the Medium Level Rise +20% Climate Change scenario for planning purposes can be made:

- When the implications of the Medium Level Rise scenario and the Medium Level Rise plus Rainfall Increase scenario are compared, it can be seen that there is a fairly significant impact of adopting a climate change scenario which includes an increase in rainfall.
- The largest number of additional lots affected is in Kemblawarra. The majority of these lots are zoned *Commercial and Industrial*.
- Approximately half of all currently developable lots (albeit with floodplain controls) in the floodplain would no longer be developable under the draft development control matrix.

High Level Rise Climate Change (HCC)

If it is assumed that the increase in 100 Year ARI extent (**Figure 2**) would be similar to the increase in the current high risk precinct extent, the following comments on adopting the High Level Rise Climate Change scenario for planning purposes can be made:

- If the High Level Rise scenario is adopted for planning purposes there may be almost 4,000 properties impacted by stricter flood planning controls than they are currently subject to.
- Approximately 50 percent of residential properties which are currently zoned medium risk precinct are likely to be classified within the high risk precinct and therefore would no longer be developable.
- There is likely to be an increase of more than 300 percent of commercial and industrial lots impacted by high risk precinct planning controls. The majority of these lots are located in Kemblawarra (Wollongong LGA) and Oak Flats (Shellharbour LGA).

The assessment shows that the incorporation of climate change scenarios in the planning and development control process will affect *Commercial and Industrial* zoned properties the most when compared with the existing conditions. However, this assessment also shows that the implications of not adopting some form of climate change condition for planning purposes will result in a large number of properties potentially being impacted by flooding significantly worse than the existing flooding conditions and the properties will not have planning strategies to cope with the flooding conditions under climate change.

The assessment also shows that there will be serious flooding implications under all four climate change scenarios. Further, the medium level rise scenario, involving an increase in rainfall, shows that increased rainfall intensities will have a significant impact on flooding in the Lake Illawarra floodplain. However, the assessment also shows that implementing a high level rise scenario immediately would dramatically alter the development controls on thousands of properties, some of which are currently only affected by low risk precinct controls or are not in the floodplain at all. These properties may not feel the implications of climate change for several decades if sea level rise is gradual.

It is also acknowledged that different types of development have different design lives. For example, small scale residential development (i.e. single lot development or alterations and additions) could be considered to have a design life of 50 to 100 years (2060 to 2100) after which the building would be expected to be rebuilt. Whereas a broad scale greenfield/brownfield development may equate to a 100 year or more design life (2100+) for subdivision, buildings and infrastructure (particularly for subdivision and infrastructure). On this basis it may be appropriate to apply different climate change scenarios to the planning provisions for different types of development.

A way forward for planning

The assessment outlined in this paper identifies that not only sea level rise but also increases in rainfall will have a significant impact on flooding behaviour in the Lake Illawarra floodplain. As such, it may be prudent to incorporate both of these components of climate change into planning provisions. The following planning provisions have been considered:

- Flood Risk Precinct Mapping (i.e. the definition of flood risk areas). Flood risk precincts are used to determine where certain development controls are applied.
- Flood Planning Levels.

When considering recommendations for these planning provisions it was considered appropriate to consider the design life of the proposed development to which the provisions would apply (i.e. less than 50 years and greater than 50 years). Development considered having a design life of 50 years or less includes those developments identified as "Concessional Development" in the Wollongong and Shellharbour City Councils' DCPs.

Flood Risk Precincts

Concessional Development

The flood risk and associated property impacts identified in this climate change assessment identified that planning provisions based on the Medium Level Rise climate change predictions would be the most appropriate for adoption for development considered to have a design life of approximately 50 years (i.e. concessional development).

The Flood Risk Precincts that could be adopted for these developments include:

- High Risk Precinct, remains equal to the existing true high hazard extent;
- Medium Risk Precinct is to be updated to be equal to the Medium Level Rise Climate Change (MCC) extent plus a freeboard of 0.55m; and
- Low Risk Precinct remains equal to the existing PMF extent.

Figure 3 shows that the adoption of these controls would protect the development for more than 50 years from flooding impacts (albeit with limited or no freeboard) even under a High Level Rise Climate Change scenario.

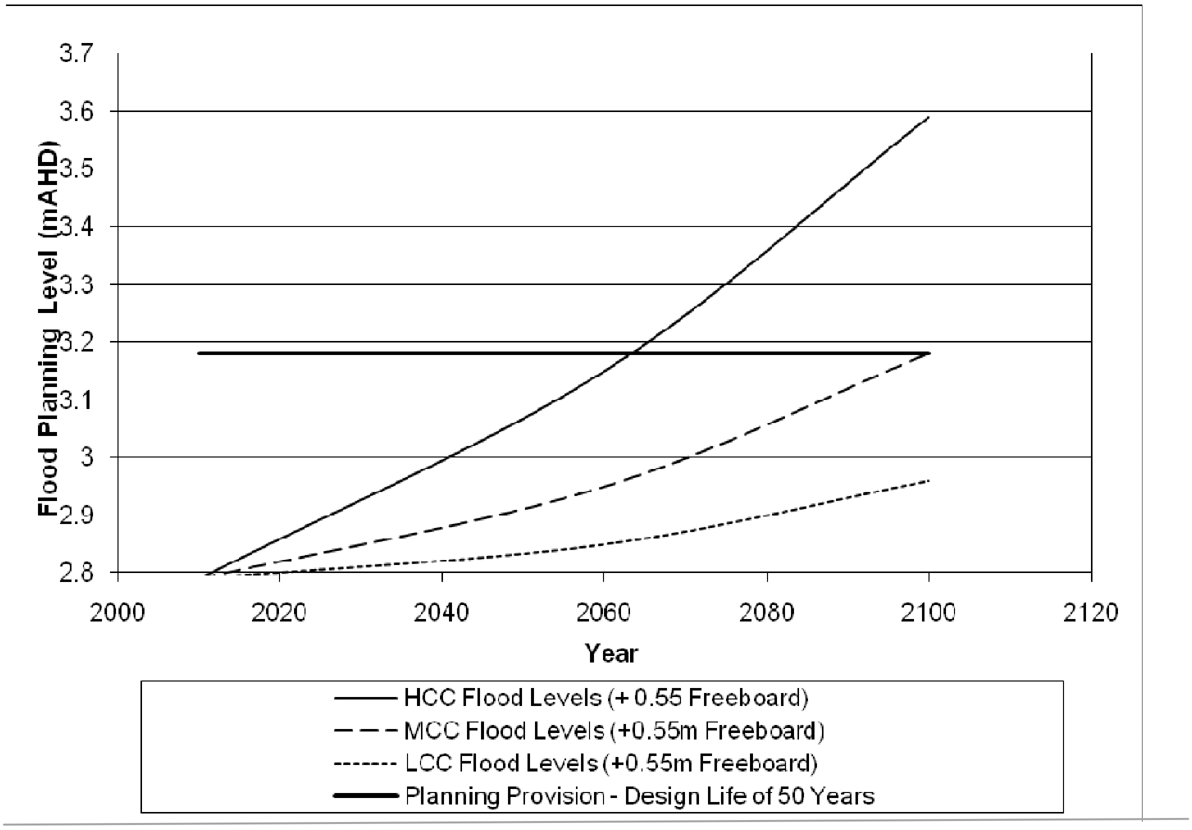

Figure 3: Predicted Flood Planning Levels Compared with Planning Provisions for Concessional and Exempt Development

The adoption of these climate change provisions is not expected to cause unnecessarily conservative controls on development with a relatively short-term timeframe in the floodplain. These planning provisions would apply at least until the next revision of the Lake Illawarra Flood Study or the publication of the IPCC 2013 report. An approach to manage this uncertainty would be to ensure that any development that is approved with the short term medium level rise approach be tagged through the Section 149 certificate process (or similar) with an explanation as to the provisions made for climate change.

Non-Concessional Development

All development that is not identified as “Concessional Development” in a DCP is considered to have a design life of greater than 50 years. The flood risk and property impacts identified in this climate change assessment identified that planning provisions based on high level rise climate change predictions would be the most appropriate for adoption for development and infrastructure considered to have a design life of greater than 50 years.

The Flood Risk Precincts that could be adopted for these developments include:

- High Risk Precinct, remains equal to the existing true high hazard extent;
- Medium Risk Precinct is to be updated to be equal to the High Level Rise Climate Change (LCC) extent plus a freeboard of 0.55m; and
- Low Risk Precinct remains equal to the existing PMF extent.

Flood Planning Levels

In addition to utilising the climate change flood result to identify properties at risk, the flood risk is also managed by applying a flood planning level to all proposed developments. The flood planning level determines minimum floor levels for those properties which are flood impacted. The flood affected properties have been identified, as discussed above, by incorporating sea level rise into the flood extents. It is therefore appropriate to incorporate the flood impacts associated with potential increases in rainfall into the flood planning levels. This could be achieved by incorporating an appropriate height into the flood planning level freeboard.

A comparison of the flood levels presented in **Table 1** for Scenario 2 (Medium level ocean rise – 0.55m and no change in rainfall intensity) and Scenario 4 (Medium level ocean rise – 0.55m and medium level increase in rainfall intensity – 20%). The difference between the two sets of results is, on average, 0.25m. This would indicate that the impact on flood levels of the increase in rainfall by 20% is approximately 0.25m for the 100 year ARI event. It may therefore be appropriate to incorporate 0.25m into the freeboard.

It should be noted that the Draft FRMS (Cardno, 2010) has also recommended the following components be included in the freeboard to be applied to all flood planning levels:

- 0.2 metres for local wave action (based on a simple fetch calculation).
- 0.1 metres for afflux.

Therefore, the resulting freeboard that was recommended in the draft FRMS (Cardno, 2010) for the Lake Illawarra Floodplain is 0.55 metres.

Conclusions

With an increasing awareness of the flood risks associated with climate change and the adoption of state policies on the matter, local Council’s are endeavouring to incorporate risk management strategies into their policies and plans. The flood impact assessment and planning recommendations presented in this paper, provide one method by which flood risk associated with climate change can be managed by local government. This method could be adapted for others locations and updated as future sea level rise and rainfall change predictions become available.

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