9.2.2 Channel Modifications

This type of option in the Lovers Jump Creek catchment mainly constitutes widening of the existing creek channel where possible. Formalising the banks with a steep or near-vertical rock embankment would provide the greatest capacity increases if space is constrained. Due to the morphology of the creek, the bed is usually on bedrock and hence deepening of the channel is generally not practical.

In some locations existing footbridge or driveway crossings of the creek may impede flows due to low bridge decks or guard rails obstructing flows.

In most locations the creek channel is contained within a drainage easement of limited width. Channel widening usually requires enlargement of the easement, which would incur monetary costs and compensation to adjacent landowners for purchase of land for the easement. These costs would need to be included in the costings of the mitigation works.

9.2.2.1 Channel enlargement, 20 The Chase Road to 32 The Chase Road, Turramurra

Flooding of properties occurs on the western branch of Lovers Jump Creek located between The Chase Road and Tennyson Avenue, downstream of Eastern Road. Dwellings in the residential complexes at 20 The Chase Road and at 22 The Chase Road are particularly affected. Channel capacity through these properties appears to be a constraint in addition to obstruction caused by driveway bridges, although channel constrictions and flow breakouts may also occur further upstream on 91B Eastern Road. Approximately 10 dwellings with above-floor flooding in the 1% AEP may benefit from channel enlargement in this location.

Hydraulic aspects

A summary of peak flows in this location is provided in Table 9-9. Approximately half the flow is conveyed in the channel in the 1% AEP event.

Table 9-9: Summary of flows in Lovers Jump Creek branch at 20 to 32 The Chase Road

Flow component	Peak Flow (m^3/s)		
	20% AEP	5% AEP	1% AEP
Total flow	17.7	27.3	40.6
Creek channel	~12	~15	~18

Qualitative constraints assessment

The channel is 5 – 8m wide (top width) along this section of the creek with overbank slopes of 1:2 to 1:6. Space is constrained by driveways which run along the creek bank. Driveway crossings also encroach on the creek in some locations and may need to be reconstructed. The driveway crossings cannot be raised to increase flow capacity due to level and space constraints.

The overbank areas are heavily landscaped with native vegetation including areas of Blue Gum High Forest and Sydney Turpentine-Ironbark Forest EECs, as shown on Figure 9-32, which would be disturbed during construction. Removal of bank vegetation would be required to widen the channel.

Extending the drainage easement and any potential removal of footbridge and vehicular access would require compensation to the landowners. These costs to allow channel widening and capacity improvement need to be considered in the costing of this option.

Detailed assessment

A 10m wide channel with near vertical sides was assessed in detail, stretching from the western end of 20 The Chase Road property for 200m down to the confluence with the main branch of Lovers Jump Creek. Refer to

Figure 9-33 for layout. It was assumed that the existing driveway and footbridge crossings would be widened to accommodate the widened channel. The elevations of the crossings would not be modified.

Figure 9-32: Footbridge at upstream end of 20 The Chase Road looking downstream (east) towards driveway crossing

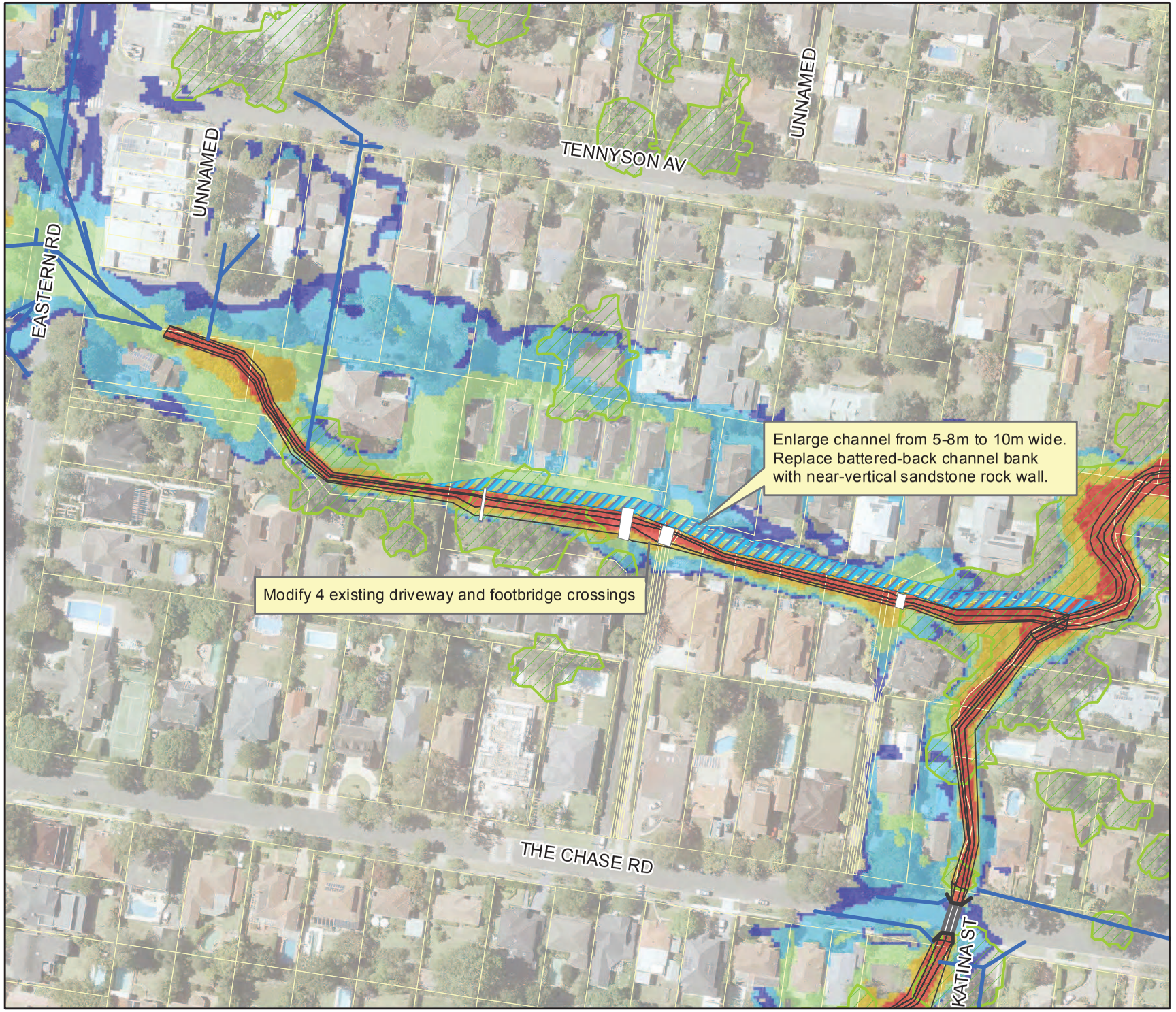
Flooding Impacts

Impacts of the mitigation measure in the 20% and 1% AEP event are presented in Figure 9-34 and Figure 9-35. Change in overall flood behaviour in the study area for Option C3 are provided below:

- Significant reductions (greater than 0.5m) in flood levels however these are restricted to the channel.
- -0.03m to -0.05m reduction in maximum flood levels at dwellings in all events.
- Localised increases in flood levels downstream (up to +0.1m) but contained in channel.
- No significant improvement to driveway access to properties.
- One less property with above floor flooding in 5% AEP event only.

Economic Evaluation

The cost for the mitigation measures was approximately $2,100,000. This mitigation option would reduce flood damages at some locations and would save approximately $173,000 over the 50 years design life. The benefit cost ratio for Option C3 was 0.10.



Legend

- Channel Modification Extent
- Existing Stormwater pipe
- Survey
- Endangered Ecological Community
- Cadastre

1% AEP Flood Existing Case

Peak Flood Depth (m)

- 0.1 - 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- > 2.0

0 20 40 80
Metres

JACOBS®

GDA 1994 MGA Zone 56

TITLE

Channel Modification (Option C3)
Lovers Jump Creek Branch
20 to 32 The Chase Road

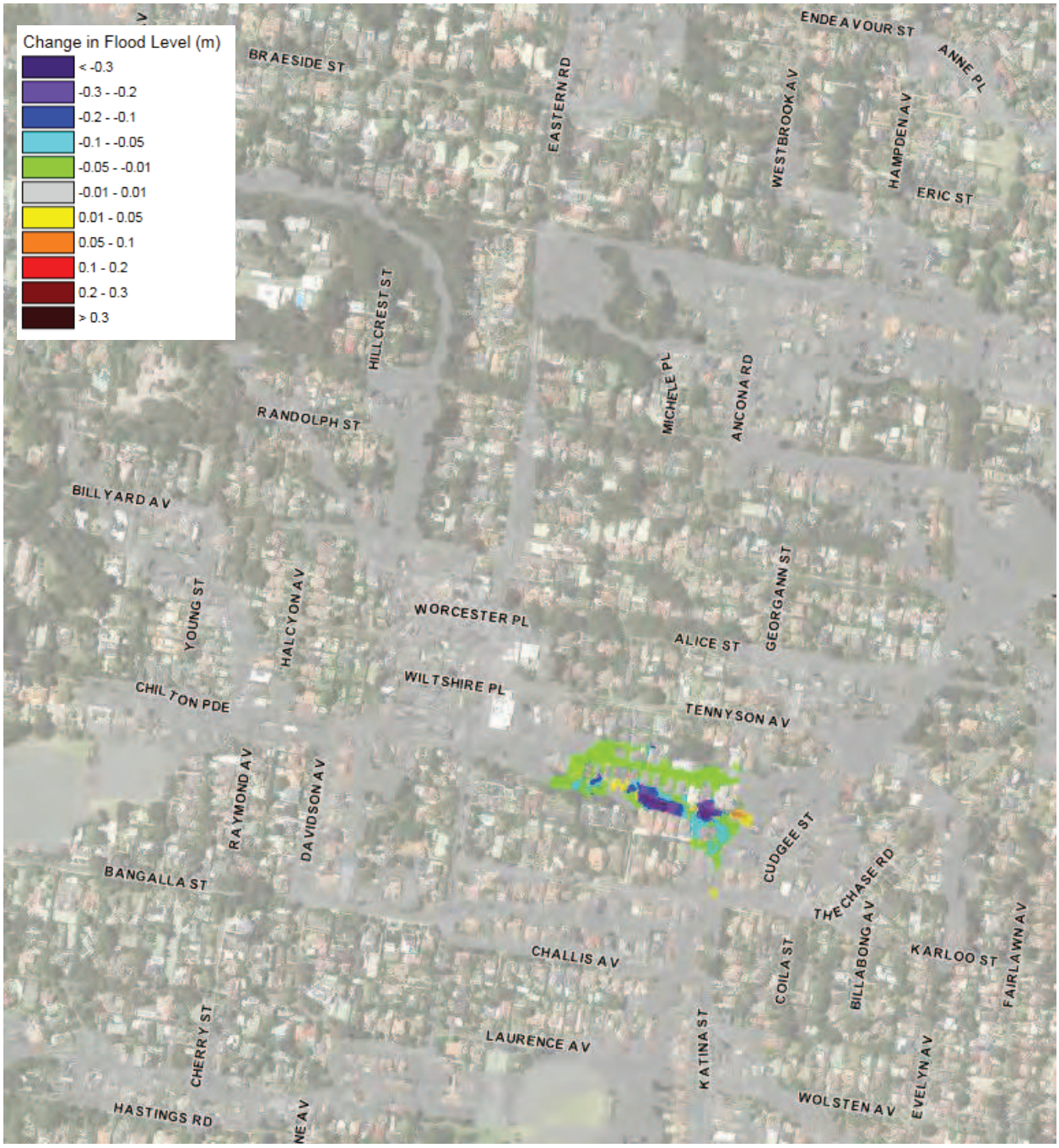
PROJECT

Lovers Jump Creek Floodplain Risk Management Study and Plan

PROJECT #	MAP #
IA159900	FIGURE 9-33
DATE	
24/01/2019	

Figure 9-34: Impact of the mitigation Option C3 – 20 to 32 The Chase Road in the 20% AEP event

Figure 9-35: Impact of the mitigation Option C3 – 20 to 32 The Chase Road in the 1% AEP event



9.2.3 Other Options Considered

Other options which were identified but not deemed to be practical are described below.

- Flood retarding basins (also called detention basins) are basin features which are usually formed by construction of an earth embankment or a retaining wall at the downstream end of the basin to store floodwaters, releasing them at a slower rate to reduce peak flows and hence flood levels and depths downstream of the basin. Flood depths in the basin area increase from the existing case as a result, hence detention basins are typically constructed in open space areas where an increase in flooding may be tolerable. Parks, reserves and sports fields which are located on drainage paths are often utilised as basin sites. Several basin options were identified, including in Karuah Park and Turramurra Memorial Park, among others, but were not considered in further detail due to large land-take, impacts on ecological communities and park function, high cost and likely relatively low improvements to flooding.
- Underground flood retention tanks: Flood retention tanks constructed from pre-cast proprietary products can be constructed underground in open space areas such as Karuah Park and Memorial Park. This option has not been considered in detail for further assessment due to the high costs of construction. Cost estimates on separate projects for Ku-ring-gai Council estimate $1 – 1.5 million for construction of a 2,500m^3 underground tank. Flood retention volumes of more than 10 times this are required for significant flood improvements on properties, hence this option is unlikely to be unfeasible.
- Clearing of creek vegetation: The bed of the creek channels is generally based on bedrock. As such, in-channel vegetation is typically sparse and would not pose a significant obstruction to flow. Bank vegetation may consist of denser shrubs and trees which may obstruct flows. However, removal of bank vegetation is not considered to be a sustainable option as the vegetation may re-establish over time without regular monitoring and maintenance. In many locations the creek flows through private property and this would be a hinderance to maintenance undertaken by Council. Removal of bank vegetation is likely to impact on bank stability and erosion in addition to habitat and ecological aspects. This option was therefore not considered further.
- Levees: Levee embankments are often placed around whole neighbourhoods or towns to protect them from more widespread riverine flooding. The terrain and nature of flooding in Lovers Jump Creek catchment is such that a levee structure would protect only a few dwellings, and would typically redirect flow onto adjacent properties outside the levee resulting in flooding impacts. The issue of internal drainage inside the area protected by the levee would also need to be addressed. This option therefore was not considered further.
- Localised raising of the road verge and driveways may be considered similar to levees in urban overland flow catchments. The purpose of these works is to contain flows in the roadway and reduce overflows into properties. Flows in these locations are generally minor, hence this option was not considered in detail as there are greater flood problems requiring other measures elsewhere in the catchment.
- Other sites for drainage upgrades and channel modification and widening were identified and broadly assessed and were not considered in further detail due to site and engineering constraints, environmental and land ownership issues and other feasibility concerns.

9.2.4 Evaluation of Options

Table 9-10 summarises the options assessment including likely constraints, hydraulic performance (changes to flooding conditions as estimated in the hydraulic model), savings in flood damages, cost of works and economic appraisal. The flood damages are presented in terms of the reduction in Net Present Value (NPV) of the damages from the base case to the mitigation case. The NPV was calculated by discounting the value of the AAD during each successive year after the present year for the design life of the proposed mitigation measures. In this study a design life of 50 years and a discount rate of 7% have been assumed. The flood damages used in the options evaluation are based on “no protection level” (refer to Section 8.6.3). The flood damages calculations are based on OEH (2016b) guidelines.

The difference in the NPV of flood damages is the theoretical savings in flood damages which can be achieved by a particular mitigation option, over the design life of the option. Comparison of this saving in NPV to the cost of the mitigation option provides a basis for evaluating the economic feasibility of an option, whereby the

reduction in NPV ("Benefit") are divided by the capital cost ("Cost"). A benefit-cost ratio greater than 1.0 would indicate that the capital cost of the works would be less than the savings in flood damages over the life of the works, and vice-versa for a ratio less than 1.0.

The options evaluation is based on a scoring system, with scores from -3 (strongly negative) to +3 (strongly positive) with 0 being a neutral score, for a range of aspects and issues relating to implementation of the mitigation options. The scoring system matrix is shown on Table 9-11.

A summary evaluation table of the mitigation options is presented in Table 9-12. Each option is given a relative rating for each criterion and is given a total score for further consideration by Council.

Note that the costings presented here for Option D1 (Burns Road crossing upgrade) are based on the drainage structures upgrades only (including removal and disposal of existing structures). It is assumed that this option could only realistically be undertaken in conjunction with the Burns Road – Killeaton Road widening project and the cost for the road widening and reinstatement at the creek crossing are excluded from this cost estimate.

The cost of Options D5(b) and D5(c), which propose trenchless microtunneling pipeline construction, are exceedingly high due largely to high mobilisation cost of specialist equipment. This and other options requiring construction of long pipelines using conventional construction techniques also incur high costs.

While some options (e.g. Option D8) may be particularly beneficial in the 1% AEP event, they may also result in flood level increases on properties in the frequent events such as the 20% AEP and 10% AEP events, hence increasing the flood damages in these events. The frequent events generally have a higher contribution to the AAD and NPV in overland flow catchments due to their higher frequency and small difference in flood depths compared to the 1% AEP. Therefore, the overall effectiveness of these options is reduced.

Costings for all options cover the basic design and construction costs and do not include the cost for locating existing underground services and utilities.

9.2.5 Climate Change Considerations

The potential mitigation options were assessed for the existing climate conditions, resulting in relatively ineffective hydraulic benefits and generally low feasibility. While the options were not assessed under a climate change scenario, where storm rainfall and flood flows may increase by up to approximately 18% in the year 2090 compared to existing climate conditions (reference: ARR DataHub. http://data.arr-software.org/), it is expected that the effectiveness and feasibility of the options would be reduced in the climate change scenario.

Table 9-10: Summary of Nominated Flood Modification Options for Detailed Assessment

Option	Location	Description	Constraints and Impacts Plus other comments	Hydraulic Benefits *And Negative Impacts if Any*	Savings in Flood Damages (50 years life, 7% Discount Factor)	Cost of Works	Benefit Cost Ratio
D1	Burns Road crossing	Additional 2x 1.75m diameter pipes; assume rebuild of existing hydraulic structures	• Disruption to major arterial road during construction. Likely closure of road with traffic diverted via local roads • Limited space for construction activities on downstream side • Some vegetation disturbance (EEC) • Potential clash with existing utilities • Existing driveways • Localised impacts to downstream landforms and vegetation from increased flow + Recommend combination with potential road widening project for Burns Road and Killeaton Road being considered by Council, to reduce stand-alone costs of the drainage upgrade works	• Reductions in flood levels up to -0.7m in 20% AEP event, and -0.2m in 1% AEP, on upstream side of road • Modest reduction in flood levels at dwellings. Up to -0.1m in 1% AEP at one dwelling only. • Road flood immunity improved. Now passable (<0.3m depth) in up to at least the 5% AEP (existing flood immunity less than 10% AEP). • No change in above floor flooding.	$22,000	$820,000	0.03
D2	Tennyson Avenue crossing	Additional equivalent 2.4m x 2.4m box culvert (could be split between two separate cells). Localised channel widening at inlet/outlet	• Limited downstream channel capacity • Localised disturbance of vegetation (EEC) • Works on private property	• Reductions in flood levels up to -0.2m in 20% AEP event, and -0.1m in 1% AEP, on upstream side of road • Modest reduction in flood levels at dwellings. Up to -0.05m in 1% AEP. • No change in above floor flooding.	$60,000	$770,000	0.08
D3	The Chase Road crossing	Replace existing bridge crossing with wider bridge spans (2x 3m x 2.4m) or single span bridge	• Limited downstream channel capacity • Localised disturbance of vegetation (small stand of EEC) • Existing utilities	• Reductions in flood levels up to -0.8m in 20% AEP event, and -0.3m in 1% AEP, on upstream side of road. • Reductions in maximum flood levels at three dwellings of up to -0.4m in the 5% AEP and -0.25m in the 1% AEP • *Increased flood levels in the channel on downstream side of road up to +0.1m with potential minor impacts to dwellings on either side* • Improvements to trafficability of road crossing in flood events, although already trafficable in the existing case • Three less properties with above floor flooding in 2% AEP, two less in 1% AEP	$500,000	$825,000	0.60
D4	Challis Avenue crossing	Additional 1.8m x 1.8m box culvert. Localised channel widening at inlet/outlet	• Limited downstream channel capacity. Localised channel widening needed • Option estimated to only provide 20% AEP flood immunity • Localised disturbance of vegetation (small stand of EEC) • Works on private property	• Reductions in flood levels up to -0.2m in 20% AEP event, and -0.06m in 1% AEP, on upstream side of road. • Minor reductions in maximum flood levels at one dwelling of up to -0.06m in the 2% AEP and -0.05m in the 1% AEP. Negligible reductions of -0.02m at three other dwellings	$100,000	$340,000	0.30

				• Minimal reduction in flooding over road crossing. No improvement in flood immunity			
D5(b)	North Shore Railway cross drainage near Winton Avenue, Warrawee, plus downstream drainage	• Additional 1.2m diameter railway pipe. • Increase the Council trunk drainage capacity from the railway down to discharge point at Karuah Park by construction of new additional trunk drainage line, to match existing culvert capacity. • Some sections through residential properties and then under road. • Microtunneling 65m length. 650m conventional pipe laying	• Works through private property, no clear easement. • Disruptive to downstream private properties with potentially less benefit to these properties • New trunk drainage in road corridor, clashes with utilities, disruption to traffic • Significant works in rail corridor, significant disruption to rail operations	• Significant reductions up to -0.9m on properties upstream of railway in 1% AEP. Reduction in maximum flood level at dwelling of -0.4m at worst-affected dwelling • Reductions up to -0.3m in 20% AEP and -0.2m in 1% AEP, between railway and Eastern Road • *Increased flood levels +0.05 - +0.25m in creek and on properties downstream of Karuah Road, larger impacts in smaller events. one property with new above floor flooding in 5% AEP as a result.* • One less property with above floor flooding in 1% and 2% AEP.	$400,000	$16,068,000	0.02
D5(c)		• Redirect upstream northern pipe branch (0.9m diameter) from Winton Street, under railway to Brentwood Avenue on downstream side. • New additional drainage line downstream of railway to discharge point at Karuah Park • Microtunneling 65m length. 650m conventional pipe laying	• No or few works in private property • New trunk drainage in road corridor, clashes with utilities, disruption to traffic • Significant works in rail corridor, significant disruption to rail operations. Risk to rail substation • Lower increase in capacity than D5(b)	• Reductions up to -0.3m on properties upstream of railway in 1% AEP. Reduction in maximum flood level at dwelling of -0.25m at worst-affected dwelling • Reductions up to -0.2m in 20% AEP event, typically -0.05 – -0.1m and -0.2m in 1% AEP, between railway and Eastern Road. Negligible reductions of -0.02m in 2% and 1% AEP. • *Increased flood levels +0.05 - +0.12m in creek and on properties downstream of Karuah Road, larger impacts in smaller events. one property with new above floor flooding in 5% AEP as a result.* • One less property with above floor flooding, in 20% AEP event.	$420,000	$14,000,000	0.03
D6	Eastern Road, south of Hastings Road	• Additional box culvert crossing 3m x 0.6m discharging to Karuah Park open channel (15m long), grated inlet in/adjacent to footpath	• Likely clash with existing utilities • Localised disturbance of vegetation (EEC) • Possible works on private property. • Possible modifications to footpath and driveways	• Reductions of -0.2 – -0.3m on properties either side of Eastern Road particularly in smaller events. Reductions of -0.1 – -0.15m in 1% AEP. • *Increased flood levels +0.02 - +0.07m in creek and on properties downstream of Karuah Road in the 20% AEP, 10% and 5% AEP events particularly around Challis Avenue and The Chase Road.*	$170,000	$270,000	0.63

				• Three less properties with above floor flooding in 1% AEP event.			
D7	Eastern Road, north of Hastings Road	• Additional box culvert crossing 2.4m x 0.6m (210m long) discharging to Turramurra Memorial Park open channel, grated inlet in/adjacent to footpath	• Likely clash with existing utilities • Localised disturbance of vegetation (EEC) • Disturbance of cricket oval and park facilities • Possible works on private property. • Possible modifications to footpath and driveways	• Reductions of -0.3 – -0.5m on properties either side of Eastern Road particularly in smaller events. Reductions of -0.1 – -0.4m in 1% AEP. • *Increased flood levels +0.02 - +0.14m in creek and on properties downstream of Karuah Road in the 20% AEP, 10% and 5% AEP events particularly around Challis Avenue and The Chase Road.* • Three less properties with above floor flooding in 1% AEP event.	$600,000	$1,000,000	0.60
D8	Billyard Avenue near Mona Street	• New 1.35m diameter pipeline running east from Mona Street down Billyard Avenue and then Eastern Road to Lovers Jump Creek branch opposite Hastings Road. • Reconstruction/rationalise some existing pipes in Eastern Road. • 415m length of works	• Likely clash with existing utilities. Significant number of main drainage lines already in place • Disruption to arterial road (Eastern Road) • Discharging additional flows to existing problem area • Potential space constraints and combined flood impacts if combined with Option D9	• Reductions of up to -0.4m in the 2% and 5% AEP, and up to -0.25m in the 1% AEP on properties between Billyard Avenue and Eastern Road. • *Increased flood levels +0.02 - +0.06m in creek and on properties downstream of Eastern Road in the 20% AEP and 10% AEP events. Increases typically +0.02m and localised up to +0.1m in the 5% AEP.* • Five less properties with above floor flooding in 1% AEP event.	$184,000	$2,260,000	0.08
C3	20 to 32 The Chase Road	• Widen existing 5-8m wide channel to 10m wide. Works on northern side of creek. Near-vertical rock retaining wall to formalise bank. Works for 200m to junction with main creek branch	• Driveways encroach on the creek on northern bank. • Driveway crossings and footbridges need to be reconstructed • Disturbance/removal of vegetation including EECs • Works on watercourse • Works required on private property, associated compensation	• Significant reductions (greater than 0.5m) in flood levels however these are restricted to the channel. • -0.03m to -0.05m reduction in maximum flood levels at dwellings in all events. • Localised increases in flood levels downstream (up to +0.1m) but contained in channel • No significant improvement to driveway access to properties • One less property with above floor flooding in 5% AEP event only.	$173,000	$2,100,000	0.08

Table 9-11 Options scoring system matrix

Aspect	Score						
	-3	-2	-1	0	1	2	3
	Negative			Neutral	Positive		
Impact on Flood Behaviour	> 100mm increase	50 – 100mm increase	< 50mm increase	Neutral, or benefits countered by negative impacts	< 50mm decrease	50 – 100mm decrease	> 100mm decrease
Number of Properties Benefited	>5 properties negatively impacted	2-5 properties negatively impacted	< 2 properties negatively impacted	Neutral, or benefits countered by negative impacts	< 2 properties benefitted	2-5 benefitted	>5 properties benefitted
Technical Feasibility	Significant issues (unproven, high risk)	Some issues (complex, some difficulty)	Minor issues	Neutral	Moderately straightforward	Straightforward	No issues (proven, well established, no risk)
Economic Merit (benefit/cost ratio)	Very low (0-0.4)	Low (0.4-0.6)	Slightly low (0.6-0.8)	Neutral (0.8-1.2)	Slightly high (1.2-1.5)	High (1.5-2)	Very high (>2)
Financial Feasibility (funding, Government assistance & grants)	Very unlikely to receive funding	-	Unlikely to receive funding	Neutral	Likely to receive funding	-	Very likely to receive funding
Environmental and Ecological Benefits	Significant disbenefits	Some disbenefits	Minor disbenefits	Neutral	Minor benefits	Some benefits	Significant benefits
Impact on Risk to Life	Significant increase in risk to life	Some increase in risk to life	Minor increase in risk to life	Neutral	Minor decrease in risk to life	Some decrease in risk to life	Significant decrease in risk to life
Impacts on SES	Significant disbenefit to SES	-	Some disbenefit to SES	Neutral	Some benefit to SES	-	Significant benefit to SES
Long-term Performance (design life & climate change)	Very low	-	Low	Neutral	High	-	Very high
Legislative & Permissibility Requirements (including political & administrative	Significant issues affecting implementation	-	Some issues affecting implementation	Minor issues affecting implementation	Negligible issues affecting implementation	-	No issues affecting implementation
Social Impact / Community Acceptance	Large majority against	Most against	Some against	Neutral	Some for	Most for	Large majority for

Table 9-12 Evaluation of Options

Option	Impact on Flood Behaviour	Number of Properties Benefited	Technical Feasibility	Economic Merit (benefit/cost ratio)	Financial Feasibility (cost, funding, Government assistance & grants)	Environmental and Ecological Benefits	Impact on Risk to Life	Impacts on SES	Long-term Performance (design life & climate change)	Legislative & Permissibility Requirements (including political & administrative)	Social Impact / Community Acceptance	Total score	Rank
D1	3	1	-2 Likely require closure of Burns Road	-3	-1	-1	2	1	1	-2 Requires to be done in conjunction with separate Burns Road widening project	-1	-2	**6**
D2	2	0	0	-3	-1	-1	0	0	1	0	-1	-3	**7**
D3	1 (+3/-2)	2	0	-1	-1	-1	0	1	1	0	-1	1	**3**
D4	2	1	0	-3	1	-1	0	0	1	0	0	1	**3**
D5(b)	0 (+3/-3)	0 (+3/-3)	-3	-3	-3	0	1	0	0	-3	-1	-12	**9**
D5(c)	0 (+2/-2)	0 (+2/-2)	-3	-3	-3	0	0	0	0	-3	-1	-13	**10**
D6	2 (+3/-1)	2	0	-1	1	-1	0	0	1	0	0	4	**1**
D7	2 (+3/-1)	2	0	-1	-1	-1	0	0	1	0	0	2	**2**
D8	2 (+3/-1)	3	-2	-3	-1	0	0	0	1	0	-1	-1	**5**
C3	1	1	-1	-3	-1	-2	0	0	0	-1	-2	-8	**8**

9.2.6 Summary of Detailed Options Assessment

9.2.6.1 Options Feasibility

All of the ten options assessed were estimated to have a slightly low (maximum BCR 0.63) to very low (minimum BCR 0.03) economic feasibility, reflecting relatively high costs of the options and relatively low savings in flood damages over the assumed lifespan of the option.

The benefits of options with a potentially high improvement to flood conditions and flood damages were offset by downstream flood impacts and high cost.

The best scoring options in order were D6 and D7, followed by D3 and D4, with scores above zero. These had relatively low BCR from 0.3 – 0.63. A neutral or “break even” BCR is 1.0.

9.2.6.2 Options Evaluation and Flood Damage Estimates

Each criterion was assumed to have an equal weighting. Higher weighting could be placed on certain criteria, in particular, improvement on risk to life. However, this is unlikely to change the outcome of the evaluation. The options with best impact to risk to life rating score very poorly in other aspects including overall cost and economic feasibility. Low cost, non-works measures could instead be implemented to address and improve the risk to life in some areas e.g. flood depth signage and improved street lighting at key road crossings including Burns Road. This is addressed later in this FRMS.

The flood damages presented in this report for baseline and mitigation scenarios were estimated based on “no protection level” on each property. Sensitivity testing “with protection level”, which imposed a nominal buffer/freeboard on the floor level in the flood damages calculation, increased the flood damages cost at each property for a given flood level. Inclusion of the protection level did not markedly change the economic feasibility of each mitigation option, at least in Lovers Jump Creek catchment, as the savings in flood damages did not markedly change with mitigation.

9.2.6.3 Potential Option Combinations or Additional Options

Combinations of options could be implemented to enhance the benefits and reduce any negative impacts of individual options, however, there were no obvious combinations which were likely to enhance each other. The most feasible options, D6 and D7, both increased downstream flows in frequent events and combining these two options would exacerbate downstream impacts. Channel widening in downstream sections would reduce the negative impacts of these options but most widening options were ruled out in the options short-listing. The additional implementation costs of these additional options may also result in the overall BCR remaining similar or potentially reducing.

There were no obvious additional or modified options which were practical or potentially feasible to enhance the assessed mitigation options effectiveness or feasibility. Further increased drainage capacities were likely to be countered by increased downstream flood impacts. Detention basins and channel modification options were previously ruled out.

9.2.6.4 Recommendations on Further Consideration of Flood Modification Measures

The identified and assessed flood modification measures for Lovers Jump Creek catchment, as stand-alone measures and likely in combination, were found to be rated as unfeasible and with generally minor flood mitigation benefits. It is not recommended to further consider these options as a part the FRMSP.

While drainage capacity upgrade of Burns Road crossing is not recommended as a part of the FRMSP due to relatively low benefits to flood damages, this does not preclude the crossing from being upgraded to improve flood immunity for trafficability reasons on this major arterial road. This could be considered as a part of a future potential widening project of Burns Road.

9.3 Property Modification Measures

9.3.1 Voluntary Purchase of High Hazard Properties

Voluntary purchase of high flood hazard properties may be considered in order to eliminate the potentially high risk of loss of life and damage to property from these areas by physically removing the dwellings at risk to hazardous flood conditions. A few dwellings were identified to be impacted by high hazard flooding. Flood modification measures were assessed for effectiveness in the hydraulic model however these were not effective in eliminating above-floor flooding or reducing the flood risk to acceptable levels on these properties. It is not practical of feasible to further develop the flood modification measures to reduce the flood hazard as there are constraints on the maximum size of increased drainage structures or creek widening to achieve this.

OEH has prepared Guidelines for Voluntary Purchase Schemes (OEH, 2013b). This describes the eligibility criteria for NSW Government funding for VP schemes, which include:

- no other feasible flood risk management options are available to address the risk to life at the property;
- residential properties and not commercial and industrial properties;
- buildings were approved and constructed prior to 1986;
- properties are located either 1) within high hazard areas where there is a significant risk to life for occupants and those who may have to evacuate or rescue them, 2) within a floodway where the removal of the house may be part of a floodway clearance program aimed to reduce the significant impacts caused by the existing development on flood behaviour elsewhere in the floodplain, or 3) within the footprint of a proposed flood mitigation measure or where a flood mitigation measure may result in a significant increase in flood risk to a house that cannot be protected.

There are seven properties (refer to Table 8-2) which are significantly impacted by a H5 or H6 flood hazard rating in the 1% AEP event, meaning buildings are at risk of significant damage or failure due to floodwaters, which makes them potentially eligible for voluntary purchase. Further investigations would be required to determine if the approval or construction date of the building qualifies these properties.

Inclusion of a property in a voluntary purchase scheme places no obligation on the owner to sell the property or on the council or NSW Government to fund the purchase of the property. Owner participation in the scheme is voluntary and there are limitations on the availability of funding. Purchase of the property would at market value. Median house prices in Turramurra for three-bedroom homes is $1.6 million[1], which is considered high for a voluntary purchase scheme and hence is likely to render such a scheme unfeasible. A voluntary purchase scheme is not considered further.

9.3.2 Redevelopment of High Hazard Properties

Given that voluntary purchase is not considered feasible in the Lovers Jump Creek catchment due to the generally high property prices in the area, it is suggested that these properties could be redeveloped according to appropriate development controls including minimum floor levels and structural strength relevant to the flood conditions. This could be achieved by:

- The property being purchased by Council (under a scheme similar to voluntary purchase), redeveloped and resold. This would address the high cost issues related to a conventional voluntary purchase scheme.
- Alternatively, the landowner could redevelop and retain or sell off the property.

However, initial assessment identifies a number of issues with this approach:

- It would be in conflict with proposed amendments to Council's LEP and DCP in addition to other planning policies which preclude (re)development in floodway and high flood hazard areas.
- Any properties acquired under a voluntary purchase scheme are to be rezoned to a flood-compatible land use. Hence, this approach would need to be fully funded by Council or the landowner.

[1] Median house prices as of 14 December 2018. Source: Domain.com.au

- Specialised building design and engineering would be required to withstand high to extreme hazard flood forces (H5 and H6 hazard rating) in the 1% AEP event and rarer and may be unfeasible.
- This approach would not reduce the risk of flooding on the population in the PMF.
- There may also be probity issues in the case of Council acquiring the property, redeveloping and reselling the property.

Further consideration by Council is required to determine if these issues can be addressed to make this a viable approach. Engineering and economic assessment to redevelop properties to a suitable flood-resistant structural design needs to be undertaken. Development controls such as floor levels above the PMF for flood refuge would need to be assessed for suitability in a town planning context.

Recommendation

- Council are to consider whether to adopt a voluntary purchase and redevelopment scheme for high hazard properties. This includes resolution of the identified policy and probity issues related to such a scheme.
- Engineering and economic assessments should be undertaken for flood-durable development designs to determine feasibility.
- Assess and impose development controls such as provision of floor levels above PMF level and/or flood-free evacuation access for such developments.

9.3.3 Voluntary House Raising

Voluntary house raising has long been a traditional response to flooding in New South Wales, as demonstrated by the number of raised houses in frequently flooded urban areas such as Lismore and Fairfield (Floodplain Development Manual, 2005). There are advantages associated with house raising which are noted as follows (Frost and Rice, 2003).

- A reduction of flood damages due to personal items being stored above the nominated flood level
- A reduction in danger to personal safety and a reduction in the cost of potentially needing to evacuate residents
- Potentially cost-effective alternative to voluntary purchase, with positive social outcomes (i.e. home owners who have strong sentimental value on their properties can remain in the same location).

Some of the disadvantages include:

- Residents' concern over security and privacy due to an open, exposed ground floor
- Accessibility issues for the elderly or people with a disability
- Following raising, residents may develop a false sense of security from impacts. This can result in a belief that they will not be impacted by flooding or reluctance to evacuate when required.
- Over time and when flooding has not occurred, residents may be inclined to utilise the ground floor and converting it to a habitable area.

OEH has prepared *Guidelines for Voluntary House Raising Schemes* (OEH, 2013a). This describes the eligibility criteria for NSW Government funding of VHR schemes including:

- not located in floodways;
- limited to areas of low flood hazard;
- the suitability of individual houses for raising;
- residential properties and not commercial and industrial properties;

- buildings were approved and constructed prior to 1986;
- properties cannot be benefiting substantially from other floodplain mitigation measures;
- VHR should generally return a positive net benefit in damage reduction relative to its cost (benefit–cost ratio greater than 1).

Inclusion of a property in a voluntary house raising scheme places no obligation on the owner to sell the property or on the council or NSW Government to fund the purchase of the property. Owner participation in the scheme is voluntary and there are limitations on the availability of funding.

Whilst house raising can be considered for a range of building types, it is easiest and cheapest for timber-framed houses clad with non-masonry materials. A large proportion of houses in the study area which area flood-affected are of single or double brick construction which are considered costly and impractical for raising. An alternative solution for these dwellings is to demolish and rebuild the house at a higher level (whether this is done by the existing owner or purchased by Council and re-sold with appropriate development controls. Refer to Section 9.3.2).

Due to the factors outline above, house raising is not considered feasible as a mitigation measure for dwellings within the study area.

9.3.4 Flood Proofing and Flood Compatible Design of Individual Buildings

Flood compatible design refers to the design and construction of buildings with appropriate water-resistant materials such that flood damage to the building itself (structural damage) and possibly its contents, is minimised should the building be inundated. *Reducing Vulnerability of Buildings to Flood Damage* (Hawkesbury-Nepean Floodplain Management Steering Committee, 2007) provides a comprehensive discussion of the various options for building design to minimise the impact of flooding. These include structural and architectural design and building materials, in addition to design considerations such as setting of electrical equipment above flood levels to reduce risk of their damage.

Flood compatible design measures should be considered for inclusion in development controls. Promotion of types of flood proofing measures should also be undertaken as a part of flood awareness and readiness improvement programs (refer Section 9.4.4).

Flood proofing of residential properties can also refer to implementing external measures such as walls or landscaping to redirect flows away from and around vulnerable parts of the house, such as doorways and other entry points. It is generally a measure that can be pursued by individual property owners in low hazard areas to prevent above floor inundation. Given the nature of development in the catchment, this option is not considered feasible due to potential diversion of flows to neighbouring properties and resultant impacts.

Recommendation

- Council should consider inclusion of requirements for flood compatible design in the development controls.
- Promotion of flood proofing measures should also be included in flood education and awareness programs.

9.3.5 Planning and development controls

9.3.5.1 General

Land use planning and development controls are an essential element in managing flood risk and the most effective way of ensuring future flood risk is managed appropriately. Planning controls including flood planning

levels, flood related development control plans and restrictions on permissible types of development in different parts of the floodplain are recommended to ensure that development in the study area occurs in an appropriate manner in relation to flooding.

A Draft Flood Planning Matrix format was developed by GHD (2018) as a part of the Blackbutt Creek Floodplain Risk Management Study and Plan. The matrix outlines the requirements in terms of permissible land uses, minimum floor levels, building materials and design, structural soundness and emergency evacuation to assist Council with prescribing appropriate flood management development controls for development applications. The matrix has been updated in this FRMSP, refer to Section 9.3.5.4 for further discussion.

9.3.5.2 Amendments to KLEP 2015 and Section 149 Certificates

Following on from discussion on KLEP 2015 in Section 4.3.4, Council's proposed amendments to the KLEP 2015 should be further advanced. This would enable inclusion of the flood controls as per the Model Local Provisions for Flood Planning and link these controls to the flood mapping and flood studies completed by Council. This will allow the notification of flood control lots on Section 149 certificates thereby signifying that the considerations and restrictions under the Exempt and Complying Development Codes SEPP (2008) would apply to that lot. Restrictions relate to re/development in floodway, flood storage and high hazard areas.

The Section 149 certificates should also include information on flooding on the properties such as 1% AEP flood levels and flood planning levels and their variation across the property (e.g. contour mapping of the flood planning levels) as these are relevant to future redevelopment of the property and also promote awareness of flooding conditions on the property with the landowner.

Recommendation

Council should continue to further advance with the proposed amendments of KLEP 2015 to include the flood controls as per the Model Local Provisions and link these to the KDCP provisions.

It is recommended that the Section 149 certificates be updated to provide notification of flood control lots in line with the proposed amendments to the KLEP 2015.

Data on flood conditions on each property should be included on the Section 149 certificates.

9.3.5.3 Amendments to KDCP

A number of amendments to KDCP are recommended for consideration by Council in relation to flood related requirements for car parking and basement areas in flood zones, inclusion of flood planning matrix and suitability of an open fence policy for floodway areas.

The proposed amendments to KLEP would allow the application of Exempt and Complying Development Codes SEPP (2008) development restrictions to re/development of flood control lots in floodway, flood storage and high hazard areas via the KDCP.

Recommendation

- Council should consider update to the DCP in relation to parking areas in overland flow zones to refer to AIDR flood hazard mapping prepared in this study, instead of velocity x depth.

- Council should consider inclusion of design requirements for underground basements for flood immunity and compatibility.
- Council should consider inclusion of the proposed flood planning matrix (refer Section 9.3.5.4) into KDCP to guide different types of appropriate development in floodplain areas including high hazard areas.
- An open fence policy for flood conveyance may not be suitable for the study area. Removal of existing solid wall boundary fencing may result in flooding impacts. Council should consider changes to property fencing on a case-by-case basis. Maintain similar fencing style in floodplain areas where possible.

9.3.5.4 Flood Planning Matrix

A draft flood planning matrix is proposed for Lovers Jump Creek and the remaining catchments in Ku-ring-gai and is presented in Appendix E. The concept of the planning matrix was developed in the late 1990's[2] which seeks to provide a structure for planning controls that can deliver a risk management approach to address flood hazards and their potential consequences to future development.

The matrix will help implement various flood planning conditions for different development types in Ku-ring-gai LGA and in different flood risk zones, or alternatively in different flood hazard or flood category zones. Such conditions include permissible development types in different flood zones, minimum floor levels, etc. The matrix allows easy referencing of the development types and flood zones and the applicable development controls.

The format of the flood planning matrix proposed in this report is similar to that of the proposed matrix format in the Blackbutt Creek FRMSP (GHD, 2018) and of the matrices adopted by other local councils in the Sydney region. There is scope to modify the format and planning controls in the matrix to suit flooding conditions in Ku-ring-gai.

The flood planning matrix proposed here and which is also used in other council areas typically refers to "flood risk precincts" (which considers flood hazard as well as flood probability) to define the different flood zones. The flood risk precincts for Lovers Jump Creek have been defined as discussed in Section 5.6 and mapped in Appendix B. Amendment of Council's planning instruments would be required to include reference to the flood risk precincts. Alternatively, the flood planning matrix could be amended to suit the flood planning mapping already prepared for Lovers Jump Creek and other catchments in Ku-ring-gai, and to Council's planning instruments.

Recommendation

It is recommended that Council consider the flood planning matrix for adoption. The suggested development controls and conditions in the proposed matrix should be reviewed by Council for appropriateness and consistency with other planning instruments. The flood risk precincts would need to be defined for Lovers Jump Creek for compatibility with the flood planning matrix. Alternatively, the flood planning matrix could be amended to suit the flood planning mapping already prepared for Lovers Jump Creek and other catchments in Ku-ring-gai, and to Council's planning instruments.

9.3.5.5 Rezoning

Review of the current land zoning in the study area and the existing potentially flood-sensitive properties indicates that there is no significant incompatibility between the land zoning and flooding conditions. Voluntary purchase of high hazard lots would usually result in rezoning of those lots, however, a voluntary purchase

[2] Bewsher & Grech, May 1997, *A New Approach to the Development of Floodplain Controls for Floodplains*, paper presented to the 37th Annual Floodplain Management Conference, Maitland.

scheme in the study area is considered unfeasible. Amendments to the land zonings are therefore not recommended.

9.3.6 Property Boundary Modification for Improved Flood Access and Evacuation

A number of properties become flood islands or trapped perimeters during flood events, where their accessways cross the creeks or flow paths and become cut-off during flood events, and egress from the properties are restricted by existing property boundary fences. Council may consider modifying property boundaries to form easements for pedestrian access out of the affected properties to adjoining flood-free roads. This would require purchase of land from adjacent properties to form the easement/s. Affected properties include (but are not limited to) some battleaxe The Chase Road.

Recommendation

It is recommended that Council considers creation of accessway easements for pedestrian access from properties which are likely to become trapped perimeter properties during flood events.

9.3.7 Property Modification for Improved Flood Access and Evacuation

Several properties are significantly affected by high hazard flooding during frequent events and access from the dwelling to the road becomes cut-off. The dwelling is likely to be unsuitable for sheltering in place during a flood event, pending further investigation on their structural stability, and hence it would be prudent to improve the flood access from the dwelling for evacuation purposes. This could be achieved with a raised walkway from the second floor (the main habitable area is on the second floor) to the road. PMF level of service may not be possible due to depths of flooding in the road in that event, however, a minimum 1% AEP level of service could be achieved. The elevated walkway would need to be specifically designed for flood forces.

Given that most of the retrofitting works would be located on private property, it may be appropriate for a voluntary program to be set up by Council to enable the installation of flood evacuation walkways for high hazard properties. Responsibility for installation would be borne by the landowner with possible financial assistance from Council.

Installation of walkways could be a requirement for redevelopment of the high hazard properties. This could be included as a condition in the KDCP update.

Recommendation

Council should consider a voluntary program for retrofitted installation of elevated flood access walkways to significantly affected high hazard properties. The program may include financial assistance from Council. A scoping study for such a program is recommended in the first instance.

Council should consider Installation of walkways as a requirement for redevelopment of significantly affected high hazard properties. This could be included as a condition in the KDCP update.

9.4 Response Modification Measures

9.4.1 Flood Warning Systems

The study area includes small local catchments, overland flow paths and watercourses where flash flooding may occur. Flash flood catchments are those defined as catchments in which less than six hours may elapse between heavy rainfall and flooding. Flash flooding usually results from relatively short intense bursts of rainfall, commonly from thunderstorms. This is problematic in urban areas where drainage systems may not cope, in addition to very small creeks and streams. Flash floods tend to be quite local and it is difficult to provide effective warning because of their rapid onset. The reasons for this have been outlined identified for flash flood catchments as follows (McKay, 2004, 2008):

- Flash floods are less predictable than larger scale flooding. Rainfall over small catchments is usually not well predicted by numerical weather prediction models
- For flash floods, there is insufficient time to develop reliable flood warnings and for effective the dissemination and response to the flood warnings. More rapid user response is required, which necessitates specialised communication systems and a high level of public flood awareness
- A reliance on rainfall triggers increases the frequency of false alarms
- The use of main river level triggers does not allow sufficient time for response

As discussed in Section 7.2, it is not possible for BOM to issue specific predictions for flash flood catchments. More importance is placed on the role of the SES to interpret the regional warnings which are provided by BOM to warn the community of the potential road closures and damage as a result of predicted storms and flash floods.

Local residents also have a role in being able to understand how the issued weather warnings may translate to flooding impacts to their properties, and in addition, be aware of ways to prepare their properties to reduce flood damages and risk to life.

Whilst challenging to establish, a basic flash flood warning system has been developed for Sydney's Northern Beaches region. The Flood Warning and Information Network program is a joint partnership venture between Northern Beaches Council with guidance from Office of Environment (OEH) and BOM. The aim of the program is to develop a basic flash flood warning system for the community by strategically installing rainfall and stream gauges (Millener *et al*, 2013).

A similar system may be appropriate for the Lovers Jump Creek catchment and other catchments in Ku-ring-gai, with a focus on real-time warnings (e.g. SMS, emails, Twitter etc.) being sent to registered users upon trigger of the alert system by high rainfall rates in and around the catchment. While there are existing BOM, MHL and Sydney Water rainfall gauges in the vicinity of Lovers Jump Creek due to often localised nature of high rainfall an additional rainfall gauge within the catchment would be preferable for a catchment-specific alert system. Analysis of hydrologic and hydraulic data is required to define appropriate rainfall rate trigger levels. An alert system based on stream gauging is not appropriate for Lovers Jump Creek as given the sharp rates of water level rise there would be virtually no warning time given. Rainfall trigger may give some minutes of warning time due to catchment response time. Additionally, maintaining a water level recorder in a channel or depression that is dry most of the time is also technically demanding. Selecting a secure location for a water level recorder could also be difficult.

Recommendation

It is recommended that Council considers a flood warning system based on rainfall gauging in and around the catchment to help address residual risk particularly to occupants of vulnerable properties. A scoping study is required in the first instance.

9.4.2 Flood Depth Signage on Roads

A number of road crossings are affected by significant flood flows, including Burns Road which is a main arterial road. Flood depth signage is recommended for key road crossings primarily to warn drivers of the flood hazard during a flood event and reduce occurrences of people driving into floodwaters. Flood depth signage may also act as a passive reminder to residents of the potential for flooding in their neighbourhood streets.

Recommendation

It is recommended that flood depth signage be installed at key road crossings as a warning of the flood hazard during a flood event and reduce occurrences of people driving into floodwaters, in addition as a passive reminder of flooding risk.

9.4.3 Local flood plan

Having a local flood plan is important for the community and State Emergency Service (SES) to be prepared when there is a flood. The plan would outline preparedness measures and the response to flooding in the area. The strategies and personnel responsible for their implementation would be detailed along with the plan for recovery afterwards. A local flood plan may prove to be a valuable resource in times of flood in order to coordinate a strategy to reduce flood risks.

Ku-ring-gai does not currently have a Local Flood Plan (LFP) which typically describes the risk to the community, outlines roles and responsibilities for the SES and supporting agencies and describes how the SES would manage flood events.

As Council progressively completes a number of Floodplain Risk Management Studies and Plans, it is recommended that a LFP is prepared for the study area. This FRMS and accompanying flood study update provide guidance on the expected flooding conditions at various locations across the catchments, particularly for at-risk properties identified in the emergency response classification mapping and the AIDR flood hazard mapping indicating where roads may be cut due to flooding.

Recommendation

It is recommended that a Local Flood Plan for Ku-ring-gai be developed by SES, based on flood studies and FRMSP's for Lovers Jump Creek and other catchments with completed studies.

9.4.4 Flood Education, Awareness and Readiness

Flood education and awareness should be promoted throughout the Lovers Jump Creek catchment. Residents living on an overland flow path should be aware of this and have personal safety plans in place in case of a flood. This can be effectively implemented through signposting. On all roads that experience a high flood hazard during the 1% AEP event, flood signage should be implemented. This includes a "Road subject to flooding" sign, along with a flood depth indicator. Signposting alerts residents to the issues of flooding in the local area and provides information about real time flooding conditions during an event and helps people manage where they travel. Additionally, Council or SES may run educational workshops or distribute information sheets to help people plan and prepare for a flood. Knowledge about local flooding issues is a valuable tool to equip the public.

Section 149 certificates issued by Council could be used to inform property owners about flood risk to their properties, where there are flood studies completed within Ku-ring-gai.

Promotion of the SES FloodSafe website (http://www.floodsafe.com.au/) and the generic or a site-specific FloodSafe brochure is recommended. This would allow people to further understand how they can prepare their property for flooding and what to do during a flood event. These could be circulated following the SES presentations and linked to Council's website.

Additionally, Council's floodplain management web page could be further developed to enhance the messaging on flood risk and flood preparation in Ku-ring-gai. This may include flood mapping on an interactive mapping portal on the website itself rather than links to the flood study reports and mapping. Comments were made by residents during community consultation that the pdf report mapping was coarse and difficult to view.

A flood education and awareness program should be developed by Council which outlines and schedules various flood education methods to be implemented (e.g. brochures, news articles highlighting previous flooding, SES events, Council web pages etc.). The program should be reviewed on a regular (e.g. 2 year) cycle to assess the effectiveness of the program, reinvigorate flood awareness in the community and plan the roll-out of new flood information as it becomes available.

Recommendation

It is recommended that Council develops a flood education program to promote flood awareness and readiness in the community. Measures may include:

- Promotion of FloodSafe brochures to help residents understand the flood risk and prepare their property and personal plans for a flooding event.
- Flood signage
- Section 149 certificates to inform property owners about flood risk to their properties
- Provide flood mapping on an interactive mapping portal on Counci's website for easier viewing
- Promotion and support for SES information events
- Enhanced messaging on flood risk in Ku-ring-gai on Council's floodplain management webpage.

The program should be reviewed on a regular (e.g. 2 yearly) basis.

9.4.5 Improved flood evacuation response and procedures

Flood evacuation in Ku-ring-gai is under the control of the SES and the SES needs to update the current evacuation planning based on information presented in this report, in particular the emergency response mapping shown in Appendix D which indicates vulnerable properties and road cut-off locations in the 1% AEP and PMF events.

Recommendation

It is recommended that the SES updates the current emergency planning, such as development of a Local Flood Plan, based on information presented in this FRMSP and from supporting flood studies.

9.5 Other Measures

9.5.1 Install Traffic Barriers in Flood-Affected Car Parks and Road Crossings

There are several existing parking areas within flood zones:

- Car park off Eastern Road at Turramurra Eastern Road shops (opposite Hastings Road)
- Part of northern car parking area in Know Grammar School.

Council should consider retrofitting of bollards etc. to help prevent vehicles being washed away in flood flows and potentially becoming hazardous flood debris in downstream areas.

Burns Road is a highly-trafficked crossing of Lovers Jump Creek. On the downstream side of the road there is currently a low link-chain fence supported by concrete posts acting as a defacto traffic barrier between the road and footpath, refer Figure 9-36. A pool-type fence is installed to the side of the footpath. The flood hazard to vehicles here is elevated compared to other roads due to the high creek flows, higher traffic loads and high drop on the downstream side of the road (5m drop to base of culvert crossing then 10m waterfall). Additionally, the road lighting is poor at night. If a vehicle were to enter floodwaters at this crossing it is not certain if the existing fencing will prevent the vehicle from being washed over the drop. Further assessment of the existing fencing for preventing vehicle wash-off should be undertaken. Installation of improved traffic barriers or bollards to prevent vehicle wash-off should be considered.

Recommendation

- It is recommended that Council considers retrofitting of bollards etc. to help prevent vehicles being washed away in existing car parking areas affected by significant overland flows.
- At Burns Creek road crossing, further assessment is recommended of the existing fencing for preventing vehicle wash-off off the road. Installation of improved traffic barriers or bollards to prevent vehicle wash-off should be considered.

Figure 9-36 Existing defacto traffic barrier on downstream side (right-side of photo) of Burns Road crossing of Lovers Jump Creek (source: google StreetView). A 5m sheer drop to the right of green fencing, then a 10m waterfall drop.

9.5.2 Site-Specific Flood Management Plans

Parts of Knox Grammar School are significantly affected by flooding in events rarer than the 1% AEP, with some built-up areas of the school affected by PMF depths exceeding 2m. Development of a flood management plan should be considered which addresses the flood risk and outlines actions and procedures in the event of a flood.

Recommendation

- Development of a flood management plan for Knox Grammar School should be considered. Council should notify the School of the flood risk and conditions and provide assistance if the School proceeds in the development of a plan.

9.6 Residual Flood Risk on High Hazard Properties

The floodplain risk management measures discussed above aim to reduce the flood risk to properties affected by high hazard flooding. However, the assessment indicates that some measures are unfeasible and hence there is residual flood risk to those properties. Discussion points provided below and made at various points earlier in this report and are distilled below:

- Ideally, the flood risk could be eliminated by removing the population at risk from those properties i.e. voluntary purchase. High property prices mean any available funding is unlikely to be sufficient and hence this measure is unfeasible.
- Based on the mitigation options assessed, flood mitigation works to benefit these properties are unlikely to be unfeasible and would not remove all flood risk in any case.

- Structural stability of existing dwellings to flood forces is unknown. Some dwellings have substantial flood depths above floor level in the 1% AEP and greater. These dwellings may not be suitable for shelter-in-place in the 1% AEP. There are numerous dwellings at risk in the PMF.
- Flood education and awareness programs and flood warning systems would potentially improve the response of occupants in a flood event. Flood emergency response may be hampered by inadequate evacuation routes from the dwelling and/or property.

In summary, there are some unknown risks relating to the structural stability of existing dwellings in high hazard areas. Assessment and potential upgrades of structures would need to be undertaken by landowners with possible assistance from Council. There are some conflicts in proposed flood planning policy which would need to be resolved to permit upgrade redevelopment of these dwellings.

Flood access off properties could be improved by property boundary adjustments and provision of access easements, and should be considered by Council. It would be appropriate for retrofitting of elevated access walkways for some high hazard dwellings to evacuate to flood-free streets.

It would be Council's responsibility to engage with high flood hazard property owners to convey messages on the risk and suggested actions, as appropriate. Implementing these actions would reduce the flood risk to high hazard properties as much as is feasible and practical.

10. Floodplain Risk Management Plan

10.1 Purpose of the Plan

The Floodplain Risk Management Plan provides input into the strategic and statutory planning roles of Councils. It provides a steering document to enable Council to effectively manage flood liable land moving forward. It also suggests an implementation plan based on priorities of floodplain risk management measures and availability of funding.

The Plan, consisting of proposed floodplain risk management measures, are provided in Table 10-1 and were developed from the recommendations made in the Floodplain Risk Management Study documented in the preceding sections of this report. Consultation with the community, Council and the FRMC on the recommendations and the preliminary proposed measures was undertaken.

10.2 Funding and Implementation

10.2.1 Estimated Costs

There are no works-based measures included in the Plan and hence the cost for implementing the Plan is expected to be relatively low. Costs were estimated for non-works based measures. The costs of planning, policy, administrative and organisational non-works measures are largely unknown to the consultant. The timing of the proposed works will be dependent on Council's overall budgetary commitments and the availability of funding from external sources. The Plan can be progressively implemented with an anticipated timeframe of 1-2 years for high priority options and 2-5 years for medium priority options.

While drainage capacity upgrade of Burns Road crossing is not recommended as a part of the Plan due to relatively low benefits to flood damages, this does not preclude the crossing from being upgraded to improve flood immunity for trafficability reasons on this major arterial road. There may be opportunity for such crossing upgrades as a part of potential future upgrade and widening of the Burns Road – Link Road arterial between Hornsby and St Ives being considered by Council.

10.2.2 Alternative Funding sources

There are a number of funding bodies, which Council could consider applying to for supplementary funds. The Office of Environment and Heritage (OEH) offer support to local Councils through Floodplain Management Grants. Assistance under this Program is usually $2 from government for every $1 from Council.

The Natural Disaster Resilience Program (NDRP) is a joint Commonwealth/State program funded through the National Partnership Agreement on Natural Disaster Resilience. It provides funding through the Floodplain Grant Scheme (FRMGS) to address flood activities allocated through the existing Floodplain Management Program managed by OEH (described above).

The Community Resilience Innovation Program (CRIP) is another program funded through the NDRP and supports a broad range of community-led projects designed to increase all-hazard disaster preparedness and build community capacity and resilience. Flood education and awareness programs may be eligible. Ku-ring-gai Council has recently used funding under this program for the "Fixing the Missing Link" project, to promote resilience and shared responsibility through digitally networked communities.

Applications for funding from State or Commonwealth programs are highly competitive and the limited funds are allocated on an annual basis. Options put forward for funding assistance must be well supported and justified through demonstrated strong cost/benefit ratio and inclusion of positive environmental and social outcomes.

In addition to State and Federal Government, Council could approach other organisations (for example RMS, SES) or private owners (such as property developers, where appropriate) to assist with funding of measures.

10.3 On-going Review of Plan

This Floodplain Risk Management Plan should be regarded as a robust document, which requires review and amendments to be made over time. At a minimum, it is recommended that the Plan be reviewed every five (5) years to ensure it remains relevant to the requirements of the area. In addition to scheduled reviews, the Plan should be reviewed following flood events, any change in State or Local Government legislation or alterations to funding availability. Implementation of the Plan should be monitored by the FRMC. The local community should continue to be informed of progress through Newsletters available via the Council website or displayed at Council Offices.

Table 10-1 Floodplain Risk Management Plan

ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
1	Update of KLEP 2015	Council	Staff costs	$0K	• Proposed amendments of KLEP 2015 to include the flood controls as per the Model Local Provisions and link these to the KDCP provisions. • Relevant to Lovers Jump Creek and other catchments in Ku-ring-gai.	**High** – this process has already been initiated by Council and is ongoing
2	Update of Section 149 certificates	Council	Staff costs	$0K	• Section 149 certificates to be updated to provide notification of flood control lots in line with the proposed amendments to the KLEP 2015 • Relevant to Lovers Jump Creek and other catchments in Ku-ring-gai. • Data on flood conditions (e.g. 1% AEP flood level, flood planning level and area, flood hazard, hydraulic category) on each property to be included on the Section 149 certificates, for catchments where flood studies have been completed.	**High** – this process has already been initiated by Council and is ongoing
3	Update of KDCP	Council	Staff costs $15K for consultant assistance in refining flood planning matrix	$0K	• Further refinement of flood planning matrix and its inclusion in the DCP. Amend Council's planning instruments to include reference to the flood risk precincts definition and mapping. Alternatively, amend flood planning matrix to suit the flood planning mapping already prepared for Lovers Jump Creek and other catchments in Ku-ring-gai, and to Council's planning instruments.	**High** – this process has already been initiated by Council and is ongoing

ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
					• Support from consultants to assist in defining the appropriate flood zones and development controls in the matrix for consistency with Council planning instruments. • Adopt AIDR flood hazard categories to reflect any changes to the future updated Floodplain Development Manual. In the interim retain FDM (2005) hazard categories for flood planning purposes. • For car parking in overland flood areas, refer to AIDR flood hazard categories instead of velocity x depth, to reflect latest guidance. • Inclusion of design requirements for underground basements for flood immunity and compatibility. • Inclusion of requirements for flood compatible design for flood control lots • Consider non-application of open fence policy in overland flood areas. Council should consider changes to property fencing on a case-by-case basis. Maintain similar fencing style in floodplain areas where possible.	
4	Identification of flood control lots for Lovers Jump Creek	Council Support from consultant	$10-20K	$0K	• Identification and tagging of specific lots where flood controls apply.	**Medium –** pending Council decision on how to administer development controls

ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
					• To be undertaken separately from this draft FRMSP	
5	Scoping study on voluntary purchase/ redevelopment scheme	Council	Staff costs	$0K	• Further investigation on feasibility of a Voluntary purchase/ redevelopment scheme for high flood hazard properties • Council to investigate and develop resolution of the identified policy and probity issues related to such a scheme. • Scheme is to recommend engineering and economic assessments be undertaken for flood-durable development designs to determine feasibility. • Include development controls such as provision of floor levels above PMF level and flood-free emergency access for such developments.	**Low** – policy and probity issues likely to be difficult to resolve. Other measures for high hazard properties may be appropriate and sufficient to manage the flood risk to acceptable levels (refer measure #9).
6	Development of a Ku-ring-gai Local Flood Plan	SES	SES costs	$0K	• Develop a local flood plan utilising information from Lovers Jump Creek Flood Study Review and FRMSP, and information for other catchments in Ku-ring-gai where studies are completed.	**Medium** – studies completed for limited number of catchments in Ku-ring-gai at this stage. Preparation of LFP could be done following completion of next study (~2 years).

ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
7	Flood warning system feasibility and installation	Council, SES	$30K	$5 – 10K p.a.	• Scoping study for a flood warning system based on rainfall recording stations in the catchment and SMS (or similar) warning dissemination. • Installation of system • Ongoing maintenance of recording, telemetry and messaging systems	**Medium** – important to understand the technical aspects and logistics of a system and likely take-up by residents.
8	Property boundary modification	Council	Not costed at this stage	$0K	• Investigate feasibility of measure in specific locations to provide pedestrian evacuation route for flood low island/trapped perimeter properties • Consultation with landowners • Purchase of land for easements to modify property boundaries • Access required for rarer than 1% AEP events	**Low** – likely high costs for easement formation. Probably resistance from affected landowners. Evacuation route likely to be used in very rare events only.
9	Voluntary program for retrofitting evacuation access for significantly affected high hazard properties	Council Support from OEH, consultants	Not costed at this stage	$0K	• Scoping study including consultation with landowners of affected properties, site constraints assessment. • The most affected properties have main habitable area on second storey. Elevated walkway could be installed to connect to street. • Potential financial assistance from Council, Govt grants etc. Seek and confirm sources of funding.	**Medium** – significantly improves accessibility for properties which become cut-off from flood-free streets in even frequent events. However, there are likely to be only a few properties eligible and

ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
						potentially low take-up by landowners.
10	Burns Road crossing flood safety improvements	Council, RMS	$10K initial review $5K flood depth indicator $30K additional street lighting/flashing signage and flood depth recorder $50K improved traffic barrier	Up to $5K p.a.	• Install flood depth indicator sign, improve street lighting at crossing and/or flashing light signage triggered by flood depth recorder • Review structural strength of existing informal traffic barrier to prevent vehicle wash-off. If inadequate, install more robust traffic barrier. • Could be undertaken as part of proposed Burns Road upgrade	**High** – would significantly improve flood safety at this highly trafficked crossing.
11	Flood safety improvements at other locations	Council	$5K per location, approx. 4 locations	$0K	• Install flood depth indicator sign at selected other road crossings. Tennyson Street, The Chase Road • Consider retrofitting of bollards etc. to help prevent vehicles being washed away in existing car parking areas affected by significant overland flows	**High** – low cost measure which improves flood safety at each location.

ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
12	Flood education and awareness program	Council, SES	$20K	Staff costs	Measures may include: • Promotion of FloodSafe brochures to help residents understand the flood risk and prepare their property and personal plans for a flooding event. • Flood signage in selected locations. • Section 149 certificates to inform property owners about flood risk to their properties. • Provide flood mapping on an interactive mapping portal on Council's website for easier viewing. Provide graphic on website showing catchments in Ku-ring-gai where studies have been completed. • Promotion and support for SES information events. • Enhanced messaging on flood risk in Ku-ring-gai on Council's floodplain management webpage. • The program should be reviewed on a regular (e.g. 2 yearly) basis.	**High** – community awareness is likely to significantly improve flood preparedness, reduce flood damages and reduce flood response and risk to people.
13	Flood management program for Knox Grammar School	Knox Grammar School, assistance from Council	$0K	$0K	• Council to engage School and advise on flood risk • School to determine need to update operational procedures i.e. development of flood management plan. • The plan is a short document that identifies the flood risk, nature of flooding etc. and outlines	**High** – need to communicate flood risks to significant stakeholder in the floodplain.

ID	Measures considered	Responsibility	Initial Cost	Ongoing Cost	Features of the Measure	Recommended Priority Rankings
					actions and protocols in the event of a flood e.g. do not shelter in lower sections of buildings in the low portions of school grounds during rising floodwaters if there are no internal evacuation routes. Also procedures for rounding up and accounting of students during flood events. • Note that the flood hazard is high only in events rarer than the 1% AEP.	
14	Replace existing boundary fencing on property upstream of Tennyson Road crossing	Council/ landowner	$1-2K	$0	• Replace existing pool-type boundary fencing on property upstream of Tennyson Road crossing with a design less likely to become dislodged in a flood and contribute to blockage of the Tennyson Road culvert. • Council to contact landowner for permission to replace fencing.	**High –** low cost option which would improve the risk of blockage of the hydraulic structure

11. References

- Australian Building Codes Board. (2013). Construction of Buildings in Flood Hazard Areas. Version 2012.1.
- Australian Institute of Disaster Resilience (2017a) Australian Disaster Resilience Handbook 7. Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia
- Australian Institute of Disaster Resilience (2017b) Guideline 7-3. Flood Hazard
- Australian National University (1992) ANUFLOOD: A Field Guide. Centre for Resource and Environmental Studies Engineers Australia (2016) Australian Rainfall and Runoff 2016
- Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2016, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia
- Frost, S. & Rice, M., 2003, 'Voluntary House Raising Program: the Fairfield Experience', Floodplain Management Authorities of NSW 43rd Annual Conference, Forbes.
- GHD (2018) Blackbutt Creek Floodplain Risk Management Study and Plan. prepared for Ku-ring-gai Council.
- Hawkesbury-Nepean Floodplain Management Steering Committee (2007) Reducing Vulnerability of Buildings to Flood Damage.
- Institution of Engineers, Australia (1987) Australian Rainfall and Runoff: A Guide to Flood Estimation , Vol. 1, Editor-in-chief D.H. Pilgrim, Revised Edition 1987 (Reprinted edition 1998), Barton, ACT
- Jacobs (2016) Lovers Jump Creek Flood Study.
- Jacobs (2018) Lovers Jump Creek Flood Study Review.
- Ku-ring-gai Council (2016) Ku-ring-gai Development Control Plan 2016
- McKay, G. 2004, 'Flash flood warning systems – Are they a waste of time?', in Staying Afloat: Floodplain Management Authorities of NSW 44th Annual Conference, May 11-14 2004, Coffs Harbour, pp.1-7.
- McKay, G. 2008, 'Guidelines for local flash flood warning system proposals', in Floodplain Management Authorities of NSW 48th Annual Conference, February 26-29 2008, Wollongong.
- Millener, D., Howley, D., Galloway, M. and Leszczynski, P. (2013) Flash Flood Warning System For Sydney's Northern Beaches, presented to the 53rd Floodplain Management Authorities Conference, 28-31 May, Tweed Heads, NSW.
- NSW Government (2005) Floodplain Development Manual, the management of flood liable land
- Office of Environment and Heritage (2013a) Floodplain Management Program Guidelines for Voluntary House Raising Schemes. Document OEH 2013/0056.
- Office of Environment and Heritage (2013b) Floodplain Management Program Guidelines for Voluntary Purchase Schemes. Document OEH 2013/0055.
- Office of Environment and Heritage (2016a) Flood Emergency Response Planning – Classification of Communities. Document OEH 2016/0736.
- Office of Environment and Heritage (2016b) Residential Flood Damage Guidelines. NSW Government. Document OEH 2016/0732.
- Queensland Government (2002) Guidance on the Assessment of Tangible Flood Damages. Department of Natural Resources and Mines
- Smith GP, Davey EK and Cox RJ (2014) Flood hazard, Technical report 2014/07, Water Research Laboratory, University of New South Wales, Sydney.
- Victorian Government (2002) Rapid-Appraisal Method (RAM) for Floodplain Management. Department of Natural Resources and Environment.

12. Glossary

Annual Exceedance Probability (AEP)

The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. In this study AEP has been used consistently to define the probability of occurrence of flooding. It is to be noted that design rainfalls used in the estimation of design floods up to and including 100 year ARI (ie. 1% AEP) events was derived from 1987 Australian Rainfall and Runoff. The following relationships between AEP and ARI applies to this study (AR&R, 2016).

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very frequent	**12**			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.50
Frequent	**1**	**63.2**	1.58	1.00
	0.69	**50.00**	2	1.44
	0.5	39.35	2.54	2.00
	0.22	**20.00**	5	4.48
	0.2	18.13	5.52	5.00
Infrequent	0.11	**10.00**	10.00	9.49
	0.05	**5.00**	20	20.0
	0.02	**2.00**	50	50.0
	0.01	**1.00**	**100**	100
Rare	0.005	0.50	**200**	200
	0.002	0.20	**500**	500
	0.001	0.10	**1000**	1000
Extremely Rare	0.0005	0.05	**2000**	2000
	0.0002	0.02	5000	5000
			↓	
Extreme			PMP	

Australian Height Datum (AHD)

A common national surface level datum approximately corresponding to mean sea level.

Average Annual Damage (AAD)

Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would

	occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrences of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
DRAINS	DRAINS is a computer program which is used to simulate local catchment rainfall-runoff and stormwater system hydraulics and is widely used across Australia.
Development	Is defined in Part 4 of the EP&A Act In fill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. New development: refers to development of a completely different nature to that associated with the former land use. Eg. The urban subdivision of an area previously used for rural purposes. New developments involve re-zoning and typically require major extensions of exiting urban services, such as roads, water supply, sewerage and electric power. Redevelopment: refers to rebuilding in an area. Eg. As urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either re-zoning or major extensions to urban services.
Effective Warning Time	The time available after receiving advise of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
Exceedances per Year (EY)	The number of times an event is likely to occur or be exceeded within any given year.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.

Flood liable land	Is synonymous with flood prone land (i.e.) land susceptibility to flooding by the PMF event. Note that the term flooding liable land covers the whole floodplain, not just that part below the FPL (see flood planning area)
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is flood prone land.
Floodplain risk management options	The measures that might be feasible for the management of particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
Floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually include both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defines objectives.
Flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the SES.
Flood planning levels (FPLs)	Are the combination of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "designated flood" or the “flood standard” used in earlier studies.
Flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings and structures subject to flooding, to reduce or eliminate flood damages.
Flood readiness	Readiness is an ability to react within the effective warning time.
Flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. Existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. Future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. Continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
Flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the

	severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
Hazard	A source of potential harm or situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community.
Local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
m AHD	Metres Australian Height Datum (AHD)
m/s	Metres per second. Unit used to describe the velocity of floodwaters.
m^3/s	Cubic metres per second or "cumecs". A unit of measurement of creek or river flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Modification measures	Measures that modify either the flood, the property or the response to flooding.
Overland flow path	The path that floodwaters can follow as they are conveyed towards the main flow channel or if they leave the confines of the main flow channel. Overland flow paths can occur through private property or along roads.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation couplet with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of

	consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall which ends up as a streamflow, also known as rainfall excess.
Stage	Equivalent to water level (both measured with reference to a specified datum)
TUFLOW	TUFLOW is a computer program which is used to simulate free-surface flow for flood and tidal wave propagation. It provides coupled 1D and 2D hydraulic solutions using a powerful and robust computation. The engine has seamless interfacing with GIS and is widely used across Australia.