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Dear Alan,

FPL ASSESSMENT FOR THE PROPOSED URBAN LAND WITHIN THE PENRITH LAKES SCHEME

Cardno have been requested by PLDC to provide advice on setting an appropriate flood planning level (FPL) for the urban areas within the Penrith Lakes Scheme.

The proposed urban areas are shown below in **Figure 1**.

The following letter report discusses the various aspects that influence setting FPLs.

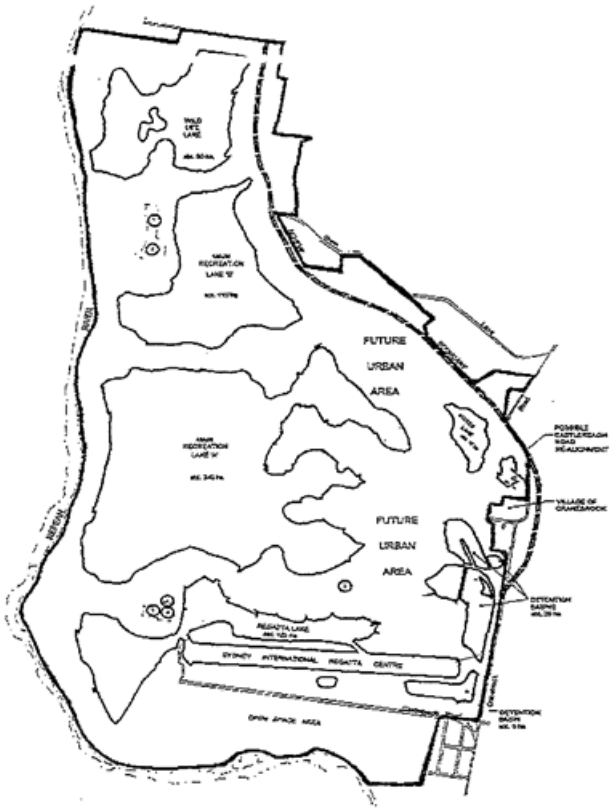

Figure 1: Future Urban Areas (from DA4 submission, July 1988)

1. FLOODING MECHANISMS

The Penrith, Emu Plains and Cranebrook regions are subject to two different flooding mechanisms:

- Flooding resulting from local catchment rainfall events, and
- Flooding resulting from elevated Nepean River levels.

For areas within the PLDC Scheme, flooding resulting from the Nepean River is the more significant flooding mechanism, and as such, the following FPL discussion will be focused on flooding occurring from elevated Nepean River levels.

2. BACKGROUND

The Flood Planning Level (FPL) for the majority of areas across New South Wales has been traditionally based on the 1% AEP flood level plus a freeboard. The freeboard for habitable floor levels is generally set between 0.3 – 0.5m for residential properties, and can vary for industrial and commercial properties.

A variety of factors are worthy of consideration in determining an appropriate FPL. Most importantly, the flood behaviour and the risk posed by the flood behaviour to life and property in different areas of the floodplain and different types of land use need to be accounted for in the setting of an FPL.

The Floodplain Development Manual (NSW Government, 2005) identifies the following issues to be considered:

- Risk to life,
- Long term strategic plan for land use near and on the floodplain,
- Existing and potential land use,
- Current flood level used for planning purposes,
- Land availability and its needs,
- Changes in potential flood damages caused by selecting a particular flood planning level,
- Consequences of floods larger than the flood planning level,
- Environmental issues along the flood corridor,
- Flood warning, emergency response and evacuation issues,
- Flood readiness of the community (both present and future),
- Possibility of creating a false sense of security within the community,
- Land values and social equity,
- Potential impact of future development on flooding,
- Duty of care.

These issues are dealt with collectively in the following sections.

3. FPL ASSESSMENT

3.1 Likelihood of Flooding

As a guide, Table 3.1 has been reproduced from the NSW Floodplain Development Manual 2005 to indicate the likelihood of the occurrence of an event in an average lifetime.

Analysis of the data presented in Table 3.1 gives a perspective on the flood risk over an average lifetime. The data indicates that there is a 50% chance of a 100yr ARI event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 100yr ARI flood event as the basis for the FPL. Given the social and economic issues associated with a flood event, and the non-tangible effects such as stress and trauma, it is appropriate to limit the exposure of people to floods.

Note that there still remains a 30% chance of exposure to at least one flood of a 200yr ARI magnitude over a 70 year period. This gives rise to the consideration of the adoption of a rarer flood event as the flood planning level for some types of development.

Table 3.1 Probability of Experiencing a Given Size Flood or Higher in an Average Lifetime (70yrs)

Likelihood of Occurrence in any year (ARI)	Probability of experiencing at least one event in 70 years (%)	Probability of experiencing at least two events in 70 years (%)
10yr	99.9	99.3
20yr	97	86
50yr	75	41
100yr	50	16
200yr	30	5

3.2 Risk to Life

Risk to life from flooding will be managed by evacuation for the future urban areas. Investigations into evacuation strategies for the future urban area are currently been undertaken by Molino Stewart. This investigation is an update of the *Sydney REP Penrith Lakes Scheme 2006: Flood Evacuation Risks Revised Assessment Report*, prepared by Molino Stewart in 2006. Based on the old report, it is assumed that shelter in place will not be part of the emergency response plan.

Therefore, risk to life is not assumed to be a major factor for determining flood planning levels.

3.3 Current Flood Planning Levels

3.3.1 Penrith City Council – Current FPL Requirements

Based on the Penrith Development Control Plan 2010, Penrith City Council currently utilises the following flood planning levels for urban development:

- For new residential development, floor levels to be at least 0.5m above the 100 year ARI peak flood level
- Any portion of buildings subject to inundation shall be built from flood compatible materials

3.3.2 Hawkesbury-Nepean Flood Management Advisory Committee Recommendations

In addition to Council's DCP, the Hawkesbury-Nepean Flood Management Advisory Committee commissioned the production of flood-specific planning guidelines. The three published guidelines are the result of a collaboration between state and local government and also involved research and testing by independent research organisations including several NSW universities (Sydney, Macquarie, Newcastle) and the CSIRO.

These guidelines were release in 2006. The guidelines published are:

- Designing Safer Subdivisions: Guidance on Subdivision Design in Flood Prone Areas,
- Managing Flood Risk Through Planning Opportunities: Guidance on Land Use Planning in Flood Prone Areas; and,
- Reducing Vulnerability of Buildings to Flood Damage: Guidance on Building in Flood Prone Areas.

A discussion on appropriate FPLs for the Hawkesbury-Nepean floodplain is provided in planning guidelines. The key points made in the document are:

- The flooding range and consequences of rare floods are exceptional in the Hawkesbury-Nepean system;
- Given the diversity of the catchment, it is reasonable for different regions to adopt different FPLs, provided that these levels are based on sound reasoning of local conditions;

- A 0.5m freeboard was found to be appropriate for managing uncertainty (see Section 3.9);
- Single storey dwellings are recommended to have their lowest habitable floor level at the flood of record level (approximately the 200yr ARI event)
- If constructed below the 200yr ARI flood level, buildings should have a second floor wherever possible to allow shelter in place.
- Any portion of buildings subject to inundation should be built from flood compatible materials; and,
- External and load bearing walls below the 200yr ARI flood level should be constructed of masonry.

3.3.3 Summary

Based on the current DCP, and FPL of 100yr ARI + 0.5m is generally adopted. The Hawkesbury-Nepean guideline recommendations give rise to consideration of two storey developments only below the 200yr ARI.

Based on this assessment criteria, an FPL of 100yr ARI + 0.5m or 200yr ARI peak levels is recommended based on existing polices and guidelines.

3.4 Incremental Height Difference Between Events

Consideration of the average height difference between various flood levels can provide another measure for selecting an appropriate FPL.

Based on the proposed development flood behaviour, the incremental height difference between events is shown in Table 3.3 for selected events.

The level differences are reported are in Main Lake A, which govern flood levels around the future urban land areas.

Table 3.3: Relative Differences Between Design Flood Levels

Event (ARI)	Diff to PMF (m)	Diff to 500yr ARI (m)	Diff to 200yr ARI (m)	Diff to 100yr ARI (m)
500yr	4.9	-	-	-
200yr	6.2	1.3	-	-
100yr	7.7	2.8	1.5	-
50yr	11.8	6.9	5.6	4.1

Table 2.2 indicates that there is a significant increase in peak flood levels between each ARI event. The greatest incremental difference is between the 50yr and 100yr ARI events (5.6m) and the 500yr ARI and PMF event (4.9m).

The incremental increases between the 100yr and 200yr ARI and the 200yr and 500yr ARI are comparatively lower (1.5m and 1.3m respectively). However, it is noted that adopting the 200yr ARI event as the flood planning level would result in 1.5m of additional height required for the future urban area.

The above assessment of differences between heights show that increasing the FPL to successive peak flood levels requires a large increase at each stage. The effectiveness of adopting higher FPLs in reducing flood damages is discussed in Section 3.7.

3.5 Overfloor Flooding Impacts Resulting from Different FPLs

Table 3.4 provides the overfloor flooding that may be expected for properties on the future urban land during large flood events for a range of alternative FPL scenarios.

Table 3.4 shows that adopting the 100yr ARI + 0.5m level results in overfloor flooding of 1.0m in the 200yr ARI event, and 2.3m in the 500yr ARI event. As these flood depths are less than 2.4m, shelter in a second floor (where evacuation has not been undertaken) is feasible for both these events, assuming that the structure is designed to withstand these depths.

Increasing the FPL to the 200yr ARI event reduces the 500yr ARI overfloor flooding to 1.3m. This is still a significant depth, and shelter out of the flood in a second story would still be recommended.

Table 3.4 also shows that none of the options are effective at reducing flood depths in the PMF to safe levels; even using the 500yr ARI level as the FPL results in a flood depth of 4.9m in the PMF.

Given that increasing the FPL does not significantly improve protection in the larger events, there is little benefit in placing the FPL at a level above the 200yr ARI. As both the 100yr ARI + 0.5m and 200yr ARI FPL scenarios allow the flexibility of shelter in place for events up to the 500yr ARI (if shelter in place is considered), either of these two scenarios would be suitable based on this assessment criteria.

Table 3.4: Flooding depths for future urban properties for various FPL scenarios

FPL Scenario	Flood Depth in PMF (m)	Flood Depth 500yr ARI (m)	Flood Depth in 200yr ARI (m)	Flood Depth in 100yr ARI (m)
100yr ARI + 0.5m	7.2	2.3	1.0	-
200yr ARI	6.2	1.3	-	-
200yr ARI + 0.5m	5.7	0.8	-	-
500yr ARI	4.9	-	-	-

3.6 Consequence of the Adopting the PMF as a Flood Planning Level

The PMF is 7.7m higher than the 100yr ARI event within the Main Lakes. If the PMF were used as the FPL, the urban landform would be required to be raised above 29.6mAHD. This would have a number of impacts:

- It would significantly reduce the available developable area due to the grades required to raise the landform to this height;
- If would reduce the aesthetics of the scheme, as no other surrounding landforms are this high; and,
- Raising this area of land out of the floodplain may have adverse flood impacts for extreme flood events.

Given this, the economic costs may in fact outweigh the benefits of using the PMF event as the FPL. The use of the PMF level as the FPL may also conflict with other development/building controls in Councils DCPs.

Given the risk of exposure outlined in Table 2.1, it is recommended that emergency response facilities be located outside of the floodplain (i.e., above the PMF) and any other likely critical facilities be limited to areas outside of the floodplain. Other critical facilities, such as schools and day care centres are suggested to have a floor level at the PMF level.

3.7 Damage Cost Differential Between Events

The annual average damage (AAD) for a property under different FPL scenarios is shown in Table 3.5. The damages are calculated based on the draft DNR (now OEH) Floodplain Management Guideline No. 4 *Residential Flood Damage Calculation* (NSW Government, 2005), with the costs converted into 2013 dollars. It was also assumed that a flooding depth of over 2.4m would result in the structure being knocked down and rebuilt. The table shows the AAD of a given property that experiences overfloor flooding, and the net present value (NPV) of those damages over 50 years at 7%.

It can be seen from Table 3.5 that the greatest economic benefits arise when properties are lifted above the 100yr ARI level. Lifting properties to the 100yr ARI, from the 50yr ARI + 0.5m, saves $36,200 in NPV, and lifting properties further to the 100yr ARI +0.5m level saves a further $22,920.

The table also shows that there is little economic benefit in raising the FPL beyond the 100yr ARI + 0.5m level. Lifting properties from the 100yr ARI + 0.5m level to the 200yr ARI level only results in a saving of $5,316 dollars over 50 years. It would cost significantly more than this to raise the terrain and residential properties from the 100yr ARI + 0.5m level to the 200yr ARI level.

Table 3.5: Damage Differential Costs

FPL Scenario	AAD	Change in AAD	NPV of AAD	Change in NPV
50yr ARI + 0.5m	$5,250	-	$72,454	-
100yr ARI	$2,625	$2,625	$36,277	$36,227
100yr ARI + 0.5m	$964	$1,661	$13,307	$22,920
200yr ARI	$579	$385	$7,991	$5,316
200yr ARI + 0.5m	$543	$36	$7,491	$500
500yr	$350	$193	$4,830	$2,661

3.8 Environmental and Social Issues

The FPL can result in housing being placed higher than it would otherwise be. This can lead to a reduction in visual amenity for surrounding property owners, and may lead to encroachment on neighbouring property rights. This may also cause conflict with other development controls already present within the Council's development assessment process.

3.9 Risk

The selection of an appropriate FPL also depends on the potential risk of different development types. For example, consideration should be given for different FPLs for industrial, commercial and residential properties, which have different implications should overfloor flooding occur.

Critical infrastructure, such as hospitals, fire stations, electricity sub-stations and other critical infrastructure, has wider spread implications should inundation occur. This type of infrastructure generally needs to be operational during and after a flood event. As such, FPLs are typically selected for these types of structures higher than for residential, commercial or industrial properties.

3.10 Freeboard Selection

As outlined in Section 10.1, a freeboard ranging from 0.3 - 0.5 m is commonly adopted in determining the FPL. It should be realised that the freeboard accounts for uncertainties in deriving the design flood levels and as such should be used as a safety margin for the adopted FPL.

The freeboard may account for factors such as:

- Changes in the catchment,
- Changes in the creek/channel vegetation,
- Accuracy of model inputs (e.g. accuracy of ground survey, accuracy of design rainfall inputs for the area),

Model sensitivity:

- Local flood behaviour (e.g. due to local obstructions etc),
- Wave action (e.g. such wind-induced waves or wash from vehicles or boats),
- Culvert blockage,

The sensitivity of the model was assessed as part of the Penrith Lakes Scheme: Flood Infrastructure Concept Design Report (Cardno, 2012). A summary of this assessment is provided below in Table 3.6.

The impact of various elements factored into a freeboard can be summarised as follows:

- Afflux (local increase in flood level due to a small local obstruction not accounted for in the modelling) (0.1m),
- Local wave action (allowances of ~0.1 m are typical) (truck wash, wind, waves, etc),
- Accuracy of ground/ aerial survey ~ +/-0.15m,
- Sensitivity of the model ~ +/-0.2m

Based on this analysis, the total sum of the likely variations is in the order of 550mm. This would suggest that a freeboard allowance of 500mm would be appropriate for the PLDC urban areas.

Table 3.6: Model Sensitivity

Variable Types	Variable	Change	Main Lakes Level Difference (m)
Model Parameters	Roughness	20%	0.56
		-20%	-0.61
	Boundary	20%	-0.25
		-20%	0.5
Infrastructure Parameters	Weir 3	Width +5m	0.01
		Width -5m	-0.01
		Crest +0.05m	0.03
		Crest -0.05m	-0.05
	Weir 6	Width +5m	-0.01
		Width -5m	0.01
		Crest +0.05m	0.04
		Crest -0.05m	-0.04
Average Increase			0.19
Average Decrease			-0.16

4. CONCLUSION

Most assessment criteria showed that either a 100yr ARI + 0.5m ARI level or a 200yr ARI level is appropriate for the FPL for the future urban areas. In Section 3.7, it was shown that there was very little improvement in flood damages if the FPL was set at the 200yr ARI level, rather than the 100yr ARI + 0.5m level. Given this, the fact the Penrith City Council currently employ an FPL of the 100yr ARI + 0.5m, and also that FPLs are not being used in this instance to reduce risk to life, it is recommended that an FPL set at the 100yr ARI plus 0.5m is appropriate for the urban land within the PLDC Scheme.

Given a peak 100yr ARI flood level in Main Lake A and B of 21.7mAHD, the resulting FPL for the Scheme is 22.2mAHD.

If you have any questions regarding this assessment, please do not hesitate to contact me on 9496 7700.

Yours sincerely,

Rhys Thomson
Senior Engineer / Economist
for **Cardno (NSW/ACT) Pty Ltd**