5. FLOOD DAMAGE ASSESSMENT

5.1 FLOOD DAMAGES DATABASE

A flood damages database was assembled for the Macquarie Park study area. The database allows assessment of the potential impacts of flooding, including the number of buildings inundated. It also allows economic assessments of the existing flood problem and various flood mitigation measures.

Buildings were included in the initial damages database if the building footprint was located within a flood risk or overland flow precinct. This yielded 722 residential properties and 81 commercial properties. For building footprints located within the 100 year ARI flood extent derived from the Flood Study, Warren Cole (Registered Surveyor) was engaged to survey floor levels. For these buildings within the 100 year flood extent and where access permitted, the surveyor provided the information listed in **Table 5.1**.

TABLE 5.1 – INFORMATION PROVIDED BY SURVEYOR

	Residential	**Commercial**
Geographic coordinates of the surveyed points (MGA 94)	Yes	Yes
Building floor level	Yes (lowest habitable floor)	Yes (main shop floor)
Ground level	Yes (adjacent to building)	No
Garage level	Yes (where applicable)	No
Specific land use	Yes (house, townhouse, unit, villa, etc)	Yes (name and type of business)
Building description	Yes (wall type, floor type, number of habitable stories, number of ground floor units)	Yes (number of stories within single premises)
Photograph	Yes	Yes

For buildings without surveyed information, levels were estimated using the Digital Elevation Model (DEM) developed for the Flood Study, based on ALS survey flown in 2007. Ground levels were extracted at a point near the building. Floor levels were estimated by adding an assumed ‘height above ground’ to each ground level estimate. Some floor levels (including all residential units and commercial buildings) were estimated by direct observation or with reference to Google Street View. For the remainder, a floor height of 0.5m was assumed.

If not surveyed, dwelling types (house, townhouse, unit, villa) were estimated with reference to GIS layers (aerial photography, cadastre, zoning) and Google Street View. If not surveyed, the type of business was estimated with reference to Google Street View and internet searches based on the address.

Flood surfaces for the 5 year, 20 year, 50 year and 100 year ARI floods and the PMF were used to extract flood levels for each building in the database.

Table 5.2 summarises the attributes and sources of information included in the Macquarie Park catchment flood damages database.

A copy of the flood damages database is included in **Appendix A**.

TABLE 5.2 – ATTRIBUTES RECORDED IN FLOOD DAMAGES DATABASE

Attribute	**Comment/Source**
Catchment	One of five Macquarie Park catchments. ('Mars' includes Culloden, Mars and University Creeks).
Land use	Residential or commercial/other land use.
PIN (UDN_CD5)	Council's unique identifier for each property.
Address	Council.
Building description	Warren Cole, Registered Surveyor. Some estimated.
Residential type	Warren Cole, Registered Surveyor, February-April 2010. Some estimated from Google Street View.
Residential code	Refers to the categories used for residential flood damage calculation (DECC, 2007).
Commercial type/name	Warren Cole, Registered Surveyor, February-April 2010. Some estimated from Google Street View.
Commercial code	Refers to categories used for commercial damage calculation (Bewsher Consulting).
Comment	Various sources.
Ground level and source	Surveyed levels from Warren Cole, Registered Surveyor (garage level preferred where available). Estimated levels from DEM derived from ALS survey flown 2007.
Floor level and source	Surveyed levels from Warren Cole, Registered Surveyor. Estimated levels derived by adding assumed floor heights to DEM.
Existing design flood levels (5, 20, 50, 100 year, PMF)	From the *Macquarie Park Flood Study*.

5.2 TYPES OF FLOOD DAMAGE

The definitions and methodology used in estimating flood damages are well established. **Figure 5.1** summarises all the types of flood damages considered in this study. The two main categories are 'tangible' and 'intangible' damages. Tangible flood damages are those that can be more readily evaluated in monetary terms. Intangible damages relate to the social cost of flooding and therefore are much more difficult to quantify.

Tangible flood damages are divided further into direct and indirect damages. Direct flood damages relate to the loss or loss in value of an object or a piece of property caused by direct contact with floodwaters, flood-borne debris or sediment deposited by the flood. Indirect flood damages relate to loss in production or revenue, loss of wages, additional accommodation and living expenses, and any extra outlays that occur because of the flood.

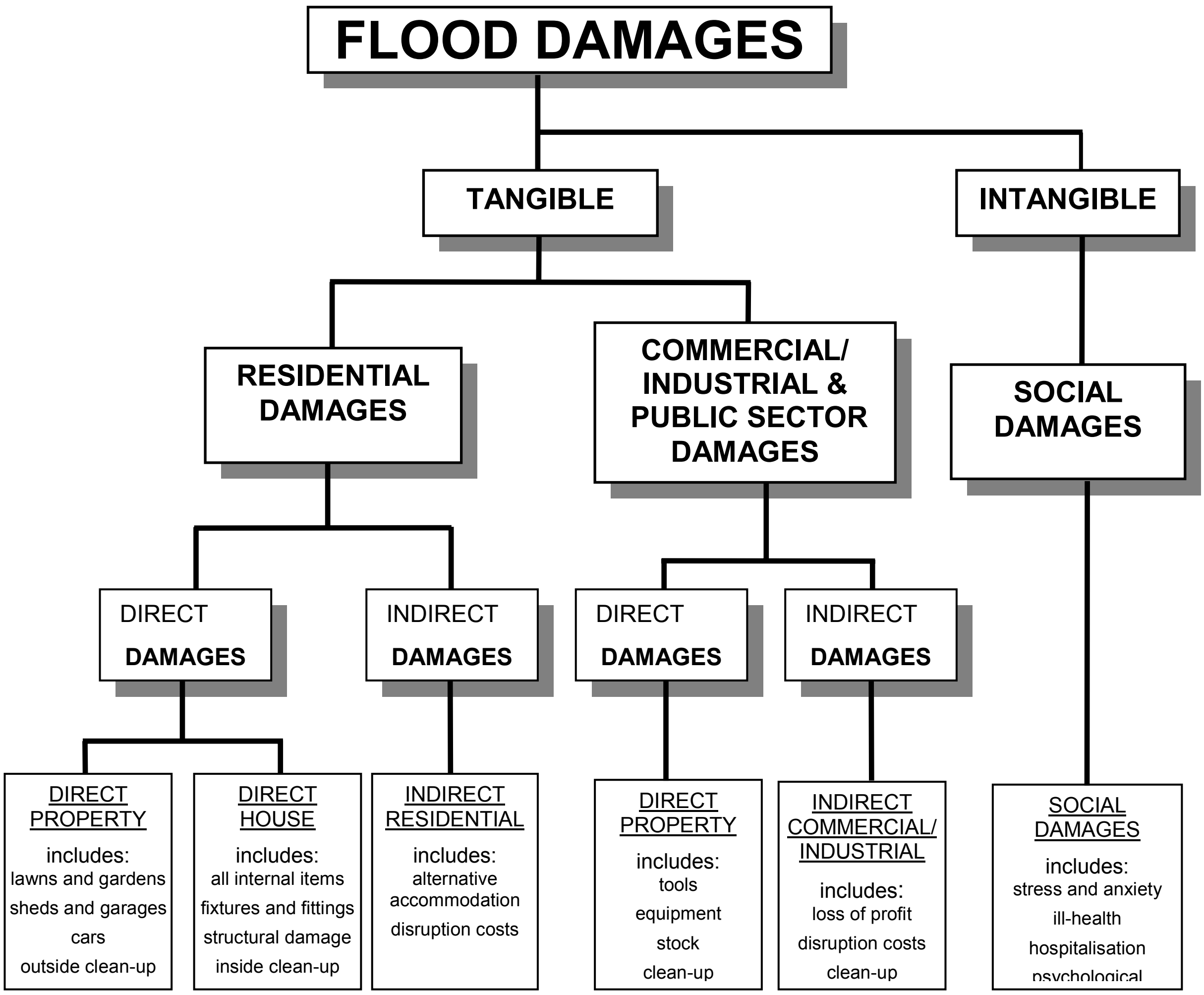

FIGURE 5.1 – TYPES OF FLOOD DAMAGE

5.3 BASIS OF FLOOD DAMAGES CALCULATIONS

Flood damages have been calculated by applying one of several stage-damage curves to every property included in the database. These curves relate the amount of flood damage that would potentially occur at different depths of inundation, for a particular property type, whether residential or commercial/industrial.

5.3.1 Residential

DECC's (2007) *Residential Flood Damages* Floodplain Risk Management Guideline is the key reference for assessing residential flood damages in NSW. This provides a standard method for deriving site-specific residential stage-damage curves. **Appendix B** shows inputs into the Macquarie Park stage-damage curve, together with the resultant outputs. Changes in Average Weekly Earnings (AWE) were used as a basis for escalating residential damages to current values.[2] An average house size of $240m^2$ was adopted. Flood warning times are short (estimated 0.5 hour) and the level of awareness was set at low. It is noted that the residential stage-damage curves make allowance for both clean-up costs and the cost of time in alternative accommodation. Nevertheless, a further measure of indirect damages was estimated by taking 20% of the direct damages, in keeping with advice from DECCW.

DECC's Guideline provides stage-damage for three categories of dwellings: low-set single storey, high-set single storey (where floor heights are at least 1.5m providing for storage underneath) or two storey. The dwellings in the database were coded according to these categories based on information from the building survey, or otherwise assumed to be low-set single storey. Damages for units were set at 75% of the high-set single storey damages (allowing for a smaller size and for a typical arrangement where there is a low-set garage/ storage space), and damages for townhouses were set at 75% of the two storey damages (allowing for a smaller size). If not surveyed, the number of ground-floor units was estimated using information about the number of units in the property (provided by Council) and photography (to estimate the number of storeys).

5.3.2 Commercial

No standard stage-damage curves have been issued for *commercial* and *industrial* damages. The stage-damage relationships used to estimate these damages in this study are based on a collation of information from investigations following floods in Sydney (1986), Bathurst (1986), Nyngan (1990), Forbes (1990), Inverell (1991) and Coffs Harbour (1996). Actual losses were estimated by applying a ratio of actual to potential damages of 0.98, consistent with the damage reduction factor applied to the residential sector. Indirect commercial/industrial losses were estimated as 20% of direct actual commercial/industrial damages, in accordance with advice received from DECCW.

5.3.3 Building Failure

An allowance is made in the DECC (2007) stage-damage data for structural damage but not for actual building failure. Middleman-Fernandes (2010) demonstrated that where buildings fail, stage-damage functions underestimate loss. Given the modest depths and velocities typically associated with overland flow, no allowance is included for building failure.

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[2] AWE ('Earnings; Persons; Total earnings') for February 2010 was 973.80 (ABS, 2010), yielding a ratio of 1.45 when compared to the base data from November 2001.

5.3.4 Infrastructure

In accordance with advice received from DECCW, the actual value of damage to infrastructure (including roads and bridges, water supply and sewerage, electricity and telephone supplies, natural gas supplies) was estimated at 15% of the 'total damages'. No allowance was made for possible damage reduction in response to flood warnings.

5.3.5 Motor Vehicles

Data from the Australian Bureau of Statistics indicate a motor vehicle ownership rate of 1.4 per household in Ryde LGA. Not all cars will be present during working hours, but others will commute to the study area. Cars were assumed to be located at the garage level or ground level as the residences with which they are associated.

Based on insurance data from the Katherine flood (Jan 1998), Wollongong flood (Aug 1998) and Canberra bushfire (Jan 2003), it is assumed that the average cost of a written-off motor vehicle is in the order of $12,000. Damage is expected to begin at a depth over the ground of 0.3m, and a write-off is assumed to occur at a depth of 0.6m over the ground. For consistency with other components of the damages assessment, the same damage reduction factor of 99% was applied in estimating actual motor vehicle damages.

5.3.6 Social

Intangible, or social, flood damages are not readily quantifiable in monetary terms. Physical contact with floodwaters can cause residents to suffer physical and mental impacts to their health. Evacuation, the loss of personal property and cleaning up can trigger significant stress and trauma. While difficult to quantify, in keeping with advice received from DECCW, social damages were estimated as 25% of 'total damages', which are interpreted as the sum of direct residential damages and direct commercial/industrial damages.

5.4 ECONOMIC ANALYSIS

An economic appraisal is required for all proposed capital works in NSW, including flood mitigation measures, in order to attract funding from the State Government's Capital Works Program. The NSW Government has published two Treasury Policy Papers to guide this process: *NSW Guidelines for Economic Appraisal* (NSW Treasury, 2007) and a summary in *Economic Appraisal Principles and Procedures Simplified* (NSW Treasury, 2007).

An economic appraisal is a systematic means of analysing all the costs and benefits of a variety of proposals. In terms of flood mitigation measures, benefits of a proposal are generally quantified as 'the avoided costs associated with flood damages'. The avoided costs of flood damage are then compared to the capital (and on-going) costs of a particular proposal in the economic appraisal process.

Average annual damage (AAD) is a measure of the cost of flood damage that could be expected each year by the community, on average. It is a convenient yardstick to compare the economic benefits of various proposed mitigation measures with each other and the existing situation.

The 'present value' of flood damage is the sum of all future flood damages that can be expected over a fixed period (usually 20 years) expressed as a cost in today's value. The present value is determined by discounting the future flood damage costs back to the present day situation, using a discount rate of 7%.

A flood mitigation proposal may be considered to be potentially worthwhile if the benefit–cost ratio (the present value of benefits divided by the present value of costs) is greater than 1.0. In other words, the present value of benefits (in terms of flood damage avoided) exceeds the present value of (capital and on-going) costs of the project.

However, whilst this direct economic analysis is important, it is not unusual to proceed with urban flood mitigation schemes largely on social grounds, that is, on the basis of the reduction of intangible costs and social and community disruption. In other words, the benefit–cost ratio could be calculated to be less than 1.0.

Net present value is a useful tool to complement the benefit–cost ratio in the economic appraisal process. A flood mitigation proposal may be considered to be potentially worthwhile if the net present value (the present value of benefits minus the present value of capital and on-going costs) is greater than zero.

5.5 SUMMARY OF INUNDATION PATTERNS

A summary of the predicted number of buildings in the Macquarie Park study area inundated above floor level in each design event is provided in **Table 5.3**. The distribution of these buildings according to catchment is summarised in **Table 5.4** and shown in **Figure 5.2**. An indication of flood depths in the 100 year ARI event is provided in **Table 5.5** and **Table 5.6**.

Key results are:

- 101 dwellings would be inundated above floor level in the 100 year ARI event, though about a quarter of these buildings are located in overland flow precincts, and more than half are expected to be inundated to only shallow depths (<0.2m);
- Most flood-prone houses are located in the large Shrimptons Creek catchment;
- 27 commercial/industrial buildings would be inundated above floor level in the 100 year ARI event, with most situated in the Porters Creek catchment, and 30% inundated to depths exceeding 1.0m;
- Potential building inundation 'hot-spots' identified from **Figure 5.2** include:

  Mars Creek catchment:
  - Culloden Creek flow path downstream of Waterloo Park;
  - University Creek flow path downstream of Dunbar Park;
  - University Creek flow path downstream of Talavera Road;

  Shrimptons Creek catchment:
  - Flow path through Doig Avenue, Denistone East;
  - Flow path through Birdwood Street/Cecil Street/Macquarie Place/North Road;
  - Flow path through Quarry Road/Rocca Street, Ryde;
  - Flow path through Danbury Close/Herring Road/Lucinda Road, Marsfield;
  - Flow path through Eastview Avenue, North Ryde;

  Industrial Creek catchment:
  - Flow path upstream of Epping Road on-ramp, North Ryde;

  Porters Creek catchment:
  - Flow path through Avon Road/Wicks Road, North Ryde;
  - Flow path through Avon Road shops, North Ryde;
  - Flow path upstream of Epping Road, North Ryde;

  Lane Cove catchment:
  - Lane Cove River flow path along River Avenue, Chatswood West.

TABLE 5.3 – BUILDINGS INUNDATED BY DESIGN EVENT AND STYLE OF INUNDATION

Flood ARI	Overland Flow Precinct			Floodplain			TOTAL		
	Res.	Comm.	Total	Res.	Comm.	Total	Res.	Comm.	Total
5 year	23	4	27	33	10	43	56	14	**70**
20 year	27	4	31	56	17	73	83	21	**104**
50 year	27	5	32	69	19	88	96	24	**120**
100 year	27	5	32	74	22	95	101	27	**127**
PMF	72	9	81	309	52	360	381	61	**441**

TABLE 5.4 – BUILDINGS INUNDATED BY CATCHMENT

Catchment	**Residential**					**Commercial/industrial**				
	5 year	20 year	50 year	100 year	PMF	5 year	20 year	50 year	100 year	PMF
Mars*	4	6	6	6	36	0	1	3	4	9
Shrimptons	24	42	52	55	227	2	7	7	8	22
Industrial	12	15	15	15	26	0	0	0	1	7
Porters	12	16	19	21	64	8	9	10	10	18
Lane Cove	4	4	4	4	28	4	4	4	4	5
TOTAL	**56**	**83**	**96**	**101**	**381**	**14**	**21**	**24**	**27**	**61**

* Includes Culloden, Mars and University Creeks

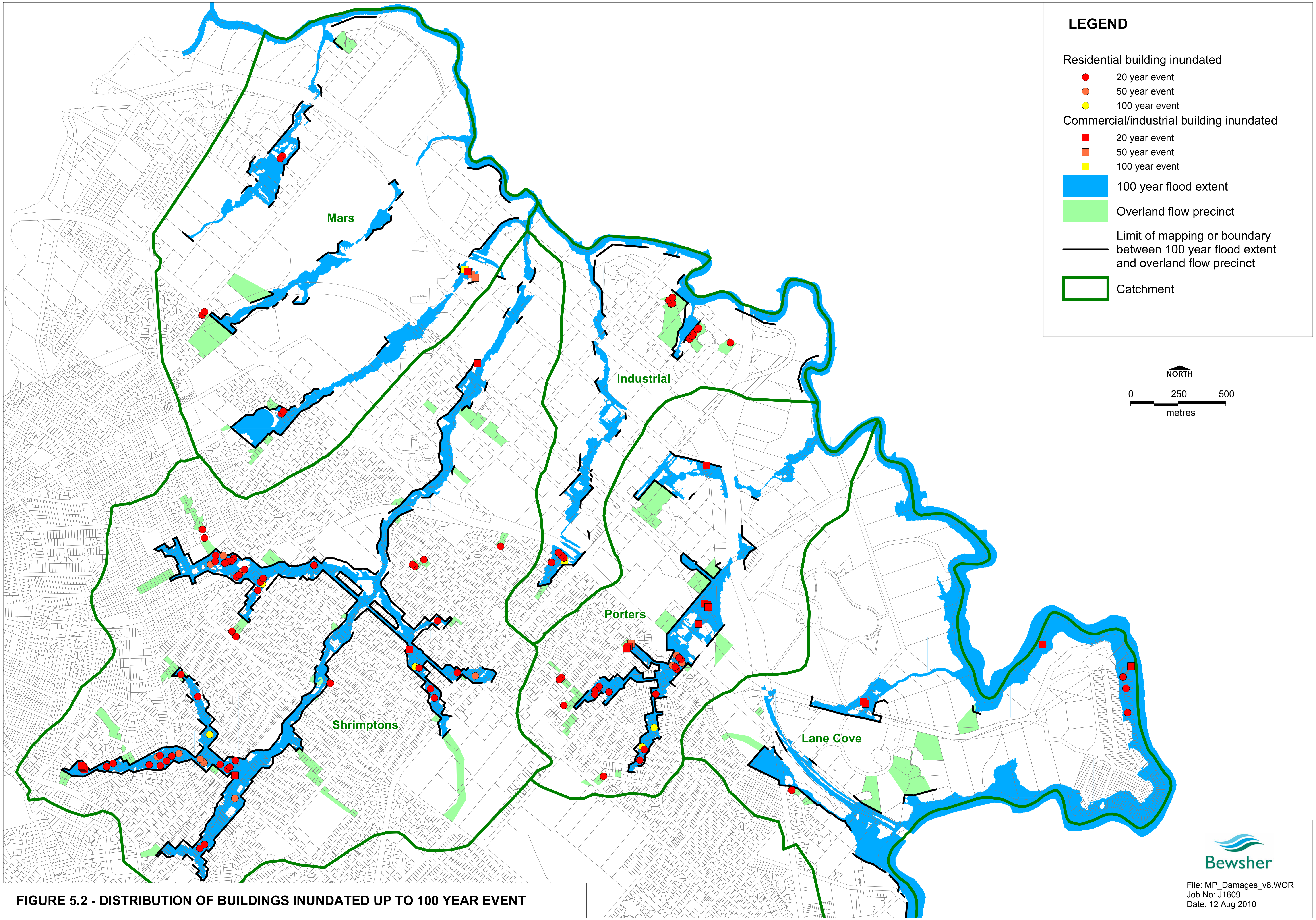

FIGURE 5.2 - DISTRIBUTION OF BUILDINGS INUNDATED UP TO 100 YEAR EVENT

TABLE 5.5 – INUNDATION DEPTHS FOR RESIDENTIAL BUILDINGS AFFECTED BY THE 100 YEAR FLOOD

Catchment	Below Floor Flooding (Number of Buildings)		Above Floor Flooding (Number of Buildings)				
	-0.5 to -0.2	-0.2 to 0.0	0.0 to 0.2	0.2 to 0.5	0.5 to 1.0	> 1.0m	TOTAL
Mars*	23	7	1	4	1	0	6
Shrimptons	102	61	35	16	4	0	55
Industrial	23	10	7	3	5	0	15
Porters	33	17	9	8	4	0	21
Lane Cove	10	0	0	1	0	3	4
TOTAL	**191**	**95**	**52**	**32**	**14**	**3**	**101**

* Includes Culloden, Mars and University Creeks

TABLE 5.6 – INUNDATION DEPTHS FOR COMMERCIAL & INDUSTRIAL BUILDINGS AFFECTED BY THE 100 YEAR FLOOD

Catchment	Below Floor Flooding (Number of Buildings)		Above Floor Flooding (Number of Buildings)				
	-0.5 to -0.2	-0.2 to 0.0	0.0 to 0.2	0.2 to 0.5	0.5 to 1.0	> 1.0m	TOTAL
Mars*	0	2	1	3	0	0	4
Shrimptons	3	11	6	1	1	0	8
Industrial	0	2	1	0	0	0	1
Porters	1	3	4	2	0	4	10
Lane Cove	2	2	0	0	0	4	4
TOTAL	**6**	**20**	**12**	**6**	**1**	**8**	**27**

* Includes Culloden, Mars and University Creeks

Garages are typically lower-lying than the main floor level of a dwelling, so inundation of garages in a given event would be more prevalent. This was the pattern recorded from historical flooding (**Section 2.2**).

Several significant roads are also inundated, as shown in **Table 5.7**. This points to the likelihood of significant disruption and a threat to inexperienced motorists during flood events. Road closures, however brief, also isolate people from the emergency services.

TABLE 5.7 – 100 YEAR INUNDATION DEPTHS AT MAJOR ROADS

Catchment	Road	Location	Max. 100 year flood depth over road
Mars*	Waterloo Road	Culloden Creek	0.9m (centre)
Mars*	Taranto Road	Culloden Creek	1.0m (centre)
Mars*	Epping Road	Mars Creek	0.7-1.0m (westbound) 0.4-0.5m (eastbound)
Mars*	Talavera Road	Mars Creek	0.4m (centre)
Mars*	Epping Road	University Creek	0.6-0.9m (westbound) 0.3-0.4m (eastbound)
Mars*	Talavera Road	University Creek	0.5m (centre)
Shrimptons	Lane Cove Road	Below North Ryde Golf Club	0.4-0.8m (southbound) 0.1-0.3m (northbound)
Shrimptons	Waterloo Road	Upslope of Macquarie Centre	0.8m (westbound) 0.7m (eastbound)
Porters	Epping Road	Upslope of 'Officeworks'	0.6-1.3m (westbound) 0.4-0.8m (eastbound)
Lane Cove	Pittwater Road	Sag point 80m north of Clarence Street intersection	0.9m (northbound) 1.0m (southbound)
Lane Cove	Delhi Road	Lane Cove River at Fullers Bridge approach	1.5m
Lane Cove	River Avenue	Sag point near No. 11 River Avenue	3.1m (centre)

* Includes Culloden, Mars and University Creeks

5.6 SUMMARY OF CALCULATED DAMAGES

Calculated flood damages are reported in **Table 5.8** and **Figure 5.3**, with a breakdown of the components contributing to average annual damages shown in **Table 5.9**.

Key results are:

- A 20 year ARI flood is expected to cause damages of $20.4 million;
- A 100 year ARI flood is expected to cause damages of $31.6 million;
- The annual average damage within the study area is about $3.9 million, which is a measure of the cost of flood damage that could be expected each year, on average, by the community;
- The present value of damages within the study area is about $41.1 million, which represents the maximum sum that could be spent on flood mitigation measures if an economic benefit/cost ratio of 1.0 is required and all flood damages can be avoided.
- The highest average annual damages are predicted in the Porters Creek and Shrimptons Creek catchment. Although fewer buildings are expected to be inundated in the former (**Table 5.4**), Porters Creek catchment contains several large commercial buildings which are predicted to flood in frequent floods (**Table 5.4**) and to depths of more than 1.0m in the 100 year flood (**Table 5.6**).
- The highest damage costs throughout the study area are sustained by the residential sector (direct and indirect damages total 45%). However, the commercial sector is also highly exposed to inundation (direct and indirect damages total 30%). Whilst relatively few commercial buildings are predicted to be inundated in flooding (**Table 5.4**), many of these are large buildings where even shallow flooding could cause high damage.

TABLE 5.8 – PREDICTED TOTAL FLOOD DAMAGES UNDER EXISTING CONDITIONS
Note: Excluding motor vehicles

Catchment	Damage in Flood Event ($M)					Average Annual Damage ($M)#	Present Value of Damage ($M)#
	5 year	20 year	50 year	100 year	PMF		
Mars*	0.5	0.8	1.0	1.2	4.5	0.2	1.8
Shrimptons	3.5	6.0	7.3	7.7	29.5	1.2	12.3
Industrial	1.1	2.8	2.9	3.0	5.0	0.5	4.8
Porters	3.9	8.4	10.8	16.3	30.2	1.6	16.7
Lane Cove	1.7	2.4	2.8	3.3	15.3	0.5	5.4
TOTAL	**10.8**	**20.4**	**24.8**	**31.6**	**84.5**	**3.9**	**41.1**

* Includes Culloden, Mars and University Creeks
# Based on treasury guidelines of a 7% discount rate and expected life of 20 years

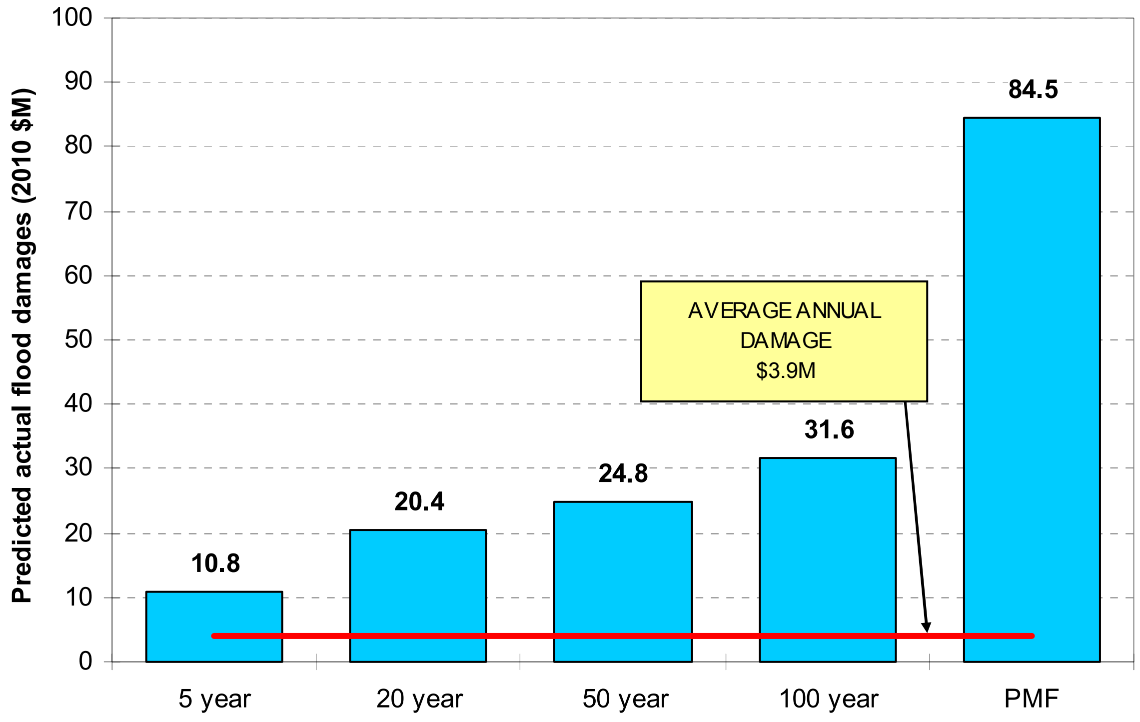

FIGURE 5.3 – ESTIMATED FLOOD DAMAGES BY DESIGN EVENT

TABLE 5.9 – COMPONENTS OF FLOOD DAMAGE FOR THE MACQUARIE PARK STUDY AREA (AAD)

	Damage Component	Method Assessed	Cost ($2010)	
A.	Direct Residential Dwelling Damage	DECCW curves	$730,000	19%
B.	Direct Residential Property Damage	DECCW curves	$720,000	19%
C.	Indirect Residential Damage	20% of (A + B)	$290,000	7%
D.	Direct Commercial Damage	BC curves	$970,000	25%
E.	Indirect Commercial Damage	20% of D	$190,000	5%
F.	Infrastructure Damage	15% of (A + B + D)	$370,000	10%
G.	Social Damage	25% of (A + B + D)	$610,000	16%
	TOTAL		**$3,920,000**	100%

H.	Residential Area Vehicle Damage	BC curves	$610,000

6. EVALUATION OF FLOODPLAIN MANAGEMENT MEASURES

Floodplain management measures can be divided into three general groups:

1) those that modify flood behaviour;
2) those that modify property in order to minimise flood damage; and
3) those that modify people's response to flooding.

Measures that modify flood behaviour usually include structural works that attempt to lower flood levels, or to divert floodwaters away from areas that would otherwise flood. These type of measures are often favoured by the community, especially the clearing of creeks.

Measures that modify property in order to minimise flood damage include voluntary house purchase, voluntary house raising or house reconstruction, 'flood-proofing' and controls on new development.

Measures that modify people's response to flooding include measures that provide additional warning of flooding, improve emergency management planning and improve public awareness of the flood risk.

A range of assessment criteria have been used for evaluating potential floodplain management measures within the study area. These are described below. A qualitative assessment has been undertaken for each floodplain risk management option according to these criteria. **Table 6.1** provides the scores used for each criterion for this qualitative assessment.

- **Number of buildings protected in the 100 year flood**

  A prime indicator of the effectiveness of a measure in reducing the potential for flood damage and the risk to life is the reduction in the number of buildings that are affected by significant floods.

- **Financial feasibility**

  Measures proposed within the FRMP must be capable of being funded. There are various sources of funding that may be utilised, including funding related to the development of new release areas (Section 94 Contributions) and funding from Council, with assistance from the Government's Floodplain Management Program administered by DECCW, for the alleviation of existing flood problems.

- **Economic merit**

  The ratio of the benefit divided by the cost (i.e. the benefit/cost ratio) is a common measure of assessing economic feasibility. Theoretically, no investment should be made on a measure if the benefit/cost ratio does not exceed one (i.e. if the benefits do not exceed the costs). However, traditionally many floodplain risk management measures have been undertaken where this is not the case because the intangible benefits (i.e. social benefits and reduced risks to life, which are not readily quantified) are considerable. Benefit/cost ratios can also be useful in ranking competing options.

- **Community acceptance**

  An understanding of community attitudes towards any proposed floodplain management measures is essential. Strongly negative community attitudes often would be enough to deter the implementation of a proposal which otherwise had merit. Community views on potential floodplain management measures were assessed early in the study through distribution of the community questionnaire. These results were discussed in **Section 3.3**. Further opportunity for comment was provided during public exhibition of the draft Macquarie Park FRMP (**Section 3.6**).

- **Environmental impact**

  Floodplain management measures involving structural works may often have significant environmental impacts. Impacts such as those on vegetation, Aboriginal heritage, visual amenity and soil erosion/sedimentation must be considered when evaluating works within floodplains.

- **Impact on flood behaviour**

  The impact on flood behaviour caused by any measure needs to be considered for upstream and downstream locations. These impacts can include changes in flood levels, changes in velocities or alteration of flow directions. Reducing impacts in one location can lead to adverse impacts elsewhere (e.g. clearing riparian vegetation in upper catchment areas or filling significant flood storage areas is – in the absence of compensatory measures – expected to increase downstream flows).

- **Performance during rare floods**

  All measures must be assessed in the knowledge that rare floods, i.e. higher than the 100 year flood, or higher than any known historical flood, will happen at some time in the future. It is vital that the options do not expose the community to unacceptable risks by providing a false sense of security.

- **Technical feasibility**

  If the proposed measures involve structural works, these works must be able to be constructed and be free from major technical constraints.

- **Political/administrative feasibility**

  Any recommended measure will have more chance of success if it involves little if any disruption to current political and administrative structures, attitudes and responsibilities. Council and other authorities also have various strategic objectives concerning development within the study area.

Potential floodplain management measures for the study area are discussed below. Each measure is included in a qualitative assessment matrix (**Table 6.2**) to assess its relative merits, thereby determining whether it should be included in the Macquarie Park FRMP.

TABLE 6.1 – EXPLANATION OF ASSESSMENT SCORES FOR QUALITATIVE ASSESSMENT MATRIX

CRITERIA	RANKING SCORE				
	– –	–	Ω	+	+ +
REDUCTION IN NUMBER OF HOUSES FLOODED ABOVE FLOOR LEVEL IN 1% AEP FLOOD	number of houses flooded above floor in 1% AEP flood would increase	number of houses flooded above floor in 1% AEP flood could increase	no existing houses protected from over-floor flooding in 1% AEP flood	1 or 2 existing houses protected from over-floor flooding in 1% AEP flood	more than 2 existing houses protected from over-floor flooding in 1% AEP flood
FINANCIAL FEASIBILITY	Very unlikely to receive funding	May not receive funding	Neutral	Would possibly receive funding	Very likely to receive funding
ECONOMIC MERIT	Benefit–Cost Ratio less than 0.1	Benefit–Cost Ratio = 0.1–0.3	Benefit–Cost Ratio = 0.3–0.7	Benefit–Cost Ratio = 0.7–1.0	Benefit–Cost Ratio greater than 1.0
COMMUNITY ACCEPTANCE	Strongly against	Not supported	Neutral	Supported	Strongly supported
ENVIRONMENTAL IMPACT AND ECOLOGICAL ENHANCEMENT	Significant negative environmental impact	Some negative environmental impact	No environmental impact and no opportunity for ecological enhancement	Some opportunity for ecological enhancement	Significant opportunity for ecological enhancement
IMPACT ON FLOOD BEHAVIOUR	Significantly increase flood levels and/or velocities	Some increase in flood levels and/or velocities	No change	Some reduction in flood levels and/or velocities	Significantly reduces flood levels and/or velocities
CONSEQUENCES IN EXTREME FLOODS	Significantly increases risk	Some increase in risk	No change in risk	Some reduction in risk	Significant reduction in risk
TECHNICAL FEASIBILITY	Very difficult	Difficult	Neutral	Easy	Very easy and straight forward
POLITICAL/ ADMINISTRATIVE / LEGAL IMPACT	Significant changes required which are very unlikely to be supported	Some changes required which may not be supported	No changes or impact	Some changes required are likely to be supported	Significant changes required which are likely to be strongly supported

TABLE 6.2 – QUALITATIVE MATRIX ASSESSMENT OF FLOODPLAIN RISK MANAGEMENT OPTIONS
Note: Decisive factors for recommending or not recommending an option are highlighted in tan

MEASURE NO.^	OPTION	DETAILS	REDUCTION OF DWELLINGS FLOODED ABOVE FLOOR LEVEL IN 1% AEP FLOOD		FINANCIAL FEASIBILITY		ECONOMIC MERIT		COMMUNITY ACCEPTANCE	ENVIRON-MENTAL IMPACTS AND ECOLOGICAL ENHANCE-MENTS	IMPACTS ON FLOOD BEHAVIOUR	CONSE-QUENCES IN EXTREME FLOODS	TECHNICAL FEASIB-ILITY OR DIFFICULTY	ADMINIS-TRATIVE / POLITICAL / LEGAL IMPACTS	RECOMMENDED FOR FURTHER CONSIDERATION
				NO. DWELLINGS		CAPITAL COST		BENEFIT–COST RATIO							
1	**CULLODEN CREEK CATCHMENT**														
1.1	Marsfield Park detention basin		Ω	0	+	N/a*	–	Low	?	– –	Ω	Ω	–	–	No
1.2	Improve Waterloo Road drainage	Lower downslope ground levels adjacent to the Waterloo Road sag point	Ω	0	++	$70K	+	>1.0#	+	Ω	+	Ω	+	–	Yes
1.3	Waterloo Park detention basin		++	4	+	$350K	+	0.7	?	Ω	+	Ω	+	–	Yes
2	**MARS CREEK CATCHMENT**														
2.1	Culloden Road (west) overland flow works	Raise level of road verge and driveways or use speed hump to direct flow away	+	2	+	N/a*	+	High	?	Ω	+/– Locally worse	Ω	– –	–	No
2.2a	Improve Epping Road drainage	Drainage upgrade	Ω	0	–	$1.0-1.5M	–	N/a#	+	Ω	+	Ω	–	Ω	No
2.2b		Lower median strip and downslope verge	Ω	0	+	$160K	+	>1.0#	+	Ω	+	Ω	+	Ω	Yes
2.3	Improve Talavera Road drainage	Drainage upgrade	Ω	0	Ω	$450K	–	Medium	+	Ω	+	Ω	–	Ω	Yes
3	**UNIVERSITY CREEK CATCHMENT**														
3.1	Dunbar Park basin enhancements	Raise basin wall etc	+	max. 2	–	N/a*	–	Low	?	Ω	+	Ω	–	–	No (i)
3.2a	Improve Epping Road drainage	Drainage upgrade	Ω	0	–	$2.5-3.0M	–	Low	+	Ω	+	Ω	–	Ω	No
3.2b		Lower median strip	Ω	0	+	$110K	+	>1.0#	+	Ω	+	Ω	+	Ω	Yes
3.3a	Improve Talavera Road drainage	Drainage upgrade	Ω	0 (4 shops)	–	$2.0-2.5M	–	Low	+	Ω	+	Ω	–	Ω	No
3.3b		Study to assess feasibility of Increasing detention basin storage upstream of Talavera Road	Ω	0	+	$40K	+	>1.0#	+	Ω	Ω	Ω	+	Ω	Yes (study)
3.4	Improve M2 drainage	Extend M2 culvert; replace upstream existing gabion/rock mattress-lined channel with larger concrete channel	For reference only (see AECOM Australia, 2010).												
4	**SHRIMPTONS CREEK CATCHMENT**														
4.1	Granny Smith Memorial Park detention basin		Ω	0	+	N/a*	–	Low	?	Ω	+	Ω	+	Ω	No
4.2a	Danbury Close/ Herring Road area works	Drainage upgrade from Danbury Close to Herring Road	++	≤ 8	–	$2.0-2.5M	Ω	0.4	+	Ω	+/– Possibly worse d/s	Ω	–	Ω	No
4.2b		Overland flow works incl. VP of one property	++	≤ 12	+	~$1.2M	++	1.1	?	Ω	+/– Possibly worse d/s	+	+	–	Yes (study first)
4.3a	Mason Street detention basin	Close Gallard Street at Jackson Crescent and construct wall across Gallard Street and around reserve	Ω	0 (4 shops)	+	$130K	–	0.2	–	Ω	+	Ω	+	–	No
4.5	Rocca Street overland flow path	Create overland flow path from Rocca Street to Santa Rosa Park; includes VP of one property	+	2	Ω	~$1.0M	Ω	0.4	– –	Ω	++	+	+	–	Yes (study first)
4.6	Heath Street/ Stephen Avenue works	Drainage upgrade or formalisation of overland flow path and lowering Quarry Road	+	1	–	N/a*	–	Low	?	Ω	+/– Worse on Quarry Rd	Ω	–	–	No
4.7a	Santa Rosa Park works	Remove 100m of trunk conduit and restore to open channel	Ω	0	Ω	$500-$600K	–	Low	?	+	+	Ω	–	–	No
4.7b		Overland flow path scheme including walls/mounds	Ω	0	+	$250K	+	>1.0#	?	Ω	++	Ω	+	–	Yes
4.8	Smalls Road detention basin		Ω	0	+	N/a*	–	Low	?	Ω	+	Ω	+	–	No
4.9	Fawcett Street overland flow path	VP one property and create overland flow path	Ω	0	–	~$800K	– –	Very low	?	Ω	+	Ω	+	–	No
4.10	Brendon Street sag point works	Construct dwarf wall at front of Nos. 13 and 15 Brendon Street	+	1	++	$35K	++	6.4	?	Ω	+	+	+	–	Yes
4.11	Ford Street overland flow path	VP one property and create overland flow path	Ω	0	–	~$800K	– –	Very low	?	Ω	+	Ω	+	–	No

MEASURE NO.^	OPTION	DETAILS	REDUCTION OF DWELLINGS FLOODED ABOVE FLOOR LEVEL IN 1% AEP FLOOD		FINANCIAL FEASIBILITY		ECONOMIC MERIT		COMMUNITY ACCEPTANCE	ENVIRON-MENTAL IMPACTS AND ECOLOGICAL ENHANCE-MENTS	IMPACTS ON FLOOD BEHAVIOUR	CONSE-QUENCES IN EXTREME FLOODS	TECHNICAL FEASIB-ILITY OR DIFFICULTY	ADMINIS-TRATIVE / POLITICAL / LEGAL IMPACTS	RECOMMENDED FOR FURTHER CONSIDERATION
				NO. DWELLINGS		CAPITAL COST		BENEFIT-COST RATIO							
4.12	North Ryde Golf Club detention basin		Ω	0 (3 in 20y)	+	$130K	++	2.7	+	Ω	++	Ω	+	–	Yes
4.13	Shrimptons Creek rehabilitation		Ω	0	+	Funded separately	+	>1.0#	++	++	+	Ω	+	+	Yes
4.14	Parklands Road overland flow path	VP one property and create overland flow path	Ω	0	–	~$800K	– –	Very low	?	Ω	+	Ω	+	–	No
4.15	Peachtree Road overland flow path	Construct 200m long blockwork wall along rear boundary of units	Ω	0	+	$160K	+	>1.0#	+	Ω	+	+	+	–	Yes
4.16a	Macquarie Shopping Centre	'Daylight' creek i.e. remove culvert covers and inner walls	Ω	0	–	~$300K	–	Low	?	++	+	–	–	– –	No
4.16b		Provide increased conduit capacity during redevelopment (various options)	Ω	0 (1 shop)	+	Funded as redeveloped	–	Low#	–	Ω	++	+	– –	Ω	Yes
4.16c		Debris control structure upstream of culvert opening	Ω	0	+	$100K	+	>1.0#	+	Ω	+/– ?	+	+	–	Yes (study first)
5	**INDUSTRIAL CREEK CATCHMENT**														
5.1a	Improve drainage at Epping Road flyover embankment	Drainage upgrade from Epping Road on-ramp to intersection of Giffnock Avenue and Coolinga Street	++	5	–	$2.5-3.0M	–	0.3	+	Ω	+/– Possibly worse d/s	Ω	–	–	No
5.1b		VP of five properties (1 house, 2 townhouses, 2 units) and redevelop	++	5	–	$3.0M	–	>0.3 if redevelop	?	Ω	Ω	++	+	–	Yes (redevelop)
5.2	Industrial Creek overland flow paths	Formalise overland flow paths during redevelopment	Ω	0	+	Funded as redeveloped	+	>1.0#	+	+	+	Ω	+	Ω	Yes
5.3	Rogal Place/ Fontenoy Road/ Tuckwell Place	Study to address micro-scale influences on inundation regime	Ω	0	+	$25K	+	>1.0#	+	Ω	Ω	Ω	+	Ω	Yes (study)
6	**PORTERS CREEK CATCHMENT**														
6.2a	Improve drainage in Morshead Street - Epping Road area	Drainage upgrade from Morshead Street to 'Officeworks'	++	7	–	~$1.5-2.0M	Ω	0.6	+	Ω	+/–	Ω	– –	Ω	No
6.2c		Culvert inlet maintenance – clear shrubs and plant short grass	Ω	0	++	$2K	++	>1.0	+	Ω	+	Ω	++	–	Yes
6.2d		Voluntary house raising	++	6	+	$300K (part-subsidy)	++	1.8	?	Ω	+	–	+	–	No
6.2e		VP of at least four properties (4 houses) and redevelop	++	4	–	$3.2M	–	>0.2 if redevelop	?	+	+	+	+	–	Yes
6.3	Improve drainage d/s 'Officeworks'	Drainage upgrade from 'Officeworks' to box culvert below M2 during redevelopment	Ω	0 (several comm'l.)	–	$6.5-7.0M	–	Low	+	Ω	++	+	–	–	Yes
6.4	Porters Creek overland flow paths	Formalise overland flow paths during redevelopment	Ω	0	+	Funded as redeveloped	+	>1.0#	+	+	+	Ω	+	Ω	Yes
6.5a	Improve access to SES headquarters	Drainage upgrade along Wicks Road	Ω	0	–	$6.0-6.5M	– –	Very low	+	Ω	+	Ω	–	Ω	No
6.5b		Form detention basin in depression upstream M2	Ω	0	–	N/a*	–	Low	?	– –	+	Ω	–	–	No
6.5c		Debris control structure upstream of M2 culvert	Ω	0	+	$100K	–	Low	?	Ω	+	+	+	–	No
6.5d		Create emergency access track from SES to M2	Ω	0	–	N/a*	–	Low	?	–	Ω	+	–	–	No
6.5e		MOU to ensure emergency access from M2 to SES via No. 160 Wicks Road	Ω	0	++	Nil		N/a	+	Ω	Ω	+	++	–	Yes
7	**LANE COVE CATCHMENT**														
7.1	Improve drainage at Pittwater Road	Lower downslope ground levels adjacent to the Pittwater Road sag point	Ω	0	+	$140K	+	N/a#	+	–	+	Ω	+	–	Yes
7.2	River Avenue VP scheme	Continue and promote the River Avenue VP scheme, and remove three dwellings with a high flood risk from the floodplain	Already being implemented by Office of Strategic Lands												
7.3	Improve access to River Avenue	MOU to ensure emergency access to River Avenue via Northern Suburbs Crematorium and Quebec Road	Ω	0	++	Nil		N/a	+	Ω	Ω	+	++	–	Yes
8	**OTHER OPTIONS**														
8.1	Voluntary house raising/ redevelopment	2 houses @ $50K subsidy per house	+	2	+	$100K (part-subsidy)	++	3.7	?	Ω	+	–	–	–	Yes

MEASURE NO.^	OPTION	DETAILS	REDUCTION OF DWELLINGS FLOODED ABOVE FLOOR LEVEL IN 1% AEP FLOOD		FINANCIAL FEASIBILITY		ECONOMIC MERIT		COMMUNITY ACCEPTANCE	ENVIRON-MENTAL IMPACTS AND ECOLOGICAL ENHANCE-MENTS	IMPACTS ON FLOOD BEHAVIOUR	CONSE-QUENCES IN EXTREME FLOODS	TECHNICAL FEASIB-ILITY OR DIFFICULTY	ADMINIS-TRATIVE / POLITICAL / LEGAL IMPACTS	RECOMMENDED FOR FURTHER CONSIDERATION
				NO. DWELLINGS		CAPITAL COST		BENEFIT–COST RATIO							
8.2	Flood-proofing	Prepare brochure and distribute	Ω	0	+	$25K	+	>1.0#	?	Ω	Ω	Ω	++	Ω	Yes
8.3	Planning and development controls	Add planning matrix for Macquarie Park to draft floodplain management DCP provisions	Ω	0	++	Minimal	++	>1.0#	+	Ω	Ω	++	++	Ω	Yes
8.4	Improve flood warning system	Provide site-specific flood warning system for Lane Cove River	Ω	0	–	$10K per rain gauge	–	Low	–	Ω	Ω	+	–	Ω	No
8.5a	Improve emergency management planning	Prepare a Local Flood Plan for the City of Ryde (SES)	Ω	0	+	SES staff costs	++	>1.0#	+	Ω	Ω	++	+	Ω	Yes
8.5b		Prepare a Flood Emergency Plan for Macquarie University (MU)	Ω	0	+	MU staff costs	++	>1.0#	+	Ω	Ω	++	+	Ω	Yes
8.5c		Prepare a Flood Emergency Plan for the Macquarie Centre (AMP Capital)	Ω	0	+	AMP Capital staff costs	++	>1.0#	+	Ω	Ω	++	+	Ω	Yes
8.6a	Improve public flood readiness	Consolidate flood data for Council's GIS database	Ω	0	+	$25K	++	>1.0#	+	Ω	Ω	++	+	Ω	Yes
8.6b		Provide flood certificates	Ω	0	+	$2K p.a.	++	>1.0#	?	Ω	Ω	++	+	–	Yes
8.6c		Prepare a FloodSafe brochure for Macquarie Park (five languages)	Ω	0	+	$30K	++	>1.0#	+	Ω	Ω	++	–	Ω	Yes

^ To locate the report section in which the measure is described, for Measure No. 1.1 read Section 6.1.1, and so on.
* Costs are not assessed where the option is considered unfeasible for other reasons.
# The benefit-cost ratio cannot be precisely calculated due to the intangible benefits of the proposal.
(i) Maintain integrity of existing basin.

6.1 CULLODEN CREEK CATCHMENT

Recommendations:
1) Regrade Waterloo Park below Waterloo Road to reduce depth of road inundation
2) Construct shallow detention basin at Waterloo Park

Four townhouses in Libya Place, Marsfield, are expected to be inundated above floor level in the 20 year flood. Inundation of Waterloo Road is also problematic.

6.1.1 Marsfield Park Detention Basin

Consideration has been given to forming a detention basin, to store stormwater runoff and release it at a controlled rate, thereby reducing peaks flows and levels downstream.

It is noted that there are already two detention basins in the Macquarie University (MU) Village property upstream of Waterloo Road. One potential site for additional storage is in Marsfield Park upstream of the MU Village site. However, the topography suggests that insufficient storage volume is available to provide benefits downstream. The site also contains Turpentine Ironbark Margin Forest (Biosphere Environmental Consultants, 2008), which is included in the Sydney Turpentine Ironbark Forest vegetation community listed as an Endangered Ecological Community under the NSW *Threatened Species Conservation Act 1995* (DECCW, 2009). No works or activities impacting on this bushland are permitted.

6.1.2 Improve Waterloo Road Drainage

Table 6.3 demonstrates that Waterloo Road is an important sub-arterial road within the Macquarie Park area. Traffic in the area is likely to increase by 20% by 2031 compared to 2007 (Bitzios Consulting, 2008). Inundation of Waterloo Road would be both disruptive and dangerous, since motorists are unfamiliar with the hazards of driving through water.

At its crossing over Culloden Creek, Waterloo Road is subject to a depth of inundation of 0.9m in the 100 year event. This significant depth reflects the situation whereby the ground levels in the downslope Council reserve (Waterloo Park) are higher than the road levels (**Figure 6.1a**). Regrading of the reserve over a length of about 50 metres to lower the 'crest' ground levels by about 0.6m would achieve a similar reduction in water depth at Waterloo Road. This measure is estimated to cost $70K and is recommended.

6.1.3 Waterloo Park Detention Basin

Another potential site for storing overland flow is within the Waterloo Park reserve. This could be formed fairly easily by constructing a 1.0m-high and 120 metres long earthen mound at the north-eastern end of Waterloo Park (**Figure 6.1b**). An advantage of this site is that it is just upstream of the existing inundation problem site (**Figure 5.2**). There is also the potential for directing outflow from the basin away from the medium density residential development and towards Libya Place. It is estimated that this would relieve above-floor inundation up to the 100 year flood, yielding benefits (damage savings) of $260K. At an estimated cost of $350K, this option is recommended.

TABLE 6.3 – BALANCED ONE HOUR TRAFFIC COUNTS AT ROAD SAG POINTS, YEAR 2007
Source: *Macquarie Park Traffic Study* (Bitzios Consulting, 2008, Appendix B)

Location	**AM peak** (0745-0845)	**PM peak** (1645-1745)
Waterloo Road @ Culloden Creek	1,205	1,015
Epping Road @ Mars Creek	3,042	3,389
Talavera Road @ Mars Creek	1,276	1,155
Epping Road @ University Creek	3,907	3,921
Talavera Road @ University Creek	1,404	1,446
Epping Road @ Porters Creek	7,086	7,005
Pittwater Road @ Lane Cove catchment	2,238	2,340

FIGURE 6.1 – CULLODEN CREEK CATCHMENT PHOTOS

a. Waterloo Road sag point showing slightly higher ground levels downslope

b. Potential site for embankment to form detention basin in Waterloo Park

6.2 MARS CREEK CATCHMENT

Recommendations:
1) Lower height of median strip and northern verge at Epping Road to reduce depth of road inundation
2) Drainage upgrade at Talavera Road to reduce depth of road inundation (low priority)

Relatively few inundation problems have been identified in the Mars Creek catchment. Two double-storey houses on Culloden Road (south of Epping Road), Marsfield, could experience above-floor inundation in frequent events due to overland flow travelling south-east down Yarwood Street. A number of major roads could be inundated in major events including Epping Road and Talavera Road, whilst three internal roads within Macquarie University are also expected to be inundated including Gymnasium Road near car park N1. Inundation within Macquarie University could pose risks to personal safety and will need to be considered within a flood emergency management plan (see **Section 6.8.5.2**).

6.2.1 Culloden Road (West) Overland Flow Works

Alleviating inundation problems at Nos. 91 and 93 Culloden Road through structural works is challenging because of the road sag point immediately upslope where the 100 year flood depth is about 0.6m (**Figure 6.2a**). One option is to raise the level of the road verge and driveways by about 0.4-0.5m. But this would exacerbate the depth of inundation in the road sag point, which is undesirable from a road safety perspective. Consideration has also been given to constructing a speed hump across Culloden Road to direct Yarwood Street flows towards Epping Road. But this would increase the volume of overland flows travelling east down the westbound lanes of Epping Road and would also block the overland flow path travelling north-east down Culloden Road, diverting water to other properties. Other issues are the angle of the speed hump (which could not be perpendicular to traffic flow given the alignment of existing driveways and the overland flow path) and the proximity of the speed hump to Epping Road which could be unsuitable.

Given the inability to satisfactorily address the road sag point inundation problem, non-structural approaches within the properties may be required (see **Section 6.8**).

6.2.2 Improve Epping Road Drainage

The high ground levels in the adjacent upslope Council reserve (Pioneer Park) prevent catchment flood flows approaching this Epping Road sag point via a direct route through the centre of the reserve. Rather they arrive at the sag point through flow occurring in both easterly and westerly directions in the westbound carriageway. This results in hazardous depths both in the sag point and as flows approach the sag point. Inundation of Epping Road would cause serious disruption (see **Table 6.3**) and danger to motorists.

To reduce *all* of the hazardous flow conditions in Epping Road up to and including the 100 year flow would require substantial drainage works over several hundred metres of the westbound carriageway plus significant pipework across the road at the sag point itself. Also accompanying drainage upgrade works would likely also be required at the university internal road which crosses Mars Creek immediately downslope of Epping Road. The cost of the works would be of the order of $1.0-1.5M.

The depth of water at the sag point (with a maximum of 1.0m in the westbound lanes) is partly a function of higher ground levels in the median strip and the eastern verge. In particular, the depth in the westbound carriageway is significantly deeper than in the eastbound carriageway due to the levels associated with the broad grassed median strip. The levels in the median strip could be lowered by about 0.3m, with a resultant similar reduction in the westbound carriageway depth. Small scale lowering of levels in the northern verge might also achieve a reduction of about 0.1m in the water depth in both carriageways. The cost of the works including wire rope safety barriers would be of the order of $160K. Given the importance of Epping Road and its relative affordability, this option is recommended.

6.2.3 Improve Talavera Road Drainage

Talavera Road is an important sub-arterial road where it crosses Mars Creek (**Table 6.3**). The flood modelling suggests that the road would be inundated by about 0.4m in the 100 year event. Here the M2 Motorway culvert is sufficiently large that it is not of itself causing 'backwater' flooding of Talavera Road. The overtopping regime therefore can only be addressed by substantially increasing the waterway area under the road (**Figure 6.2b**). The cost of the works would be of the order of $450K.

Given the expanding usage of this route with the growth of Macquarie Park, this measure is recommended but as a low priority.

FIGURE 6.2 – MARS CREEK CATCHMENT PHOTOS

a. Sag-point in front of Nos. 93 and 91 Culloden Road, Marsfield

b. Mars Creek culvert at Talavera Road

6.3 UNIVERSITY CREEK CATCHMENT

Recommendations:
1) Maintain Dunbar Park basin
2) Lower height of median strip at Epping Road to reduce depth of road inundation
3) Talavera Road basin enlargement scoping study

Relatively few inundation problems have been identified in the University Creek catchment. Two double-storey houses in Biara Close downstream of Dunbar Park are expected to be inundated above floor level in the 20 year flood. Several commercial units at No. 112 Talavera Road are also exposed to flooding when the pipe conveying University Creek through the property is surcharged. The flood modelling also shows inundation of some important roads including Epping Road, Talavera Road and the M2 Motorway. At Macquarie University, Research Park Drive and University Avenue are subject to major flooding under existing conditions. It is noted that a flood mitigation strategy prepared for Macquarie University proposes to raise campus roads crossing University Creek in order to increase flood storage volume upstream and reduce road overtopping, and to modify the outlet control structure prior to Talavera Road in order to improve the outflow capacity and protect Talavera Road from flooding (TTW, 2010). At the time of writing (September 2010), this proposal was subject to technical review, so none of its proposed measures can be incorporated into the recommendations of this study.

6.3.1 Dunbar Park Detention Basin Enhancements

After the November 1984 flood, Dunbar Park was converted into a detention basin by the construction of an embankment around its north-eastern edge (**Figure 6.3a**). The basin appears to fill to capacity in the 100 year event, with a flood level only about 100mm below the design crest level of 75.36m AHD. Spilling occurs on the southern side of the amenities block. The efficiency with which the basin is performing suggests that there is little potential to improve the flooding regime downstream.

It might be possible to increase basin capacity by raising the wall, and some works at the southern corner could encourage overland flow into the basin rather than through the yards of private properties facing Sobraon Road. This option would be expensive and technically difficult, and since under existing conditions only two houses downstream of the basin are predicted to be inundated above floor level (and these are also affected by overland flows not controlled by the basin), the benefit-cost is not expected to be favourable.

Consideration was also given to directing spills from the basin away from the private properties downstream and towards Sobraon Road by regrading the Dunbar Park carpark and/or constructing a fence along the carpark's north-eastern boundary. This proposal is not feasible however, since Sobraon Road is elevated above the carpark which has more than a 1.0m grade from the boundary near Sobraon Road to the overland flow path on its north-western edge.

Hence, no additional works are recommended at Dunbar Park. The integrity of the existing detention basin should be maintained. Downstream flooding problems may need to be mitigated through non-structural measures (see **Section 6.8**).

FIGURE 6.3 – UNIVERSITY CREEK CATCHMENT PHOTOS

a. Dunbar Park detention basin embankment

b. View downstream to Talavera Road culvert

c. Detention basin upstream of Talavera Road

d. Channel upstream of M2 Motorway

6.3.2 Improve Epping Road Drainage

Epping Road at its crossing of University Creek is an important arterial road (**Table 6.3**), inundation of which would pose serious disruption and danger to motorists. In the 100 year flood the westbound carriageway at its intersection with Sobraon Road has a maximum depth of about 0.9m, while depths in Sobraon Road 20 metres west reach up to 1.4m.

Elimination of hazardous conditions in Epping Road (and also in the Sobraon Road/Waring Street intersection) up to and including the 100 year flow would require piping of all flood flow from the intersection to an appropriate location downslope of Epping Road. Since the property immediately downslope of Epping Road is an aged persons facility it is considered that it would be undesirable – from an incremental increase in hazard viewpoint – to allow surcharge to occur within it. Hence the supplementary pipework would need to extend to the open channel at the western (upslope) boundary of Macquarie University. This constitutes about 225 metres of pipework and an approximate construction cost of $2.5-3.0M. Additional easements through the aged care facility and in Macquarie University would also need to be negotiated.

As elsewhere along Epping Road, the median strip at this location is somewhat higher than the carriageways. It is considered that the levels in the median strip could be lowered by about 0.2m and if this was done there would be a resultant similar reduction in water levels immediately upstream. The cost of the works including wire rope safety barriers would be of the order of $110K. Whilst the proposal would only partly address the serious flooding problem at Epping Road, its relative affordability commends its inclusion in the recommended Plan.

6.3.3 Improve Talavera Road Drainage

Talavera Road is an important sub-arterial road where it crosses University Creek (**Table 6.3**). Usage is expected to increase with its upgrade to five lanes as part of the M2 Upgrade (Mr Garret O'Connor, Transurban, Aug 2010, pers. comm.).[3] The centreline depth in the 100 year event at this location is about 0.5m.

There are potentially two ways of reducing/eliminating this road overtopping. They are to either:

[3] No culvert upgrade at Talavera Road is planned as part of this road widening.

(1) construct supplementary pipes from the upslope edge of Talavera Road to an appropriate location downslope of Talavera Road (**Figure 6.3b** shows the current pipe); or

(2) increase the capacity of the current in-creek detention basin which is located immediately upstream of the roadway within Macquarie University (**Figure 6.3c** shows the current basin).

Since there is no suitable location for a surcharge structure within the immediate downslope commercial property, the pipework would need to carry flows all the way through that property. This would involve a total of about 135 metres of pipework through private property and a construction cost of approximately $2.0-2.5M.

Of the two options, a basin upgrade is favoured because it would involve less construction work and would also help to reduce inundation problems through the downslope property (No. 112 Talavera Road). The work would however require negotiation of an agreement with Macquarie University, which has an existing proposal to alleviate flooding at Talavera Road (TTW, 2010) – currently subject to technical review. It is recommended that a scoping study for an enlarged basin be undertaken prior to this option being further pursued.

In terms of the predicted flooding of commercial units at No. 112 Talavera Road, residual problems could be addressed through flood-proofing (see **Section 6.8.2**).

6.3.4 Improve M2 Drainage

The *Macquarie Park Flood Study* did not include local drainage modelling for the M2 Motorway, so its depiction of inundation there should be regarded as approximate only. With this caveat in mind, the modelling suggests shallow flow (<0.2m) across the westbound carriageway of M2 Motorway at University Creek.

As part of the *M2 Upgrade Environmental Assessment*, AECOM Australia (2010) proposed extending the existing box culvert (No. 35) under the M2 by 2.4m on its westbound side, and replacing an existing overgrown gabion and rock mattress-lined channel running eastwards along the westbound side of the motorway (**Figure 6.3d**), with a concrete-lined and slightly larger channel. This is intended to improve the hydraulic capacity and reduce flood levels through this area. It is described here for reference only and is not costed in the FRMP.

6.4 SHRIMPTONS CREEK CATCHMENT

Recommendations:
1) Prepare a scoping study then implement proposed overland flow control scheme in Crotoye Place/Danbury Close/Herring Road area, including VP of one property
2) Maintain drainage pits routinely, especially in the catchment above the Doig Avenue shops
3) Prepare a scoping study then create an overland flow path between Rocca Street and Santa Rosa Park, including VP of one property (low priority)
4) Overland flow works in Santa Rosa Park
5) Construct a dwarf wall at No. 15 Brendon Street, North Ryde
6) Construct the proposed North Ryde Golf Club detention basin
7) Rehabilitate Shrimptons Creek riparian corridor
8) Construct a boundary wall along the rear of Peachtree Road units
9) Consider opportunities to increase conduit capacity through Macquarie Centre during redevelopment
10) Install debris control structure upstream of Shrimptons Creek culvert at Waterloo Road

As the largest catchment in the study area, it is not surprising that Shrimptons Creek contains the largest number of buildings subject to above-floor inundation (**Table 5.4**). However, these buildings are not evenly distributed – few buildings along the main open channel of the creek are flood-prone, while elsewhere there are some concentrations of buildings such as in the Crotoye Place/Danbury Close/Herring Road area and in the reach downstream of the North Ryde Golf Club (see **Figure 5.2**).

6.4.1 Granny Smith Memorial Park Detention Basin

Potential exists for earthworks to form a minor basin within Granny Smith Memorial Park (No. 50 Threlfall Street, Eastwood), commanding and detaining overland flows through the park which currently enter properties facing Kingsford Avenue and Abuklea Road (before then flowing down Abuklea Road).

However, this option has not been pursued further since no buildings in the immediate area downstream of the site are shown as flood-affected, so benefits would be minor.

6.4.2 Crotoye Place/Danbury Close/Herring Road Area Works

The area around Crotoye Place/Danbury Close/Herring Road, Marsfield, has been identified as a flood 'hot-spot', with nine houses anticipated to be inundated above floor level in the 20 year flood, and another three in the 50 year flood (**Figure 5.2**). There are two overland flow paths from Kotara Park upslope of Crotoye Place/Danbury Close – a major flow path from the direction of Abuklea Road (noting that the remainder of the overland flow in Abuklea Road directly enters Crotoye Place) and a minor north-to-south flow regime across Kotara Park (**Figure 6.4**). Flows associated with both paths enter the rear of private properties. There is an opportunity to do relatively low cost works within the park to control the impacts of those two flow regimes by constructing mounds/walls along the park boundary, which might also serve as minor detention basins (**Figure 6.4**). The major flow path could be controlled by a wall along the southern edge of the tennis court complex car park. The minor flow path could be controlled by mounding, though it is noted that this is of lower priority. Costs for this work are estimated at about $250K, mostly for a wall with an average height of 1.5m. (The benefits are considered with the overland flow works described below).

One option to address the trapped low point inundation in Danbury Close is to do a major pipe upgrade from Danbury Close to Herring Road (140 metres). To convey 100 year flows, however, would cost in the order of $2.0-2.5M. If closer examination indicates that surcharging the additional drainage at Herring Road is inappropriate hence requiring the extension of the pipe upgrade to a suitable surcharge location within the Kent Road Public School (320 metres), the overall cost would be about $4.5-5.0M.

Another option to alleviate inundation in Danbury Close is to create a relieving overland flow path on the southern side of the street, together with the raising of the footpath and driveways to the east in order to encourage flow towards the formal path. This would require the voluntary purchase and subsequent demolition of one residence (**Figure 6.4**). Minor lowering of ground levels would be required within the County Road reservation corridor at the boundary of No. 11 Danbury Close. There would also be merit in extending the overland flow path through the reservation corridor to a 'spill' location at the eastern end of the last Herring Road property. Permissions for this work need to be secured from the Department of Planning (as landowner) and the Roads and Traffic Authority.[4] The cost of this proposal is estimated at about $860K, the vast bulk of which is for the acquisition of one property. But the benefits of the combined overland flow control scheme (including the works in Kotara Park described above) are substantial – calculated as almost $1.3M. The total cost ($1.1M) yields a favourable benefit-cost ratio of 1.2, commending the inclusion of this proposal in the recommended Plan.

A first step towards the implementation of the proposed overland flow scheme depicted in **Figure 6.4** is a scoping study which would involve further consultation with the Department of Planning and RTA as well as initial discussions with the affected community. The scoping study would also need to model the overland flow paths and assess the appropriate location for dispersing the flow near Herring Road (or downslope). An allowance of $40K has been included in the Plan.

[4] At the time this report was being prepared in September 2010, the Department of Planning provided the following advice: *'Any use of the land in an interim sense requires the concurrence of the RTA to ensure it does not conflict with future road plans. My initial assessment is that an overland flow path and detention basin is not ideal as it would create surface infrastructure that would conflict with its held purpose i.e. road.'*

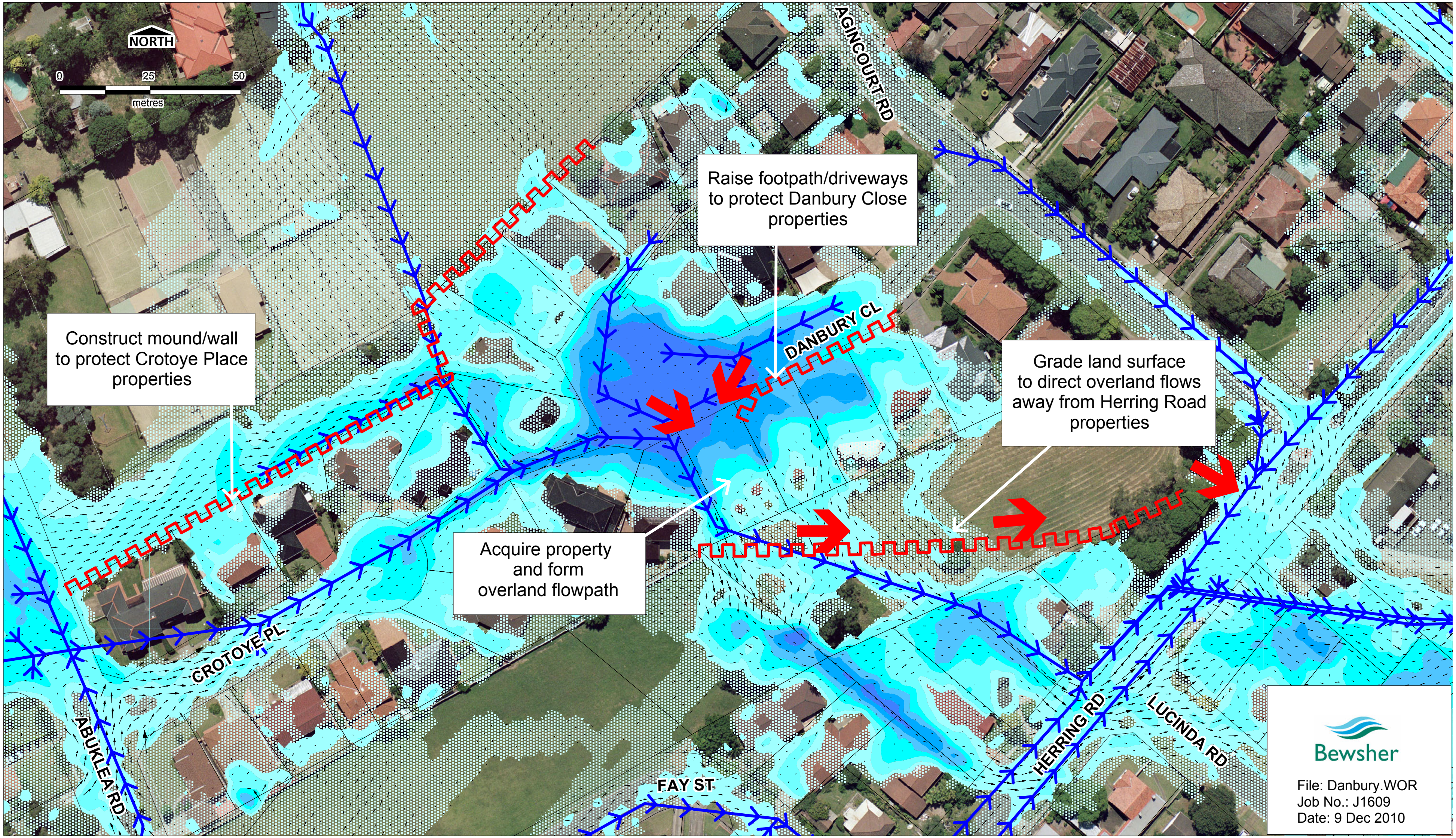

FIGURE 6.4 - PROPOSED WORKS IN DANBURY CLOSE AREA

Note: Existing 100 year flood depths and velocity vectors shown in background, plus existing pipe network

6.4.3 Mason Street Options

Six commercial premises in Doig Avenue, Denistone East, are subject to frequent flooding. Initially, two structural options were considered:

(1) further improvements to the underground drainage system capacity by constructing new inlets at the intersection of Gallard Street and Mason Street and associated new pipework along Mason Street and Richmond Street, connecting to the pit at the Doig Avenue/Richmond Street intersection corner just below the shops (assuming that surcharge at that street location can be satisfactorily managed, which is doubtful);

(2) closing Gallard Street at Jackson Crescent and constructing a detention basin wall across Gallard Street and around the eastern and southern perimeters of the small treed reserve (**Figure 6.5a**).

Of the two options, the second would be much cheaper at about $130K. However, because of the modest depths of inundation and the low value class of the shops, the calculated benefits of preventing inundation up to and including the 100 year flood amounts to only about $20K, so that even the cheaper detention basin option would have an unfavourable benefit-cost ratio. Other works to enhance underground drainage were considered in response to a submission during public exhibition of the draft report, but were not recommended due to the required scale of work and large cost (see **Section 3.6**). However, a recommendation to routinely maintain drainage pits in the area has been added to the draft FRMP in line with the submission. Flood-proofing measures could also be appropriate for these shops (see **Section 6.8.2**).

6.4.4 Cecil Street/Macquarie Place Area Options

Overland flows from the direction of Doig Avenue are joined by flows from the direction of Kings Road and Birdwood Avenue, and together cause problems in the area of Cecil Street and Macquarie Place, where the damages assessment indicates that six dwellings are subject to shallow above-floor inundation in the 20 year event. Some of these appear to be fairly new slab-on-ground structures, which highlights the need for the application of appropriate minimum floor level controls during the planning stage of the redevelopment process (see **Section 6.8.3**). Consideration of the drainage network in the area reveals no obvious opportunities for a pipe upgrade, which is assessed as being of low economic merit. There may be potential to offer a small financial subsidy for redevelopment in a flood-compatible manner or to provide advice about flood-proofing (see **Section 6.8**).

6.4.5 Rocca Street Overland Flow Path

Flooding of four dwellings may be attributed to an overland flow path travelling south-east down Rocca Street, Ryde. In the 100 year flood, depths up to about 1.0m and high flow velocities result in high hazard conditions along Rocca Street. Conditions could be somewhat alleviated by fashioning an overland flow path through the properties between the cul-de-sac bulb and Santa Rosa Park. Council is also supportive of achieving pedestrian linkages where possible, though a pedestrian linkage is not intrinsically required, and the main reason residents of Rocca Street opposed this proposal at public exhibition was the broader implications of creating a pedestrian linkage (see **Section 3.6**).

Given the current arrangement of buildings, little space is available for an overland flow path. One option is to acquire a property, demolish the building, and fashion an overland flow path through the purchased property (some grading in the cul-de-sac bulb may also be required to encourage flow into the designed path) (see **Figure 6.6**). An assessment was made of the benefits of acquiring and removing one house and reducing the depths of inundation up to and including the 100 year flood by half for three other houses. This yielded benefits (damage savings) of about $430K. Assuming a total cost for property acquisition, demolition and formalisation of an overland flow path of about $1.0M, yields a modest benefit-cost ratio of 0.4.[5] Given the current owner's opposition to the proposal, the scheme is unlikely to be implemented in the short-term. However, the Floodplain Management Committee, having considered other options, decided to retain the proposed scheme in the draft FRMP, though as a low priority (see **Section 3.6**). If in the future the owner of the property identified for voluntary purchase was amenable to the proposal, and if Government funding was available, a more detailed scoping study including modelling would be required.

6.4.6 Heath Street/Stephen Avenue Works

Flood modelling points to a significant overland flow path through the backyards of properties fronting Heath Street and Stephen Avenue, just west (upslope) of Quarry Road, Ryde. Quarry Road itself is about 0.3m higher than the ground surface just upstream, and there is a 0.5m afflux across the road during the 100 year event. However, only one building upstream is flooded (to a very shallow depth) above floor level in the 100 year event. It is therefore difficult to justify either a drainage upgrade or formation of an overland flow path through this area. Lowering Quarry Road would provide some mitigation of flood levels upstream, but this is unlikely to gain support for public safety reasons.

6.4.7 Santa Rosa Park Overland Flow Path

Flood modelling shows a complex picture of overland flows near the western (upslope) end of Santa Rosa Park, Ryde, with flows coming from Rocca Street, Quarry Road and Fawcett Street. Whilst no inundation of houses in this area is predicted for the 100 year flood, depths of up to 1.5m are anticipated in the backyards of several Fawcett Street private properties, with accompanying high hazard conditions. Ground levels above the trunk conduit from Quarry Road are raised and there is no complementary overland flow path, which forces overland flows to the lower-lying rear yards of the Fawcett Street properties (see **Figure 6.5b**). Several options to address this problem have been considered:

(1) Construct a levee along the boundary of the Fawcett Street properties to exclude floodwaters from the direction of Quarry Road.

    This option is not feasible because it would trap overland flows approaching from the south-east behind the levee.

(2) Remove part of the trunk conduit and restore open channel

    There is potential to remove about 100 metres of the trunk conduit – corresponding to about four Fawcett Street properties – and open up a 'natural' open channel to provide more flood flow conveyance capacity through that part of the park. This would reduce the current backyard flood regime. The cost of this option has been estimated at about $500-600K.

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[5] If this proposal was to be pursued, a formal valuation of the property proposed to be purchased would be required.

(3) Overland flow works

A third option is depicted in **Figure 6.6**. This would see the construction of a mound/wall through the western and central parts of Santa Rosa Park with an alignment *starting* along the southern boundary and then *crossing* the trunk conduit such that the flow on the western side of the mound (including the major overland flow paths from Rocca Street and Quarry Road) is separated from the Fawcett Street flows on the eastern side, rejoining the open channel downstream of the trunk conduit outlet. Under this option the overland flows passing through the Fawcett Street properties would be substantially reduced. The cost of works are estimated at about $250K. Whilst the calculated benefits of the scheme are low, the intangible benefits are significant. Moreover, the scheme would go some way towards addressing the *unnatural* flood problem associated with the bulk of the trunk conduit.

The third option is recommended.

FIGURE 6.5 – SHRIMPTONS CREEK CATCHMENT PHOTOS

a. Potential detention basin site at Mason Road upstream of Doig Avenue shops

b. View of Shrimptons Creek upstream to trunk drainage outlet, Santa Rosa Park; lower-lying Fawcett Street properties are on left

c. Potential detention basin site at Smalls Road

d. View of Brendon Street sag point with proposed site for dwarf wall on right

e. Condition of Shrimptons Creek riparian corridor between Kent and Epping Roads, May 2010

f. Macquarie Centre de facto overland flow path with a three cell box culvert under the full width of the road

g. Entrance to three cell box culvert conduit upstream of Waterloo Road

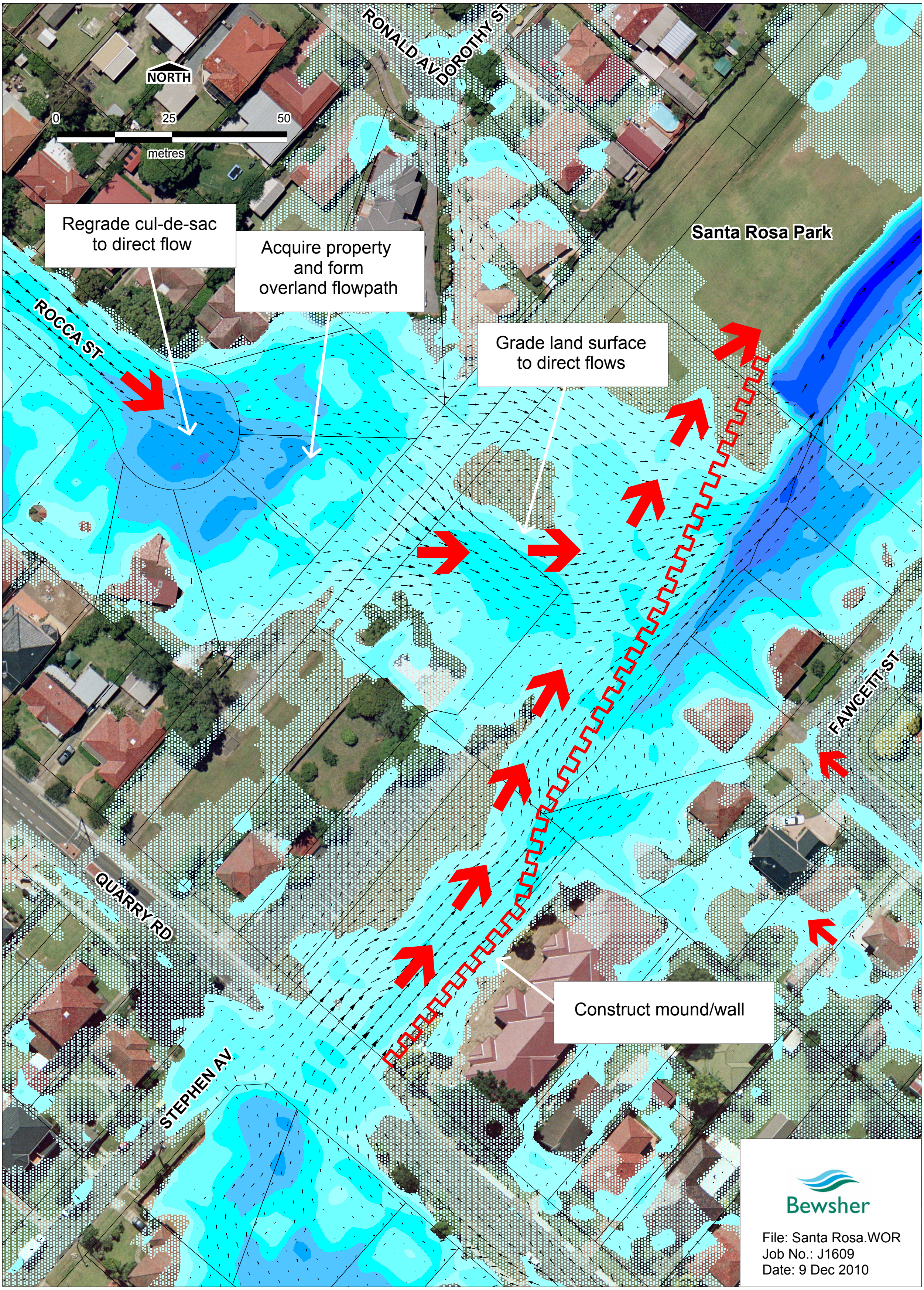

FIGURE 6.6 - PROPOSED WORKS AT ROCCA STREET AND SANTA ROSA PARK

Note: Existing 100 year flood depths and velocity vectors shown in background

6.4.8 Smalls Road Detention Basin

A potential detention basin site has been identified within the playing field reserve located at 3B Smalls Road, Ryde (**Figure 6.5c**). Since surface flows from Lavarack Street already spill into the lower playing field, the basin works may only involve earthworks (no excavation) to create the storage. This would reduce flows downstream.

However, the assessment of potential flood damages shows that despite a substantial overland flow path cutting through the block bounded by Smalls Road, Warren Street, Fawcett Street and Neville Street (see **Figure 2.4i**), no above-floor inundation is predicted for events up to and including the 100 year flood. This means that the benefits of a basin would be minor (confined to reducing nuisance damages to garages, sheds and the like) and the benefit-cost ratio would be unfavourable. Accordingly, this option is not recommended.

6.4.9 Fawcett Street Overland Flow Path

Consideration was given to formalising an overland flow path by purchasing one or two properties where surface flows spill across Fawcett Street near its junction with Warren Street, Ryde, en route to Santa Rosa Park. However, no above-floor inundation in events up to and including the 100 year flood is predicted, so the works are not viable.

6.4.10 Brendon Street Sag Point Works

A slab-on-ground house at No. 15 Brendon Street, North Ryde, is subject to shallow above-floor inundation even in frequent flood events. The inundation is most likely to come from surcharge associated with the Council sag point pit in Brendon Street. It is highly likely that above floor level inundation could be solved by a significant upgrade of the current pit and pipe system (which runs around the south-eastern and north-eastern sides of the property).

However, an alternative and much cheaper scheme is to build a solid, dwarf wall along the front boundary of the property and the neighbouring western property such that additional ponding can occur in the street before spill is initiated (**Figure 6.5d**). (Whilst measures that result in increased flood affectation in roads are not encouraged in general, Brendon Street is a minor road and alternative access is available). In addition to the wall, some regrading of the verge may be required. The wall could have the appearance and function of a front fence and need not have the same appearance in front of each property. A legal instrument may be required to prevent any future demolition/modification to the wall.

As a first step, some detailed survey is required to confirm that the scheme is feasible. In particular, care needs to be taken that the wall directs overland flow towards Flinders Road and not down the driveway of No. 13 Brendon Street. Also, the level of the driveway of No. 15 Brendon Street needs to be confirmed to check that flow could not enter the property at that point. If technically feasible, negotiations could be opened with the relevant landowners.

Excluding flooding from 15 Brendon Street is assessed to provide benefits (damage savings) of $220K. The dwarf wall scheme is expected to cost $30-40K and is recommended.

6.4.11 Ford Street Overland Flow Path

Consideration was given to either upgrading the pipe system or formalising an overland flow path by purchasing a property where surface flows spill across Ford Street, North Ryde, upslope of Nos. 67 and 69. However, no above-floor inundation in events up to and including the 100 year flood is predicted, so the works are not viable.

6.4.12 North Ryde Golf Club Detention Basin

Flooding in November 1984 reached significant depths in Lane Cove Road, Ford Street, Eastview Avenue and Ada Street (see **Figure 2.4**). It is noted that Council has since done some additional trunk drainage works in Ford Street but modelling confirms that several buildings in this reach are still subject to above-floor inundation in the 20 year event (**Figure 5.2**) and that some road sections are subject to high hazard conditions in the 100 year event.

A detention basin in North Ryde Golf Course just upslope of Lane Cove Road has been a long-standing proposal to reduce peak flows downstream, but has yet to be constructed. Detailed design has already been done and included discussions with the Golf Club to determine the basin crest level (Storm Consulting, 2007). A bund height of RL 62.45m was set, realising a storage capacity of 3,200m^3. The resultant reductions in overland flows are reported in **Table 6.4**. It is seen that the proposed basin would not spill in the 10 year flood and that overflows would be much reduced in the 20 year event and reduced by about half in the 50 year event.

TABLE 6.4 – OVERLAND FLOWS FROM NORTH RYDE GOLF COURSE
Source: *North Ryde Golf Course Flood Mitigation Investigation* (Storm Consulting, 2007)

ARI	Existing		With proposed basin	
	Flow (m^3/s)	Critical duration	Flow (m^3/s)	Critical duration
10 year	3.64*	1.5 hours	0 (contained)	N/a
20 year	3.64*	1.5 hours	0.55	2 hours
50 year	4.76	1.5 hours	2.25	2 hours
100 year	5.91	2 hours	3.58	1 hour

* Likely error in source document

Benefits of the project have been estimated by applying reductions in flood levels in properties downstream of the proposed basin site as far as Ada Street. This yields benefits of about $360K. Costs for constructing the basin were estimated in 2007 at about $80K, with an additional cost of over $40K to extend the existing golf netting barrier (Storm Consulting, 2007) (~$130K total factoring up to 2010 using CPI). It is clear that the benefit-cost ratio of the proposed detention basin is highly favourable. However, it is understood that the project has not proceeded due to disagreements over cost-sharing. Implementation of this proposal is again strongly recommended to reduce flood problems downstream.

6.4.13 Shrimptons Creek Rehabilitation

Parts of the Shrimptons Creek riparian corridor are infested with weeds (**Figure 6.5e**). The *Ryde Fauna and Flora Study* (Biosphere Environmental Consultants, 2008, p.42) made the following observations for ELS Hall Park:

> *'Problem weeds mostly border Shrimptons Creek … and include African Olive, the Privets, Lantana, Madeira Vine, Turkey Rhubarb, English Ivy, Kikuyu, Buffalo Grass, Ehrharta and Cape Broom.'*

Council's *Water Sensitive Urban Design* report (EDAW, 2009) lists as an objective the establishment of an ecological connection along the riparian zone of Shrimptons Creek downstream to Waterloo Road, which would see rehabilitation of the riparian vegetation. The City of Ryde DCP 2010 also requires vegetation rehabilitation and weed management to reinstate and rehabilitate the Shrimptons Creek corridor (CoR, 2010, Part 4.5, Schedule 1, p.136).

From a flooding perspective, the current proliferation of weeds can inhibit the conveyance of floodwaters and also generate material that could exacerbate blockage of culverts, with the potential to locally increase flooding. The study therefore supports the recommendation of the WSUD report to rehabilitate the riparian corridor, with a preference for flood-compatible native species. A strategy to implement this rehabilitation would be beneficial and could have the following objectives:

- *To remove exotic plant species from the creek corridor to improve the hydraulic function of the creek.*
- *To provide for the rehabilitation of the creek corridor with endemic plant species which are tolerant of riverine conditions.*
- *To create an environment which is sympathetic to the ecology of the creek and, in particular, fauna habitat.*
- *To create a rehabilitated creek corridor which allows for access by the general community for recreation and education.*
- *To ensure that the potential for soil erosion and destabilisation of the creek banks is addressed by providing for the managed and staged rehabilitation of the creek.*

Under the *Water Management Act 2000* a controlled activity approval may be required for the removal of vegetation.

6.4.14 Parklands Road Overland Flow Path

Consideration was given to either upgrading the pipe system or formalising an overland flow path by purchasing a property where surface flows spill across Parklands Road, North Ryde, upslope of Nos. 91 to 95. However, no above-floor inundation in events up to and including the 100 year flood is predicted, so the works are not viable.

6.4.15 Peachtree Road Overland Flow Path

Medium density unit blocks in Peachtree Road, Macquarie Park, are susceptible to inundation when spill occurs from the nearby trunk drainage works in the adjoining Department of Housing development. While the inundation problems appear to be limited to garage inundation the problems are likely to be quite pronounced particularly at the most downslope property (which is closest to Shrimptons Creek itself). It is very likely that this spill issue could be wholly addressed by modifying the common boundary conditions through upgrading the existing wall and/or building a new wall (200 metres long; 1.0m high). This is estimated to cost about $160K and is recommended.

6.4.16 Macquarie Shopping Centre Options

Shrimptons Creek is conveyed through the Macquarie Shopping Centre via three 2.6 x 2.7m cell box culverts. The internal road above the box culverts was severely flooded in the November 1984 event (**Figure 2.4f**). Flood modelling shows that even in unblocked conditions, about 18 m^3/s and 28 m^3/s is conveyed down the road as overland flow in the 50 year and 100 year events respectively (and about 90 m^3/s conveyed in the conduit), with high flow velocities. If the entrance to the box culverts upstream of Waterloo Road is even partially blocked, the proportion of total flow conveyed as overland flow approximately doubles (see site S22 in Table 12 in the *Macquarie Park Flood Study* report). It is also prudent to consider that flows considerably larger that the 100 year flood are possible, and that the area is sensitive to climate change flood risk (**Figure 4.2**).

Given the undesirability of flooding on this road and through adjacent carparks from a public safety perspective, and in very severe floods also through shops on the lowest 'undercroft' level, the Floodplain Management Committee requested consideration of ways to reduce the danger.

One option raised in Council's WSUD report (EDAW, 2009) is the 'daylighting' of the creek through the Macquarie Centre (see **Appendix C**). Removing the culvert covers and inner walls is estimated to cost about $300K and would marginally increase the capacity for the transmission of floodwaters. A more radical 'naturalisation' of the channel would cost more and by increasing hydraulic roughness could have an adverse effect on flood behaviour. Both options appear to be impractical given the current development footprint and layout of the shopping centre.

Another option is to install an additional box culvert. However, inspection of plans shows that the existing three cell box culvert almost completely takes up the ~9.0m wide easement that is available, and that the existing buildings and piers provide no space for an additional culvert in this easement (see **Figure 6.5f**). It also appears difficult though still technically possible to fit a new culvert beneath the carparking area to the east of the existing culvert given the alignment and spacing of piers relative to the required direction.

Another option is to expand capacity via provision of a tunnel under the existing culvert, but this is considered impractical given the need to extend the tunnel to the downstream side of the M2.[6]

Hence it appears that the most feasible way of increasing conduit capacity through the Macquarie Centre could be to replace the existing three 2.6 x 2.7m cell box culverts with deeper culverts. This option would also be expensive and the tangible (measurable) benefit might be very low (benefit-cost ratio <0.1). Given the intense competition for the limited funds available for works under the State Government's Floodplain Management Program, it is unlikely that it would secure external funding.

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[6] An estimate of the tunnel option has been prepared. This tunnel would need to extend from upstream of Waterloo Road to downstream of the M2 (a distance of about 650 metres), since the current three box culvert outlet downstream of Talavera Road is at the natural creek level. The tunnel inlet's invert might need to be higher than the current three cell box culvert inlet's invert to maintain low flows through the existing channel below Talavera Road. Using the construction costs for the West Ryde stormwater tunnel, and the cost estimates prepared for the *Eastwood and Terrys Creek FRMS&P* (Bewsher Consulting, 2009), the cost of constructing a tunnel sufficient to convey that portion of the 100 year flood currently conveyed as overflow through the Macquarie Centre (in the unblocked scenario) is estimated at about $16M. The other options for increasing conduit capacity which are canvassed above will likely cost somewhat less than the $16M tunnel option.

However, given the scale of the existing flood risk to public safety and the significant benefits of reducing overland flows, the Committee recommends that if any redevelopment is planned, the property owner give consideration to means of providing increased conduit capacity. The Committee recommends that Council's planners review the best means to ensure this can be implemented as part of Council's development assessment process.

Another option under consideration is the installation of a debris control structure upstream of the entrance to the existing three cell box culvert at Waterloo Road (**Figure 6.5g**). This would provide confidence that the culverts would perform to their design capacity during major flooding.[7] Given the relatively large size of the culverts, the objects of most concern are larger objects such as motor vehicles, sections of fencing or trees that could cover a culvert opening and grow as smaller debris is attached to it. Riley et al. (1986) reported that a large willow tree partially blocked this culvert inlet in the November 1984 event (see **Section 2.2**).[8] Installing a series of appropriately spaced 'soldier posts' a short distance upstream could capture large objects before they reach the culvert. Other considerations influence the feasibility of a debris control structure. First, Council-owned or public land with easy access needs to be available for construction and maintenance of the structure. In the case of the site of interest, whilst Council land is available on the western bank (with access from No. 12A Cottonwood Crescent), an easement may need to be taken over the area bordering Shrimptons Creek at No. 82-84 Waterloo Road. A second and critical requirement is for adequate space around the proposed site so that flooding on private property is not exacerbated. Confirmation of no adverse local effects will require flood modelling. Given the sensitivity of the flood regime to blockage of this culvert and the shopping centre downstream this culvert partly protects, it is recommended that further investigation be conducted. Subject to these two requirements being met (re access and flood effects), a debris control structure is recommended upstream of this culvert inlet.

It must be noted that even with a functioning debris control structure, inundation within the Macquarie Centre is expected under existing conditions, requiring rigorous emergency management measures. These are discussed in **Section 6.8.5**.

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7 A comparison of the 100 year 'blocked' model run (which applies a 35% blockage factor to this culvert) with the equivalent 'unblocked' model run, shows that overland flows are up to about 0.5m higher through the Macquarie Centre under blocked conditions.

8 Based on Council photographs of the inlet taken after the event and the Consultant's modelling of the November 1984 flood as reported in the *Macquarie Park Flood Study* (Bewsher Consulting, April 2010), it is unlikely that blockage of the inlet was the major cause of inundation of the Macquarie Centre in 1984. Note also that Council estimated that woody debris caused 15% blockage in the flood of 12 February 2010 (see **Figure 2.4k**).

6.5 INDUSTRIAL CREEK CATCHMENT

Recommendations:

1) VP five properties upstream of the Epping Road flyover embankment (and redevelop)

2) Formalise overland flow paths as the area is redeveloped

3) Prepare a site-specific study to address inundation problems in medium-density developments at Rogal Place, Fontenoy Road and Tuckwell Place

A 'hot-spot' where several buildings are subject to above-floor flooding has been identified for that part of the Industrial Creek catchment immediately upslope of Epping Road. The community questionnaire (**Section 3.3**) and the damages assessment (**Figure 5.2**) also identified problems in medium density developments at Rogal Place, Fontenoy Road and Tuckwell Place, Macquarie Park, with three townhouses at No. 12 Tuckwell Street reporting above-floor inundation (one by 1.0m) in the past.

6.5.1 Epping Road Flyover Embankment Options

Flood modelling points to significant depths of inundation upslope of the Epping Road flyover embankment at Lane Cove Road (**Figure 6.7a**). The issue is a lack of consideration of overland flows when the road works were constructed (several decades ago). **Figure 6.8** shows the extent of hydraulic impacts upstream towards Paul Street. Five dwellings are liable to above-floor inundation in the 20 year event (and three of these in more frequent events also). The above-floor depths of inundation are predicted to reach 0.8m in the 100 year event, which is verging on high hazard conditions. In the sag point in the Epping Road on-ramp, the 100 year depths are predicted to exceed 1.5m.

FIGURE 6.7 – INDUSTRIAL CREEK CATCHMENT PHOTO

a. Epping Road flyover embankment, with affected properties on right

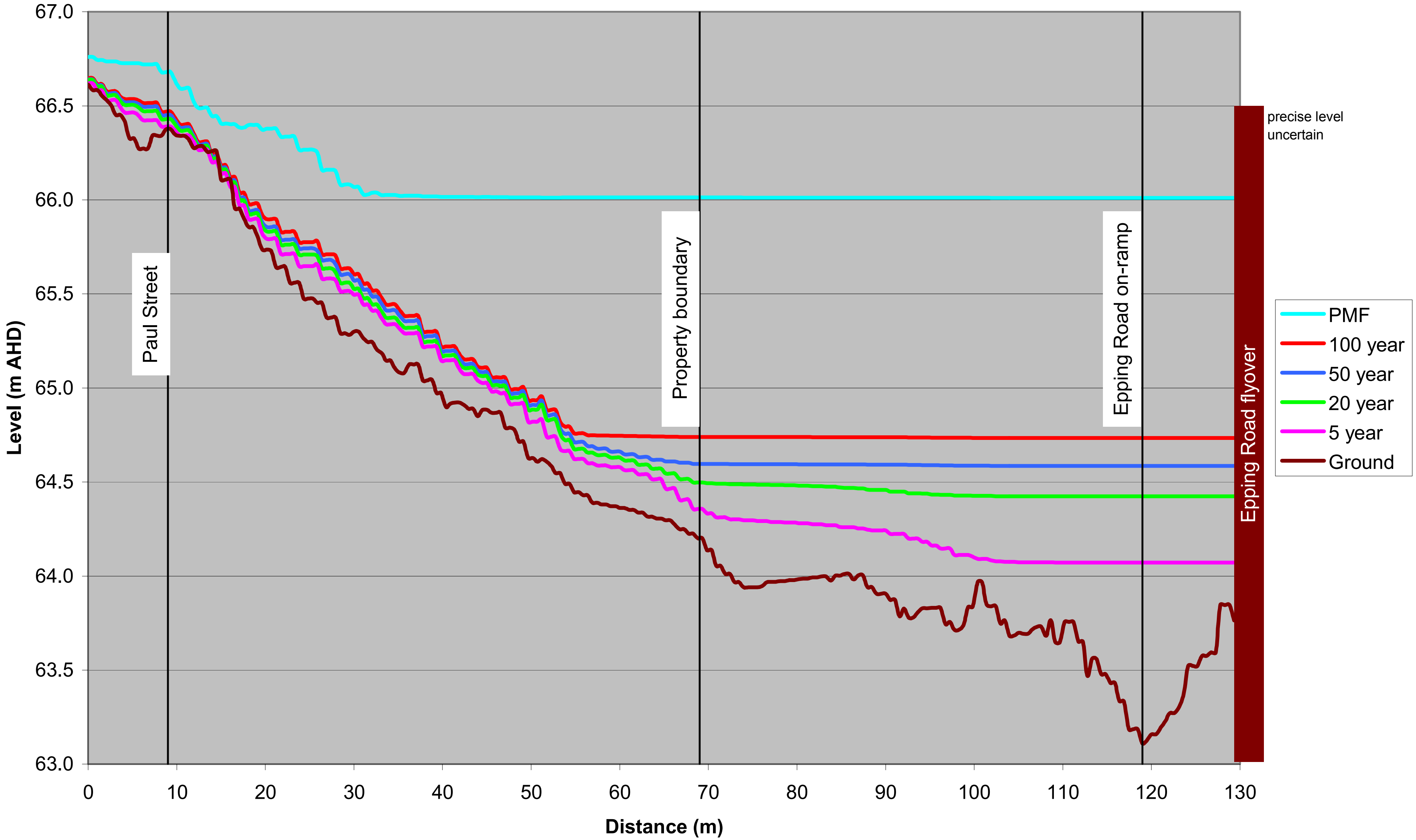

FIGURE 6.8 – HYDRAULIC EFFECT OF EPPING ROAD FLYOVER, INDUSTRIAL CREEK

One structural option to alleviate this flood problem is a new pipe system to carry flows 'around' the flyover embankment. The flood modelling shows overland flows of 4.1 m^3/s. An important consideration is how and where the piped flows would be surcharged, since removing what amounts to a detention storage function at the flyover embankment would probably increase downstream flow peaks. (It could be argued that existing downstream drainage works did not take account of the man-made storage impact so the loss of storage may not actually matter). A conservative approach could demand the provision of pipework to the downstream side of the M2 Motorway (a distance of about 1,300 metres), whilst a more affordable alternative would be to provide pipework along the alignment of Epping Road to the Shrimptons Creek bridge (a distance of about 800 metres). It is noted that Council's WSUD report (EDAW, 2009) and *DCP 2010* (CoR, 2010) promote the formalisation of overland flow paths along the alignment of the (formerly) natural creekline (see **Appendix C**). Given this intention, it may be acceptable to surcharge on the downstream side of Waterloo Road (a distance of about 520 metres based on the existing conduit alignment) or possibly further upslope at the intersection of Giffnock Avenue and Coolinga Street[9] (a distance of about 350 metres). The latter option would cost about $2.5-3.0M.

Another structural option is to construct massive detention storage tanks under the Epping Road on-ramp roadway (or under properties upstream if these are purchased). As noted above, the flyover works actually function as a de facto basin. Constructing detention storage tanks would formalise this function. However, it is likely that the existing pipework in front of the affected properties is quite shallow in which case provision of massive underground storage would not be able to drain away by gravity flow without new pipeworks which would be a smaller version of the overall pipework diversion scheme. Hence the large capacity pipe diversion scheme would be more cost effective.

A non-structural option is the voluntary acquisition of the five properties where above-floor inundation is predicted in the 20 year event (Nos. 126 to 130 Epping Road). This would provide benefits (damage savings) of about $780K but based on median suburb sales prices is estimated to cost in the order of $3.0M including demolition, yielding a benefit-cost ratio of 0.3. Given the identified cause of the problem, it could be argued that at least a portion of this expense should be funded by the Roads and Traffic Authority. The costs of the project could be defrayed by redeveloping this area in a flood-compatible manner with a more appropriate land use (e.g. extending the commercial complex from 124A Epping Road).

The shortest piping option and the VP scheme have similar capital costs, but the potential to recover some costs through appropriate redevelopment commends the latter option.

6.5.2 Formalise Overland Flow Paths during Redevelopment

Council's WSUD report (EDAW, 2009) recommends restoring vegetation and overland flow paths along the natural creekline for Industrial Creek between Waterloo Road and Talavera Road (see **Appendix C**). *DCP 2010* Section 4.5 (CoR, 2010) builds on this by including vegetated swales to convey stormwater where overland flow paths are located, for both the proposed Central Park and proposed linear parks to the north and south of Central Park. Flood modelling indicates overland flows at Waterloo Road of 4.5 m^3/s in the 20 year event and 6.6 m^3/s in the 100 year event. Whilst no buildings are predicted to be inundated above floor level in these events, the inundation will affect roads, carparks and landscaping. As areas are redeveloped, retrofitting the land to formalise the overland flowpaths is recommended in this study.

[9] Coolinga Street is named 'Road 9' in *DCP 2010*.

6.5.3 Rogal Place, Fontenoy Road and Tuckwell Place Options

Community consultation and the damages assessment has pointed to inundation problems in medium-density developments at No. 4 Rogal Place, No. 46 Fontenoy Road and Nos. 4, 6 and 12 Tuckwell Place, Macquarie Park. This is despite Council doing some works in the past to alleviate problems. In these areas, inundation may relate to inadequate pipe capacities, inadequate maintenance of pipes, or inadequate provision of overland flow paths through the developments when the pipes inevitably surcharge. To consider the micro-scale influences on inundation regimes in these areas requires a specialist study, which is recommended (cost ~$25K).

6.6 PORTERS CREEK CATCHMENT

Recommendations:

1) Remove shrubs from entrance to 'Officeworks' culvert inlet and maintain as short grass cover

2) VP at least four properties upstream of Epping Road (and redevelop)

3) Drainage upgrade between Officeworks and M2 during redevelopment

4) Formalise overland flow paths as the area is redeveloped

5) Develop a MOU with the Hills Motorway and landowners on the proposed route to enable emergency access to the SES Local Headquarters when Wicks Road is cut

Despite its relatively small size, the Porters Creek catchment has significant inundation problems. **Table 5.4** indicates 21 houses and 10 businesses are expected to be inundated above floor level in the 100 year flood. Concentrations of flood-prone properties include Nos. 42-48 Avon Road, the Avon Road community shops, houses between Morshead Street and Epping Road, and low-set commercial uses along Wicks Road (**Figure 5.2**). Epping Road carries a large volume of traffic at its Porters Creek crossing (**Table 6.3**) but would be inundated to depths of up to 1.1m in the 20 year flood and 1.2m in the 100 year flood, posing massive disruption and potential danger. A selection of photos is presented in **Figure 6.9**.

6.6.1 Avon Road Options

Overland flows between Avon Road and Wicks Road expose five dwellings to above-floor inundation in the 20 year event. Some of these dwellings appear to be relatively new slab-on-ground structures, which highlights the need for the application of appropriate minimum floor level controls during the planning stage of the redevelopment process (see **Section 6.8.3**). Consideration of the drainage network in the area reveals no obvious opportunities for a pipe upgrade, which is assessed as being of low economic merit. There may be potential to offer a small financial subsidy for redevelopment in a flood-compatible manner or to provide advice about flood-proofing (see **Section 6.8**).

6.6.2 Morshead Street – Epping Road Area Options

Figure 6.10 presents modelled flood gradients from Morshead Street to Officeworks on the northern side of Epping Road. It shows depths exceeding 1.0m upslope of Epping Road, and several houses there are expected to be inundated above floor level in the 20 year or 50 year floods (**Figure 5.2**). Epping Road's median strip and eastbound carriageway are elevated above ground levels on the upslope side. It also appears as though the 'Officeworks' site influences upslope flood levels to a degree.

FIGURE 6.9 – PORTERS CREEK CATCHMENT PHOTOS

a. View upslope across Epping Road sag-point at Officeworks

b. Western end of culvert inlet at Officeworks

c. Blocked culvert inlet at Officeworks

d. Culvert surcharge outlet at downstream end of Officeworks

e. View upslope at Wicks Road underpass

f. SES Local Headquarters (left) in relation to M2

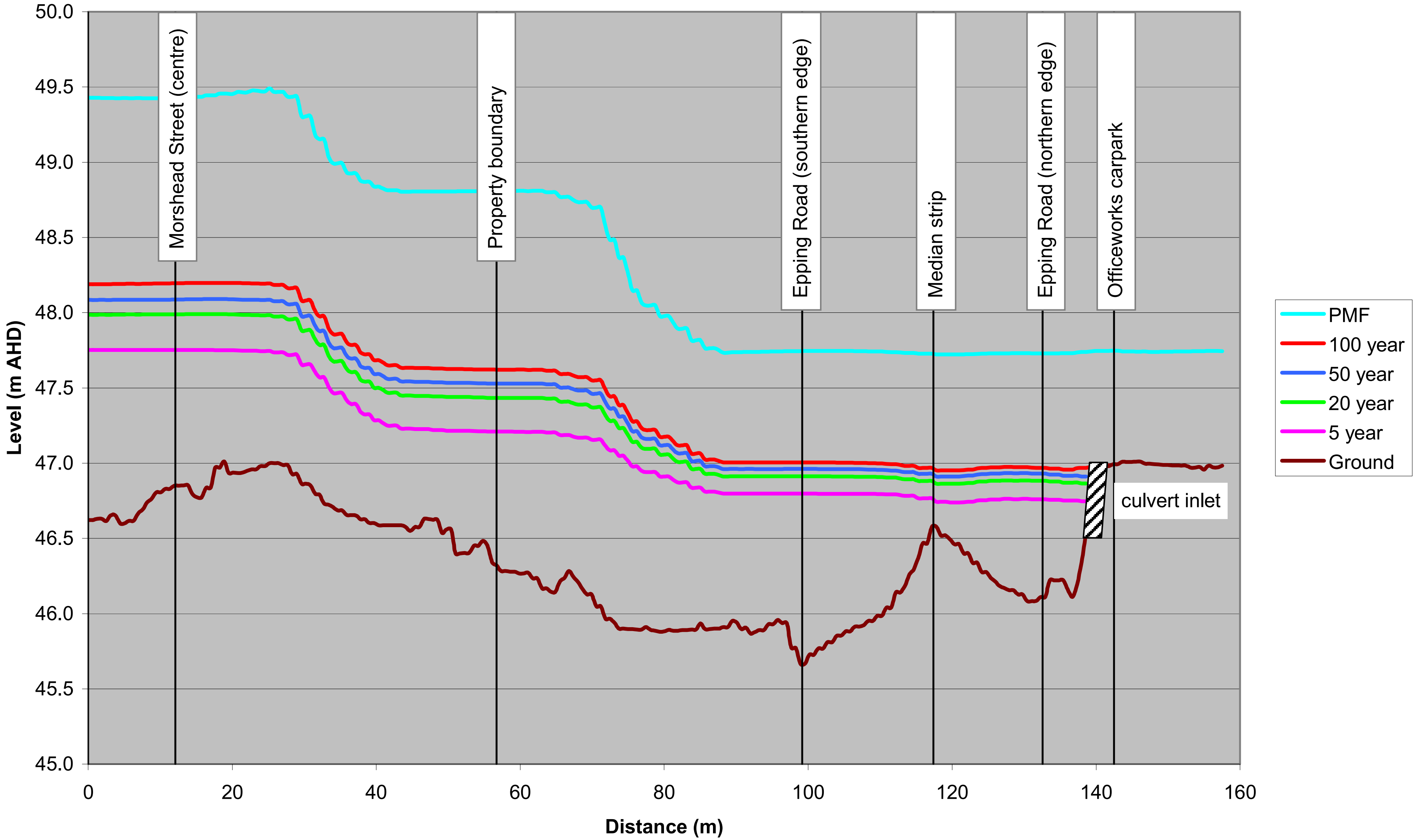

FIGURE 6.10 – PORTERS CREEK FLOOD PROFILE FROM MORSHEAD STREET TO EPPING ROAD

6.6.2.1 Drainage upgrade

Consideration has been given to a major pipe upgrade through this section. Flood modelling indicates that the 1.5m diameter pipe conduit across Epping Road conveys 5.0 m^3/s and is at full capacity in the 20 year and 100 year events, with three times as much flow (14.5 m^3/s) and four times as much flow (20.6 m^3/s) conveyed as overland flow in the 20 year and 100 year events, respectively. At first glance then it appears as though there could be merit in providing additional piping beneath Epping Road. However, the flood modelling also indicates that the large 5.0 x 4.2m culvert along the western side of Officeworks is nearly at capacity. This means that there would be little benefit in upgrading pipe capacity across (and upslope of) Epping Road, unless commensurate upgrades could be completed through the Officeworks site. Unfortunately the current development footprint indicates there is no space for a significant culvert upgrade through this site. Consequently, the proposal for a major pipe upgrade is not recommended at this time. Should the area downstream of Epping Road be redeveloped in coming years such that more space is available (as per the vision espoused in Council's WSUD report and *DCP 2010*), then a major upgrade to both the underground drainage and overland flow paths should be pursued.

6.6.2.2 Overland flow path

Due to the Epping Road level and the raised carpark at the 'Officeworks' site, the creation of an overland flowpath seems to be unworkable. It is noted that Council's WSUD report (EDAW, 2009) and the Ryde *DCP 2010* Section 4.5 (CoR, 2010) promote the formation of an overland flow path from Epping Road downstream to the M2, though the current development constraints mean that this vision is 'aspirational' and may not be realised for decades (see **Section 6.6.4**).

6.6.2.3 Culvert inlet maintenance

An inspection of the large culvert inlet below the Officeworks carpark shows that much of it is blocked by vegetation (**Figure 6.9b,c**). Should a flood come at the present time, this large culvert inlet could effectively be blocked, significantly exacerbating the upslope impacts. It is recommended that this vegetation be cleared from the culvert entrance immediately, that the area be planted with grass and that legal mechanisms be explored to enforce maintenance of this area.

6.6.2.4 Voluntary house raising (VHR)

Given the constraints inhibiting the implementation of structural options, non-structural options for alleviating the flood problem upslope of Epping Road are considered.

In the case of the seven houses between Morshead Street and Epping Road inundated above floor level in the 100 year flood (including four having depths exceeding 0.5m), house raising appears to be technically feasible for six (all are built on piers but one has a second storey). The suitability of each building structure would need to be confirmed through building inspections. Given the proximity of Epping Road, higher houses could expose the occupants to more noise pollution, which may deter landowners from participating in a VHR scheme. The main reason counting against raising these houses is the nature of inundation through these properties, where depths exceed 1.0m in the modelled 5 year event and 1.5m in the 100 year event, and high hazard conditions prevail. Raising houses in such situations does not negate the risk especially the risk of trauma-related health impacts when water surrounds a building (see **Section 6.8.1**). The *Floodplain Development Manual* (NSW Government, 2005, p.J-4) recognises that voluntary house raising is in general suitable only for low hazard areas of the floodplain. For this reason, voluntary house raising is not recommended at this location.

6.6.2.5 *Voluntary purchase/redevelopment*

Another potential solution is to voluntarily acquire these properties (or at least the four worst-affected i.e. Nos. 75, 77 Morshead Street and Nos. 42, 44 Epping Road) and demolish the existing building. Costs are estimated at about $800K/house based on median suburb sales prices ($3.2M for four). Removal of the four listed dwellings as a flood exposure would yield benefits (damage savings) of $720K. The benefit-cost ratio is calculated as an unfavourable 0.2. However, as suggested for the houses upstream of the Epping Road flyover embankment (**Section 6.5.1**), the costs of the project could be defrayed by redeveloping the area (or if required a slightly larger area) in a flood-compatible manner with a more appropriate land use (e.g. part open space, part commercial or residential high rise). Such a redevelopment could be cost neutral to Council and is recommended.

6.6.3 'Officeworks' to M2 Drainage Upgrade

A number of large commercial/industrial buildings downstream of the 'Officeworks' site are highly flood-prone. The large culvert through the 'Officeworks' site is designed to surcharge at the property boundary (**Figure 6.9d**), and the pipe immediately downstream is much smaller (1.8m diameter), leading to significant overland flow in that area (18.3 m^3/s in the 100 year event). Additional flows are contributed from the direction of Wicks Road. The stepped topography means that some deep flooding is expected in the 100 year event (~2.0m). A possible solution to this problem is for a major drainage upgrade beginning at the end of the 'Officeworks' culvert.

It is estimated that upgrading the 100 metres length of conduit through No. 113 Wicks Road which appears to be providing the major constraint, so as to convey the 100 year flow, would cost about $1.0M. It is likely, however, that the connecting downstream pipe (which is of the same size) through Nos. 119-127 Wicks Road would then also require upgrading at least as far as Waterloo Road, for a combined cost of about $3.0-3.5M. But allowing the upgraded conduit to discharge at Waterloo Road, without a commensurate enlargement of the M2 culvert, might possibly exacerbate inundation at the Wicks Road underpass. If such inundation was unacceptable, an upgrade would be required all the way from the downstream end of 'Officeworks' to the twin 2.4 x 1.8m cell box culvert that begins downstream of the M2 – a distance of about 620 metres, at a total cost of about $6.5-7.0M. It is unlikely that the State Government's Floodplain Management Program would fund this work given the limited availability of monies and since the flood problem relates to commercial/industrial development. Nevertheless, it is recommended that a privately-funded drainage upgrade be implemented as redevelopment of this area takes place over coming years. To avoid ad hoc upgrades on a property by property basis, Council should coordinate any drainage upgrades on individual properties.

In the interim, some advice about flood-proofing could be provided to tenants (see **Section 6.8.2**).

6.6.4 Formalise Overland Flow Paths during Redevelopment

Council's WSUD report (EDAW, 2009) and *DCP 2010* Section 4.5 (CoR, 2010) envision a linear park in alignment with Porters Creek downstream of Epping Road, which would contain a 'low urban creek' or 'vegetated swale' for the transmission of overland flow (the WSUD report also proposes a parallel road to convey overland flow). Flood modelling indicates significant overland flows downstream of the Officeworks site. Currently several low-set buildings are highly flood-prone. The approach set out in the WSUD report and *DCP 2010* is therefore supported, seeing the formalisation of overland flow paths as land is redeveloped.

6.6.5 Improve Access to SES Headquarters

The City of Ryde SES local Headquarters (LHQ) and the local Emergency Operations Centre (EOC) is located at No. 137 Wicks Road, Macquarie Park. Whilst flood modelling shows the site to be free of inundation during the 100 year event, it could be affected by rare events – it is shown as affected by the PMF. More concerning is the access to the site along Wicks Road, with peak inundation depths along Wicks Road at the M2 overpass (**Figure 6.9e**) predicted to be about 0.6m in the 20 year event and 0.8m in the 100 year event. The depths are greater at the Wicks Road sag point just south of the Waterloo Road intersection – 0.8m in the 20 year event and 1.1m in the 100 year event. In addition, the 100 year flow velocities along Wicks Road in places exceed 3.0 m/s. This combination of depths and velocities results in high hazard conditions along Wicks Road from about the former High School to the SES LHQ. Modelled flood hydrographs offer some insight into potential rate-of-rise and flood duration at the Wicks Road underpass (**Figure 6.11**). The rapid rise suggests that insufficient warning time would be available to deploy SES resources prior to the road being inundated. Durations are highly dependent on the storm duration, with the modelled 9 hour storm yielding a duration of flooding of several hours (noting that the road might be open to 4WD vehicles for some of this time). Of course longer storm durations would lead to longer durations of flooding. In such circumstances, SES and other emergency management personnel would be unable to reach the LHQ/EOC, and personnel at the LHQ would be unable to leave the site to attend call-outs, potentially compromising the SES's response to the flood emergency.

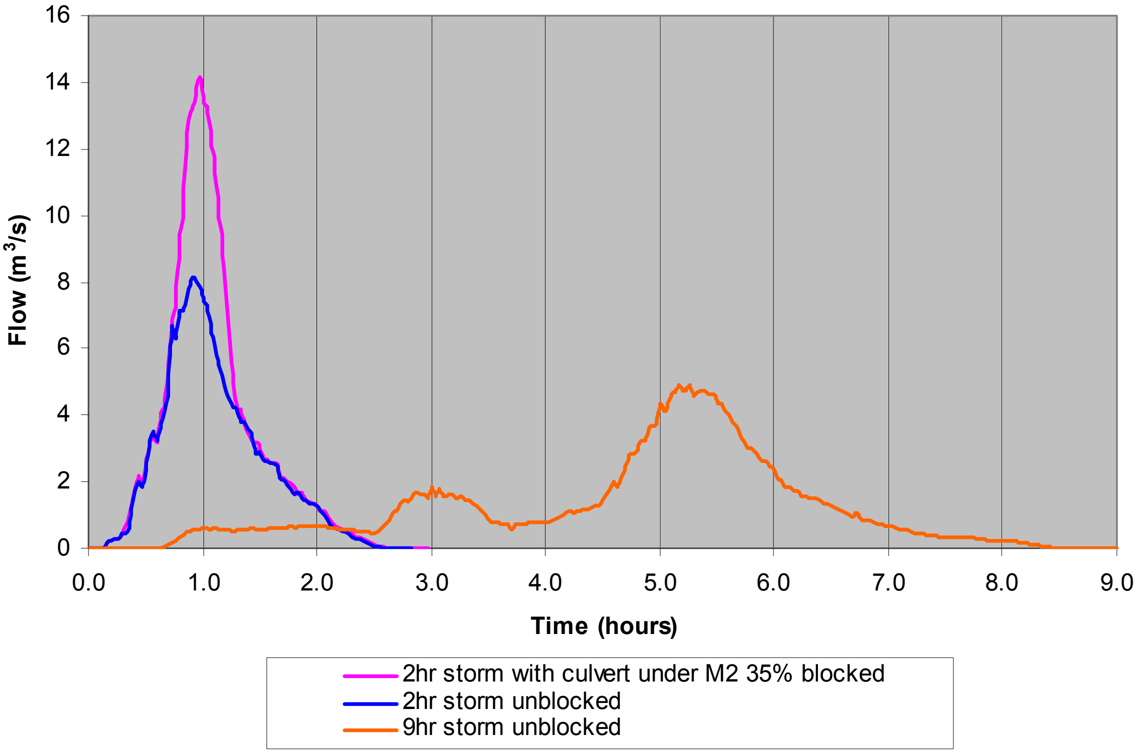

FIGURE 6.11 – MODELLED 100 YEAR HYDROGRAPHS FOR OVERLAND FLOW AT WICKS ROAD UNDERPASS

A number of options have been considered to address this issue (**Figure 6.12**). First, a significant drainage upgrade along Wicks Road itself would alleviate the flood depths. Containing the existing 100 year Wicks Road surface flow would require a large culvert extending a distance of about 520 metres from the former High School to the twin 2.4 x 1.8m cell box culvert that begins downstream of the M2. This would cost an estimated $6.0-6.5M and would be difficult to justify for improving access alone.

Another option is to formalise a detention basin in the depression immediately to the east of Wicks Road and south of the M2.[10] Such a basin might reduce the flood hazard at the Wicks Road underpass. However, significant pipework would be required further upslope in Wicks Road to direct street flows to the basin so as to provide improved conditions all the way along Wicks Road where inundation conditions are currently problematic. This pipework would significantly increase costs.

Installing a debris control structure upslope of the M2 culvert would reduce the potential for this important culvert blocking and thereby increasing overland flows at the Wicks Road underpass (see **Figure 6.11**). This typically costs about $100K and would be difficult to justify on the grounds of improved access alone.

Another option that has been considered is providing alternative emergency access to the LHQ/EOC (see **Figure 6.12**). Whilst it may be a remote possibility given likely administrative, safety and technical issues, one option is the construction of an emergency (gated) access track from the SES LHQ up to the M2 (see **Figure 6.9f**). If Wicks Road was inundated, such a track could allow emergency access to the LHQ/EOC via the proposed Christie Road east-bound M2 on-ramp, and egress via the existing Delhi Road east-bound M2 off-ramp. In such circumstances SES operations could be hampered by other local road closures, but having direct emergency access to the M2 would at least allow the SES access to the eastern part of the LGA, and when the proposed Herring Road west-bound M2 off-ramp is constructed, to the Shrimptons Creek area (via the Delhi Road off-ramp).

Aerial photography suggests that alternative emergency access to the LHQ/EOC may already be available via a gate from the eastbound M2 carriageway located 510 metres north-west of the Wicks Road underpass, through Council's Porters Creek Construction Recycling Depot, to Wicks Road *north-east* of the LHQ/EOC (see **Figure 6.12**). It is recommended that the SES liaise with Council and Hills Motorway to develop a MOU for the usage of this route (including keys) on the rare occasions that Wicks Road is cut. Although it is understood other SES units may be tasked to respond to requests for assistance should the Ryde SES unit be isolated, this is not ideal. Ensuring the availability of alternative access during flood-time is important and should be documented in the Local Flood Plan (**Section 6.8.5**).

[10] This area is shown as 'deferred matter' in LEP 2008.

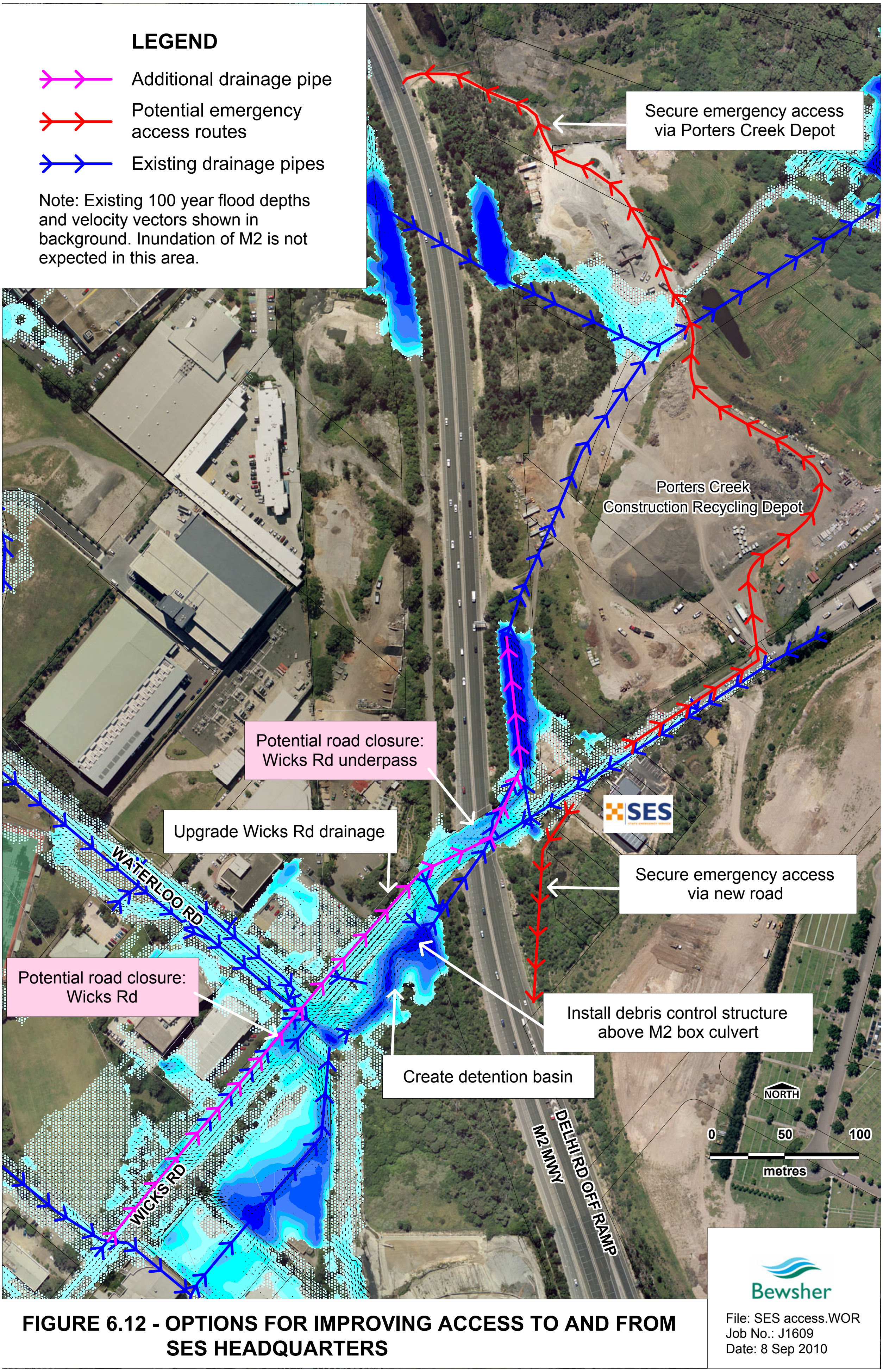

FIGURE 6.12 - OPTIONS FOR IMPROVING ACCESS TO AND FROM SES HEADQUARTERS

6.7 LANE COVE CATCHMENT

Recommendations:

1) Lower downslope ground levels adjacent to the Pittwater Road sag point

2) Continue and promote the River Avenue VP scheme, and remove three dwellings with a high flood risk from the floodplain (OSL)

3) Develop a MOU with the Northern Suburbs Crematorium to enable emergency access to Quebec Road when River Avenue is cut (SES)

Relatively few flood problems have been identified in the Lane Cove catchment (**Figure 5.2**). Some low-lying warehouses in Plassey Road are shown as subject to above-floor flooding in the 20 year flood. A number of the few remaining houses located between River Avenue and the Lane Cove River are also subject to deep and frequent flooding.

6.7.1 Improve Drainage at Pittwater Road Sag Point

Flood modelling indicates significant ponding (0.9-1.0m in the 100 year event) at the Pittwater Road sag point located about 80 metres north of the Clarence Street intersection. However this ponding is very much a function of elevated ground levels immediately downslope of the roadway sag point (**Figure 6.13**). It is likely that lowering of those elevated ground levels (by potentially as much as 0.8 metres) would reduce the ponding depth to less than 0.2 metres. These works are estimated to cost $140K and are recommended.

6.7.2 River Avenue VP Scheme

In the Macquarie Park study area, the only area where flooding of dwellings is considered particularly dangerous is for three River Avenue houses next to the Lane Cove River where above-floor depths exceed 1.0m in the 100 year flood (e.g. see **Figure 6.14a**). The Office of Strategic Lands (OSL)[11] has for many years been operating a VP scheme for properties located between River Avenue and the Lane Cove River, with most properties now acquired and incorporated into Lane Cove National Park under DECCW ownership.

Lands reserved for open space purposes are generally acquired when the owner initiates acquisition action in accordance with the provisions of the *Lands Acquisition (Just Terms Compensation) Act 1991*. There is no specific budget provision due to the unpredictable timing of land owner actions. Land owners affected by acquisition proposals for public purposes are generally aware of the proposal as a result of the public nature of the planning process and notations on Section 149 certificates.[12]

[11] The Office of Strategic Lands (OSL) operates within the Land and Property Management Authority, on behalf of the Minister for Planning corporation (Corporation Sole) and the Sydney Region Development Fund, to identify, acquire, manage (on an interim basis) and transfer to other government agencies land that is required for planning purposes throughout Sydney Region.

[12] Mr Ken Taylor, Land and Property Management Authority, Jul 2010, pers. comm.

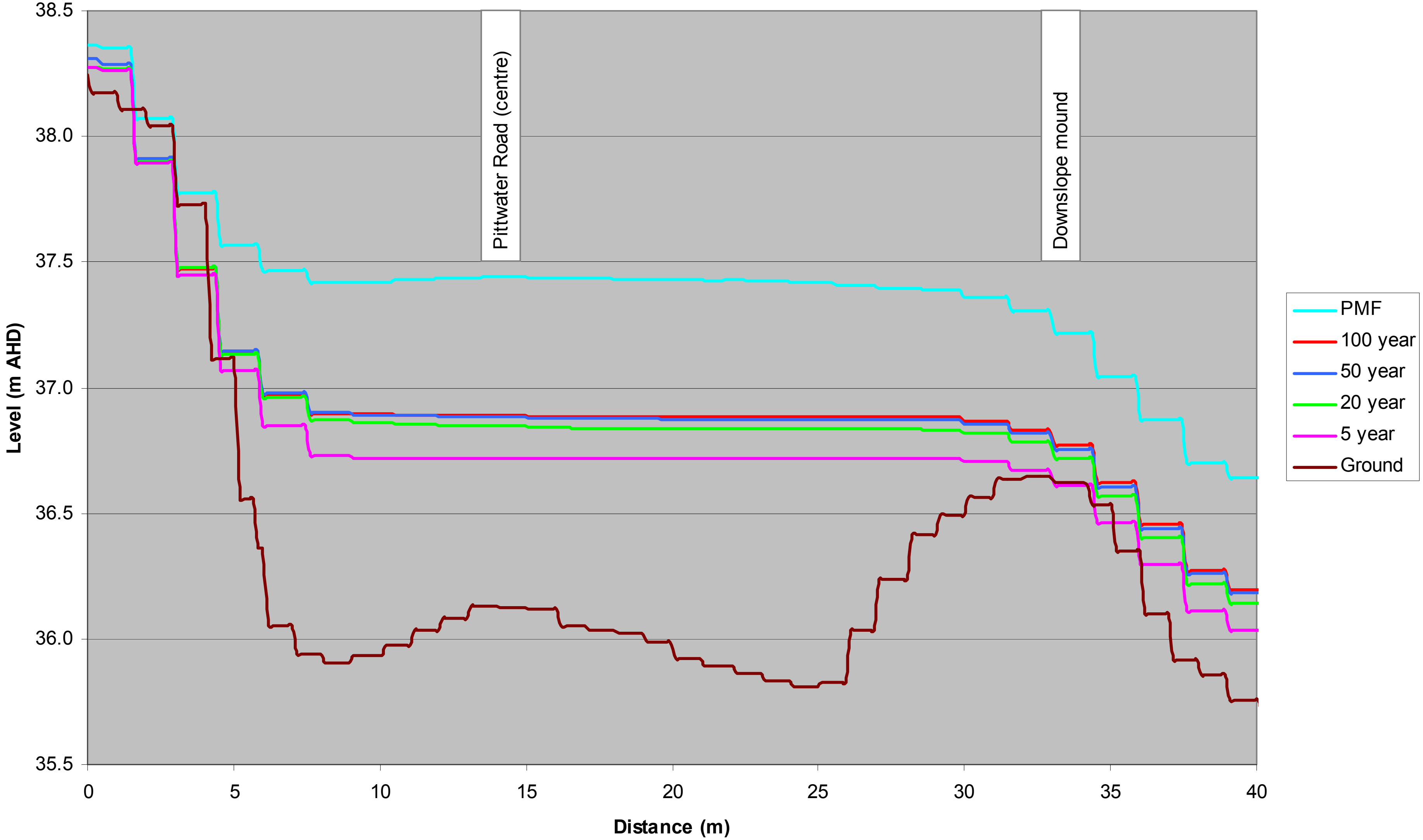

FIGURE 6.13 – PROFILE AT PITTWATER ROAD SAG POINT

It is recommended that this VP scheme be continued as a high priority. The objective from a flood risk perspective is actual removal of buildings from the floodplain, since these are not safe for residential occupation. It is noted that although No. 11 River Avenue is owned by Government, it is now being used as staff housing (**Section 3.6**). It is understood that the *Lane Cove River National Park Plan of Management* is under review, which provides an opportunity for Council to make a submission regarding removal of the three dwellings exposed to high flood risks. After this study is adopted, it is also suggested that the owners of the two other seriously affected houses (i.e. Nos. 1, 31 River Avenue) be approached and reminded of the flood risk in this area (e.g. see **Figure 2.4h**) and of Government's offer to purchase their properties.

FIGURE 6.14 – LANE COVE CATCHMENT PHOTOS

a. Lane Cove River floodplain looking upstream towards No. 11 River Avenue

Note: levels (m AHD) marked on photo have not been precisely plotted

b. A low-point on River Avenue

c. Emergency access to dwellings isolated by flooding of River Avenue could possibly be arranged via the Northern Suburbs Crematorium and this gate to Quebec Road

6.7.3 Improve Access to River Avenue

An important emergency management consideration for the Lane Cove catchment is the isolation of about 140 houses (360 people) in Chatswood West when River Avenue is cut by flooding from the Lane Cove River (**Figure 6.14b**). **Figure 6.15** plots the modelled 100 year hydrograph for the critical 9 hour storm for the Lane Cove River near No. 19 River Avenue, suggesting that the road could be cut for about ten hours in such an event. Flood-time access for the emergency services including the Ambulance Service and Fire Brigade is a concern. One option could be for the SES to arrange a MOU with the Northern Suburbs Crematorium for emergency access via the gate onto Quebec Road (**Figure 6.14c**). Any arrangements should be recorded in the Local Flood Plan (see **Section 6.8.5**).

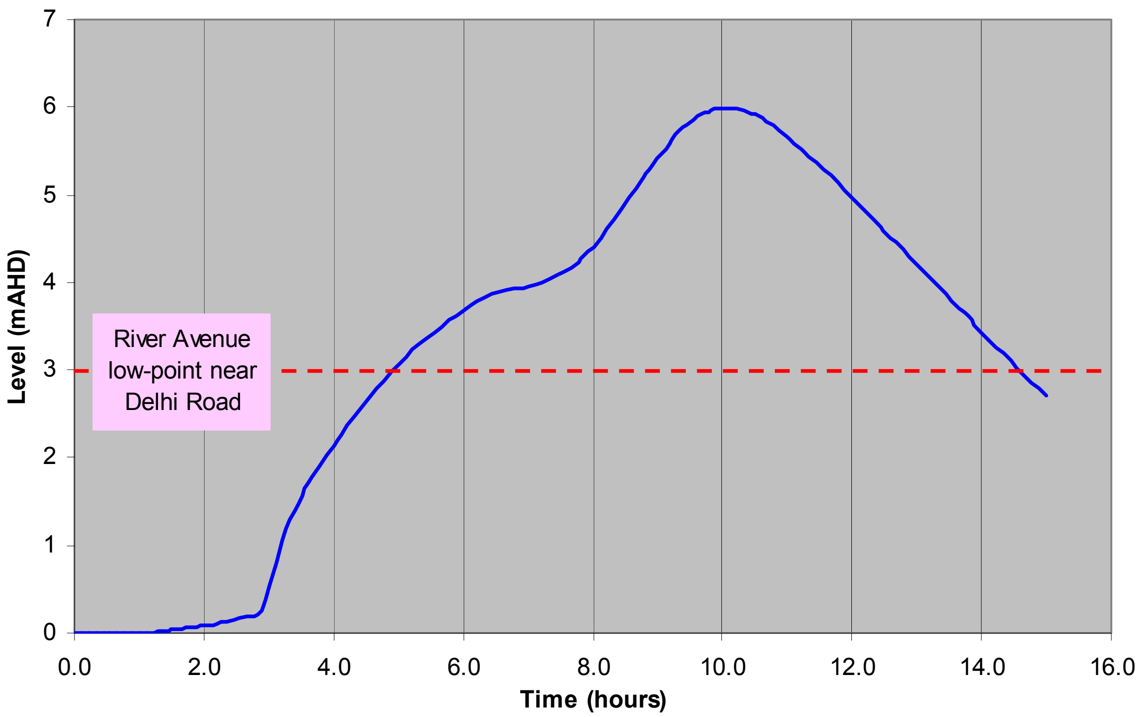

FIGURE 6.15 – MODELLED 100 YEAR HYDROGRAPH FOR LANE COVER RIVER NEAR RIVER AVENUE

6.8 OTHER FLOODPLAIN MANAGEMENT MEASURES

Recommendations:

1) Invite owners of two dwellings to participate in VHR scheme with $50K/dwelling subsidy to redevelop properties to comply with DCP provisions

2) Prepare a brochure summarising potential flood-proofing techniques and distribute to all buildings expected to be inundated above floor in the 100 year event

3) Amend the draft floodplain management DCP provisions by adding a planning matrix for Macquarie Park (same as Eastwood and Terrys Creek matrix)

4) Improve emergency management planning in the following ways:

a) Prepare a Local Flood Plan for the City of Ryde (SES)

b) Prepare a Flood Emergency Plan for Macquarie University (MU)

c) Prepare a Flood Emergency Plan for the Macquarie Centre (AMP Capital)

5) Improve public flood readiness in the following ways:

a) Consolidate flood modelling and mapping outputs into Council's GIS system

b) Provide flood certificates at regular intervals

c) Prepare a FloodSafe brochure for Macquarie Park (SES)

6.8.1 Voluntary House Raising/Redevelopment

Raising houses with low-set floor levels has proved to be an effective floodplain management measure for various locations throughout NSW. For example, Fairfield City Council has been implementing a successful house raising program in the Prospect Creek catchment for many years.

Advantages of house raising include:

- reducing tangible flood damages and alleviating anxiety about future floods;
- providing under-house space for non-habitable uses such as garages and laundries; and
- an enhanced resale value.

Disadvantages of house raising include:

- modified streetscape unless all the houses in an area are raised;
- difficult access for some people (e.g. elderly, people with a disability); and
- people living in raised houses are often less likely to evacuate, which can exacerbate risk to life in rare floods that overtop the raised floor or when people panic with water under the house.

Various forms of house raising schemes can be considered. The easiest form of house raising occurs where houses are of either timber or fibro construction. Fairfield Council's experience in Prospect Creek has shown that such houses can be raised by 1-2m for a cost of $80K (in 2010 dollar values).

Physically raising houses of brick veneer or full brick construction is more costly, and in most cases impractical. One solution for these dwellings is to completely *rebuild* the house at a higher level, which may or may not be accompanied by a change in home ownership. (With a change in ownership, Council would acquire the property, demolish the existing house and sell the vacant building lot with appropriate development controls). Based on the experience of Fairfield Council, net costs are slightly higher than for raising timber or fibro dwellings.

The State and Commonwealth Governments provide financial subsidies for house raising schemes, depending on the relative priority of works on a State-wide basis. Partly-subsidised schemes are considered preferable to fully-subsidised schemes to reduce the administrative and financial burden on Government, to foster local ownership, and because they offer greater flexibility for owners of 'difficult' houses (provided that the ultimate goal of raising habitable floor levels to the FPL is achieved).

In the Macquarie Park study area, several houses subject to inundation have been identified where drainage improvements and other structural works are not practical. In these cases, a financial subsidy could be used to encourage either house raising or redevelopment in such a way as to reduce the risk of flooding. Here an issue is what threshold of flood affectation would qualify a building for subsidy. In the consultant's opinion, an above-floor depth in the 100 year flood in excess of 0.5m constitutes a reasonable threshold. Another issue is what level of subsidy to offer any qualified properties. Whilst Council naturally seeks value for money, a landowner requires sufficient incentive to participate in a scheme to which he/she will also be inputting capital. Based on these considerations, and mindful of other measures proposed in this study, it is recommended that the owners of two dwellings – No. 93 Culloden Road and No. 9 Lucinda Road – be invited to participate in a VHR scheme with a maximum Government subsidy of $50K/house to redevelop the buildings in such a way as to comply with the flood risk management provisions which apply to the residential land use in the medium flood risk precinct (including habitable floor levels no lower than the 100 year flood level plus freeboard). Damage savings of $370K are expected, yielding a benefit-cost ratio of 3.7.

6.8.2 Flood-proofing

Individual properties can be modified to reduce the impacts of flooding through flood-aware design. *Reducing Vulnerability of Buildings to Flood Damage* (HNFMSC, 2007) details the many ways buildings and building components can be designed to minimise the impact of flooding. Council's draft floodplain management DCP provisions prepared as part of the *Eastwood and Terrys Creek Floodplain Risk Management Plan* (Bewsher Consulting, 2009) list flood compatible building materials to be applied when developing or redeveloping buildings located in the floodplain. For existing buildings, there may still be some opportunity to apply 'flood-proofing' techniques. Fairfield City Council provided subsidies of up to $20K for double-brick or two storey houses to assist in flood proofing the lower ground floor by raising electrical power points, installing a water sensor device to shut off power, replacing building materials liable to flood damage, and constructing local flood walls so long as adjoining properties were not adversely affected (Frost & Rice, 2003).

Several buildings in the Macquarie Park study area could benefit from flood-proofing techniques, though the negligible flood warning times mean that strategies reliant upon detecting the rising water (e.g. manually installing temporary flood barriers) may not be practical. Technologies such as the 'Self Closing Flood Barrier' which protects to depths of up to 2.5m and rises automatically in response to the rising flood, could be appropriate for commercial and industrial premises.[13]

One strategy would be for Council to produce a brochure outlining techniques for flood-proofing, at a cost of about $25K. These should be distributed to commercial/industrial premises and to houses flooded above floor level in the 100 year flood, for which no other options have been recommended.

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[13] www.floodingsolutions.com.au/

6.8.3 Planning and Development Controls

Land use planning and development controls are key mechanisms by which Council can manage flood-affected areas within the catchment. Such mechanisms will influence future development (and redevelopment), with benefits accruing gradually over time. Without comprehensive floodplain planning, existing problems may be exacerbated.

A comprehensive review of planning controls and flood risk management policies was undertaken as part of the *Eastwood & Terrys Creek FRMS&P* (Don Fox Planning, 2008; Bewsher Consulting, 2009). It recommended inclusions to the template LEP and drafted floodplain risk management controls as a chapter of Council's consolidated DCP. It also recommended raising the freeboard for areas within flood risk precincts from 0.3m to 0.5m due to the uncertainties associated with the impact of climate change on rainfall intensities.

Consideration of the flood risk setting for the Macquarie Park study area suggests that the planning matrix prepared for Eastwood and Terrys Creek is also appropriate for Macquarie Park. The analysis of the potential flood impacts of climate change (**Section 4.3**) suggests that the 0.5m freeboard recommended for the Eastwood and Terrys Creek catchment is appropriate. It is recommended that the *DCP 2010* be amended by adding a matrix for Macquarie Park.

6.8.4 Improve Flood Warning System

The Macquarie Park study area consists of small urban catchments where inundation is typically 'flash flooding', often defined as areas where flooding occurs within six hours of rain. Indeed, urban areas reportedly flooded just 10 to 20 minutes after the commencement of heavy rain on 8 November 1984 (Riley et al., 1985, 1986).

For flash flood catchments, the provision of an effective flood warning service is problematic. The 'total flood warning system' has five components that need to be completed during a flood emergency – prediction, interpretation, message construction, communication and appropriate response (Commonwealth of Australia, 2009). But several challenges to the effective operation of such a system have been identified for flash flood catchments (McKay, 2004, 2008):

a) Flash floods are less predictable than larger scale flooding. Rainfall over small catchments is usually not well predicted by numerical weather prediction models.

b) For flash floods, there is insufficient time to develop reliable flood warnings and for effective 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.

c) A reliance on rainfall triggers increases the frequency of false alarms.

d) The use of river level triggers does not allow sufficient time for response.

For these reasons, the Bureau of Meteorology traditionally has not issued specific flood predictions for flash flood catchments. The Bureau does offer more general services that may be of some benefit in alerting the emergency services and community to the threat of flooding (**Table 6.5**).

A potential location for a site-specific flood warning service is the Lane Cove River at Fullers Bridge where the rate of rise would typically be longer than for other parts of the study area, though it is still a flash flood situation (see **Figure 6.15**). However, the Bureau would only provide a detailed flash flood warning service if Council was willing to fund an end-to-end service, including direct warning dissemination and detailed public education campaigns to underpin the local response. Moreover, given the progress of the River Avenue VP scheme, the direct residential exposure in this area is gradually being reduced to nil, and the Bureau would not provide a new flood warning service only for road closures. For these reasons, the development of a formal flood warning scheme in the Macquarie Park study area is not practical.

TABLE 6.5 – BUREAU OF METEOROLOGY WARNING SERVICES OF POTENTIAL BENEFIT IN FLASH FLOOD CATCHMENTS

Sources: McKay, 2004, p.3; www.bom.gov.au

General Weather forecast
General weather forecasts may indicate the likelihood of heavy rain from synoptic scale events, typically with more than 24 hours notice.

Flood Watch
A 'Flood Watch' is issued by the NSW Flood Warning Centre, typically providing 24 to 48 hours notice that flooding is *possible* based upon current catchment conditions and future rainfall, which is predicted by computer models of the atmosphere.

Severe Weather Warning
A 'Severe Weather Warning' is issued for synoptic scale events when one or more of the following hazardous phenomena are forecast:

- Gale force winds (average 10-minute wind speed exceeding 62 km/h)
- Damaging winds (peak wind gusts exceeding 89 km/h)
- Destructive winds (peak wind gusts exceeding 124 km/h)
- Torrential rain and/or flash flooding
- Damaging surf conditions leading to significant beach erosion

Severe Thunderstorm Warning
A 'Severe Thunderstorm Warning' is issued by the Severe Weather Team, typically providing 0.5 to 2 hours' notice of impending severe storms. These forecasts are based upon radar and, if available, data from field stations, reports from storm spotters, as well as an analysis of the synoptic situation. For the Greater Sydney region the Bureau issues more detailed graphical Severe Thunderstorm Warnings when actual thunderstorms have been detected.

6.8.5 Improve Emergency Management Planning

6.6.2.1 Ryde Local Flood Plan

At the current time, no Local Flood Plan (LFP) has been prepared for the City of Ryde. LFPs typically detail:

- responsibilities for managing flood emergencies;
- what is to be done to prepare for floods;
- the conduct of response operations; and
- the coordination of immediate recovery measures from flooding.

Given the growing understanding of historical and potential flood problems across the LGA including at Eastwood and Terrys Creek and in the Macquarie Park study area, the preparation of a LFP is strongly recommended. Flood studies and floodplain management studies contain much information that will be useful for this task, including:

- design flood levels, depths and extents for every property within the floodplain;
- surveyed or estimated ground and floor levels for every property within the floodplain;

- flood risk precincts including high hazard areas;
- the location of buildings subject to above-floor inundation (e.g. **Figure 2.6**; **Figure 5.2**);
- critical roads subject to inundation (including Epping Road, Lane Cove Road and Fullers Bridge – see **Table 5.7**); and
- communities subject to isolation as a result of road inundation (e.g. River Avenue, Chatswood West – see **Section 6.7.3**).

6.6.2.2 Macquarie University Flood Emergency Response Plan

Macquarie University campus is crossed by Mars Creek on its northern side and University Creek on its southern side. Modelling shows that under existing conditions important pedestrian and vehicular access routes could be inundated, as well as some student housing in rare events. **Figure 6.16** shows two of these access routes between the 'hub' of the University and transport facilities (in the case of Mars Creek, private transport towards Culloden Road; in the case of University Creek, the Macquarie University railway station). Students of the University will be unfamiliar with local flood regimes and could act inappropriately by trying to cross flooded roads. It is recommended that the University incorporate consideration of flooding into its emergency response plans. This may involve a rapid response to close thoroughfares.

FIGURE 6.16 – MACQUARIE UNIVERSITY PHOTOS

a. Pedestrian walkway across University Creek at Macquarie University

b. Mars Creek sag-point in Gymnasium Road at Macquarie University

6.6.2.3 Macquarie Shopping Centre Flood Emergency Response Plan

Both the experience of the November 1984 event and flood modelling demonstrate that the internal access road between Waterloo and Talavera Roads and nearby carparks in Macquarie Shopping Centre are subject to serious flooding (see **Figure 2.4f,g**). Given the limited, practical opportunities to alleviate flooding through structural works (see **Section 6.4.16**) and the serious risk to life and property, it is vital that a rigorous flood emergency response plan be prepared. Aspects of the plan should include:

- measures to detect an emerging flood threat (e.g. Bureau of Meteorology services listed in **Table 6.5**; installing an automatic water level recorder, a camera and/or positioning staff to safely observe the water level in Shrimptons Creek upstream of Waterloo Road);
- measures to prevent shoppers from acting inappropriately by attempting to exit the carpark only to drive into deep water (e.g. using the boom-gates to prevent egress from the carparks);
- measures to communicate the flood situation and safety advice to the public (e.g. installing permanent flood level signage and variable message signs; note that a range of warning messages should be pre-prepared with a view to incorporating appropriate language);
- measures to protect shops on the undercroft level and any critical infrastructure that may be exposed to floodwater (e.g. temporary flood protection devices such as a Self Closing Flood Barrier); and
- measures to prevent floating vehicles leaving the site (e.g. vehicle barriers/restraints).

6.8.6 Improve Public Flood Readiness

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 [SES], 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.'* (Keys, 2002, p.52)

Building and maintaining flood-ready communities in the Macquarie Park study area is challenging due to the high turnover of population (see **Section 2.3**) and what seems to be the low profile of flood hazards in community consciousness (consider the response rates of about 10% to the questionnaire and 1.5% to the public display – **Sections 3.3, 3.4**). The low profile may be understandable given the relatively shallow inundation typically experienced in most catchments (with the exception of Lane Cove River flooding).

The City of Ryde has taken some steps to raise community awareness of the risks of flooding throughout the study area. The community consultation undertaken for this FRMS&P and the intended public exhibition, is in itself an important means of raising community awareness.

A variety of educational measures are recommended to gradually build and sustain a reasonable degree of community flood awareness.

First, there is a need to consolidate the flood data and flood risk mapping prepared during the FRMS into Council's computer-based GIS system. This will provide Council with ready access to flood information for supply to the public on request. A cost of $25K has been included for this purpose in the recommended Plan.

Second, in the Consultant's view, perhaps the key measure for building and maintaining a community's awareness of flooding is via the *regular* issuing of flood certificates to all occupiers of the floodplain. These flood certificates would inform individual property owners of the flood situation at their *particular* property (e.g. flood levels for a range of design events; ground and floor levels where available). It is the site-specific nature of this advice that offers the best chance of overcoming scepticism. These certificates could be appended to Section 149(5) certificates and also be delivered with Council's rates notices every 2 years, along with advice about how people should respond to flooding.

A third option is to prepare a FloodSafe brochure for the Macquarie Park study area. This would describe the flood risk and outline appropriate responses during flood situations. An important safety message for residents of Macquarie Park is to avoid driving or walking through floodwater. The FloodSafe brochure should be made available in English, Cantonese, Mandarin, Italian and Korean, placed on Council's web-site and periodically distributed to all occupiers of the floodplain (possibly in conjunction with a flood certificate).

7. FLOODPLAIN RISK MANAGEMENT PLAN

7.1 RECOMMENDATIONS

A Floodplain Risk Management Plan (FRMP) showing the preferred floodplain risk management measures for the Macquarie Park study area is presented in this chapter. The recommended measures have been selected from the range of measures discussed in **Chapter 6**, after an assessment of each measure's impact on flood risk, as well as consideration of environmental, social, and economic factors. The recommended measures are presented in **Table 7.1** and on **Figure 7.1**. The principal components of the Plan are presented below according to priority, which is assessed on the basis of how easily (quickly) each measure can be implemented and on value for money. The timing of the proposed works will depend on Council's overall budgetary commitments, and the availability of funds from other sources.

7.2 PRIORITISED MEASURES

High priority measures include:

- Maintain integrity of existing Dunbar Park detention basin (Measure No. 3.1);
- Scoping study to assess feasibility of enlarging detention basin in Macquarie Uni to improve Talavera Road drainage at University Creek (Measure No. 3.3b);
- Maintain drainage pits routinely, especially in the catchment above the Doig Avenue shops (Measure No. 4.3c);
- Brendon Street sag point works (Measure No. 4.10);
- Rehabilitate Shrimptons Creek riparian corridor (Measure No. 4.13);
- Study to address micro-scale influences on inundation regime at Rogal Place/Fontenoy Road/ Tuckwell Place, Macquarie Park (Measure No. 5.3);
- Remove shrubs from entrance to 'Officeworks' culvert inlet and maintain as short grass cover *(property owner)* (Measure No. 6.2c);
- Arrange MOU between SES, Council and Hills Motorway to ensure emergency access to and from SES LHQ via Porters Creek Depot *(SES)* (Measure 6.5e);
- Continue and promote the River Avenue VP scheme, and remove three dwellings with a high flood risk from the floodplain *(OSL)* (Measure No. 7.2);
- Arrange MOU between SES and Northern Suburbs Crematorium to ensure emergency access to River Avenue via Quebec Road *(SES)* (Measure No. 7.3);
- Add planning matrix for Macquarie Park to draft floodplain management DCP provisions (Measure No. 8.3);
- Prepare City of Ryde Local Flood Plan *(SES)* (Measure No. 8.5a);
- Prepare Macquarie University Flood Emergency Plan *(MU)* (Measure No. 8.5b);
- Prepare Macquarie Shopping Centre Flood Emergency Plan *(AMP Capital)* (Measure No. 8.5c); and
- Consolidate flood data into Council's GIS (Measure No. 8.6a).

Medium-high priority measures include:

- Overland flow works in Danbury Close/Herring Road area including VP of one property (Measure No. 4.2b); and
- Prepare a brochure summarising potential flood-proofing techniques and distribute (Measure No. 8.2).

Medium priority measures include:

- Improve Waterloo Road drainage by lowering downslope ground levels (Measure No. 1.2);
- Create detention basin at Waterloo Park (Measure No. 1.3);
- Improve Epping Road drainage at Mars Creek by lowering median strip and downslope verge (Measure No. 2.2b);
- Improve Epping Road drainage at University Creek by lowering median strip (Measure No. 3.2b);
- Overland flow works in Santa Rosa Park (Measure No. 4.7b);
- Create detention basin at North Ryde Golf Club (Measure No. 4.12);
- Overland flow works at rear of Peachtree Road units (Measure No. 4.15);
- Consider opportunities to increase conduit capacity through Macquarie Centre during redevelopment (Measure No. 4.16b);
- Install debris control structure upstream of Shrimptons Creek culvert at Waterloo Road (Measure No. 4.16c);
- Improve Pittwater Road drainage by lowering downslope ground levels (Measure No. 7.1);
- Invite owners of two properties to redevelop in flood-compatible manner with $50K Government subsidy (Measure No. 8.1);
- Provide flood certificates at regular intervals (Measure No. 8.6b); and
- Prepare FloodSafe brochure for Macquarie Park *(SES)* (Measure No. 8.6c).

Medium-low priority measures include:

- VP five properties upslope of Epping Road flyover embankment and redevelop (Measure No. 5.1b); and
- VP at least four properties upslope of Epping Road at Porters Creek and redevelop (Measure No. 6.2e).

Low priority measures include:

- Improve Talavera Road drainage at Mars Creek by drainage upgrade (Measure No. 2.3);
- Overland flow works in Rocca Street including VP of one property (Measure No. 4.5);
- Formalise Industrial Creek overland flow paths during redevelopment (Measure No. 5.2);
- Upgrade drainage between Officeworks and M2 during redevelopment (Measure No. 6.3); and
- Formalise Porters Creek overland flow paths during redevelopment (Measure No. 6.4).

7.3 FUNDING AND IMPLEMENTATION

The total capital cost of implementing the Plan is estimated to be $10.7M, with $65K annual maintenance costs. The timing of proposed works will depend on overall budgetary commitments of Council and the availability of funds from other sources. It is envisaged that the Plan would be implemented progressively over a 5 to 10 year time frame.

A variety of sources of funding may be drawn upon to implement the Macquarie Park FRMP including:

- Council funds;
- State funding for flood mitigation measures through DECCW;
- Commonwealth and State funding through the Natural Disaster Resilience Program;
- Funds from other organisations (e.g. RTA, SES) and private owners;
- Commonwealth funds through Caring for Our Country grants (which incorporates the Natural Heritage Trust, the National Landcare Program and the Environmental Stewardship Program), and funds through the Sydney Metropolitan Catchment Management Authority, to assist in rehabilitating the creek corridors; and
- Section 94 Contributions from future development where flooding may be exacerbated by such development;
- Volunteer labour from community groups.

Council can expect to receive the majority of financial assistance through DECCW. These funds are available to implement measures that contribute to reducing existing flood problems. Funding assistance is usually provided on a 2:1 basis (State: Council) or a 1:1:1 basis (Commonwealth:State:Council).

Although much of the Plan may be eligible for Government assistance, funding can not be guaranteed, since the limited Government funds are allocated on an annual basis to competing projects throughout the State. Options that receive Government funding must be of significant benefit to the community. Funding of investigation and design activities as well as any works is normally available. Maintenance, however, is usually the responsibility of Council.

7.4 ON-GOING REVIEW OF PLAN

The *Macquarie Park FRMP* should be regarded as a dynamic instrument requiring review and modification over time. The catalyst for change could include flood events, revised flood modelling, better information about potential climate change flood impacts, legislative change, alterations in the availability of funding, or changes to the area's planning strategies. In any event, a thorough review every five years is recommended to ensure the ongoing relevance of the Plan.

TABLE 7.1 – MACQUARIE PARK FLOODPLAIN RISK MANAGEMENT PLAN

Measure No.^	Description	Capital Expenditure		Maintenance		Priority
		Est. Cost ($)	Funding Sources	Est. Cost ($ pa)	Funding Sources	
	CULLODEN CREEK CATCHMENT					
1.2	Improve Waterloo Road drainage by lowering downslope ground levels	$70K	COR, DECCW	N/a		Medium
1.3	Create detention basin at Waterloo Park	$350K	COR, DECCW	N/a		Medium
	MARS CREEK CATCHMENT					
2.2b	Improve Epping Road drainage at Mars Creek by lowering median strip and downslope verge	$160K	COR, DECCW	N/a		Medium
2.3	Improve Talavera Road drainage at Mars Creek by drainage upgrade	$450K	COR, DECCW	N/a		Low
	UNIVERSITY CREEK CATCHMENT					
3.1	Maintain integrity of existing Dunbar Park basin	N/a		~$2K	COR	High
3.2b	Improve Epping Road drainage at University Creek by lowering median strip	$110K	COR, DECCW	N/a		Medium
3.3b	Scoping study to assess feasibility of enlarging detention basin in Macquarie Uni to improve Talavera Road drainage at University Creek	$40K	MU, COR, DECCW	N/a		High
	SHRIMPTONS CREEK CATCHMENT					
4.2b	Overland flow works in Danbury Close/Herring Road area including VP of one property	$1.2M	COR, DECCW	N/a		Medium -High
4.3c	Routinely maintain drainage pits, especially in the catchment above the Doig Avenue shops	N/a		~$50K	COR	High
4.5	Overland flow works in Rocca Street including VP of one property	$1.0M	COR, DECCW	N/a		Low
4.7b	Overland flow works in Santa Rosa Park	$250K	COR, DECCW	N/a		Medium
4.10	Brendon Street sag point works	$35K	COR, DECCW	N/a		High
4.12	Create detention basin at North Ryde Golf Club	$130K	COR, DECCW	N/a		Medium
4.13	Rehabilitate Shrimptons Creek riparian corridor	Funded separately	COR, Sydney Metropolitan CMA	~$10K	COR	High
4.15	Overland flow works at rear of Peachtree Road units	$160K	COR, DECCW	N/a		Medium
4.16b	Consider opportunities to increase conduit capacity through Macquarie Centre during redevelopment	Funded as redeveloped	Property owner	N/a		Medium
4.16c	Install debris control structure upstream of Shrimptons Creek culvert at Waterloo Road	$100K	COR, DECCW	~$1K	COR	Medium
	INDUSTRIAL CREEK CATCHMENT					
5.1b	VP five properties upslope of Epping Road flyover embankment and redevelop	$3.0M*	COR, DECCW, RTA	N/a		Medium -Low
5.2	Formalise Industrial Creek overland flow paths during redevelopment	Funded as redeveloped	Developer	N/a		Low
5.3	Study to address micro-scale influences on inundation regime at Rogal Place/Fontenoy Road/ Tuckwell Place, Macquarie Park	$25K	COR, DECCW	N/a		High
	PORTERS CREEK CATCHMENT					
6.2c	Remove shrubs from entrance to 'Officeworks' culvert inlet and maintain as short grass cover	$2K	Property owner	Minimal	Property owner	High
6.2e	VP at least four properties upslope of Epping Road at Porters Creek and redevelop	$3.2M*	COR, DECCW	N/a		Medium -Low
6.3	Drainage upgrade between Officeworks and M2 during redevelopment	Funded as redeveloped	Developer	N/a		Low

Measure No.^	Description	Capital Expenditure		Maintenance		Priority
		Est. Cost ($)	Funding Sources	Est. Cost ($ pa)	Funding Sources	
6.4	Formalise Porters Creek overland flow paths during redevelopment	Funded as redeveloped	Developer	N/a		Low
6.5e	Arrange MOU between SES, Council and Hills Motorway to ensure emergency access to and from SES LHQ via Porters Creek Depot	Nil	SES	N/a		High
	LANE COVE CATCHMENT					
7.1	Improve Pittwater Road drainage by lowering downslope ground levels	$140K	COR, DECCW	N/a		Medium
7.2	Continue and promote the River Avenue VP scheme, and remove three dwellings with a high flood risk from the floodplain	Nil (already being implemented)	Office of Strategic Lands (OSL); COR	N/a		High
7.3	Arrange MOU between SES and Northern Suburbs Crematorium to ensure emergency access to River Avenue via Quebec Road	Nil	SES	N/a		High
	OTHER FLOODPLAIN MANAGEMENT MEASURES					
8.1	Invite owners of two properties to redevelop in flood-compatible manner with Gov't subsidy	$100K	COR, DECCW	N/a		Medium
8.2	Prepare a brochure summarising potential flood-proofing techniques and distribute	$25K	COR, DECCW	N/a		Medium -High
8.3	Add planning matrix for Macquarie Park to draft floodplain management DCP provisions	Minimal	COR	N/a		High
8.5a	Prepare City of Ryde Local Flood Plan	SES staff costs	SES	Minimal	SES	High
8.5b	Prepare Macquarie University Flood Emergency Plan	MU staff costs	Macquarie University	Minimal	Macquarie University	High
8.5c	Prepare Macquarie Shopping Centre Flood Emergency Plan	AMP Capital staff costs	AMP Capital	Minimal	AMP Capital	High
8.6a	Consolidate flood data into Council's GIS	$25K	COR, DECCW	N/a		High
8.6b	Provide flood certificates at regular intervals	N/a		~$2K	COR	Medium
8.6c	Prepare FloodSafe brochure for Macquarie Park	$30K	SES, COR, sponsors	N/a		Medium
	TOTAL	**$10.7M**		**$65K**		

^ To locate the report section in which the measure is described, for Measure No. 1.2 read Section 6.1.2, and so on.

* Capital costs can be reduced by the partial redevelopment of the site in a flood-compatible manner and with a suitable land use

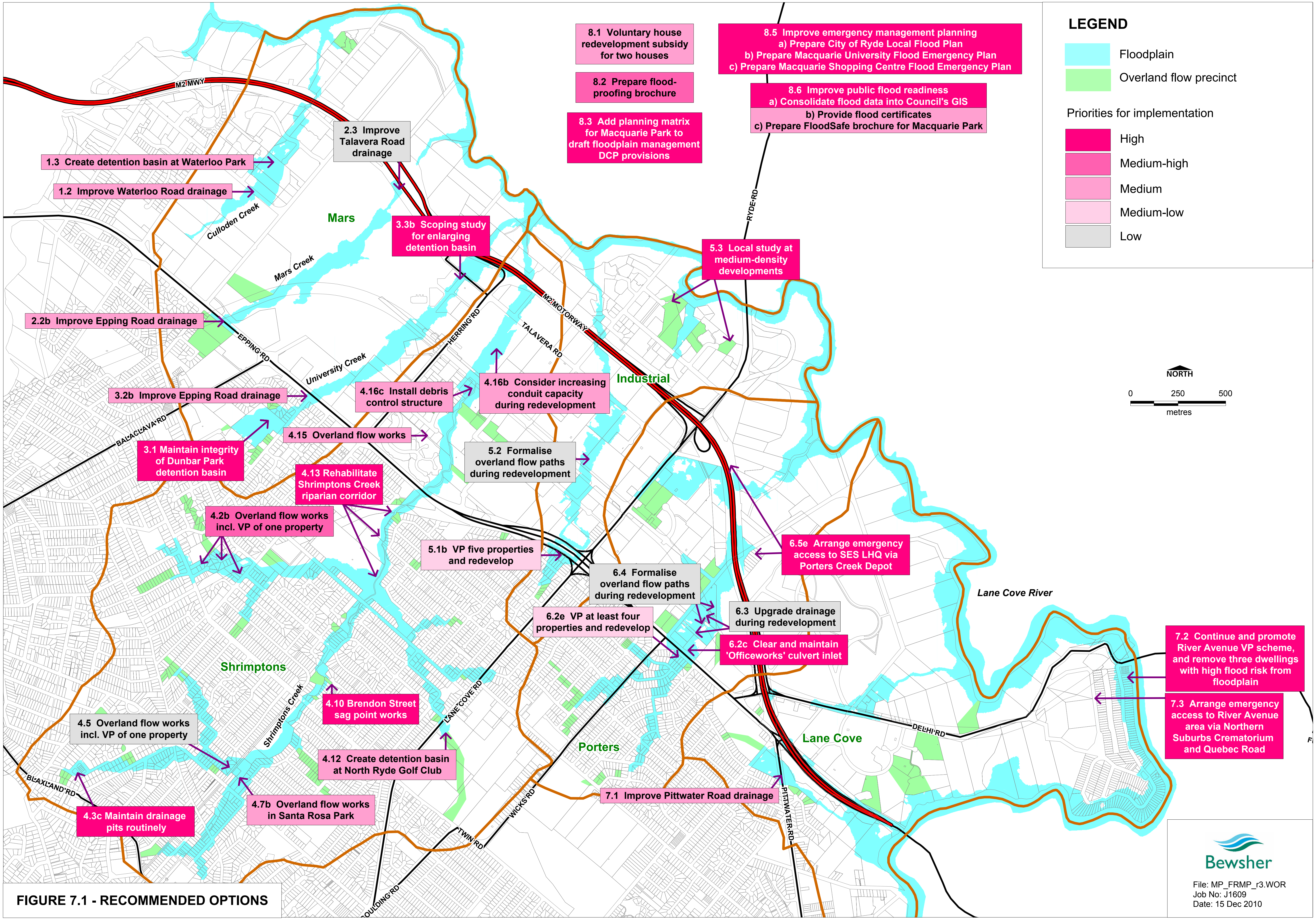

FIGURE 7.1 - RECOMMENDED OPTIONS

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9. GLOSSARY

Note that terms shown in bold are described elsewhere in this Glossary.

100 year flood	A **flood** that occurs on average once every 100 years. Also known as a 1% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
50 year flood	A **flood** that occurs on average once every 50 years. Also known as a 2% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
20 year flood	A **flood** that occurs on average once every 20 years. Also known as a 5% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
Afflux	The increase in flood level upstream of a constriction of flood flows. A road culvert, a pipe or a narrowing of the stream channel could cause the constriction.
annual exceedance probability (AEP)	AEP (measured as a percentage) is a term used to describe **flood** size. It is a means of describing how likely a flood is to occur in a given year. For example, a 1% AEP flood is a **flood** that has a 1% chance of occurring, or being exceeded, in any one year. It is also referred to as the '100 year flood' or 1 in 100 year flood'. The terms **100 year flood**, **50 year flood**, **20 year flood** etc, have been used in this study. See also **average recurrence interval (ARI)**.
Australian Height Datum (AHD)	A common national plane of level approximately equivalent to the height above sea level. All **flood levels**, floor levels and ground levels in this study have been provided in metres AHD.
average annual damage (AAD)	Average annual damage is the average flood damage per year that would occur in a nominated development situation over a long period of time.
average recurrence interval (ARI)	ARI (measured in years) is a term used to describe **flood** size. It is the long-term average number of years between floods of a certain magnitude. For example, a 100 year ARI flood is a flood that occurs or is exceeded on average once every 100 years. The terms **100 year flood**, **50 year flood**, **20 year flood** etc, have been used in this study. See also **annual exceedance probability (AEP)**.
catchment	The land draining through the main stream, as well as tributary streams.
Development Control Plan (DCP)	A DCP is a plan prepared in accordance with Section 72 of the *Environmental Planning and Assessment Act, 1979* that provides detailed guidelines for the assessment of development applications.
DNR	Department of Natural Resources, formerly the Department of Infrastructure, Planning & Natural Resources (DIPNR).
discharge	The rate of flow of water measured in terms of volume per unit time, for example, **cubic metres per second (m^3/s)**. Discharge is different from the speed or **velocity** of flow, which is a measure of how fast the water is moving.
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the *Local Government Act 1993*.

effective warning time	The time available after receiving advice 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.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
EP&A Act	*Environmental Planning and Assessment Act, 1979*.
extreme flood	An estimate of the **probable maximum flood (PMF)**, which is the largest flood likely to occur.
flood	A relatively high stream flow that 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 awareness	An appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood hazard	The potential for damage to property or risk to persons during a **flood**. Flood hazard is a key tool used to determine flood severity and is used for assessing the suitability of future types of land use.
flood level	The height of the **flood** described either as a depth of water above a particular location (eg. 1m above a floor, yard or road) or as a depth of water related to a standard level such as **Australian Height Datum** (eg the flood level was 7.8m AHD). Terms also used include **flood stage** and **water level**.
flood liable land	Land susceptible to flooding up to the **probable maximum flood (PMF)**. Also called **flood prone land**. Note that the term flood liable land now covers the whole of the **floodplain**, not just that part below the **flood planning level**.
flood planning levels (FPLs)	The combination of flood levels and **freeboards** selected for planning purposes, as determined in **floodplain management studies** and incorporated in **floodplain management plans**. The concept of flood planning levels supersedes the designated flood or the flood standard used in earlier studies.
flood prone land	Land susceptible to flooding up to the **probable maximum flood (PMF**). Also called **flood liable land**.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate damages during a **flood**.
Flood risk precinct	An area of land with similar flood risks and where similar development controls may be applied by a council to manage the flood **risk**. (The flood risk is determined based on the existing development in the precinct or assuming the precinct is developed with normal residential uses). Usually the floodplain is categorised into three flood risk precincts – 'low', 'medium' and 'high' – although other classifications can sometimes be used. (See also risk).
Flood Study	A study that investigates flood behaviour, including identification of flood extents, **flood levels** and flood velocities for a range of flood sizes.

floodplain	The area of land that is subject to inundation by floods up to and including the probable maximum flood event, that is, **flood prone land** or **flood liable land**.
Floodplain Risk Management Plan	The outcome of a **Floodplain Risk Management Study**. (Note that the term 'risk' is often dropped in common usage.
Floodplain Risk Management Study	Studies carried out in accordance with the *Floodplain Development Manual* (NSW Government, 2005) that assesses options for minimising the danger to life and property during **floods**. These measures, referred to as 'floodplain management measures/options', aim to achieve an equitable balance between environmental, social, economic, financial and engineering considerations. The outcome of a Floodplain Risk Management Study is a **Floodplain Risk Management Plan**.
floodway	Those areas of the **floodplain** where a significant discharge of water occurs during **floods**. Floodways 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**.
flow	see **discharge**
foreshore building line	A line fixed by resolution of Council in respect of land fronting any bay, river, creek, lagoon, harbour or ocean, which provides a setback distance where buildings or other structures would normally be prohibited.
freeboard	A factor of safety expressed as the height above the **design flood level**. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the **floodplain**, such and wave action, localised **hydraulic** behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such as "greenhouse" and climate change.
high flood hazard	For a particular size **flood**, there would be a possible danger to personal safety, able-bodied adults would have difficulty wading to safety, evacuation by trucks would be difficult and there would be a potential for significant structural damage to buildings.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and **velocity**.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of **peak discharges**, flow volumes and the derivation of hydrographs (graphs that show how the discharge or stage/flood level at any particular location varies with time during a flood).
Local Environmental Plan (LEP)	A Local Environmental Plan is a plan prepared in accordance with the *Environmental Planning and Assessment Act*, 1979, that defines zones, permissible uses within those zones and specifies development standards and other special matters for consideration with regard to the use or development of land.
low flood hazard	For a particular size flood, able-bodied adults would generally have little difficulty wading and trucks could be used to evacuate people and their possessions should it be necessary.
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 for creek or river flows or **discharges**. It the rate of flow of water measured in terms of volume per unit time.
merit approach	The principles of the merit approach are embodied in the *Floodplain Development Manual* (NSW Government, 2005) and weigh up social, economic, ecological and cultural impacts of land use options for different **flood prone** areas together with flood damage, **hazard** and behaviour implications, and environmental protection and well being of the State's rivers and **floodplains**.
overland flow path	The path that floodwaters can follow if they leave the confines of the main flow channel. Overland flow paths can occur through private property or along roads. Floodwaters travelling along overland flow paths, often referred to as 'overland flows', may or may not re-enter the main channel from which they left — they may be diverted to another water course.
peak discharge	The maximum **flow** or **discharge** during a flood.
present value	In relation to flood damage, is the sum of all future flood damages that can be expected over a fixed period (usually 20 years) expressed as a cost in today's value.
probable maximum flood (PMF)	The largest flood likely to ever occur. The PMF defines the extent of **flood prone land** or **flood liable land**, that is, the **floodplain**. The extent, nature and potential consequences of flooding associated with the PMF event are addressed in the current study.
reliable access	During a **flood**, reliable access means the ability for people to safely evacuate an area subject to imminent flooding within **effective warning time**, having regard to the depth and **velocity** of floodwaters, the suitability of the evacuation route, and other relevant factors.
risk	Risk is measured in terms of consequences and likelihood. In the context of floodplain management, it is the likelihood and consequences arising from the interaction of floods, communities and the environment. For example, the potential inundation of an aged person's facility presents a greater flood risk than the potential inundation of a sports ground amenities block (if both buildings were to experience the same type and probability of flooding). Reducing the probability of flooding reduces the risk, increasing the consequences increases risk. (See also **flood risk precinct**).
runoff	The amount of rainfall that ends up as flow in a stream, also known as rainfall excess.
SES	State Emergency Service of New South Wales.
stage–damage curve	A relationship between different water depths and the predicted flood damage at that depth.
velocity	the term used to describe the speed of floodwaters, usually in **m/s**.
water level	see **flood level**.
water surface profile	A graph showing the height of the **flood** (**flood stage**, **water level** or **flood level**) at any given location along a watercourse at a particular time.
WSUD	Water Sensitive Urban Design.

10. FREQUENTLY ASKED QUESTIONS

Why do flood levels change over time?

There is a chance that floods of various magnitudes will occur in the future. As the size of a flood increases, the chance that it will occur becomes rarer. Because some of these rare floods have never been experienced or accurately recorded since European settlement, the height of future floodwaters is normally predicted using computer models. These computer models simulate flood levels and velocities for a range of flood sizes and flood probabilities. Given the importance of estimating flood levels accurately, councils and the NSW Department of Environment, Climate Change and Water (DECCW) engage experts to establish and operate the computer models.

From time to time the computer models are revised and predicted flood levels can change. The resultant change in flood levels however is normally very small. The reasons why the computer models are revised can include:

- new rainfall or ground topography information becomes available;
- new floods occur which provide additional data from which to fine-tune the models;
- better computer models become available as the science of flood modelling improves and computer capabilities increase; or
- flood mitigation works may have been carried out, or development within the catchment may have occurred, that was not previously simulated in the models.

How are these studies funded?

Flood studies and floodplain risk management studies are often carried out under State Government guidelines and are funded on a 1:1:1 basis among the Federal and State Governments, and councils. This funding arrangement is also available for the construction of flood mitigation works.

My property is in a Low Flood Risk Precinct. What does this mean?

The classification of a 'Low Flood Risk Precinct' can differ slightly between councils. Generally it means that your property would not be inundated in a 100 year flood but still has a very slight chance of inundation from larger (i.e. rarer) floods.

If you are a residential property owner, there will be virtually no change to how you may develop your property. However, there may be controls on the location of essential services such as hospitals, evacuation centres, nursing homes and emergency services.

My property is in a Medium Flood Risk Precinct. What does this mean?

The classification of a 'Medium Flood Risk Precinct' can differ slightly between councils. Often it means that your property is inundated in a 100 year flood, however conditions are not likely to be hazardous during such a flood. If you are a residential property owner development controls will probably be similar to those that currently exist.

My property is in a High Flood Risk Precinct. What does this mean?

The classification of a 'High Flood Risk Precinct' can differ slightly between councils. Often it means that your property will be inundated in a 100 year flood and that hazardous conditions may occur. This could mean that there would be a possible danger to personal safety, able bodied adults may have difficulty wading to safety, evacuation by trucks may be difficult, or there may be a potential for significant structural damage to buildings. This is an area of higher hazard where stricter controls may be applied.

Will my property value be altered if I am in a Flood Risk Precinct?

Any change in a council's classification of properties can have some impact on property values. Nevertheless, councils normally give due consideration to such impacts before introducing a system of flood risk classifications or any other classification system (e.g. bushfire risks, acid sulphate soil risk, etc). If your property is now classified as being in a Flood Risk Precinct, the real flood risks on your property have not changed, only its classification has altered. A prospective purchaser of your property could have previously discovered this risk if they had made enquiries themselves.

If you are in a Low Flood Risk Precinct, generally there will be no controls on normal residential type development. Previous valuation studies have shown that under these circumstances, your property values will not alter significantly over the long term. Certainly, when a new system of classifying flood risks is introduced, there may be some short-term effect, particularly if the development implications of the precinct classification are not understood properly. This should only be a short-term effect however until the property market understands that over the long-term, the Low Flood Risk Precinct classification will not change the way you use or develop your property.

Ultimately, however, the market determines the value of any residential property. Individual owners should seek their own valuation advice if they are concerned that the flood risk precinct categorisation may influence their property value.

My property was never classified as 'flood prone' or 'flood liable' before. Now it is in a Low Flood Risk Precinct. Why?

The State Government changed the meaning of the terms 'flood prone', 'flood liable' and 'floodplain' in 2001. Prior to this time, these terms generally related to land below the 100 year flood level. Now it is different. These terms now relate to all land that could possibly be inundated, up to an extreme flood known as the probable maximum flood (PMF). This is a very rare flood.

The reason the Government changed the definition of these terms was because there was always some land above the 100 year flood level that was at risk of being inundated in rarer and more extreme flood events. History has shown that these rarer flood events can and do happen (e.g. the 1990 flood in Nyngan, the November 1996 flood in Coffs Harbour, the January 1998 flood in Katherine, the August 1998 flood in Wollongong, the 2002 floods in Europe, Hurricane Katrina in 2005, etc).

Will I be able to get house and contents insurance if my house is in a Flood Risk Precinct?

In contrast to the USA and many European countries, flood insurance has generally not been available in Australia for residential property. Following the disastrous floods in Coffs Harbour in November 1996 and in Wollongong in August 1998, very limited flood cover began to be offered by some insurance companies. From 2008, many insurance companies started offering wider cover although the extent of the cover particularly for very flood prone properties is still not well known and may differ between insurers. The most likely situation is that your insurer will now offer you some flood cover although this will be dependent of the flood level information that the insurer has for your property. (This may not necessarily be the same as that available from Council). If flood cover is offered, the classification of your property within a Flood Risk Precinct per se, is unlikely to alter the availability of cover. Obviously insurance policies and conditions may change over time or between insurance companies, and you should confirm the specific details of your situation with your insurer.

Will I be able to get a home loan if my land is in a Flood Risk Precinct?

Most banks and lending institutions do not account for flood risks when assessing home loan applications unless there is a very significant risk of flooding at your property. The system of Flood Risk Precinct classification will make it clear to all concerned, the nature of the flood risks. Under the previous system, if a prospective lending authority made appropriate enquiries, they could have identified the nature of the flood risk during assessment of home loan applications. As a result, it is not likely that the classification of your property within a Flood Risk Precinct will alter your ability to obtain a home loan. Nevertheless, property owners who are concerned about their ability to obtain a loan should clarify the situation with their own lending authority.

How have the flood risk maps been prepared?

Because some large and rare floods have often not been experienced or accurately recorded since European settlement commenced, computer models are used to simulate the depths and velocities of major floods. These computer models are normally established and operated by flooding experts employed by local and state government authorities. Because of the critical importance of the flood level estimates produced by the models, such modelling is subjected to very close scrutiny before flood information is formally adopted by a council. Maps of flood risks (e.g. 'low', 'medium' and 'high') are prepared after consideration of such issues as:

- flood levels and velocities for a range of possible floods;
- ground levels;
- flood warning time and duration of flooding;
- suitability of evacuation and access routes; and
- emergency management during major floods.

What is the probable maximum flood (PMF)?

The PMF is the largest flood that could possibly occur. It is a very rare and improbable flood. Despite this, a number of historical floods in Australia have approached the magnitude of a PMF. Every property potentially inundated by a PMF will have some flood risk, even if it is very small. Under the State Government's Floodplain Development Manual (2005), councils must consider all flood risks, even these potentially small ones, when managing floodplains. As part of the State Government's Manual, the definitions of the terms 'flood liable', flood prone' and 'floodplain' refer to land inundated by the PMF.

What is the 100 year flood?

A 100 year flood is the flood that will occur or be exceeded on average once every 100 years. It has a probability of 1% of occurring in any given year. If your area has had a 100 year flood, it is a fallacy to think you will need to wait another 99 years before the next flood arrives. Floods do not happen like that. Some parts of Australia have received a couple of 100 year floods in one decade. On average, if you live to be 70 years old, you have a better than even chance of experiencing a 100 year flood.

Why do councils prepare floodplain management studies and plans?

Under NSW legislation, councils have the primary responsibility for management of development within floodplains. To appropriately manage development, councils need a strategic plan which considers the potential flood risks and balances these against the beneficial use of the floodplain by development. To do this, councils have to consider a range of environmental, social, economic, financial and engineering issues. This is what happens in a floodplain risk management study. The outcome of the study is the floodplain risk management plan, which details how best to manage flood risks in the floodplain for the foreseeable future.

Floodplain risk management plans normally comprise a range of works and measures such as:

- improvements to flood warning and emergency management;
- works (e.g. levees or detention basins) to protect existing development;
- voluntary purchase or house raising of severely flood-affected houses;
- planning and building controls to ensure future development is compatible with the flood risks; and
- measures to raise the community's awareness of flooding so that they are better able to deal with the flood risks they face.

Will the Flood Risk Precinct maps be changed?

Yes. All mapping undertaken by council is subjected to ongoing review. As these reviews take place, it is conceivable that changes to the mapping will occur, particularly if new flood level information or ground topography information becomes available. However, this is not expected to occur very often and the intervals between revisions to the maps would normally be many years. Many councils have a policy of reviewing and updating floodplain management studies and plans about every five to ten years. This is the likely frequency at which the maps may be amended.

APPENDIX A

FLOOD DAMAGES DATABASE

Confidential

APPENDIX B

FLOOD DAMAGES SPREADSHEETS

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT			
Version 3.00 October 2007		Queries to duncan.mcluckie@dnr.nsw.gov.au	
PROJECT	**DETAILS**	**DATE**	**JOB No.**
Macquarie Park Floodplain Risk Management Study & Plan		May-10	J1609

BUILDINGS

Regional Cost Variation Factor	1.00	*From Rawlinsons*					
Post late 2001 adjustments	1.45	*Changes in AWE see AWE Stats Worksheet*					
Post Flood Inflation Factor	1.40	*1.0*	*to*	*1.5*			
Multiply overall structural costs by this factor		*Judgement to be used. Some suggestions below*					
	Regional City			*Regional Town*			
	Houses Affected		*Factor*	*Houses Affected*		*Factor*	
Small scale impact	<	*50*	*1.00*	<	*10*	*1.00*	
Medium scale impacts in Regional City		*100*	*1.20*		*30*	*1.30*	
Large scale impacts in Regional City	>	*150*	*1.40*	>	*50*	*1.50*	
Typical Duration of Immersion	2	hours					
Building Damage Repair Limitation Factor	0.85	*due to no insurance*		*short duration*		*long duration*	
		Suggested range		*0.85*	*to*	*1.00*	
Typical House Size	240	m^2		*240 m^2 is Base*			
Building Size Adjustment	1.0						
Total Building Adjustment Factor	**1.73**						

CONTENTS

Average Contents Relevant to Site	$ 60,000		*Base for 240 m^2 house*	*$*	*60,000*	
Post late 2001 adjustments	1.45	*From above*				
Contents Damage Repair Limitation Factor	0.75	*due to no insurance*	*short duration*		*long duration*	
Sub-Total Adjustment Factor	1.09	*Suggested range*	*0.75*	*to*	*0.90*	
Level of Flood Awareness	low	*low or high only. Low default unless otherwise justifiable.*				
Effective Warning Time	1	hour				
Interpolated DRF adjustment (Awareness/Time)	0.98	IDRF = Interpolated Damage Reduction Factor				
Typical Table/Bench Height (TTBH)	0.90	*0.9m is typical height. If typical is 2 storey house use 2.6m.*				
Total Contents Adjustment Factor AFD <= TTBH	**1.07**	AFD = Above Floor Depth				
Total Contents Adjustment Factor AFD > TTBH	**1.09**					

Most recent advice from Victorian Rapid Assessment Method

Low level of awareness is expected norm (long term average) any deviation needs to be justified.

Basic contents damages are based upon a DRF of	*0.9*				
Effective Warning time (hours)	***0***	***3***	***6***	***12***	***24***
RAM Average IDRF Inexperienced (Low awareness)	*0.90*	*0.80*	*0.80*	*0.80*	*0.70*
DRF (ARF/0.9)	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
RAM AIDF Experienced (High awareness)	*0.80*	*0.80*	*0.60*	*0.40*	*0.40*
DRF (ARF/0.9)	*0.89*	*0.89*	*0.67*	*0.44*	*0.44*
Site Specific DRF (DRF/0.9) for Awareness level for iteration	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
Effective Warning time (hours)	*0*	*3*	*1*		
Site Specific iterations	*1.00*	*0.89*	*0.98*		

ADDITIONAL FACTORS

Post late 2001 adjustments	1.45	*From above*
External Damage	$ 6,700	*$6,700 recommended without justification*
Clean Up Costs	$ 4,000	*$4,000 recommended without justification*
Likely Time in Alternate Accommodation	2	weeks
Additional accommodation costs /Loss of Rent	$ 220	*$220 per week recommended without justification*

TWO STOREY HOUSE BUILDING & CONTENTS FACTORS

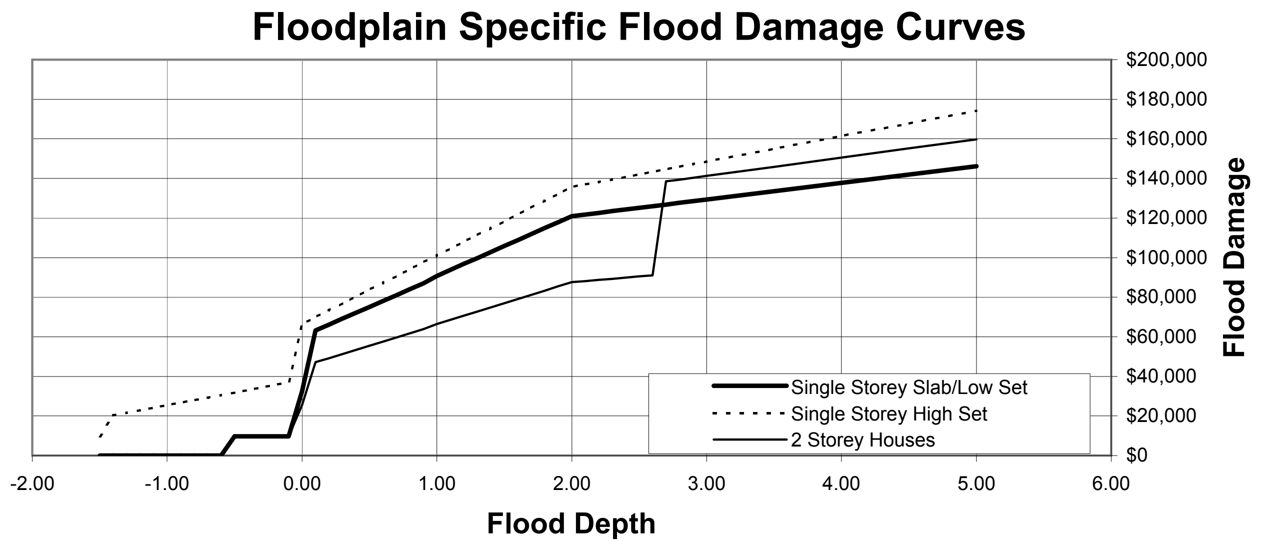
Up to Second Floor Level, less than	2.6	m	70%	Single Storey Slab on Ground
From Second Storey up, greater than	2.6	m	110%	Single Storey Slab on Ground

Base Curves

		AFD = Above Floor Depth				
Single Storey Slab/Low Set	13164	+	4871	x	AFD in metres	
Structure with GST	AFD	greater than	0.0	m		
Validity Limits	AFD	less than or equal to		6	m	
Single Storey High Set	16586	+	7454	x	AFD	
Structure with GST	AFD	greater than	-1.50	m		
Validity Limits	AFD	less than or equal to		6	m	
Contents	20000	+	20000	x	AFD	
Contents with GST	AFD	greater than		0		
Validity Limits	AFD	less than or equal to		2		

Floodplain Specific Damage Curves for Individual Residences

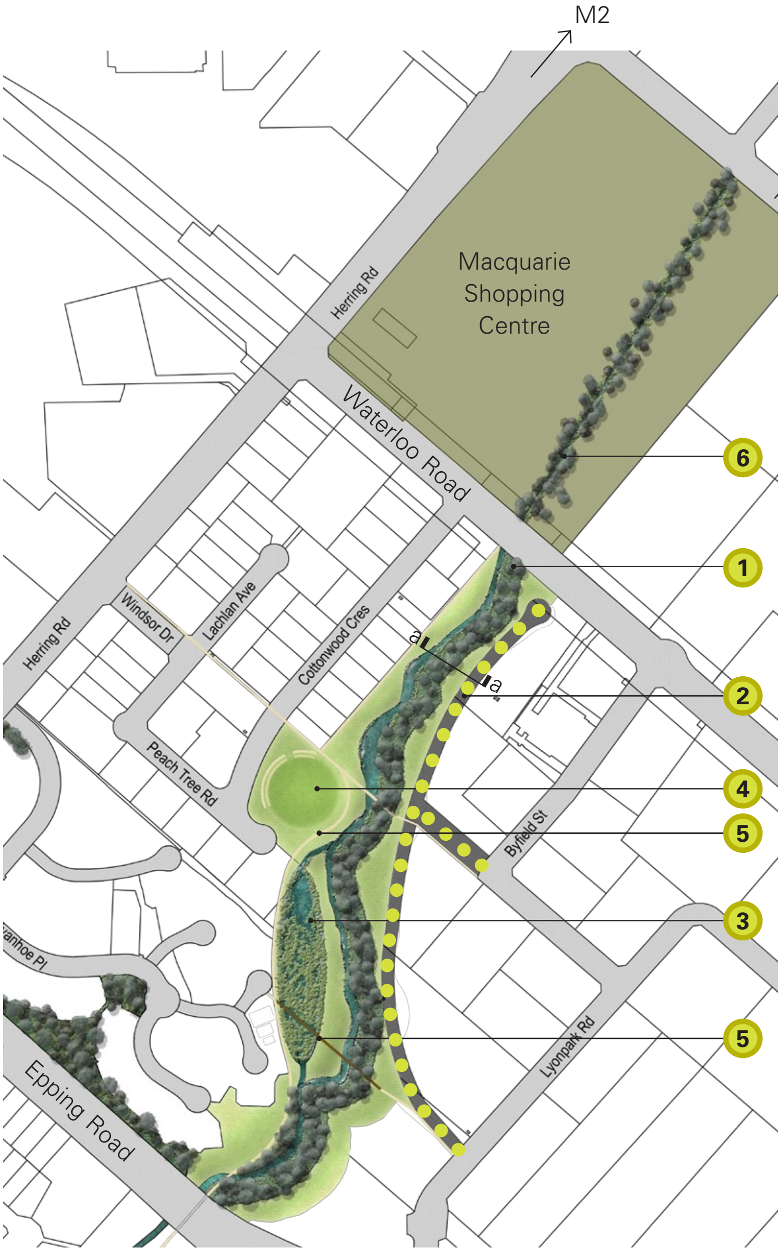
Steps in Curve	0.1	m	
	Single Storey High Set	Single Storey Slab/Low Set	2 Storey Houses
Type	1	2	3
AFD from Modelling	Damage	Damage	Damage
-5.00	$0	$0	$0
-1.50	$9,715	$0	$0
-1.40	$20,328	$0	$0
-1.30	$21,614	$0	$0
-1.20	$22,900	$0	$0
-1.10	$24,186	$0	$0
-1.00	$25,473	$0	$0
-0.90	$26,759	$0	$0
-0.80	$28,045	$0	$0
-0.70	$29,331	$0	$0
-0.60	$30,617	$0	$0
-0.50	$31,903	$9,715	$9,715
-0.40	$33,189	$9,715	$9,715
-0.30	$34,475	$9,715	$9,715
-0.20	$35,762	$9,715	$9,715
-0.10	$37,048	$9,715	$9,715
0.00	$66,522	$32,429	$25,615
0.10	$69,983	$63,189	$47,147
0.20	$73,444	$66,165	$49,230
0.30	$76,905	$69,140	$51,312
0.40	$80,366	$72,115	$53,395
0.50	$83,827	$75,090	$55,478
0.60	$87,289	$78,065	$57,560
0.70	$90,750	$81,040	$59,643
0.80	$94,211	$84,016	$61,725
0.90	$97,672	$86,991	$63,808
1.00	$101,133	$90,772	$66,455
1.10	$104,594	$93,787	$68,565
1.20	$108,055	$96,802	$70,676
1.30	$111,516	$99,818	$72,787
1.40	$114,977	$102,833	$74,898
1.50	$118,439	$105,849	$77,009
1.60	$121,900	$108,864	$79,119
1.70	$125,361	$111,880	$81,230
1.80	$128,822	$114,895	$83,341
1.90	$132,283	$117,911	$85,452
2.00	$135,744	$120,926	$87,563
2.10	$137,030	$121,767	$88,151
2.20	$138,316	$122,607	$88,739
2.30	$139,603	$123,447	$89,328
2.40	$140,889	$124,288	$89,916
2.50	$142,175	$125,128	$90,504
2.60	$143,461	$125,969	$91,093
2.70	$144,747	$126,809	$138,519
2.80	$146,033	$127,650	$139,443
2.90	$147,319	$128,490	$140,368
3.00	$148,605	$129,331	$141,292
3.50	$155,036	$133,533	$145,915
4.00	$161,467	$137,735	$150,537
4.50	$167,897	$141,938	$155,160
5.00	$174,328	$146,140	$159,782



APPENDIX C

EXTRACTS FROM WATER SENSITIVE URBAN DESIGN REPORT (EDAW, 2009)

Shrimptons Creek WSUD Concepts



Plan
Not to Scale

Legend

Existing roads
New roads
Pedestrian pathways

Sections

Storm flows generated from new roads will be directed towards street tree bioretention basins, minimising the impact of increased runoff on adjacent low flow channel.

Objectives

/ Establish an ecological connection along the riparian zone of Shrimptons Creek downstream to Waterloo Road. This ecological connection would see rehabilitation of the riparian vegetation and improvement in the aquatic ecology.

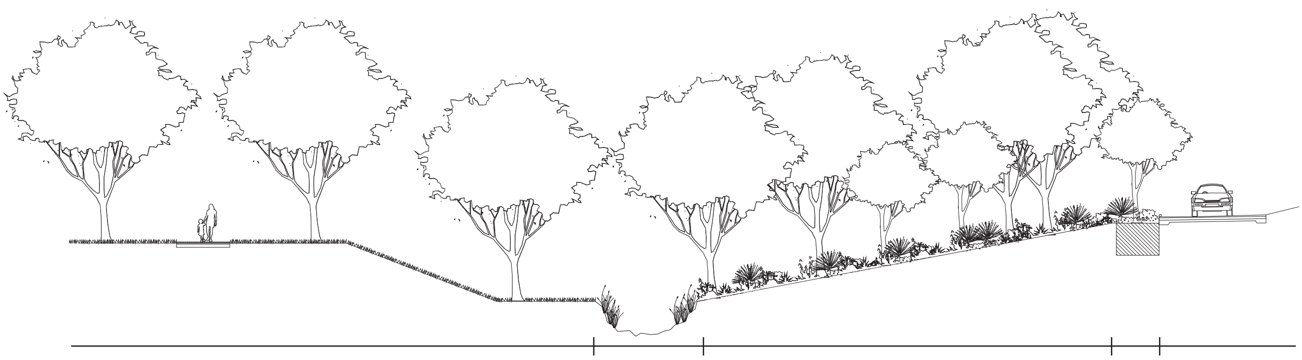
/ Improve pedestrian access along riparian corridor from residential and commercial areas to Waterloo Road.

/ Protect the creek from the water quality impacts of adjoining residential and commercial areas, by treating these catchments to the targets identified in the WSUD Chapter of the City of Ryde DCP.

/ WSUD strategy to complement Councils open space plans of management and strategies

Strategy

1. Establish a wildlife corridor along the steeper south-eastern riparian zone, through rehabilitation of the riparian zone.
2. Install a bioretention system to treat stormwater from the Type 4 road buffering the commercial precinct and wildlife corridor.
3. Construct a wetland in the passive recreation park adjacent to the residential area for local or regional stormwater quality treatment.
4. Incorporate flood detention functions into the redesign of playing field.
5. Increase pedestrian and cycle activity along and across the creek line through the:
   a. Construction of better links and/or augmentation of pedestrian network from existing residential and commercial areas to the creek corridor;
   b. Provision of passive recreation e.g. creek viewing platforms / picnic areas;
   c. Pedestrian links and passive recreation areas are designed to ensure pedestrian safety (e.g. through lighting, appropriate fencing and other "safety by design" considerations).
6. Where practicable, daylight creek between Waterloo and Talavera Roads within the existing Macquarie Shopping Centre site and enhance pedestrian links along creek line (NB. This option is unlikely given the current development footprint, layout of the shopping centre and cost involved).



Section A
Not to Scale

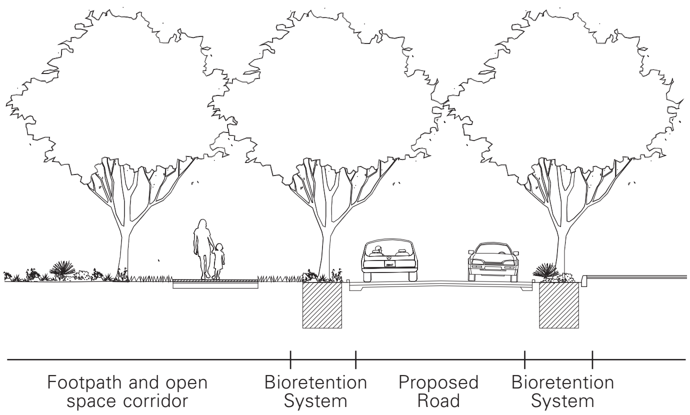
Industrial Creek WSUD Concepts

Plan
Not to Scale

Legend

Existing roads

New roads



Section A
Not to Scale

Objectives

/ Visual connectivity. That is, the creek corridor for its length through Macquarie Park is identified and enhanced by appropriate vegetation and access points along the proposed open space network.

/ Retention and rehabilitation of natural vegetation along the creek corridor and accommodation of overland flows within this zone.

/ The open space network contributes significantly to activating pedestrian movement.

/ Align with Councils deep soil planting requirements

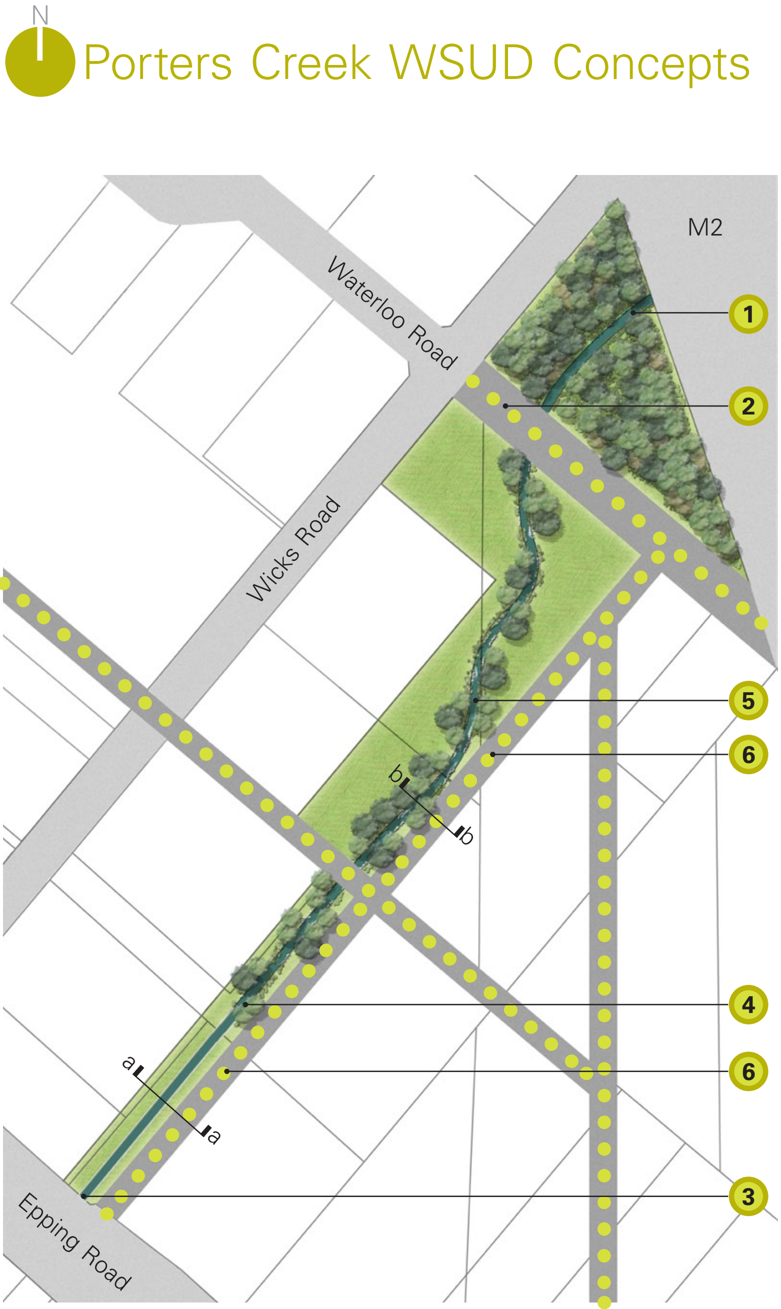
Strategy

1. Epping Road to Waterloo Road:
   a. Enhance visual pedestrian and vehicular mobility and connectivity,
   b. Microclimate control through WSUD elements to enhance street activation and visual appeal,
   c. Blend setbacks, open space and WSUD elements along the road and within adjacent private developments to create a significant and enjoyable pedestrian boulevard
2. Waterloo Road to Talavera Road:
   a. Maximise the quality of urban and open space design, particularly in the vicinity of Central Park,
   b. Conserve and/or restore appropriate vegetation, pedestrian and view corridors and the overland flow paths along the natural creekline,
   c. Preserve the natural vegetation,
   d. Incorporate best Practice WSUD into roads.
3. Talavera Road to the M2:
   a. Extend the daylighting of the creek downstream from Talavera Road.

Sections

Storm flows generated from new roads will be directed towards street tree bioretention basins.

Porters Creek WSUD Concepts



Plan
Not to Scale

Legend
Existing roads
New roads

Objectives

/ Maximise the open space corridor proposed in the Macquarie Park DCP.

/ Achieve a vegetated corridor along the drainage line, which incorporates public and private land and provides appropriate pedestrian access.

/ All new roads including the extension of Waterloo Road are to incorporate best practice WSUD.

/ Retain the natural condition and rehabilitate the creek and bushland zone between the Waterloo Road extension and the M2.

/ Address the interface between the low flow channel / piped system and the natural section of Porters Creek north of the Waterloo Road extension to enhance the geomorphology of the creek.

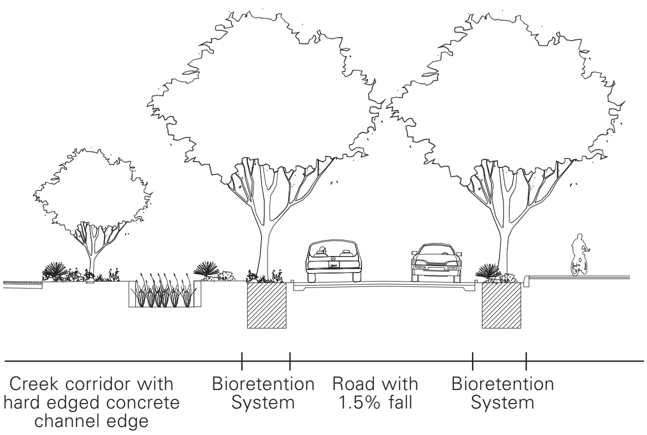
/ Align with Councils deep soil planting requirements

Strategy

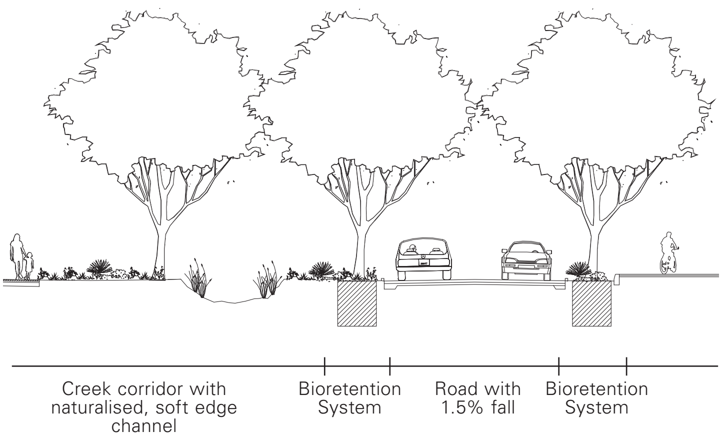
1. Maintain the existing creek and rehabilitate creek and surrounding bushland.
2. Extension of Waterloo Road to include works to improve the geomorphology of Porters Creek downstream.
3. Low flows from Porters creek to be diverted from underneath the current Officeworks site to a 2m wide low flow urban creek adjacent to the new road.
4. The low flow urban creek to transition from hard edged urban stream upstream to a natural rock lined channel downstream. Appropriate vegetation, open space areas and pedestrian links to be incorporated into the design of the channel.
5. The low flow urban creek should be designed to provide stormwater treatment, for example through a bioretention swale. The design of the treatment system will be influenced by the quantity of stormwater diverted and the surrounding landscape design.
6. Overland flows to be accommodated in the design of the road to minimise the impact on the low flow channel.

Sections

Storm flows generated from new roads will be directed towards street tree bioretention basins, minimising the impact of increased runoff on adjacent low flow channel.



Section A
Not to Scale



Section B
Not to Scale