Prepared for the Georges River Floodplain Management Committee

GEORGES RIVER FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

Volume 1 – Main Report

Final Report

May 2004

Bewsher Consulting Pty Ltd

GEORGES RIVER FLOODPLAIN MANAGEMENT COMMITTEE

Comprising Liverpool City Council, Fairfield City Council, Bankstown City Council, Sutherland Shire Council, State Emergency Service, Department of Infrastructure, Planning and Natural Resources, and community representatives.

GEORGES RIVER
FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

Volume 1 – Main Report

FINAL REPORT

May 2004

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EXECUTIVE SUMMARY

Reasons for the Study and Plan

The Georges River is one of the most populated catchments in Australia. The river and its tributary creeks represent Sydney's most immediate flood problem, both in terms of the number of properties affected by flooding and the potential for increased flood damage due to development pressures within the catchment.

Bewsher Consulting was commissioned by Bankstown City Council and Liverpool City Council in June 2001 to develop a floodplain risk management study and plan for the Georges River. The study was later expanded to incorporate parts of Fairfield City Council and Sutherland Shire Council.

Numerous flood investigations have been undertaken on the Georges River over the years. Most have focused on specific problem areas along the river, and in many cases flood mitigation schemes have been developed to tackle these problems. Many of the schemes have since been implemented, or are in the process of being implemented. Whilst there has been substantial progress in reducing the extent of flooding problems along the river, there remains a significant flood risk to many properties. There has also been no overall strategic floodplain risk management study that considers the broader catchment-wide measures, such as flood warning, emergency management measures, public awareness and consistent planning controls for future development.

The Study report has been produced in two volumes – a main report (Volume 1) and a supplementary report covering planning issues (Volume 2), given the critical importance of the latter to floodplain management on the Georges River.

Responsibilities

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 risk management studies and for the implementation of works identified in any subsequent floodplain risk management plan.

The Georges River Floodplain Management Committee oversaw the Study. This committee includes Councillors and staff from Bankstown, Liverpool, Fairfield and Sutherland Shire Councils. Officers form the Department of Land and Water Conservation (now the Department of Infrastructure, Planning and Natural Resources) and the State Emergency Service were also represented on the committee, along with a number of community representatives.

The Study Area

The Georges River has a catchment area of 960 km^2, and a population of approximately 1 million people. The river itself is about 100km in length and has a number of important tributaries, such as Cabramatta Creek, Prospect Creek, Harris and Williams Creek, Salt Pan Creek and the Woronora River.

The study area includes all the floodplains of the Georges River in the Liverpool, Fairfield and Bankstown Council areas, together with the floodplains upstream of the Woronora River junction in Sutherland Shire.

Consultation

Community consultation has been an important component of the current study. As well as improving the community's awareness of and readiness for flooding, the consultation has aimed to inform the community about the development of the floodplain management study and its likely outcomes.

Key elements of the consultation process have been as follows:

- regular meetings of the Georges River Floodplain Management Committee;
- development of a study web site for the project (www.bewsher.com.au/georges);
- preparation of an SES FloodSafe brochure for the Georges River;
- preparation and distribution of a notification pack for all residents potentially affected by flooding;
- distribution of a short questionnaire to all residents, followed by a more detailed questionnaire;
- organisation of ten public workshops;
- liaison with government agencies and other groups; and
- the intended public exhibition of the recommended floodplain risk management study and plan, prior to formal consideration by each Council.

Modelling of Flood Behaviour

Design flood levels for the Georges River, between East Hills and Liverpool, were determined using a physical model during the 1980s. Flood levels from the physical model were published in the 1991 Georges River Flood Study report, and have been applied by Liverpool, Fairfield and Bankstown Councils since this time.

A computer model of the Georges River, from Botany Bay to upstream of Liverpool, was established as part of the current study. The model was used to verify results from the previous flood study and to test the impact of development and other works that have occurred on the floodplain since the mid 1980s. The computer model also provides additional information on flood behaviour, including flow rates, velocities and flood hazard information.

Whilst some recent floodplain activities are believed to have had a detrimental impact on flood behaviour, the change in flood levels is relatively small (less than 200mm). There may also be some opportunities to redress these problems in the near future. Therefore, no change to the previously adopted design flood levels would appear to be warranted.

The computer model also provides flood information in the lower Georges River, downstream of East Hills, where previously there was no data. Results from the model can therefore be used to define design flood levels in the lower river, principally for use by Sutherland Shire.

The Flood Problem

The April 1988 and August 1986 floods are the largest floods to have occurred on the Georges River over the last 30 years. Over 1,000 residential properties along the Georges River, Prospect Creek and Cabramatta Creek were inundated from the 1988 flood, with a damage bill estimated at $18M (1988 values). Both these floods are estimated to be about a 20 year flood.

The largest flood to have occurred in the 1900s was the February 1956 flood. Whilst some newspaper reports quoted this event as being the "biggest Sydney storm in living memory", much larger floods are reported to have occurred in the late 1800s. The largest flood is thought to have occurred in February 1873. This flood was about 2m higher than the 1956 flood, and about 3m higher than either the 1986 and 1988 floods (at Liverpool).

A flood damages database of potentially flood affected property has been prepared as part of the study. The database provides details of those properties likely to be inundated in different sized floods and allows the quantification of potential flood damages. Key results from the database indicate that:

- 5,204 residential homes and 591 commercial buildings would be flooded above floor level in a probable maximum flood (PMF);
- 721 residential homes and 216 commercial buildings would be flooded above floor level in a 100 year flood;
- the predicted flood damage in the 100 year flood is $99M, whilst the average annual flood damage is estimated at $8.2M and the present value of all future flood damages is estimated at $91M.

Flood Risk Mapping & Development Controls

The Georges River floodplain has been divided into three flood risk precincts (high, medium and low). Different development controls are proposed for the catchment, depending on the type of development and the flood risk area that the development is located. It is proposed that the development controls be applied through a Development Control Plan (DCP) in each Local Government Area (LGA). Draft DCPs for each Council have been prepared and are included in the Volume 2 report. The DCPs cover the whole of each LGA and include both river flooding and overland flow issues resulting from stormwater inundation.

Within the three flood risk precincts that are proposed:

- the high flood risk area is where high flood damages, potential risk to life, or evacuation problems are anticipated. It is recommended that most development is restricted within this area.
- the medium flood risk area is where there is still a significant risk of flood damage, but where these damages can be minimised by the application of appropriate development controls.
- the low flood risk area is that area where the risk of flood damage is low. Most land uses would be permitted within this area (subject to other planning considerations).

The Recommended Floodplain Management Measures

The draft Georges River Floodplain Risk Management Plan is shown on **Figure 10.1**, and summarised in **Table 10.1**. The principal components of the Plan are as follows:

- voluntary acquisition of the remaining 71 properties in the Liverpool Voluntary Purchase Scheme at Moorebank (99 properties have been purchased to date);
- voluntary acquisition of the remaining 4 properties in the Bankstown Voluntary Purchase Scheme at Milperra (21 properties purchased to date);
- minor adjustments to the crest level on the Kelso levee;
- relocation/removal of 7 buildings within the East Hills Flood Mitigation Scheme;
- the preparation of local catchment studies;
- a flood study on Anzac Creek;
- airborne laser scanning to provide improved topographic data;
- compensatory measures to offset the impacts of recent developments;
- adoption of consistent planning and development controls;
- flood warning enhancements to link flood warning predictions with a property database;
- improved emergency management operations; and
- improved public awareness and information on flooding through the issue of flood certificates, S149 notifications and the construction of flood markers to indicate the levels of historic floods.

The recommended measures also include the findings of a review of floodplain management works undertaken within the study area since the early 1980s. In some cases, variations to previous measures have been proposed. Some additional measures are also proposed in other areas. However, the most effective components of the Plan are the catchment-wide measures. These measures are expected to provide significant benefits over the full range of floods that can be anticipated within the catchment, and can be implemented at a relatively low cost.

Several other floodplain management works were also investigated, but have not been recommended due to high capital costs, low economic benefits, and/or significant environmental issues associated with these proposals. Works that were considered, but not recommended include:

- a large flood mitigation dam in the upper catchment;
- dredging of the river; and
- a levee to protect the Milperra Industrial Estate.

Timing and Funding

The total cost of implementing all the recommended measures is approximately $33.6M. This amount is dominated by the $30M that is estimated to be required for the completion of the Liverpool Voluntary Purchase Scheme at Moorebank.

The $30M for the Liverpool Voluntary Purchase Scheme is a high financial burden on both Liverpool Council and the State Government. The investigation of alternative self-funding initiatives, involving private sector development within the voluntary purchase area, has been recommended. If such initiatives are fruitful, then the total cost of the Georges River Floodplain Risk Management Plan will reduce to a much more modest $3.6M.

The timing of the proposed works will depend on the overall budgetary commitments of each Council and the availability of funds from other sources (eg State Government, potential Section 94 contributions, private sector contributions etc).

1. INTRODUCTION

1.1 BACKGROUND

The Georges River catchment is located south west of Sydney. It is the home of approximately one million people, making it one of the most populated catchments in Australia. Not surprisingly, the river and its tributary creeks represent Sydney's most immediate flood problem, both in terms of the number of properties affected by flooding and the potential for increased flood damage due to development pressures within the catchment.

Bewsher Consulting was commissioned by Bankstown City Council and Liverpool City Council in June 2001 to develop a floodplain risk management study and plan for the Georges River. The study was later expanded to also incorporate the Fairfield City Council and the Sutherland Shire areas. These four council areas share the main flood burden within the catchment. Funding for the study was provided jointly by the four councils and the Department of Infrastructure, Planning and Natural Resources (DIPNR), formerly the Department of Land and Water Conservation (DLWC).

Numerous flood investigations (see Section 2.3) have been undertaken on the Georges River and its tributaries over the years. Most of these studies have been focused on the tributary creeks or in specific areas along the main river. In many instances, these studies have recommended various flood mitigation measures to address the flood problems of the area. Many of the schemes have since been implemented, or are in the process of being implemented. Progress over the last 20 years has been substantial, with major levee bank schemes, finger levees, voluntary purchase schemes, house-raising schemes, creek improvement works and other measures being implemented.

Whilst there has been substantial progress on reducing the extent of flooding problems within the catchment, there remains a significant flood risk to many properties. There has also been no overall strategic floodplain risk management study that considers the broader catchment-wide measures, such as flood warning, emergency management measures, public awareness and consistent planning controls for future development.

The objectives of the Georges River Floodplain Risk Management Study have included:

- a review of flood behaviour;
- an assessment of the impact of recent catchment development on flooding;
- quantification of the flood problem;
- review of floodplain management measures undertaken to date;
- consideration of other potential floodplain management measures, particularly the broader catchment-wide measures;
- recommended planning controls to manage the flood risk, which are consistent between the four councils; and

- the preparation of a floodplain risk management plan, which outlines recommended measures to reduce the risk of flooding.

The Georges River Floodplain Management Committee was established to oversee the study. This committee includes representatives from each of the four councils, the Department of Infrastructure, Planning and Natural Resources, the State Emergency Service and a number of community representatives. The committee has met regularly to consider progress reports from the consultant and to provide direction during the progress of the study.

1.2 THE STUDY AREA

The study area includes all the floodplain areas of the Georges River in the Liverpool, Fairfield and Bankstown Council areas, together with the floodplain areas upstream of the Woronora River junction in Sutherland Shire. The study area is further described in **Section 2**, and is also illustrated on **Figure 2.2**.

The floodplain is defined in the Floodplain Management Manual [NSW Government, 2001] as all land that is potentially at risk from flooding up to the probable maximum flood (PMF). This is an important consideration for the current study, as previous flood risk management considerations on the Georges River were limited to land up to the 100 year flood. The broader definition of the floodplain now provides an onus on each Council to consider the flood risk over a larger area of land.

The study area also includes the lower reaches of a number of tributary creeks, where flooding can also occur due to backwater from the Georges River. Specific studies have been undertaken on most of these tributary creeks, and in many cases, floodplain management measures proposed to reduce the risk of flooding. As there is a degree of overlap in flooding on the lower reaches of these creeks with flooding on the Georges River, these lower creeks can also be considered as part of the study area. Measures that may be considered for the Georges River, particularly catchment-wide measures and planning controls, will supplement other measures previously considered for these creeks.

Tributary creeks that fall within the study area include:

- Cabramatta Creek (downstream of the Hume Highway);
- Prospect Creek (downstream of the Hume Highway);
- Milperra Drain;
- Harris and Williams Creeks (downstream of Heathcote Road);
- Deadmans Creek (downstream of Heathcote Road);
- Little Salt Pan Creek; and
- Salt Pan Creek (downstream of Canterbury Road).

The entire Georges River catchment area has also been considered to determine catchment flows, and to assess development and potential floodplain management measures within the catchment that could affect flood behaviour throughout the study area.

1.3 THE GOVERNMENT'S FLOODPLAIN MANAGEMENT PROCESS

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

A Flood Prone Land Policy and a *Floodplain Management Manual* [NSW Government, 2001] forms the basis of floodplain management in NSW.

The objectives of the Policy include:

- reducing the impact of flooding and flood liability on existing developed areas by flood mitigation works and measures, including ongoing emergency management measures, voluntary purchase and house raising programs, flood mitigation works, and development controls; and
- reducing the potential for flood losses in new development areas by the application of ecologically sensitive planning and development controls.

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

The implementation of the Flood Prone Lands Policy generally culminates in the preparation and implementation of a Floodplain Management Plan, which is the objective of the current study.

The steps in the floodplain management process are summarised on **Figure 1.1**.

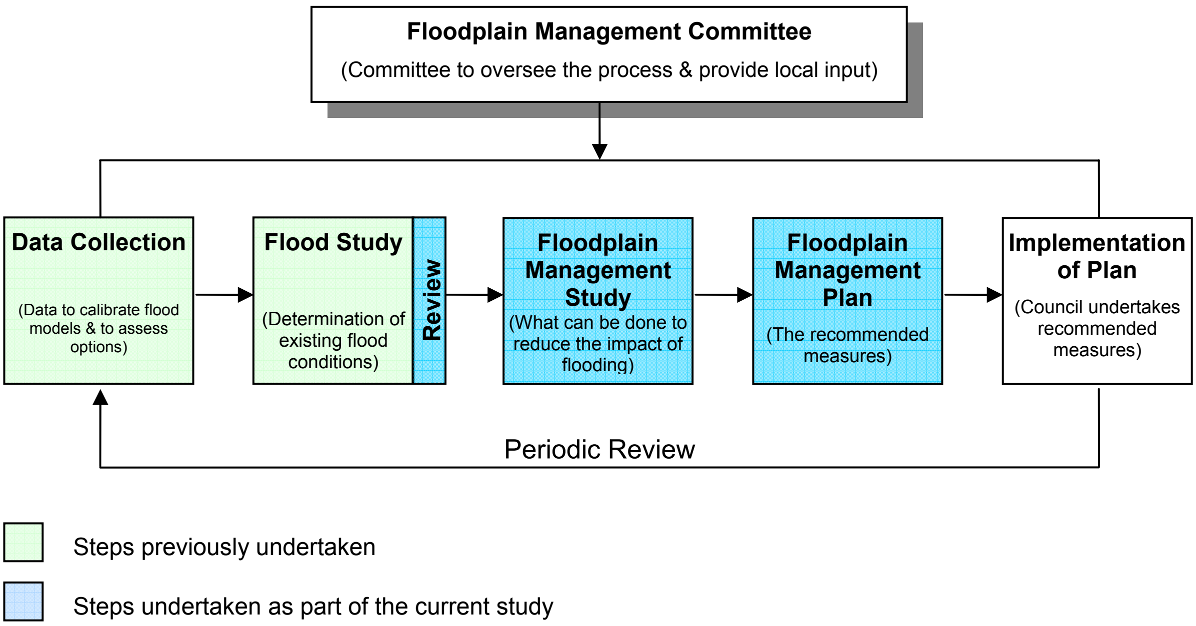


FIGURE 1.1
THE FLOODPLAIN MANAGEMENT PROCESS

1.4 REPORTING

The Georges River Floodplain Risk Management Study is presented as two volumes:

Volume 1 – The Main Study Report (this document); and

Volume 2 – Planning Issues.

Volume 1 provides an assessment of:

- previous flood investigations;
- results of the community consultation program undertaken as part of the study;
- additional flood modelling results;
- a description of flood behaviour, including estimated flood damages;
- floodplain management measures previously undertaken;
- other floodplain management measures that could be considered; and
- recommended measures to reduce the flood risk within the study area.

Volume 2, which was prepared by Don Fox Planning Pty Ltd for Bewsher Consulting, provides an assessment of:

- environmental, social and other planning issues related to the study;
- a review of existing flood-related planning instruments and policies; and
- recommended planning controls for future development, which are consistent across the four council areas and recognise the flood risk of the area and the type of landuse proposed. The controls are to be implemented as new development control plans for each of the four councils.

2. BACKGROUND INFORMATION

2.1 THE GEORGES RIVER CATCHMENT

The Georges River catchment, shown on **Figure 2.1**, has a total catchment area of 960 km^2. The river itself is about 100km long. From its headwaters near Appin, the river flows north towards Campbelltown, through Liverpool and the Chipping Norton Lakes Scheme, and then east through Bankstown to Botany Bay.

The upper catchment area, south of Campbelltown, is largely undisturbed and is still in its natural forested state. Much of the river through this area lies within a deep and narrow gorge. Campbelltown itself, is located on a tributary creek known as the Bunbury Curran Creek, and is not directly affected by flooding from the Georges River.

From Campbelltown to Liverpool the steep river valley gives way to more gently undulating terrain. Development starts to become more prevalent on either side of the river towards Liverpool. The river banks remain relatively high, and all but very large floods are contained in-bank.

The tidal limit of the river is at the Liverpool weir. This structure was constructed in 1836 as a causeway crossing of the river and a source of water for Liverpool. The weir still exists today, with its historical significance recognised by the National Trust and the Australian Heritage Commission.

The next 20 kilometres of the river, between Liverpool and Picnic Point, includes the major floodplain area of the river. This area, being located within the southwest portion of Sydney's metropolitan area, is heavily urbanised and there are significant flood problems. Major tributaries within this reach include Cabramatta Creek, Prospect Creek, Harris and Williams Creek, and Salt Pan Creek. A major feature is also the Chipping Norton Lakes Scheme. This scheme consists of a series of lakes adjoining the river, which were formed in the 1970's and 1980's as part of the rehabilitation of former sand mining activities that had previously been undertaken in this area.

The final 20 kilometres of the lower river, between Picnic Point and Botany Bay, are typical of a deeply incised broad estuary and hence there are numerous bays and small inlets. Intensive development has occurred along both banks of the river, most of which is perched high above river flood levels. Major tributaries in the lower river include Salt Pan Creek and the Woronora River.

In total, about one-third of the catchment is occupied by some form of urban development, particularly in the lower end of the catchment. The remaining two-thirds of the catchment is comprised predominantly of bushland, national parks, reserves or rural lands.

The Georges River catchment is also the home of approximately one million people. The catchment also contains significant areas that have been identified for future urban development under the Sydney Region Urban Development Program. The majority of these areas are located within the Campbelltown, Liverpool, Fairfield and Sutherland Shire council areas. The Metropolitan Strategy [DUAP, 1998] is planned to accommodate up to 43,000 new dwellings in the catchment over the next 20 to 25 years. A significant component of this future growth is anticipated to occur within the Cabramatta Creek catchment.

The administrative framework for managing the river, the floodplain and the catchment is quite complex. There are 12 different local government authorities within the catchment, namely:

- Wollondilly Shire Council;
- Wollongong City Council;
- Campbelltown City Council;
- Liverpool City Council;
- Fairfield City Council;
- Holroyd City Council;
- Bankstown City Council;
- Canterbury City Council;
- Sutherland Shire Council;
- Hurstville City Council;
- Kogarah Municipal Council; and
- Rockdale City Council.

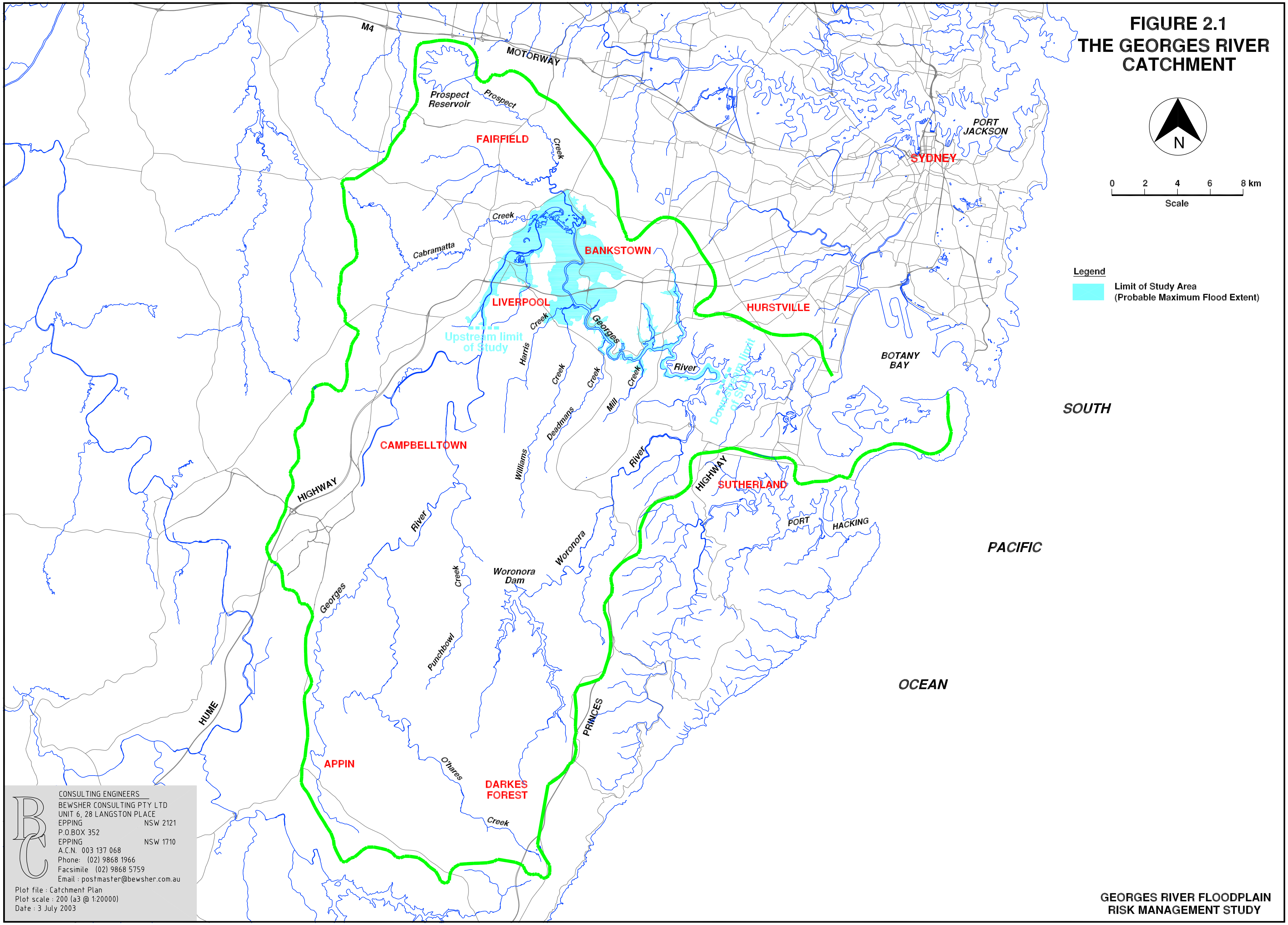
Each Council has their own planning controls to manage the risk of flooding and to safeguard the environmental qualities of the river. There are also many other Government Departments and Agencies with an interest in the river or the catchment, such as the Department of Infrastructure Planning and Natural Resources (DIPNR), Environment Protection Authority (EPA), NSW Fisheries, Georges River Combined Councils and others.

The army also owns approximately 20% of the catchment, including the Holsworthy Barracks, School of Military Engineering at Chatham Village, and other bushland that has been classified as “Military Reserve”.

As previously mentioned, the study area for this floodplain risk management study comprises the floodplain of the lower reaches of the river that is shared between Liverpool, Fairfield, Bankstown and Sutherland Shire Councils. This area is depicted on **Figure 2.2**.

Discussion on the environmental qualities, social aspects and other planning issues within the catchment that are relevant to the current study are presented in **Volume 2** of the Floodplain Management Study.

FIGURE 2.1 THE GEORGES RIVER CATCHMENT



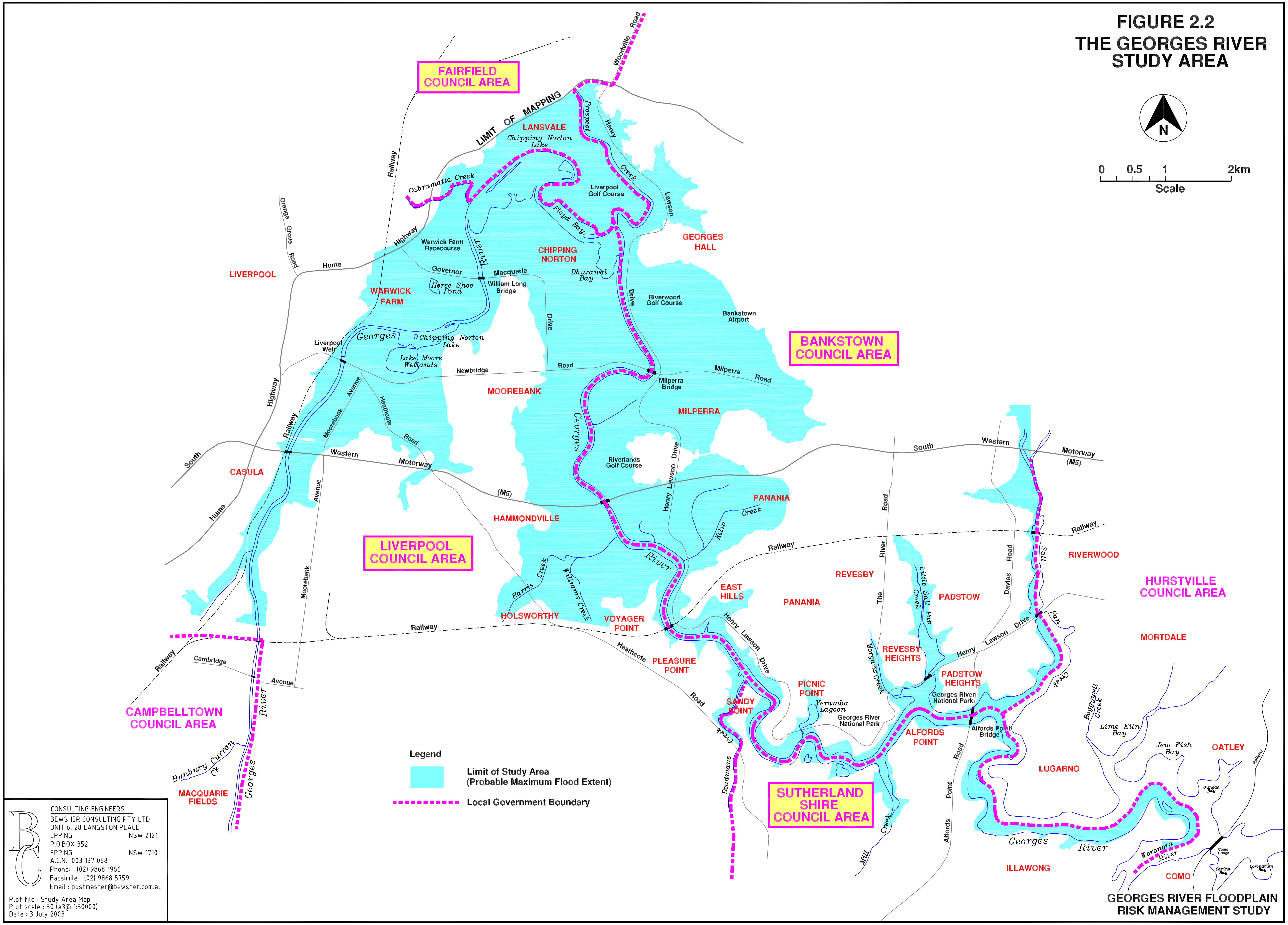


FIGURE 2.2
THE GEORGES RIVER STUDY AREA

2.2 HISTORY OF FLOODING

Many people living near the Georges River will remember the heartache and damage caused by the August 1986 and April 1988 floods. These are the largest floods to have occurred over the last 30 years, and are estimated to be about a 20 year flood [PWD, 1991]. The 1988 flood was estimated to have inundated over 1,000 residential properties along the Georges River, Prospect Creek and Cabramatta Creek, with an estimated damage of over $18M (1988 values).

Fewer people may remember the February 1956 flood. This flood was about 1 metre higher than the 1986 and 1988 floods throughout much of the river, but is still estimated to be less than a 100 year event. The Sydney Morning Herald refers to this flood as the "biggest Sydney storm in living memory". It also refers to properties worth millions of pounds being destroyed, with 8,000 people left homeless.

But much larger floods are believed to have occurred during the 1800's. The largest observed flood is thought to have occurred in February 1873. On the basis of literature searches, this was probably the greatest flood since about 1800.

The 1873 flood level at Liverpool has been estimated to be 2m higher than the 1956 flood, and 3m higher than the 1986 and 1988 floods. It is also estimated as being higher than the 100 year flood.

An extract from the Sydney Morning Herald immediately following the 1873 flood is shown opposite. Whilst the report notes the severity of the flood and property being destroyed, it must be remembered that Liverpool at the time was considered to be a rural outpost of Sydney. The consequences of the flood would have been more far reaching if there had been more development near the river, as there is today.

Sydney Morning Herald, 27th February, 1873

THE FLOODS.

The reports we have received from the country districts show that the floods have been disastrous. A very large amount of private property has been destroyed, and public works also have been injured.

LIVERPOOL.

The highest flood known in the district occurred at Liverpool on Tuesday night. Several houses were swept away. The residence of a farmer near the dam fell into the river. The woolwashing establishment of the Hon. Saul Samuel was partially covered, and the flood has entailed considerable loss.

The Holdsworthy farmers have been washed out, and their hay has been destroyed. A subscription to afford them relief has been already set on foot.

In the town there has been much inconvenience, but no serious damage has been done.

The Paper Company's Works at one time were thought to be in great danger, but they have escaped with the loss only of the pumping-engine, which was carried away.

Some idea of the height of the flood may be obtained by those who know the country, when it is stated that George's River and a creek which runs through Mr. Wooll's farm, met. The rush of water displaced large quantities of soil, and injured the railway.

The river is now falling rapidly.

The late 1800's appears to have been a considerably intense period for floods, both on the Georges River and other nearby catchments, such as the Hawkesbury-Nepean. Other very large floods, similar to the estimated 100 year flood, are also reported to have occurred in 1889, 1887 and 1860.

Historical data on flooding is available from a variety of sources. These include:

- historical references and newspaper articles, such as those mentioned above;
- flood heights that have recorded at key locations throughout the catchment, particularly at the Liverpool weir and some of the older bridges;

- investigation, field survey and documentation of debris levels immediately after a flood, for example reports prepared following the 1986 and 1988 floods;
- data from recent floods, which are now recorded at a number of automatic water level gauges along the river; and
- research undertaken by others that have critically reviewed the available data.

The most complete record of observed flood heights have been recorded at the Liverpool weir, which was built in 1836 and provides a convenient location in which to observe and record flood levels. Today, an automatic water level recorder continually monitors the water level at this location. Flood levels for 30 different flood events have been recorded at the weir, or close to the weir, since the 1873 flood. These results are included in **Table 2.1**.

The Lansdowne Bridge on the Hume Highway crossing of Lower Prospect Creek is another structure of historical significance where a number of flood observations have been recorded. Flood levels for 16 different flood events have been recorded at this bridge, dating back to 1809. These results are also included on **Table 2.1**, along with some more recent results for William Long Bridge (Governor Macquarie Drive), Milperra Bridge and the East Hills Footbridge.

The historical flood records for the Liverpool weir and Lansdowne Bridge have been represented as two different flood histograms on **Figure 2.3**. These two plots effectively show the pattern of flooding over the last 140 years.

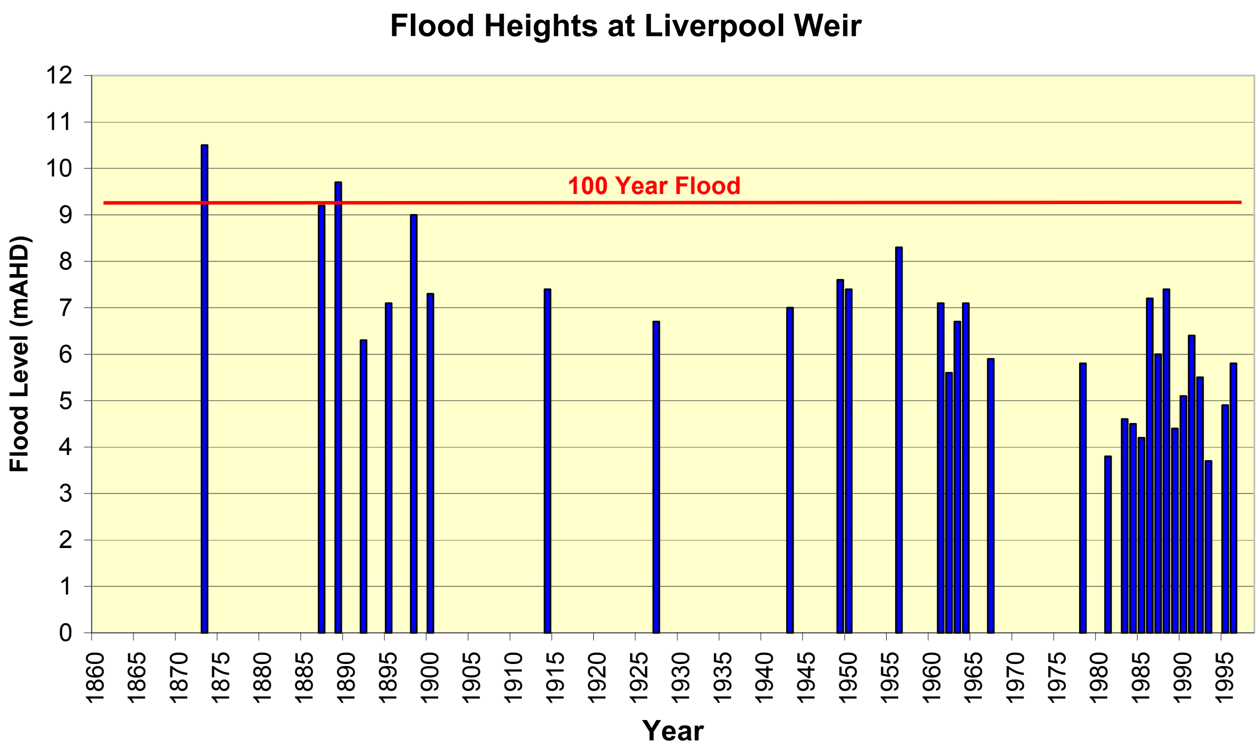
Both histograms indicate that the 1873 flood was the largest flood at both Liverpool and the Lansdowne Bridge, in both cases being at least 2m higher than the estimated 100 year flood level. The 1889 flood also appears to have been a very significant flood event at both locations. It is the second highest flood at Liverpool and the third highest at the Lansdowne Bridge. In both cases it is about 1m higher than the estimated 100 year flood level. A slightly larger flood is also reported to have occurred at the Lansdowne Bridge in 1860, although there are no supporting records from the Liverpool weir.

More importantly, both histograms confirm that floods that occurred in the latter half of the 1800's were significantly larger than floods that occurred during the 1900's. Flooding that has been experienced over the last century on the Georges River has therefore been relatively minor compared to the earlier flood events. Therefore those floods that are remembered by residents, such as those depicted on Photos 1 to 4, are relatively small in comparison to others that are possible, and that have occurred in the past. Consequently, public awareness of the potential magnitude of flooding within the catchment will be very poor.

It is important to note that nothing has happened within the catchment to mitigate major flooding. Some local improvements may have occurred in the vicinity of the Chipping Norton Lakes Scheme, but elsewhere conditions remain the same and possibly exacerbated by increased development that has taken place during the 1900's. It is just fortuitous that we have experienced a century of relatively low floods on the Georges River.

TABLE 2.1
Historical Flood Records
(All levels expressed in meters to Australian Height Datum)

Date	Liverpool Weir	William Long Br	Lansdowne Bridge	Milperra Bridge	East Hills Bridge	Source of Data (Reference)
May 1809			8.2			Sonter
April 1860			7.5			Sonter
Feb 1873	10.5		8.0			Stewart, 1968
April 1887	9.2					Stewart, 1968
May 1889	9.7		7.2			Stewart, 1968
1892	6.3					Scholer, 1966
Jan 1895	7.1					Scholer, 1966
Feb 1898	9.0		5.5			Sonter
July 1900	7.3					Stewart, 1968
Mar 1914	7.4					Stewart, 1968
1927	6.7					Stewart, 1968
1943	7.0					Scholer, 1966
June 1949	7.6					Stewart, 1968
June 1950	7.4		5.3	3.5		Stewart - MHL,1986
Feb 1956	8.3	6.5	5.7	4.8	3.7	PWD,1991
Nov 1961	7.1	5.7	4.6	3.8	2.8	Sonter - MHL,1986
Dec 1962	5.6					Stewart, 1968
Aug 1963	6.7	4.6		3.3		Stewart - MHL,1986
June 1964	7.1	5.2		3.6		Stewart - MHL,1986
April 1967	5.9					Stewart, 1968
Mar 1978	5.8		3.7	2.9	2.1	PWD, 1991
April 1981	3.8				1.2	Auto gauge
Mar 1983	4.6	2.4	1.5	1.2	0.9	MHL,1986
July 1984	4.5				1.3	Auto gauge
May 1985	4.2				1.1	Auto gauge
Aug 1986	7.2	5.7	5.1	4.4	3.2	MHL,1987
Oct 1987	6.0				2.4	Auto gauge
April 1988	7.4	5.9	5.8	4.9	3.6	MHL,1989
April 1989	4.4		1.3	1.2		Auto gauge
Feb 1990	5.1		3.1	2.9		Auto gauge
June 1991	6.6		4.7	3.8		Auto gauge
Aug 1996	5.8		2.4	2.0		Auto gauge



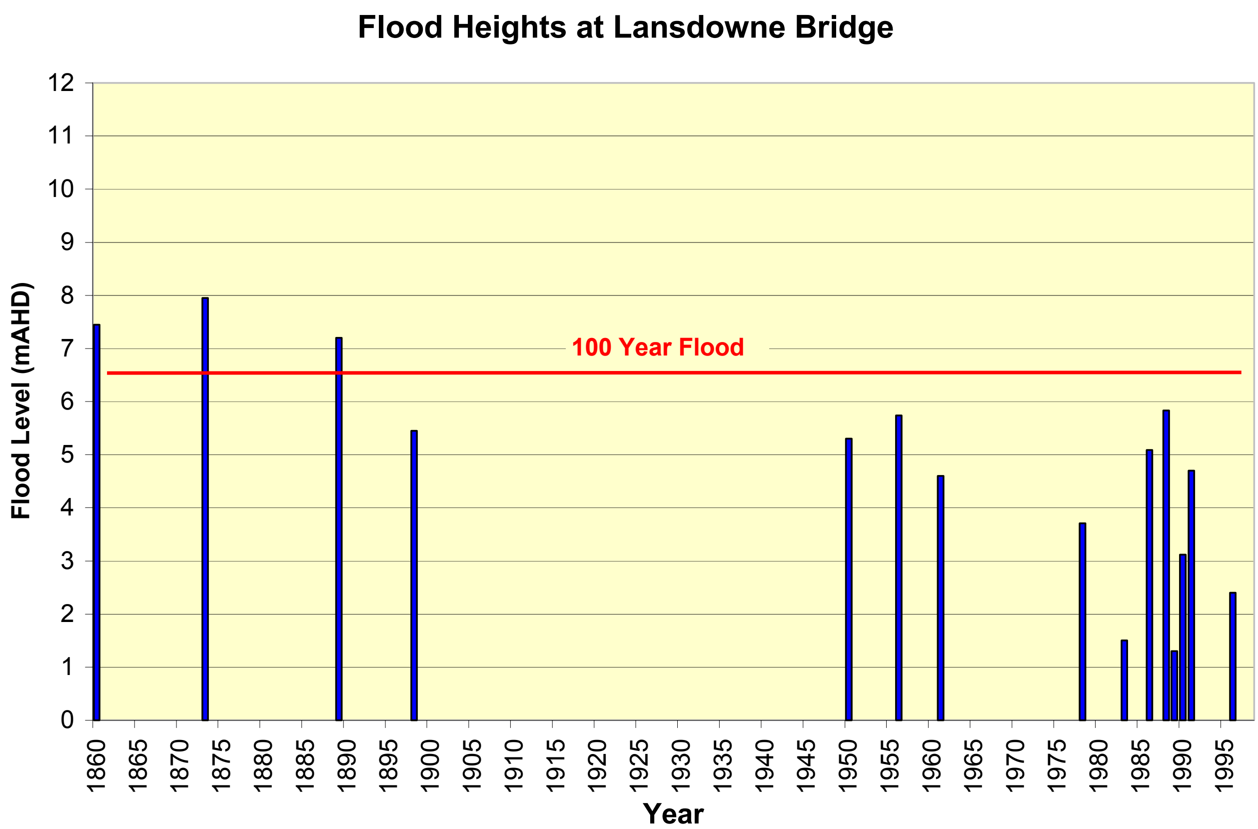


FIGURE 2.3
HISTORICAL FLOOD HEIGHTS AT LIVERPOOL AND LANSDOWNE BRIDGE

Photo 1 – Rescue during 1956 flood, Newbridge Road at Moorebank

Photo 2 – 1964 flood near East Hills Footbridge

Photo 3 – 1986 flood, looking upstream to Milperra Bridge

Photo 4 – 1986 flood, on the lower reaches of Prospect Creek

2.3 PREVIOUS FLOOD INVESTIGATIONS

Flood behaviour on the Georges River has been extensively studied since the mid 1960's. The methods of analysis have varied markedly, including simplified numerical procedures, flood frequency analysis on recorded flood data, physical model studies of the river and floodplain, and more recently, computer modelling.

The more recent flood studies that have been undertaken have defined flood conditions throughout the majority of the study area. The only exception being the Georges River downstream of East Hills. There have also been a number of floodplain management investigations undertaken on specific problem areas (refer Section 2.3.6). One of the main objectives for the current study is to consider the individual studies and to develop a strategic floodplain risk management plan for the wider catchment.

This Section gives a brief summary of some of the studies that have previously been undertaken on the Georges River, starting with the earlier work and concluding with the more recent studies.

2.3.1 Simplified Procedures

The first major investigation of flooding on the Georges River was probably a report prepared in 1966 by the NSW Public Works Department, titled "Georges River Flood Mitigation – Flood Forecasting Scheme for the Lower Georges River" [Scholer, 1966]. The objective of the study was to develop a flood warning procedure that would assist the State Emergency Service during floods.

Flood levels were derived on the assumption that the floodplain between Liverpool and East Hills was comprised of four interconnected ponds. A relationship was then derived between water levels in each pond and the flood height at the Liverpool gauge, based on the analysis of floods that occurred in 1950, 1956, 1961, 1963 and 1964. A flood prediction model, comprising a number of charts, was developed.

2.3.2 Flood Frequency Analyses

Further research on flood behaviour was carried out during the late 1960's, based on flood frequency analyses of the historical flood records at Liverpool. Investigations were undertaken by various researchers, including Munro, Stewart, and Rowe and Ennis. Unfortunately, the results differed considerably, due largely to different assumptions regarding the accuracy of the early flood records.

In a study titled "The Georges River Hydraulic, Hydrologic and Reclamation Studies" [Munro et al, 1967] a table was produced ranking flood heights recorded at Liverpool from 1873 to 1967. A flood frequency analysis was undertaken on this data to determine flood levels for nominated flood frequencies (eg the 100 year flood). Subsequent investigations in a report titled "Frequency of Floods in the City of Liverpool [Munro et al, 1968] concluded that some of the early flood records were difficult to substantiate, and floods prior to 1890 were excluded from the flood frequency analysis. This eliminated the very large floods that had been reported in 1873, 1887 and 1889 and subsequently lowered flood level estimates by a significant amount. Flood levels determined at Liverpool were also transferred to other locations on the Georges River, assuming that the flood gradient that was observed during the 1956 flood would be typical for all other floods.

Other studies, such as the "Report on Georges River, with Particular Reference to Levels at Liverpool Bridge" [Stewart, 1968] or "Land at Chipping Norton – Determination of Flood Levels" [Rowe and Ennis, 1970] were based on the analysis of either the full record of flood data or data that was filtered to remove recorded flood heights that could not be substantiated. Whilst the results of the various analyses varied considerably, it is interesting to note that both Munro and Rowe & Ennis arrived at the same dates for the three greatest floods; namely 1873, 1898 and 1956, in that order.

In 1978, the Public Works Department commissioned consultants Sinclair Knight and Partners to investigate flooding between Liverpool and East Hills. The study reviewed earlier flood frequency investigations at Liverpool, and adopted Munro's 1968 analysis. The 1956 flood gradient was then used to transfer the computed flood levels at Liverpool to elsewhere on the Georges River. The results of the study were used to prepare preliminary floodplain maps that defined the extent of flooding for the 20 year, 50 year and 100 year flood.

Limitations with the above approach include:

- it relied on the results of a flood frequency analysis, which had been shown to vary considerably between different researchers;
- it assumed that all floods would behave in a similar manner to the 1956 flood; and
- the extent of flooding shown on the floodplain maps was determined solely on the basis of the 2m contour mapping that was available for the catchment.

2.3.3 Physical Model Studies

Most of the subsequent flood mitigation investigations were carried out by the Public Works Department at their Manly Hydraulics Laboratory (MHL), using physical models. The first investigation was an investigation of flood mitigation options for the Milperra-Moorebank floodway, which ultimately led to the adoption of extensive voluntary purchase schemes for both Liverpool and Bankstown City Councils.

The physical model covered some three kilometres of the river, centred on the Milperra Bridge and had a horizontal scale of 1:200 and a vertical scale of 1:50. This same model was later extended to include the reach downstream to East Hills for investigations of the proposed M5 motorway crossing. It was later extended further downstream to Picnic Point, to allow investigations of flood mitigation works at East Hills and Carinya Road.

A separate physical model was constructed at the Manly Hydraulics Laboratory in 1979/80 to examine various aspects of the tidal hydraulics of the proposed Chipping Norton Lakes Scheme. This model had a horizontal scale of 1:250 and a vertical scale of 1:50, but did not contain overbank floodplain areas. In 1982 the model was modified to include overbank flow paths for the purpose of flood investigations for the Lakes Scheme. The model was later extended to incorporate investigations for both Prospect Creek and Rabaul Road.

A limitation of these physical model studies is that they looked at isolated areas of the river. Boundary conditions, in the form of inflow hydrographs and downstream tailwater levels, were not known to a high degree of confidence, and so a range of flows and tailwater levels were usually investigated.

In 1983, the Public Works Department commissioned the University of New South Wales Water Research Laboratory to undertake the Georges River Flood Study [PWD, 1991]. This study utilised a much larger physical model, which extended between Liverpool and Picnic Point. It had a horizontal scale of 1:500 and a vertical scale of 1:70. Unlike other physical models, this model was capable of operating under both steady-state flood conditions (simulating peak flood conditions only), or dynamic conditions (simulating the complete progress of the flood). The physical model had separate inflow sources to represent floodwater from the Georges River (upstream of Liverpool), Cabramatta Creek, Prospect Creek, Harris & Williams Creek, Deadmans Creek, and other major drainage inflows.

The physical model was calibrated in two phases. The first phase involved calibrating the main river section against data collected from a spring tide that was gauged by the Department in 1977, and minor floods that occurred in 1978 and 1983. The second phase involved calibrating the floodplain section of the river to data collected from larger floods. The 1956 flood was initially used for this purpose. During the course of the study, the 1986 and 1988 floods occurred, providing additional data for calibration.

The Georges River Flood Study report, which was released in 1991, provides design flood level estimates on the Georges River for the 20 year, 50 year and 100 year floods, as well as a PMF flood. These levels have been adopted by the relevant Councils, and are still used today.

There were two limitations with the physical model. Firstly, due to scaling affects, it was not always possible to analyse the impacts of various development scenarios or other changes to the river or floodplain. Secondly, the model occupied a considerable area, and the expense of keeping the model available indefinitely was high. Consequently, the model was dismantled in about 1993.

2.3.4 Computer Modelling

Considerable advances in computer modelling techniques have been made since the 1980's. Consequently, more recent studies have involved the development of computer models to simulate flood behaviour on the Georges River and its tributary creeks.

The Georges River Model Study [PWD, 1992] established a computer model, known as MIKE-11, to simulate the tidal behaviour of the Georges River, between Liverpool and Botany Bay. The model was calibrated to data collected during a spring tide in August 1991, and verified against other tidal data collected in 1989 and 1979.

The model was only intended to analyse tidal behaviour in the river, with cross sections extending only up to the top of bank. As a result, there is no description of the floodplain in the model, and the analysis of floods was not possible.

In 1998 the Department of Land and Water Conservation, in conjunction with Liverpool City Council, commenced the Upper Georges River Flood Study [DLWC, 1998]. These investigations utilised a MIKE-11 computer model to simulate flood conditions upstream of the area covered by the main Georges River physical model (ie upstream of the Liverpool weir).

River cross sections were derived on the basis of photogrammetric analysis of aerial photography and a hydrographic survey of the river that was undertaken in 1997. Boundary conditions for the model were determined from the physical model, to ensure consistency between the two models. The MIKE-11 model was calibrated to flood data that was available for the 1986 and 1988 flood.

Bewsher Consulting was later commissioned by Liverpool Council to convert the MIKE-11 tidal model downstream of Liverpool into a full flood model, by adding overbank sections and additional floodplain flow paths to the original model. This model was than joined to the Upper Georges River MIKE-11 model to provide a single computer model extending between Botany Bay and Cambridge Avenue [Bewsher Consulting, 1999]. This is discussed in more detail in **Section 4**.

2.3.5 Flood Data Collection Reports

In recent years, considerable data has been collected following significant floods. This data consists of records from automatic water level recorders and field survey of debris marks throughout the floodplain. Gauging teams from the then Public Works Department (PWD) have also gauged river flows and levels at various locations, including William Long Bridge, Lansdowne Bridge, Milperra Bridge and East Hills Footbridge.

The data collected has been compiled in separate data collection reports. These reports are available for the March 1983 flood [MHL, 1983], the August 1986 flood [MHL, 1987] and the April-May 1988 flood [MHL, 1989].

2.3.6 Flood Investigations in Specific areas

A number of other studies have been undertaken on specific parts of the study area. These include studies undertaken for the following areas:

<u>Lower Cabramatta Creek</u>

The draft Lower Cabramatta Creek Floodplain Management Study [Bewsher Consulting, 1999] was completed for Liverpool and Fairfield Councils in 1999. This report provides design flood levels in Cabramatta Creek and recommends various floodplain management measures to be implemented in the catchment. Results from the study for the area downstream of the Hume Highway are relevant to the current Georges River Study.

Lower Prospect Creek

The Lower Prospect Creek Floodplain Management Study [Willing & Partners, 1990] provides design flood level estimates and recommended floodplain management measures for Prospect Creek, between its confluence with the Georges River and the Cabramatta-Granville railway line. Results from the study downstream of the Hume Highway are relevant to the current Georges River Study. It is understood that Council has recently commissioned a review of this study, in light of flood mitigation works undertaken to date and the results from a recent flood experienced in the catchment.

Rabaul Road

The Rabaul Floodway Study [PWD, 1985] examined the flood hazard to existing residential development located along Rabaul Road. The study recommended that three properties be included in a voluntary purchase scheme and that specific development controls be applied to the area to reduce the flood hazard as redevelopment occurred.

Moorebank and Milperra Floodways

Studies were undertaken on Moorebank and Milperra Floodways for Liverpool Council and Bankstown Council [PWD, 1983]. The studies concluded that both areas represented extremely hazardous floodways, and recommended voluntary purchase schemes to gradually remove existing development. Both Councils adopted voluntary purchase schemes shortly afterwards, and the schemes continue to operate today. A total of 195 properties are included in the two schemes, with 120 properties purchased to date.

Milperra Drain

Milperra Drain is a tributary of the Georges River that is particularly susceptible to high flood damages, largely due to the type of industrial development located adjacent to the Drain. The Milperra Industrial Area Hydraulic Study [Willing & Partners, 1990] investigated flood conditions in this area for Bankstown Council and investigated options to reduce the level of flooding. Major channel augmentation measures were subsequently adopted by Council, and implementation of these works are now largely completed. A study to review flooding in the Milperra Drain catchment was recently commissioned (July 2003) by Council.

Moorebank

The Moorebank Flood Study [Willing & Partners, 1996] was undertaken for land between the M5 Motorway and Newbridge Road at Moorebank for Liverpool Council. The study evaluated the impacts of previous dredging and land fill activities on this parcel of land and assessed other development proposals.

M5 Motorway Bridge

The F5 Tollroad Bridge Over the Georges River – Verification of Flood Impacts [PWD, 1992] study was undertaken to assess the impact on flooding of the proposed bridge over the Georges River. The assessment was initially undertaken using one of the smaller Georges River physical models, and later repeated using the broader physical model. The model results were used to determine an appropriate bridge span across the floodplain.

Kelso Levee

A number of investigations have been undertaken concerning the levee at Kelso Park. This includes the original Kelso Park Levee Design Feasibility Study [PWD, 1984] and various studies of the level of internal ponding behind the levee, from local catchment runoff, when the levee gates are closed. These levels were recently reviewed for Bankstown Council as part of the Kelso Creek Floodplain Study [Bewsher Consulting, 2000].

East Hills

The East Hills Floodway Model Investigation [PWD, 1987] report was undertaken for Bankstown Council in 1987 to assess various flood mitigation measures at East Hills. The investigations recommended the construction of a series of ‘finger levees’ to reduce flood velocities that would be experienced by houses adjacent to the river. The scheme was adopted by Council and the works were recently constructed. The works were recently reviewed as part of the “2D Modelling of East Hills Flood Management Works” study [WBM, 2001] undertaken for Council.

Carinya Road

A similar study, titled “Carinya Road Floodway Investigation” [PWD, 1984] was undertaken for Picnic Point. The recommended measures included the construction of an upstream deflector levee and several ‘finger levees’ to reduce flood velocities. The scheme was implemented some time ago.

Little Salt Pan Creek

A flood study of Little Salt Pan Creek [MHL, 1995] was carried out using a MIKE-11 hydraulic model. Design flood levels were determined for Little Salt Pan Creek between the East Hills Railway Line and the Georges River. These flood levels are still applicable today.

Salt Pan Creek

A flood study was undertaken to determine design flood levels for Salt Pan Creek [Webb McKeown & Associates, 1991]. The study area included Salt Pan Creek and its major tributaries, between the Georges River, Arab Road, Canterbury Road and Moxon Road. Flood levels were determined using the RUBICON hydraulic model. Flood levels determined from the study are still applicable today.

Deadmans Creek

The Deadmans Creek Flood Study [DLWC, 1997] was undertaken for Sutherland Shire Council. Design flood levels were determined between Heathcote Road and the Georges River using the MIKE-11 hydraulic model. These levels are still applicable today.

3. COMMUNITY CONSULTATION

3.1 CONSULTATION PROCESS

The success of any floodplain management plan hinges on its acceptance by the community, residents within the study area, and other stakeholders. This can only be achieved by involving the local community at all stages of the decision-making process. This includes the collection of their ideas and knowledge on flood behaviour in the study area, together with discussing the issues and outcomes of the study with them.

Community consultation has been an important component of the current study. As well as improving the community's awareness of and readiness for flooding, the consultation has aimed to inform the community about the development of the floodplain management study and its likely outcomes. It has also provided an opportunity to collect feedback and ideas on potential floodplain management measures and other related issues.

The key elements of the consultation process have been as follows:

- regular meetings of the Georges River Floodplain Management Committee;
- development of a study web site for the project;
- preparation of an SES FloodSafe brochure for the Georges River;
- preparation and distribution of a notification pack for all residents potentially affected by flooding;
- distribution of a short questionnaire to all residents, followed up with a more detailed questionnaire;
- organisation of ten public workshops;
- liaison with government agencies Interest Groups; and
- public exhibition of the recommended floodplain risk management study and plan, prior to formal consideration by each Council.

These elements are discussed further below.

3.2 GEORGES RIVER FLOODPLAIN MANAGEMENT COMMITTEE

The study has been overseen by the Georges River Floodplain Management Committee. This committee comprises representatives from:

- Liverpool City Council;
- Fairfield City Council;
- Bankstown City Council;
- Sutherland Shire Council;
- State Emergency Service;
- Department of Infrastructure, Planning and Natural Resources; and
- community members.

The Committee has met regularly to hear progress reports by the consultant, and to provide direction as the study progressed. As many of the representatives on the Committee are themselves members of other associations or groups, the committee has provided a valuable mechanism for the views of many interested parties to be represented.

3.3 PROJECT WEB SITE

A special web site was developed at an early stage of the study. The web site contained information and photographs about the current study and floods that have occurred in the past along the Georges River.

The web site was divided into a number of linked pages, providing details on:

- general information about the study and the web site (home page);
- the history of flooding on the Georges River;
- the current floodplain risk management risk study;
- floodplain management measures likely to be considered;
- publications relevant to the study;
- the detailed study questionnaire;
- a newsletter providing more information about the study; and a
- feedback page.

The site was located at www.bewsher.com.au/georges.htm.

3.4 SES FLOODSAFE BROCHURE

A 'FloodSafe' brochure was prepared for the Georges River, in cooperation with the State Emergency Service (SES), as part of the study.

The brochure was issued under the banner of the Georges River Floodplain Management Committee, and carried the logos of the State Emergency Service and the four participating Councils. The brochure was aimed at raising public awareness of flooding on the Georges River. It included several photographs of past flood events and a map showing the extent of maximum flooding possible (ie the PMF). The brochure also provided advice to the public on what to do in the event of a flood.

The brochure was mailed to residents potentially affected by flooding in October 2002 and was distributed at workshops that were held for the study during November and December.

3.5 COMMUNITY NOTIFICATION PACK

Every property owner potentially affected by flooding from the Georges River received a notification pack in October 2002, advising of the risk of flooding and providing details about the floodplain risk management study.

Approximately 7,000 property owners received:

- an individually addressed letter;
- a copy of the Georges River FloodSafe brochure; and
- a short questionnaire.

The objective of the notification pack was to raise awareness of both the flood risk on the Georges River and the current study. The letter invited residents to visit the study web site for further information about the study, or to contact one of the four Council liaison officers. The letter also invited residents to attend one of a series of planned community workshops to discuss the study.

The short questionnaire provided a mechanism to determine community interest in the study and issues that the community would like the study to address.

3.6 SHORT QUESTIONNAIRE

The short questionnaire asked four questions:

- "would you like to be included on the mailing list for the study?";
- "would you like to be sent a (detailed) questionnaire?";
- "would you like to participate in a workshop?"; and
- "are there any issues that the study should address?".

The response rate for the questionnaire is provided in **Table 3.1**, with results to the four questions summarised in **Table 3.2**.

TABLE 3.1
Short Questionnaire Response Rate

Council Area	Distribution	Response	Percentage
Liverpool	3,019	276	9%
Fairfield	781	49	6%
Bankstown	2,949	331	11%
Sutherland	247	24	10%
TOTAL	6,996	680	10%

TABLE 3.2
Short Questionnaire Results

Question	Council Area	Total 'yes' responses	Rate
Would you like to be included on a mailing list?	Liverpool	268	97%
	Fairfield	44	90%
	Bankstown	298	90%
	Sutherland	24	100%
	TOTAL	634	93%
Would you like to be sent a (detailed) questionnaire?	Liverpool	199	72%
	Fairfield	35	71%
	Bankstown	221	67%
	Sutherland	20	83%
	TOTAL	475	70%
Would you like to participate in a workshop?	Liverpool	112	41%
	Fairfield	16	33%
	Bankstown	111	34%
	Sutherland	16	67%
	TOTAL	255	38%
Are there any issues that the study should address?	Liverpool	80	29%
	Fairfield	16	33%
	Bankstown	88	27%
	Sutherland	8	33%
	TOTAL	192	28%

A complete list of issues, or other comments that were raised, is included in **Appendix A**. The most common issues raised include:

- concern over the impact of recent development (34 responses)
- request for additional flood information (17 responses);
- concern over stormwater issues (17 responses); and
- support for improved emergency management measures (16 responses).

3.7 DETAILED QUESTIONNAIRE

Detailed questionnaires were distributed to all property owners that requested one. Questionnaires were also made available at workshops and through the study web site. A total of 207 questionnaires were completed and returned, representing a response rate of about 43%.

The questionnaire was divided into a number of parts, dealing with flood readiness, flood experience, attitudes to council's controls on development, opinions on floodplain management measures, and other details. Results from the questionnaire are summarised below.

3.7.1 Part A – Flood Readiness

A relatively high proportion of property owners who responded (63%) believe that their property could be flooded some time in the future. This is a particularly high response given that the study area extends up to the PMF, and many property owners are unlikely to have experienced a flood in recent times.

Whilst some property owners (38%) had received information about flooding from Council, most others had learnt about flooding from their own experiences (29%) or from information from neighbours or friends (16%). Others (33%) had received no information from any source.

3.7.2 Part B – Flood Experience

Some 34% of property owners had experienced flooding on their property. The April 1988 flood was the largest flood experienced by 26% of property owners, whilst the August 1986 flood was also experienced by 22% of property owners. Only a very small proportion (5%) had experienced the larger 1956 flood, which suggests that public awareness of large floods is quite low.

A small proportion of owners (8%) had experienced flooding above floor level, mainly from the 1988 and 1986 floods. The average depth of flooding above floor level for these events was 0.8m.

The majority of owners believed there was little warning time available for them to take action to reduce possible flood damage.

3.7.3 Part C – Attitudes to Council's Controls on Development

Property owners were asked to rank development types that were most important to protect them from flooding. These were, in priority order:

i) residential development;

ii) critical utilities;

iii) essential community facilities;

iv) commercial and industrial development;

v) new residential subdivisions;

vi) minor developments and additions; and

vii) recreation or agricultural land.

Some significant number of respondents (34%) believed that Council should place restrictions, such as minimum floor levels, on new development to reduce the potential for flood damage. Slightly more respondents (38%) also believed that new development in hazardous areas should be prohibited.

The majority of property owners (70%) were in favour of every resident and property owner being advised on the potential flood risk of their property on a regular basis. Only a few (15%) believed that such advice should only be given to those who made an enquiry to Council.

3.7.4 Part D – Opinions on Floodplain Management Measures

Property owners were asked to list their five most favoured floodplain management measures that should be considered for the Georges River. The most favoured options are listed in **Table 3.3**. Owners were also asked to list their five least favoured options, which are listed in **Table 3.4**.

TABLE 3.3
Measures Most Favoured by the Community

Measure	Top 5 Priority	Highest Priority
1) Dredge the river	35%	14%
2) Review/Maintain existing flood mitigation works	33%	8%
3) Construct upstream dam(s)	30%	8%
4) Maintenance programs/clear unnecessary vegetation	29%	6%
5) Construct permanent levees	31%	4%

TABLE 3.4
Measures Least Favoured by the Community

Measure	Least 5 Priority	Least Priority
1) Dredge the river	20%	10%
2) Enlarge bridges	18%	9%
3) Construct permanent levees	16%	6%
4) Flood proofing individual properties	15%	6%
5) Accelerate voluntary purchase scheme	15%	<1%

It is interesting to note that dredging the river was both the most popular floodplain management measure and also the least popular measure. Those favouring dredging possibly saw this measure as one that could potentially lower flood levels. Those that did not favour dredging may have been concerned over the environmental consequences of such action, or believed that there would only be limited flood benefits.

The construction of permanent levees also figured in both the most popular five measures and the least popular five measures.

Other measures that were most popular included the review and maintenance of existing flood mitigation measures, the construction of one or more upstream dams, and maintenance programs to clear the river of unnecessary vegetation.

Property owners were also asked to comment on an extensive list of floodplain management measures, results of which are shown in **Figure 3.1**.

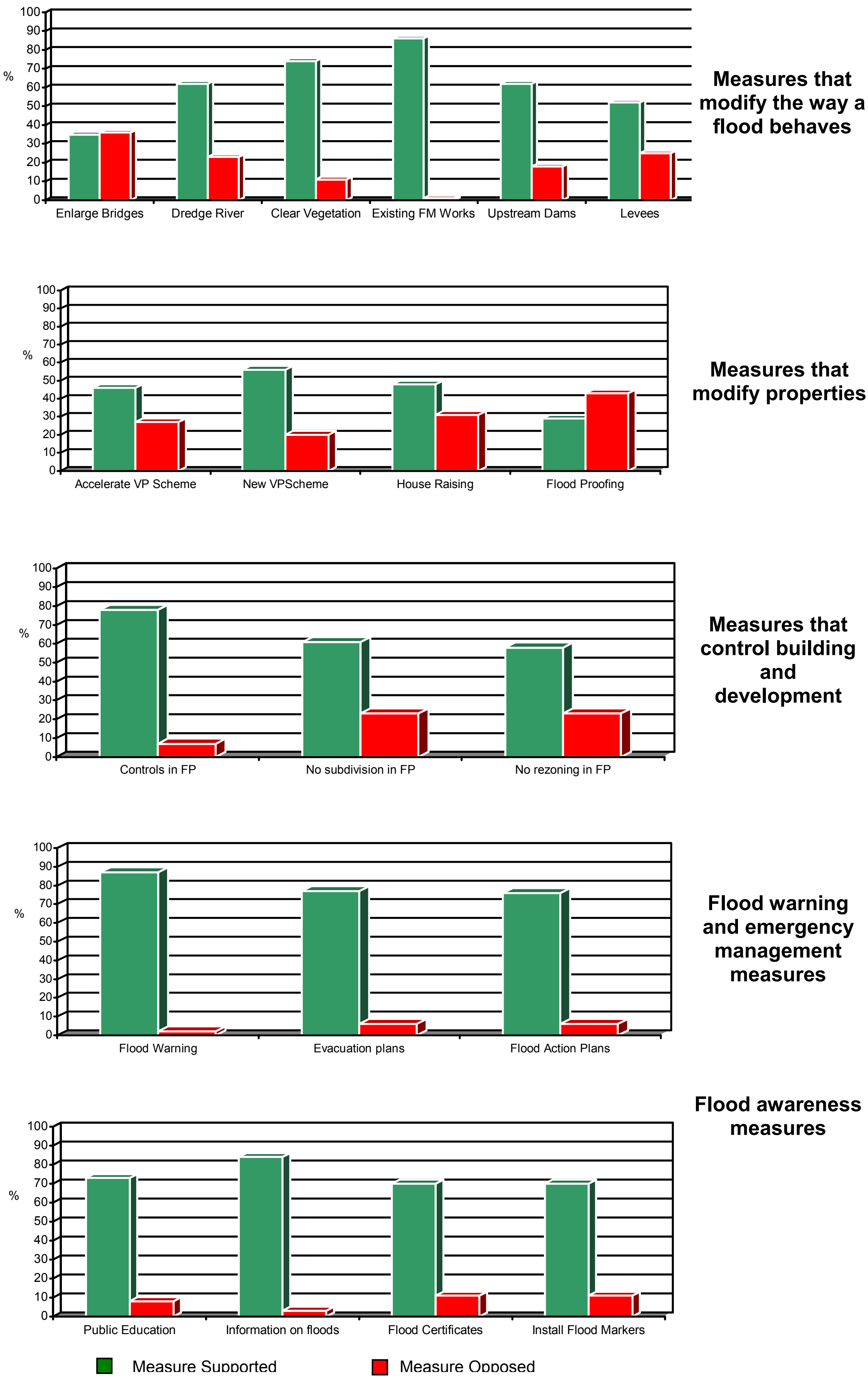


FIGURE 3.1
COMMUNITY VIEWS ON FLOODPLAIN MANAGEMENT MEASURES

The above results generally show that measures that modify the way that a flood behaves were all reasonably well supported (particularly the review and maintenance of existing flood mitigation works and maintenance programs to clear the river of unnecessary vegetation). There was also some opposition to some of these measures (including enlarging bridges, dredging the river, upstream dams and the construction of permanent levees).

Measures that aim to modify property in order to reduce potential flood damage (eg voluntary purchase schemes, house raising schemes and flood proofing) did not attract much community support.

The majority of property owners were in favour of building controls in the floodplain to minimise future flood damage. There was also support for prohibiting subdivisions and rezoning within the floodplain, although there was also some opposition to these latter two measures.

Flood warning and emergency management measures (flood warning, evacuation plans and flood action plans) all ranked very highly, with between 76% to 87% support, and with very little opposition.

All flood awareness measures (public education, providing information on flood risks, flood certificates and the installation of flood markers) also ranked very highly, with little opposition.

3.7.5 Part E – About Your Property

The majority of property owners who responded to the survey (93%) were residential owners with a house in the study area. The average time at this address is 20 years, and the average number of people living in the house is 3.0. The owner has little expectation to subdivide his property (2%), build a dual occupancy (3%), or to build a new dwelling (5%). There was a greater expectation to undertake minor extensions or alterations (26%).

3.7.6 Part F – More Information

Residents were asked to provide additional comments on floodplain management measures, or other issues that the floodplain management plan should consider. Written comments were provided by 46 respondents (22%). These responses have been included in **Appendix B**. The most common issues raised were as follows:

- need for controls on future development to limit runoff;
- stormwater issues, including maintenance of stormwater drains;
- objections to areas of the floodplain being filled, especially at Bankstown Airport;
- more information on flooding being made available; and
- insurance issues.

3.8 PUBLIC WORKSHOPS

A series of workshops were held during November and December 2002 to present details of the study to the community and to get feedback on some of the preliminary results from the study.

Ten workshops were held, including:

- two in the Liverpool Council area;
- three in the Fairfield Council area (two of these were part of related investigations in Prospect Creek);
- four in the Bankstown Council area; and
- one in the Sutherland Shire Council area.

A panel of speakers addressed each workshop, including representatives from the relevant council, the SES, the then DLWC (now DIPNR) and the consultant. Each workshop had two set question periods, and there was an opportunity for individuals to talk informally to members of the panel at the conclusion of each workshop. A series of “frequently asked questions” were also prepared and distributed at each of the workshops.

Preliminary results from the study were presented, including a review of past flood events, results of computer modelling, the proposed flood risk precincts and the likely development controls that would apply to each precinct, and a map showing these different flood risk areas.

The workshops were all relatively well received by the public. The main issues raised included:

- concern over the impact of new development on flood behaviour;
- stormwater flooding problems;
- what it means if you are classified as being in a low flood risk area;
- can anything be done to reduce the flood problems?;
- concern over the impact of the study on insurance and the availability of bank loans; and
- concern on the impact on property values.

Many of these issues had been addressed in the “frequently asked questions” (refer Appendix B), whilst others required some further explanation. The main controversial issues involved local issues that were not part of the current study, such as recent development decisions by the particular council that had not been well supported by the community.

3.9 LIAISON WITH GOVERNMENT AGENCIES AND GROUPS

There are numerous government agencies, authorities and other groups that have assets, interests and/or infrastructure in the Georges River study area. Liaison with these organisations was therefore seen as an important component of the community consultation strategy for the floodplain management plan.

The list of organisations to be consulted was determined with the Committee's assistance. Each organisation was then sent an introductory letter, special questionnaire, and a map of the study area showing the extent of the floodplain. Organisations that were consulted are listed in **Table 3.5**.

A formal response was received from 13 of the 66 organisations contacted (a response rate of 20%). A number of the organisations were also represented on the floodplain management committee, and have had an opportunity to express their views on aspects of the study through the committee. Issues raised by the organisations responding to the questionnaire are summarised below.

3.9.1 Sydney Water Corporation Ltd

Sydney Water advised that they were in the process of preparing an EIS for a proposed water re-use pipeline from the Glenfield and Liverpool sewage treatment plants to Malabar. The project would pipe treated water to Malabar, rather than discharging to the Georges River. Re-use water would be available for watering parks and golf courses along the route of the pipeline.

The re-use pipeline appears to be approximately 1050mm in diameter and will be bored under the Georges River near Cambridge Avenue (upstream of Liverpool) and between Newbridge Road and Governor Macquarie Drive (near Liverpool). The pipeline is also to be bored under Cabramatta Creek and is to cross over Prospect Creek (upstream of the Hume Highway), before turning east and heading towards Malabar. The pipeline is to be trenched from Glenfield to at least Prospect Creek, with sequential excavation and fill to minimise disruption.

Sydney Water requested information on current flood level estimates in the vicinity of the Glenfield and Liverpool sewage treatment plants. Sydney Water also advised that the embankment around the Liverpool plant was at RL 10.36m AHD, which puts it above the estimated 100 year flood level at this location, but just below the estimate for the probable maximum flood.

3.9.2 NSW Fisheries

NSW Fisheries advised that under the *Fisheries Management Act, 1994* approval would be required for any works involving dredging or reclamation of any part of the waterway. This potentially includes stormwater control devices, waterway crossings, sea walls or similar structures. It was noted that NSW Fisheries will not approve the piping or channelling of waterways.

It was also noted that approval from NSW Fisheries was required for any works that:

- potentially harm marine vegetation, macroalgae, seagrasses or mangroves;
- result in any blockage to fish passage;
- could potentially impact any aquatic threatened species;
- involves the removal of snags, including vegetation or boulders.

TABLE 3.5
Consultation with Agencies, Authorities and Groups

Department	Attention	Address		
Main Agencies				
Department of Land and Water Conservation	Environmental Coordinator	PO Box 3935	PARRAMATTA NSW 2124	
Department of Land and Water Conservation	Mr Arthur Low	PO Box 867	WOLLONGONG NSW 2520	
Chipping Norton Lakes Authority	Mr Scott Renwick	PO Box 867	WOLLONGONG NSW 2520	
Public Works Department	Regional Manager	Bankstown Civic Tower	66-72 Rickard Road	BANKSTOWN NSW 2200
Planning NSW	The Manager	GPO Box 3927	SYDNEY NSW 2001	
Planning NSW (Sydney Region West)	The Regional Manager	PO Box 404	PARRAMATTA NSW 2124	
NSW Environment Protection Authority	Policy Advisor	PO Box 668	PARRAMATTA NSW 2124	
NSW Environment Protection Authority	Policy Advisor	PO Box A290	SYDNEY SOUTH NSW 1232	
Sydney Water Corporation Limited	The Manager	PO Box A53	SYDNEY SOUTH NSW 1235	
Sydney Water Corporation Limited	The Manager	PO Box 367	BLACKTOWN NSW 2148	
NSW Fisheries	Lesley Diver	PO Box 21	CRONULLA NSW 2230	
NSW National Parks and Wildlife Service	The Manager	PO Box 1967	HURSTVILLE NSW 2220	
Department of Transport	Strategic Planning Manager	GPO Box 1620	SYDNEY NSW 2001	
Roads and Traffic Authority	Strategic Planning Manager	PO Box 558	BLACKTOWN NSW 2148	
State Rail Authority	Manager, Planning	PO Box K349	HAYMARKET NSW 2000	
Rail Infrastructure Corporation	Manager, Planning	GPO Box 47	SYDNEY NSW 2001	
Rail Estate	Manager, Planning	PO Box K349	HAYMARKET NSW 2000	
State Emergency Service	State Planning Coordinator	Level 4, 6-8 Regent Street	WOLLONGONG NSW 2500	
State Emergency Service	Divisional Controller	PO Box M54	MANAHAN NSW 2200	
Bureau of Meteorology	Gordon MacKay	PO Box 413	DARLINGHURST NSW 1300	
NSW Aboriginal Land Council	Officer in charge	PO Box W125	PARRAMATTA NSW 2150	
Gandangara Aboriginal Land Council	Officer in charge	PO Box 1038	LIVERPOOL BC NSW 1871	
Energy Australia	Network Planner	GPO Box 4009	SYDNEY NSW 2001	
Integral Energy Australia	Network Planner	PO Box 6366	BLACKTOWN NSW 2148	
A.G.L. Gas Company	Manager, Planning	AGL Centre	Locked Bag 944	NORTH SYDNEY NSW 2059
Telstra	Manager, Planning	231 Elizabeth Street	SYDNEY NSW 2000	
Optus	Manager, Planning	101 Miller Street	NORTH SYDNEY NSW 2060	
Vodafone Head Office	Manager, Planning	799 Pacific Highway	CHATSWOOD NSW 2067	
Department of Education and Training	Property Management Division	35 Bridge Street	SYDNEY NSW 2000	
Councils				
Campbelltown City Council	Dick Webb	PO Box 57	CAMPBELLTOWN NSW 2560	
Hurstville City Council	Mick Ward	PO Box 205	HURSTVILLE BC NSW 1481	
Rockdale City Council	The General Manager	PO Box 21	ROCKDALE NSW 2216	
Kogarah Council	The General Manager	Locked Bag 8	KOGARAH NSW 2217	
Wollondilly Council	The General Manager	PO Box 21	PICTON NSW 2571	
Army				
Department of Defence	Captain Stephen Brumby	DCSO Liverpool	Liverpool Military Area	MOOREBANK NSW 2174
Department of Defence	The Environmental Officer	Liverpool Military Area	Moorebank Avenue	MOOREBANK NSW 2174
School of Military Engineering	The Environmental Officer	Moorebank Avenue	MOOREBANK NSW 2174	

TABLE 3.5 (cont)
Consultation with Agencies, Authorities and Groups

Department	Attention	Address		
Committees etc				
Fairfield Five Creeks Committee	The Chairman	C/- Fairfield City Council	PO Box 21	FAIRFIELD NSW 2165
Southern Sydney Catchment Management Board	Jeanne Thuez	PO Box 3935	PARRAMATTA NSW 2124	
The Australian Conservation Foundation	The Secretary	33 George Street	SYDNEY NSW 2000	
Botany Bay and Catchment Alliance	Lynda Newman	PO Box 77	MATRAVILLE NSW 2036	
Georges River Riverkeeper Program	Samantha Rich	PO Box 795	SUTHERLAND NSW 1499	
Chambers of Commerce				
City of Liverpool Chamber of Commerce	Officer in charge	PO Box 167	LIVERPOOL NSW 2170	
Bankstown Chamber of Commerce	Officer in charge	93 Glassop Street	YAGOONA NSW 2199	
Historical Societies				
Liverpool and District Historical Society	Officer in charge	PO Box 90	LIVERPOOL NSW 2170	
Bankstown Historical Society	Officer in charge	4/127 Edgar Street	BANKSTOWN NSW 2200	
Golf Clubs				
Liverpool Colf Club	The General Manager	Hollywood Drive	LANSVALE NSW 2166	
Bankstown Golf Club	The General Manager	PO Box 51	MILPERRA NSW 2214	
Riverwood Golf Club	The General Manager	255 Henry Lawson Drive	GEORGES HALL NSW 2198	
Riverlands Golf Club	The General Manager	56 Prescot Parade	MILPERRA NSW 2214	
New Brighton Golf Club	The General Manager	180 Nuwarra Road	MOOREBANK NSW 2170	
Other Clubs & Associations				
Deepwater Motor Boat Club	The Manager	C/- East Hills RSL Club Ltd	Cnr Marco Ave & Childs St	PANANIA NSW 2213
Bankstown Bushland Society	Ms Patricia Bell	PO Box 210	PANANIA NSW 2213	
Sandy Point Residents Association	David West	C/- 9 Gambier Avenue	SANDY POINT NSW 2171	
Illawong/Alfords Pont Progress Association	Steve Borg	C/- 20 Casuarina Road	ALFORDS POINT NSW 2234	
Picnic Point Progress Association	The secretary	C/- The Scout Association	5 Rogers Avenue	HABERFIELD NSW 2045
Milperra and District Progress Association	The secretary	19 Glencorse Avenue	MILPERRA NSW 2214	
Georges Hall Progress Association	Keith Robey	176 Rex Road	GEORGES HALL NSW 2198	
Save Lansvale Committee	The secretary	121 Hollywood Drive	LANSVALE NSW 2166	
Blue Gum Farm Zoo	The Manager	Maxwell Avenue	MILPERRA NSW 2214	
Industy				
Bankstown Airport Limited	The General Manager	Airport Avenue	Bankstown Airport	BANKSTOWN NSW 2200
Hawker De Havilland	The Manager	361 Milperra Road	MILPERRA NSW 2200	
Goyen Controls Company Pty Ltd	The Manager	268 Milperra Road	MILPERRA NSW 2214	
Pirelli Power Cables & Systems Australia P/L	The Manager	1 Heathcote Road	LIVERPOOL NSW 2170	
Linter Link Roads	John Lindoy	PO Box 700	MOOREBANK, NSW, 1875	
Interlink Roads Pty Ltd	The Manager	Toll Plaza M5 South/West Motorway	HAMONDVILLE NSW 2170	

3.9.3 Department of Transport

Transport NSW advised that the Department administers bus interchanges and commuter car parks across the Greater Metropolitan Area. Their facilities within the study area include:

- bus/rail interchange and multi storey car park at Padstow Railway Station;
- multi-storey car park at Holsworthy Railway Station;
- bus/rail interchange at Liverpool Railway Station; and
- multi-storey commuter car park at Warwick Farm Railway Station.

Other State transport assets are managed by the Roads and Traffic Authority, Rail Infrastructure Corporation and Rail Estate.

3.9.4 Rail Infrastructure Corporation

The Rail Infrastructure Corporation provided details of assets that could be damaged by floodwater. This includes:

- rail bridge at Como (estimated potential damage $20,000);
- rail bridge at East Hills($20,000); and
- track assets at Holsworthy ($500,000).

3.9.5 Bureau of Meteorology

The Bureau of Meteorology provided a list of reference reports applicable to the current study. The Bureau also advised that it holds rain and river records at 3 hourly intervals since 1988.

The Bureau maintains a flood warning scheme for the valley, and questioned the adequacy of flood awareness within the community. It was noted that this lack of flood awareness could diminish the effectiveness of the warning system. It was also noted that people located above the 100 year flood level may believe that they are flood free, and that there was likely economic hardship should an extreme flood (greater than 100 years) occur.

3.9.6 AGL Gas Company

Agility Management Pty Ltd (AGL Gas) advised of potential damage to assets from floods. This includes potential damage to:

- pipes in road corridors (actual damage difficult to quantify);
- district pressures regulators in streets ($50,000 upwards); and
- gas meters in properties ($300 per household);

AGL believed it was desirable to produce flood contour maps showing flood free transport routes for emergency vehicles during flood periods.

3.9.7 Kogarah Council

Kogarah Council returned the questionnaire, but provided little detail or issues for the study to address.

3.9.8 Southern Sydney Catchment Management Board

A community representative responded on behalf of the Southern Sydney Catchment Board.

Reference was made to potential damage to parks, reserves and boardwalks during flood events.

It was also noted that there were a number of relevant studies on the Georges River, which were held in the Georges River Environmental Education Centre.

A number of issues were suggested for the current study, including:

- reference to the Georges River REP and the Southern Sydney Catchment Board Blueprint;
- the principle of no net loss of riparian vegetation and instream habitats (eg saltmarsh, mangrove and seagrasses) as criteria for any works; and
- any works should not impact negatively in terms of biodiversity or aesthetics on rivers or creek lines.

3.9.9 Bankstown Bushland Society

The Bankstown Bushland Society raised a number of concerns, mainly related to activities at Bankstown Airport.

There was concern that fill had been placed on flood prone land on the airport site, and that the impact of this fill on flood behaviour had not been quantified. There was also concern that flooding from the "Airport Creek" drain would impact on endangered bushland at Deverall Park. There was also concern over the potential impact to the Milperra Wetlands (corner Milperra Road and Henry Lawson Drive), which contains a number of plants that are regionally rare.

3.9.10 Sandy Point Residents Association

The Sandy Point Progress Association provided comments regarding the effect of flooding on sewerage and other infrastructure at Sandy Point. It was noted that the main pumping station at the river end of St George Crescent and two other intermediate pumping stations serve over 250 homes. There was some concern that unofficial connections may overload the system in relatively minor floods, resulting in sewerage overflows prior to the design cut-off flood level of the system.

The vulnerability of telephones, water and electricity supply was also noted.

Road access issues were also raised. Heathcote Road was cut by floodwater in both the 1986 and 1988 floods on the Liverpool side of Deadmans Creek Bridge. The road was closed for some time, which could be a problem for school buses trying to return to Sandy Point in the afternoon. Heathcote Road was also likely to be cut at the Williams and Harris Creek bridges, which would affect people at Pleasure Point and Voyager Point. It was noted that Heathcote Road is a major arterial road serving Sydney's South West, and any closure along this road had a major impact on traffic over a large area.

3.9.11 Save Lansvale Committee

The Save Lansvale Committee is a group of residents whose main aim is to stop undesirable development of flood prone land. The committee recommended that all flood affected property should be rezoned to prohibit any filling on flood prone land, as per Zone 6B. It was noted that where there needed to be an exception to this rule, it should be put to the wider community, not just a couple of surrounding properties.

There was concern that a major development involving 2m of fill at the corner of the Hume Highway and Knight Street had been permitted by Council, whilst at the same time minor development by residents in Knight Street had been refused.

3.9.12 Pirelli Power Cables

Pirelli Power Cables is a manufacturing organisation located on the eastern bank of the Georges River at Liverpool, which employs approximately 500 personnel. Potential flood damage to electrical systems was estimated to be as high as $5M in a major flood.

The organisation would like the current study to focus on methods to reduce the impact of future flooding.

3.9.13 Interlink Roads Pty Ltd

Interlink Roads have responsibility for managing the M5 motorway, including bridges over the Georges River at Hammondville and at Casula.

The road pavement and bridge piers could potentially sustain flood damage. The amount of damage would be dependent on the depth of inundation, duration of flooding and flood velocity. It was noted that potential flood damage costs were difficult to estimate, but could be as high as $2M/km of damaged road pavement and $40M for bridge repairs should piers be damaged through flood scour.

It was recommended that the impact of vegetation on the floodplain be considered as part of the current study.

3.10 PUBLIC EXHIBITION OF DRAFT REPORTS

A draft copy of the Georges River Floodplain Risk Management Study and Plan was placed on public exhibition from 21^{st} January to 5^{th} March, 2004.

Copies of Volume 1 (Main Report) and Volume 2 (Planning Issues) were exhibited at Liverpool, Fairfield, Bankstown and Sutherland Councils. The proposed flood risk precinct maps and other details were also exhibited, along with an executive summary that was available for people to take away. The reports were also published on the Internet and made available on CD to anyone requesting a full copy of the reports.

The exhibition did not generate a large response from the community. Whilst there were a number of general enquiries concerning the study, only 9 formal submissions were received (4 from Liverpool, 1 from Fairfield and 4 from Bankstown). A summary of these submissions is included in **Appendix C**.

4. MODELLING OF FLOOD BEHAVIOUR

4.1 PURPOSE

Design flood levels on the Georges River are available from the Georges River Flood Study [PWD, 1991]. This study used a physical scale model of the Georges River to simulate flood conditions between Picnic Point and Liverpool. Flood level contours from this report are included in **Appendix D**.

A number of other studies have also been undertaken to define flood conditions upstream of Liverpool and for the main tributary creeks of the Georges River. These studies include:

- Upper Georges River Flood Study [DLWC, 1999];
- Draft Cabramatta Creek Floodplain Management Study [Bewsher Consulting, 1999];
- Lower Prospect Creek Floodplain Management Study [Willing & Partners, 1990];
- Milperra Industrial Area Hydraulic Study [Willing & Partners, 1990];
- Little Salt Pan Creek Flood Study [Manly Hydraulics Laboratory, 1995];
- Salt Pan Creek Flood Study [PWD, 1991];
- Deadmans Creek Flood Study [DLWC, 1997].

A single computer model of the Georges River study area was recently developed by Bewsher Consulting for Liverpool Council. This model has been used as part of further flood investigations for the current floodplain management study. The purpose of the new modelling was to:

- verify flood levels from previous studies;
- consolidate the results of various models into a single computer model;
- provide additional information on flood behaviour, including velocities and other hazard indicators that were unavailable from the physical model; and
- verify whether or not recent development within the catchment has had any significant impact on design flood levels, and whether a revision of the design flood levels is warranted;
- test the impact of potential flood mitigation works in lowering flood levels; and
- provide flood level estimates in areas where these were previously unavailable (ie downstream of East Hills, through the Sutherland Shire part of the study area).

4.2 GEORGES RIVER MIKE-11 MODEL

The computer model used to simulate flood conditions in the Georges River is known as MIKE-11. This is a commercially available program that is used extensively throughout Australia and overseas, and is supported by the Danish Hydraulics Institute. It is a one-dimensional branch network model that simulates flood behaviour over the full duration of a flood, not just at the peak of the flood.

The Georges River MIKE-11 model was developed from various sources. The origin of the model was a MIKE-11 in-bank tidal model, which was first developed by the Public Works Department to study tidal behaviour between Liverpool and Botany Bay [PWD, 1992]. The tidal model was subsequently extended by Bewsher Consulting to incorporate the floodplain, by extending model cross sections and inserting additional overbank flow paths. A separate MIKE-11 model, developed as part of the Upper Georges River Flood Study [DLWC, 1998], was also added to the main model to extend it upstream of Liverpool.

The model extends over a distance of some 46km, from above Cambridge Avenue to Botany Bay. There are over 278 cross sections and a number of separate overland flow paths. A schematic diagram showing the location of model cross sections is provided on **Figures 4.1** and **4.2**.

The overbank topography was based on the 1:4000 scale orthophotomaps with 2m contours for the area downstream of Picnic Point. This is considered to be of a suitable accuracy due to the steeply sloping river banks and relatively wide river bed. Between Picnic Point and Liverpool the overbank topography was based on the same survey data used to construct the physical model of the Georges River in the 1980's. This consisted of orthophotomaps with 2m contours and overlays to these maps with additional survey data that had been assembled from various sources. The topography upstream of Liverpool was based on photogrammetric and ground survey undertaken as part of the Upper Georges River Flood Study.

Inflow boundary conditions for the model were the same as those adopted from the Georges River Flood Study [PWD, 1991]. However, due to the model's greater extent, additional inflows were required to account for Little Salt Pan Creek, Salt Pan Creek, Woronora River and other local catchment areas.

The adopted tailwater boundary condition for the model was a typical spring tide in Botany Bay. The timing of the tide was adjusted so that the peak discharge in the river coincided with the peak tidal level (ie RL 0.6m AHD). Whilst these tailwater level conditions were appropriate for use in the model, higher levels in Botany Bay and the Lower Georges River estuary, due to astronomic and other storm tide conditions, were adopted as design levels (as shown on Figure 4.3).

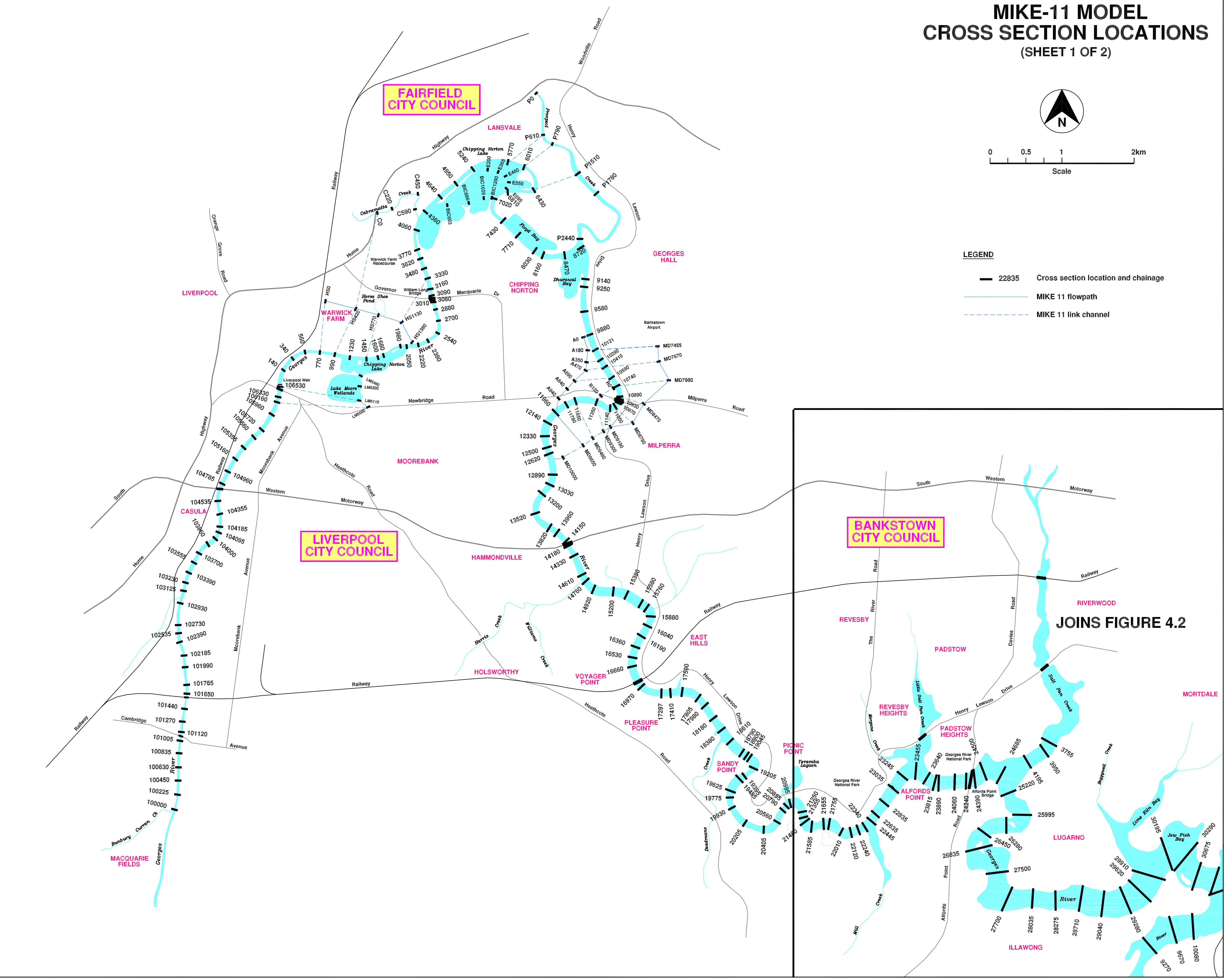
4.3 MODEL CALIBRATION

It is usual practise to calibrate a model to data collected from one or more historical flood events. This principally involves adjusting model roughness coefficients for the river and floodplain so that computed flood levels match observed or expected flood levels. Calibration of the MIKE-11 model has been considered over three separate reaches.

The reach of the model upstream of Liverpool, which was originally developed as part of the Upper Georges River Flood Study, had already been calibrated to flood data available from the 1986 and 1988 floods. Further calibration of this part of the model was therefore unnecessary.

GEORGES RIVER FLOODPLAIN
RISK MANAGEMENT STUDY

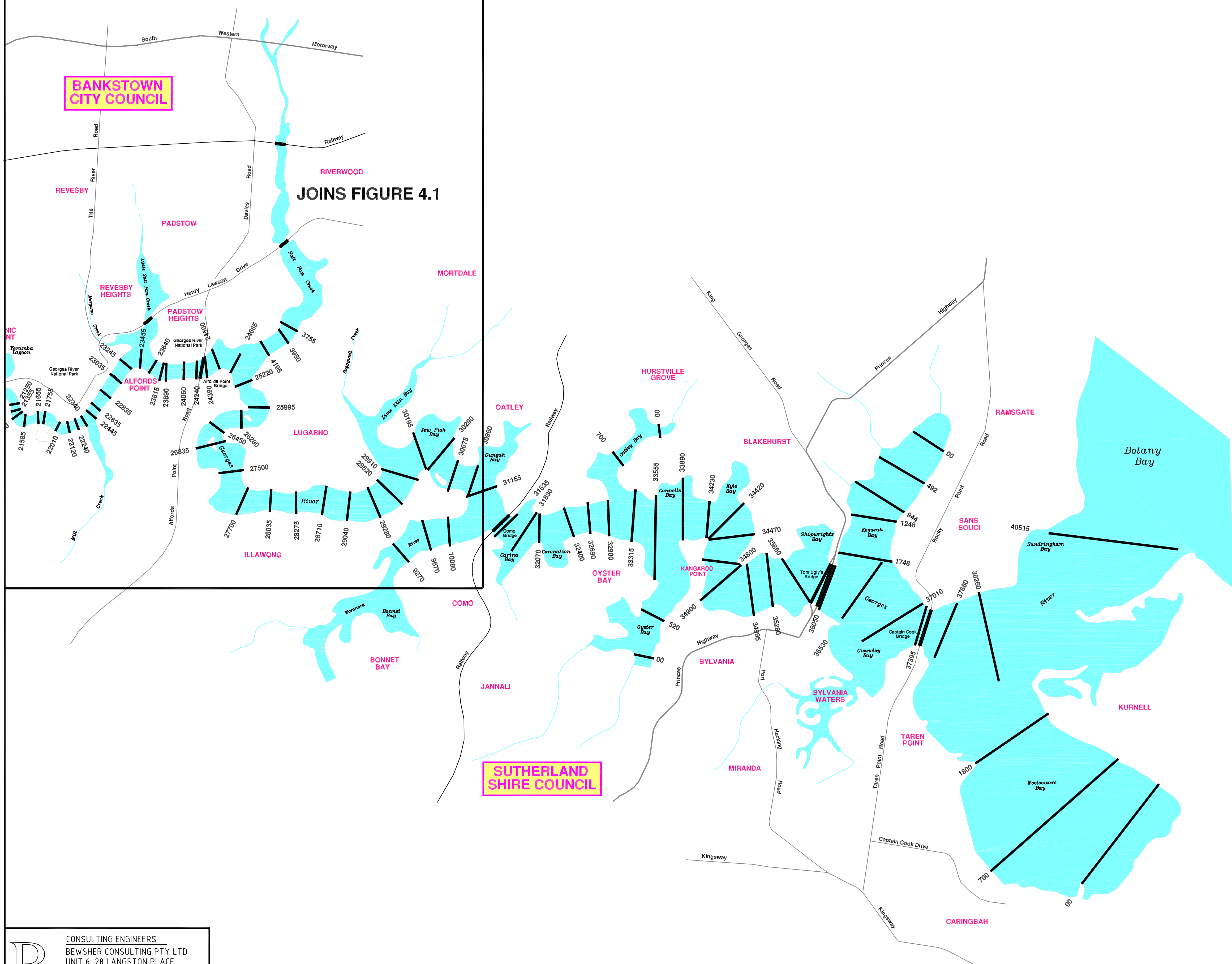
FIGURE 4.1
MIKE-11 MODEL
CROSS SECTION LOCATIONS
(SHEET 1 OF 2)



CONSULTING ENGINEERS
BEWSHER CONSULTING PTY LTD
UNIT 6, 28 LANGSTON PLACE
EPPING NSW 2121
P.O.BOX 352
EPPING NSW 1710
A.C.N. 003 137 068
Phone: (02) 9868 1966
Facsimile (02) 9868 5759
Email : postmaster@bewsher.com.au

Plot file : Model-Cross-sections
Plot scale : 50 (a3 @ 1:50000)
Date : 3 July 2003

FIGURE 4.2
MIKE-11 MODEL
CROSS SECTION LOCATIONS
(SHEET 2 OF 2)



LEGEND

▬ 22835 Cross section location and chainage

Scale: 0 – 0.5 – 1 – 2km

N

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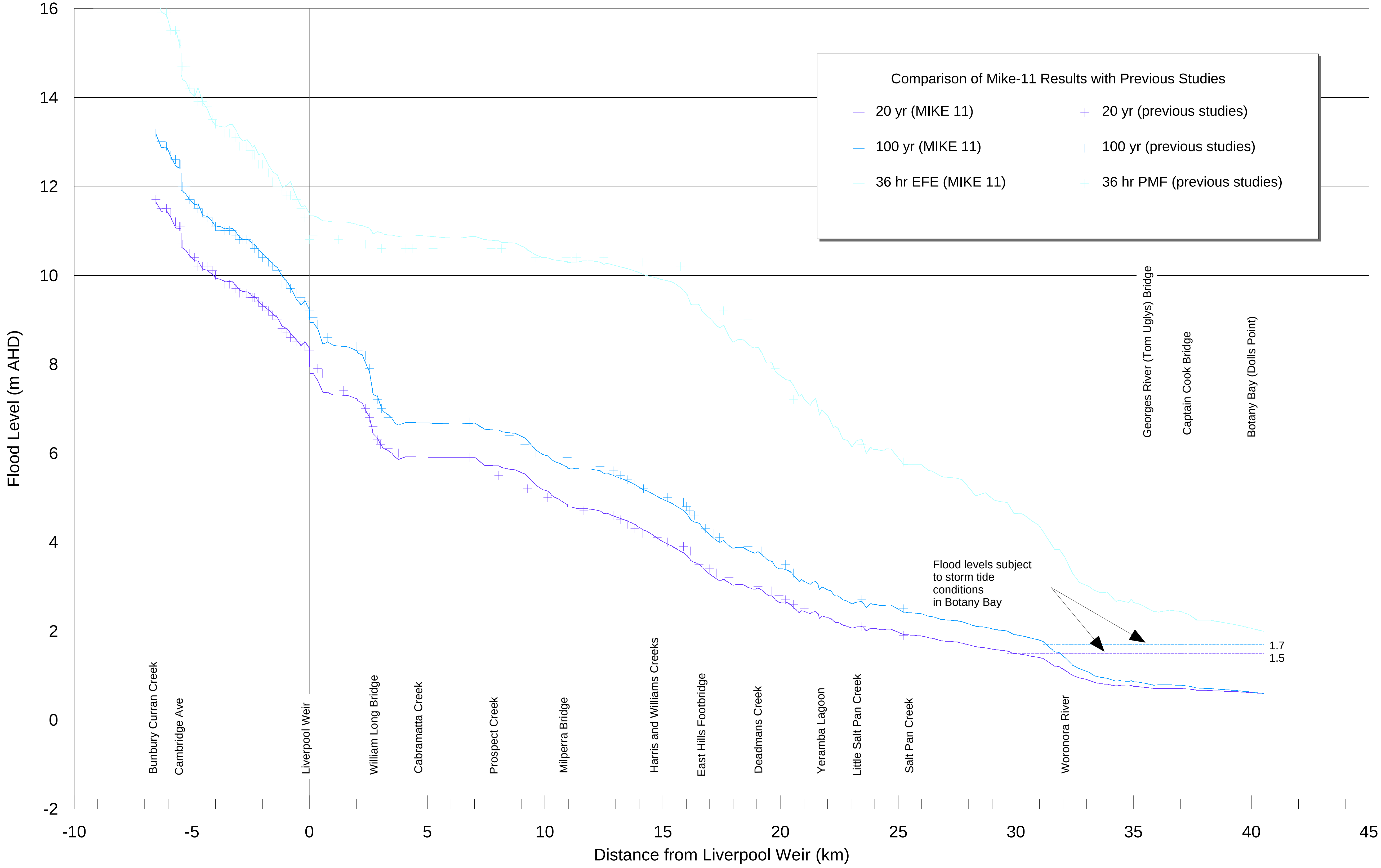
Plot file : Model-Cross-sections
Plot scale : 50 (a3 @ 1:50000)
Date : 3 July 2003

GEORGES RIVER FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE 4.3
VERIFICATION OF THE GEORGES RIVER MIKE-11 MODEL



The mid section of the model, between Liverpool and Picnic Point, effectively represents the area covered by the previous Georges River physical model. This model had been extensively calibrated over a number of years to floods that occurred in 1956, 1978, 1986 and 1988. Consequently there is a high degree of confidence in the results from the physical model in this part of the study area. Also, as the main purpose of the model in this reach was to test the impact of recent development and potential floodplain management measures, it was considered appropriate to calibrate the MIKE-11 model to results from the physical model (particularly the 100 year flood).

The downstream part of the model, from Picnic Point to Botany Bay, represents a new area for flood modelling. There is no documented information on historic flood levels within this reach of the river. Roughness coefficients determined from the MIKE-11 tidal model, which had been calibrated to data collected during two spring tides, were therefore maintained in the current model. Floodplain coefficients were estimated on the basis of aerial photography. Comparison was also possible with some previous flood level estimates that were determined by the Public Works Department at the confluence of Little Salt Pan Creek, Salt Pan Creek and the Woronora River.

A comparison of the computed MIKE-11 flood profiles with other previous flood level estimates is shown on **Figure 4.3**. Results indicate good agreement for the 20 year and 100 year floods, with most points lying within ±0.1m of previous results. There is more variability with the PMF estimates with most points lying within about ±0.3m. Given the magnitude of this extreme flood, the new estimates are still considered to be relatively consistent with the previous results.

The floodplain represented in the MIKE-11 model has matched, as closely as possible, conditions that were represented in the former physical model. These conditions coincide approximately to 1986 floodplain conditions. The model has subsequently been used to assess changes in the floodplain that have occurred since this date, which could potentially have an impact on design flood levels. Results of this assessment are discussed below.

4.4 IMPACTS OF RECENT DEVELOPMENT

The short questionnaire that was distributed to all residents in the study area invited people to suggest issues of concern that the current study should address. By far the most common issue raised was concern over the impact of recent development on flood behaviour. This issue was raised by 34 different people, representing 18% of those people who made written submissions in response to the questionnaire.

A number of changes have occurred throughout the catchment and study area since 1986. Aerial photography of the catchment that was flown in 1986, 1996, and 2001 has assisted in identifying some of these changes. The main changes that are evident include:

- upstream catchment development;
- the Chipping Norton Lakes Scheme;
- filling on Bankstown Airport;

- Moorebank/Milperra floodway scheme;
- sand extraction and stockpiling activities at Moorebank;
- the M5 Motorway Bridge over the Georges River;
- Kelso Park levee;
- flood mitigation works constructed at East Hills; and
- flood mitigation works constructed at Carinya Road.

4.4.1 Upstream Catchment Development

Much of the development that has occurred in the Georges River catchment over the last 10 years has been in new development areas located in the upper reaches of the catchment. Areas in upper Prospect Creek and Cabramatta Creek have been developed, or are in the process of being developed. There has also been substantial growth in the Campbelltown area.

New development usually leads to an increase in impervious catchment area, leading to increased runoff, with the potential to increase downstream flooding. Fairfield, Liverpool and Campbelltown Councils have developed drainage strategies in these new developing areas to ensure that the impacts of increased catchment runoff are mitigated by appropriate compensating measures. The three Councils have adopted schemes with a number of detention basins to ensure that post-developed flows do not exceed pre-developed flows.

Given the scale of the development that has taken place over the last 15 years in relation to the total catchment area, coupled with the drainage strategies adopted by the Councils concerned, the impact on flood levels in the Georges River should be very small.

4.4.2 Chipping Norton Lake Scheme

The Chipping Norton Lakes scheme involves the rehabilitation of former sand mining sites adjacent to the river by the creation of a series of inter-connected lakes and other recreational areas. The scheme commenced in 1977 and is largely complete today.

Both the former physical model and the current MIKE-11 model incorporate the scheme as it existed in 1986. Comparison of aerial photography between 1986 and 1996 indicates only marginal changes to the extent of the lake scheme. Only minor changes have occurred to the extent of Chipping Norton Lake and Dhurawal Bay as dredging operations have come to an end.

Flood behaviour through the Lakes scheme is largely influenced by channel constrictions at Long Point, Coot Island, and also the reach of the Georges River downstream of Dhurawal Bay. As these do not appear to have changed since 1986, it is expected that minor changes to the Lakes area will have negligible impact on flood behaviour.

4.4.3 Filling on Bankstown Airport

Of the residents that raised concerns over the impact of recent development on flood behaviour, many specifically referred to filling that had recently taken place, and continued to occur, on Bankstown airport. Many members of the Georges River Floodplain Management Committee also raised this as a major concern.

The airport site is on land that is owned by the Commonwealth of Australia. The airport and its facilities are operated by Bankstown Airport Limited, an independent public company wholly owned by the Commonwealth of Australia. Being Commonwealth land, there are no obligatory requirements for Bankstown Airport Limited to seek approval from Bankstown Council for activities undertaken on the site, including the filling of land.

The airport runways and main tarmac appear to be located on land that is at or above the 100 year flood. Other areas to the south, near Milperra Road and Henry Lawson Drive, are lower and have previously been affected by both the 1986 and 1988 floods (see Photo 3). These floods are estimated to be approximately 20 year flood events and more widespread flooding can be expected in larger events. This low-lying land has been filled, or is in the process of being filled, to a level similar to the 100 year flood level.

Filling of this site will result in a loss in floodplain storage and also a loss in flood conveyance in larger floods. Given the scale of the earthworks undertaken to date, it was considered that this activity was likely to lead to an increase in flood levels, both at the site and elsewhere along the river and floodplain. These works were therefore included in the MIKE-11 model to assess their potential impact on flood behaviour. Results from the assessment are summarised in **Table 4.1**.

TABLE 4.1
Impact of Filling at Airport on Georges River Flood Levels

Location	River Chainage (Km)	Section No. (Refer Fig. 4.1)	Change in 100 year Flood Level (mm)
Liverpool Weir	0	UPPERGEORGES 106530	0
William Long Bridge	3060	CNWEIR 3060	+13
Cabramatta Creek	4360	CNWEIR 4360	+18
Prospect Creek	8720	MILCN 8720	+23
Rabaul Road	9880	MILCN 9880	+34
Moorebank VP area	N/A	ARTHUR 180	+47
Airport Site	N/A	MIL DRAIN 7670	+65
Milperra Road	10930	MILCN 10930	+37
Milperra Drain	12620	SPMIL 12620	+37
M5 Motorway	14150	SPMIL 14150	+37
Williams Creek	14760	SPMIL 14760	+32
Kelso Creek	15880	SPMIL 15880	+31
East Hills Railway	16970	SPMIL 16970	+30
Deadmans Creek	18610	SPMIL 18610	+28
Salt Pan Creek	25220	SPMIL 25220	+19
Como Bridge	31635	GEORGES 31635	+1

As can be seen from the above results, the filling of the airport site is estimated to lead to an increase in the 100 year flood level of 30 to 40mm over a distance of some 8km along the river. Larger increases are also evident at and adjacent to the airport site.

The floodplain management committee is concerned about the impact of this activity, and has pursued the matter on several occasions either through letters issued by Bankstown Council or the Committee. However, neither Bankstown Council nor the Committee have any jurisdiction over the airport site, and a course of corrective action is yet to be agreed to.

4.4.4 Moorebank/Milperra Floodway Scheme

Liverpool and Bankstown Councils adopted voluntary purchase plans in the early 1980s for the gradual removal of development from the Moorebank-Milperra floodway. A total of 170 properties are included in the scheme on the Liverpool side of the river and 24 properties on the Bankstown side. To date, just over half of the Liverpool properties and most of the Bankstown properties have been acquired and removed from the floodway.

The removal of houses from the floodway results in less obstruction to floodwaters, and consequently a slight change in flood behaviour can be anticipated. This change was assessed by reducing the MIKE-11 model roughness coefficients in locations where buildings have been removed. This is a somewhat subjective change, but nevertheless provides an indication of the potential change in flood levels. A summary of model results for this activity is provided in **Table 4.2**.

TABLE 4.2
Impact of Removal of Buildings from the Moorebank/Milperra Floodway

Location	River Chainage (Km)	Section No. (Refer Fig. 4.1)	Change in 100 year Flood Level (mm)
Liverpool Weir	0	UPPERGEORGES 106530	0
William Long Bridge	3060	CNWEIR 3060	-7
Cabramatta Creek	4360	CNWEIR 4360	-8
Prospect Creek	8720	MILCN 8720	-10
Rabaul Road	9880	MILCN 9880	-14
Milperra Road	10930	MILCN 10930	-9
Milperra Drain	12620	SPMIL 12620	+5
M5 Motorway	14150	SPMIL 14150	+6
Williams Creek	14760	SPMIL 14760	+6
Kelso Creek	15880	SPMIL 15880	+5
East Hills Railway	16970	SPMIL 16970	+5
Deadmans Creek	18610	SPMIL 18610	+4
Salt Pan Creek	25220	SPMIL 25220	+4
Como Bridge	31635	GEORGES 31635	0

Results from the assessment indicate that there will be a small reduction in flood levels upstream of the floodway of up to 14mm, as the floodway becomes more efficient. However, downstream of the floodway, levels increase marginally by up to 6mm.

4.4.5 Activities at Moorebank

There have been various sand extraction and stockpiling activities on land at Moorebank, located between Newbridge Road and the M5 Motorway, since the early

1970s. This has resulted in the alteration of the natural floodplain, with consequential loss in flood storage and flood conveyance since this time.

Much of these activities occurred prior to 1986, and therefore the topography represented in both the physical model and the new MIKE-11 model already incorporate the majority of these changes.

A separate study on the impact of past activities at this location was undertaken for Liverpool Council, titled “Moorebank Flood Study” [Willing & Partners, 1996]. This study assessed flood behaviour using a fairly detailed computer model that represented a small reach of the river and floodplain upstream of the M5 motorway. The findings of that report indicate that activities undertaken to that time had possibly increased the 100 year flood level by as much as 120mm in the 100 year flood at Newbridge Road.

It is understood that the conditions of consent in relation to the activities undertaken on in this area include a requirement that the site be rehabilitated to “natural” floodplain conditions on completion of the operations. This would then negate the impact of the former activities on flood behaviour. As these operations draw to a conclusion, it is important that this requirement is not overlooked.

As most of the changes in topography are largely incorporated in both the physical model and MIKE-11 model, these impacts are already factored into the design flood levels that have been determined for the Georges River. However, there is an opportunity to improve flood conditions when rehabilitation takes place.

4.4.6 M5 Motorway Bridge

In 1991 the Roads and Traffic Authority entered into an agreement with Interlink Roads Pty Ltd to build and manage the M5 Motorway between King Georges Road and Moorebank Avenue. The project included the construction of a 540m bridge across the Georges River and its western floodplain at Hammondville. The size of the bridge was chosen to limit the impact on flood behaviour, based on an assessment using the previous physical model.

A temporary access track was formed beside the bridge alignment in order to assist with the construction of the bridge. It is understood that approval for this temporary access track was conditional on its removal within 12 months of the completion of the bridge. This was largely due to concerns that the access track, in combination with the bridge, may have a more significant impact on flood behaviour.

A catchment inspection undertaken by the Georges River Floodplain Management Committee in December 2001 revealed that the temporary access track had not been removed. The access track was observed to be 1-2m above natural floodplain levels immediately downstream of the bridge. This prompted further assessment of the impacts of the bridge and access track in the MIKE-11 computer model. The results of the assessment are summarised in **Table 4.3**.

Results from the assessment indicate that the access track and bridge result in a maximum increase in the 100 year flood of 74mm on the upstream side of the bridge. The majority of this increase is considered to be attributable to the access track, rather than the Motorway Bridge. The constriction does, however, provide a smaller reduction in flood levels on the downstream side of the bridge of up to 51mm. Given the properties potentially affected by flooding on the upstream side of the bridge, the net result of the constriction is considered to be undesirable.

TABLE 4.3
Impact of M5 Motorway Bridge and Access Track

Location	River Chainage (Km)	Section No. (Refer Fig. 4.1)	Change in 100 year Flood Level (mm)
Liverpool Weir	0	UPPERGEORGES 106530	0
William Long Bridge	3060	CNWEIR 3060	+3
Cabramatta Creek	4360	CNWEIR 4360	+4
Prospect Creek	8720	MILCN 8720	+9
Rabaul Road	9880	MILCN 9880	+25
Milperra Road	10930	MILCN 10930	+42
Milperra Drain	12620	SPMIL 12620	+52
M5 Motorway	14150	SPMIL 14150	+74
Williams Creek	14760	SPMIL 14760	-51
Kelso Creek	15880	SPMIL 15880	-50
East Hills Railway	16970	SPMIL 16970	-47
Deadmans Creek	18610	SPMIL 18610	-41
Salt Pan Creek	25220	SPMIL 25220	-3
Como Bridge	31635	GEORGES 31635	-1

The Committee has been liaising with Interlink Roads in relation to the matter, and it is understood that Interlink Roads have agreed to remove the access track.

4.4.7 Kelso Park Levee

The Kelso levee was constructed by Bankstown Council in 1986 to provide protection to an estimated 148 houses at Panania in a 100 year flood. As the levee reduces the available floodplain storage for floodwater from the Georges River to pond, some increase in flood levels can be expected.

The levee was under consideration at the time of the physical model tests, and was included in all model design runs. It was also included in the current MIKE-11 model. Therefore, whilst a slight increase in flood levels is anticipated as a result of the levee, all model runs have already incorporated this increase in the current estimates.

The feasibility study undertaken for the levee in 1984 [PWD, 1984] estimated that the levee would reduce the available floodplain storage by 300,000m^3. At the time, this was not considered to result in a significant impact on flood behaviour, and that the benefits of the scheme far outweighed any small adverse impacts.

As the levee was approved many years ago, and already factored into current flood level estimates, further assessments do not appear to be warranted.

4.4.8 Flood Mitigation Works at East Hills

Flood mitigation works have recently been completed by Bankstown Council at East Hills. The scheme consists of the construction of an upstream deflector levee and five ‘finger levees’ that were to be constructed along property boundaries, perpendicular to the direction of river flows. The objective of the scheme is not to prevent flood inundation, but to reduce flood velocities, thereby reducing the flood hazard for existing buildings in this area (which is dependent on both flood depths and flood velocities).

The scheme was first investigated as part of the East Hills Floodway Model Investigation [PWD, 1987], with construction first commencing in 1995. The scheme has now essentially been completed, except for one of the proposed finger levees where agreement with property owners could not be reached.

The levees reduce the flow of water across the floodplain and consequently some change in flood behaviour can be expected. The scheme was therefore included in the MIKE-11 model, by increasing roughness coefficients on the floodplain to reduce its capacity to convey floodwaters at this location. Results of the assessment are shown in **Table 4.4**.

TABLE 4.4
Impact of East Hills Flood Mitigation Works

Location	River Chainage (Km)	Section No. (Refer Fig. 4.1)	Change in 100 year Flood Level (mm)
Liverpool Weir	0	UPPERGEORGES 106530	0
William Long Bridge	3060	CNWEIR 3060	+1
Cabramatta Creek	4360	CNWEIR 4360	+2
Prospect Creek	8720	MILCN 8720	+2
Rabaul Road	9880	MILCN 9880	+3
Milperra Road	10930	MILCN 10930	+3
Milperra Drain	12620	SPMIL 12620	+3
M5 Motorway	14150	SPMIL 14150	+5
Williams Creek	14760	SPMIL 14760	+6
Kelso Creek	15880	SPMIL 15880	+7
East Hills Railway	16970	SPMIL 16970	0
Deadmans Creek	18610	SPMIL 18610	-1
Salt Pan Creek	25220	SPMIL 25220	0
Como Bridge	31635	GEORGES 31635	0

The change in flood levels from the scheme are small, and limited to about 7mm. It should be noted however, that local increases in flood level immediately adjacent to individual levee walls could be substantially higher, though confined to a relatively small area.

4.4.9 Flood Mitigation Works at Carinya Road

A finger levee scheme, similar to that described above for East Hills, was also implemented at Carinya Road several years earlier.

The impact of the Carinya Road flood mitigation scheme was also assessed using the MIKE-11 model. Results of the assessment are provided in **Table 4.5**.

The maximum increase in the 100 year flood due to the scheme is estimated to be 21mm. This is a larger impact than that for the East Hills Flood Mitigation Works, but is still relatively small and dissipates quickly upstream of the works. Local increases in flood levels adjacent to individual levee walls could occur.

TABLE 4.5
Impact of Carinya Road Flood Mitigation Works

Location	River Chainage (Km)	Section No. (Refer Fig. 4.1)	Change in 100 year Flood Level (mm)
Liverpool Weir	0	UPPERGEORGES 106530	0
William Long Bridge	3060	CNWEIR 3060	0
Cabramatta Creek	4360	CNWEIR 4360	+1
Prospect Creek	8720	MILCN 8720	+2
Rabaul Road	9880	MILCN 9880	+4
Milperra Road	10930	MILCN 10930	+6
Milperra Drain	12620	SPMIL 12620	+6
M5 Motorway	14150	SPMIL 14150	+9
Williams Creek	14760	SPMIL 14760	+9
Kelso Creek	15880	SPMIL 15880	+12
East Hills Railway	16970	SPMIL 16970	+17
Deadmans Creek	18610	SPMIL 18610	+21
Salt Pan Creek	25220	SPMIL 25220	-1
Como Bridge	31635	GEORGES 31635	-1

4.4.10 Deepwater Motor Boat Club

The Deepwater Motor Boat Club is located on the eastern bank of the Georges River at Milperra, downstream of the M5 Motorway bridge. Part of the car park for the Club was filled in 1998 by former owners of the Club.

Whilst the filling that occurred on this site has not been included in the current MIKE-11 model, it was assessed as part of a previous study requested by Bankstown Council. That investigation indicated that the fill could result in an increase in upstream flood levels of up to 10mm in the 100 year flood.

4.4.11 Conclusions

The cumulative impact of all of the measures that were assessed using the MIKE-11 model has been computed and is summarised in **Table 4.6** for the 100 year flood. It should be noted that in some instances, development or works have resulted in an increase in flood levels in some locations, and a reduction in flood levels at other locations.

The maximum cumulative impact of all works modelled is estimated to be 146mm, which is estimated to occur immediately upstream of the M5 Motorway Bridge. The increase in flood levels gradually reduces to 100mm at Milperra Road, 33mm at the Prospect Creek confluence, and 15mm at William Long Bridge. The cumulative impact downstream of the M5 Motorway Bridge is substantially lower, with a maximum increase of less than 27mm.

The two main contributors to the increase in flood levels are the access track beside the M5 Motorway Bridge and the filling of the airport site. The Georges River Floodplain Management Committee has pursued both issues with the organisations responsible for these works, and is hopeful that the works will be removed or other compensatory measures provided.

TABLE 4.6
Cumulative Impact of Development (measures assessed in the MIKE-11 model)

Location	River Chainage (Km)	Section No. (Refer Fig. 4.1)	Change in 100 year Flood Level (mm)
Liverpool Weir	0	UPPERGEORGES 106530	0
William Long Bridge	3060	CNWEIR 3060	+15
Cabramatta Creek	4360	CNWEIR 4360	+23
Prospect Creek	8720	MILCN 8720	+33
Rabaul Road	9880	MILCN 9880	+63
Milperra Road	10930	MILCN 10930	+100
Milperra Drain	12620	SPMIL 12620	+117
M5 Motorway	14150	SPMIL 14150	+146
Williams Creek	14760	SPMIL 14760	+14
Kelso Creek	15880	SPMIL 15880	+18
East Hills Railway	16970	SPMIL 16970	+18
Deadmans Creek	18610	SPMIL 18610	+23
Salt Pan Creek	25220	SPMIL 25220	+27
Como Bridge	31635	GEORGES 31635	+2

Given that flood level increases are generally less than 100mm and within the existing freeboard allowance, and that these increases may be further reduced in the near future, the Committee decided that no change in design flood level estimates previously adopted by the four councils would appear to be warranted. That is, results from the previous flood studies on the Georges River and its tributary creeks would appear to be still valid, and should continue to be used.

Flood level contours determined from the Georges River Flood Study [PWD, 1991] are included in **Appendix D**.

4.5 DESIGN FLOOD LEVELS IN THE LOWER GEORGES RIVER

There have been no previous studies to define design flood levels on the Georges River for the area downstream of Picnic Point, in the Sutherland Shire part of the study area. Results from the current MIKE-11 modelling therefore provides Sutherland Shire Council with flood level estimates for this purpose.

Flooding in the lower reaches of the Georges River can be caused by high river flows or by elevated water levels in Botany Bay arising from storm tide conditions. Modelling of flood conditions in the lower river have assumed that both the 100 year river flows and 20 year river flows coincide with a mean high water level in Botany Bay. The PMF assessment, which represent a more extreme flood event, has assumed that PMF river flows coincide with an extreme storm tide level.

The mean high water level in Botany Bay is about RL 0.6m AHD. The highest tides, that are typically experienced twice a year, usually reach about RL1.1m AHD. Tide levels can be further elevated by two other storm processes. These include:

- storm surge, due to low pressure systems and wind stress across a body of water; and
- wave set-up, due to the action of large waves that break across the inlet of a bay or river entrance.

Advice received from the Coastal Branch and Flood Branch of the former Department of Land and Water Conservation is that there have been no formal investigations on storm tide levels conducted in Botany Bay. However, on the basis of investigations undertaken in Sydney Harbour, and elsewhere, the levels provided in **Table 4.7** have been recommended for Botany Bay.

Design flood levels for the Lower Georges River are shown on **Figures 4.4**, **4.5** and **4.6** for the 20 year, 100 year and PMF events. These flood levels are based on the higher level from either the modelling of river flood flows, or the estimated storm tide levels from Botany Bay.

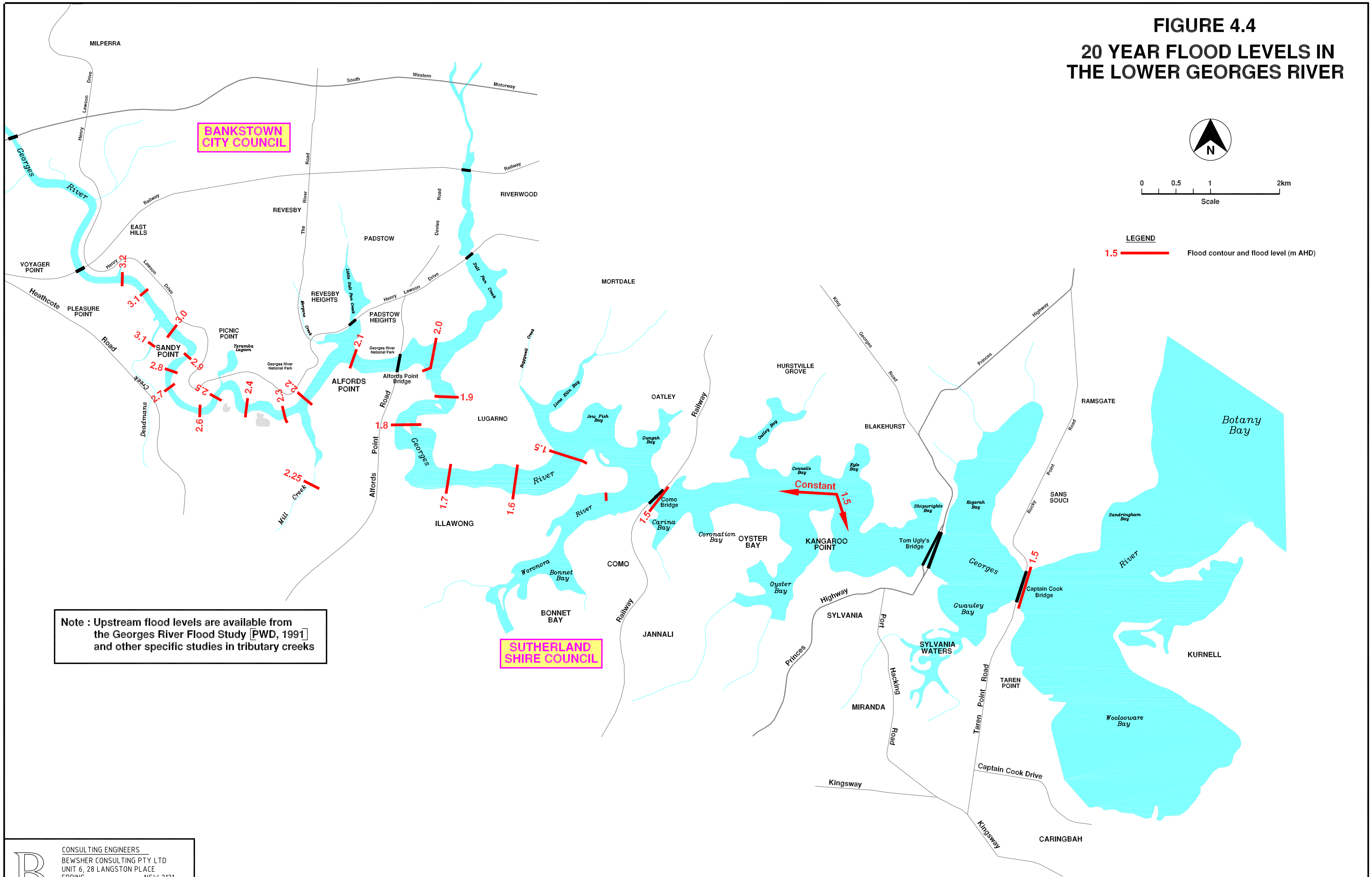
TABLE 4.7
Recommended Storm Tide Levels in Botany Bay
(Source: personal communications with Department of Land & Water Conservation, 2002)

Type of Tide	Peak Water Level (m AHD)
Normal High Tide	0.6
High Spring Tide	1.1
20 year Storm Tide	1.5
100 year Storm Tide	1.7
Extreme Storm Tide	2.0

The results of the assessment are also consistent with tailwater levels that were assumed for the Georges River as part of other major studies undertaken on the Woronora River, Deadmans Creek, Salt Pan Creek and Little Salt Pan Creek.

The Georges River is tidal up to the Liverpool weir. High tide levels for Liverpool will be similar to high tide levels at Botany Bay, but will occur some 2-3 hours later. However, the influence of the tide on flooding becomes relatively insignificant upstream of the Woronora River in all but minor flood events.

FIGURE 4.4
20 YEAR FLOOD LEVELS IN THE LOWER GEORGES RIVER



Note : Upstream flood levels are available from the Georges River Flood Study [PWD, 1991] and other specific studies in tributary creeks

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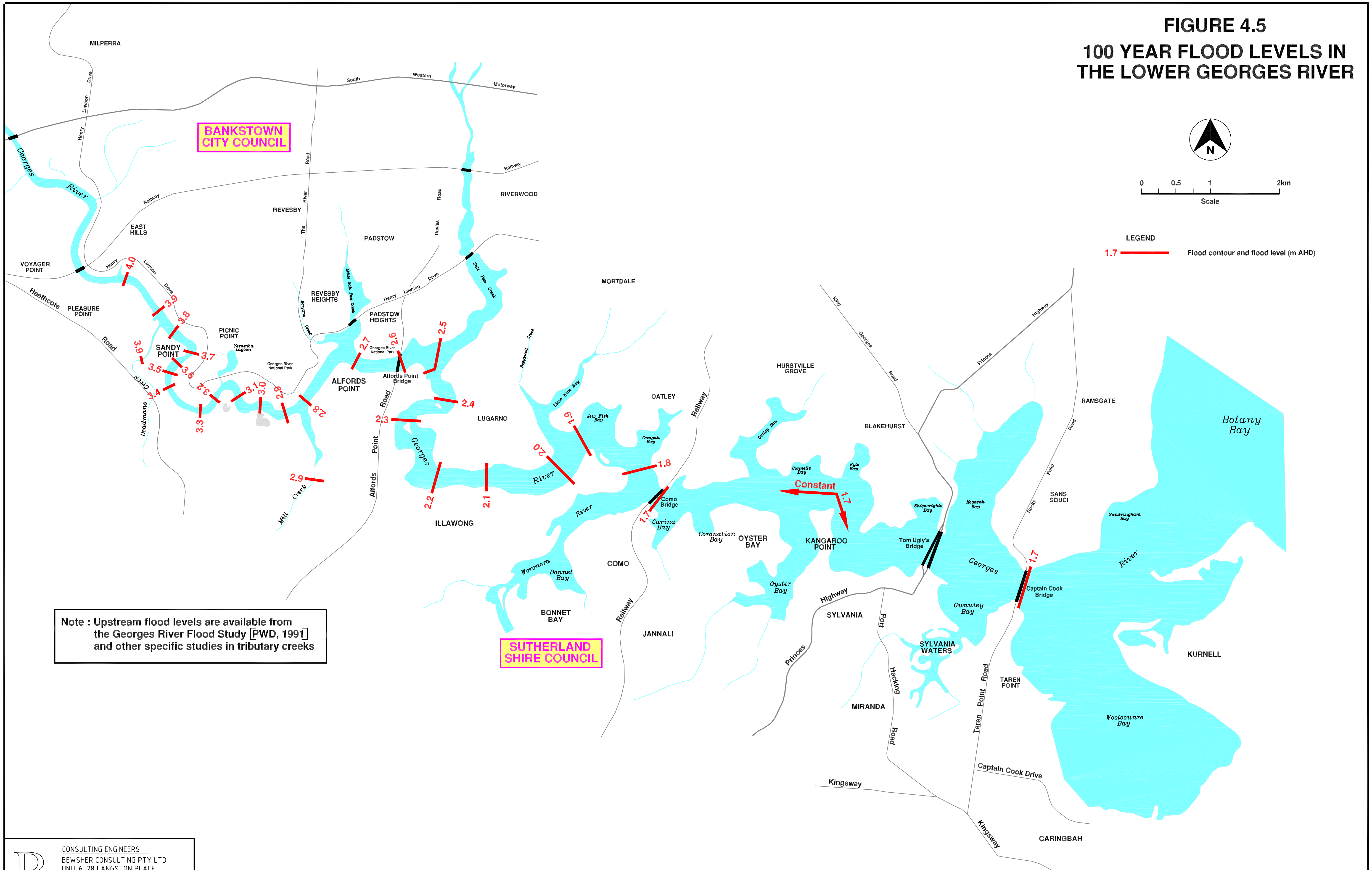
Date : 3 July 2003

FIGURE 4.5
100 YEAR FLOOD LEVELS IN THE LOWER GEORGES RIVER



Note : Upstream flood levels are available from the Georges River Flood Study [PWD, 1991] and other specific studies in tributary creeks

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Plot scale : 50 (a3 @ 150000)
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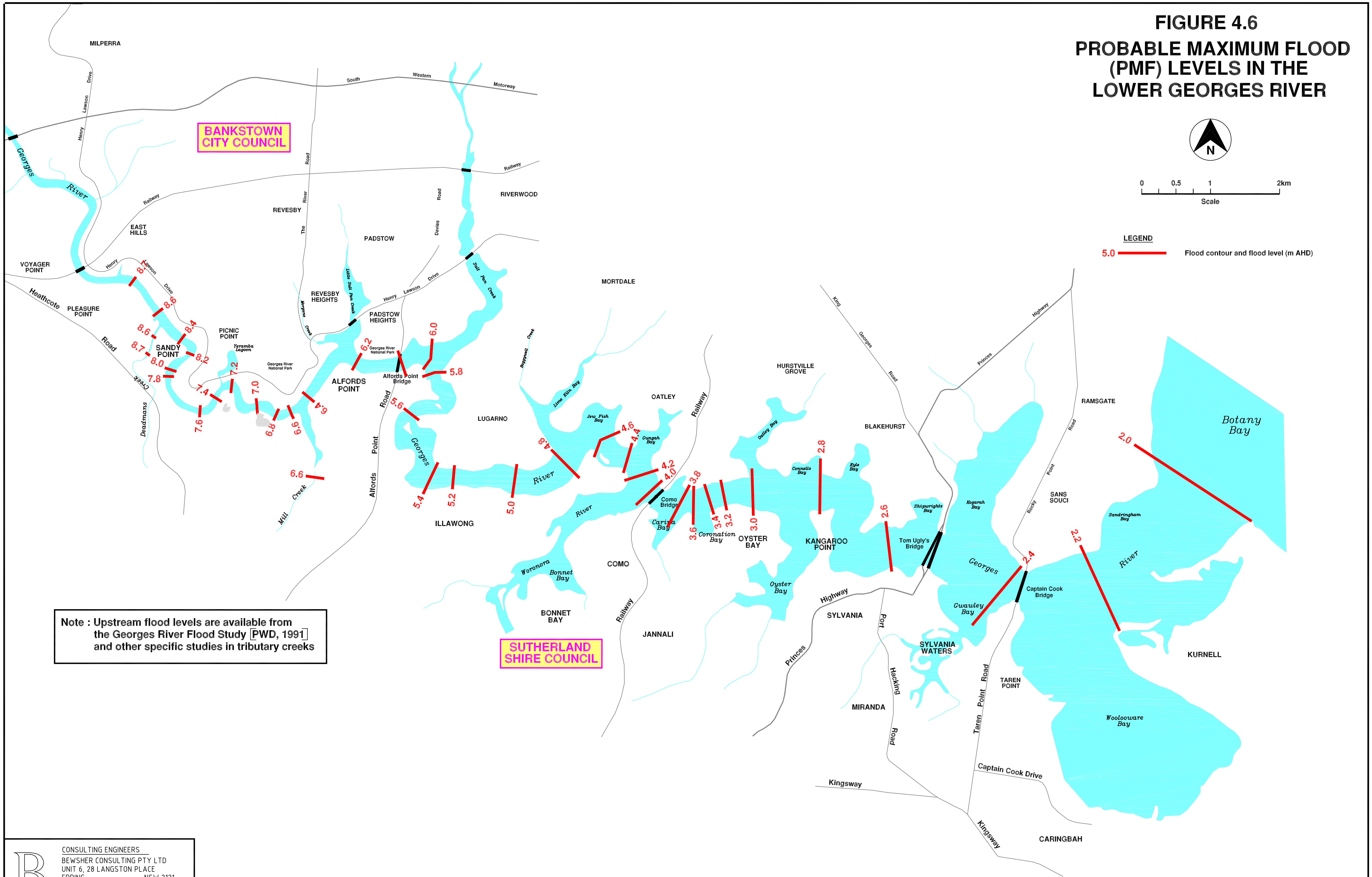
FIGURE 4.6

PROBABLE MAXIMUM FLOOD (PMF) LEVELS IN THE LOWER GEORGES RIVER



Note : Upstream flood levels are available from the Georges River Flood Study [PWD, 1991] and other specific studies in tributary creeks

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5. DESCRIPTION OF FLOOD BEHAVIOUR

5.1 SOURCE OF FLOOD DATA

Information on design flood levels throughout the study area is available from the Upper Georges River Flood Study [DLWC, 1999], the Georges River Flood Study [PWD, 1991] and other flood studies undertaken on tributary creeks. The current Georges River MIKE-11 model provides similar estimates (generally within ±0.2m) of the design flood levels published in these studies.

No flood studies have been undertaken on the Lower Georges River, below Picnic Point, hence levels provided in the current modelling can be used for design flood levels in this part of the river. Flood contours for the Lower Georges River were presented on **Figures 4.4**, **4.5** and **4.6**.

Results from the current modelling also provides additional information that was previously unavailable, including information on flood depths, velocities, flood hazard and the extent of inundation.

5.2 SUMMARY OF PROPERTY INUNDATION

A flood damages database of potentially flood affected buildings has been prepared for the study area. The database, which is discussed in more detail in **Section 6**, provides details of those properties likely to be inundated in different sized floods.

The number of residential, and commercial/industrial properties that are potentially affected by flooding in the Georges River study area is shown in **Tables 5.1** and **5.2**.

Results from **Tables 5.1** and **5.2** show that:

- In the **probable maximum flood** it is estimated that:
  5,697 residential properties (containing a house) would be flooded
  5,204 residential homes would be flooded above floor level
  617 commercial or industrial properties (containing buildings) would be flooded
  591 commercial and industrial buildings would be flooded above floor level;
- In the **100 year flood** it is estimated that:
  1,363 residential properties (containing a house) would be flooded
  721 residential homes would be flooded above floor level
  261 commercial or industrial properties (containing buildings) would be flooded
  216 commercial and industrial buildings would be flooded above floor level;
- There are substantially more residential properties affected by flooding than there are commercial or industrial properties affected;
- The number of homes that would be flooded in the 100 year flood for the four council areas are as follows:-

Liverpool City Council	308
Fairfield City Council	239
Bankstown City Council	156
Sutherland Shire Council	18
TOTAL	721

TABLE 5.1
Residential Property (Containing a Home) Affected by Flooding

Location	20 Year Flood		100 Year Flood		PMF	
	Property	Homes	Property	Homes	Property	Homes
Liverpool City Council Area						
Upstream of Newbridge Road at Liverpool	131	61	264	168	587	547
Newbridge Road to Governor Macquarie Dr	9	5	97	23	333	285
Governor Macquarie Drive to M5 Bridge	70	40	319	81	1296	1251
Downstream of M5 Bridge	21	12	52	36	421	380
TOTAL	*231*	*118*	*732*	*308*	*2,637*	*2,463*
Fairfield City Council						
TOTAL	*227*	*136*	*326*	*239*	*656*	*645*
Bankstown City Council Area						
North of Milperra Road	11	10	22	17	344	304
South of Milperra Road	98	35	179	122	1335	1118
Kelso Levee area	17	0	60	17	642	602
TOTAL	*126*	*45*	*261*	*156*	*2321*	*2024*
Sutherland Shire Council Area						
Sandy Point Area	14	5	20	11	36	35
Illawong Area	18	6	24	7	47	37
TOTAL	*32*	*11*	*44*	*18*	*83*	*72*
TOTAL	**616**	**310**	**1,363**	**721**	**5,697**	**5,204**

TABLE 5.2
Commercial/Industrial Property (Containing a Building) Affected by Flooding

Location	20 Year Flood		100 Year Flood		PMF	
	Property	Building	Property	Building	Property	Building
Liverpool City Council Area						
Upstream of Newbridge Road at Liverpool	25	4	107	88	168	167
Newbridge Road to Governor Macquarie Dr	0	0	10	4	19	19
Governor Macquarie Drive to M5 Bridge	24	17	45	30	77	77
Downstream of M5 Bridge	0	0	0	0	2	2
TOTAL	*49*	*21*	*162*	*122*	*266*	*265*
Fairfield City Council						
TOTAL	*23*	*15*	*34*	*30*	*85*	*84*
Bankstown City Council Area						
North of Milperra Road	10	9	11	13	42	43
South of Milperra Road	32	27	52	51	*217*	*192*
Kelso Levee area	0	0	2	0	7	7
TOTAL	*42*	*36*	*65*	*64*	*266*	*242*
Sutherland Shire Council Area						
Sandy Point Area	0	0	0	0	0	0
Illawong Area	0	0	0	0	0	0
TOTAL	*0*	*0*	*0*	*0*	*0*	*0*
TOTAL	**114**	**72**	**261**	**216**	**617**	**591**

The **depth of flooding** experienced by residential homes affected by the 100 year ARI flood is indicated in **Table 5.3**. The depth of flooding experienced by other buildings is indicated in **Table 5.4**. The main points to note are:

Liverpool City Council Area

- the majority of homes in the Liverpool Council area (62%) would be inundated by more than 0.5m above floor level in a 100 year flood;
- the majority of industrial and commercial properties (57%) would be inundated by less than 0.5m above floor level in a 100 year flood;
- most of these homes and commercial/industrial buildings that are affected by the 100 year flood are located upstream of Newbridge Road at Liverpool.

Fairfield City Council Area (Lansvale)

- properties in the Fairfield Council area generally experience the greatest inundation depths in a 100 year flood, when compared with the other three council areas;
- almost one half of the homes in the Lansvale area (48%) would be inundated by more than 1.0m above floor level in a 100 year flood;
- commercial/industrial buildings are similarly affected (40%) by more than 1.0m in a 100 year flood.

Bankstown City Council Area

- the majority of homes in the Bankstown area (54%) would be inundated by less than 0.5m above floor level in a 100 year flood;
- the majority of the commercial, industrial or public sector buildings in the study area (78%) would be inundated by more than 0.5m above floor level in a 100 year flood;
- the Kelso levee area provides reasonable protection for floods up to the 100 year event (only 17 homes estimated to be inundated above floor level) but little protection in larger floods (602 homes inundated above floor level in the PMF).

Sutherland Shire Council Area

- only 18 homes are estimated to be affected by flooding above floor level in the 100 year flood. No industrial/commercial properties would appear to be affected.
- both the Sandy Point and Illawong areas would be equally affected in a 100 year flood, with problems occurring in isolated areas.

TABLE 5.3
Inundation Depths for Homes in the 100 Year Flood

Location	Below Floor (No. Houses)		Above Floor Flooding (Number of Houses)				
	-.5 to -.2	-.2 to 0	0 to 0.2	.2 to.5	.5 to 1	> 1.0m	TOTAL
Liverpool City Council Area							
Upstream of Newbridge Road at Liverpool	56	40	28	30	45	65	168
Newbridge Road to Governor Macquarie Dr	40	34	6	8	4	5	23
Governor Macquarie Drive to M5 Bridge	201	39	21	11	15	34	81
Downstream of M5 Bridge	5	11	6	8	12	10	36
TOTAL	*302*	*124*	*61*	*57*	*76*	*114*	*308*
Fairfield City Council							
TOTAL	*46*	*29*	*18*	*32*	*75*	*114*	*239*
Bankstown City Council Area							
North of Milperra Road	6	1	4	0	5	8	17
South of Milperra Road	31	17	20	43	29	30	122
Kelso Levee area	30	13	11	6	0	0	17
TOTAL	*67*	*31*	*35*	*49*	*34*	*38*	*156*
Sutherland Shire Council Area							
Sandy Point Area	3	0	2	1	4	4	11
Illawong Area	4	3	0	2	5	0	7
TOTAL	*7*	*3*	*2*	*3*	*9*	*4*	*18*
TOTAL	**422**	**187**	**116**	**141**	**194**	**270**	**721**

TABLE 5.4
Inundation Depths for Commercial Buildings in the 100 Year Flood

Location	Below Floor (No. Buildings)		Above Floor Flooding (Number of Buildings)				
	-.5 to -.2	-.2 to 0	0 to 0.2	.2 to .5	.5 to 1	> 1.0m	TOTAL
Liverpool City Council Area							
Upstream of Newbridge Road at Liverpool	11	8	19	38	28	3	88
Newbridge Road to Governor Macquarie Dr	3	3	0	4	0	0	4
Governor Macquarie Drive to M5 Bridge	7	8	4	4	5	17	30
Downstream of M5 Bridge	0	0	0	0	0	0	0
TOTAL	*21*	*19*	*23*	*46*	*33*	*20*	*122*
Fairfield City Council							
TOTAL	*2*	*2*	*4*	*5*	*9*	*12*	*30*
Bankstown City Council Area							
North of Milperra Road	0	0	0	1	3	9	13
South of Milperra Road	13	6	4	9	15	23	51
Kelso Levee area	2	0	0	0	0	0	0
TOTAL	*15*	*6*	*4*	*10*	*18*	*32*	*64*
Sutherland Shire Council Area							
Sandy Point Area	0	0	0	0	0	0	0
Illawong Area	0	0	0	0	0	0	0
TOTAL	*0*	*0*	*0*	*0*	*0*	*0*	*0*
TOTAL	***38***	***27***	***31***	***61***	***60***	***64***	***216***

Each property in the flood damages database has been classified within one of three different **flood risk areas** (high, medium and low). The hazard classification is based on the depth and velocity of floodwater over the floodplain and consideration of evacuation issues. This flood risk categorisation is further discussed in the following Section.

Where properties are located within different flood risk areas, the higher flood risk area has generally been adopted. The number of properties within the different flood risk areas is indicated in **Table 5.5**.

The distribution of properties within the three flood risk areas are as follows:

- 2,648 are classified as High Risk (31%);
- 1,342 are classified as Medium Risk (16%); and
- 4,440 are classified as Low Risk (53%);

It is important to note that many of the properties identified as being in a high flood risk area may only be partially affected by this risk category. Other parts of the property, including the location of existing buildings, may be subject to a lower flood risk category.

TABLE 5.5
Number of Properties in Each Flood Risk Area

Location	Flood Risk Area			
	High Risk	Medium Risk	Low Risk	Total
Liverpool City Council Area				
Upstream of Newbridge Road at Liverpool	269	91	552	912
Newbridge Road to Governor Macquarie Dr	42	182	237	461
Governor Macquarie Drive to M5 Bridge	243	96	1261	1600
Downstream of M5 Bridge	54	53	463	570
TOTAL	*608*	*422*	*2513*	*3543*
Fairfield City Council				
TOTAL	*389*	*148*	*288*	*825*
Bankstown City Council Area				
North of Milperra Road	354	130	378	862
South of Milperra Road	1176	292	875	2343
Kelso Levee area	99	298	368	765
TOTAL	*1629*	*720*	*1621*	*3970*
Sutherland Shire Council Area[1]				
Sandy Point Area	22	15	0	37
Illawong Area	0	37	18	55
TOTAL	*22*	*52*	*18*	*92*
TOTAL	**2648**	**1342**	**4440**	**8430**

[1] Additional property in Sutherland Shire Council area with existing buildings above the PMF are not included.

5.3 FLOOD RISK MAPPING

Different parts of the floodplain are subject to different degrees of hazard, or flood risk. The Georges River Floodplain Management Committee agreed that the study area should be categorised into three different grades of flood risk, namely high, medium and low. This approach is similar to the categorisation of other natural risks, such as bush fire risk.

The committee also recognised that it would be unreasonable to apply the same types of development controls to properties that have a low risk of flooding as those that may have a high risk. Therefore, development controls that are considered later in this study have recognised both the type of development and the flood risk of the area where the development is located. Further discussion on the approach to floodplain planning is provided in **Volume 2** of the floodplain risk management study.

The three flood risk areas, which are defined below, are shown on **Figure 5.1**.

High Flood Risk	Land below the 100 year flood that is either subject to a high hydraulic hazard (ie provisional high hazard in accordance with the criteria outlined in the *Floodplain Management Manual*) or where there are significant evacuation difficulties.
Medium Flood Risk	Land below the 100 year flood level that is not subject to high hydraulic hazard and where there are no significant evacuation difficulties.
Low Flood Risk	All land within the floodplain (ie. within the PMF extent) but not identified as either in a high flood risk or medium flood risk area.

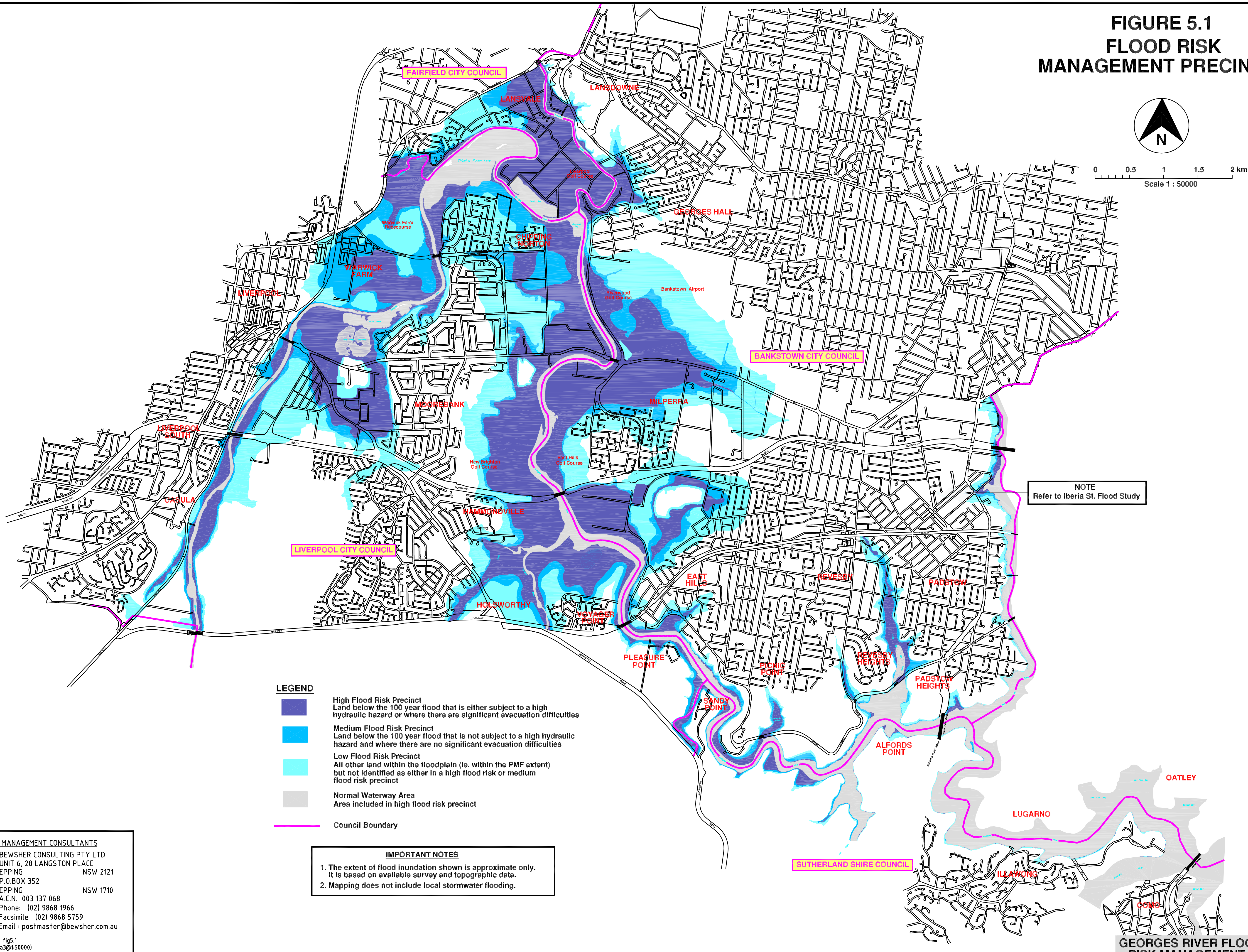
The high flood risk area is where high flood damages, potential risk to life, or evacuation problems are anticipated. Most development should be restricted in this area.

The medium flood risk area is where there is still a significant risk of flood damage, but where these damages can be minimised by the application of appropriate development controls.

The low flood risk area is that area above the 100 year flood, where the risk of damage is low. Most land uses would be permitted within this area.

The risk mapping is intended to be ultimately incorporated in GIS computer systems of the four councils. This will provide a valuable source of information for Council to manage the flood risk, and will also assist with future emergency management operations.

FIGURE 5.1
FLOOD RISK MANAGEMENT PRECINCTS



LEGEND

- **High Flood Risk Precinct** — Land below the 100 year flood that is either subject to a high hydraulic hazard or where there are significant evacuation difficulties
- **Medium Flood Risk Precinct** — Land below the 100 year flood that is not subject to a high hydraulic hazard and where there are no significant evacuation difficulties
- **Low Flood Risk Precinct** — All other land within the floodplain (ie. within the PMF extent) but not identified as either in a high flood risk or medium flood risk precinct
- **Normal Waterway Area** — Area included in high flood risk precinct
- Council Boundary

IMPORTANT NOTES

1. The extent of flood inundation shown is approximate only. It is based on available survey and topographic data.
2. Mapping does not include local stormwater flooding.

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Plot file : J1046-fig5.1
Plot scale : 50 (a3@1:50000)
Date : 5 May 2004

GEORGES RIVER FLOODPLAIN RISK MANAGEMENT STUDY

5.4 THE PROBABLE MAXIMUM FLOOD

Some residents along the Georges River will remember the 1986 and 1988 floods, which are estimated to be close to a 20 year flood. A few residents may also remember the larger flood that occurred in 1956. But even larger floods have occurred in the late 1800's, and are likely to occur again in the future. The 1873 flood, for example, is estimated to have been over 2m higher than the 1956 flood, and also over 1m higher than the estimated 100 year flood at Liverpool (refer to Figure 2.3).

This begs the question – how much higher again can floods rise?

In order to gain an appreciation of the upper limit of possible flooding, an extreme flood event, known as the probable maximum flood (or PMF) can be calculated. This flood was investigated as part of the Georges River Flood Study [PWD, 1991], however the results of the analysis appear to have been largely overlooked. With the release of the 2001 Floodplain Management Manual, the State Government has recognised the importance of considering such extreme floods. Consequently, there is now a greater obligation on all Councils to consider what might happen in such an extreme flood.

To illustrate the magnitude of the PMF in relation to the 100 year flood and other floods experienced by some residents, these levels are shown relative to a typical house located in Newbridge Road at Moorebank. The watermark left from the 1986 flood can be clearly seen on this two-storey house, at a level that would inundate the upper floor. The 100 year flood is higher, and the PMF is about 4m higher yet again, well over the roof of most two storey houses in this locality.

The topography of the Georges River is fairly unique, in that the river downstream of East Hills is confined to a narrow gorge. This acts as a restriction during very large floods, and consequently there is a wide range in flood levels between the 100 year flood and larger floods. Unlike other most other flood prone communities where the difference can be as little as one metre, the difference on the Georges River can be as much as five metres.

This has significant consequences for development that is located just above the 100 year flood, which is the traditional flood planning level that has been adopted by many councils in New South Wales. For example, almost the entire suburb of Chipping Norton has been built on land that is just above the 100 year flood level (see photo 6). An extreme flood would result in widespread inundation of this area, and other areas along the Georges River. Over 5,200 homes are likely to be flooded in such an event.

The magnitude of the flood problem on the Georges River puts greater emphasis on the need to maximise the use of flood warning in the catchment, and the ability of emergency personnel and the community to effectively respond to such warnings. Community awareness of the risks of flooding is also an important consideration, particularly for those residents who are just above the 100 year flood, and mistakenly interpret this to mean they are free from the risk of flooding.

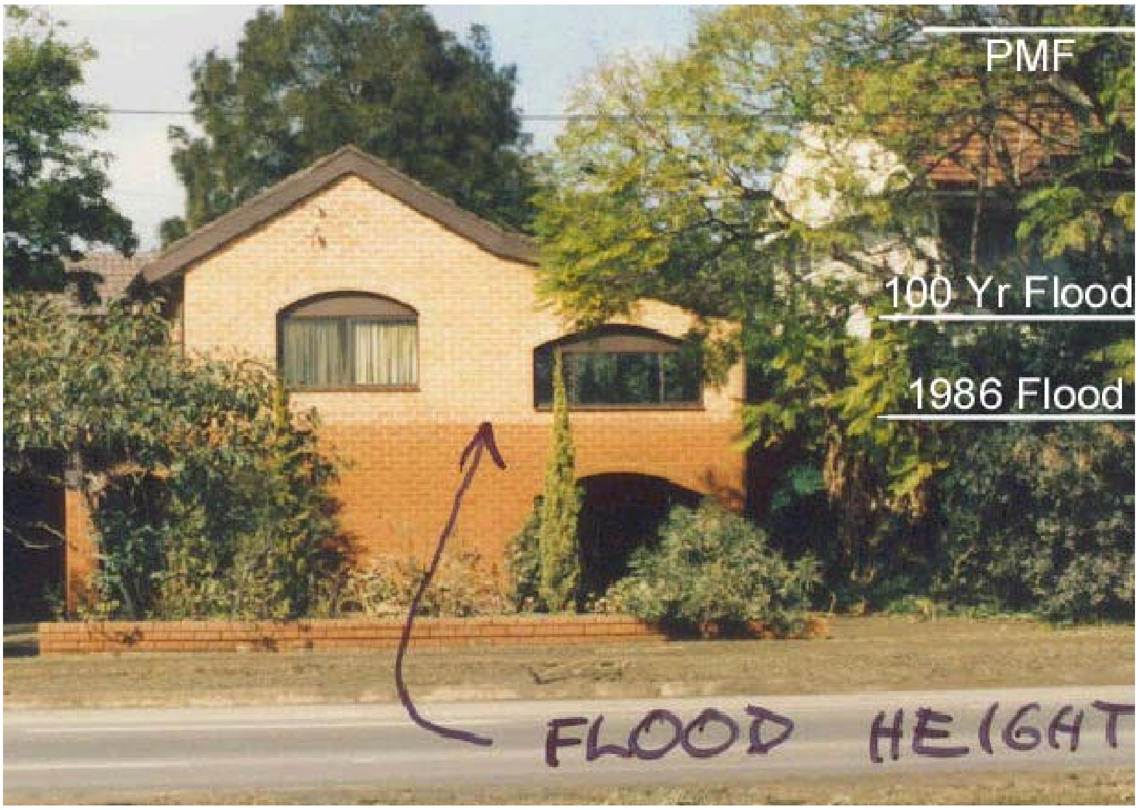

Photo 5 – The range in flood levels for many houses in Moorebank

Photo 6 – Chipping Norton in the 1986 flood

5.5 ROAD INUNDATION PROBLEMS

An appreciation of where and when roads are cut by floodwaters is an important issue for residents in the Georges River catchment. Residents that are directly affected by flooding may need to evacuate their homes. Other people may be indirectly affected by flooding where road closures restrict them from travelling to or from work, or other destinations. Road access is also an important issue for the planning of emergency management operations in response to flooding.

Flooding along the major arterial roads through the study area has been investigated as part of this study. This includes an assessment of potential problem areas along:

- The Hume Highway;
- Newbridge Road;
- Milperra Road; and
- Henry Lawson Drive.

The road inundation assessment is based on a variety of available survey data. Spot levels along the Hume Highway (Prospect Creek), Newbridge Road and Milperra Road were obtained as part of the Georges River Flood Study [PWD, 1991]. Contours at 0.25m intervals were available for the Hume Highway at Cabramatta Creek from the Cabramatta Creek Floodplain Management Study [Bewsher Consulting 1999]. Other data along Henry Lawson Drive was based on Bankstown Council's survey of road pits.

Heathcote Road is also recognised as a major arterial road, which is potentially cut by floodwaters at Harris Creek, Williams Creek and Deadmans Creek. However, there is insufficient survey data to assess the level of overtopping. Further survey and review of flood conditions at these locations may therefore be warranted.

A map of the study area showing the major arterial roads and locations potentially affected by flooding is shown on **Figure 5.2**. Long section plots for nine potential problem areas are also shown on **Figures 5.3** and **5.4**. These problem areas are briefly discussed below.

5.5.1 Hume Highway at Prospect Creek

The Hume Highway is potentially cut by floodwaters on the southern side of the Lansdowne Bridge, on Prospect Creek. The road is first inundated at about the 20 year flood level. The highway would be inundated in the 100 year flood over a length of some 330m, with a maximum depth of about 0.9m. At this level the road would be impassable by most vehicles. The bridge itself is above the 100 year flood, but could be affected in more extreme floods.

5.5.2 Hume Highway at Cabramatta Creek

Flooding problems are greater on the Hume Highway near the Cabramatta Creek crossing. The highway is inundated well before the 20 year flood at three different locations on either side of the bridge. The depth of inundation in the 20 year flood is approximately 0.6m, which would be impassable by normal vehicular traffic.

Inundation depths increase to 1.5m in the 100 year flood, with the road and bridge inundated over a distance of 1km.

5.5.3 Newbridge Road at Liverpool

The bridge over the Georges River at Liverpool is high and not affected by flooding. Newbridge Road drops down from the bridge in an easterly direction, and is first inundated by floodwater some 600m to the east of the bridge. The depth of inundation in the 20 year flood is estimated to be 0.8m, making it impassable to most vehicles. Inundation depths increase to 1.7m in the 100 year flood, with the road being inundated over a length of about 450m.

5.5.4 Newbridge Road/Milperra Road

Newbridge Road is also severely affected by flooding on the western side of Milperra Bridge, on the Liverpool side of the river. The worst affected area is approximately 1km west of the bridge, where the road is as low as 2.0m AHD. Inundation can be anticipated at this location and the road will be impassable to most vehicles on a very frequent basis. The 20 year flood results in a maximum inundation depth of 2.8m and extends over a distance of 1.4km to the west of Milperra Bridge. Inundation depths increase to 3.8m in the 100 year flood.

Major problems also occur on the Bankstown side of the river on Milperra Road, adjacent to Bankstown airport. The road is inundated by at least 0.9m in the 20 year flood, and also inundated over a length of 1.4km. Inundation depths increase to 1.9m in the 100 year flood.

Milperra Bridge effectively becomes an Island in relatively frequent floods. The bridge itself is above the 100 year flood, but can be inundated during more extreme floods.

5.5.5 Henry Lawson Drive

Henry Lawson Drive is potentially cut by floodwaters at a number of locations. The road can be cut in at least three different locations between Milperra Road and the Hume Highway. The timing and depth of inundation is similar at the three locations. Inundation depths of 1.4 to 1.5m can be anticipated for the 20 year flood, with depths increasing by a further 1m during the 100 year flood.

The road is also cut at various locations to the south of Milperra Road. The worst affected area is adjacent to the Kelso Creek levee, where inundation depths can be as great as 2.0m in the 20 year flood, and 3.0m in the 100 year flood.

5.6 OTHER FLOODING CHARACTERISTICS

The duration of flooding and the rate at which floodwaters can be expected to rise are also important characteristics of flood behaviour. However, it is important to realise that not all floods will behave in the same manner, and whilst some floods may rise rapidly, or persist over a long duration, other floods may behave differently.

In order to gain an appreciation of the likely range of these characteristics, plots of flood height versus time have been prepared at Liverpool and Milperra for the 100 year flood, and for the 1986, 1988 and 1996 floods. These plots are illustrated on **Figure 5.5**, with additional details provided in **Tables 5.6** and **5.7**.

TABLE 5.6
Flooding Characteristics at Liverpool Weir

Flood Event	Max Rate of Rise (m/hr) (based on 3 hr period)	Duration of Flooding (Hours)	
		(Above RL 6.0m AHD)	(Above RL 7.0m AHD)
100 Year	0.8	16	13
August 1986	0.3	22	7
April 1988	0.4	13	5
August 1996	0.6	n/a	n/a

TABLE 5.7
Flooding Characteristics at Milperra Bridge

Flood Event	Max Rate of Rise (m/hr) (based on 3 hr period)	Duration of Flooding (Hours)	
		(Above RL 3.0m AHD)	(Above RL 4.0m AHD)
100 Year	0.5	23	16
August 1986	0.3	31	17
April 1988	0.3	20	12
August 1996	0.3	n/a	n/a

The 1996 flood was a fairly small flood, but has been included because the rate of rise for this flood was quite rapid. If the flood had continue to rise at the rate in which it commenced for another 6-7 hours, then the flood would have been similar to the 100 year flood (at Liverpool). This flood would then have become a major event, rather than just a nuisance flood.

The maximum rate of rise of floodwater at Liverpool has varied between 0.3m/hour to 0.6m/hour for the three historical floods, and 0.8m/hour for the 100 year flood. The rate of rise at Milperra Bridge (and elsewhere downstream) is generally slower, at 0.3m/hour for the three historic floods and 0.5m/hour for the 100 year flood. For planning purposes, a rate of rise of 0.5m/hour would appear to be an appropriate value to adopt for the majority of the river.

The duration of flooding was based on the time that a particular flood height was exceeded. Two levels were chosen for this assessment, a relatively low level where only minor flood conditions are expected, and a higher level where more significant flooding problems are anticipated. The results indicate that the duration of flooding generally increases between Liverpool and Milperra. Minor flooding can persist for up to 31 hours (based on the 1986 flood), but significant flooding is more likely to be limited to less than 20 hours.

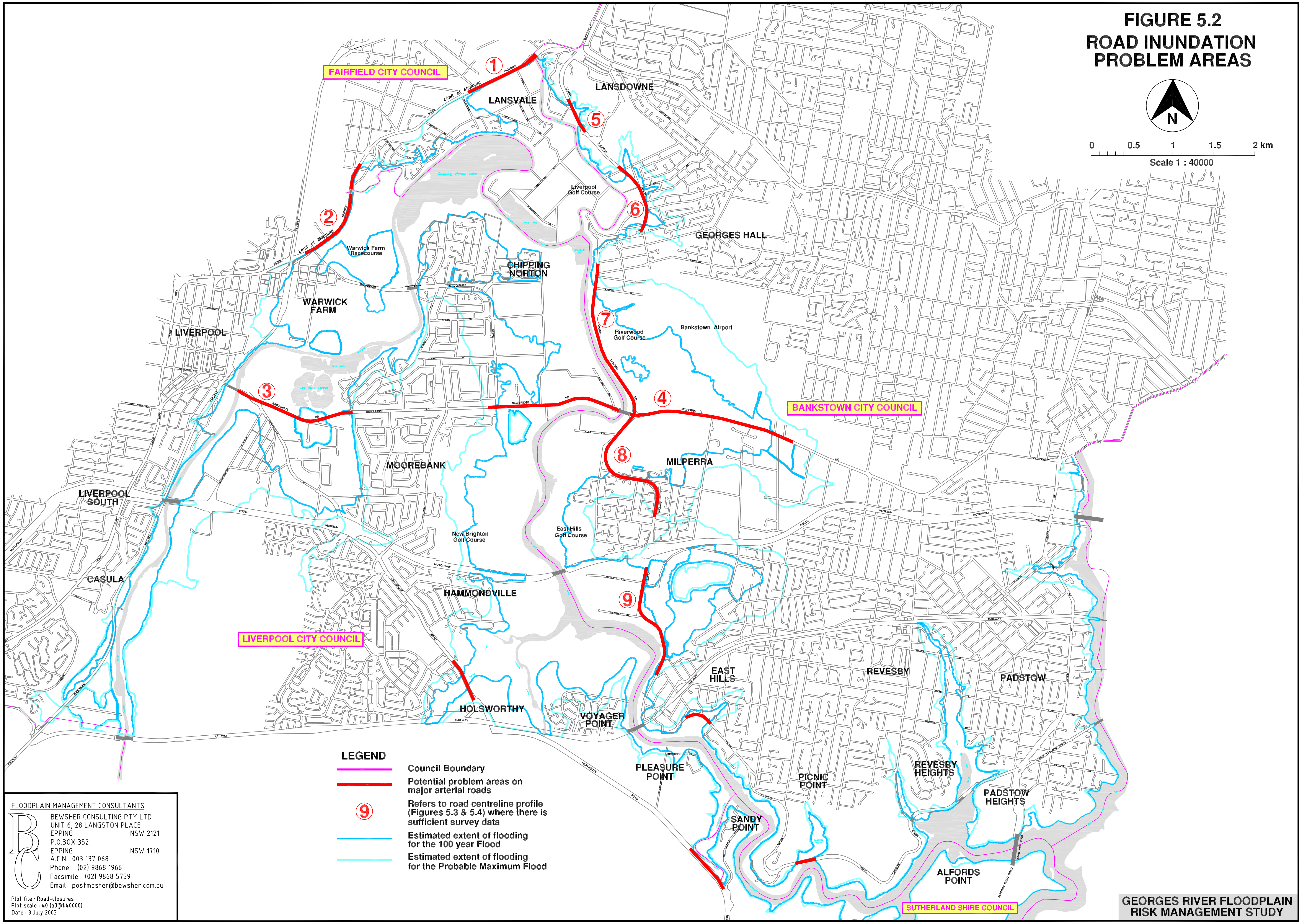
FIGURE 5.2
ROAD INUNDATION PROBLEM AREAS
N
0 0.5 1 1.5 2 km
Scale 1 : 40000
FAIRFIELD CITY COUNCIL
BANKSTOWN CITY COUNCIL
LIVERPOOL CITY COUNCIL
SUTHERLAND SHIRE COUNCIL
LANSVALE
LANSDOWNE
Liverpool Golf Course
GEORGES HALL
Warwick Farm Racecourse
CHIPPING NORTON
WARWICK FARM
LIVERPOOL
Riverwood Golf Course
Bankstown Airport
MOOREBANK
MILPERRA
LIVERPOOL SOUTH
New Brighton Golf Course
East Hills Golf Course
CASULA
HAMMONDVILLE
EAST HILLS
REVESBY
PADSTOW
HOLSWORTHY
VOYAGER POINT
PLEASURE POINT
PICNIC POINT
REVESBY HEIGHTS
PADSTOW HEIGHTS
SANDY POINT
ALFORDS POINT
Limit of Mapping
1
2
3
4
5
6
7
8
9
LEGEND
Council Boundary
Potential problem areas on major arterial roads
9 Refers to road centreline profile (Figures 5.3 & 5.4) where there is sufficient survey data
Estimated extent of flooding for the 100 year Flood
Estimated extent of flooding for the Probable Maximum Flood
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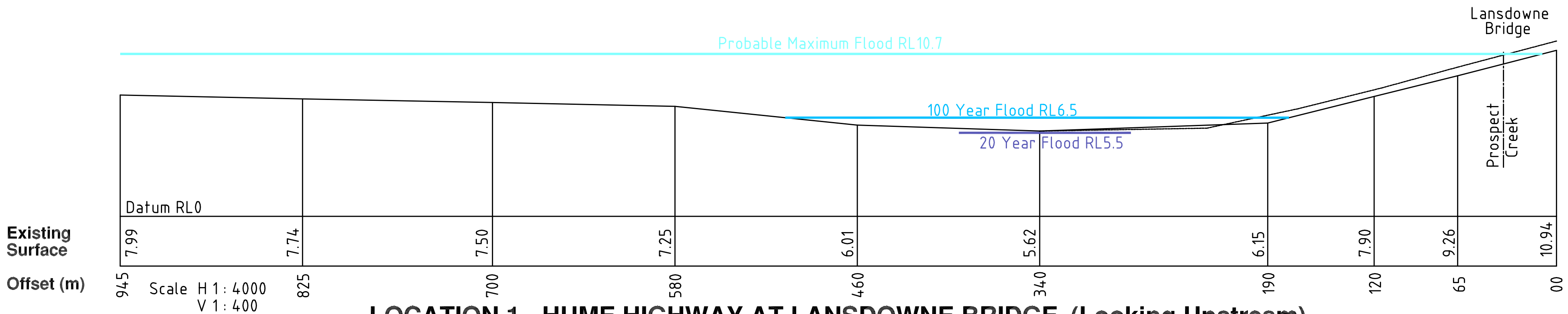
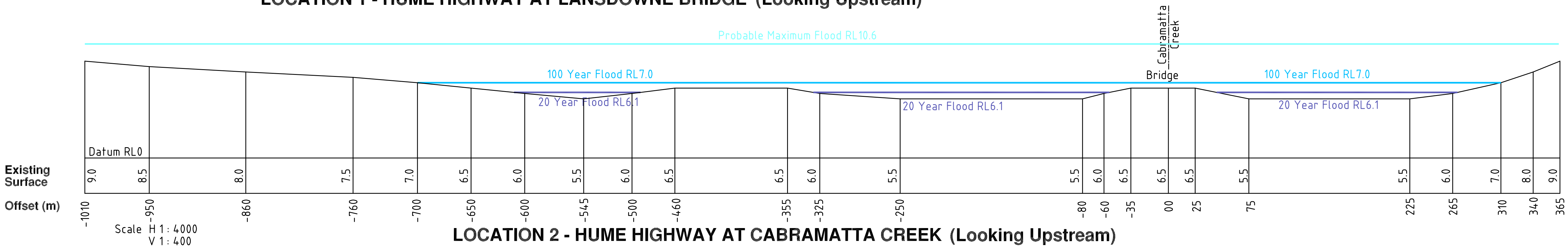
Plot file : Road-closures
Plot scale : 40 (a3@1:40000)
Date : 3 July 2003
GEORGES RIVER FLOODPLAIN
RISK MANAGEMENT STUDY

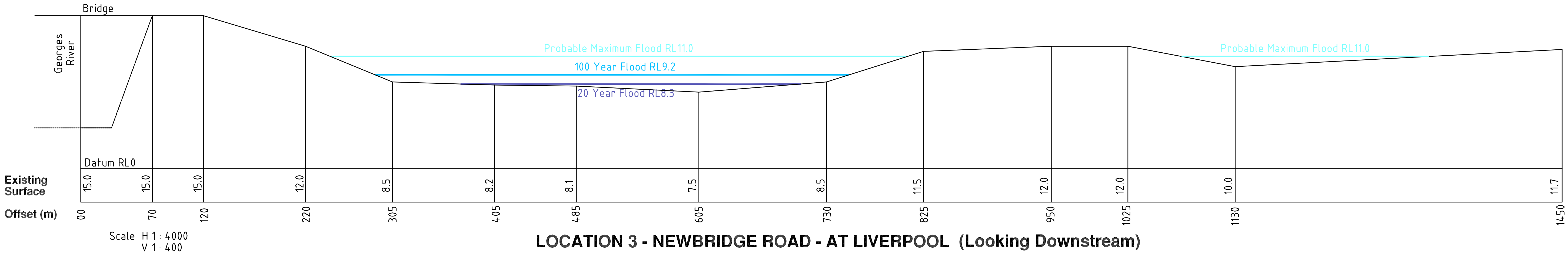
FIGURE 5.3
ROAD INUNDATION CENTRELINE PROFILES
(Sheet 1 of 2)



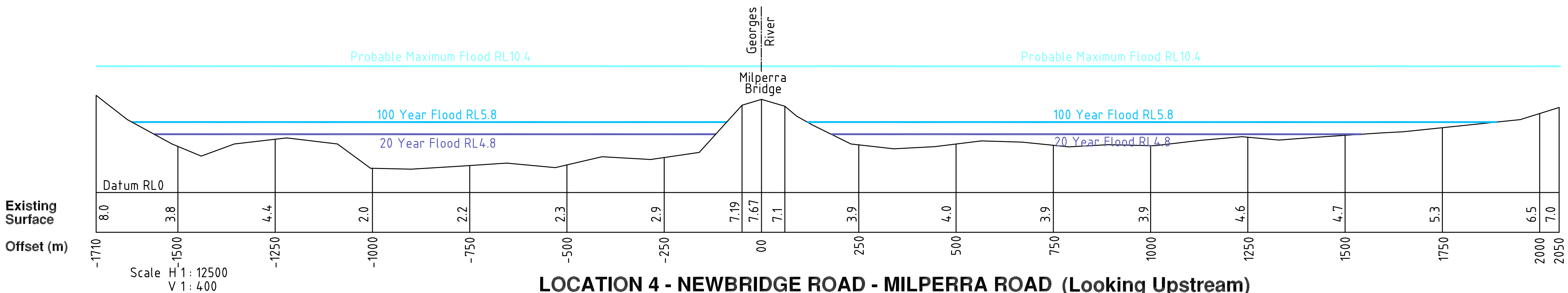
LOCATION 1 - HUME HIGHWAY AT LANSDOWNE BRIDGE (Looking Upstream)



LOCATION 2 - HUME HIGHWAY AT CABRAMATTA CREEK (Looking Upstream)



LOCATION 3 - NEWBRIDGE ROAD - AT LIVERPOOL (Looking Downstream)



LOCATION 4 - NEWBRIDGE ROAD - MILPERRA ROAD (Looking Upstream)

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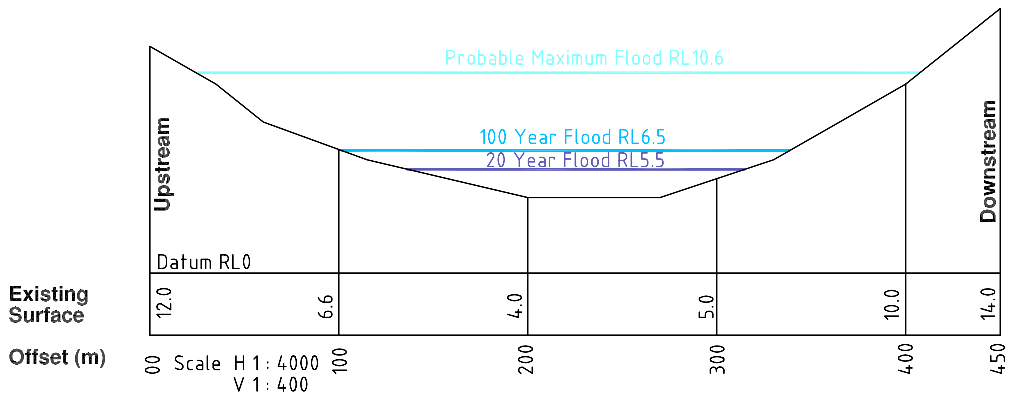
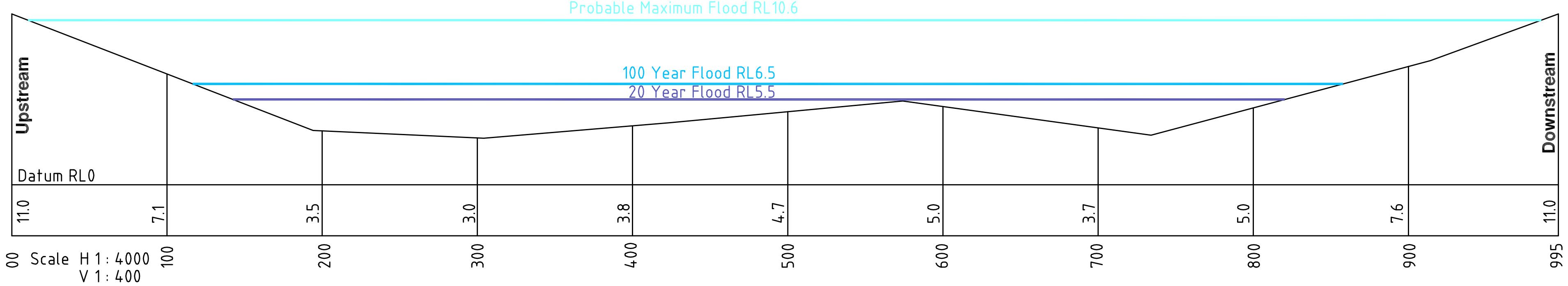
Plot file : J1046-fig5.3
Plot scale : 40 (a3@1:40000)
Date : 5 May 2004

Notes :
1. Refer to Figure 5.2 for locations
2. Profiles are viewed as indicated
3. All levels to Australian Height Datum (AHD)

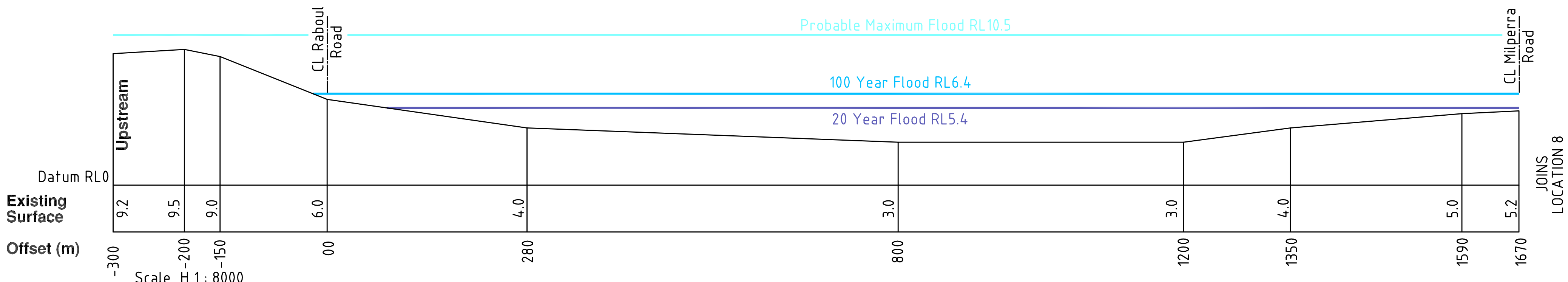
FIGURE 5.4
ROAD INUNDATION CENTRELINE PROFILES
(Sheet 2 of 2)



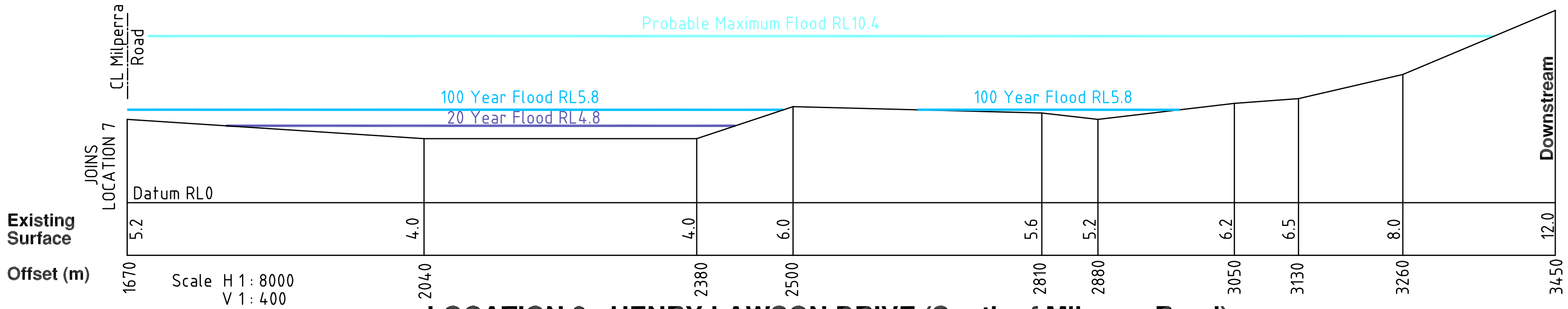
LOCATION 5 - HENRY LAWSON DRIVE



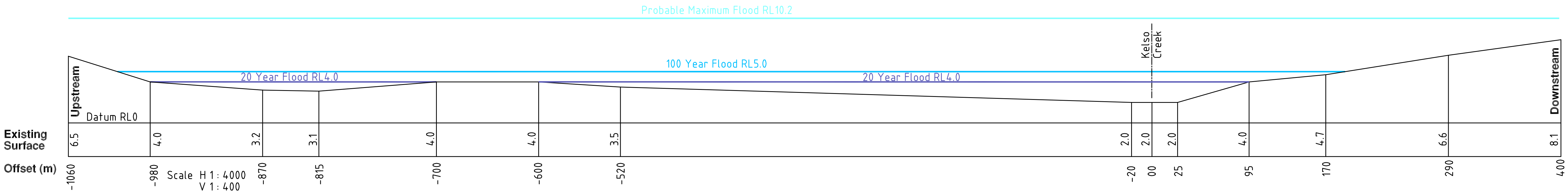
LOCATION 6 - HENRY LAWSON DRIVE



LOCATION 7 - HENRY LAWSON DRIVE (North of Milperra Road)



LOCATION 8 - HENRY LAWSON DRIVE (South of Milperra Road)



LOCATION 9 - HENRY LAWSON DRIVE - KELSO LEVEE

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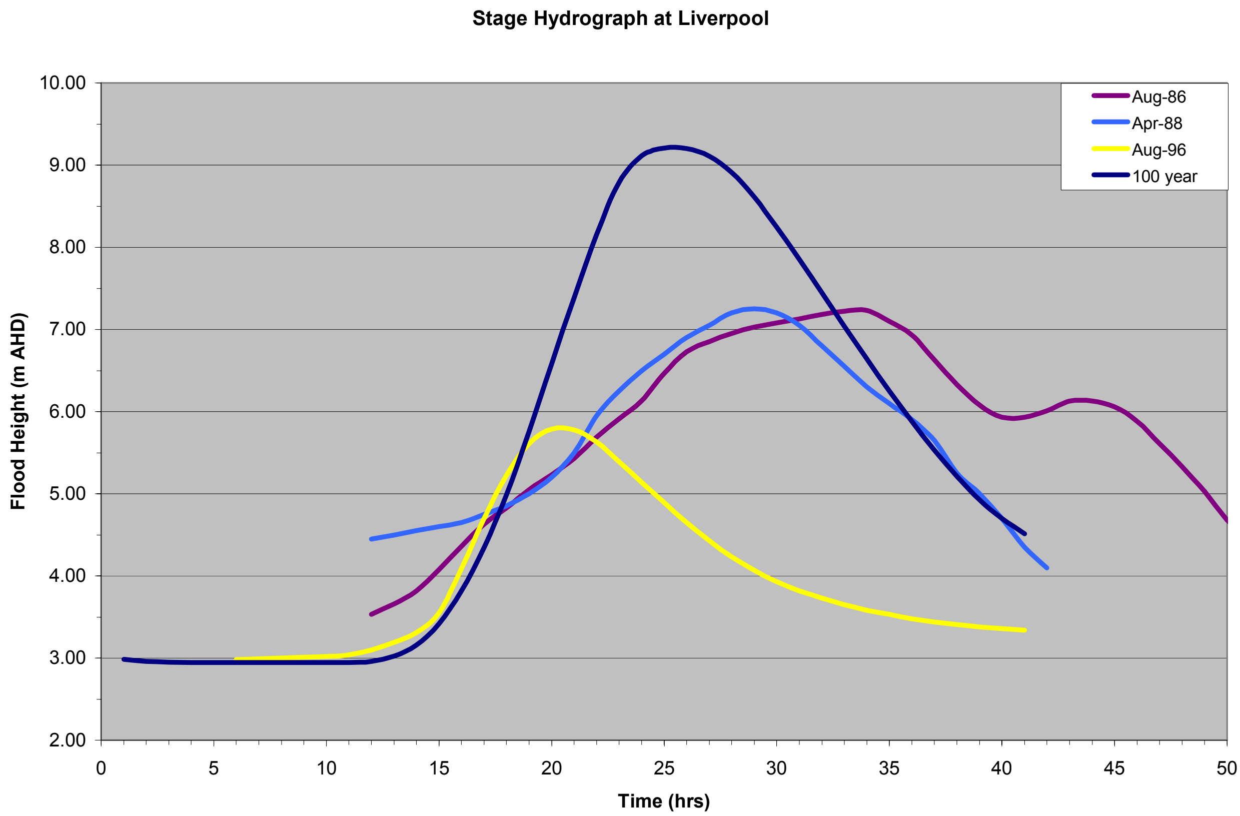
Plot file : J1046-fig5.4
Plot scale : 40 (a3@1:40000)
Date : 5 May 2004

Notes :
1. Refer to Figure 5.2 for locations
2. Profiles are viewed as indicated
3. All levels to Australian Height Datum (AHD)



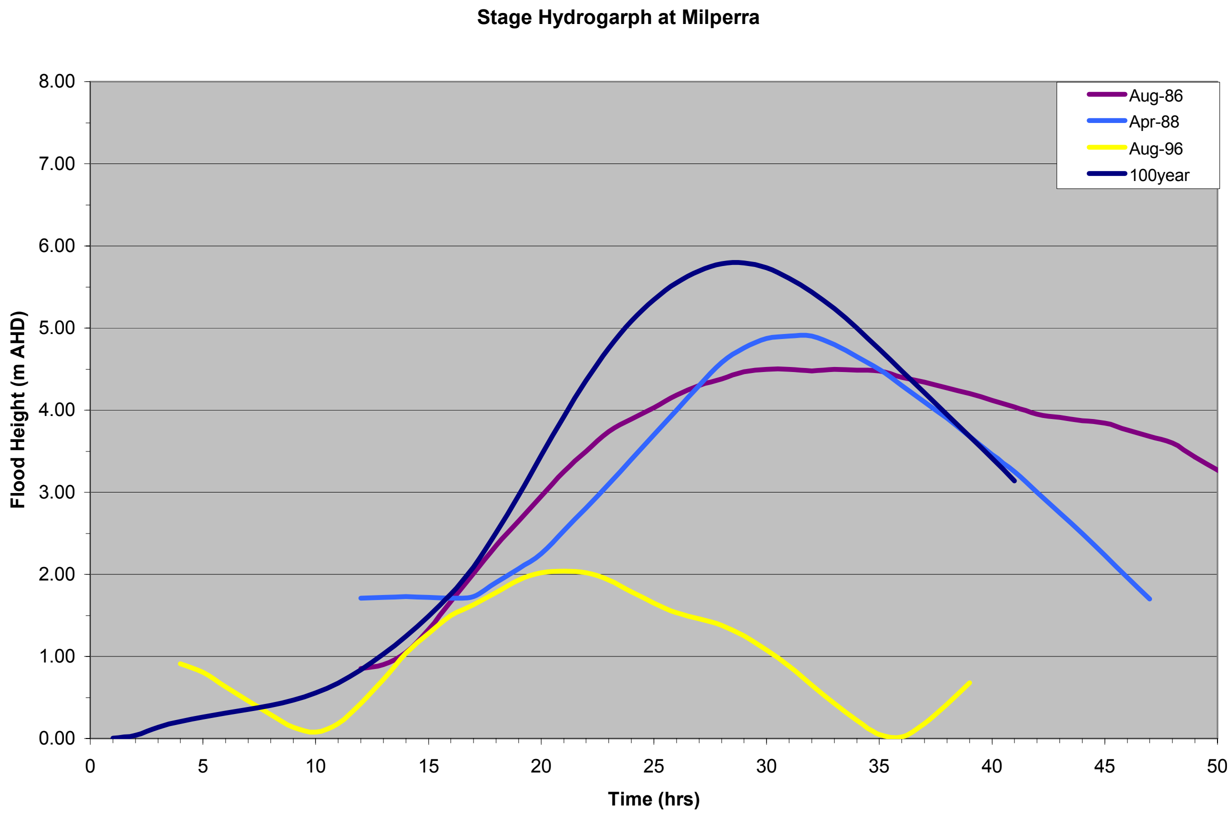


FIGURE 5.5
FLOOD HYDROGRAPHS AT LIVERPOOL AND MILPERRA

6. FLOOD DAMAGES ASSESSMENT

6.1 FLOOD DAMAGES DATABASE

A flood damages database has been established for this study to quantify the economic impacts of flooding in the Georges River study area, and to allow an economic appraisal of potential floodplain management measures.

6.1.1 Property within the Database

The flood damages database contains details of those properties that are potentially affected by flooding up to the probable maximum flood (PMF). Properties within the database were identified using flood level estimates for the PMF from the Georges River Model Study (Bewsher Consulting, 1998), which was updated as part of the current floodplain management study. Property details were then extracted for this region using Council's computerised geographical information system (GIS) and rates database.

There are some 8,800 properties included in the database. These have been divided into four separate council areas. Each Council area was then further subdivided into a number of sub-areas, as shown in **Table 6.1**.

TABLE 6.1
PROPERTIES INCLUDED IN THE DATABASE

Area	Total Properties (including vacant lots)		
	Residential	**Industrial/ Commercial**	**Total**
Liverpool City Council Area			
Upstream of Newbridge Road at Liverpool	716	196	912
Newbridge Road to Governor Macquarie Drive	438	23	461
Governor Macquarie Drive to M5 Bridge	1,508	92	1,600
Downstream of M5 Bridge	560	10	570
TOTAL	*3,222*	*321*	*3,543*
Fairfield City Council			
TOTAL	*714*	*111*	*825*
Bankstown City Council Area			
North of Milperra Road	762	100	862
South of Milperra Road	2,041	302	2,343
Kelso Levee area	756	9	765
TOTAL	*3,559*	*411*	*3,970*
Sutherland Shire Council Area [1]			
Sandy Point Area	199	1	200
Illawong Area	285	1	286
TOTAL	*484*	*2*	*486*
TOTAL	**7,979**	**845**	**8,824**

1. Sutherland Shire data includes a number of steeply sloping properties with buildings located above the PMF flood level.

6.1.2 Ground and Floor Level Estimates

Representative ground levels and floor levels (where buildings are present) were assigned to each property in the database.

Where available, actual floor and ground level survey data has been used. Survey data was available from various sources that have been collected over a number of years from previous investigations. Recent building and development applications also contained some additional ground and floor level data. Actual survey data was available for about 9% of buildings within the flood damages database.

Where there was no survey data, floor and ground levels were estimated from a digital terrain model, developed by Bewsher Consulting using available topographic and other survey data. Ground levels were extracted from the terrain model at the 'tag point' of each property (usually the centre of the property). Floor levels were then estimated by adding an average 'height above ground' level of 0.5m to the ground level estimates. This value was determined from a correlation of surveyed floor levels (where available) and ground level estimates.

6.1.3 Flood Level Estimates for Flood Damage Assessment

Flood level estimates from the MIKE-11 model were determined at the tag point location for every property within the database. Estimates were provided for the 20 year, 100 year and PMF floods.

It is important to note that the MIKE-11 model results are an approximation only (within about 0.2m for the 100 year flood) of the design flood levels that have previously been adopted by each of the four Councils. The MIKE-11 results are appropriate for use with flood damage estimates, but should <u>not</u> be used when specifying minimum floor levels or related development controls. Reference should always be made to the flood level results in the adopted flood study reports (eg Upper Georges River Flood Study, Georges River Flood Study, Cabramatta Creek Flood Study, Lower Prospect Creek Flood Study, Little Salt Pan Creek Flood Study, Salt Pan Creek Flood Study and Deadmans Creek Flood Study).

6.1.4 Output from the Flood Damages Database

The database provides the following information:

- which properties are subject to flooding over the range of floods considered;
- the depth of inundation above floor level for each property subject to inundation;
- the provisional flood hazard (subject to site conditions) for each property, based on depth of inundation and velocity of floodwaters in a 100 year flood; and
- the potential flood damage for each property in the database for existing or proposed flood conditions.

The database also allows quantification of flood damages and identification of problem areas within different parts of the study area. It also allows quantification of economic flood benefits of measures that lower flood levels in the study area.

Copies of the database have been provided to each Council.

6.2 TYPES OF FLOOD DAMAGE

The definitions and methodology used in estimating flood damage have been established by a number of previous investigations. **Figure 6.1** summarises all the types of flood damages examined in this study. The two main categories are 'tangible' and 'intangible' damages. Tangible flood damages are those that can be more readily evaluated in monetary terms, while intangible damages relate to the social cost of flooding and therefore are much more difficult to quantify.

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

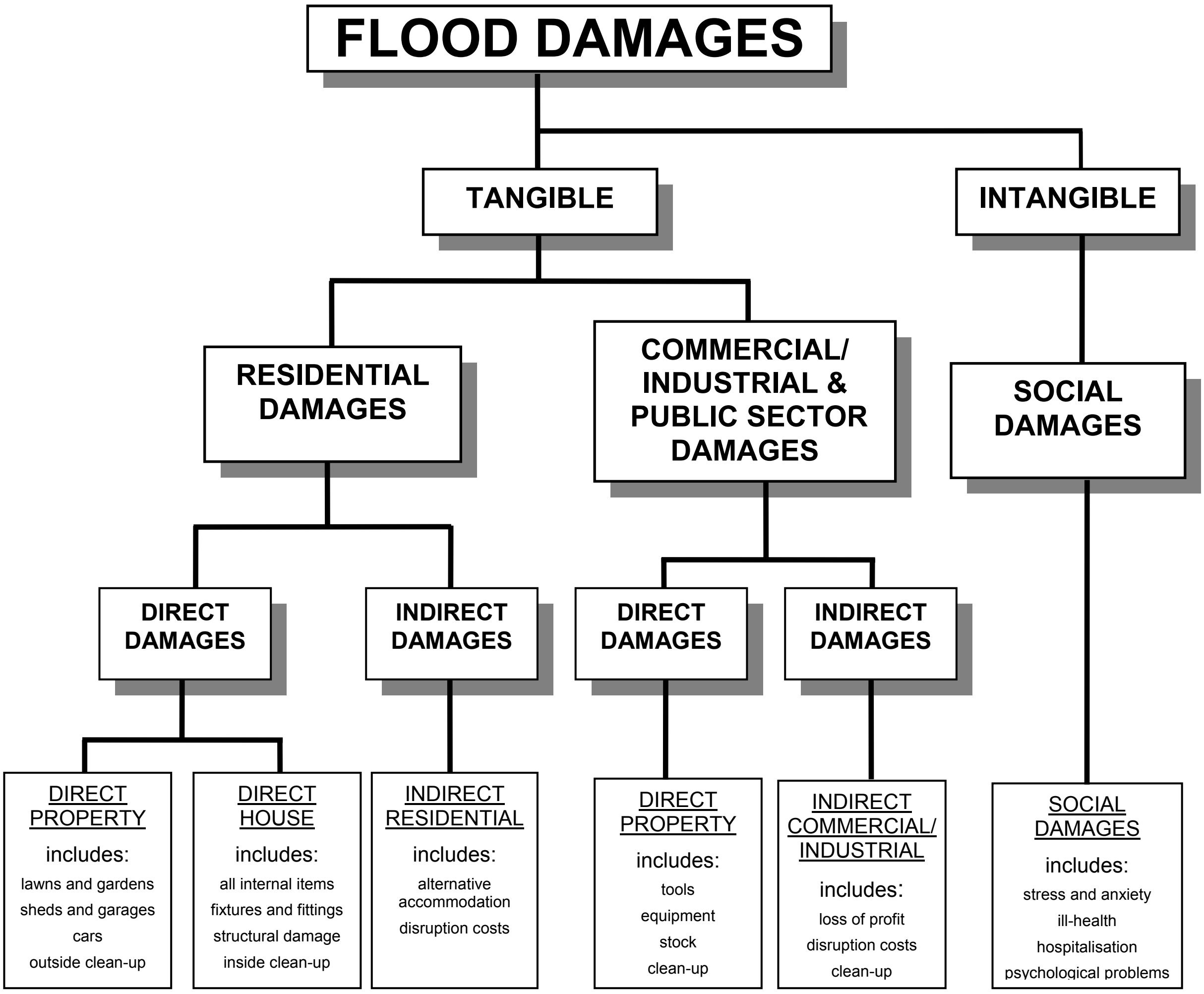


FIGURE 6.1
TYPES OF FLOOD DAMAGE

6.3 BASIS OF FLOOD DAMAGE CALCULATIONS

Potential flood damages have been calculated by applying a number of stage-damage curves to every property included in the database. These curves relate the amount of flood damage that would potentially occur at different depths of inundation, for a particular property type.

Predicted flood damages have then been estimated by reducing the potential flood damage to allow for damage reduction measures that are likely to be taken during an actual flood. This will depend on the effective flood warning time and the flood awareness of the community.

The stage-damage curves for the Georges River have been based on specific consideration of the types of development within the catchment, information available from previous investigations, and flood damage surveys undertaken following major floods in Coffs Harbour (1996); Inverell (1991); Forbes (1990); Nyngan (1990); and the Georges River (1986). The damage estimates also include a multiplier of two, to allow for anticipated under valuing of some insurable loss data in these studies (based on advice from the then DLWC in 2001). All estimates have been updated to reflect current values.

Different stage damage curves for direct property damage have been derived for:

- residential dwellings (categorised into small, typical or raised categories);
- commercial premises (categorised into low, medium or high damage categories);
- industrial premises (categorised into low, medium or high damage categories).

The database also accounts for other flood damage components, including:

- indirect residential, commercial and industrial damages, taken as a percentage of the direct damages;
- infrastructure damage, based on a percentage of the total value of residential and business flood damage; and
- intangible or social damages, based on an average cost per flood affected household.

All stage damage curves and other economic assumptions are included in a full listing of the flood damages database, which has been provided to each Council.

6.4 SUMMARY OF FLOOD DAMAGES

'Average annual damage' (AAD) and 'present value' are financial terms that are often used in the economic appraisal of flood damages and flood mitigation measures. The AAD is a measure of the cost of flood damage that could be expected each year, on average, by the community. The present value of flood damage is usually calculated to allow a direct comparison with the capital and on-going costs of proposed flood mitigation measures. This has been determined on the basis of a 7% discount rate and an expected life of 20 years, in accordance with guidelines provided by the NSW Treasury.

Flood damage calculations for each area have been determined from the flood damages database. The different components of flood damage in the Georges River study area is illustrated on **Figure 6.2**, whilst **Table 6.2** summarises the predicted flood damages.

The following key points are relevant from these results:

- Components of expected average annual flood damages within the study area are estimated as:

- Direct House Damage	$ 2,981,000	(31%)
- Direct Property Damage	$ 793,000	(10%)
- Indirect Residential Damage	$ 188,000	(3%)
- Direct Industrial & Commercial	$ 1,373,000	(17%)
- Indirect Industrial & Commercial	$ 754,000	(9%)
- Infrastructure & Public Sector Damage	$ 1,828,000	(22%)
- Social Damages	$ 289,000	(4%)
- TOTAL	$ 8,200,000	

- Flood damage (average annual damage) is distributed within the study area as follows:

Liverpool City Council Area	$3.8M
Fairfield City Council Area	$1.6M
Bankstown City Council Area	$2.7M
Sutherland Shire Council Area	$0.1M
	$8.2M

- The present value of expected flood damages within the study area is estimated at $91M.

- The total expected flood damage estimated to occur in a 100 year flood is $99M;

The flood damages database provides a valuable tool for assessing the economic merits of various flood mitigation options that may be considered for the Georges River. Flood level estimates within the flood damages database can be readily updated to reflect new conditions arising from proposed flood mitigation measures. The flood damages are then recalculated and the savings in flood damages can be calculated.

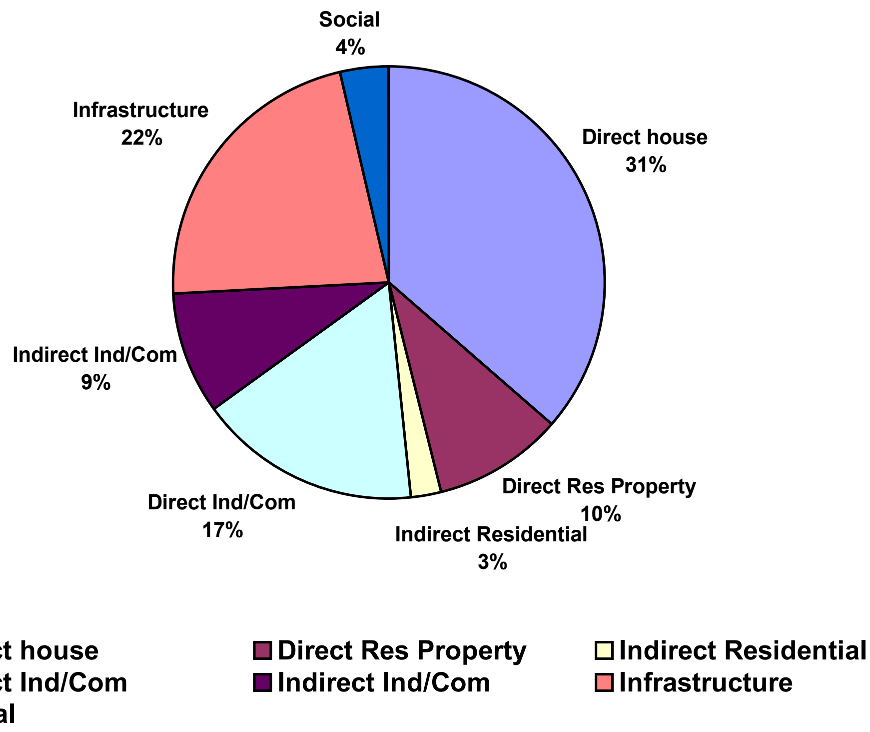


FIGURE 6.2
COMPONENTS OF FLOOD DAMAGE FOR THE GEORGES RIVER (AVERAGE ANNUAL DAMAGE)

TABLE 6.2
Predicted Total Flood Damages under Existing Conditions

Location	**Damage in Flood Event ($)**			**Average Annual Damage**	**Present Value of Damage**
	20 Year	100 Year	PMF		
Liverpool City Council Area					
Upstream of Newbridge Rd at Liverpool	4,020,000	26,250,000	121,950,000	1,450,000	15,940,000
Newbridge Rd to Governor Macquarie Dr	450,000	2,960,000	41,600,000	300,000	3,270,000
Governor Macquarie Dr to M5 Bridge	5,430,000	15,570,000	194,710,000	1,670,000	18,390,000
Downstream of M5 Bridge	860,000	2,970,000	49,620,000	370,000	4,060,000
TOTAL	10,760,000	47,750,000	407,870,000	3,790,000	41,660,000
Fairfield City Council					
TOTAL	8,910,000	22,420,000	104,830,000	1,590,000	18,010,000
Bankstown City Council Area					
North of Milperra Rd	2,740,000	5,740,000	50,090,000	550,000	6,150,000
South of Milperra Rd	5,870,000	20,990,000	187,280,000	1,780,000	19,580,000
Kelso Levee area	60,000	1,170,000	72,940,000	400,000	4,240,000
TOTAL	8,660,000	27,890,000	310,300,000	2,720,000	29,940,000
Sutherland Shire Council Area					
Sandy Point Area	360,000	930,000	3,750,000	60,000	710,000
Illawong Area	230,000	470,000	3,200,000	40,000	470,000
TOTAL	590,000	1,400,000	6,950,000	100,000	1,180,000
TOTAL	**28,920,000**	**99,460,000**	**829,950,000**	**8,200,000**	**90,790,000**