9. FLOODPLAIN RISK MANAGEMENT MEASURES

This FRMS aims to identify and assess risk management measures which could be put in place to mitigate flood risk and reduce flood damages. As well as the hydraulic impacts, flood risk management measures are assessed against the legal, structural, environmental, social and economic conditions or constraints of the local area. In the following sections a range of management options are considered to determine the effectiveness in managing existing and future flood risks in the Manly Lagoon catchment.

9.1. Categories of Floodplain Risk Management Measures

The 2005 NSW Government's Floodplain Development Manual (Reference 2) separates risk management measures into three broad categories;

- **Flood modification measures (Section 9.2)** modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, channel improvement, levees or defined floodways. Pit and pipe improvement and even pumps may also be considered where practical.

- **Response modification measures (Section 9.3)** modify the response of the community to flood hazard by educating flood affected property owners about the nature of flooding so that they can make better informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community, and provision of flood insurance.

- **Property modification measures (Section 9.4)** modify the existing land use and development controls for future development. This is generally accomplished through such means as flood proofing, house raising or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls, or voluntary purchase / voluntary house raising.

In addition, the following measures were specifically requested to be assessed as part of the Management Study:

- Any possible options to mitigate nuisance flooding at Balgowlah/Kenneth Road, including:
  - Installing a tidal flap/valve on the pipe;
  - Implications of insufficient maintenance or pipe failure;
  - Raising Balgowlah Road and the Manly Senior Citizens carpark;
  - Incorporating in-pipe storage in the upper catchment; and
  - Underground detention (with possible retention for reuse) in Keirle Park.
- Emergency management to consider the impacts of flooding on Manly SES headquarters, Manly Council depot and Quirk Road electrical substation;

- Levee and in-line check valve on stormwater pipes at the Manly Lagoon end of Campbell Parade;
- Allambie Heights drainage augmentations;
- Review options identified in the 1996 Manly Lagoon FRMS and identify any options which could be reinvestigated;
- Assess the impact of lowering the storage level of Manly Dam; and
- Assess the impact of extending the low flow channel under Stuart Somerville Bridge by lowering the bed rock level.

Table 18 provides a summary of all the options considered in this study. Details of their assessment is included in the following sections, and their approximate location shown on Figure 31.

Table 18: Manly Lagoon Catchment management options considered

Category	Option	ID	Description	Reference	Recommended
Flood Modification Measures	Levee	LV01	Levee around Riverview Parade area as per 1996 Floodplain Management Study. Levee set to the 1% AEP level without freeboard.	9.2.1.1	No
		LV02	New levee located upstream of Warringah Mall near Clearview Place to prevent mainstream flooding. Levee set to 1% AEP level without freeboard.	9.2.1.2	**Yes**
		LV03	Levee located around properties in hotspot location A (Kenneth Road & Balgowlah Road) as per 1996 Floodplain Management Study. Levee set to 1% AEP level without freeboard.	9.2.1.3	No
		LV04	Levee located along Campbell Parade and along Manly Creek, constructed to the 5% AEP level.	9.2.1.3	No
	Temporary Flood Barriers	TB01	Use of temporary flood barriers to protect small areas or individual properties.	9.2.2	No
	Floodways / diversion channels	DC01	New flow path created south of Pittwater Bridge to recreate the original channel which was piped over in 1952.	9.2.3	No
	Channel modification	CM01	Lowering the creek upstream of Clearview Place by approximately 0.5 m for 20 m.	9.2.4.1	No
		CM02	Lowering the open channel upstream of Warringah Mall by 0.5 m for 250 m.	9.2.4.2	No
		CM03	Rock channel upstream of the twin low-flow pipes is extended upstream of Stuart Somerville Bridge by 60 m.	9.2.4.3	No
		CM04	Lowering the 25 m long bed rock beneath Stuart Somerville Bridge by 0.4 m.	9.2.4.4	No
	Drainage Modification	DM01	Installation of new pipe system (2 x 0.6 m pipes) along Balgowlah Road.	9.2.5.1	No
		DM02	Installation of new pipe system (2 x 0.6 m pipes) along Balgowlah Road.	9.2.5.2	No
		DM03	Installation of flap valve where the pipe at Keirle Park discharges into the lagoon to prevent ingress of waters from the lagoon into the drainage system during smaller events.	9.2.5.3	No
		DM04	New pipe system (2 x 0.6 m pipes) in Balgowlah starting at Pitt Street until Manly West Park	9.2.5.4	No
		DM05	Installing new pipe network (2 x 0.6 m pipes) along Kenneth Road between Rosebery Street and Quirk Road	9.2.5.4	No

Flood Modification Measures		DM06	New pipe system (2 x 0.6 m) along Green Street and William Street to reduce local overland flows.	9.2.5.4	No
		DM07	New 1500 m trunk drainage system through Brookvale (box culvert of 3 m x 1.5 m)	9.2.5.7	No
	Drainage maintenance	DR01	Dredging at Pittwater Bridge to a channel level of -1.5 mAHD	9.2.6.1	No
		DR02	Dredging upstream and downstream of Stuart Somerville Bridge to the rock bar level (0.2 mAHD)	9.2.6.2	No
	Retention basins	RT01	New basin on Manly Creek at Millers and David Thomas Reserve. Spillway 2 m above bottom of basins (total storage volume of 146 000 m^3).	9.2.7.1	No
		RT02	Installing underground detention tank in Keirle Park. (1000 m^3 storage)	9.2.7.2	No
	Dams	MD01	Lowering the initial water level of Manly Dam to the operating level, 34.14 mAHD.	9.2.8.1	**Yes**
		MD02	Lowering initial water level in the Manly Dam by 0.2 m below the crest level to 35.64 mAHD to assess the impact of storing water in the dam.	9.2.8.2	**Yes**
		MD03	Lowering initial water level in the Manly Dam by 0.4 m below the crest level to 35.44 mAHD to assess the impact of storing water in the dam.	9.2.8.3	**Yes**
		MD04	Lowering initial water level in the Manly Dam by 0.8 m below the crest level to 35.04 mAHD to assess the impact of storing water in the dam.	9.2.8.4	**Yes**
Response Modification Measures	Emergency Planning	RM01	Development of Local Flood Plan	9.3.1	**Yes**
	Flood Warning	RM02	Add new stream gauges on each of the three creeks, continuation of Northern Beaches Flash Flooding Warning System	9.3.2	**Yes**
	Improving road access	RM03	Raising Balgowlah Road and the Senior Citizens Carpark. The road was raised by 1 m - 1.5 m for approximately 560 m. The carpark was raised by 1.5 m in the west and 1.3 m in the east.	9.3.3	No
	Road Closures	RM04	Add list of affected roads to Local Flood Plan. Flag some for depth indicators	9.3.4	**Yes**
	Community Education and Awareness	RM05	Community engagement to prepare an ongoing flood education program (and appropriate evaluation system)	9.3.5	**Yes**
Property Modification Measures	Voluntary House Raising	PM01	Assesses raising eligible residential properties to reduce flood damages.	9.4.1	No
	Voluntary House Purchase	PM02	Assesses purchasing eligible residential properties to remove residents from high flood risk areas and reduce floodway obstruction.	9.4.2	No
	Flood Proofing	PM03	Future development of commercial properties within FPA should incorporate flood proofing up to the FPL	9.4.3	**Yes**
	Land Use Zoning	PM04	Changes to land use zoning should consider flood compatibility using outcomes from this report.	9.4.4	**Yes**
	Flood Planning Levels	PM05	Based on the 1% AEP + 0.5m as defined in this study	9.4.5	**Yes**
	Flood Planning Area	PM06	As defined in this study	9.4.6	**Yes**
	Changes to Planning Policy	PM07	DCP updated with FPL and FPA as discussed above	9.4.7	**Yes**
	S149 Certificates	PM08	Provide flooding info on Council's website, include up to date flooding info on future s149 (2) and (5) certificates requested	9.4.8	**Yes**

9.2. Flood Modification Measures

9.2.1. Levees and Embankments

DESCRIPTION

Levees involve the construction of raised embankments between the watercourse and flood affected areas so as to prevent the ingress of floodwater up to a design height. Levees usually take the form of earth embankments but can also be constructed of concrete walls or similar where there is limited space or other constraints. They are more commonly used on large river systems, for example on the Hunter River at Maitland, but can also be found on small creeks in urban areas and in overland flow situations where they usually take the form of smaller bunds.

Flood gates, flap valves and pumps are often associated with levees to prevent backing up of drainage systems in the area protected by a levee and/or to remove ponding of local water behind the levee.

DISCUSSION

Once constructed, levee systems generally have a low maintenance cost although the levee system needs to be inspected on a regular basis. Although a levee can keep out flood waters, flooding can occur behind the levee due to local runoff being unable to drain. In addition, as the levee causes a displacement of water from one area of the floodplain to another they should be carefully designed so as to ensure the levee does not increase flood risk to an adjacent area.

The design height of the levee is the event for which it prevents flooding and usually also includes a freeboard to allow for settlement of the structure overtime or variations in flood levels due to the behaviour of the flood event and uncertainties.

OPTIONS CONSIDERED

Four levee options were assessed and are discussed in the following sections. Note that at this stage freeboard has not been included in setting levee design crest levels, however this will be a necessary inclusion should any levee options be progressed. Freeboard accounts for uncertainty in modelled flood levels, localised changes in flood level, wind setup, wave action, and settlement and defects in the levee banks.

9.2.1.1. LV01: Levee Option 1 – Riverview Parade

The Riverview Parade residential area is separated by a channel at Lakeside Crescent. Consequently two levees were modelled which aimed to alleviate mainstream flooding in hotspot C (Figure 8). The levees are designed to 3.1 mAHD (approximately the 1% AEP level without freeboard). The first is 1200 m long and encloses properties along Palm Avenue and Riverview Parade, while the second levee is 485 m long, and encircles a number of properties between Pittwater Road and Rowe Street.

Figure 32 and Figure 33 show the impact on peak flood levels for the 1% AEP and 5% AEP design events respectively. The two levees displace water during flood events and cause an increase in flood levels both upstream and downstream of the newly protected areas. In the 1% AEP event a volume of 107,500 m^3 is displaced from within the levee, while in the 5% AEP 77,800 m^3 is displaced. Increases to flood levels of 0.1 m occur upstream of the levee system in the 1% AEP event, and peak levels across the entire lagoon downstream of the levee also increase by 0.01 m. With the levees in place 93 houses are no longer flooded in the 1% AEP event, and 84 are no longer flooded in the 5% AEP event. However, one property is newly flooded during the 1% AEP Event.

☒	**LV01 Recommendation** The levee is not recommended due to the adverse impacts it causes to flood levels upstream and downstream of the protected area.

9.2.1.2. LV02: Levee Option 2 - Clearview Place

A levee at Clearview Place was modelled which aimed to reduce mainstream flooding in hotspot D (Figure 8). The modelled levee is 90 m long and height set to the 1% AEP level (23.1 mAHD). No additional outlet pipes have been modelled at this stage.

The impact on peak flood levels for the 1% AEP and 5% AEP design events is shown in Figure 34 and Figure 35 respectively. In the 1% AEP event there is a reduction in peak levels of up to 0.5 m at Clearview Place, and a reduction in peak flow, as shown in Table 19. However, the levee creates an obstruction to the flow, resulting in higher flood levels upstream of Clearview Place. This results in two new properties being flood affected in the PMF. This could be addressed with further levee design optimisation.

There is an existing culvert starting just downstream of the proposed levee running directly beneath Clearview Place. Table 19 notes the flow rates over the road and through the culvert beneath Clearview Place to compare current flows with those expected with levee construction (taken at approximately No. 8 Clearview Pl).

Table 19: Flow at Clearview Place for existing condition and LV02 option.

Location	Existing 1% AEP peak flow (m^3/s)	LV02CP 1% AEP peak flow (m^3/s)
Overland flow path Clearview Place	32.08	10.97
Flow through culvert below Clearview Place	39.26	45.07
Total flow through Clearview Place	**71.34**	**56.04**

More of the previously overland flow is now routed through the existing culvert, which would make the area sensitive to blockage or constricted pipe flow. However, given the significant potential reduction in flood levels this option should be considered further.

☑	**LV02 Recommendation** This option causes benefits and should be investigated further, however sensitivity to blockage should not be overlooked.

9.2.1.3. LV03: Levee Option 3 – Kenneth Road

A levee to protect the flooded properties in hotspot location A (Burnt Bridge Creek near Kenneth Street and Balgowlah Road) was originally considered in the 1996 Floodplain Management Study but was dismissed due to the low benefit-cost ratio (estimated at 0.6). The option was reinvestigated as part of the current study.

A similar levee configuration was modelled, with the levee running from Pacific Parade to Cameron Avenue for approximately 790 m at a design height of 2.97 mAHD (approximately the 1% AEP level without freeboard). The design includes flap valves installed on the existing pipe system to prevent ingress of floodwaters from the lagoon.

The impact on peak flood levels for the 1% AEP and 5% AEP design events are shown on Figure 36 and Figure 37 respectively. Whilst the levee protects the residential area from lagoon flooding, the existing pipe system has insufficient capacity to drain the local flows from behind the levee, which reduces the overall benefit. Flood levels are reduced by 0.02 m in the 5% AEP event and 0.22 m in the 1% AEP event.

LV03 Recommendation

This option is not recommended as the benefits available are minor and unlikely to justify the significant cost of construction and maintenance. Local drainage may also be an issue.

9.2.1.4. LV04: Levee Option 4 – Campbell Parade

The option models a levee located along Campbell Parade and Manly Creek to protect the small commercial precinct bounded by Campbell Parade, Quirk Road and Lovett Street in Hotspot C. The design includes flap valves installed on the existing pipe system.

The levee has been set to 2.77 mAHD (5% AEP design height, no freeboard). The levee is 450 m long and the impact on peak water levels shown on Figure 38 and Figure 39. The figures show a reduction of flood levels of approximately 0.1 m in the 5% AEP event and negligible increase in peak flood level. As expected, the levee does not have any impact on flood levels in the 1% AEP event.

A levee on the same alignment but at the height of the 1% AEP event was also modelled, however it did not have any impact on flood damages and hence has not been reported upon.

LV04 Recommendation

This option is not recommended as the benefits available are minor and unlikely to justify the significant cost of construction and maintenance.

SUMMARY

Four levee options have been investigated with a range of outcomes. Generally the levees do provide benefits in terms of reductions in flood levels, though these are either too minor to justify the extensive cost of construction, or come at the expense of other residential areas in the form of worsened flood impacts (usually upstream of the levee). The exception is Option LV02, in which the upstream area is largely not developed, and provides significant benefits downstream. Further investigation and optimisation of the levee is recommended to ensure that no properties upstream of the levee are adversely impacted, and to ensure the culvert beneath Clearview Place can be maintained and free of blockage, as it will be the preferential levee outlet.

9.2.2. Temporary Flood Barriers

DESCRIPTION

Temporary flood barriers include demountable defences, wall systems and sandbagging for deployment prior to the onset of flooding. Demountable defences can be used to protect large areas and are often used to assist in current mitigation measures rather than as sole protection measures. For example, they are best used to fill gaps in levees or to raise them as the risk of levee overtopping develops. The effectiveness of these measures relies on sufficient warning time and the availability of a workforce to install them, and suitable sites for storage when not in use. They are more likely to be used for mainstream fluvial flooding from rivers which have sufficient warning time and are not a suitable technique for smaller catchments with shorter response times.

DISCUSSION

The short warning time available in the Manly Lagoon catchment significantly limits the opportunities to deploy temporary flood barriers on a large scale. This type of option is more suitable for riverine flooding in rural towns where there are fewer unprotected properties, and significantly longer warning time, as their deployment requires substantial resources (both man hours and vehicles for transportation of barriers from storage to the site).

SUMMARY

While temporary flood barriers may provide some benefit as a property-level protection measure for those properties located near the Lagoon, they are not recommended for wide scale implementation in this catchment.

☒	**Recommendation** Not recommended as the required warning time to allow for deployment is not generally available in this catchment.

9.2.3. Floodway and Diversion Channels

DESCRIPTION

Floodway or bypass channels redirect a portion of the flood waters away from the main channel. The opportunities for their implementation are limited by topography, availability of land, potential flood level impacts and ecological considerations.

DISCUSSION

In a heavily urbanised and well established catchment like Manly Lagoon, there is little opportunity to create significant diversion channels due to lack of available land and/or high costs associated with land acquisition. However, one option to more formally manage overland flow routes was explored and is described below.

OPTION CONSIDERED

DC01: Diversion Channel Option 01 – Pittwater Bridge

Prior to the 1950s, Manly Creek divided into the North and South channel at what is now Pittwater Road, before merging again downstream of Hinkler Park. As part of the bridge upgrade works undertaken in the mid-1950s, the south channel was disconnected and replaced with a pipe, as shown in the design drawings replicated in Diagram 5.

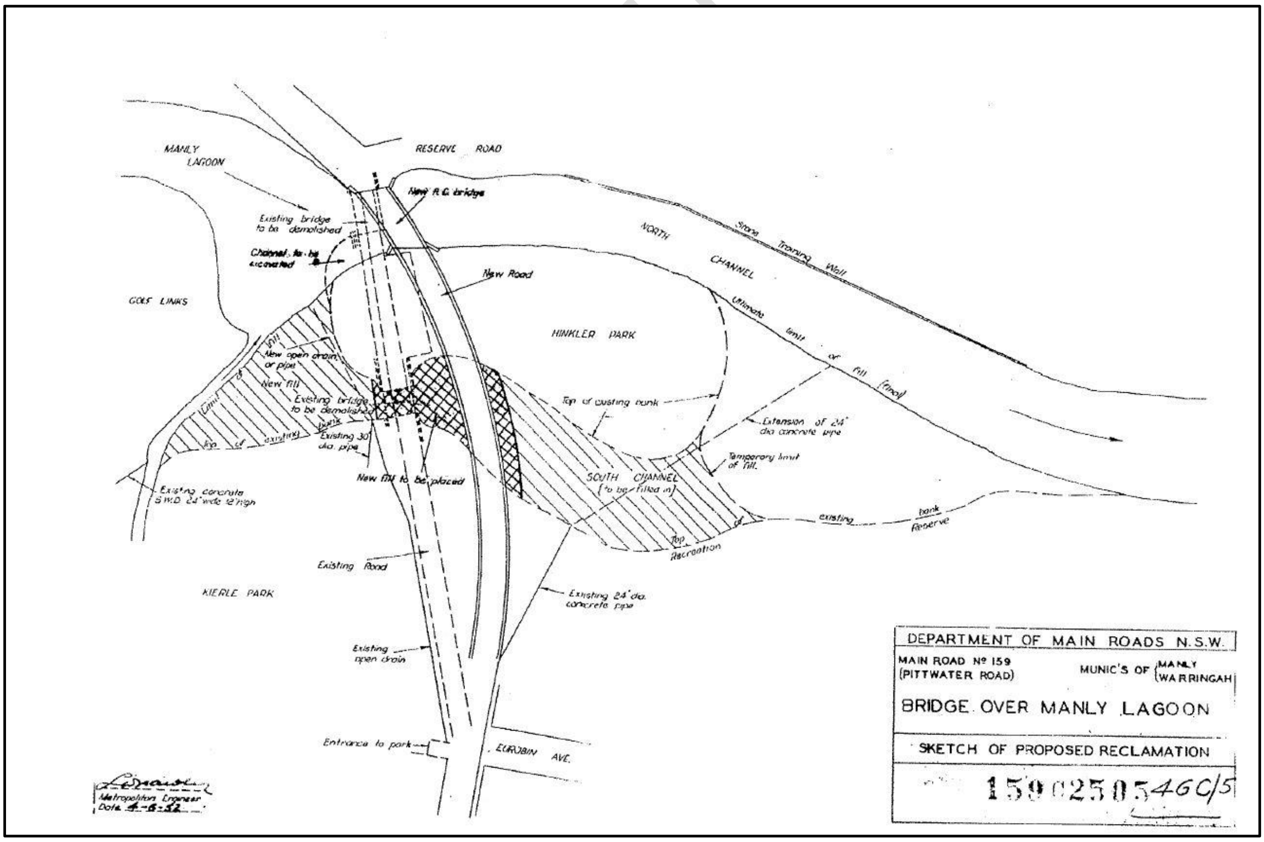

Diagram 5 Proposed Bridge over Manly Lagoon (Dept. Main Roads NSW, 1952)

Option DC01 modelled the reinstatement of the South channel, with the bed level set to -1.5 mAHD, resulting in 4980 m^3 of material being “removed”. These works caused a redistribution of flow, as noted on Figure 40, with more of the flow conveyed through the newly excavated channel and a reduction in the northern peak flow. However, the works did not provide any benefits in terms of flood levels in the 1% AEP event, also shown on Figure 40 . The option was also modelled for the 5% AEP event (Figure 41), which showed a localised decrease in peak flood levels upstream of the channel but no widespread flood level impacts.

SUMMARY

This option is likely to have a more significant impact for the smaller, more regular flood events and may also assist with improving the ecology in the lagoon. However, from a flood risk management perspective it is not considered a feasible option due to the negligible impacts on the larger flood events.

☒	**DC01 Recommendation** In a well-established and heavily urbanised catchment like Manly Lagoon, there is no land immediately available to construct a secondary channel, and any such works would involve significant land acquisition costs (assuming the land could be acquired at all) and construction costs.

9.2.4. Channel Modification

DESCRIPTION

Channel modifications are undertaken to improve the conveyance and/or capacity of a river/creek system. This includes a range of measures from straightening, concrete lining and removal/augmentation of structures.

DISCUSSION

The hydraulic capacity of a river channel to discharge floodwater can be increased by widening, deepening or re-aligning the channel, and by clearing the channel banks and bed of obstructions to flow (Reference 2). The effectiveness of channel modifications depends upon the characteristics of the river channel and valley in which it lies.

As a management measure, channel modifications have a number of potential disadvantages, for example:

- They facilitate the transfer of floodwaters downstream and can accentuate downstream flooding problems;
- The potential impacts of such works on channel bed and bank stability both upstream and downstream of the site;
- The high cost of maintenance;
- The destruction of riverine habitat; and
- The visual impact of replacing naturally varying channel sections with a section of more uniform geometry.

OPTIONS CONSIDERED

Four options have been identified and assessed in the Manly Lagoon catchment. Two are related to Brookvale Creek and two are related to the entrance and the Stuart Somerville Bridge.

9.2.4.1. CM01: Channel Modification Option 1 - Clearview Place

This option explored lowering the bed of Brookvale Creek upstream of Clearview place by approximately 0.5 m for a 20 m stretch to help increase the storage volume within the creek itself so as to reduce overland flooding. However, this option had no impact on flood levels in the 1% AEP event due to the magnitude of waters being conveyed in such an event (Figure 42). There is a small impact (-0.01 m) for the 5% AEP event (Figure 43).

9.2.4.2. CM02: Channel Modification Option 2 – Warringah Mall

This option explored lowering the open channel upstream of Warringah Mall by 0.5 m for 250 m and was modelled in the 1% AEP and 5% AEP design events. This showed localised benefits for the land located adjacent to the lowered section (Figure 44 and Figure 45), with peak flood levels reduced by 0.16 m for the 1% AEP and 0.39 m for the 5% AEP event.

9.2.4.3. CM03: Channel Modification Option 3 - Stuart Somerville Bridge

Currently a rock channel is located upstream of twin low flow pipes near the lagoon entrance, which ends downstream of the Stuart Somerville bridge. Option CM03 investigates the impact of extending this lower channel upstream of the bridge, involving the removal of 205 m^3 of material and a finished invert of 0.00 mAHD.

The option results in a marginal reduction in peak flood levels by up to 0.02 m in the 1% AEP event (Figure 46) and 5% AEP event Figure 47.

9.2.4.4. CM04: Channel Modification Option 4 - Stuart Somerville Bridge

This option modelled the impact of lowering the rock bar level below the bridge. Currently this rock bar is set at 0.2 mAHD. This rock bar was lowered by 0.4 m, removing 92 m^3 of material. The result shows a small impact for the 1% AEP event (Figure 48) and 5% AEP event (Figure 49).

SUMMARY

☒	**CM01, CM02, CM03 and CM04 Recommendation** Channel modification measures CM01, CM03 and CM04 were shown to provide little benefit to developed land. Additionally, environmental impacts are likely to be significant. As such, channel modification was not considered further and accordingly the associated economic, social and environmental impacts of implementation have not been investigated. Option CM02 did show benefits in terms of flood level reduction, however it does not reduce property damages, and constructability costs are expected to be significant given the easement constrictions between commercial buildings. This option is therefore not recommended

9.2.5. Drainage Modification

DESCRIPTION

Like channel modification, drainage modification measures are undertaken to improve the conveyance of the existing drainage system, in this case the stormwater pipe network. Measures may include increasing pipe sizes or number of pipes, altering system layouts, or removing potential constrictions.

DISCUSSION

Drainage modification works had strong community support based on the survey data, and 7 options across the Manly Lagoon catchment have been considered and are discussed in the following sections.

9.2.5.1. DM01: Drainage Modification Option 1 – Balgowlah Road

This location was flagged by the community during consultation as a hotspot, and many residents were keen to improve flooding at this location. To address this, the installation of two 0.6 m diameter pipes along Balgowlah Road, between Kenneth Road and the lagoon, were modelled for the 1% AEP and 5% AEP mainstream event. This option however had no impact in either event, due to the small capacities of the pipes relative to the volume of floodwaters. Impacts are shown for the 1% AEP event in Figure 50 and the 5% AEP event in Figure 51.

9.2.5.2. DM02: Drainage Modification Option 2 - Balgowlah Road

This option tests Option DM01 during the 1% AEP local rainfall event with varying tide conditions, rather than during a mainstream flooding event. Two tide cases were modelled: a full lagoon with water level at 1.4 mAHD (Figure 52A) and an empty one where the water level in the lagoon is 0.34 mAHD (Figure 52B). Installation of additional pipes showed a slight benefit during a high tide scenario, with peak flood levels reduced by up to 0.05 m in the golf course. The benefit of the additional pipes was more extensive in the low tide scenario, benefitting the golf course and some residential properties on Golf Parade, Role Street and Alexander Street near Balgowlah Road, though flood level reductions were still limited at less than 0.05 m.

This option is ineffective for both mainstream and local flooding as the proposed pipe invert level is below the warning level in the lagoon. Balgowlah Road is not sufficiently higher than the lagoon to allow the pipe outlet to be at an effective elevation (i.e. above the lagoon water level during an event). Hence the pipe would be full (and backwatering) rather than providing any flood relief. Figure 53 shows a long section of Balgowlah Road, running from south to north with Chainage 0 at Kenneth Road.

9.2.5.3. DM03: Drainage Modification Option 3 – Keirle Park

This option explored installing tidal flap valves on the pipes discharging into Manly Lagoon at Keirle Park. Under current conditions water from the lagoon enters the drainage system and discharges during small events. Flap valves would prevent this from happening whilst still allowing water to discharge when the lagoon levels are lower. This option has been modelled for the 10% AEP event and 20% AEP event, with impacts shown on Figure 54 and Figure 55 respectively. There are no impacts on flood levels in either event.

9.2.5.4. DM04: Drainage Modification Option 4 – Pitt Street

This option simulated the installation of two 0.6 m diameter pipes from Pitt Street to Manly West Park. There is only a very small impact on peak flood levels in the 1% AEP event along the pipe alignment (Figure 56), close to 0.01 m. In the 5% AEP event (Figure 57), peak levels are reduced by up to 0.05 m. Both events show minor localised increases up to 0.05 m at the downstream outlet of the pipe.

9.2.5.5. DM05: Drainage Modification Option 5 – Kenneth Road

This option simulated two 0.6 m diameter pipes on Kenneth Road, near the SES headquarters which is located just west of the commercial precinct near Condamine Street, Balgowlah Road and Kenneth Street. The impact in the 1% AEP event is shown on Figure 58 and presents a minor decrease in flood levels around the pipe line up to 0.05 m. The pipes are more effective in the 5% AEP event, with reductions in flood levels up to 0.1 m as shown on Figure 59, however there is an associated increase in flood levels around the pipe outlet up to 0.05 m.

9.2.5.6. DM06: Drainage Modification Option 6 – William Street

This mitigation option investigated installing a new twin pipe system along William Street, discharging into Brookvale Creek. These pipes were modelled as 2 × 0.6 m diameter pipes and were assessed for both the 1% AEP and 5% AEP flood event. Impacts from this mitigation option are shown in Figure 60 and Figure 61 for these two events respectively. The 1% AEP event showed local reductions of up to 0.05 m, while the 5% AEP event showed reductions of up to 0.2 m. There are minimal increases in water level as a result of the mitigation option with only a small portion of Brookvale Creek at the point of discharge experiencing an increase of up to 0.05 m. The peak flow on William Street is 4.43 m^3/s during a 1% AEP event. The pipe system reduces the flow by 1.85 m^3/s.

9.2.5.7. DM07: Drainage Modification Option 7 – Clearview Place to Motorway

This mitigation option investigated installing a new trunk system through Brookvale. These pipes were modelled as a box culvert of 3 m by 2 m and were assessed for both the 1% AEP and 5% AEP flood events. The impacts of this mitigation option are shown in Figure 62 for the % AEP event and Figure 63 for the 5% AEP event. Results showed that the proposed system provide local reductions of up to 0.3 m for the 5% AEP event and 0.2 m for the 1% AEP event. Downstream of the pipe outlet there are minimal increases in flood level, however these are limited to the golf course and are within 0.05 m of the current design flood levels. The pipe system reduces the overland flow by 14.34 m^3/s during a 1% AEP event and 9.9 m^3/s during a 5% AEP event.

SUMMARY

☒	**DM01-DM07 Recommendation** While some drainage modification options had minor benefits on flood levels, the associated costs in the densely urbanised environments would be prohibitive. As such, drainage modification was not considered further and accordingly the associated economic, social and environmental impacts of implementation have not been investigated.

9.2.6. Drainage Maintenance

DESCRIPTION

Ongoing maintenance of the drainage network is important to ensure it is operating with maximum efficiency and to reduce risk of blockage or failure. Maintenance involves regularly removing unwanted vegetation and other debris from the drainage network, particularly at culverts and small bridges. For natural channels, environmental policy can govern how the creek channel is maintained by restricting creek clearing and vegetation management.

Blockage has the potential to considerably increase flood levels in the catchment. A proactive approach to drainage maintenance will help manage the risk of blockage occurring during a flood event. Dredging is a retroactive solution that has been assessed for effectiveness as a flood management strategy below, however is usually a costly exercise with negative environmental impacts and is not likely to be recommended.

DISCUSSION

Structure Blockage

Blockage of structures can be reduced through the establishment of ongoing maintenance protocols or policies to ensure that drainage assets are effectively managed and regularly maintained. Regular clearing of leaf litter and other debris from the channel banks will reduce the available material which may block structures. Installation of gross pollutant traps, particularly in proximity to at risk structures, can also ensure that the structures remain clear.

Creek Channel Maintenance

Actions such as maintaining appropriate types and density of channel vegetation, and clearing excessive litter and silt may temporarily increase the flow conveyance and reduce flood levels in the vicinity of open channel reaches. However, such work must be undertaken on a regular basis as silt and vegetation will re-accumulate with time. In general, such activities provide some benefit for the smaller, more frequent floods, however, have limited impact on significant events. This type of work is strongly supported by the community during the consultation period.

9.2.6.1. DR01: Dredging Option 1 – Pittwater Bridge

Dredging part of the channel beneath Pittwater Bridge to a bed level of -1.5 mAHD was modelled. The quantity of material removed is approximately 1191 m^3. This had no impact on flood levels in the 1% AEP design event (shown on Figure 64) nor the 5% AEP event (shown on Figure 65), as the increased cross sectional area was insignificant compared to the overall design flows.

9.2.6.2. DR02: Dredging Option 2 – Stuart Somerville Bridge

Dredging upstream and downstream of Stuart Somerville Bridge to the rock bar level of 0.2 mAHD was modelled in the 1% AEP and 5% AEP design event (Figure 66 and Figure 67). A volume of 260 m^3 of material was removed for this option. No impact on flood levels occurred, due to the relatively insignificant increase in waterway area compared to the flood volumes. Moreover the eroded entrance is already close to the rock bar level. The depth of dredging is directly related to the height of the rock bar. Any change of the rock bar level would increase the volume of sand removed.

SUMMARY

☒	**DR01 and DR02 Recommendation** No creek channel maintenance strategies were identified as suitable for flood mitigation in the study area. As such, channel maintenance was not considered further and the associated economic, social and environmental impacts of implementation have not been investigated.

9.2.7. Retarding Basins

DESCRIPTION

Retarding basins work by storing floodwaters during an event and then controlling the release of the water once the peak has passed. These can be either installed as part of a new development to prevent increases in runoff rates, or retrofitted into existing catchment drainage systems to assist in alleviating existing flood problems.

DISCUSSION

Retarding basins can significantly reduce peak flows and are typically cost effective and easy to implement provided there is a suitable location available. Hydraulic structures, such as low flow culverts at the bottom of a basin, can be used to restrict the discharge rates from site to a variable rate, dependent on rainfall volumes and the hydraulic head in the retarding basin.

Large retarding basins can be a safety hazard. Appropriate safety controls such as fencing and signage should be included as part of the overall asset. In NSW, particularly large basins may be prescribed by the Dam Safety Committee (DSC) which means that the DSC will maintain a continuing oversight of their safety. This is applicable to basins identified as a possible threat to communities downstream in case of failure. Like the rest of the drainage system, retarding basins have maintenance requirements. Regular checks and maintenance will be required by Council or agreements put in place with the developer and land holder. This is particularly applicable to basins identified as being a threat to communities downstream in case of failure.

The community questionnaire respondents showed a marginal preference for retarding basins. A review of the catchment identified three potential locations, discussed further in the following sections.

9.2.7.1. RT01: Retention Basin Option 1 – Millers and David Thomas Reserve

This option involves the construction of two new retarding basins at David Thomas and Miller Reserve. They are 1 m deep and have 1 m levees around them. The total volume of storage available in the basins is close to 170,000 m^3. The option was modelled in the 1% AEP and 5% AEP event, with impacts shown in Figure 68 and Figure 69 respectively. Quite widespread reduction in flood levels was seen downstream of the retention basins in both modelled events. Impacts in the 1% AEP event showed reductions up to only 0.1 m, and no properties no longer flooded. Benefits were greater in the 5% AEP event, where widespread reductions of up to 0.2 m were noted and a number of locations no longer flooded.

There were no notable reductions in property damages however, and the cost of construction and maintenance would not be justified by the slight reduction in flood levels.

9.2.7.2. RT02: Retention Basin Option 2 – Keirle Park

This option modelled the construction of an underground water storage facility below Keirle Park. It measures 5 m by 100 m with a height of 2 m. Due to the elevation of the Park the storage 'basin' would be affected by the tide and warning level in the lagoon. Therefore, flap valves have been added to pipes upstream and downstream from the structure. A new twin 0.6 m pipe has been added along Kenneth Road and connected to the structure. This option has been modelled for the 10% AEP event and 20% AEP event, shown in Figure 70 and Figure 71. The retention basin does not reduce the peak flood level in either event, as the capacity is insignificant compared to the volume present during a flood event.

☒	**RT01 and RT02 Recommendation** No retarding basins were identified as suitable for flood mitigation in the study area. Moreover the volume of water during a flood makes any flood storage in a basin ineffective. As such, retarding basins were not considered further and the associated economic, social and environmental impacts of implementation have not been investigated.

9.2.8. Dams

DESCRIPTION

Dams are built to control and store large quantities of water. They are built for a variety of purposes, including water supply, irrigation, flood control, environmental control and hydro-electricity. They may be built to solely serve one of these objectives, or multiple purposes.

Dams serve a flood mitigation role by impounding flood waters and releasing them at lower, controlled rates, thereby reducing flood levels downstream of the dam.

DISCUSSION

Manly Dam was originally built for water supply in the 1890's, however since 1939 it has been designated a reserve for public recreation due to its relatively low storage capacity. Water is also extracted from the Dam by Manly Hydraulics Laboratory, and a small portion of the storage capacity is controlled for flood mitigation. Manly Dam is also used for public recreation, including mountain biking trails, bushwalking and a number of water sports such as swimming, water skiing, kayaking and fishing.

As discussed in Section 2.1.4 Manly Dam has a storage capacity of approximately 2,000 ML, with the crest of the Dam at 35.84 mAHD. The water level in the Dam is maintained at 34.1 mAHD (1.7 m below the crest). The water levels in the Dam are controlled and monitored by Sydney Water and Northern Beaches Council, with Sydney Water primarily releasing water for dam safety control, and Council for flood mitigation.

OPTIONS CONSIDERED

Four options have been modelled, based on varying initial water levels in the dam. The flood study, and subsequently the modelling undertaken as part of this study, assumes the dam is at full storage capacity of 35.84 mAHD (crest level). This is 1.7 m above the operating level. Option 1 below investigates using the operating level (34.14) as the initial water level. The subsequent options investigate initial water levels between the operating level and full storage capacity to optimise the available storage.

9.2.8.1. MD01: Manly Dam Option 1 - Operating Level

This option assumes the dam level is at 34.14 mAHD, which is the designated operating level and 1.7 m below the water level adopted for modelling in the Flood Study and other options assessed in this report.

In the 1% and 5% AEP event, seen in Figure 72 and Figure 73, this option provided a widespread reduction in flood levels compared to the design case scenario. The greatest impacts are seen on Manly Creek immediately downstream of the dam before entering the lagoon, with some areas no longer flooded, and others experiencing reductions of more than 0.3 m. Downstream of Condamine Street, the impacts to flood peaks are lower (up to 0.2 m), though widespread.

There is no change to peak flood levels in the upper reaches of Brookvale Creek or Burnt Bridge Creek. Figure 72 and Figure 73 show the impact for a short duration (2 hour) critical duration as established in Section 2.3.2. This option has also been assessed for 4.5h, 6h, 9h and 12h durations. The results show that the benefits of maintaining the operating level stand for a duration lower than 12h. See Table 20 below.

Table 20: Reduction of Peak flood level for the 1% AEP event and different duration at Manly Lagoon

Duration	Impact (m)
2 hour	-0.16
4.5 hour	-0.23
6 hour	-0.23
9 hour	-0.25
12 hour	-0.13

9.2.8.2. MD02: Manly Dam Option 2 - Lowering Initial Water Level by 0.2 m

This option models an initial water level in the dam of 35.64 mAHD, 0.2 m lower than the design case scenario of full storage capacity, and 1.5m above the operating level.

The extent of the impacts mimic those shown in Option 1 and are presented Figure 74 and Figure 75 for the 1% AEP and 5% AEP event respectively, however, flood level reductions are smaller in magnitude. On Manly Creek, there are some small areas of reductions of up to 0.3 m, though most flood levels are reduced by 0.1 m or less. Downstream of Condamine Street as well as in the lower reaches of Brookvale Creek and Burnt Bridge Creek, flood levels are reduced by at most 0.05 m.

9.2.8.3. MD03: Dam Option 3 - Lowering Initial Water Level by 0.4 m

This option models an initial water level in the dam of 35.44 mAHD, being 0.4 m lower than the design case scenario of full storage capacity, and 1.3 m above the operating level.

The extent of the impacts again mimics those shown in Option 1, Figure 76 and Figure 77. On Manly Creek, there are some small areas of reductions of more than 0.3 m, though most are reduced by 0.2 m or less. Downstream of Condamine Street as well as in the lower reaches of Brookvale Creek and Burnt Bridge Creek, flood levels are reduced by at most 0.1 m.

9.2.8.4. MD04: Dam Option 4 - Lowering Initial Water Level by 0.8 m

This option models an initial water level in the dam of 35.04 mAHD, being 0.8 m lower than the design case scenario of full storage capacity, and 0.9 m above the operating level.

The same area experiences reduced flood levels, with some land on Manly Creek no longer flooded, and flood levels general reduced by more than 0.3 m, Figure 78 and Figure 79. Downstream of Condamine Street as well as in the lower reaches of Brookvale Creek and Burnt Bridge Creek, flood levels are reduced by up to 0.2 m.

SUMMARY

☑	**MD01, MD02, MD03 and MD04 Recommendation** The above analysis has showed that having a lower water level in the dam is beneficial to the downstream catchment in the event of a storm. Further investigation is recommended to assess methods to increase airspace (either by lowering the operating level or raising the spillway), while meeting requirements of other stakeholders and dam users.

9.2.9. Economic Assessment of Site Specific Measures

The cost effectiveness of management measures in reducing flood liability within the catchment was determined using the benefit/cost (B/C) approach. A costing was estimated for each measure and this was compared, where appropriate, to the measure's reduction in AAD. Where no significant benefit to AAD was found, the measure's cost effectiveness was assessed qualitatively.

9.2.9.1. Costing

High level cost estimates have been prepared for each flood mitigation measure assessed in this study. The estimates are suitable for use in the preliminary economic assessment (in Section 9.2.9.3), however it is noted that the rates and quantities on which the costings are based are subject to change over time. For this reason, the preliminary cost estimates (summarised in Table 21) should be reviewed prior to the detailed design phase of any recommended measures to obtain a more accurate costing. A preliminary detailed costing for Option LV02 is available in Appendix D.

Table 21: Costings of Management Measures

Option	Capital	Maintenance per year
DM01 - Twin 0.6 m Diameter pipe along Balgowlah Road Mainstream Event	$1,932,000	$3,000
DM02 - Twin 0.6 m Diameter pipe along Balgowlah Road Local Event	$1,932,000	$3,000
DM03 - Flat Valve at Keirle Park	$12,000	$1,000
DM04 - Twin 0.6 m Diameter pipe from Pitt Street to Quirk Road	$3,305,000	$5,000
DM05 - Twin 0.6 m Diameter pipe from Roseberry Street to Quirk Road	$1,319,000	$2,000
DM06 - Twin 0.6 m Diameter pipe from William Street to Brookvale Creek	$2,616,000	$4,000
DM07 - Box Culvert from Clearview Place to Brookvale creek	$13,811,000	$14,000
RT01 - Retention Basin Millers and David Thomas Reserve	$29,336,000	$10,000
RT02 - Retention Basin Keirle Park	$295,000	$10,000
DR01 - Dredging Option Pittwater Bridge	$190,000	$5,000
DR02 - Dredging Option Stuart Somerville Bridge	$354,000	$9,000
DC01 - New flowpath through Pittwater	$2,675,000	$10,000
CM01 - Creek lowered at Clearview Place	$313,000	$8,000
CM02 - Creek lowered upstream Warringah Mall	$414,000	$10,000
CM03 - Rock Channel extended upstream of Stuart Somerville bridge	$225,000	-
CM04 - Rock Bar lowered at Stuart Somerville Bridge	$96,000	-
LV01 - Levee around Riverview Parade	$8,184,000	$17,000
LV02 - Levee at Clearview Place	$424,000	$1,000
LV03 - Levee at Balgowlah Road	$3,351,000	$8,000
LV04 - Levee at Campbell Parade	$1,909,000	$5,000

Table 21 shows that the retention basin Measure RT01 is the most costly. It is followed by the more localised upgrades, all of which require significant works. It should be noted that all cost estimates are largely approximate due to the uncertainty around possible additional costs arising from construction complications in a densely urbanised area, which may include costs related to easement access and land acquisition. The costs should be used mainly to indicate the relative cost of the measures.

9.2.9.2. Damage Assessment of Measures

The total damage costs were evaluated for all measures and compared against the existing base case, as shown in Table 22. The assessment for the measures was carried out in accordance with OEH guidelines utilising data obtained from the flood level survey and height-damage curves that relate the depth of water above the floor with tangible damages. The damages were evaluated for a range of design events from the 0.5 EY up to the PMF.

Table 22: Average Annual Damage Reduction of Management Measures

Option	AAD	Reduction in AAD due to Measure
DM01 - Twin 0.6 m Diameter pipe along Balgowlah Road Mainstream Event	$5,096,000	-$6,000
DM02 - Twin 0.6 m Diameter pipe along Balgowlah Road Local Event	$5,102,000	-
DM03 - Flat Valve at Keirle Park	$5,102,000	-
DM04 - Twin 0.6 m Diameter pipe from Pitt Street to Quirk Road	$5,100,000	-$2,000
DM05 - Twin 0.6 m Diameter pipe from Roseberry Street to Quirk Road	$5,078,000	-$23,000
DM06 - Twin 0.6 m Diameter pipe from William Street to Brookvale Creek	$5,018,000	-$83,000
DM07 - Box Culvert from Clearview Place to Brookvale creek	$4,971,000	-$131,000
RT01 - Retention Basin Millers and David Thomas Reserve	$4,310,000	-$791,000
RT02 - Retention Basin Keirle Park	$5,102,000	-
DR01 - Dredging Option Pittwater Bridge	$5,074,000	-$28,000
DR02 - Dredging Option Stuart Somerville Bridge	$5,097,000	-$5,000
DC01 - New flowpath through Pittwater	$5,013,000	-$89,000
CM01 - Creek lowered at Clearview Place	$5,089,000	-$12,000
CM02 - Creek lowered upstream Warringah Mall	$5,098,000	-$4,000
CM03 - Rock Channel extended upstream of Stuart Somerville bridge	$5,084,000	-$17,000
CM04 - Rock Bar lowered at Stuart Somerville Bridge	$5,089,000	-$12,000
LV01 - Levee around Riverview Parade	$4,300,000	-$801,000
LV02 - Levee at Clearview Place	$5,060,000	-$41,000
LV03 - Levee at Balgowlah Road	$5,061,000	-$40,000
LV04 - Levee at Campbell Parade	$5,102,000	-

The results show that the large scale levee LV01 and the retention basin RT01 has the greatest reduction in AAD, with a reduction close to $800,000, approximately 20% of the catchment's AAD.

9.2.9.3. Benefit Cost Ratio of Measures

Following estimation of the measure's cost and AAD, the benefit/cost ratios (B/C) of the measures were calculated. The B/C is the ratio of the net present worth of the reduction in flood damages (benefit) compared to the total NPW of costs (including capital and annual maintenance over 50 years) and is used to compare the economic worth of assessed mitigation options. Table 23 lists the reduction in AAD due to the measures, and compares this to the works' respective capital and maintenance costs to produce a B/C. The measures' B/C was between 0.0 and 2.04, with values above 1 indicating that the economic benefit of the measure is greater than its cost.

Table 23: Benefit/Cost Ratio for Management Measures

Measures	AAD	Reduction in AAD	NPW of AAD Reduction*	Capital	Maintenance (Annual)	NPW of Costs*	B/C Ratio
DM01	$5,096,000	-$6,000	-$85,000	$1,932,000	$3,000	$1,970,000	0.04
DM02	$5,102,000	-	-	$1,932,000	$3,000	$1,970,000	-
DM03	$5,102,000	-	-	$12,000	$1,000	$19,000	-
DM04	$5,100,000	-$2,000	-$25,000	$3,305,000	$5,000	$3,372,000	0.01
DM05	$5,078,000	-$23,000	-$347,000	$1,319,000	$2,000	$1,346,000	0.26
DM06	$5,018,000	-$83,000	-$1,229,000	$2,616,000	$4,000	$2,670,000	0.46
DM07	$4,971,000	-$131,000	-$1,933,000	$13,811,000	$14,000	$14,013,000	0.14
RT01	$4,310,000	-$791,000	-$11,687,000	$29,336,000	$10,000	$29,476,000	0.40
RT02	$5,102,000	-	-	$295,000	$10,000	$435,000	-
DR01	$5,074,000	-$28,000	-$409,000	$190,000	$5,000	$256,000	1.60
DR02	$5,097,000	-$5,000	-$68,000	$354,000	$9,000	$478,000	0.14
DC01	$5,013,000	-$89,000	-$1,312,000	$2,675,000	$10,000	$2,815,000	0.47
CM01	$5,089,000	-$12,000	-$183,000	$313,000	$8,000	$423,000	0.43
CM02	$5,098,000	-$4,000	-$57,000	$414,000	$10,000	$559,000	0.10
CM03	$5,084,000	-$17,000	-$258,000	$225,000	-	$225,000	1.15
CM04	$5,089,000	-$12,000	-$185,000	$96,000	-	$96,000	1.92
LV01	$4,300,000	-$801,000	-$11,830,000	$8,184,000	$17,000	$8,420,000	1.40
LV02	$5,060,000	-$41,000	-$607,000	$424,000	$1,000	$438,000	1.38
LV03	$5,061,000	-$40,000	-$594,000	$3,351,000	$8,000	$3,462,000	0.17
LV04	$5,102,000	-	-	$1,909,000	$5,000	$1,972,000	-

* NPW: Net present worth calculated over 50 years at 7%,

Five measures presented in Table 23 have a B/C ratio above 1, indicating they are potentially justifiable on economic grounds alone. The high B/C ratio for options CM03 and CM04 in particular is however a reflection of their low capital cost estimates, rather than their efficacy in reducing flood damages. As described in this section, the high-density urban area means that both the cost of works and the estimate of property damage have large uncertainties. As described, the cost has factored the space constraints into the estimate, but there may be further construction issues that increase the cost. With regards to damages, they may be much higher than have been estimated (and therefore the reduction in damages also larger), but are difficult to estimate in further detail without damage curves specific to the various types of commercial development.

The analysis does not consider social factors, environmental factors and risk to life which cannot be quantified in monetary terms but would be a net contributor to the benefits that could be gained from these management measures. These factors have been considered in the Option Assessment Matrix in Section 9.5.

9.3. Response Modification Measures

Response modification measures aim to reduce risk to life and property in the event of flooding through improvements to flood prediction and warning, improvements to emergency management capabilities, evacuation and planning, and better flood-educated communities.

9.3.1. RM01: Flood Emergency Management Planning

DESCRIPTION

Effective planning for emergency response is a vital way of reducing risk to life and property, particularly for infrequent floods that are not managed through flood or property modification. The NSW State Emergency Service (SES) is the legislated combat agency for floods in NSW and is responsible for the control of flood operations. Residents living in and proprietors working on the floodplain can also prepare individual plans tailored to their situation.

DISCUSSION

The Manly Lagoon catchment is not currently covered by a Local Flood Plan. Planning for flooding is a vital way of reducing flood risks to life and property. Plans need to be reviewed after flooding and after new information is made available from flood investigations, such as the Flood Study and this FRMS. NSW SES has the lead role in planning for and responding to floods, and should coordinate with Councils on concerns such as road closures and establishing flood-free detours. During community consultation respondents were marginally for flood emergency management planning.

SUMMARY

Collaboration between Council and SES is recommended to draft a Local Flood Plan, a document which would note hotspots as identified in Section 5.1, identify roads affected by inundation and outline flood warning and evacuation protocols, which are described in the subsequent sections.

☑ **RM01: Recommendation**
Development of a Local Flood Plan is recommended, based on outcomes of this report and collaboration between Council and the SES.

9.3.2. RM02: Flood Warning and Emergency Response Strategies

DESCRIPTION

Early evacuation is the NSW SES's preferred emergency response for flooding. This reflects the understanding that the safest place to be in a flood is well away from the affected area (Reference 5). Evacuation should be the primary strategy where the available warning time and resources permit (Reference 5). The alternative to evacuating is shelter-in-place which is to shelter in a building within the floodplain.

The SES contends that sheltering in a building that does not have a habitable floor level above the level of the PMF is not low risk and does present a number of concerns:

- Floodwater reaching the place of shelter (unless the shelter is above the PMF level);
- Structural collapse of the building that is providing the place of shelter (unless the building has been designed to withstand the forces of floodwater, buoyancy and debris in a PMF);
- Isolation, with possible loss of power, water and sewerage;
- People's unpredictable behaviour (e.g. drowning if they change their mind and attempt to evacuate through flooded roads);
- People's mobility (not being able to reach the highest part of the building);
- People's safety (fire and accident); and
- People's health (pre-existing condition or sudden onset e.g. heart attack).

Accordingly, where sufficient warning time for safe evacuation is available, early evacuation from the floodplain is recommended.

DISCUSSION

As described in Section 6.2, the Manly Lagoon catchment is already covered by the Northern Beaches Flash Flooding Warning System (Reference 6). This system provides live, publically available data on the rainfall and stream gauges situated in the Northern Beaches area. The current gauges located within the Manly Lagoon catchment are:

- Manly Lagoon at Queenscliff
- Manly Lagoon at Riverview Parade

The biggest shortfall with the current flood warning system is the lack of integration with flood risk or consequence, i.e., flooding implications at particular gauge records. Providing some linkages between gauge recordings and key locations – access roads or predictors of property inundation – would greatly improve the system.

9.3.2.1. Opportunities for Increasing Available Warning Time

Decisions made on the basis of rainfall observations carry a significant degree of uncertainty. Forecast Rainfall has an even greater degree of uncertainty associated with estimating flood affectation. Evacuations based on uncertain triggers 'may be theoretically defensible in a purely risk-avoidance context but are likely to be viewed as socially and economically unsustainable' (Reference 5). Frequent 'false alarms' could lead to a situation where warnings are ignored by most of the community.

Accordingly, no opportunities for increasing available warning time have been identified for the Manly Lagoon catchment.

9.3.2.2. Opportunities for Reducing Required Warning Time

Opportunities to reduce the required warning time can also be considered. The Flood Warning Manual (Reference 7) also makes the point that especially in catchments which have limited warning times, there is value in setting up warning messages before flooding occurs. The NSW SES could draft a series of messages for various scenarios, which would enable more rapid broadcast and dissemination during a flood emergency.

An important question is how the people affected by flooding can best be given the appropriate information. An automated text messaging system could be implemented for residents of the Manly Lagoon floodplain. The ability of such a system to quickly reach a large number of subscribers is often beneficial for mitigating flood risk. However, as mentioned previously, implementation of such a system would still not allow enough time to safely evacuate the floodplain. Instead these warnings could be used to inform residents of flood risk and road closures and request that residents stay in their homes.

9.3.2.3. Shelter-In-Place Feasibility Assessment

Shelter-in-place has been investigated as a possible means of risk mitigation for the study area. As noted in Section, the SES has a number of concerns about this approach. Consideration, in broad terms, of the safety of sheltering-in-place in the Manly Lagoon floodplain is investigated in this section.

As mentioned, response modification measures aim to reduce risk to life and property in the event of flooding. This includes provisions to facilitate flood emergency response. There are two main forms of flood emergency response that may be adopted by people living within the floodplain:

- Evacuation: the movement of occupants out of the floodplain before the property and access roads becomes flood affected; and
- Shelter-in-place: the movement of occupants to a building that provides vertical refuge on the site or near the site before their property becomes flood affected.

As described in Section 6.4.2, the evacuation potential of the Manly Lagoon catchment in the event of flooding is limited. Accordingly, it was concluded that safe evacuation is not possible for a large number of properties within the Catchment, and in some instances may actually exacerbate risk by increasing the chance of motorists entering flood waters. This conclusion is in accordance with the Australasian Fire and Emergency Service Authorities Council (2013, Reference 5) guideline which states that evacuation is the most effective strategy, provided that evacuation can be safely implemented. Additionally, a review of flood fatalities in Australia has found that the large majority (76%) of fatalities occurred not in the home, but outside when people have entered flood waters (Reference 8). A key issue with shelter-in-place is whether floor levels are sufficiently high to be above the level of the PMF and what hazard classification is experienced at the property for various events.

SUMMARY

Due to the short available warning times and the various factors described in the previous sections, the provision of an effective flood warning service for flooding in the Manly Lagoon catchment is difficult. Issuing evacuation orders in many cases may actually exacerbate risk by requiring people to leave their homes leading to an increased risk of motorists attempting to traverse floodwaters.

☑	**RM02: Recommendations** ► NSW SES to prepare a Local Flood Plan for the Manly Lagoon catchment in consultation with Council. ► Link existing gauge information as well as outputs from this and other reports with thresholds for road closures. ► Shelter-in-place preferred to evacuation for properties with sufficiently high floor levels.

9.3.3. RM03: Improved Flood Access – Pittwater Road

DESCRIPTION

As described in Section 5.1, flood access is a concern for two residential areas and one commercial area in the Manly Lagoon catchment. Improving flood access in these areas could significantly improve a community's response to flooding, as well as reducing risk to life, burden on SES resources and flood damages.

DISCUSSION

Providing flood free access through road raising is typically only achievable near areas which are sparsely populated and where flood depths are relatively shallow. For the critical areas, roads are flooded by approximately 1 m in the 1% AEP event and are located in heavily urbanised areas. Furthermore, the road raising would need to occur across significant lengths. However, for completeness one road raising scenario was modelled, as discussed below.

This option involved raising Pittwater Road south of Pittwater Bridge to the edge of the floodplain in order to provide flood-free access for the isolated properties in this area. However, the road functions as an important flow path during a mainstream event. This option has been investigated for the 1% and 5% AEP. Any change to the road elevation would cause negative impacts (Figure 80 and Figure 81). Moreover as per the levee options outlined, the raised road would prevent the water from the local catchment entering the lagoon.

SUMMARY

Due to its cost and negative impacts on flood levels, this option is not recommended and no further economic analysis has been undertaken.

☒	**RM03: Recommendation** The raising of Pittwater Road south of Pittwater Bridge is not recommended as it provides flood-free access at the cost of increasing flooding for a number of properties and obstruction of the existing flow path.

9.3.4. RM04: Road Closures, Early Notifications and Creek Crossing Deterrents

DESCRIPTION

Due to the issues described in Section 9.3.3, alternatives to raising access roads are considered to mitigate the potential risk of motorists and pedestrians using flooded roads. Options include road closures, warning signs and depth mark indicators. Due to the short warning times within the Manly Lagoon catchment, options to automate these processes are explored wherever possible. Table 24 below lists major roads at risk of overtopping during a range of flood events.

Table 24 Roads at risk of overtopping

Road	Location	Depth overtopped (m)		
		2 Yr. ARI	10% AEP	1% AEP
Balgowlah Road	Between Pittwater and Kenneth Road	0.65	0.95	1.4
Sydney Road	Between Maretimo Street and Pickworth Avenue	0.16	0.18	0.22
Pittwater Road	Oliver Street intersection	0.5	0.75	1.2
Condamine Street	Just south of Manly Creek overbridge	-	0.2	0.3
Condamine Street	Between Kenneth Road and Burnt Bridge Creek Deviation	-	0.5	0.9
Kenneth Road	Near Roseberry Street Roundabout	0.32	0.7	1
Balgowlah Road	East of Hill Street	0.3	0.4	0.45
Balgowlah Road	Between Suwarrow Street and Daintrey Street	0.17	0.22	0.25
Pittwater Road	Hope Avenue intersection	0.22	0.25	0.28
Pittwater Road	150m North of Condamine Street	0.26	0.32	0.4
Wakehurst Parkway	300m South of Aquatic Drive	0.1	0.23	0.27
Warringah Road	250m east of Wakehurst Parkway intersection	0.2	0.25	0.28
Burnt Bridge Creek Deviation	At Kitchener Street Overpass	-	0.2	0.35

DISCUSSION

9.3.4.1. Automatic Road Closures and Boom Gates

Currently, road closures are only implemented by Council, SES or RMS once they have been notified of flooding of an access road. This means that the road is flooded well before it is closed thus greatly increasing the risk or pedestrians and motorists attempting to cross floodwaters.

Automated road closures could provide a viable alternative through either:

1. Automated warning signs and boom gates that signal (using telemetry technology) once a trigger level has been reached at a nearby gauge. This would significantly reduce the time taken to close roads by negating the need for Council and SES personnel to determine the need for, and travel to, the road closure site. Cost per gate including telemetry technology is estimated to be $20,000 not including the cost of the gauge.

2. Flood gates which self-deploy during periods of high flow. The flood gates are locked in the open position at low-lying crossings and are designed to automatically unlock and close road access when floodwaters reach a pre-set depth. In flood situations the gates provide a highly visual barrier to warn motorists and discourage attempts to cross flooded waterways. When water recedes to an acceptable level the flood gate is

deactivated by Council officers to allow vehicle access to the crossing. The cost per gate is estimated to be $60,000.

A system which allows a visual check may be required to prevent accidents or injury caused by automated boom gate closure.

9.3.4.2. Automatic Warning Signs and Depth Indicators

In addition or as an alternative to closing flooded roads, warning signs, lights and depth indicators could be used to alert residents of flooded roads (and their potential closure).

Automatic flashing warning signs (triggered by the gauges described in Section 9.3.4.1) and early notification of flooded roads could be used. Automatic flashing warning signs are estimated to cost approximately $20,000 not including the cost of the gauge, and depth indicators are estimated to cost $5,000 per location.

☑	**RM04: Recommendation** Installation of flood depth indicators, warning signs and road closure gates to be implemented where required as funds become available.

9.3.5. RM05: Community Flood Education

DESCRIPTION

Actual flood damages can be reduced, and safety increased, where communities are flood-ready:

'People who understand the environmental threats they face and have considered how they will manage them when they arise will cope better than people who lack such comprehension…Many people who live and work in flood liable areas have little idea of what flooding could mean to them – especially in the case of large floods of severities well beyond their experience or if a long period has elapsed since flooding last occurred. It falls to the combat agency, with assistance from councils and other agencies, to raise the level of flood consciousness and to ensure that people are made ready for flooding. In other words, flood-ready communities must be purposefully created. Once created, their flood-readiness must be purposefully maintained and enhanced.' (Reference 9).

Based on learnings from recent disasters, the focus of community disaster education has now turned from a concentration on raising awareness and preparedness to building community resilience through learning. Simply disseminating information to community does not necessarily trigger changed attitudes and behaviours. Flood education programs are most effective when they:

- Are participatory i.e. not only consisting of top-down provision of information but where the community has input to the development, implementation and evaluation of education activities;

- Involve a range of learning styles including experimental learning (e.g. field trips, flood commemorations), information provision (e.g. via pamphlets, DVDs, the media), collaborative group learning (e.g. scenario role plays with community groups) and community discourse (e.g. forums, post-event debriefs);
- Are aligned with structural and other non-structural methods used in floodplain risk management and with emergency management measures such as operations and flooding; and
- Are ongoing programs rather than one-off, unintegrated 'campaigns', with activities varied for the learner.

It is difficult to accurately assess the benefits of a community flood education program but the consensus is that the benefits far outweigh the costs. Nevertheless, sponsors must appreciate that ongoing funding is required to sustain the gain that has been made.

DISCUSSION

Table 25 provides a list of methods to build and sustain flood readiness, which may be developed and supported by NSW SES and Council. These include methods both to inform and to prepare the community, with the objective of building resilience.

Table 25: Methods to Increase Flood Awareness and Preparedness

Method	Comment
S149 certificate notifications	Section 149 planning certificates should record whether the land is subject to any planning and development controls due to its flood affectation. Council also has the opportunity to provide more detailed information about the land's flood affectation under S149(5) of the EP&A Act 1979. This information may be particularly valued by prospective purchasers but has a limited reach and is typically issued only upon request and payment of a fee.
Letter/certificate/ pamphlet from Council	These may be sent annually with a rates notice or separately. A Council database of flood liable properties makes this a relatively inexpensive and effective measure. The intention of flood certificates is to inform individual property owners of the flood situation (flood levels, ground levels) at their particular property. It is the site-specific nature of this advice that offers a chance of overcoming the scepticism typical of a community that has not experienced serious flooding for some years. Only after floodplain occupants accept that they could have a problem are they ready to take on board ideas about addressing that problem. A pamphlet can inform residents of the on-going implementation of the Floodplain Risk Management Plan and provide tips to respond appropriately to flooding (e.g. shelter-in-place). Proactive and regular issuance is desirable.
Council website	The Northern Beaches Council currently provides a link to the Northern Beaches Flood Information Network on its website. This site shows the location of rainfall and water level gauges, and notes the key rainfall intensities to watch out for (70 mm in 3 hours or 150 mm in 24 hours).
Community Working Group	Council could initiate a Community Working Group framework to provide a valuable two way conduit between the local residents and Council.

Method	Comment
School project	School students can learn about historical floods by interviewing older residents and documenting what happened. A project could also involve talks from various authorities (e.g. NSW SES) and can be combined with topics relating to water quality, drainage management, etc.
Articles in local newspapers	Ongoing articles in the newspapers will ensure that the flood issues are not forgotten. Historical features and remembrance of past events are interesting for local residents and can provoke preparedness for future events.
Library display	The library could collect historical flood photos and stories to prepare a display, which could be accompanied by appropriate flood safety messages.
Mobile display	Such a display as described above could also be used at local festivals and for school visitations, accompanied by NSW SES staff, who should be trained to encourage and equip households to prepare flood emergency plans.
NSW SES FloodSafe Guide	Continued distribution of the local FloodSafe guide which should be revised based on the findings of the current study, and again upon implementation of the FRMP.
NSW SES Business FloodSafe Breakfast	The NSW SES has prepared a FloodSafe Business template, which businesses can use to plan for flooding. A breakfast barbeque could be convened at an appropriate location to promote completion of plans and to provide site-specific flood information.
'Meet the street' events	'Meet-the-street' events involve NSW SES and Council setting up a 'stall' at an appropriate time and visible location. The event would be advertised through a specific letter box drop to the targeted neighbourhood or vulnerable site. The stall could consist of flood maps on boards, NSW SES banners, NSW SES materials to hand out. These materials are used to engage with people and make them aware of flood risk, encourage preparedness behaviours (e.g. develop emergency plans) and help them understand what to do during and after a flood. A meeting could also encourage property owners to develop self-help networks and particularly people checking on neighbours if a flood is imminent. Longer-term residents with flood experience could be used to help provide other residents with an understanding of previous floods and how to prepare for future flooding.
Historical flood markers and flood depth markers	Signs or marks can be prominently displayed on telegraph poles or similar to indicate the level reached in historical and design floods. Depth indicators advise of potential hazards, particularly to drivers. These are inexpensive and effective but in some flood communities are not well accepted as it is perceived that they affect property values. Flood marker poles could be installed in frequently visited locations to show the height flood waters reached in previous historic flood events.

Assessment of implementation of a community education program is examined in the Option Assessment Matrix (see Section 9.5)

☑ **RM05: Recommendation**
Engage with community to prepare an ongoing flood education program, with appropriate methods for program evaluation to be undertaken by SES and Council.

9.4. Property Modification Measures Considered

9.4.1. PM01: Voluntary House Raising

DESCRIPTION

Voluntary House raising involves lifting the main habitable floors above a designated design level (typically the 1% AEP or PMF). It has been widely used throughout NSW to eliminate or significantly reduce flooding particularly in lower hazard areas of the floodplain, albeit in limited overall numbers. However it has limited application as it is not suitable for all building types, or properties in high hazard areas.

DISCUSSION

The benefit of house raising is that it eliminates above floor flooding and consequently reduces flood damages. It is best suited to non-brick, single storey houses. House raising also provides a safe refuge during a flood, assuming that the building is suitably designed for the water and debris loading. However, the potential risk to life is still present if residents choose to enter floodwaters or are unable to leave the house during larger floods than the design flood, particularly in high hazard areas. Ideally floor levels should be raised to be above the level of the PMF and therefore areas with deep flood depths during this event may not be suitable for house raising.

The cost of raising a house can vary considerably depending on the specific details of the house. Additionally, the type of construction of a house can make raising unfeasible, either technically or economically and not all buildings are viable for raising for the following reasons:

- it is more cost effective to construct a new house;
- generally only single storey houses can be raised;
- generally only timber, fibro and other non-masonry construction can be raised;
- generally only pier and non-slab on ground construction can be raised; and
- there can be many additional construction difficulties (brick fire place, brick garage attached to house, awnings or similar attached to house).

SUMMARY

House raising as a flood mitigation option in the Manly Lagoon catchment is not considered an appropriate measure as the houses are generally slab-on-ground construction.

☒	**PM01: Recommendation** Voluntary house raising is not considered appropriate in this catchment due to the slab-on-ground construction of majority of properties.

9.4.2. PM02: Voluntary Purchase

DESCRIPTION

Voluntary purchase involves the acquisition of high risk flood affected properties, particularly those frequently inundated in high hazard areas, or located within the floodway, and demolition of the residence to remove it from the floodplain. Removal of properties can help to restore the natural hydraulic capacity of the floodplain and reduces the number of people living in high flood risk areas.

DISCUSSION

Voluntary purchase is mainly used in more hazardous areas over the long term as a means of removing isolated or remaining buildings to free both residents and potential rescuers from the danger and cost of future floods. The land is given over to public space and should be rezoned as an appropriate use such as E2 Environmental Conservation or similar in the LEP so that no future development can take place. Voluntary purchase is an effective strategy where it is impractical or uneconomic to mitigate high flood hazard to an existing property and it is often employed as part of a wider management strategy. Government funding for voluntary purchase schemes can be made available through the Floodplain Development Program as long as a number of complying criteria are met.

Commercial and industrial buildings are not eligible for voluntary purchase, and there are few residential properties located within the various floodways (see Hydraulic Categories in Section 5.2). Furthermore, the cost of acquiring eligible properties in this location would be significant and prohibitive given current property values. Therefore voluntary purchase is not considered an appropriate measure in the Manly Lagoon catchment.

☒	**PM02: Recommendations** There are few properties eligible for voluntary purchase within the catchment, and it is likely house prices would be prohibitive. This option is not recommended in the Manly Lagoon catchment.

9.4.3. PM03: Flood Proofing

DESCRIPTION

This measure applies to all future developments undertaken within the flood planning area (as defined in Section 9.4.6), including refurbishment of existing dwellings and construction of new buildings.

Part 3 of the SEPP relates to the *"General Housing Code"*. Section 3.36C (3b) states that "*The development must, to the extent it is within a flood planning area: have the part of the development at or below the flood planning level constructed of flood compatible material."* Retrofitting permanent flood proofing measures can be difficult and costly, and therefore permanent flood proofing is best implemented during construction.

DISCUSSION

Flood proofing is often divided into two categories: wet proofing and dry proofing. Wet proofing assumes that water will enter a building and aims to minimise damage and/or reduce recovery times by choice of materials which are resistant to flood waters and facilitate drainage and ventilation after flooding. Dry proofing aims to totally exclude flood waters from entering a building and is best incorporated into a structure at the construction phase.

As an alternative to retrofitting permanent flood proofing measures to existing properties, individual temporary flood barriers can be used. These include sandbags, plastic sheeting and other smaller barriers which fit over doors, windows and vents and are deployed by the occupant before the onset of flooding.

Temporary flood barriers such as sandbagging and floodgates can be a cheaper option for existing properties, and can be useful where there is frequent shallow flooding, although it relies on someone to implement it and therefore requires adequate flood warning times. Sandbagging, often used in conjunction with plastic sheeting, can provide a solution for dealing with flooding in smaller areas and at individual properties. Whilst sandbags and plastic sheeting seldom prevent the ingress of floodwaters entirely, they can substantially decrease the depth of over floor flooding and the foulness of floodwaters, thus aiding the clean-up process.

SUMMARY

Whilst it is a requirement of the Floodplain Development Manual (Reference 2) that new residential properties have their flood levels above the 1% AEP event plus a freeboard, commercial properties are not subject to such a requirement unless stipulated by Council. New commercial buildings can be required to be flood proofed to the Flood Planning Level when constructed which would include consideration of suitable materials, electrical and other service installations, and efficient sealing of any possible entrances for water. Council would make these requirements through planning controls in the DCP. It is recommended that planning controls allow some flexibility in the type of proofing adopted, and for temporary flood gate options to also be included in building design for low risk non-habitable development.

☑	**PM03: Recommendation** Future development of commercial properties within the flood planning area should incorporate flood proofing up to the flood planning level.

9.4.4. PM04: Land Use Zoning

DESCRIPTION

Appropriate land use planning can assist in reducing flood risk and ensure development on flood affected areas is flood compatible. Appropriate land use controls in flood affected areas can prevent inappropriate development from occurring and thus reduce flood risk. Land use zones are generally governed by a Local Environmental Plan (LEP). To make any significant changes to the provisions of a LEP, a planning proposal must be prepared.

DISCUSSION

Zoning can be a powerful tool in reducing flood damages, however, overly restrictive zoning can discourage redevelopment that is more flood compatible causing areas to degenerate over time. Progressive zoning can be used to encourage long term change in flood resilience. The current land use zones for Manly Lagoon catchment are presented in Figure 2 and comply with the current NSW standards. No changes to the current land use zoning are recommended from a flood mitigation perspective.

SUMMARY

This FRMS&P recommends that in the event that the land use zoning is altered, Council should carefully consider flood behaviour and affectation determined by the Flood Study and this FRMS&P.

☑	**PM04: Recommendation** Changes to land use zoning in the Northern Beaches LGA should consider flood compatibility using outcomes from this report.

9.4.5. PM05: Flood Planning Levels

DESCRIPTION

Flood Planning Levels (FPLs) are an important tool in floodplain risk management. Appendix K of the Floodplain Development Manual (the Manual) provides a comprehensive guide to the purpose and determination of FPLs. The FPL provides a development control measure for managing future flood risk and is derived form a combination of a flood event and a freeboard. The Manual states that, in general, the FPL for a standard residential development would be the 1% AEP event plus a freeboard which is typically 500 mm.

The purpose of the freeboard, as described in the Manual, is to provide reasonable certainty that the reduced flood risk exposure provided by selection of a particular flood as the basis of the FPL, is actually provided given the:

- Uncertainty in estimating flood levels;
- Differences in water level because of local factors; and
- Potential changes due to climate change.

The FPL is used to in planning control primarily to define minimum habitable floor levels but also for other factors such as evacuation, storage of hazardous goods, etc.

DISCUSSION
The current approach to define the FPL is to remain consistent with current best practice. Therefore, FPLs should be revised based on the revised modelling (described in Section 2.3.2).

	PM05: Recommendation
☑	FPLs should be revised based on the findings of this study.

9.4.6. PM06: Flood Planning Area

DESCRIPTION
The Flood Planning Area (FPA) is an area to which flood planning controls are applied. An FPA map is a required outcome of the FRMS&P.

It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk. Typically, and as per the Floodplain Development Manual, the FPA will be based on the flood extent formed by the 1% AEP mainstream flooding event plus 500 mm freeboard, and therefore, extend further than the extent of the 1% AEP event. Planning controls may therefore be applied to development which is not flooded in a 1% AEP event. The purpose of extending the FPA past the 1% AEP flood extent is to allow for model uncertainties, any future increases in flood extent due to climate change, as well as allow for differences between flood behaviour during events.

The NSW Standard Instrument LEP does not include a specific land use zone classification for flood prone land, rather it permits a Flood Planning Area map to be included as a layer imposed across all land use zones.

DISCUSSION
The FPA as defined by the Floodplain Development Manual is suitable for areas of mainstream flooding. The FPA for both Councils have been revised as part of the current study. FPA maps for both Councils should be updated based on the findings of this FRMS. The proposed FPA is shown in Figure 82 and is provided to Council as a GIS layer.

☑	**PM06: Recommendation** Adoption of FPA based on results of this study, as shown in Figure 82.

9.4.7. PM07: Changes to Planning Policy

DESCRIPTION

Appropriate planning restrictions which ensure that development is compatible with flood risk can significantly reduce flood damages. Planning instruments can be used as tools to:

- Guide new development away from high flood risk locations;
- Ensure that new development does not increase flood risk elsewhere; and
- Develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population.

Examination of existing risk throughout the study area indicates that managing this risk is particularly problematic due to the ineffective warning times available, lack of access routes, and frequent flooding (see Section 9.3.2). However, effective planning policy has the power to reduce this risk over time as the areas redevelop. Council should consider the long term management of these areas and how this can be facilitated by planning tools. For example, high risk areas may need to be rezoned or have more stringent development controls applied to ensure areas of safe refuge onsite for shelter-in-place (Section 9.3.2.3) and flood compatible

DISCUSSION

Council addresses development in flood risk areas in its DCP and provides matrices which applying varying degrees of restrictions to development based on the land use and flood risk. Applying stricter development controls in the hotspot areas has the potential to reduce the long term flood risk.

☑	**PM07: Recommendation** Council should consider applying more stringent, and specific, planning and development controls to the areas classified as Low Flood Islands / Low Trapped Perimeter Areas. Flood Mapping for the DCP should be updated based on the findings of this current study, taking into consideration the FERP classifications described in Section 6.3.

9.4.8. PM08: Modification to the S149 Certificate

DESCRIPTION

The Environmental Planning and Assessment Regulation 2000 (the Regulation), at Clause 279 and Schedule 4, prescribes that Councils must provide a disclosure document whereby any interested party can learn the zone and any other planning controls that may apply to a parcel of land.

Schedule 4 of the Regulation prescribes the format of the Planning Certificate. Part 7A of Schedule 4 states:

7A Flood related development controls information

(1) Whether or not development on that land or part of the land for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing) is subject to flood related development controls.

(2) Whether or not development on that land or part of the land for any other purpose is subject to flood related development controls.

(3) Words and expressions in this clause have the same meanings as in the standard instrument set out in the Standard Instrument (Local Environmental Plans) Order 2006.

Legal reviews of the effectiveness of s.149 Planning Certificates have suggested it would be appropriate to also provide information as to the scale of the risk (low moderate or high) and also whether flooding applies generally to the area or more specifically to the land which is the subject of the certificate.

DISCUSSION

Because of the wide range of different flood conditions across NSW, there is no standard way of conveying flood related information. As such, Councils are encouraged to determine the most appropriate way to convey information for their areas of responsibility. This will depend on:

- The type of flooding;
- Whether flooding is from major rivers or local overland flooding; and
- The extent of flooding (whether widespread or relatively confined).

It should be noted that the s.149 Planning Certificate only relates to the subject land and not any specific building on the property.

While the legislation currently does not mandate revealing the extent of flood inundation in a s.149(2) Planning Certificate, there is scope within a s.149(5) Planning Certificate for providing this additional type of information.

There can be a general perception from the public that insurance companies, lending authorities or other organisations may disadvantage flood liable properties that have only a very small part of their property inundated by floodwaters. Some Councils have addressed this concern by adding information in s.149(5) Planning Certificates to show the percentage of the property inundated as well as floor levels and other flood related information. In addition, the hazard category could be provided, and also advice regarding climate change increases in flood level.

The compulsory s.149(2) Planning Certificate should include, in terms of flood risk:

- Whether or not the property is in the FPA;
- Any development controls due to the property being within the FPA;
- Responsibility for maintenance and compliance for OSD features; and
- Highlight any drainage easements through the property and controls that apply.

Some Councils include detailed flooding information in s.149(5) Planning Certificate as standard practice. This ensures that residents are made fully aware of flood risks before purchasing a property. However, people who are current property owners often feel that this information devalues their properties and would rather not know. Flood related information in s.149(5) Planning Certificates should include:

- Flood levels / depths over the property;
- Percentage of property which is flood affected;
- The likelihood of flooding;
- Floor levels (from Council's floor level survey if available); and
- Potential flood hazard.

SUMMARY

As Council information for s.149 Planning Certificates and Development Restriction Certificates is obtained mainly from computerised databases and maps, Council should investigate ways to make property-based flooding information more accessible via its website.

Data from the hydraulic modelling used in this FRMS&P should be incorporated into Council's s.149 Planning Certificate database. All residents should be advised by personalised mail from Council if their land is affected. Council should determine the appropriate event for advising residents and ensure that the same criteria is used as in establishing the FPA.

☑ **Recommendations**

Publish up-to-date information on all future s149 certificates issued, based on this FRMS. It is encouraged that full details are provided in Part(5) as standard practice when a Part(2) is requested.

Provide flooding information on Councils' website.

9.5. Option Assessment Matrix

9.5.1. Background

Multi-variate decision matrices are recommended in the Floodplain Development Manual (Reference 2) and therefore it is also a recommendation of this report that multi-variate decision matrices be developed for specific management options, allowing benefit/cost estimates, community involvement in determining social and other intangible values, and local assessment of environmental impacts.

The criteria assigned a value in the management matrix are:

- Risk to life;
- Impact on flood behaviour (reduction in flood level, hazard or hydraulic categorisation) over the range of flood events;
- Number of properties benefited by measure;
- Compliance with EP&A Act 1979 (whether the work adversely impacts existing development, involves development in the floodway, or encourages development which increases spending on flood mitigation, infrastructure or services)
- Technical feasibility (design considerations, construction constraints, long-term performance);
- Community acceptance and social impacts;
- Economic merits (capital and recurring costs versus reduction in flood damages);
- Financial feasibility to fund the measure;
- Long term performance;
- Environmental and ecological benefits;
- Impacts on the State Emergency Services;
- Political and/or administrative issues; and
- Long-term performance given the potential impacts of climate change.

The scoring system for the above criteria is provided in Table 26. Tangible costs and damages are also used as the basis of B/C analysis for some measures.

Table 26: Matrix Scoring System

SCORE:	-3	-2	-1	0	1	2	3
Impact on Flood Behaviour	>100mm increase	50 to 100mm increase	<50mm increase	no change	<50mm decrease	50 to 100mm decrease	>100mm decrease
Number of Properties Benefited	>5 adversely affected	2-5 adversely affected	<2 adversely affected	none	<2	2 to 5	>5
Compliance with EP&A Act 1979	major issues	moderate issues	minor issues	neutral	moderately straight-forward	Straight-forward	no issues
Technical Feasibility	major issues	moderate issues	minor issues	neutral	moderately straight-forward	Straight-forward	no issues
Community Acceptance	majority against	most against	some against	neutral	minor	most	majority
Economic Merits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Financial Feasibility	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Environmental & Ecological Benefits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Impacts on SES	major disbenefit	moderate disbenefit	minor disbenefit	neutral	minor benefit	moderate benefit	major benefit
Political / administrative Issues	major negative	moderate negative	minor negative	neutral	few	very few	none
Long Term Performance	major disbenefit	moderate disbenefit	minor disbenefit	neutral	positive	good	excellent
Risk to Life	major increase	moderate increase	minor increase	neutral	minor benefit	moderate benefit	major benefit

The assessment matrix is given in Table 27 , with each of the assessed flood modification management options scored against the range of criteria. 'Community Acceptance' has been allocated a draft score at this time, and will be updated following the public exhibition period. The draft score is based on initial consultation undertaken at the commencement of the Study. It is important to note that the approach undertaken does not provide an absolute "right" answer as to what should be included in the Management Plan but is rather for the purpose of providing an easy framework for comparing the various options on an issue by issue basis which stakeholders can then use to make a decision. For the same reason, the total score given to each option, and the subsequent rank, is only an indicator to be used for general comparison.

Table 27 Multi-Criteria Matrix Analysis (Flood Modification Measures Assessed)

Type of Option	Option ID	Option	Section in Report	Impact on Flood Behaviour	Number of Properties Benefited	Technical Feasibility	Community Acceptance*	Economic Merits	Financial Feasibility	Environmental/Ecological Benefits	Impact on SES	Political/Admin Issues	Long Term Benefit	Risk to Life	Total Score	Rank
Levee	LV01	1% AEP Levee around Riverview Parade area	9.2.1.1	0	0	-3	-3	1	-3	-2	-2	-3	-2	-3	-20	22
	LV02	Levee upstream of Warringah Mall near Clearview Place	9.2.1.2	3	3	2	3	2	2	-1	3	-2	2	3	20	2
	LV03	Levee located around Kenneth Road & Balgowlah Road hotspot	9.2.1.3	0	0	-2	-1	-2	-2	-1	0	-2	-1	0	-11	14
	LV04	Levee 5% AEP level located along Campbell Parade and along Manly Creek	9.2.1.3	0	1	-1	-1	-2	-2	0	0	-2	-1	0	-8	6
Temporary Flood Barriers	TB01	Use of temporary flood barriers to protect small areas or individual properties.	9.2.2	0	0	0	1	1	1	0	-1	-2	-1	0	-1	3
Diversion channels	DC01	New flow path created south of Pittwater Bridge to recreate the original channel (piped over in 1952).	9.2.3	0	0	-3	-3	-3	-3	-3	1	-3	1	1	-15	21
Channel modification	CM01	Lowering the creek upstream of Clearview Place by approximately 0.5 m for 20 m.	9.2.4.1	0	0	-2	-1	0	-3	-1	0	-2	0	0	-9	9
	CM02	Lowering the open channel upstream of Warringah Mall by 0.5 m for 250 m.	9.2.4.2	1	1	-2	-2	0	-3	-1	0	-2	0	0	-8	6
	CM03	Rock channel upstream of the twin low-flow pipes is extended upstream of Stuart Somerville Bridge by 60 m.	9.2.4.3	0	0	-2	-1	1	-3	-1	0	-2	0	0	-8	6
	CM04	Lowering the 25 m long rock beneath Stuart Somerville Bridge by 0.4 m.	9.2.4.4	0	0	-2	-1	2	-3	-1	0	-2	0	0	-7	4
Drainage Modification	DM01	Installing a new pipe system (2 x 0.6 m pipes) along Balgowlah Road	9.2.5.1	0	0	-3	-1	-3	-3	-1	1	-3	0	0	-13	18
	DM02	Installing a new pipe system (2 x 0.6 m pipes) along Balgowlah Road, tested for impacts in the 1% AEP local event.	9.2.5.2	1	0	-3	-1	-3	-3	-1	1	-3	0	0	-12	17
	DM03	Installing tidal flap valve where the pipe at Keirle Park discharges into the lagoon	9.2.5.3	0	0	-3	-1	-3	-3	-1	1	-3	0	0	-13	18
	DM04	New pipe system (2 x 0.6 m pipes) in Balgowlah starting at Pitt Street until Manly West Park	9.2.5.4	1	1	-3	-1	-3	-3	-1	1	-3	0	0	-11	14
	DM05	Installing new pipe network (2 x 0.6 m pipes) along Kenneth Road between Rosebery Street and Quirk Road	9.2.5.4	1	2	-3	-1	-3	-3	-1	1	-3	0	0	-10	12
	DM06	New pipe system (2 x 0.6 m) along Green Street and William Street to reduce local overland flows.	9.2.5.4	1	2	-3	-1	-3	-3	-1	1	-3	0	0	-10	12
	DM07	New 1500 m trunk drainage system through Brookvale (box culvert of 3 m x 1.5 m)	9.2.5.7	2	2	-3	-1	-3	-3	-1	1	-3	0	0	-9	9
Drainage maintenance	DR01	Dredging at Pittwater Bridge to a channel level of -1.5 mAHD	9.2.6.1	0	0	-2	-1	1	-3	-3	0	-3	0	0	-11	14
	DR02	Dredging upstream and downstream of Stuart Somerville Bridge to the rock bar level (0.2 mAHD)	9.2.6.2	1	0	-2	-1	-3	-3	-3	1	-3	0	0	-13	18
Retention basins	RT01	New basin on Manly Creek at Millers and David Thomas Reserve. Spillway 2 m above bottom of basins (total storage volume of 146 000 m^3).	9.2.7.1	1	0	-2	-1	-3	-3	-1	1	-2	1	0	-9	9
	RT02	Installing underground detention tank in Keirle Park. (1000 m^3 storage)	9.2.7.2	0	0	-1	1	-3	-3	-1	0	-1	1	0	-7	4
Dams	MD01-MD04	Further investigation into methods of increasing airspace in Manly Dam	9.2.8.1	3	3	2	2	3	2	1	3	3	2	2	26	1

*'Community Acceptance' has been given a draft score and will be updated following a community information session as part of the Public Exhibition

(yellow) Recommended in Draft Floodplain Risk Management Plan for further investigation

9.5.2. Results

As shown in the matrix, the flood modification options assessed are largely ineffective in improving flood levels and reducing property damages, with most options scoring zero for these two criteria. Furthermore, a number of options are considered either technically or financially unfeasible. This is due to the heavily urbanised catchment and floodplain, in which any construction works would be especially costly due to space constraints and issues with land acquisition. Given these constraints, the localised reductions in flood levels are generally negligible in comparison with the overwhelming volume of water moving through the area during a flood event.

Option LV02 and MD01-4 were the exceptions, with both these options causing reduction in flood levels and an improvement in property affectation. Response and property modification measures have not been assessed in this matrix.