SOUTH CREEK

FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

For the Liverpool Local Government Area

Cover Photo: South Creek between Elizabeth Drive and Overett Avenue, Kemps Creek

Final Report

VOLUME 1 — STUDY REPORT AND RECOMMENDED PLAN

December 2004

Bewsher Consulting Pty Ltd

LIVERPOOL CITY COUNCIL

SOUTH CREEK

FLOODPLAIN RISK MANAGEMENT

STUDY AND PLAN

FOR THE LIVERPOOL LOCAL GOVERNMENT AREA

FINAL REPORT

VOLUME 1 — STUDY REPORT AND RECOMMENDED PLAN

DECEMBER 2004

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FOREWORD

In New South Wales, the prime responsibility for local planning and the management of flood liable land rests with local government. To assist local government with floodplain management, the NSW Government has adopted a Flood Prone Land Policy in conjunction with the *Floodplain Management Manual*.

The Policy is directed at providing solutions to existing flood problems and to ensure that new development is compatible with the flood hazard and does not create additional flood problems.

The Policy sets out four sequential stages in the development of a floodplain management system:

1. Flood Study — Assessment to define the nature and extent of flooding.
2. Floodplain Risk Management Study — Comprehensive evaluation of management options with respect to existing and proposed development.
3. Floodplain Risk Management Plan — Formal adoption by Council of a management plan for floodplain risks.
4. Implementation of the Plan — Measures undertaken to reduce the impact of flooding on existing development, and implementing controls to ensure that new development is compatible with the flood hazard.

This *Floodplain Risk Management Study* and recommended *Floodplain Risk Management Plan* constitutes the second and third stages of the management process for the South Creek study area within the Liverpool Local Government Area, and has been prepared for Liverpool City Council by Bewsher Consulting Pty Ltd in association with Don Fox Planning Pty Ltd.

In broad terms, this *Floodplain Risk Management Study* has investigated what can be done to minimise the effects of flooding in the South Creek study area, and has recommended a strategy in the form of a recommended *Floodplain Risk Management Plan*.

This *Floodplain Risk Management Study* has been prepared in two volumes:

- **Volume 1** — Main Report (this report), which includes the Executive Summary, the Floodplain Risk Management Study, recommended *Floodplain Risk Management Plan* and the Appendices;
- **Volume 2** — Town Planning Issues, which includes a review of planning and development controls for the study area, together with a draft Flood Risk Management Development Control Plan for the Liverpool Local Government Area and Planning Matrix of planning and development controls for the South Creek study area.

A Flood Damages Data Base of potentially flood-affected properties has been supplied separately to Council (see **Section 3.5**).

The next stage of the floodplain risk management process will be for Liverpool City Council to formally adopt the recommended *Floodplain Risk Management Plan*.

VOLUME 1 — STUDY REPORT AND RECOMMENDED PLAN

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EXECUTIVE SUMMARY

FLOODPLAIN RISK MANAGEMENT IN NEW SOUTH WALES

The prime responsibility for planning and management of flood prone lands in New South Wales (NSW) rests with local government. The NSW Government's Flood Prone Land Policy and the *Floodplain Management Manual* (NSW Government, 2001) form the basis of floodplain management in New South Wales.

The NSW Government provides assistance on state-wide policy issues and technical support. Financial assistance is also provided to undertake flood and floodplain management studies, and for the implementation of works identified in these studies.

The Flood Prone Land Policy also provides some legal protection for Councils, other public authorities and their staff against claims for damages resulting from the issuing of advice or granting approvals on floodplains, providing they have acted substantially in accordance with the principles contained in the *Floodplain Management Manual*.

STUDY OBJECTIVES

The primary objective of the *South Creek Floodplain Risk Management Study and Plan for the Liverpool Local Government Area (LGA)* is to bring together, and place in appropriate context, all past, current and proposed future activities related to flood risk in the study area. In broad terms, the current study has investigated what can be done to minimise the effects of flooding in the South Creek study area and recommended a strategy in the form of a recommended *Floodplain Risk Management Plan*. This study and plan constitute key components of the NSW Government's floodplain risk management process as outlined in the *Floodplain Management Manual*.

STUDY RESPONSIBILITIES

The Liverpool City Council Floodplain Management Committee, an official committee of Council, has overseen and is responsible for, the current study.

The committee has assisted and advised Council in the development of the recommended *South Creek Floodplain Risk Management Study and Plan for the Liverpool LGA* and has provided the vital link between the consultant, Council, the Department of Infrastructure, Planning and Natural Resources (DIPNR) (formerly the Department of Land and Water Conservation (DLWC)), other government agencies and the local community.

To provide the wider community with an opportunity to comment on the draft plan proposals, the final stage of community consultation for this study was the public exhibition of the Draft Study Report and the draft Plan between July and September 2004.

During the public exhibition period, written submissions were invited from the local community, as well as the Floodplain Management Committee, relevant Council staff, government agencies and other key stakeholders. The issues raised in these submissions have been incorporated in this final version of the report. This Final Report was put before Council for formal adoption in December 2004.

STUDY AREA

Liverpool City Council has commissioned Bewsher Consulting Pty Ltd, in association with Don Fox Planning Pty Ltd, to undertake this study and Plan for those portions of the South Creek and Thompson Creek floodplains that lie within the Liverpool LGA.

The study area of this *Floodplain Risk Management Study* covers only a small portion of the total South Creek catchment. The South Creek catchment is a significant tributary of the Hawkesbury–Nepean River and is located about 40km to the west of the Sydney Central Business District.

South Creek flows generally from south to north through the study area. The northern boundary of the study area is Elizabeth Drive, while the southern boundary is Bringelly Road and The Northern Road, approximately 7km to the south. The western boundary of the study area is South Creek's catchment boundary with Badgerys Creek, while the eastern boundary is the catchment boundary with Kemps Creek.

FLOOD HISTORY

Like all waterways, South Creek is prone to flooding. Flooding in the study area occurs from the normal mechanism of water spilling out of the main channels and inundating the floodplains.

The study area is not affected by backwater flooding from the Hawkesbury–Nepean River nor from the large dams located on South Creek about 2–3km downstream of Elizabeth Drive.

Two major flood events occurred in the South Creek catchment in the 1980s. The August 1986 flood and the April 1988 flood are two of the largest floods to have occurred in the catchment since European settlement.

The April 1988 flood was in the order of a 100 year average recurrence interval (ARI) flood through the study area. A flood in February 1956 was about a 10 year ARI flood and floods in 1961, 1964 and the August 1986 flood were all just larger than about a 5 year ARI flood though the study area.

Following the major floods of the 1980s and the *1991 South Creek Floodplain Management Study* (Willing and Partners, 1991) (the *1991 FPM Study*), the Overett Avenue area, just upstream of Elizabeth Drive, and the Victor Avenue area about 3km upstream of Elizabeth Drive, were identified as the main flood problem areas of South Creek in the Liverpool LGA.

DESIGN FLOWS AND FLOOD LEVELS

A RAFTS model was originally established and calibrated for the entire South Creek catchment as part of the *1990 Flood Study for South Creek* (Department of Water Resources, 1990) and used in the *1991 FPM Study*. These results were used in the analysis of flood mitigation options for the Overett Avenue and Victor Avenue areas and have been adopted for use in the current study.

A MIKE-11 model, together with a series of HEC-2 models, were originally established and calibrated for the major creeks within the South Creek catchment as part of the *1990 Flood Study.* These models were then used in the *1991 FPM Study*. To examine flood mitigation options for the Overett and Victor Avenue areas in more detail, a more detailed MIKE-11 submodel with additional cross-sections was established from the main South Creek model in the mid-1990s.

Modelling in the study area over the years has now evolved into the '2003 MIKE-11' model (established as part of this study) that covers all of the study area and includes all the flood mitigation works completed in the study area. This '2003 MIKE-11' model for the South Creek and Thompsons Creek floodplains is now the best representation available for the current flood behaviour in the study area.

IMPACTS AND COSTS OF FLOODING

Table ES.1 summarises the number of properties that would be flooded in different flood sizes, together with the flood damage that would occur in the South Creek study area.

TABLE ES.1: IMPACTS AND COSTS OF FLOODING

FLOOD	RESIDENTIAL PROPERTIES		BUSINESS PROPERTIES		FLOOD DAMAGE (3) ($mil)
	Floor level (1)	Yard only (2)	Floor level (1)	Yard only (2)	
5 year	2	17	0	0	$0.5
20 year	9	32	0	0	$1.4
50 year	17	43	0	0	$2.4
100 year	19	46	0	0	$3.1
'200 yr'	34	58	1	3	na
'500 yr'	50	69	2	3	na
PMF	95	128	3	3	$22.8
Average Annual Damage					$0.42
Present Worth of Damages (7% pa; 20 years)					$4.5

Notes: PMF = probable maximum flood
'200 yr' = approx. 100 year + 0.3m
'500 yr' = approx. 100 year + 0.6m
(1) house flooded above floor level
(2) ground around house/business flooded
(3) potential flood damage

About 270 residential and commercial properties in the study area can be considered to be 'affected by flooding' i.e. at least some point of their property would be inundated in the largest flood that can occur, known as the probable maximum flood.

FLOODPLAIN RISK MANAGEMENT OPTIONS EXAMINED

The *Floodplain Management Manual* divides ways to manage the flood risk into three groups in the following order of importance:

- ***property modification measures*** — these were included as 'non-structural' measures in the *Floodplain Development Manual* (NSW Government, 1986);

- ***response modification measures*** — these were also included as 'non-structural' measures in the *Floodplain Development Manual*;

- ***flood modification measures*** — these were formerly referred to as structural measures in the *Floodplain Development Manual*.

A summary of all the floodplain risk management measures examined as part of this study, is presented in **Tables ES.2, ES.3 and ES.4**. These three tables list those options that have been recommended and not recommended for further consideration. Those options recommended for further consideration have been determined from the range of available measures after an assessment of the impacts on flooding, together with environmental, social, and economic considerations.

ENVIRONMENTAL CONSIDERATIONS

As part of the investigations for the flood mitigation works at Overett Avenue and Victor Avenue, a Review of Environmental Factors (REF) (Kinhill, 1994b) (the *1994 REF*) was undertaken to examine the likely environmental constraints in the area of the two recommended design options.

It was concluded in the *1994 REF* at the time that the environmental impacts of the proposed flood mitigation works at Overett Avenue and Victor Avenue would be too high to allow them to proceed in their current form. Consequently, the Victor Avenue works were shelved altogether and the Overett Avenue works were significantly scaled down from those originally proposed.

The conclusions reached in the *1994 REF* are still (and even more) applicable for the current Floodplain Risk Management Study and Plan. Therefore, it has been concluded in the current study that the environmental impacts of large-scale channel works, floodways and the necessary compensatory works associated with the construction of levees, would be significant, and Council or DIPNR would not support these types of works.

Consequently, no new flood modification works have been identified as part of the current study

It can also be concluded from the *1994 REF* that any stream clearing works undertaken by Council would be subject to strict environmental controls to ensure the integrity of the riparian corridor is maintained and there are no adverse impacts on vegetation communities of regional significance to Western Sydney.

FLOOD MITIGATION WORKS CONSTRUCTED

Flood mitigation works that have been completed in the vicinity of Overett Avenue and Elizabeth Drive since the mid-1990s, include the following:

- ***Stage 1 Works*** — involved construction of a flood mitigation channel from a bend in South Creek about 150m south (upstream) of Elizabeth Drive to a bend in South Creek about 50m north (downstream) of Elizabeth Drive. The channel is about 300m long, about 20m wide at the base and generally about 2m deep. The works also included the construction of an additional bridge over Elizabeth Drive over the newly constructed channel about 150m east of the main South Creek crossing;

- ***Stage 2 Works*** — involved the purchase of three flood-affected properties at the western end of Overett Avenue , removal of the houses and creation of Overett Reserve;

- ***Stage 3A Works*** — involved construction of a floodway, approximately 250m long, 20m wide at the base and about 2m deep to join the two bends in South Creek through the newly created Overett Reserve;

- ***Stage 3B Works*** — involved bank shaping works just upstream of the Stage 3A floodway and just upstream of the main South Creek bridge over Elizabeth Drive.

The construction of these flood mitigation works has resulted in a 0.5m–0.8m drop in flood levels in the Overett Avenue area for large and small floods.

As part of the proposed upgrade of Elizabeth Drive to a four-lane road by the Roads and Traffic Authority, a new two-lane bridge over the main channel of South Creek was constructed in about 1996. It is understood that the design of this new bridge did not allow for any increase in the waterway area under this bridge, In addition, the level of the road was not altered as part of the works.

PLANNING CONTROLS AND POLICIES

Land use planning, development controls and specific flood-related policies are key mechanisms by which Council can manage flood-affected areas. Such mechanisms will influence future development (and redevelopment) and therefore the benefits will accrue gradually over time. Without comprehensive floodplain planning, existing problems may be exacerbated and opportunities to reduce flood risks may be lost.

It will therefore be important that Council ensure that the planning outcomes derived from this study are integrated with all other existing and future floodplain risk management studies currently under preparation in their LGA, to provide a consistent platform for dealing with the issue of flooding with future development.

The Planning Matrix Approach

The Planning Matrix Approach to floodplain risk management considers the range of land uses, and their potential risk to flooding, within the floodplain up to the level of the probable maximum flood. Using this approach, a matrix of development controls, based on the flood hazard and the land use, can be developed which balances the risk exposure across the floodplain.

The Flood Risk Management Development Control Plan

The most appropriate mechanism for specifying detailed planning and development controls (associated with the Planning Matrix) to be applied to new development to manage issues of floodplain risk, would be a Flood Risk Management Development Control Plan (DCP).

Liverpool City Council is currently preparing a comprehensive Flood Risk Management DCP, which is yet been adopted by Council, pending the outcome of other studies such as those for the Georges River.

The Flood Risk Management DCP (updated as part of this study) involves a preamble of provisions that establishes a framework to allow for the outcomes of multiple Floodplain Risk Management Studies to be incorporated into the document, of which the current study will be one.

Flood Risk Precincts

A key component of the Planning Matrix Approach is to divide the floodplain into different areas of similar risk, known as Flood Risk Precincts. Different parts of the floodplain are subject to different degrees of flood hazard and different degrees of flood risk. This study recognises that different development controls should apply to different flood risk areas, or precincts.

It should be noted that 'flood hazard' and 'flood risk' are not interchangeable terms. Once the 'flood hazard' has been determined for a particular location, and considered together with the consequences of that flooding, the 'flood risk' can then be determined.

Whereas 'flood hazard categories' describe the severity of the flood behaviour on development and people, 'flood hydraulic categories' describe the severity of development activity on flood behaviour. Like flood hazard, 'flood hydraulic categories' are also a key tool used to determine the suitability of future types of land use in the floodplain.

Three Flood Risk Precincts have been recommended for the South Creek Study Area, namely 'high risk', 'medium risk' and 'low risk', defined as follows:

- ***High Flood Risk Precinct*** —refers generally to land below the 100 year flood level subject to a high hydraulic hazard in a 100 year flood (in accordance with the provisional criteria outlined in the *Floodplain Management Manual*). The High Flood Risk Precinct is where high flood damages, potential risk to life, or evacuation problems would be anticipated;

- ***Medium Flood Risk Precinct***— refers generally to land below the 100 year flood level subject to low hydraulic hazard in a 100 year flood. In this precinct, there may still be a significant risk of flood damage or risk to life, but these could be minimised with application of appropriate development controls;

- ***Low Flood Risk Precinct*** — refers to all other land within the floodplain that is not in a High or Medium Flood Risk Precinct, i.e. land above the 100 year flood level and below the level of the probable maximum flood (PMF). The Low Flood Risk Precinct would be where risk of damages would be low for most land uses and so most land uses would be permitted within this precinct. One of the main purposes of the Low Flood Risk Precinct is to identify and recognise the potential flood risk for all persons and properties affected by the PMF, regardless of whether any specific development controls are to be applied.

Some Proposed Development Controls

Some of the development controls in the Planning Matrix are as follows:

- ***Low Risk Precinct*** — in this precinct, there would be practically no change in development potential. Generally all land uses would be permitted, except 'critical uses and facilities', including hospitals, nursing homes and those that are likely to have a high impact on the emergency management resources in times of flood;

- ***Medium Risk Precinct*** — in this precinct, generally most land uses would be permitted, except 'critical' and 'sensitive uses and facilities'. 'Sensitive' land uses include assisted accommodation, housing for older persons or the disabled, as well as industries that store dangerous materials. Filling activities would be strictly controlled. All permitted development would be subject to flood-related building controls such as minimum floor levels, flood-compatible building components, structural integrity in times of flood, minimum levels for car-parking and driveways to aid in evacuation, and no increased reliance on NSW State Emergency Service (SES) resources in times of flood;

- ***High Risk Precinct*** — most development would not be permitted in this precinct. No additional residential properties would be permitted and there could be no subdivision of land. Filling activities would be very strictly controlled. It is important to note, however, that existing development in this Precinct would not be sterilised. House extensions, sheds and garages would all be permitted with limits as to the size of the development. Rebuilding an existing house with the same size but less flood risk (e.g. a raised house) would also be permitted. Any permitted development would have strict building controls, similar in nature to those listed above for a Medium Flood Risk Precinct, and would be subject to Council approval;

- ***Extensions to Existing Homes, and Construction of Garages and Garden Sheds —*** These types of development are referred to as "concessional development" and would generally be permitted in all areas of the floodplain with limits as to size. Concessional development would be subject to range of flood-related building controls, similar in nature to those listed above for a Medium Flood Risk Precinct and would be subject to Council approval;

- ***Rebuilding of Existing Homes —*** If a house is to be rebuilt in the same location and size to substantially reduce its flood risk (for example by building it at a higher level), this would also be classified as 'concessional development', meaning that it would be permitted in all areas of the floodplain (subject to Council approval);

- ***New Detached Dwelling*** — The rural-residential zoning in the South Creek study area allows a second dwelling to be built on each property. No new dwellings would be permitted in a High Flood Risk Precinct. In a Medium or Low Risk Precinct, the development would be subject to a range of flood-related building controls similar in nature to those listed above for a Medium Flood Risk Precinct and would be subject to Council approval;

- ***Commercial and Industrial Development*** — This type of development would not be permitted in a High Flood Risk Precinct. In a Medium or Low Risk Precinct, the development would be subject to a range of flood-related building controls similar in nature to those listed above for a Medium Flood Risk Precinct and would be subject to Council approval;

- ***Subdivision of Land*** — This type of development would not be permitted in a High Flood Risk Precinct. In a Medium Flood Risk Precinct, an engineer's report would be required to certify that the development would not increase flood effects elsewhere and it would have to be demonstrated that the development could be evacuated in accordance with the requirements of the Flood Risk Management DCP. All subdivisions would be subject to Council approval;

- ***Filling Of Land*** — to assist Council in assessing when filling of land is and is not acceptable in the floodplain, guidelines have been prepared as part of this study entitled "Guidelines for the Assessment of Earthworks and Filling in Floodplain Areas of Non-Urban land in Liverpool" in accordance with the draft Flood Risk Management DCP and the Planning Matrix for South Creek;

- ***Fencing*** — It is important that fencing does not result in the undesirable obstruction of floodwaters or is not washed away, becoming potentially dangerous moving debris, during a flood. All fencing proposed in the floodplain would need to be certified by a suitably qualified engineer to ensure that it could withstand the forces of floodwaters, or collapse in a controlled manner to prevent an undesirable impediment of floodwaters.

RECOMMENDED SOUTH CREEK FLOODPLAIN RISK MANAGEMENT PLAN FOR LIVERPOOL LGA.

The recommended floodplain risk management measures for inclusion in the *South Creek Floodplain Risk Management Plan for the Liverpool LGA* have been determined from the range of available measures discussed presented in **Tables ES.2, ES.3** and **ES.4**, after an assessment of the impacts on flooding, as well as environmental, social, and economic considerations.

Table ES.5 provides a summary of elements of the recommended *Floodplain Risk Management Plan*:

The total cost of the recommended *Floodplain Risk Management Plan* would be in the order of $820,000.

About $680,000 of the total cost of the recommended plan would involve an extensive voluntary house-raising program for all properties that would be flooded above floor level in a 100 year flood. About six of the most frequently flood-affected properties would qualify for a 'full-cost subsidy' of about $70,000 per property towards raising their houses to a level that would allow vertical evacuation to a level above the probable maximum flood. Another 13 properties would qualify for a 'partial-cost subsidy' of about $20,000 per property. A 'partial cost subsidy' will provide homeowners of less frequently flood-affected properties, who were considering raising their homes, further incentive to do so.

One of the key components of the recommended *Floodplain Risk Management Plan* is the recommendation of planning and building controls — these controls are sensitive to the flood problems in the study area and will reduce the future flood risk to the study area community.

The *Floodplain Risk Management Plan* also contains important recommendations relating emergency management and community flood awareness.

The costs for implementation of elements relating to floodplain planning, emergency management and community awareness would be borne mainly by Council and SES staff. Most of these elements have been assigned a high priority because they are essential for ensuring that flood risks in the South Creek study area are not increased in the future.

It should be noted that even with the completion of all the elements of the recommended *Floodplain Risk Management Plan*, there would be no change in the height of design flood levels from current conditions. However, the most important consideration is that there would be a significant reduction in flood risk to the people of the South Creek study area.

Once Council adopts the recommended Plan, Council can then apply for funding to commence the works.

TABLE ES.1: PROPERTY MODIFICATION MEASURES — SUMMARY OF FLOODPLAIN RISK MANAGEMENT OPTIONS EXAMINED

REPORT SECTION NO.	FLOODPLAIN RISK MANAGEMENT MEASURE	DESCRIPTION OF OPTION	RECOMMENDED FOR FURTHER CONSIDERATION
8	**PROPERTY MODIFICATION MEASURES**		
8.1	**Planning Controls and Policies**	‣ amendments to Sydney Regional Environmental Plan No.20 — Hawkesbury–Nepean River (SREP No.20), including development of strategy to fast-track incorporation and adoption; ‣ amendments to Liverpool Local Environmental Plan), including development of strategy to fast-track incorporation and adoption; ‣ adoption of Planning Matrix Approach ‣ adoption of High, Medium and Low Risk Precincts ‣ adoption of Flood Risk Management Development Control Plan	yes yes yes yes yes
8.2	**Voluntary Purchase of Properties**	‣ Properties with over-floor flooding in a 5 year flood (Option VP5): – No.35 Victor Avenue; – No.82 Victor Avenue. ‣ Properties with over-floor flooding in a 20 year flood (Option VP20): – Nos.120 and 150 Overett Avenue; – Nos.10, 20, 50 and 60 Victor Avenue; – No.100 Watts Road.	 no no no no no
8.3	**Voluntary House Raising**	‣ Properties with over-floor flooding in a 5 year flood — full-cost subsidy (Option HR5): – No.35 Victor Avenue; – No.82 Victor Avenue. ‣ Properties with over-floor flooding in a 20 year flood — full-cost subsidy (Option HR20a): – Nos.10, 20 and 50 Victor Avenue; – No.100 Watts Road. ‣ Properties with over-floor flooding in a 20 year flood — partial cost subsidy (Option HR20b): – Nos.120 and 150 Overett Avenue; – No.60 Victor Avenue. ‣ Properties with over-floor flooding in a 100 year flood — partial cost subsidy (Option HR100): – No.70 Kelvin Park Drive. – Nos. 80, 124, 135 and 145 Overett Avenue; – Nos. 5, 32, 50 (second house) and 70 Victor Avenue; – No.1 May Avenue.	 yes yes yes yes yes yes yes yes yes yes yes
8.4	**Flood Proofing**	‣ development of 'Flood Proofing Guidelines' for the study area.	yes

TABLE ES.3: RESPONSE MODIFICATION MEASURES — SUMMARY OF FLOODPLAIN RISK MANAGEMENT OPTIONS EXAMINED

REPORT SECTION NO.	FLOODPLAIN RISK MANAGEMENT MEASURE	DESCRIPTION OF OPTION	RECOMMENDED FOR FURTHER CONSIDERATION
9	**RESPONSE MODIFICATION MEASURES**		
9.1	**Flood Warning**	‣ Study is in 'flash flood' area and so no formal flood warning service available from Bureau of Meteorology. Only formal warnings would be a 'Flood Watch' or 'Severe Thunderstorm Warning'; ‣ development of triggers for rainfall and river height station in and close to the study area; ‣ linking of triggers to local base stations, particularly local SES headquarters; ‣ installation of three additional ALERT rainfall stations in the upper parts of the South Creek catchment.	na yes yes yes
9.2	**Emergency Management**	‣ all flood intelligence information from current study be made available to SES in a form appropriate for inclusion in next version of Liverpool City Local Flood Plan; ‣ provision for 'vertical evacuation' in the planning and development controls; ‣ preparation of FloodSafe brochure either for just current study area or for all South Creek upstream of limit of Hawkesbury–Nepean flooding	yes yes yes
9.3	**Community Flood Awareness**	‣ production of Flood Precinct Maps; ‣ updating of Council's GIS and use of information available from this study; ‣ preparation of brochure 'Guidelines on Flood-Related Building Controls' ‣ preparation and sending out of 'Flood Information Packs' that would include: – Flood Notification Letter; – Flood Information Brochure; – Frequently Asked Questions; – SES FloodSafe brochure and associated SES information; ‣ issuing of Flood Certificates when Development Applications are submitted ‣ appropriate notification on Section 149 Certificates; ‣ public exhibition of Study Report and draft Floodplain Risk Management Plan; ‣ installation of flood markers at Elizabeth Drive and Bringelly Road. Note that Council and the Floodplain Risk Management Committee would confirm the exact details of a Community Flood Awareness Strategy before implementation.	yes yes yes yes yes yes yes yes yes yes yes yes

TABLE ES.4: RESPONSE MODIFICATION MEASURES — SUMMARY OF FLOODPLAIN RISK MANAGEMENT OPTIONS EXAMINED

REPORT SECTION NO.	FLOODPLAIN RISK MANAGEMENT MEASURE	DESCRIPTION OF OPTION	RECOMMENDED FOR FURTHER CONSIDERATION
10	**FLOOD MODIFICATION MEASURES**		
10.1	**Flood Modification Measures for the Overett Avenue Area**	‣ earthen levee to protect all low lying properties in Overett Avenue and the south side of Elizabeth Drive from flooding in a 100 year flood; ‣ enlargement of the existing road bridge over South Creek; ‣ construction of a second bridge at Elizabeth Drive including associated connecting floodways upstream and downstream of Elizabeth Drive, plus voluntary purchase of three properties in Overett Avenue; ‣ widening (including large-scale clearing) of the main South Creek channel downstream of Elizabeth Drive; ‣ widening (including large-scale clearing) of the main South Creek channel upstream of Elizabeth Drive; ‣ construction of floodway at the end of Overett Avenue; ‣ bank shaping works to aid water flow between channel widening works and floodways.	no no yes — constructed as Stages 1 & 2 Works no no yes — constructed as Stage 3A Works yes — constructed as Stage 3B Works
10.2	**Flood Modification Measures for the Victor Avenue Area**	‣ earthen levee to protect all low lying properties in Victor Avenue, Watts Road and Ramsay Road from flooding in a 100 year flood; ‣ widening of the main South Creek channel, including cutting a bench into one or both of the creek banks and where the creek meandered, the construction of a trapezoidal second channel, or floodway, to 'short cut' the meander.	no no
10.3.1	**Construction of Detention Basins**	‣ construction of detention basins upstream of and within the study area;	no
10.3.2	**Impacts of Large Dams on Flood Behaviour**	‣ investigation into whether large dams in region have an impact on flood behaviour in the study area.	no
10.3.3	**Works at Bringelly Road bridge**	‣ road raising and associated enlargement of bridge waterway area	no
10.3.4	**Safety Improvements for at The Retreat bridge**	‣ safety improvement program for The Retreat crossing of Thompsons Creek: – signage at bridge; – associated community awareness program; – investigation into flood escape route to Badgerys Creek Road.	 yes yes yes
10.3.5	**Creek Maintenance Strategy**	‣ large-scale channel clearing as a flood mitigation measure; ‣ development of Creek Maintenance Strategy to ensure: – vegetation levels do not increase flood levels; – environmental considerations clearly identified; – dumped rubbish is systematically removed; – more vigilant policing of dumping practices including signage.	no yes yes yes yes yes

REPORT SECTION NO.	FLOODPLAIN RISK MANAGEMENT MEASURE	DESCRIPTION OF OPTION	RECOMMENDED FOR FURTHER CONSIDERATION
10.3.6	**Works at Australian Native Landscapes site**	‣ filling and associated by-pass floodway as compensatory works at Australian Native Landscapes site as described in 1991 FPM Study.	no
10.3.7	**Levee at Masterfield Street, Rossmore**	‣ investigation into impacts of levee outside study area (just upstream of Bringelly Road)	no
10.4.1	**Integrated Approach to Flood-plain Risk Manage-ment in the South Creek Catchment**	‣ integrated and coordinated approach to floodplain risk management throughout the entire South Creek catchment	yes
10.4.2	**Thompsons Creek and Bardwell Gully Flood Study, Floodplain Risk Management Study and Plan**	‣ flood study, floodplain risk management study and plan for those areas of Bardwell Gully and Thompsons Creek upstream of The Northern Road in both Liverpool and Camden LGAs	yes

TABLE ES.5: RECOMMENDED MEASURES FOR SOUTH CREEK FLOODPLAIN RISK MANAGEMENT PLAN FOR THE LIVERPOOL LGA

ITEM (Report Section No.)	DESCRIPTION	REDUCTION IN NO. PROPERTIES FLOODED ABOVE FLOOR LEVEL IN 100 YEAR FLOOD	BENEFIT–COST RATIO	ESTIMATED COST	FUNDING SOURCES	PRIORITY
8	**PROPERTY MODIFICATION MEASURES**					
8.1	**Planning Controls and Policies:** ‣ amendments to Sydney Regional Environmental Plan No.20 — Hawkesbury–Nepean River (SREP No.20), including strategy to fast-track adoption ‣ amendments to Liverpool Local Environmental Plan, including strategy to fast-track adoption ‣ adoption of Planning Matrix Approach ‣ adoption of High, Medium and Low Risk Precincts ‣ adoption of Flood Risk Management Development Control Plan	na	na	Council Staff Costs	Current Council responsibility	high
8.3	**Voluntary House Raising:**					
8.3.2	‣ Properties with over-floor flooding in a 5 year flood — full-cost subsidy (Option HR5): – No.35 Victor Avenue; – No.82 Victor Avenue.	2	2.4	$140,000	Council, DIPNR, possibly some residents' costs	high
8.3.2	‣ Properties with over-floor flooding in a 20 year flood — full-cost subsidy (Option HR20a): – Nos.10, 20 and 50 Victor Avenue; – No.100 Watts Road.	4	0.8	$280,000	Council, DIPNR, possibly some residents' costs	medium
8.3.2	‣ Properties with over-floor flooding in a 20 year flood — partial cost subsidy (Option HR20b): – Nos.120 and 150 Overett Avenue;	2	2.0	$40,000	Council, DIPNR, residents	low
	– No.60 Victor Avenue.	1		$20,000		medium

ITEM (Report Section No.)	DESCRIPTION	REDUCTION IN NO. PROPERTIES FLOODED ABOVE FLOOR LEVEL IN 100 YEAR FLOOD	BENEFIT–COST RATIO	ESTIMATED COST	FUNDING SOURCES	PRIORITY
8.3.2	‣ Properties with over-floor flooding between a 20 year flood and a 100 year flood — partial cost subsidy (Option HR100): – No.70 Kelvin Park Drive. – Nos. 80, 124, 135 and 145 Overett Avenue; – Nos. 5, 32, 50 (2nd house) and 70 Victor Avenue; – No.1 May Avenue.	10	0.5–1.0	$200,000	Council, DIPNR, residents	low
8.4	**Flood Proofing —** ‣ development of 'Flood Proofing Guidelines' for study area.	na	na	$5,000 plus Council staff costs	Council, (residents' costs to implement)	medium
9	**RESPONSE MODIFICATION MEASURES**					
9.1	**Flood Warning:** *As the South Creek study area would be in a 'flash flood' area, there would be no formal flood warning service available from the Bureau of Meteorology. A Flood Watch or Severe Thunderstorm Warning issued by the Bureau of Meteorology would be the only 'formal' means of flood warning for the study area.*					
9.1.3	‣ development of triggers for rainfall and river height station in and close to the study area;	na	na	Bureau of Meteorology and SES staff costs	Council, Bureau of Meteorology and SES	high
9.1.3	‣ linking of triggers for rainfall and river height stations to local base stations, particularly local SES headquarters, to identify to local authorities when flooding may be imminent;	na	na	Council, Bureau of Meteorology and SES staff costs plus computer costs	Council, Bureau of Meteorology, SES	high
9.1.4	‣ installation of three additional ALERT rainfall stations in the upper parts of the South Creek catchment, including the development and linking of triggers to local base stations.	na	na	$20,000 for capital and installation plus $2,000–$3,000 per annum for maintenance	Council, DIPNR	high

ITEM (Report Section No.)	DESCRIPTION	REDUCTION IN NO. PROPERTIES FLOODED ABOVE FLOOR LEVEL IN 100 YEAR FLOOD	BENEFIT–COST RATIO	ESTIMATED COST	FUNDING SOURCES	PRIORITY
9.2	**Emergency Management:**					
9.2.2 9.2.3	‣ all flood intelligence information from current study be made available to SES in a form appropriate for inclusion in next version of Liverpool City Local Flood Plan	na	na	$10,000 plus SES staff costs	SES, Council	high
9.2.4	‣ provision for 'vertical evacuation' in the planning and development controls	na	na	Council staff costs	Current Council responsibility	high
9.2.5	‣ preparation of FloodSafe brochure either for just current study area or for all South Creek upstream of limit of Hawkesbury–Nepean flooding	na	na	$5,000 (for design of brochure) plus SES staff costs	Council, SES	high
9.3	**Community Flood Awareness**					
9.3.2	‣ production of Flood Precinct Maps	na	na	Council staff costs	Council	high
9.3.3	‣ updating of Council's GIS and use of information available from this study	na	na	Council staff costs	Council	high
9.3.4	‣ preparation of brochure 'Guidelines on Flood-Related Building Controls'	na	na	$5,000 plus Council staff costs	Council	high
9.3.5	‣ preparation and sending out of 'Flood Information Packs' to all residents in the floodplain, that would include: (a) Flood Notification Letter; (b) Flood Information Brochure; (c) Frequently Asked Questions about Floodplain Risk Management Studies; (d) SES FloodSafe brochure and associated SES information.	na	na	‣ Council staff costs (a) Council staff costs (b) $5,000 (for design of brochure) plus Council staff costs (c) already completed (d) SES staff costs	Council (a) Council (b) Council (c) Council (d) Council, SES	high
9.3.6	‣ issuing of Flood Certificates when Development Applications are submitted	na	na	Council staff costs	Council	high

ITEM (Report Section No.)	DESCRIPTION	REDUCTION IN NO. PROPERTIES FLOODED ABOVE FLOOR LEVEL IN 100 YEAR FLOOD	BENEFIT–COST RATIO	ESTIMATED COST	FUNDING SOURCES	PRIORITY
9.3.7	‣ installation of flood markers at Elizabeth Drive and Bringelly Road	na	na	$20,000	Council, DIPNR	low
9.3.8	‣ appropriate notification on Section 149 Certificates	na	na	Council staff costs	Council	high
10	**FLOOD MODIFICATION MEASURES**					
10.3.4	**Safety improvement program for The Retreat crossing of Thompsons Creek:**					
10.3.4	‣ signage at bridge and associated community awareness program	na	na	$5,000 plus Council staff costs	Council	high
10.3.4	‣ investigation into flood escape route to Badgerys Creek Road via an existing access way	na	na	Council and SES staff costs	Council, SES	high
10.3.5	**Development of Creek Maintenance Strategy, including:** ‣ the amount of appropriate vegetation be determined so that flood levels would not start to increase; ‣ clear identification of environmental considerations; ‣ systematic removal of dumped rubbish; ‣ more vigilant policing of dumping practices in the study — this could involve the installation of signs at key problem areas with large fines for dumping of rubbish.	na	na	$10,000 plus Council staff costs	Council, possibly some volunteers for implementation of strategy	high
10.4.1	**Integrated Approach to Floodplain Risk Management in the South Creek Catchment**	na	na	Council staff costs	Council, DIPNR	high
10.4.2	**Thompsons Creek and Bardwell Gully Flood Study, Floodplain Risk Management Study and Plan**	na	na	$50,000	Council (Liverpool and Camden), DIPNR	medium
	TOTALS	**19**		**$815,000**		

1. INTRODUCTION

Liverpool City Council has commissioned Bewsher Consulting Pty Ltd, in association with Don Fox Planning Pty Ltd, to undertake a *Floodplain Risk Management Study and Plan* for those portions of the South Creek and Thompson Creek floodplains that lie within the Liverpool Local Government Area (LGA). A locality plan and location of the study area in relation to the South Creek catchment are shown on **Figure 1.1**.

This Study Report provides a culmination of the background information, the community consultation strategy, the analysis of floodplain risk management options and presents the recommended *South Creek Floodplain Risk Management Plan within the Liverpool LGA*.

The Liverpool City Council Floodplain Management Committee, an official committee of Council, has overseen and is responsible for, the current study. The committee has assisted and advised Council in the development of the *recommended South Creek Floodplain Risk Management Study and Plan for the Liverpool LGA* and has provided the vital link between the consultant, Council, the Department of Infrastructure, Planning and Natural Resources (DIPNR) (formerly the Department of Land and Water Conservation (DLWC)), other government agencies and the local community.

To provide the wider community with an opportunity to comment on the draft plan proposals, the final stage of community consultation for this study was the public exhibition of the Draft Study Report and the draft *South Creek Floodplain Risk Management Study and Plan for the Liverpool LGA*.

Public displays of the Draft Study Report and draft Plan were placed at Council's Administration Centre, Council's Customer Service Centre, Liverpool City Library and the Austral Bowling Club between July and September 2004.

During the public exhibition period, written submissions were invited from the local community, as well as the Floodplain Management Committee, relevant Council staff, government agencies and other key stakeholders. The issues raised in these submissions have been incorporated in this final version of the report. This Final Report was put before Council for formal adoption in December 2004.

The structure of this Study Report is as follows:

- **Chapter 2** describes the behaviour of floods in the study area, including a brief outline of the flood history, as well as the hydrological and hydraulic modelling undertaken for the study area;

- **Chapter 3** presents background information available for the study including mapping, ground survey and information from Liverpool City Council's Geographical Information System (GIS);

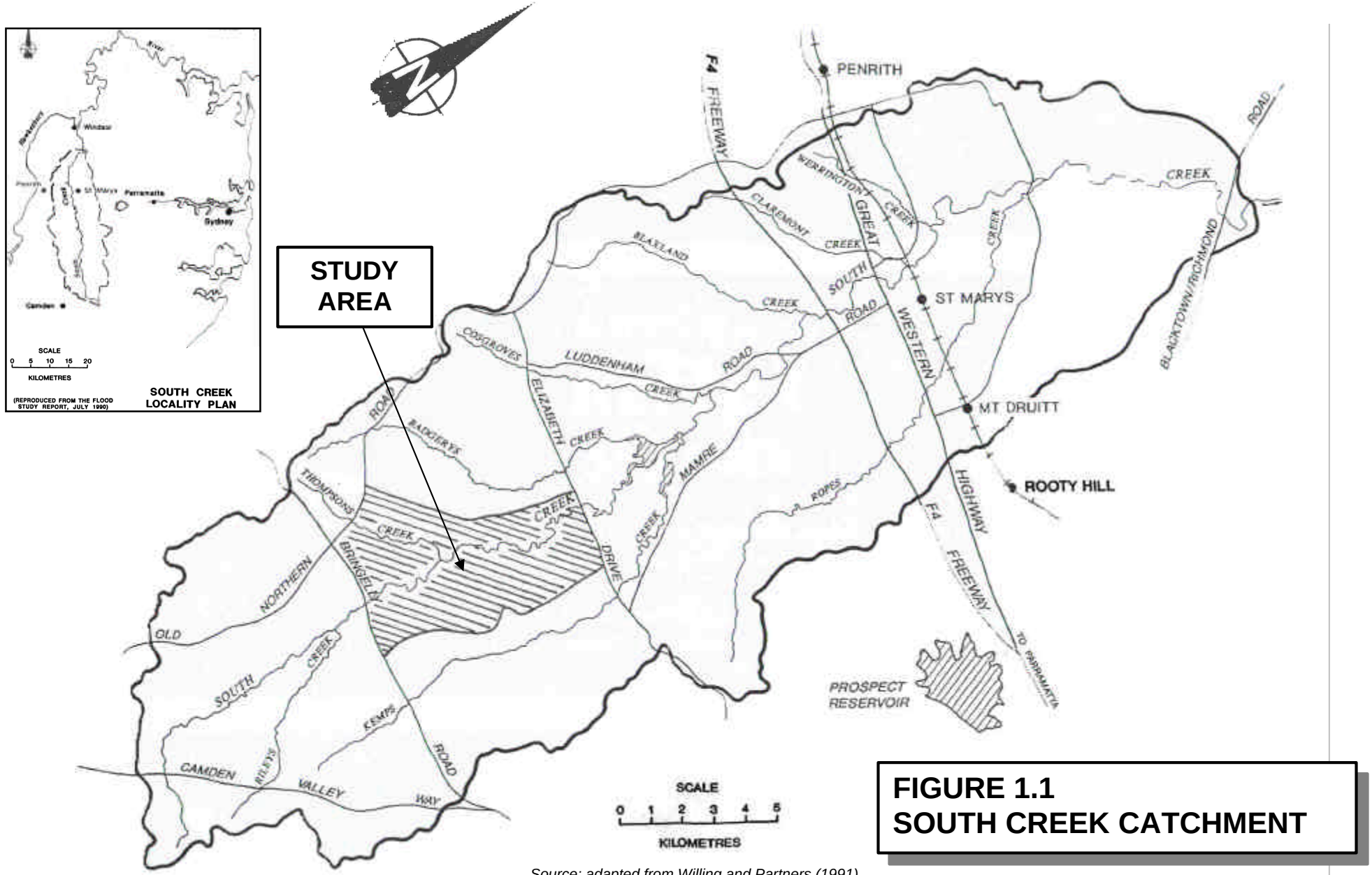

FIGURE 1.1
SOUTH CREEK CATCHMENT

Source: adapted from Willing and Partners (1991)

- **Chapter 4** summarises the impacts and costs of flooding in the study area, including the mapping of design flood events, a description and the mapping of Flood Risk Precincts, the number of properties affected by flooding, the impacts of flooding on roads in the study area together with an estimation of the amount of flood damage that could be expected, in monetary terms;

- **Chapter 5** provides details of the community consultation aspects of the study including the community newsletter, community survey, liaison with stakeholders, the study web site, the community workshop and public exhibition of the study;

- **Chapter 6** presents an overview of the available range of floodplain risk management measures including the criteria used for their assessment in this study. A discussion on environmental considerations is also presented in this chapter;

- **Chapter 7** presents a summary of all the potential floodplain risk management measures that have been considered in this study, while a detailed discussion of the floodplain risk management options examined is presented in the following three chapters:

  - **Chapter 8** — property modification measures, such as planning controls, voluntary purchase of properties, house raising and flood proofing;

  - **Chapter 9** — response modification measures, such as flood warning, emergency management and community flood awareness;

  - **Chapter 10** — flood modification measures, such as detention basins, enlargement of waterway areas under bridges, levees, channel widening and the construction of floodways;

- **Chapter 11** presents the recommended *South Creek Floodplain Risk Management Plan for the Liverpool LGA*;

- **Chapter 12** lists all the documents that have been referenced in this Study Report.

Don Fox Planning Pty Ltd has prepared a stand-alone document entitled *Town Planning Issues* as part of this study (Don Fox Planning, 2004). Because planning and development controls are such an integral component of the recommended *Floodplain Risk Management Plan*, the report has been included in its entirety as **Volume 2** of the current report. A Draft Development Control Plan (DCP) for Flood Risk Management for Liverpool City Council is included as an Appendix in **Volume 2**. Key components of the **Volume 2** report have been summarised in appropriate locations throughout the main body of this report.

A Glossary of terms used in this study is provided as **Appendix A** of this report, while **Appendix B** is a Bibliography of all documents, plans, etc which are relevant to this Floodplain Risk Management Study. Most of the items listed in the Bibliography have been reviewed as part of the current study.

1.1 STUDY AREA

1.1.1 Creeks and Floodplains

The South Creek catchment is a significant tributary of the Hawkesbury–Nepean River and is located about 40km to the west of the Sydney Central Business District. The South Creek catchment is generally bounded by the suburbs of Windsor in the north, Narellan (near Camden) in the south, Penrith in the west and Blacktown in the east. South Creek flows in a generally northerly direction for about 70km. The total catchment area of South Creek is about 490 square kilometres (Willing and Partners, 1991). A locality plan is provided as part of **Figure 1.1**.

The study area of this *Floodplain Risk Management Study* covers only a small portion of the total South Creek catchment, as shown in **Figure 1.1**. The study area covers only the following floodplain areas:

- those parts of the main South Creek catchment located within the Liverpool LGA;
- those parts of the Thompsons Creek catchment, a tributary of South Creek, located within the Liverpool LGA, as far upstream as The Northern Road.

Flooding issues of other minor tributaries of South Creek located within the boundaries of the study area, as well as the areas of Thompsons Creek upstream of The Northern Road, have not been examined as part of the current study.

A detailed plan of the study area is provided as **Figure 1.2**.

South Creek flows generally from south to north through the study area. The northern boundary of the study area is Elizabeth Drive, while the southern boundary is Bringelly Road and The Northern Road, approximately 7km to the south. To the north of Elizabeth Drive, is the Penrith LGA; while to the south of Bringelly Road is Camden LGA. As shown on **Figure 1.2**, the western boundary of the study area is South Creek's catchment boundary with Badgerys Creek, while the eastern boundary is the catchment boundary with Kemps Creek — both of these creeks are tributaries of South Creek, joining South Creek about 2–2.5km downstream of Elizabeth Drive.

The catchment area of South Creek at Bringelly Road is about 56 square kilometres, while at Elizabeth Drive the catchment area is about 90 square kilometres. Parts of the suburbs of Badgerys Creek, Kemps Creek, Rossmore and Bringelly are located within the study area.

Thompsons Creek joins the western floodplain of South Creek about midway through the study area. Thompsons Creek rises about 2km south of Greendale Road, Bringelly, flowing in a north-easterly direction for about 6.5km towards South Creek. The total catchment area of Thompsons Creek is about 10.3 square kilometres. A major tributary of Thompsons Creek is Bardwell Gully. Bardwell Gully flows generally from west to east, parallel to Greendale Road, before joining Thompsons Creek just upstream of The Northern Road.

FIGURE 1.2: STUDY AREA

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Bardwell Gully and the Thompsons Creek catchment upstream of The Northern Road, within the Liverpool LGA have not been included in the current study. However, a study for this area has been recommended as part of this *Floodplain Risk Management Plan* (see **Section 10.4.2**).

The names South Creek, Thompsons Creek and Bardwell Gully are all registered with the Geographical Names Board of New South Wales. The name South Creek dates back to the early 1890s (Geographical Names Board, 2003).

1.1.2 Topography

The subject study area forms an extensive area of the south-west section of the Cumberland Plain. Generally, the topography of the Cumberland Plain is a gentle undulating basin, dipping westward from Parramatta to the Nepean River and from Wilberforce and Richmond, south-west of Picton and Menangle (**Volume 2**, Don Fox Planning, 2004).

The soils landscape within the study area have been classified by publication of the (then) Soil Conservation Service of NSW (Bannerman & Hazelton, 1990). The commonly occurring soil landscape *"South Creek (sc)"* is located within the South Creek floodplain. Fertility of the soil is generally low and erodability is very high. The remaining soils within the study area, outside of the floodplain, are the commonly occurring *"Blacktown (bt) soil landscape"*. Soils in this area are generally shallow to moderately deep (less than 1m) and are moderately erodable (**Volume 2**, Don Fox Planning, 2004).

1.1.3 Vegetation

The original vegetation of the study area would have comprised mostly Cumberland Plain Woodland vegetation communities with River-Flat Forest along the creeklines, and some patches of Castlereagh Woodland. The bushland remnants today comprise mostly pockets of Cumberland Plain Woodlands and River-Flat Forest. The remainder of the study area is either cleared for agriculture or greatly modified through underscrubbing and grazing, leaving a generally open woodland environment with scattered mature trees. Where agricultural pursuits have ceased, some regeneration of the typical Grey Box (*Eucalyptus mollucana*) and Forest Red Gum (*Eucalyptus tereticornis*) overstorey is occurring. Generally, the majority of the vegetation within the study area is concentrated within a riparian zone along the creeks, with a varying width, generally 100m–200m wide (**Volume 2**, Don Fox Planning, 2004).

The past land habitats within the study area are generally unsuitable for most native fauna, however some of the more resilient indigenous fauna species remain in the riparian habitat and Grey Box Woodland. Farm dams also provide habitat for frogs and waterfowl. Ecological pressures from introduced predators such as foxes, dogs and cats and competition from rabbits, hares and livestock, have impacted upon the original biodiversity of the region (**Volume 2**, Don Fox Planning, 2004).

The *Liverpool Rural Lands Study* (Don Fox Planning, 1994) identified the vegetation within the South Creek riparian corridor. The study recommended that the narrow band of riparian vegetation along South Creek, dominated by She Oaks, with some Forest Red Gums, Grey Boxes and Rough-barked Apples be considered to be of regional significance and should be protected from further degradation because of its value as a remnant of the original riparian vegetation of the region together with the habitat links provided for native fauna. (**Volume 2**, Don Fox Planning, 2004)

For this and other environmental considerations related to floodplain risk management of the South Creek study area, refer to **Section 6.4** of this report.

1.1.4 Land Use and Population

The predominant land use in the South Creek study area comprises rural-residential allotments and houses. There is also a variety of agricultural and non-urban uses throughout the study area, including a number of home-based businesses. There are also several large parcels of land in the study area owned by large companies, including:

- Australian Native Landscapes Pty Ltd in Martin Road;
- Boral Bricks (NSW) Pty Ltd in Martin Road;
- Ingham's Chickens off Badgerys Creek Road west of South Creek;
- Telstra and Commonwealth Land off Badgerys Creek Road west of South Creek;
- Department of Defence land off Badgerys Creek Road west of South Creek;
- Novartis Animal Health Pty Ltd in Western Road;
- Roladuct Spiral Tubing, a metal pipe manufacturing company, in Elizabeth Drive;
- Conifer Craft Homes, a manufacturer of kit homes, located on the Roladuct site.

Section 2.2 of **Volume 2** (Don Fox Planning, 2004), discusses the census data for the study area (in terms of Post Code Area 2171) and compares the general trends with the rest of the Liverpool LGA and Sydney overall. Some of the conclusions drawn from that discussion are as follows:

- although the Liverpool LGA has experienced substantial growth over the last 15 years, much of this growth has occurred outside the study area;

- the proportion of 17% youths aged 5 to 14 in the study area, is higher than for Liverpool LGA (16.4%) and Sydney overall (13.4%);

- the proportion of 6.1% aged persons aged 65 or greater in the study area, is lower than for Sydney overall (11.7%);

- a particularly high percentage of the population in the study area is overseas born (33.4%) and speaks English poorly (59.7%) compared to the Liverpool LGA (6.8%) and Sydney overall (4.4%). This has significant implications for community awareness programs, requiring that multi-lingual information is distributed or access to interpretive facilities is provided.

1.1.5 South West Urban Release Investigation Area

The NSW Department of Infrastructure, Planning and Natural Resources' (DIPNR) Managing Sydney's Urban Growth Team are currently investigating a major new urban release area in Sydney's south west. The investigation area extends from the Nepean River in the west, east to the M4 Motorway, north of Badgerys Creek and south to Narellan. The area covers parts of the Liverpool, Camden and Campbelltown LGAs (PlanningNSW, 2003).

The current South Creek study area forms part of a larger area within the South West Urban Release Investigation Area known as the Bringelly Investigation Area. This current Floodplain Risk Management Study has not taken into consideration the flood risks associated with potential future urban releases within the study area, as the exact nature of the future development remains undetermined and is currently under investigation at the time of preparing the report (see also **Section 5.3.1**).

1.2 STUDY OBJECTIVES

The primary objective of the *South Creek Floodplain Risk Management Study and Plan* is to bring together, and place in appropriate context, all past, current and proposed future activities related to flood risk in the study area. In broad terms, the current study has investigated what can be done to minimise the effects of flooding in the South Creek study area and recommended a strategy in the form of a *Floodplain Risk Management Plan*. This study and plan constitute key components of the NSW Government's floodplain risk management process as outlined in the *Floodplain Management Manual* (NSW Government, 2001) (see **Section 1.3**).

Some of the objectives of the study include:

- a review of the hydrological and hydraulic modelling activities that have been undertaken for the study area to date, including the collation of all previously calculated design flood levels for the study area and determination of a definitive set of design flood levels for use in this and all future assessments in the study area;

- the implementation of a community consultation strategy, to ensure community input is obtained at key times throughout the study;

- a description and quantification of the flood problems in the South Creek study area, including the likely cost of flooding to the local community;

- the identification and assessment of potential floodplain risk management measures to reduce the risks and hazards of flooding;

- a detailed review of issues relating to planning and development controls within the floodplain.

- the development of a recommended *Floodplain Risk Management Plan* for the South Creek study area that outlines the best measures to reduce flood damage, based on environmental, social, economic, financial and engineering considerations.

1.3 THE NSW GOVERNMENT'S FLOODPLAIN RISK MANAGEMENT PROCESS

The prime responsibility for planning and management of flood prone lands in NSW rests with local government. The NSW Government provides assistance on state-wide policy issues and technical support. Financial assistance is also provided to undertake flood and floodplain management studies, and for the implementation of works identified in these studies.

The NSW Government's Flood Prone Land Policy and the *Floodplain Management Manual* (NSW Government, 2001) form the basis of floodplain management in New South Wales. The *Floodplain Management Manual* supersedes the *Floodplain Development Manual* (NSW Government, 1986). The steps in the floodplain risk management process are summarised on **Figure 1.3**.

The Flood Prone Land Policy is provided in Appendix A of the *Floodplain Management Manual*, its primary objective being to:

- "reduce the impacts of flooding and flood liability on individual owners and occupiers of flood-prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible."

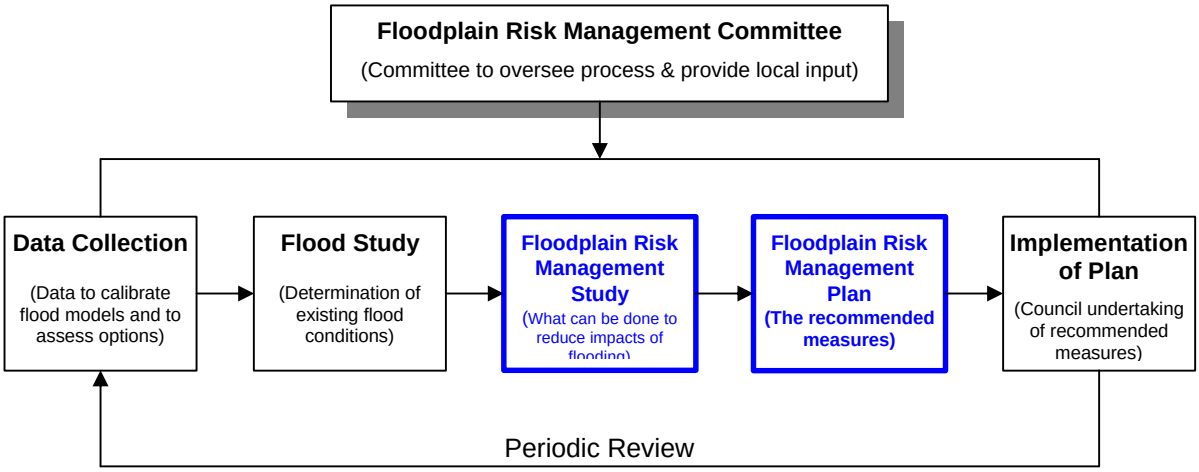
One of the primary aims of the 2001 *Floodplain Management Manual* is to foster the following floodplain risk management principles:

- "to reduce the social and financial costs that result from the risks of occupying the floodplain;
- to increase the sustainable social, economic, and ecological benefits of using the floodplain;
- to improve or maintain the diversity and well-being of native riverine and floodplain ecosystems."

In order to follow these principles, the *Floodplain Management Manual* encourages a risk management approach and provides the following hierarchy of floodplain risk management measures that should be considered:

- avoidance of the flood risk;
- minimisation of the flood risk using appropriate planning controls;
- mitigation of the flood risk — this is considered the least preferred option in the new Manual, as it is often costly and is most likely to adversely affect the natural environment.

The Flood Prone Land Policy also provides some legal protection for Councils, other public authorities and their staff against claims for damages resulting from the issuing of advice or granting approvals on floodplains, providing they have acted substantially in accordance with the principles contained in the *Floodplain Management Manual*.



Source: *Floodplain Management Manual* (NSW Government, 2001)

FIGURE 1.3: NSW GOVERNMENT FLOODPLAIN RISK MANAGEMENT PROCESS

1.4 FUNDING OF FLOODPLAIN RISK MANAGEMENT PLAN

In NSW, the primary source of funding for the various elements of the floodplain risk management plan is generally via State Government funding through the Department of Infrastructure, Planning and Natural Resources (DIPNR) (formerly the Department of Land and Water Conservation (DLWC)). The Commonwealth Government also provides funding for flood mitigation projects in outer metropolitan areas such as the South Creek study area, generally matching the State's contribution on a 'one-to-one' basis.

Although much of an adopted *Floodplain Risk Management Plan* may be eligible for Government assistance (be it State or Commonwealth), funding cannot be guaranteed. Government funds are allocated on a prioritised basis to competing projects throughout the State. Funding of investigation and design activities is also normally available. Maintenance costs, however, are the responsibility of Council.

In addition, funding of flood risk management measures is only available to implement measures that contribute to reducing existing flood problems — they are not available for the avoidance of future flood risks arising from new development.

1.5 ROLES AND RESPONSIBILITIES OF ORGANISATIONS

Many government and non-government organisations have various responsibilities in the management of flood risks in NSW. **Table 1.1** summarises the key responsibilities of these organisations before, during and after a flood.

TABLE 1.1: ROLES AND RESPONSIBILITIES IN FLOOD RISK MANAGEMENT

ORGANISATION	ROLES AND RESPONSIBILITIES
Liverpool City Council	‣ overall management of flood-liable land; ‣ calculation of flood levels and determination of flood behaviour of all major streams and from local drainage problems; ‣ adoption of flood levels and other flood-related information; ‣ provision of flood levels (and other flood-related information) to the public; ‣ coordination of floodplain management activities and flood mitigation works; ‣ preparation and adoption of flood-related planning instruments; ‣ closing of local roads during a flood (in association with NSW Police Service and State Emergency Service). ‣ collection of flood levels after a flood.
NSW State Government NSW Department of Infrastructure, Planning and Natural Resources (DIPNR)	‣ NSW Government Department responsible for development and administration of Flood Prone Land Policy; ‣ provides an oversight and coordination role for all flood related matters across NSW; ‣ administers state government funding of elements of the Floodplain Risk Management Plan.
State Emergency Service of NSW (SES)	‣ formal responsibility for emergency management operations in response to flooding, including coordination of other organisations for flood-related response tasks; ‣ establishes the 'flood planning process' through and involving the Local Emergency Management Committee; ‣ responsible for preparation of Local Flood Plans; ‣ coordinates evacuation (if required) during a flood including notification of who should evacuate.
NSW Roads and Traffic Authority	‣ responsible for road closures for major roads during a flood (in association with the NSW Police Service and the SES).
NSW Department of Community Services (DOCS) (DOCS, 2004)	‣ through it Disaster Recovery Service, provides support to help the community recover from the disaster of a flood. This can include practical assistance such as beds, food, accommodation, through to personal support and counselling; ‣ manage Evacuation Centres (short-term assistance) during and immediately after a flood, providing food, accommodation, first aid, clothing, blankets, registration of victims and information; ‣ manage Recovery Centres for longer term assistance to deal with advice on insurance, counselling, financial assistance, etc.; ‣ works with non-government agencies including the Red Cross, Salvation Army, St Vincent de Paul Society, the Seventh Day Adventist Church and Anglicare.
Commonwealth Government Commonwealth Bureau of Meteorology	‣ collection of rainfall, streamflow and water level data; ‣ responsible for issuing flood warnings in catchments where formal warning systems exist; ‣ issues 'Severe Thunderstorm Warnings' and 'Flood Watches' in catchments where 'flash flooding' occurs.
Commonwealth Department of Transport and Regional Services (DOTARS) (DOTARS, 2004)	‣ through the Regional Flood Mitigation Programme, DOTARS provides funding for flood mitigation projects in outer metropolitan areas such as the South Creek study area; ‣ administers Natural Disaster Relief Arrangements.

2. FLOOD BEHAVIOUR

Like all waterways, South Creek is prone to flooding. Flooding in the study area occurs from the normal mechanism of water spilling out of the main channels and inundating the floodplains. The study area is not affected by backwater flooding from the Hawkesbury–Nepean River nor from the large dams located on South Creek about 2km–3km downstream of Elizabeth Drive.

This chapter describes the flood behaviour and the flood modelling that has been undertaken in the study area. A brief history of the large floods to have affected the study area is presented in **Section 2.1**. Hydrological modelling, including design flow rates that have been adopted for use in this study using the existing RAFTS model, is outlined in **Section 2.2**. **Section 2.3** describes the evolution of the MIKE-11 hydraulic modelling of the study area and the processes undertaken to create a '2003 MIKE-11 model' for the study area that has been used in this study. **Section 2.3** also presents the adopted design flood levels for the 5 year average recurrence interval (ARI) flood, the 20 year ARI flood, the 50 year ARI flood, the 100 year ARI flood and probable maximum flood.

It should be noted that, in this report, the size of a particular flood is described in terms of average recurrence interval or ARI, for example '100 year ARI flood'. A '100 year ARI flood' will occur, on average, once every 100 years. Similarly, a '20 year ARI flood' will occur, on average, once every 20 years. The size of a flood can also be described in terms of its probability of occurring in any one year. For example, a '100 year ARI flood' can also be called a '1% annual exceedance probability (AEP)' flood. A '1% AEP flood' has a 1% chance or 1-in-100 chance of occurring in any one year.

For improved clarity in this report, a '100 year ARI flood' will be simply referred to as a '100 year flood', a '20 year ARI flood' will be referred to as a '20 year flood', and so on (refer to the Glossary in **Appendix A** for more information).

2.1 FLOOD HISTORY

2.1.1 River Gauging Stations

River gauging stations measure the water height at a particular location in a stream. Most modern river gauging stations continually and automatically measure water height, while some older stations are only manually read at regular intervals, usually once a day. Using flow measuring equipment, a 'rating curve' is developed for a particular gauging station, so that for any water height measured in the stream, the corresponding flow in the stream can be determined.

There are two river gauging stations relevant to the South Creek study area, both located in the vicinity of Elizabeth Drive.

River Gauging Station No.212321, which is no longer in operation, was located on the west bank of South Creek about 50m downstream of Elizabeth Drive and was operated by the University of New South Wales from 1955 to 1992.

River Gauging Station No.212320 is the currently operating station and is located on the west bank of a pool in South Creek about 200m upstream of Elizabeth Drive. A concrete V-notched weir controls low flows for this station. The operation of this station was started in 1955 by the University of NSW and has been operated by predecessors of the Department of Infrastructure, Planning and Natural Resources (DIPNR) since 1970.

Water height information from Station No.212320, 'South Creek at Elizabeth Drive' for the previous week is available from the DIPNR website at the following address:

- www.waterinfo.dlwc.nsw.gov.au/drr/southcoast/

2.1.2 Major Floods of the 1980s

Two major flood events occurred in the South Creek catchment in the 1980s. The August 1986 flood and the April 1988 flood are two of the largest floods to have occurred in the catchment since European settlement. Large amounts of data from both of these floods were collected. **Table 2.1** summarises flood levels measured in the study area for these two floods.

TABLE 2.1: FLOOD LEVELS IN THE STUDY AREA FROM THE AUGUST 1986 AND APRIL 1988 FLOODS

LOCATION	AUGUST 1986 FLOOD LEVEL (mAHD)	APRIL 1988 FLOOD LEVEL (mAHD)
Opposite Masterfield Street, Rossmore (about 500m upstream (south) Bringelly Road)	—	59.42
Just downstream of Bringelly Road bridge	—	57.59
May Avenue, Rossmore (200m–1,200m downstream Bringelly Road)	—	56.09
Wishart Road, Kemps Creek (about 3,500m upstream of Elizabeth Drive)	—	51.47
Victor Avenue, Kemps Creek (about 2,800m upstream of Elizabeth Drive)	48.56	49.10
Overett Avenue, Kemps Creek (about 300m upstream of Elizabeth Drive)	—	43.41
Just upstream of Elizabeth Drive bridge	42.73	43.33
Just downstream of Elizabeth Drive bridge	42.06	42.66

Source: Department of Water Resources, 1990

2.1.3 Top Ten Floods in South Creek at Elizabeth Drive — 1955 to 1988

As well as the two major floods of the 1980s, large floods also occurred in South Creek in February 1956, November 1961 and June 1964. **Table 2.2** lists the ten largest floods in South Creek in terms of peak flow rate at Elizabeth Drive between 1955 and 1988. These historical floods are compared to the latest design flood levels (see **Section 3.2**). **Table 2.2** shows that the April 1988 flood was in the order of a 100 year flood through the study area, while the 1956 flood was about a 10 year flood and the 1961, 1964 and 1986 floods were all just larger than about a 5 year flood.

TABLE 2.2: HISTORICAL AND DESIGN FLOOD LEVELS AND FLOWS AT ELIZABETH DRIVE

HISTORICAL FLOODS (1955 to 1988)		DESIGN FLOOD[2]	PEAK WATER LEVEL[2]	PEAK FLOW[1]	COMMENTS[2],[3]
RANK	DATE	(ARI)	(mAHD)	(m^3/s)	
		PMF	44.68	1,710	
1	01 May 1988		43.30	440	Station 212320
		100 YEAR	42.91	433	
		50 YEAR	42.78	372	
		20 YEAR	42.48	281	
2	10 Feb 1956		43.0 (u/s) 42.14 (d/s)	230	Station 212321 (for d/s level)
3	19 Nov 1961		42.20	176	Station 212321
4	11 Jun 1964		42.14	162	Station 212321
5	06 Aug 1986		42.69	160	Station 212320
		5 YEAR	42.03	158	
6	15 Apr 1969		42.11	157	Station 212321
7	06 Mar 1967		42.11	157	Station 212321
8	13 Nov 1969		42.18	152	Station 212321
9	09 Nov 1966		42.08	152	Station 212321
10	08 Jan 1962		41.86	121	Station 212321

PMF — Probable maximum flood; *ARI — Average Recurrence interval*
mAHD — metres Australian Height Datum; *d/s — downstream; u/s — upstream*

Notes: *(1)* *Floods are ranked by peak flow at Elizabeth Drive.*
(2) *Sources for historical flows and levels are Kinhill Engineers (1994) and Willing and Partners (1991); Source for peak design water levels is 2003 Model results (CS16.413). i.e. assumes current channel and bridge conditions at Elizabeth Drive (see **Section 3.2**); Source for peak design flows for 20 year, 50 year, 100 year and PMF is Willing and Partners (1991); Source for peak flow for 5 year flood is Kinhill Engineers (1994).*
(3) *River Gauging Station No.212321 was located about 50m downstream of Elizabeth Drive, while River Gauging Station No.212320 is located about 200m upstream of Elizabeth Drive..*

Following the major floods of the 1980s and from the conclusions reached as part of the *1991 Floodplain Management Study* (Willing and Partners, 1991), the Overett Avenue area, just upstream of Elizabeth Drive, was identified as one of the main flood problem areas of South Creek in the Liverpool LGA. A number of studies were undertaken during the 1990s to examine flood mitigation options for this area, and as a result, a number of flood mitigation works were undertaken in this area. These works are discussed in detail in **Section 10.1.2**.

These flood mitigation works have resulted in a reduction in flood levels of about 0.5m–0.8m in the Overett Avenue area (see **Section 10.1.2**). Therefore, the flood level upstream of Elizabeth Drive recorded in the 1956 flood would be equivalent to the current 100 year flood level with today's bridge and channel conditions at Elizabeth Drive. If a flood of the size of the 1956 flood occurred today, the flood level upstream of Elizabeth Drive would be likely to be more than 0.5m lower.

2.2 HYDROLOGIC MODELLING

This section outlines the hydrological modelling that has been undertaken to date within the study area. A RAFTS model was originally established and calibrated for the entire South Creek catchment as part of the *1990 Flood Study for South Creek* (Department of Water Resources, 1990) and used in the *1991 Floodplain Management Study* (Willing and Partners, 1991). These results were used in the analysis of flood mitigation options for the Overett Avenue and Victor Avenue areas and have been adopted for use in the current study.

2.2.1 Hydrologic Modelling From Previous Studies

1990 Flood Study Report for South Creek

A RAFTS hydrological model for the entire South Creek (excluding Eastern Creek) was established and calibrated as part of the *1990 Flood Study Report for South Creek* (Department of Water Resources, 1990) (referred to as the '*1990 Flood Study*').

Figure 2.1 shows a layout of the 76-subcatchment RAFTS model for South Creek from the *1990 Flood Study*. **Figure 2.2** shows the approximate subcatchment boundaries located within the current study area, while **Figure 2.3** shows more detail in the vicinity of Elizabeth Drive and Overett Avenue.

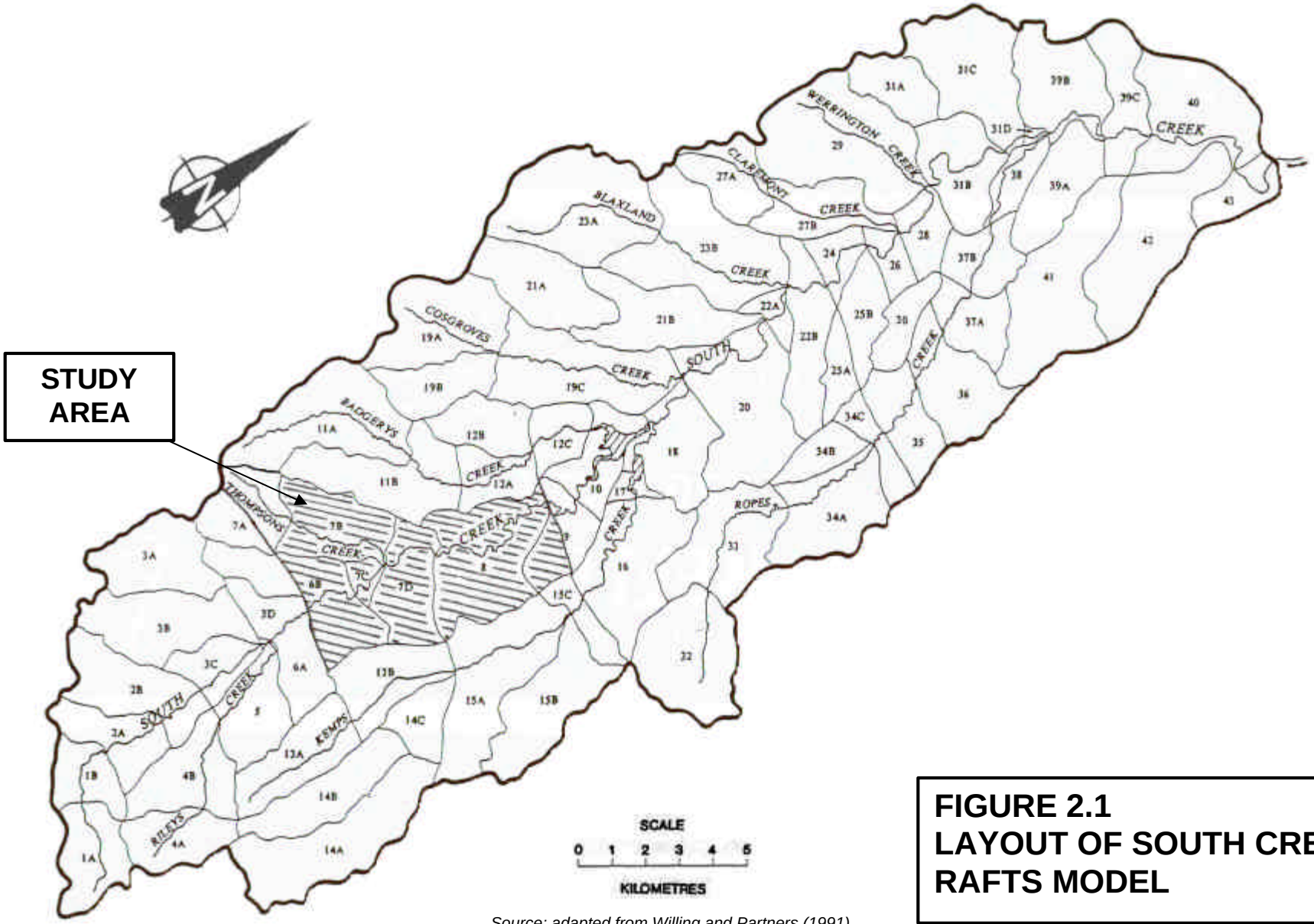
The August 1986 and April 1988 flood events were used to calibrate the 1990 RAFTS model. There are four major river gauging stations within the South Creek catchment that were used in the calibration process, one being located on South Creek at Elizabeth Drive within the current study area as described in **Section 2.1.1**.

Calibration of the 1990 RAFTS model was carried out by adjustment of the 'BX' multiplier together with adjustments to the initial and continuing rainfall losses. A value of 'BX' of 1.3 was adopted. For the April 1988 flood (the larger of the two calibration events), an initial loss of 35mm and a continuing loss of zero were adopted. For the August 1986 flood, an initial loss of 104mm and a continuing loss of 0.4mm/h were adopted.

The 1990 Flood Study concluded that '*calibration and verification has yielded a model quite representative of the hydrology of the catchment*'.

Only the 100 year design flood was modelled with the 1990 RAFTS model. A 'BX' value of 1.3, an initial loss of 10mm and a continuing loss of 1.0mm/h were used.

The critical duration storm was found to be 40 hours for South Creek itself, while the critical duration storm for most of the tributaries, including Thompsons Creek, was found to be 9 hours.



Source: adapted from Willing and Partners (1991)

FIGURE 2.1
LAYOUT OF SOUTH CREEK RAFTS MODEL

FIGURE 2.2: HYDROLOGIC AND HYDRAULIC MODELLING IN THE STUDY AREA

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FIGURE 2.3: HYDROLOGICAL AND HYDRAULIC MODELLING IN THE OVERETT AVENUE AREA

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1991 South Creek Floodplain Management Study

The *1991 South Creek Floodplain Management Study* (Willing and Partners, 1991) (referred to as the '*1991 FPM Study*') used the 1990 RAFTS model as the basis for all its analyses and calculations. In the *1991 FPM Study*, design flows were calculated for the 20 year, 50 year and the probable maximum flood (PMF) as well as the 100 year flows already calculated from the *1990 Flood Study*.

As well as flows for existing catchment conditions, flows were also calculated in the *1991 FPM Study* for full development of the catchment assuming planning considerations of the time. Scenarios with and without detention basins to manage the increase in flows because of the development were also examined.

The critical duration storm for the PMF was found to be 6 hours. An initial loss of 1mm and a continuing loss of zero were adopted for the PMF. The critical storm durations and losses for the smaller design floods remained the same as the *1990 Flood Study*.

A copy of the 1991 RAFTS model and a large number of output files were made available from DIPNR on CD.

1994–1997 Flood Mitigation Studies for the Overett and Victor Avenue Areas

The Flood Mitigation Studies carried out for the Overett and Victor Avenue areas in the 1990s included the following studies:

- 1994 Overett and Victor Avenues, Kemps Creek. Flood Management Study (Kinhill Engineers, 1994a) (referred to as the *'1994 Kinhill Study'*);
- 1994 Review of Environmental Factors for Proposed Flood Mitigation Works for South Creek. (Kinhill Engineers, 1994b) (referred to as the *'1994 REF'*);
- 1996 Overett Avenue, Flood Mitigation Alternatives Study (Kinhill Engineers, 1996) (referred to as the *'1996 Kinhill Study'*);
- 1997 Hydraulic Modelling of Proposed Floodway — Overett Avenue, Kemps Creek Study (Kinhill, 1997) (referred to as the '*1997 Kinhill Study*').

Each of these studies used the results from the 1991 RAFTS model for all calculations and analyses.

In the *1994 Kinhill Study*, flow rates for the 1 year and 5 year flood events were calculated as part of the economic analysis of flood mitigation options for the Overett and Victor Avenue areas. The peak flow rates for these floods were determined using a statistical analysis of the river gauging data for South Creek at Elizabeth Drive. The 20 year hydrograph was then appropriately scaled so that 1 year and 5 year hydrographs could be estimated for use in the MIKE-11 hydraulic model.

2.2.2 Design Flows for South Creek for Current Study

The 1991 RAFTS model is the most up-to-date hydrological model applicable to the South Creek catchment for the current study. Therefore, the results of the 1991 RAFTS model, particularly in the form of hydrographs for use in the MIKE-11 hydraulic model (see **Chapter 3**), have been used directly in the current study for all analyses and calculations. The 1991 RAFTS model has not been re-run as part of the current study.

Table 2.3 summarises design peak flow rates for the available design floods at key locations along South Creek and Thompsons Creek within the study area.

TABLE 2.3: DESIGN FLOWS WITHIN THE STUDY AREA

LOCATION	RAFTS SUBCATCH-MENT NO.	PEAK FLOWS (m^3/s)[1]					
		100 YEAR[2]	50 YEAR[2]	20 YEAR[2]	5 YEAR[3]	1 YEAR[3]	PMF[2]
SOUTH CREEK							
Just upstream of Bringelly Road bridge	6A	299	259	201	—	—	1,210
Just upstream of confluence with Thompsons Creek	7C	328	287	216	—	—	1,360
Northern end of Wishart Road	7D	379	327	247	—	—	1,540
Just upstream of Elizabeth Drive bridge	8	433	372	281	158	33	1,710
Just upstream of confluence with Badgerys Creek	9	444	383	287	—	—	1,760
THOMPSONS CREEK							
At confluence with South Creek	7B	67	56	44	—	—	251

PMF — Probable Maximum Flood

Notes: (1) From 1991 Floodplain Management Study, critical duration storm would be 40 hours for South Creek and 9 hours for Thompsons Creek for 20 year, 50 year and 100 year floods and 6 hours for the PMF.

(2) Source: 1991 Floodplain Management Study. Note that the flows quoted for South Creek are likely to be from the 1991 MIKE-11 model rather than taken directly from the 1991 RAFTS model.

(3) Source: 1994 Kinhill Study

2.3 HYDRAULIC MODELLING

This section outlines the hydraulic modelling that has been undertaken to date within the study area. A MIKE-11 model, together with a series of HEC-2 models, were originally established and calibrated for the major creeks within the South Creek catchment as part of the *1990 Flood Study.* These models were then used in the *1991 FPM Study*. To examine flood mitigation options for the Overett and Victor Avenue areas in more detail, a more detailed MIKE-11 submodel with additional cross-sections was established from the main South Creek model in the mid-1990s. The evolution of the hydraulic modelling for the current study area is described in **Appendix C**.

Outside the area of this more detailed submodel, the 1991 MIKE-11 model for South Creek and the 1991 HEC-2 model for Thompsons Creek were the most up-to-date means of determining flood levels prior to the current study. **Section 2.3.2** outlines the methodology used in the current study to produce a MIKE-11 model that covers all of the current study area and includes all the flood mitigation works completed in the vicinity of Elizabeth Drive.

2.3.1 Hydraulic Modelling from Previous Studies

A MIKE-11 model, together with a series of HEC-2 models, were originally established and calibrated for the major creeks within the South Creek catchment as part of the *1990 Flood Study*. The main South Creek model consisted of about 230 cross-sections, 27 structures and 40 input hydrograph locations. Inflow hydrographs from the RAFTS model described in **Section 2.2** were used in the MIKE-11 and HEC-2 models. Of the HEC-2 models established as part of the *1990 Flood Study*, the only tributary of South Creek within the current study area modelled was Thompsons Creek. The Thompsons Creek model covered the floodplain between South Creek and The Northern Road.

Calibration of the South Creek MIKE-11 Model

The South Creek MIKE-11 model was calibrated in the 1990 Flood Study using recorded flood levels from the August 1986 and August 1988 floods. The primary calibration parameter used was Manning's 'n', however some 'fine tuning' was done using structure parameters and other head loss coefficients.

The *1990 Flood Study* concluded that '*the adopted BX value of 1.3 gave the best calibration (of the RAFTS model) but the hydraulic model gave a better overall fit to the hydrograph shape (than the RAFTS model)*'.

Calculation of the Hydraulic Floodway for South Creek

As part of the *1991 FPM Study*, the hydraulic floodway limit was estimated for South Creek and its tributaries for the 100 year flood under catchment conditions at that time. This floodway limit was calculated by blocking each cross-section in the MIKE-11 model equally on both sides so that upstream flood levels did not increase by more than 100mm and there was a maximum redistribution of flows of 10%. With all cross-sections blocked, the maximum downstream impacts were reported to be an increase in flood levels of 20mm and an increase of 5% in flow rates (*1991 FPM Study*).

This hydraulic floodway limit has been used in the calculation of the 'boundary of significant flow' as described in **Section 4.2.2**.

Evolution of MIKE-11 Modelling

Since the *1990 Flood Study*, the original MIKE-11 model of South Creek and the HEC-2 model for Thompsons Creek have evolved into the '2003 MIKE-11' model that covers all of the current study area and includes all the flood mitigation works completed in the study area. **Appendix C** summarises the evolution of MIKE-11 modelling for the current study.

Design Flood Levels from Previous Studies

Appendix D tabulates all the design flood levels within the study area published in previous studies. Design flows are also provided. The explanatory notes given on page D-7 should be read in conjunction with the results presented in the tables in **Appendix D**. **Table D.1** provides a summary of the best available design flood levels (and their source) published in previous studies, for the current study area, prior to the '2003 MIKE-11 modelling' being undertaken. The results in **Table D.1** have been used to compare the hydraulic modelling undertaken for this study to ensure that latest results were within reasonable limits when compared to previous studies.

2.3.2 Establishment of the 2003 MIKE-11 model

This section outlines the procedure used in the current study to ensure that there was a working MIKE-11 model for the South Creek and Thompsons Creek floodplains that best represented the current flood behaviour in the study area.

Utilising Previous MIKE-11 Models for the Current Study

The latest MIKE-11 hydraulic model, undertaken by the then Kinhill Engineers in the late 1990s, that covered the majority of the study area, was available for use in the current study. It was understood that this MIKE-11 model represented the design runs of the latest flood mitigation works undertaken on South Creek in the vicinity of Elizabeth Drive and Overett Avenue. The 1991 MIKE-11 model for the entire South Creek was also made available from the then Department of Land and Water Conservation (DLWC) (now DIPNR).

All the MIKE-11 modelling undertaken as part of previous studies had been carried out using Version 2.1 of MIKE-11, a DOS version from the late 1980s. The first step for the current study, therefore, was to convert all the existing modelling to a more up to date version. Essentially all the MIKE-11 models from the then Kinhill Engineers and the then DLWC were converted by the Software Support Centre of DHI Australia to MIKE-11 Version 2000B.

Following conversion of the files, it was found that there was no information or documentation available to indicate which files should be used for the various simulation runs. Therefore, in order to ensure that the files to be used represented the current South Creek floodplain, particularly in the vicinity of Elizabeth Drive, the cross-section data provided by Kinhill Engineers was manually checked against the available survey and design plans.

Utilising the Existing Thompsons Creek HEC-2 Model

Prior to the current study, the 1991 HEC-2 model was the best available hydraulic modelling for the Thompsons Creek floodplain. In the current study, the following steps were taken to incorporate Thompsons Creek into the 2003 South Creek MIKE-11 model:

- the existing HEC-2 cross-sections were used directly in the creation of a separate Thompsons Creek branch;

- values of Manning's 'n' hydraulic roughness, distances and other cross-section parameters were taken directly from the 1991 HEC-2 model;

- hydrographs at the upstream end of the Thompsons Creek branch at The Northern Road (RAFTS subcatchment 7A) was taken directly from the output files of the 1991 RAFTS model provided by DIPNR (the 1991 RAFTS model was not re-run as part of the current study). Hydrographs from the 20 year flood, 50 year flood, 100 year flood and PMF were available. The 5 year flood was not examined as part of the *1991 FPM Study*.

The 2003 South Creek MIKE-11 model

The 2003 South Creek MIKE-11 model represents the best available information for the South Creek and Thompsons floodplains in their current form.

The 2003 Model includes Stages 1, 2 and 3A flood mitigation works, together with the minor bank shaping works carried out as the Stage 3B works. The only other modifications that were necessary involved CS16.413 to incorporate the floodway included in the Stage 1 Flood Mitigation Works and the minor excavation of western bank of South Creek near the river gauging station included as part of the Stage 3B Flood Mitigation Works (see **Section 10.1.2** for details of the Flood Mitigation Works undertaken in the Overett Avenue area).

It was beyond the scope of the current study to undertake any further review of the MIKE-11 modelling for the study area.

The 2003 MIKE-11 model has been run for the 5 year, 20 year, 50 year, 100 year and probable maximum flood events. However, results are not available for the 5 year flood for Thompsons Creek.

Due to uncertainties and instabilities with the 1 year flood event from the Kinhill Engineers' MIKE-11 model, 1 year flood levels have not been quoted in the current study.

The locations of all the MIKE-11 cross-sections applicable to the current study are shown on **Figure 2.2**, while **Figure 2.3** shows the more detailed modelling undertaken in the vicinity of Elizabeth Drive and Overett Avenue. **Appendix E** provides the details of the various MIKE-11 files required to run the 2003 MIKE-11 model for existing conditions.

2.3.3 Design Flood Levels For South Creek For Current Study

Table 2.4 presents the results from the MIKE-11 modelling undertaken as part of the current study. These design flood levels are recommended for use in the current *Floodplain Risk Management Study* and are referred to as the '2003 model results'. Design flood levels are presented for the 5 year, 20 year, 50 year, 100 year and probable maximum floods (PMF) for South Creek and the 20 year, 50 year, 100 year and PMF for Thompsons Creek.

Table 2.4 also shows the differences in flood levels between the 'best available from previous studies' (from **Table D.1**) and the '2003 model results'. These results show that:

- in a 50 year and 100 year flood, the '2003 model results' are generally within ±100mm from previous studies, except for one location near Overett Avenue on South Creek (CS1.580) where the '2003 model results' are 120mm lower than previous studies, and one location on Thompsons Creek (CS1.680) where the '2003 model results' are 230mm to 260mm lower;

- in a 20 year flood, again the '2003 model results' are generally within ±100mm from previous studies, except at several locations in South Creek and Thompsons Creek where differences are between ±100mm to 280mm;

- in a 5 year flood, the '2003 model results' are generally within ± 200mm from previous studies, except at several locations, particularly downstream of Elizabeth Drive, where there the '2003 model results' are up to 470mm lower than for previous studies;

- in a probable maximum flood, the '2003 model results' are generally within ±200mm from previous studies.

The mostly likely reason for the isolated differences in flood levels between the '2003 model results' and those from previous studies, would relate to the updating of internal calculation techniques used in the newer version of MIKE-11, particularly at bridges, culverts and other structures in the floodplain.

Design flow velocities for the 100 year flood are tabulated in **Appendix F**. It should be noted that MIKE-11 only provides one average flow velocity across the entire cross-section width for a particular design run. No further breakdown of velocities has been undertaken as part of the current study.

TABLE 2.4: ADOPTED FLOOD LEVELS FOR SOUTH CREEK FOR EXISTING CONDITIONS

MIKE-11 CHAINAGE (km)	CROSS-SECTION NAME	DESCRIPTION	100 Year ARI Flood Level (mAHD)			50 Year ARI Flood Level (mAHD)			20 Year ARI Flood Level (mAHD)			5 Year ARI Flood Level (mAHD)			PMF Level (mAHD)		
			Previous Studies (1)	2003 Model	Difference	Previous Studies (1)	2003 Model	Difference	Previous Studies (1)	2003 Model	Difference	Previous Studies (1)	2003 Model	Difference	Previous Studies (1)	2003 Model	Difference
SOUTH CREEK — MAIN CHANNEL																	
8.923	5.00	Just upstream Bringelly Road, Rossmore	59.36	59.30	-0.06	59.07	59.01	-0.06	58.60	58.55	-0.05	no calc	57.96		60.28	60.18	-0.10
9.003	4.35	Just downstream Bringelly Road, Rossmore	58.30	58.27	-0.03	58.20	58.18	-0.02	58.10	58.04	-0.06	57.90	57.80	-0.10	59.60	59.63	0.03
9.308	4.34		57.60	57.62	0.02	57.60	57.53	-0.07	57.40	57.40	0.00	57.20	57.16	-0.04	58.90	58.94	0.04
9.543	4.33	Opposite Bellfield Avenue, Rossmore	57.10	57.05	-0.05	57.00	56.97	-0.03	56.80	56.84	0.04	56.70	56.63	-0.07	58.40	58.40	0.00
9.888	4.32		56.10	56.05	-0.05	56.00	55.96	-0.04	55.80	55.82	0.02	55.60	55.58	-0.02	57.30	57.29	-0.02
10.283	4.31		55.50	55.44	-0.06	55.40	55.36	-0.04	55.20	55.22	0.02	55.10	54.99	-0.12	56.60	56.55	-0.05
10.693	4.30		54.60	54.57	-0.03	54.50	54.49	-0.01	54.40	54.36	-0.05	54.20	54.18	-0.02	55.80	55.83	0.03
11.063	4.29		53.80	53.76	-0.04	53.70	53.65	-0.05	53.50	53.47	-0.03	53.30	53.22	-0.08	55.30	55.26	-0.04
11.378	4.28	Confluence with Thompsons Creek	53.30	53.31	0.01	53.20	53.20	0.00	53.00	53.03	0.03	52.90	52.75	-0.15	54.80	54.79	-0.02
11.603	4.27		52.90	52.88	-0.02	52.80	52.78	-0.02	52.70	52.65	-0.05	52.50	52.38	-0.12	54.30	54.25	-0.05
11.728	4.26		52.60	52.54	-0.07	52.50	52.44	-0.06	52.30	52.30	0.00	52.10	52.02	-0.08	53.90	53.93	0.03
12.013			52.00	51.97	-0.03	51.90	51.86	-0.04	51.70	51.71	0.01	51.60	51.45	-0.15	53.40	53.41	0.01
12.298	4.25	Opposite Fifteenth Avenue, Kemps Creek	51.50	51.46	-0.04	51.40	51.36	-0.04	51.20	51.18	-0.02	51.00	50.89	-0.12	53.00	52.99	-0.01
12.738	4.24		50.70	50.67	-0.03	50.60	50.53	-0.07	50.30	50.31	0.01	50.10	49.95	-0.15	52.50	52.39	-0.12
13.218	4.23	Opposite Watts Road, Kemps Creek	49.90	49.87	-0.03	49.80	49.72	-0.08	49.50	49.49	-0.01	49.30	49.11	-0.20	51.80	51.66	-0.14
13.638	4.22	Opposite East/West part Victor Ave, Kemps Creek	49.10	49.11	0.00	49.00	48.97	-0.03	48.80	48.75	-0.05	48.50	48.37	-0.13	51.00	50.99	-0.02
13.958			48.10	48.09	-0.01	48.00	47.97	-0.03	47.80	47.80	0.00	47.60	47.48	-0.12	49.80	49.78	-0.02
14.303	4.21		47.00	46.94	-0.06	46.90	46.85	-0.05	46.70	46.70	0.00	46.50	46.39	-0.11	48.30	48.25	-0.05
14.583	4.20		46.40	46.39	-0.01	46.30	46.32	0.02	46.20	46.21	0.00	46.10	45.97	-0.13	47.70	47.67	-0.03
14.903	4.19		45.75	45.74	-0.01	45.68	45.66	-0.02	45.56	45.56	0.00	45.39	45.38	-0.01	47.16	47.15	-0.01
15.188			45.28	45.27	-0.02	45.20	45.18	-0.02	45.06	45.05	-0.01	44.81	44.80	-0.01	46.83	46.81	-0.02
15.473	4.18		44.70	44.68	-0.02	44.60	44.58	-0.02	44.43	44.43	0.00	44.09	44.08	-0.01	46.36	46.33	-0.03
15.653	4.17		44.27	44.25	-0.02	44.16	44.14	-0.02	43.99	43.98	-0.01	43.63	43.62	-0.01	46.01	45.97	-0.04
15.913			43.69	43.67	-0.02	43.58	43.56	-0.02	43.41	43.40	-0.01	43.08	43.08	0.00	45.51	45.45	-0.06
16.153	4.15	Opposite Overett Avenue, Kemps Creek	43.39	43.36	-0.03	43.25	43.22	-0.03	43.01	43.00	-0.01	42.58	42.61	0.03	45.30	45.22	-0.08
16.240			43.29	43.26	-0.03	43.15	43.12	-0.03	42.89	42.89	0.00	42.44	42.48	0.04	45.18	45.09	-0.09
16.413	4.14		42.96	42.92	-0.04	42.81	42.77	-0.04	42.52	42.49	-0.04	42.05	42.03	-0.02	44.80	44.69	-0.11
16.583	4.13	Just upstream Elizabeth Drive, Kemps Creek	42.65	42.64	-0.01	42.50	42.49	-0.01	42.21	42.21	0.00	41.79	41.80	0.01	44.52	44.42	-0.10
16.683	4.09	Just downstream Elizabeth Drive, Kemps Creek	42.63	42.61	-0.02	42.49	42.47	-0.02	42.20	42.20	0.00	41.78	41.79	0.01	44.23	44.16	-0.07
16.720			42.06	42.05	-0.02	41.98	41.96	-0.02	41.83	41.82	-0.01	41.58	41.57	-0.01	43.16	43.15	-0.01
16.780			not publ	41.99		not publ	41.92		not publ	41.79		not publ	41.56			43.00	
16.953	4.08		40.90	40.99	0.09	40.80	40.91	0.11	40.60	40.80	0.20	40.50	40.46	-0.04	42.00	42.16	0.16
17.243	4.07		40.20	40.18	-0.02	40.10	40.05	-0.05	39.90	39.86	-0.04	39.70	39.33	-0.37	41.60	41.61	0.01
17.573	4.06		39.70	39.66	-0.04	39.50	39.49	-0.01	39.30	39.22	-0.08	39.00	38.58	-0.42	41.20	41.17	-0.03
17.793	4.05		39.30	39.26	-0.04	39.10	39.10	0.00	38.90	38.84	-0.06	38.70	38.23	-0.47	40.90	40.85	-0.05
17.963	4.04		39.10	39.08	-0.02	39.00	38.93	-0.07	38.70	38.71	0.01	38.50	38.10	-0.40	40.70	40.66	-0.04
18.243	4.03		38.80	38.81	0.01	38.70	38.69	-0.02	38.50	38.49	-0.01	38.20	37.96	-0.24	40.30	40.35	0.05
18.663	4.02		38.70	38.64	-0.06	38.50	38.54	0.04	38.40	38.37	-0.03	37.90	37.86	-0.04	40.00	39.98	-0.02
18.963	4.01	Upstream extent of South Creek Dam	38.60	38.61	0.01	38.50	38.51	0.01	38.30	38.34	0.04	37.80	37.84	0.04	39.90	39.89	-0.01
19.278	4.00		38.60	38.60	0.00	38.50	38.51	0.01	38.30	38.34	0.04	37.80	37.84	0.04	39.90	39.87	-0.03

MIKE-11 CHAINAGE (km)	CROSS-SECTION NAME	DESCRIPTION	100 Year ARI Flood Level (mAHD)			50 Year ARI Flood Level (mAHD)			20 Year ARI Flood Level (mAHD)			5 Year ARI Flood Level (mAHD)			PMF Level (mAHD)		
			Previous Studies (1)	2003 Model	Difference	Previous Studies (1)	2003 Model	Difference	Previous Studies (1)	2003 Model	Difference	Previous Studies (1)	2003 Model	Difference	Previous Studies (1)	2003 Model	Difference
MINOR BRANCHES IN VICINITY OF OVERETT AVENUE																	
0.000		"OVERETT" (also CS15.913)	not publ	43.67		not publ	43.56		not publ	43.40		not publ	43.08		not publ	45.45	
1.245		"OVERETT" between No.10 Sumbray and 14 Overett	not publ	43.57		not publ	43.48		not publ	43.36		not publ	43.07		not publ	45.33	
1.495		"OVERETT" just upstream road (Overett Avenue)	43.60	43.54	-0.06	43.50	43.43	-0.07	43.40	43.16	-0.24	43.1	42.84	-0.26	45.10	44.92	-0.18
1.580		"OVERETT" just downstream road (Overett Avenue)	43.40	43.29	-0.12	43.30	43.18	-0.12	43.10	42.89	-0.21	42.8	42.58	-0.22	44.80	44.69	-0.11
1.880		"OVERETT" upstream side of Elizabeth Drive	not publ	43.22		not publ	43.14		not publ	42.80		not publ	41.38		not publ	44.15	
1.940		"OVERETT" downstream side of Elizabeth Drive	not publ	41.69		not publ	41.38		not publ	41.13		not publ	40.65		not publ	43.69	
2.360		"OVERETT"	not publ	40.99		not publ	40.91		not publ	40.80		not publ	40.46		not publ	42.16	
0.000		"2nd CHAN" (also CS16.413)	not publ	42.92		not publ	42.77		not publ	42.49		not publ	42.03		not publ	44.69	
0.130		"2nd CHAN" upstream side of Elizabeth Drive	42.70	42.78	0.08	42.50	42.62	0.12	42.20	42.33	0.13	41.7	41.87	0.17	44.40	44.52	0.12
0.180		"2nd CHAN" downstream side of Elizabeth Drive	42.40	42.46	0.06	42.30	42.34	0.04	42.00	42.10	0.10	41.7	41.74	0.03	43.10	43.28	0.18
0.215		"2nd CHAN"	not publ	42.29		not publ	42.19		not publ	42.02		not publ	41.72		not publ	43.10	
0.310		"2nd CHAN"	not publ	41.99		not publ	41.92		not publ	41.79		not publ	41.56		not publ	43.00	
0.000		"Link 2"	not publ	43.29		not publ	43.18		not publ	42.89		not publ	42.58		not publ	44.69	
0.200		"Link 2"	not publ	43.14		not publ	43.01		not publ	42.67		not publ	42.25		not publ	46.44	
0.500		"Link 2"	not publ	42.92		not publ	42.77		not publ	42.49		not publ	42.03		not publ	44.69	
0.000		"Link 3"	not publ	43.29		not publ	43.18		not publ	42.89		not publ	42.58		not publ	44.69	
0.250		"Link 3"	not publ	43.16		not publ	43.05		not publ	42.67		not publ	42.17		not publ	44.58	
0.450		"Link 3"	not publ	42.78		not publ	42.62		not publ	42.32		not publ	41.82		not publ	44.34	
0.510		"Link 3"	not publ	42.01		not publ	41.94		not publ	41.83		not publ	41.63		not publ	43.39	
0.580		"Link 3"	not publ	41.99		not publ	41.92		not publ	41.79		not publ	41.56		not publ	43.00	
0.000		"Link 4"	not publ	42.78		not publ	42.62		not publ	42.33		not publ	41.87		not publ	44.52	
0.100		"Link 4"	not publ	42.78		not publ	42.62		not publ	42.33		not publ	41.86		not publ	44.40	
0.200		"Link 4"	not publ	42.78		not publ	42.62		not publ	42.32		not publ	41.82		not publ	44.34	
THOMPSONS CREEK (2)																	
0.00	18.15	Just downstream of The Northern Road	69.80	69.77	-0.03	69.72	69.68	-0.04	69.62	69.58	-0.04	no calc	no calc	na	70.50	70.43	-0.07
0.47	18.14		67.06	67.04	-0.02	67.02	66.95	-0.07	66.93	66.83	-0.10	no calc	no calc	na	67.71	67.66	-0.05
0.93	18.13	Opposite corner Kelvin Park Drive & Medich Place	64.48	64.46	-0.02	64.39	64.37	-0.02	64.33	64.25	-0.08	no calc	no calc	na	64.90	64.88	-0.02
1.26	18.12		62.39	62.40	0.01	62.29	62.33	0.04	62.24	62.23	-0.01	no calc	no calc	na	63.00	62.94	-0.06
1.68	18.11		60.64	60.38	-0.26	60.51	60.28	-0.23	60.42	60.14	-0.28	no calc	no calc	na	61.43	61.28	-0.15
1.90	18.10	Approx. 120m upstream of The Retreat	59.14	59.07	-0.07	59.04	59.00	-0.04	59.00	58.92	-0.08	no calc	no calc	na	59.85	59.74	-0.12
2.09	18.08	Just upstream of The Retreat	58.86	58.90	0.04	58.81	58.87	0.06	58.78	58.81	0.03	no calc	no calc	na	59.42	59.41	-0.01
2.10	18.07	Approx. 20m downstream of The Retreat	58.53	58.63	0.09	58.49	58.53	0.04	58.45	58.37	-0.08	no calc	no calc	na	59.37	59.54	0.17
2.21	18.06		58.05	58.00	-0.05	57.90	57.86	-0.04	57.80	57.70	-0.10	no calc	no calc	na	58.84	58.95	0.11
2.41	18.05		57.19	57.26	0.07	57.11	57.16	0.05	57.05	57.07	0.02	no calc	no calc	na	57.77	57.82	0.05
2.56	18.04		56.78	56.78	0.00	56.70	56.73	0.03	56.65	56.68	0.03	no calc	no calc	na	57.24	57.29	0.05
2.89	18.03		55.24	55.26	0.02	55.15	55.19	0.04	55.11	55.06	-0.05	no calc	no calc	na	55.72	55.74	0.02
3.21	18.02		54.05	54.00	-0.05	53.98	53.95	-0.03	53.94	53.90	-0.04	no calc	no calc	na	54.43	54.43	0.00
3.41	18.01	Approx. 250m upstream confluence South Creek	52.90	52.88	-0.02	52.81	52.78	-0.03	52.66	52.65	-0.01	no calc	no calc	na	54.25	54.25	0.00

Notes: *(1) 'Previous Studies' indicates 'Best available design flood levels from Previous Studies' as presented in **Appendix C***

(2) MIKE-11 chainages for Thompsons Creek are slightly different to HEC-2 chainages given in 1991 FPM Study

not publ = no published flood level available; no calc = has not been calculated in previous studies; na = not applicable; no flow = modelling indicates cross-section would be dry.

Source: output file J1184_M11_sum4.xls

TABLE 4.1: FREQUENCY AND DEPTH OF OVER-FLOOR RESIDENTIAL FLOODING

DEPTH OF ABOVE FLOOR FLOODING (m)	5 YEAR FLOOD	20 YEAR FLOOD	50 YEAR FLOOD	100 YEAR FLOOD	100 YEAR FLOOD + 0.3m*	100 YEAR FLOOD + 0.6m**	PMF
0m–0.2m above floor level	1	5	7	6	na	na	12
0.2m–0.5m above floor level	1	3	7	9	na	na	16
0.5m–1.0m above floor level	0	1	3	4	na	na	22
1.0m–1.5m above floor level	0	0	0	0	na	na	23
1.5m–2m above floor level	0	0	0	0	na	na	10
more than 2m above floor level	0	0	0	0	na	na	12
TOTAL ABOVE FLOOR LEVEL	**2**	**9**	**17**	**19**	**34**	**50**	**95**
Maximum depth of flooding (m)	0.25	0.62	0.86	0.99	1.29	1.59	2.84
Average depth of flooding above floor (m)	0.18	0.22	0.29	0.38	na	na	1.01

TABLE 4.2: FREQUENCY AND DEPTH OF OVER-GROUND FLOODING NEAR MAIN RESIDENTIAL DWELLING

DEPTH OF OVER GROUND FLOODING (m)	5 YEAR FLOOD	20 YEAR FLOOD	50 YEAR FLOOD	100 YEAR FLOOD	100 YEAR FLOOD + 0.3m*	100 YEAR FLOOD + 0.6m**	PMF
0m–0.2m above ground level	7	11	9	6	na	na	17
0.2m–0.5m above ground level	7	12	18	19	na	na	16
0.5m–1.0m above ground level	3	8	12	16	na	na	32
1.0m–1.5m above ground level	0	1	4	5	na	na	17
1.5m–2m above ground level	0	0	0	0	na	na	19
more than 2m above ground level	0	0	0	0	na	na	27
TOTAL ABOVE GROUND LEVEL	**17**	**32**	**43**	**46**	**58**	**69**	**128**
Maximum depth of flooding (m)	0.76	1.13	1.37	1.50	1.80	2.10	3.35
Average depth of flooding above ground level near main dwelling or building (m)	0.27	0.38	0.48	0.56	na	na	1.19

TABLE 4.3: FREQUENCY AND DEPTH OF FLOODING OF LOW POINT OF RESIDENTIAL PROPERTIES

DEPTH OF FLOODING ABOVE PROPERTY LOW POINT (m)	5 YEAR FLOOD	20 YEAR FLOOD	50 YEAR FLOOD	100 YEAR FLOOD	PMF
0m–0.2m above property low point	7	7	3	1	7
0.2m–0.5m above property low point	19	21	12	8	15
0.5m–1.0m above property low point	36	38	44	45	30
1.0m–1.5m above property low point	33	44	37	42	18
1.5m–2m above property low point	24	37	46	38	26
more than 2m above property low point	24	46	56	67	173
TOTAL ABOVE PROPERTY LOW POINT	**143**	**193**	**198**	**201**	**269**
Maximum depth of flooding (m)	4.10	4.41	4.58	4.68	6.45
Average depth of flooding above property low point (m)	1.27	1.45	1.59	1.67	2.46

TABLE 4.4: FLOODING OF COMMERCIAL PROPERTIES

PART OF COMMERCIAL PROPERTY INUNDATED	5 YEAR FLOOD	20 YEAR FLOOD	50 YEAR FLOOD	100 YEAR FLOOD	100 YEAR FLOOD + 0.3m*	100 YEAR FLOOD + 0.6m**	PMF
Properties flooded above level of main work area	0	0	0	0	1	2	3
Properties flooded above ground near main building	0	0	0	0	3	3	3
Properties flooded above low point of property	4	4	4	4	na	na	5

*Notes: * approximately equivalent to a 200 year flood*
*** approximately equivalent to a 500 year flood*
PMF = probable maximum flood; na = not available

Therefore, wherever possible, these 2m contours have been supplemented by other surveys for the current study. This additional ground survey is described below.

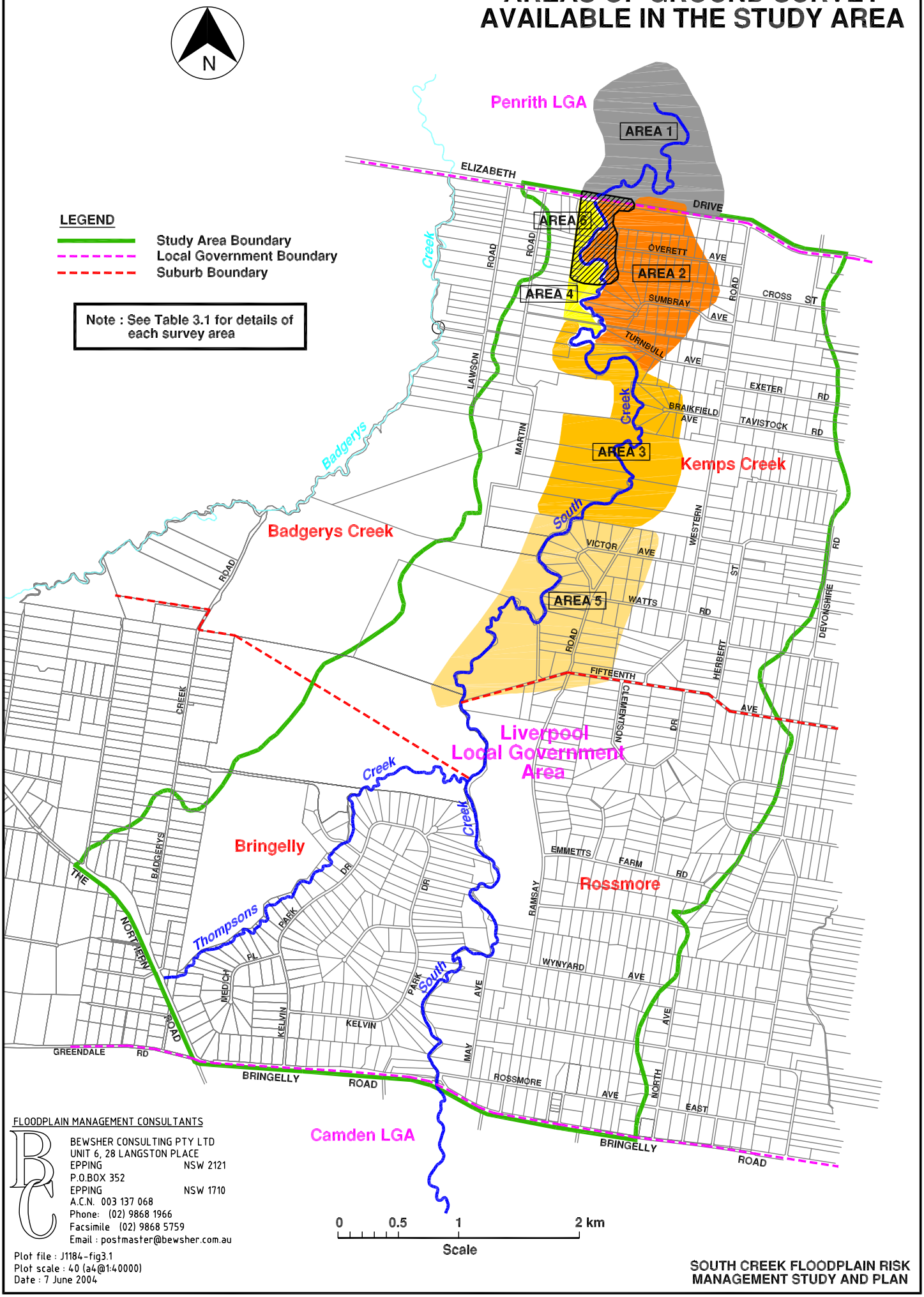
3.2.1 Ground Survey of South Creek Floodplain Area

In preparation for, and as part of, the *1994 Kinhill Study*, a number of ground survey exercises were undertaken by Liverpool City Council and Lean, Lackenby and Haywood Pty Ltd in the late 1980s and 1990s. The locations of these surveys have been labelled Areas 1 to 6 for the purposes of the current study and are shown on **Figure 3.1**. These surveys extend to well above the level of the 100 year flood level. **Table 3.1** summarises the source of the survey information for each of the areas, as well as some additional survey information received from Lean, Lackenby and Haywood during the course of the current study.

TABLE 3.1: AREAS OF AVAILABLE GROUND SURVEY IN THE SOUTH CREEK FLOODPLAIN AREA

AREA	DESCRIPTION	SOURCE	DATE	TYPE
1	Downstream of Elizabeth Drive: for approximately 1.2km both sides of South Creek	Lean, Lackenby and Hayward Pty Ltd survey (no title). File No. 53007. Scale 1:3,000	7th December 1993	Hand Drawn
2	Overett Avenue area: eastern side of South Creek only	Liverpool City Council. "South Creek Flood Levels — Overett Avenue". Drawing No.90/88. Scale 1:3,000.	1988	Hand Drawn
3	Between Overett Avenue area and Victor Avenue area: both sides of South Creek	Lean Lackenby and Hayward Pty Ltd survey "Plan of Levels for Kinhill Engineers" File No.53007. Scale 1:3,000	18th November 1992	Hand Drawn
4	Opposite Overett Avenue area: west bank of South Creek	Lean Lackenby and Hayward Pty Ltd survey referenced in 1994 Kinhill Report but not available for the current study. Most this area however, is covered by Area 6 and survey marked with (*) in this table	—	—
5	Victor Avenue area: both sides of South Creek	Lean Lackenby and Hayward Pty Ltd survey "Plan of Levels and Detail for Kinhill Engineers" File No.53008. Scale 1:3,000	July 1993	Hand Drawn
6	Overett Avenue Flood Mitigation Works area: both sides of South Creek,	Liverpool City Council Design Services. Overett Avenue Flood Mitigation Works — Stage 3. South Creek — 150m upstream to 190m downstream of Overett Avenue, Kemps Creek Drawing No. 2 of 9 "Survey Plan — Existing Site" Contract No.E03/98 Job No. 96060DA	March 1997	Digital form (2D format)
—	Elizabeth Drive Road Levels	Lean Lackenby and Hayward Pty Ltd survey "Elizabeth Drive. South Creek. Plan of Levels and Detail" 3 sheets File No.53007 ED. Amendment B Scale 1:400	March 1995	Hand Drawn
— (* see Area 4)	Stormwater Channel to the South of Overett Avenue and some parts of Area 4	Lean Lackenby and Hayward Pty Ltd survey "Kemps Creek. Level and Detail Survey" 5 sheets File No.53007. Option 2	September 1995	Hand Drawn

FIGURE 3.1
AREAS OF GROUND SURVEY AVAILABLE IN THE STUDY AREA



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Plot file : J1184-fig3.1
Plot scale : 40 (a4@1:40000)
Date : 7 June 2004

SOUTH CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

The surveys for Areas 1 to 6 generally include the following information:

- cadastral information based on Council's 1:8,000 cadastral plans of that time;
- spot levels of sufficient detail to draw 0.5m contours;
- 0.5m contours;
- locations of buildings;
- floor levels of buildings;
- road centreline levels (particularly at Elizabeth Drive).

3.2.2 Cross-sections for Hydraulic Modelling of South Creek and Thompsons Creek

A total of 480 creek cross-sections were surveyed in the mid to late 1980s for the 1990 South Creek Flood Study. It is understood that these cross-sections were surveyed using essentially only a staff and level and their location plotted by hand on cadastral and orthophoto maps available at that time. The majority of the cross-sections of South Creek and Thompsons Creek used in the 2003 MIKE-11 model are from this original survey.

Several additional cross-sections were extracted from the survey outlined in **Table 3.1** and added to the model during the 1994–1997 Kinhill Studies. Some of the surveys described in **Table 3.1** were also used in the 1996 Kinhill Study to define the MIKE-11 branches in the vicinity of Overett Avenue, namely 'Overett', '2ndChan', 'Link 2', 'Link 3' and 'Link 4'. These minor branches are shown on **Figure 2.3**.

3.2.3 Floor Levels of Properties in the Floodplain

Floor levels of properties in the Overett and Victor Avenue areas were surveyed as part of the 1994–1997 Kinhill studies. However, because of the difficulties in determining which levels were still applicable (for example, some houses have been raised or rebuilt and there have been some additional houses built in these areas since the time of the surveys), as part of the current study Council commissioned the survey of all house and commercial floor levels in the study area up to at least the level of the probable maximum flood (PMF). This ensured accuracy and consistency across the study area. Independent surveyors undertook this floor level survey in February 2004.

The following information was gathered as part of the floor level survey:

- the main habitable floor level of all residential dwellings was determined to Australian Height Datum (AHD) with an accuracy of ±50mm;

- the main floor level of the main commercial building at a particular property was determined to AHD with an accuracy of ±50mm;

- the ground level adjacent to the dwelling and/or main commercial building was estimated, relative to the floor level, to an accuracy of ±100mm;

- for each property, the following was also noted:

  - the number of storeys;

- the main construction material;
- whether the building was built on piers or 'slab-on-ground';
- for commercial properties, the nature of the business was described;
- the number and broad description of any other buildings on the property such as sheds or garages.

Figure 3.2 shows the locations of the properties whose floor levels were surveyed and the above information collected. A list of all floor levels and the additional information collected during the February 2004 survey will be provided separately to Council at the conclusion of the study.

Figure 3.2 also shows the extent of the 'flood damages data base' (see **Section 3.5**). The extent of the 'flood damages data base' represents the conservative estimate made at the beginning of the current study to ensure that all those properties that may be affected by the PMF were considered in all analyses during the course of the study. All properties that have any part of their land flood-affected, albeit small, have been included in the 'flood damages data base'.

Within the limits of the 'flood damages data base', the floor levels of residential and business properties have either been surveyed as part of the survey described above or have been estimated using the available ground level information. **Figure 3.2** shows which properties have been included in the floor level survey and where floor levels have been estimated.

The properties where floor levels have been estimated have been generally limited to the larger properties where a small portion of the lowest lying area would be flood-affected while the house is located well above the level of the PMF.

3.3 DIGITAL TERRAIN MODEL ESTABLISHED FOR THIS STUDY

A Digital Terrain Model (DTM) of the study area was established as part of the current study and has been used to map all flood extents, flood hazard areas and flood risk precincts.

As discussed above, for the majority of study area, the only available ground survey was the 2m contour information from Council's GIS. As part of the current study, these 2m contours were converted to a 3-dimensional format to form the basis of the DTM for the study area. Using the additional survey information listed in **Table 3.1**, the hand drawn surveys were then manually digitised to supplement the 2m contours wherever possible. The digital information from Area 6 was converted to a 3-dimensional format and contour information for flood mitigation works in the vicinity of Elizabeth Drive and Overett Avenue were added to the DTM.

The DTM was established using the program AutoCAD 2000 Land Development Desktop. Copies of the relevant data files will be provided to Council for possible incorporation into their GIS on completion of the study.

FIGURE 3.2: HOUSE FLOOR LEVEL SURVEY

A3 COLOUR

AUTOCAD filename: J1184-fig3.2

3.4 OTHER TOPOGRAPHICAL INFORMATION

Appendix B provides a bibliography of all documents, survey information and plans relevant to the study area. All the survey information listed in **Table 3.1** has been included in the bibliography. There are also some additional design plans that have provided limited amounts of topographical information through the course of the study.

Other mapping and topographical information available for the study area from the Land and Property Information Centre of the NSW Department of Lands is summarised in **Table 3.2**.

TABLE 3.2: AVAILABLE MAPPING FROM LAND AND PROPERTY INFORMATION CENTRE

SCALE	MAP NAME	MAP NO.	INFORMATION	CONTOUR INTERVAL	DATE OF ISSUE
1:100,000	Penrith	9030	Topographical	20m	1975
1:50,000	Liverpool	9030-S	Topographical	20m	—
1:25,000	Penrith	9030-3N	Topographical Cadastral Aerial photo	10m	2001
1:25,000	Warragamba	9030-3S	Topographical Cadastral Aerial photo	10m	2000
1:25,000	Prospect	9030-2N	Topographical Cadastral Aerial photo	10m	2001
1:25,000	Liverpool	9030-2S	Topographical Cadastral Aerial photo	10m	2001
1:10,000	Badgerys Creek	U-7345	Orthophoto	4m	Aerial photo approx. 1983
1:10,000	Bringelly	U-7337	Orthophoto	4m	Aerial photo approx. 1983
1:10,000	Bringelly Creek	U-6437	Orthophoto	4m	Aerial photo approx. 1983
1:4,000	Badgerys Creek	U-7345 Maps: 2, 3, 5, 6, 7, 8, 9	Orthophoto	2m	Aerial photo approx. 1983
1:4,000	Bringelly	U-7337 Maps: 1, 2, 3, 4, 5, 6	Orthophoto	2m	Aerial photo approx. 1983

3.5 FLOOD DAMAGES DATA BASE

In order to quantify the impacts and damage caused by flooding within the study area, a 'flood damages data base' has been established for all residential and commercial properties in and immediately adjacent to the South Creek and Thompsons Creek floodplains within the study area. The extent of the 'flood damages data base' is shown on **Figure 3.2**. There are just over 300 properties included in the 'flood damages data base'.

A printout of potentially flood-affected properties from the 'flood damages data base' has been provided separately to Council. This printout includes the following information about residential and commercial properties:

- the information available for each property, as described below;
- the stage–damage curve (or depth versus damage relationship) adopted for each property (see **Section 4.6.1**);
- the flood risk categorisation for each property (see **Section 4.4**);
- calculated flood levels for each property;
- depths of flooding at the property for a range of flood sizes.

The following information is included in the data base for each of these properties

- ***DTM ID No.*** — the flood damages data base is listed in alphabetical order by street name and house number. The DTM ID No. is simply used as a numerical counter for each property for ease of identification;
- ***Council ID No.*** — this number is Liverpool City's Council's Property Identification Number from their GIS data base and rates assessment information;
- ***easting and northing*** — the easting and northing coordinates have been taken directly from Council's GIS data base and are used to determine the location of the property in the Digital Terrain Model (DTM) established as part of this study (see **Section 3.3**). The coordinates generally represent the centroid of the each of properties in the DTM;
- ***address*** — the street number, name, suburb, postcode and as well as the Lot and DP number are included;
- ***property details*** — the following information is included:
  - property area (from Council's GIS);
  - whether the property is vacant or whether there is a building on site;
  - number of storeys;

- main construction material (eg. brick, timber, fibro etc);

- foundation type (eg. whether the building is on piers or has been constructed as 'slab-on-ground');

- the number, size (small or large) and type (colour bond, corrugated iron etc) of other buildings on the property such as garages, sheds, greenhouses and poultry sheds — this information was collected as part of the floor level survey completed in February 2004;

- ***residential damage code*** — because most of the properties in the study area are on large rural residential blocks, many with large sheds, greenhouses and the like, it is difficult to determine a 'typical house and property type' for the calculation of residential flood damages. The mix of older and newer areas of the study area further complicates this calculation of damages. Therefore, as described in **Section 4.6.1**, one of six different codes has been assigned to each property to reflect the likely damages that could occur to the house and to the improvements within the property area such as sheds and greenhouses;

- ***business damage code*** — these codes categorise the commercial and industrial enterprises into low, medium and high potential for flood damage (see **Section 4.6.1** for a description of how commercial damages have been estimated in this study);

- ***property levels*** — for each property, three levels, all to metres Australian Height Datum (mAHD), have been determined:

  - *house floor level* — as described in **Section 3.2.3**, a survey was undertaken in February 2004 of houses and commercial floor levels in the study area up to at least the level of the probable maximum flood (PMF) as part of the current study. Within the limits of the 'flood damages data base', the floor levels of residential and commercial properties have either been surveyed as part of the February 2004 survey or have been estimated using the available ground level information from the DTM. The properties where floor levels have been estimated have been generally limited to the larger properties where a small portion of the lowest lying area would be flood-affected while the house is located well above the level of the PMF;

  - *property ground level* — as part of the February 2004 survey, at properties where floor levels were surveyed, the ground level adjacent to the house and/or main commercial building was estimated. At other properties in the data base, the 'property ground level' has been estimated using information in the DTM. This 'property ground level' has been assumed to represent the level to which floodwaters can reach without causing significant damage to improvements to the properties such as garages, sheds and greenhouses. Flood damage to these improvements has been assumed to be based on the depth above this 'property ground level' for each property;

- *property low point* — many of the properties in the study area extend right to South Creek and have large undeveloped low-lying areas that, when flooded, would cause little or no damage. Therefore, the 'property low point' in this study has only been used as an indicator to show whether the property is flood-affected, and has not been used for the calculation of flood levels. The 'property low point' has been estimated using the available ground level information from the DTM;

- ***flood risk category*** — **Section 4.2** describes how the floodplain has been divided into three different levels of flood risk — high, medium or low. These are known as Flood Risk Precincts. **Section 4.4** describes the assumptions used in the current study to provide a unique flood risk category for each property in the data base;

- ***flood levels at the property for 5 year, 20 year, 50 year, 100 year and PMF*** — flood levels for each property for each of these flood sizes have been determined by the DTM at the coordinates of the easting and northing of the low point of the property. The coordinates of the low point of the property are generally slightly different to those of the centroid of the property provided in Council's GIS. It was necessary to use the property low point to determine the flood levels at each property, as it is not possible to determine a flood level in the data base if the ground level is higher than the flood level. The coordinates used for the calculation of flood levels at the property low point may not necessarily correspond exactly to the location of the house or the improvements on the property such as sheds and greenhouses. However, this is considered sufficiently accurate for the determination of flood levels at each property, as the slope of the flood is not large through the study area, meaning that there is not usually a significant difference in flood levels across any one property;

- ***maximum depth of inundation*** — three depths of inundation are calculated for each property for each flood size:

  - the maximum depth over the dwelling floor based on the surveyed or estimated floor level;

  - the maximum depth of flooding over the 'property ground level' adjacent to the house as described above;

  - the maximum depth of flooding over the low point of the property as described above;

- ***total potential flood damage for each of the flood sizes*** — flood damages are calculated using the relationships between flood depth and potential damage (or 'stage–damage curves') as discussed in **Section 4.6.1**.

4. IMPACTS AND COSTS OF FLOODING

This chapter describes and quantifies the impacts of flooding in the study area for existing catchment conditions for a range of flood sizes, using the results of the hydraulic modelling described in **Section 2.3** and the calculated outputs of the 'flood damages data base described in **Section 4.6**. The following results are presented in this chapter:

- mapping of design flood events, including flood extents and flood contours, which Council should use these results for all future development assessments (**Section 4.1**);
- the introduction of the concept of Flood Risk Precincts, including a map of Flood Risk Precincts for the study area. Flood Risk Precincts are used to define areas of similar flood risk in the floodplain and have been used in the determination of a range of flood-related planning controls that form part of the recommended *Floodplain Risk Management Plan* (**Section 4.2**);
- the number of properties affected by flooding (**Section 4.3**);
- the flood risk categorisation of properties in the floodplain (**Section 4.4**);
- the likely depth of flooding over roads at various locations within the study area (**Section 4.5**);
- cost of flooding to the local community in terms of flood damage and how these flood damages have been calculated (**Section 4.6**).

4.1 MAPPING OF DESIGN FLOOD EVENTS

As discussed in **Section 2.3**, the '2003 MIKE-11 model' represents the best available information for the South Creek floodplain in its current form. This model includes Stages 1, 2 and 3A flood mitigation works, together with the minor bank shaping works carried out as the Stage 3B works. It is a recommendation of this study (see **Section 9.3.3**) that Council use the '2003 MIKE-11 model' results for all future development assessments, as the basis for flood information placed on Section 149 Certificates (see **Section 9.3.8**) and for all relevant day-to-day activities of Council.

The '2003 MIKE-11 model' has been run for the 5 year, 20 year, 50 year, 100 year and probable maximum flood events. Due to uncertainties and instabilities with the 1 year flood event from the 1997 model, 1 year flood levels have not been quoted in this study. **Table 2.4** presented the flood levels for each of these flood events.

The following figures present flood contours at 0.2m intervals and approximate flood extents from the 2003 MIKE-11 modelling:

- **Figure 4.1** — 20 year flood;
- **Figure 4.2** — 50 year flood;
- **Figure 4.3** — 100 year flood;
- **Figure 4.4** — probable maximum flood.

FIGURE 4.1: 20 YEAR FLOOD CONTOURS AND EXTENTS FOR EXISTING CONDITIONS

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FIGURE 4.2: 50 YEAR FLOOD CONTOURS AND EXTENTS FOR EXISTING CONDITIONS

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FIGURE 4.3: 100 YEAR FLOOD CONTOURS AND EXTENTS FOR EXISTING CONDITIONS

A3 COLOUR

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FIGURE 4.4: PROBABLE MAXIMUM FLOOD (PMF) FLOOD CONTOURS AND EXTENTS FOR EXISTING CONDITIONS

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As flood levels for the 5 year flood were not available for Thompsons Creek, 5 year flood contours have not been presented in this report. However, approximate extents of the 5 year flood for South Creek have been included on **Figure 1.2**.

The flood contours depicted on **Figures 4.1–4.4** provide the best overview of flood levels in the study area. However, it should be emphasised that flood contours are only approximate as flood levels and extents have only been calculated at MIKE-11 cross-section locations. Between cross-sections, flood levels have been linearly interpolated. Widths of flood contours have been drawn using the available survey information. These flood contours have been derived electronically from the flood surface layer. In some areas, the provision of more accurate ground survey may increase or decrease the extent of flooding and the width of the flood contours.

Flood levels for individual properties should not be interpolated from the flood contours provided in **Figures 4.1–4.4** or from the tabulated flood levels provided in **Table 2.4**. To obtain design flood levels for an individual property reference should be made to the flood surface layer that will be provided digitally to Council on completion of the study.

It should be noted that any changes to the South Creek catchment, for example as a result of urban development, filling activities or changes to the amount and type of vegetation within the floodplain, could change the flood levels and/or flow velocities in small and/or large floods.

4.2 MAPPING OF FLOOD RISK PRECINCTS

Land use planning, development controls and specific flood-related policies are key components of the recommended *South Creek Floodplain Risk Management Plan.*

Volume 2 of this study entitled *Town Planning Issues* (Don Fox Planning, 2004) presents a detailed discussion on the proposed approach to floodplain planning recommended in this study. The recommended approach to planning and development controls is known as the Planning Matrix Approach. The key issues of **Volume 2** of the current study are summarised in **Section 8.1** of this report.

A key component of the Planning Matrix Approach is to divide the floodplain into different areas of similar risk, known as Flood Risk Precincts. Different parts of the floodplain are subject to different degrees of flood hazard and different degrees of flood risk. This study recognises that different development controls should apply to different flood risk areas, or precincts.

It should be noted that ‘flood hazard’ and ‘flood risk’ are not interchangeable terms. Once the ‘flood hazard’ has been determined for a particular location, and considered together with the consequences of that flooding, the ‘flood risk’ can then be determined.

4.2.1 Flood Hazard Categories

Flood hazard is a term used in the *Floodplain Management Manual* (NSW Government, 2001). 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 hazard takes into account such factors as:

- danger to human life;
- difficulty and danger of evacuating people and their possessions;
- potential for damage to the structure and contents of houses;
- social disruption, including isolation of houses;
- loss of production, particularly in industrial areas;
- damage to infrastructure, such as roads, services and open space areas.

Appendix G of the *Floodplain Management Manual* describes how the floodplain can be divided up to reflect the risk to personal safety and property damage. The two flood hazard categories defined in the *Floodplain Management Manual* are:

- ***high hazard*** — where there is 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;

- ***low hazard*** — where able-bodied adults would generally have little difficulty wading and trucks could be used to evacuate people and their possessions should it be necessary.

Flood hazard is firstly evaluated by considering the hydraulic behaviour of the flood — by taking into account the depth and velocity of floodwaters in relation to ground levels for a range of flood sizes. **Figure 4.5** shows how high and low hazard categories are determined using only the depth and velocity of floodwaters.

The flood hazard can then refined subjectively in light of other factors affecting the safety of individuals. By then combining the flood hazard and the consequences of the flood, the 'flood risk' is determined.

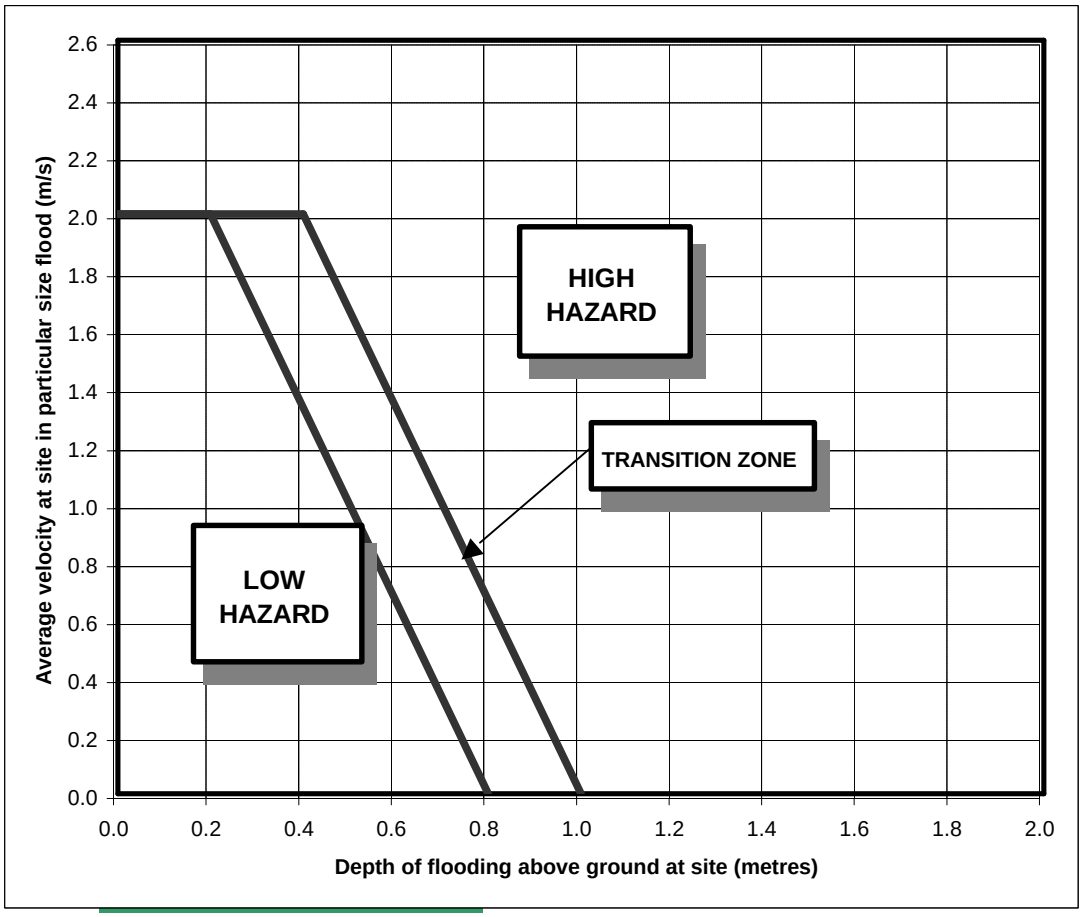
4.2.2 Flood Hydraulic Categories

Whereas 'flood hazard categories' describe the severity of the flood behaviour on development and people, 'flood hydraulic categories' describe the severity of development activity on flood behaviour. Like flood hazard, 'flood hydraulic categories' are described in the *Floodplain Management Manual* (NSW Government, 2001) and are also a key tool used to determine the suitability of future types of land use in the floodplain.

Appendix G of the *Floodplain Management Manual* defines the three flood hydraulic categories used to describe floodprone land:

- ***floodways*** — these are areas of the floodplain where a significant volume of water flows during floods and if even only partially blocked, would cause a significant increase in flood levels and/or redistribution of flood flow, which may cause an unacceptable impact on nearby properties;

- ***flood storage areas*** — these are areas of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. if the capacity of the flood storage volume is reduced through blockage of the floodplain, flood levels in nearby areas may rise, flows in downstream areas may be increased, and/or redistribution of flood flows may occur;



Source: Adapted from Figure G.2 of Floodplain Management Manual (DLWC, 2001)

Notes: (1) This is a provisional flood hazard diagram only.

(2) In the Transition Zone, the degree of hazard is dependent on site conditions and the nature of the development.

FIGURE 4.5: MEASURING PROVISIONAL FLOOD HAZARD

- ***flood fringe areas*** — these are areas of the floodplain that are not in a floodway or a flood storage area. Development in the flood fringe area is not likely to have a significant effect on flood behaviour.

Ideally, the boundaries of 'floodway' and 'flood storage areas' would be calculated using the hydraulic computer model of the floodplain, such as MIKE-11. In the case of South Creek, this would involve calculations both upstream and downstream of the study area by using the original MIKE-11 model established as part of the *1991 FPM Study*. To resurrect this model and use it to determine 'floodways' and 'flood storage areas' for the study area would have been a time-consuming and costly exercise.

Therefore, to incorporate the concept of 'flood hydraulic categories' into the current study the following methodology has been used:

- As part of the *1991 FPM Study*, the floodway limit was estimated for South Creek and its tributaries for the 100 year flood under catchment conditions at that time. Plans showing floodways were presented in the *1991 FPM Study*. The '1991 floodway limit' has been used as the basis of the 'floodway' for the current study area;

- When the '1991 floodway limit' was superimposed over the flood extents calculated using the DTM in the current study, some anomalies were noted. These anomalies are most likely due to different plotting techniques used in *1991 FPM Study* and the current study. However, the '1991 floodway limit' was generally similar in many locations to the extent of the 20 year flood determined as part of the current study;

- Therefore, the resultant 'floodway' defined for this study is therefore generally the '1991 floodway limit' and, where anomalies exist, combined with the 20 year flood extent from the DTM developed for the current study;

- Because the resultant 'floodway' would not be a 'true' floodway, the term 'Boundary of Significant Flow' has been used in this study to represent the 'floodway'. The Boundary of Significant Flow is show as a dashed line on the plan of 100 year flood contours presented as **Figure 4.3**;

- The location of the Boundary of Significant Flow depicted on **Figure 4.3**, shows that it lies very close to the 100 year flood extent. This leaves only a narrow band for the Flood Storage Area between the Boundary of Significant Flow and the 100 year flood extent. Therefore, for this study, a conservative approach to the 'Flood Storage Area' has been adopted and it has been assumed that the outer extent of the Flood Storage Area coincides with the extent of the 100 year flood;

- The Flood Fringe Area is that area of the floodplain not included in the 'floodway' and the 'flood storage area'. Therefore, for the purposes of this study, the Flood Fringe Area is that area between the extent of the 100 year flood and the probable maximum flood.

4.2.3 Flood Risk Precincts for the South Creek Study Area

Three Flood Risk Precincts have been recommended for the South Creek Study Area, namely 'high risk', 'medium risk' and 'low risk'. The Flood Risk Precincts, together with the Boundary of Significant Flow, are shown on **Figure 4.6**. The Flood Risk Precincts have been determined using the following information:

- definitions of 'flood hazard categories' and 'flood hydraulic categories' from the *Floodplain Management Manual*;
- the relationship between flood depth and velocity shown in **Figure 4.5**;
- design flood levels provided in **Table 2.4**;
- average flow velocities tabulated in **Appendix F**.

The definitions of Flood Risk Precincts for the South Creek study area are as follows:

- ***High Flood Risk Precinct*** —refers generally to land below the 100 year flood level subject to a high hydraulic hazard in a 100 year flood (in accordance with the provisional criteria outlined in the *Floodplain Management Manual*). The High Flood Risk Precinct is where high flood damages, potential risk to life, or evacuation problems would be anticipated. Most development should generally be restricted in this precinct;
- ***Medium Flood Risk Precinct***— refers generally to land below the 100 year flood level subject to low hydraulic hazard in a 100 year flood. In this precinct, there may still be a significant risk of flood damage or risk to life, but these could be minimised with the application of appropriate development controls;
- ***Low Flood Risk Precinct*** — refers to all other land within the floodplain that is not in a High or Medium Flood Risk Precinct, i.e. land above the 100 year flood level and below the level of the PMF. The Low Flood Risk Precinct would be where risk of damages would be low for most land uses and so most land uses would be permitted within this precinct. One of the main purposes of the Low Flood Risk Precinct is to identify and recognise the potential flood risk for all persons and properties affected by the PMF, regardless of whether any specific development controls are to be applied.

When defining the extents of the Flood Risk Precincts, only a preliminary consideration of potential flood evacuation difficulties has been made as part of this study. For example, in locations where a Medium Flood Risk Precinct is an 'island' surrounded by a High Flood Risk Precinct, then the Medium Risk land has been defined as High Risk. When evacuation and other emergency management risks are more thoroughly assessed as part of the future revision of the Liverpool City Local Flood Plan (see **Section 9.2**), this may also alter some of the precinct boundaries.

Details of the planning and development controls that would apply in each of the Flood Risk Precincts are presented in **Section 8.1**.

FIGURE 4.6: FLOOD RISK PRECINCTS FOR THE SOUTH CREEK STUDY AREA

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4.3 PROPERTIES AFFECTED BY FLOODING

The following tables summarise the number of properties and the likely depth of flooding for a range of flood sizes for residential properties in the floodplain:

- over-floor residential flooding — **Table 4.1**;
- over-ground flooding near the main residential dwelling — **Table 4.2**;
- flooding over low point of property — **Table 4.3**.

Tables 4.1–4.3 also present the maximum depth and average depth of flooding for each flood event. The results for commercial properties are presented in **Table 4.4**.

Table 4.5 summarises the number of properties flooded above floor and above ground (near the main residential dwelling) in different areas of the floodplain. The results for commercial properties are presented in **Table 4.6**.

Figure 4.7 illustrates the extent of flooding in the study area. All properties that would be flood-affected in a probable maximum flood (PMF) have been shown shaded on this figure — all of these properties would require an appropriate notation on their Section 149 Planning Certificates (see **Section 9.3.8**)

Figure 4.7 also shows those properties that would be flooded above floor level in a 5 year, 20 year, 50 year, 100 year, 100 year plus 0.3m, 100 year plus 0.6m and a PMF.

For the purposes of this study, a height of 0.3m above the level of the 100 year flood would be approximately equivalent to a 200 year flood. Similarly, a height of 0.6m above the level of the 100 year flood would be approximately equivalent to a 500 year flood.

Some key results from **Tables 4.1–4.6** and **Figure 4.7** can be summarised as follows:

- two houses in Victor Avenue would be flooded above floor level to a maximum depth of 0.25m in a 5 year flood;

- nine houses in the study area (including the two houses flooded in the 5 year flood) would be flooded above floor level in a 20 year flood. Two of these houses would be located in Overett Avenue, while the remainder are located in the Victor Avenue area. The maximum depth of flooding over the floor would be about 0.6m, while the average depth would be about 0.2m;

- in a 50 year flood, seventeen houses in the study area would be flooded above floor level (including the nine flooded in a 20 year flood). Between the 20 year flood and the 50 year flood, an additional three houses in Overett Avenue, another four houses in Victor Avenue and one house in Kelvin Park Drive would be flooded above floor level. The maximum depth of flooding over the floor would be about 0.9m, while the average depth would be about 0.3m;

- in a 100 year flood, one house in May Avenue and another house in Overett Avenue would be flooded above floor level, making nineteen houses flooded in a 100 year flood. The maximum depth of flooding over the floor would be about 1.0m, while the average depth would be about 0.4m

TABLE 4.1: FREQUENCY AND DEPTH OF OVER-FLOOR RESIDENTIAL FLOODING

DEPTH OF ABOVE FLOOR FLOODING (m)	5 YEAR FLOOD	20 YEAR FLOOD	50 YEAR FLOOD	100 YEAR FLOOD	100 YEAR FLOOD + 0.3m*	100 YEAR FLOOD + 0.6m**	PMF
0m–0.2m above floor level	1	5	7	6	na	na	12
0.2m–0.5m above floor level	1	3	7	9	na	na	16
0.5m–1.0m above floor level	0	1	3	4	na	na	22
1.0m–1.5m above floor level	0	0	0	0	na	na	23
1.5m–2m above floor level	0	0	0	0	na	na	10
more than 2m above floor level	0	0	0	0	na	na	12
TOTAL ABOVE FLOOR LEVEL	**2**	**9**	**17**	**19**	**34**	**50**	**95**
Maximum depth of flooding (m)	0.25	0.62	0.86	0.99	1.29	1.59	2.84
Average depth of flooding above floor (m)	0.18	0.22	0.29	0.38	na	na	1.01

TABLE 4.2: FREQUENCY AND DEPTH OF OVER-GROUND FLOODING NEAR MAIN RESIDENTIAL DWELLING

DEPTH OF OVER GROUND FLOODING (m)	5 YEAR FLOOD	20 YEAR FLOOD	50 YEAR FLOOD	100 YEAR FLOOD	100 YEAR FLOOD + 0.3m*	100 YEAR FLOOD + 0.6m**	PMF
0m–0.2m above ground level	7	11	9	6	na	na	17
0.2m–0.5m above ground level	7	12	18	19	na	na	16
0.5m–1.0m above ground level	3	8	12	16	na	na	32
1.0m–1.5m above ground level	0	1	4	5	na	na	17
1.5m–2m above ground level	0	0	0	0	na	na	19
more than 2m above ground level	0	0	0	0	na	na	27
TOTAL ABOVE GROUND LEVEL	**17**	**32**	**43**	**46**	**58**	**69**	**128**
Maximum depth of flooding (m)	0.76	1.13	1.37	1.50	1.80	2.10	3.35
Average depth of flooding above ground level near main dwelling or building (m)	0.27	0.38	0.48	0.56	na	na	1.19

TABLE 4.3: FREQUENCY AND DEPTH OF FLOODING OF LOW POINT OF RESIDENTIAL PROPERTIES

DEPTH OF FLOODING ABOVE PROPERTY LOW POINT (m)	5 YEAR FLOOD	20 YEAR FLOOD	50 YEAR FLOOD	100 YEAR FLOOD	PMF
0m–0.2m above property low point	7	7	3	1	7
0.2m–0.5m above property low point	19	21	12	8	15
0.5m–1.0m above property low point	36	38	44	45	30
1.0m–1.5m above property low point	33	44	37	42	18
1.5m–2m above property low point	24	37	46	38	26
more than 2m above property low point	24	46	56	67	173
TOTAL ABOVE PROPERTY LOW POINT	**143**	**193**	**198**	**201**	**269**
Maximum depth of flooding (m)	4.10	4.41	4.58	4.68	6.45
Average depth of flooding above property low point (m)	1.27	1.45	1.59	1.67	2.46

TABLE 4.4: FLOODING OF COMMERCIAL PROPERTIES

PART OF COMMERCIAL PROPERTY INUNDATED	5 YEAR FLOOD	20 YEAR FLOOD	50 YEAR FLOOD	100 YEAR FLOOD	100 YEAR FLOOD + 0.3m*	100 YEAR FLOOD + 0.6m**	PMF
Properties flooded above level of main work area	0	0	0	0	1	2	3
Properties flooded above ground near main building	0	0	0	0	3	3	3
Properties flooded above low point of property	4	4	4	4	na	na	5

*Notes: * approximately equivalent to a 200 year flood*
*** approximately equivalent to a 500 year flood*
PMF = probable maximum flood; na = not available

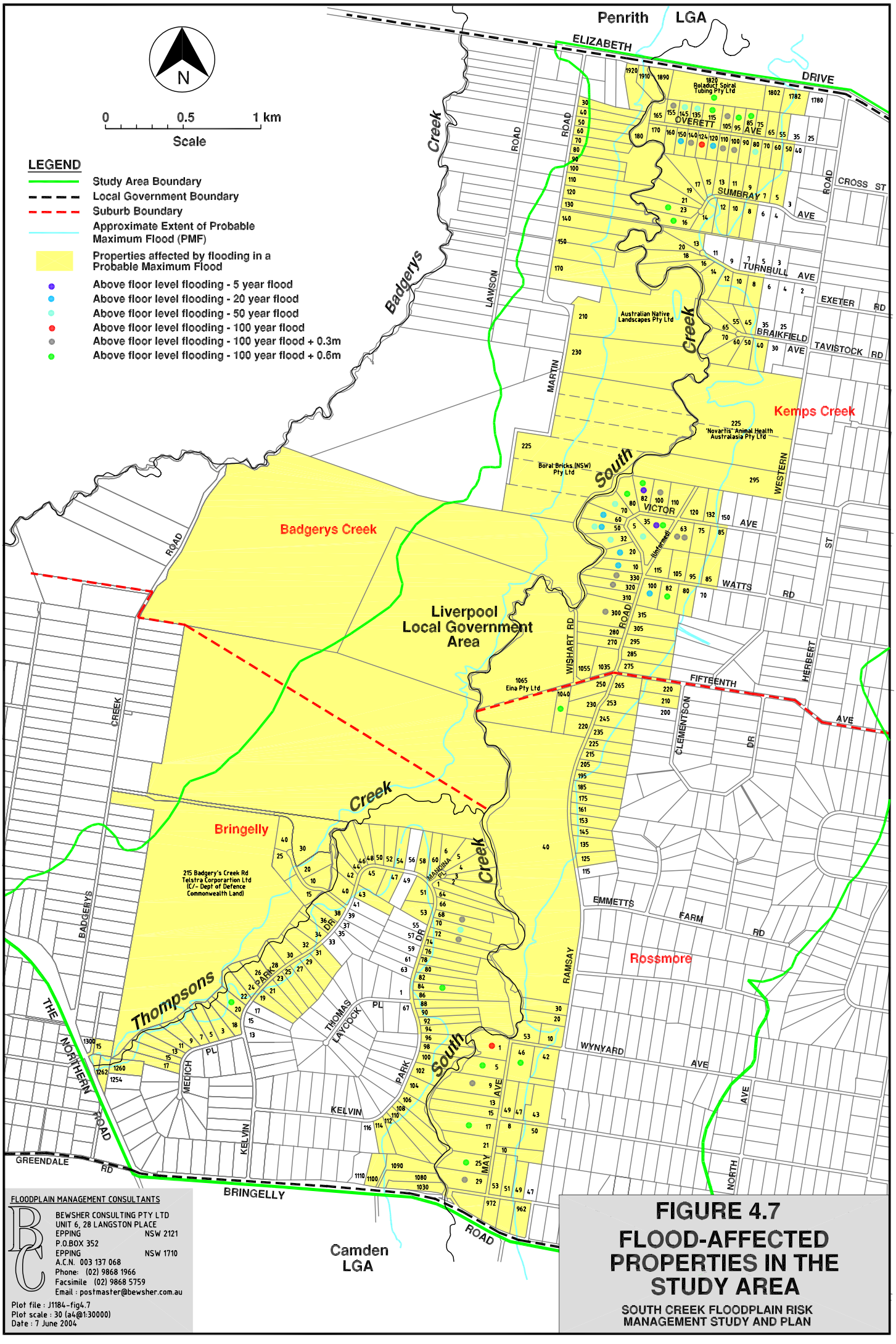
TABLE 4.5: FREQUENCY OF RESIDENTIAL FLOODING AREA BY AREA

FLOODPLAIN AREA	NUMBER OF RESIDENTIAL PROPERTIES ***													
	5 YEAR FLOOD		20 YEAR FLOOD		50 YEAR FLOOD		100 YEAR FLOOD		100 YEAR FLOOD + 0.3m*		100 YEAR FLOOD + 0.6m**		PROBABLE MAXIMUM FLOOD	
	Over-floor flooding	Over-ground flooding	Over-floor flooding	Over-ground flooding	Over-floor flooding	Over-ground flooding	Over-floor flooding	Over-ground flooding	Over-floor flooding	Over-ground flooding	Over-floor flooding	Over-ground flooding	Over-floor flooding	Over-ground flooding
Overett Avenue area	0	3	2	8	5	15	6	15	11	18	16	19	26	33
Victor Avenue area	2	9	7	17	11	19	11	22	17	27	22	28	39	54
May Avenue area	0	4	0	5	0	7	1	7	3	8	7	9	13	15
Kelvin Park Drive area	0	1	0	2	1	2	1	2	3	5	5	13	17	26
Martin Road area	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	**2**	**17**	**9**	**32**	**17**	**43**	**19**	**46**	**34**	**58**	**50**	**69**	**95**	**128**

TABLE 4.6: FREQUENCY OF COMMERCIAL FLOODING AREA BY AREA

FLOODPLAIN AREA	NUMBER OF COMMERCIAL PROPERTIES***													
	5 YEAR FLOOD		20 YEAR FLOOD		50 YEAR FLOOD		100 YEAR FLOOD		100 YEAR FLOOD + 0.3m*		100 YEAR FLOOD + 0.6m**		PROBABLE MAXIMUM FLOOD	
	Over-floor flooding	Over-ground flooding	Over-floor flooding	Over-ground flooding	Over-floor flooding	Over-ground flooding	Over-floor flooding	Over-ground flooding	Over-floor flooding	Over-ground flooding	Over-floor flooding	Over-ground flooding	Over-floor flooding	Over-ground flooding
Overett Avenue area	0	0	0	0	0	0	0	0	0	2	1	2	2	2
Victor Avenue area	0	0	0	0	0	0	0	0	1	1	1	1	1	1
May Avenue area	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kelvin Park Drive area	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Martin Road area	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**3**	**2**	**3**	**3**	**3**

Notes: ** approximately equivalent to a 200 year flood*
*** approximately equivalent to a 500 year flood*
**** Over-ground flooding refers to flooding of the ground near the main residential dwelling or commercial building; over-floor flooding for commercial properties refers to flooding of main work area.*



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Plot file : J1184-fig4.7
Plot scale : 30 (a4@1:30000)
Date : 7 June 2004

FIGURE 4.7
FLOOD-AFFECTED PROPERTIES IN THE STUDY AREA

SOUTH CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

- in a flood 0.3m higher than a 100 year flood, 34 houses would be flooded above floor level, while in a flood 0.6m higher than a 100 year flood, 50 houses would be flooded above floor level;

- Nearly 100 houses would be flooded above floor level in a PMF, with a maximum depth over the floor of about 2.8m and an average depth of about 1.0m;

- Of the five commercial properties included in the data base, three would experience over-floor flooding in a PMF while one of these properties would be flooded above the floor in '100 year plus 0.6m' flood;

- Nearly half the properties in the residential and commercial data bases, i.e. nearly 150 properties, would have flooding over the low point of their property in a 5 year flood. The majority of these properties would not experience any damage or inconvenience if this type of flooding occurred;

- Flooding in a PMF would have some impact at about 270 residential and commercial properties in the study area, i.e. the lowest point of the property would be flooded in a PMF. These properties are shown as shaded on **Figure 4.7**.

4.4 FLOOD RISK CATEGORISATION OF PROPERTIES

Using the map of Flood Risk Precincts depicted on **Figure 4.6**, each property inundated in a PMF in the flood damages data base has been assigned a flood risk category. The Flood Risk categories for each property are shown on **Figure 4.8**, while a summary of the number of properties in each category is provided in **Table 4.7**.

TABLE 4.7: NUMBERS OF PROPERTIES IN EACH FLOOD RISK CATEGORY

TYPE OF PROPERTY	NUMBER OF PROPERTIES IN FLOOD RISK CATEGORY		
	LOW	MEDIUM	HIGH
Residential	67	46	166
Commercial	0	0	5

Although many of the properties in the study area are large with areas well above the level of the PMF, the highest applicable risk has been assigned to all properties. If the highest applicable risk only covers a negligible area of the property, the next lowest Flood Risk Precinct has been adopted.

By using the highest applicable risk, this provides a 'flag' to Council during the development application process, that flood issues need to be carefully considered on that property.

FIGURE 4.8: FLOOD RISK CATEGORISATION OF PROPERTIES IN THE STUDY AREA

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4.5 FLOODING OF ROADS IN THE STUDY AREA

Table 4.8 summarises the depth of flooding that could be expected over roads for different flood sizes, at key locations in the study area. These locations are shown on **Figure 4.9**. A road is generally considered to be impassable to traffic and is closed by the Police or the SES if the depth of water is about 0.3m or greater.

It should be noted that as the hydraulic model only extends as far upstream as the downstream side of The Northern Road Bridge on Thompsons Creek, the depth of flooding over this road could not be determined.

The results from **Table 4.8** can be summarised as follows:

- there would be more than 1m of water over the road in a 5 year flood at the corner of Wynyard Avenue and May Avenue (Point No.3) and at the lowest point in Victor Avenue (Point No.6);
- the intersection of Ramsay Road, Victor Avenue and Watts Road (Point No.5) would be impassable to traffic in a 20 year flood;
- the end of Overett Avenue (Point No.10) would be inundated by about 0.6m in a 20 year flood;
- the bridge over Thompsons Creek at The Retreat (Point No.13) would be impassable to traffic in a 50 year flood;
- Bringelly Road (Point No.1) would be almost overtopped in a 100 year flood and would be impassable to traffic in a '100 year plus 0.6m' flood;
- Elizabeth Drive (Point No.11) would be overtopped by about 0.2m in a 100 year flood, and so is likely to just remain trafficable in such a flood. In a flood slightly larger than a 100 year flood, Elizabeth Drive would need to be closed to traffic at the South Creek crossing;
- the low point of Kelvin Park Drive (Point No.12) would be impassable to traffic in a flood only slightly higher than a 100 year flood.

4.6 THE COST OF FLOODING

4.6.1 Calculation of Flood Damages

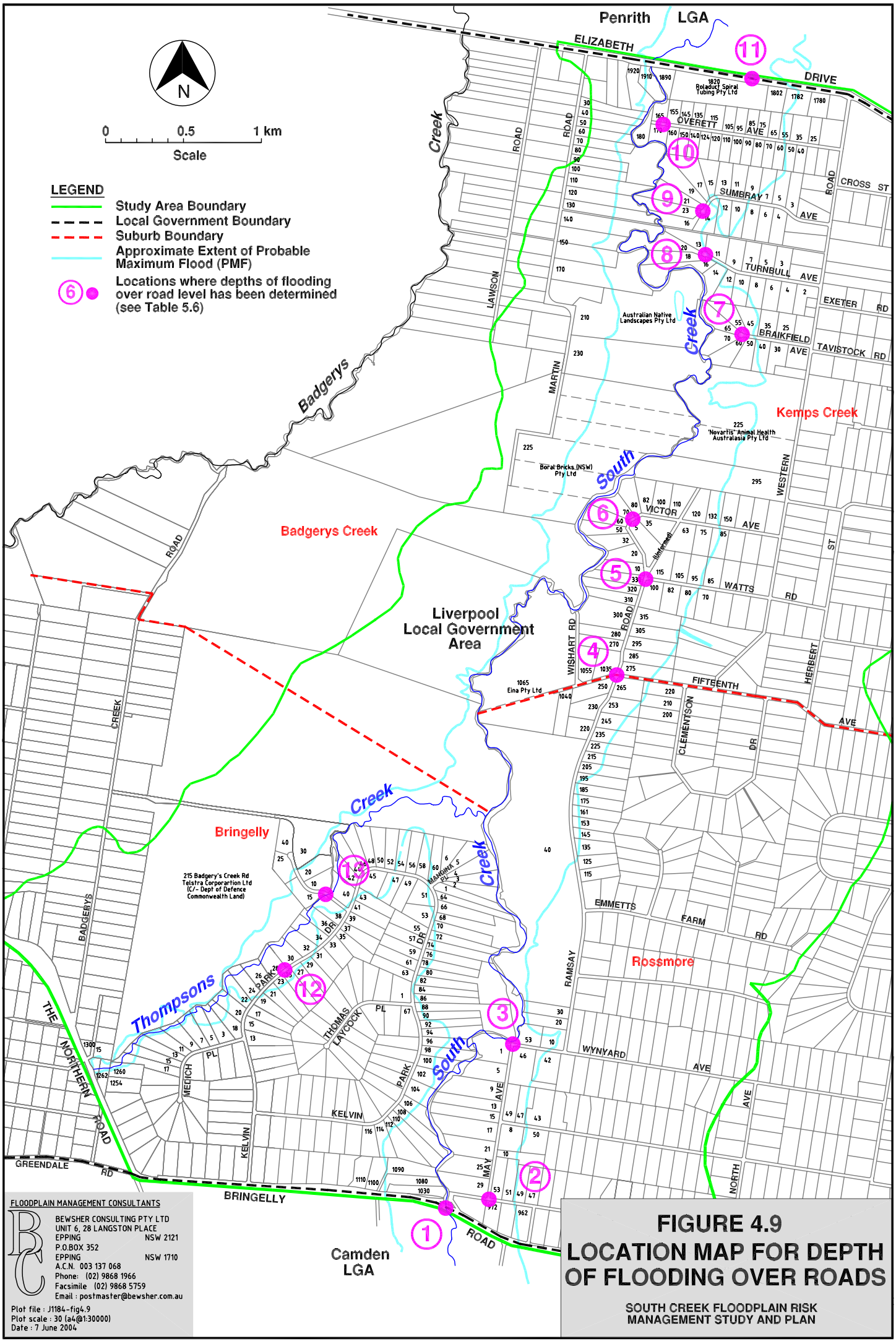
The total potential damage bill for a particular sized flood is divided into a number of components. The definitions and methodologies used in estimating flood damage have been established by a number of previous investigations. **Figure 4.10** summarises the types of flood damages that have been considered in this study.

There are two main categories of flood damages, namely 'tangible' and 'intangible' damages. Tangible flood damages are those that can be more readily evaluated in monetary terms, while intangible damages relate to the social cost of flooding and hence are much more difficult to quantify.

TABLE 4.8: DEPTH OF FLOODING OVER ROADS AT KEY LOCATIONS IN THE STUDY AREA

LOCATION NUMBER (see Figure 5.3)	ROAD LOCATION	APPROXIMATE ROAD LEVEL* (mAHD)	APPROXIMATE DEPTH OF FLOODING (metres)				
			5 YEAR FLOOD	20 YEAR FLOOD	50 YEAR FLOOD	100 YEAR FLOOD	PMF
1	Low point of Bringelly Road crossing of South Creek	59.26**	—	**-0.8**	**-0.3**	**-0.1**	0.7
2	Corner of Rossmore Avenue and May Avenue	57.8	—	0.1	0.2	0.3	1.6
3	Corner of Wynyard Avenue and May Avenue	54.2	1.1	1.4	1.5	1.6	2.8
4	Corner of Fifteenth Avenue and Ramsay Road	51.8	—	—	—	—	0.8
5	Intersection of Victor Avenue, Watts Rd and Ramsay Rd	49.2	—	0.3	0.5	0.6	2.4
6	Low point in Victor Avenue, near No.70 and No.80	47.2	1.3	1.7	1.9	2.0	3.9
7	End of cul-de-sac of Braikfield Avenue	46.7	—	—	—	—	0.6
8	End of cul-de-sac of Turnbull Avenue	46.3	—	—	—	—	0.3
9	End of cul-de-sac of Sumbray Avenue	45.3	—	—	—	—	0.7
10	End of cul-de-sac of Overett Avenue	42.4	0.2	0.6	0.8	0.9	2.8
11	Low point of Elizabeth Drive crossing of South Creek	43.0	—	**-0.7**	**-0.2**	0.2	1.0
12	Low point in Kelvin Park Drive, near No.30 and No.32	60.5	na	—	—	0.2	1.0
13	Low point of The Retreat crossing of Thompsons Creek	58.57**	na	0.2	0.3	0.3	1.0

Notes: * = *Road levels have been determined using the DTM, except when ** shown.*
** = *Road levels have been determined from the MIKE-11 hydraulic model.*
— = *road above flood level so flood level not available from DTM.*
na = no 5 year flood levels are available for Thompsons Creek.
negative depths indicate depth of flooding below road



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Date : 7 June 2004

FIGURE 4.9
LOCATION MAP FOR DEPTH OF FLOODING OVER ROADS

SOUTH CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

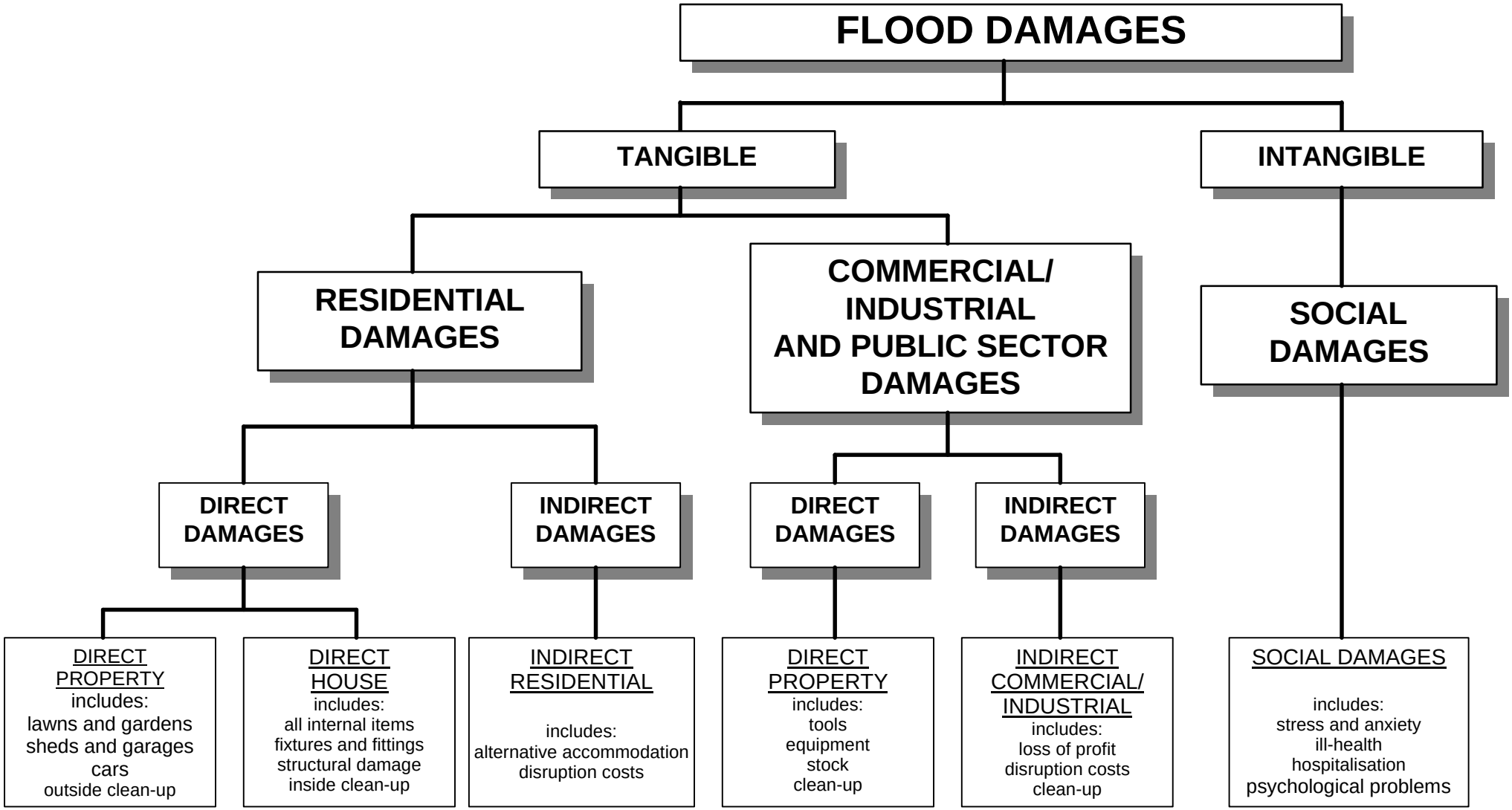


FIGURE 4.10: TYPES OF FLOOD DAMAGE

'Tangible' damages include damage to residential and business properties. The assumptions and methodology used in the calculation of potential damage to residential properties, business properties (including commercial properties, industrial properties, infrastructure services and utilities) and intangible damages (also known as 'social' damages) are described in **Appendix G**.

All the calculation techniques used for estimating flood damages used in this study relate to 'potential' flood damage — representing a situation where damages are not mitigated in any way. 'Actual' damages make allowances for mitigating effects, such as flood awareness, warning time and the availability of residents to effectively save their possessions. The assumptions relating to the differences between 'Potential' and 'actual' flood damages for all the different types of flood damages are discussed in **Appendix G**.

4.6.2 Economic Appraisal

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.

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. Economic appraisal is also referred to as Cost Benefit Analysis. The *NSW Government Guidelines for Economic Appraisal* (NSW Treasury, 1997) details the State Government's requirements for economic appraisal, while a summary document entitled *Economic Appraisal — Principles and Procedures Simplified* (NSW Treasury, 1999) aims to improve the understanding of the principles of economic appraisal.

The following terms used in the economic appraisal of flood mitigation measures, relating to flood damage are described in this section as follows:

- average annual damage;
- present value of flood damage;
- benefit–cost ratio;
- net present value.

Traditional economic analysis principally deals with tangible costs but consideration also needs to be given to the following intangible costs as outlined in the *Floodplain Management Manual* (NSW Government, 2001):

- social costs, even though these are difficult to quantify;
- ecological costs, particularly considering the principles of ecologically sustainable development (ESD) and the valuation of environmental assets and services;
- equity issues.

The consideration of intangible benefits becomes even more important in areas where traditional economic appraisal techniques are more difficult to apply.

Average Annual Damage

Average annual damage (AAD) is a measure of the cost of flood damage that could be expected each year by the community, on average. This cost is not attributed separately to the bearers of the costs; rather it is the total cost to the community. It is a convenient yardstick to compare the economic benefits of various proposed mitigation measures with each other and the existing situation.

The average annual damage is equal to the average total damage caused by floods of all different sizes over a long period of time. It takes into account, for example, that the total damages for a 100 year flood would have a 1% chance of being incurred every year, the total damages for a 20 year flood would have a 5% chance of being incurred every year, etc., for a range of different sized floods.

Present Value of Flood Damage

To allow direct comparison between the costs of proposed mitigation measures and the average annual flood damage in the economic appraisal process, 'the present value of flood damage' is calculated. The present value of flood damage is determined by discounting the future flood damage costs (in terms of average annual damage) back to the present day situation.

The present value is calculated using guidelines from the NSW Treasury document, namely an expected life of 20 years and a real discount rate of 7% (with calculations at 4% and 10% for sensitivity purposes). Predictions related to inflation are not included.

Benefit–Cost Ratio

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 (NSW Government, 2001). In other words, the benefit–cost ratio would be calculated to be less than 1.0.

Net Present Value

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.

4.6.3 The Cost of Flooding in the Study Area

Table 4.9 provides a summary of the potential cost of flooding, in terms of potential flood damages, which could be expected in the floodplain communities along South Creek and Thompsons Creek in the study area. As well as flood damages, these results include the number of properties affected for a range of flood sizes, the average annual flood damage and the present value of potential flood damages (assuming a discount rate of 7% and a period of 20 years).

Table 4.9 shows that, for example, if the people of the study area took no action to mitigate against the effects of a 100 year flood, a damage bill of about $3.1 million could be expected. Similarly, in a 5 year flood, the damage bill could be up to $0.5 million. The average yearly flood damage bill over time (i.e. the average annual damage), if no mitigating actions were taken would be in the order of $420,000 every year.

Similarly, **Table 4.10** provides a summary of the 'predicted actual' cost of flooding, given the likely actions by the community to protect their property such as moving their cars out of the paths of floodwaters. **Table 4.10** shows that, even with the likely short warning time, the actual damage bill for a 100 year flood is likely to be reduced by about 10% to about $2.9 million. Similarly, in a 5 year flood, the damage bill is also likely to be reduced by about 10%. This would result in a 'predicted actual' average yearly flood damage bill over time of about $390,000 per year.

The results from **Tables 5.7** and **5.8** show that in a 100 year flood for existing catchment conditions, the distribution of flood damages would be as follows:

- damage to residential property (including 'home-based' businesses) — 73%;
- damage to infrastructure and services — 21%;
- social or 'intangible' damages — 6%;
- damage to the business sector — less than 1% of the total damage bill.

TABLE 4.9: SUMMARY OF POTENTIAL FLOOD DAMAGES FOR THE SOUTH CREEK AND THOMPSONS CREEK STUDY AREA FOR EXISTING CONDITIONS

POTENTIAL FLOOD DAMAGES
Existing Flood Conditions

Flood size*		Residential properties										Industrial, commercial & public sector properties									Social damages	Total potential damages
		No. properties								Flood damages					No. properties**							Flood damages				
ARI	AEP	Property flood liable	Max depth	House flood liable	Max depth	Flood Risk Precinct				Direct property damage	Direct house damage	Total direct residential	Indirect residential		Property flood liable	Max depth	Work area flood liable	Max depth	Flood Risk Precinct				Direct industrial & commercial	Indirect industrial & commercial	Infrastructure & public sector damage		
						High	Med	Low	None										High	Med	Low	None					
(years)	(%)		(m)		(m)	166	46	67	32	($)	($)	($)	($)			(m)		(m)	5	0	0	0	($)	($)	($)	($)	**($)**
PMF	0%	128	3.35	95	2.84					6,220,000	7,401,000	13,621,000	613,000		3	1.65	3	1.48					3,048,000	1,509,000	3,334,000	700,000	22,830,000
100	1%	46	1.50	19	0.99					1,498,000	683,000	2,181,000	98,000		0	0.00	0	0.00					0	0	654,000	191,000	3,120,000
50	2%	40	1.35	15	0.84					1,186,000	506,200	1,692,200	76,000		0	0.00	0	0.00					0	0	507,600	161,000	2,436,000
20	5%	32	1.13	9	0.62					718,000	241,000	959,000	43,000		0	0.00	0	0.00					0	0	288,000	116,000	1,410,000
5	20%	17	0.76	2	0.25					259,000	42,000	301,000	14,000		0	0.00	0	0.00					0	0	90,000	50,500	460,000
2****	50%																										
Average annual damage (AAD):										193,000	85,000	278,000	13,000										15,000	8,000	80,000	30,000	**420,000**
Present value of potential damages																											
Discount rate	No. years																										
4%	20									2,623,000	1,155,000	3,778,000	177,000										204,000	109,000	1,087,000	408,000	5,760,000
7%	**20**									**2,045,000**	**900,000**	**2,945,000**	**138,000**										**159,000**	**85,000**	**848,000**	**318,000**	**4,490,000**
10%	20									1,643,000	724,000	2,367,000	111,000										128,000	68,000	681,000	255,000	3,610,000
											sum of house and property damage	**5%** of total direct **actual** damage												**55%** of total direct **actual** damage	**20%** : PMF **30%** : 50yr, 100yr **30%** : 20yr, 10yr and 5yr		

Notes: * *AEP = annual exceedance probability (chance of flood occurring in any one year);* *ARI = average recurrence interval*

** *No. of properties includes all industrial, commercial and public sector properties.*

*** *Infrastructure damage = a percentage of total direct + indirect residential + business damage (as shown)*

**** *For the purposes of calculation of flood damages, damage in a 2 year flood is assumed to be nil.*

***** *Residential damages include home based businesses located in residentail areas.*

TABLE 4.10: SUMMARY OF 'PREDICTED' ACTUAL FLOOD DAMAGES FOR THE SOUTH CREEK AND THOMPSONS CREEK STUDY AREA FOR EXISTING CONDITIONS

"PREDICTED" ACTUAL FLOOD DAMAGES
Existing Flood Conditions

Flood size*		Residential properties											Industrial, commercial & public sector properties											Social damages	Total 'predicted' actual damages
		No. properties								Flood damages				No. properties**								Flood damages				
ARI	AEP	Property flood liable	Max depth	House flood liable	Max depth	Flood Risk Precinct				Direct property damage	Direct house damage	Total direct residential	Indirect residential	Property flood liable	Max depth	Work area flood liable	Max depth	Flood Risk Precinct				Direct industrial & commercial	Indirect industrial & commercial	Infrastructure & public sector damage		
(years)	(%)		(m)		(m)	High	Med	Low	None	($)	($)	($)	($)		(m)		(m)	High	Med	Low	None	($)	($)	($)	($)	
Actual damage as a percentage of potential damages:										**90%**	**90%**											**90%**		**100%**	**90%**	
						166	46	67	32									5	0	0	0					
PMF	0%	128	3.35	95	2.84					5,598,000	6,661,000	12,259,000	613,000	3	1.65	3	1.48					2,743,000	1,509,000	3,334,000	630,000	21,090,000
100	1%	46	1.50	19	0.99					1,348,000	615,000	1,963,000	98,000	0	0.00	0	0.00					0	0	654,000	172,000	2,890,000
50	2%	40	1.35	15	0.84					1,067,200	455,800	1,523,000	76,000	0	0.00	0	0.00					0	0	507,600	144,800	2,254,000
20	5%	32	1.13	9	0.62					646,000	217,000	863,000	43,000	0	0.00	0	0.00					0	0	288,000	104,000	1,300,000
5	20%	17	0.76	2	0.25					233,000	38,000	271,000	14,000	0	0.00	0	0.00					0	0	90,000	45,000	420,000
2****	50%																									
Average annual damage (AAD)										173,000	77,000	250,000	13,000									14,000	8,000	80,000	27,000	**390,000**
Present value of actual damages																										
Discount rate	No. years																									
4%	20									2,351,000	1,046,000	3,398,000	177,000									190,000	109,000	1,087,000	367,000	5,330,000
7%	**20**									**1,833,000**	**816,000**	**2,649,000**	**138,000**									**148,000**	**85,000**	**848,000**	**286,000**	**4,150,000**
10%	20									1,473,000	656,000	2,128,000	111,000									119,000	68,000	681,000	230,000	3,340,000
												sum of house and property damage	**5%** of total direct **actual** damage										**55%** of total direct **actual** damage	**20%** : PMF **30%** : 50yr, 100yr **30%** : 20yr, 10yr and 5yr		

Notes:

* *AEP = annual exceedance probability (chance of flood occurring in any one year)*
ARI = average recurrence interval

** *No. of properties includes all industrial, commercial and public sector properties.*

*** *Infrastructure damage = a percentage of total direct + indirect residential + business damage (as shown)*

**** *For the purposes of calculation of flood damages, damage in a 2 year flood is assumed to be nil.*

***** *Residential damages include home based businesses located in residential areas.*

5. COMMUNITY CONSULTATION

The success of any floodplain risk management plan hinges on its acceptance by the floodplain community, residents within the study area and other stakeholders. During the current study, this has been achieved by involving the local community at all stages of the decision-making process. This includes the collection of their ideas and information, together with discussing the issues and outcomes of the study with them.

Key elements of the consultation process have been as follows:

- regular meetings with, and presentations to, the Liverpool Floodplain Management Committee (**Section 5.1**);
- the distribution of a newsletter and community survey to residents and businesses within the study area (**Section 5.2**);
- liaison with a range of government and private stakeholders who may have an interest and/or assets within the study area (**Section 5.3**);
- development of an internet web site (**Section 5.4**);
- organisation of a community workshop to discuss the findings of the study and obtain feedback from the community (**Section 5.5**);
- public exhibition of draft *Floodplain Risk Management Study Report* and the recommended draft *Floodplain Risk Management Plan*, prior to formal consideration by Council (**Section 5.6**).

5.1 LIVERPOOL FLOODPLAIN MANAGEMENT COMMITTEE

The Liverpool Floodplain Management Committee, an official committee of Council, has overseen and is responsible for, the current study. The committee has assisted and advised Council in the development of the *South Creek Floodplain Risk Management Study and Plan* and has provided the vital link between the consultant, Council, the Department of Infrastructure, Planning and Natural Resources (DIPNR) (formerly the Department of Land and Water Conservation (DLWC)), other government agencies and the local community.

The Committee is responsible for recommending the outcomes of the study for formal consideration by Council.

Members of the Liverpool Floodplain Management Committee include representatives from the following:

- staff from Liverpool City Council;
- staff from DIPNR (formerly DLWC) Sydney/South Coast Region;
- staff from Camden, Bankstown, Campbelltown and Fairfield City Councils;
- a representative from the State Emergency Service (SES);
- five community representatives.

Every two to four years, expressions of interest are sought in the local press for people from all over the Liverpool LGA to become community representatives on the committee.

5.2 COMMUNITY NEWSLETTER AND SURVEY

In October 2003, a covering letter from Liverpool City Council, community newsletter and community survey (questionnaire) were posted to the owners of all properties in and immediately adjacent to the South Creek and Thompsons Creek floodplains within the study area. The properties included in this mail out are shown on **Figure 3.1** — these properties represent all those properties included in the 'flood damages data base' (see **Section 3.5**). This represented about 290 properties. Just prior to this mail out, an advertisement for the study was placed in Council's information page in two weekly local papers, *The Liverpool City Champion* and *The Liverpool Leader*.

Copies of the advertisement, covering letter, newsletter and survey have been included as **Appendix H**.

5.2.1 Community Newsletter

A community newsletter was prepared that provided information about the study to the local community and other stakeholders with an interest in the study area. The newsletter, accompanied by the community survey, was included in the mail out in October 2003. It was also included with the mail out of stakeholder surveys (see **Section 5.3**) and is available for download from the web site (see **Section 5.4**).

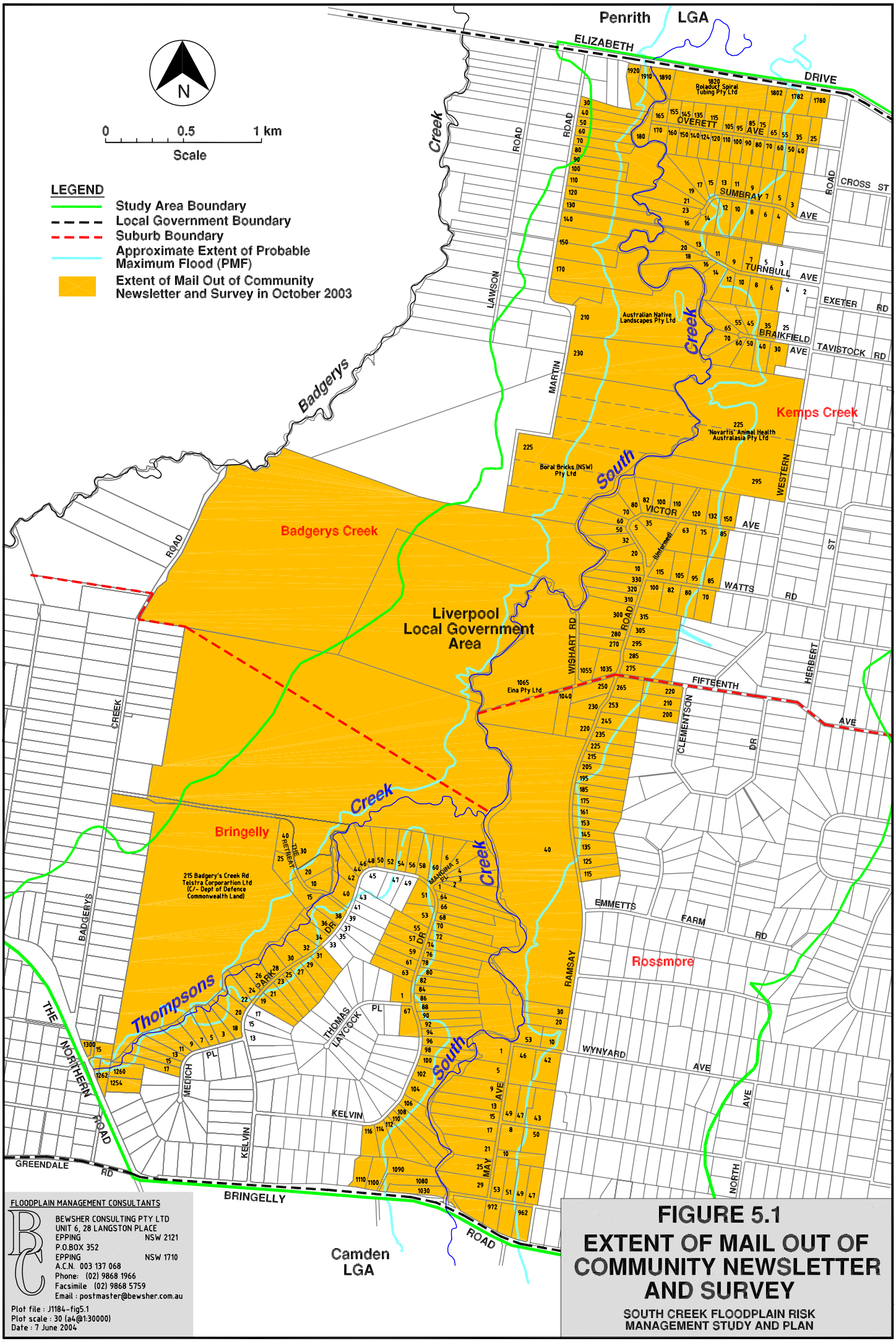
The newsletter provides an introduction and background to the study, including answers to the following questions:

- Why do we need to worry about floods?
- Why do we need a study?
- Who is responsible for the study?
- What will the study be about?
- What flood mitigation works have already been completed?
- What is a '100 year flood'?
- What is a 'probable maximum flood'?
- How can I become more involved in the study?
- How can I find out more about the study?

5.2.2 Community Survey

In October 2003, a community survey (questionnaire) was posted to the owners of all properties in and immediately adjacent to the South Creek and Thompsons Creek floodplains within the study area.

The results of the survey provide an important means by which to gauge community opinion about possible floodplain risk management measures and provide a good indication of people's concerns and priorities about flood-related issues. Respondents were also encouraged to suggest their own options for alleviating flood problems.



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Plot scale : 30 (a4@1:30000)
Date : 7 June 2004

FIGURE 5.1
EXTENT OF MAIL OUT OF COMMUNITY NEWSLETTER AND SURVEY

SOUTH CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Approximately 290 surveys were distributed. In total, 80 surveys were completed and returned, representing a response rate of about 28%. This is considered a good response rate for a survey of this nature.

The survey was divided into six parts. The first five parts (Parts A to E) were applicable to residential properties, while the last part (Part F) was directed at businesses and organisations only.

Some of the key results from each of the six parts are discussed below. A summary of all responses, together with statistical results and community comments, are presented in **Appendix I**.

Part A — Your Flood Experience

The first part of the survey gauged the amount of flood experience that the floodplain community has in the study area and found that:

- about 30% of respondents had experienced a flood and nearly all of these residents had experienced flooding above ground level at their property;
- about 25% of respondents had experienced the April 1988 flood (in the order of a 100 year flood through the study area) and about 10% had experienced the August 1986 flood (about a 5 year flood through the study area);
- only 5% of respondents had been flooded above floor level;
- just more than half those residents who had experienced a flood had less that 2 hours warning to take action against the flood;
- nearly half of the respondents believed that their property could be flooded sometime in the future, while only 1% believed their house could be flooded above floor level.

Part B — Opinions on Floodplain Risk Management Measures

This part of the survey gauged the awareness of works Council or owners have carried out to reduce flood risks. As shown in **Table 5.1**, it is encouraging that almost 50% of residents are aware of some form of floodplain risk management measure, even if it is only that Council imposes minimum floor levels in floodplain areas.

TABLE 5.1: COMMUNITY AWARENESS OF FLOODPLAIN RISK MANAGEMENT MEASURES

EXISTING MEASURES THAT MAY REDUCE FLOOD RISK	PERCENTAGE OF RESPONDENTS AWARE OF MEASURE
Not aware of any measures	56%
Creek enlarged by widening	24%
House built at specified flood level	18%
Bridges added or enlarged	14%
Floodway constructed	13%
House raised	8%
Property protected by levees of flood walls	4%
Other	3%
Flood-compatible building materials used	1%
Flood proofing measures used	1%

Part C — Opinions on Council's Controls on Development

This part of the survey sought to gauge people's opinions about the amount of control that Council should place on new development in the floodplain. It can be seen from the results in **Table 5.2** that, compared to other floodplain communities in NSW, there appears not to be a great deal of concern for placing some restrictions on new development in the floodplain to minimise flood-related risks. Ten percent of respondents thought there should be no restrictions to developing in the floodplain, while nearly 40% of respondents thought that Council should only advise of the flood risk and allow residents to choose themselves how they should be managed. However, it was encouraging that more than 50% of respondents thought that all new buildings should have a minimum floor level above the flood level.

TABLE 5.2: COMMUNITY VIEWS ON THE LIMITS THAT SHOULD BE ON NEW DEVELOPMENT IN THE FLOODPLAIN

LIMITS TO BE PLACED ON NEW DEVELOPMENT IN THE FLOODPLAIN	PERCENTAGE OF RESPONDENTS IN FAVOUR
Make sure any new building has a minimum floor level above the flood level	53%
Advise owners of the flood risks, and allow people to choose how they would reduce flood damage	38%
Make sure any new buildings are built with materials that are suitable for areas that have flood problems	34%
Stop all new development only in the most dangerous areas of the floodplain	20%
Stop subdivision/rezoning only in the most dangerous areas of the floodplain	19%
Stop subdivision/rezoning of properties on land with any possibility of flooding	13%
There should be no limits on building in flood-affected areas	10%
Stop all development on land with any possibility of flooding	8%

The survey then asked how people thought Council should let residents know about the possibility of flooding and what information should be provided. As shown in **Table 5.3**, there is strong support for Council to provide flood information and community awareness, with only 1% of respondents indicating that Council should provide no advice about flooding and means to reduce the risk. Nearly half the respondents thought notification of flood-affectation through the sending out of Flood Certificates was a good idea.

TABLE 5.3: COMMUNITY VIEWS ON HOW THEY SHOULD BE INFORMED ABOUT FLOOD RISKS

FLOOD AWARENESS MEASURE	PERCENTAGE OF RESPONDENTS IN FAVOUR
Send a certificate to all residents that says if their property is flood-affected	49%
All information about potential risks of flooding should be available on Council's web site	46%
Install flood markers as reminders of heights of previous floods	45%
Advise property buyers of possible flood problems	43%
Have maps available on Council's web site	40%
Council should help residents and business owners to make a Flood Action Plan — what to do, where to go and who to contact in the event of a flood	39%
There should be community education, participation and flood awareness programs	25%
Tell only those people who ask Council for information, about possible flood problems	21%

Part D — About Your Property

The responses to this part of the survey provided some information about the demographics of the South Creek floodplain community and whether any future development is proposed for the floodplain corridors within the catchment. The questionnaire found that:

- more than 70% of properties contained a single residential dwelling while 25% of the properties contained two residential dwellings (as permitted by the current Council zoning);
- 90% of the respondents were owner-occupiers;
- there appears to be an owner-occupied business at about one-quarter of the properties;
- the average number of people at the properties was 4.1, which is considerably higher that the typical average occupancy rate for Australia of about 2.5. About one-quarter of the properties had five or more people living there;

- the properties appear to be occupied by relatively short-term residents with only 25% of the respondents living at the property for more than 15 years. The average length of time for living at the property was about 13 years;

- more than 60% of respondents have some intentions of undertaking further development on their property:

  - 13% had thought about minor extensions only;

  - 9% had thought about building a new single dwelling;

  - 6% had thought about knocking down an existing dwelling and rebuilding a dwelling on the same site;

  - 16% had thought about building a second house on their property (which is permitted under the current zoning);

  - 29% had thoughts about subdividing their land (which would generally not be permitted at most locations under current zoning due to land size);

- only about 30% of those who had thought about undertaking some development in the future had taken any steps to get approval for the development;

- more than half the respondents have received no information at all about flooding at their property, while only 20% of respondents had received some sort of flood advice from Council. About 30% of respondents had found out about flooding of their property through experiencing a flood or from relatives, friends, neighbours or the previous owner;

  It should be noted that Council currently provides flood information to the community in the following ways:

  - on Section 149 Certificates upon application (for more information on Section 149 Certificates, see **Section 9.3.8**);

  - through maps and advice to those who enquire at Council;

  A detailed community consultation strategy is a key recommendation of the recommended *South Creek Floodplain Risk Management Plan* and is described in **Section 9.3**.

Part E — Other Information

The last part of the residential section of the survey asked people whether they would like to be put on a mailing list as part of the study. A very high, 70% of respondents requested to be put on a mailing and provided their details. A copy of this mailing list has been provided separately to Council.

About one-quarter of respondents were also interested in attending a community workshop later in the study (see **Section 5.5**).

Table 5.4 summarises the opinions of local residents with regard to how they believe is the best way to get input and feedback from the local community about the results and proposals from the study. As indicated by the previous question, mail out to residents is clearly the most popular means to achieve this.

TABLE 5.4: COMMUNITY VIEWS ON HOW TO GET INPUT AND FEEDBACK ABOUT RESULTS AND PROPOSALS FROM THIS STUDY

MEANS OF PROVIDING INFORMATION	PERCENTAGE OF RESPONDENTS IN FAVOUR
Mail outs to residents in the study area	70%
Articles in the local newspaper	36%
Council's web site	30%
Public Meetings	20%
Open days or drop-in days	15%
Through the Floodplain Management Committee	11%
Community Workshops	9%
At formal Council meetings	8%
Other	5%

Part F — Questions for Businesses and Organisations Only

The last part of the community survey was directed at businesses and organisations. Only 10% of respondents completed this section of the survey. Of the businesses in the floodplain, about one-third involved agricultural activities and one-quarter involved a home-based business. At all but one business, there are less than five employees.

The second portion of the business part of the survey involved only those businesses that had experienced a flood at their business. Only 25% of the businesses that responded to the survey had experienced a flood and of these, there had been none that were flooded above the floor level of work areas and no flood damage or related problems were sustained.

5.3 LIAISON WITH STAKEHOLDERS

In November 2003, fifty-five stakeholder surveys (including an introductory letter and the community newsletter described in **Section 5.2.1**) were sent to a range of government agencies, various utility and community service authorities, industries and other groups that may have an interest or assets located within the study area. These interests or assets were not necessarily located in the study area floodplain. A copy of the introductory letter and survey has been included as **Appendix J**.

The Stakeholder Survey for Agencies, Authorities and Interest Groups was divided into the following five parts:

- Part A: — Contact Details;
- Part B: — Potential Flood Damage to Property, Assets or Services;
- Part C: — Possible Future Works Close to the Creek;
- Part D: — Relevant Reports, Studies and Designs;
- Part E: — Comments and More Information.

Table 5.5 lists the stakeholders who were sent the survey and those who returned a completed response. Where key issues were raised on a particular survey, these have been noted in **Table 5.5** and presented in the sections below. A detailed list of all stakeholders including contact details has been provided separately to Council.

5.3.1 NSW Department of Infrastructure, Planning and Natural Resources

The Department of Infrastructure, Planning and Natural Resources (DIPNR) was created following the NSW State Elections in March 2003 and comprises large portions of the former Department of Land and Water Conservation and Planning NSW, together with some parts of the Department of Transport. As DIPNR is such a large department, separate surveys were sent to five different sections.

A meeting was held in mid-December 2003 between the Sydney Flood Group and the Managing Sydney's Urban Growth Team to discuss the implications of the future South West Urban Release Area on the study. A combined response was received from DIPNR's Managing Sydney's Urban Growth Team dated 16 December 2003. Key issues raised in this letter are quoted as follows:

- *"Government recently investigated the future urban potential in the South West of Sydney, including the area identified in your 'South Creek Floodplain Risk Management Study'. The workshop findings are expected to be available for public comment in early February 2004. A preferred plan, including staging and timing provisions would not be endorsed by Government until after the consultation period.*

  Initial findings suggest urban development around your floodplain study area is unlikely to occur within a 10–15 year period. DIPNR has no objection to Council progressing the Study provided flood-related works do not preclude any future urban development on adjoining non-flood-affected lands.

  The Department will continue to provide technical assistance and advice to Council on floodplain risk management matters, and the development of the Structure Plans through its representation on Council's Floodplain Risk Management Committee."

TABLE 5.5: LIST OF STAKEHOLDERS AND RESPONSE RECEIVED FROM STAKEHOLDER SURVEY

STAKEHOLDER (TO WHOM SURVEY WAS SENT)	COMPLETED SURVEY RETURNED	SUMMARY OF RESPONSE FROM SURVEY	REPORT SECTION SUMMARISING KEY ISSUES RAISED
MAIN AGENCIES			
Department of Infrastructure Planning & Natural Resources (formerly Department of Land and Water Conservation, Planning NSW and part of Department of Transport) — (5 surveys)	YES	DIPNR combined response in letter from Andrew Abbey dated 16/12/03, signed by Steve Brown (Director — Managing Sydney's Urban Growth)	Section 5.3.1
Department of Environment and Conservation (formerly Environment Protection Authority)	YES	Part A: Contact Details completed and returned 05/12/03	—
Sydney Water Corporation Limited	NO		—
NSW Fisheries	YES	Part A: Contact Details and Part E: Comments completed and returned mid-December 2003	Section 5.3.2
NSW National Parks and Wildlife Service	NO		—
Roads and Traffic Authority	NO		—
State Emergency Service — (3 surveys)	YES	Completed survey received 10/12/03. One report noted, comments included and draft brief attached for specific information to be included in future Floodplain Risk Management Studies for the SES This information has been incorporated in **Section 9.2**.	Section 5.3.3
Bureau of Meteorology	YES	Completed survey received early Dec 2003. One report noted and comments provided. Also detailed phone call 02/12/03 outlining Flood Warning situation and options for the catchment. This information has been incorporated in **Section 9.1**.	Section 5.3.4
NSW Aboriginal Land Council	NO		—
Gandangara Local Aboriginal Council	NO		—
Energy Australia	YES	Survey returned but not completed 05/12/03 with note stating that Energy Australia has no properties in the study area.	—
Integral Energy	NO		—
Telstra	YES	Parts A: Contact Details and Part B: Potential Flood Damage returned via email 15/12/03. Noted that Telstra owned 'Bringelly Radio Receiving Station' is administered by United KFPW on behalf of Telstra. Also noted that copies of Telstra external plant records plans can be obtained from the 1100 'Dial-before-you-dig' service.	Section 5.3.5
Optus	NO		—
NSW Heritage Office	NO		—

STAKEHOLDER (TO WHOM SURVEY WAS SENT)	COMPLETED SURVEY RETURNED	SUMMARY OF RESPONSE FROM SURVEY	REPORT SECTION SUMMARISING KEY ISSUES RAISED
Agility Management Pty Ltd (asset arm of AGL Gas Networks)	YES	Agility Management is a wholly owned subsidiary of AGL (Australian Gas Light Company). Covering letter and plans of gas mains in the study area were received on 08/01/04. Two secondary gas mains (1,050kPa) are located within the South Creek floodplain.	Section 5.3.6
Department of Education & Training	NO		—
Department of Mineral Resources (now part of Department of Primary Industries)	YES	Completed survey received 23/12/03. Interested in being kept informed about the study because any underground coal mining in the future may cause some subsidence and may affect 100 year flood levels.	Section 5.3.7
Department of Housing	NO		—
Transgrid	YES	Completed survey received 08/01/04. Transgrid has no property or assets in the study area. However, the Kemps Creek 500/330kV substation is located about 500m to the east of Kemps Creek near the corner of Gurner Avenue and Fourth Avenue, Austral	Section 5.3.8
Department of Commerce	NO		—
COUNCILS			
Camden Council	NO		—
Penrith City Council	NO		—
Blacktown City Council	NO		—
Hawkesbury City Council	YES	Completed survey received by fax 19/12/03. Main concerns by Hawkesbury City Council are the impacts of any measures recommended in the current study area, on downstream areas of South Creek. Requested that they be included in the review of the outcomes of the current study.	—
WSROC	NO		—
CHAMBERS OF COMMERCE			
City of Liverpool Chamber of Commerce	NO		—
SCHOOLS			
Kemps Creek Public School	YES	Completed survey received early December 2003. Survey noted that if school buildings were inundated then $60,000 worth of carpets would have to be replaced. About 200 children would be unable to come to school for at least 2 weeks. It should be noted that the school is located well above the level of the PMF from South Creek.	—
Bringelly Public School			
INDUSTRY			
Boral Bricks (NSW) Pty Ltd	YES	Completed survey received 16/12/03. Survey notes that South Creek is only at the very lowest part of the property.	—
Eina Pty Ltd	NO		—

STAKEHOLDER (TO WHOM SURVEY WAS SENT)	COMPLETED SURVEY RETURNED	SUMMARY OF RESPONSE FROM SURVEY	REPORT SECTION SUMMARISING KEY ISSUES RAISED
4 Brothers (NSW) Pty Ltd	NO		—
Russian Sports Association	YES	Completed survey received early December 2003. Survey describes possible damage to property at 82, 84 and 86 Watts Road, which is likely to be inundated in a 100 year flood. There is a request for more information about flooding, including the best way to 'flood-proof' the property	Section 5.3.9
Invelda Pty Ltd	NO		—
Urmar Pty Ltd	NO		—
Novartis Animal Health Australasia Pty Ltd	NO		—
Australian Native Landscapes	NO		—
T Milford Pty Ltd	NO		—
Peter Medich Props Pty Ltd	NO		—
Ciba Research Centre	NO		—
Roladuct Spiral Tubing Pty. Ltd	NO		—
FIRE BRIGADE			
Bush Fire Brigade	NO		—
PLACES OF WORSHIP			
Holy Innocents Church	NO		—
Aust. Buddhist Association	NO		—
LOCAL COMMUNITY GROUPS			
Badgerys Creek Progress Association	NO		—
Outer Liverpool Community Services	NO		—
People Against Australian Native Landscapes	YES	Completed survey received mid-December 2003. Survey notes that there is no possibility that the property could be affected by any flooding, as it is high and a long way from South Creek and Thompson's Creek.	—
Greenhouse Action Program	NO		—
COMMITTEES ETC			
Hawkesbury–Nepean Local Government Advisory Group	NO		—

5.3.2 NSW Fisheries

The following comments were provided on the stakeholder survey:

- *"NSW Fisheries would not support hard engineering works designed to increase flow velocities in the creek. This includes: channelisation, removal of large woody debris, isolation of undeveloped floodplains with levee banks, removal of instream and riparian vegetation, channel widening or on-line detention basins".*

5.3.3 NSW State Emergency Service

A completed stakeholder survey was received on 10 December 2003 from Steve Opper, SES State Planning Coordinator. The SES notes that roads, as the main escape routes from residential areas during evacuation, are a key service that could be affected by floodwaters. It is critical that the SES know at what height and when particular roads would be closed by floodwaters. There is a definite link between flood warning and mitigation against the impacts of floods.

The SES is interested in proposals for new urban areas, particularly those built on floodplains below the level of the probable maximum flood (PMF), to assess any potential implications there may be for possible evacuations during large flood events.

The survey also notes that the SES is currently working on a revised Liverpool City Local Flood Plan (SES, 2001). The Liverpool City Local Flood Plan is discussed in detail in **Section 9.2.1**.

A draft brief currently being developed between the SES and DIPNR was also attached to the completed survey to be included in future floodplain risk management studies in NSW. The brief notes the importance of a review of the Local Flood Plan and the provision of flood intelligence to the SES as part of these types of studies to ensure the needs of the SES are met.

Issues relating to emergency management in the study area are discussed in **Section 9.2**.

5.3.4 Commonwealth Bureau of Meteorology

A completed stakeholder survey was returned in early December 2003 by Gordon Mackay (Manager, NSW Flood Warning Centre) with comments provided as follows:

- *"Bureau of Meteorology has four real-time radio telemetered rain gauges in the South Creek catchment. There is also a real-time river gauge about half way along the creek. We have not yet been approached to help set up a Flash Flood, or other flood warning system for South Creek".*

The completed survey also notes a relevant published report as being prepared by GHD in December 1980 for the then Public Works Department entitled 'Hawkesbury Valley Floodplain Management Study'. The report has not been reviewed as part of this study but has been listed in the Bibliography for possible future reference.

In addition, a detailed phone conversation was held with Gordon Mackay during December 2003 to discuss the flood warning situation and possible options for flood warning for the catchment and study area. The outcomes of this conversation have been incorporated in the discussion of flood warning in **Section 9.1**.

5.3.5 Telstra

Responses were received from two sections of Telstra, namely Access Planning and Telstra Mobiles.

The Access Planning Group notes that the study area is serviced from four exchanges: Bringelly, Austral, Kemps Creek and Leppington.

The majority of Telstra's assets consist of conduits, pits, manholes, underground copper cable, optical fibre cable, pillars, poles and aerial cables. These are generally located along all footpaths and under roads and on bridges at numerous locations. "*Stationary water should not affect operation of this asset. Fast flowing water can 'suck' the pit and manhole covers off, leaving exposed jointing chambers, which would present a hazard for pedestrians and vehicles. … Telstra is more likely to incur damage as a result of wind and flying debris. This damage would (only) affect the aerial network*".

There is a Remote Customer Multiplexer (the Leppington Exchange) located in Bringelly Road, Rossmore, opposite Allenby Road. This is well above the level of the probable maximum flood (PMF) of South Creek. If water was to enter this asset, electrical equipment would be damaged and the cost to repair would be in the order of $135,000. This would result in about 200 homes in the Bringelly area being without service over the cable network for about 2 months.

There is also a Remote Integrated Multiplexer located at the corner of Western Road and Elizabeth Drive, Kemps Creek. Again, this is well above the level of the probable maximum flood (PMF) of South Creek. If water was to enter this asset, electrical equipment would be damaged and the cost to repair would be in the order of $200,000. This would result in about 400 homes being without service over the cable network for about 2 months.

The Telstra Mobiles Group notes four mobile base stations that service the study area. None of these base stations is located in the study area.

5.3.6 Agility Management Pty Ltd

Agility Management Pty Ltd is a wholly owned subsidiary of AGL (Australian Gas Light Company), established in June 2000. Agility manages and operates the high pressure and gas distribution networks in NSW. It is responsible for metering, repairs and maintenance together with project management activities including design, approvals and construction of infrastructure.

A covering letter and plans of gas mains in the study area were received. Two secondary gas mains (1,050kPa) are located within the South Creek floodplain and could be damaged by floodwaters. The only mains larger than a secondary main are a trunk main (7,000kPa) and a primary main (3,500kPa). One of the secondary mains is a

200mm diameter steel main located on the south side of Bringelly Road at its crossing of South Creek. The other is a 150mm diameter steel main located on the northern side of Elizabeth Drive at its crossing of South Creek.

5.3.7 NSW Department of Mineral Resources

The following comments were provided by the then NSW Department of Mineral Resources (now incorporated into the NSW Department of Primary Industries) on the returned stakeholder survey:

- *"Liverpool LGA is underlain by coal bearing strata and potentially minerable coal resources. These resources are distant from existing operations, are poorly explored and are known to occur under deep cover. They may, however, be of interest in the longer term. Should an underground operation be established in the vicinity of South Creek in the future, the resultant subsidence would have the potential to change the 1% flood line. This therefore has resource recovery implications and the Department would wish to be involved in the consultation process of the Risk Management Study."*

5.3.8 Transgrid

The returned survey noted that:

"*Transgrid has no property or assets in the study area. However, the Kemps Creek 500/330kV substation is located about 500m to the east of Kemps Creek near the corner of Gurner Avenue and Fourth Avenue, Austral. Damage to control systems would occur if the substation were inundated by more than 0.5m. This damage would cost approximately $6 million and take up to 6 weeks to repair. This would interrupt power supplies to a wide area around the substation, outside flooded areas. The RL of the site is in the order of 65m, with the main control buildings having an RL of 68m."*

The survey noted that sandbagging may be a means to protect the substation from inundation.

5.3.9 Russian Sports Association

The Russian Sports Association owns an indoor sports stadium (with a wooden floor) and two adjacent houses at 82–86 Watts Road, Kemps Creek. Results from the flood damages data base indicate that:

- ground levels around these buildings would be about 0.3m above the level of the 100 year flood;
- the floor level of the stadium would be about 0.3m above the level of the 100 year flood;
- the floor levels of the houses would be about 0.5m above the level of the 100 year flood;
- all buildings on the site would be flooded by more than 1.2m in a probable maximum flood.

The survey notes that "*the floor (of the stadium) will warp if in great contact with water. (There would be) $120,000 of damage to 945m^2 of flooring (and the) stadium could not be used for sports and social events for 2–3 months. (Also the) interior of the houses will be damaged by water eg. carpet, floor etc. (There would be) about $50,000 of damage (and the) houses may be unsuitable to live in for tenants for 1–2 months*".

It is noted that, at present, this damage could not be reduced if there was adequate warning time before the flood. Hence, the survey requests that more information on flood impacts be provided, particularly "*advice on how to mitigate the interior of the association's buildings from floods i.e. water proofing doors, sand bagging, etc*".

5.4 WEB SITE

An internet web site was developed as part of the community consultation strategy for this study. This provided another medium for the community to become involved in the study and also provides a means by which they can forward their views directly to the study team.

The web site can be viewed via the Bewsher Consulting web site (www.bewsher.com.au) or directly at www.bewsher.com.au/southck/sthck-1.htm. The web site address was included on all correspondence to residents and stakeholders and is also linked to the Liverpool City Council's web site and the Bewsher Consulting home page.

The web site provides some background to the study together with some photographs of the study area. During the community survey phase of the study in late 2003, links were provided to view and/or download copies of the community newsletter (**Section 5.2.1**), the community survey (**Section 5.2.2**) and a map of the study area. During the public exhibition (see **Section 5.6**), links were provided to view and/or download copies of the Draft Report, the Executive Summary and the exhibition poster. There is also a facility within the web site where feedback can be sent directly to Council and the study team.

Following adoption by Council, a copy of the Final Report and recommended *South Creek Floodplain Risk Management Plan* will be made available on Council's web site.

5.5 COMMUNITY WORKSHOP

In the evening of 23 March 2004, a community workshop was held at Bringelly Community Centre to:

- provide the local community with an overview of the study, including some background information on the floodplain management process and the roles of agencies and organisations;
- provide the local community with the preliminary results and recommendations of the study;
- provide the study team with a means to obtain feedback from the local community before the recommended draft *Floodplain Risk Management Plan* was presented to the Liverpool Floodplain Management Committee.

To advertise the community workshop, an invitation flyer was sent to all the owners of properties in the flood damages data base (see **Section 3.5**), which included all those people who had received a community survey in October 2003. An invitation flyer was also sent to all the stakeholders who had received a stakeholder survey in November 2003. Council also placed advertisements in the local press.

The community workshop was well supported, with approximately 30 people attending. Other than representatives from Liverpool City Council and the study team, representatives from DIPNR, SES and Penrith City Council were also present. Most attendees listed their names on an attendance register.

The majority of the issues raised were either dealt with successfully at the workshop or have been incorporated in the discussions on floodplain risk management options in **Chapters 6 to 10** of this report.

The following materials were available to take home from the community workshop:

- a brochure on 'Frequently Asked Questions on Floodplain Risk Management Studies', a copy of which is provided as **Appendix K**;
- a copy of the October 2003 Newsletter (see **Section 5.2.1**);
- a number of community flood awareness brochures produced by the SES;
- a feedback form, with space for additional comments to be provided if necessary — no completed feedback forms were returned to the study team.

5.6 PUBLIC EXHIBITION OF THE STUDY

To provide the wider community with an opportunity to comment on the draft plan proposals, the final stage of community consultation for this study was the public exhibition of the draft *South Creek Floodplain Risk Management Study and Plan for the Liverpool LGA*.

Following a recommendation by the Floodplain Management Committee in May 2004, a report was presented to Council in July 2004, recommending that the draft Study Report and Plan be placed on public exhibition. Council resolved that this recommendation be adopted.

Public displays of the Draft Study Report and Plan were subsequently placed at Council's Administration Centre, Council's Customer Service Centre, Liverpool City Library and the Austral Bowling Club between 21 July and 22 September 2004 (a period of 64 days).

At each of the display centres, a poster summarising the study background, findings and recommendations of the study was exhibited. A copy of the draft Study Report and Plan was also available for perusal at each centre, together with copies of the Executive Summary that could be taken home by visitors.

Advertisements for the public exhibition were placed in the local press (Liverpool Champion and Liverpool Leader) on 21 July, 4 August and 25 August 2004. In addition, residents who attended the community workshop were personally notified of the exhibition by a letter from Council.

Copies of the draft Study Report and Plan were also sent to the following people and/or organisations for review:

- members of the Liverpool Council Floodplain Management Committee;
- relevant Council staff;
- all schools and businesses in the study area;
- an extensive list of government agencies and organisations from the stakeholders list (see **Section 5.3**);
- the six neighbouring Councils to Liverpool (Bankstown, Blacktown, Camden, Fairfield, Hawkesbury and Penrith);
- other stakeholders with an interest in the local area.

Written submissions were received from Liverpool City Council staff, the Sydney Flood Group of DIPNR and from the NSW Department of Primary Industries (which now incorporates the NSW Department of Mineral Resources). A copy of these submissions together with a summary of how each issue raised has been incorporated and addressed in this final version of the Report and Plan is presented in **Appendix L**.

All submissions received were considered in the modification of the June 2004 draft Study Report and Plan to produce this final version (December 2004) of the *South Creek Floodplain Risk Management Study* and recommended *Floodplain Risk Management Plan.*

It is important to note that the study has only undergone minor modification as a result of the comments received during the exhibition period, with no changes to the overall intent of the study.

Following the public exhibition and the incorporation of comments, this final version of the *South Creek Floodplain Risk Management Study* and recommended *Floodplain Risk Management Plan* was presented to the Floodplain Management Committee in November 2004 for the Committee's formal recommendation that Council adopt the Study and Plan.

The final stage of the project was then the formal adoption of the Study and Plan by Council in December 2004.

6. OVERVIEW OF FLOODPLAIN RISK MANAGEMENT MEASURES

Chapters 6 to 11 of this report provide details of the floodplain risk management options that have been examined for the study area, as follows:

- an overview of floodplain risk management measures, as outlined in the NSW Government's *Floodplain Management Manual* (2001) (the *2001 Manual*), is presented in this chapter. This includes the selection of a Flood Planning Level, the criteria for assessment of floodplain risk management options and environmental considerations relevant to the study area;

- a summary of the floodplain risk management options examined as part of this study is provided in **Chapter 7**;

- a detailed discussion of the floodplain risk management options examined as part of this study is presented in the following three chapters, namely:

  - **Chapter 8** — property modification measures, such as planning controls, voluntary purchase of properties, house raising and flood proofing;

  - **Chapter 9** — response modification measures, such as flood warning, emergency management and community flood awareness;

  - **Chapter 10** — flood modification measures, such as detention basins, enlargement of waterway areas under bridges, levees, channel widening and the construction of floodways;

- the recommended *South Creek Floodplain Risk Management Plan (for the Liverpool LGA)* is presented in **Chapter 11.**

One of the primary aims of the NSW Government's *Floodplain Management Manual* (2001) (the *2001 Manual*) is to foster the following floodplain risk management principles:

- "to reduce the social and financial costs that result from the risks of occupying the floodplain;

- to increase the sustainable social, economic, and ecological benefits of using the floodplain;

- to improve or maintain the diversity and well-being of native riverine and floodplain ecosystems."

An integral component of the floodplain risk management process is the selection of one, or where applicable, a number of, flood planning levels. Flood planning levels are used to determine the extent of land that is subject to flood-related development controls and are discussed in **Section 6.1**.

In order to follow the floodplain risk management principles of the *2001 Manual*, the Manual provides the following broad hierarchy of floodplain risk management measures that should be considered:

- avoidance of the flood risk;
- minimisation of the flood risk using appropriate planning controls;
- mitigation of the flood risk — this is considered to be the least preferred option in the *2001 Manual*, as it is often costly and is most likely to adversely affect the natural environment.

Using this hierarchy of measures, the *Floodplain Management Manual* divides ways to manage the flood risk into three groups in the following order of importance (**Section 6.2**):

- those that modify property in order to minimise flood damage (**Section 6.2.1**);
- those that modify people's response to flooding (**Section 6.2.2**);
- those that modify flood behaviour (**Section 6.2.3**).

The criteria used in this study to assess the various floodplain risk management measures are described in **Section 6.3**. Some environmental considerations and recommendations relating to the examination of flood modification options or 'structural flood mitigation options' in the study area are discussed in **Section 6.4**.

6.1 SELECTION OF FLOOD PLANNING LEVEL

An integral component of the floodplain risk management process is the selection of one, or where applicable, a number of, flood planning levels.

The flood planning level (FPL), previously known as the 'designated flood level' or 'flood standard', is the flood level selected for planning purposes, and will directly determine the area of land that should be subject to flood-related building and development controls.

Selection of the flood planning level is one of the most critical decisions in floodplain management, and is not an easy one. It should be based on an understanding of the flood behaviour, together with the balancing of social, economic and ecological issues, including the potential for property damage and the risk to human life. Traditionally, only one flood planning level has been selected for a particular area, but current thinking is to now consider more than one flood planning level for different types of developments or locations within the floodplain.

The adoption of a singular flood planning level may be unduly restrictive for some types of land uses. For example, whilst it may be appropriate for some land uses, such as a hospital, to be located above the level of a probable maximum flood (PMF), it could be argued that residential, industrial or recreational land uses do not require such restrictive control.

In addition, the adoption of a single flood planning level causes misconceptions by the community regarding flood risk. Most importantly, residents within the floodplain (i.e. the area below the PMF), but above the flood planning level, often mistakenly believe they are not at risk from flooding.

To overcome the shortcomings of a singular flood planning level, a 'graded' set of controls, which consider the variation of risk of damage with flood frequency and land use, have been proposed for the South Creek study area. These are contained in the 'Planning Matrix' approach, which is discussed in detail in **Volume 2** of this report entitled 'Planning Issues' (Don Fox Planning, 2004) and summarised in this report in **Section 8.1**.

The planning matrix approach does not rely on the definition of a singular flood planning level. Rather, the approach makes use of a range of flood planning levels for various land uses within the flood-affected land below the level of the probable maximum flood, such as controls on floor levels, flood compatible materials and evacuation.

Within the planning matrix, the selection of the controls and the various flood conditions at which the controls apply, has been based on:

- the procedures and philosophy espoused in the *2001 Manual*;
- consideration of the social, economic and environmental impacts of flooding and the proposed controls;
- investigations carried out within the current study;
- community attitudes expressed during the current study;
- minimising Council's exposure to legal actions in relation to flooding;
- Council's previous development policies;
- experience gained from the development of planning controls and flood policies for various communities across NSW in recent years.

As discussed in **Volume 2**, Planning Issues, the 100 year flood level has been retained as the principal floor level control for residential land uses in the study area. This is an important component of the proposed planning controls, the decision being based on the following considerations:

- the unacceptable increase in flood risks and damages, should a lower level be adopted;
- an unacceptable impost on future development, if a higher level was adopted;
- a review of the consequences of floods between the 100 year flood and the PMF;
- inconsistencies with recent development approvals if a level different from the 100 year flood was adopted;

- recognition that the community generally views the control on residential floor levels as the principal component of the Council floodplain controls, and that changes to this control should not be made unless very strong arguments exist.

6.2 RANGE OF AVAILABLE FLOODPLAIN RISK MANAGEMENT MEASURES

The *Floodplain Management Manual* divides ways to manage the flood risk into three groups in the following order of importance:

- ***property modification measures*** — these measures were included as 'non-structural' measures in the *Floodplain Development Manual* (NSW Government, 1986);

- ***response modification measures*** — these measures were also included as 'non-structural' measures in the *Floodplain Development Manual*;

- ***flood modification measures*** — these measures were formerly referred to as 'structural' measures in the *Floodplain Development Manual*.

6.2.1 Property Modification Measures

Property modification measures refer to the following:

- modifications to existing development such as voluntary purchase of properties, house raising or flood proofing;

- planning and development controls on future development of property and community infrastructure.

Whilst the options to modify existing development are expensive and generally less favoured by the community, controls on future development can be implemented for minimal cost and would ensure that the potential for flood damage does not increase in the future.

6.2.2 Response Modification Measures

Measures that modify people's response to flooding include measures that provide additional warning of flooding, improvements to emergency management measures during floods and improved public awareness of the flood risk. All these measures were well supported by the community in the community survey.

6.2.3 Flood Modification Measures

Measures that modify flood behaviour usually include structural or engineering works that attempt to lower flood levels, or to divert floodwaters away from areas that would otherwise flood. Examples include dams, retarding basins, levee banks, bridge enlargements and modifications to the watercourse to improve its ability to convey floodwaters.

These types of options are generally very expensive and often have high environmental impacts. They are therefore generally subject to detailed environmental and ecological assessment in accordance with the relevant environmental protection legislation (see **Section 6.4**).

6.3 CRITERIA FOR THE ASSESSMENT OF FLOODPLAIN RISK MANAGEMENT MEASURES

In evaluating potential floodplain management measures for the South Creek study area, a range of assessment criteria has been developed for use in this study. This assessment procedure was outlined during the course of the study and presented to the Floodplain Management Committee. The Committee considered the criteria and procedure to be appropriate for use in this study.

For each criterion, a qualitative assessment has been undertaken for each floodplain risk management option. **Table 6.1** provides the scores used for each criterion for this qualitative assessment.

Each of the criteria in the qualitative assessment is described in this section.

6.3.1 Number of Houses Protected from Flooding Above Flood Level in the 100 Year Flood

Measures that reduce the number of buildings that are affected by significant floods are a prime indicator of the effectiveness of the measure in reducing the potential for flood damage and the risk to life. In this study, the reduction in the number of existing buildings that would be flooded above floor level in a 100 year flood is considered.

6.3.2 Financial Feasibility

Measures proposed in the *Floodplain Risk Management Plan*, must be capable of being funded from an available funding source.

These funding sources include:

- funding from Liverpool City Council, with assistance from the Government's Floodplain Management Program administered by the Department of Infrastructure, Planning and Natural Resources (DIPNR) (formerly the Department of Land and Water Conservation (DLWC)). The Government's Floodplain Management Program generally provides two-thirds of the capital cost of measures that address existing flood problems. The Floodplain Management Program does not provide funding for avoidance of future flood risks arising from new development;

- funding related to new development that may increase the future risk (Section 94 Contributions).

TABLE 6.1: EXPLANATION OF ASSESSMENT SCORES FOR QUALITATIVE ASSESSMENT MATRIX

CRITERIA	RANKING SCORE				
	– –	–	O	+	+ +
REDUCTION IN NUMBER OF HOUSES FLOODED ABOVE FLOOR LEVEL IN 100 YEAR FLOOD	number of houses flooded above floor in 100 year flood would increase	number of houses flooded above floor in 100 year flood could increase	no existing houses protected from over-floor flooding in 100 year flood	1 or 2 existing houses protected from over-floor flooding in 100 year flood	more than 2 existing houses protected from over-floor flooding in 100 year 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 in community survey and community workshop	Not supported in community survey and community workshop	Neutral	Supported in community survey and community workshop	Strongly supported in community survey and community workshop
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

6.3.3 Economic Merit

As described in **Section 4.6.2**, the benefit–cost ratio is a common measure of assessing economic merit. Theoretically, a measure should only be recommended if the benefit–cost ratio exceeds 1.0 (i.e. the benefits exceed the costs). However, traditionally many floodplain management measures have been undertaken where the benefit–cost ratio is less than 1.0, because of social and other intangible benefits.

As recommended by the *2001 Manual*, whilst 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. Benefit–cost ratios can, however, be useful in ranking competing options.

6.3.4 Community Acceptance

Assessment of possible community attitudes towards any proposed floodplain management measures is essential. If community attitudes are strongly negative, this may be often enough to deter the implementation of the proposals which otherwise may have significant merit. Community views on potential floodplain management measures were obtained early in the study through distribution of the community survey (see **Section 5.2.2**) and later in the study at the Community Workshop (see **Section 5.5**).

6.3.5 Environmental Impact and Ecological Enhancement

Floodplain risk management measures involving structural works may often have significant environmental impacts. Impacts on terrestrial and aquatic habitats, vegetation, visual amenity and soil erosion/sedimentation, are issues that must be addressed when evaluating works within the floodplain. Conversely, the measure may provide opportunities for environmental enhancement. It is important that opportunities for ecologically sustainable development (ESD) be considered within the floodplain management planning process.

Some environmental considerations and recommendations relating to the examination of flood modification options or 'structural flood mitigation options' in the study area are discussed in **Section 2.4**.

6.3.6 Impact on Flood Behaviour

The impact on flood behaviour caused by any measure needs to be considered at both upstream and downstream locations. These impacts can include such things as changes in flood levels, changes in velocities or alteration of flow directions.

6.3.7 Performance during Large Floods

All measures must be assessed acknowledging that floods larger than the 100 year flood, or larger than any known historical flood, can occur. It is therefore imperative that the options do not expose the community to unacceptable risks by providing a false sense of security should a large flood occur.

6.3.8 Technical Feasibility

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

6.3.9 Political/Administrative Impact

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.

For example, one potential 'political impact' could be a floodplain risk management measure that impacts on the development expectations of the South West Urban Release Area, of which the current study area is a part. As discussed in **Section 5.3.1**, the response provided in the Stakeholder Survey from the 'Managing Sydney's Urban Growth Team' noted that *"initial findings suggest urban development around your floodplain study area is unlikely to occur within a 10–15 year period. DIPNR has no objection to Council progressing the Study provided flood-related works do not preclude any future urban development on adjoining non-flood-affected lands".*

6.4 ENVIRONMENTAL CONSIDERATIONS

Following the major floods of the 1980s and the *1991 South Creek Floodplain Management Study* (Willing and Partners, 1991) (the *1991 FPM Study*), the Overett Avenue area, just upstream of Elizabeth Drive, and the Victor Avenue area about 3km upstream of Elizabeth Drive, were identified as the main flood problem areas of South Creek in the Liverpool LGA.

A detailed study was undertaken in 1994 to examine flood mitigation options for both these areas in detail (Kinhill Engineers, 1994a), entitled *'Overett and Victor Avenues, Kemps Creek. Flood Management Study. Final Report*' (referred to as the *1994 Kinhill Study*). These options are discussed in more detail in **Sections 10.1** and **10.2**.

As part of the investigations for the flood mitigation works at Overett Avenue and Victor Avenue, a Review of Environmental Factors (REF) (Kinhill, 1994b) (the *1994 REF*) was undertaken to examine the likely environmental constraints in the area of the two recommended design options. The report was entitled '*Review of Environmental Factors. Proposed Flood Mitigation Works for South Creek*'.

6.4.1 Flora, Fauna and Vegetation Communities

As part of the *1994 REF*, a site survey of the area was conducted to identify the presence of flora species with particular reference to rare, protected or regionally significant species. This included a visual assessment and consultation of a range of literature relevant to the flora of the region.

Also, as part of the *1994 REF*, a site survey was conducted to identify the presence of fauna species, including aural identification, hand capturing, scat and track identification and other signs of animal habitation. Again, a range of literature was consulted.

The *1994 REF* concluded, *"the impacts of the natural environment as a result of the proposed works were found to be minimal. … The results of the flora survey found there to be a minimal impact of vegetation. There were no rare or threatened flora species identified in the Overett Avenue and Victor Avenue. There are no endangered terrestrial or aquatic fauna species likely to occur in the region."*

However, the report does note that the works would have impacted on areas of vegetation of regional significance to Western Sydney.

Figure 6.1 shows the location of the important pockets of vegetation near Overett Avenue and Victor Avenue identified as part of the *1994 REF*. The *1994 REF* categorises the vegetation communities along South Creek into three broad natural communities:

- Riparian Woodland;
- Eucalypt Woodland;
- aquatic and semi-aquatic vegetation.

The *1994 REF* notes that the:

> "*riparian woodland community adjoins the banks of the creek, occasionally widening to cover more significant areas where there is low lying ground. The community is dominated by Swamp Oak (Casuarina glauca) with scattered other species. … Virtually all of South Creek adjacent to the proposed works for the Victor Avenue area, has a fringe of Swamp Oaks that occasionally spreads away from the stream by 50m or more. Some of the trees are notably old and there is a reasonable proportion of native species in the understorey in places. There are also a number of original trees that have been left.*
>
> *Swamp Oak (Casuarina glauca) is conserved in Western Sydney, although riparian vegetation generally has conservation value as refuge or habitat for fauna, landscape values, bank stabilisation and water quality. It is therefore important that this habitat be maintained.*
>
> *Areas where the proposed works should most avoid are those areas, which have retained some native character in their subsidiary species or contain old trees. These include an area near the southern end of the proposed works at Overett Avenue and several patches in the vicinity of Victor Avenue, two of significant size. Although the study area is largely regrowth and is relatively low in species, the larger areas north of Elizabeth Drive, along part of the line of the proposed levee at Overett Avenue and the two larger blocks in the Victor Avenue area are in better condition and of some conservation value in the Western Sydney region."*

6.4.2 Aboriginal Archaeology

An important part of the *1994 REF*, was an investigation into the identification of aboriginal archaeological sites that may be affected by the proposed flood mitigation works.

FIGURE 6.1: SIGNIFICANT VEGETATION AND SENSITIVE ARCHAEOLOGICAL SITES

A3 Colour

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A search was made of the NSW National Parks and Wildlife Service archaeological sites register. Two "*extensive and scientifically important*" sites were identified close to the proposed flood mitigation works — one just to the north of Elizabeth Drive on the eastern side of South Creek (ID No. 45-5-496) and one within the Novartis Animal Health land at the northern end of the proposed Victor Avenue works, also on the eastern side of South Creek (ID No.45-5-213).

Following the identification of these two sites, a ground reconnaissance inspection was carried out to determine the likelihood of locating surface archaeological sites and to identify archaeological land units.

During this inspection, an open archaeological site comprising a scatter of stone artefacts was observed in a drain located near Nos. 80 and 82 Victor Avenue and leading into the Novartis Animal Health site, close to South Creek. *"A range of raw materials similar to those found in other sites on the Cumberland Plain was present, and the site is similar to other open campsites in the region."* It was concluded that the site was comparable to the other two sites already registered in the study area and immediately adjacent to the study area.

The *1994 REF* concluded that the:

> *"preliminary investigation has indicated that prehistoric Aboriginal archaeological sites occur within the broader area of the proposed flood mitigation works and may occur in areas which will be disturbed by these works. Further archaeological investigations are therefore recommended for some specific areas of proposed disturbance".*

Four areas were recommended for further archaeological investigation as archaeologically sensitive areas, and are shown on **Figure 6.1**.

> *"The Aboriginal community has not yet been involved in the review of environmental factors, and has not been asked to comment on the significance to them of the archaeological sites in the area. This will be essential before any archaeological investigations are commenced. … It will be necessary for the archaeologists … to contact the Gandangara Local Aboriginal Land Council …".*

It should be noted that the Gandangara Local Aboriginal Council was sent a Stakeholder Survey in November 2003 as part of the current study. However, no response was received.

6.4.3 Conclusions on Environmental Considerations

It was concluded in the *1994 REF* at the time that the environmental impacts of the proposed flood mitigation works at Overett Avenue and Victor Avenue would be too high to allow them to proceed in their current form. As a consequence, the Victor Avenue works were shelved altogether and the Overett Avenue works were significantly scaled down from those originally proposed.

The conclusions reached in the *1994 REF* are still (and even more) applicable for the current Floodplain Risk Management Study and Plan. Therefore, it has been concluded in the current study that the environmental impacts of large-scale channel works, floodways and the necessary compensatory works associated with the construction of levees, would be significant, and Council or DIPNR would not support these types of works. This is described in more detail in **Chapter 10**.

It can also be concluded from the *1994 REF* that any stream clearing works undertaken by Council would be subject to strict environmental controls to ensure the integrity of the riparian corridor is maintained and there are no adverse impacts on vegetation communities of regional significance to Western Sydney (see **Section 10.3.5**).

7. SUMMARY OF FLOODPLAIN RISK MANAGEMENT OPTIONS FOR STUDY AREA

This chapter summarises all the potential floodplain risk management options that have been considered for the South Creek study area.

Figure 7.1 provides a map of the study area, showing each of the options considered, while **Figure 7.2** shows a more detailed map of the options considered for the Overett Avenue area. A listing of all the options is presented in **Table 7.1**. **Figures 7.1** and **7.2**, together with **Table 7.1,** show those options that have been recommended for inclusion in the *Floodplain Risk Management Plan.*

Each of the options considered was assessed on the basis of the various criteria outlined in **Section 6.3** using the explanation table provided in **Table 6.1**. The results of this assessment are summarised in a 'qualitative assessment matrix' that compares the relative merits of each of the option, based on the criteria. The 'qualitative assessment matrix' is presented in **Table 7.2**.

Table 7.2 also summarises the quantitative analysis undertaken for each option including:

- capital cost;
- benefit–cost ratio;
- reduction in the number of houses flooded above floor level in a 100 year flood.

Using the hierarchy of measures as described in the *2001 Manual*, the floodplain risk management options assessed for the South Creek study area are discussed in detail in the following three chapters:

- **Chapter 8** — property modification measures;
- **Chapter 9** — response modification measures;
- **Chapter 10** — flood modification measures.

Chapter 11 presents the recommended *South Creek Floodplain Risk Management Plan (for the Liverpool LGA)*.

FIGURE 7.1: FLOODPLAIN RISK MANAGEMENT OPTIONS FOR THE STUDY AREA

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A3 FIGURE

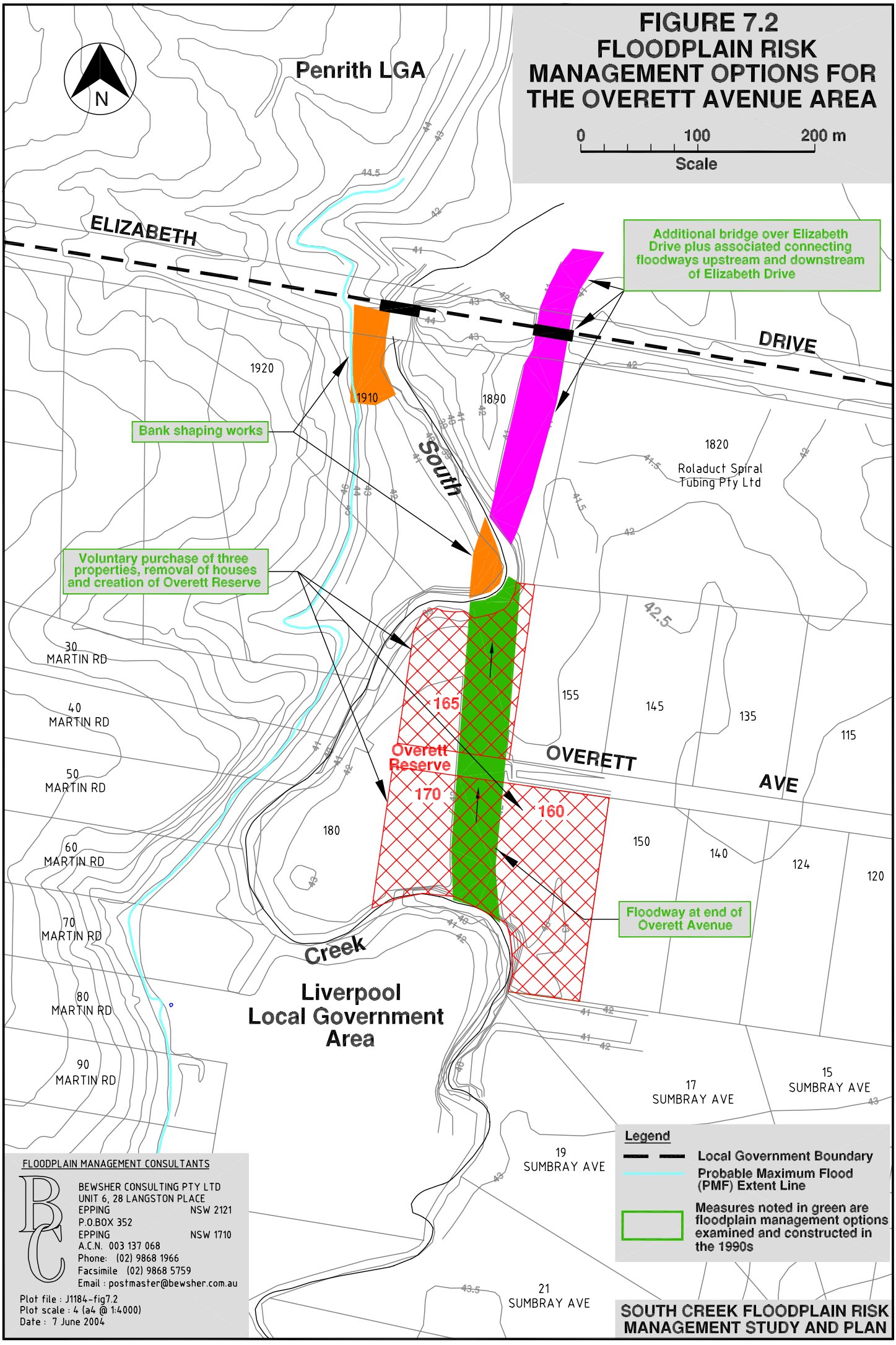
FIGURE 7.2
FLOODPLAIN RISK MANAGEMENT OPTIONS FOR THE OVERETT AVENUE AREA
0
100
200 m
Scale
N
Penrith LGA
ELIZABETH
DRIVE
Additional bridge over Elizabeth Drive plus associated connecting floodways upstream and downstream of Elizabeth Drive
Bank shaping works
South
Creek
Voluntary purchase of three properties, removal of houses and creation of Overett Reserve
Overett Reserve
OVERETT
AVE
Floodway at end of Overett Avenue
Liverpool Local Government Area
Roladuct Spiral Tubing Pty Ltd
30 MARTIN RD
40 MARTIN RD
50 MARTIN RD
60 MARTIN RD
70 MARTIN RD
80 MARTIN RD
90 MARTIN RD
17 SUMBRAY AVE
15 SUMBRAY AVE
19 SUMBRAY AVE
21 SUMBRAY AVE
Legend
Local Government Boundary
Probable Maximum Flood (PMF) Extent Line
Measures noted in green are floodplain management options examined and constructed in the 1990s
FLOODPLAIN MANAGEMENT CONSULTANTS
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Plot file : J1184-fig7.2
Plot scale : 4 (a4 @ 1:4000)
Date : 7 June 2004
SOUTH CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

TABLE 7.1: PROPERTY MODIFICATION MEASURES — SUMMARY OF FLOODPLAIN RISK MANAGEMENT OPTIONS EXAMINED

REPORT SECTION NO.	FLOODPLAIN RISK MANAGEMENT MEASURE	DESCRIPTION OF OPTION	RECOMMENDED FOR FURTHER CONSIDERATION
8	**PROPERTY MODIFICATION MEASURES**		
8.1	**Planning Controls and Policies**	‣ amendments to Sydney Regional Environmental Plan No.20 — Hawkesbury–Nepean River (SREP No.20), including development of strategy to fast-track incorporation and adoption; ‣ amendments to Liverpool Local Environmental Plan), including development of strategy to fast-track incorporation and adoption; ‣ adoption of Planning Matrix Approach ‣ adoption of High, Medium and Low Risk Precincts ‣ adoption of Flood Risk Management Development Control Plan	yes yes yes yes yes
8.2	**Voluntary Purchase of Properties**	‣ Properties with over-floor flooding in a 5 year flood (Option VP5): – No.35 Victor Avenue; – No.82 Victor Avenue. ‣ Properties with over-floor flooding in a 20 year flood (Option VP20): – Nos.120 and 150 Overett Avenue; – Nos.10, 20, 50 and 60 Victor Avenue; – No.100 Watts Road.	 no no no no no
8.3	**Voluntary House Raising**	‣ Properties with over-floor flooding in a 5 year flood — full-cost subsidy (Option HR5): – No.35 Victor Avenue; – No.82 Victor Avenue. ‣ Properties with over-floor flooding in a 20 year flood — full-cost subsidy (Option HR20a): – Nos.10, 20 and 50 Victor Avenue; – No.100 Watts Road. ‣ Properties with over-floor flooding in a 20 year flood — partial cost subsidy (Option HR20b): – Nos.120 and 150 Overett Avenue; – No.60 Victor Avenue. ‣ Properties with over-floor flooding in a 100 year flood — partial cost subsidy (Option HR100): – No.70 Kelvin Park Drive. – Nos. 80, 124, 135 and 145 Overett Avenue; – Nos. 5, 32, 50 (second house) and 70 Victor Avenue; – No.1 May Avenue.	 yes yes yes yes yes yes yes yes yes yes yes
8.4	**Flood Proofing**	‣ development of 'Flood Proofing Guidelines' for the study area.	yes

TABLE 7.2: RESPONSE MODIFICATION MEASURES — SUMMARY OF FLOODPLAIN RISK MANAGEMENT OPTIONS EXAMINED

REPORT SECTION NO.	FLOODPLAIN RISK MANAGEMENT MEASURE	DESCRIPTION OF OPTION	RECOMMENDED FOR FURTHER CONSIDERATION
9	**RESPONSE MODIFICATION MEASURES**		
9.1	**Flood Warning**	‣ Study is in 'flash flood' area and so no formal flood warning service available from Bureau of Meteorology. Only formal warnings would be a 'Flood Watch' or 'Severe Thunderstorm Warning'; ‣ development of triggers for rainfall and river height station in and close to the study area; ‣ linking of triggers to local base stations, particularly local SES headquarters; ‣ installation of three additional ALERT rainfall stations in the upper parts of the South Creek catchment.	na yes yes yes
9.2	**Emergency Management**	‣ all flood intelligence information from current study be made available to SES in a form appropriate for inclusion in next version of Liverpool City Local Flood Plan; ‣ provision for 'vertical evacuation' in the planning and development controls; ‣ preparation of FloodSafe brochure either for just current study area or for all South Creek upstream of limit of Hawkesbury–Nepean flooding	yes yes yes
9.3	**Community Flood Awareness**	‣ production of Flood Precinct Maps; ‣ updating of Council's GIS and use of information available from this study; ‣ preparation of brochure 'Guidelines on Flood-Related Building Controls' ‣ preparation and sending out of 'Flood Information Packs' that would include: – Flood Notification Letter; – Flood Information Brochure; – Frequently Asked Questions; – SES FloodSafe brochure and associated SES information; ‣ issuing of Flood Certificates when Development Applications are submitted ‣ appropriate notification on Section 149 Certificates; ‣ public exhibition of Study Report and draft Floodplain Risk Management Plan; ‣ installation of flood markers at Elizabeth Drive and Bringelly Road. Note that Council and the Floodplain Risk Management Committee would confirm the exact details of a Community Flood Awareness Strategy before implementation.	yes yes yes yes yes yes yes yes yes yes yes yes

TABLE 7.3: RESPONSE MODIFICATION MEASURES — SUMMARY OF FLOODPLAIN RISK MANAGEMENT OPTIONS EXAMINED

REPORT SECTION NO.	FLOODPLAIN RISK MANAGEMENT MEASURE	DESCRIPTION OF OPTION	RECOMMENDED FOR FURTHER CONSIDERATION
10	**FLOOD MODIFICATION MEASURES**		
10.1	**Flood Modification Measures for the Overett Avenue Area**	‣ earthen levee to protect all low lying properties in Overett Avenue and the south side of Elizabeth Drive from flooding in a 100 year flood; ‣ enlargement of the existing road bridge over South Creek; ‣ construction of a second bridge at Elizabeth Drive including associated connecting floodways upstream and downstream of Elizabeth Drive, plus voluntary purchase of three properties in Overett Avenue; ‣ widening (including large-scale clearing) of the main South Creek channel downstream of Elizabeth Drive; ‣ widening (including large-scale clearing) of the main South Creek channel upstream of Elizabeth Drive; ‣ construction of floodway at the end of Overett Avenue; ‣ bank shaping works to aid water flow between channel widening works and floodways.	no no yes — constructed as Stages 1 & 2 Works no no yes — constructed as Stage 3A Works yes — constructed as Stage 3B Works
10.2	**Flood Modification Measures for the Victor Avenue Area**	‣ earthen levee to protect all low lying properties in Victor Avenue, Watts Road and Ramsay Road from flooding in a 100 year flood; ‣ widening of the main South Creek channel, including cutting a bench into one or both of the creek banks and where the creek meandered, the construction of a trapezoidal second channel, or floodway, to 'short cut' the meander.	no no
10.3.1	**Construction of Detention Basins**	‣ construction of detention basins upstream of and within the study area;	no
10.3.2	**Impacts of Large Dams on Flood Behaviour**	‣ investigation into whether large dams in region have an impact on flood behaviour in the study area.	no
10.3.3	**Works at Bringelly Road bridge**	‣ road raising and associated enlargement of bridge waterway area	no
10.3.4	**Safety Improvements for at The Retreat bridge**	‣ safety improvement program for The Retreat crossing of Thompsons Creek: – signage at bridge; – associated community awareness program; – investigation into flood escape route to Badgerys Creek Road.	 yes yes yes
10.3.5	**Creek Maintenance Strategy**	‣ large-scale channel clearing as a flood mitigation measure; ‣ development of Creek Maintenance Strategy to ensure: – vegetation levels do not increase flood levels; – environmental considerations clearly identified; – dumped rubbish is systematically removed; – more vigilant policing of dumping practices including signage.	no yes yes yes yes yes

REPORT SECTION NO.	FLOODPLAIN RISK MANAGEMENT MEASURE	DESCRIPTION OF OPTION	RECOMMENDED FOR FURTHER CONSIDERATION
10.3.6	**Works at Australian Native Landscapes site**	‣ filling and associated by-pass floodway as compensatory works at Australian Native Landscapes site as described in 1991 FPM Study.	no
10.3.7	**Levee at Masterfield Street, Rossmore**	‣ investigation into impacts of levee outside study area (just upstream of Bringelly Road)	no
10.4.1	**Integrated Approach to Flood-plain Risk Manage-ment in the South Creek Catchment**	‣ integrated and coordinated approach to floodplain risk management throughout the entire South Creek catchment	yes
10.4.2	**Thompsons Creek and Bardwell Gully Flood Study, Floodplain Risk Management Study and Plan**	‣ flood study, floodplain risk management study and plan for those areas of Bardwell Gully and Thompsons Creek upstream of The Northern Road in both Liverpool and Camden LGAs	yes

TABLE 7.4: QUALITATIVE MATRIX ASSESSMENT OF FLOODPLAIN RISK MANAGEMENT OPTIONS

REPORT SECTION NO.	FLOODPLAIN RISK MANAGEMENT MEASURE	DESCRIPTION OF OPTION	REDUCTION OF HOUSES FLOODED ABOVE FLOOR LEVEL IN 100 YEAR 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. HOUSES		CAPITAL COST		BENEFIT–COST RATIO							
8	**PROPERTY MODIFICATION MEASURES**														
8.1	**Planning Controls and Policies**	• amendments to Sydney Regional Environmental Plan No.20 plus strategy for fast-track implementation • amendments to Liverpool Local Environmental Plan (LEP) plus strategy for fast-track implementation • adoption of Planning Matrix Approach • adoption of High, Medium and Low Risk Precincts • adoption of Flood Risk Management Development Control Plan	O	na	++	Council staff costs	++	na	+	++	O	++	++	–	yes
8.2	**Voluntary Purchase of Properties**	Properties with over-floor flooding in a 5 year flood (Option VP5): • Nos.35 and 82 Victor Avenue	+	2	+	$2 million	O	0.5	–	+	O	++	++	– –	no
		Properties with over-floor flooding in a 20 year flood (Option VP20): • Nos.120 and 150 Overett Avenue; • Nos.10, 20, 50 and 60 Victor Ave.; • No.100 Watts Road.	++	7	+	$6 million	–	0.2	–	+	O	+	++	– –	no
8.3	**Voluntary House Raising**	Properties with over-floor flooding in a 5 year flood — full-cost subsidy (Option HR5): • Nos. 35 and 82 Victor Avenue	+	2	++	$140,000	++	2.4	+	O	O	++	+	O	yes
		Properties with over-floor flooding in a 20 year flood — full-cost subsidy (Option HR20a): • Nos.10, 20 and 50 Victor Avenue; • No.100 Watts Road.	++	4	++	$280,000	+	0.8	+	O	O	++	+	O	yes
		Properties with over-floor flooding in a 20 year flood — partial cost subsidy (Option HR20b): • Nos.120 and 150 Overett Avenue; • No.60 Victor Avenue.	++	3	++	$60,000	++	2.0	+	O	O	++	– to +	O	yes
		Properties with over-floor flooding in a 100 year flood — partial cost subsidy (Option HR100): • No.70 Kelvin Park Drive; • Nos. 80, 124, 135 and 145 Overett Ave; • Nos. 5, 32, 50 (second house) and 70 Victor Avenue; • No.1 May Avenue.	++	10	++	$200,000	+	0.5 – 1.0	+	O	O	++	– to +	O	yes
8.4	**Flood Proofing**	Development of 'Flood Proofing Guidelines' for the study area.	O	na	+	$5,000 plus Council staff costs	++	na	O	O	O	+	++	–	yes
9	**RESPONSE MODIFICATION MEASURES**														
9.1	**Flood Warning**	Development of triggers for rainfall & river height stations in vicinity of study area.	O	na	+	Met. Bureau staff costs	++	na	+	O	O	++	++	+	yes
		Linking of triggers to local base stations, particularly local SES headquarters.	O	na	+	Met. Bureau staff costs	++	na	+	O	O	++	++	+	yes

REPORT SECTION NO.	FLOODPLAIN RISK MANAGEMENT MEASURE	DESCRIPTION OF OPTION	REDUCTION OF HOUSES FLOODED ABOVE FLOOR LEVEL IN 100 YEAR 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. HOUSES		CAPITAL COST		BENEFIT–COST RATIO							
9.1	**Flood Warning (cont.)**	Installation of three additional ALERT rainfall stations in the upper parts of the South Creek catchment.	O	na	++	$20,000	++	na	++	O	O	++	++	+	yes
		All flood intelligence information from current study be made available to SES in a form appropriate for inclusion in next version of Liverpool City Local Flood Plan.	O	na	++	$10,000 plus SES staff costs	++	na	O	O	O	++	++	+	yes
		Provision for 'vertical evacuation' in the planning and development controls.	O	na	++	Council staff costs	++	na	+	O	O	++	++	–	yes
		Preparation of FloodSafe brochure either for just current study area or for all South Creek upstream of limit of Hawkesbury–Nepean flooding.	O	na	+	$5,000 plus SES staff costs	++	na	++	O	O	++	++	+	yes
9.3	**Community Flood Awareness**	production of Flood Precinct Maps	O	na	++	Council staff costs	++	na	++	O	O	++	++	–	yes
		updating of Council's GIS and use of information available from this study	O	na	++	Council staff costs	++	na	++	O	O	++	++	–	yes
		preparation of brochure 'Guidelines on Flood-Related Building Controls'	O	na	+	$5,000 plus Council staff costs	++	na	++	O	O	++	++	+	yes
		Preparation and sending out of 'Flood Information Packs' that would include: • Flood Notification Letter; • Flood Information Brochure; • Frequently Asked Questions; • SES FloodSafe brochure and associated SES information;	O	na	++	$5,000 (for brochure) plus Council and SES staff costs	++	na	++	O	O	++	++	–	yes
		issuing of Flood Certificates when Development Applications are submitted	O	na	++	Council staff costs	++	na	++	O	O	++	++	–	yes
		appropriate notification on Section 149 Certificates;	O	na	++	Council staff costs	++	na	+	O	O	++	++	–	yes
		installation of flood markers at Elizabeth Drive and Bringelly Road	O	na	+	$20,000	+	na	++	O	O	+	+	–	yes
10	**FLOOD MODIFICATION MEASURES**														
10.1	**Flood Modification Measures for the Overett Avenue Area**	Earthen levee to protect all low lying properties in Overett Avenue and the south side of Elizabeth Drive from flooding in a 100 year flood	++	approx. 25 (see Note 1)	– –	$5.2 million (see Note 1)	+	0.9	–	– –	O	– –	–	– –	no
		Enlargement of the existing road bridge over South Creek	O	not calculated	– –	not calculated	– –	<0.1	+	–	– and +	+	–	– –	no
		Construction of a second bridge at Elizabeth Drive including associated connecting floodways upstream and downstream of Elizabeth Drive, plus voluntary purchase of 3 properties in Overett Avenue	++	15 (see Note 2)	na	na	na	na	na	na	na	na	na	na	**yes — constructed as Stage 1 and 2**
		Widening (including large-scale clearing) of the main South Creek channel downstream of Elizabeth Drive	++	3 (see Note 3)	– –	>$4 million (see Note 3)	–	<0.5	+	– –	+	+	–	– –	no
		Widening (including large-scale clearing) of the main South Creek channel upstream of Elizabeth Drive	++	3 (see Note 3)	– –	>$3 million (see Note 3)	–	<0.5	+	– –	+	+	–	– –	no
		Construction of floodway at end of Overett Avenue	++	15 (see Note 2)	na	na	na	na	na	na	na	na	na	na	**yes — constructed**

REPORT SECTION NO.	FLOODPLAIN RISK MANAGEMENT MEASURE	DESCRIPTION OF OPTION	REDUCTION OF HOUSES FLOODED ABOVE FLOOR LEVEL IN 100 YEAR 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. HOUSES		CAPITAL COST		BENEFIT–COST RATIO							
10.1	**Overett Ave Area works (cont.)**	Bank shaping works to aid water flow between channel widening works and floodways	++	15 (see Note 2)	na	na	na	na	na	na	na	na	na	na	**yes — constructed as Stage 3B**
10.2	**Flood Modification Measures for the Victor Avenue Area** (see Note 4)	Earthen levee to protect all low lying properties in Victor Avenue, Watts Road and Ramsay Road from flooding in a 100 year flood	++	15 (see Note 4)	– –	>$3.5 million (see Note 4)	++	1.3	–	– –	O	– –	–	– –	no
		Widening of the main South Creek channel, including cutting a bench into one or both of the creek banks and where the creek meandered, the construction of a trapezoidal second channel, or floodway, to 'short cut' the meander	++	15 (see Note 4)	– –	>$3.5 million (see Note 4)	++	1.3	–	– –	O	– –	–	– –	no
10.3.1	**Construction of Detention Basins**	Construction of detention basins upstream of and within the study area	na	not calculated	– –	>$10 million	– –	<0.1	+	– –	+	+	– –	– –	no
10.3.2	**Impacts of Large Dams on Flood Behaviour**	Investigation into whether large dams in region have an impact on flood behaviour in the study area.	O	na	– –	na	– –	na	++	O	O	O	++	O	no
10.3.3	**Works at Bringelly Road bridge**	Road raising and associated enlargement of bridge waterway area	na	not calculated	–	na	na	na	–	O	– and +	+	–	–	no
10.3.4	**Safety Improvements for at The Retreat bridge**	Safety improvement program for The Retreat crossing of Thompsons Creek: • signage at bridge and associated community awareness program	O	na	++	$5,000 plus Council staff costs	++	na	+	O	O	++	++	–	yes
		• investigation into flood escape route to Badgerys Creek Road.	O	na	++	Council and SES staff costs	++	na	+	O	O	++	++	–	yes
10.3.5	**Creek Maintenance Strategy**	Large-scale channel clearing as a flood mitigation measure	na	not calculated	– –	na	O	na	+	– –	+	+	+	– –	no
		Development of Creek Maintenance Strategy	O	na	++	$10,000 plus Council staff costs	++	na	++	++	O	+	+	–	yes
10.3.6	**Australian Native Landscapes site works**	Filling and associated by-pass floodway as compensatory works at Australian Native Landscapes site as described in 1991 FPM Study.	O	0	– –	na	– –	na	– –	– –	O	+	–	– –	no
10.3.7	**Levee at Masterfield St., Rossmore**	Investigation into impacts of levee outside study area (just upstream of Bringelly Road)	O	0	– –	na	– –	na	+	– –	O	– –	–	O	no
10.4.1	**Integrated Approach to Floodplain Risk Management**	Integrated and coordinated approach to floodplain risk management throughout the entire South Creek catchment	O	0	++	Council staff costs	na	na	++	+	na	++	+	–	yes
10.4.2	**Thompsons Creek and Bardwell Gully Study**	Flood study, floodplain risk management study and plan for those areas of Bardwell Gully and Thompsons Creek upstream of The Northern Road in both Liverpool and Camden LGAs	O	0	++	$50,000	na	na	+	+	na	+	–	+	yes

Notes:
1. *Number of houses protected from above-floor flooding for Option 1A from 1994 Kinhill Study (includes levees and compensatory channel works) (see **Section 10.1**).*
2. *Number of houses protected refers to a combination of the completed works (Stages 1, 2, 3A and 3B) (see **Section 10.1.2**).*
3. *Source: 1994 Kinhill Study (see **Section 10.1** for more information).*
4. *Number of houses protected from above floor flooding and benefit–cost ratio from combination of levees and channel works for Option 2 from 1994 Kinhill Study (see **Section 10.2**).*

8. PROPERTY MODIFICATION MEASURES

Property modification measures refer to either of the following:

- controls on the future development of property and community infrastructure;
- modifications to existing development such as voluntary purchase of properties, voluntary house raising or flood proofing.

These types of measures are described in this chapter in the following sections:

- planning controls and policies (**Section 8.1**);
- voluntary purchase of properties (**Section 8.2**);
- voluntary house raising (**Section 8.3**);
- flood proofing (**Section 8.4**).

8.1 PLANNING CONTROLS AND COUNCIL POLICIES

Land use planning, development controls and specific flood-related policies are key mechanisms by which Council can manage flood-affected areas. Such mechanisms will influence future development (and redevelopment) and therefore the benefits will accrue gradually over time. Without comprehensive floodplain planning, existing problems may be exacerbated and opportunities to reduce flood risks may be lost.

It will therefore be important that Council ensures that the planning outcomes derived from this study are integrated with all other existing and future floodplain risk management studies currently under preparation in their LGA, to provide a consistent platform for dealing with the issue of flooding with future development.

Volume 2 of this report, entitled *Town Planning Issues* (Don Fox Planning, 2004) presents a detailed discussion of town planning aspects of the South Creek Floodplain Risk Management Study. This includes a review of existing planning and development controls and the proposed approach to floodplain planning recommended in this study. The key issues of **Volume 2** are outlined in this section, as follows:

- an overview of existing planning and development controls and recommendations are discussed in **Section 8.1.1**;
- the proposed approach to floodplain planning is outlined in **Section 8.1.2**;
- the recommended approach to floodplain planning involves a series of development controls presented in the form of a Planning Matrix. The Planning Matrix Approach is described in **Section 8.1.3**;
- a summary of some of the key development controls recommended for the Planning Matrix for the South Creek study area are presented in **Section 8.1.4**;
- a summary of the recommended planning and policy changes is presented in **Section 8.1.5.**

8.1.1 Review of Existing Planning and Development Controls

Section 2.3 of **Volume 2** identifies and examines various forms of planning instruments and associated controls that apply to the study area. These planning instruments may appropriate in the implementing of planning controls to guide future development within the study area. Not all of the planning instruments reviewed would be applicable to the recommended *Floodplain Risk Management Plan*, however, they have been reviewed for the purposes of completeness and to provide a general overview of planning controls and strategic planning direction for the area.

The following planning instruments are discussed in Section 2.3 of **Volume 2**:

- ***State Environmental Planning Policies (SEPPs)***;

- ***Regional Environmental Plans (REPs)*** — An REP is prepared in accordance with the Environmental, Planning and Assessment Act (EP&A, Act) by the Department of Infrastructure, Planning & Natural Resources (DIPNR) and eventually approved by the Minister. An REP provides objectives and controls for environmental planning for a region, or part of a region. The study area lies wholly within the area of application of Sydney Regional Environmental Plan No.20 — Hawkesbury-Nepean River (SREP No.20). This plan prevails over any other regional environmental plan or local environmental plan where there is an inconsistency. The plan contains planning principles to help councils prepare local environmental plans that apply to land within the catchment, and provides specific development controls in regard to various land uses.

  It is recommended that some of the provisions and terminology adopted in SREP No.20 be amended to provide a consistent framework for flood planning for the Liverpool LGA;

- ***Advisory Circulars from DIPNR***;

- ***Section 117 Directions*** — these are ministerial directions prepared under Section 117(2) of the EP&A, Act that specify matters which Councils must take into consideration in the preparation of their Local Environmental Plans (LEPs);

- ***Local Environmental Plans (LEPs)*** — An LEP is a plan prepared in accordance with the EP&A, Act, which defines zones, permissible uses within those zones and specific development standards with regard to the use or development of land. Liverpool LEP 1997 applies to the South Creek study area;

  It is recommended that some of the provisions and terminology adopted in the Liverpool LEP be amended to provide a consistent framework for more detailed controls to be provided in the Flood Risk Management DCP;

- ***Development Control Plans (DCPs)*** — A DCP is a plan prepared in accordance with Section 72 of the EP&A that provides detailed guidelines for the assessment of development applications.

Various DCPs of some relevance apply in the study area, including:

- DCP Nos. 32 and 33 dealing with exempt and complying development;
- DCP No.47 — Domestic On-site Sewage Management;
- DCP No.8 — Natural Assets;
- DCP No.4 — Environmentally Responsive Residential Development;
- draft DCP dealing with land filling and earth dams.

- ***Liverpool City Council policies;***

- ***Development Application assessment;***

- ***Section 149 Certificates*** — A Section 149 Certificate is a zoning certificate issued under the provisions of the EP&A, Act, which must be attached to a contract prepared for the sale of property (see **Section 9.3.8** of this report for more information and recommendations relating to Section 149 Certificates);

- ***Section 94 Contributions Plan*** — A Section 94 Contributions Plan prepared under the EP&A, Act provides a basis for the levying of contributions from developers to construct drainage and flood mitigation works required as a result of future development. Section 94 contributions can only be applied to fund works associated with the new development and cannot be applied for the purposes of rectifying past inadequacies.

To ensure the effective management of future growth in the floodplain, it will be important that the recommended changes and amendments to all planning policies be implemented as a high priority. This will be particularly important for SREP No.20, the Liverpool LEP and the Flood Risk Management DCP (see **Section 8.1.3**).

Liverpool Council is currently preparing the draft Flood Risk Management DCP for a proposed public exhibition in early 2005. However, to be fully effective, the new DCP will need to be supported by the Liverpool LEP and SREP No.20.

Therefore, it is recommended, as a high priority measure, that a strategy be developed to fast-track the proposed changes to the Liverpool LEP and SREP No.20. This strategy would identify all the steps involved and a timetable to ensure both these documents are revised and updated.

8.1.2 Proposed versus Traditional Approach to Floodplain Planning

Generally, the real flood hazard (and hence the flood risks) within floodplains are poorly understood and appreciated by the community.

The flood planning level (FPL), previously known as the ‘designated flood’ level or ‘flood standard’, is the flood level selected for planning purposes, and will directly determine the area of land that should be subject to flood-related building and development controls.

Often the community considers there is a flood risk only on land below the flood planning level, that is, the level below which the Council has placed restrictions on development. This flood planning level is commonly the level of the 100 year flood. In the community's mind, it is often perceived that there is no flood risk of flooding above the 100 year flood level. In fact, floods can and have occurred well above this level in catchments all over Australia.

Traditional floodplain planning has relied almost entirely on the definition of a singular flood planning level, usually the 100 year flood level, for the purposes of applying floor level controls. While such an approach has been generally adequate to reduce flood risks, the approach has not worked well everywhere and has led to a number of problems including:

- creation of a 'hard edge' to development at the flood planning level;
- distribution of development within the floodplain in a manner that does not recognise the risks to life or the economic costs of flood damage;
- unnecessary restrictions on some land uses below the flood planning level, while allowing other inappropriate land uses to occur immediately above the flood planning level. For example, whilst it may be appropriate for some land uses, such as a hospital, to be located above a probable maximum flood (PMF), it could be argued that residential, industrial or recreational land uses do not require such restrictive control;
- polarisation of the floodplain into perceived 'flood prone' and 'flood free' areas;
- lack of recognition of the significant flood risk that may exist above the flood planning level (and as a result, there may be few measures in place to manage the consequences of flooding above the flood planning level);
- creation of a political climate where the redefinition of the flood planning level (due to the availability of more accurate flood behaviour data, or for other reasons) is fiercely opposed by some parts of the community. There are often concerns about the significant impacts on land values (despite the fact that such effects are likely to only short term), particularly on land, which was previously perceived to be 'flood free', that would be recognised as 'flood prone'.

To overcome the shortcomings of a singular flood planning level, a 'graded' set of planning and development controls that consider the variation of damage risk, with flood frequency and land use, have been proposed for the South Creek study area. This approach is known as the Planning Matrix Approach. The Planning Matrix Approach is gradually being introduced to other floodplains within the Liverpool LGA.

8.1.3 The Planning Matrix Approach

Overview

The Planning Matrix Approach to floodplain risk management considers the range of land uses, and their potential risk to flooding, within the floodplain up to the level of the probable maximum flood. Using this approach, a matrix of development controls, based on the flood hazard and the land use, can be developed which balances the risk exposure across the floodplain.

The Planning Matrix Approach was first introduced with the Eastern Creek and Tributaries Floodplain Management Plan (Blacktown City Council) in the late 1990s and has now been adopted and recommended for many other areas. These areas include the management of floodplains that are jointly administered by more than one local council (eg. Cabramatta Creek Floodplain Risk Management Study where management is jointly the responsibility of Fairfield and Liverpool City Councils), or where Councils have a number of floodplains within their local government area (such as at Liverpool).

The Planning Matrix Approach is fully consistent with the Floodplain Management Manual (NSW, Government, 2001).

The Flood Risk Management Development Control Plan

The most appropriate mechanism for specifying detailed planning and development controls associated with the Planning Matrix to be applied to new development to manage issues of floodplain risk, would be a Flood Risk Management Development Control Plan (DCP). Such a DCP could form an overall comprehensive and broader flood management policy. The DCP should be accompanied by a map that identifies all the Flood Risk Precincts described in **Section 4.2**, and depicted on **Figure 4.6**.

Liverpool City Council currently does not have a DCP related to floodplain risk management and relies on interim policy provisions. Notwithstanding, Liverpool City Council embarked on the preparation of a comprehensive Flood Risk Management DCP some years ago, which has not yet been adopted by Council, pending the outcome of other studies such as the *Georges River Floodplain Risk Management Study* (Bewsher Consulting, 2004) and the subject South Creek study.

The recommended Flood Risk Management DCP involves a preamble of provisions that establishes a framework to allow for the outcomes of multiple Floodplain Risk Management Studies to be incorporated into the document, of which the current South Creek Floodplain Risk Management Study will be one. Wherever possible, existing controls from other floodplains in the Liverpool LGA will be integrated into the Floodplain DCP, to increase the convenience for Council to accelerate the adoption of the plan.

The recommended draft Flood Risk Management DCP for the Liverpool LGA is effectively a more advanced version of Council's original draft DCP, being also authored by Don Fox Planning in association with Bewsher Consulting. A copy of the recommended draft Flood Risk Management DCP is provided as Appendix C of **Volume 2** and forms an integral component of the recommended *South Creek Floodplain Risk Management Plan*.

Components of the Planning Matrix

The development of the Planning Matrix involves three major components:

- ***categorisation of the floodplain*** — as discussed in **Section 4.2** and depicted in **Figure 4.6**, the South Creek study area floodplain has been divided into three Flood Risk Precincts, namely the High Risk Precinct, the Medium Risk Precinct and the Low Risk Precinct;

- ***prioritisation of land uses within the floodplain*** — different land uses are categorised into similar levels of sensitivity to the flood hazard. Definitions of the following Land Use Categories adopted for the South Creek study area are provided in Schedule 1 of the draft DCP provided as Appendix C of **Volume 2**:

  – critical uses and facilities;
  – sensitive uses and facilities;
  – subdivision;
  – residential;
  – commercial and industrial;
  – tourist related development;
  – recreation and non-urban;
  – concessional development;

- ***controls to modify building form and community response*** — different planning controls are assigned, which modify building form and the ability of the community to respond in times of flooding, depending upon the type of land use and the location of that land use within the floodplain. The types of controls can be categorised under the following main headings:

  – floor levels;
  – building components and method;
  – structural soundness;
  – flood effects;
  – car parking and driveway access;
  – evacuation;
  – management and design;

  A discussion of the types of development controls applicable to each of these issues is provided in Section 4.5 of **Volume 2** of this report. A summary of controls is presented in **Section 8.1.4** of the current report.

Selection of Controls

The selection of the planning and development controls for the Planning Matrix and the various flood conditions at which these controls should apply, has been based on the following issues and criteria:

- the procedures and philosophy espoused in the *Floodplain Management Manual*;

- consideration of the social, economic and environmental impacts of flooding;

- investigations carried out within the current study;
- community attitudes inferred during the current study;
- minimising the council's exposure to legal actions in relation to flooding;
- the council's previous development policies;
- views expressed by the officers of Council and DIPNR;
- experience gained from the development of planning controls and flood policies for various communities across NSW in recent years.

The 100 year flood level has been retained as the principal floor level control for residential land uses in the study area. The 100 year flood has also been used as the basis of defining the three Flood Risk Precincts (see **Section 4.2**). This adoption of the use of the 100 year flood has been an important considerations for the development of planning controls for the study area and has been based on consideration of the following issues:

- recognition that the community is most familiar with the term '100 year flood' and any variation from the use of a flood of this magnitude may undermine the current good work done in improving community awareness of flood-related issues;
- assessment of the impacts of floods between a 100 year flood and a probable maximum flood (PMF). The level of the PMF is only about 1.0m–1.5m above the level of the 100 year flood. For floods larger than a 100 year flood, there would be no significant changes in flood behaviour of flood affection, for example, no new significant overland flow paths would develop and no areas would become inaccessible islands with rising floodwaters;
- recognition that the community views the residential floor level control as the principal component of the council floodplain controls, and that changes to the level of this control should not be made unless very strong arguments exist;
- the unacceptable increase in flood risks and damages, should a level lower than the 100 year flood be adopted;
- an unacceptable impost on future development, should a level higher than a 100 year flood be adopted;
- inconsistencies with recent development approvals if a level different from the 100 year flood was adopted.

Planning Matrix for the South Creek Study Area

The recommended Planning Matrix for the South Creek study area is presented as **Table 8.1**. It has been included as Schedule 6 of the recommended draft Flood Risk Management DCP presented as Appendix C of **Volume 2** of this report (Don Fox Planning, 2004).

TABLE 8.1: PROPOSED PLANNING MATRIX FOR THE SOUTH CREEK STUDY AREA

Schedule 6 of Flood Risk Management DCP

South Creek Floodplain

Planning & Development Controls

Planning Consideration	Flood Risk Precincts (FRP's)																							
	Low Flood Risk								Medium Flood Risk								High Flood Risk							
	Critical Uses & Facilities	Sensitive Uses & Facilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Critical Uses & Facilities	Sensitive Uses & Facilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Critical Uses & Facilities	Sensitive Uses & Facilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development
Floor Level		3		2,6,7	5,6,7	2,6,7	1,6	4,7				2,6,7	5,6,7	2,6,7	1,6	4,7							1,6	4,7
Building Components		2		1	1	1	1	1				1	1	1	1	1							1	1
Structural Soundness		3		2	2	2	2	2				2	2	2	2	2							1	1
Flood Effects		2	2	2	2	2	2	2			1	2	2	2	2	2							1	1
Car Parking & Driveway Access		1,3,5,6,7		1,3,5,6,7	1,3,5,6,7	1,3,5,6,7	2,4,6,7	6,7,8				1,3,5,6,7	1,3,5,6,7	1,3,5,6,7	2,4,6,7	6,7,8							2,4,6,7	6,7,8
Evacuation		2,3,4	6	2,3	1 or 2, 3	2,3	4,3	2,3			6	2,3	1,3	2,3	4,3	2,3							4,3	2,3
Management & Design		4,5	1		2,3,5	2,3,5	2,3,5	2,3,5			1		2,3,5	2,3,5	2,3,5	2,3,5							2,3,5	2,3,5

COLOUR LEGEND: Not Relevant; Unsuitable Land Use

General Notes

1	Freeboard equals an additional height of 500mm.
2	The relevant environmental planning instruments (generally the Local Environmental Plan) identify development permissible with consent in various zones in the LGA. Notwithstanding, constraints specific to individual sites may preclude Council granting consent for certain forms of development on all or part of a site. This matrix identifies where flood risks are likely to determine where certain development types will be considered "unsuitable" due to flood related risks.
3	Filling of the site, where acceptable to Council, may change the FRP considered to determine the controls applied in the circumstances of individual applications.
4	Refer to Section 2.5 of the DCP for planning considerations for proposals involving only the erection of a fence. Any fencing that forms part of a proposed development is subject to the relevant flood effects and Structural Soundness planning considerations of the applicable landuse category.
5	Refer to section 2.7 of the DCP for special considerations such as for house raising proposals and development of properties identified for voluntary acquisition.
6	Terms in italics are defined in the glossary of this plan and Schedule 3 specifies development types included in each land use category. These development types are generally as defined within Environmental Planning Instruments applying to the LGA.
7	Council has prepared mapping showing the *Boundary of Significant Flow* and the *Flood Storage Areas* for the South Creek floodplain.

Floor Level

1	All floor levels to be no lower than the 5 year flood level plus freeboard unless justified by site specific assessment.
2	*Habitable floor* levels to be no lower than the 100 year flood level plus freeboard.
3	*Habitable floor* levels to be no lower than the *PMF* level. Non-*habitable floor* levels to be no lower than the *PMF* level unless justified by a site specific assessment.
4	Floor levels to be no lower than the *design floor level*. Where this is not practical due to compatibility with the height of adjacent buildings, or compatibility with the floor level of existing buildings, or the need for access for persons with disabilities, a lower floor level may be considered. In these circumstances, the floor level is to be as high as practical, and, when undertaking alterations or additions, no lower than the existing floor level.
5	The level of *habitable floor areas* to be equal to or greater than the 100 year *flood* level plus *freeboard*. If this level is impractical for a development in a Business zone, the floor level should be as high as possible.
6	Non-*habitable floor* levels to be no lower than the 5 year flood level plus *freeboard* unless justified by site specific assessment.
7	A restriction is to be placed on the title of the land, pursuant to S.88B of the Conveyancing Act, where the lowest *habitable floor area* is elevated more than 1.5m above finished ground level, confirming that the undercroft area is not to be enclosed.

Building Components & Method

1	All structures to have *flood compatible building components* below the 100 year flood level plus *freeboard.*
2	All structures to have *flood compatible building components* below the *PMF* level.

Structural Soundness

1	Engineers report to certify that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a 100 year flood plus *freeboard,* or a *PMF* if required to satisfy evacuation criteria (see below).
2	Applicant to demonstrate that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a 100 year flood plus *freeboard,* or a *PMF* if required to satisfy evacuation criteria (see below). An engineers report may be required.
3	Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a *PMF* An engineers report may be required.

Flood Effects

1	Engineers report required to certify that the development will not increase flood effects elsewhere, having regard to: (I) loss of flood storage; (ii) changes in flood levels and velocities caused by alterations to the flood *conveyance*; and (iii) the cumulative impact of multiple potential developments in the floodplain.
2	The flood impact of the development to be considered to ensure that the development will not increase flood effects elsewhere, having regard to: (I) loss of flood storage; (ii) changes in flood levels and velocities caused by alterations to the flood *conveyance*; and (iii) the cumulative impact of multiple potential developments in the floodplain. An engineers report may be required.

Note: (1) Any development inside the *Boundary of Significant Flow* will normally be unacceptable as it will reduce flood conveyance and increase flood effects elsewhere. (2) When assessing the loss of flood storage, filling of up to 400 square metres for a dwelling house (including driveway and/or attached garage) or 50 square metres for an *outbuilding,* may be ignored. (3) Except for the specific exemption noted in Note (2) above, any filling within the *Flood Storage Area* (except where this occurs by compensatory excavation), will normally be unacceptable as it will reduce the volume of flood storage available on the floodplain and increase flood effects elsewhere. (4) Outside the Boundary of Significant Flow and/or the Flood Storage Area, development may still increase flood effects elsewhere and therefore be unacceptable.

Car Parking and Driveway Access

1	The minimum surface level of open car parking spaces or carports shall be as high as practical, but no lower than the 5 year flood level plus *freeboard* or the level of the crest of the road at the location where the site has access. In the case of garages, the minimum surface level shall be as high as practical, but no lower than the 5 year flood level plus *freeboard*.
2	The minimum surface level of open car parking spaces, carports or garages, shall be as high as practical.
3	Garages capable of accommodating more than 3 motor vehicles on land zoned for urban purposes, or *enclosed car parking,* must be protected from inundation by floods equal to or greater than the 100 year flood.
4	The driveway providing access between the road and parking space shall be as high as practical and generally rising in the egress direction.
5	The level of the driveway providing access between the road and parking space shall be no lower than 0.3m below the 100 year flood or such that the depth of inundation during a 100 year flood is not greater than either the depth at the road or the depth at the car parking space. A lesser standard may be accepted for single detached dwelling houses where it can be demonstrated that risk to human life would not be compromised.
6	*Enclosed car parking* and car parking areas accommodating more than 3 vehicles (other than on Rural zoned land), with a floor level below the 5 year flood level plus *freeboard* or more than 0.8m below the 100 year flood level, shall have *adequate warning systems, signage and exits*.
7	Restraints or vehicle barriers to be provided to prevent floating vehicles leaving a site during a 100 year flood
8	Driveway and parking space levels to be no lower than the *design ground/floor levels*. Where this is not practical , a lower level may be considered. In these circumstances, the level is to be as high as practical, and, when undertaking alterations or additions, no lower than the existing level.

Note: (1) A flood depth of 0.3m is sufficient to cause a typical vehicle to float. (2) *Enclosed car parking* is defined in the glossary and typically refers to carparks in basements.

Evacuation

1	Reliable access for pedestrians or vehicles required during a 100 year flood.
2	Reliable access for pedestrians or vehicles is required from the building, commencing at a minimum level equal to the lowest *habitable floor* level to an area of refuge above the *PMF level*, or a minimum of 20% of the gross floor area of the dwelling to be above the *PMF* level.
3	The development is to be consistent with any relevant *flood evacuation strategy, Flood Plan adopted by Council* or similar plan.
4	The evacuation requirements of the development are to be considered. An engineers report will be required if circumstances are possible where the evacuation of persons might not be achieved within the *effective warning time*.
5	Reliable access for pedestrians or vehicles required to a publicly accessible location above the *PMF.*
6	Applicant to demonstrate that evacuation in accordance with the requirements of this DCP is available for the potential development flowing from the subdivision proposal.

Management and Design

1	Applicant to demonstrate that potential development as a consequence of a subdivision proposal can be undertaken in accordance with this DCP.
2	*Site Emergency Response Flood Plan* required where floor levels are below the *design floor level,* (except for single dwelling-houses).
3	Applicant to demonstrate that area is available to store goods above the 100 year flood level plus *freeboard.*
4	Applicant to demonstrate that area is available to store goods above the *PMF* level.
5	No storage of materials below the *design floor level* which may cause pollution or be potentially hazardous during any flood.

8.1.4 Summary of Key Development Controls for the South Creek Floodplain

Based on the Planning Matrix shown as **Table 8.1**, some of the key development controls that would apply to the South Creek study area are discussed in this section.

It should be noted that some properties may be covered by more than one Flood Risk Precinct. If, for example, some of the block was high risk and the remainder medium risk and the owner wished to build in the medium risk area, then controls for the Medium Flood Risk Precinct would apply.

Low Flood Risk Precinct

The Low Flood Risk Precinct refers to land that would be flooded in the 100 year flood but would not be flooded in a probable maximum flood (PMF).

In this precinct, there would be practically no change in development potential. Generally all land uses would be permitted, except 'critical uses and facilities', including hospitals, nursing homes and those that are likely to have a high impact on the emergency management resources in times of flood. Floor levels for most residential and business development in this precinct would have to be above the 100 year flood plus 0.5m freeboard.

Medium Flood Risk Precinct

The Medium Flood Risk Precinct refers to land that would be flooded in a 100 year flood with shallow depths and/or low speed of floodwaters (i.e. low flood hazard).

In this precinct, generally most land uses would be permitted, except 'critical' and 'sensitive uses and facilities'. 'Sensitive' land uses include assisted accommodation, housing for older persons or the disabled, as well as industries that store dangerous materials. Filling activities would be strictly controlled.

All permitted development would be subject to most of the flood-related building controls such as:

- minimum floor levels (generally, the 100 year flood plus 0.5m freeboard);
- flood-compatible building components;
- structural integrity in times of flood;
- minimum levels for car-parking and driveways to aid in evacuation;
- no increased reliance on SES resources in times of flood.

High Flood Risk Precinct

The High Flood Risk Precinct refers to land that would be flooded in a 100 year flood with deep and fast-flowing water (i.e. high flood hazard).

Most development would not be permitted in this precinct. No additional residential properties would be permitted and there could be no subdivision of land. Filling activities would be very strictly controlled.

It is important to note, however, that existing development in a High Flood Risk Precinct would not be sterilised. House extensions, sheds and garages would all be permitted with limits as to the size of the development. Rebuilding an existing house with the same size but less flood risk (e.g. a raised house) would also be permitted. Any permitted development would have strict building controls, similar in nature to those listed above for a Medium Flood Risk Precinct, and would be subject to Council approval.

Extensions to Existing Homes, and Construction of Garages and Garden Sheds

These types of development are referred to as "concessional development" and would generally be permitted in all areas of the floodplain. Concessional development would be subject to range of flood-related building controls, similar in nature to those listed above for a Medium Flood Risk Precinct, and would be subject to Council approval.

To be classified as "concessional development", the extra area of the home must not be more than 10% of the original area or 50 square metres, whichever is the larger. Similarly, a new garage or garden shed, not attached to the main house, can not be larger than 50 square metres.

Rebuilding of Existing Homes

If a house is to be rebuilt in the same location and size to substantially reduce its flood risk (for example by building it at a higher level), this would also be classified as 'concessional development', meaning that it would be permitted in all areas of the floodplain. Again, the development would be subject to the range of flood-related building controls similar in nature to those listed above for a Medium Flood Risk Precinct, and would be subject to Council approval.

New Detached Dwelling

The rural-residential zoning in the South Creek study area allows a second dwelling to be built on each property. No new dwellings would be permitted in a High Flood Risk Precinct. In a Medium or Low Risk Precinct, the development would be subject to a range of flood-related building controls similar in nature to those listed above for a Medium Flood Risk Precinct, and would be subject to Council approval. In Medium Flood Risk Precinct, the building up of land by filling to construct a new dwelling would be strictly controlled.

Commercial and Industrial Development

This type of development would not be permitted in a High Flood Risk Precinct. In a Medium or Low Risk Precinct, the development would be subject to a range of flood-related building controls similar in nature to those listed above for a Medium Flood Risk Precinct, and would be subject to Council approval.

Subdivision of Land

This type of development would not be permitted in a High Flood Risk Precinct. In a Medium Flood Risk Precinct, an engineer's report would be required to certify that the development would not increase flood effects elsewhere and it would have to be

demonstrated that the development could be evacuated in accordance with the requirements of the Flood Risk Management DCP. All subdivisions would be subject to Council approval.

Filling Of Land

To assist Council in assessing when filling of land is and is not acceptable in the floodplain, guidelines have been prepared as part of this study entitled "Guidelines for the Assessment of Earthworks and Filling in Floodplain Areas of Non-Urban Land in Liverpool" in accordance with the draft Flood Risk Management DCP and the Planning Matrix for South Creek. These guidelines have been reviewed by Council and have been provided separately to Council.

These guidelines cover the following three types of filling activities that could occur in a floodplain:

- the importation of fill material not associated with the construction of a building;
- the importation of fill material to be used as a fill pad for the construction of a new dwelling or an outbuilding (shed, detached garage, etc.);
- the movement of material around a property with no net importation of fill, known as compensatory works.

A summary of the controls relating to the filling of land is as follows:

- Council consent would be required if there is importation of fill material that is more than 100mm in depth or more than 250 square metres in area;
- an Assessment Of Flood Effects (see Schedule 2 of the draft Flood Risk Management DCP) would be required if only compensatory works were carried out and fill depths were more than 1m, or more than 250 square metres of land was involved. All compensatory works within the Boundary of Significant Flow (see **Section 4.2.2**) would be subject to an Assessment of Flood Effects;
- there would be concessions in all areas of the floodplain to allow for small volumes of imported fill to be used solely as a fill pad for the construction of a dwelling, extension, garage or shed, namely:
  - for a new dwelling (including the driveway and garage) in a Medium Flood Risk Precinct, a total area of 400 square metres of fill would be permitted for a fill pad;
  - for a new detached garage or shed (not associated with a new dwelling) a total area of 50 square metres would be permitted for a fill pad in all areas of the floodplain;

  Development involving such importation of fill, however, would still be required to carry out an Assessment of Flood Effects (see Schedule 2 of the draft Flood Risk Management DCP) to ensure that there was no reduction in the existing flood conveyance due to the filling activities (It has been assessed that the maximum

possible loss of flood storage from the cumulative impacts of allowing these type of fill pads, based on the current rural-residential zoning rules, would be negligible when compared with the total flood storage volume of the South Creek floodplain).

Fencing

It is important that fencing does not result in the undesirable obstruction of floodwaters or is not washed away, becoming potentially dangerous moving debris, during a flood.

All fencing proposed in the floodplain would need to be certified by a suitably qualified engineer to ensure that it could withstand the forces of floodwaters, or collapse in a controlled manner to prevent an undesirable impediment of floodwaters.

In a High Flood Risk Precinct or within the Boundary of Significant Flow, only open or permeable type fencing would be permitted. A Development Application (DA), would be required for all solid fencing in the High and Medium Flood Risk Precincts.

8.1.5 Planning Controls and Policies — Recommendations

Findings: *It is recommended that some of the provisions and terminology adopted in Sydney Regional Environmental Plan No.20 — Hawkesbury–Nepean River (SREP No.20) be amended to provide a consistent framework for flood planning for the Liverpool LGA. It is recommended that the Liverpool Floodplain Management Committee formally endorses the recommended changes to the SREP No.20 provided in Appendix A of Volume 2 of this report, for referral to Department of Infrastructure, Planning & Natural Resources (DIPNR), together with the development of a strategy to fast-track the necessary revisions.*

It is recommended that Council considers amending some of the provisions and terminology adopted in the Liverpool LEP as outlined in Volume 2 of this report, to provide a consistent framework for more detailed controls to be provided in the Flood Risk Management DCP, together with the development of a strategy to fast-track the necessary revisions.

*It is recommended that the Liverpool Floodplain Management Committee endorse the planning approach outlined within Volume 2 of this report. This planning approach requires the adoption of a graded set of planning controls (The Planning Matrix, see **Table 8.1**) for different land uses relative to different levels of flood risk within the study area, consistent with the requirements of the NSW Floodplain Management Manual. This would also involve the adoption of High, Medium and Low Flood Risk Precincts as described in **Section 4.2**.*

*It is recommended that Council finalise the draft Flood Risk Management Development Control Plan included as Appendix C of **Volume 2** of this report, and provides for its formal preparation and adoption in accordance with the procedures outlined by the Environmental Planning and Assessment Act, 1979.*

8.2 VOLUNTARY PURCHASE OF PROPERTIES

8.2.1 Overview

Under a voluntary purchase scheme, Council would offer to purchase flood liable properties if and when they became available for purchase, subject to the availability of funds at the time. Voluntary purchase is not compulsory acquisition and affected property owners can expect to receive market values, or higher than market values, for their properties. In other words, the valuation made for a property assumes that no voluntary purchase scheme is in place and disregards development constraints that may apply on that land due to its flood prone nature.

Voluntary purchase schemes, by their very nature, cannot be implemented immediately. To be successful, the majority of owners in the area need to take up the offer and a suitable allocation of funds must be available to purchase the properties. There needs to be an ongoing commitment from Council to continue to purchase properties into the future as they become available, in spite of changes to Council's elected officers and senior staff.

The cost of this measure is high and does not address flooding problems elsewhere in the catchment. The nature of flooding is such that expenditure of this nature is often difficult to justify. Therefore, only the most severely affected properties are usually considered for inclusion in voluntary purchase schemes.

Liverpool City Council already has a voluntary purchase scheme for a number of properties in the Moorebank area for properties severely affected by flooding from the Georges River. This scheme has been ongoing for a number of years. Unfortunately, the escalating Sydney property market has meant that Council can purchase fewer and fewer properties each year and so the scheme has many years before it will be fully implemented. Consequently, Council is reluctant to embark on additional voluntary purchase schemes in other floodplain areas in its LGA.

8.2.2 Voluntary Purchase in the South Creek Study Area

Because of the high cost of voluntary purchase, only the most severely flood-affected properties are usually considered for the scheme. A review of real estate prices in March 2004 found that a 2ha property in the Kelvin Park area, with a fairly new house would cost about $1.5million, while a typical property in the ‘older’ areas of the study area would cost in the order of $750,000 to $1.1million.

The following two options were considered for the South Creek study area:

- ***Option VP5: Voluntary purchase of properties with over-floor flooding in a 5 year flood*** — The following two properties would fall into this category:

  - Nos. 35 and 82 Victor Avenue;

  Both these properties have a second house on the property whose floor levels would be above the level of the 100 year flood. Therefore these properties are likely to cost in excess of $1million each. This option was considered cost prohibitive and has not been recommended further;

- ***Option VP20: Voluntary purchase of properties with over-floor flooding in a 20 year flood*** — The following seven properties would fall into this category:

  - Nos. 120 and 150 Overett Avenue;
  - Nos. 10, 20, 50 and 60 Victor Avenue;
  - No.100 Watts Road;

  An economic analysis found that to purchase these properties, would yield a benefit–cost ratio of about 0.2. Given the scheme would cost in the order of $6million, this option is considered to be cost prohibitive and has not been considered further.

Findings: No voluntary purchase is recommended for the South Creek study area.

8.3 VOLUNTARY HOUSE RAISING

8.3.1 Overview

The raising of timber and fibro houses has proved to be an effective floodplain management measure for various locations throughout NSW. More recently, techniques have been developed so that brick-veneer homes can also be successfully raised.

Fairfield City Council has been implementing a house-raising program in Prospect Creek for many years now, with over 120 houses being successfully raised. House raising has also been carried out in the Lake Macquarie City Council area, and in other parts of northern New South Wales. It has also been proposed in several recently completed floodplain risk management plans, including those for the Blacktown, Narrabri, Scone, Molong, and Mudgee floodplains.

Recent experience by Holroyd City Council and Fairfield City Council has indicated that timber, fibro and brick veneer houses can be raised to create a two-storey home for a typical cost of about $70,000.

There are various forms of house raising schemes that can be considered. The easiest form of house raising is where houses are of either timber or fibro construction. Where houses are built with a brick veneer, full brick construction and/or are two storeys in height, the physical raising of the house is often more difficult and in some cases impractical. Under these circumstances, variations to the traditional house-raising concept may need to be considered. One solution would be to build a first floor extension on top of the existing building, and convert the lower floor to a non-habitable form. A disadvantage of this option is that there will be a temptation by the owner to occupy both floors, and the objective of minimising flood damage may be lost.

An alternative to house raising is to completely rebuild the house at a higher level, which may or may not be accompanied by a change in home ownership. If offered for sale, Council could buy the property, demolish the existing house, and sell the vacant building lot with appropriate floor level controls. Typical net costs for these options are likely to up to $100,000 per house.

The NSW Government provides financial assistance for house raising schemes that are carried out as part of the implementation of an adopted floodplain risk management plan. Where it can be economically justified, this is often a 'full-cost subsidy'. With these schemes, the full cost of the house-raising would provided to the owner, up to a maximum cost. This would be generally limited to those houses that are located in the most hazardous areas during a flood.

Where a 'full-cost subsidy' cannot be economically justified, a 'partial subsidy' could be considered as part of the *Floodplain Risk Management Plan*. This would most likely apply to houses that would be flooded less frequently and to a lesser depth. A 'partial subsidy' scheme could provide, say, $15,000–$20,000 towards the cost of house raising, with the homeowner required to pay the remainder. The 'partial subsidy' would offer homeowners who were considering raising their homes, further incentive to do so.

Recent advice from DIPNR has indicated that if an owner of a house in a house-raising scheme wanted to demolish an existing house and rebuild it at a higher level, such that the upper storey was built above the level of the probable maximum flood to allow 'vertical evacuation' (see **Section 5.2.4**), then that owner would be eligible for the relevant house-raising subsidy.

There are a number of disadvantages associated with house raising, for example:

- steps to gain access to the house may not be suitable for older people or those with disabilities;
- other property damage within the property, e.g. damage to parked cars and equipment, may still occur;
- after raising, residents may 'close in' any downstairs area to create further habitable areas (without Council approval) and thus increase future flood damage potential;
- there may be aesthetic and town planning constraints associated with raising some houses. For example, isolated raising of individual properties in a street may be less desirable than schemes that include a group of properties within that location.

8.3.2 Voluntary House Raising in the South Creek Study Area

This section provides the details of the voluntary house raising options considered for the South Creek study area. It has been assumed that the cost of 'full-cost subsidy' house raising would be $70,000, while the cost of a 'partial-cost subsidy' house raising would be $20,000. These subsidies would be subject to increases in the Consumer Price Index (CPI) and other fluctuations in the construction industry.

The house raising options considered for the South Creek study area are as follows:

- ***Option HR5: Voluntary house raising of properties with over-floor flooding in a 5 year flood*** — The following two properties would fall into this category:

- No.35 Victor Avenue — one-storey weatherboard home;
- No.82 Victor Avenue — one-story brick slab-on-ground home;

Both these properties appear suitable for house raising. An economic analysis found that, at a 'full subsidy' cost of $140,000 (i.e. $70,000 each), this option would yield a benefit–cost ratio of about 2.4.

It should be noted that each of these properties has a second house on the property whose floor levels would be above the level of the 100 year flood.

Therefore, Option HR5 with a 'full subsidy' cost of $140,000 is recommended for further consideration as a high priority;

- ***Option HR20: Voluntary house raising of properties with over-floor flooding in a 20 year flood*** — Of the seven properties that would fall into this category, four of the dwellings appear suitable for house raising as they are all one-storey. These are:

  - Nos. 10, 20, and 50 Victor Avenue;
  - No.100 Watts Road;

  An economic analysis found that, at a 'full subsidy' cost of $280,000 (i.e. $70,000 each), this option would yield a benefit–cost ratio of about 0.8.

  Therefore, Option HR20a with a 'full subsidy' cost of $280,000 is recommended for further consideration as a medium priority.

  The remaining three properties that would be flooded above floor level in a 20 year flood are two-storey dwellings and would be difficult to raise. These are:

  - Nos. 120 and 150 Overett Avenue;
  - No.60 Victor Avenue;

  The second storey of the properties in Overett Avenue would be high enough to be above the level of a PMF, so vertical evacuation would be possible. However, the house at No.60 Victor Avenue would have a depth of 2.5m of water over the lower floor in a PMF, so the upper storey may still be flooded above floor level in a very large flood.

  At a 'partial subsidy' cost of $60,000 (i.e. $20,000 each), this option would yield a benefit cost ratio in the order of 2.0.

  Therefore, Option HR20b with a 'partial subsidy' cost of $60,000 is recommended for further consideration, with the two houses in Overett Avenue as a low priority and No.60 Victor Avenue as a medium priority;

- ***Option HR100: Voluntary house raising of properties with over-floor flooding between a 20 year flood and 100 year flood*** — There are ten properties that fall into this category:

- No.70 Kelvin Park Drive;
- Nos. 80, 124, 135 and 145 Overett Avenue;
- Nos. 5, 32, 50 (second house) and 70 Victor Avenue;
- No.1 May Avenue.

At a 'partial subsidy' cost of $200,000 (i.e. $20,000 each), this option would yield a benefit cost ratio in the order of 0.5–1.0.

Therefore, Option HR100 with a 'partial subsidy' cost of $200,000 is recommended for further consideration as a low priority measure.

8.3.3 Voluntary House Raising — Recommendations

Findings: *A 'full-cost subsidy' voluntary house raising scheme is recommended for six properties in the study area flooded above floor level in a 20 year flood, at a cost of $420,000 (Options HR5 and HR20a):*

- *Nos. 35 and 82 Victor Avenue — high priority;*
- *Nos. 10, 20, and 50 Victor Avenue — medium priority;*
- *No.100 Watts Road — medium priority;*

Findings: *A 'partial-cost subsidy' voluntary house raising scheme is recommended for three properties in the study area flooded above floor level in a 20 year flood, at a cost of $60,000 (Option HR20b):*

- *No.60 Victor Avenue — medium priority;*
- *Nos. 120 and 150 Overett Avenue — low priority;*

Findings *A 'partial-cost subsidy' voluntary house raising scheme is recommended for ten properties in the study area flooded above floor level between a 20 year flood and a 100 year flood, at a cost of $200,000 (Option HR100):*

- *No.70 Kelvin Park Drive — low priority;*
- *Nos. 80, 124, 135 and 145 Overett Avenue — low priority;*
- *Nos. 5, 32, 50 (second house) and 70 Victor Avenue — low priority;*
- *No.1 May Avenue — low priority.*

8.4 FLOOD PROOFING

Individual properties, particularly commercial properties, can be modified to reduce the impacts of flooding by a number of flood proofing techniques. These techniques include, but not limited to, the following:

- construction of small flood-retaining walls around the immediate perimeter of the house or around a small proportion of the property. These types of walls are similar to levees in function and so if walls are to be extended beyond the immediate perimeter of the house, the same issues as levees need to be considered before they are installed (see **Section 10.1**). Generally it must be ensured that the walls would not adversely affect the flood behaviour at neighbouring properties;

- fitting waterproof doors and/or waterproofing walls of houses;

- locating shelves and storage areas at a height above the likely flood level for the storage of electronic equipment and personal effects (particularly photographs, diaries, clothes and other memorabilia).

Generally these flood proofing measures have been found to be most effective for short duration floods as extended periods of inundation increases the likelihood and extent of leaks through the waterproofing measures.

There are other flood proofing measures such as installing, or having on-site, 'Inverell-style' shutters (which can be placed across doors and windows to protect them from inundation) or having a supply of sandbags readily available. However such measures rely on some form of flood warning to be effective — this may not be possible for the South Creek study area.

Flood proofing measures are a private cost and so could be implemented with minimal cost to Council.

Results from the community survey indicated that one-third of the respondents thought that "new buildings should be built with materials that are suitable for areas that have flood problems". Therefore, the preparation of 'Flood Proofing Guidelines' is recommended for inclusion in the *Floodplain Risk Management Plan*. The estimated cost for production of these guidelines in about $5,000.

Some examples of some flood compatible materials and building techniques are included as Schedule 1 of the draft Development Control Plan (see **Volume 2** — Planning Issues (Don Fox Planning, 2004)).

Findings: *Preparation of 'Flood Proofing Guidelines' is recommended for inclusion in the Floodplain Risk Management Plan at a cost of about $5,000 as a medium priority measure.*

9. RESPONSE MODIFICATION MEASURES

Measures that modify people's response to flooding include measures that provide additional warning of flooding, improvements to emergency management measures during floods and improved public awareness of the flood risk. All these measures were well supported by the community in the October 2003 community survey.

These types of measures are described in this chapter in the following sections:

- flood warning (**Section 9.1**);
- emergency management (**Section 9.2**);
- community flood awareness (**Section 9.3**).

9.1 FLOOD WARNING

9.1.1 Overview of Flood Warning

Flood warning is an important part of floodplain risk management. It provides information on impending flooding so that people and relevant agencies can take action to minimise the impacts of flooding. It provides information to the public and to agencies that have a specific function during flood emergencies. Without this information, the ability of the public and the agencies to respond is severely restricted.

The Emergency Management Australia's '*Flood Warning — An Australian Guide*' (1995) defines the purpose of flood warning as:

> *"… to provide advice on impending flooding so people can take action to minimise its impacts. This will involve some people taking individual actions on their own behalf and others taking action as part of agency functions.*
>
> *Flood warnings are effective if they persuade people to take action to lessen the impact of a flood and help agencies carry out their roles during flood events."*

Recent surveys of floodplain communities in other catchments have shown that there is generally strong community support for improved flood warning procedures in flood-affected catchments.

Through its Flood Warning Service Program, the Bureau of Meteorology is the government agency normally responsible for issuing flood warnings throughout Australia. The primary function of the Flood Warning Service Program is the provision of an effective flood forecasting and warning service in each Australian State and Territory. This service is provided in cooperation with other government agencies such as State/Territory emergency management agencies, water authorities, local Councils and Flood Warning Consultative Committees (Bureau of Meteorology, 2004a).

There are three stages for flood warning to consider:

- a predictive tool that looks at weather patterns that are likely cause flood producing rain — an example of this, is the Bureau of Meteorology's 'Flood Watch' system;

- a system that operates once the rain has started to fall — this is a 'Flood Warning' system and is devised specifically for the local area using information from local rainfall stations;

- communication of the flood warning — with the knowledge gained from the two systems above, it is usually the responsibility of the State Emergency Service (SES) to ensure local residents are aware of the warnings and aware of the appropriate actions they should take (see **Section 9.2**).

9.1.2 Flood Warning Options

Flood warning systems generally monitor rainfall and river gauges in the upper parts of catchments in real time and, through hydrologic/hydraulic models, predict the resulting flow and flood levels at some time in the future in the lower catchment. Forecasts of continuing rain or anticipated changes in rainfall intensity can also be included in the models to provide additional forecasting ability.

Flash Flood and Non-Flash Flood Areas

If the time between the start of rain and the start of flood problems is greater than 6 hours, then it is possible that the Bureau of Meteorology could provide a flood warning service given there was enough rainfall and stream height information. These catchments are referred to as 'non-flash flood' areas.

When there is less than 6 hours between the start of rainfall and the start of flood problems, the Bureau of Meteorology classifies these locations as 'flash flood' areas. In these catchments, by the time the Bureau of Meteorology is aware of the excessively high rainfalls, the flooding has already occurred. Consequently, the Bureau of Meteorology cannot provide a flood warning service in these catchments.

As the study area at South Creek has a catchment area of about 60km^2–90km^2, the Bureau of Meteorology suggests that there would be about 3–4 hours between the start of rain and the start of flood problems. This means that the study area would be classified as a 'flash flood' area and a flood warning service would not be available. A severe thunderstorm could cause flooding in less than one hour.

It should be noted that this 'time for the onset of flooding' of 3–4 hours is quite different to the 40-hour 'critical duration' determined from the 1991 RAFTS modelling of the South Creek catchment (*1991 FPM Study*). The critical duration storm represents the duration of the storm that would produce the highest flows and hence highest flood levels at certain locations in the catchment, including that at Bringelly Road and Elizabeth Drive. The 'onset of flooding' time, however, represents the time between when rain starts to fall in the catchment and when the start of flood problems can be expected.

Flood Watch

Flood Watch is a predictive tool used by the Bureau of Meteorology to identify certain weather patterns that indicate that flooding MAY be an imminent problem. It is more suited to identifying moderate and major floods.

Flood Watch is a large-scale model only and looks at a generalised weather patterns over say the whole east coast of NSW. If, for example, a large amount of rain was expected over the next 12 hours over the east coast, a Flood Watch could be issued. This is not a flood warning, rather it is an early alert that heavy rain is expected in some areas and that flooding may be a problem. This would notify SES, Local Authorities and even the community that something MAY happen.

This would be the only form of 'formal flood warning' available for the study area. However, because Flood Watch is a large-scale model, different areas would be affected differently. Some relatively small areas, such as the study area, may not ultimately be affected.

The Bureau of Meteorology is currently working on the best means of communicating a 'Flood Watch'. This could be via radio eg. within weather or traffic reports. Education is needed at all levels that the Flood Watch is not a warning that a flood is likely to occur. Rather, it should be emphasised that the Flood Watch is an alert that heavy rain is expected that COULD cause flooding in some areas. The issuing of a Flood Watch should be a trigger for the community to go through the check lists provided on such things as the flood information guides issued by the SES.

Severe Thunderstorm Warning

This is another predictive tool used by the Bureau of Meteorology. This system provides about 1 hour's notice that severe weather is likely. This type of warning gives no indication of the amount of rain that can be expected.

The Bureau of Meteorology makes thunderstorm warnings within the Newcastle–Sydney–Wollongong area. This advice is based on information available from synoptic charts and Sydney radar. The warnings are made before the rainfall actually occurs. It is usually provided for general areas and is not specifically targeted at individual, small areas, such as in the current study area.

9.1.3 Real Time Rainfall and River Height Information

The Bureau of Meteorology's web site (www.bom.gov.au) provides almost real time rainfall and river height information for the whole of Australia. 'Real time' means that information is available almost as soon as it happens. The on-line information is updated hourly.

The web site gives rainfall data in the last hour, 2 hours, 3 hours, 4 hours, 5 hours, 6 hours, 24 hours and since 9am that morning. The information is presented in map and table form. The easy to read on-line map provides readily available information to all those with internet access.

Most of the 'real time' rainfall stations in the Sydney region provided on the Bureau of Meteorology web site are one of the following two types:

- an automatic weather station (AWS); or

- an ALERT station. ALERT stations are radio telemetry stations programmed to notify base stations with a signal when more than a certain amount of rainfall occurs (usually 1mm) or there is a river rise of a particular height (usually 10mm).

There are three 'real time' rainfall stations in the vicinity of the study area:

- South Creek at Elizabeth Drive (an ALERT station);
- Badgerys Creek at Airport site (AWS);
- "Maryland" (an ALERT station located just to the west of The Old Northern Road near the Cobbity Pony Club in the upper reaches of the South Creek catchment).

Other 'real time' rainfall stations shown on the Bureau of Meteorology web site that surround the study area include:

- St. Clair;
- South Creek at Great Western Highway (an ALERT station);
- Horseley Park (AWS);
- Fairfield City Farm;
- Liverpool;
- Liverpool at Scrivener Street (Georges River) (an ALERT station);
- Holsworthy (AWS);
- Ingleburn Reserve;
- Kentlyn;
- Camden.

River height data is also provided on the Bureau of Meteorology website for South Creek at Elizabeth Drive, as well as for South Creek at the Great Western Highway.

To gain access to real-time rainfall and river height information shown on the Bureau of Meteorology's web site, the computer program 'Enviromon' is used as the real time data collection and display package (Bureau of Meteorology, 2004b).

There are about twenty base stations located in the offices of 'local authorities' around the Sydney Region area that have access to this real-time data. These base stations are mostly located in the local offices of the State Emergency Service (SES) and in some local Councils. It is understood that this link is not yet available to the local Liverpool SES Headquarters.

To obtain real-time access, the SES (or any local authority) would need a computer and would need to meet all the costs associated with keeping the base station up and running. The Bureau of Meteorology would provide technical assistance and would install the 'Enviromon' program.

Alarming systems are currently being developed where certain triggers are programmed in to notify these base stations that there may be a flood problem developing at a particular location.

These triggers do not necessarily have to be linked to the traditional 'minor', 'moderate' and 'major' flood warnings. For smaller catchments, such as the South Creek study area, linking the triggers to certain recurrence intervals may be more appropriate. It would therefore be possible to identify, in advance, critical rainfall intensities at these rainfall stations above which floodwaters can be expected to enter flood-affected localities downstream. This information would not give emergency personnel much time to effect road closures and evacuations, but it would provide a high degree of certainty that flooding was imminent.

The Bureau of Meteorology is currently working on a combined radar and rainfall system to provide a more accurate predictive tool and to provide better on-line information on their web site and to the local Base Stations. An operational version of this system is estimated to be about 5 years away.

The development of triggers from nearby rainfall stations to identify when flooding may be imminent and linking these triggers to the base stations, particularly the local Liverpool SES Headquarters, is recommended for the study area as a high priority measure for the *Floodplain Risk Management Plan*.

9.1.4 Additional Rainfall Stations for the South Creek Catchment

Just because a flood warning system is not possible for the study area, this does not mean that there are no options to try to give the community some warning that a flood may be possible or a flood may be imminent. Some warning, based on upstream rainfalls, may be possible, albeit with limited time to take action.

Following discussions with the Bureau of Meteorology's Flood Warning Service (Bureau of Meteorology, 2003), including a preliminary review of the map of the locations of the rainfall stations around the South Creek study area, suitable locations for additional 'real time' rainfall stations in the South Creek catchment have been investigated.

This review has shown that there is scope to provide up to three rainfall stations in the upper reaches of the South Creek catchment at the following indicative locations:

- at the South Creek crossing of Camden Valley Way;
- at the Rileys Creek crossing of Camden Valley Way;
- at or near Oran Park Raceway in the uppermost reaches of the catchment.

Rainfall gauges are usually located on private property, such as golf courses or factories, to limit vandalism and theft.

Further advice from the Bureau of Meteorology (Bureau of Meteorology, 2004b) suggests that a total cost of about $20,000 would cover the capital cost of the equipment for the rainfall station, and is likely to cover all the installation costs. The Bureau of Meteorology would provide technical assistance such as siting of the rainfall station, ordering of equipment, and radio path testing. Installation would be carried out by Council staff or by a contractor.

Once installed, the data gathered from the rainfall stations would be available to existing base stations on a real-time basis. The data would also be available on the Bureau of Meteorology web site, updated hourly, for all to access.
If triggers were developed for these rainfall gauges, local SES base stations could then be notified if a certain amount of rainfall fell in, say, 1 hour or a total amount of rainfall fell, say, over 2–3 hours (based on design rainfalls for different recurrence intervals).

The rainfall stations would be owned by Council, who would be responsible for their maintenance. However, the Bureau of Meteorology would continue to cooperatively assist Council with technical advice and training on maintenance of the stations. Maintenance usually consists of an annual routine check on the equipment. Typical maintenance costs have been found to be about $500–$1,000 per year (Bureau of Meteorology, 2004b)

The installation of three additional rainfall stations is recommended for inclusion in the *Floodplain Risk Management Plan* as a high priority measure.

9.1.5 Flood Warning — Recommendations

Findings: *As the South Creek study area would be in a 'flash flood' area, there would be no formal flood warning service available from the Bureau of Meteorology.*

A Flood Watch or Severe Thunderstorm Warning issued by the Bureau of Meteorology would be the only 'formal' means of flood warning for the study area.

Three real time ALERT rainfall gauges and a river height station are operated in and close to the study area. The development of triggers for these rainfall and river height stations and the linking of these triggers to local base stations, particularly the local Liverpool SES Headquarters, to identify to local authorities, such as the SES, when flooding may be imminent is recommended for the Floodplain Risk Management Plan as a high priority measure.

The installation of three additional ALERT rainfall stations in the upper reaches of South Creek at a total cost of about $20,000 is recommended for the Floodplain Risk Management Plan as a high priority measure. The development of triggers for these new stations to alert local base stations of imminent flooding is also recommended as part of the establishment process.

9.2 EMERGENCY MANAGEMENT

The NSW State Emergency Service (SES) has formal responsibility for emergency management operations in response to flooding. This includes the coordination of other organisations for flood-related response tasks. Other organisations that normally provide assistance include:

- Commonwealth Bureau of Meteorology;
- local councils;

- NSW Department of Infrastructure, Planning and Natural Resources (DIPNR);
- NSW Department of Community Services;
- NSW Police Service;
- NSW Fire Brigade;
- Rural Fire Service;
- Volunteer Rescue Association;
- Ambulance Service of NSW;
- Roads and Traffic Authority (RTA);
- a range of community groups, services clubs and sports clubs.

9.2.1 Liverpool City Local Flood Plan

The *Draft Liverpool City Local Flood Plan* (SES, 2001) has been developed by the SES, and covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures for flooding within all of the city of Liverpool.

The *Draft Liverpool City Local Flood Plan* describes the procedures that will be used by the SES to manage a flood, including:

- the development of flood warning systems (see **Section 9.1**);
- the development of flood intelligence (see **Section 9.2.2**);
- communication of flood warnings and dissemination of SES Flood Bulletins;
- road and traffic control;
- evacuations;
- flood rescues;
- recovery coordination.

A number of annexes are provided as part of all *Local Flood Plans,* which include information relating to:

- Annex A: the flood threat — which is a description of the physical behaviour of the flood including weather systems likely to be associated with flooding, flood history, peak flows, flood patterns, design floods, extreme floods and any flood mitigation systems;

- Annex B: the effects of flooding on the community — which describes the likely flood behaviour at specific flood risk areas, together with the likely roads that are likely to be cut during floods;

- Annex C — information about river height gauges monitored by the SES local headquarters;

- Annex D — information about the media outlets (television stations, radio stations and newspapers) where SES Flood Bulletins are distributed in times of flood;

- Annex E — a template of standard wording for an evacuation warning message;

- Annex F — the evacuation arrangements for the Liverpool City area including details of the four phases of evacuation:

- Phase 1: Warning — this includes the gauge height triggers at which certain areas should start to prepare for evacuation and the evacuation routes they should take;

- Phase 2: Withdrawal — this phase is the actual removal of people from potentially dangerous areas;

- Phase 3: Shelter — the primary purpose of evacuation centres is to meet the immediate needs of victims. Evacuation centres in Liverpool and their capacities are listed;

- Phase 4: Return — this includes the process for the authorisation of the return of evacuees to their normal or alternative place of residence once it is safe to do so;

- Annex G — arrangements for the evacuation of caravan parks and the relocation of caravans;

- Annex H — details of any requirements for resupply of essential services;

- Annex I — details of any dams that may potentially fail during a large flood.

The *Draft Liverpool City Local Flood Plan* has been developed under the *State Emergency and Rescue Management Act, 1989* and the *State Emergency Service Act, 1989*. The Sydney Southern SES Division Controller and the Liverpool City Local Emergency Management Committee have accepted the Plan. It is a sub-plan of the Liverpool City Local Disaster Plan.

The South Creek study area is located within Sydney Southern Division of the SES and for emergency management purposes is part of the Sydney South West Emergency Management District. The Liverpool SES Local Controller reports to the Sydney Southern SES Division Controller.

It is understood that, as a result of the community workshop held as part of this study, a member of the local community who lives in Overett Avenue, has recently volunteered to be a Local Flood Warden. The Local Flood Warden would act as the 'local ears and eyes' in times of flood and would report to the Liverpool SES Local Controller.

Advice from the SES State Planning Coordinator late in 2003 suggests that the SES is currently updating the draft *Liverpool City Local Flood Plan* (SES, 2003).

9.2.2 Flood Intelligence from the Floodplain Risk Management Study

Flood intelligence describes flood behaviour and its effects on the community. These effects include:

- inundation of property which could lead to the need for evacuation and/or property protection;

- isolation, which could lead to the need for resupply of essential goods and/or rescue of people;

- disruption to community activities, for example, disruption through loss of transport routes.

Flood intelligence is obtained by gathering and assessing flood-related information so as to estimate the likely impacts of pending and future floods. Flood intelligence is an essential tool used by the SES for operational decision making and the provision of flood warnings and other information to agencies and the community.

A great deal of information provided in Floodplain Risk Management Studies can be an invaluable source of flood intelligence for the updating of Local Flood Plans. Representatives from the SES and Department of Infrastructure, Planning and Natural Resources (DIPNR) are currently discussing ways to formalise the type of information that should be prepared as part of a floodplain risk management study for inclusion in Local Flood Plans. This information relates mainly to Annex A (The Flood Threat) and Annex B (The Effects of Floods on the Community) as described above in **Section 5.2.1** (SES, 2003).

Some of the flood intelligence information that will be available from the current study for inclusion in the *Liverpool City Local Flood Plan* included the following:

- a detailed description of the flood behaviour including:

  - inundation maps for various flood sizes;
  - flood risk precinct maps;
  - river long-sections;

- a description of specific flood risk areas and the consequences that occur at various river heights or design flood events, such as:

  - when the area first becomes affected by flooding;
  - when certain roads become inundated and then untrafficable;
  - when houses begin to flood above floor level;
  - the maximum number of properties inundated;
  - when the area becomes isolated;

- information about all properties in the floodplain from the flood damages data base including floor and property levels and the number of storeys for all dwellings (see **Section 3.5**).

9.2.3 South Creek Study Area and the Liverpool City Local Flood Plan

The *Draft Liverpool City Local Flood Plan* covers the whole of the Liverpool Local Government area. However the current *draft 2001 Local Flood Plan* concentrates mainly on flooding from the Georges River and its tributaries (Prospect Creek, Cabramatta Creek and Harris Creek). There is only very limited mention of any flood intelligence and flood problems along South Creek within the current study area.

The *draft 2001 Local Flood Plan* does mention that the Bringelly Community Hall in Greendale Road, Bringelly and the Kemps Creek Community Centre in Elizabeth Drive are designated evacuation centres in times of flood. Both these centres have a capacity to temporarily accommodate about 100 people each (SES, 2001).

There is certainly an opportunity for information from the current Floodplain Risk Management Study to be incorporated into the next version of the Liverpool City Local Flood Plan.

Therefore, as part of the recommended *South Creek Floodplain Risk Management Plan*, it is recommended that all 'flood intelligence' information from the current study be made available to the SES for incorporation into the next version of the Liverpool City Local Flood Plan. This could be the format as suggested from the discussions between SES and DIPNR, as outlined in SES (2003). The likely cost for this would be $5,000 to $10,000. This is considered to be a high priority measure.

9.2.4 'Vertical Evacuation' in 'Flash Flood' Areas

As part of recent studies in the Wollongong area, there have been a number of recent discussions with the SES regarding evacuation in 'flash flood' areas (see **Section 9.1.2**). In the August 1998 flood in Wollongong, many parts of the city were devastated by flash floods that were in the order of a 100 year flood or larger.

As a result of experiences in the Wollongong floods, the current thinking of the SES is that the safest course of action for people flooded in 'flash flood' areas is for them to actually stay in their house (provided that house is not in danger of structural collapse). This is now considered safer than people attempting to drive out along flooded roads, when it often dark and it is pouring with rain.

These new thoughts are now being reflected in the planning controls being adopted for these areas. Planning controls have been developed to reflect this type of evacuation where there is essentially no warning time — the first 'warning' people get is when water physically enters the house. The controls require that ground floor levels should be at least at the 100 year flood plus freeboard, but for floods larger than the 100 year flood, there should be a 'safe haven' above the PMF. This 'safe haven' would generally be in the form of an upper storey. Hence, people are able to 'vertically evacuate'.

However, even with this 'vertical evacuation' during the time of the flood, the SES advises that evacuation is still likely to be necessary after the flood has passed. Evacuation may be necessary because of the health risks associated with the disruption of services such as sewer, electricity and water supply.

Planning controls that encourage 'vertical evacuation' are only possible in 'flash flood' areas, such as the South Creek study area, for the following reasons:

- because the PMF is usually less than one storey (i.e. about 2.4m) higher than the 100 year flood;

- because this 'safe haven' above the level of the PMF would only be needed for a relatively short period of time as floods pass through this catchment quite quickly — the SES would not have the resources to assist the people who had 'vertically evacuated' if they required emergency assistance.

This type of 'vertical evacuation', however, is not practical and is even dangerous, if the PMF is greater than one storey (about 2.4m) above the level of the 100 year flood. A submerged upper floor may mean there would be little or no way for occupants to evacuate. Fortunately, this is not the case in the South Creek study area.

Therefore, second storey additions may be permitted in areas of even high flood risk as they provide added safety for flood-affected residents. They also provide an area for people to take their possessions, if they have time, thereby reducing the overall damage sustained by the community. Non-habitable areas are encouraged in all lower storey areas.

From an emergency management perspective, it is unknown how many residences in the floodplain currently have a 'reliable access' to an area above the PMF. However, this could be estimated using the information in the flood damages data base as part of the collation of flood intelligence information for the Local Flood Plan.

It is therefore recommended that there be a provision for 'vertical evacuation' in the planning controls developed for the South Creek study area. This is considered a high priority measure as part of the recommended *Floodplain Risk Management Plan*.

9.2.5 SES FloodSafe Brochure

The NSW State Emergency Service's (SES) FloodSafe program has produced area-specific brochures that describe what to do in a flood, how the SES can help and broadly describe the flood problem of the area. The brochures also include a broad scale map showing the approximate extent of the floodplain up to the probable maximum flood.

The Hawkesbury–Nepean valley has a number of these brochures for different local government areas. The SES, in conjunction with Blacktown City Council, has recently produced a FloodSafe brochure for that part of Blacktown affected by flooding from the Hawkesbury–Nepean River. A copy of this brochure and other general flood awareness brochures produced by the SES are presented in **Figure 9.1.**

A FloodSafe brochure, prepared in conjunction with the SES, is recommended as a high priority measure as part of the *Floodplain Risk Management Plan*. The cost to prepare information for the SES for the FloodSafe brochure is estimated to be $5,000. This brochure, together with other, more general flood awareness information prepared by the SES, would be included in the 'Flood Information Packs' described in **Section 9.3.5**. Preliminary discussions have been held with the SES about whether a brochure should be prepared for just the current study area, or alternatively, for all of South Creek upstream of the limit of Hawkesbury–Nepean River flooding. Preliminary indications are that a FloodSafe brochure covering all of South Creek upstream of the limit of Hawkesbury–Nepean River flooding would be the more desirable.

FIGURE 9.1: EXAMPLE OF STATE EMERGENCY SERVICE FLOODSAFE BROCHURE AND OTHER FLOOD AWARENESS INFORMATION

FIGURE 9.1 EXAMPLE OF STATE EMERGENCY SERVICE FLOODSAFE BROCHURE AND OTHER FLOOD AWARENESS INFORMATION (continued)

9.2.6 Emergency Management — Recommendations

Findings: *All 'flood intelligence' information from the current study be made available to the SES for incorporation into the next version of the Liverpool City Local Flood Plan. The likely cost for this would be $5,000 to $10,000. This is considered to be a high priority measure.*

A provision for 'vertical evacuation' in the planning and development controls developed for the South Creek study area. This is considered to be a high priority measure.

A FloodSafe brochure, prepared in conjunction with the SES, is recommended as a high priority. The cost to prepare information for the SES for the FloodSafe brochure is estimated to be $5,000. Preliminary discussions have been held with the SES about whether a brochure should be prepared for just the current study area, or alternatively, for all of South Creek upstream of the limit of Hawkesbury–Nepean River flooding. Preliminary indications are that a FloodSafe brochure covering all of South Creek upstream of the limit of Hawkesbury–Nepean River flooding would be the more desirable.

9.3 COMMUNITY FLOOD AWARENESS

9.3.1 Overview

Flood awareness is critical to reducing the flood risk to the floodplain community and flood awareness is essential for flood readiness. In order to be 'flood ready', the floodplain community needs to know, in the event of a flood:

- what to do;
- where to go;
- who to contact.

Actual flood damages can be reduced if community awareness of flood issues is raised. Flood damage surveys undertaken throughout NSW (Water Studies Pty Ltd, 1992) have shown that potential flood damage can be greatly reduced where there are effective warning times and a flood aware community.

A comprehensive community flood awareness strategy is a key recommendation of the *South Creek Floodplain Risk Management Plan*. Most of the components of this strategy relate to the release of flood information to the community.

Respondents to the community survey (**Section 5.2.2**) were generally in favour of those options that provided them with more information about the potential risks of flooding, including:

- provision of a flood certificate to all residents stating whether their property is flood-affected (49% thought it was a 'good idea');

- provision of all information about potential risks of flooding, including flood maps, on Council's web site (46% thought it was a 'good idea');

- installation of flood markers (for example on telegraph poles) to act as a constant reminder of the heights of previous floods (45% thought it was a 'good idea').

Recent surveys of floodplain communities in other catchments have shown that both residents and business proprietors are generally strongly in favour of gaining more information about the potential risks of flooding. These surveys have shown that people generally want answers to questions, such as:

- 'How does flooding affect my property?'
- 'How does flooding affect me personally?'
- 'Does flooding affect the way I want to improve or develop my property?'.

The following methods are discussed in this section as a means to raise flood awareness in the study area:

- production of maps that depict the Flood Risk Precincts as described in **Section 4.2** (**Section 9.3.2**);

- updating of the Council's Geographical Information System (GIS) with the information now available from this study (**Section 9.3.3**);

- preparation of a brochure outlining a simplified explanation of the flood-related building controls that would apply to 'typical' residential development (**Section 9.3.4**);

- preparation of 'Flood Information Packs' that would be sent to all residents in the floodplain (**Section 9.3.5**);

- issuing of Flood Certificates that would be used for more formal situations, such as when Development Applications are submitted (**Section 9.3.6**);

- installation of flood markers (likely to be at two locations, say, at Elizabeth Drive and Bringelly Road) to act as constant reminders of the heights of past floods (**Section 9.3.7**);

- appropriate notification on Section 149 Certificates, which are zoning certificates that must be attached to a contract prepared for the sale of property, that are issued under the provisions of the *Environmental Planning and Assessment (EP&A) Act, 1979* (**Section 9.3.8**);

- public exhibition of this Study Report and draft *Floodplain Risk Management Plan* for community comment (**Section 9.3.9**).

These methods comply with the requirements of the *Floodplain Management Manual* (NSW Government, 2001) and Section 149 of the *Environmental Planning and Assessment (EP&A) Act, 1979.*

9.3.2 Flood Risk Precinct Maps

Flood Risk Precinct maps show all known areas of the floodplain up the probable maximum flood. They show the limits of the three Flood Risk Precincts (low, medium and high) as described in **Section 4.2**. Flood levels, flood depths or flood extents of floods of varying probabilities would not necessarily be shown — only areas of similar flood risk. The maps would include notations and advice that not all land with potential flood risks may be identified, particularly areas at risk of inundation from overland flows and surcharging piped drainage systems.

There are likely to some locations within the study area where the flood problem has not been defined by a formal study, but anecdotal or other information suggests the property may be potentially flooded from overland flows or from one of the many small tributaries of South Creek within the study area. These areas would be referred to as 'potentially flooded'.

Future discussions with Liverpool City Council and its Floodplain Management Committee will be required to determine the most appropriate, albeit approximate, means of identifying the 'potentially flooded' properties and including them on the Flood Risk Precinct maps. The draft Flood Risk Management Development Control Plan (DCP) outlines the process to be followed when submitting a Development Application (DA) in these areas.

It is recommended that the Flood Risk Precinct maps be readily available to the public. This would preferably be via Council's web site. The maps should, at least, be available at the Council's inquiry counters and on the GIS data base systems (see **Section 5.3.3**). This ensures that Council is 'making it easy' for members of the community to obtain information about flood risks.

9.3.3 Updating of Council's Geographical Information System and Use of Information Available from this Study

Following the completion of the current study, there will be a large amount of flood-related information available from this study, particularly from the Digital Terrain Model and the Flood Damages Data Base, which could be input into Council's property Geographical Information System (GIS).

The following information is available for each house in the study area listed in the flood damages data base (see **Section 3.5**):

- house floor levels, ground levels (adjacent to the house) and property low points;
- construction material of the house, including number of storeys;
- description of other buildings on the property, such as sheds and garages;
- Flood Risk Categorisation (High, Medium or Low);
- flood levels for the 5 year, 20 year, 50 year, 100 year and PMF flood events.

The '2003 MIKE-11 model' represents the best available information for the South Creek floodplain in its current form. It is a recommendation of this study that Council use the '2003 MIKE-11 model' results for all future development assessments, as the basis for flood information placed on Section 149 Certificates (see **Section 9.3.8**) and for all relevant day-to-day activities of Council.

The updating of the Council's GIS and the use of information from this study are recommended as important means of raising flood awareness, not only in the local community, but with Council staff as well.

9.3.4 Guidelines on Flood-Related Building Controls

To help the community understand how the Flood Risk Precinct Maps and the associated planning controls would affect the way they may want to improve their property, a brochure (in the form of guidelines) outlining a simplified explanation of flood-related building controls for residential development is proposed. Answers to the questions, such as the following, would outline the constraints and opportunities for residential development for each of the three Flood Risk Precincts:

- "Does flooding affect the way I want to improve my property?";
- "What is a 'Flood Risk Precinct'?";
- "What building controls would apply if I wanted to extend or rebuild my existing home?";
- "What building controls would apply if I wanted to build an additional home on my property?";
- "What building controls would apply if I wanted to build a new home on a vacant block of land?";
- "What building controls would apply if I wanted to build a shed or a garage separate from my house?";
- "What if I wanted to place fill on my land?";
- "What if I wanted to subdivide my land?";
- "Who should I contact for more information".

The answers to these questions would be taken directly from the Planning Matrix and would include whether that type of development would be permitted and the flood-related building controls that would apply.

Such a brochure is recommended for inclusion in the *Floodplain Risk Management Plan* as a high priority measure. The cost of the design of the brochure has been estimated to be about $5,000.

9.3.5 Flood Information Packs

Flood notification to all residents in the floodplain (that is up to the level of the probable maximum flood) is recommended as a key means of raising flood awareness in the catchment. It is important with such notifications that the recipients of the information understand that the supplied information actually applies to them and is not a part of a general mail out to everyone in the Council area.

The exact details of implementation of the strategy would need to be discussed with Council officers and the Floodplain Management Committee to examine issues such as the timing of the release of information. For example, all the information could be sent out at the one time at regular intervals (say every 1–2 years) or different information could be sent out every, say, 3–6 months. The Flood Information Packs that would be sent to all residents (owners and occupiers) in the floodplain would include the information detailed below.

Flood Notification Letter

The Flood Notification Letter would explain that the particular property is located in a floodplain, how flooding may affect the property, generally what development controls would apply and how more information could be obtained. A similar letter has recently been sent out to all residents whose properties would be affected by a probable maximum flood from the Georges River.

Flood Information Brochure

This A4-size folded brochure would broadly describe flooding, the flood problems in the study area, the Flood Risk Precincts, the Flood Risk Precinct Maps and some key flood-related development constraints and opportunities. Such a brochure could be prepared in conjunction with the 'Guidelines for Flood-Related Building Controls' described above (**Section 9.3.4**).

The cost of the design of the brochure has been estimated to be about $5,000.

Frequently Asked Questions about Floodplain Risk Management Studies

A brochure on 'Frequently Asked Questions about Floodplain Risk Management Studies' is also proposed for inclusion in the Flood Information Packs, as well as being available at Council's inquiry counter. A copy of the brochure was available as a handout at the Community Workshop held in March 2004.

A copy of the 'Frequently Asked Questions' brochure is presented in **Appendix K**. The handout provides simplified explanations to the following questions:

- "Why do councils prepare Floodplain Management Studies and Plans?";
- "What are Flood Studies?";
- "How are these studies funded?";
- "What is a probable maximum flood or PMF?";
- "What is the 100 year flood?";
- "Why is the 100 year flood adopted as the Flood Planning Level?";
- "How are computer models used to determine flood behaviour?";
- "Why do flood levels need to be reviewed over time?";

- "How have the Flood Risk Maps been prepared?";
- "My property is in a Low Flood Risk Precinct. What does this mean?";
- "My property is in a Medium Flood Risk Precinct. What does this mean?";
- "My property is in a High Flood Risk Precinct. What does this mean?";
- "Will my property value be altered if I am in a Flood Risk Precinct?";
- "My property was never classified as 'flood prone' or 'flood liable' before. Now it is in a Low Flood Risk Precinct. Why?";
- "Will I be able to get house and contents insurance if I am in a Flood Risk Precinct?";
- "Will I be able to get a home loan if I am in a Flood Risk Precinct?";
- "Will the Flood Risk Precinct maps be changed over time?".

The handout can also include the 'Glossary of Terms used in Floodplain Risk Management Studies' provided in **Appendix A**.

SES FloodSafe Brochures and Associated Information

The NSW State Emergency Service's (SES) FloodSafe program has produced area-specific brochures that describe what to do in a flood, how the SES can help and broadly describe the flood problem of the area. These brochures have concentrated on flooding in the Hawkesbury–Nepean valley to date.

These brochures also include a broad scale map showing the approximate extent of the floodplain up to the probable maximum flood. The SES, in conjunction with Blacktown City Council, has recently produced a FloodSafe brochure for that part of Blacktown affected by flooding from the Hawkesbury–Nepean River. A copy of this brochure and other general flood awareness brochures produced by the SES are presented as **Figure 9.1**.

There is also a lot of community awareness information available on the following two web sites:

- SES web site — www.ses.nsw.gov.au;
- Hawkesbury–Nepean FloodSafe program website — www.floodsafe.nsw.gov.au.

The preparation of FloodSafe brochure either for the entire South Creek (upstream from the extent of Hawkesbury–Nepean River flooding) or just for that part of South Creek in the Liverpool LGA is recommended for inclusion in the 'Flood Information Packs' as part of the *Floodplain Risk Management Plan*.

It is also recommended that the Flood Information Packs, or the FloodSafe brochure itself, also note that there is a large amount of community awareness information readily available on the SES's web site and the Hawkesbury–Nepean FloodSafe Program's web site.

9.3.6 Flood Certificates

In addition to the use of Flood Notification Letters, Flood Certificates are recommended for use in more 'formal' situations such as when a Development Application is submitted or a Section 149 Certificate is issued.

A Flood Certificate would contain information such as the expected flood levels for a range of design floods. It would also provide information on ground and floor levels where this information is available. This would allow an assessment of the depths of flooding over the property and building floor. The Flood Risk Categorisation applicable to that property would also be included. Where property levels are unknown, residents could be encouraged to obtain these levels using a registered surveyor, or to request council to provide these levels for a fixed fee.

The information provided on the certificates would be derived from Council's GIS using the information provided by the current study (**Section 9.3.3**) or from information held by Council from other investigations or studies.

A sample flood certificate is included as **Figure 9.2**. The property owners' name does not necessarily need to be shown on the certificate.

9.3.7 Flood Markers

Another method of raising flood awareness, which is also recommended, is the installation of one or more flood markers in the study area. These could be constructed in parks, reserves or along low points in roads. The most appropriate locations are likely to be beside the two main bridges across South Creek, namely Elizabeth Drive and Bringelly Road. The heights of the August 1986 and April 1988 floods together with design flood levels could be indicated on the marker. This would provide a constant visual reminder of the height of previous floods.

Flood markers have been estimated to cost up to about $10,000 each and have been recommended as a low priority measure for inclusion in the *Floodplain Risk Management Plan*.

9.3.8 Section 149 Certificates

Overview

A Section 149 Certificate is a zoning certificate issued under the provisions of the *Environmental Planning and Assessment Act, 1979,* which can be obtained to confirm zoning controls pertaining to individual properties, and must be attached to a contract prepared for the sale of property. The current standard wording used often causes inconsistencies to arise between local councils about the extent of information they provide on flooding.

The problems associated with the current procedures for wording on Section 149 Certificates are detailed in Section 2.3.10 of **Volume 2** of this report (Don Fox Planning, 2003).

Section 149 Certificates should not be used as a broad community education tool as they have only limited circulation. The majority of flood-affected properties would not be reached in a given year. In addition, with the existing system of notifications on Section 149(2) certificates, if no notification appears, then it is often misunderstood to mean that the property is "flood-free" rather than it has no development controls. Misunderstandings are also reported from people who have access to them, particularly when trying to understand whether there are actually any flood risks affecting a particular property.

It is important that all properties in the floodplain (that is, up to the probable maximum flood be notified. Notification should include the Flood Risk Precinct, if known, and the existence of the relevant Development Control Plan (DCP). If the property is 'potentially flood affected' this should also be notified. A notation should be provided that states that while all reasonable efforts are employed to identify lands subject to any potential flood risk, all properties so affected may not have been identified. While it is considered that the majority of potentially flood affected properties have been identified, Council may determine that a site-specific flood study is required on land not currently identified as flood affected, for the purposes of assessing a development application.

Types of Inundation

It should be noted that 'inundation' refers to inundation in any flood up to the probable maximum flood. There are two potential sources of inundation that need to be addressed on the Section 149 certificate notifications, namely:

- inundation from creeks and rivers;
- inundation from stormwater and overland flow.

Generally, inundation from 'local drainage', as defined in Section 1.9 of the *Floodplain Management Manual* (NSW Government, 2001), would not be included under 'inundation from stormwater and overland flow'. It should be recognised that inundation could occur from either or both sources and the wording on the Section 149 certificates should reflect this. Usually the most severe form of inundation will dominate the planning controls to be applied to new development. However, the Section 149 Certificate should identify both sources of possible inundation.

Status of Inundation

For each of the two types of inundation listed above, it is recommended that the inundation status be defined in one of the following three ways:

- ***Category A*** — Category A would apply when the inundation of the property has been defined by a flood study. In this case, the flood behaviour at the property has been quantified and velocities and depths are known for a range of floods. There would be sufficient information available to define the flood risk as 'low', 'medium' or 'high';

- ***Category B*** — Category B would apply when the property is thought to be inundated, but the flood behaviour has not been quantified to the level described in Category A above. For example, there may be anecdotal evidence of flooding but no formal flood study has yet been carried out;

- ***Category C*** — Category C would apply when the property is not thought to be inundated having regard to available information.

Wording of Flood Notations on Section 149 Certificates

Guidance on the wording of Section 149(2) and 149(5) certificates is provided in Appendix L of the *Floodplain Management Manual*. Using this information, **Table 9.1** presents suggested wording for S149 (2) certificates for the South Creek study area. For each property in the study area, one of the three categories listed above (A, B or C) would be applied for each type of flooding (i.e. flooding from creeks or rivers and flooding from stormwater or overland flow). **Table 9.1** shows the matrix of possible outcomes for the wording on an individual Section 149 Certificate. Not all these outcomes may apply within the study area, however all possible outcomes have been included for completeness.

For S149 (5) certificates, it is recommended that a Flood Certificate (**Section 9.3.6**) be appended to the certificate. In addition, where Category B applies, the certificate should provide additional details of the potential flood affectation and/or suggest that the applicant contact Council's Stormwater/Floodplain Engineer for further details.

9.3.9 Public Exhibition of this Study

To provide the wider community with an opportunity to comment on the draft plan proposals, the draft *South Creek Floodplain Risk Management Study and Plan for the Liverpool LGA* was placed on public exhibition between July and September 2004 (see **Section 5.6**).

This recommended component of the Community Awareness Strategy for the recommended Plan has now been completed.

TABLE 9.1: PROPOSED WORDING FOR FLOOD NOTATIONS ON SECTION 149(2) CERTIFICATES

		STATUS OF INUNDATION FROM CREEKS AND RIVERS				
		Category 'A' and 'Low' Flood Risk	**Category 'A' And 'Medium' Flood Risk**	**Category 'A' and 'High' Flood Risk**	**Category 'B' (i.e. potentially inundated)**	**Category 'C' (i.e. not thought to be inundated)**
STATUS OF INUNDATION FROM STORMWATER AND OVERLAND FLOW	**Category 'A' And 'Low' Flood Risk**	Part or all of the property is located within a Low Flood Risk area. [Plus Note 2]	Part or all of the property is located within a Medium Flood Risk area. [Plus Note 2]	Part or all of the property is located within a High Flood Risk area. [Plus Note 2]	Part or all of the property is located within a Low Flood Risk area due to overland flow. The property is also potentially affected by creek/river flooding. [Plus Note 2]	Part or all of the property is located within a Low Flood Risk area due to overland flow. [Plus Note 2]
	Category 'A' and 'Medium' Flood Risk	Part or all of the property is located within a Medium Flood Risk area due to overland flow . [Plus Note 2]	Part or all of the property is located within a Medium Flood Risk area. [Plus Note 2]	Part or all of the property is located within a High Flood Risk area. [Plus Note 2]	Part or all of the property is located within a Medium Flood Risk area due to overland flow. The property is also potentially affected by creek/river flooding. [Plus Note 2]	Part or all of the property is located within a Medium Flood Risk area due to overland flow. [Plus Note 2]
	Category 'A' And 'High' Flood Risk	Part or all of the property is located within a High Flood Risk area due to overland flow. [Plus Note 2]	Part or all of the property is located within a High Flood Risk area due to overland flow. [Plus Note 2]	Part or all of the property is located within a High Flood Risk area. [Plus Note 2]	Part or all of the property is located within a High Flood Risk area due to overland flow. The property is also potentially affected by creek/river flooding. [Plus Note 2]	Part or all of the property is located within a High Flood Risk area due to overland flow. [Plus Note 2]
	Category 'B' (i.e. potentially inundated)	Part or all of the property is located within a Low Flood Risk area. The property is also potentially affected by overland flow. [Plus Note 2]	Part or all of the property is located within a Medium Flood Risk area. The property is also potentially affected by overland flow. [Plus Note 2]	Part or all of the property is located within a High Flood Risk area. The property is also potentially affected by overland flow. [Plus Note 2]	Part or all of the property is potentially affected by creek/river flooding and overland flow. [Plus Note 2]	Part or all of the property is potentially affected by overland flow. [Plus Note 2]
	Category 'C' (i.e. not thought to be inundated)	Part or all of the property is located within a Low Flood Risk area. [Plus Note 2]	Part or all of the property is located within a Medium Flood Risk area. [Plus Note 2]	Part or all of the property is located within a High Flood Risk area. [Plus Note 2]	Part or all of the property is potentially affected by creek/river flooding. [Plus Note 2]	Based on the information available to Council, the property is not affected by creek/river flooding or overland flow from major drainage.

Notes

1. *This table provides specific wording for S149(2) notations based on the status of inundation from creeks/rivers and from stormwater/overland flow.*
2. *The following additional wording is be added to each notation where indicated in the table:*
   - *The term "Flood Risk" relates to the potential danger to personal safety and property. Further details are provided in the NSW Government's Floodplain Management Manual, 2001, or are available from Council..*
   - *Council's Development Control Plan No… "Managing Our Flood Risks" applies to this property. This DCP specifies controls on development to manage potential flood risks within the property and adjacent areas*
3. *The rows shown shaded in the table will not generally apply as mapping of Flood Risk Precincts may not be available for stormwater/overland flow.*
4. *All S149(2) Certificates shall also include within the list of applicable Development Control Plans — "Development Control Plan No. … Managing our Flood Risks."*

..... City Council

Flood Certificate

Certificate Issued for Property at: 16 Jones Street, Riverville
Lot 14, DP 25843

Owners Name: Mr & Mrs John Smith

1. Classification of Flood Risk

Part or all of the property is located within a Medium Flood Risk area. Council's Development Control Plan, No. …., "Flood Risk Management" applies to this property.

2. Known Floor and Ground Levels

The lowest floor level of the main building on this property:	44.6m AHD
Source of information :	Council Survey Dec 2003
The lowest ground level on this property is :	44.0m AHD
Source of information :	Est. from DTM

If the floor level and/or ground level are currently unknown and you would like to know what the levels are; this can be surveyed by a registered surveyor. Alternatively, Council can arrange this for a fee of $xx.

3. Estimated Flood Levels

Flood levels in the vicinity of the property have been extracted from the ..... Creek Flood Study/Floodplain Risk Management Study dated ..... by .....

Size of Flood*	Flood Level	Depth over Lowest Floor Level	Depth over Lowest Ground Level
Probable Maximum Flood	46.9m AHD	2.3m	2.9m
100 Year Flood	45.0m AHD	0.4m	1.0m
20 Year Flood	44.5m AHD	Not flooded	0.5m
5 Year Flood	44.1m AHD	Not flooded	0.1m

***The Probable Maximum Flood (or PMF) is extremely rare. It is the largest that could happen.*
A 100 year flood is a large flood. A flood of this size, or larger, will occur, on average, once every 100 years.
A 20 year flood is a smaller flood than a 100 year flood. A flood of this size, or larger, will occur, on average, once every 20 years.
A 5 year flood is a more frequent and smaller flood. A flood of this size, or larger, will occur, on average, once every 5 years.

4. Issued by _____ Date: _____

FIGURE 9.2: SAMPLE FLOOD CERTIFICATE

9.3.10 Community Flood Awareness — Recommendations

Findings: *The following methods of raising community flood awareness are recommended for inclusion in the Floodplain Risk Management Plan as high priority measures.*

- *production of Flood Risk Precinct Maps;*
- *updating of the Council's Geographical Information System (GIS) with the information now available from this study;*
- *preparation of 'Guidelines on Flood-Related Building Controls' (cost of about $5,000);*
- *preparation of 'Flood Information Packs' that would be sent to all residents in the floodplain and would include a Flood Notification Letter, a Flood Information Brochure (cost of about $5,000), a handout on 'Frequently Asked Questions about Floodplain Risk Management Studies' and a SES FloodSafe brochure and associated FloodSafe information;*
- *issuing of Flood Certificates when Development Applications are submitted;*
- *appropriate notification on Section 149 Certificates;*
- *public exhibition of the Draft Study Report and draft Floodplain Risk Management Plan for community comment (now complete).*

Findings: *The following method of raising community flood awareness is recommended for inclusion in the Floodplain Risk Management Plan as a low priority measures.*

- *installation of flood markers (likely to be at two locations, say, at Elizabeth Drive and Bringelly Road) to act as constant reminders of the heights of past floods (cost of about $20,000);*

10. FLOOD MODIFICATION MEASURES

Measures that modify flood behaviour usually include structural or engineering works that attempt to lower flood levels, or to divert floodwaters away from areas that would otherwise flood. These measures include:

- channel widening works, including:
  - benching of the creek — where a channel is cut into the bank of the creek;
  - construction of floodways — where a channel is constructed between two meanders to provide a 'short cut' for the meander;
- stream clearing;
- levees;
- enlargement of the waterway area under bridges and culverts;
- upstream flood mitigation storages or detention basins.

These options are considered to be the least preferred types of options in the *Floodplain Management Manual*, as they are often costly and are most likely to adversely affect the natural environment. Therefore they require careful consideration before recommending them for inclusion in a floodplain risk management plan.

Flood modification measures for the South Creek study area were examined in detail as part of the *1991 South Creek Floodplain Management Study* (Willing and Partners, 1991) (the *1991 FPM Study*) and the *1994 Overett and Victor Avenues, Kemps Creek. Flood Management Study* (Kinhill Engineers, 1994a) (the *1994 Kinhill Study*).

As discussed in **Section 6.4**, as part of the investigations for the flood mitigation works at Overett Avenue and Victor Avenue, a Review of Environmental Factors (REF) (Kinhill Engineers, 1994b) (the *1994 REF*) was undertaken to examine the likely environmental constraints of the recommended flood mitigation works. The conclusions reached in the *1994 REF* are still (and even more) applicable for the current Floodplain Risk Management Study and Plan — that the environmental impacts of large-scale channel works, floodways, large-scale stream clearing and the necessary compensatory works associated with the construction of levees, would be significant, and Council or DIPNR would not support these types of works.

This chapter describes the flood modification works that have been examined in past studies for the South Creek study area. No new flood modification works have been identified as part of the current study.

Section 10.1 presents the flood modification measures that have been examined and constructed for the Overett Avenue area, while those for the Victor Avenue area are presented in **Section 10.2**. Other flood modification works that have been examined for the study area in previous studies are presented in **Section 10.3**.

10.1 FLOOD MODIFICATION MEASURES FOR THE OVERETT AVENUE AREA

10.1.1 Measures Examined in Past Studies

Following the major floods of the 1980s and from the conclusions reached as part of the *1991 FPM Study*, the Overett Avenue area, just upstream of Elizabeth Drive, was identified as one of the main flood problem areas of South Creek in the Liverpool LGA. A number of studies were undertaken during the 1990s to examine flood mitigation options for this area, namely:

- *1994 Overett and Victor Avenues, Kemps Creek. Flood Management Study* (Kinhill Engineers, 1994) (referred to as the '*1994 Kinhill Study'*);
- *1996 Overett Avenue, Flood Mitigation Alternatives Study* (Kinhill Engineers, 1996) (referred to as the '*1996 Kinhill Study'*);
- *1997 Hydraulic Modelling of Proposed Floodway — Overett Avenue, Kemps Creek Study* (Kinhill, 1997) (referred to as the '*1997 Kinhill Study'*).

As part of these studies, the following types of flood mitigation works were examined for the Overett Avenue area:

- an earthen levee to protect all low lying properties in Overett Avenue and the south side of Elizabeth Drive from flooding in a 100 year flood;
- enlargement of the existing road bridge over South Creek;
- construction of a second bridge at Elizabeth Drive including associated connecting floodways upstream and downstream of Elizabeth Drive;
- widening (including large-scale clearing) of the main South Creek channel downstream of Elizabeth Drive;
- widening (including large-scale clearing) of the main South Creek channel upstream of Elizabeth Drive;
- construction of floodway at the end of Overett Avenue;
- bank shaping works to aid water flow between channel widening works and floodways.

Table 10.1 provides details of all flood mitigation measures examined for the Overett Avenue area and includes those recommended and those actually constructed. These works were shown on **Figure 7.2**.

TABLE 10.1: FLOOD MODIFICATION MEASURES EXAMINED FOR THE OVERETT AVENUE AREA

FLOOD MITIGATION WORKS EXAMINED	WORKS EXAMINED AS PART OF WHICH REPORT	RECOMMENDATIONS	WORKS CONSTRUCTED
Earthen levee to protect all low lying properties in Overett Avenue and the south side of Elizabeth Drive from flooding in a 100 year flood	1994 Kinhill Study — Option 1A & Option 1B	▸ found to cause substantial increases in flood levels if constructed without compensatory channel widening works — NOT RECOMMENDED IN ISOLATION. ▸ only considered as part of options that also involved channel widening, floodways or the additional bridge over Elizabeth Drive. ▸ internal drainage of water trapped behind levee from local runoff, deemed to be 'manageable'. ▸ earthen levee (1,900m long, average height of 2m, height of 0.5m above 100 year flood level) examined as part of Option 1B of *1994 Kinhill Study* in conjunction with voluntary purchase and floodway at end of Overett Avenue — RECOMMENDED OPTION FOR 1994 KINHILL STUDY.	Levees as recommended in Option 1B of *1994 Kinhill Study* not constructed. No levees have been constructed in the Overett Avenue area.
	1996 Kinhill Study — Options D and E	▸ Option E of 1996 Kinhill Study was essentially the same as Option 1B from *1994 Kinhill Study* but with internal drainage behind levee examined in more detailed. Extensive excavation on private property was found to be required, which found to be cost prohibitive — NOT RECOMMENDED. ▸ Option D of 1996 Kinhill Study looked at partial levee in conjunction with large floodway at end of Overett Avenue. Study concluded that all properties could only be protected from flooding above floor level in a 100 year flood with the construction of a levee. However, there were still community concerns and Option was only just economically viable — NOT RECOMMENDED.	No levees recommended or constructed in the Overett Avenue area
Enlargement of existing road bridge over South Creek	1994 Kinhill Study	▸ not considered practical because of problems with traffic diversion — NOT RECOMMENDED.	No enlargement of main bridge at Elizabeth Drive crossing of South Creek recommended or constructed.
	1996 Kinhill Study	▸ replacement of main bridge over South Creek at Elizabeth Drive examined for flood mitigation benefits. It was found that an increase in waterway area could not be achieved that was large enough to reduce flood levels — NOT RECOMMENDED.	***RTA works only*** — new two lane bridge constructed as part of dual carriageway upgrade of Elizabeth Drive. No flood mitigation benefits (no change to road level and waterway area) (see **Section 6.1.2**)

FLOOD MITIGATION WORKS EXAMINED	WORKS EXAMINED AS PART OF WHICH REPORT	RECOMMENDATIONS	WORKS CONSTRUCTED
Construction of second bridge at Elizabeth Drive and associated connecting floodways upstream and downstream of Elizabeth Drive	1994 Kinhill Study — Option 1A,	▸ found to have a substantial effect in reducing flood levels upstream of Elizabeth Drive, but only in conjunction with the construction of a floodway or channel widening works opposite the end of Overett Avenue — RECOMMENDED IN 1994 KINHILL STUDY.	***Stage 1 Flood Mitigation Works*** — construction of a flood mitigation channel from a bend in South Creek about 150m south (upstream) of Elizabeth Drive to a bend in South Creek about 50m north (downstream) of Elizabeth Drive. The channel is about 300m long, about 20m wide at the base and generally about 2m deep. The works also included the construction of an additional bridge over Elizabeth Drive over the newly constructed channel about 150m east of the main South Creek crossing (see **Section 6.1.2**). ***Stage 2 Flood Mitigation Works*** — purchase of three flood-affected properties at the western end of Overett Avenue (house Nos. 160, 165 and 170), removal of the houses and creation of Overett Reserve (see **Section 6.1.2**).
Widening of South Creek downstream of Elizabeth Drive (including large-scale stream clearing)	1994 Kinhill Study — Option 2C	▸ *1994 Kinhill Study* looked at cutting a bench or floodway into one or both of the banks so as to operate in times of high flow — NOT RECOMMENDED IN ISOLATION. ▸ widening proposal examined in conjunction with widening works upstream of Elizabeth Drive and second bridge (but with no levees in Overett Avenue) as part of Option 2C of *1994 Kinhill Study* — NOT RECOMMENDED.	There has been no large scale channel widening works or large-scale stream clearing of South Creek downstream of Elizabeth Drive recommended or constructed
Widening of South Creek upstream of Elizabeth Drive (including large-scale stream clearing)	1994 Kinhill Study — Option 1A 1994 Kinhill Study — Option 2A, 2B & 2C	▸ *1994 Kinhill Study* looked at cutting a bench or floodway into one or both of the banks so as to operate in times of high flow — NOT RECOMMENDED IN ISOLATION. ▸ large scale widening proposed as part of Option 1A of *1994 Kinhill Study* in conjunction with levee and second bridge — NOT RECOMMENDED. ▸ widening proposals of varying sizes were examined in conjunction with the second bridge (but with no levees) as part of Options 2A, 2B and 2C of *1994 Kinhill Study* — NOT RECOMMENDED.	There were no large scale channel widening works or large-scale stream clearing of South Creek upstream of Elizabeth Drive recommended or constructed.
	1996 Kinhill Study — Options A, B, C, D and E	▸ widening of about 250m of the west bank of South Creek between Overett Avenue and Elizabeth Drive included in all options examined as part of this study — OPTION A ADOPTED BY COUNCIL FROM 1996 KINHILL REPORT.	Channel widening works as adopted in Option A were not constructed.

FLOOD MITIGATION WORKS EXAMINED	WORKS EXAMINED AS PART OF WHICH REPORT	RECOMMENDATIONS	WORKS CONSTRUCTED
Widening of South Creek upstream of Elizabeth Drive (including large-scale stream clearing) (continued)	1997 Kinhill Study	‣ channel widening and floodways proposals identified in Option A of the 1996 Kinhill Study saw unacceptable impacts on riparian corridor vegetation and the Water Level Recording Station located upstream of Elizabeth Drive — OPTION A FROM 1996 STUDY NOT RECOMMENDED. ‣ channel widening of South Creek upstream of Elizabeth Drive — NOT RECOMMENDED FOR FURTHER CONSIDERATION.	There have been no channel widening works or large-scale stream clearing of South Creek upstream of Elizabeth Drive in the Overett Avenue area.
Construction of floodway at the end of Overett Avenue	1994 Kinhill Study — Option 1B	‣ *1994 Kinhill Study* looked at cutting a bench or floodway into one or both of the banks so as to operate in times of high flow — NOT RECOMMENDED IN ISOLATION. ‣ large floodway proposed (500m long, maximum width of 125m and maximum depth of 2.5m) as part of Option 1B of *1994 Kinhill Study* in conjunction with voluntary purchase and levee — RECOMMENDED OPTION FOR 1994 KINHILL STUDY.	Floodway at end of Overett Avenue as recommended in Option 1B of 1994 Kinhill Report was not constructed.
	1996 Kinhill Study — Options A, B and C	‣ floodway proposals of varying widths were examined in conjunction with the second bridge, voluntary purchase and some channel widening works (but with no levees) as part of Options A, B and C of 1996 Kinhill Study. ‣ Option A with smallest floodway, 450m long with 20m base width and 2.5–3.0m depth in conjunction with second bridge, voluntary purchase and some channel widening works — OPTION A ADOPTED BY COUNCIL FROM 1996 KINHILL REPORT.	Floodway at end of Overett Avenue as recommended in Option A of 1994 Kinhill Report was not constructed.
	1997 Kinhill Study — Options 1, 2 and 3	‣ channel widening and floodways proposals identified in Option A of the 1996 Kinhill Study saw unacceptable impacts on riparian corridor vegetation and the Water Level Recording Station located upstream of Elizabeth Drive — OPTION A FROM 1996 STUDY NOT RECOMMENDED. ‣ floodway about 250m long, 20m wide and about 2m deep through purchased properties at the end of Overett Avenue. Three options had varying surface types (grass versus rock) and erosion protection measures (rock mattresses versus rock) — OPTION 2 (GRASS LINED FLOODWAY WITH ROCK PROTECTION AT INLET AND OUTLET) ADOPTED BY COUNCIL FROM 1997 REPORT.	***Stage 3A Flood Mitigation Works*** — construction of a floodway, approximately 250m long, 20m wide at the base and about 2m deep to join the two bends in South Creek through the newly created Overett Reserve (where two properties had been purchased (see **Section 6.1.2**).
Bank shaping works to aid water flow between constructed channel widening works and floodways	Internal investigations by Council following 1997 Kinhill Report	‣ as part of the design of the floodway at the end of Overett Avenue, some minor excavation works were proposed just upstream of the floodway and just upstream of Elizabeth Drive to aid water flow into the floodway and through the main Elizabeth Drive bridge.	***Stage 3B Flood Mitigation Works*** — minor works involving bank shaping works just upstream of the Stage 3A floodway and just upstream of the main South Creek bridge over Elizabeth Drive (see **Section 6.1.2**).

Notes: 1994 Kinhill Study = Kinhill Engineers (1994a); 1996 Kinhill Study = Kinhill Engineers (1996) 1997 Kinhill Study = Kinhill (1997)
RTA = Roads and Traffic Authority

The enlargement, straightening, benching, clearing and lining of creek channels, together with the construction of floodways and overland flow paths have been popular throughout NSW as flood mitigation measures up until the late 1990s. However, their significant construction costs and environmental impacts now often preclude them as a viable flood mitigation option.

The widening and/or clearing of the watercourses generally leads to disturbance of the existing riverbed and banks. This may initiate increased erosion, water turbidity, downstream siltation, and loss of aquatic habitat. The benching of a creek bank disturbs riparian vegetation and other habitats of the riverine corridor.

Current Department of Infrastructure, Planning and Natural Resources (DIPNR) (formerly DLWC) policy now requires that when any channel works are proposed, the works should ideally be designed to restore a more natural creek system and provide increased ecological values. For all works within 40m of the top of the bank of a creek, DIPNR requires that a Part 3A permit is obtained under the *Rivers & Foreshores Improvement Act, 1948*.

It should also be noted that for any proposal that involves earthworks along a creekline, a permit is required from NSW Fisheries under the *Fisheries Management Act, 1994*.

Similarly, levees have been a popular flood mitigation measure in NSW for many years. They too have their problems and are now not generally recommended as a desirable floodplain risk management measure. Some of the issues that need to be evaluated when considering levees include the following:

- ***hydraulics and loss of floodplain area*** — the construction of a levee would generally cause floodwaters to be diverted away from a particular area and cause floodwaters to be constricted to a much narrower width. This often results in an increase in flood levels in areas not protected by the levee, which is not acceptable;

- ***drainage behind the levee*** — for all levees it must be ensured that all rain that falls on the local catchment behind the levee can drain to the stream and ponding does not occur behind the levee. Another problem is the surcharging of the local drainage system behind the levee;

- ***perceived safety*** — if a levee is overtopped (as occurred in Nyngan in 1990), inundation of properties within the perceived protected area could occur. There is often a community perception that once a levee is constructed, it provides a 'flood-free' area behind the levee. This often leads to a false sense of security. Unless the levee is constructed to the level of the probable maximum flood, floods larger than the flood the levee was designed for, can occur;

- ***aesthetics*** — levees can be designed and landscaped so that they are not visually intrusive, particularly earthen levees. Levees constructed as concrete walls are often not visually acceptable. Many communities do not like levees because the levees block their views of the waterway;

- ***erosion and undermining of foundations*** — this is a potential problem with levees and often occurs without careful design, particularly in creeks with fast flood velocities.

10.1.2 Flood Mitigation Works Constructed in the Overett Avenue Area

Description of Works

Figure 10.1 shows the flood mitigation works that have been completed in the vicinity of Overett Avenue and Elizabeth Drive since the mid-1990s. These works include the following:

- ***Bridge over main crossing of South Creek*** — as part of the proposed upgrade of Elizabeth Drive to a four-lane road by the Roads and Traffic Authority, a new two-lane bridge over the main channel of South Creek was constructed in about 1996. It is understood that the design of this new bridge did not allow for any increase in the waterway area under this bridge. In addition, the level of the road was not altered as part of the works. The second two-lane bridge is yet to be constructed (Kinhill Engineers, 1996);

- ***Stage 1 Flood Mitigation Works*** — these works involved construction of a flood mitigation channel from a bend in South Creek about 150m south (upstream) of Elizabeth Drive to a bend in South Creek about 50m north (downstream) of Elizabeth Drive. The channel is about 300m long, about 20m wide at the base and generally about 2m deep. The works also included the construction of an additional bridge over Elizabeth Drive over the newly constructed channel about 150m east of the main South Creek crossing;

- ***Stage 2 Flood Mitigation Works*** — these works involved the purchase of three flood-affected properties at the western end of Overett Avenue (house Nos. 160, 165 and 170), removal of the houses and creation of Overett Reserve;

- ***Stage 3A Flood Mitigation Works*** — these works involved the construction of a floodway, approximately 250m long, 20m wide at the base and about 2m deep to join the two bends in South Creek through the newly created Overett Reserve;

- ***Stage 3B Flood Mitigation Works*** — these minor works involved bank shaping works just upstream of the Stage 3A floodway and just upstream of the main South Creek bridge over Elizabeth Drive.

Benefits of Works

The 2003 MIKE-11 hydraulic model for the study area (i.e. the current model), and hence the design flood levels quoted in this study (see **Section 2.3.3**), includes all the flood mitigation works for the Overett Avenue area described above.

FIGURE 10.1: FLOOD MITIGATION WORKS COMPLETED AT ELIZABETH DRIVE

A4 COLOUR

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By comparing the best available flood level information that represents the Overett Avenue area before any works were constructed and the results from the 2003 MIKE-11 model, the following changes in flood levels have occurred with the construction of these flood mitigation works:

- just upstream of the Elizabeth Drive, there would be about a 0.6m reduction in flood levels in a 20 year, 50 year and 100 year flood, and about a 0.2m reduction in flood level in a probable maximum flood (PMF);

- about 150m upstream of Elizabeth Drive, about half way between Elizabeth Drive and Overett Avenue, there would be about a 0.7m–0.8m reduction in flood levels in all floods up to a PMF;

- opposite Overett Avenue, there would be about a 0.5m reduction in flood levels in all floods up to a PMF;

- about 900m upstream of Elizabeth Drive (opposite about the end of Sumbray Avenue) there would be essentially no impact from the flood mitigation works;

- up to about 300m downstream of Elizabeth Drive, there would be up to 0.1m–0.2m increase in flood levels in all floods up to the PMF.

Table 10.2 summarises the benefits of the flood mitigation works for the Overett Avenue area in terms of:

- the reduction of the number of houses flooded above floor level;
- the reduction in the number of yards adjacent to houses that would be flooded.

TABLE 10.2: IMPROVEMENTS TO FREQUENCY OF PROPERTY INUNDATION WITH FLOOD MITIGATION WORKS AT ELIZABETH DRIVE

FLOOD EVENT	BEFORE CONSTRUCTION OF FLOOD MITIGATION WORKS AT ELIZABETH DRIVE*		AFTER CONSTRUCTION OF FLOOD MITIGATION WORKS AT ELIZABETH DRIVE**	
	NO. HOUSES FLOODED ABOVE FLOOR LEVEL	NO. PROPERTIES FLOODED AT GROUND LEVEL ADJACENT TO HOUSE	NO. HOUSES FLOODED ABOVE FLOOR LEVEL	NO. PROPERTIES FLOODED AT GROUND LEVEL ADJACENT TO HOUSE
5 YEAR	4	19	0	3
20 YEAR	11	23	2	8
50 YEAR	18	26	5	15
100 YEAR	21	28	6	15
PMF	37	45	26	33

Notes: PMF = probable maximum flood
** Source: 1994 Kinhill Study*
*** Source: Flood Damages Data Base developed for this study (**Section 3.5**)*

In addition to the residential properties shown in **Table 10.2**, the grounds of the Roladuct Spiral Tubing property surrounding the main building at No.1820 Elizabeth Drive would now be just above the level of the 100 year flood, while the floor level of the main building would now be about 0.6m above the level of the 100 year flood.

These results show the properties on the south side of Overett Avenue would benefit from about a 0.4m–0.5m reduction in flood levels for most flood sizes, while the properties on the northern side would benefit from about a 0.5m–0.8m reduction in flood level for most flood sizes.

The reductions in the frequency of property flooding in the Overett Avenue area as a result of the flood mitigation works, as shown in **Table 10.2**, indicate that the flood mitigation works have provided the area with a solution to the majority of its over-floor flood problem up to about a 20 year flood. However, there would still be widespread over-ground flooding of the area in a 5 year flood and two houses would still be flooded above floor level in a 20 year flood. Therefore, it will important that community education and community flood awareness programs for the study area emphasise that the Overett Avenue area would still suffer regular inundation and that residents should be 'flood ready' to cope with the larger floods.

10.1.3 Flood Modification Measures for Overett Avenue Area — Recommendations

Findings: *A range of flood modification measures have been examined, recommended and constructed for the Overett Avenue area since the mid 1990s. Social, economic and environmental constraints now mean that no further flood mitigation works will be constructed.*

Hence no flood modification works will be recommended for the Overett Avenue area as part of the Floodplain Risk Management Plan.

Findings *It can be concluded from the 1994 REF that any stream clearing works undertaken by Council would be subject to strict environmental controls to ensure the integrity of the riparian corridor is maintained and there are no adverse impacts on vegetation communities of regional significance to Western Sydney.*

10.2 FLOOD MODIFICATION MEASURES FOR THE VICTOR AVENUE AREA

Following the major floods of the 1980s and from the conclusions reached as part of the *1991 FPM Study*, the Victor Avenue area, about 3km upstream of Elizabeth Drive, was identified as one of the main flood problem areas of South Creek in the Liverpool LGA. The *1994 Kinhill Study* examined a range of flood mitigation options for this area.

As part of this study, the following flood mitigation works were examined for the Victor Avenue area:

- an earthen levee to protect all low lying properties in Victor Avenue, Watts Road and Ramsay Road from flooding in a 100 year flood;

- widening of the main South Creek channel, including cutting a bench into one or both of the creek banks and where the creek meandered, the construction of a trapezoidal second channel, or floodway, to 'short cut' the meander.

Table 10.3 provides details of the flood mitigation measures examined for the Victor Avenue area, including those recommended at the time. It was concluded in the *1994 REF*, which was completed shortly after the *1994 Kinhill Study*, that the environmental impacts of the proposed flood mitigation works at Victor Avenue would be too high to allow them to proceed. Consequently, the Victor Avenue works recommended in the *1994 Kinhill Report* were shelved and are not likely to be constructed in the future.

Findings: *A range of flood modification measures were examined and even recommended for the Victor Avenue area during 1990s. However, environmental constraints mean that no flood mitigation works will be constructed. Hence no flood modification works will be recommended for the Victor Avenue area as part of the Floodplain Risk Management Plan.*

Findings *It can be concluded from the 1994 REF that any stream clearing works undertaken by Council would be subject to strict environmental controls to ensure the integrity of the riparian corridor is maintained and there are no adverse impacts on vegetation communities of regional significance to Western Sydney.*

10.3 OTHER FLOOD MODIFICATION MEASURES FOR STUDY AREA

This section describes other flood modification measures, outside the Overett and Victor Avenue areas, the majority of which were examined as part of the *1991 FPM Study*. Some of these works have been constructed. The following works are discussed:

- the construction of detention basins in the upper parts of the South Creek and Thompsons Creek catchments (**Section 10.3.1**);
- the impacts of large dams on the flood behaviour in the study area (**Section 10.3.2**);
- enlargement of waterway area and road raising at the Bringelly Road crossing of South Creek (**Section 10.3.3**);
- safety improvements at The Retreat crossing of Thompsons Creek (**Section 10.3.4**);
- creek maintenance strategy including stream clearing (**Section 10.3.5**);
- filling of Australian Native Landscapes site at 210 Martin Road with compensating by-pass floodway (**Section 10.3.6**);
- levee at Masterfield Street at Rossmore, just upstream of the study area at Bringelly Road (**Section 10.3.7**).

No new flood modification works have been identified as part of the current study.

TABLE 10.3: FLOOD MODIFICATION MEASURES EXAMINED FOR THE VICTOR AVENUE AREA

FLOOD MITIGATION WORKS EXAMINED	WORKS EXAMINED AS PART OF WHICH REPORT	RECOMMENDATIONS	WORKS CONSTRUCTED
Earthen levee to protect all low lying properties in Victor Avenue, Watts Road and most of Ramsay Road from flooding in a 100 year flood	1994 Kinhill Study — Option 2	▸ found to cause substantial increases in flood levels if constructed without compensatory channel widening works — NOT RECOMMENDED IN ISOLATION ▸ only considered as part of options that also involved channel widening ▸ internal drainage of water trapped behind levee from local runoff, deemed to 'pose considerable local drainage problems'' with large scale diversion works envisaged but not investigated. ▸ earthen levee (1,600m long, average height of 2m, maximum height of 3m, minimum height of 0.5m above 100 year flood level, 5m top width) examined as part of Option 2 of *1994 Kinhill Study* in conjunction with creek widening (benching plus floodway) — RECOMMENDED OPTION FOR 1994 KINHILL STUDY	Levees as recommended in Option 2 of *1994 Kinhill Study* not constructed. No levees have been constructed in the Overett Avenue area.
	1994 Kinhill REF	▸ channel widening and floodways proposals identified in Option 2 of the *1994 Kinhill Study* saw unacceptable impacts on riparian corridor vegetation and Aboriginal archaeology — OPTION 2 FROM 1994 KINHILL STUDY NOT RECOMMENDED	No levees have been constructed in the Overett Avenue area.
Widening and large-scale channel clearing of South Creek	1994 Kinhill Study — Option 2 1994 Kinhill Study — Option 3A, 3B & 3C	▸ *1994 Kinhill Study* looked at cutting a bench into one or both banks of the creek and where the creek meandered, the construction of a trapezoidal second channel, or floodway, to 'short cut' the meander were considered. The base of the bench or second channel would be 1.0m–1.5m above the invert of the existing channel so as to operate in times of high flow — NOT RECOMMENDED IN ISOLATION ▸ large scale works proposed, mainly as compensatory works for levees as part of Option 2 of *1994 Kinhill Study*. 1,300m creek widening comprising 340m of 'floodway' (20m wide, 3.5m deep) and 960m of benching (20m wide and 3m deep) — RECOMMENDED OPTION FOR 1994 KINHILL STUDY ▸ channel widening proposals of varying widths were examined in conjunction with voluntary purchase (but with no levees) as part of Options 3A, 3B and 3C of *1994 Kinhill Study* ▸ Option 3A with the smallest scale works (floodway — 340m long, 10m wide and 2.5m deep plus benching — 960m long, 20m wide and 2m deep) in conjunction with voluntary purchase shown to be cost effective but — NOT RECOMMENDED FOR FURTHER CONSIDERATION	Channel widening works as recommended in Option 2 of *1994 Kinhill Study* not constructed.
	1994 Kinhill REF	▸ channel widening and floodways proposals identified in Option 2 of the *1994 Kinhill Study* saw unacceptable impacts on riparian corridor vegetation and Aboriginal archaeology — OPTION 2 FROM 1994 KINHILL STUDY NOT RECOMMENDED	No channel widening works have been constructed in the Overett Avenue area.

Notes: 1994 Kinhill Study = Kinhill Engineers (1994a); 1994 Kinhill REF = Kinhill Engineers (1994b)

10.3.1 Construction of Detention Basins

Upstream dams or detention basins provide an opportunity to temporarily store floodwater during floods, often resulting in a reduction in downstream flood levels.

Their main disadvantage is that they generally take up large areas of land. This land must be purchased and so the cost of detention basins is usually very large. Another issue to consider is that when the detention basin fills, flood levels upstream of the basin can often be higher than without the detention basin in place. Many detention basins are prescribed under the *NSW Dams Safety Act, 1978*.

The *1991 FPM Study* examined nearly twenty detention basin sites within the catchment of South Creek and its tributaries. The main purpose of these detention basin sites was to ensure that, with the urban development of the South Creek Valley Sector (now known as the South West Urban Release Area), post-development stream flows would be maintained at pre-development levels. It is unknown whether these detention basin sites are still being considered as part of the current studies for the South West Urban Release Area.

Three of the detention basin sites identified in the *1991 FPM Study* may impact on the current study area, namely:

- South Creek just upstream of Camden Valley Way;
- Thompsons Creek just upstream of Greendale Road;
- South Creek just upstream of Bringelly Road.

Flood mitigation benefits for existing flood problems from the detention basins examined as part of the *1991 FPM Study*, were only examined at one site. The detention basin site identified upstream of Bringelly Road was examined as a large lake formed by damming South Creek near its confluence with Rileys Creek and Lowes Creek. The area of permanent water was envisaged to be about one square kilometre, with a total storage volume of 2,500ML. Some flood mitigation benefits downstream of the lake were envisaged with the construction of this lake, however these were not quantified in the *1991 FPM Study*.

Examination of detention basin sites as a floodplain risk management measure has not been addressed further as part of the current study. To provide flood mitigation benefits for the current study area, detention basins would have to be located on tributaries leading into South Creek. It is likely that several detention basins would be required to provide the desired level of reduction in downstream flood levels. Each of these basin sites would be located on private land and so this land would need to be purchased. This would make the construction of detention basins prohibitively expensive.

The construction of detention basins would also impact on land identified for development as part of the South West Urban Release Area as the land required for a detention basin would 'preclude future urban development on adjoining non-flood-affected lands' (see **Section 5.3.1**). The Managing Sydney's Urban Growth Team of DIPNR would therefore not support such works.

Findings: *No detention basin sites are recommended for inclusion in the Floodplain Risk Management Plan.*

10.3.2 Impacts of Large Dams on Flood Behaviour

Community comments raised in the community survey (October 2003) and the community workshop (March 2004) show that there is community concern for the impacts that large dams in the region may have on the flood behaviour in the study area.

An examination of hydrographs from the August 1986 and April 1988 floods (DIPNR, 2004) confirms that flood levels in the Hawkesbury–Nepean River and releases from Warragamba Dam would not have prevented flood flows from draining from the current study area. The flood profiles provided in the *1991 FPM Study* also confirm that flood levels in the Hawkesbury–Nepean River would not affect the flood levels in the current study area.

The 'backing up of water' that was observed by the local residents during the floods of the 1980s, at about the same time that releases were being made from Warragamba Dam, should therefore be considered to be a coincidence. This 'backing up of water' was more likely caused by a constriction to flood flows much closer to Overett Avenue and Elizabeth Drive. Two possible explanations are provided as follows:

- ***large dams downstream of Elizabeth Drive*** — there are two large farm dams located on South Creek, Badgerys Creek and Kemps Creek about 2km downstream of Elizabeth Drive. One is about 40ha in area, while the other has an area of about 10ha. Flood profiles from the *1991 FPM Study* show that in very large floods, the level in the larger dam may have an impact on flood levels almost as far upstream as Elizabeth Drive. These flood profiles show, however, that the level in the dam would have negligible impacts on flood levels upstream of Elizabeth Drive at Overett Avenue;

- ***Elizabeth Drive crossing of South Creek*** — at the time of the large floods of the 1980s, there was only one bridge crossing of South Creek at Elizabeth Drive. The *1994 Kinhill Study* showed through hydraulic computer modelling that it was the bridge at Elizabeth Drive that was acting as the major constriction to flows, rather than the size of the South Creek channel upstream and downstream of the bridge. With the construction of the second bridge over South Creek, much of this constriction has now been removed, which should see less 'backing up of water' in future flood events.

Findings: *Large dams in the region do not have an impact on flood behaviour in the study area. No further investigation is recommended as part of the Floodplain Risk Management Plan.*

10.3.3 Works at Bringelly Road Bridge

Bridges, culverts and piped drainage systems are often designed to carry flows much less than in a 100 year flood. Consequently they often act as a restriction to flood flows in major floods, leading to an increase in upstream flood levels. When enlarging such structures, to allow more water to flow through them, the impacts of allowing more water downstream should always be carefully assessed to ensure flood levels are not increased in downstream properties.

Enlargement of the Bringelly Road bridge was examined as part of the *1991 FPM Study*. The study concluded that '*implementation of bridge waterway enlargements at Bringelly Road … may be warranted if traffic requirements dictate*'. However, no works have been carried out to date.

The area upstream of the Bringelly Road bridge is outside the current study area (in Camden LGA) and so any impacts on flood behaviour that may occur because of constriction or afflux at the bridge have not been investigated as part of this study. Any enlargement of the waterway area at the bridge to alleviate upstream flood problems would have to carefully consider impacts on properties downstream of Bringelly Road.

The '2003 MIKE-11 model' of South Creek indicates that the lowest point of Bringelly Road would remain trafficable in a flood just larger than a 100 year flood. In a probable maximum flood, the maximum depth of flooding over the road would be about 0.7m. Because this section of Bringelly Road is not a critical evacuation route, road raising and associated enlargement of the bridge waterway has not been considered further in this study.

Findings: *No road raising or associated enlargement of bridge waterway area for Bringelly Road is recommended as part of the Floodplain Risk Management Plan.*

Any works at the Bringelly Road bridge investigated as part of a Floodplain Risk Management Study for South Creek in the Camden LGA would need to carefully consider the impacts on properties downstream of Bringelly Road in the current study area.

10.3.4 Safety Improvements for The Retreat Crossing of Thompsons Creek

The '2003 MIKE-11 model' of Thompsons Creek indicates that the lowest point of The Retreat would become untrafficable in a flood just larger than a 50 year flood. In a probable maximum flood the maximum depth of flooding over the road would be about 1.0m. This bridge over Thompsons Creek is the main access to the six or so houses located in The Retreat on the western side of Thompsons Creek.

Floods in Thompsons Creek would rise and fall very quickly and residents would not have to wait very long for the water levels to go down enough for the bridge to be safely crossed. However, there is a safety hazard at the bridge if residents tried to cross it while it was flooded.

Although it is unlikely that a higher bridge could be economically justified, there are a few measures that could be undertaken to improve the safety of crossing. These could include:

- signage at the bridge warning of the dangers of crossing the bridge if there is water over the road;
- a small site specific community awareness program — this could be undertaken at the same time as the warning signs were installed;

- No.30 The Retreat contains an historical homestead and it appears that it may have access to Badgerys Creek Road via an access way through the Commonwealth Land that fronts Badgerys Creek Road. The SES and/or Council could approach the owner of No.30 The Retreat to investigate the possibility of allowing limited access via this access way for emergency services and other residents of The Retreat in times of flood.

Findings: *A safety improvement program is recommended for The Retreat crossing of Thompsons Creek as part of the Floodplain Risk Management Plan as a high priority measure. This would include signage at the bridge and an associated community awareness program, with an estimated cost of $5,000. There is also the opportunity to investigate the possibility of providing a flood escape route via an access way to Badgerys Creek Road.*

10.3.5 Creek Maintenance Strategy

Large-scale stream clearing was raised at the Community Workshop of March 2004 as a possible means of reducing flood levels in the study area. There was community concern that South Creek is choked with weeds, rubbish and particularly large trees. It is acknowledged that there is a significant dumping problem within the riverine corridor of the study area, particularly at the causeway at the end of Wishart Road.

As part of the examination of flood mitigation works for the Overett Avenue and Victor Avenue in the 1994 Kinhill Study, the MIKE-11 computer modelling showed that large-scale channel widening works would be necessary to reduce flood levels by meaningful amounts. Therefore it can be concluded that even large-scale clearing of the creek would only reduce flood levels by negligible amounts and hence would not be a viable flood mitigation option.

The other consideration for large-scale stream clearing is the environmental impacts. From the recommendations made in the *1994 REF* and current environmental legislation, Council must carefully consider the environmental consequences of removing riparian vegetation, including fallen trees and logs within the creek itself. All provide valuable habitat for terrestrial and aquatic fauna. In addition, many of the vegetation communities along the riparian corridor are of regional significance to Western Sydney. DIPNR and NSW Fisheries would need to be consulted on any such proposed works.

Despite the constraints on clearing activities along South Creek and Thompsons Creek, a formal Creek Maintenance Strategy is recommended as a high priority measure for the *Floodplain Risk Management Plan*. Such a strategy would ensure:

- the amount of vegetation that would be appropriate is determined so that flood levels would not start to increase;

- environmental considerations are clearly identified;

- dumped rubbish is removed in a systematic way;

- more vigilant policing of dumping practices in the study — this could involve the installation of signs at key problem areas with large fines for dumping of rubbish.

Development of the Creek Maintenance Strategy has been estimated to cost about $10,000. However, it should be noted that grant funding under the NSW Government's Flood Program would not be available for maintenance activities associated with the strategy.

Findings: *Large-scale stream clearing, as a flood mitigation measure, will not be considered further.*

A Creek Maintenance Strategy is recommended as a high priority measure in the Floodplain Risk Management Plan. Development of the strategy has been estimated to cost about $10,000.

10.3.6 Works at Australian Native Landscapes Site

The Australian Native Landscape Site is located on the high western side of South Creek in Martin Road, Badgerys Creek opposite Braikfield Avenue, Kemps Creek. As part of the *1991 FPM Study*, filling of part of the site with an associated by-pass floodway, to compensate against the adverse flood impacts of the filling, was examined and modelled.

The proposal was to construct a filled area about 1,100m long and up to 1.1m high within the western floodplain of South Creek. The proposed compensatory works were to be located on both sides of South Creek for a distance of about 900m on the western side (maximum depth of 1.0m) and 700m on the eastern side (maximum depth of 1.3m).

There is no record of any Development Application for these works being lodged with Liverpool Council and no indication that these works have been constructed. It would be unlikely that the compensatory works proposed in 1991 would now be considered acceptable based on the environmental considerations discussed in **Section 6.4**.

Findings: *Works at the Australian Native Landscape site in Martin Road, Badgerys Creek not considered further as part of the recommended Floodplain Risk Management Plan.*

10.3.7 Levee at Masterfield Street, Rossmore

Masterfield Street, Rossmore, is located just upstream of Bringelly Road, outside the current study area in the Camden LGA. An earthen levee, 1,300m long and up to 3m high was examined and modelled as part of the *1991 FPM Study* to protect flood-affected properties in Masterfield Street from flooding in a 100 year flood.

In 1990, a Review of Environmental Factors (*1990 REF*) was undertaken for Camden Municipal Council for the levee and the associated compensatory works (Sinclair, Knight & Partners, 1990). The compensatory works involved:

- straightening of about a 300m section of South Creek just upstream of Bringelly Road;

- filling-in of the existing South Creek channel adjacent to the creek straightening to allow for construction of the levee;

- excavation of material behind the levee to provide for local drainage behind the levee;

- construction of an additional culvert under Bringelly Road (between South Creek and Masterfield Street) and associated open grass drains to allow for drainage of water behind the levee back to South Creek downstream of Bringelly Road

The 1990 REF claimed that there was some discrepancies in the hydraulic modelling undertaken for the 1990 Flood Study (DWR, 1990) in this area and so a '*numerical model which predicted flood levels was utilised … this model was calibrated using those flood heights observed in the 1988 flood, and it was used to generate new 1 in 100 year flood levels for the area*'. The report indicates that there would be no increase in flood levels in the 100 year flood because of the works.

It is understood that this levee has been constructed but because the area upstream of the Bringelly Road bridge is outside the current study area, any impacts on flood behaviour that may occur because of the levee and its associated works have not been investigated as part of this study. Issues such as these highlight the need for an integrated approach to floodplain risk management in the entire South Creek catchment (see **Section 10.4.1**).

Findings: *Levee at Masterfield Street, Rossmore not considered further as part of the recommended Floodplain Risk Management Plan.*

10.4 FURTHER FLOODPLAIN STUDIES IN THE SOUTH CREEK CATCHMENT

10.4.1 An Integrated Approach to Floodplain Risk Management in the South Creek Catchment

The total area of the South Creek catchment is nearly 500 square kilometres. The area of the current study area is only about 34 square kilometres. About 56 square kilometres of the South Creek catchment lies upstream of the current study area, in the Camden Local Government Area (LGA).

The success of the recommended measures of the *Floodplain Risk Management Plan*, as well as the flood mitigation works already completed in the vicinity of Elizabeth Drive, relies on the important assumption that the flood behaviour within the study area will not change over time. It is therefore critical that management of the floodplain upstream of the study area does not translate into adverse impacts, not only within the current study area, but also within the reaches of South Creek further downstream in the Penrith and Hawkesbury LGAs. This will be particularly relevant, as parts of the South Creek catchment upstream of Bringelly Road have been designated as 'high priority' for urbanisation as part of the South West Urban Release Area (see **Section 1.1.5**).

Therefore, an integrated and coordinated approach to floodplain risk management throughout the entire South Creek catchment is recommended.

An important first step for this integrated approach would be representation of each of the four Councils (Camden, Liverpool, Penrith and Hawkesbury) on each of the Councils' Floodplain Management Committees. It is understood that this is already occurring to some extent at some of the Councils. Consultation and on-going liaison will also be important to ensure floodplain risk management for South Creek is considered on a catchment-wide basis.

Findings: *An integrated and coordinated approach to floodplain risk management throughout the entire South Creek catchment is recommended for inclusion in the South Creek Floodplain Risk Management Plan as a high priority measure.*

10.4.2 Thompsons Creek and Bardwell Gully Flood Study, Floodplain Risk Management Study and Plan

Thompsons Creek joins the western floodplain of South Creek about midway through the study area. Thompsons Creek rises about 2km south of Greendale Road, Bringelly, flowing in a north-easterly direction for about 6.5km towards South Creek. The total catchment area of Thompsons Creek is about 10.3 square kilometres. A major tributary of Thompsons Creek is Bardwell Gully. Bardwell Gully flows generally from west to east, parallel to Greendale Road, before joining Thompsons Creek just upstream of The Northern Road.

Like the rural-residential areas of the current study area, Thompsons Creek upstream of The Northern Road, including Bardwell Gully, are also experiencing development pressures within potentially flood-affected areas. This area has not been included in the current study area and there is currently no information on flood risks for this area. Also, there is only very limited ground survey information for the area

The extension of the study area upstream of The Northern Road is a logical inclusion to the recommended Floodplain Risk Management Plan. This extension was discussed during the course of the current study, with Council concluding that it would be more cost effective to wait until the upcoming aerial laser survey of the whole Liverpool LGA had been completed, rather than to undertake an expensive ground survey of just the area upstream of The Northern Road.

Findings: *A Flood Study and Floodplain Risk Management Study and Plan for Thompsons Creek and Bardwell Gully upstream of The Northern Road is recommended for inclusion Floodplain Risk Management Plan as a medium priority measure.*

*In accordance with the recommended coordinated approach to floodplain risk management in the South Creek catchment (see **Section 10.4.1**), it would be appropriate to include both Liverpool and Camden Council parts of the Thompsons Creek catchment in the study.*

Assuming that adequate survey is available, the total cost of the study would be in the order of $50,000.

11. RECOMMENDED SOUTH CREEK FLOODPLAIN RISK MANAGEMENT PLAN FOR THE LIVERPOOL LGA

This chapter presents the recommended floodplain risk management measures for inclusion in the *South Creek Floodplain Risk Management Plan for the Liverpool LGA* .

The preferred measures have been determined from the range of available measures discussed in **Chapters 6 to 10**, after an assessment of the impacts on flooding, as well as environmental, social, and economic considerations.

Table 11.1 provides a summary of the following information about each recommended element of the *Floodplain Risk Management Plan*:

- reduction in number of properties flooded above floor level in a 100 year flood;
- benefit–cost ratio where appropriate;
- estimates of capital cost, where appropriate;
- likely sources of funding;
- indicative priority (high, medium and low).

Each of the elements of the recommended *Floodplain Risk Management Plan* is presented on **Figure 11.1**.

The total cost of the recommended *Floodplain Risk Management Plan* would be in the order of $820,000.

About $680,000 of this cost would involve an extensive voluntary house-raising program for all properties that would be flooded above floor level in a 100 year flood. About six of the most frequently flood-affected properties would qualify for a ‘full-cost subsidy’ of about $70,000 per property towards raising their houses to a level that would allow vertical evacuation to a level above the probable maximum flood. Another 13 properties would qualify for a ‘partial-cost subsidy’ of about $20,000 per property. A ‘partial cost subsidy’ will provide homeowners of less frequently flood-affected properties, who were considering raising their homes, further incentive to do so.

One of the key components of the recommended *Floodplain Risk Management Plan* is the recommendation of planning and building controls — these controls are sensitive to the flood problems in the study area and will reduce the future flood risk to the study area community. The recommended *Floodplain Risk Management Plan* also contains important recommendations relating emergency management and community flood awareness.

The costs for implementation of elements relating to floodplain planning, emergency management and community awareness would be borne mainly by Council and SES staff. Most of these elements have been assigned a high priority because they are essential for ensuring that flood risks in the South Creek study area are not increased in the future.

It should be noted that even with the completion of all the elements of the recommended *Floodplain Risk Management Plan*, there would be no change in the height of design flood levels from current conditions. However, the most important consideration is that there would be a significant reduction in the amount of flood risk to the people of the South Creek study area.

Once the recommended Plan is adopted by Council, Council can then apply for funding to commence the works.

TABLE 11.1: RECOMMENDED MEASURES FOR THE SOUTH CREEK FLOODPLAIN RISK MANAGEMENT PLAN

ITEM (Report Section No.)	DESCRIPTION	REDUCTION IN NO. PROPERTIES FLOODED ABOVE FLOOR LEVEL IN 100 YEAR FLOOD	BENEFIT–COST RATIO	ESTIMATED COST	FUNDING SOURCES	PRIORITY
8	**PROPERTY MODIFICATION MEASURES**					
8.1	**Planning Controls and Policies:** ‣ amendments to Sydney Regional Environmental Plan No.20 — Hawkesbury–Nepean River (SREP No.20), including strategy to fast-track adoption ‣ amendments to Liverpool Local Environmental Plan, including strategy to fast-track adoption ‣ adoption of Planning Matrix Approach ‣ adoption of High, Medium and Low Risk Precincts ‣ adoption of Flood Risk Management Development Control Plan	na	na	Council Staff Costs	Current Council responsibility	high
8.3	**Voluntary House Raising:**					
8.3.2	‣ Properties with over-floor flooding in a 5 year flood — full-cost subsidy (Option HR5): – No.35 Victor Avenue; – No.82 Victor Avenue.	2	2.4	$140,000	Council, DIPNR, possibly some residents' costs	high
8.3.2	‣ Properties with over-floor flooding in a 20 year flood — full-cost subsidy (Option HR20a): – Nos.10, 20 and 50 Victor Avenue; – No.100 Watts Road.	4	0.8	$280,000	Council, DIPNR, possibly some residents' costs	medium
8.3.2	‣ Properties with over-floor flooding in a 20 year flood — partial cost subsidy (Option HR20b): – Nos.120 and 150 Overett Avenue;	2	2.0	$40,000	Council, DIPNR, residents	low
	– No.60 Victor Avenue.	1		$20,000		medium

ITEM (Report Section No.)	DESCRIPTION	REDUCTION IN NO. PROPERTIES FLOODED ABOVE FLOOR LEVEL IN 100 YEAR FLOOD	BENEFIT–COST RATIO	ESTIMATED COST	FUNDING SOURCES	PRIORITY
8.3.2	‣ Properties with over-floor flooding between a 20 year flood and a 100 year flood — partial cost subsidy (Option HR100): – No.70 Kelvin Park Drive. – Nos. 80, 124, 135 and 145 Overett Avenue; – Nos. 5, 32, 50 (2nd house) and 70 Victor Avenue; – No.1 May Avenue.	10	0.5–1.0	$200,000	Council, DIPNR, residents	low
8.4	**Flood Proofing —** ‣ development of 'Flood Proofing Guidelines' for study area.	na	na	$5,000 plus Council staff costs	Council, (residents' costs to implement)	medium
9	**RESPONSE MODIFICATION MEASURES**					
9.1	**Flood Warning:** *As the South Creek study area would be in a 'flash flood' area, there would be no formal flood warning service available from the Bureau of Meteorology. A Flood Watch or Severe Thunderstorm Warning issued by the Bureau of Meteorology would be the only 'formal' means of flood warning for the study area.*					
9.1.3	‣ development of triggers for rainfall and river height station in and close to the study area;	na	na	Bureau of Meteorology and SES staff costs	Council, Bureau of Meteorology and SES	high
9.1.3	‣ linking of triggers for rainfall and river height stations to local base stations, particularly local SES headquarters, to identify to local authorities when flooding may be imminent;	na	na	Council, Bureau of Meteorology and SES staff costs plus computer costs	Council, Bureau of Meteorology, SES	high
9.1.4	‣ installation of three additional ALERT rainfall stations in the upper parts of the South Creek catchment, including the development and linking of triggers to local base stations.	na	na	$20,000 for capital and installation plus $2,000–$3,000 per annum for maintenance	Council, DIPNR	high

ITEM (Report Section No.)	DESCRIPTION	REDUCTION IN NO. PROPERTIES FLOODED ABOVE FLOOR LEVEL IN 100 YEAR FLOOD	BENEFIT–COST RATIO	ESTIMATED COST	FUNDING SOURCES	PRIORITY
9.2	**Emergency Management:**					
9.2.2 9.2.3	‣ all flood intelligence information from current study be made available to SES in a form appropriate for inclusion in next version of Liverpool City Local Flood Plan	na	na	$10,000 plus SES staff costs	SES, Council	high
9.2.4	‣ provision for 'vertical evacuation' in the planning and development controls	na	na	Council staff costs	Current Council responsibility	high
9.2.5	‣ preparation of FloodSafe brochure either for just current study area or for all South Creek upstream of limit of Hawkesbury–Nepean flooding	na	na	$5,000 (for design of brochure) plus SES staff costs	Council, SES	high
9.3	**Community Flood Awareness**					
9.3.2	‣ production of Flood Precinct Maps	na	na	Council staff costs	Council	high
9.3.3	‣ updating of Council's GIS and use of information available from this study	na	na	Council staff costs	Council	high
9.3.4	‣ preparation of brochure 'Guidelines on Flood-Related Building Controls'	na	na	$5,000 plus Council staff costs	Council	high
9.3.5	‣ preparation and sending out of 'Flood Information Packs' to all residents in the floodplain, that would include: (a) Flood Notification Letter; (b) Flood Information Brochure; (c) Frequently Asked Questions about Floodplain Risk Management Studies; (d) SES FloodSafe brochure and associated SES information.	na	na	‣ Council staff costs (a) Council staff costs (b) $5,000 (for design of brochure) plus Council staff costs (c) already completed (d) SES staff costs	Council (a) Council (b) Council (c) Council (d) Council, SES	high
9.3.6	‣ issuing of Flood Certificates when Development Applications are submitted	na	na	Council staff costs	Council	high

ITEM (Report Section No.)	DESCRIPTION	REDUCTION IN NO. PROPERTIES FLOODED ABOVE FLOOR LEVEL IN 100 YEAR FLOOD	BENEFIT–COST RATIO	ESTIMATED COST	FUNDING SOURCES	PRIORITY
9.3.7	‣ installation of flood markers at Elizabeth Drive and Bringelly Road	na	na	$20,000	Council, DIPNR	low
9.3.8	‣ appropriate notification on Section 149 Certificates	na	na	Council staff costs	Council	high
10	**FLOOD MODIFICATION MEASURES**					
10.3.4	**Safety improvement program for The Retreat crossing of Thompsons Creek:**					
10.3.4	‣ signage at bridge and associated community awareness program	na	na	$5,000 plus Council staff costs	Council	high
10.3.4	‣ investigation into flood escape route to Badgerys Creek Road via an existing access way	na	na	Council and SES staff costs	Council, SES	high
10.3.5	**Development of Creek Maintenance Strategy, including:** ‣ the amount of appropriate vegetation be determined so that flood levels would not start to increase; ‣ clear identification of environmental considerations; ‣ systematic removal of dumped rubbish; ‣ more vigilant policing of dumping practices in the study — this could involve the installation of signs at key problem areas with large fines for dumping of rubbish.	na	na	$10,000 plus Council staff costs	Council, possibly some volunteers for implementation of strategy	high
10.4.1	**Integrated Approach to Floodplain Risk Management in the South Creek Catchment**	na	na	Council staff costs	Council, DIPNR	high
10.4.2	**Thompsons Creek and Bardwell Gully Flood Study, Floodplain Risk Management Study and Plan**	na	na	$50,000	Council (Liverpool and Camden), DIPNR	medium
	TOTALS	**19**		**$815,000**		

FIGURE 11.1: RECOMMENDED MEASURES FOR SOUTH CREEK FLOODPLAIN RISK MANAGEMENT PLAN (FOR LIVERPOOL LGA)

A3 Colour

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APPENDICES