LIVERPOOL CITY COUNCIL

AUSTRAL FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

Review and Finalisation

September 2003

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Job No: NC812 File: P:\Perrens\NC812 –Austral\Docs\Austfpms.doc	Date Saved: 19-Sep-03 Revision No.: 5.0	Author: AAT Review: SJP

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EXECUTIVE SUMMARY

S1. SETTING THE SCENE

The Austral - Kemps Creek area faces a number of flood related problems which are unusual and arise from a number of natural and human imposed features of the area:

- Flooding is a natural feature of the Austral area.
- To date, changes in land use within the catchment do not appear to have led to changes in flood magnitude, although minor localised changes in flood flows have occurred as a result of filling of the land and diversion of minor watercourses.
- The area has relatively small natural channels and a wide floodplain. Typically, the channel capacity is only sufficient to carry floods of magnitude up to the flood which can be expected to occur once per year on average (ie has an average recurrence interval [ARI] of 1 year). When the flood exceeds the capacity of the channel the excess spreads over a wide floodplain as a relatively shallow, slow moving flow.
- Because of the carrying capacity of the wide floodplain, the difference in flood depth between a 5 year ARI flood and a 100 year ARI flood is relatively small and is generally of the order of 0.5 m.
- The wide floodplain covers a relatively large proportion of the Austral - Kemps Creek area and about 30% of the land (1,100 ha) is flood prone at the PMF (Probable Maximum Flood).
- About 450 ha of floodplain land acts as a floodway and conveys the majority of flood water.
- The original subdivision for the Austral area in 1887 was laid out as small rural landholdings of about 2 ha covering the whole area. The subdivision layout paid no attention to topography and drainage patterns and no land was reserved for drainage purposes, according to the usual practice at that time.
- While some land is in public ownership, the majority of the natural creek and floodplain system remains in private ownership.
- It appears from Council's files that residents have unrealistic expectations of the level of service which can be provided by rural drainage schemes. This has resulted in considerable pressure on council officers to deal with perceived flooding problems which are in fact part and parcel of the normal operation of the rural drainage system.

These features of the area provide conditions in which flooding is a regular problem for the residents, but the topography and land ownership patterns lead to a number of fundamental constraints on what Council or individuals can hope to achieve in the future. Consequently, there are limited opportunities to make improvements, and those which could be made would only achieve minor improvements in the impact of flooding on the community.

- The frequency, depth and velocity of flooding are such that there should be no further development in the floodway (450 ha) and all flood prone land should be subject to planning controls.
- Earlier proposals to channelise the trunk drainage system in the Austral - Kemps Creek area should not be considered further because of the problems such a scheme would create. In addition to the excessive cost, which is beyond the means of Council to fund, these problems would result in increased speed of flow of water through the area and would severely exacerbate flooding downstream of Elizabeth Drive. Such an effect is not socially acceptable. In addition, the creation of deep fast flowing channels would increase the flood hazard within the Austral area.

- The road system which has been developed within the Austral area is generally consistent with the rural nature of the area and the low population density. The road system has two features which are characteristic of rural roads but which cause concern to the community:
  - Frequent flooding of creek crossings which prevents access for a few hours during typical flood events.
  - Nuisance flooding associated with table drains.
- There are opportunities to marginally improve the flood capacity of some road culverts. Upgrading all roads and culverts to be flood free at greater than about a 5 year ARI flood is not practicable for hydraulic and cost reasons.
- Table drains on rural roads function differently to kerb and gutter drainage in an urban setting. In particular, table drains are provided to drain water from the road and discharge it back to the land. Table drains cannot be expected to provide sufficient capacity for through drainage. Given the proximity of urban areas with a fully integrated stormwater drainage system, many residents appear to have unrealistic expectations about the level of service which can be expected from rural roads.

Land within the Austral-Kemps Creek area is included within the South West Sector Core Area, which is currently being considered by the NSW Government for large scale development to house around 200,000 people. Investigations are currently being carried out regarding various issues including housing, infrastructure, services, employment opportunities, biodiversity values, conservation etc. Council will need to be aware of the implications of the South West Sector planning options for floodplain management, once the investigations have been completed. This study does not take into account any future landuse (re-zoning), however, the flood characteristics of the Austral area need to be taken account of in any planning undertaken for the South West Sector.

S2. HOW FLOODING AFFECTS THE COMMUNITY

The Floodplain Management Study included a significant effort to consult with the people of the community and to find out how they are affected by flooding and what they would like to be done. Consultation was carried out both in 1995 and 2003.

While major floods have the potential to cause significant damage to both residential and rural properties in the area, the most common concern was the nuisance and inconvenience caused by floods which cut roads. The community recognises that these floods do not persist for more than a few hours, but would like to have better flood free access throughout the area.

An assessment of the economic impact of flooding on the community indicates that there are a number of residential properties which would be damaged by floods as summarised in Table S2.1.

Table S2.1
Estimated Flood Damages in the Austral Area

Average Recurrence Interval of flood (years)	Number of residential properties damaged by flooding	Damage caused by flooding to all classes of properties ($)
1	21	630,000
5	50	1,845,000
20	82	3,645,000
100	102	8,365,000
PMF	173	17,785,000

The average annual damage caused by flooding in the Austral area is estimated to be about $1.8 million of which about 25% is attributable to losses from rural industries.

At various meetings in the course of the study the community was invited to contribute views about priorities for action. Further views were also sought from a workshop convened to consider matters which should be included in the Floodplain Management Plan. The issues, which were consistently considered to be of importance by the community, were that the Floodplain Management Plan should:

- provide safe transport access;
- be acceptable to, and meet the expectations of, the community;
- reduce damages and hazards.

The workshop expressed a clear preference for a plan of action which would produce immediate and progressive improvement and which minimised the costs to the residents.

Subsequent to the completion of the updating of the draft Floodplain Management Study in 2003, the community and relevant government agencies were given the opportunity to review the findings and recommendations of the study and provide feedback. Posters summarising the findings and recommendations were put on exhibition at a number of locations in the Council LGA, a brochure was made available and a public information session was held. The feedback received from the 2003 consultation program was incorporated in the final report.

S3. FLOOD RISK

In accordance with the requirements of the *Floodplain Management Manual* (NSW Government, 2001), this Plan identifies three broad categories of management actions:

1. Management of the existing flood risk faced by the existing development.
2. Management of future flood risk that might arise from new development or redevelopment of the existing housing stock.
3. Management of the continuing flood risk that remains after all floodplain management measures are implemented.

S3.1 Management of Existing Flood Risk

The management of existing flood risks is concerned with reducing flood impacts on the existing housing stock and community facilities.

S3.1.1 Flood Management and Drainage Improvement Measures

The applicability of a variety of floodplain management and drainage measures was reviewed for the study. The findings are given below:

S3.1.1.1 Stream Clearing and Stabilisation

Extensive stream clearing and stabilisation along the trunk drainage system is not a viable option for solving the area's flooding problems. However, clearing the creek in areas identified in the study will locally reduce flooding, improve the environment and are generally supported by the community. Council should consider a one-off scheme in a short reach of Bonds Creek downstream of Scalabrini Village, which could function as a demonstration project to promote appropriate riparian and vegetation management. A program of stream clearing and minor channel regrading in conjunction with a levee could be used to provide a high level of protection for this development. Currently, problems are experienced during even minor flood flows.

Some areas of the creek system are showing considerable erosion and bank stability problems, mainly in areas which have previously been excavated by Council to improve capacity. Examples are on Bonds Creek, particularly downstream of the Eighth Avenue culvert and on Scalabrini Creek, near Sixth Avenue. A program of extensive channel stabilisation along the length of the creek system would require re-battering the creek banks, erosion control structures and involves the acquisition of land. It would be expensive and difficult to implement. In the short term, it is recommended that stabilisation be confined to the area immediately downstream of Eighth Avenue, where there is a residence quite close to the eroding creek bank. An allowance of $180,000 should be made for this work.

S3.1.1.2 Culvert Upgrading

Reductions in flood levels achieved by upgrading culverts are quite localised. The main benefit of this measure is improved access during flood periods. Significant increases in the level of serviceability could be achieved by culvert upgrading at the locations shown on Table S3.1. They were also identified by the community as problem locations.

Table S3.1
Cost of Upgrading Culverts

Location	Hydraulic Capacity (ARI Years) Existing	Upgraded	Capital Cost $
Bonds Creek			
Fourth Ave	2	10	650,000
Eight Ave	2	5	525,000
Edmondson Ave	2	5	450,000
Tributary 2			
Edmondson Ave	2	7	175,000
Tributary 3			
Fifteenth Ave	2	100	175,000

Note: * Capacity limited by downstream channel.

Thirteenth Avenue on Tributary 2 was also identified as a problem location, but improvements at this location will also require channel improvements, as described in the next section.

S3.1.1.3 Channel Improvements

A major constraint on the feasibility of these schemes is the uncertainty of acquiring the land for their construction. It is to be noted here that Council's preference is to place acquired land into Drainage Reserves (or similar), so that beneficial multiple uses can be achieved; for example, parks or wetlands. Two locations where channel improvements, in conjunction with culvert upgrading, are economically viable (Section 5 of the Report) and would be supported by the community are given in Table S3.2 below:

Table S3.2
Cost of Channel Improvements

Location	Capacity ARI years	Capital Cost ($) 2002 values
Scalabrini Creek		
d/s Fifth Avenue	5	890,000
Tributary 2		
Near Twelfth and Fourth Avenues	100	1.35M

These schemes will reduce residential flooding as well as improving road access. In the case of the Scalabrini Creek scheme, flooding along Fourth Avenue will also be reduced thereby improving the serviceability of the road, in addition to reducing property damage by flooding. For the second scheme, a new channel is required to replace the ill-defined course of Tributary 2 along Twelfth Avenue. The proposed scheme will give a high level of protection against flooding at the intersection and is therefore quite expensive. Additional investigation is warranted to optimise its size. It is to be noted that the costs presented do not include land acquisition. At times these costs can affect the viability of a scheme.

S3.1.1.4 Scalabrini Village

This residential development is located on the left bank of Bonds Creek downstream of Fifth Avenue. The incidence of damaging flooding, which presently occurs at around 1 year ARI, could be reduced by the construction of a levee. A levee costing around $220,000 will protect the area up to 5 year ARI flood levels. Additional measures may be required to control interior drainage which will need to be temporarily stored behind the levee.

A higher levee will provide a greater level of protection but will require a detailed hydraulic investigation to ensure that flow patterns are not adversely affected and flood levels are not significantly increased. Some compensatory channel improvements may also be required.

Savings in the cost of the levee project may be realised by implementing a stream clearing project on Bonds Creek downstream of Fifth Avenue, as previously discussed.

An Evacuation Plan has been prepared by the operators of Scalabrini Village detailing the procedures to be followed in the event of flooding. Liaison with the local SES unit regarding the incorporation of this Plan into the overall Plan for the area is recommended.

S3.2 Management of Future Flood Risk

Management of future flood risk is concerned with ensuring that future development is not subject to unacceptable risk and that existing flood conditions are not exacerbated by unwise future development. The recommended floodplain planning measures are contained in several existing or proposed policy documents, as outlined below.

S3.2.1 Update LEP and Review Planning Documents

It is recommended that Liverpool LEP be updated to incorporate the definitions as proposed by Don Fox Planning (refer Appendix F) to ensure consistency with the Floodplain Management Manual (FMM) (2001). It is also recommended that all of Council's DCPs be reviewed to ensure consistency with the LEP and with the definitions from the FMM.

S3.2.2 Landfill and Earth Dams Policy

This policy has been developed by Council and has been reviewed and updated to integrate the planning requirements of Austral and other rural areas in Liverpool. The policy deals with landfill principally from the perspective of its impact on drainage and flooding. It also deals with some of the issues involved in siting and designing houses to reduce the likelihood of future flooding problems.

The objective of the policy is to prevent the exacerbation of flooding in rural areas through the conservation, as far as possible, of natural drainage paths and storages using controls on landfill. Proposals must meet a set of performance criteria, formulated to ensure landfill will not create adverse impacts on other people and properties, including:

- limits on areas of filling;
- prohibition of filling in floodways;
- restrictions on diversion of flow.

It is recommended that this draft policy be revised and formally adopted after amendment in line with the recommendations for alteration to definitions provided by Don Fox Planning.

S3.2.3 Austral Floodplain Management Study Draft Development Control Plan

This draft plan, once adopted, would reflect floodplain related planning controls applying to the Austral and Kemps Creek areas. A gradation of planning controls should be developed to apply to Council's three "flood risk zones" (low, medium and high) within the flood planning area. These controls should be integrated into a Planning Matrix (refer Table 5.2 in Report).

S3.2.4 Flood Related Line of Limitation

As a result of previous studies of the Austral-Kemps Creek area, there are some areas which have had flood-related Lines of Limitation placed on Section 88B of the Property Title. This is currently being enforced by Council through Council's Floodplain Management Plan (adopted December, 1987).

Under the proposed Planning Controls Matrix, the flood-related Line of Limitation will no longer be required to be enforced by Council as the matrix proposes variable controls across the floodplain. However, until such time as the Planning Controls Matrix is fully implemented by Council, the following process should apply:

- Any Development Application submitted to Council shall be assessed in accordance with the Planning Controls Matrix.
- The applicant, if they so wish, may apply at any time to extinguish the flood-related Lines of Limitation on their property at their own cost.

S3.2.5 Rural Land Use Management for Flood Prone Land

The Austral Floodplain Risk Management Study recommends that Council develop a set of recommended guidelines for rural activities on flood prone land. The objective of these guidelines will be to encourage rural landholders to undertake activities in a manner that seeks to minimise the losses in agricultural production and to agricultural facilities from flooding. The recommended guidelines would include recommended measures to:

- Allow passage of floodwaters through properties with minimal obstruction.
- Appropriate design of buildings to allow passage of floodwater (eg arrange greenhouses with long axis in direction of flow, "skirt" which can be lifted by flood).
- Location of key assets above flood levels.
- Erosion control measures.
- Flood awareness and planning.

S3.2.6 Creek and Floodplain Management

The Liverpool City Council Floodplain Management Committee (LCC FPMC) contains representatives from the Community, Relevant Agencies, Councillors and Council Officers and is responsible for the management of the Austral catchment. The primary ongoing task of this Committee in the Austral area is to promote joint management of the flood prone lands through such activities as:

- Promotion of appropriate land and vegetation management of the creek and floodplain;
- Provide a focus for Total Catchment Management and Rivercare activities, including the identification of projects and co-ordination of funding applications.
- Providing a channel for ongoing "seed" funding from Council to enable initial channel restoration or vegetation clearing projects to be undertaken.
- Providing a forum for ongoing dialogue between Council and the community for the exchange of information in order to reduce the apparent cynicism and mistrust which currently exists.

These tasks could be carried out in the Austral area by the FPMC itself or a sub-committee of the FPMC, as decided by the FPMC. It has been assumed that no additional funding would be required for this initiative.

S3.3 The Residual Flood Risk

Even if all flood mitigation options suggested in this study were implemented, there would still be a residual (continuing) risk associated with flooding at the PMF as the flood mitigation works recommended only address flood mitigation at the 1% AEP flood or less. The continuing flood risk is the risk to lives and property from the PMF, even after all possible flood mitigation works have been implemented.

The management of continuing flood risk is concerned with ensuring that impacts on the community are minimised in the event of floods larger than those used to designate planning controls such as FPLs. This will be achieved by the following actions:

S3.3.1 Flood Education and Readiness

It is recommended that Council undertake a flood education and awareness campaign in conjunction with SES. This would involve an initial campaign followed up every second year on an ongoing basis. It is estimated that such a campaign might cost around $5,000, with $5,000 every second year. As part of this campaign a Flood Information Leaflet should be prepared in conjunction with SES.

S3.3.2 Flood Warning and Response System

The times of rise of the streams in the Austral area are quite short and hence the potential warning time is limited to 2 to 3 hours on the main arms and less on the tributaries. Most of the residents work in areas remote from the catchment and therefore there is a problem with dissemination of the warning itself and promoting an adequate response which will result in a reduction in flood damages. Consequently, a formal flood warning system for the study area will have limited success in reducing flood damages and would not be economically justified.

However, it is recommended that Council, in conjunction with SES, commission an investigation into a simple warning system for the catchment. Such a review would include consultation with the Bureau of Meteorology. While sophisticated forecasting approaches may not be justified, there are cost effective methods of warning dissemination available which may be appropriate for the Austral area. Further research in this area should be included in the investigation into the warning scheme.

The State Emergency Service (SES) has prepared a draft (September 2001) Liverpool Local Flood Plan, which is a sub-plan of the Liverpool Local Disaster Plan. The draft plan has not yet been formally adopted. It is recommended that the SES should complete and further develop the Local Flood Plan, based on the information presented in the study, to include annexures dealing specifically with the Kemps Creek area. Additional elements would include a graded response plan and an evacuation plan.

The preparation of Flood Intelligence Cards, as recommended in Flood Warning: An Australian Guide (published by Emergency Management Australia, 1995) would be an appropriate activity in connection with developing this graded response plan.

S3.3.3 Recovery Planning

It is recommended that the Recovery Plan be reviewed to ensure it is adequate to deal with the recovery process in the Austral area.

Council should implement a procedure to ensure that data is collected after each flood event. This information should include:

- water information (levels, rates of rise an fall, velocities, areas inundated);
- details of damage;
- information which did or did not become available when needed during the flood;
- actions which were taken during the flood.

S3.3.4 Section 149 Certificates

It is recommended that Council ensures that, when required, 149(2) and 149(5) certificates be issued with the appropriate information attached for those properties within the floodplain (that is the area inundated during the PMF). It is recommended that Council review the advice provided with the certificates and, if necessary, adapt it to reflect the risks associated with the relevant flood risk zone as well as including the required planning controls based on the Flood Planning Matrix. It has been assumed that this task can be carried out in the course of normal Council work and that no additional budget would be required to complete it.

S3.4 Funding

Broad funding requirements for the recommended works and measures updated to 2002 values are given in Table S3.3 below, along with a priority ranking in the overall plan. These works, if carried out, would result in improved access via the road system during flooding and rectification of the worst problem areas. The community should not expect that the works would remove all flooding in the area.

S4. IMPLEMENTATION PROGRAM

The steps in progressing the floodplain management process from this point onwards are set out as follows:

- Council considers the Floodplain Management Committee's recommendations;
- Exhibit the draft Plan and Study Report and seek community comment;
- Consider public comment, modify the Plan if and as required and submit the final Plan to Council;
- Council adopts the Plan and submits an application for funding assistance to DIPNR;
- Council uses the Plan as a basis for input to South West Sector Planning;
- As funds become available from DIPNR and/or Council's own resources, construct the works and implement the measures in accordance with the established priorities.

The Plan should be regarded as a dynamic instrument requiring review and modification over time. The catalysts for change could include new flood events and experiences, legislative change, alterations in the availability of funding, reviews of the city planning strategies and importantly, the outcome of some of the studies proposed in this report as part of the Plan. In any event, a thorough review every five years is warranted to ensure the ongoing relevance of the Plan.

The action program for implementing the Plan is therefore:

- confirm the projects set out in the study and their priority ranking.
- carry out design studies for schemes, liaise with residents and implement projects according to priority and funding constraints.

Table S3.3
Funding Requirements for Recommended Works and Measures

Project	Rank	Cost ($)
A. Improve road access during flooding (all costs are capital costs, exclusive of land acquisition, where required)		
• Fourth Avenue culvert on Bonds Creek	13	650,000
• Fourth Avenue/Twelfth Avenue upgraded culverts and improved channel on Tributary 2 (also reduces property damage)	12	1,350,000
• Scalabrini Creek d/s Fifth Avenue improved channel and upgraded culvert. (improves access on Fourth Avenue and reduces property damage)	15	890,000
• Edmondson Avenue upgraded culvert on Tributary 2	11	175,000
• Eighth Avenue upgraded culvert on Bonds Creek	18	525,000
• Edmondson Avenue upgraded culvert on Bonds Creek	15	450,000
• Fifteenth Avenue upgraded culvert on Tributary 3	18	175,000
B. Stream clearing, vegetation management project	13	140,000
C. Bond Creek levee d/s Fifth Ave to protect Scalabrini Village	10	220,000
D. Stabilisation/bank protection Bonds Creek d/s Eighth Avenue	15	180,000
E. Planning Measures		
• Update LEP to incorporate definitions from FMM	1	Council Costs
• Review and update all DCPs to ensure consistency of definitions with LEP and FMM.	1	Council Costs
• Prepare and adopt Austral Floodplain Management Study Draft DCP (including Planning Matrix)	6	Council Costs
• Formally adopt the Landfill Policy	6	Council Costs
• Develop Rural Land Use Management for Flood Prone Land Guidelines	6	Council Costs
F. Response Modification Measures		
• Flood Education and Readiness Campaign	1	$5,000 (initially) +$5,000 (every 2nd yr)
• Flood Warning Scheme Investigation	1	$10,000
• Recovery Planning Review and Update	1	$5,000
• Section 149 Certificates Review	6	No additional budget required

Notes: (1) Projects with the same ranking indicate same weighted score in Table 6.1 in main document.

(2) Cost of land acquisition **not** included in the cost of structural works.

1. INTRODUCTION

1.1 Background

In 1995, Liverpool City Council (LCC) commissioned Lyall and Macoun Consulting Engineers (LMCE) to prepare a Drainage Study to investigate flooding and drainage matters in the Austral - Kemps Creek area (as shown in Figure 1.1) and to prepare a Flood Management Plan in accordance with the procedure set out in the NSW Government's "Floodplain Development Manual" (1986).

The 1986 Manual described the procedures to be followed by local government authorities in arriving at a comprehensive Floodplain Management Plan which would be the basis for any State Government and Commonwealth assistance sought by Council in implementing the Plan. The Floodplain Management Process, as described in the 1986 Manual, is outlined below:

Establish	➔ **Undertake**	➔ **Undertake**	➔ **Adopt**	➔ **Implement**
Floodplain Management Committee	Flood Study	Floodplain Management Study & Plan	Floodplain Management Plan	• Response, Flood and Property Modification Measures • Public Education & Awareness programs • Improve Flood Warnings

By 1995, Council had completed the following steps:

- Established a Floodplain Management Committee (FPMC). The Committee, which is composed of Local and State Government and community representatives, held its first meeting on 31 August 1994.
- Carried out a Flood Study. A flood study for the whole of the South Creek catchment was carried out by the Department of Water Resources (re-organised into the Department of Land & Water Conservation (DLWC) in July 1995 and then, together with PlanningNSW, into the Department of Infrastructure, Planning & Natural Resources (DIPNR) in 2003). That report provided few details for the Kemps Creek catchment and was amplified in LMCE's study.
- Adopted an Interim Floodplain Management Policy in December 1987. Council's Interim Floodplain Development Policy was subsequently amended to require floor levels to be 500 mm above the 100 year ARI flood level.
- Selected an Interim Designated Flood using the 100 year ARI flood levels as defined for the Austral - Kemps Creek area in a drainage study of the area carried out by DJ Dwyer & Associates in 1979.

LMCE's Floodplain Management Study addressed the following items:

- Provided further details of the hydrology and hydraulics of creeks within the Austral - Kemps Creek area.
- Collected data on Social, Economic and Ecological issues.
- Recommended a Designated Flood to confirm the interim standard adopted.
- Prepared a detailed Floodplain Management Study. The Study recommendations formed the basis of the Draft Floodplain Management Plan.

LMCE completed the draft Floodplain Management Study and Plan in December 1995, but the Plan was never formally adopted by Council.

1.2 Study Scope

In 2002, Council commissioned Perrens Consultants (formerly LMCE – see note below) to review and update the 1995 Study and Plan, in order to provide Council with:

1. A revised and updated Floodplain Risk Management Plan taking into account, among other documents, the *Floodplain Management Manual* (NSW Government, 2001) and the requirements of current legislation governing the management of vegetation and floodplains.
2. A review of the current flood warning and response system and the local Flood Plan, in consultation with SES and Bureau of Meteorology.
3. A review of the works, measures and restrictions identified in the current Floodplain Management Study and draft Plan in line with the outcomes of Items 1 and 2 above, together with the identification of any new works that may be appropriate.
4. A qualitative assessment of the effectiveness of these works and measures to reduce the effects of flooding on the community and development, both existing and future.
5. Provision of cost estimates for the components of the Floodplain Management Study/Plan to reflect present day costs.
6. Identification of required modifications to current policies.
7. Preparation of a revised Draft Austral Floodplain Management Study and Draft Floodplain Management Plan.
8. Workshop the Draft Floodplain Management Study and Plan with the FPMC and Council staff.
9. Amendment and presentation of the Draft documents to the FPMC.
10. Preparation of a public exhibition display, developed in consultation with Council and the FPMC, to assist Council in the exhibition of the revised draft Floodplain Management Plan.
11. Review the submissions received from the exhibition and report and present the outcomes of this review to the FPMC.
12. Finalisation of the Floodplain Management Plan.

Note that Perrens Consultants initially traded in partnership with LMCE but commenced operating independently in 2000. However, some of the staff who worked on the 1995 report were involved with this current review.

1.3 The Floodplain Management Manual

The 2001 Floodplain Management Manual (FMM) replaces the 1986 Floodplain Development Manual. The FMM supports the NSW Government's Flood Prone Land Policy, which provides for the development of sustainable strategies for managing human occupation and use of the floodplain from within a risk management hierarchy covering avoidance, minimisation (using planning controls) and finally mitigation works.

The Policy has the following primary objective:

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

The FMM embodies substantial revision of the 1986 manual and incorporates:

- the results of a detailed public review of floodplain risk management issues in NSW;
- significant improvements to policy and practice introduced by successive governments;
- increased emphasis on the integrated and strategic management of floodplains, both urban and rural.

Changes and new areas incorporated in the present edition include:

- an emphasis on the importance of developing Floodplain Risk Management Plans that address existing, future and continuing flood risk for flood prone land on a strategic rather than an ad hoc or individual proposal basis;
- an emphasis on the need to incorporate the relevant portions of management plans into Councils' environmental planning instruments (EPI);
- more explicit recognition of the need to consider the full range of flood sizes, up to and including the probable maximum flood (PMF), but recognising that such rare floods should not preclude or unnecessarily hamper development;
- recognition of the need for local flood plans (prepared under the guidance of SES) that address readiness, response and recovery;
- the addition of rural flooding in the management process through Part VIII of the Water Act or under the regulations of the Water Management Act;
- the inclusion of local overland flooding in the management process;
- strategic consideration of flood risk related development policies within the framework of the Floodplain Risk Management Plan rather than on an ad-hoc basis at the development consent stage. This enables the effective consideration of cumulative impacts;
- providing the basis for Councils amending EPIs and planning controls with respect to new types of development activity in flood prone land outside those identified as appropriate in the existing Floodplain Risk Management Plan;
- an emphasis on maintaining and enhancing the riverine and floodplain environments, including consideration of the needs of threatened species, population and ecological communities, as part of flood modification measures;
- incorporation of the principles of ESD when managing risks associates with human occupation of the floodplain.

This current report takes into account the changes in the 2001 Manual and updates, where necessary, the 1995 study in keeping with the revised approach.

1.4 Note on Flood Frequency

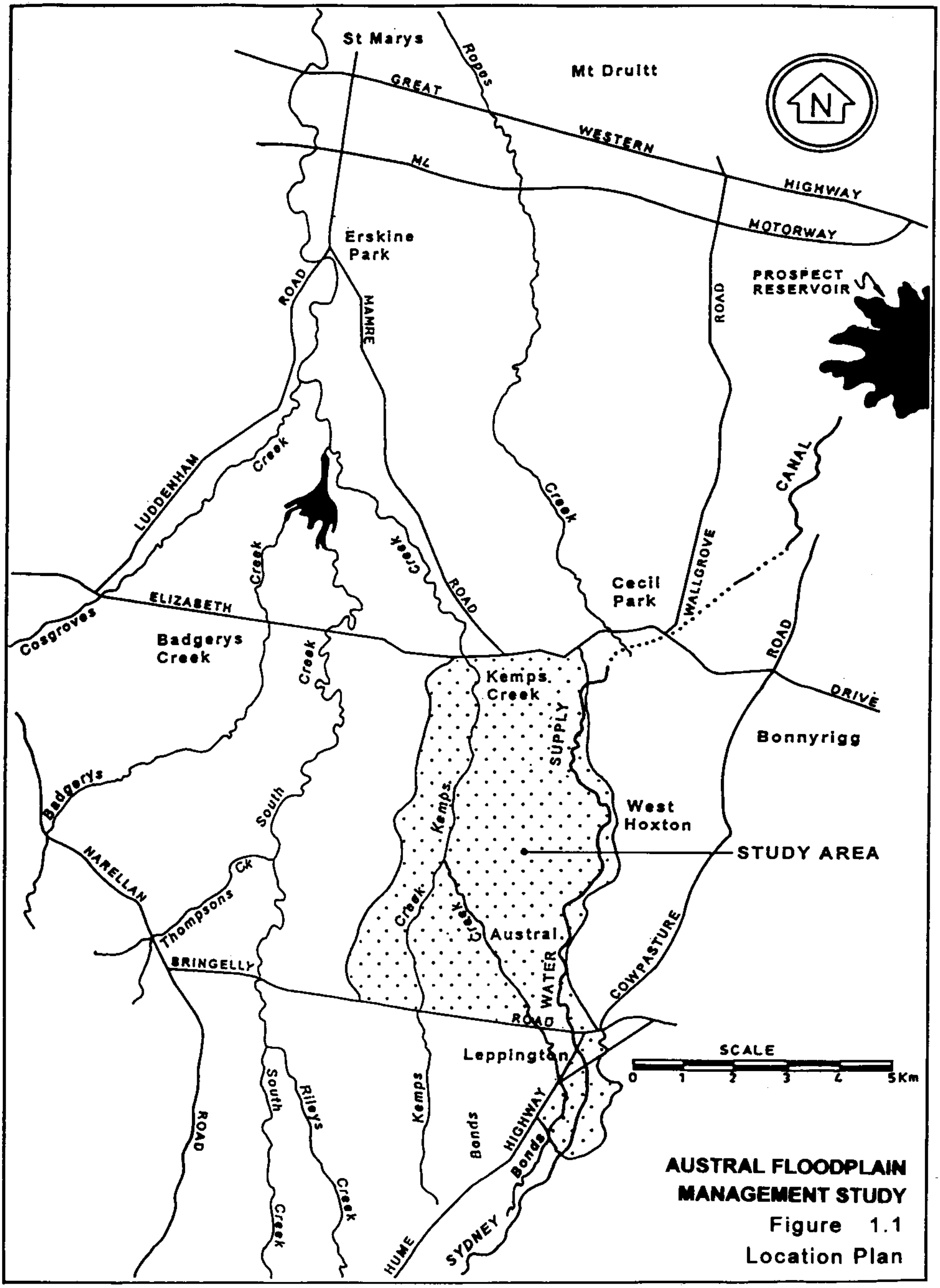
In this report the frequency of floods is generally referred to in terms of their Average Recurrence Interval (ARI) in years. The frequency of floods can also be referred to in terms of their Annual Exceedance Probability (AEP). The approximate correspondence between these two systems is:

Annual Exceedance Probability (AEP) %	**Average Recurrence Interval (ARI) years**
1	100
5	19.5
20	4.5
50	1.4

The definition of the two terms, as provided in the Floodplain Management Manual, is as follows:

Annual exceedance of probability (AEP)	the chance of a flood of a given size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge has an AEP of 1%, it means that there is 1% chance (that is one-in-100) of that peak flood discharge or larger occurring in any one year.
Average recurrence interval (ARI)	the long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 100 year ARI flood event will occur on average once every 100 years. ARI is another way of expressing the likelihood of occurrence of a flood event.

Reference is also made in the report to the probable maximum flood (PMF). This flood occurs as a result of the probable maximum precipitation (PMP). The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards rainfall production. The PMP is used to estimate PMF discharges using a rainfall - runoff routing method. Land inundated by the PMF defines the extent of flood prone land or flood liable land (both terms are synonymous for the purposes of floodplain management).



AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure 1.1

Location Plan

2. THE AUSTRAL - KEMPS CREEK STUDY AREA

2.1 General

This Chapter outlines the existing conditions within the study area and the impact of flooding on the area and its community. The Chapter also provides background data which will be used in the assessment of potential management measures:

- Engineering
- Social and Cultural
- Environmental
- Economic
- Administrative.

2.2 Floodplain Definition and Topography

The Austral Floodplain Risk Management Study is concerned with those parts of the catchment of Kemps Creek upstream of Elizabeth Drive which lie within the Liverpool City Council (LCC) area. The two main streams, Kemps Creek and Bonds Creek, rise in low foothills south of Cowpasture Road and flow in a northerly direction towards Elizabeth Drive (Figure 2.1). The catchment is elongated, having a length of 12 km and an average width of 4 km, giving a total drainage area above Elizabeth Drive of about 4,900 ha of which 3,200 ha lies within the study area.

Downstream of the steeper portion of the catchment on the northern side of Bringelly Road, the stream bed flattens from 1% to around 0.5% gradient. Major flows are conveyed along the drainage network as a wide expanse of slowly moving water, with most of the discharge conveyed on the floodplain.

There are several significant unnamed tributaries of the two main streams, which together drain about 30% of the total catchment upstream of Elizabeth Drive. The major tributaries have been denoted Tributaries 1, 2 and 3 on Figure 2.1.

- Tributary 1, also known locally as Scalabrini Creek, joins the west bank of Bonds Creek near Seventh Avenue and has a total catchment area of 577 ha.
- Tributary 2 drains the eastern part of the catchment including the village of Austral, and joins the east bank of Kemps Creek at Fifteenth Avenue just downstream of the junction of Bonds and Kemps Creeks. It has a catchment area of 324 ha.
- Tributary 3 drains the north-east part of the catchment and joins the east bank of Kemps Creek near Elizabeth Drive. It has a catchment area of 721 ha.

Bonds Creek (including Tributary 1) has a catchment area of 1,909 ha at its junction with Kemps Creek.

The drainage channels in the Austral - Kemps Creek area are indistinct and of low capacity except in sections that have been excavated to achieve a local reduction in flood levels. Examples of creek excavation are found on Bonds Creek between Bringelly Road and Ninth Avenue, and Tributary 1 between Sixth and Seventh Avenues.

The streams flow through a semi-rural setting although urbanisation has increased in recent years. Drainage problems are experienced in several residential centres which have encroached onto the floodplain, several examples of which are given below. These problems are attributable to:

- limited hydraulic capacity in the creek channels;
- inadequate hydraulic capacity at culverts and bridges;
- filling activities on the floodplain.

At Eighth Avenue, several houses have been constructed on low ground on the east bank of Bonds Creek downstream of the bridge. The bridge structure has been raised above the level of the approach road. This has resulted in surcharges of the creek being directed over the road and toward the houses. In major flooding it is expected that above floor inundation would occur.

Residential properties along Kemps Creek at Twelfth Avenue and Gurner Avenue are flooded in small flood events. The channel downstream of Twelfth Avenue is small and has extensive weed growth.

Properties between Fifth Avenue and the excavated channel in Scalabrini Creek are frequently inundated. The creek waterway area in this reach is smaller than the waterway area of the excavated channel. An inspection of this channel indicated that most of the flows bypass the creek and the excavated channel altogether and run along Fourth Avenue.

The intersection of Twelfth Avenue and Fourth Avenue on Tributary 2 is flooded regularly. Photographs from the past show the intersection and properties extensively inundated. The stream capacity appears to be reduced due to the sudden bend of the creek at the corner of this intersection.

In the Scalabrini Village on Bonds Creek downstream of Sixth Avenue, flooding occurs for small storm events. Flooding problems commence at around the 1 year ARI flood. They result from inadequacies in the local trunk drainage system, coupled with coincident backwater flooding from the creek.

There has been considerable earthworks activity within the catchment which has been undertaken to control water in some way, including:

- construction of dams to store water for irrigation and watering of domestic stock;
- filling of land to reduce the impact of flooding;
- construction of channels or banks to help drainage escape or to divert the flow of water;
- enlarging the creek channel to reduce flood levels.

Some of these activities have been carried out by Council in a planned and coordinated manner. A large number of these earthworks activities appear, however, to have been carried out without proper planning and in an ad-hoc manner by landholders themselves. Because of the ad-hoc nature of these activities, their effect has been to alter the direction of flow, impede the passage of flow over the floodplain or otherwise disturb the natural drainage system in the area. As a result there is considerable concern within the area about the effects of unplanned earthworks on flooding.

Locations where earth-filling works have been carried out are situated in Kemps Creek and Tributary 2. The presence of fill in the creek bed of Kemps Creek between Gurner Avenue and Elizabeth Drive reduces the hydraulic capacity of the stream. Earth fill has also been placed immediately downstream of Fourth Avenue on Tributary 2. The presence of fill on the floodplain further exacerbates flooding by reducing the area available for flow and flood storage, thus raising flood levels. In some instances it may be more cost effective for Council to remove landfill rather than to provide mitigation measures or commence litigation.

2.3 Hydrologic and Hydraulic Modelling

Flood flows, water surface profiles and the extent of flooding have been estimated using computer models for a range of average recurrence intervals (ARI). The RAFTS and HEC-2 computer programs were adopted for the hydrologic and hydraulic modelling respectively.

The RAFTS model, used to calculate flood flows, requires the sub-division of the study catchment along interior watershed lines and assignment of catchment storage to the sub-catchments within the system. Sub-catchment slopes were derived from inspection of 1:10,000 and 1:4,000 orthophotomaps. The percentage of impervious area for each sub-catchment was also measured from the orthophotomaps and confirmed by site inspection. Initial and continuing losses for the 100 year ARI and probable maximum flood (PMF) were adopted from DWR (1990). Losses were obtained from Walsh et al (1991) for the lesser storm events. The approach for calibrating the model was to compare results achieved in previous studies. In addition, a sensitivity analysis was undertaken to test the parameters adopted. The hydrologic modelling for storms of 1, 5, 20, 100 years ARI and the PMF is described in detail in Appendix A.

Flood levels, velocities and the extent of flooding have been defined using a one-dimensional steady state backwater computer model, based on the HEC-2 program (Hydrologic Engineering Centre, 1991). HEC-2 is a computer based application of the standard step method and uses the Manning equation to compute friction head loss between cross sections. Full details of the hydraulic modelling are contained in Appendix B.

The topographic data needed for the HEC-2 model was obtained by photogrammetric methods from a set of low level aerial photographs taken especially for this study. These photographs were also used to prepare a set of detailed maps of the study area at a scale of 1:2000 with contour spacing of 1.0 m. For reference purposes, the cross sections used in the HEC-2 model were designated with a simple code which designated the creek and the branch of that creek, and were then numbered with the cross sections sequentially running upstream. For example, as shown on Figure 2.1, the main arm of Kemps Creek is designated KC00 and four branches which drain the western side of the catchment are denoted KC01, 02, 03 and 07.

2.4 Characteristics of Flooding

2.4.1 General

The hydrologic and hydraulic modelling of the catchment shows a number of characteristics which are symptomatic of the flooding and drainage problems facing the area:

- About 30% of the study area comprises naturally flood prone land. The term “flood prone” land applies to land inundated by the PMF.

- The creek channels generally have a small hydraulic capacity and in many areas the creek will overflow in a storm with an ARI of about 1 year. Therefore "flooding", as indicated by water flowing outside a defined watercourse, can be expected to occur frequently in the area.

- Flooding of road crossings is a common occurrence. There are 33 road bridges or culverts in the study area. Of these, 15 appear to have inadequate hydraulic capacity to carry the 1 year ARI flood and a further 10 have inadequate capacity to carry the 2 year ARI flood.

- The main floodplain of Kemps Creek, Bonds Creek and the major tributaries is relatively flat. Once a flood has broken out of the channel the flow will tend to extend across the width of the floodplain as shallow low velocity flow.

- The width of the floodplain provides flow capacity which allows larger flood flows to be carried with moderate increases in flood depth. Thus, in most of the main floodplain areas, the difference between the flood level for a 5 year ARI flood and a 100 year ARI flood is of the order of 0.5 m.

- The extra area affected by the more rare floods is relatively small compared to the area affected by relatively frequent floods as summarised in Table 2.1 below.

Table 2.1
Area Inundated by Flooding

Flood Frequency ARI (years)	Area Inundated (ha)
1	240
5	510
20	650
100	750
PMF	1,080

2.4.2 Kemps Creek Main Arm and Branches

A large flood prone area exists upstream of Elizabeth Drive where Tributary 3 joins. Flows greater than 1 year ARI surcharge the channel and begin to fill the floodplain. Progressively larger areas of land are flooded up to the 100 year event, but there is comparatively little increase in the area flooded for larger floods. There is generally a range of only 1 m between 1 and 100 year ARI flows. The PMF profile is about 1 m higher still. However, because of the shape of the floodplain there is a comparatively narrow strip averaging about 50 m on the western side of the floodplain between these two flood events. Because of the flat topography on the eastern side of Kemps Creek between Gurner Avenue and Elizabeth Drive, the extent of the PMF is as much as 200 m greater than the 100 year ARI flood.

There are several crossings which significantly restrict flow and cause ponding upstream. Elizabeth Drive, Fifteenth Avenue and Bringelly Road bridges have the highest hydrologic capacities but cause a significant afflux particularly for major flood events. At the 100 year ARI flood, for example, there is a 200 mm head difference across Elizabeth Drive, 300 mm at Fifteenth Avenue and 500 mm at Bringelly Road. Within the backwater influence of the bridge embankments, flow velocities are reduced. Culverts at Twelfth Avenue have a low hydrologic capacity and are overtopped by a 1 year ARI flood.

Average bed slopes of the four tributaries draining the western side of the catchment range between 0.7 and 1.5%, considerably steeper than in the main streams occupying the floodplain. Typically, backwater effects from Kemps Creek extend up a tributary for 100 - 200 m from the confluence. Above the zone of influence of main stream flooding, the water surface profiles tend to converge showing only around 0.5 to 1 m range between 1 and 100 year ARI floods. Apart from the Devonshire Road crossing of Branch KC01, which has a 20 year hydraulic capacity, all of the crossings are overtopped by minor floods of the order of 1 to 2 year ARI.

2.4.3 Bonds Creek Main Arm and Branches

The reach modelled on Bonds Creek extends over 6 km from the junction with Kemps Creek to Denham Court Road. Flows are generally contained within the creek or its immediate overbank areas up to the 1 year ARI, but larger flows spread out over a floodplain which is several hundred metres wide at the 100 year level of flooding. The channel is steeper than Kemps Creek and this results in generally higher flow velocities which average around 1.8 m/s. In the constricted areas near bridges velocities are considerably higher.

Nine bridges and culverts are located on the main waterways in this area. Road crossings generally have a hydrologic capacity around 2 years ARI except for Bringelly Road and Cowpasture Road which have a 10 year capacity. For the 20 year flood the head drop across these two structures amounts to 600 mm and 1.3 m respectively. Afflux caused by the lower level crossings is less because the roads are overtopped by even minor flooding, thereby providing a large increase in hydraulic capacity for a comparatively small increase in upstream flood level.

2.4.4 Tributary 1 (Scalabrini Creek)

This tributary joins Bonds Creek upstream of Seventh Avenue and extends upstream for approximately 1,200 m to Bringelly Road. The HEC-2 model cross sections were located so that the recently excavated channel downstream of Fifth Avenue was accurately modelled. The Fifth Avenue crossing has a waterway area of only 0.4 m2 and a corresponding hydrologic capacity of less than 1 year ARI.

The backwater influence of Bonds Creek extends for about 400 m upstream of the confluence. Within this reach, the range between 1 and 100 year ARI peak flood levels is approximately 1.5 m with a further 800 mm rise to the PMF. Flow velocities are around 1 m/s in the channel and 0.3 m/s on the floodplain.

Above the influence of the backwater, flow velocities increase to over 2 m/s in the channel and are dependent on the bed slope which averages about 0.55%. Between Fifth and Sixth Avenues there is a sudden drop in bed levels of around 2 m with the upstream bed acting as a hydraulic control where critical depths occur. However upstream of this point the bed slope flattens to an average gradient of 0.28 % for the remaining 550 m to Bringelly Road and velocities reduce to 1 - 1.5 m/s in the channel.

2.4.5 Tributary 2 and Branches

Tributary 2 joins the right bank of Kemps Creek just downstream of Fourteenth Avenue. Backwaters from Kemps Creek influence flood levels for a distance of 500 m upstream of the junction. Above this point the average bed slope over the remaining 2.6 km to Tenth Avenue is around 0.8% and the water surface profiles converge with a range of 0.5 m between the 1 and 100 year ARI.

The waterway opening at Fourth Avenue was assumed ineffective for flow although the hydraulic effect of the road, which acts as a broad crested weir, was incorporated in the model. The five crossings included in the Tributary 2 model all have a low hydrologic capacity.

2.4.6 Tributary 3 and Branches

Tributary 3 joins Kemps Creek 500 m upstream of Elizabeth Drive and extends over 5 km from the junction to Fourteenth Avenue. For the first 3 km above the junction with Kemps Creek, the bed slope averages about 0.57%. Backwater influences from Kemps Creek extend about 700 m upstream. Above this point, there is a range of about 1 m between the 1 year and 100 year ARI flood levels and a further 1 m to the PMF. As with the other major streams, flows above 1 year ARI spread out over the floodplain. Flow velocities in the channel at the 100 year ARI level are generally less than 1 m/s, and 0.5 m/s on the floodplain.

Upstream of Eighteenth Avenue the bed slope increases, averaging 1% in the remaining 2 km to Fourteenth Avenue, which is the upstream limit of modelling. Channel velocities generally increase to 1.5 - 2 m/s except in the ponds upstream of road crossings. The water surface profiles converge and have a range of less than 0.5 m between the 1 and 100 year ARI. There are five culverts in this reach all of which have a hydrologic capacity no greater than 1 year ARI.

2.5 Floodplain Zoning and Controls

Both the current and possible future land use pattern within the Austral - Kemps Creek area are governed by both State and local planning instruments, policies and controls. Any consideration of the potential for development of the area, and thus the impact of that development on the floodplain, must be considered within the context of those instruments and controls which are summarised below. Further details are given in Appendix F. Figure 2.2 shows land zoning within the study area.

2.5.1 SEPP No.19 - Bushland in Urban Areas

State Environmental Planning Policy (SEPP) No. 19 aims to protect and preserve bushland within the urban area because of:

(a) its value to the community as part of the natural heritage;

(b) its aesthetic value; and

(c) its value as a recreational, educational and scientific resource.

The Liverpool City Council area forms part of the land to which the policy applies. The specific aims of the policy are summarised in Appendix F. The State Policy applies generally to development on land zoned or reserved for public open space, or development on land which is adjacent to such land. Part of the Austral - Kemps Creek study area is zoned for open space purposes and as such any development measures which are both proposed as part of the recommendations of the Austral - Kemps Creek Floodplain Risk Management Study, and apply to land to which SEPP No. 19 applies, must be assessed in terms of the impact on urban bushland in the area. Areas identified as "urban bushland" are discussed briefly in Section 2.10 and presented in more detail in Appendix D.

2.5.2 Rivers and Foreshores Improvement Act

Any development within 40 m of a watercourse requires a permit under the provisions of Part 3A of the Rivers and Foreshores Act. In recent years DIPNR has sought to use its powers under the Act to demand a very high standard of restoration of the riparian zone during the development process.

There is a general desire by the community for “natural” creeks to be maintained as part of the development process. However, with the changes in flow resulting from urbanisation (increased discharge, increased persistence of high flows, persistent low flow), the natural creek channels, if left to themselves, will go through a natural process of adjustment. Most probably, this will entail channel widening, with accompanying erosion and redistribution of sediments. This adjustment would naturally occur in an episodic manner (during larger floods) and could take a considerable time to reach a new equilibrium. An important aspect of any plan for the trunk drainage system will be the necessary works to retain a “natural” form of creek that is capable of accommodating the changed regime.

Filling on the fringes of the floodplain has been a traditional part of the development process in order to maximise the developable land. In areas of salinity hazard, such filling, even when carried out in a sympathetic manner, can lead to increased salinity and soil structural degradation at the toe of the fill slope. Any filling or other earthworks will need to be approached with caution in the light of the salinity hazard associated with the creek lines in the area.

2.5.3 Liverpool Local Environmental Plan 1997

Liverpool City Council has numerous planning instruments which collectively control land use development within the City. Council has prepared a planning instrument which aims to consolidate all existing planning instruments into a modern planning document. The consolidating instrument is Liverpool Local Environmental Plan 1997.

Council has commissioned Don Fox Planning to update the definitions in the LEP to be in agreement with those presented in the Floodplain Management Manual (2000). A number of definitions have been proposed, as outlined in Appendix F.

2.5.4 Draft Landfill and Earth Dams DCP (March 1998)

This policy has been developed by Council and has been reviewed and updated to integrate the planning requirements of Austral and other rural areas in Liverpool but not yet formally adopted. The policy deals with landfill principally from the perspective of its impact on drainage and flooding. It also deals with some of the issues involved in siting and designing houses to reduce the likelihood of future flooding problems.

The objective of the policy is to prevent the exacerbation of flooding in rural areas through the conservation, as far as possible, of natural drainage paths and storages using controls on landfill. Proposals must meet a set of performance criteria, formulated to ensure landfill will not create adverse impacts on other people and properties, including:

- limits on areas of filling;
- prohibition of filling in floodways;
- restrictions on diversion of flow.

2.6 South West Sector Development

Land within the Austral-Kemps Creek area is included within the South West Sector Core Area, which is currently being considered by the NSW Government for large scale development to house around 200,000 people. The area under consideration is shown on Figure 2.3. Investigations are currently being carried out regarding various issues including housing, infrastructure, services, employment opportunities, biodiversity values, conservation etc.

Council will have ongoing active input to the South West Sector planning options, including those related to for floodplain management. This study does not take into account any future landuse (re-zoning), however, the flood characteristics of the Austral area need to be taken account of in any planning undertaken for the South West Sector.

2.7 Land Use

In May 1994, Liverpool City Council released its Liverpool Rural Lands Study. That study, inter alia, provides comprehensive details of the land use pattern in the rural areas of the City. Within the Austral - Kemps Creek Floodplain Risk Management Study area, the following land uses were identified:

- Schools
- Vacant land
- Agriculture, including the following subcategories:
  - grazing
  - market gardens
  - green houses
  - poultry
- Rural Residential
- Extractive Industry
- Training Tracks (Horse/dogs)
- Electricity Substation
- Council Depot
- Showground
- Commercial Activities
- Residential
- Bowling Club.

The original subdivision of the study area in 1887 was laid out as small rural landholdings of about 2 ha covering the whole area. It is interesting to note that none of the creeks draining the area is shown on the DP. This deficiency in recognising flooding and drainage issues in the planning process of the area has to some extent been carried on to the present day. The result is that considerable residential and commercial development is located in flood prone land resulting in the potential for considerable flood damages to be experienced, even for smaller floods (a quantitative assessment of damages is given in the following section).

The low hydraulic capacity of the natural drainage system, coupled with generally low culvert capacity and a road layout which is not sensitive to flooding patterns has compounded problems, particularly those of access during flood periods. The fact that most of the creek system is in private ownership hampers the process of implementing measures to improve the situation. Further discussion on the local community's perception of flooding problems, as determined during the formal process of community consultation, is given in Section 2.9 of the report.

2.8 Flood Damages

A detailed assessment of potential flood damages for floods from 1 year ARI up to the PMF was carried out and is reported in Appendix C. Depths of inundation for buildings were derived from spot levels at a corner of each building taken from the aerial photography and a visual assessment of the floor level relative to the ground. The damages were assessed using well-recognised techniques developed and tested in numerous urban and rural flooding situations in NSW. Damages to residential, industrial, commercial and public buildings were included.

There are no data available on historic flood damages in the Austral - Kemps Creek area. Accordingly it was necessary to transpose data on damages experienced as a result of recent flooding in other centres. To that extent, the computed values are "potential" damages rather than damages actually experienced. A small percentage reduction was also made to allow for property evacuation, which may reduce the damages actually experienced to values below these potential damages.

The resulting numbers of flood affected properties (ie flooded above allotment level), flood damaged properties (flooded above floor level) and flood damages are summarised in Tables 2.2 and 2.3. The average annual damages are contained in Table 2.4. Average annual damages are the average damages per year that would occur over a very long period of time. Note that these damages were originally calculated in 1995 values and have been updated for this present study to 2002 values based on the CPI rate presented in the Australian Bureau of Statistics Website (1.18).

In addition residential, commercial and public damages have been increased by multiplying by a factor of 2, based on data obtained from more recent flooding events. Recent data presented by the Bureau of Transport and Regional Economics (2002) and R. Blong (2001) have indicated that residential damages should be increased by at least 2 x URBLOSS damages (approximately $70,000 at 2 m depth of inundation). We have also applied these findings to industrial/commercial and public properties, using the same line of reasoning. Agricultural damages have been adjusted by applying the CPI rate only, as these damages were based on original research specific to the Austral-Kemps Creek area carried out in 1995.

Table 2.2
Residential Properties Affected by Flooding

ARI of Flood (years)	Kemps Creek & Branches on west bank		Bonds Creek & Scalabrini Creek (Trib. 1)		Tributary 2		Tributary 3		Total	
	A	B	A	B	A	B	A	B	A	B
1	11	4	12	9	10	8	3	0	36	21
5	22	16	41	26	13	8	4	0	80	50
20	25	20	72	52	15	9	6	1	118	82
100	38	29	89	61	17	10	7	2	151	102
PMF	65	51	116	95	27	17	13	10	221	173

Note: - A = Property affected by flooding in allotment (includes B)
B = Property damaged by flood

Table 2.3
Estimated Total Flood Damages Austral - Kemps Creek (2002 Values)

Flood Event ARI years	Damages $ x 10^3			
	Residential		Commercial, Industrial, Agricultural and Public	Total
	Bonds Creek Catchment	Kemps Creek Catchment		
1	145	340	145	630
5	785	660	400	1,845
20	1,935	960	750	3,645
100	2,615	1,440	4,310	8,365
PMF	4,935	3,635	9,215	17,785

Table 2.4
Estimated Average Annual Damages (2002 Values)

Location	Average Annual Damages $ x 10^3
Residential Bonds Creek Catchment	706
Residential Kemps Creek Catchment	591
Commercial and Industrial/Agricultural/Public	474
Total	**1,771**

Three hundred and fifty nine residential dwellings were identified in the 1995 drive-by survey and were included in the damages assessment. Table 2.2 shows that 102 of these properties are flooded at the 100 year ARI level of flooding, of which 61 are located adjacent to Bonds Creek and Scalabrini Creek. Residential flood damages commence at the 1 year ARI level when 21 properties are flooded of which 9 are located on the Bonds/Scalabrini Creek system and 8 on Tributary 2 of Kemps Creek.

Sixty-eight residential dwellings are located within the extent of the high hazard floodway. Of these, 47 are "flood affected" in the 100 year ARI event. For the 20 year, 100 year and PMF events 23, 35 and 43 dwellings respectively within the floodway are "flooded damaged", ie flooded above floor level.

At the 100 year ARI level of flooding, around $8.4M of damages would be experienced of which commercial and industrial damages contributes $4.3M and residential damages $4.1M.

These damages are tangible damages and relate to the impact of flooding on the economic operation of the area. There are also intangible damages or losses which relate to the social impact of that flooding. Social or intangible losses which arising from flooding include:

- inconvenience and loss of access
- isolation during flooding
- physical ill-health

It is not feasible to assign meaningful dollar values to intangible damages.

2.9 Community Concerns and Public Consultation

Community concerns relating to flooding issues were identified through a community consultation process carried out in 1995. This process involved contact with local residents, relevant public utilities and the Council. Additional consultation was carried out in 2003 to publicise the findings of the study and to obtain the community's feedback on the proposed plan. More details of all aspects of the community consultation process are provided in Appendix G.

2.9.1 1995 Consultation Program

The 1995 consultation program was developed with the objectives of:

- obtaining local data on the frequency, extent and duration of flooding and possible mitigation measures
- obtaining feedback on community issues and concerns
- informing and educating the public about the nature of the flood threat and options for managing the threat
- resolving issues which are in dispute or conflict with the objectives of the draft Floodplain Risk Management Plan
- encouraging future ownership of the Management Plan by local residents.

The consultation process was subdivided into Resident, Public Utility and Council Consultation and included:

Resident Consultation

- a resident questionnaire (108 respondents)
- resident interviews (12 interviewees)
- newsletters
- attendance at precinct committee meetings and Floodplain Risk Management Committee meetings
- holding of a workshop to present the study findings and to obtain residents' views

Public Utility Consultation

- Local public authorities and relevant statutory authorities were contacted to obtain comments on the flooding situation in the area and/or the environmental effects of possible flood mitigation measures.
- Authorities directly affected by flooding through impacts on infrastructure and facilities were asked to identify locations of flooding and possible flood mitigation measures.
- Relevant authorities (eg EPA and DIPNR) were requested to supply requirements/guidelines relating to the implementation of flood mitigation works ie creek clearing, construction of levees, detention basins etc.

Council Consultation

- a council complaint database (44 pieces of correspondence collected).

The consultation process enabled specific flooding locations to be identified and investigated and revealed a widespread and frequent flooding problem in the study area with a number of houses being flooded above floor level in the last 20 years. Severe rainstorms often affect road access, with the low lying area of Fourth Avenue being a particular source of complaint.

The types of solutions most favoured by the residents in the area included improving creek channels by removal of debris and vegetation in conjunction with upgrading of piped drainage both under and along the side of roads. Other suggestions involved the construction of levees and detention basins, protection of creek banks against erosion and the raising of road levels. Other issues identified included illegal filling and inappropriate land zoning in the area.

Specific problem areas and possible mitigation measures were investigated using the hydraulic model of the creek system discussed in Appendix B and Chapter 5 of this report.

As a result of meetings with the Floodplain Management Committee, the relevant Precinct Committees and the community workshop, a set of criteria for assessing the possible flood management and drainage improvement measures was identified (refer Chapter 6) and an action plan proposed. Where suitable, items from this plan have been incorporated in the draft Floodplain Risk Management Plan.

Local public authorities and relevant statutory authorities were contacted to obtain comments on the flooding situation in the area and/or the environmental effects of possible flood management measures.

Council's files relating to specific flooding and drainage problems in the area were studied in order to identify any further flooding issues and a detailed database of complaints recorded by Council, both external and internal, was set up. In addition, consultation and liaison with Council staff was carried out throughout the study.

2.9.2 2003 Consultation

The 2003 consultation program was developed in order to publicise the findings of the study and to obtain feedback from relevant government agencies and the community.

As part of the program a poster summarising the study background, findings and recommendations was prepared and exhibited at eight locations including the study area, Liverpool City Council offices and libraries. As part of this exhibition the Austral Floodplain Management Study report was available for perusal and a take home brochure was offered to residents. A copy of the brochure is reproduced in Appendix G.

Three hundred and fifty residents within the Austral area were notified of the exhibition via a letter box drop and through an advertisement in the local press. The exhibition was displayed from 18th June to 16th August 2003. In addition, an information session for the public was held in Austral on 23rd June 2003 where Council officers and a representative from Perrens Consultants were available to address concerns and answer questions. Approximately 50 people attended this meeting.

A copy of the draft report was sent to the following for review:

- Liverpool Council Floodplain Management Committee;
- All Liverpool City Councillors;
- Relevant Council staff;
- The EPA, DIPNR (formerly PlanningNSW and DLWC), Sydney Water, NPWS, RTA, Penrith City Council, NSW Fisheries, Bankstown City Council, Camden Council, SES, Fairfield City Council.

In response to the 2003 consultation process, comments were received from EPA, DIPNR and Liverpool City Council's Stormwater Engineer (contained in Appendix G). Where appropriate, these comments were incorporated and addressed within this report prior to finalisation.

2.10 Ecological Considerations

An ecological survey of the study area was carried out for this study. The detailed findings of that survey are presented in Appendix D.

Most of the areas of remnant vegetation within the study area are too small and too heavily disturbed to be of conservation significance. However, there are two main sections along the drainage lines which needed to be considered in developing a Floodplain Risk Management Plan or assessing options for flood mitigation works.

One is the bushland beside Kemps Creek between Gurner Avenue and Elizabeth Drive. Most of this area has been proposed as a nature reserve since 1978 and has been identified by a number of authors (eg Benson (1992); Mt King (1991); Doherty (1987)) as being of high regional conservation significance. The National Parks and Wildlife Service regards this area of being state significance due to the presence of three poorly preserved vegetation communities and two nationally listed rare plant species.

The other significant area is a triangular shaped alluvial fan above the confluence of Kemps and Bonds Creeks. Here, as in the Kemps Creek section, there is a good stand of cabbage gum open forest. Due to past widespread clearing for agriculture, cabbage gum associations are regarded as vulnerable and inadequately conserved at a state level (Benson, 1987). Furthermore, three of the main canopy species (cabbage gum, broad-leaved apple and coast grey box) are considered vulnerable and of particular conservation significance in the western Sydney region (Benson & McDougall, 1991). The regional office of the National Parks and Wildlife Service advises that any bushland remnants on the Cumberland Plain over 2 ha in size should be conserved as they are of regional conservation importance (D. Stellar pers comm).

Both areas discussed above are habitat for a range of fauna, mostly birds, not found in the surrounding cleared or fragmented habitats. They could also be habitat for rare and regionally significant birds such as turquoise parrot, swift parrot, glossy black cockatoo and red-capped robin.

The in-stream vegetation is not considered to be of significance as it is badly disturbed by previous drainage “improvements” and weed invasion. However, the remnant riparian corridors provide an opportunity for rehabilitation and revegetation in order to provide fauna corridors through the area. Two aquatic plants regarded as vulnerable in western Sydney, *Schoenoplectus mucronatus* and *Persicaria lapathifolia*, are quite common along the creeks. Unlike the terrestrial vegetation these species are more amenable to translocation and replanting.

2.11 Administrative/Political Considerations

The entire floodplain within the study area lies within the City of Liverpool, the NSW State seats of Badgerys Creek and the Federal electorate of Macarthur.

Administrative interfaces on issues relating to the Floodplain Risk Management Study occur with respect to the following:

- Flood warning — Bureau of Meteorology, Council and the SES.
- Planning Controls — DIPNR, Council. The regional planning powers of the Department and its overview of zoning matters is important in any rezoning.
- Funding — Commonwealth Government, State Government, Council. Any request for funds to implement the recommendations of this report will be submitted through DIPNR with assistance sought from the State and Commonwealth.
- Floodplain crossings — The Roads and Traffic Authority owns bridge and approach embankment works on the floodplain (Elizabeth Drive and Bringelly Road) and will be vitally interested in any recommendation concerning these works.
- Welfare Management — Department of Family and Community Services, a range of Service Groups, Council, SES, Police. The complex arrangements under the State Emergency Management Organisation structure create numerous interfaces in the delivery of welfare services.
- Total Catchment Management — Local advisory board, EPA, Department of Health, Council.

2.12 Transport Links

There are several high level road crossings of the Kemps Creek floodplain, in addition to numerous low level bridges and causeways. Their hydraulic performance is summarised in Appendix B. The high level crossings are:

- The Elizabeth Drive Bridge crossing of Kemps Creek. The bridge waterway flows free up to the 100 year ARI flood level, but causes significant increase in water level upstream of the bridge, particularly at the PMF.

- The Bringelly Road crossings of Kemps Creek and Bonds Creek. Both of these crossings are flood free up to the 10 year ARI flood.

Most other roads can expect to be cut at some location by a flood with an ARI of 1 - 2 years. This poses special problems for many residents in the Austral area whose access is cut off in times of flood. The duration of closure for many of these crossings is usually a few hours, but this nevertheless causes considerable discontent with the community, many of whom work outside the area.

2.13 Hydraulic Categorisation

2.13.1 Hydraulic Definitions

Hydraulic categories are used to identify the areas that convey either most, partial or none of the flow. These categories aid in the management of landuse planning of flood prone land. The "*Floodplain Management Manual"* (NSW Government, 2001) provides the following definitions for each hydraulic category:

- **Floodway**
  Areas conveying a significant proportion of the flow, where any partial blockage of the flow path will adversely affect flood behaviour. The definition of what is "significant proportion of flow" is a qualitative assessment, and should be based on a site-specific basis.
- **Flood Storage**
  Areas outside the floodway that significantly influence flood behaviour. Floodplain alteration within this area would cause peak flood levels to increase by greater than 0.1 m, or peak discharge to increase by greater than 10%.
- **Flood Fringe**
  The remaining area of land affected by flooding, where floodplain alteration would have no significant impact on flood behaviour.

The boundaries for these hydraulic categories are not static and will fluctuate with increasing or decreasing flood magnitude and changes to floodplain morphology.

2.13.2 Hydraulic Categories

The hydraulic categorisation process involved identifying the floodway, flood storage and flood fringe within the catchment based on the HEC-RAS model analysis undertaken for this study.

The flood extent for the PMF and the 100 year ARI floodway are shown on Figure B4.2 in Appendix B.

The flood fringe, as identified by this study, lies between the floodway associated with the 100 year ARI flood and the Probable Maximum Flood extent. It includes the 100 year ARI flood fringe and the outer floodplain.

2.14 Flood Hazard Categorisation

2.14.1 Hazard Definitions

Flood hazard refers to the potential for damage to properties or loss of life during a flood. Hazard categories are divided into 'high' and 'low' and are defined by the NSW Government's (2001) *"Floodplain Management Manual"* as:

- **High Hazard** – Possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty in wading to safety; potential for significant structural damage to buildings.
- **Low Hazard** – trucks could evacuate people if necessary; able-bodied adults would have little difficulty wading to safety.

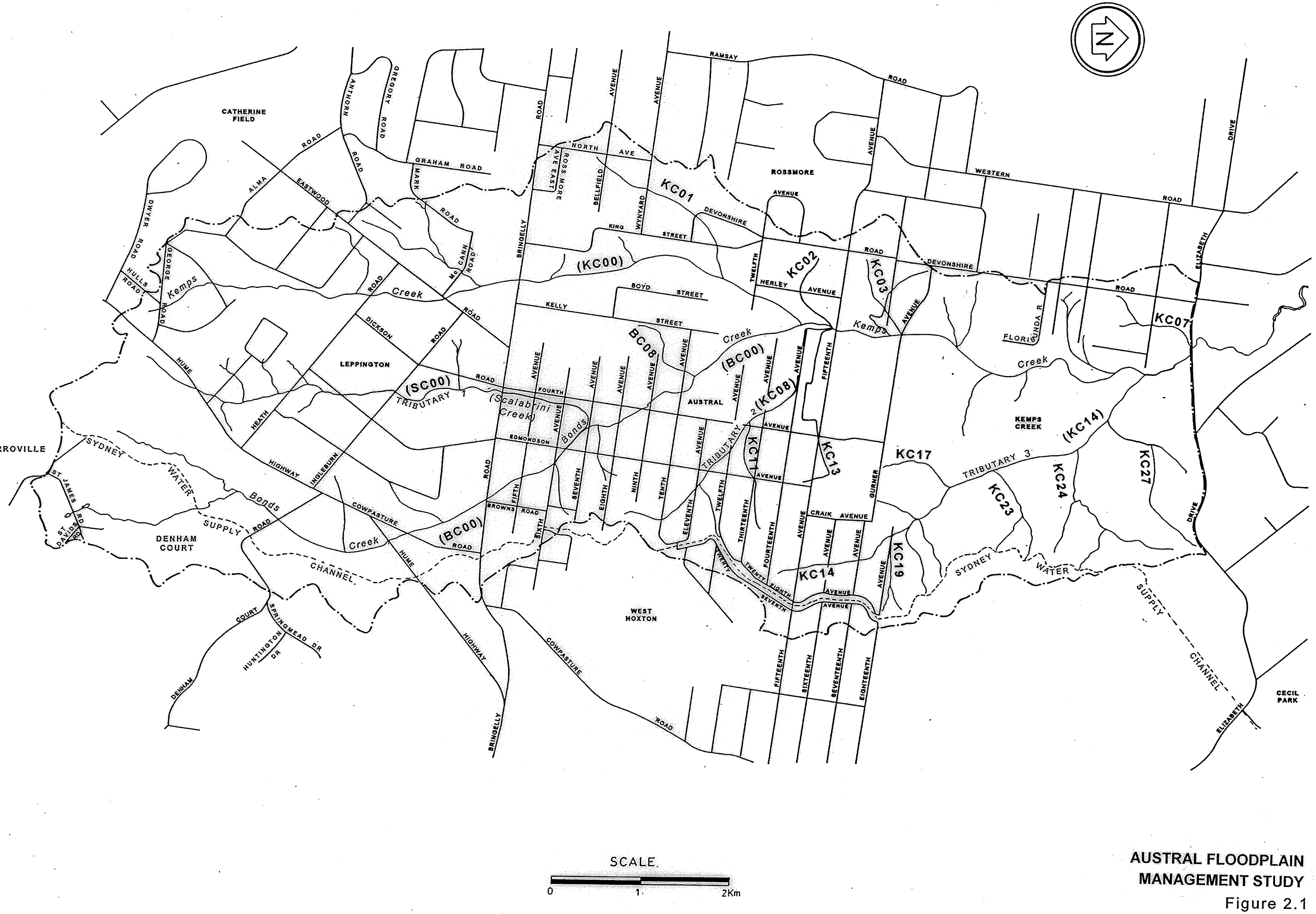
The provisional flood hazard is a measure of the combination of depth and velocity at a particular location. Figure G2 in the Manual shows the provisional hazard ratings and the interface between High and Low hazard conditions. This classification has been used to assess the area subject to high hazard within the study area. That analysis showed that the high hazard area generally fell within the floodway area. For the study area the floodway has been defined at the width of unimpeded floodway necessary to carry the 100 year ARI flood flow without causing a significant increase in flood levels (greater than 100 mm). (See Appendix B for further details).

The provisional hazard can be increased or reduced after consideration of the following factors:

- effective warning time
- flood awareness
- rate of rise of floodwaters
- duration of flooding
- evacuation problems
- access
- potential flood damages.

Consideration of all of the above factors, particularly the short warning time and the evacuation and access problems in the area, would tend to result in an increase of the provisional hazard rating. For planning purposes it is recommended that the floodway area be adopted as a high hazard area.

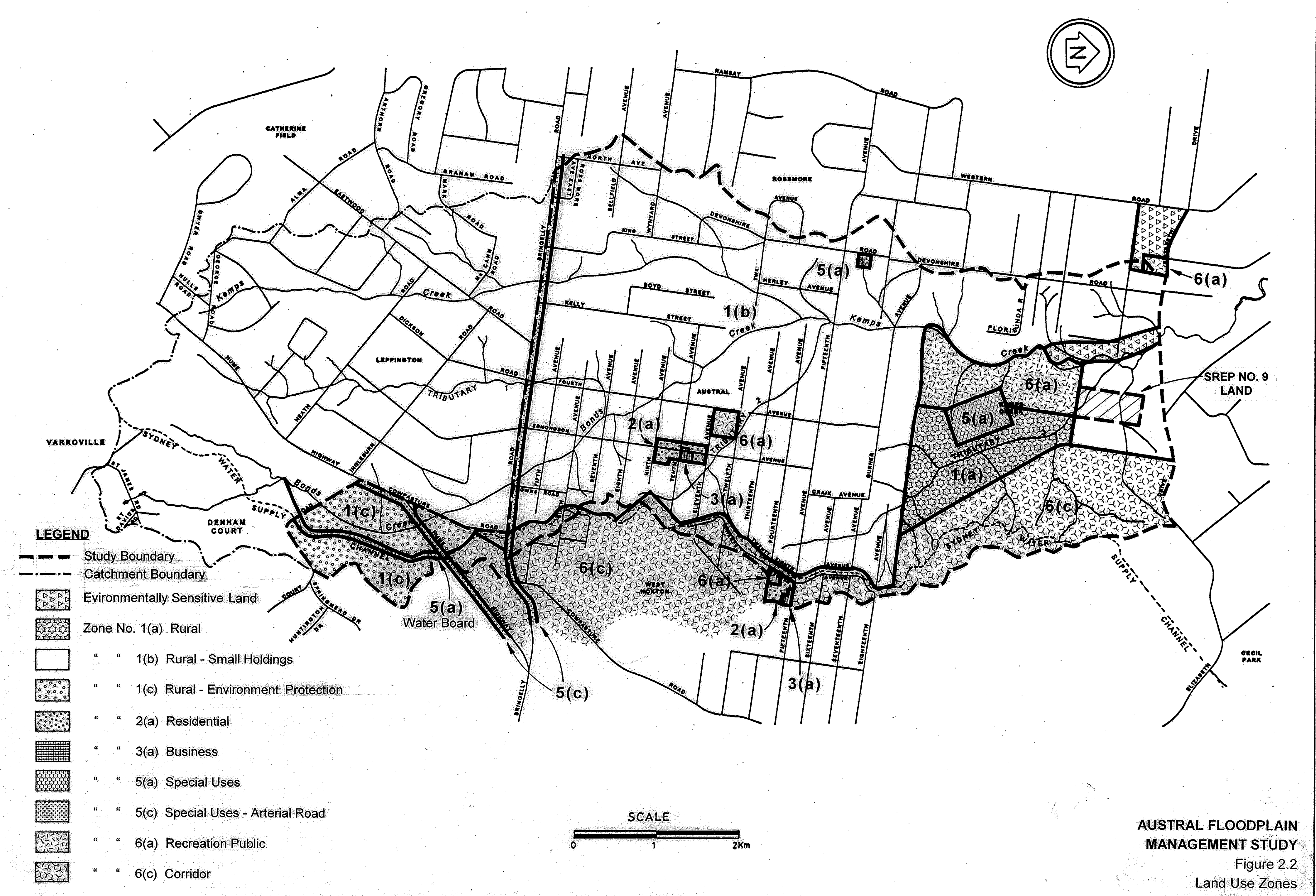
Section 3.2.11 presents the definition of High, Medium and Low Flood Risk Zones for the **purposes of planning controls.** These Risk Zones are based on the hydraulic categories identified through the hydraulic analysis. Section 5.2.3 presents the Planning Matrix, which applies to these risk zones, proposed for incorporation in the Austral Floodplain Management Study DCP.



AUSTRAL FLOODPLAIN MANAGEMENT STUDY

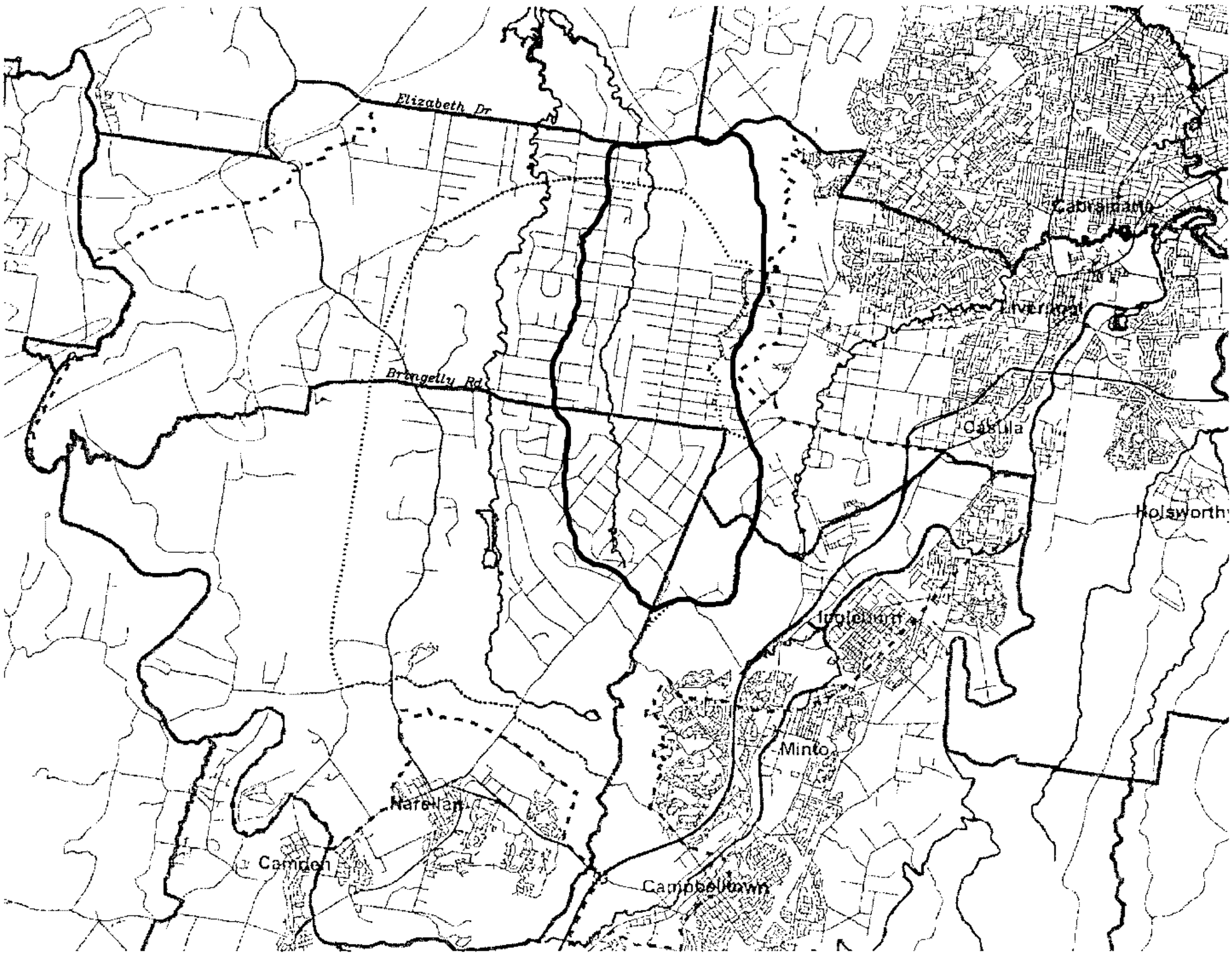
Figure 2.1

CATCHMENT PLAN



AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure 2.2
Land Use Zones



(Reference: Penrith City Council)

Legend

- Main Roads
- Roads
- Major Drainages
- ANEF 20 (Option A)
- Core Study Area (modified)
- Bringelly Investigation Area
- LGA Boundary
- **Austral Study Area**

N

0 2.5

Kilometres

AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure 2.3
South West Investigation Area and Core Study Area

3. FLOOD PLANNING LEVELS AND FLOOD RISK ZONES

This section discusses the issues associated with the selection of Flood Planning Levels and the incorporation of these within the Flood Planning Matrix.

3.1 General

The merit based approach to floodplain management introduced by the NSW Government's *Floodplain Management Manual* (2001) raises the need to select a flood planning area (FPA) and flood planning levels (FPLs) based on the particular local circumstances of flooding rather than adopting a statewide standard. Definitions of the flood planning area and levels provided in the Manual are as follows:

- Flood planning area: the area of land subject to flood related development controls.
- Flood planning levels: the combination of flood levels and freeboards selected for planning purposes within the flood planning area.

Various land uses are subject to alternate consequences (risks) from the flood hazard (eg the consequences of the flooding of a hospital are significantly different to the consequences of the flooding of an amenities block in park land). Accordingly, there needs to be a simple approach reflecting the different flood risk to different land uses within the floodplain, while maintaining an understanding that flood risks still exist. The planning matrix approach is an appropriate methodology (refer Section 5.2 below) to address these issues.

The merit approach is inherent in the selection of a FPL. It involves comparing social and economic considerations with the consequences of flooding, with a view to balancing the potential for property damage and danger to personal safety against the value of floodplain occupation. If the adopted FPL is too low for the type of development, new developments may be inundated relatively frequently, people may be subject to unnecessary danger and damage to associated public services will be greater. Alternatively, adoption of an excessively high FPL may subject land that is rarely flooded to unwarranted controls, reducing its productive usage to flood compatible activities.

The following section of the report sets out the factors that influence the selection of the flood planning levels and recommends the appropriate standard for the Austral - Kemps Creek area. Section 5.2 provides information on the incorporation of selected Flood Planning Levels within the Planning Controls Matrix.

3.2 Flood Planning Level Factors

The key factors in selecting the Flood Planning Level (and corresponding Flood Planning Area) can be summarised as:

- Topography and zoning
- Long term strategic plan for land use near and on the floodplain
- Existing and potential land use
- Current flood level used for planning purposes
- Potential flood damages
- Consequences of floods larger than the FPL
- Environmental issues
- Flood warning, emergency response and evacuation issues

- Flood readiness
- Land values and social equity
- Floods as the basis for setting FPLs (FPL = Flood + freeboard).

3.2.1 Land Use and Topography

The Issue: **Is there a characteristic of the local topography which points to a particular flood used to derive the FPL? This may arise from sudden changes in elevation and width of floodplain.**

The Austral - Kemps Creek area topography as it relates to the extent of flooding is characterised by the following features:

- The 20 year ARI flood inundates the main floodplain of Kemps Creek, Bonds Creek and the major tributaries. In Kemps Creek below Gurner Avenue and in Bonds Creek below Bringelly Road, typical flood levels are 1 - 1.2 m higher than the 1 year ARI flood levels (which is about the capacity of the channel). Further upstream the 20 year flood depth declines and is typically 500 - 700 mm above the 1 year ARI flood. The area affected by the 20 year ARI flood covers about 650 ha of land which contains about 120 residences and about 10 market gardens. Of these about 80 residences can be expected to be damaged by flooding above floor level and all the market gardens could expect to suffer substantial damage to growing crops and loss of cultivated soil.

- The 100 year ARI flood is generally 200 to 300 mm higher than the 20 year ARI flood, but does not result in a great increase in the extent of flooding due to the comparatively steep and continuous rise in the topography away from the river flats. The flooded area at the 100 year ARI flood is about 750 ha and affects about 150 residences and 30 market gardens. Of these about 100 residences can be expected to be damaged by flooding above floor level and all the market gardens could expect to suffer substantial damage to growing crops and loss of cultivated soil.

- The PMF is about 500 - 700 mm higher than the 100 year ARI event for all the study area upstream of Gurner Avenue. Below Gurner Avenue, the PMF is 900 - 1,200 mm higher than the 100 year ARI flood. Due to the topography, the additional area inundated by the PMF is only 330 ha which is relatively small compared to towns on major rivers. At the PMF about 220 properties would be flood affected and about 60 market gardens. Of these about 170 residences could be expected to be damaged by flooding above floor level and all the market gardens could expect to suffer substantial damage to growing crops and loss of cultivated soil.

Consequently, from an examination of the topography and development patterns and from the gradual nature of incremental inundation between the 20 year ARI and PMF levels, there appear to be good reasons to adopt the PMF as the basis for the FPL for imposition of planning controls.

Conclusion: Appropriate basis for the FPL is the PMF.

3.2.2 Long Term Strategic Plan for Land Use near and on the Floodplain

The Issue: **Will the choice of flood used to derive the FPL affect future trends in flood damages, either adversely or beneficially?**

Most of the floodplain is zoned for rural dwelling with only two parcels of land in public ownership: a parcel of about 38 ha of land at the junction of Kemps and Bonds Creeks and land on the right (east) floodplain of Kemps Creek to the south of Elizabeth Drive, some of which is jointly owned by DIPNR and private owners.

The large areas of floodplain and creek which are in private ownership pose special problems for the future development within the study area. In particular there appears to be a conflict between the expectations of a landholder to develop and use the land for permissible purposes and the needs of the community to retain an unimpeded floodplain and creek channel. These problems are exacerbated by the relatively small size of the creek channel in many locations which tends to give landholders the false impression that it is only a minor creek and that minor earthworks to divert or store water are appropriate developments.

Because the majority of the area affected by all levels of flooding is in private hands, and because of the need to redress some of the problems caused by inappropriate developments in the past, it would be appropriate to establish some level of control over all flood affected land.

The flood affected land forms a valuable resource from which residents derive income from agricultural pursuits and gain amenity by way of enjoyment of open space. Many of these pursuits are compatible with the functioning of the land for flood conveyance and storage. There is a need, however, to place much more stringent controls on earthworks and housing development in the flood affected area. Without planning controls on these areas, there is potential for intensification of land use and hence an increase in potential flood damages. The potential for this to occur in Austral - Kemps Creek is serious, given that the area adjoins the development areas of Hoxton Park and is close to the site of Sydney West airport. If a lower than desirable flood were to be selected as the basis for the FPL, the flood characteristics of the area could lead to severe flood damage in the future.

In summary, development patterns in Austral - Kemps Creek present a significant constraint in the selection of the FPL and warrant the adoption of a FPL based on at least the 100 year ARI flood.

Conclusion: Appropriate basis for the FPL is at least the 100 year ARI flood level.

3.2.3 Current Flood Level Used for Planning Purposes

It has been Council's practice in recent years to require new houses to have a floor level 500 mm above the 100 year ARI flood level. This minimum floor level is close to the PMF flood level in most of the settled area of Austral and Kemps Creek. The relatively small difference between the 100 year ARI flood and the PMF is good reason to adopt the PMF as a basis for the FPL. At the 20 year ARI level, the river flats have already been inundated and there is only a small increase in flood level up to the 100 year ARI event. Consequently if a lesser flood were adopted as the basis for the FPL, there would not be a large amount of land suddenly freed from development constraints because of flooding.

Consequently, from an examination of the topography and development patterns and from the gradual nature of incremental inundation between the 20 year ARI and PMF levels, there appear to be good reasons to adopt the PMF as the basis for the FPL for imposition of planning controls.

Conclusion: Appropriate basis for the FPL is the PMF.

3.2.4 Potential Flood Damages

The Issue: **Does the nature or rate of increase of flood damages vary greatly within the feasible range of floods associated with the FPL?**

Current zoning has resulted in the potential for flood damages to start at the 1 year ARI flood. The number of residences damaged by over-floor flooding increases steadily with larger magnitude floods and there is no clear change in flood damage potential at any particular flood level.

On the basis of the potential for flood damages under present day conditions and the shape of the damages-frequency relationship (Figure C7.1 in Appendix C), a FPL based on at least the 100 year ARI flood appears reasonable.

Conclusion: Appropriate basis for the FPL should be at least the 100 year ARI flood level.

3.2.5 Environmental Issues

The Issues: **Does the riverine environment suffer or benefit from the selection of a particular flood to define the FPL?**

The major environmental consequences for the Kemps Creek floodplain relate to the management controls which might be placed on floodplain vegetation.

It would appear that a FPL based on a flood greater than the 100 year ARI flood is warranted for the Austral - Kemps Creek area to achieve a desirable balance of economic, environmental and social factors in the future.

Conclusion : Appropriate basis for the FPL is PMF.

3.2.6 Flood Warning, Emergency Response and Evacuation Issues

The times of rise of the streams in the Austral area are quite short and hence the potential warning time is limited to 2 to 3 hours on the main arms and less on the tributaries. Most of the residents work in areas remote from the catchment and therefore there is a problem with dissemination of the warning itself and promoting an adequate response which will result in a reduction in flood damages. Consequently, a formal flood warning system for the study area will have limited success in reducing flood damages.

The State Emergency Service (SES) has prepared a draft (September 2001) Liverpool City Local Flood Plan, which is a sub-plan of the Liverpool Local Disaster Plan. The area covered by this plan includes Kemps Creek.

However, because of the relatively rapid generation of flooding in response to rainfall in this area, it is difficult to envisage any significant evacuation response in <u>advance</u> of actual flooding with current forecasting technology.

Faced with this situation, it would be appropriate to impose a FPL such that people in flood prone areas can safely remain within their property until flood waters recede without needing to evacuate. The FPL should be based on a flood that is sufficiently high that damage is not incurred when property owners cannot return home in time to lift belongings to higher levels and protect their property against damage.

Conclusion : Appropriate basis for the FPL at least the 100 year ARI flood level.

3.2.7 Flood Readiness

The Issue: **Does the flood history in Austral - Kemps Creek suggest a FPL based on a particular flood? This involves a consideration of the magnitude and frequency of historic floods as well as the "flood awareness" of the population.**

There are limited records of some severe floods in the study area, including those occurring in 1867, 1956 and 1978 (DWR, 1991). More information is available for the floods of 1986 and 1988. The 1988 event appears to be one of the largest floods on record within the study and, according to the Flood Study (DWR, 1990), could be considered to be comparable to a 50 year ARI flood. Although this flood is within living memory, its effects may now be becoming outside the experience of many residents, especially those newly moved to the area.

Consultation with the community indicates that the major concern is frequent flooding which cuts road crossings rather than major damage to houses and property. The Austral - Kemps Creek area has been fortunate in recent years, as flooding has been restricted to minor, nuisance events such as that occurring in July 1990. Few residents appear to have had experience of a major flood and there is therefore a limited basis on which residents can make an informed judgment. Residents have expectations that Council should provide a FPL comparable to that in a suburban area and expect a much higher hydrologic standard for many of the roads. This implies that residents would support a FPL based on a flood greater than the 20 year ARI flood.

Conclusion: Appropriate basis for the FPL is greater than 20 year ARI flood level.

3.2.8 Land Values and Social Equity

The Issue: **Is there a range of FPL standards which would have a marked economic or social impact?**

With regard to economic impact, a very restrictive FPL carries with it the burden of unwarranted development costs which flow through to the community cost of living. On the other hand, too low a FPL encourages unwise development and increases average annual flood damages.

The Austral study area contains about 3,200 ha of land of which about 70% is flood free at the PMF. There is therefore a substantial area of land available for further development, if required. Whatever level of future development is proposed for the Austral - Kemps Creek area, planning controls will be necessary to:

- Control the increase in runoff rate from increased impervious area on flood free land.
- Control the location, density and floor level of developments on flood affected land. The main flood related controls which would be required in the area between the 100 year ARI floodway and the PMF are minimum floor levels.

Any proposal for increasing the density of development within the Austral - Kemps Creek area would require substantial investment in infrastructure services to support higher density of population. The overall economic impact of adopting the FPL based on the PMF would be small compared to the other costs associated with development and the flood damage which would result if a FPL based on a lesser flood were adopted.

The major social impacts associated with flooding are the inconvenience caused by flooding of roads and the stress and trauma associated with flooding of residences. The flood characteristics of the Austral - Kemps Creek area are such that a high FPL is needed to ensure that the current level of problems are not exacerbated in the future.

In summary, it would appear that a FPL based on a flood greater than the 100 year ARI flood is warranted for the Austral - Kemps Creek area to achieve a desirable balance of economic, environmental and social factors in the future.

Conclusion : Appropriate basis for the FPL is the PMF.

3.3 Recommended Flood Planning Levels

The final choice of a FPL must be based on qualitative rather than quantitative grounds. The Sections above indicate that a range of Flood Planning Levels across the entire floodplain is appropriate for implementation in the Austral area. It is recommended that Council adopt:

- for residential development: - 100 year ARI + 0.5 m freeboard
- for critical utilities: - PMF + 0.5 m freeboard
- for flood awareness: - PMF.

A gradation of planning controls should be developed that applies to land that falls within the extent of the PMF. Recommendations are contained within the matrix of planning controls, which is presented in more detail in Section 5.2.2.

3.4 Flood Risk Zones

It is recommended that Council adopts:

- The extent of the **Probable Maximum Flood** (PMF) as defining the area that will be subject to flood related planning and development controls in the Austral area.
- The **high hazard** hydraulic zone associated with the **100 year ARI** discharge as the **high flood risk zone**.
- The **low hazard** hydraulic zone associated with the **100 year ARI** discharge as the **medium flood risk zone**.
- The area between the **100 year ARI extent** and the **PMF extent** as the **low flood risk zone**.

The flood risk zones (FRZ) for the Austral area referred to above are defined as:

- **High Flood Risk** This is the area of land subject to high hydraulic hazard in a 100 year ARI flood event. The high flood risk zone is where major impacts on flood behaviour, high flood damages, potential risk to life or evacuation problems would be anticipated. Most development should be restricted in this precinct. There would be a significant risk of flood damages and changes in flood behaviour in this precinct without compliance with flood related building and planning controls.
- **Medium Flood Risk** This applies to land below the 100 year ARI flood level subject to low hydraulic hazard. In this zone there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls.
- **Low Flood Risk** This applies to all land within the floodplain (ie within the extent of the probable maximum flood) not identified as being within either high or medium flood risk zone, that is land above the 100 year ARI flood extent. In this zone the risk of damages is low for most land uses and therefore most land uses would be permitted.

The Low Flood Risk Zone is that area above the 100 year ARI flood which is potentially subject to flooding but not included in any of the other FRZs. This area is still subject to some flood-related risk. Those uses considered to be critical or requiring maximum protection against risk from flooding should be identified as undesirable land uses in this zone.

The other major purpose of this FRZ is to identify and recognise the potential flood risk for all persons and properties affected by the PMF, regardless of whether any specific development controls are to be applied. This provides a basis for flood awareness programs, evacuation and emergency planning and to maximise the preparedness of the community.

These FRZs have been formulated to provide a basis for strategic planning and development control having regard to the specific characteristics of the Austral Floodplain.

4. EXISTING FLOODPLAIN MANAGEMENT MEASURES

4.1 Planning Measures

Existing planning measures were reviewed in Section 2.5. As stated, land use in the study area is mainly controlled by the Liverpool Local Environmental Plan 1997. The document contains measures restricting the use of flood liable land including filling.

The LEP generally provides adequate provisions relating to flooding within the City. However, the LEP should be updated to include changes to the definitions in keeping with the FMM. Recommendations for these changes are presented in Appendix F.

4.2 Drainage Improvement Measures

A number of structural measures have been constructed over the years, mainly to combat localised drainage problems.

Council have constructed a channel upstream of Sixth Avenue on Scalabrini Creek. This excavated channel is approximately 150 m long and 18 m wide. This channel does not perform to its potential capacity during high stormwater flows. The upstream natural gully, approximately 200 m long, which runs from Fifth Avenue to the improved channel, has minimum capacity. The flows bypass the channel, run along Fifth Avenue and eventually are conveyed along Fourth Avenue, which acts as a floodway. Further analysis of the channel is described in Section 5.13.2.

A number of small levees exist in Kemps Creek and Bonds Creek. It appears that some of these levees were constructed by the landowners to protect their properties from flooding.

Council carried out excavation of Bonds Creek between Edmondson Avenue and a point just upstream of the confluence with Kemps Creek. The creek channel and banks are generally clear of debris and vegetation. However, considerable erosion of the banks is evident, particularly downstream of Eighth Avenue. Section 5.13.5 reviews a previous proposal for upgrading the channels.

In 1999 Council replaced the existing flood damaged culverts at Gurner Avenue on Kemps Creek with new culverts of the same size (2 x 750 mm).

5. POTENTIAL FLOODPLAIN MANAGEMENT MEASURES

This section identifies the full range of measures available for flood mitigation. However, not all are necessarily appropriate for the Austral catchment or acceptable to the Austral community. The measures are reviewed for appropriateness and those that are recommended are ranked according to various criteria in Section 6.

5.1 Flood Risk and Available Measures

There are three types of flood risk that affect flood prone areas, namely:

- the existing flood risk associated with existing development;
- the future flood risk associated with any new development;
- the continuing flood risk, which is the risk which remains after floodplain management measures are implemented.

The 1986 Floodplain Development Manual dealt with both existing and future risk by considering flood mitigation and development controls. The new manual takes a more strategic approach requiring assessment and consideration of all three types of risk.

Each type of flood risk involves two distinct elements. These are the **danger to personal safety** and the **potential for property damage** resulting from the flood risk. Both of these elements need to be considered for each type of flood risk and may require different management measures. Management measures to deal with flood risk are broken down into three categories, as shown in Table 5.1 below.

Table 5.1
Floodplain Risk Management Measures

Type of Risk	Property Modification Measures	Response Modification Measures	Flood Modification Measures
Existing	• voluntary purchase • house raising • flood proofing buildings • flood access		• flood control dams • retarding basins • levees • bypass floodways • channel improvements • flood gates
Future	• zoning • building and development controls		
Residual/ Continuing		• community awareness • community readiness • flood prediction and warning • local flood plans • evacuation arrangements • recovery plans	

Property modification refers to reducing risk to properties through measures such as land use zoning, minimum floor level requirements or house raising. Such options are largely planning measures, as they are aimed at ensuring that the use of floodplains and the design of buildings are consistent with flood risk. They are a mix of structural and non-structural methods of damage prevention. These measures are usually applicable for two types of risk:

- measures to prevent future flood risk problems - primarily planning measures;
- measures to alleviate existing flood risk problems - house raising, flood proofing, voluntary purchase of flood affected properties.

Response modification refers to changing the response of flood prone communities to the flood risk by increasing flood awareness by the installation of flood warning systems and the development of contingency plans for property evacuation. These options are wholly non-structural and usually applicable for addressing continuing flood risk.

Flood modification refers to changing the behaviour of floods in regard to discharges and water surface levels to reduce flood risk. This can be done by stream clearing, culvert upgrading, channel improvements, or construction of levees and retarding basins. Such measures are also known as "structural" options as they may involve the construction of engineering works. They are usually applicable for existing flood risk.

The applicability of each measure for the Austral area is reviewed in the following sections. Results are presented of modelling options using the HEC-2 hydraulic model. The model results are quoted to the nearest 10 mm given by the calculations carried out within the models. The important aspect to note is that these results represent differences between water levels calculated by the model when all things have been kept the same except the particular option under investigation. These differences should not be used to determine the absolute flood level after the implementation of the scheme. The accuracy of the overall hydraulic model is considered to be limited to 100 mm.

PROPERTY MODIFICATION MEASURES

5.2 Planning Measures

The results of the Floodplain Management Study indicate that the most effective activity for Council to adopt in the Austral area is strong floodplain management planning, applied consistently by all branches of Council.

Planning measures are contained in several existing or proposed policy documents. Recommendations for specific improvements are outlined below. In general, however, it is recommended that Council embark on a strategic plan to update all DCPs, as they are generally not consistent with each other or the *Floodplain Management Manual* (2001).

5.2.1 Liverpool LEP 1997

The LEP generally provides adequate provisions relating to flooding within the City. However, the LEP should be updated to reflect the definitions provided within the new *Floodplain Management Manual* (2001). Appendix F contains suggested amendments, prepared by Don Fox Planning, to definitions within the LEP.

5.2.2 Austral Floodplain Management Study Draft DCP

This draft Development Control Plan, once adopted, will reflect floodplain related planning controls applying to the Austral and Kemps Creek areas. The DCP is the appropriate instrument through which to implement controls via the Planning Matrix. More details regarding the Planning Matrix are provided in Section 5.2.3.

It is recommended that Council adopt:

The extent of the **Probable Maximum Flood** (PMF) as defining the area which will be subject to flood related planning controls in the Austral area.

- The **high** hazard hydraulic zone associated with the 100 year ARI discharge as the **high risk zone**.
- The **low** hazard hydraulic zone associated with the 100 year ARI discharge as the **medium risk zone**.

The principal controls contained within the matrix or elsewhere within the DCP include:

Within Flood Planning Area:

- Minimum floor level of a proposed dwelling located within the medium and low flood risk zone must be the flood level corresponding to the 100 year ARI flood plus 500 mm.
- Controls on earthworks and fill that alter land surface levels.
- Controls on the location of essential services such as hospitals and emergency services.

Within High Flood Risk Zone:

- No new buildings - developments must be located outside the 100 year ARI floodway as defined in the Austral Floodplain Management Study.
- Strict controls on earthworks and fill that alter land surface levels.

5.2.3 The Planning Matrix

The planning matrix approach distributes land uses within the floodplain and controls development to minimise the flood consequences. Using this approach, a matrix of development controls based on the flood hazard and the land use can be developed that balances the risk exposure across the floodplain. The following steps are required to prepare a Planning Matrix:

Step 1 – Categorising the Floodplain

The first step in the preparation of the planning matrix is to identify different flood risk zones (FRZs), reflective of the variable flood hazard within the separate floodplains. These risk zones were defined in Section 3.4 above and are summarised as follows:

Low Flood Risk Zone
The classification of a ‘Low Flood Risk Zone’ means that property would be unlikely to be inundated in a 100 year ARI flood but likely to be inundated from larger (ie rarer) floods.

Medium Flood Risk Zone
The classification of a ‘Medium Flood Risk Zone’ means that a property would be inundated in a 100 year ARI flood, however conditions are not likely to be hazardous.

High Flood Risk Zone
The classification of a ‘High Flood Risk Zone’ means that property will be inundated in a 100 year ARI flood and that hazardous conditions and significant impacts to flood behaviour may occur. This could mean that there would be a possible danger to personal safety, able bodied adults may have difficulty wading to safety, evacuation by trucks may be difficult, or there may be a potential for significant structural damage to buildings and significant impacts to flood behaviour. This is an area of higher hazard where stricter controls will be applied.

Step 2 – Prioritising Land Uses in the Floodplain

The next component in the preparation of the planning matrix is to prioritise land uses within the floodplain. This is achieved by identifying discrete categories of land uses of similar levels of sensitivity to the flood hazard. For Austral the following categories have been adopted:

- Critical uses and facilities
- Sensitive uses and facilities
- subdivision
- residential
- commercial and industrial
- tourist related development
- recreation and non-urban
- concessional development.

These categories are listed under each FRZ in the planning matrix depending on the level of flood risk which is considerable acceptable. This provides a basis for specifying whether certain categories are unsuitable land uses in different parts of the floodplain or whether they are suitable subject to varying degrees of development control.

Step 3 – Controls to Modify Building Form and Community Response

The next component in the preparation of the planning matrix is to assign different planning controls in order to modify building form and the ability of the community to respond in times of flooding. The controls assigned depend on the type and location of land use within the floodplain. The type of controls can be categorised under seven main headings as follows:

- floor levels
- building components
- structural soundness
- flood effect on others
- evacuation
- management and design.

There should be variance to the stringency of development controls reflecting the attitudes of the community, the sensitivity of the land use category to the flood hazard and the location of the land use within the floodplain.

The most appropriate mechanism for the implementation of the planning matrix is its adoption by Council within the Austral Floodplain Management Study DCP. In addition to the preparation of the DCPs, Council will need to undertake discrete changes to its LEP in order to ensure consistency with definitions, special flood development control clauses and to restrict development within the high FRZ.

The Planning Matrix prepared for the Austral area is presented in Table 5.2 as part of the recommended planning measures.

Table 5.2: Proposed Planning Controls Matrix

Flood Risk Precincts (FRPs) – Low Flood Risk

Planning Consideration	Critical Uses & Facilities	Sensitive Uses & Facilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development
Floor Level		3		2,6	1,5,6	2,6	1	4
Building Components		2		1	1	1	1	1
Structural Soundness		3		2		2		
Flood Effects		2	2		2	2		
Car Parking & Driveway Access		1,3,5, 6,7		1,3,5, 6,7	1,3,5, 6,7	1,3,5, 6,7	2,4,6, 7	2,3,4, 6,7
Evacuation		2,3,4	2,3,4, 5	2,3	1,3	2,3		
Management & Design		4,5	1					

Flood Risk Precincts (FRPs) – Medium Flood Risk

Planning Consideration	Critical Uses & Facilities	Sensitive Uses & Facilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development
Floor Level				2,6	1,5,6	2,6	1	4
Building Components				1	1	1	1	1
Structural Soundness				1	1	1	1	1
Flood Effects			1	2	2	2	2	2
Car Parking & Driveway Access				1,3,5, 6,7	1,3,5, 6,7	1,3,5, 6,7	2,4,6, 7	2,3,4, 6,7
Evacuation			2,3,4, 5	2,3	1,3	2,3	4	2
Management & Design			1		2,3,5	2,3,5	2,3,5	2,3,5

Flood Risk Precincts (FRPs) – High Flood Risk

Planning Consideration	Critical Uses & Facilities	Sensitive Uses & Facilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development
Floor Level							1	4
Building Components							1	1
Structural Soundness							1	1
Flood Effects							1	1
Car Parking & Driveway Access							2,4,6, 7	2,3,4, 6,7
Evacuation							4	2
Management & Design							2,3,5	2,3,5

Notes: Not Relevant Unsuitable Land Use

1 *Freeboard* equals an additional height of 500 mm.
2 The relevant environmental planning instruments (generally the Local Environmental Plan) identify development permissible with consent in various zones in the LGA. Notwithstanding, constraints specific to individual sites may preclude Council granting consent for certain forms of development on all or part of a site. The above matrix identifies where flood risks are likely to determine where certain development types will be considered "unsuitable" due to flood related risks.
3 Filling of the site, where acceptable to Council, may change the FRP considered to determine the controls applied in the circumstances of individual applications.

Floor Level

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

Building Components & Method

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

Structural Soundness

1 Engineers report to certify that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP *flood* plus *freeboard.*
2 Applicant to demonstrate that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a 1% AEP *flood* plus *freeboard.* An engineer's report may be required.
3 Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a *PMF*. An engineer's report may be required.

Flood Effects

1 Engineers report required to certify that the development will not increase *flood* effects elsewhere, having regard to: (i) loss of flood storage; (ii) changes in flood levels, flows and velocities caused by alterations to flood flows; and (iii) the cumulative impact of multiple similar developments in the vicinity.
2 The impact of the development on flooding elsewhere to be considered having regard to the three factors listed in consideration 1.

Car Parking and Driveway Access

1 The minimum surface level of a car parking space, which is not enclosed (eg. open parking space or carport) shall be as high as practical, but no lower than the 5% AEP *flood* level or the level of the crest of the road at the location where the site has access.
2 The minimum surface level of a car parking space, which is not enclosed, shall be as high as practical.
3 *Enclosed car parking* or Basement carparks capable of accommodating more than 3 motor vehicles on land zoned for urban purposes, must be protected from inundation by *floods* equal to or greater than the 1% AEP flood plus 0.1m.
4 The driveway providing access between the road and parking space shall be as high as practical and generally rising in the egress direction.
5 The level of the driveway providing access between the road and parking space shall be a minimum of 0.1m above the 1% AEP *flood* or such that depth of inundation during a 1% AEP *flood* is not greater than either the depth at the road or the depth at the car parking space. A lesser standard may be accepted for single detached dwelling houses where it can be demonstrated that risk to human life would not be compromised.
6 *Enclosed car parking* and car parking areas accommodating more than 3 vehicles at a level below the 5% AEP *flood* level or at a level that is more than 0.8m below the 1% AEP *flood* level shall have *adequate warning systems, signage and exits*
7 Restraints or vehicle barriers to be provided to prevent floating vehicles leaving a site during a 1% AEP *flood*
Note: A flood depth of 0.3m is sufficient to cause a typical vehicle to float

Evacuation

1 Reliable access for pedestrians required during a 1% AEP *flood.*
2 Adequate *flood* warning is available to allow safe and orderly evacuation without increased reliance upon the SES or other authorised emergency services personnel.
3 The development is to be consistent with any relevant *flood evacuation strategy* or similar plan.
4 The evacuation requirements of the development are to be considered. An engineers report will be required if circumstances are possible where the evacuation of persons might not be achieved within the *effective warning time*.
5 Reliable access for pedestrians or vehicles required during a *PMF* to a publicly accessible location above the *PMF.*

Management and Design

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

5.2.4 Flood Related Line of Limitation

As a result of previous studies of the Austral-Kemps Creek area, there are some areas which have had flood-related Lines of Limitation placed on Section 88B of the Property Title. This is currently being enforced by Council through Council's Floodplain Management Plan (adopted December, 1987).

Under the proposed Planning Controls Matrix (refer Table 5.2 above), the flood-related Line of Limitation will no longer be required to be enforced by Council as the matrix proposes variable controls across the floodplain. However, until such time as the Planning Controls Matrix is fully implemented by Council, the following process should apply:

- Any Development Application submitted to Council shall be assessed in accordance with the Planning Controls Matrix.
- The applicant, if they so wish, may apply at any time to extinguish the flood-related Lines of Limitation on their property at their own cost.

5.2.5 Rural Land Use Management for Flood Prone Land

It is recommended that Council develop a set of recommended guidelines for rural activities on flood prone land. The objective of these guidelines will be to encourage rural landholders to undertake activities in a manner that seeks to minimise the losses in agricultural production and to agricultural facilities from flooding. The recommended guidelines would include recommended measures to:

- Allow passage of floodwaters through properties with minimal obstruction.
- Appropriate design of buildings to allow passage of floodwater (eg arrange greenhouses with long axis in direction of flow, "skirt" which can be lifted by flood).
- Location of key assets above flood levels.
- Erosion control measures.
- Flood awareness and planning.

5.2.6 Landfill and Earth Dams Development Control Plan

This draft DCP has been developed by Council and applies to the Liverpool LGA, including Austral. The DCP deals with landfill principally from the perspective of its impact on drainage and flooding. It also deals with some of the issues involved in siting and designing houses to reduce the likelihood of future flooding problems.

The objective of the DCP is to prevent the exacerbation of flooding in rural areas through the conservation, as far as possible, of natural drainage paths and storages using controls on landfill. Proposals must meet a set of performance criteria, formulated to ensure landfill will not create adverse impacts on other people and properties, including:

- limits on areas of filling;
- prohibition of filling in floodways;
- restrictions on diversion of flow.

It is recommended that this draft policy be revised and formally adopted after amendment in line with the recommendations for alteration to definitions provided by Don Fox Planning.

5.2.7 Floodplain Management Committee

Many of the flooding problems in the Austral - Kemps Creek area stem from the flood characteristics of the area, the relatively small size of landholdings and the fact that most of the creek and its floodplain are in private ownership. In this regard, the Austral - Kemps Creek area is beset by a lack of publicly owned areas to convey drainage (as commonly found in urban areas), while not having landholdings of sufficient size to accommodate floods without serious impact on the enjoyment of the landholder. The area has the worst of both worlds.

The combination of flooding problems and land ownership patterns is almost unique and therefore requires innovative initiatives by Council and the willing collaboration of the community. The flooding problems which face the area cannot be reduced by either party acting on its own.

The Liverpool City Council Floodplain Management Committee (LCC FPMC), which contains representatives from the Community, Relevant Agencies, Councillors and Council Officers, is responsible for advising Council on the management of the Austral catchment. The primary task of this Committee is to promote ongoing joint management of the flood prone lands through such activities as:

- Promotion of appropriate land and vegetation management of the creek and floodplain by:
  - Referring to Council's Vegetation and Conservation Strategy (adopted March 1995).
  - Preparing a riparian vegetation management plan suitable for use by landholders.
  - Identifying specific projects for funding assistance requests to Rivercare and other appropriate sources.
  - Liaising with the relevant Catchment Management Committee for funding and assistance for weed control within the riparian zone.
  - Preparing and promoting appropriate "Channel Restoration Guidelines" for the rehabilitation of eroded sections of the creek with the objective of creating stable and maintainable channels, which conform to the general hydrologic performance of the creek system in the area.

- Provide a focus for Total Catchment Management and Rivercare activities, including the identification of projects and co-ordination of funding applications.
- Providing a channel for ongoing "seed" funding from Council to enable initial channel restoration or vegetation clearing projects to be undertaken. The objective of this funding would be to create conditions in which the subsequent ongoing management of an area of land can be effectively managed by the individual landholder. To establish such a scheme Council would need to work with the Committee to establish agreed principles for funding of such projects and the undertakings required from affected landholders to be eligible for funding.
- Providing a forum for ongoing dialogue between Council and the community for the exchange of information in order to reduce the apparent cynicism and mistrust which currently exists.

These tasks could be carried out in the Austral area by the LCC FPMC itself or a sub-committee of the FPMC, as decided by the FPMC. It has been assumed that no additional funding would be required for this initiative.

5.3 Voluntary Purchase Schemes

Removal of housing is a means of correcting previous decisions to build in high hazard areas in the floodplain. The voluntary purchase of residential property in hazardous areas has been part of subsidised floodplain management programs in NSW for over 15 years. After purchase, land is subsequently cleared and the site redeveloped for public open space or some other flood compatible use.

A further criterion applied by State Government agencies is that the property must be in a floodway, that is, in the path of flowing floodwaters where the depth and velocity are such that life could be threatened, damage of property is likely and evacuation difficult.

Where a property is considered to qualify for a voluntary purchase scheme the owner is notified that the body controlling the scheme (usually but not always Council) is prepared to purchase the property when the owner is ready to sell. There is no compulsion whatsoever to sell at any time. The price is determined by independent valuers and the Valuer General, and by negotiation between Council and the owners. Valuations are not reduced due to the flood affected nature of the site.

The timing of any agreed purchase is at the discretion of the landowner. Once the property is purchased, buildings are usually demolished. The land is then used for flood compatible activities.

A voluntary purchase scheme is not considered appropriate for the Austral area, as it would put a huge financial burden on Council and the community. The scheme would not be cost-effective and may take 10 to 20 years to acquire the properties, subject to funding.

5.4 Flood Proofing

This term refers to procedures undertaken, usually on a property by property basis, to protect structures from damage by floodwaters. The required floor level can be achieved in existing structures by jacking up the house, constructing new supports, stairways and balconies and reconnecting services. It is generally not practical or economical to raise brick or masonry houses and the technique is therefore limited to weatherboard and similar structures.

Other procedures to flood proof properties include the construction of levees or diversion banks to deflect floodwaters away from residences. These banks could take the form of grass mounding or low block walls. Each situation should be evaluated separately and a site plan prepared showing the required works. Runoff from within protected areas must be catered for by temporary storage or drainage to downstream areas. On occasions, micro-pump out systems have been used to dispose of internal drainage. Waterproofing the outer skins of structures and providing floodgates/shutters on doorways and windows have also been used. This method is usually only applied to brick or masonry structures, is not common and not usually very aesthetically pleasing. House raising is most applicable to areas which are not in high hazard zones.

The State and Federal Governments have recently agreed that flood mitigation funds will be available for house raising, subject to the same economic evaluation and subsidy arrangements that apply to other structural and non-structural flood mitigation measures.

In accepting schemes for eligibility the Government has laid down the following conditions:

- house raising should be part of an adopted Floodplain Risk Management Plan
- the scheme should be administered by the local authority
- there should be no retrospective payment of subsidy for houses previously raised by the owner.

The Government also requires that Councils carry out ongoing monitoring in subsidised voluntary house raising areas to ensure that redevelopment does not occur by way of re-establish habitable areas below the design floor level. In addition, it is expected that Councils will ensure that subsequent owners are made aware of restrictions on development below the design floor level by documentation provided during the conveyancing process.

Council's principal role in subsidised voluntary house raising is to:

- define a habitable floor level, which it will have already done in exercising controls over new house building in the area
- guarantee a payment to the builder after satisfactory completion of the agreed work
- monitor the area of voluntary house raising to ensure that redevelopment does not occur to re-establish habitable areas below the design floor level.

Most of the contractors who specialise in house raising are not interested in the building aspects of the work and it is therefore likely that two contractors would be involved. The approximate cost to raise a medium sized (150 square metres) house is around $30,000 in 2002 values, based on past experience in Murwillumbah and Grafton. Fairfield Council's experience in Prospect Creek indicates that fibro and timber houses can be raised 1-2 metres for an average cost of about $37,000.

The flood proofing option could be considered in the study area for properties that are flood affected but are outside the floodway. The number of residential properties which would require flood proofing works based on this approach is approximately 86 at the 100 year ARI level of flooding, or 156 at the PMF. Not many of these properties would be suitable for house raising, however, due to the prevalence of slab on ground construction in the study area.

RESPONSE MODIFICATION MEASURES

Response modification measures are outlined in Sections 5.5 to 5.10 below. In order to prepare these sections consultation was carried out with representatives of State Headquarters, the Sydney Southern Division and the local division of the State Emergency Services, who also reviewed and provided feedback to the information presented below.

5.5 Flood Education

Information regarding flood education is reproduced from the *Floodplain Management Manual* (NSW Govt, 2001), with additional information supplied by SES State Headquarters, the Sydney Southern Division and the local division.

The key step towards modifying the community's response to a flood event is to ensure that the community is fully aware that floods are likely to interfere with normal activities in the floodplain. This must be done purposefully because awareness of flooding and readiness for its consequences cannot be assumed.

Flood readiness can be enhanced by various simple education strategies such as:

- advice about flooding to residents from time to time;
- articles in local newspapers;
- display of flood photographs and newspaper articles in the council chambers or in shopping centres;
- flood information leaflets on flooding in specific areas;
- videos of historic floods in the area;

- erecting signs or street markers showing flood levels from previous significant flood events or the flood planning level for residential floors;
- signposting of evacuation routes;
- school projects on floods and flood management;
- flood commemorations;
- advertising campaigns in the media;
- public meetings explaining the flood threat.

Experience has shown that the major factor determining the degree of flood readiness of a community is usually the frequency of moderate to large floods in the recent history of the area. The more recent the flooding, the greater the community flood awareness and readiness is likely to be.

However, unless the recent experience of community has been of large, rare floods, there are likely to be two common and potentially dangerous misunderstandings:

- those used to managing smaller floods need to be aware that occasionally a very large flood will require substantially different and quicker actions;
- those not normally affected by floods will not be aware that a severe flood could seriously affect them. Residents protected by levees, living in houses set with elevated floor levels, or on land not subject to flood related development controls (ie above the FPL), are prime examples of common sources of misunderstanding.

Even when residents have a high level of flood awareness there will always be people moving into an area who may not experienced flooding in the areas from which they originated. It should be assumed that some people are likely to be unaware of basic flood readiness activities and of the flood risk and the nature of flooding in their location. Awareness raising activities must be devised to ensure that newcomers become aware and the long term residents do not forget. These activities must be repeated regularly to maintain consciousness of the risk.

Recent SES experience has found that getting out into the community using displays and demonstrations in public places, such as school fetes, malls and informal community events (BBQs, film nights) is the most effective way to disseminate localised flood risk information. In other words, bring the information to the community, rather than expecting the community to get hold of it themselves.

Sustaining an appropriate level of flood readiness is not easy. It involves a continuous effort by Council in cooperation with the SES. The cost of such efforts should be regarded as the 'maintenance cost' of a flood warning, defence and evacuation scheme.

5.5.1 Flood Information Leaflets

It is recommended that flood information leaflets (FloodSafe Guides) be prepared by the SES to convey an indication of the range of flood risk to which residents in the Austral areas are exposed. The leaflets would have the aim of informing people of:

- whether the area where they live is exposed to a risk of flooding. General historical flood information or photos could also be provided;
- what range of risk they are exposed to;
- the need to be flood ready, indicating what the resident should do in planning for a future flood event. This could include an explanation of flood warnings and what the resident should do in regard to warnings of different levels of flooding, as appropriate;
- location of appropriate evacuation centres;

- contact details for provision of further information.

The SES aims to eventually prepare FloodSafe Guides for all local communities threatened by flooding. In the interim, however, Council could prepare one for the Kemps Creek area after contacting the SES and State HQ to obtain advice on appropriate content.

5.6 Community Flood Readiness

Information regarding flood readiness is reproduced from the *Floodplain Management Manual* (NSW Govt, 2001), with additional information supplied by SES State Headquarters.

Community awareness needs to be used to create community readiness for floods.

Effective local flood plans need to be developed and the community must be made and remain aware of the role of agencies in mitigating flood impacts. There is also a role for individuals through avoiding unsafe routes once flooding has begun, protecting personal goods and possessions or evacuating from their houses. Families and businesses can be encouraged to prepare their own flood plans. The SES can provide advice regarding the preparation of flood plans.

Flood readiness includes the ability of flood affected people to control and minimise their potential losses from the flood threat by appropriate preparatory and evacuation measures. Readiness involves deciding, or at least considering, what goods and possessions to move and how and where to put or take them.

Irrespective of the available warning time, there is widespread variation in flood awareness and resulting response capability. When regularly flooded, people become well prepared for a flood. It should be noted that such readiness declines quickly after floods. The longer the time since the last flood, the lower the effective level of readiness. By 10 years after a significant floods real readiness can be considered to no longer exist.

It is important that preparation should not be solely for the more common and/or less severe floods. The community needs also to be prepared for the flood that is outside the experience of anyone in the floodplain. There eventually will be a flood which overwhelms the access routes usually used at flood time, overtops levees which have not been overtopped before and which inundate areas that are not known to have previously been affected. The key message is that for these rare floods, different actions must be taken.

The first step in creating readiness is creating awareness. It is recommended that Council undertake a flood education and awareness campaign in conjunction with SES. This would involve an initial campaign followed up every second year on an ongoing basis. It is estimated that such a campaign might cost around $5,000, with $5,000 every second year. Other steps will follow which may include the development of warning services, local flood plans and planning for the recovery from flooding, as outlined in Sections 5.7, 5.8 and 5.9 below.

5.7 Emergency Management - NSW Arrangements

This section is reproduced from Emergency Management Australia's website: *http://www.ema.gov.au)* and outlines the legislation governing emergency management as well as the roles and responsibilities of various individuals and groups involved in emergency management in NSW. This information is included to provide some background information for the subsequent sections covering Flood Warning, Response and Recovery Planning.

5.7.1 Legislation

The State Emergency and Rescue Management Act 1989 establishes the legislative base for NSW disaster management. Specifically, the Act provides for:

- the responsibilities of the Minister;
- a State Emergency Operations Controller;
- the State Disaster Council;
- the State Emergency Management Committee
- the State Disaster Plan; and
- a State Emergency Operations Centre.

At District and Local levels the Act also requires Emergency Management Committees to be established and Emergency Management Operations Controllers be appointed. These operate from established Emergency Operations Centre during emergencies.

The State Emergency Service Act 1989 establishes the State Emergency Service and defines its functions as well as making provision for the handling of certain emergencies.

5.7.2 Emergency Management - State Level

The Minister for Emergency Services - The Minister for Police and Emergency Services has overall responsibility for ensuring that arrangements are made at State level to prevent, prepare for, respond to and assist recovery from emergencies.

State Disasters Council - The Council is responsible for advising the Minister on all aspects relating to prevention of, preparation for, response to and recovery from emergencies, including coordination. It comprises the Minister as Chairperson, the State Emergency Operations Controller and any other person determined by the Minister.

State Emergency Management Committee - The Committee comprises a Chairperson, the State Emergency Operations Controller, senior representatives of the emergency services and other agencies as determined by the Minister. This is the principal committee for emergency management planning at State level. The resources of the State (both government and non-government) are grouped into functional areas for emergency management purposes and the appointed State coordinator for each functional area is a member of the State Emergency Management Committee.

A Secretary and a small permanent staff service the SEMC. Their mission is "to provide functional and support services to the Minister, the State Emergency Operations Controller, the State Disaster Council, the SEMC and functional areas and to provide the necessary staff to maintain and operate the State Emergency Operations Centre".

5.7.3 Emergency/Disaster Management - Below State Level

For emergency management purposes, New South Wales is divided into emergency management districts. Each Emergency Management District has a District Emergency Management Committee reflecting the membership of the SEMC. The Committee is chaired by the District Emergency Operations Controller (DEOCON), supported by the District Emergency Management Officer (DEMO). The DEMO is also responsible for assisting local committees and communities within the relevant District on emergency management matters.

The State is further divided into Local Government areas. At this level there is a Local Emergency Management Committee reflecting the membership of the District Emergency Management Committee. This committee is chaired by a senior representative of the council for the area and is supported by a Council appointed Local Emergency Management Officer (LEMO). The Local Emergency Operations Controller is appointed by the Commissioner of Police for each Local Government area.

5.7.4 Emergency Plans

There is a State Disaster Plan (DISPLAN), the objective of which is to ensure a coordinated response to emergencies. DISPLAN may be activated by the Minister without the need for a declaration of a state of emergency. Functional Area plans to support DISPLAN are endorsed by the SEMC and approved by the Minister. Disaster Plans are also required at District and Local Government levels. State-level Sub-Plans have been produced for some specific hazards to ensure the appropriate emergency management arrangements are in place.

5.7.5 Control and Coordination of Operations

DISPLAN details the roles and responsibilities of agencies for differing types of response operations. Emergency Operations Centres are activated to either control the operation directly (in the absence of an identified combat agency) or to coordinate resource support as required.

Local Emergency Operations Controllers operate from a Local Emergency Operations Centre. Emergency operations which involve more than one Local Government area are controlled at District level utilising District Emergency Operations Controllers, which operate from a District Emergency Operations Centre.

Emergency operations involving more than one District, and other major operations when considered necessary, are controlled at State level. The State Emergency Operations Controller controls operations from the State Emergency Operations Centre. Emergency Service Organisations Controllers and Functional Area Coordinators operate from their own control/coordination centres.

5.7.6 Authority to Request Commonwealth Assistance

The person authorised as the single point of contact for requesting Commonwealth assistance to emergency operations in NSW is the State Emergency Operations Controller, who exercises this authority through his operational staff at the State Emergency Operations Centre.

5.8 Flood Warning and Response System

5.8.1 General

Flood warning is being increasingly used as a means of mitigating flood damage. Flood warning may be considered as one element of a "Flood Emergency System" which consists of five separate processes:-

- identification of the areas at risk from flooding
- forecasting the time of arrival and height of the flood peak
- the dissemination of warnings to flood prone residents
- the evacuation of people and possessions from flood threatened areas
- the recovery of the community in the flood aftermath.

The Local Flood Plan, a sub-plan of the Local Disaster Plan (DisPlan) created under the State Emergency and Rescue Management Act 1989, places responsibility for dissemination of flood warning with SES Division HQ.

For flash flood warning situations, the consolidation of flood warning actions into one agency (in this case SES) closest to the local scene is considered the best way to achieve optimum effectiveness. Such local flash flood warning systems have proven to be dependent on the needs and economies of the situation. Cheaper and more reliable modern electronics have resulted in a trend towards more automated systems.

5.8.2 Application to Austral-Kemps Creek Area

The times of rise of the streams in the Austral area are quite short and hence the potential warning time is limited to 2 to 3 hours on the main arms and less on the tributaries. Most of the residents work in areas remote from the catchment and therefore there is a problem with dissemination of the warning itself and promoting an adequate response which will result in a reduction in flood damages. Consequently, a formal flood warning system for the study area will have limited success in reducing flood damages.

The State Emergency Service (SES) has prepared a draft (September 2001) Liverpool Local Flood Plan, which is a sub-plan of the Liverpool Local Disaster Plan. The draft plan has not yet been formally adopted. The area covered by this plan includes all of the Liverpool City Council area. However, the Plan appears incomplete and does not provide any specific information regarding the Kemps Creek area. Evacuations are dealt with only generally and no detailed evacuation plan has been prepared.

Because of the relatively rapid generation of flooding in response to rainfall in this area, it is difficult to envisage any significant evacuation response in **advance** of actual flooding, with current forecasting technology. What is needed is more time between the issue of a warning and the occurrence of the flooding to allow for an adequate response by both the SES and residents. The only practical way to achieve this would be to base the warnings on forecasts of flood producing rainfalls, with the forecasts made several hours in advance of the actual rainfalls. The technology to do this reliably does not exist and is unlikely to exist in the foreseeable future.

Council has some elements of an ALERT telemetered flood warning system, including software and some hardware. The Bureau of Meteorology operates a limited number of telemetered rain gauges in the Liverpool area. In order to utilise this equipment as part of a flood warning system, there would need to be additional instrumentation in Kemps Creek catchment, and a detailed daily hydrologic model would need to be set up and calibrated using data obtained over a reasonable period of time, say a minimum of one year. In addition, at least two staff members would need to be trained to operate the system. This would be a very expensive process and it is unlikely that much practical improvement in response to warnings would result because the warning period would still be insufficient. **As such the scheme could not be economically justified.** However, it is recommended that Council commission an investigation into a possible warning system for the catchment. Such a review would include consultation with the Bureau of Meteorology.

While sophisticated forecasting approaches may not be justified, there are cost effective methods of warning dissemination available which may be appropriate for the Austral area. These include “PC Cops”, which is a system programmed to dial up homes under threat and play a pre-recorded warning message. It asks for a response and then records whether or not this is received. The “Expedite” SMS messaging system is another option which may be appropriate. Further research in this area should be included in the investigation referred to above.

It is recommended that the Local Flood Plan should be completed and further developed by SES to include annexures dealing specifically with the Kemps Creek area. Additional elements would include a graded response plan and an evacuation plan comprising:

- Ranking the threatened houses according to their hazard situation, taking account of depth and velocity of floodwaters, and means of access, as a flood develops;
- Preparing a detailed response plan which focuses on initial evacuations from the most hazardous locations, followed by further evacuations in descending rank of hazard;
- Preparing a plan for traffic management which takes account of the sequence of road flooding as a flood develops. This plan would aim to:
  - maximise opportunities for the community to evacuate
  - ensure access for SES operators
  - prevent unnecessary traffic through the affected area
- Assessing the resources required to door knock the area.
- Addressing the appropriate location of helicopter landing pads;
- Assessing whether the size of identified community centres appropriate for receiving the estimated number of evacuees;

The preparation of Flood Intelligence Cards, as recommended in Flood Warning: An Australian Guide (published by Emergency Management Australia, 1995) would be an appropriate activity in connection with developing this graded response plan.

5.9 Recovery Planning

As part of the provisions of the State Emergency and Rescue Management Act (1989) a Recovery Plan is formulated as part of the Local Flood Plan. The Plan should recognise that after a flood:

- Council and other authorities will need to restore and clean up their assets;
- individuals will be engaged in some clean up activities;
- SES has a continuing role as necessary eg to assist clean out house and check power before residents return;
- Council will be expected to provide some assistance, even if only in carting material to the tip;
- authorities such as Department of Community Services will provide welfare services;
- meetings to share flood experiences and subsequent problems could include trauma counselling to help people realise they are not alone in the floodplain;

It is recommended that the Recovery Plan be reviewed for its adequacy to address these issues.

The period after the flood is an opportunity for Council to collect data that will help to better deal with the next flood event. This information should include:

- water information (levels, rates of rise an fall, velocities, areas inundated);
- details of damage;
- information which did or did not become available when needed during the flood;
- actions which were taken during the flood.

Council should implement a procedure to ensure that this information is collected after each flood event. In addition, the Flood Risk Management Plan should be reviewed after every flood event to incorporate the collected information if appropriate.

5.10 Section 149 Certificates

A Section 149 certificate issued by Council under Section 149 of the EP&A Act (1979) must be attached to a vendor's contract documents when selling a property in NSW. A Section 149(2) certificate provides information that Liverpool City Council is legally obliged to provide. However, under Section 149(5) Council may also provide advice, in good faith, on relevant matters affecting the land of which Council is aware. Under Section 149(6) of the EP&A Act (1979) councils are provided with indemnity from liability in respect of advice provided in good faith under Section 149(5) of the EP&A Act (1979). Section 149 certificates are provided to applicants for a nominal cost.

It is recommended that Council ensures that, when required, 149(2) and 149(5) certificates be issued with the appropriate information attached for the floodplain (that is the area inundated during the PMF). It is recommended that Council review the advice provided with the certificates and, if necessary, adapt it to reflect the risks associated with the relevant flood risk zone as well as including the required planning controls based on the Planning Controls Matrix. It has been assumed that this task can be carried out in the course of normal Council work and no additional budget would be required to complete it.

FLOOD MODIFICATION MEASURES

Flood modification measures for dealing with the existing flood risk are outlined in Sections 5.11 to 5.15 below. Any flood mitigation works should be undertaken in accordance with DIPNR's requirements regarding flood issues and environmental management (provision of ecological connectivity along bed and banks of a channel and under any road crossing via a Vegetation Management Plan).

5.11 Stream Clearing and Stream Stabilisation

5.11.1 Issues

The issues to be considered in deciding upon which areas are worth clearing are:

- the effect of clearing on flood levels
- the cost of clearing
- the ongoing cost of maintaining the creek in its cleared state
- who should be responsible for carrying out initial clearing and the ongoing maintenance.

5.11.2 Hydraulic Analysis of Stream Clearing

Stream clearing may be an effective measure to reduce flood levels in the floodplain in situations where the channel or floodplain contains dense weeds or vegetation. Clearing the channel of these obstructions may increase the hydraulic capacity of a stream.

The hydraulic HEC-2 model was used to investigate the effectiveness of stream clearing in Kemps, Bonds and Scalabrini Creeks and their tributaries. Clearing of the streams was simulated in the model by reducing the hydraulic roughness values Manning's 'n'. For existing conditions, channel roughness values are in the range of 0.04 to 0.1. The majority of the creek channels has considerable weed growth and roughness values are commonly around 0.08. A run of the model for each storm event was carried out for all creeks adopting a Manning's 'n' value of 0.04 to assess the effects on flood levels of clearing the creek channel. The reduction in Manning's 'n' was applied to the main channel only and the floodplain roughness was not altered.

Table 5.3 shows the impact of the above modifications on model results at key locations, in terms of maximum reduction of flood levels for the 5 year and 100 year ARI. The results indicate that flood levels would reduce by an average of 260 mm in Kemps Creek between Gurner Avenue and Elizabeth Drive in the 100 year ARI event. Upstream of Gurner Avenue, the average reduction in flood levels for the 100 year ARI flood was 90 mm.

The average reduction in flood levels for the 100 year ARI event in Bonds Creek, Scalabrini Creek, Tributary 2 and Tributary 3 are 150 mm, 80 mm, 40 mm and 80 mm respectively. It should be noted that clearing alone would have negligible effect just upstream of bridges and culverts due to the low flow velocities in the ponded areas upstream of these crossings.

Table 5.3
Effects of Stream Clearing at Key Locations

Approximate Location	Maximum Reduction 5 year ARI (mm)	Maximum Reduction 100 year ARI (mm)	Approximate Location	Maximum Reduction 5 year ARI (mm)	Maximum Reduction 100 year ARI (mm)
		KEMPS CREEK			
1 km u/s of Elizabeth Dr	410	330	600 m u/s of Fifteenth Ave	30	260
3 km u/s of Elizabeth Dr	220	180	300 m u/s of Twelfth Ave	50	70
300 m u/s of Gurner Ave	60	40	900 m u/s of Twelfth Ave	50	30
600 m u/s of Gurner Ave	Negligible	70	1.8 km u/s of Twelfth Ave	80	80
300 m u/s of Fifteenth Ave	80	90	2.5 km u/s of Twelfth Ave	Negligible	50
		BONDS CREEK			
Confluence of Bonds Creek to Edmondson Ave	No clearing required	No clearing required	600 m u/s of Bringelly Road	140	210
150 m u/s of Sixth Ave	120	110	1 km u/s of Bringelly Road	260	10
200 m u/s of Sixth Ave	130	160	400 m u/s of Hume Hwy	110	120
200 m u/s of Bringelly Rd	480	320			
		SCALABRINI CREEK			
150 m u/s of Fifth Ave	Negligible	80			
		TRIBUTARY 2			
600 m u/s of confluence with Kemps Creek	Negligible	Negligible	100 m u/s of Edmondson Ave	30	Negligible
200 m u/s of 13th Ave	20	50	250 m u/s of Eleventh Ave	190	120
150 m u/s of Twelfth Ave	40	40			
		TRIBUTARY 3			
1 km u/s of confluence with Kemps Creek	170	170	350 m u/s of Eighteenth Ave	240	170
1.5 km u/s of confluence with Kemps Creek	170	90	100 m u/s of Sixteenth Ave	30	Negligible
2.5 km u/s of confluence with Kemps Creek	100	130	200 m u/s of Fifteenth Ave	Negligible	Negligible
3 km u/s of confluence with Kemps Creek	110	70			
200 m u/s of 18th Ave	Negligible	Negligible			

5.11.3 Economics of Stream Clearing and Stabilisation

Fairfield Council has previously undertaken a program of weed clearing and vegetation management on one side of Cabramatta Creek. One of the objectives of that work was to minimise future maintenance. That work is reported to have cost of the order of $70,000 (updated to 2003 value) to treat 100 m of creek bank.

It might be possible to undertake clearing works at a much lower cost by spraying and cutting back weed species. However, such an approach is likely to require further ongoing work each year to prevent regrowth.

Based on the above rate, the capital costs are estimated to be $5.6M along Kemps Creek, $3.4M along Tributary 2 and its side arms and $2.4M along Bonds Creek. In the case of Bonds Creek, additional costs would be incurred stabilising the section of creek which was excavated by Council (Section 4.2). This could result in a total cost of over $4.8M for the scheme.

Annual maintenance costs, which could amount to 3% of the capital cost, should also be allowed for. These costs and the average annual damages prevented, which represent the benefits of the scheme, have been converted to present worth values using a discount rate of 7% and a time period of 30 years. The results are shown on Table 5.4.

Table 5.4
Economic Analysis of Stream Clearing and Stabilisation

Stream	Net Present Worth Values $M				Benefit Cost Ratio
	Capital Cost	Maintenance Cost	Total Cost	Benefits (Damages Prevented)	
Kemps Creek	5.6	2.1	7.7	0.7	0.1
Bonds Creek	4.8	1.8	6.6	4.6	0.7
Tributary 2 and Branches	3.4	1.3	4.7	0.2	0.04

No significant reduction in flood damages would result from clearing of Scalabrini Creek and Tributary 3 and hence the measure has not been considered further.

Stream clearing schemes on Kemps Creek, Bonds Creek and Tributary 2 are not economically viable in terms of having a benefit cost ratio greater than unity. However, Council could consider a clearing and minor improvement program in a small reach of a creek as a pilot program. A possible location is on Bonds Creek downstream of Scalabrini Village, in the reach between Edmondson and Fifth Avenues. As mentioned previously, this area is flood-affected at the 1 year ARI level of flooding and implementation of an improvement program could significantly reduce the flood risk (although additional measures such as a levee may also be required to achieve protection against a major flood event).

On the basis of the rate adopted an allocation of $140,000 would treat a 200 m reach of creek. However, other methods of clearing and bank treatment, which may be less expensive, could be investigated. Potential difficulties with implementing the scheme which would need to be resolved are:

- Liaison with the community to gain acceptance for the proposal and overcoming the problems of private ownership of the creek;

- Funding of the scheme. Opportunities should be explored for implementing the scheme as a Council sponsored Landcare project.

5.12 Culvert Upgrading

An alternative method of reducing flood levels in the vicinity of road crossings is the upgrading of existing culverts to reduce the backwater effects caused by these structures. The extent to which the culvert can be upgraded will depend on road levels and the potential for locally widening the existing creek.

As discussed in Appendix B, the majority of culvert crossings in Kemps and Bonds Creek and their tributaries have insufficient capacity to convey the flows for small storm events. The effect of upgrading the majority of the culverts within the catchment was therefore investigated.

Locations at which the culvert capacity is less than the 5 year ARI event were chosen for the analysis. For the purposes of analysis, culvert sizes were chosen which were compatible with the existing channel in the vicinity of the road crossing and did not require substantial raising of the road. The reductions in flood levels as assessed using the HEC-2 model are shown in Table 5.5.

The outcome of the modelling indicates that the maximum reduction in flood levels is achieved for the smaller floods such as the 5 year ARI. In general, the reduction for the larger events is negligible because most of the water flows over the road.

Following an inspection of properties near culvert crossings, it appeared that significant reductions in flood affectation could be achieved by upgrading the culverts at the locations shown on Table 5.6.

However, the reductions in flood levels achieved by culvert upgrading are quite localised. The benefits mainly result from improving access within the area during flood times. Achieving substantial reductions in flood damages would also require improvements in the adjacent channel capacity. Schemes aimed at achieving these objectives are described in the following section.

Table 5.5
Reduction in Flood Levels due to Culvert Upgrading

Location	Existing Size	Upgraded Size	Maximum Reduction in Flood Level (mm)	Frequency at which reduction occurred (year ARI)
KEMPS CREEK				
Twelfth Ave	4 x 1350 dia RCP	2 x 3600 x 1200	80	1
BONDS CREEK				
Tenth Ave	1 x 6000 x 2800 (equiv)	4 x 3000 x 3000 RCBC	20	1
Ninth Ave	2 x 1080 x 690 (equiv)	2700 x 750 RCBC	30	20
Fourth Ave	3 x 3300 x 2100 (equiv)	5 x 3300 x 2100 RCBC	440	5
Eight Ave	1 x 5450 x 3200 (equiv)	3 x 3600 x3300 RCBC	640	5
Edmondson Ave	4 x 3000 x 950 RCBC	5 x 3000 x 900 RCBC	320	5
Bringelly Road	3 x 3000 x 1500 RCBC	4 x 3000 x 1500 RCBC	70	1
Cowpasture Road	3 x 3300 x 1800 RCBC	4 x 3300 x 1800 RCBC	10	1
Hume Hwy.	4 x 1950 x 1000 RCBC	6 x 2100 x 900 RCBC	170	100
Denham Court Rd	3 x 1500 x 900 RCBC	5 x 1500 x 900 RCBC	40	100

Table 5.5
Reduction in Flood Levels due to Culvert Upgrading

Location	Existing Size	Upgraded Size	Maximum Reduction in Flood Level (mm)	Frequency at which reduction occurred (year ARI)
SCALABRINI CREEK				
Fifth Avenue	1 x 750 dia RCP	1200 x 750 RCBC	Negligible	-
TRIBUTARY 2				
Thirteenth Ave	1 x 750 dia RCP	1500 x 750 RCBC	330	1
Edmondson Ave	2900 x 750 RCBC	2 x 2700 x 750 RCBC	350	1
Eleventh Ave	1 x 750 dia RCP	1500 x 750 RCBC	10	all
Tenth Ave	4 x 525 dia RCP	1200 x 600 RCBC	310	1
TRIBUTARY 3				
Eighteenth Ave	1 x 800 dia RCP	1 x 800 x 900 RCBC	30	1
Seventeenth Ave	2 x 3000 x 1200 RCBC	3 x 3000 x 1200 RCBC	40	5
Sixteenth Ave	1 x 2450 x 1200 RCBC	2 x 2400 x 1200 RCBC	60	20
Fifteenth Ave	3 x 750 dia RCP	2 x 2400 x 750 RCBC	220	100
Fourteenth Ave	2 x 450 dia RCP	4 x 450 x 450 RCBC	30	100

Table 5.6
Cost of Upgraded Culverts

Location	Hydraulic Capacity (ARI Years) Existing	Hydraulic Capacity (ARI Years) Upgraded	Capital Cost $
Bonds Creek			
Fourth Ave	2	10	650,000
Eight Ave	2	5	525,000
Edmondson Ave	2	5	450,000
Tributary 2			
Thirteenth Ave	<1	<1*	90,000
Edmondson Ave	2	7	175,000
Tributary 3			
Fifteenth Ave	2	100	175,000

Note: * Capacity limited by downstream channel.

5.13 Channel Works

5.13.1 General

Widening, deepening or straightening the existing creek can increase the hydraulic capacity of a channel. The scope of such improvements can vary from minor channel works such as widening the creek, to major channel excavations such as those carried out on Bonds Creek upstream of Eleventh Avenue.

Careful attention to design is required to ensure that stability of the channel is maintained and that scour and sediment build up is minimised. This is particularly important in the Austral area where the soils appear to be quite dispersive. A degree of sinuosity is usually provided in the channel route for aesthetic reasons. The potential risk of increasing downstream flood peaks as a consequence of channel improvements also needs to be considered prior to undertaking final design.

A number of reaches were identified where there is potential for major channel works to reduce flooding of affected properties. As most of the properties in question are affected during small storm events, the analysis was undertaken for channel works generally designed to mitigate flooding up to the 5 year ARI event, although in some cases larger design floods were evaluated.

Channel improvements in this study were modelled with the HEC-2 program, assuming they comprised a grassed trapezoidal channel with side slopes of 1 vertical to 4 horizontal and roughness of 0.035. A freeboard of 300 mm was allowed where possible. The bed width and channel depth were adjusted to provide the design discharge capacity.

The following sections generally describe channel improvements to mitigate flooding up to the 5 year ARI event. However, these improvements would have some effect on larger flood events. The results of the economic analysis are summarised in Table 5.7. As part of the review and finalisation for this Floodplain Management Study, the indicative costs for channel works have been substantially increased, based on recent work done for Council for a concept design of the recommended scheme on Tributary 2 at Fourth Avenue.

A potential major constraint on the feasibility of these schemes is the private ownership of the creeks. The costs given in the following sections **do not** include the cost of Council acquiring the land in the improved reach.

5.13.2 Scalabrini Creek

Scalabrini Creek joins Bonds Creek just upstream of Seventh Avenue and is characterised by two distinct reaches. Upstream of Seventh Avenue, the creek comprises an excavated channel 18 m wide which extends approximately 150 m. It then diminishes significantly to a narrow gully for 200 m up to Fifth Avenue where it joins the existing creek. The excavated channel was constructed several years ago by the Council to mitigate flooding in the adjacent properties.

An inspection of the channel and creek was undertaken in the course of this study. The inspection, together with the results obtained from the HEC-2 model of the existing conditions, indicates that the channel is not performing to its potential capacity in small floods. During such events, flows bypass the creek and the channel altogether and run along Fourth Avenue.

A hydraulic study of the unimproved reach between the upstream limit of the excavated channel and Fifth Avenue indicates an existing channel capacity of 0.3 m^3/s. Higher discharges flow overland along Fourth Avenue.

In order to contain and direct flows between the existing creek at Fifth Avenue and the head of the excavated channel, a channel of similar geometry would be required connecting the two reaches.

A channel to convey a 5 year ARI design flood discharge of 18 m^3/s was investigated. A channel approximately 200 m long and 16 m wide was required. A culvert upgrading at Fifth Avenue would also be necessary to reduce the afflux upstream of this crossing. An initial trial culvert size of 2 x 1200 x 1200 RCBC was selected.

In addition to the above works, a drop structure was required just upstream of the junction with the excavated channel. This is to reduce the slope of the proposed channel bed to obtain acceptable flow velocities.

The HEC-2 model was run incorporating the above modifications. It was found that the maximum reduction in flood levels for the 5 year ARI and 100 year ARI events was approximately 780 mm and 380 mm respectively.

The capital cost of the proposed channel and culvert works is estimated to be $890,000. Allowing a 3% annual maintenance cost, the present worth value of the scheme is around $1.22M. The benefit of this option is to increase the level of service of the drainage system to the 5 year ARI event and to make the area between Fourth Avenue and the existing excavated channel flood free up to the 5 year ARI flood.

The average annual damages saved due to implementing the channel works amount to approximate value of $95,000, equivalent to a present worth value of around $1.2M at a 7% discount rate. The scheme is therefore only just economically viable (B:C = 1). Access along Fourth Avenue during flood times would also be improved.

5.13.3 Tributary 2 at Junction of Twelfth and Fourth Avenue

Downstream of the culvert crossing at Twelfth Avenue the creek alignment turns abruptly through a right angled bend and runs alongside Twelfth Avenue. It makes another abrupt change in direction just before the junction with Fourth Avenue and continues for a further 120 m along the road until passing under Fourth Avenue via a culvert crossing.

Generally, the channel is ill defined along the entire reach between Twelfth and Fourth Avenues and upstream of Twelfth Avenue for a further 40 m. The abrupt changes in channel alignment have the effect of reducing the culvert capacities to less than their full potential.

A hydraulic study of the reach between Twelfth and Fourth Avenues showed that the existing capacity is as small as 0.3 m^3/s in places. The channel overflows at less than the 1 year ARI event. Flooding in this vicinity mainly results from overland flows which flood the surrounding area and inundate Fourth and Twelfth Avenues. This behaviour was confirmed by inspecting photographs of recent flooding in the area. The photographs show that the intersection of Twelfth Avenue and Fourth Avenue is completely inundated.

In order to mitigate flooding at this intersection, the construction of a new channel along a straight alignment was investigated. A channel designed to contain the 100 year flood discharge of 24 m^3/s was considered. The required channel would be 18 m wide, 1.6 m in depth and 500 m in length. The existing culverts at Twelfth and Fourth Avenues would be replaced with 2 x 3,000 x 900 RCBC at each crossing.

The HEC-2 model was modified incorporating the above changes and it was found that flood levels for the 100 year ARI event were approximately 400 mm lower than existing flood levels.

The capital cost of the proposed channel and culvert works is estimated to be $1.35M. The present worth cost is $1.85M after allowing for annual maintenance costs. The benefit of this option is to increase the level of service to 100 year ARI and reduce flooding to nearby residential properties. Access to Fourth and Twelfth Avenues in this area, up to the 100 year ARI would also be assured.

The average annual damages saved due to implementing the channel works amount to approximate value of $230,000, equivalent to a present worth value of around $2.8M at a 7% discount rate. The scheme is therefore economically viable (B:C = 1.5). The community consultation process identified flooding at the Twelfth-Fourth Avenue intersection as a major concern. It is to be noted that culvert improvements alone will not yield significant benefits. Their effects would be quite localised. A lesser hydrologic design standard could also yield substantial benefits at lower cost and should be investigated in a more detailed study than is practicable in this report.

5.13.4 Kemps Creek Near Twelfth Avenue

Channel improvements extending from downstream of Twelfth Avenue to the confluence with Bonds Creek was investigated. The existing channel in this reach narrows and makes a right angle turn near the confluence with Bonds Creek. The creek overtops at floods greater than the 5 year ARI. The existing 4 x 1350 mm diameter pipes under Twelfth Avenue have a capacity of approximately 12 m^3/s which is close to the 1 year ARI flow in Kemps Creek. It should be noted that flows greater than the 5 year ARI merge with overflows from Bonds Creek which also overtops at floods greater than the 5 year ARI.

The channel improvements were tested in the HEC-2 model for floods ranging between 1 and 100 year ARI. The existing culverts under Twelfth Avenue have recently been upgraded by Council and were not altered.

The results indicated that the 1 year ARI flood levels will be reduced approximately 300 mm just downstream of Twelfth Avenue. However, the flood levels in the 5 and 20 year ARI event will be reduced by 150 mm at this location. The change in levels upstream of the culvert crossing was negligible. The reduction in flood levels at the 100 year ARI is negligible for the entire reach of the proposed channel.

The estimated cost of this channel improvement would be $600,000 and no significant reduction in flood damages resulted from the channel improvements for any flood event. Consequently, the works are not economically viable.

Table 5.7
Economic Analysis of Channel Works plus Culvert Upgrading

Location	Net Present Worth Values $				Benefit Cost Ratio
	Capital Cost	Maintenance Cost	Total Cost	Benefits (Damages Prevented)	
Scalabrini Creek d/s Fifth Ave	890,000	330,000	1.22M	1.2M	1.0
Tributary 2 near Twelfth & Fourth Ave	1.35M	500,000	1.85M	2.8M	1.5
Kemps Creek near Twelfth Ave	600,000	225,000	825,000	Neg	0.0

Note: Costs do not include cost of acquisition of land.

5.13.5 Review of Previous Proposals for Channel Improvements

The channel works proposed by D.J. Dwyer & Associates (DJDA) for Liverpool City Council in their report of August 1979 for Liverpool Council was reviewed as part of this study.

The proposed channel works are located on Bonds Creek and its tributaries and extend to the confluence with Kemps Creek. Earth channels were proposed which consisted of composite trapezoidal sections comprising a central channel 1.5 m deep with 1:2 side slopes and an outer section 600 mm deep with side slopes of 1:6. The width varies according with the design discharge.

The design discharges adopted in the DJDA report are similar to the design flows derived in this present 1995 study (compare columns 2 and 3 of Table 5.8). The DJDA design discharges were calculated using the Rational Method and the RAFTS model was used in this study.

A hydraulic analysis was undertaken to estimate the capacity of the proposed channels. The results are shown on column 4 (with freeboard) and column 5 (without freeboard) in Table 5.8. It was found that the channels would have a capacity up to the 100 year ARI discharge (1995 estimate), but with no freeboard.

Table 5.8
Hydraulic Analysis of Major Channel Improvements (DJDA, 1979)

Location	LMCE, 1995 100 y ARI Discharge (m^3/s)	DJDA 1979 Design Discharge (m^3/s)	Capacity of Proposed Channel (m^3/s)	
			500 mm freeboard	no freeboard
(1)	(2)	(3)	(4)	(5)
Scalabrini Creek				
Confluence with Bonds Ck	44	48	27	48
Bonds Creek				
At Edmondson Avenue	79	71	50	83
At Fourth Avenue	127	123	76	124
Junction u/s of confluence with Kemps Creek	140	127	82	128
Kemps Creek				
At Fifteenth Avenue	240	210	140	210

The culvert crossings suggested in the DJDA proposal would require the raising of roads in order to fit the proposed culverts.

The proposed channels and upgrade of culvert crossings would eliminate flooding to properties in the Bonds Creek catchment for floods up to 100 year ARI. However, the following factors militate against adoption of the scheme:

1. This is a major engineering scheme and is estimated to cost over $6M, allowing for maintenance of the channels, but not including land acquisition costs.
2. The channels will be excavated in dispersive clays and will require measures to ensure that they remain stable over their design life. The scheme does not appear to allow for such measures, which would include either a low flow pipe or a concrete invert and add substantially to the cost.
3. The channel has a large capacity and will increase downstream flows and flood levels, particularly in the lower reaches of Bonds Creek and Kemps Creek. These effects will exacerbate flood problems downstream of the study area, ie north of Elizabeth Drive.
4. The existing shallow and slow moving flow over the floodplain will be substituted by a deep and fast moving channel flow which will substantially increase the local flood hazard.

The scheme should not be considered further because of the problems it would create.

5.14 Levees

5.14.1 General

Levees are an effective means of protecting flood affected properties up to the design flood level provided account is taken of potential re-distribution of flood flows, the requirements for disposal of internal drainage from the protected area and the possibility of overtopping the levee in floods greater than the design event.

Levees are constructed of compacted soil won from local sources and carefully placed to strict engineering standards. The DIPNR has issued criteria to provide assistance to a local authority in preparing specifications for levees which include the following recommendations:

- design and construction supervision to be undertaken by a professional engineer
- crest width sufficient to allow the passage of vehicles
- a freeboard for the crest level above the design flood of at least one metre
- geotechnical investigation required to determine side slopes, assess material suitability and foundation conditions.

Many private levees are not constructed according to the above criteria but levees constructed with public funds to protect urban areas must follow them.

Concrete block walls are often used in situations where urbanisation abuts the creek and there is insufficient land available for earth banks. Block walls are provided with reinforced concrete footings of sufficient width to withstand overturning during flood events.

5.14.2 Location of Possible Levees

An assessment of the topography of the floodplain was undertaken and it was found that most of the land is relatively flat and not suitable for levees. Levees are not a viable option in these areas due to the difficulty of tying into high ground at the upstream and downstream ends so that the levee is not outflanked by floodwaters.

One possible location for a small levee is on Bonds Creek 150 m downstream of Fifth Avenue to protect the Scalabrini Village. Part of the village, is located at a lower level than the creek’s overbank level and approximately 100 m west of Bonds Creek. At present, this area is flooded at around 1 year ARI.

A levee that will protect this area up to the 5 year ARI flood was investigated. Since the 5 year ARI at this location is approximately at R.L. 69.5 and the ground at R.L. 69.0, a 0.5 m high levee as a minimum would be required for a length of 130 m.

In addition to the construction of a levee, minor channel works would be required to redirect flows from the protected area to the creek downstream of the proposed levee. The extent of these works and any additional drainage works should be determined at the detail design phase. These works could involve clearing the stream downstream of this levee which would decrease flood levels by approximately 200 mm and hence provide a freeboard to the levee.

The present worth cost (capital and maintenance) of constructing this levee is approximately $300,000. This cost does not allow for any alterations to the local drainage system. The levee would be constructed from locally won material suitable placed and compacted to form an earth mound.

The average annual damages saved due to the construction of the levee amount to an approximate value of $295,000, equivalent to a present worth value of around $3.6M at a 7% discount rate. The scheme is therefore economically viable (B:C = 12).

Constructing a levee at this location will protect the Scalabrini Village from creek flooding up to the 5 year ARI. A higher levee will provide a greater level of protection but will require a detailed hydraulic study to demonstrate that flow patterns and flood levels are not significantly increased. Some compensatory excavation of the channel may be required. Also, the potential exists for ponding of local runoff behind a higher levee and surcharging of the local stormwater system, control of which would increase the overall cost of the scheme.

5.15 Retarding Basins

5.15.1 General

The construction of one or more retarding basins in flood prone areas is often an effective flood mitigation measure. Basins temporarily store water during a storm event and so lessen flow rates and water levels downstream. Their impact will be greatest in the areas immediately downstream and will diminish as tributary flow enters downstream of the basin. It is also necessary to ensure that peak flows downstream of tributary junctions are not increased as a result of synchronisation of the post-basin hydrographs. They therefore need to control a considerable proportion of the catchment to be effective.

5.15.2 Retarding Basins in the Bonds Creek Catchment

There are a considerable number of flood prone properties on Scalabrini and Bonds Creeks (Table 2.2). On Scalabrini Creek the best location for a basin is upstream of Bringelly Road, as a considerable percentage of the catchment of this stream is controlled. On Bonds Creek, a basin on the upstream side of the Hume Highway would be effective in mitigating damaging flooding which presently occurs in the reach between the Hume Highway and the junction with Scalabrini Creek.

5.15.3 Retarding Basins in the Kemps Creek Catchment

On Kemps Creek, there are a number of flood prone properties downstream of Bringelly Road and additional properties on each side of Herley Avenue and in the reach between Fifteenth and Gurner Avenue. A basin immediately upstream of Bringelly Road would command a considerable proportion of the catchment area. However, there are also a number of flood prone properties further downstream along the reach between Elizabeth Drive and Floribunda Road. It is likely that such a basin would not have a great effect on flow this far downstream of Bringelly Road.

Considering the tributary streams, there are damage centres in the stream between Tenth and Kelly Streets on Tributary 2. It is not feasible to locate a basin at the upstream end of this reach, as it would not command a sufficient catchment area. There are no obvious sites further downstream.

On Tributary 3 in the Kemps Creek catchment between Fourteenth and Eighteenth Avenues, there are a considerable number of flood prone properties. However the proportion of catchment which would be controlled by a basin near Fourteenth Avenue is quite small and therefore a basin would not be an effective flood mitigation strategy.

5.15.4 Basin Sizes

A preliminary analysis was undertaken to investigate the basin sizes that would be required in order to reduce flooding at the above locations.

The RAFTS model was used to estimate the sizes required to reduce flows from the 100 year to the 1 year ARI event. A second analysis was carried out for basins to reduce flows from the 5 year to the 1 year ARI event at the outlet of each basin. In general the 1 year ARI unretarded flows within the catchment are 35 % of the 5 year ARI and 14% of the 100 year ARI.

Table 5.9 shows the sizes of basins required at the above locations.

Table 5.9
Retarding Basin Sizes

Location	Reduction of Flows from 100 y ARI to 1 y ARI		Reduction of Flows from 5 y ARI to 1 y ARI	
	Volume (ML)	Area (ha)	Volume (ML)	Area (ha)
Kemps Ck u/s of Bringelly Ave	543	54.3	212	21.2
Bonds Ck u/s of Bringelly Ave	685	68.5	255	25.5
Scalabrini Ck u/s of Bringelly Ave	432	43.2	169	16.9
Tributary 2 u/s of Twelfth Ave	86	8.6	35	3.5

The area required for each basin was estimated assuming an average depth of ponding of one metre within the storage area.

The large areas of land required for the retarding basins indicate that the option of having basins is unlikely to be economically feasible.

5.16 Summary

The results of this appraisal of possible flood management measures are summarised in Table 5.10.

Table 5.10

Summary of Potential Floodplain Risk Management Measures

Measure	Purpose	Comment
Property Modification		
Zoning and building controls	Reduce potential flood hazard and losses (Section 5.2).	• Mainly applies to redevelopment of existing sites and future developments in floodplain. Adoption of controls based on the PMF flood to identify the area to which land use related planning controls apply and 100 year ARI flood to define high and medium hazard zones are recommended. Control of building floor levels through implementation of the Planning Matrix within a new DCP supported for inclusion in Floodplain Risk Management Plan. Update LEP to reflect new definitions from FMM.
Voluntary Property Purchase	Purchase of residential properties in flood liable areas (Section 5.3).	• Applies to the high hazard floodway zone on main arms and tributaries. Not recommended because of cost to Council and community.
Flood Proofing	Prevent flooding of individual buildings (Section 5.4).	• Flood proofing achieved by house raising (wooden frame only); could be considered in low hazard areas on all streams but not likely to provide major benefits, as most properties are slab on ground.
Response Modification		
Flood Education	Enhances flood readiness through education strategies.	• Section 5.5 outlines recommendations, including preparation of flood leaflets. Recommended for inclusion in Floodplain Risk Management Plan.
Flood Readiness	Development of local flood plans to create community readiness for floods.	• Section 5.6 outlines recommendations. Recommended for inclusion in Floodplain Risk Management Plan.
Flood Warning System	Part of flood response emergency plan. Desirably, enables people to evacuate and/or move property to reduce actual flood damages.	• Short warning time, particularly on tributaries and difficulties with dissemination of warning and effective response reduces effectiveness of this measure. However, suggestions are given in Section 5.8 for SES to improve evacuation procedures.
Recovery Planning	Cleanup, welfare, counselling and data collection.	• Section 5.9 outlines recommendations
Section 149 Certificates	Provide information on flood levels and planning controls at residential properties.	• Section 5.10 outlines recommendations

Table 5.10

Summary of Potential Floodplain Risk Management Measures

Measure	Purpose	Comment
Flood Modification Stream Clearing and Stream Stabilisation	Reduce flood levels by clearing channel and banks of weed growth, bushes and flow obstructions. Note: continuing program of maintenance required. (Section 5.11)	• Clearing in Kemps Creek downstream of Gurner Ave is effective but not economically viable. • Clearing in Bonds Creek upstream of Sixth Ave is effective and economically viable. • Clearing in Tributary 2 is not effective and not economically viable. • Clearing in Tributary 3 and Scalabrini Creek is not effective in reducing damages. • **Summary:** Extensive steam clearing and stabilisation along the lengths of the streams is not a viable option for solving the area's flooding problems, except in Bonds Creek. Council could consider an improvement scheme for the stabilisation of Bonds Creek just downstream of Eighth Ave to protect property on right bank (Section 5.11.3).
Culvert Upgrading	Reduce flood level upstream of culvert crossing (Section 5.12)	• Results in a local reduction in levels; locations where significant reductions achieved along with costs of upgrading are shown on Table 5.4.
Channel Works (Figure 5.1)	Increase hydraulic capacity of creek and reduce flood levels (Section 5.13).	• Channel works upstream of existing channel up to Fifth Ave in Scalabrini Creek effective and economically viable. Works will also reduce flooding along Fourth Ave and improve road access. (Section 5.13.2). • Channel works in Tributary 2 at junction of Twelfth and Fourth Ave effective and economically viable. (Section 5.13.3). • Channel works in Kemps Creek between Twelfth and the confluence with Bonds Creek not effective and not economically viable. (Section 5.13.4). • Channel works in Bonds Creek as suggested by D.J. Dwyer and Associates effective but not economically and environmentally viable.
Levees (Figure 5.1)	Prevent flooding of protected area (Section 5.14).	• A levee for the Scalabrini Village in Bonds Creek is effective and economically viable. Further investigations are required to optimise levee height and consider control of local runoff (Section 5.14.2)
Retarding Basins (Figure 5.1)	Reduce downstream flooding by throttling flows (Section 5.15).	• Basins on tributary creeks, either single or multiple, not practicable due to large land take required.

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Figure 5.1

Floodplain Management Options

6. ASSESSMENT OF FLOOD MITIGATION OPTIONS

6.1 Background

The selection of the mix of works (eg levees, culvert upgrading, channel improvements) and measures (eg. land use, zoning, flood warning) that should be included in the overall Floodplain Risk Management Plan involves making choices with regards to the array of options which are available and the variety of factors (criteria) which can be used to judge between alternatives.

Each community will have different priorities and, therefore, each needs to develop its own set of criteria by which to choose between different options. The criteria adopted by a community must, however, recognise the State Government requirements for floodplain management as set out in the Floodplain Management Manual and other relevant policies.

The selection of appropriate criteria should also recognise that elements of the plan may be eligible for subsidy from State and Federal Government sources. The requirements of these bodies should also be considered in arriving at an appropriate range of criteria. Typically, State and Federal Government funding is given on the basis of merit as judged by a range of criteria:

- Degree of flood hazard
- Number of properties affected
- Annual average damage
- Damage in project design flood
- Benefit/Cost ratio
- Strategic planning
- Total Catchment Management compatibility
- Community involvement
- Local funding.

It is common practice to consider the criteria which might be adopted under the following broad headings:

- Social
- Environmental
- Economic
- Technical.

In the course of drawing up a range of criteria to be adopted for evaluation, consideration needs to be given to:

- specifying the criteria to be used
- defining how the criteria are to be evaluated
- deciding on the relative weighting or importance to be placed on different criteria.

In this study, the assessment of community acceptance is based on a variety of consultations with the community by means of responses to questionnaires, interviews with selected residents, perusal of Council's files relating to flooding and drainage in the area, attendance at Precinct Committee meetings and a Workshop (refer Appendix G). It is clear from these sources that there is strong community expectation for an improved standard of drainage and availability of flood free access in the event of minor frequent flooding. The freedom to go about their daily business without inconvenience is clearly important to the community.

In 1995, the Floodplain Management Committee and the Precinct Committees proposed and ranked selection criteria which would be suitable for assessing the floodplain mitigation measures in Austral (refer Appendix G). They proposed the following selection criteria (ranked in order of preference):

1. Community acceptance and expectations
2. Planning objectives (and future development limits)
3. Environmental impact
4. Economic feasibility
5. Financial feasibility
6. Performance in exceedance floods (catastrophe potential)
7. Ecologically sustainable development (ESD)/Government policies
8. Administrative/political

These criteria have been used with other criteria necessary to satisfy government policies related to floodplain and riparian zone management. The ranking has been used to assist categorise the selection criteria as either "essential", "desirable" or "a consideration" only (see Section 6.6).

In the following section an outline of the different criteria used for the evaluation of possible measures is presented. These are then drawn together into a set of criteria and their relative importance for Austral. These concepts are applied in Section 6.7 and the results summarised in the matrix presented in Table 6.1.

6.2 Social Criteria

Social criteria encompasses all those issues which are not directly economic or environmental in character and can be classified under a range of headings:

- Community acceptance and expectations
- Planning objectives, including future development limits
- Administrative and political issues
- Public safety.

6.2.1 Community Acceptance and Expectations

Works and measures can have a range of effects on the community. These effects, if strongly negative, are often enough to deter the implementation of a proposal which might otherwise have significant merit.

The issues impacting upon community or individual acceptance of a proposed measure included:

- potential for financial loss/gain
- reduction in disruption to daily life by drainage improvements
- improvement in road access during floods
- perception of fair play
- public safety (reduction in flood hazard).

The following ranking was adopted:

2 Received strong community support in general and strongly supported by those affected
1 Received community support and supported by those affected
0 Neutral - community opinion and those affected not for or against
-1 Opposed by the community or those affected
-2 Strongly opposed by the community or those affected.

6.2.2 Planning Objectives

The Council has developed a set of planning policies for the future development of the rural lands within Liverpool including the Austral - Kemps Creek area, which reflect the long term goals of the community. These policies are embodied in the Liverpool LEP 1997 and Austral Floodplain Management Study Draft DCP, which were reviewed in Sections 2 and 5.

The following scoring was adopted:

2 Measure strongly supports planning objectives
1 Measure largely in accord with planning objectives
0 No impact on planning objectives
-1 Measure in mild conflict with planning objectives
-2 Measure strongly in conflict with planning objectives

6.2.3 Administrative/Political Issues

The management of the impacts of floods on a community will involve a range of different authorities, which include community groups, Council and state government agencies. They are represented by the Floodplain Risk Management Committee and the various Precinct Committees.

Clearly any recommendation contained in the Floodplain Risk Management Plan will have more chance of success if it involves little disruption to current political and administrative structures, attitudes and responsibilities. On the other hand, should an alteration to the political/ administrative system be clearly beneficial to the Plan, it should be so stated and the implications accepted.

The ranking under this criterion are made on the basis of the need to alter political/administrative structures and/or the likely attitudes of the political/administrative bodies concerned.
The following system of scoring was adopted:

2 No radical change to current structures or change widely supported
1 No change of substance to current structures or change probably supported
0 Neutral - retain status quo
-1 Significant changes to current structures or change probably opposed
-2 Radical change to current structures or change strongly opposed.

6.3 Environmental Issues

6.3.1 ESD and Relevant Government Policies

Ecologically Sustainable Development
Environmental issues form a core set of criteria by which any Floodplain Risk Management Plan should be assessed. Compared to environmental planning principles used during the last two decades, Ecologically Sustainable Development (ESD) changes the focus from and assessment of ways to minimise the environmental impacts of a project to a much wider set of considerations including:

- sustainable use of resources;
- maintenance of ecological diversity;
- adoption of the precautionary principle (scientific uncertainly should be sufficient reason to not proceed with a project).

In practice the objectives and principles of ESD may be expressed as four main themes:

- Improve individual community well being and welfare
- Improve equity within and between generations
- Maintain and, where practicable, enhance ecological processes
- Maintain and, where practicable, enhance bio-diversity.

For a policy, plan or project to be consistent with ESD it must advance at least one of these four objectives without adversely impacting the others. For the purposes of evaluating the impact of a particular proposal, it is probably sufficient to adopt an assessment of whether or not ESD principles are upheld.

Relevant Government Policies

The NSW Government has developed a number of polices which are of direct relevance to floodplain management. The first of these are the policies enshrined in the Floodplain Management Manual which forms the basis for the formulation of Floodplain Risk Management Plans. The second is the State Rivers and Estuaries Policy (NSW Water Resources Council, 1993) which is the umbrella policy statement for subsidiary policies including:

- Wetlands Policy
- Stream Management Policy
- Riparian Zone Policy

Of these, the proposed Riparian Zone Policy is most pertinent to the management of the floodplain in the Austral - Kemps Creek area. The policy suggests that the overall objective should be:

To manage the riparian zones of NSW in ways which:

- *slows, halts or reverses the overall rate of degradation*
- *ensures the long term sustainability of essential biophysical functions*
- *maintains the beneficial use of these resources.*

The suggested specific objectives are:

- *to increase the community's awareness of the value of the riparian zone and its importance in maintaining a healthy river;*
- *to promote the maintenance or restoration of the functions which the zone performs (including bank and channel stability, habitat and buffer functions);*
- *to improve our knowledge of the functions of the zone and of the requirements for its sound management.*

For the purposes of floodplain management the riparian zone may be taken as the area above the low flow level to the inner edge of the floodplain. In practice, the riparian zone merges into the floodplain and any management policies or actions should not stop at artificially defined boundaries.

The policy is being introduced to encourage consideration of all aspects of the functioning of the riparian zone and its value to the environment and community, including:

Natural/Ecological	**Human Needs**
• Stream stability	• Scenic amenity
• Ecology and habitat	• Recreation
• Buffer strip	• Agriculture
• Groundwater	• Resources (sand, gravel etc)

The following scoring system was adopted:

2 significant benefits for ESD and the riparian zone
1 some benefits in terms of halting degradation or ensuring long term sustainability
0 no benefits or disbenefits
-1 some loss of the riparian zone value and some impacts on ESD
-2 significant harm to ESD and riparian zone.

6.3.2 Environmental Impact and Water Quality

Environmental Impact

Few floodplain management measures could be proposed if the impact on the environment was extremely adverse. Although it is outside the scope of this study to conduct detailed environmental assessments of each measure, a subjective assessment of the impact is necessary.

The environment, for the purposes of the study, may be divided into:

- Creek Corridor - creek channels and banks and the immediate riparian zone.
- Floodplains - the extensive areas of floodplain which include some public open space and reserves.

Water Quality

In common with creeks in any closely settled and urban fringe area, the creek system in the Austral - Kemps Creek area is subject to a number of pressures which lead to a deterioration in water quality which is manifested by:

- Increased sediment loads derived form the extensive areas used for horticulture and other intensive agriculture. Some sediment is deposited in the channels and gradually decreases conveyance capacity in some places.
- Increased levels of nitrogen and phosphorus which promote weed growth in the creeks and further reduce the conveyance capacity.
- Transport of exotic weed species which invade the floodplain areas and tend to decrease the conveyance capacity of the floodplain.

Measures which reduce soil erosion and restrict runoff from intensive agriculture can be expected to show indirect benefits in maintaining the stability of the creek system.

The following scoring was adopted:

2 Strongly positive environmental impact or improvement to water quality
1 Positive environmental impact or improvement to water quality
0 Little or no impact
-1 Negative environmental impact or deterioration to water quality
-2 Strongly negative environmental impact or deterioration to water quality.

6.4 Economic Issues

6.4.1 Economic Feasibility

There is a range of procedures available to judge the economic worth of making an investment in floodplain management works measures. The most common is the Benefit/Cost ratio (B/C). On a purely theoretical approach no investment should be made in a measure if the B/C ratio does not exceed unity, that is if the benefits do not exceed the costs. Many public projects are undertaken where this is not the case because the intangible benefits, those not able to be quantified, are considered.

The benefits of floodplain management measures are largely the savings in damages to existing properties or developments and the savings in damages achieved by preventing flood liable developments. The costs are primarily the capital and operating costs of structural works and of non structural measures.

The damage assessments made in Section 2.8 can be used to quantify benefits from potential works and measures where appropriate. Where possible a measure of the B/C ratio has been estimated for contending measures. Not all of the measures applicable to the Austral- Kemps Creek area lend themselves to meaningful B/C analysis. Where required, a qualitative estimate of economic worth was made based on whether the B/C ratio is likely to be high or low.

For the purposes of assessment the following scoring was adopted:

2	B/C likely to be very high, much greater than 1.0
1	B/C likely to be greater than 1.0
0	B/C likely to be under one but unquantifiable benefits would raise the ratio
-1	B/C likely to be under one with few unquantifiable benefits
-2	B/C likely to be very low with few unquantifiable benefits

6.4.2 Financial Feasibility

Measures proposed for the drainage and floodplain management plan for Austral - Kemps Creek must be capable of being funded over the proposed period of construction/implementation. The sources of funding are traditionally:

- Council
- NSW Government

Contributions from these sources are such that, where the costs were attributable to floodplain management activities, Council would bear 33% of the overall cost with the remainder provided by the State Government NSW.

The limitations on Council funding are related to the magnitude of Council income in any one year, its borrowing capacity and existing commitments. The total allocation and sources of funds will vary in any one year and are dependent on special grants. The funds which are available for drainage and floodplain management measures will be dependent on Council priorities.

The State Government contribution is limited by the allocation to flood mitigation programs on an annual basis. The allocations are made available through DIPNR, the controlling authority, on behalf of NSW and the Commonwealth. The average funding in recent times has been about $5 million per year *(Richard Smith, DIPNR Newcastle, pers comm).*

Liverpool would have to take its place alongside other centres competing for funding. In addition, the Austral - Kemps Creek area would have to compete with other areas within the City for allocation of such funds. Since Council has many demands for drainage/flood mitigation works and flood free road access, the financial feasibility is likely to be a significant constraint to the rate at which works can be undertaken. For the purpose of assessing the various competing works and measures in the Austral - Kemps Creek area, the following annual funding limits were adopted for the purposes of ranking:

2	Under $150,000
1	$150,000 to $300,000
0	$300,000 to $450,000
-1	$450,000 to $750,000
-2	Over $750,000

Council's share of the above would be 33%.

6.5 Technical Issues

6.5.1 Engineering Feasibility

Floodplain management works, as distinct from measures, must be readily constructable and free of major engineering constraints to become an acceptable element of any plan. Maintenance requirements should also be considered in this evaluation.

All works were assessed on the following basis:

2	Easily constructable with local resources, no engineering design constraints
1	Constructable with access to external resources and/or with some design or maintenance difficulties
0	No engineering aspects
-1	Constructable with some difficulty and/or depends on complex design solution, probably with costly maintenance
-2	Unclear as to how it could be designed and/or constructed.

6.5.2 Performance in Exceedance Floods

As described in Chapter 3, in 1995 the Floodplain Management Committee recommended the PMF flood as defining the extent of land subject to development controls. Floor levels of future development within the floodplain are to be set at the 100 year ARI level plus 500 mm. Any potential works or measures must be assessed assuming that at some future time they will be exposed to floods in excess of the 100 year ARI flood.

It is therefore imperative that the works and measures under consideration do not expose the community to unacceptable risks far beyond those experienced without the work or measure, should an extreme flood occur.

The following scores were adopted:

2	No adverse impact in exceedance floods
1	Minor adverse impact in exceedance floods
0	Exceedance not an issue
-1	Significant adverse impact in exceedance floods
-2	Unacceptable impact in exceedance floods.

6.6 Selection of Elements for the Draft Floodplain Risk Management Plan

The criteria discussed above do not necessarily have equal weighting in the assessment of options for the Austral - Kemps Creek area. Although multi-objective criteria techniques are now well accepted by Government in selecting one from a range of competing projects, the decision to provide state funds is still linked closely to **economic and financial** factors. The Floodplain Management Committee and the Community, however, have expectations which give more weight to social, environmental and planning issues (refer Appendix G). These views were considered in adopting the appropriate weight to be given to the various criteria.

The selection of elements for inclusion in the Plan was achieved through the following steps:

1. Possible assessment criteria were identified (see preceding sections of this chapter).
2. Assessment criteria were categorised as being either essential, desirable or a consideration and a weighting assigned to each category.
3. A score was assigned to mitigation measures under each criteria.
4. The score was weighted according to the criteria categorisation.

5. The weighted scores were totalled to provide a total score for each measure.
6. The measures were ranked based on the total scores.

This process was undertaken through the use of a matrix, with the measures forming the rows and the criteria the columns.

6.6.1 Assessment of Criteria Category

For the purposes of assembling the Draft Floodplain Risk Management Plan, each of the above listed criteria has been ranked by allocating them to the categories of "essential", "desirable" or "a consideration". The ranking is based on the results of the community consultation process and on the Consultants' assessment. The adopted categorisation is as follows:

"Essential"
Community Acceptance
Planning Objectives
Environmental Impacts

"Desirable"
Economic Feasibility
Financial feasibility
Performance in Exceedance Floods

"A Consideration"
Government Policies (ESD, RZP)
Administrative/Political

6.6.2 Criteria Ranking

A numeric form of ranking has been used in assessing the proposed flood mitigation works and measures, as outlined in the sections above.

6.6.3 Weighting

In order to allocate the relative importance of each criterion a weighting system has been adopted.

- Where the criterion is deemed essential, its ranking score will be multiplied by 1.0.
- Desirable criteria will be multiplied by a factor of 0.5, and
- Considerations criteria will be multiplied by 0.25.

6.7 Assessment of Options

Existing flood mitigation measures were described in Chapter 4 and potential measures were reviewed in Chapter 5, mainly from the viewpoint of engineering feasibility, effect on flood behaviour and cost. This section evaluates the measures in terms of the assessment procedures outlined above.

The assessment matrix is shown on Table 6.1 with criteria grouped into the three categories "essential", "desirable" and "a consideration".

The ranking resulting from the assessment can be seen in the final column of the assessment matrix, where '1' indicates the highest ranked, and therefore the highest priority, option. This ranking has been used as the basis for prioritising the components of the draft Floodplain Risk Management Plan. Where options have been awarded the same weighted score, they are given the same ranking in Table 6.1.

Table 6.1
Floodplain Management Potential Options Assessment Matrix

OPTION	ESSENTIAL			DESIRABLE			A CONSIDERATION		TOTAL SCORES			WEIGHTED SCORES	RANKING
	Community Acceptance	Planning Objectives	Environmtl Impacts	Economic Feasibility	Financial Feasibility	Exceedance Floods	Govt. Policies (ESD, RZP)	Admin/ Political	Essential (E)	Desirable (D)	Consid. (C)	(E)x1 + (D)x0.5 +(C) x 0.25	
A. Improve road access during flooding (all costs are capital costs, exclusive of land acquisition, where required)													
- Fourth Avenue culvert on Bonds Creek	2	2	0	0	-1	1	0	0	4	0	0	4.00	13
- Fourth Avenue/Twelfth Avenue upgraded culverts and improved channel on Tributary 2 (also reduces property damages).	2	2	1	1	-2	1	0	-2	5	0	-2	4.50	12
- Scalabrini Creek d/s Fifth Avenue improved channel and upgraded culvert (improves access on Fourth Avenue and reduces property damage).	2	2	0	1	-2	1	0	-2	4	0	-2	3.50	15
- Edmondson Avenue upgraded culvert on Tributary 2	2	2	0	0	1	1	0	0	4	2	0	5.00	11
- Eighth Avenue upgraded culvert on Bonds Creek	1	2	0	0	-1	1	0	0	3	0	0	3.00	18
- Edmondson Avenue upgraded culvert on Bonds Creek	1	2	0	0	0	1	0	0	3	1	0	3.50	15
- Fifteenth Avenue upgraded culvert on Tributary 3	1	1	0	0	1	1	0	0	2	2	0	3.00	18
B. Stream clearing, vegetation management project	1	1	1	-1	1	0	2	2	3	0	4	4.00	13
C. Bond Creek levee d/s Fifth Ave to protect Scalabrini Village	2	2	1	2	1	0	0	1	5	3	1	6.75	10
D. Stabilisation/bank protection Bonds Creek d/s Eighth Avenue	1	1	0	-1	1	1	2	2	2	1	4	3.50	15
E. Zoning and Building Controls													
- Update LEP to incorporate definitions from FMM	2	2	2	2	2	2	2	2	6	6	4	10.00	1
- Review and update DCPs to ensure consistency with LEP and FMM definitions	2	2	2	2	2	2	2	2	6	6	4	10.00	1
- Prepare and adopt Austral Floodplain Management Study Draft DCP	1	2	2	2	2	2	2	2	5	6	4	9.00	6
- Formally adopt Landfill Policy	1	2	2	2	2	2	2	2	5	6	4	9.00	6
- Develop Rural Land Use Management for Flood Prone Land Guidelines	1	2	2	2	2	2	2	2	5	6	4	9.00	6
F. Response Modification Measures													
- Flood Education and Readiness	2	2	2	2	2	2	2	2	6	6	4	10.00	1
- Flood warning scheme investigation	2	2	2	2	2	2	2	2	6	6	4	10.00	1
- Review and update Recovery Plan	2	2	2	2	2	2	2	2	6	6	4	10.00	1
- Review Section 149 Certificates	1	2	2	2	2	2	2	2	5	6	4	9.00	6

7. DRAFT FLOODPLAIN MANAGEMENT PLAN

In accordance with the requirements of the *Floodplain Management Manual* (NSW Government, 2001), this Plan identifies three broad categories of management actions:

1. Management of the existing flood risk faced by the existing development.
2. Management of future flood risk that might arise from new development or redevelopment of the existing housing stock.
3. Management of the continuing flood risk that remains after all floodplain management measures are implemented.

7.1 Management of Existing Flood Risk

The management of existing flood risks is concerned with reducing flood impacts on the existing housing stock and community facilities. With the benefit of hindsight it can be seen that some buildings are located inappropriately or have floor levels that give rise to an unnecessarily high risk of flood damage. Management of the existing flood risk is concerned with correcting the worst of these existing problems.

7.1.1 Flood Management and Drainage Improvement Measures

The applicability of a variety of floodplain management and drainage measures was reviewed for the study. The findings are given below:

7.1.1.1 Stream Clearing and Stabilisation

Extensive stream clearing and stabilisation along the trunk drainage system is not a viable option for solving the area's flooding problems with the exception of within Bonds Creek. However, clearing the creek in areas identified in the study will locally reduce flooding, improve the environment and are generally supported by the community. Council should consider a one-off scheme in a short reach of Bonds Creek downstream of Scalabrini Village, which could function as a demonstration project to promote appropriate riparian and vegetation management. A program of stream clearing and minor channel regrading in conjunction with a levee could be used to provide a high level of protection for this development. Currently, problems are experienced during even minor flood flows. Potential difficulties with implementing the scheme which would need to be resolved are:

- Liaison with the community to gain public acceptance for the proposal and overcoming the problem of private ownership of the creek.
- Funding of the scheme. Opportunities should be explored for implementing the scheme as a Council sponsored Landcare project.

On the basis of experience in Fairfield Council area, an allocation of $140,000 would treat a 200 m reach of creek. However, other methods of clearing and bank stabilisation could be considered which may be less expensive. (Note that this allocation does not include the cost of the Scalabrini Village levee, which is discussed later).

Some areas of the creek system are showing considerable erosion and bank stability problems, mainly in areas which have previously been excavated by Council to improve capacity. Examples are on Bonds Creek, particularly downstream of the Eighth Avenue culvert and on Scalabrini Creek, near Sixth Avenue. A program of extensive channel stabilisation along the length of the creek system would require re-battering the creek banks, erosion control structures and involves the acquisition of land. It would be expensive and difficult to implement. In the short term, it is recommended that stabilisation be confined to the area immediately downstream of Eighth Avenue, where there is a residence quite close to the eroding creek bank. An allowance of $180,000 should be made for this work.

7.1.1.2 Culvert Upgrading

Reductions in flood levels achieved by upgrading culverts are quite localised. The main benefit of this measure is improved access during flood periods. Significant increases in the level of serviceability could be achieved by culvert upgrading at the locations shown on Table 7.1. They were also identified by the community as problem locations.

Table 7.1
Cost of Upgrading Culverts

Location	Existing Capacity ARI years	Proposed Capacity ARI years	Capital Cost ($)
Bonds Creek			
Fourth Avenue	2	10	650,000
Eighth Avenue	2	10	525,000
Edmondson Avenue	2	5	450,000
Tributary 2			
Edmondson Avenue	2	5	175,000
Tributary 3			
Fifteenth Avenue	2	100	175,000

Thirteenth Avenue on Tributary 2 was also identified as a problem location, but improvements at this location will also require channel improvements, as described in the next section.

7.1.1.3 Channel Improvements

A major constraint on the feasibility of these schemes is the uncertainty of acquiring the land for their construction. It is to be noted here that Council's preference is to place acquired land into Drainage Reserves (or similar), so that beneficial multiple uses can be achieved; for example, parks or wetlands. Two locations where channel improvements, in conjunction with culvert upgrading, are economically viable and would be supported by the community are given in Table 7.2 below:

Table 7.2
Cost of Channel Improvements

Location	Capacity ARI years	Capital Cost $
Scalabrini Creek		
d/s Fifth Avenue	5	890,000
Tributary 2		
Near Twelfth and Fourth Avenues	100	1.35M

These schemes will reduce residential flooding as well as improving road access. In the case of the Scalabrini Creek scheme, flooding along Fourth Avenue will also be reduced thereby improving the serviceability of the road, in addition to reducing property damage by flooding. For the second scheme, a new channel is required to replace the ill-defined course of Tributary 2 along Twelfth Avenue. The proposed scheme will give a high level of protection against flooding at the intersection and is therefore quite expensive. Additional investigation is warranted to optimise its size. It is to be noted that the costs presented do not include land acquisition, as reliable information is not presently available. At times these costs can affect the viability of a scheme.

7.1.1.4 Scalabrini Village

This residential development is located on the left bank of Bonds Creek downstream of Fifth Avenue. The incidence of damaging flooding, which presently occurs at around 1 year ARI, could be reduced by the construction of a levee. A levee costing around $220,000 will protect the area up to 5 year ARI flood levels. Additional measures may be required to control interior drainage which will need to be temporarily stored behind the levee.

A higher levee will provide a greater level of protection but will require a detailed hydraulic investigation to ensure that flow patterns are not adversely affected and flood levels are not significantly increased. Some compensatory channel improvements may also be required.

Savings in the cost of the levee project may be realised by implementing a stream clearing project on Bonds Creek downstream of Fifth Avenue, as previously discussed.

An Evacuation Plan has been prepared by the operators of Scalabrini Village detailing the procedures to be followed in the event of flooding. Liaison with the local SES unit regarding the incorporation of this Plan into the overall Plan for the area is recommended.

7.1.1.5 Other Measures

Measures such as retarding basins were investigated but are not worthy of further consideration because of excessive land-take and cost. The catchments are large and require major basins.

7.2 Management of Future Flood Risk

Management of future flood risk is concerned with ensuring that future development is not subject to unacceptable risk and that existing flood conditions are not exacerbated by unwise future development. The recommended floodplain planning measures are contained in several existing or proposed policy documents, as outlined below.

7.2.1 Update LEP and Review Planning Documents

It is recommended that Liverpool LEP be updated to incorporate the definitions as proposed by Don Fox Planning (refer Appendix F) to ensure consistency with the Floodplain Management Manual (FMM) (2001). It is also recommended that all of Council's DCPs be reviewed to ensure consistency with the LEP and with the definitions from the FMM.

7.2.2 Landfill and Earth Dams Development Control Plan

This DCP has been developed by Council and has been reviewed and updated to integrate the planning requirements of Austral and other rural areas in Liverpool. The DCP deals with landfill principally from the perspective of its impact on drainage and flooding. It also deals with some of the issues involved in siting and designing houses to reduce the likelihood of future flooding problems.

The objective of the DCP is to prevent the exacerbation of flooding in rural areas through the conservation, as far as possible, of natural drainage paths and storages using controls on landfill. Proposals must meet a set of performance criteria, formulated to ensure landfill will not create adverse impacts on other people and properties, including:

- limits on areas of filling;
- prohibition of filling in floodways;
- restrictions on diversion of flow.

It is recommended that this draft policy be revised and formally adopted after amendment in line with the recommendations for alteration to definitions provided by Don Fox Planning.

7.2.3 Austral Floodplain Management Study Draft Development Control Plan

This draft plan, once adopted, will reflect floodplain related planning controls applying to the Austral and Kemps Creek areas. A gradation of planning controls should be developed to apply to Council's three "flood risk zones" (low, medium and high) within the flood planning area. These controls should be integrated into a Planning Matrix (refer Table 5.2). The principal aspects of the DCP include:

Within Flood Planning Area:

- Minimum floor level of a proposed dwelling located within the flood planning area must be the flood level corresponding to the 100 year ARI flood plus 500 mm;
- Controls on earthworks and fill that alter land surface levels;
- Controls on the location of essential services such as hospitals and emergency services.

Within High Flood Risk Zone:

- No new buildings - developments must be located outside the floodway as defined in the Austral Floodplain Management Study.
- Strict controls on earthworks and fill that alter land surface levels.

7.2.4 Rural Land Use Management for Flood Prone Land

The Austral Floodplain Risk Management Study recommends that Council develop a set of recommended guidelines for rural activities on flood prone land. The objective of these guidelines will be to encourage rural landholders to undertake activities in a manner that seeks to minimise the losses in agricultural production and to agricultural facilities from flooding. The recommended guidelines would include recommended measures to:

- Allow passage of floodwaters through properties with minimal obstruction.
- Appropriate design of buildings to allow passage of floodwater (eg arrange greenhouses with long axis in direction of flow, "skirt" which can be lifted by flood).
- Location of key assets above flood levels.
- Erosion control measures.
- Flood awareness and planning.

7.2.5 Creek and Floodplain Management

The Liverpool City Council Floodplain Management Committee (LCC FPMC) contains representatives from the Community, Relevant Agencies, Councillors and Council Officers and is responsible for the management of the Austral catchment. The primary ongoing task of this Committee in the Austral area is to promote joint management of the flood prone lands through such activities as:

- Promotion of appropriate land and vegetation management of the creek and floodplain;
- Provide a focus for Total Catchment Management and Rivercare activities, including the identification of projects and co-ordination of funding applications.
- Providing a channel for ongoing "seed" funding from Council to enable initial channel restoration or vegetation clearing projects to be undertaken.
- Providing a forum for ongoing dialogue between Council and the community for the exchange of information in order to reduce the apparent cynicism and mistrust which currently exists.

These tasks could be carried out in the Austral area by the FPMC itself or a sub-committee of the FPMC, as decided by the FPMC. It has been assumed that no additional funding would be required for this initiative.

7.3 The Residual Flood Risk

Even if all flood mitigation options suggested in this study were implemented, there would still be a residual risk (continuing risk) associated with flooding at the PMF as the flood mitigation works recommended only address flood mitigation at the 1% AEP flood or less. The continuing flood risk is the risk to lives and property from the PMF, even after all possible flood mitigation works have been implemented.

The management of continuing flood risk is concerned with ensuring that impacts on the community are minimised in the event of floods larger than those used to designate planning controls such as FPLs. This will be achieved by the following actions:

7.3.1 Flood Education and Readiness

It is recommended that Council undertake a flood education and awareness campaign in conjunction with SES. This would involve an initial campaign followed up every second year on an ongoing basis. It is estimated that such a campaign might cost around $5,000, with $5,000 every second year. As part of this campaign a Flood Information Leaflet should be prepared in conjunction with SES.

7.3.2 Flood Warning and Response System

The times of rise of the streams in the Austral area are quite short and hence the potential warning time is limited to 2 to 3 hours on the main arms and less on the tributaries. Most of the residents work in areas remote from the catchment and therefore there is a problem with dissemination of the warning itself and promoting an adequate response which will result in a reduction in flood damages. Consequently, a formal flood warning system for the study area will have limited success in reducing flood damages and would not be economically justified.

However, it is recommended that Council, in conjunction with SES, commission an investigation into a simple warning system for the catchment. Such a review would include consultation with the Bureau of Meteorology.

While sophisticated forecasting approaches may not be justified, there are cost effective methods of warning dissemination available which may be appropriate for the Austral area. These include “PC Cops”, which is a system programmed to dial up homes under threat and play a pre-recorded warning message. It asks for a response and then records whether or not this is received. The “Expedite” SMS messaging system is another option which may be appropriate. Further research in this area should be included in the investigation into the warning scheme.

The State Emergency Service (SES) has prepared a draft (September 2001) Liverpool Local Flood Plan, which is a sub-plan of the Liverpool Local Disaster Plan. The draft plan has not yet been formally adopted. The area covered by this plan includes all of the Liverpool City Council area. However, the Plan appears incomplete and does not provide any specific information regarding the Kemps Creek area. Evacuations are dealt with only generally and no detailed evacuation plan has been prepared.

It is recommended that the SES should be complete and further develop the Local Flood Plan, based on the information presented in the study, to include annexures dealing specifically with the Kemps Creek area. Additional elements would include a graded response plan and an evacuation plan comprising:

- Ranking the threatened houses according to their hazard situation, taking account of depth and velocity of floodwaters, and means of access, as a flood develops;

- Preparing a detailed response plan which focuses on initial evacuations from the most hazardous locations, followed by further evacuations in descending rank of hazard;
- Preparing a plan for traffic management which takes account of the sequence of road flooding as a flood develops. This plan would aim to:
  - maximise opportunities for the community to evacuate
  - ensure access for SES operators
  - prevent unnecessary traffic through the affected area
- Assessing the resources/methodology appropriate to disseminate the warning;
- Assessing whether the size of identified community centres appropriate for receiving the estimated number of evacuees;

The preparation of Flood Intelligence Cards, as recommended in Flood Warning: An Australian Guide (published by Emergency Management Australia, 1995) would be an appropriate activity in connection with developing this graded response plan.

7.3.3 Recovery Planning

It is recommended that the Recovery Plan be reviewed to ensure it is adequate to deal with the recovery process in the Austral area.

Council should implement a procedure to ensure that data is collected after each flood event. This information should include:

- water information (levels, rates of rise an fall, velocities, areas inundated);
- details of damage;
- information which did or did not become available when needed during the flood;
- actions which were taken during the flood.

7.3.4 Section 149 Certificates

It is recommended that Council ensures that, when required, 149(2) and 149(5) certificates be issued with the appropriate information attached for the floodplain (that is the area inundated during the PMF). It is recommended that Council review the advice provided with the certificates and, if necessary, adapt it to reflect the risks associated with the relevant flood risk zone as well as including the required planning controls based on the Flood Planning Matrix. It has been assumed that this task can be carried out in the course of normal Council work and no additional budget would be required to complete it.

7.4 Funding

Broad funding requirements for the recommended works and measures updated to 2002 values and increased based on recent estimates carried out for Council are given in Table 7.3 below, along with a priority ranking in the overall plan. The locations of the works are also shown on the attached figure. These works, if carried out, would result in improved access via the road system during flooding and rectification of the worst problem areas. The community should not expect that the works would remove all flooding in the area.

Annual maintenance costs, which are estimated at around 3% of capital cost, have not been included in the estimated costs provided below, but are included in the economic evaluations of Section 5 of the Report.

The estimated costs are the total costs for each scheme, irrespective of where that funding may be obtained. The costs do **not** include costs for land acquisition, nor do they include compensation to landholders where drainage works are carried out on their land. Payment of compensation, in cases where works are carried out on private property for the assistance of the landholder, may render the scheme not cost effective.

7.5 Implementation Program

The steps in progressing the floodplain management process from this point onwards are set out as follows:

- Council considers the Floodplain Management Committee’s recommendations;
- Exhibit the draft Plan and Study Report and seek community comment;
- Consider public comment, modify the Plan if and as required and submit the final Plan to Council;
- Council adopts the Plan and submits an application for funding assistance to DIPNR;
- Council uses the Plan as a basis for input to South West Sector Planning;
- As funds become available from DIPNR and/or Council's own resources, construct the works and implement the measures in accordance with the established priorities.

The Plan should be regarded as a dynamic instrument requiring review and modification over time. The catalysts for change could include new flood events and experiences, legislative change, alterations in the availability of funding, reviews of the city planning strategies and importantly, the outcome of some of the studies proposed in this report as part of the Plan. In any event, a thorough review every five years is warranted to ensure the ongoing relevance of the Plan.

The LCC Floodplain Management Committee’s action program for implementing the Plan is therefore:

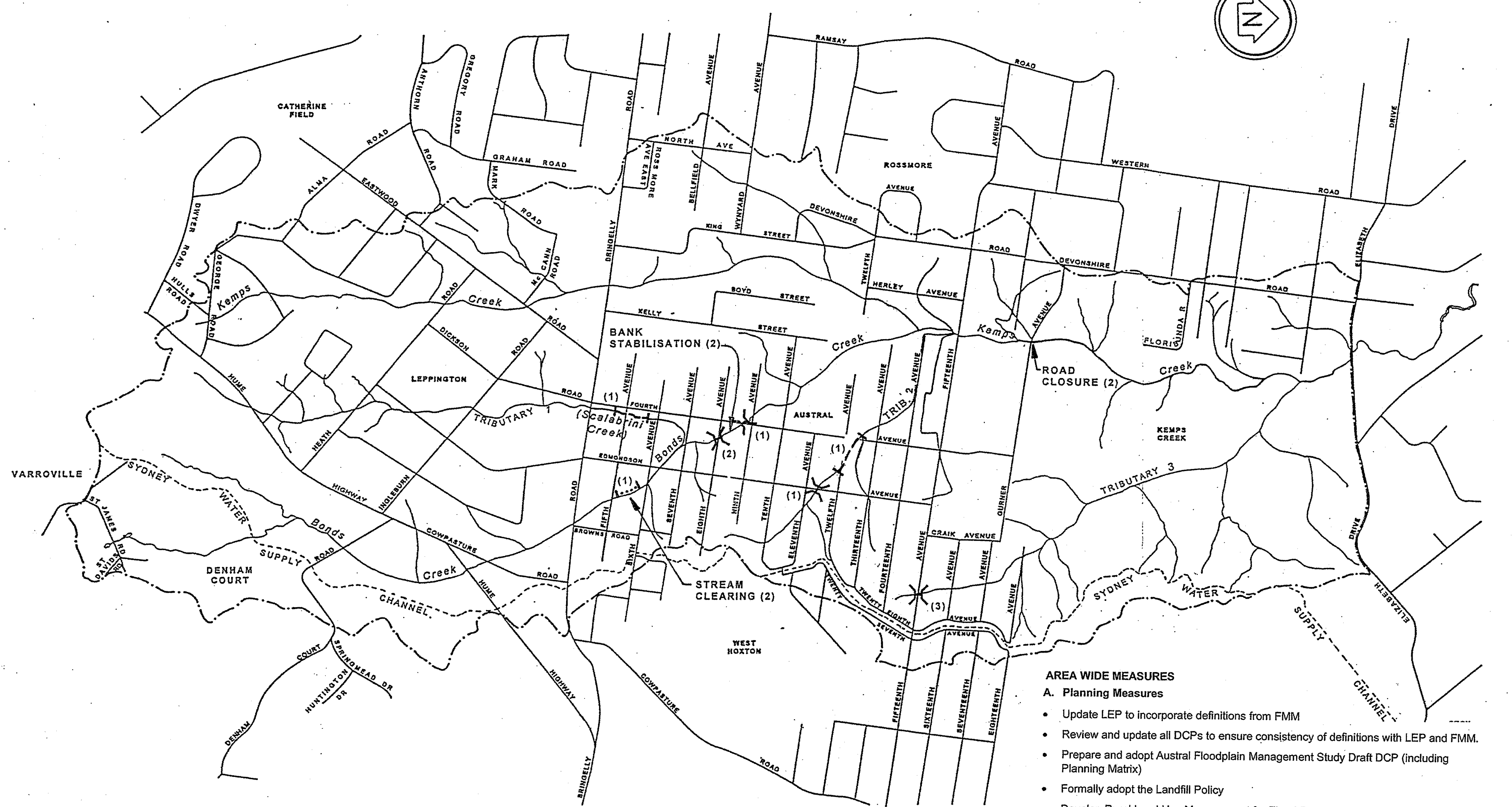
- confirm the projects set out in Section 6 and their priority ranking.
- carry out design studies for schemes, liaise with residents and implement projects according to priority and funding constraints.

Table 7.3
Funding Requirements for Recommended Works and Measures

Project	Rank	Cost ($)
A. Improve road access during flooding (all costs are capital costs, exclusive of land acquisition, where required)		
• Fourth Avenue culvert on Bonds Creek	13	650,000
• Fourth Avenue/Twelfth Avenue upgraded culverts and improved channel on Tributary 2 (also reduces property damage)	12	1,350,000
• Scalabrini Creek d/s Fifth Avenue improved channel and upgraded culvert. (improves access on Fourth Avenue and reduces property damage)	15	890,000
• Edmondson Avenue upgraded culvert on Tributary 2	11	175,000
• Eighth Avenue upgraded culvert on Bonds Creek	18	525,000
• Edmondson Avenue upgraded culvert on Bonds Creek	15	450,000
• Fifteenth Avenue upgraded culvert on Tributary 3	18	175,000
B. Stream clearing, vegetation management project	13	140,000
C. Bond Creek levee d/s Fifth Ave to protect Scalabrini Village	10	220,000
D. Stabilisation/bank protection Bonds Creek d/s Eighth Avenue	15	180,000
E. Planning Measures		
• Update LEP to incorporate definitions from FMM	1	Council Costs
• Review and update all DCPs to ensure consistency of definitions with LEP and FMM.	1	Council Costs
• Prepare and adopt Austral Floodplain Management Study Draft DCP (including Planning Matrix)	6	Council Costs
• Formally adopt the Landfill Policy	6	Council Costs
• Develop Rural Land Use Management for Flood Prone Land Guidelines	6	Council Costs
F. Response Modification Measures		
• Flood Education and Readiness Campaign	1	$5,000 (initially) +$5,000 (every 2nd yr)
• Flood Warning Scheme Investigation	1	$10,000
• Recovery Planning Review and Update	1	$5,000
• Section 149 Certificates Review	6	No additional budget required

Notes: (1) Projects with the same ranking indicate same weighted score in Table 6.1 in main document.

(2) Cost of land acquisition **not** included in the cost of structural works.



LEGEND

- Potential Grassed Channel
- Potential Levee Scheme
- Upgraded Culvert

Note: Values in brackets show ranking of project.
(1) = high priority
(2) = medium priority
(3) = low priority

SCALE
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AREA WIDE MEASURES

A. Planning Measures

- Update LEP to incorporate definitions from FMM
- Review and update all DCPs to ensure consistency of definitions with LEP and FMM.
- Prepare and adopt Austral Floodplain Management Study Draft DCP (including Planning Matrix)
- Formally adopt the Landfill Policy
- Develop Rural Land Use Management for Flood Prone Land Guidelines

B. Response Modification Measures

- Flood Education and Readiness Campaign
- Flood Warning Scheme Investigation
- Recovery Planning Review and Update
- Section 149 Certificates Review

AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure 7.1

FLOODPLAIN MANAGEMENT PLAN

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9. GLOSSARY

Annual exceedance of probability (AEP)	the chance of a flood of a given size occurring in any one year, and usually expressed as a percentage. For example, if a peak flood discharge has an AEP of 1%, it means that there is 1% chance (that is one-in-100) of that peak flood discharge or larger occurring in any one year.
Average recurrence interval (ARI)	the long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 100 year ARI flood event will occur on average once every 100 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Average annual damage	the average damage per year that would occur from flooding over a very long period.
Catchment	the land area draining to a particular point. It always relates to a specific location.
Catchment values	key catchment characteristics that are important to the community and other stakeholders.
Continuing flood risk	the risk a community is exposed to after floodplain risk management measures have been implemented.
Development control plan (DCP)	a plan prepared in accordance with the environmental Planning and Assessment Act (1974), which provides guidelines for the assessment of development applications.
Discharge	the rate of flow of water expressed as volume per unit time (m3/s).
DIPNR	Department of Infrastructure, Planning and Natural Resources (formerly DLWC and PlanningNSW)
DLWC	Department of Land and Water Conservation.
DWR	Department of Water Resources
Effective warning time	the time available after receiving advice of an impending flood and before floodwaters prevent appropriate flood response actions being taken.
Existing flood risk	the risk a community is exposed to as a result of its location on the floodplain.
Flood	relatively high flow of water that has overtopped stream banks or artificial channels, and/or local overland flooding associated with major drainage systems being inadequate to convey all flow.
Flood liable land	land susceptible to flooding by the probable maximum flood (PMF) event. This is defined as the floodplain.
Floodplain	see 'flood liable land'. An area of land subject to inundation by floods up to and including the probable maximum flood.
Flood planning area	the area of land below the flood planning level and thus subject to flood related planning and development controls.

Flood planning levels	the combination of flood levels and freeboards selected for planning purposes, as determined in floodplain risk management studies.
Flood proofing	the alteration of individual buildings or structures subject to flooding to reduce the severity of, or eliminate flooding.
Flood storage areas	those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway	areas of the floodplain where a significant proportion of the flood discharge is conveyed. These areas are often along natural creeks, or associated with the trunk drainage in a floodplain.
Flood hazard	is the degree of hazard produced by flooding conditions with respect to cause damage to the community.
Freeboard	a factor of safety used in the setting of flood planning levels. It is the difference in height between the adopted flood planning level and the flood used to determine the flood planning level.
Future flood risk	the risk a community is exposed to as a result of new development on the floodplain.
HEC-2/ HEC-RAS	hydraulic computer modelling software which estimates the flood level based on actual surveyed land levels and estimates of hydraulic parameters. Such a model gains its accuracy by being calibrated to historical flooding conditions.
High flood hazard area	an area where a combination of flood depth and/or velocity produce conditions which pose a risk to life and/or property.
RAFTS model	a hydrological model used to generate flows. In a flood study this model is used for input into the hydraulic model for estimation of flood levels.
Local overland flooding	inundation of land by local runoff rather than from mainstream flooding from a river, creek or stormwater channel.
Mainstream flooding	inundation of land occurring when water overtops the banks of a natural or artificial channel.
Nitrogen	a naturally occurring plant nutrient that is responsible for excessive algal production in waterways, and phytoplankton blooms in estuaries. It takes the forms of nitrate, nitrite and ammonia in solution.
Peak discharge	the maximum discharge occurring during a flood event (see discharge).
Phosphorous	a plant nutrient that is usually bound to sediment, although also has dissolved forms. It is not found in large quantities in Australian soils. This element also contributes to algal blooms (eutrophication).
Probable maximum flood (PMF)	the largest flood that could conceivably occur at a particular location, usually estimated from the probable maximum precipitation. The PMF defines the extent of flood prone land.
Riparian vegetation	vegetation adjacent to streams.
Runoff	the amount of rainfall which does not infiltrate into the soil resulting in the presence of surface water.

LIVERPOOL CITY COUNCIL

AUSTRAL FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

Review and Finalisation

Appendices

September 2003

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Job No: NC812 File: P:\Perrens\NC812 –Austral\Docs\Austfpms.doc	Date Saved: 18-Sept-03 Revision No.: 5.0	Author: AT Review: SP

APPENDICES

LIVERPOOL CITY COUNCIL

AUSTRAL FLOODPLAIN MANAGEMENT STUDY

APPENDIX A

FLOOD HYDROLOGY

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FIGURES

A1. INTRODUCTION

A1.1 Background

Liverpool City Council (LCC) is developing a comprehensive Drainage and Floodplain Management Plan for the Austral-Kemps Creek area. The study area is primarily a rural residential area and is drained by Kemps Creek and Bonds Creek, two major tributaries of South Creek which is itself part of the Hawkesbury Nepean system. Figure A1.1 shows the location of the study area, which extends from Elizabeth Drive upstream to Bringelly Road. The study area also includes a small portion of the Bonds Creek catchment lying within the jurisdiction of LCC upstream of the Hume Highway.

This appendix details the results of the hydrologic modelling carried out for the study. Design flows were required for a range of flood frequencies as inputs to hydraulic models of the main drainage lines, so that water surface profiles and flow patterns could be assessed. Appendix B contains details of the hydraulic modelling.

A1.2 Study Objectives

The principal objectives of the hydrologic analysis were to:

- Collate and review existing flood data and previous investigations.
- Review the previous hydrologic modelling undertaken by the Department of Water Resources (DWR) (renamed Department of Land & Water Conservation in July 1995) for that portion of the South Creek catchment relevant to the present study and to refine the definition of the individual sub-catchments contained in that model to allow derivation of flows up to the limit of the trunk drainage. For the purposes of this study, the limit of trunk drainage has been defined as the point at which the 100 year Average Recurrence Interval (ARI) flow exceeds 5 m^3/s. (see Section A1.5 for some notes on terminology)
- Assess flows under existing catchment conditions for 1, 5, 20, and 100 year ARI events and the Probable Maximum Flood (PMF).
- Assess the effects of future urbanisation within the Austral area and in the area under the jurisdiction of Camden City Council upstream of Bringelly Road.

A1.3 Previous Investigations

Previous flood studies have been carried out for the South Creek catchment and its tributaries by the Department of Water Resources (DWR) and various consultants.

DWR produced the South Creek Flood Study Report in July 1990 (DWR, 1990). The hydrologic component of that study was carried out using the Runoff Analysis and Flow Training Simulation (RAFTS) package (WP, 1985). The hydrologic model was calibrated using data from floods that occurred in 1986 and 1988. In constructing their RAFTS model, DWR measured subcatchment areas and slopes from 1:10,000 and 1:4,000 scale orthophotomaps. Cross sections along Kemps Creek, which had been surveyed for a previous DWR flood study (DWR, 1985), were used in the channel routing component of RAFTS.

Subsequently, Willing and Partners Pty Ltd, produced the South Creek Floodplain Management Study for DWR (DWR, 1991). That investigation used flows generated from DWR's RAFTS model as input to two hydraulic models. The two models were set up using MIKE-11, an unsteady flow model, and HEC-2, a steady state model. MIKE-11 was used to model flood behaviour in South Creek and the lower reaches of Ropes Creek, Kemps Creek and Badgerys Creek. HEC-2 was used on other tributaries, including Kemps Creek upstream of Elizabeth Drive. Bonds Creek was not modelled.

In 1994, Kinhill Engineers Pty Ltd produced a Floodplain Management Study for Overett and Victor Avenues for LCC (LCC, 1994). The objective of that study was to investigate and develop measures to mitigate flooding of South Creek. The study was based on the DWR's MIKE-11 model. The area investigated for that study does not form part of the present study area. The Kinhill study did, however, provide useful background information.

Prior to these recent studies, the Austral Drainage Study was produced by D.J. Dwyer and Associates Pty Ltd for LCC (LCC, 1979). However, that study pre-dated the latest version of Australian Rainfall and Runoff (1987), and is largely superseded with regard to design storm hyetographs. In addition, the major channel improvements recommended had disadvantages with respect to extent of land required for their construction and cost, and were not implemented.

A1.4 Study Approach

The RAFTS program has been adopted for this study to allow for a comparison with the results of previous investigations and for the purpose of having a uniform approach to hydrologic modelling in the area.

The catchments draining the study area have a total area of about 49 km^2, a relatively small fraction of the 414 km^2 comprising the area investigated in the South Creek Flood Study. The study area incorporates only eight subareas of the DWR's model which had a total of 76 subareas. Considerable refinement of the DWR's model was therefore required to achieve the necessary definition of flows required for the present investigation.

Calibration of the DWR's model was based on recorded runoff at four gauging stations on South Creek and Ropes Creek. The catchments in the present study are ungauged. No data was therefore available on historic flows on Kemps and Bonds Creek for a formal calibration of the refined model. The approach adopted in this present investigation was to compare results achieved by the two models at various locations within the study area. This represents "tuning" of the refined model rather than a calibration.

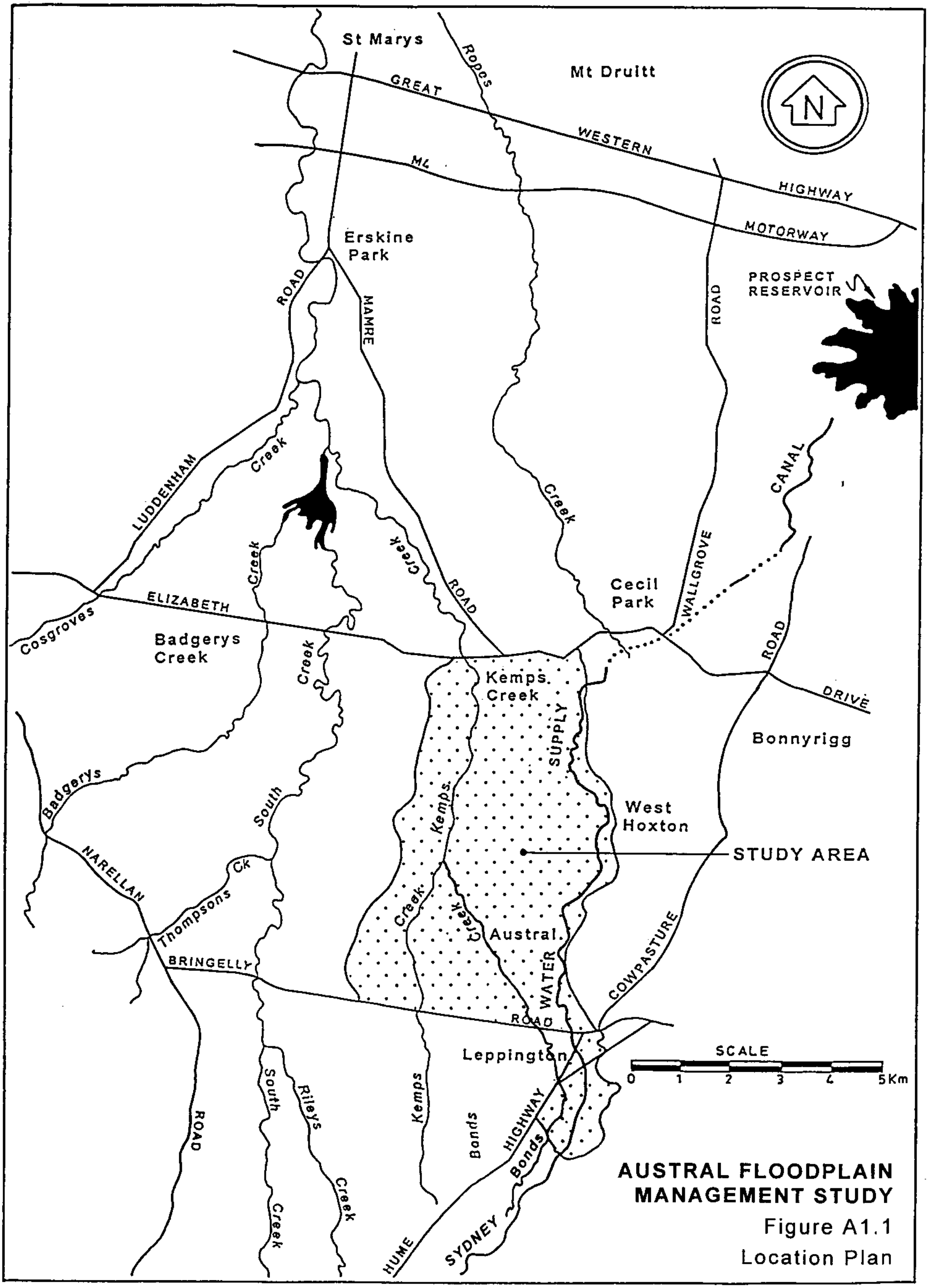
Because of the coarseness with which parameters such as the slope of the stream, impervious areas and lag times were defined in the DWR model, it is difficult to achieve correspondence of flows between the models, although the results were similar. There were also differences between results achieved with the two models which are associated with differences in the durations of critical storms. Long duration storms of up to 40 hours were reported to be critical in the DWR investigation, whereas shorter storms of around 9 to 12 hours duration were critical in the present study. Adopted loss rates are also different. As a consequence, peak flows are somewhat higher than those achieved using the DWR model. The results are described in Section A4.

A1.5 Note on Flood Frequency

The frequency of floods is generally referred to in terms of their Annual Exceedance Probability (AEP) or Average Recurrence Interval (ARI). For example, for a flood magnitude having 5% AEP, there is a 5% probability that there will be floods of greater magnitude each year. As another example, for a flood having 5 year ARI there will be floods of equal or greater magnitude once in 5 years on average. The approximate correspondence between these two systems is:

Annual Exceedance Probability (AEP) (%)	Average Recurrence Interval (ARI) (years)
0.5	200
1	100
5	19.5
20	4.5

In this report the term ARI is used. Reference is also made in the report to the probable maximum flood (PMF). This flood occurs as a result of the probable maximum precipitation (PMP). The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards rainfall production. The PMP is used to estimate PMF discharges using a model which simulates the conversion of rainfall to runoff.



AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure A1.1

Location Plan

A2. STUDY CATCHMENTS

The two main streams, Kemps Creek and Bonds Creek, rise in low foothills south of Bringelly Road and flow in a northerly direction towards Elizabeth Drive (Figure A2.1). The catchment is elongated, having a length of 12 km and an average width of 4 km, giving a total drainage area above Elizabeth Drive of 49 km^2 (4,900 ha).

Downstream of Bringelly Road, the stream bed slope flattens to an average of 0.5% as far as Twelfth Avenue from where it flattens further to 0.3%. Major flows are conveyed along the drainage network as a wide expanse of slowly moving water, with most of the discharge conveyed on the floodplain at a velocity generally less than 1 m/s.

There are several significant unnamed tributaries of the two main streams, which together drain about 30 % of the catchment. They have been denoted Tributaries 1, 2 and 3 on Figure A2.1. Tributary 1, also known locally as Scalabrini Creek, joins the left bank of Bonds Creek near Seventh Avenue and has a total catchment area of 580 ha. Tributary 2 drains the eastern part of the catchment including the village of Austral, and joins the right bank of Kemps Creek at Fifteenth Avenue just downstream of the junction of Bonds and Kemps Creeks. It has a catchment area of 325 ha. Tributary 3 drains the north-east part of the catchment and joins the right bank of Kemps Creek near Elizabeth Drive. It has a catchment area of 720 ha. Bonds Creek (including Tributary 1) has a catchment area of 1909 ha at its junction with Kemps Creek.

The drainage channels are indistinct and of low capacity except in sections that have been excavated to achieve a local reduction in flood levels. Examples of this are found on Bonds Creek between Bringelly Road and Ninth Avenue, and on Tributary 1 between Sixth and Seventh Avenues. The streams flow through a semi rural setting in which intensity of settlement has increased in recent years. Drainage problems are experienced in several residential centres which have encroached onto the floodplain. These drainage problems are reviewed in detail in Appendix C. These problems are caused by inadequate hydraulic capacity in the channels and at road crossings and by filling activities on the floodplain, as illustrated in the following examples.

At Eighth Avenue, several houses have been constructed on low ground on the right bank of Bonds Creek downstream of the bridge. The bridge structure has been raised above the level of the approach road. This has resulted in surcharges of the creek being directed over the road and toward the houses. In major flooding it is expected that above floor inundation of these houses would occur.

At Floribunda Road on the left bank of Kemps Creek upstream of Elizabeth Drive, problems result from inadequacies in the local drainage system, coupled with coincident backwater flooding from the creek. Uncontrolled overland flow travels down Floribunda Road towards an escape channel which has been excavated to convey flows to the creek.

In some areas residents have constructed low banks to protect themselves from flooding and this has tended to distort local flow patterns or reduce floodplain storage.

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AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure A2.1

CATCHMENT PLAN

A3. HYDROLOGIC MODEL

A3.1 Model Description

The RAFTS hydrologic model requires the subdivision of the study catchment along interior watershed lines and assignment of catchment storage to the sub-catchments within the system. The sub-catchments are further divided automatically into ten sub-areas along isochronal boundaries. Rainfall excess is routed through conceptual storages using a non-linear storage relationship of the form:

$$S = Bq^{(n+1)} \qquad \text{....A3.1}$$

where	S	=	storage (m^3)
	q	=	discharge (m^3/s)
	n	=	storage non-linearity coefficient
	B	=	storage delay time coefficient

The default value of the exponent 'n' in the above equation is set by the model at -0.285, thereby assuming a non-linear behaviour by the catchment. (That is, catchment storage does not increase linearly with outflow). Non-linear behaviour is generally acceptable for flows at least up to bankfull capacity. There is some evidence, however, that catchments behave in a linear manner for major flood events which extensively cover the floodplain. For this present study, the default value was adopted as the best estimate for frequencies up to the 1% AEP level. For the PMP event, a linear model, i.e. with 'n' set equal to zero was adopted as the best estimate of catchment response. No adjustment was made to the storage coefficient 'B' to compensate for the adjustment in n. The resulting PMF discharges (Table A4.2) were in the range from three to six times the 100 year ARI peak discharges. This is the range which is normally experienced in catchments of this size.

The storage delay coefficient 'B' may either be entered into the program or a default value may be adopted which is calculated according to the regression equation below, derived by Aitken (1975).

$$B = 0.285A^{0.52}(1+U)^{-1.97}Sc^{0.50}. \qquad \text{...A3.2}$$

where	A	=	sub-catchment area in km^2
	U	=	fraction of the catchment urbanised
	Sc	=	main drainage slope in %

The parameter U is related to the percentage of impervious area in each sub-catchment, increasing from zero, (for zero imperviousness), to 1.0, (for 100 per cent imperviousness).

Calibration of the model is generally achieved by the alteration of 'B'. This has the effect of adding or removing storage in each of the 10 conceptual storages for each sub-catchment. Thus, as B is increased, the resultant larger storage tends to reduce the modelled peak discharges and lengthen the hydrograph. 'B' may be varied using the multiplication factor BX which is entered as data. The parameter BX uniformly modifies all sub-catchment B values which are either set or computed according to equation A3.2.

The model allows storm rain falling on the catchment to be converted to discharge hydrographs using a runoff routing process. The model can then be used to generate design hydrographs from design rainfalls derived from Australian Rainfall and Runoff (ARR, 1987).

A3.2 Model Set-Up and Parameters

A3.2.1 Set-Up

The catchments of Bonds Creek and Kemps Creek were defined using 1:10,000 and 1:4,000 scale orthophotomaps and compared to those produced by DWR. The study area comprises sub-catchments 13A, 13B, 14A, 14B, 14C, 15A, 15B, 15C of the DWR's RAFTS models. The extent and size of the areas were found to agree satisfactorily and further sub-divisions were then made to obtain the level of definition required for this study.

Figure A3.1 is a schematic diagram of the RAFTS Model for which the sub-catchment characteristics are given in Table A3.1. For reference purposes Figure A3.1 also shows the location of strategic roads.

Channel section data for the main tributaries were obtained from the DWR model and stream lengths were measured from the orthophotomaps. Sub-catchment slopes were derived from the orthophotomaps using the equal area method. The percentage of impervious area for each subcatchment was also measured from the orthophotomaps and confirmed by site inspection. The total impervious area was calculated for each model and found to differ in some locations from the DWR model values.

Two methods were used for routing flows down the reaches. In those reaches where the channel section was defined in the DWR model, the channel routing module of RAFTS was used. This module uses the Muskingum-Cunge routing procedure which is based on a simultaneous solution of the storage equation and a simplified version of the momentum equation. For the remaining reaches the simple lagging approach was adopted. Selected lag times for each reach were computed from uniform flow calculations. Lag times were determined by an iterative method with the initial starting velocity obtained from DWR output files.

Table A3.1
Sub-Area Characteristics of the Hydrologic Model

Sub-Catchment Number	Description	Sub-Catchment Area (ha)	Impervious (Existing) (%)	Sub-Catchment Slope (m/m)
1.000	Kemps Creek u/s Bringelly Rd	376	2.0	0.010
1.010		210	1.9	0.005
1.020		108	0.7	0.005
1.030		70	1.4	0.005
1.040		71	2.4	0.005
2.000		25	1.4	0.006
2.010		115	1.4	0.008
2.020		69	2.5	0.008
1.060	Kemps Creek 400 m u/s Fifteenth Ave	58	1.7	0.005
3.000		210	2.5	0.009
3.010		253	2.0	0.008
3.020	Trib.1 100 m d/s Seventh Ave	114	2.0	0.008
4.000		228	0.0	0.012

Table A3.1
Sub-Area Characteristics of the Hydrologic Model

Sub-Catchment Number	Description	Sub-Catchment Area (ha)	Impervious (Existing) (%)	Sub-Catchment Slope (m/m)
5.000		165	0.0	0.012
4.020	Bonds Creek u/s Denham Court Rd	66	3.0	0.012
6.000		26	2.1	0.025
6.010		17	2.1	0.030
4.030	Bonds Creek 800 m d/s Denham Ct Rd	99	3.0	0.012
7.000		14	2.9	0.032
7.010		10	0.0	0.016
4.040		126	1.1	0.012
8.000		24	1.7	0.030
8.010		24	1.7	0.029
4.050		16	0.1	0.012
4.060	Bonds Creek u/s Bringelly Rd	32	0.1	0.005
36.000		33	3.8	0.025
4.070		3	3.8	0.005
37.000		32	3.8	0.024
4.080		23	3.8	0.005
4.090	Bonds Creek 100 m d/s Seventh Ave	60	3.8	0.005
38.000		14	3.8	0.025
38.010		26	3.8	0.020
9.000		10	2.0	0.034
9.010		12	5.0	0.030
3.040		34	3.3	0.033
10.000		21	1.0	0.020
10.010		38	2.9	0.012
3.050		78	4.1	0.003
3.060	Bonds Creek 300 m d/s Thirteenth Ave	103	2.3	0.033
11.000		16	2.0	0.040
11.010		44	4.1	0.010
12.000		21	1.0	0.020
13.000		14	6.0	0.060
12.010		24	4.0	0.020
12.020		40	7.0	0.016
14.000		10	5.0	0.020
14.010		50	5.0	0.020

Table A3.1
Sub-Area Characteristics of the Hydrologic Model

Sub-Catchment Number	Description	Sub-Catchment Area (ha)	Impervious (Existing) (%)	Sub-Catchment Slope (m/m)
12.030		50	7.0	0.020
15.000		14	6.0	0.030
12.040	Trib.2 250 m d/s Thirteenth Ave	19	7.0	0.040
16.000		25	3.0	0.040
16.010		47	5.0	0.025
12.050	Trib.2 100 m d/s Fourteenth Ave	10	5.0	0.027
1.080		46	5.0	0.004
17.000		21	3.0	0.029
17.010		57	5.0	0.028
1.090	Kemps Creek u/s Gurner Ave	92	2.0	0.001
18.000		16	0.0	0.023
18.010		17	0.0	0.040
1.100		135	0.0	0.005
19.000		13	1.0	0.032
19.010		25	0.0	0.013
1.11		11	0.0	0.005
20.000		14	0.0	0.033
20.010		15	0.0	0.030
1.120	Kemps Creek 1.9 km d/s Gurner Ave	25	0.0	0.005
21.000		22	7.0	0.028
21.010		24	4.0	0.023
1.130		50	0.0	0.005
1.140	Kemps Creek 650 m u/s Elizabeth Drive	34	2.0	0.005
22.000		14	5.0	0.038
23.000		15	3.3	0.045
23.010		7	4.2	0.023
22.010		30	5.3	0.044
24.000		25	2.6	0.059
22.020	Trib.3 50 m d/s Eighteenth Ave	105	3.7	0.025
25.000		16	0.0	0.056
22.030		17	0.0	0.029
26.000		18	3.9	0.027
22.040		13	0.0	0.016
27.000		16	0.0	0.090

Table A3.1
Sub-Area Characteristics of the Hydrologic Model

Sub-Catchment Number	Description	Sub-Catchment Area (ha)	Impervious (Existing) (%)	Sub-Catchment Slope (m/m)
27.010		7	0.0	0.050
22.050		13	0.0	0.028
28.000		19	4.0	0.044
28.010		44	2.0	0.021
22.060		33	0.0	0.023
29.000		14	0.0	0.071
29.010		17	0.0	0.020
30.000		37	0.0	0.039
30.010		21	0.0	0.032
22.070		10	0.0	0.040
31.000		18	0.0	0.050
32.000		16	0.0	0.068
32.010		57	0.0	0.020
31.010		10	0.0	0.030
31.020		30	0.0	0.033
22.080		46	0.0	0.018
22.090		26	0.0	0.027
22.100	Trib.3 u/s jnct with Kemps Creek	27	0.0	0.013
33.000		124	0.0	0.060
34.000		15	0.0	0.084
34.010		13	0.0	0.023
33.010		45	0.0	0.030
1.160		38	0.0	0.020
35.000		26	1.0	0.020
35.010		55	3.0	0.020
1.170	Bonds Creek u/s Elizabeth Drive	31	1.0	0.005

A3.2.2 Model Parameters

The DWR's RAFTS model parameters were reviewed as part of this study. Previous investigations for South Creek indicated that a value of BX equal to 1.3 was appropriate for that catchment and this value has been adopted for the present investigation. There was no information to indicate that any other value would be preferable.

Losses adopted by DWR for the assessment of the 100 year ARI flows were as follows:

Initial Loss (IL)	34 mm
Continuing Loss (CL)	1 mm/h

and those for the PMF were as follows:

Initial Loss (IL)	0 mm
Continuing Loss (CL)	1 mm/h

These values were also adopted for the refined model for the above events. They are at the low end of the range of commonly encountered values, but as such will lead to slightly conservative results.

Initial and continuing losses have been investigated by Walsh et al, (1991), who concluded that design losses were a function of flood frequency. Recommended values are given for use with a non-linear runoff routing model with continuing loss set at 2.5 mm/h. Initial loss values increase from 50 mm at the 2 year ARI to a maximum of 60 mm at 10 year ARI and then reduce to 40 mm for the 100 year ARI event. For the present investigation initial loss values were adopted which conformed with this trend. They are shown on Table A3.2. The sensitivity of model results to variations in initial and continuing losses is discussed in Section A4.

Table A3.2
Design Values of Initial Loss

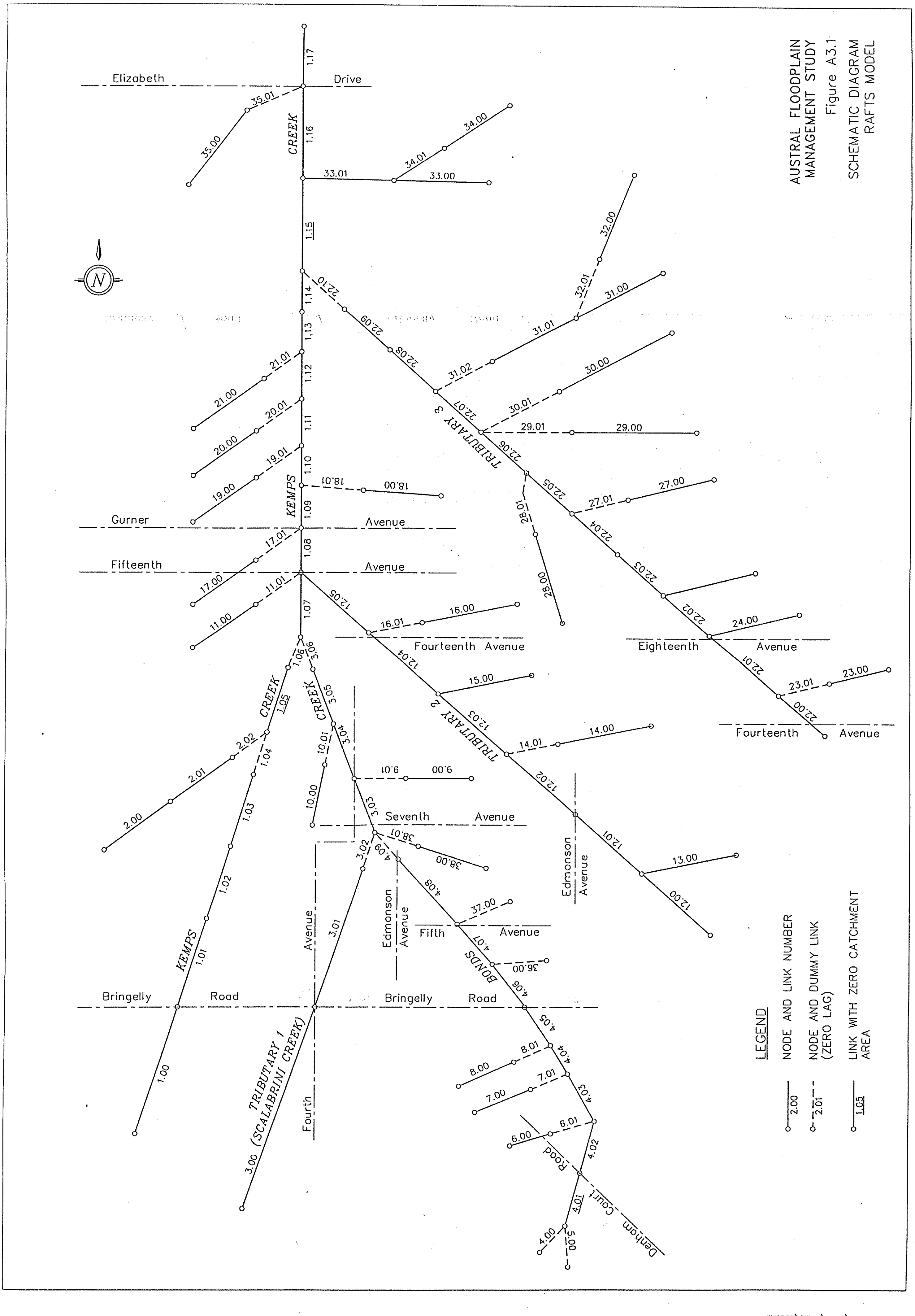
ARI (years)	Initial Loss (mm)
1	40
5	45
20	45
100	34

A3.2.3 Design Storms

DWR supplied data for some design storms, however further data were required for the events not modelled by them. LCC provided intensity-frequency-duration data for the Austral area which allowed derivation of the remaining design storms.

The rainfall data for the PMF design events was obtained using methods detailed in the Bureau of Meteorology's Bulletin 51, (1985). This publication gives estimates of Probable Maximum Precipitation (PMP) for durations up to 6 hours.

Table A3.3 shows average rainfall intensities for various storm durations.



AUSTRAL FLOODPLAIN MANAGEMENT STUDY
Figure A3.1
SCHEMATIC DIAGRAM
RAFTS MODEL

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Table A3.3
Average Rainfall Intensities for Design Storm Events

ARI (years)	Storm Duration (hrs)							
	2	3	4	4.5	6	9	12	18
1	15.2	12.0	-	9.1	8.0	6.2	5.2	4.0
5	25.7	20.2	-	15.9	13.3	10.5	8.8	7.0
20	33.9	26.6	-	20.8	17.5	13.8	11.6	9.2
100	44.8	35.1	-	27.4	23.0	17.5	15.3	12.1
PMP	184.0	138.0	116.0	-	88.0	-	-	-

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A4. MODEL RESULTS

A4.1 Critical Storm Duration

Storms of 6, 9, 12 and 18 hours duration for an ARI of 100 year were applied to the RAFTS model in order to determine the critical storm duration. Peak flows at nominated locations are summarised in Table A4.1. The critical storm duration for the majority of the sub-catchments was found to be 9 hours. Sub-catchments near the catchment outlet were found to have a 12 hour critical storm duration. Storms of 1.5 and 36 hours duration were also investigated. The 1.5 hours storm gave flows less than for the other durations. In several locations, the 36 hour storm gave flows greater than for the shorter storms. This effect is an artifact of the losses and the temporal distribution of rainfall. Adoption of such a long storm for a relatively small catchment was not considered reasonable.

A similar procedure was followed for the 1, 5 and 20 year ARI events and the PMF. The critical storm duration for the 5 year ARI flood varied between 9 and 24 hours depending on the location within the catchment. Similarly, the critical storm duration for the 20 year ARI flood varied between 9 and 12 hours; for the 1 year ARI flood between 12 and 24 hours; and for the PMF event between 2 and 6 hours. The maximum flows for each critical duration storm at the outlet of each sub-catchment are presented in Table A4.2.

A4.2 Sensitivity of Flows to Initial and Continuing Losses

Design values of initial and continuing losses were presented in Section A3.2.

The sensitivity of 100 year ARI flows to variations in initial loss was investigated. Alternative initial losses of 30 mm and 40 mm were considered, with a continuing loss remaining fixed at 1 mm/h. Sensitivity to variations in continuing loss was also investigated by assessing flows produced with an initial loss of 34 mm and a continuing loss of 2.5 mm/h. The results are tabulated in Tables A4.3 and A4.4 respectively. In general, it was found that flows were not sensitive to variations in initial loss. Greater sensitivity is shown to changes in continuing loss, with a reduction in peak flows of 7% from increasing the continuing loss from 1.0 mm/h to 2.5 mm/h.

Although 2.5 mm/h is a widely used value of continuing loss, 1.0 mm/h was adopted to provide consistency with the DWR model, as well as remaining slightly conservative.

A4.3 Sensitivity of Flows to Variation in BX

In the absence of any data with which to calibrate the model, a value of BX equal to 1.3 was adopted on the basis of previous work for South Creek catchment (see section A3.2.2). To investigate the sensitivity of peak flows to variation in this parameter, the model was run for the case of 100 year ARI with design values for losses, but with BX changed by ± 10%. At the catchment outlet the peak flows were changed by ± 4%, with a reduction in BX causing an increase in peak flow, and vice versa.

Table A4.1
100 Year ARI Peak Flows (m^3/s)

Location	Total Catchment Area (ha)	Storm Duration (hr)			
		6	9	12	18
Kemps Creek - u/s Bonds Creek junction	1,101	65	83	73	51
Tributary 1 - u/s Bonds Creek junction	577	36	44	39	29
Bonds Creek - Denham Court Road	393	28	36	34	24
Bonds Creek - Cowpasture Road	600	41	54	51	35
Bonds Creek - Bringelly Road	845	56	71	63	42
Bonds Creek - u/s Tributary 1 junction	996	63	79	70	50
Bonds Creek - d/s Tributary 1 junction	1,613	101	124	109	81
Bonds Creek - u/s Kemps Creek junction (Fourteenth Avenue)	1,909	115	140	128	95
Kemps Creek - d/s Bonds Creek junction	3,011	180	221	196	145
Tributary 2 - Fourteenth Avenue	242	26	28	26	22
Tributary 2 - u/s Kemps Creek junction	324	35	38	36	30
Kemps Creek - d/s Tributary 2 junction (Gurner Avenue)	3,611	204	246	243	169
Kemps Creek - Pratten Street	3,882	212	254	247	175
Kemps Creek - u/s Tributary 3 junction	4,012	214	256	251	179
Tributary 3 - Eighteenth Avenue	196	25	24	22	19
Tributary 3 - u/s Kemps Creek junction	721	65	72	66	50
Kemps Creek - d/s Tributary 3 junction	4,733	241	286	296	205
Kemps Creek - Elizabeth Drive	4,968	245	292	307	213

Table A4.2
Peak Link Inflows (m^3/s) for Various Frequencies

Sub-Catchment Number	Location	Average Recurrence Interval (yr)				
		1	5	20	100	PMF
1.00		4	12	21	31	74
1.01		6	18	30	46	114
1.02		7	21	35	54	138
1.03		7	23	38	59	153
1.04		8	24	41	63	169
2.00		0	1	2	3	11
2.01		2	5	9	12	41
2.02		3	7	12	18	61
1.05		9	30	50	79	224
1.06	**Kemps Creek** - u/s Bonds Creek junction	10	31	52	83	238
3.00		2	7	12	18	48
3.01		5	15	24	37	100
3.02	**Tributary 1** - u/s Bonds Creek junction	6	18	29	44	124
4.00		3	8	14	20	53
5.00		2	6	10	15	43
4.01	**Bonds Creek** - Denham Court Road	5	13	24	36	96
4.02		5	16	28	42	115
6.00		1	2	3	3	15
6.01		1	3	4	6	25
4.03	**Bonds Creek** - Cowpasture Road	7	20	36	53	156
7.00		0	1	2	2	9
7.01		1	2	3	3	15
4.04		8	24	43	65	198
8.00		1	2	3	3	15
8.01		1	3	5	6	29
4.05		9	25	45	68	214
4.06	**Bonds Creek** - Bringelly Road	9	26	47	71	224
36.00		1	2	3	4	19
4.07		9	26	48	72	232
37.00		1	2	3	4	19
4.08		9	27	49	75	247
4.09	**Bonds Creek** - u/s Tributary 1 junction	9	29	52	79	264

Table A4.2
Peak Link Inflows (m^3/s) for Various Frequencies (ctd)

Sub-Catchment Number	Location	Average Recurrence Interval (yr)				PMF
		1	5	20	100	
38.00		0	1	2	2	9
38.01		1	3	4	5	24
3.03	**Bonds Creek** - d/s Tributary 1 junction	15	46	81	124	384
9.00		0	1	1	2	7
9.01		1	2	3	3	15
3.04		15	48	83	127	397
10.00		0	1	2	3	12
10.01		1	3	5	7	30
3.05		16	51	88	134	431
3.06	**Bonds Creek** - u/s Kemps Creek junction (Fourteenth Avenue)	17	54	91	140	453
1.07	**Kemps Creek** - d/s Bonds Creek junction	26	84	143	221	690
11.00		0	1	2	3	11
11.01		1	3	6	7	29
12.00		0	1	2	3	12
13.00		0	1	2	3	10
12.01		1	4	6	8	34
12.02		2	6	10	13	56
14.00		0	1	1	1	7
14.01		1	4	6	7	33
12.03		5	12	20	25	111
12.04	**Tributary 2** - Fourteenth Avenue	5	14	22	28	125
16.00		1	2	3	4	16
16.01		2	5	7	9	42
12.05	**Tributary 2** - u/s Kemps Creek junction	7	18	30	38	165
1.08		28	92	153	240	813
17.00		1	2	2	3	13
17.01		2	5	8	10	45
1.09	**Kemps Creek** - d/s Tributary 2 junction (Gurner Avenue)	29	95	157	245	841
18.00		0	1	2	2	10
18.01		1	2	3	4	20
1.10		30	98	162	251	872

Table A4.2
Peak Link Inflows (m^3/s) for Various Frequencies (ctd)

Sub-Catchment Number	Location	Average Recurrence Interval (yr)				PMF
		1	5	20	100	
19.00		0	1	1	2	9
1.11		30	99	163	253	880
20.00		0	1	2	2	9
20.01		1	2	3	4	18
1.12	**Kemps Creek** - Pratten Street	30	99	164	254	889
21.00		1	2	3	3	14
21.01		1	3	5	6	28
1.13		30	100	165	256	908
1.14	**Kemps Creek** - u/s Tributary 3 junction	30	100	165	256	915
22.00		0	1	2	2	10
23.00		0	1	2	3	10
23.01		1	2	3	4	15
22.01		2	5	8	10	43
24.00		1	2	3	4	16
22.02	**Tributary 3** - Eighteenth Avenue	5	13	20	25	104
25.00		0	1	2	3	11
22.03		6	15	23	29	122
26.00		0	1	2	3	12
22.04		6	17	27	32	139
27.00		1	1	2	3	11
27.01		1	2	3	4	16
22.05		7	19	30	37	158
28.00		1	2	2	3	13
28.01		2	4	7	8	35
22.06		9	24	39	47	205
29.00		0	1	2	3	10
29.01		1	2	3	4	20
30.00		1	3	4	5	22
30.01		1	4	6	7	33
22.07		11	30	48	58	252
31.00		1	1	2	3	12
32.00		1	1	2	3	11
32.01		2	4	7	9	36

Table A4.2
Peak Link Inflows (m^3/s) for Various Frequencies (ctd)

Sub-Catchment Number	Location	Average Recurrence Interval (yr)				PMF
		1	5	20	100	
31.01		2	6	10	12	52
22.09		13	33	57	72	336
22.10	**Tributary 3** - u/s Kemps Creek junction	13	32	56	71	343
1.15	**Kemps Creek** - d/s Tributary 3 junction	33	116	193	298	1138
33.00		0	1	2	2	9
34.00		1	1	2	3	11
34.01		1	2	3	4	19
33.01		2	6	9	11	49
1.16		33	117	195	303	1168
35.00		1	2	3	3	15
35.01		2	5	8	10	42
1.17	**Kemps Creek** - Elizabeth Drive	34	118	196	307	1194

Table A4.3
Variation in Peak Flows (m^3/s) with Initial Loss for 100 Year ARI, 9 Hour Storm

Location	Initial Loss (mm)		
	30	34	40
Kemps Creek - u/s Bonds Creek junction	84	83	80
Tributary 1 - u/s Bonds Creek junction	44	44	43
Bonds Creek - Denham Court Road	36	36	35
Bonds Creek - Cowpasture Road	54	54	52
Bonds Creek - Bringelly Road	72	71	69
Bonds Creek - u/s Tributary 1 junction	80	79	77
Bonds Creek - d/s Tributary 1 junction	126	124	121
Bonds Creek - u/s Kemps Creek junction (Fourteenth Ave)	142	140	136
Kemps Creek - d/s Bonds Creek junction	224	221	214
Tributary 2 - Fourteenth Avenue	28	28	28
Tributary 2 - u/s Kemps Creek junction	38	38	38
Kemps Creek - d/s Tributary 2 junction (Gurner Avenue)	250	246	237
Kemps Creek - Pratten Street	259	254	2453
Kemps Creek - u/s Tributary 3 junction	261	256	247
Tributary 3 - Eighteenth Avenue	24	24	24
Tributary 3 - u/s Kemps Creek junction	72	72	71
Kemps Creek - d/s Tributary 3 junction	293	286	274
Kemps Creek - Elizabeth Drive	299	292	279

Table A4.4
Variation in Peak Flows (m^3/s) with Continuing Loss for 100 year ARI, 9 hour Storm

Location	Continuing Loss (mm/h)	
	1.0	2.5
Kemps Creek - u/s Bonds Creek junction	83	77
Tributary 1 - u/s Bonds Creek junction	44	41
Bonds Creek - Denham Court Road	36	34
Bonds Creek - Cowpasture Road	54	50
Bonds Creek - Bringelly Road	71	67
Bonds Creek - u/s Tributary 1 junction	79	74
Bonds Creek - d/s Tributary 1 junction	124	116
Bonds Creek - u/s Kemps Creek junction (Fourteenth Ave)	140	130
Kemps Creek- d/s Bonds Creek junction	221	206
Tributary 2 - Fourteenth Avenue	28	27
Tributary 2 - u/s Kemps Creek junction	38	36
Kemps Creek - d/s Tributary 2 junction (Gurner Avenue)	246	228
Kemps Creek - Pratten Street	254	235
Kemps Creek - u/s Tributary 3 junction	256	237
Tributary 3 - Eighteenth Avenue	24	24
Tributary 3 - u/s Kemps Creek junction	72	68
Kemps Creek - d/s Tributary 3 junction	286	263
Kemps Creek - Elizabeth Drive	292	268

A4.4 Design Flood Flows

For purposes of hydraulic modelling (see Appendix B) the peak flood flows set out in Table A4.2 were adopted.

A4.5 Catchment Urbanisation

Two cases of possible future urbanisation were investigated:

- Urbanisation of the catchment within the LCC area only.
- Urbanisation of the entire catchment including the portion upstream of Bringelly Road within the jurisdiction of Camden Council.

In each case it was assumed that urban development of the catchment proceeded to a level which gave a total of 25% impervious area. This value, which compares with 35% imperious area found in fully urbanised catchments, was adopted to reflect the fact that the wide floodplain of the catchment would constrain the intensity of development within the flood affected area (about 30% of the catchment). It was also assumed that further urbanisation was allowed to occur with no compensating increase in flood storage within the catchment (either by means of on-site detention within allotments or by means of detention basins). The peak flow results from this analysis therefore reflect a likely "worst case" condition for the Kemps Creek catchment.

The effects of future urbanisation of the catchment are summarised in Tables A4.5 and A4.6 for the 100 year and 5 year ARI floods.

The results in column 3 of the tables indicate that there would be a very small increase in flows for urbanisation within the LCC area. There are some instances where the model predicted a small decrease in peak discharge. This could be due to the fact that urbanisation changes the synchronisation of the flows from the various subcatchments.

Results for urbanisation of the whole catchment are shown in column 4 of the tables. At Elizabeth Drive, flows increase by 15% and 22% for the 100 and 5 year ARI respectively. The tendency for the effects of catchment urbanisation to reduce with increasing ARI (i.e. flood magnitude) is in keeping with results of other catchment studies. The effects of urbanisation expressed in terms of increased flood levels are discussed in Appendix B.

Table A4.5
Effects of Future Catchment Urbanisation on 100 year ARI Peak Discharge

Location **(1)**	**Existing Conditions** **(2)**	**Development in Austral** **(3)**	**Development in Austral and Camden Council Areas** **(4)**
Kemps Creek - u/s Bonds Creek junction (Fourteenth Avenue)	83	96	112
Tributary 1 - Bonds Creek junction	44	41	41
Bonds Creek - u/s Kemps Creek junction (Fourteenth Avenue)	140	132	172
Kemps Creek - d/s Bonds Creek junction (Fourteenth Avenue)	221	224	269
Tributary 2 - u/s Kemps Creek junction	38	46	46
Tributary 3 - u/s Kemps Creek junction	72	79	79
Kemps Creek - Gurner Avenue	246	254	301
Kemps Creek - Elizabeth Drive	307	311	356

TABLE A4.6
Effects of Future Catchment Urbanisation on 5 year ARI Peak Discharge

Location (1)	Existing Conditions (2)	Development in Austral (3)	Development in Austral and Camden Council Areas (4)
Kemps Creek - u/s Bonds Creek junction (Fourteenth Avenue)	31	29	47
Tributary 1 - Bonds Creek junction	18	17	24
Bonds Creek - u/s Kemps Creek junction (Fourteenth Avenue)	53	52	71
Kemps Creek - d/s Bonds Creek junction (Fourteenth Avenue)	83	81	102
Tributary 2 - u/s Kemps Creek junction	18	22	22
Tributary 3 - u/s Kemps Creek junction	32	34	34
Kemps Creek - Gurner Avenue	95	95	121
Kemps Creek - Elizabeth Drive	118	118	144

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LIVERPOOL CITY COUNCIL

AUSTRAL FLOODPLAIN MANAGEMENT STUDY

APPENDIX B

HYDRAULIC MODELLING

September 2003

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Job No NC812 File: f:\documents\austral fms\construction files\appb.doc	Date: 18 September 2003 Rev: 5.0	Principal: SJP Reviewer: BWL

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B1. APPROACH TO HYDRAULIC MODELLING

B1.1 Introduction

This appendix deals with the hydraulic modelling phase of the Austral Drainage Study. Flood levels, velocities and the extent of flooding have been defined using a computer based mathematical model of the streams in the Study Area. Kemps Creek, Bonds Creek, the tributary streams and minor branches have been modelled using the HEC-2 program (Hydrologic Engineering Center, 1991) which is a one-dimensional steady state backwater model.

HEC-2 is a computer based application of the standard step method and uses the Manning equation to compute friction head loss between cross sections. In the HEC-2 program, the waterway is described by a series of cross sections across the channel and floodplain, which are oriented at right angles to the presumed direction of flow. Appropriate values of hydraulic roughness are assigned to the main channel and the overbank areas. Streams in the study area have flat gradients and exhibit flow in the “subcritical” regime, apart from isolated constrictions, typically at bridge crossings or sudden drops in the channel bed, where localised “supercritical” conditions may occur. Calculations start with an assigned downstream water level and proceed upstream, with the water level being computed at each successive cross section.

Cross sections for the HEC-2 model were generally derived from photogrammetric survey prepared for this study. Some data were also taken from surveys carried out for the South Creek Flood Study (DWR, 1990). Details of bridge waterways at the various road crossings were obtained from field measurements during site inspections.

The HEC-2 program contains several alternative routines for analysing flow through bridges and culverts. The “normal” bridge routine represents the bridge cross section as a normal cross section, except that the portion of the bridge deck and piers below water level is subtracted from the total area and the wetted perimeter is increased accordingly. The “special” bridge routine on the other hand uses hydraulic formulae to compute the bridge afflux under conditions of low, pressure and weir flow. The HEC-2 model restricts the analysis of pressure flow to one trapezoidal representation of the actual bridge opening and is capable of allowing for specific losses due to piers.

A recent inclusion in HEC-2 is the ability to model groups of pipe and box culverts. This option is called the “special culvert” method and is similar to the special bridge method, except that the US Federal Highway Administration (FHWA) standard equations for culvert hydraulics are used to compute losses through the structure.

For modelling the study area, both the special bridge and special culvert options have been used. Several of the structures involved rather unusual combinations of ARMCO type part-circular openings which were approximated as equivalent pipes or rectangular sections, as appropriate.

To model the expansion and contraction of flows through bridges and culverts surveyed cross sections were repeated 20 m downstream and 10 m upstream of each structure.

B1.2 Scope

The main streams described in this appendix comprise Kemps Creek and its two main tributaries denoted Tributary 2 and Tributary 3, as well as Bonds Creek and Tributary 1. (Tributary 1 is known locally as Scalabrini Creek.) A number of other minor branches comprising the trunk drainage system were also modelled.

The extent of modelling is shown on Figure B1.1. Kemps Creek and Scalabrini Creek were modelled as far as Bringelly Road, while modelling for Bonds Creek was continued upstream to Denham Court Road. For reference purposes the creeks and their cross sections were designated by a simple code. Streams in the Kemps Creek catchment were given the prefix “KC” and streams in the Bonds Creek catchment are prefixed “BC”. The main arms of Kemps and Bonds Creeks were denoted KC00 and BC00 respectively while tributary creeks were designated KC01, KC02 etc..

Flow profiles were computed for the 1, 5, 20 and 100 year average recurrence interval (ARI) events and for the probable maximum flood (PMF) (see Appendix A for further details of the hydrologic analysis). Peak water surface elevations have been tabulated along with flow velocities in the main channel and floodplain (for the major tributaries).

B2. PREVIOUS INVESTIGATIONS

The Department of Water Resources (DWR) (now Department of Infrastructure, Planning and Natural Resources) as part of its South Creek Flood Study (DWR, 1990) computed water surface profiles on Kemps Creek and other major tributary streams in the South Creek catchment using a steady state backwater analysis based on the HEC-2 program. The HEC-2 model extended from Elizabeth Drive to a point 1 km upstream of Heath Road and was based on a total of 43 cross sections over this reach.

Documented historic flood levels on Kemps Creek are scarce. Historic flood level information is concentrated along the main stream (South Creek). Accordingly, design roughness values on Kemps Creek were mainly based on experience. Estimated flood levels and velocities for the 100 year ARI event were presented in the DWR report.

The DWR’s HEC-2 model was later used in the Floodplain Management Study (DWR, 1991). The study report gives details of flood behaviour for South Creek for the range of flood frequencies between 1 year ARI and the PMF, under both existing conditions and with the catchments fully urbanised.

LEGEND

KC01 Kemps Creek or Branches

BC08 Bonds Creek or Branches

SC00 Scalabrini Creek

○ Crossing modelled

◌ Crossing assessed as ineffective for conveying flow

Shows extent of hydraulic modelling

AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B1.1

CREEKS MODELLED USING HEC-2

B3. RESULTS OF HYDRAULIC MODELLING

B3.1 Model Set Up

Model cross sections for the present investigation were initially obtained from the results of the photogrammetric survey of the study area as tabulations of easting, northing and level for each point on the section. They were converted into tables of elevations and offset distances across the section and then into HEC-2 format using the HEC-2 editor.

No quantitative data on historic flooding which could be used for model calibration were uncovered for Bonds Creek or the tributary streams during the process of community consultation. As mentioned, some limited data on Kemps Creek had been collected by DWR in their flood study (DWR, 1990) and it is understood that these were incorporated in their calibrated model of that stream. The HEC-2 model of Kemps Creek developed for the present investigation comprised DWR sections as well as sections derived from the photogrammetric survey as described above. DWR's roughness values were reviewed during site inspections of the study area and amended where considered appropriate.

Roughness values for Bonds Creek and the remaining drainage lines were initially estimated during site inspections carried out for the present study, and a series of model runs was also carried out to test the sensitivity of results to variations in model parameters.

In general, it was found that model results were not particularly sensitive to variations in roughness. The results presented in later sections are based on a "best estimate" of roughness.

B3.2 Kemps Creek Catchment

This section presents results for the main arm of Kemps Creek (KC00) and four branches which drain the eastern side of the catchment. These branches are denoted KC01, 02, 03 and 07 on Figure B1.1.

The Kemps Creek model extends from a point a short distance downstream of Elizabeth Drive to Bringelly Road, a distance of 9.1 km. The model comprises 41 sections at an average spacing of 220 m, which enables a close degree of definition of the flow pattern. Five bridges and culverts over Kemps Creek are included in the model, details of which are shown on Table B3.1. The approximate hydrologic capacity, in terms of the ARI of the peak flow corresponding with the structure's capacity without overtopping, is shown in the last column of this table. Larger flows than those shown in Table B3.1 will result in overtopping of the bridge/culvert deck or the approach embankment.

Table B3.1
Details of Bridges and Culverts - Kemps Creek and Branches

Stream	Location	Opening	Waterway Area (m^2)	Approx. Capacity ARI years
Main Arm KC00	Bringelly Road	Gross Span 6.7 m Width of Pier 0.4 m	10	10
	Twelfth Avenue	4 off 1350 RCP	5.7	< 1
	Fifteenth Avenue	Gross Span 40 m Width of Pier 2.25 m	122	50
	Gurner Avenue	2 off 900 RCP	1.5	<1
	Elizabeth Drive	Gross Span 19.3 m Width of Pier 1.44 m	100	>100
Branch KC01	Wynyard Avenue	2 off 1050 RCP	1.0	2
	Devonshire Road	2 off box culverts 3200 x 900	5.8	20
	King Street	900 x 1200 oval pipe	0.9	Ineffective
Branch KC02	Herley Avenue	2 off 600 RCP	0.3	2
Branch KC07	Cross Street	1 off 600 RCP	0.3	2

Peak water surface elevations and velocities along Kemps Creek are shown in Tables B3.2 to B3.6 for the five design storm events modelled, while Tables B3.7 to B3.10 give peak water surface elevations for the 4 branches. The locations of cross sections listed in these tables may be seen on Figure B4.2.

Water surface profiles along Kemps Creek and its branches are plotted on Figures B3.1 to B3.5. Figure B3.6 (3 sheets) shows typical cross sections of Kemps Creek and its floodplain on which peak flood levels are shown, together with rating curves showing Discharge vs Water Surface Elevation.

Table B3.2
Hydraulic Model Results Kemps Creek - 1 Year ARI

Location	Surveyed X-Section No	HEC-2 X-Section No	Peak Water Level (m AHD)	Velocity (m/s)		
				Left Overbank	Channel	Right Overbank
	KC0046	1.18	43.6	0.0	0.8	0.1
	KC0045	1.19	44.5	0.0	0.8	0.7
Elizabeth Drive	KC0044	1.2	45.0	0.0	0.9	0.0
	KC0042	1.22	45.0	0.0	0.9	0.0
	KC0041	1.24	45.8	0.6	0.7	0.3
	KC0040	1.245	46.3	0.4	0.8	0.6
	KC0038	1.25	46.5	0.4	0.4	0.2
	KC0037	1.255	46.8	0.5	0.6	0.0
	KC0035	1.26	47.6	0.0	0.6	0.3
	KC0033	1.27	49.2	0.2	0.6	0.0
	KC0031	1.28	50.0	0.4	0.6	0.5
	KC0029	1.29	51.2	0.7	0.7	0.3
	KC0028	1.3	52.6	0.3	0.6	0.4
	KC0027	1.31	53.4	0.4	0.7	0.3
Gurner Avenue	KC0026	1.33	54.6	0.3	0.8	0.4
	KC0025	1.34	54.7	0.3	0.8	0.4
	KC0025	1.35	54.7	0.4	0.5	0.3
	KC0024	1.36	54.8	0.3	0.7	0.3
	KC0022	1.37	55.3	0.0	0.8	0.4
	KC0021	1.38	55.9	0.1	0.9	0.3
Fifteenth Ave	KC0020	1.39	56.1	0.0	0.6	0.0
	KC0019	1.4	56.1	0.0	0.6	0.0
	KC0019	1.41	56.1	0.0	0.6	0.0
	KC0018	1.42	56.2	0.0	0.6	0.0
	KC0017	1.43	56.8	0.0	1.8	0.0
	KC0015	1.44	58.4	1.0	1.3	0.0
	KC0014	1.451	59.7	0.0	0.6	0.0
Twelfth Avenue	KC0014	1.452	59.7	0.0	0.1	0.0
	KC0014	1.453	59.9	0.0	0.0	0.0
	KC0014	1.454	59.9	0.0	0.4	0.0
	KC0012	1.46	61.0	0.5	1.3	0.0
	KC0010	1.47	63.5	0.4	0.6	0.3
	KC0008	1.48	65.9	0.0	1.0	0.6
	KC0007	1.49	67.7	0.7	1.0	0.4
	KC0005	1.5	71.7	0.6	0.8	0.0
	KC0004	1.51	73.2	0.0	0.7	0.0
Bringelly Road	KC0003	1.52	73.6	0.6	0.9	1.0
	KC0002	1.53	73.6	0.0	0.8	0.0
	KC0001	1.54	73.7	0.0	1.8	0.9
	-	1.55	74.6	0.0	0.8	0.0

Table B3.3
Hydraulic Model Results Kemps Creek - 5 year ARI

Location	Surveyed X-Section No	HEC-2 X-Section No	Peak Water Level (m AHD)	Velocity (m/s)		
				Left Overbank	Channel	Right Overbank
	KC0046	1.18	44.6	0.3	1.0	0.8
	KC0045	1.19	45.3	0.0	0.7	0.9
Elizabeth Drive	KC0044	1.2	45.9	0.0	1.8	0.0
	KC0042	1.22	45.9	0.0	1.8	0.0
	KC0041	1.24	46.5	0.7	0.8	0.5
	KC0040	1.245	47.0	0.6	0.8	0.7
	KC0038	1.25	47.2	0.5	0.5	0.3
	KC0037	1.255	47.5	0.7	0.8	0.4
	KC0035	1.26	48.3	0.3	0.7	0.5
	KC0033	1.27	49.8	0.4	0.8	0.3
	KC0031	1.28	50.7	0.5	0.8	0.7
	KC0029	1.29	51.8	0.6	1.0	0.6
	KC0028	1.3	53.0	0.4	0.5	0.5
	KC0027	1.31	53.6	0.5	0.8	0.5
Gurner Avenue	KC0026	1.33	54.9	0.4	0.9	0.6
	KC0025	1.34	55.0	0.4	0.9	0.6
	KC0025	1.35	55.0	0.6	0.6	0.5
	KC0024	1.36	55.0	0.5	0.9	0.4
	KC0022	1.37	55.6	0.5	0.7	0.3
	KC0021	1.38	56.1	0.4	1.2	0.6
Fifteenth Avenue	KC0020	1.39	56.6	0.0	1.3	0.0
	KC0019	1.4	56.7	0.0	1.2	0.0
	KC0019	1.41	56.7	0.0	1.2	0.0
	KC0018	1.42	56.8	0.0	1.2	0.0
	KC0017	1.43	57.7	0.5	1.5	0.5
	KC0015	1.44	58.7	0.4	0.7	0.7
	KC0014	1.451	60.1	0.0	0.2	0.2
Twelfth Avenue	KC0014	1.452	60.1	0.2	0.3	0.2
	KC0014	1.453	60.1	0.2	0.3	0.2
	KC0014	1.454	60.1	0.0	0.2	0.2
	KC0012	1.46	61.5	0.4	0.7	0.3
	KC0010	1.47	63.6	1.0	1.3	0.7
	KC0008	1.48	66.2	0.0	0.7	0.5
	KC0007	1.49	68.1	0.5	1.0	0.5
	KC0005	1.5	71.8	0.4	0.5	0.6
	KC0004	1.51	73.3	0.5	1.1	0.0
Bringelly Road	KC0003	1.52	73.9	0.3	1.2	0.5
	KC0002	1.53	74.3	0.0	0.3	0.3
	KC0001	1.54	74.3	0.5	1.1	0.4
	-	1.55	74.9	0.0	1.6	0.4

Table B3.4
Hydraulic Model Results Kemps Creek - 20 year ARI

Location	Surveyed X-Section No	HEC-2 X-Section No	Peak Water Level (m AHD)	Velocity (m/s)		
				Left Overbank	Channel	Right Overbank
	KC0046	1.18	44.8	0.5	1.1	0.9
	KC0045	1.19	45.5	0.2	0.8	1.0
Elizabeth Drive	KC0044	1.2	46.1	0.0	2.6	0.0
	KC0042	1.22	46.2	0.0	2.6	0.0
	KC0041	1.24	46.9	0.8	0.8	0.6
	KC0040	1.245	47.3	0.6	0.8	0.7
	KC0038	1.25	47.6	0.5	0.6	0.4
	KC0037	1.255	47.9	0.9	0.9	0.4
	KC0035	1.26	48.6	0.3	0.8	0.6
	KC0033	1.27	50.0	0.5	0.9	0.5
	KC0031	1.28	50.9	0.5	0.8	0.7
	KC0029	1.29	52.1	0.6	1.0	0.7
	KC0028	1.3	53.2	0.4	0.6	0.6
	KC0027	1.31	53.8	0.5	0.8	0.6
Gurner Avenue	KC0026	1.33	55.0	0.5	0.9	0.7
	KC0025	1.34	55.1	0.5	1.0	0.7
	KC0025	1.35	55.1	0.7	0.6	0.6
	KC0024	1.36	55.2	0.6	1.0	0.5
	KC0022	1.37	55.8	0.6	0.8	0.4
	KC0021	1.38	56.3	0.6	1.1	0.7
Fifteenth Avenue	KC0020	1.39	56.7	0.0	2.1	0.0
	KC0019	1.4	56.9	0.0	1.9	0.0
	KC0019	1.41	56.9	0.0	1.8	0.0
	KC0018	1.42	57.0	0.0	1.8	0.0
	KC0017	1.43	58.0	0.6	1.3	0.5
	KC0015	1.44	58.8	0.4	0.9	0.8
	KC0014	1.451	60.1	0.1	0.3	0.4
Twelfth Avenue	KC0014	1.452	60.1	0.3	0.5	0.3
	KC0014	1.453	60.1	0.3	0.5	0.3
	KC0014	1.454	60.1	0.1	0.3	0.3
	KC0012	1.46	61.7	0.5	0.8	0.4
	KC0010	1.47	63.7	1.1	1.4	0.8
	KC0008	1.48	66.3	0.0	0.8	0.6
	KC0007	1.49	68.2	0.5	1.0	0.5
	KC0005	1.5	71.8	0.6	0.9	0.9
	KC0004	1.51	73.5	0.3	0.6	0.5
Bringelly Road	KC0003	1.52	73.9	0.6	2.2	0.9
	KC0002	1.53	74.4	0.1	0.4	0.4
	KC0001	1.54	74.4	0.5	1.1	0.4
	-	1.55	75.0	0.2	2.1	0.6

Table B3.5
Hydraulic Model Results Kemps Creek - 100 year ARI

Location	Surveyed X-Section No	HEC-2 X-Section No	Peak Water Level (m AHD)	Velocity (m/s)		
				Left Overbank	Channel	Right Overbank
	KC0046	1.18	45.1	0.6	1.1	1.1
	KC0045	1.19	45.8	0.3	1.0	1.1
Elizabeth Drive	KC0044	1.2	46.5	0.0	3.5	0.0
	KC0042	1.22	46.7	0.0	3.4	0.0
	KC0041	1.24	47.7	0.7	0.6	0.5
	KC0040	1.245	47.9	0.6	0.6	0.7
	KC0038	1.25	48.0	0.5	0.5	0.4
	KC0037	1.255	48.3	1.0	1.0	0.5
	KC0035	1.26	48.9	0.4	0.8	0.7
	KC0033	1.27	50.2	0.6	1.1	0.7
	KC0031	1.28	51.2	0.7	0.9	0.9
	KC0029	1.29	52.3	0.7	1.1	0.7
	KC0028	1.3	53.4	0.5	0.7	0.7
	KC0027	1.31	54.0	0.6	0.8	0.6
Gurner Avenue	KC0026	1.33	55.2	0.6	1.0	0.8
	KC0025	1.34	55.3	0.6	1.0	0.8
	KC0025	1.35	55.3	0.8	0.7	0.7
	KC0024	1.36	55.4	0.7	1.1	0.7
	KC0022	1.37	55.9	0.7	0.8	0.5
	KC0021	1.38	56.4	0.7	1.2	0.8
Fifteenth Avenue	KC0020	1.39	56.9	0.0	2.9	0.0
	KC0019	1.4	57.5	0.5	1.0	0.5
	KC0019	1.41	57.5	0.5	0.9	0.4
	KC0018	1.42	57.6	0.5	1.0	0.5
	KC0017	1.43	58.1	0.8	1.7	0.7
	KC0015	1.44	59.1	0.5	1.0	0.8
	KC0014	1.451	60.0	0.1	0.5	0.6
Twelfth Avenue	KC0014	1.452	60.1	0.5	0.8	0.5
	KC0014	1.453	60.1	0.4	0.7	0.5
	KC0014	1.454	60.1	0.1	0.4	0.5
	KC0012	1.46	61.8	0.6	0.9	0.5
	KC0010	1.47	63.8	1.3	1.7	1.0
	KC0008	1.48	66.5	0.0	0.9	0.7
	KC0007	1.49	68.3	0.6	1.1	0.6
	KC0005	1.5	71.7	1.0	1.4	1.5
	KC0004	1.51	73.5	0.4	0.7	0.6
Bringelly Road	KC0003	1.52	74.0	0.5	1.8	0.9
	KC0002	1.53	74.5	0.1	0.5	0.5
	KC0001	1.54	74.5	0.5	1.1	0.4
	-	1.55	75.2	0.4	2.3	0.7

Table B3.6
Hydraulic Model Results Kemps Creek - PMF

Location	Surveyed X-Section No	HEC-2 X-Section No	Peak Water Level (m AHD)	Velocity (m/s)		
				Left Overbank	Channel	Right Overbank
	KC0046	1.18	46.3	1.3	1.5	1.5
	KC0045	1.19	47.1	0.9	1.5	1.9
Elizabeth Drive	KC0044	1.2	47.5	2.1	2.3	2.4
	KC0042	1.22	48.8	1.1	1.2	1.3
	KC0041	1.24	49.0	1.4	1.1	1.0
	KC0040	1.245	49.4	1.0	0.8	1.0
	KC0038	1.25	49.6	0.9	0.7	0.7
	KC0037	1.255	49.8	0.9	0.9	0.7
	KC0035	1.26	50.2	0.7	1.0	0.8
	KC0033	1.27	51.2	0.9	1.1	1.0
	KC0031	1.28	52.2	1.1	1.3	0.9
	KC0029	1.29	53.3	1.0	1.3	0.9
	KC0028	1.3	54.3	0.7	0.8	1.0
	KC0027	1.31	54.8	0.9	0.9	0.9
Gurner Avenue	KC0026	1.33	56.0	1.0	1.3	1.2
	KC0025	1.34	56.1	1.0	1.3	1.2
	KC0025	1.35	56.1	1.2	0.9	1.1
	KC0024	1.36	56.1	1.1	1.4	1.0
	KC0022	1.37	56.8	1.0	1.0	0.9
	KC0021	1.38	57.2	1.1	1.2	1.2
Fifteenth Avenue	KC0020	1.39	57.8	1.3	2.4	1.3
	KC0019	1.4	57.9	1.1	2.0	1.1
	KC0019	1.41	58.0	1.1	1.9	1.1
	KC0018	1.42	58.0	1.1	2.0	1.1
	KC0017	1.43	59.0	1.0	1.8	1.1
	KC0015	1.44	59.8	1.0	1.4	1.1
	KC0014	1.451	60.6	0.4	0.8	0.9
Twelfth Avenue	KC0014	1.452	60.6	0.4	1.2	0.8
	KC0014	1.453	60.8	0.4	1.0	0.7
	KC0014	1.454	60.8	0.3	0.7	0.7
	KC0012	1.46	61.9	1.4	2.0	1.1
	KC0010	1.47	64.4	0.9	1.1	0.8
	KC0008	1.48	66.6	0.3	1.6	1.5
	KC0007	1.49	68.5	1.0	1.7	1.0
	KC0005	1.5	72.1	1.0	1.5	1.5
	KC0004	1.51	73.8	0.6	0.9	0.9
Bringelly Road	KC0003	1.52	74.3	0.6	1.6	1.1
	KC0002	1.53	74.7	0.2	0.9	1.0
	KC0001	1.54	74.8	0.7	1.3	0.6
	-	1.55	75.5	0.8	2.9	1.3

Table B3.7
Branch KC01 of Kemps Creek- Peak Water Surface Elevations

Location	Surveyed X-Section No	HEC-2 X-Section No	Channel Invert (m AHD)	Peak Water Level (m AHD)				
				1 y ARI	5 y ARI	20 y ARI	100 y ARI	PMF
Confluence with			60.00	61.6	62.1	62.2	62.3	62.5
Kemps Creek	KC0117.1	117.1	60.00	61.6	62.1	62.2	62.3	62.5
	KC0117	117	61.50	62.2	62.3	62.3	62.4	62.6
	KC0116	116	63.50	63.9	64.1	64.3	64.3	64.6
King Street	KC0115.1	115.1	64.38	64.4	64.5	64.5	64.6	64.7
	KC0115	115	64.38	64.5	64.6	64.7	64.7	64.9
	KC0114	114	63.55	64.5	64.6	64.7	64.7	64.9
	KC0113	113	64.93	65.3	65.4	65.5	65.6	65.9
	KC0112	112.1	65.09	66.2	66.6	66.7	66.9	67.2
Devonshire Road	KC0112	112	65.09	66.3	66.6	66.8	66.9	67.3
	KC0110	110.1	65.40	66.3	66.7	66.9	67.0	67.3
	KC0110	110	65.40	66.3	66.7	66.9	67.0	67.3
	KC0109	109	66.34	66.5	66.9	67.0	67.1	67.6
	KC0108	108	67.56	68.7	69.0	69.2	69.3	69.7
	KC0107	107.1	69.84	70.2	70.6	70.8	70.9	71.4
Wynyard Avenue	KC0107	107	69.84	70.6	70.9	71.1	71.3	71.7
	KC0105	105.1	70.01	70.8	71.3	71.5	71.5	71.8
	KC0105	105	70.01	70.9	71.4	71.6	71.5	71.9
	KC0104	104	73.00	73.7	73.5	73.7	73.8	74.3
	KC0103	103.1	73.94	75.2	75.4	75.5	75.6	75.8
Bellfield Avenue	KC0103	103	74.00	75.3	75.4	75.5	75.6	75.9

Table B3.8
Branch KC02 of Kemps Creek - Peak Water Surface Elevations

Location	Surveyed X-Section No	HEC-2 X-Section No	Channel Invert (m AHD)	Peak Water Level (m AHD)				
				1 y ARI	5 y ARI	20 y ARI	100 y ARI	PMF
Confluence with			54.97	56.8	57.7	58.0	58.1	59.0
Kemps Creek	KC0205	205	56.60	57.0	57.7	58.0	58.1	59.0
	KC0204	204.1	59.77	60.3	60.8	60.7	60.9	61.4
Herley Avenue	KC0204	204	59.77	60.5	60.7	61.1	61.3	61.5
	KC0202	202.1	60.39	61.1	61.4	61.5	61.5	61.7
	KC0202	202	60.39	61.2	61.4	61.5	61.5	61.8
	KC0201	201	62.83	63.0	63.1	63.2	63.5	63.9

Table B3.9
Branch KC03 of Kemps Creek - Peak Water Surface Elevations

Location	Surveyed X-Section No	HEC-2 X-Section No	Channel Invert (m AHD)	Peak Water Level (m AHD)				
				1 y ARI	5 y ARI	20 y ARI	100 y ARI	PMF
Confluence with			52.86	55.3	55.6	55.8	55.9	56.8
Kemps Creek	KC0304	304	55.00	55.5	55.7	55.9	56.1	56.9
	KC0303	303	55.10	55.5	55.7	55.9	56.1	56.9
	KC0302	302	57.58	57.8	57.9	58.0	58.0	58.3
	KC0301	301	60.32	60.6	60.7	60.7	60.7	60.7

Table B3.10
Branch KC07 of Kemps Creek - Peak Water Surface Elevations

Location	Surveyed X-Section No	HEC-2 X-Section No	Channel Invert (m AHD)	Peak Water Level (m AHD)				
				1 y ARI	5 y ARI	20 y ARI	100 y ARI	PMF
Confluence with			43.00	45.0	45.9	46.2	46.7	48.8
Kemps Creek	KC0704	704	45.71	46.3	46.5	46.6	47.3	48.9
	KC0703	703	48.14	48.8	49.0	49.2	49.3	49.4
	KC0702	702	51.02	51.7	51.9	51.9	51.9	52.4
	KC0701.4	701.4	51.20	51.9	52.0	52.1	52.2	52.6
Cross Street	KC0701.3	701.3	52.00	52.7	53.2	53.6	53.8	53.8
	KC0701.2	701.2	52.20	53.9	54.0	54.0	54.0	54.3
	KC0701.1	701.1	52.20	53.9	54.0	54.0	54.0	54.3
	KC0701	701	53.41	53.9	54.1	54.6	54.6	55.3

B3.3 Bonds Creek Main Arm and Branches

This section deals with the main arm of Bonds Creek and a minor tributary BC08 which joins the west bank downstream of Tenth Avenue. Water surface profiles are plotted on Figures B3.7 and B3.8. Figure B3.9 (3 sheets) shows typical cross sections and rating curves for Bonds Creek.

Bonds Creek extends over 6 km from the junction with Kemps Creek to Denham Court Road. The model comprises 65 cross sections at an average spacing of about 100 m. Nine culverts are included in the model, details of which are shown on Table B3.11.

Table B3.11
Details of Culverts - Bonds Creek

Location	Opening	Waterway Area (m^2)	Approx. Capacity ARI years
Denham Court Road	3 off box culverts 1500 x 900	4	2
Hume Highway	4 off box culverts 1950 x 1000	8	2
Cowpasture Road	3 off box culverts 3300 x 1800	18	10
Bringelly Road	3 off box culverts 3000 x 1500	13.5	10
Edmonson Avenue	4 off box culverts 3000 x 950	11.5	2
Eighth Avenue	1 semi circular Armco pipe 5450 x 3200	17.5	2
Fourth Avenue	3 semi circular Armco pipes 3300 x 2100	21	2
Ninth Avenue	2 semi circular pipes 1080 x 690	1.5	<1
Tenth Avenue	1 semi circular Armco pipe 8000 dia.(approx)	20	2

Peak water surface elevations and velocities along Bonds Creek are shown in Tables B3.12 to B3.16 for the five design storms modelled while Table B3.17 gives peak water surface elevations for Branch BC08.

Table B3.12

Hydraulic Model Results Bonds Creek - 1 Year ARI

Location	Surveyed X-Section No	HEC-2 X-Section No	Peak Water Level (m AHD)	Velocity (m/s)		
				Left Overbank	Channel	Right Overbank
Confluence With	KC0017	1.43	56.8	0.0	1.8	0.0
Kemps Creek	BC0060	2.6	57.9	0.0	1.1	0.2
	BC0059	2.59	58.6	0.3	1.1	0.0
	BC0058	2.58	59.0	0.2	1.1	0.0
	BC0057	2.57	59.7	0.0	1.7	0.0
	BC0054	2.541	60.8	0.0	1.0	0.0
Tenth Avenue	BC0054	2.54	60.8	0.0	1.8	0.0
	BC0052	2.521	61.0	0.0	1.7	0.0
	BC0052	2.52	61.1	0.0	0.8	0.0
	BC0051	2.51	61.3	0.0	1.4	0.0
	BC0050	2.501	61.9	0.0	1.3	0.0
Ninth Avenue	BC0050	2.5	63.4	0.7	2.3	0.0
	BC0048	2.481	63.7	0.3	1.0	0.4
	BC0048	2.48	63.8	0.0	0.4	0.0
	BC0047	2.47	63.8	0.0	0.6	0.0
	BC0046	2.461	63.8	0.0	0.7	0.0
Fourth Avenue	BC0046	2.46	63.8	0.0	0.8	0.0
	BC0044	2.441	63.8	0.0	0.8	0.0
	BC0044	2.44	63.8	0.0	0.6	0.0
	BC0043	2.43	63.8	0.0	1.3	0.0
	BC0042	2.421	64.1	0.0	1.5	0.0
Eighth Avenue	BC0042	2.42	64.1	0.0	1.8	0.0
	BC0040	2.401	64.2	0.0	1.7	0.0
	BC0040	2.4	64.2	0.0	1.9	0.0
	BC0039	2.39	65.1	0.0	1.4	0.0
Seventh Avenue	BC0037	2.37	65.5	0.0	1.4	0.0
Confluence With	BC0034	2.34	66.2	0.0	1.1	0.0
Scalabrini Creek	BC0033	2.331	66.8	0.0	1.9	0.0
Edmonson Avenue	BC0033	2.33	67.3	0.0	2.0	0.0
	BC0031	2.311	67.5	0.0	1.3	0.0
	BC0031	2.31	67.7	0.2	0.7	0.0
	BC0030	2.3	68.1	0.3	0.6	0.0
Sixth Avenue	BC0028	2.28	68.6	0.3	0.4	0.0
	BC0026	2.26	69.5	0.0	0.7	0.0
Fifth Avenue	BC0024	2.24	70.5	0.0	0.7	0.0
	BC0022	2.22	71.4	0.0	0.7	0.3
	BC0021	2.211	72.6	0.0	0.8	0.0
Bringelly Road	BC0021	2.21	72.8	0.0	1.0	0.0
	BC0019	2.191	72.8	0.0	1.0	0.0
	BC0019	2.19	73.0	0.0	1.1	0.0
	BC0018	2.18	74.3	0.3	0.4	0.2
	BC0016	2.16	75.8	0.4	0.9	0.3
	BC0014	2.141	77.2	0.2	0.7	0.1
Cowpasture Road	BC0014	2.14	77.2	0.0	1.5	0.0
	BC0012	2.121	77.3	0.0	1.3	0.0
	BC0012	2.12	77.5	0.0	0.9	0.0
	BC0011	2.111	78.4	0.3	0.7	0.2
Hume Highway	BC0011	2.11	78.5	0.0	1.3	0.0
	BC0009	2.091	78.6	0.0	1.2	0.0
	BC0009	2.09	78.7	0.0	0.5	0.4

Table B3.12

Hydraulic Model Results Bonds Creek - 1 Year ARI

Location	Surveyed X-Section No	HEC-2 X-Section No	Peak Water Level (m AHD)	Velocity (m/s)		
				Left Overbank	Channel	Right Overbank
	BC0008	2.08	79.5	0.0	0.8	0.0
	BC0007	2.07	80.4	0.4	0.8	0.4
	BC0005	2.05	81.9	0.0	0.8	0.0
	BC0004	2.04	83.8	0.0	0.4	0.5
	BC0003	2.031	85.3	0.0	0.9	0.2
Denham Court Road	BC0003	2.03	85.5	0.0	2.6	0.0
	BC0001	2.011	85.8	0.0	1.7	0.0
	BC0001	2.01	86.0	0.1	0.1	0.1

TABLE B3.13

HYDRAULIC MODEL RESULTS BONDS CREEK - 5 YEAR ARI

Location	Surveyed X-Section No	HEC-2 X-Section No	Peak Water Level (m AHD)	Velocity (m/s)		
				Left Overbank	Channel	Right Overbank
Confluence with	KC0017	1.43	57.7	0.5	1.5	0.5
Kemps Creek	BC0060	2.6	58.7	0.4	1.6	0.4
	BC0059	2.59	59.5	0.4	1.7	0.0
	BC0058	2.58	59.9	0.3	1.5	0.0
	BC0057	2.57	60.5	0.7	2.1	0.0
	BC0054	2.541	61.9	0.3	1.1	0.0
Tenth Avenue	BC0054	2.54	61.7	0.0	3.7	0.0
	BC0052	2.521	62.4	0.2	1.1	0.3
	BC0052	2.52	62.4	0.2	0.8	0.1
	BC0051	2.51	62.5	0.0	2.1	0.0
	BC0050	2.501	63.0	0.0	1.5	0.0
Ninth Avenue	BC0050	2.5	63.7	0.7	3.1	1.2
	BC0048	2.481	63.9	0.6	2.4	0.9
	BC0048	2.48	64.0	0.2	0.9	0.1
	BC0047	2.47	63.9	0.0	1.7	0.2
	BC0046	2.461	64.0	0.0	1.9	0.1
Fourth Avenue	BC0046	2.46	64.1	0.0	2.1	0.0
	BC0044	2.441	64.5	0.0	1.5	0.6
	BC0044	2.44	64.6	0.0	1.1	0.2
	BC0043	2.43	64.8	0.2	1.8	0.3
	BC0042	2.421	65.1	0.3	2.5	0.0
Eighth Avenue	BC0042	2.42	65.2	0.0	3.6	0.0
	BC0040	2.401	65.9	0.4	1.5	0.3
	BC0040	2.4	65.9	0.4	1.1	0.3
	BC0039	2.39	66.1	0.4	2.0	0.3
Seventh Avenue	BC0037	2.37	66.5	0.0	2.1	0.2
Confluence With	BC0034	2.34	67.3	0.0	1.3	0.0
Scalabrini Creek	BC0033	2.331	67.5	0.0	1.7	0.0
Edmonson Avenue	BC0033	2.33	67.7	0.0	2.8	0.0
	BC0031	2.311	68.3	0.5	0.5	0.0
	BC0031	2.31	68.3	0.4	0.5	0.3
	BC0030	2.3	68.5	0.5	0.6	0.0
Sixth Avenue	BC0028	2.28	68.8	0.4	0.5	0.0
	BC0026	2.26	69.9	0.2	1.3	0.5

TABLE B3.13
HYDRAULIC MODEL RESULTS BONDS CREEK - 5 YEAR ARI

Location	Surveyed X-Section No	HEC-2 X-Section No	Peak Water Level (m AHD)	Velocity (m/s)		
				Left Overbank	Channel	Right Overbank
Fifth Avenue	BC0024	2.24	71.2	0.3	0.8	0.1
	BC0022	2.22	72.1	0.1	1.0	0.4
	BC0021	2.211	73.3	0.1	0.9	0.4
Bringelly Road	BC0021	2.21	73.3	0.0	2.1	0.0
	BC0019	2.191	73.5	0.0	1.9	0.0
	BC0019	2.19	73.7	0.3	0.5	0.4
	BC0018	2.18	74.4	0.7	0.9	0.4
	BC0016	2.16	76.0	0.4	0.7	0.4
	BC0014	2.141	77.3	0.4	1.2	0.4
Cowpasture Road	BC0014	2.14	77.5	0.0	3.0	0.0
	BC0012	2.121	78.0	0.0	2.0	0.0
	BC0012	2.12	78.3	0.5	0.8	0.3
	BC0011	2.111	78.7	0.5	1.1	0.6
Hume Highway	BC0011	2.11	78.9	0.0	1.0	0.7
	BC0009	2.091	79.2	0.2	0.4	0.2
	BC0009	2.09	79.2	0.2	0.3	0.2
	BC0008	2.08	80.0	0.4	0.9	0.0
	BC0007	2.07	80.8	0.6	1.0	0.6
	BC0005	2.05	82.4	0.3	1.2	0.3
	BC0004	2.04	84.0	0.3	0.5	0.6
	BC0003	2.031	85.6	0.4	1.5	0.6
Denham Court Road	BC0003	2.03	86.1	0.0	0.7	0.4
	BC0001	2.011	86.3	0.1	0.2	0.1
	BC0001	2.01	86.3	0.1	0.2	0.1

TABLE B3.14
HYDRAULIC MODEL RESULTS BONDS CREEK - 20 YEAR ARI

Location	Surveyed X-Section No	HEC-2 X-Section No	Peak Water Level (m AHD)	Velocity (m/s)		
				Left Overbank	Channel	Right Overbank
Confluence With	KC0017	1.43	58.0	0.6	1.3	0.5
Kemps Creek	BC0060	2.6	58.8	0.5	2.0	0.6
	BC0059	2.59	59.7	0.5	1.6	0.2
	BC0058	2.58	60.2	0.4	1.7	0.2
	BC0057	2.57	60.8	0.8	2.2	0.4
	BC0054	2.541	62.2	0.3	1.2	0.1
Tenth Avenue	BC0054	2.54	62.2	0.4	2.0	0.0
	BC0052	2.521	62.5	0.3	1.3	0.3
	BC0052	2.52	62.5	0.3	1.0	0.2
	BC0051	2.51	62.8	0.2	3.0	0.1
	BC0050	2.501	63.4	0.2	2.1	0.3
Ninth Avenue	BC0050	2.5	63.9	0.8	3.5	1.1
	BC0048	2.481	63.9	0.9	3.5	1.3
	BC0048	2.48	64.1	0.3	1.2	0.2
	BC0047	2.47	64.0	0.2	2.8	0.4
	BC0046	2.461	64.2	0.2	2.7	0.3
Fourth Avenue	BC0046	2.46	64.4	0.0	2.6	0.9
	BC0044	2.441	64.9	0.4	1.9	0.5

TABLE B3.14
HYDRAULIC MODEL RESULTS BONDS CREEK - 20 YEAR ARI

Location	Surveyed X-Section No	HEC-2 X-Section No	Peak Water Level (m AHD)	Velocity (m/s)		
				Left Overbank	Channel	Right Overbank
	BC0044	2.44	64.9	0.2	1.4	0.4
	BC0043	2.43	65.2	0.5	1.9	0.6
	BC0042	2.421	65.5	0.7	2.8	0.4
Eighth Avenue	BC0042	2.42	65.9	0.6	2.3	0.4
	BC0040	2.401	66.2	0.4	1.7	0.4
	BC0040	2.4	66.3	0.4	1.2	0.4
	BC0039	2.39	66.4	0.6	2.2	0.5
Seventh Avenue	BC0037	2.37	66.9	0.4	2.1	0.5
Confluence With	BC0034	2.34	67.7	0.3	1.8	0.2
Scalabrini Creek	BC0033	2.331	68.0	0.1	2.0	0.2
Edmonson Avenue	BC0033	2.33	68.3	0.4	1.8	0.5
	BC0031	2.311	68.5	0.5	0.5	0.4
	BC0031	2.31	68.5	0.5	0.5	0.4
	BC0030	2.3	68.7	0.7	0.7	0.3
Sixth Avenue	BC0028	2.28	69.0	0.5	0.5	0.0
	BC0026	2.26	70.5	0.4	0.6	0.5
Fifth Avenue	BC0024	2.24	71.2	0.6	1.4	0.2
	BC0022	2.22	72.4	0.4	0.9	0.5
	BC0021	2.211	73.5	0.4	1.1	0.7
Bringelly Road	BC0021	2.21	73.3	0.0	3.9	0.0
	BC0019	2.191	74.1	0.0	0.6	0.4
	BC0019	2.19	74.1	0.3	0.4	0.4
	BC0018	2.18	74.6	0.9	1.1	0.5
	BC0016	2.16	76.2	0.5	0.8	0.5
	BC0014	2.141	77.5	0.6	1.4	0.6
Cowpasture Road	BC0014	2.14	78.0	0.0	3.8	0.0
	BC0012	2.121	78.8	0.0	0.6	0.3
	BC0012	2.12	78.8	0.2	0.4	0.2
	BC0011	2.111	78.9	0.6	1.2	0.8
Hume Highway	BC0011	2.11	79.0	0.0	1.5	1.1
	BC0009	2.091	79.3	0.3	0.6	0.3
	BC0009	2.09	79.3	0.3	0.5	0.4
	BC0008	2.08	80.3	0.5	0.8	0.2
	BC0007	2.07	80.9	0.7	1.2	0.8
	BC0005	2.05	82.7	0.5	1.4	0.6
	BC0004	2.04	84.1	0.5	0.6	0.6
	BC0003	2.031	85.7	0.7	1.8	0.8
Denham Court Road	BC0003	2.03	86.1	0.0	1.2	0.7
	BC0001	2.011	86.4	0.2	0.3	0.2
	BC0001	2.01	86.4	0.2	0.3	0.2

TABLE B3.15
HYDRAULIC MODEL RESULTS BONDS CREEK - 100 YEAR ARI

Location	Surveyed Cross Section Number	HEC-2 Cross Section Number	Peak Water Level (M AHD)	Velocity (M/S)		
				Left Overbank	Channel	Right Overbank
Confluence With	KC0017	1.43	58.1	0.8	1.7	0.7
Kemps Creek	BC0060	2.6	59.1	0.5	2.0	0.7
	BC0059	2.59	59.9	0.6	1.7	0.3
	BC0058	2.58	60.4	0.5	1.9	0.4
	BC0057	2.57	61.0	0.9	2.5	0.6
	BC0054	2.541	62.4	0.4	1.2	0.2
Tenth Avenue	BC0054	2.54	62.4	0.4	1.8	0.5
	BC0052	2.521	62.6	0.4	1.8	0.4
	BC0052	2.52	62.6	0.4	1.3	0.3
	BC0051	2.51	63.3	0.4	2.0	0.4
	BC0050	2.501	63.4	0.2	3.2	0.5
Ninth Avenue	BC0050	2.5	64.0	0.9	3.6	1.0
	BC0048	2.481	64.1	1.0	3.9	1.2
	BC0048	2.48	64.2	0.4	1.5	0.2
	BC0047	2.47	64.8	0.4	1.6	0.4
	BC0046	2.461	64.6	0.5	3.2	0.7
Fourth Avenue	BC0046	2.46	65.1	0.4	2.3	0.7
	BC0044	2.441	65.1	0.5	2.4	0.7
	BC0044	2.44	65.2	0.4	1.7	0.5
	BC0043	2.43	65.5	0.6	2.0	0.7
	BC0042	2.421	65.8	0.9	3.1	0.6
Eighth Avenue	BC0042	2.42	66.1	0.8	2.6	0.5
	BC0040	2.401	66.3	0.6	2.3	0.5
	BC0040	2.4	66.4	0.6	1.6	0.5
	BC0039	2.39	66.7	0.7	2.4	0.7
Seventh Avenue	BC0037	2.37	67.1	0.5	2.7	0.8
Confluence With	BC0034	2.34	67.8	0.4	2.4	0.4
Scalabrini Creek	BC0033	2.331	68.3	0.2	2.0	0.5
Edmonson Avenue	BC0033	2.33	68.5	0.5	1.9	0.6
	BC0031	2.311	68.6	0.7	0.6	0.5
	BC0031	2.31	68.6	0.6	0.6	0.5
	BC0030	2.3	68.8	0.9	0.8	0.5
Sixth Avenue	BC0028	2.28	69.2	0.6	0.5	0.0
	BC0026	2.26	70.6	0.5	0.7	0.5
Fifth Avenue	BC0024	2.24	71.3	0.7	1.4	0.5
	BC0022	2.22	72.6	0.5	1.0	0.6
	BC0021	2.211	73.6	0.6	1.1	0.8
Bringelly Road	BC0021	2.21	73.8	0.0	1.3	0.8
	BC0019	2.191	74.2	0.4	0.5	0.4
	BC0019	2.19	74.3	0.4	0.5	0.5
	BC0018	2.18	74.8	1.0	1.0	0.6
	BC0016	2.16	76.3	0.6	0.8	0.6
	BC0014	2.141	77.6	0.6	1.4	0.7
Cowpasture Road	BC0014	2.14	78.4	0.0	4.3	0.0
	BC0012	2.121	79.4	0.2	0.3	0.2
	BC0012	2.12	79.4	0.2	0.3	0.2
	BC0011	2.111	79.4	0.5	0.8	0.4
Hume Highway	BC0011	2.11	79.4	0.5	0.8	0.4

TABLE B3.15
HYDRAULIC MODEL RESULTS BONDS CREEK - 100 YEAR ARI

Location	Surveyed Cross Section Number	HEC-2 Cross Section Number	Peak Water Level (M AHD)	Velocity (M/S)		
				Left Overbank	Channel	Right Overbank
	BC0009	2.091	79.5	0.3	0.6	0.4
	BC0009	2.09	79.5	0.3	0.5	0.4
	BC0008	2.08	80.5	0.6	1.0	0.2
	BC0007	2.07	81.2	0.8	1.3	0.9
	BC0005	2.05	82.8	0.5	1.6	0.8
	BC0004	2.04	84.2	0.5	0.6	0.7
	BC0003	2.031	86.1	0.5	0.8	0.4
Denham Court Road	BC0003	2.03	86.2	0.0	1.7	0.9
	BC0001	2.011	86.5	0.3	0.4	0.3
	BC0001	2.01	86.5	0.3	0.4	0.3

TABLE B3.16
HYDRAULIC MODEL RESULTS BONDS CREEK - PMF

Location	Surveyed Cross Section Number	HEC-2 Cross Section Number	Peak Water Level (M AHD)	Velocity (M/S)		
				Left Overbank	Channel	Right Overbank
Confluence With	KC0017	1.43	59.0	1.0	1.8	1.1
Kemps Creek	BC0060	2.6	59.8	0.9	2.6	1.0
	BC0059	2.59	60.7	0.7	1.6	0.7
	BC0058	2.58	61.1	0.9	2.4	0.8
	BC0057	2.57	61.8	1.3	2.9	1.0
	BC0054	2.541	63.0	0.6	1.6	0.5
Tenth Avenue	BC0054	2.54	63.1	0.6	2.2	0.6
	BC0052	2.521	63.0	0.8	2.9	0.6
	BC0052	2.52	63.0	0.7	2.2	0.6
	BC0051	2.51	63.8	0.8	2.5	0.6
	BC0050	2.501	64.4	0.9	2.8	0.7
Ninth Avenue	BC0050	2.5	64.6	1.3	4.1	1.1
	BC0048	2.481	64.6	1.4	4.5	1.1
	BC0048	2.48	64.7	0.8	2.4	0.6
	BC0047	2.47	65.4	1.0	2.7	0.9
	BC0046	2.461	65.6	1.2	4.2	1.5
Fourth Avenue	BC0046	2.46	66.0	1.0	3.3	1.3
	BC0044	2.441	66.0	1.0	3.5	1.3
	BC0044	2.44	66.1	0.9	2.4	1.0
	BC0043	2.43	66.5	0.9	2.2	0.9
	BC0042	2.421	66.7	1.5	3.6	1.3
Eighth Avenue	BC0042	2.42	66.8	1.5	4.3	1.2
	BC0040	2.401	67.0	1.2	3.7	1.1
	BC0040	2.4	67.1	1.2	2.6	1.1
	BC0039	2.39	67.7	0.9	2.7	1.0
Seventh Avenue	BC0037	2.37	67.9	1.0	2.9	1.2
Confluence With	BC0034	2.34	68.6	0.7	2.3	0.8
Scalabrini Creek	BC0033	2.331	68.9	0.8	2.8	1.0
Edmonson Avenue	BC0033	2.33	69.1	0.9	2.4	1.0
	BC0031	2.311	69.1	1.1	1.0	0.9
	BC0031	2.31	69.2	1.1	0.9	1.0

TABLE B3.16
HYDRAULIC MODEL RESULTS BONDS CREEK - PMF

Location	Surveyed Cross Section Number	HEC-2 Cross Section Number	Peak Water Level (M AHD)	Velocity (M/S)		
				Left Overbank	Channel	Right Overbank
	BC0030	2.3	69.4	1.5	1.2	1.1
Sixth Avenue	BC0028	2.28	69.9	0.8	0.7	0.4
	BC0026	2.26	70.7	1.3	1.7	1.5
Fifth Avenue	BC0024	2.24	72.0	0.9	1.1	0.7
	BC0022	2.22	73.1	1.0	1.6	1.3
	BC0021	2.211	74.3	0.9	1.2	1.1
Bringelly Road	BC0021	2.21	74.4	1.0	1.1	0.9
	BC0019	2.191	74.8	0.7	0.9	0.8
	BC0019	2.19	74.9	0.7	0.8	0.8
	BC0018	2.18	75.6	1.2	1.1	1.0
	BC0016	2.16	76.9	0.8	1.1	0.9
	BC0014	2.141	78.1	0.9	1.7	1.1
Cowpasture Road	BC0014	2.14	78.7	0.0	1.0	0.8
	BC0012	2.121	79.4	0.6	1.0	0.6
	BC0012	2.12	79.4	0.5	1.0	0.6
	BC0011	2.111	79.6	1.1	1.7	0.8
Hume Highway	BC0011	2.11	79.7	1.0	1.5	0.8
	BC0009	2.091	79.8	0.7	1.2	0.8
	BC0009	2.09	79.8	0.7	1.0	0.8
	BC0008	2.08	80.7	1.4	2.0	0.8
	BC0007	2.07	81.9	1.0	1.5	1.1
	BC0005	2.05	83.3	0.8	1.9	1.0
	BC0004	2.04	84.7	0.8	1.0	0.9
	BC0003	2.031	86.7	0.7	1.0	0.6
Denham Court Road	BC0003	2.03	86.7	0.7	1.0	0.7
	BC0001	2.011	86.9	0.6	0.8	0.6
	BC0001	2.01	86.9	0.5	0.8	0.6

TABLE B3.17
BRANCH BC08 OF BONDS CREEK - PEAK WATER SURFACE ELEVATIONS

Location	Surveyed Cross Section Number	HEC-2 Cross Section Number	Channel Invert (M AHD)	Peak Water Level (M AHD)				
				1 y ARI	5 y ARI	20 y ARI	100 y ARI	PMF
Confluence with Bonds			61.90	62.1	62.4	62.5	62.6	63.0
Creek - Tenth Avenue	BC0803	803	62.77	62.8	62.9	62.9	62.9	63.1
	BC0802	802.1	65.20	65.8	65.9	66.0	66.0	66.2
	BC0802	802	66.89	67.1	67.2	67.2	67.2	67.5
	BC0801	801	70.50	70.8	70.9	70.9	70.9	71.0

B3.4 Tributary 1 (Scalabrini Creek)

This tributary joins Bonds Creek upstream of Seventh Avenue and was modelled for a length of approximately 1200 m to Bringelly Road. The model comprises 13 sections at an average spacing of 150 m. The sections are located so that the recently excavated channel downstream of Fifth Avenue was accurately modelled. Water surface profiles are plotted on Figure B3.10. Several sections of Scalabrini Creek and their corresponding rating curves are shown on Figure B3.11 (2 sheets).

The Fifth Avenue crossing was modelled but has a low hydrologic capacity, as shown in Table B3.18.

TABLE B3.18
DETAILS OF BRIDGES - TRIBUTARY 1 (SCALABRINI CREEK)

Location	Opening	Waterway Area (m^2)	Approx. Capacity ARI years
Bringelly Road	Not Modelled	-	-
Fifth Avenue	1 off 750 RCP	0.4	< 1

Peak water surface elevations and velocities along Tributary 1 are shown in Tables B3.19 to B3.23.

TABLE B3.19
HYDRAULIC MODEL RESULTS TRIBUTARY 1 (SCALABRINI CREEK) - 1 YEAR ARI

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	PEAK WATER LEVEL (m AHD)	VELOCITY (m/s)		
				LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
Confluence With	BC0037	2.37	65.5	0.0	1.4	0.0
Bonds Creek	SC0015	3.15	65.9	0.0	0.7	0.0
	SC0014	3.14	66.1	0.0	0.8	0.0
	SC0013	3.13	66.8	0.8	1.3	0.0
Sixth Avenue	SC0010	3.1	67.3	0.0	1.2	0.0
	SC0009	3.9	68.8	0.0	1.9	0.0
	SC0008.1	3.81	69.9	1.0	0.9	0.0
	SC0008	3.8	70.2	0.2	0.2	0.1
	SC0007	3.71	70.5	0.9	1.4	0.0
Fifth Avenue	SC0007	3.7	70.7	0.3	0.5	0.0
	SC0005	3.51	70.7	0.6	1.6	0.0
	SC0005	3.5	70.8	0.2	0.4	0.2
	SC0004	3.4	71.7	0.2	0.4	0.2
Bringelly Road	SC0003	3.3	72.5	0.0	1.2	0.2

TABLE B3.20
HYDRAULIC MODEL RESULTS TRIBUTARY 1 (SCALABRINI CREEK) - 5 YEAR ARI

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	PEAK WATER LEVEL (m AHD)	VELOCITY (m/s)		
				LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
Confluence With	BC0037	2.37	66.5	0.0	2.1	0.2
Bonds Creek	SC0015	3.15	66.9	0.1	0.7	0.0
	SC0014	3.14	66.9	0.0	0.8	0.0
	SC0013	3.13	67.3	1.3	1.8	0.0
Sixth Avenue	SC0010	3.1	67.9	0.0	1.7	0.0
	SC0009	3.9	69.6	0.5	2.1	0.1
	SC0008.1	3.81	70.0	1.2	1.3	0.5
	SC0008	3.8	70.3	0.3	0.4	0.2
	SC0007	3.71	70.6	1.0	1.3	0.0
Fifth Avenue	SC0007	3.7	70.8	0.4	0.8	0.0
	SC0005	3.51	70.9	0.8	1.9	0.0
	SC0005	3.5	71.0	0.3	0.6	0.3
	SC0004	3.4	71.7	0.5	1.1	0.6
Bringelly Road	SC0003	3.3	73.1	0.0	1.1	0.4

TABLE B3.21
HYDRAULIC MODEL RESULTS TRIBUTARY 1 (SCALABRINI CREEK) - 20 YEAR ARI

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	PEAK WATER LEVEL (m AHD)	VELOCITY (m/s)		
				LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
Confluence With	BC0037	2.37	66.9	0.4	2.1	0.5
Bonds Creek	SC0015	3.15	67.3	0.2	0.7	0.0
	SC0014	3.14	67.3	0.1	0.8	0.0
	SC0013	3.13	67.6	1.4	1.9	0.0
Sixth Avenue	SC0010	3.1	68.2	0.0	2.0	0.0
	SC0009	3.9	69.7	0.6	2.0	0.4
	SC0008.1	3.81	70.1	1.3	1.5	0.7
	SC0008	3.8	70.5	0.4	0.5	0.2
	SC0007	3.71	70.7	0.9	1.2	0.3
Fifth Avenue	SC0007	3.7	70.9	0.5	0.9	0.0
	SC0005	3.51	70.9	0.9	2.0	0.0
	SC0005	3.5	71.0	0.4	0.7	0.4
	SC0004	3.4	71.8	0.6	1.2	0.7
Bringelly Road	SC0003	3.3	73.2	0.1	1.2	0.5

TABLE B3.22
HYDRAULIC MODEL RESULTS TRIBUTARY 1 (SCALABRINI CREEK) - 100 YEAR ARI

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	PEAK WATER LEVEL (m AHD)	VELOCITY (m/s)		
				LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
Confluence With	BC0037	2.37	67.1	0.5	2.7	0.8
Bonds Creek	SC0015	3.15	67.5	0.3	0.7	0.1
	SC0014	3.14	67.6	0.2	0.9	0.0
	SC0013	3.13	67.9	1.7	2.1	0.0
Sixth Avenue	SC0010	3.1	68.5	0.5	2.2	0.0
	SC0009	3.9	69.8	0.7	2.2	0.6
	SC0008.1	3.81	70.1	1.6	1.8	0.8
	SC0008	3.8	70.6	0.4	0.6	0.3
	SC0007	3.71	70.8	0.9	1.1	0.4
Fifth Avenue	SC0007	3.7	71.0	0.6	1.0	0.0
	SC0005	3.51	71.0	0.9	2.1	0.0
	SC0005	3.5	71.1	0.5	0.8	0.4
	SC0004	3.4	71.9	0.7	1.2	0.7
Bringelly Road	SC0003	3.3	73.3	0.3	1.2	0.6

TABLE B3.23
HYDRAULIC MODEL RESULTS TRIBUTARY 1 (SCALABRINI CREEK) - PMF

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	PEAK WATER LEVEL (m AHD)	VELOCITY (m/s)		
				LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
Confluence With	BC0037	2.37	67.9	1.0	2.9	1.2
Bonds Creek	SC0015	3.15	68.3	0.4	0.8	0.2
	SC0014	3.14	68.4	0.3	0.7	0.2
	SC0013	3.13	68.4	1.1	2.6	0.7
Sixth Avenue	SC0010	3.1	69.3	0.8	2.5	0.4
	SC0009	3.9	70.2	0.9	2.5	1.0
	SC0008.1	3.81	70.4	1.9	2.3	1.1
	SC0008	3.8	70.9	0.7	0.9	0.5
	SC0007	3.71	71.2	0.9	1.2	0.7
Fifth Avenue	SC0007	3.7	71.3	0.8	1.2	0.6
	SC0005	3.51	71.4	0.9	1.6	0.9
	SC0005	3.5	71.4	0.8	1.2	0.7
	SC0004	3.4	72.3	0.9	1.5	0.9
Bringelly Road	SC0003	3.3	73.7	0.6	1.6	0.9

B3.4.1 Tributary 2 and Branches

Tributary 2 joins the west bank of Kemps Creek just downstream of Fourteenth Avenue. It has been modelled for a distance of 3.1 km to Tenth Avenue. Road crossings included in the model are shown on Table B3.24. The waterway opening at Fourth Avenue was assumed ineffective for flow, although the hydraulic effect of the road which acts as a broad crested weir, was incorporated in the model. The five crossings included in the Tributary 2 model all have a low hydrologic capacity.

TABLE B3.24
DETAILS OF CULVERTS - TRIBUTARY 2

Stream	Location	Opening	Waterway Area (m^2)	Approx. Capacity ARI years
Tributary 2	Tenth Avenue	4 off 525 RCP	0.3	< 1
	Eleventh Avenue	1 off 750 RCP	0.4	< 1
	Edmonson Avenue	1 off box culvert 2900 x 750	2.2	2
	Fourth Avenue			Ineffective
	Thirteenth Avenue	1 off 750 RCP	0.4	< 1
KC 11	Edmonson/Thirteenth Avenue	1 off 600 RCP	0.3	< 1
KC 13	Fourth Avenue	4 off 525 RCP	0.3	< 1

Peak water surface elevations and velocities for Tributary 2 are shown in Tables B3.25 to B3.29 while peak water surface elevations for branches KC11 and 13 are given in Tables B3.30 and B3.31.

Water surface profiles are shown on Figures B3.12 to B3.14 and typical cross sections and rating curves on Figure B3.15 (2 sheets).

TABLE B3.25
HYDRAULIC MODEL RESULTS TRIBUTARY 2 - 1 YEAR ARI

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	PEAK WATER LEVEL (m AHD)	VELOCITY (m/s)		
				LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
Confluence With	KC0018	1.42	56.2	0.0	0.6	0.0
Kemps Creek	KC0832	832	56.2	0.0	0.7	0.0
	KC0831	831	56.9	0.0	0.6	0.2
	KC0830	830	58.1	0.8	1.1	0.0
	KC0829	829	58.9	0.4	0.2	0.0
	KC0825	825	61.2	0.2	0.6	0.2
	KC0823	823.1	62.4	0.0	1.2	0.0
Thirteenth Avenue	KC0823	823	62.7	0.2	0.8	0.3
	KC0821	821.1	62.7	1.0	1.6	1.1
	KC0821	821	62.8	0.0	0.9	0.3
	KC0820	820	64.1	0.3	0.8	0.2
	KC0819	819	64.7	0.0	0.8	0.5
	KC0818	818.1	65.6	0.0	0.8	0.0
Fourth Avenue	KC0818	818	65.7	0.0	0.4	0.0
	KC0817	817	65.7	0.0	0.0	0.0
	KC0815	815.1	66.0	0.0	1.1	0.9
Twelfth Avenue	KC0812	812	68.6	0.2	0.7	0.2
	KC0811	811.1	69.6	0.0	1.3	0.0
	KC0811	811	69.9	0.0	1.6	0.0
	KC0809	809.1	70.2	0.0	1.4	0.0
Edmonson Avenue	KC0809	809	70.4	0.1	0.4	0.1
	KC0808	808	70.6	0.0	1.2	0.0
	KC0807	807.1	71.8	0.0	0.6	0.0
Eleventh Avenue	KC0807	807	72.0	0.0	3.0	0.0
	KC0805	805.1	72.5	0.4	0.7	0.0
	KC0805	805	72.6	0.2	0.3	0.0
	KC0804	804	74.3	0.3	1.0	0.0
	KC0803	803.1	77.1	0.2	0.8	0.1
Tenth Avenue	KC0803	803	77.3	0.0	3.3	0.0
	KC0801	801.1	77.8	0.1	0.1	0.1
	KC0801	801	77.8	0.0	0.1	0.1

TABLE B3.26
HYDRAULIC MODEL RESULTS TRIBUTARY 2 - 5 YEAR ARI

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	PEAK WATER LEVEL (m AHD)	VELOCITY (m/s)		
				LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
Confluence With Kemps Creek	KC0018	1.42	56.8	0.0	1.2	0.0
	KC0832	832	57.0	0.2	0.4	0.2
	KC0831	831	57.1	0.2	0.4	0.3
	KC0830	830	58.2	1.0	1.7	0.0
	KC0829	829	59.3	0.6	0.4	0.2
	KC0825	825	61.2	0.4	1.6	0.6
	KC0823	823.1	62.9	0.3	0.8	0.2
Thirteenth Avenue	KC0823	823	62.9	0.3	0.8	0.3
	KC0821	821.1	62.9	1.3	2.4	1.0
	KC0821	821	63.1	0.3	0.9	0.4
	KC0820	820	64.2	0.5	1.2	0.4
	KC0819	819	64.9	0.0	0.8	0.5
	KC0818	818.1	65.7	0.0	0.9	0.0
Fourth Avenue	KC0818	818	65.8	0.0	0.5	0.0
	KC0817	817	65.8	0.1	0.1	0.1
	KC0815	815.1	66.0	0.1	1.3	1.1
Twelfth Avenue	KC0812	812	68.8	0.3	0.8	0.3
	KC0811	811.1	69.9	0.2	1.9	0.4
	KC0811	811	70.3	0.0	2.8	0.0
	KC0809	809.1	70.7	0.2	0.5	0.2
Edmonson Avenue	KC0809	809	70.7	0.2	0.4	0.2
	KC0808	808	70.7	0.3	2.6	0.0
	KC0807	807.1	72.2	0.2	0.6	0.2
Eleventh Avenue	KC0807	807	72.3	0.0	1.1	0.4
	KC0805	805.1	72.7	0.6	1.1	0.0
	KC0805	805	72.7	0.3	0.5	0.0
	KC0804	804	74.7	0.5	1.1	0.3
	KC0803	803.1	77.2	0.4	1.2	0.3
Tenth Avenue	KC0803	803	77.4	0.0	1.2	0.6
	KC0801	801.1	77.6	0.4	0.5	0.3
	KC0801	801	77.7	0.0	0.4	0.3

TABLE B3.27
HYDRAULIC MODEL RESULTS TRIBUTARY 2 - 20 YEAR ARI

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	PEAK WATER LEVEL (m AHD)	VELOCITY (m/s)		
				LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
Confluence With	KC0018	1.42	57.0	0.0	1.8	0.0
Kemps Creek	KC0832	832	57.3	0.2	0.3	0.2
	KC0831	831	57.4	0.2	0.4	0.3
	KC0830	830	58.2	1.1	1.8	0.0
	KC0829	829	59.5	0.6	0.5	0.2
	KC0825	825	61.2	0.6	1.9	0.9
	KC0823	823.1	63.0	0.4	0.9	0.3
Thirteenth Avenue	KC0823	823	63.1	0.3	0.9	0.3
	KC0821	821.1	63.0	0.8	2.3	0.9
	KC0821	821	63.2	0.4	1.0	0.5
	KC0820	820	64.3	0.6	1.1	0.5
	KC0819	819	65.0	0.2	1.1	0.6
	KC0818	818.1	65.7	0.0	1.1	0.0
Fourth Avenue	KC0818	818	65.8	0.0	0.6	0.0
	KC0817	817	65.8	0.1	0.1	0.1
	KC0815	815.1	66.1	0.1	1.6	1.3
Twelfth Avenue	KC0812	812	68.9	0.3	0.8	0.4
	KC0811	811.1	70.1	0.4	1.8	0.5
	KC0811	811	70.5	0.3	0.8	0.3
	KC0809	809.1	70.7	0.2	0.7	0.2
Edmonson Avenue	KC0809	809	70.8	0.2	0.5	0.2
	KC0808	808	71.1	0.7	2.1	0.2
	KC0807	807.1	72.3	0.2	0.8	0.3
Eleventh Avenue	KC0807	807	72.4	0.0	1.7	0.7
	KC0805	805.1	72.7	0.8	1.5	0.0
	KC0805	805	72.8	0.4	0.6	0.0
	KC0804	804	74.8	0.6	1.2	0.3
	KC0803	803.1	77.3	0.6	1.4	0.4
Tenth Avenue	KC0803	803	77.5	0.3	0.7	0.3
	KC0801	801.1	77.7	0.5	0.8	0.5
	KC0801	801	77.7	0.1	0.6	0.4

TABLE B3.28
HYDRAULIC MODEL RESULTS TRIBUTARY 2 - 100 YEAR ARI

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	PEAK WATER LEVEL (m AHD)	VELOCITY (m/s)		
				LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
Confluence With	KC0018	1.42	57.6	0.5	1.0	0.5
Kemps Creek	KC0832	832	57.6	0.2	0.3	0.1
	KC0831	831	57.7	0.2	0.2	0.2
	KC0830	830	58.2	1.3	2.1	0.0
	KC0829	829	59.4	0.8	0.6	0.3
	KC0825	825	61.3	0.6	1.8	0.9
	KC0823	823.1	63.1	0.5	1.0	0.3
Thirteenth Avenue	KC0823	823	63.1	0.3	0.9	0.3
	KC0821	821.1	63.1	0.8	2.1	0.9
	KC0821	821	63.2	0.4	1.1	0.6
	KC0820	820	64.3	0.6	1.2	0.5
	KC0819	819	65.0	0.3	1.1	0.7
	KC0818	818.1	65.8	0.0	1.1	0.0
Fourth Avenue	KC0818	818	65.8	0.0	0.6	0.0
	KC0817	817	65.9	0.1	0.1	0.1
	KC0815	815.1	66.1	0.1	1.6	1.4
Twelfth Avenue	KC0812	812	68.9	0.4	0.9	0.4
	KC0811	811.1	70.2	0.5	2.1	0.6
	KC0811	811	70.5	0.3	0.9	0.3
	KC0809	809.1	70.8	0.3	0.8	0.3
Edmonson Avenue	KC0809	809	70.8	0.3	0.6	0.3
	KC0808	808	71.1	0.8	2.2	0.3
	KC0807	807.1	72.3	0.3	0.8	0.3
Eleventh Avenue	KC0807	807	72.4	0.3	0.9	0.4
	KC0805	805.1	72.7	1.0	1.7	0.0
	KC0805	805	72.9	0.4	0.6	0.1
	KC0804	804	74.9	0.6	1.2	0.4
	KC0803	803.1	77.3	0.7	1.5	0.5
Tenth Avenue	KC0803	803	77.5	0.4	0.9	0.4
	KC0801	801.1	77.7	0.5	0.9	0.6
	KC0801	801	77.8	0.2	0.7	0.5

TABLE B3.29
HYDRAULIC MODEL RESULTS TRIBUTARY 2 – PMF

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	PEAK WATER LEVEL (m AHD)	VELOCITY (m/s)		
				LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
Confluence With	KC0018	1.42	58.0	1.1	2.0	1.1
Kemps Creek	KC0832	832	58.3	0.4	0.6	0.4
	KC0831	831	58.4	0.3	0.4	0.4
	KC0830	830	58.6	1.9	2.5	0.9
	KC0829	829	60.4	0.7	0.8	0.6
	KC0825	825	61.7	1.0	2.0	1.4
	KC0823	823.1	63.7	0.9	1.5	0.7
Thirteenth Avenue	KC0823	823	63.8	0.6	1.4	0.5
	KC0821	821.1	63.8	0.8	1.7	0.9
	KC0821	821	63.8	0.8	1.2	0.8
	KC0820	820	64.7	1.0	1.6	0.8
	KC0819	819	65.4	0.6	1.4	1.0
	KC0818	818.1	66.0	0.0	1.6	0.0
Fourth Avenue	KC0818	818	66.1	0.0	1.1	0.0
	KC0817	817	66.1	0.3	0.4	0.3
	KC0815	815.1	66.5	3.7	2.4	2.1
Twelfth Avenue	KC0812	812	69.5	0.7	1.3	0.7
	KC0811	811.1	70.6	1.1	2.7	1.1
	KC0811	811	71.0	0.7	1.7	0.7
	KC0809	809.1	71.2	0.7	1.7	0.7
Edmonson Avenue	KC0809	809	71.3	0.7	1.3	0.7
	KC0808	808	71.8	1.1	2.1	0.8
	KC0807	807.1	72.7	0.5	1.2	0.5
Eleventh Avenue	KC0807	807	72.8	0.5	1.2	0.5
	KC0805	805.1	72.9	1.8	3.1	1.5
	KC0805	805	73.3	0.6	1.1	0.5
	KC0804	804	75.5	0.8	1.6	0.8
	KC0803	803.1	77.7	1.0	2.0	0.9
Tenth Avenue	KC0803	803	77.9	0.7	1.3	0.7
	KC0801	801.1	78.0	1.1	2.1	1.4
	KC0801	801	78.1	0.6	1.3	1.0

TABLE B3.30
BRANCH KC11 OF TRIBUTARY 2 - PEAK WATER SURFACE ELEVATIONS

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	CHANNEL INVERT (m AHD)	PEAK WATER LEVEL (m AHD)				
				1 YR ARI	5 YR ARI	20 YR ARI	100 YR ARI	PMF
Confluence with KC 08			64.35	65.7	65.8	65.8	65.9	66.1
	KC1108	1108.1	65.20	65.7	65.9	66.2	66.2	66.4
	KC1108	1108	66.83	67.9	68.2	68.3	68.3	68.7
	KC1104	1104.1	70.37	71.0	71.3	71.4	71.4	71.7
Intersection of Edmonson	KC1104	1104	70.93	71.7	71.7	71.7	71.7	72.0
Avenue and Thirteenth	KC1102	1102.1	70.93	71.8	71.9	71.9	72.0	72.3
Avenue	KC1102	1102	70.93	71.8	71.9	71.9	72.0	72.3
	KC1101	1101	77.43	77.6	77.6	77.6	77.7	77.8

TABLE B3.31
BRANCH KC13 OF TRIBUTARY 2 - PEAK WATER SURFACE ELEVATIONS

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	CHANNEL INVERT (m AHD)	PEAK WATER LEVEL (m AHD)				
				1 YR ARI	5 YR ARI	20 YR ARI	100 YR ARI	PMF
Confluence with KC 08			57.82	58.9	59.3	59.5	59.4	60.4
	KC1310	1310	59.71	60.2	60.4	60.4	60.3	60.5
	KC1309	1309	62.82	63.4	63.6	63.5	63.7	64.0
	KC1308	1308.1	65.70	66.4	66.5	66.7	66.6	67.0
Intersection of Fourth	KC1308	1308	65.70	66.5	66.6	66.7	66.7	67.1
Avenue and Fifteenth	KC1306	1306.1	65.90	66.5	66.6	66.7	66.7	67.2
Avenue	KC1306	1306	65.39	66.6	66.7	66.8	66.8	67.2
	KC1302	1302	68.18	68.9	68.9	69.0	69.0	69.6
	KC1301	1301	71.73	71.9	72.2	72.2	72.0	72.4

B3.5 Tributary 3 and Branches

Tributary 3 joins Kemps Creek approximately 600 m upstream of Elizabeth Drive and extends over 5 km from the junction to Fourteenth Avenue. The model comprises 36 sections at an average spacing of 140 m. Five culverts are included in the model, details of which are shown on Table B3.32. All except the culvert on Seventh Avenue have a hydrologic capacity no greater than 1 year ARI.

TABLE B3.32
DETAILS OF CULVERTS - TRIBUTARY 3

Stream	Location	Opening	Waterway Area (m^2)	Approx. Capacity ARI years
Tributary 3	Fourteenth Avenue	2 off 450 RCP	0.3	< 1
	Fifteenth Avenue	3 off 750 RCP	1.3	< 1
	Sixteenth Avenue	1 off box culvert 2450 x 1200	2.9	1
	Seventeenth Avenue	2 off box culvert 3000 x 1200	7.2	> 100
	Eighteenth Avenue	1 off 800 RCP	0.5	< 1

Peak water surface elevations and velocities for the five design events modelled along Tributary 3 are shown in Tables B3.33 to B3.37. Peak water surface elevations for branches KC17, 19, 23, 24 and 27 are given in Tables B3.38 to B3.42.

Water surface profiles are shown on Figures B3.16 to B3.21 and several typical cross sections and rating curves are shown on Figure B3.22 (2 sheets).

TABLE B3.33
HYDRAULIC MODEL RESULTS TRIBUTARY 3 - 1 YEAR ARI

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	PEAK WATER LEVEL (m AHD)	VELOCITY (m/s) LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
Confluence With	KC0038	1.25	46.5	0.4	0.4	0.2
Kemps Creek	KC0038	1.251	46.4	0.2	2.0	0.0
	KC1436	1436	50.9	0.2	0.6	0.3
	KC1434	1434	52.5	0.3	0.9	0.5
	KC1432	1432	55.0	0.3	0.8	0.2
	KC1431	1431	55.8	0.0	1.0	0.3
	KC1430	1430	57.5	0.3	0.6	0.3
	KC1429	1429	58.6	0.4	0.5	0.2
	KC1427	1427	60.4	0.2	0.5	0.2
	KC1426	1426	61.3	0.3	0.7	0.5
	KC1424	1424	62.5	0.0	0.8	0.0
	KC1422	1422	63.2	0.4	0.6	0.2
	KC1420	1420.1	65.1	0.5	1.6	0.0
Eighteenth Avenue	KC1420	1420	65.4	0.4	0.7	0.0
	KC1418	1418.1	65.5	0.2	0.4	0.2
	KC1418	1418	65.6	0.3	0.2	0.0
	KC1417	1417	66.8	0.0	2.1	0.0
	KC1416	1416.1	67.6	0.0	0.6	0.0
Seventeenth Avenue	KC1416	1416	67.6	0.0	0.4	0.0
	KC1414	1414.1	67.6	0.0	0.4	0.0
	KC1414	1414	67.8	0.4	1.3	0.0
	KC1413	1413	69.3	0.5	0.4	0.0
	KC1412	1412.1	70.7	0.0	1.9	0.0
Sixteenth Avenue	KC1412	1412	71.0	0.0	0.8	0.0
	KC1410	1410.1	71.0	0.0	0.9	0.0
	KC1410	1410	71.1	0.0	1.1	0.0
	KC1409	1409	72.3	0.0	0.4	0.2
	KC1408	1408	73.6	0.0	1.3	0.0
	KC1407	1407.1	75.7	0.0	0.8	0.0
Fifteenth Avenue	KC1407	1407	75.8	0.0	0.5	0.0
	KC1405	1405.1	76.1	0.0	0.8	0.0
	KC1405	1405	76.4	0.1	0.8	0.0
	KC1404	1404	78.3	0.0	0.4	0.2
	KC1403	1403.1	80.8	0.0	1.5	0.0
Fourteenth Avenue	KC1403	1403	81.2	0.0	0.9	0.0
	KC1401	1401.1	81.5	0.0	0.3	0.0
	KC1401	1401	81.5	0.1	0.1	0.0

TABLE B3.34
HYDRAULIC MODEL RESULTS TRIBUTARY 3 - 5 YEAR ARI

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	PEAK WATER LEVEL (m AHD)	VELOCITY (m/s)		
				LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
Confluence With	KC0038	1.25	47.2	0.5	0.6	0.3
Kemps Creek	KC0038	1.251	47.3	0.3	0.5	0.2
	KC1436	1436	50.8	0.8	2.4	1.0
	KC1434	1434	53.1	0.3	0.7	0.4
	KC1432	1432	55.0	0.7	1.9	0.5
	KC1431	1431	56.2	0.1	0.9	0.3
	KC1430	1430	57.6	0.4	0.8	0.5
	KC1429	1429	59.0	0.5	0.8	0.3
	KC1427	1427	60.7	0.4	0.7	0.2
	KC1426	1426	61.5	0.6	0.9	0.7
	KC1424	1424	62.9	0.5	1.1	0.2
	KC1422	1422	63.5	0.6	0.7	0.3
	KC1420	1420.1	65.3	1.1	2.0	0.0
Eighteenth Avenue	KC1420	1420	65.6	0.3	0.7	0.5
	KC1418	1418.1	65.7	0.4	0.7	0.3
	KC1418	1418	65.7	0.3	0.3	0.0
	KC1417	1417	67.3	0.7	1.6	0.3
	KC1416	1416.1	68.1	0.0	0.9	0.0
Seventeenth Avenue	KC1416	1416	68.1	0.0	0.5	0.4
	KC1414	1414.1	68.2	0.2	0.5	0.0
	KC1414	1414	68.2	0.4	0.6	0.0
	KC1413	1413	69.3	1.1	0.9	0.0
	KC1412	1412.1	71.2	0.0	1.1	0.7
Sixteenth Avenue	KC1412	1412	71.3	0.0	1.6	0.0
	KC1410	1410.1	71.5	0.0	1.5	0.0
	KC1410	1410	71.7	0.2	0.5	0.3
	KC1409	1409	72.3	0.0	1.0	0.5
	KC1408	1408	73.9	0.0	0.9	0.5
	KC1407	1407.1	75.8	0.0	1.7	0.0
Fifteenth Avenue	KC1407	1407	76.1	0.0	1.0	0.0
	KC1405	1405.1	76.6	0.0	0.3	0.2
	KC1405	1405	76.6	0.2	0.3	0.1
	KC1404	1404	78.3	0.0	1.4	0.8
	KC1403	1403.1	81.2	0.3	0.8	0.3
Fourteenth Avenue	KC1403	1403	81.4	0.0	2.0	0.0
	KC1401	1401.1	81.8	0.1	0.1	0.0
	KC1401	1401	81.8	0.1	0.1	0.0

TABLE B3.35
HYDRAULIC MODEL RESULTS TRIBUTARY 3 - 20 YEAR ARI

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	PEAK WATER LEVEL (m AHD)	VELOCITY (m/s)		
				LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
Confluence With	KC0038	1.25	47.6	0.5	0.7	0.3
Kemps Creek	KC0038	1.251	47.6	0.3	0.6	0.2
	KC1436	1436	50.9	1.0	2.8	1.1
	KC1434	1434	53.3	0.3	0.8	0.4
	KC1432	1432	55.1	0.7	1.9	0.7
	KC1431	1431	56.4	0.2	1.1	0.4
	KC1430	1430	57.8	0.5	0.9	0.6
	KC1429	1429	59.2	0.7	0.9	0.4
	KC1427	1427	60.9	0.4	0.8	0.3
	KC1426	1426	61.7	0.7	1.0	0.8
	KC1424	1424	63.1	0.7	1.2	0.5
	KC1422	1422	63.7	0.7	0.8	0.4
	KC1420	1420.1	65.4	1.4	2.3	0.0
Eighteenth Avenue	KC1420	1420	65.8	0.4	0.7	0.5
	KC1418	1418.1	65.8	0.4	0.7	0.3
	KC1418	1418	65.8	0.4	0.4	0.1
	KC1417	1417	67.4	0.8	1.8	0.5
	KC1416	1416.1	68.3	0.0	1.2	0.2
Seventeenth Avenue	KC1416	1416	68.4	0.3	0.5	0.3
	KC1414	1414.1	68.4	0.3	0.5	0.1
	KC1414	1414	68.4	0.4	0.6	0.1
	KC1413	1413	69.3	1.7	1.4	0.0
	KC1412	1412.1	71.4	0.3	1.1	0.8
Sixteenth Avenue	KC1412	1412	71.5	0.0	2.1	0.0
	KC1410	1410.1	71.8	0.3	0.6	0.3
	KC1410	1410	71.8	0.2	0.4	0.3
	KC1409	1409	72.3	0.0	1.4	0.7
	KC1408	1408	74.1	0.0	0.8	0.6
	KC1407	1407.1	75.9	0.0	1.7	0.6
Fifteenth Avenue	KC1407	1407	76.2	0.0	1.3	0.0
	KC1405	1405.1	76.7	0.1	0.2	0.1
	KC1405	1405	76.7	0.2	0.3	0.1
	KC1404	1404	78.3	0.0	1.5	0.9
	KC1403	1403.1	81.2	0.4	0.9	0.3
Fourteenth Avenue	KC1403	1403	81.4	0.0	2.8	0.0
	KC1401	1401.1	81.8	0.1	0.1	0.0
	KC1401	1401	81.8	0.1	0.1	0.0

TABLE B3.36
HYDRAULIC MODEL RESULTS TRIBUTARY 3 - 100 YEAR ARI

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	PEAK WATER LEVEL (m AHD)	VELOCITY (m/s)		
				LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
Confluence With	KC0038	1.25	48.0	0.6	0.7	0.4
Kemps Creek	KC0038	1.251	48.1	0.3	0.5	0.2
	KC1436	1436	51.0	1.1	3.0	1.2
	KC1434	1434	53.5	0.3	0.9	0.5
	KC1432	1432	55.2	0.7	1.9	0.7
	KC1431	1431	56.5	0.3	1.2	0.5
	KC1430	1430	57.9	0.5	0.9	0.6
	KC1429	1429	59.2	0.7	1.0	0.5
	KC1427	1427	61.0	0.4	0.8	0.3
	KC1426	1426	61.8	0.7	1.1	0.9
	KC1424	1424	63.1	0.8	1.3	0.6
	KC1422	1422	63.8	0.7	0.8	0.4
	KC1420	1420.1	65.5	1.4	2.3	0.0
Eighteenth Avenue	KC1420	1420	65.9	0.4	0.7	0.5
	KC1418	1418.1	65.9	0.4	0.7	0.3
	KC1418	1418	65.9	0.4	0.4	0.1
	KC1417	1417	67.4	0.8	1.8	0.6
	KC1416	1416.1	68.4	0.1	1.3	0.3
Seventeenth Avenue	KC1416	1416	68.5	0.3	0.5	0.3
	KC1414	1414.1	68.5	0.3	0.6	0.1
	KC1414	1414	68.5	0.5	0.6	0.2
	KC1413	1413	69.4	1.8	1.5	0.0
	KC1412	1412.1	71.4	0.3	1.2	0.8
Sixteenth Avenue	KC1412	1412	71.5	0.0	2.6	0.0
	KC1410	1410.1	71.9	0.3	0.6	0.3
	KC1410	1410	71.9	0.2	0.5	0.3
	KC1409	1409	72.3	0.0	1.4	0.8
	KC1408	1408	74.1	0.0	0.9	0.6
	KC1407	1407.1	76.0	0.0	1.8	0.8
Fifteenth Avenue	KC1407	1407	76.2	0.0	1.7	0.0
	KC1405	1405.1	76.7	0.2	0.3	0.2
	KC1405	1405	76.7	0.2	0.3	0.2
	KC1404	1404	78.3	0.0	1.7	1.1
	KC1403	1403.1	81.3	0.4	0.9	0.3
Fourteenth Avenue	KC1403	1403	81.6	0.0	3.1	0.0
	KC1401	1401.1	82.1	0.1	0.1	0.0
	KC1401	1401	82.1	0.1	0.1	0.0

TABLE B3.37
HYDRAULIC MODEL RESULTS TRIBUTARY 3 - PMF

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	PEAK WATER LEVEL (m AHD)	VELOCITY (m/s)		
				LEFT OVERBANK	CHANNEL	RIGHT OVERBANK
Confluence With	KC0038	1.25	49.6	1.1	1.0	0.7
Kemps Creek	KC0038	1.251	49.6	0.5	0.8	0.4
	KC1436	1436	51.4	1.9	4.5	2.2
	KC1434	1434	54.5	0.7	1.3	0.7
	KC1432	1432	56.1	0.9	2.0	1.0
	KC1431	1431	57.3	0.6	2.0	0.9
	KC1430	1430	59.0	0.9	1.5	0.9
	KC1429	1429	60.2	0.9	1.7	0.8
	KC1427	1427	62.0	0.7	1.2	0.6
	KC1426	1426	62.7	1.2	1.5	1.3
	KC1424	1424	63.8	1.1	1.7	1.1
	KC1422	1422	64.5	1.3	1.3	0.9
	KC1420	1420.1	66.1	1.9	3.0	0.9
Eighteenth Avenue	KC1420	1420	66.5	0.6	0.9	0.4
	KC1418	1418.1	66.5	0.6	0.9	0.5
	KC1418	1418	66.5	0.5	0.6	0.3
	KC1417	1417	67.7	1.5	2.7	1.2
	KC1416	1416.1	69.0	0.8	1.9	0.9
Seventeenth Avenue	KC1416	1416	69.1	0.6	1.0	0.5
	KC1414	1414.1	69.1	0.6	1.1	0.4
	KC1414	1414	69.2	0.8	0.9	0.5
	KC1413	1413	70.1	2.3	2.4	1.0
	KC1412	1412.1	72.1	0.9	1.7	1.3
Sixteenth Avenue	KC1412	1412	72.3	0.6	1.1	0.7
	KC1410	1410.1	72.3	0.7	1.4	0.8
	KC1410	1410	72.4	0.6	1.0	0.7
	KC1409	1409	72.9	0.5	1.3	1.1
	KC1408	1408	74.5	0.3	1.9	1.5
	KC1407	1407.1	76.6	0.5	1.8	1.1
Fifteenth Avenue	KC1407	1407	76.7	0.3	0.8	0.4
	KC1405	1405.1	76.9	0.4	0.6	0.4
	KC1405	1405	76.9	0.5	0.6	0.4
	KC1404	1404	78.6	0.0	1.7	1.5
	KC1403	1403.1	81.5	0.7	1.2	0.6
Fourteenth Avenue	KC1403	1403	81.8	0.4	0.7	0.0
	KC1401	1401.1	82.0	0.3	0.5	0.0
	KC1401	1401	82.0	0.2	0.3	0.2

TABLE B3.38
BRANCH KC17 OF TRIBUTARY 3 - PEAK WATER SURFACE ELEVATIONS

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	CHANNEL INVERT (m AHD)	PEAK WATER LEVEL (m AHD) 1 YR ARI	5 YR ARI	20 YR ARI	100 YR ARI	PMF
Confluence with KC 14			57.99	58.6	59.0	59.2	59.2	60.2
	KC1703	1703	58.28	58.8	59.1	59.3	59.4	60.4
	KC1702	1702	61.46	61.8	62.0	62.1	62.1	62.3
	KC1701	1701	66.96	67.1	67.2	67.2	67.3	67.6

TABLE B3.39
BRANCH KC19 OF TRIBUTARY 3 - PEAK WATER SURFACE ELEVATIONS

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	CHANNEL INVERT (m AHD)	PEAK WATER LEVEL (m AHD) 1 YR ARI	5 YR ARI	20 YR ARI	100 YR ARI	PMF
Confluence with KC 14			62.31	63.2	63.5	63.7	63.8	64.5
	KC1902	1902	65.26	65.4	65.5	65.5	65.5	65.7
	KC1901	1901.1	67.00	67.3	67.5	67.5	67.6	67.9
	KC1901	1901	70.87	71.1	71.3	71.6	71.7	72.0

TABLE B3.40
BRANCH KC23 OF TRIBUTARY 3 - PEAK WATER SURFACE ELEVATIONS

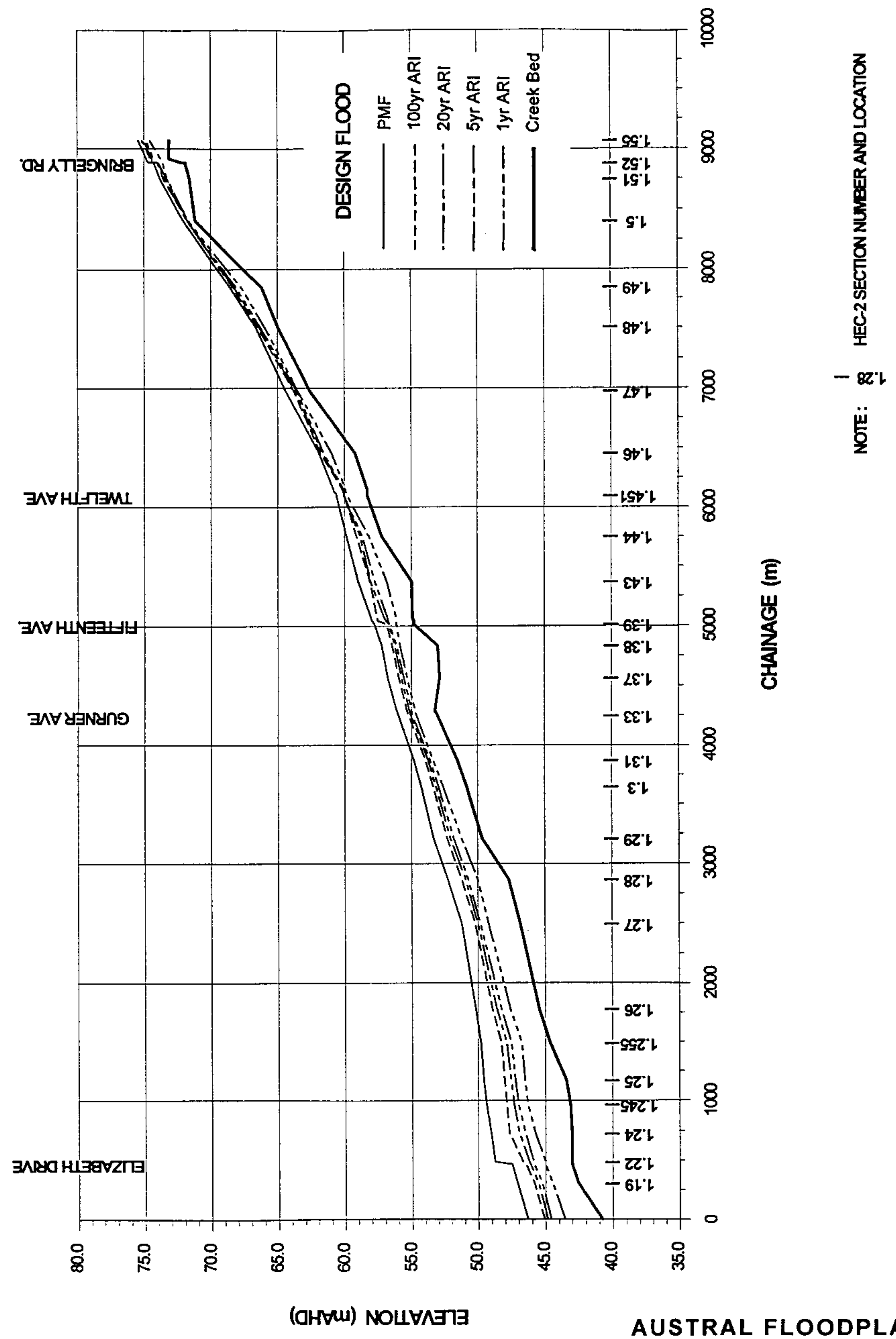
LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	CHANNEL INVERT (m AHD)	PEAK WATER LEVEL (m AHD) 1 YR ARI	5 YR ARI	20 YR ARI	100 YR ARI	PMF
Confluence with KC 14			54.03	55.8	56.2	56.4	56.5	57.3
	KC2302	2302	56.00	56.5	56.6	56.8	56.9	57.8
	KC2301	2301.1	59.50	59.8	60.2	60.3	60.3	60.8
	KC2301	2301	62.92	63.6	63.9	64.1	64.1	64.3

TABLE B3.41
BRANCH KC24 OF TRIBUTARY 3 - PEAK WATER SURFACE ELEVATIONS

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	CHANNEL INVERT (m AHD)	PEAK WATER LEVEL (m AHD)				
				1 YR ARI	5 YR ARI	20 YR ARI	100 YR ARI	PMF
Confluence with KC 14			51.80	52.5	53.1	53.3	53.5	54.5
	KC2405	2405	53.91	54.1	54.1	54.2	54.2	54.9
	KC2404	2404	55.70	56.1	56.3	56.4	56.4	56.6
	KC2403	2403	57.71	58.2	58.2	58.3	58.3	59.0
	KC2402	2402	62.29	62.9	63.3	63.4	63.4	63.5
	KC2401	2401	72.71	72.9	73.0	73.0	73.1	73.3

TABLE B.3.42
BRANCH KC27 OF TRIBUTARY 3 - PEAK WATER SURFACE ELEVATIONS

LOCATION	SURVEYED CROSS SECTION NUMBER	HEC-2 CROSS SECTION NUMBER	CHANNEL INVERT (m AHD)	PEAK WATER LEVEL (m AHD)				
				1 YR ARI	5 YR ARI	20 YR ARI	100 YR ARI	PMF
Confluence with KC 14			49.59	50.9	50.9	50.9	51.0	51.4
	KC2705.2	2705.2	51.70	52.0	52.5	52.9	53.0	54.0
	KC2705.1	2705.1	55.00	55.8	55.7	55.9	56.0	56.9
	KC2705	2705	56.55	56.8	57.0	57.2	57.2	57.9
	KC2704	2704	58.76	59.5	59.6	59.6	59.6	59.9
	KC2702	2702	68.45	68.8	69.2	69.4	69.4	70.1
	KC2701	2701	78.62	78.8	78.7	78.8	78.8	79.0

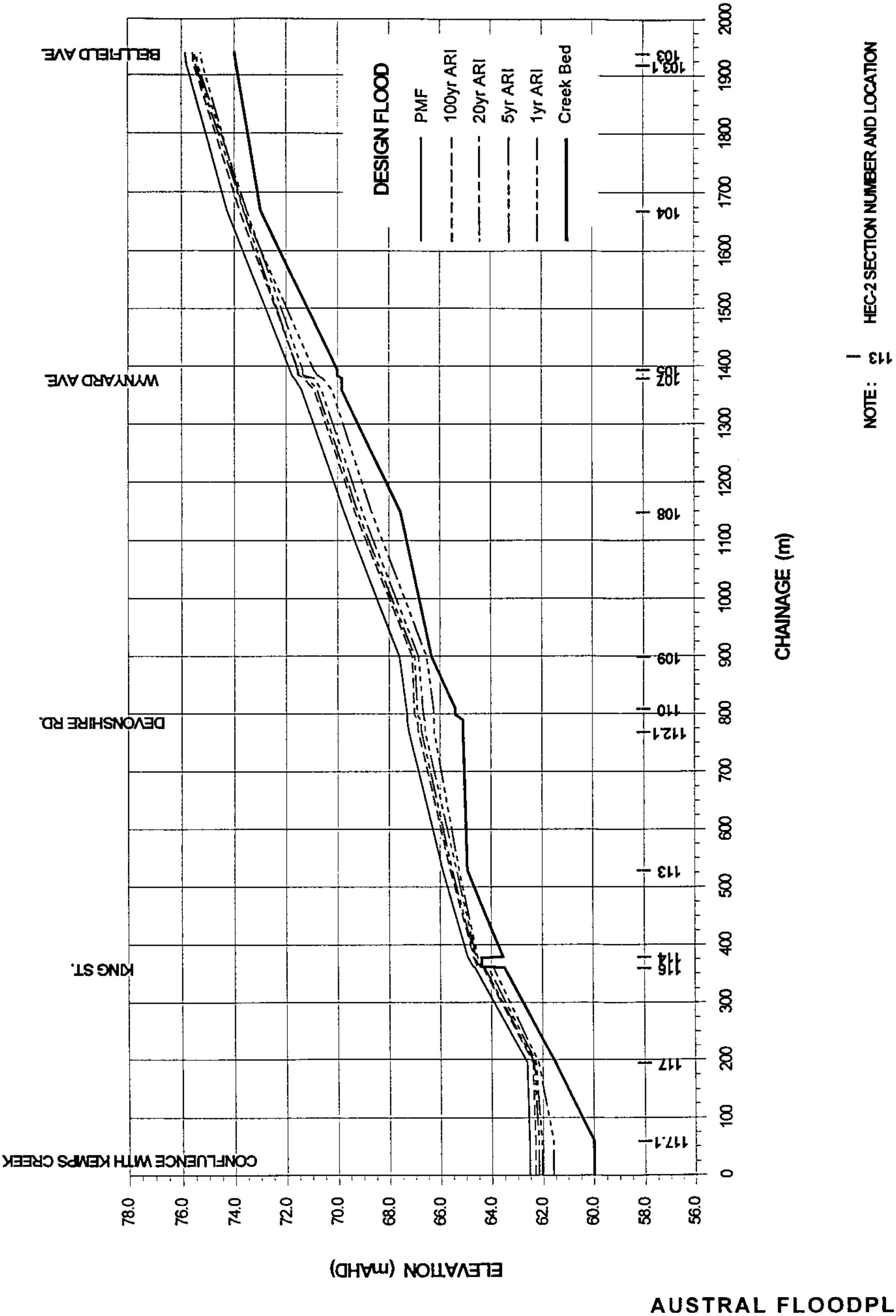


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.1

KEMPS CREEK

WATER SURFACE PROFILES - EXISTING CONDITIONS

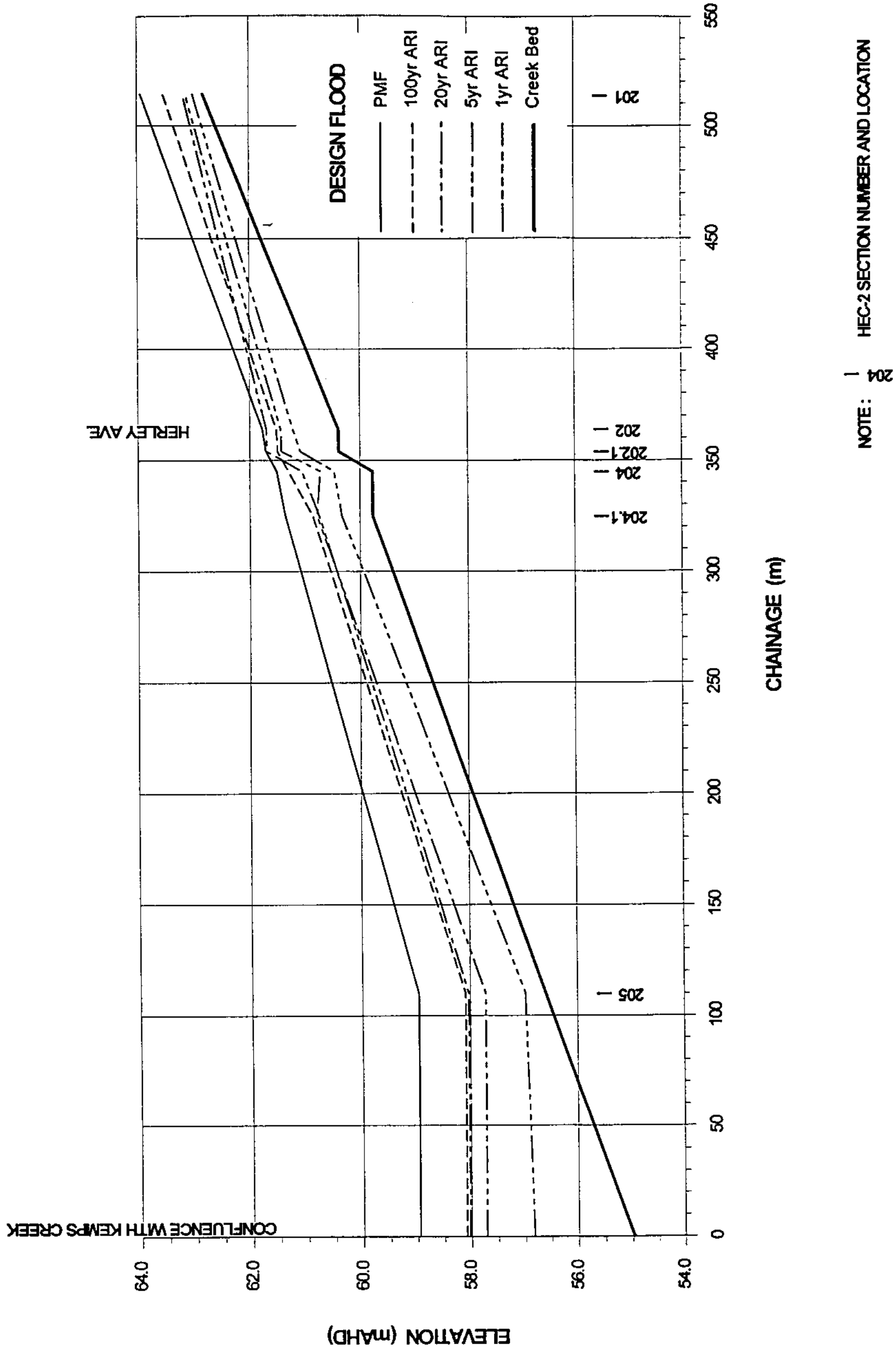


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.2

BRANCH KC01 OF KEMPS CREEK

WATER SURFACE PROFILES - EXISTING CONDITIONS

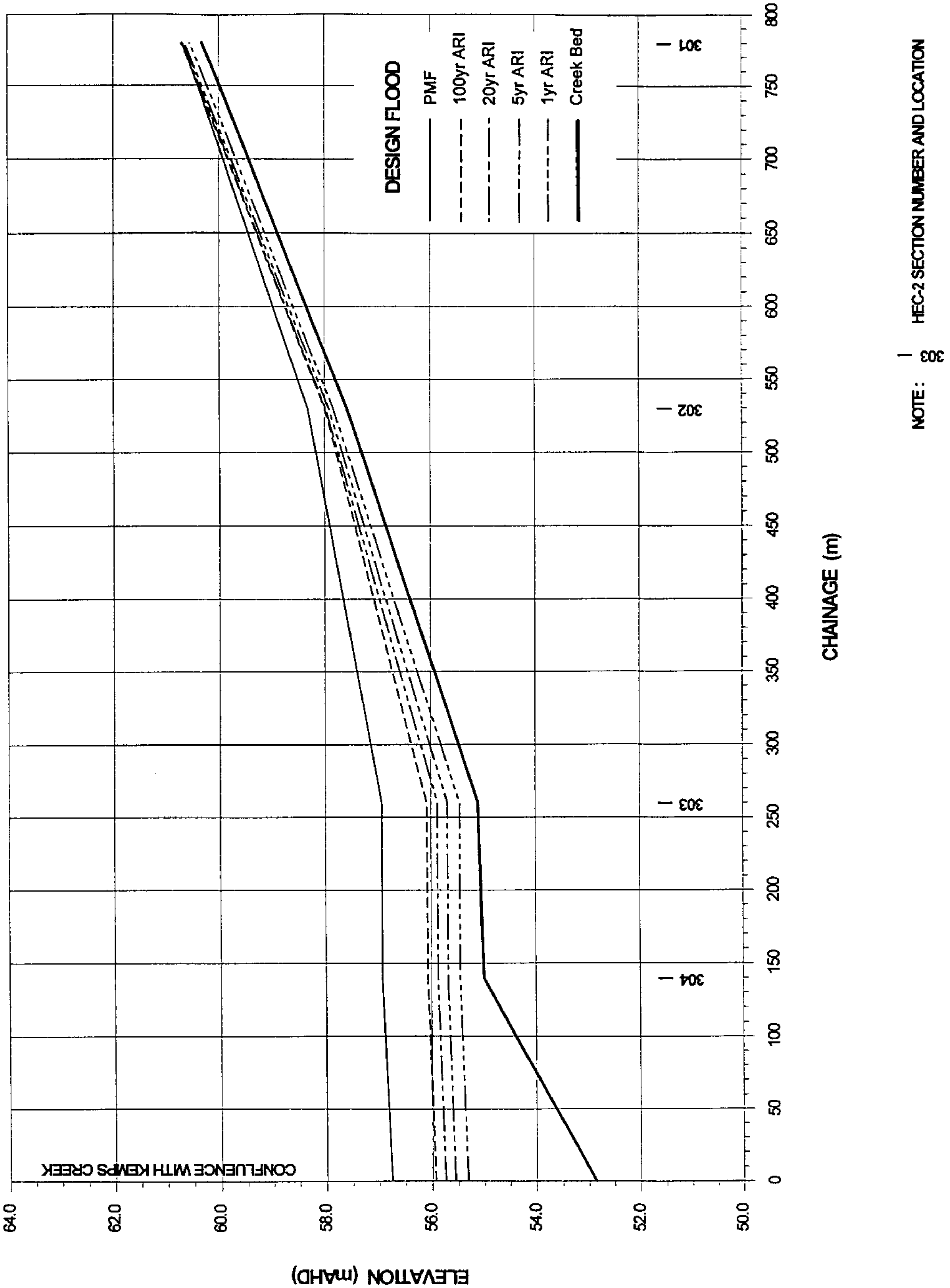


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.3

BRANCH KC02 OF KEMPS CREEK

WATER SURFACE PROFILES - EXISTING CONDITIONS

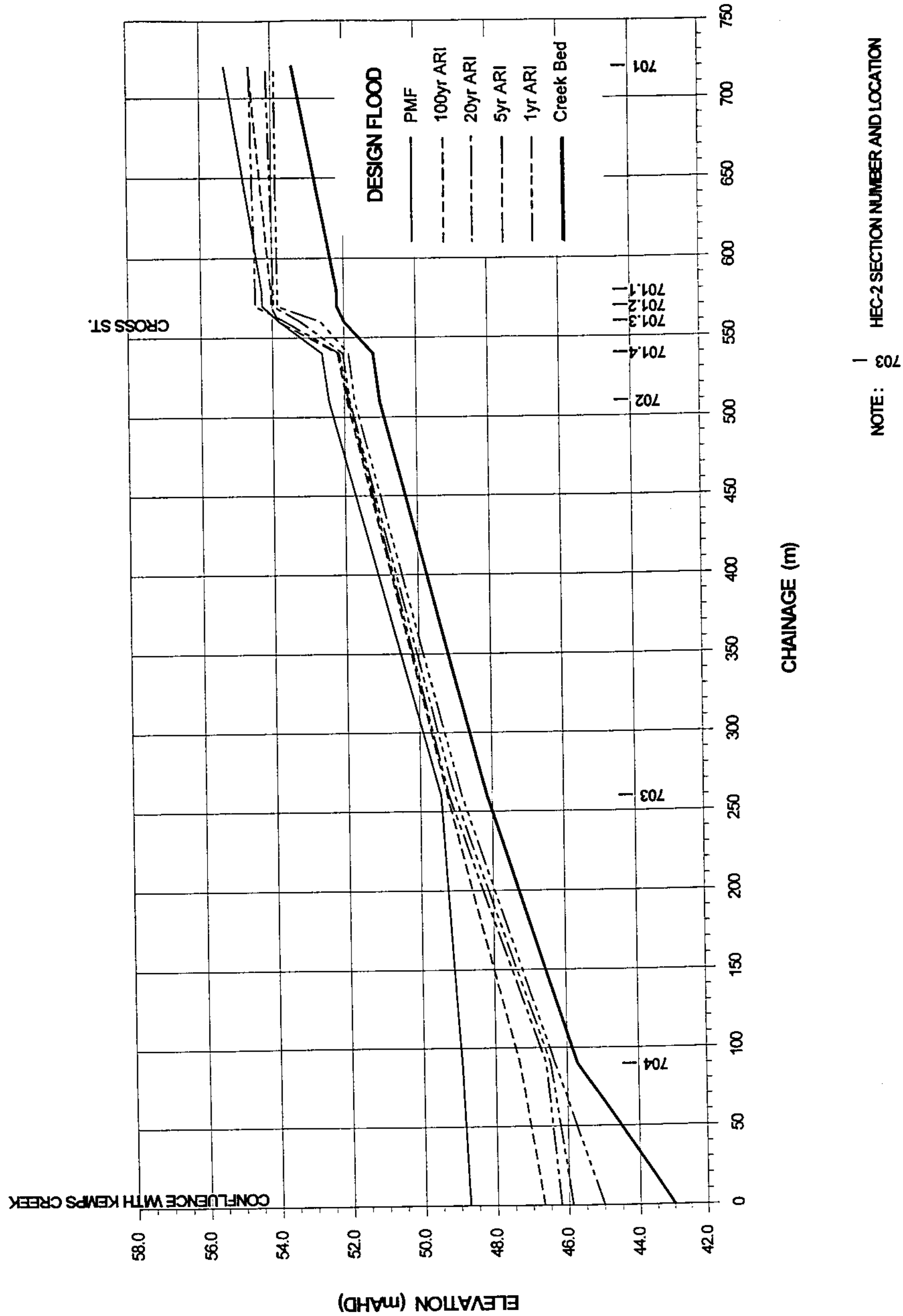


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.4

BRANCH KC03 OF KEMPS CREEK

WATER SURFACE PROFILES - EXISTING CONDITIONS

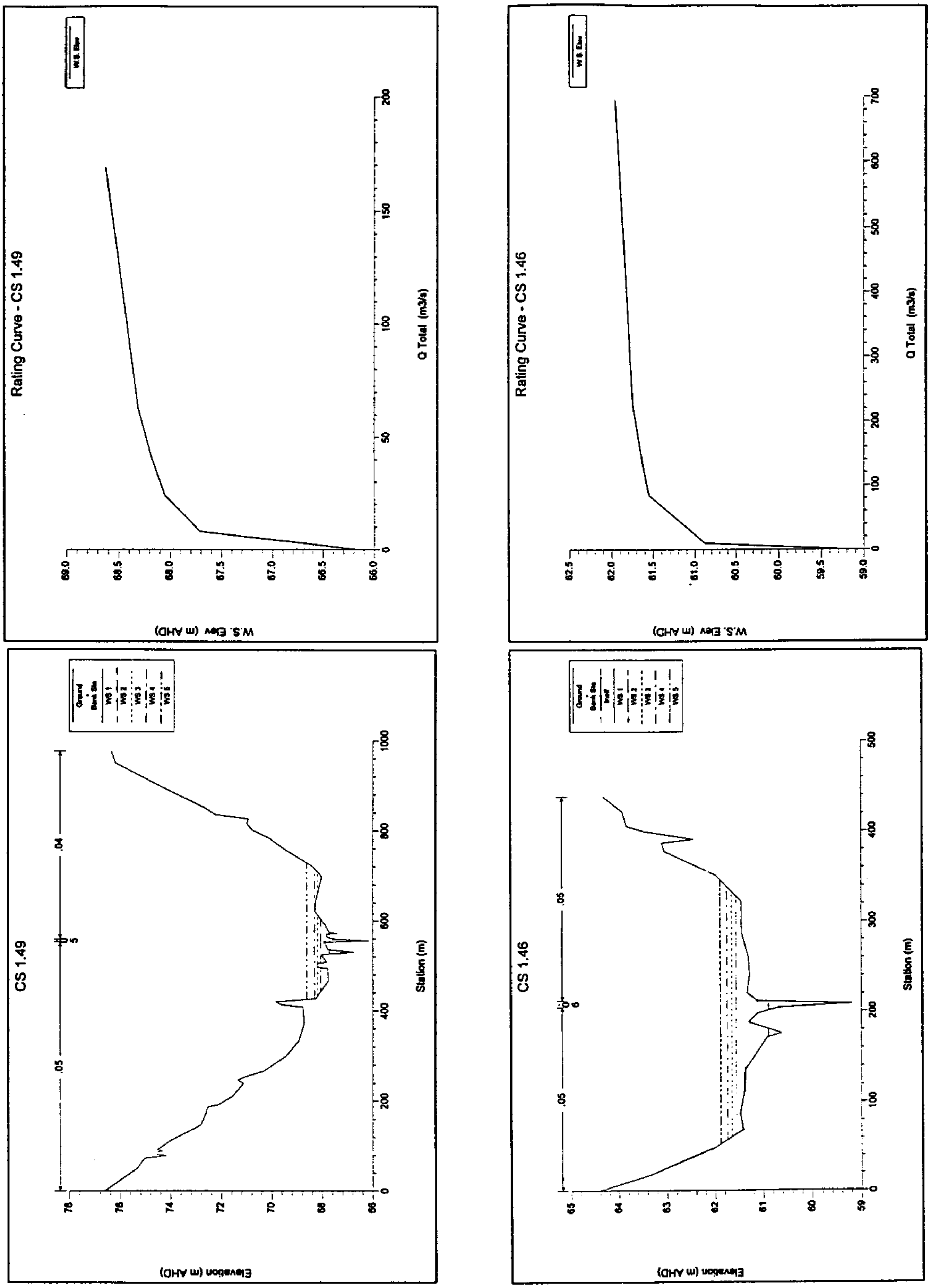


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.5

BRANCH KC07 OF KEMPS CREEK

WATER SURFACE PROFILES - EXISTING CONDITIONS

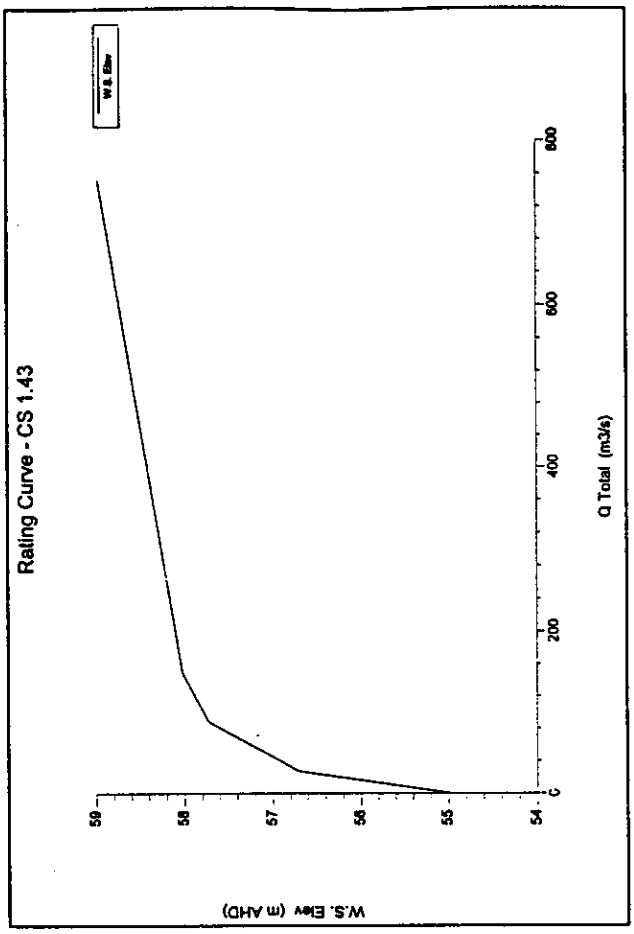


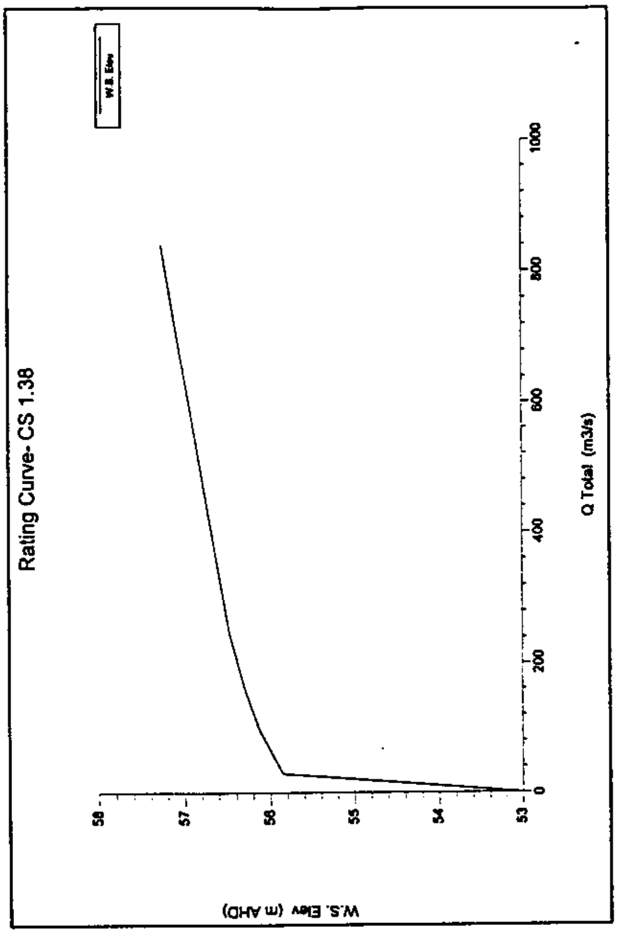
AUSTRAL FLOODPLAIN MANAGEMENT STUDY

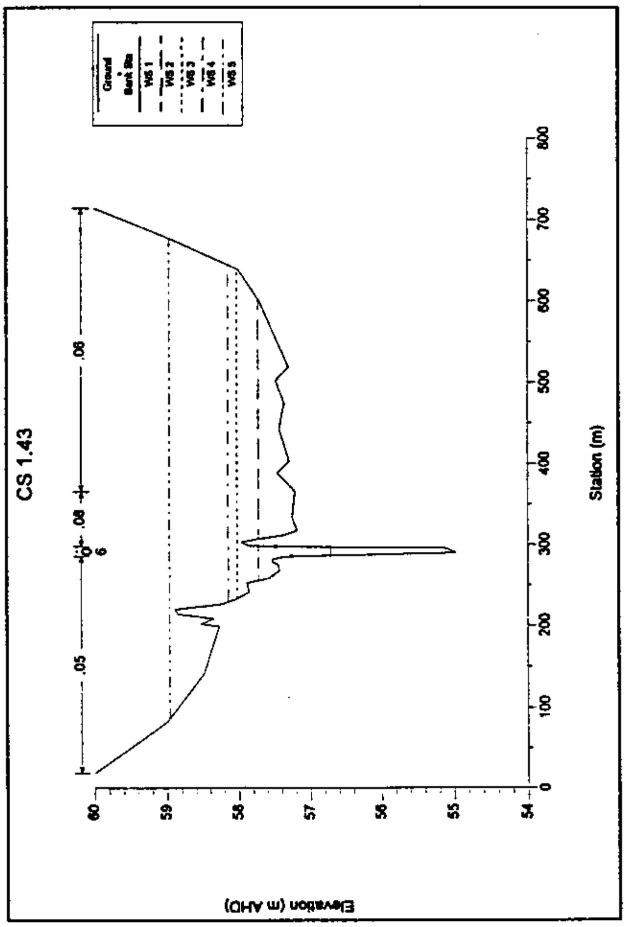
Figure B3.6

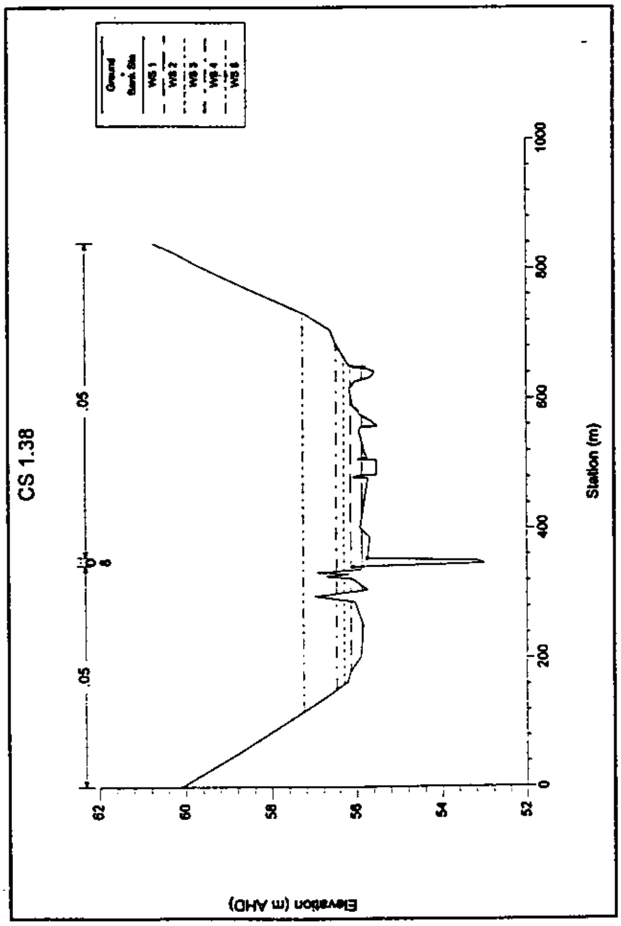
KEMPS CREEK

TYPICAL CROSS SECTIONS AND RATING CURVES







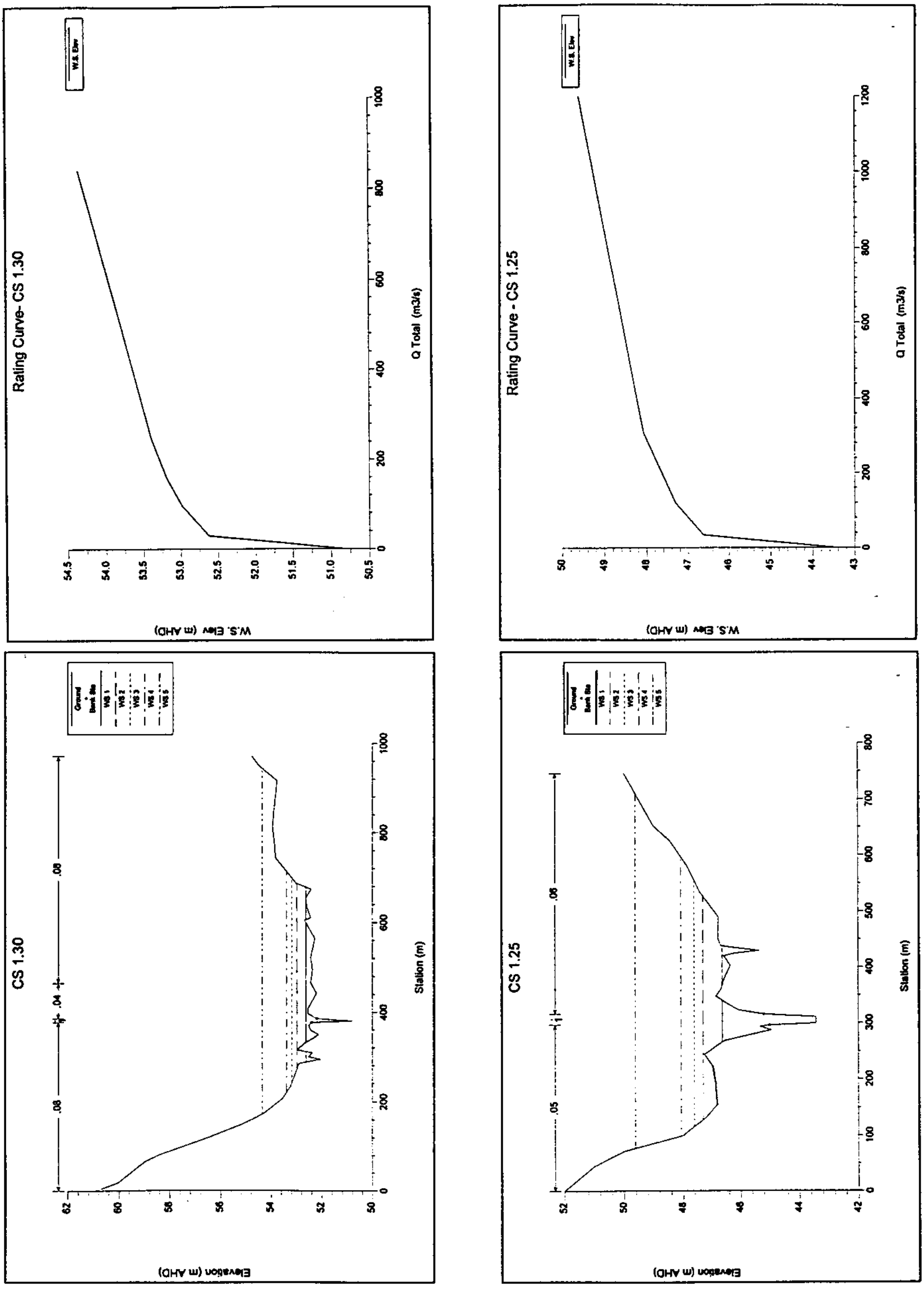


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.6 (cont.)

KEMPS CREEK

TYPICAL CROSS SECTIONS AND RATING CURVES

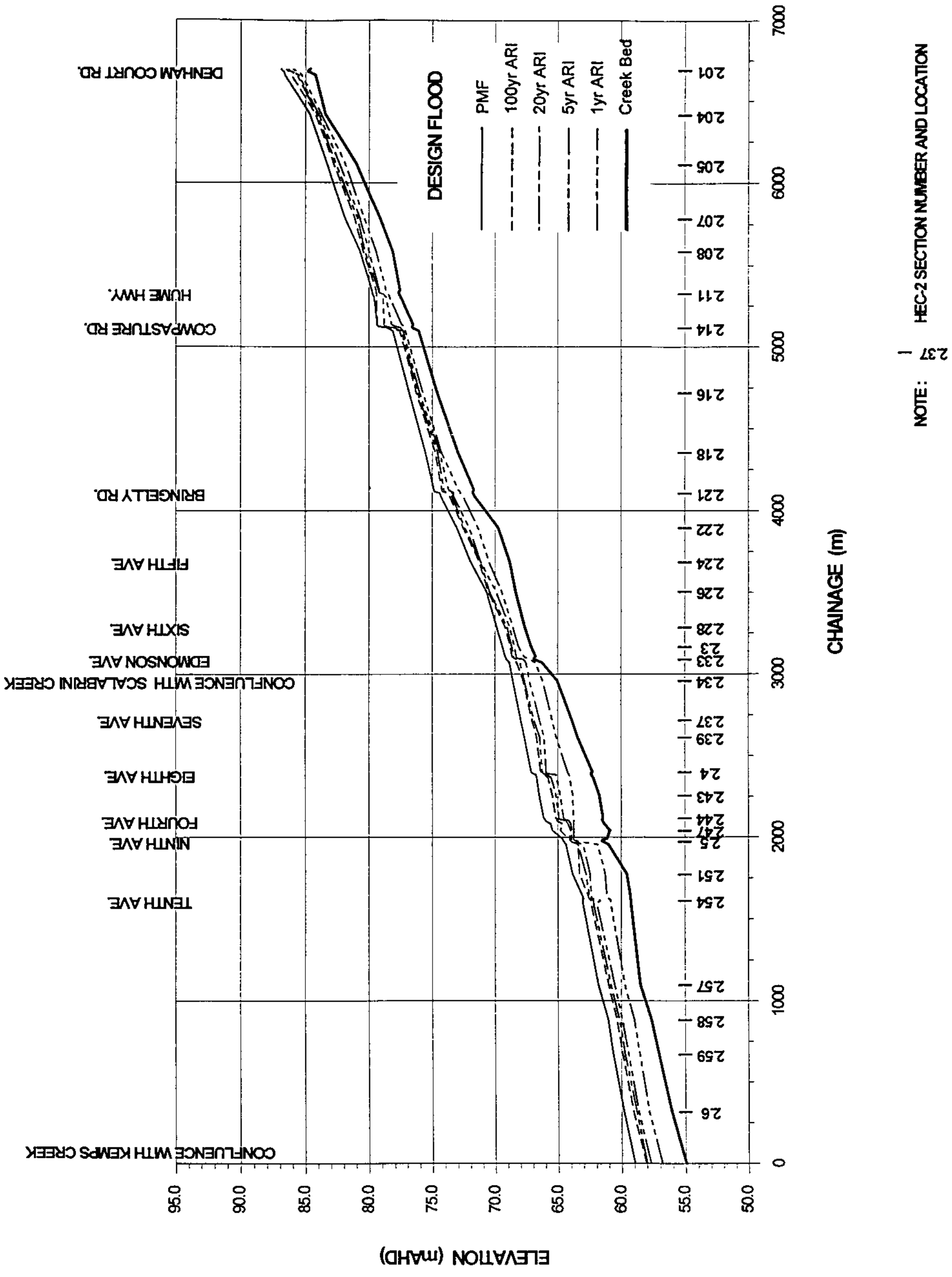


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.6 (cont.)

KEMPS CREEK

TYPICAL CROSS SECTIONS AND RATING CURVES

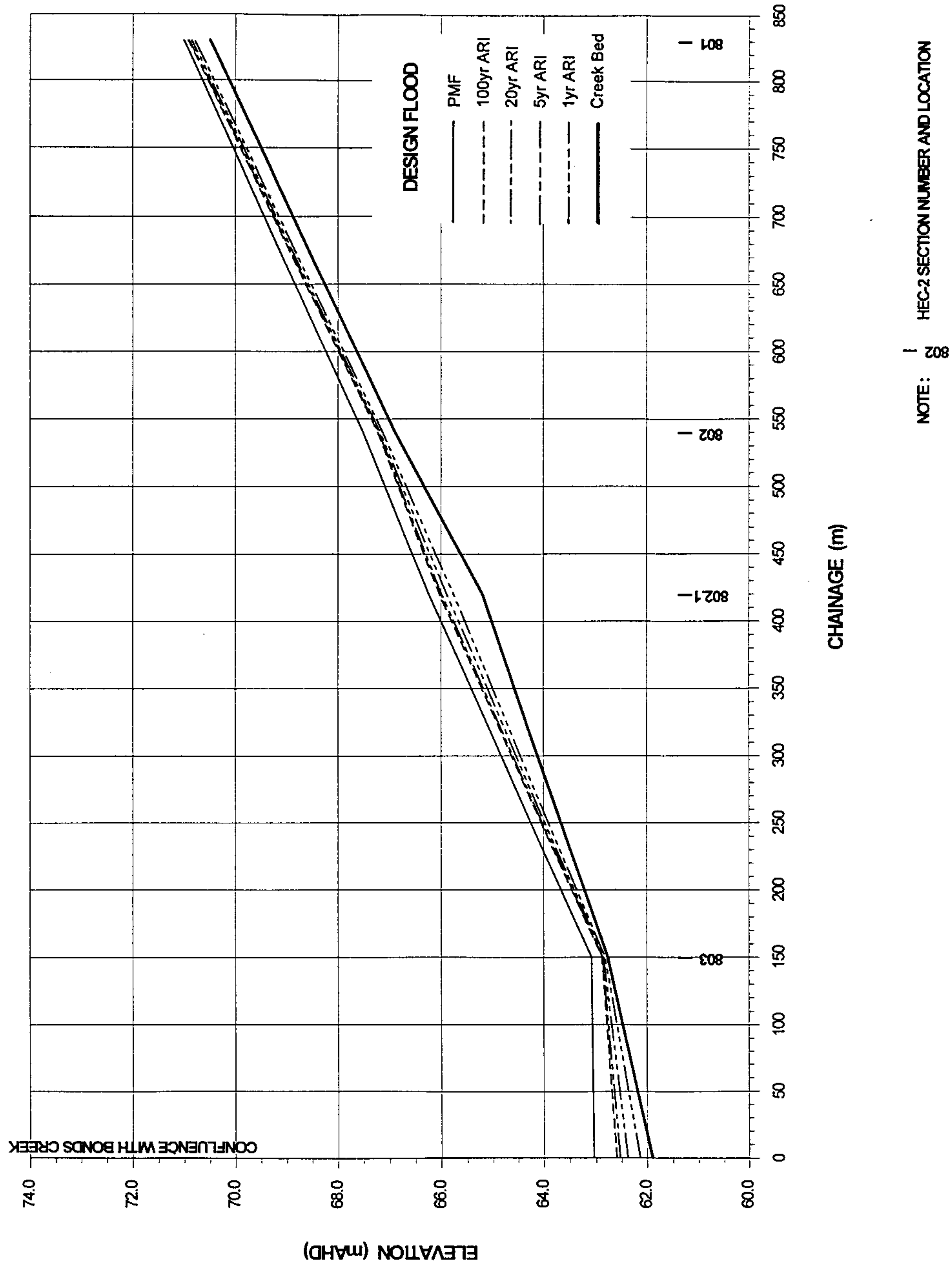


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.7

BONDS CREEK

WATER SURFACE PROFILES - EXISTING CONDITIONS

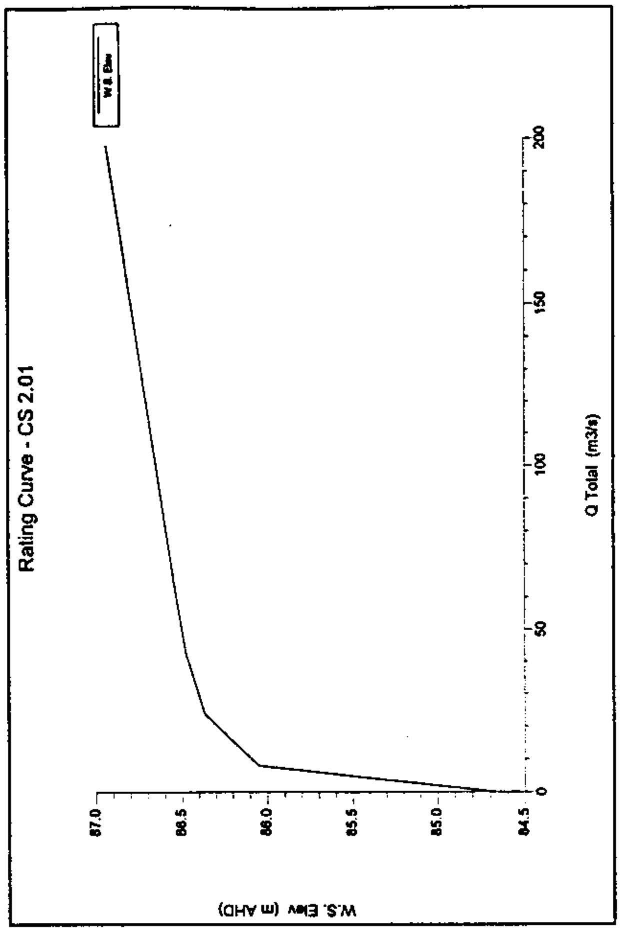


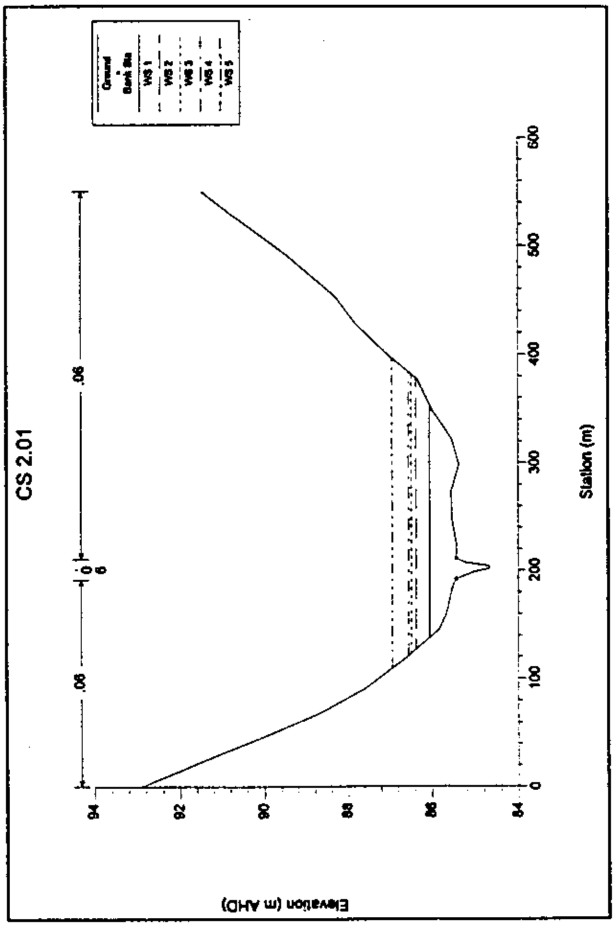
AUSTRAL FLOODPLAIN MANAGEMENT STUDY

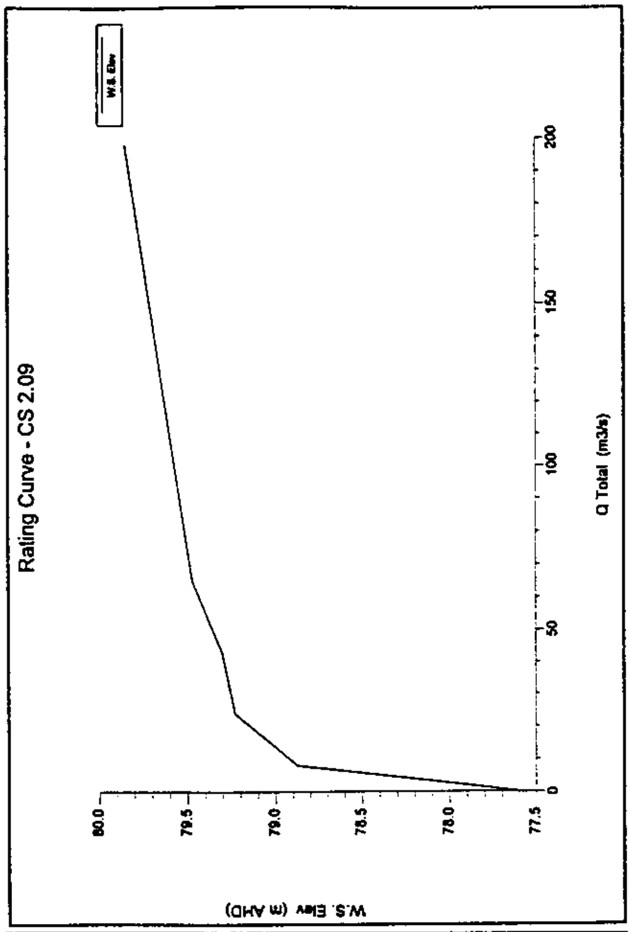
Figure B3.8

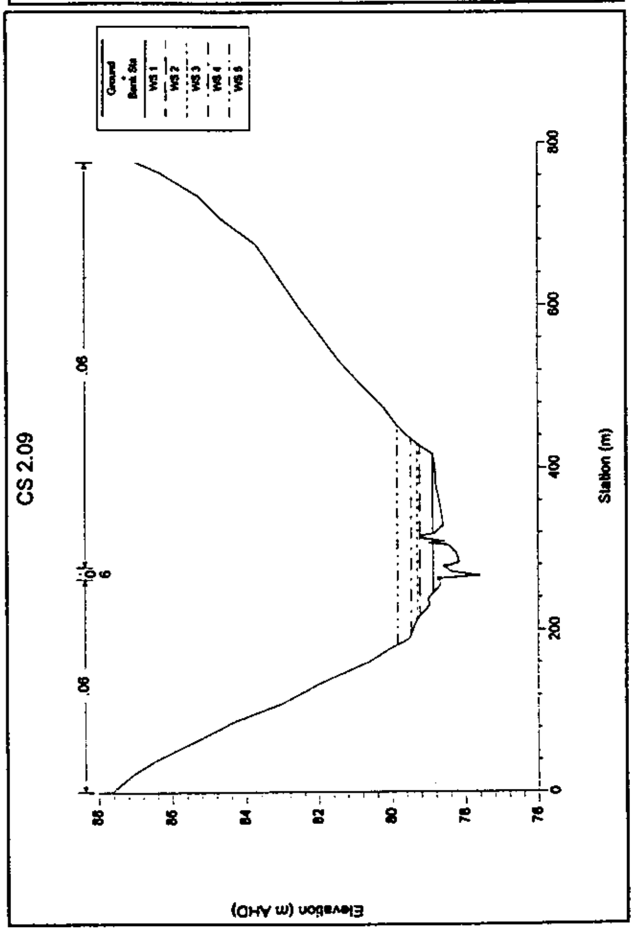
BRANCH BC08 OF BONDS CREEK

WATER SURFACE PROFILES - EXISTING CONDITIONS







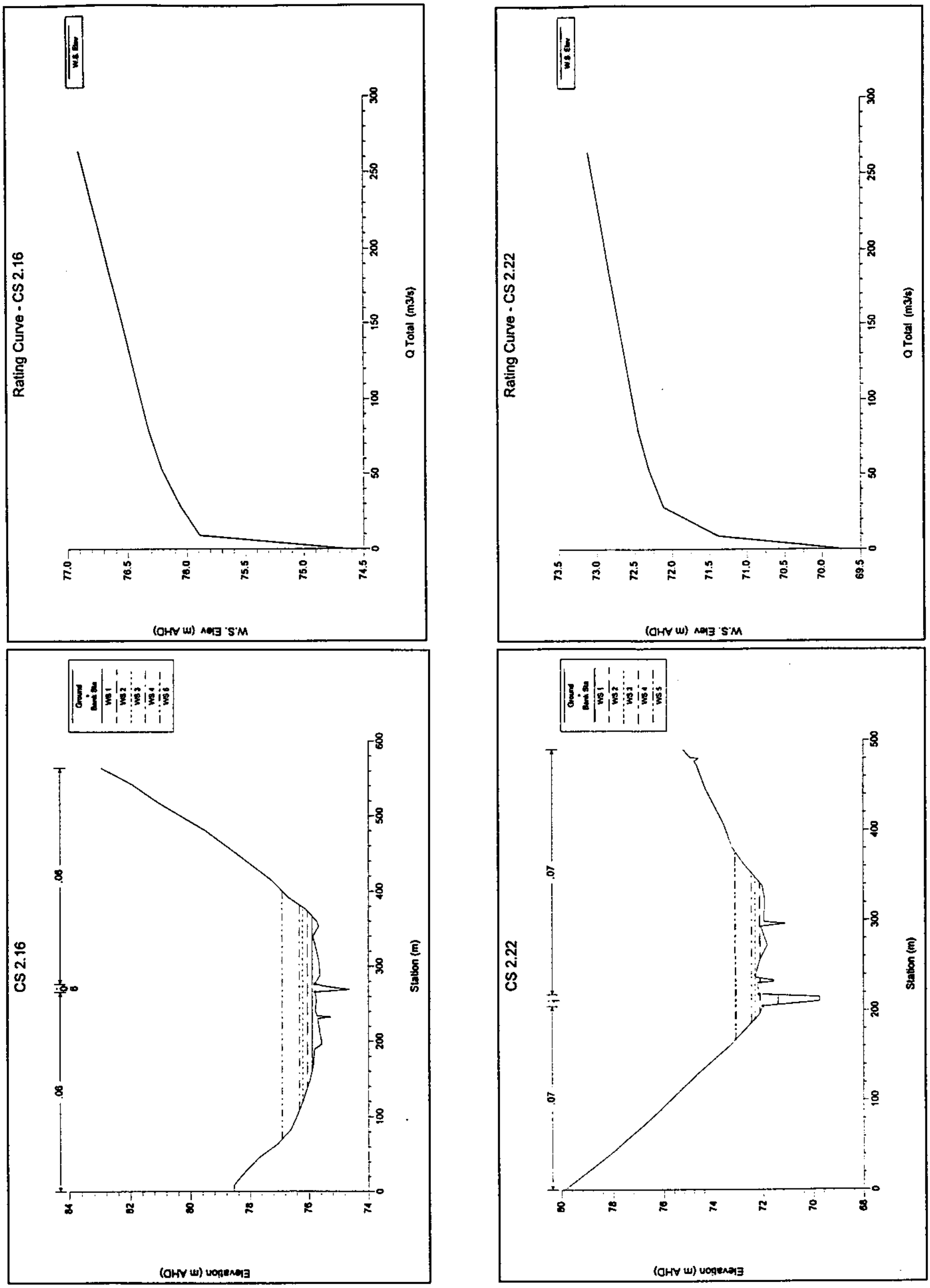


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.9

BONDS CREEK

TYPICAL CROSS SECTIONS AND RATING CURVES

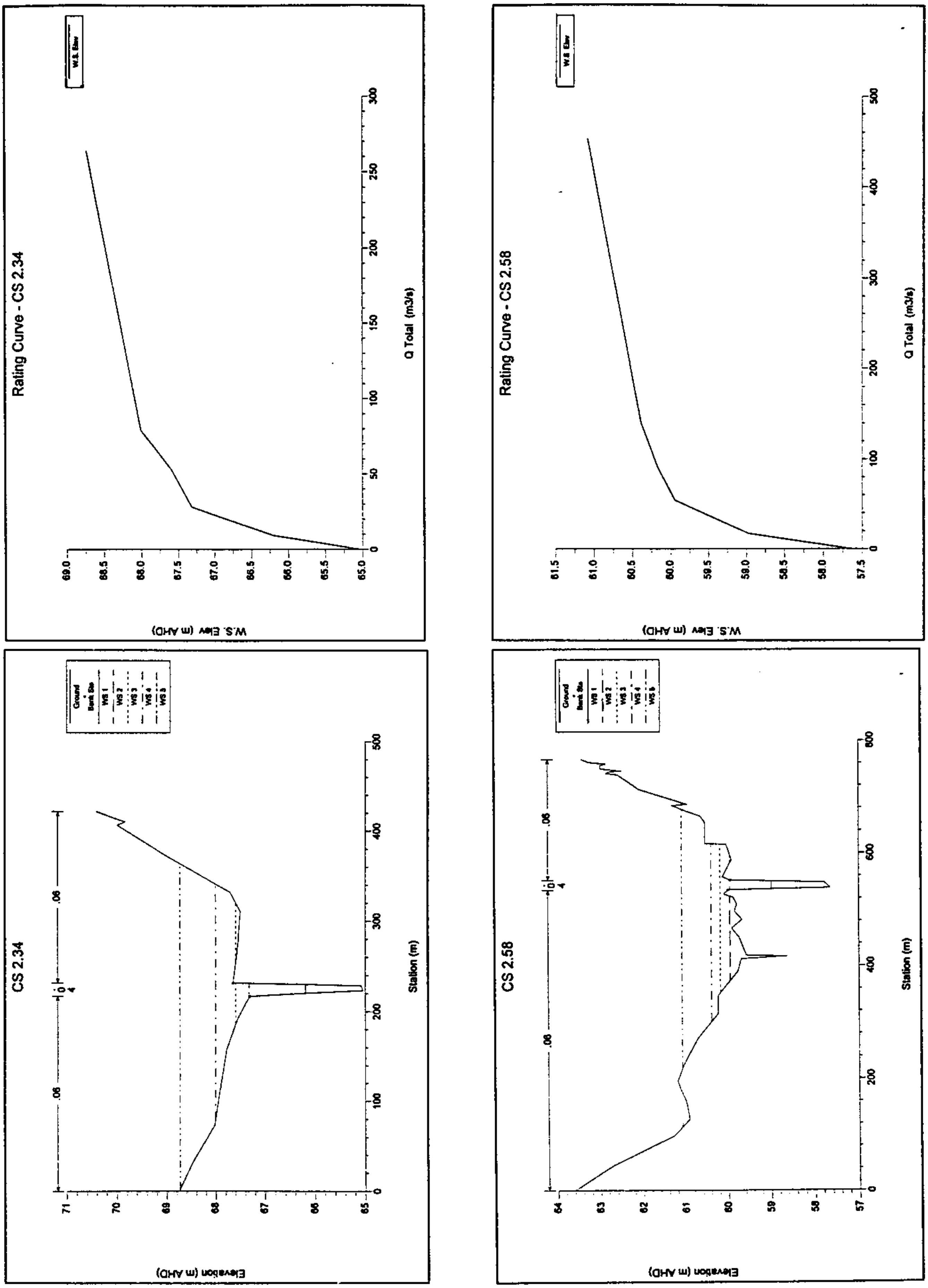


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.9 (cont.)

BONDS CREEK

TYPICAL CROSS SECTIONS AND RATING CURVES

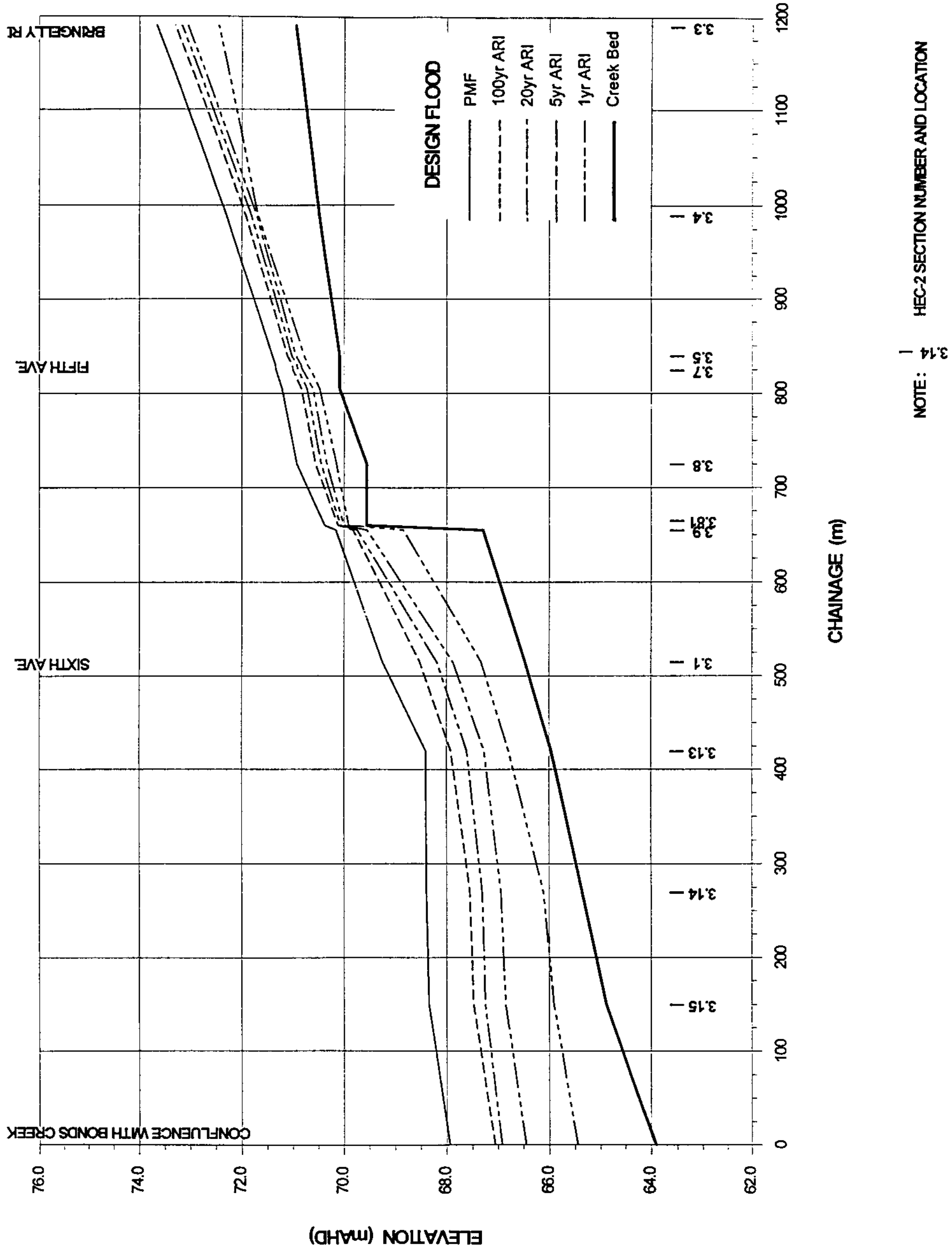


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.9 (cont.)

BONDS CREEK

TYPICAL CROSS SECTIONS AND RATING CURVES

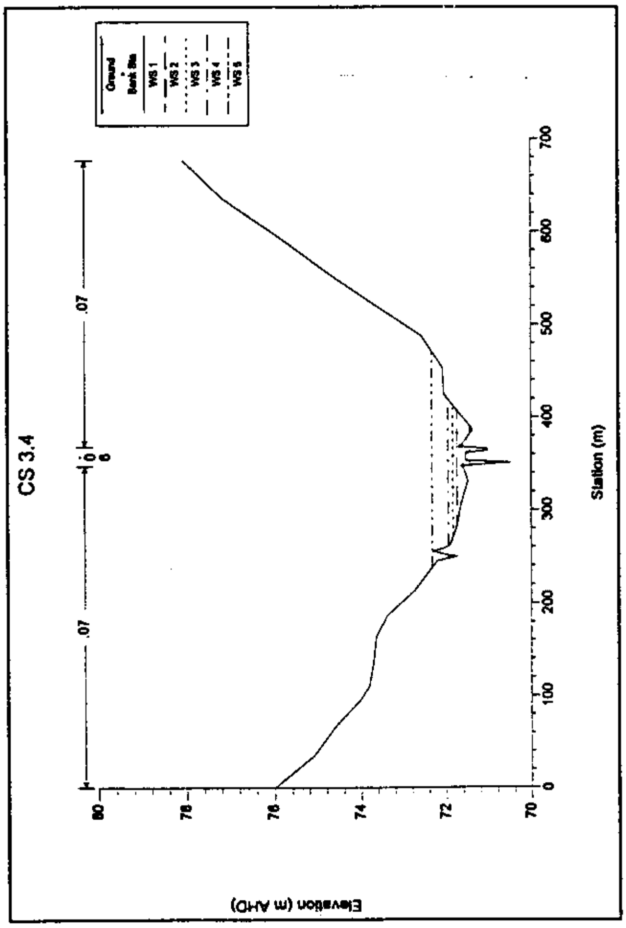


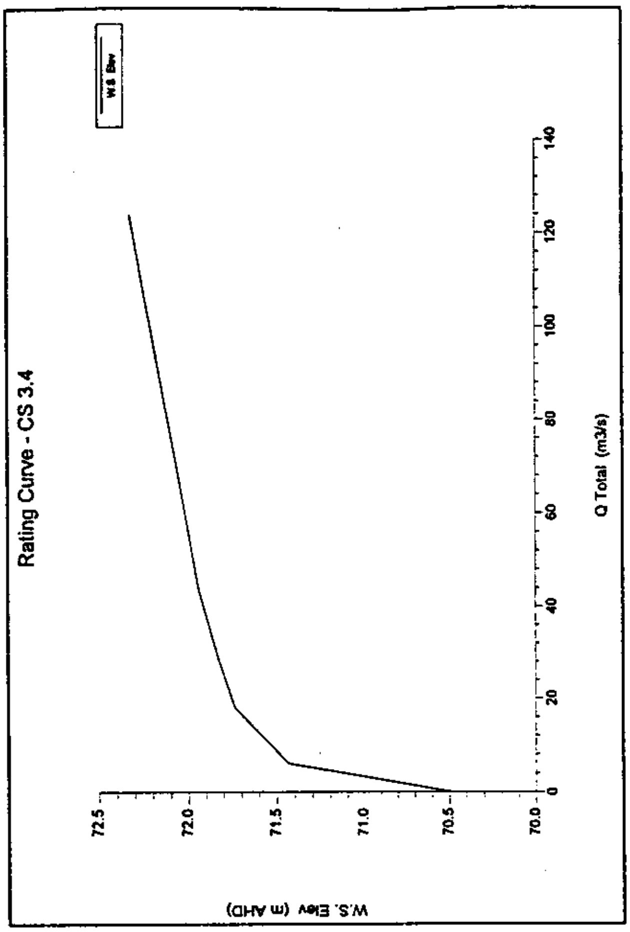
AUSTRAL FLOODPLAIN MANAGEMENT STUDY

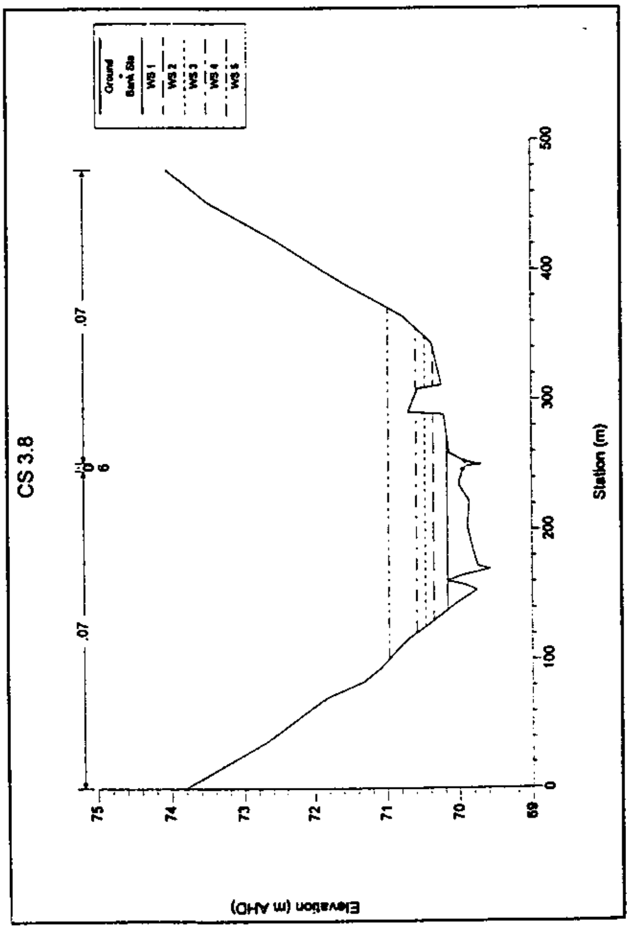
Figure B3.10

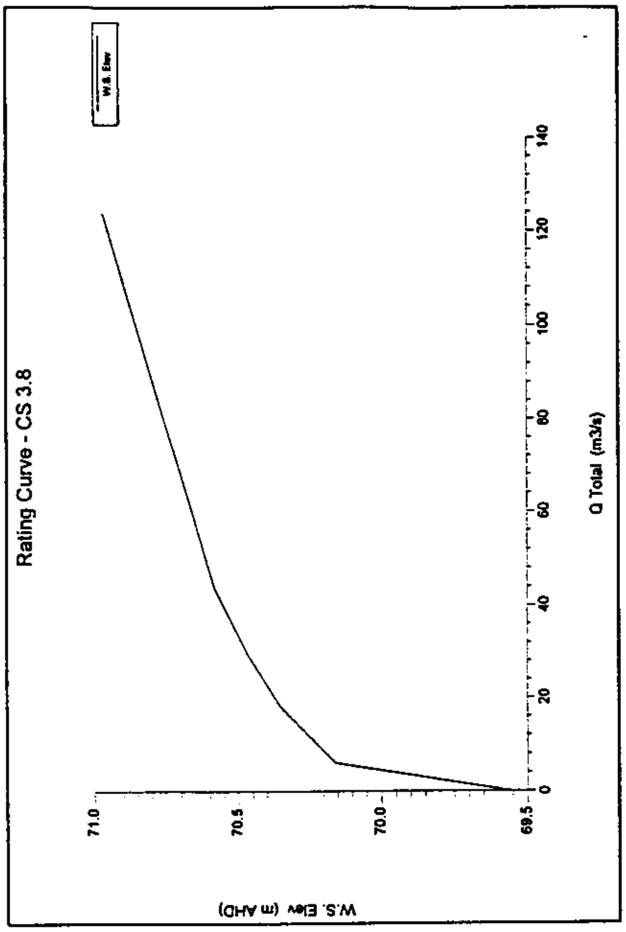
TRIBUTARY 1 (SCALABRINI CREEK)

WATER SURFACE PROFILES - EXISTING CONDITIONS







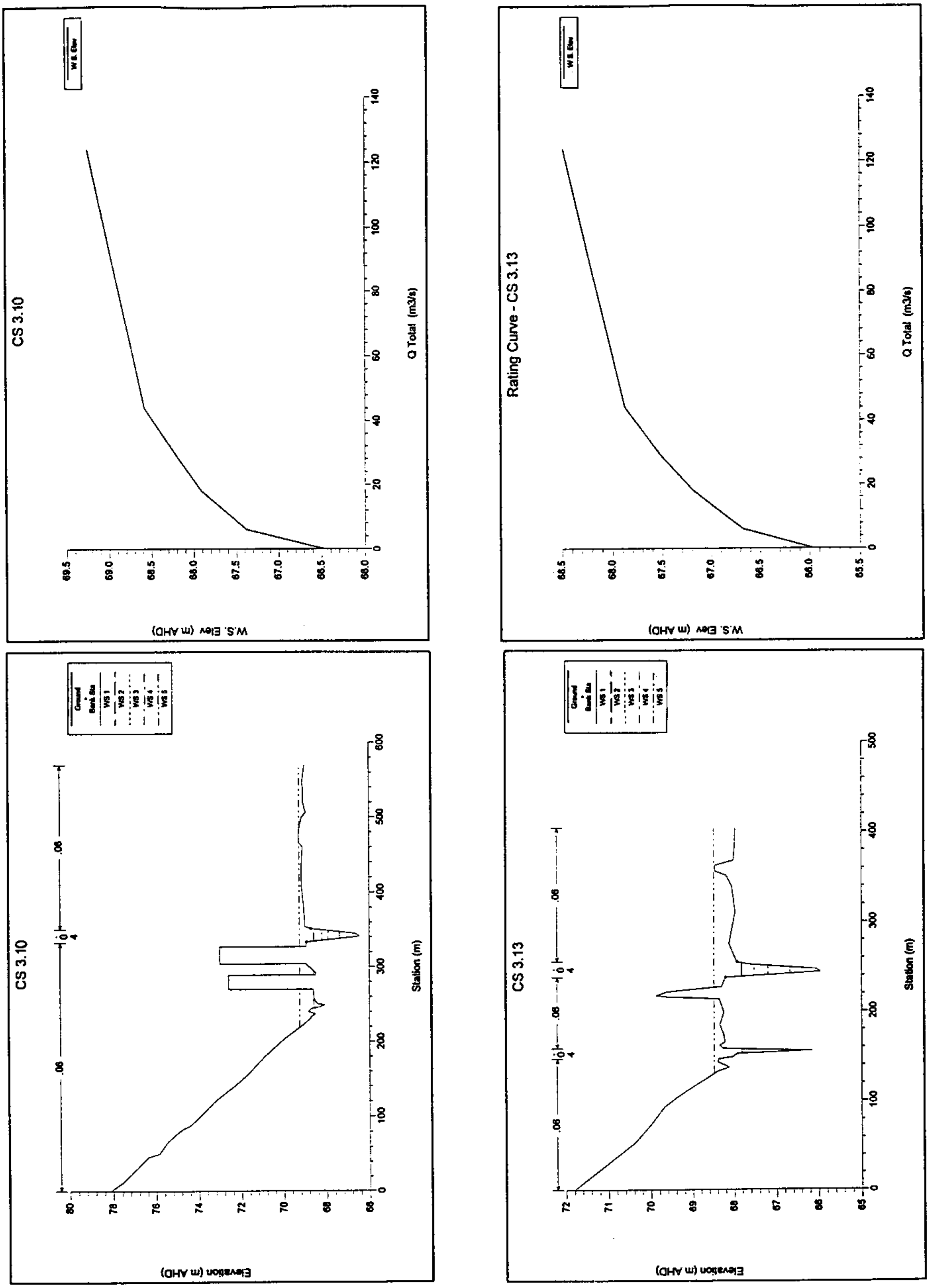


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.11

TRIBUTARY 1 (SCALABRINI CREEK)

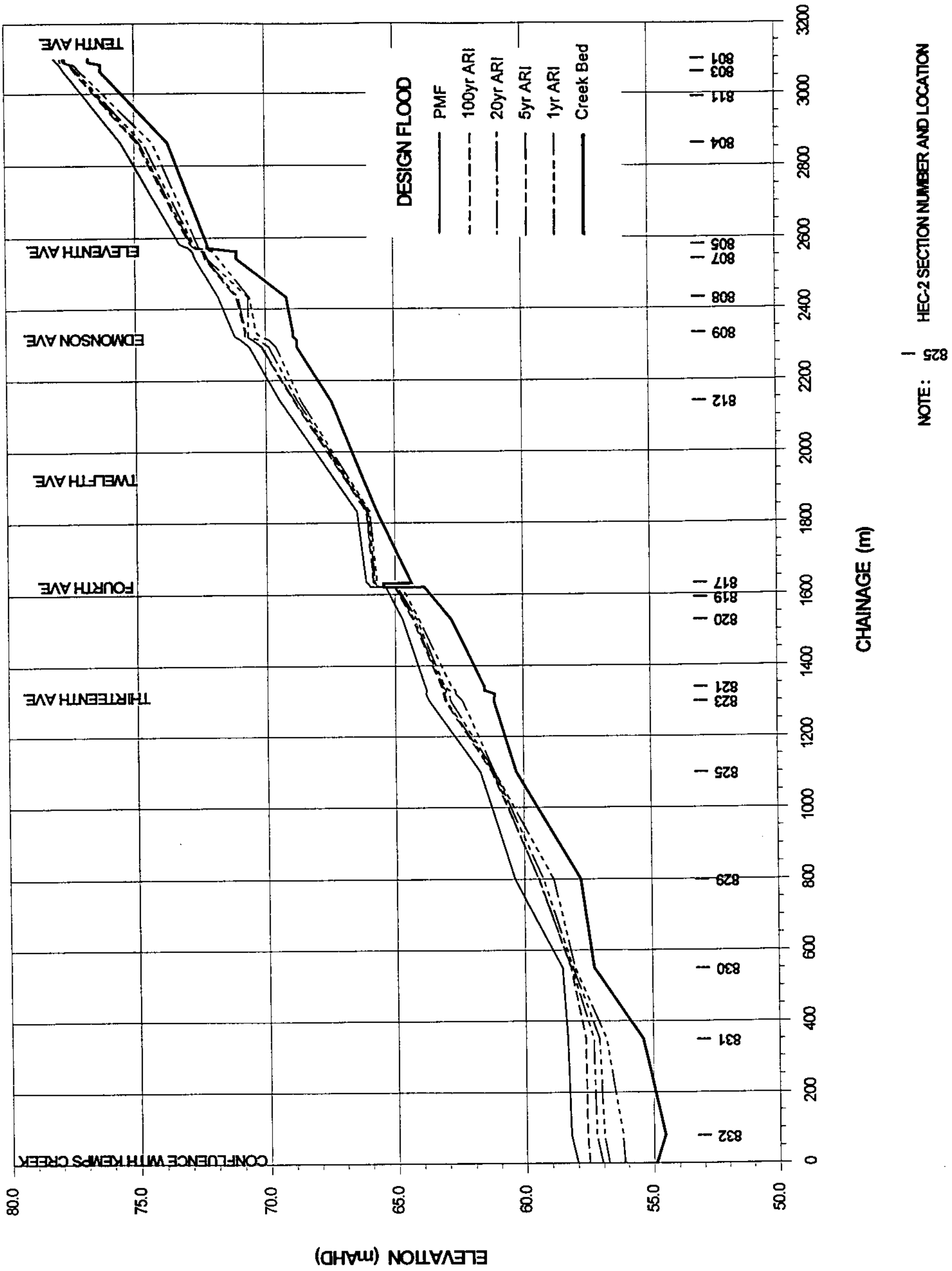
TYPICAL CROSS SECTIONS AND RATING CURVES



AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.11 (cont.)

TRIBUTARY 1 (SCALABRINI CREEK)
TYPICAL CROSS SECTIONS AND RATING CURVES

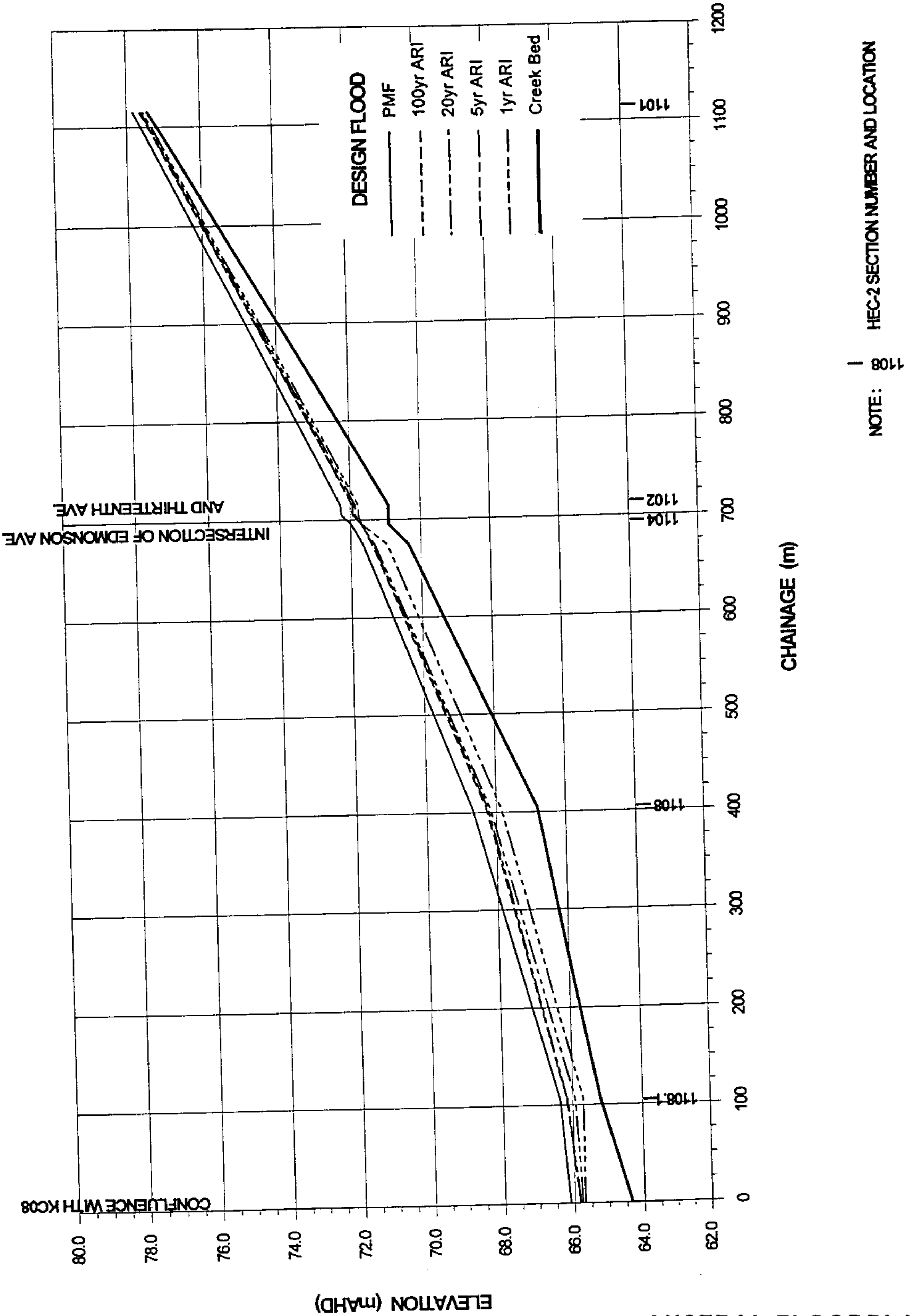


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.12

TRIBUTARY 2 (KC08)

WATER SURFACE PROFILES - EXISTING CONDITIONS

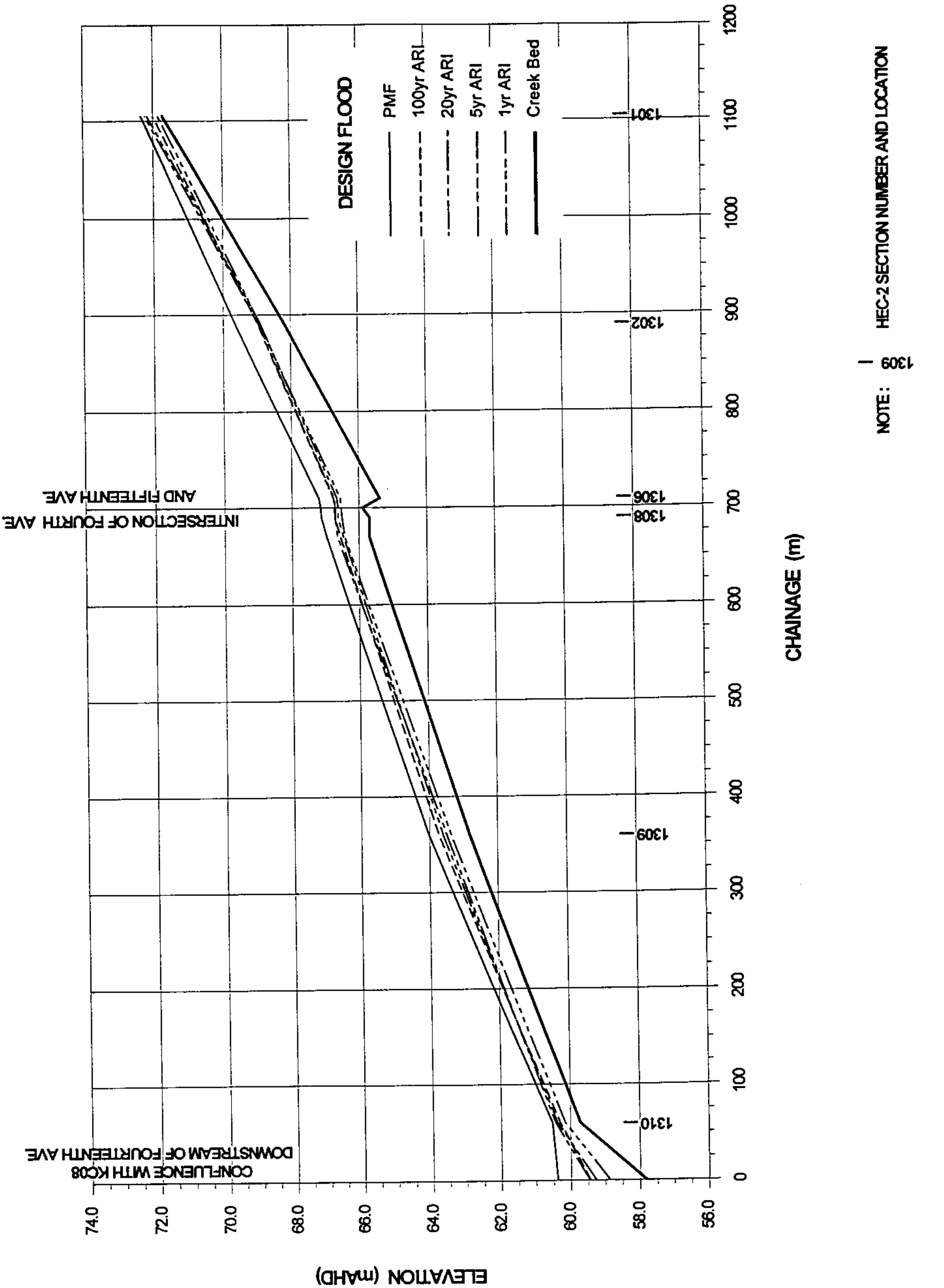


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.13

BRANCH KC11 OF TRIBUTARY 2

WATER SURFACE PROFILES - EXISTING CONDITIONS

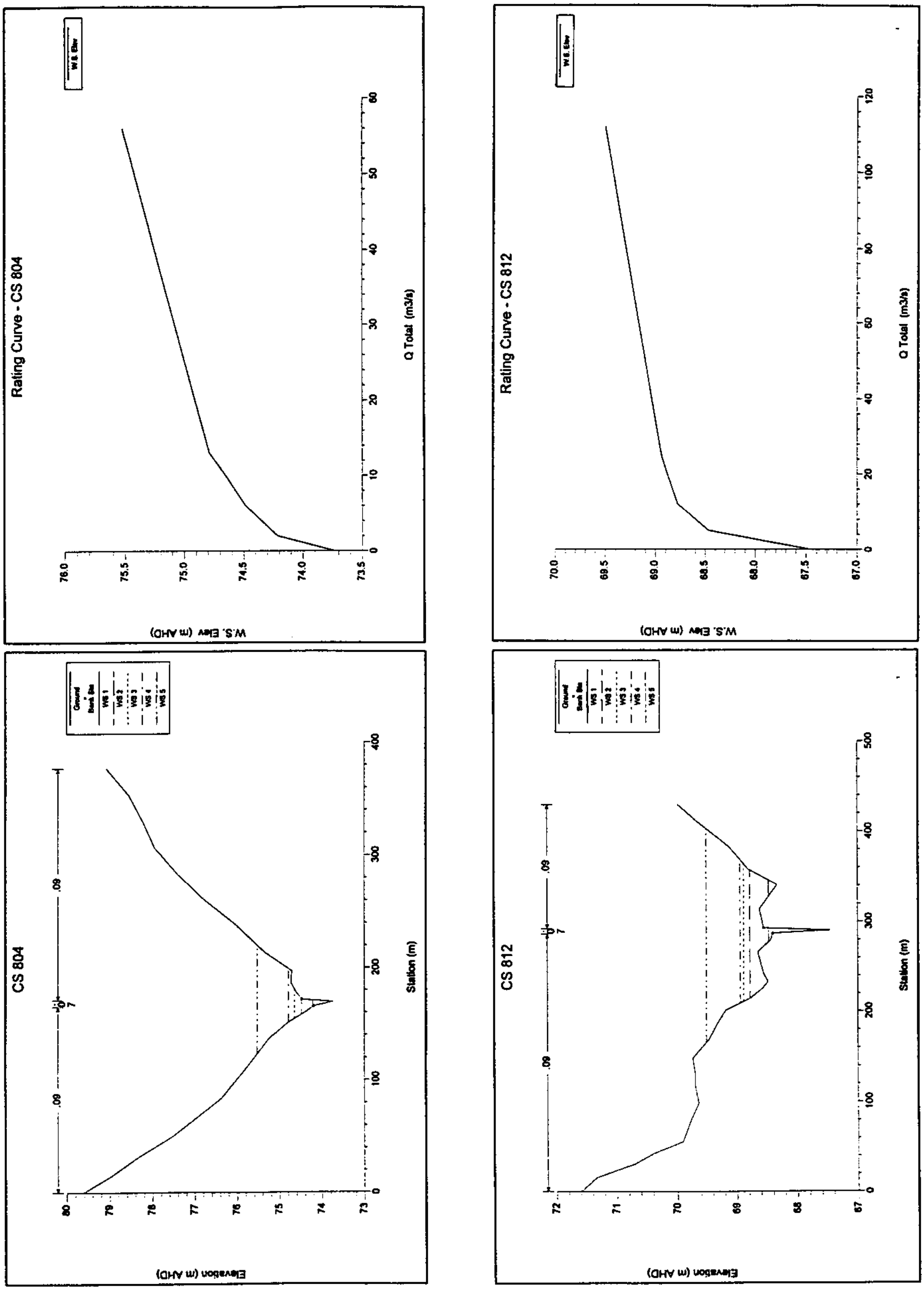


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.14

BRANCH KC13 OF TRIBUTARY 2

WATER SURFACE PROFILES - EXISTING CONDITIONS

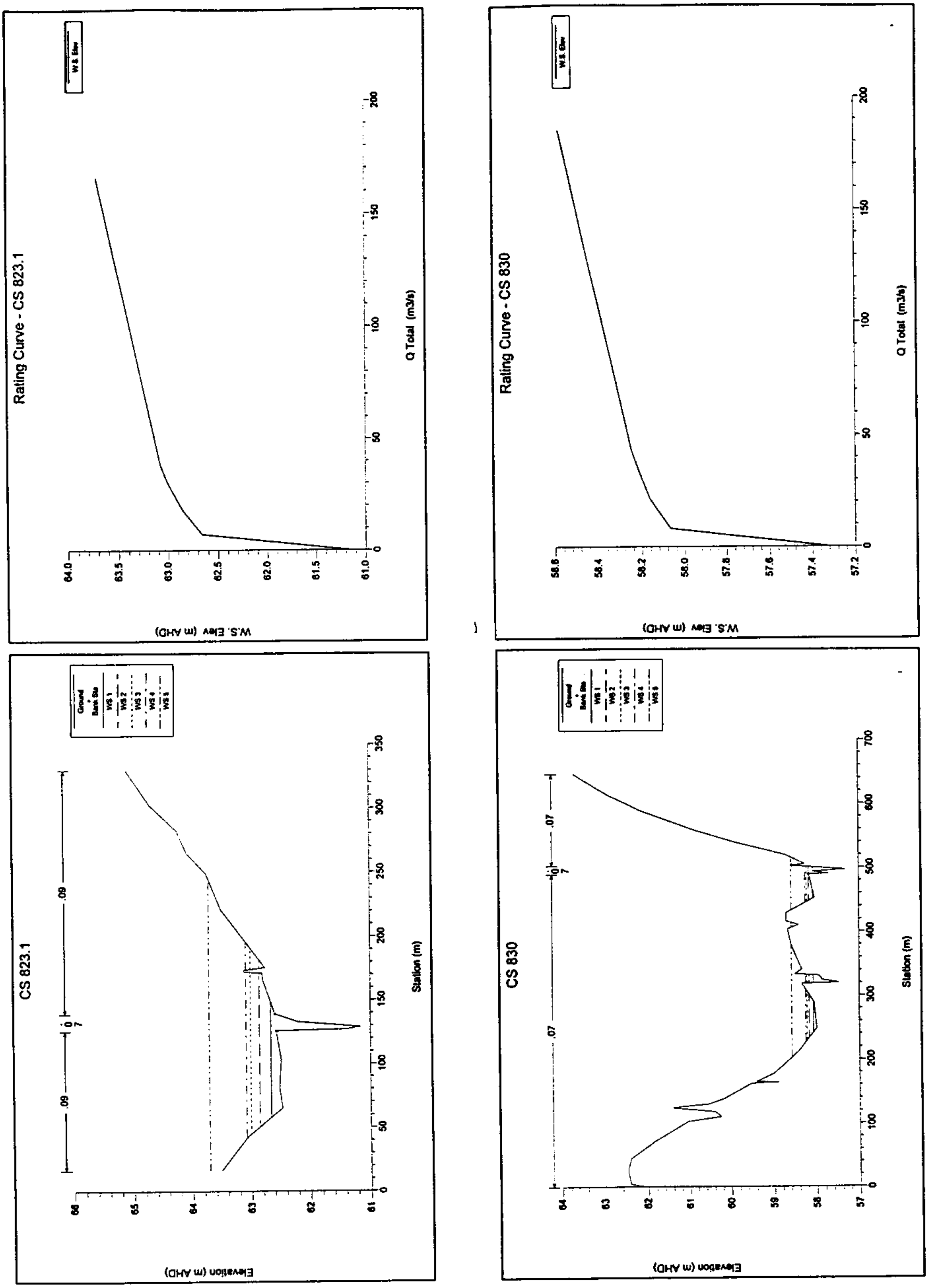


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.15

TRIBUTARY 2

TYPICAL CROSS SECTIONS AND RATING CURVES

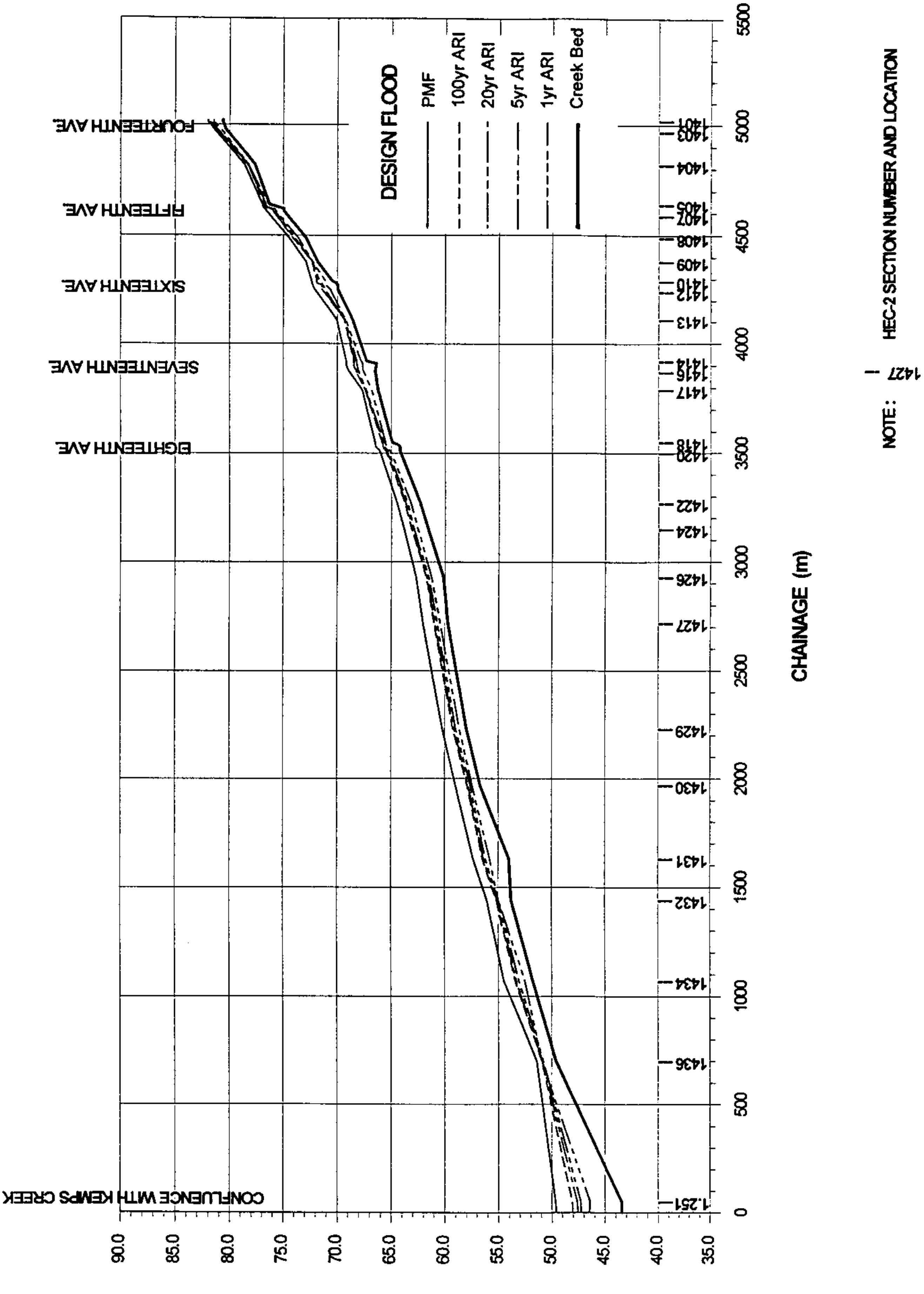


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.15 (cont.)

TRIBUTARY 2

TYPICAL CROSS SECTIONS AND RATING CURVES

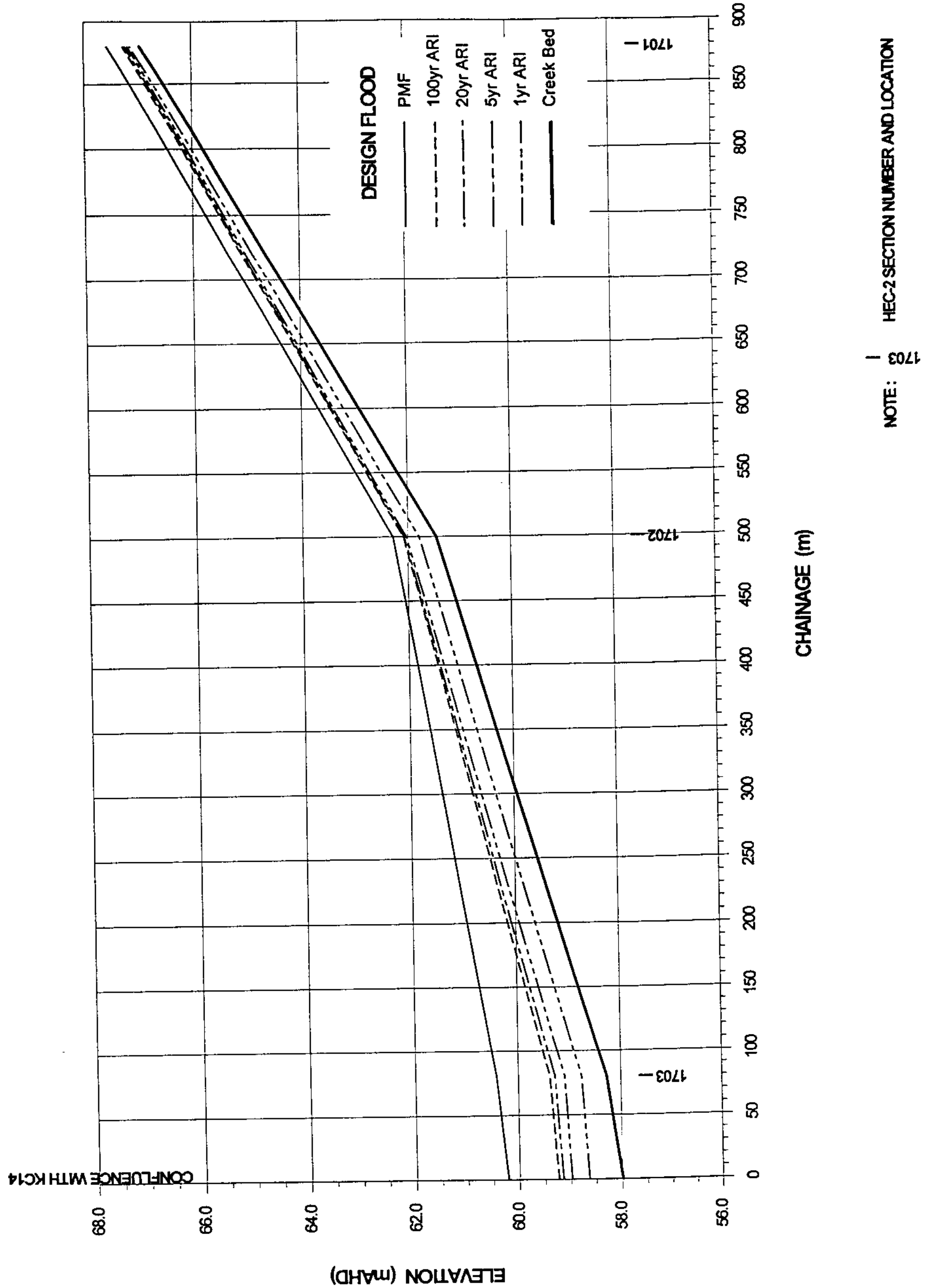


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.16

TRIBUTARY 3 (KC14)

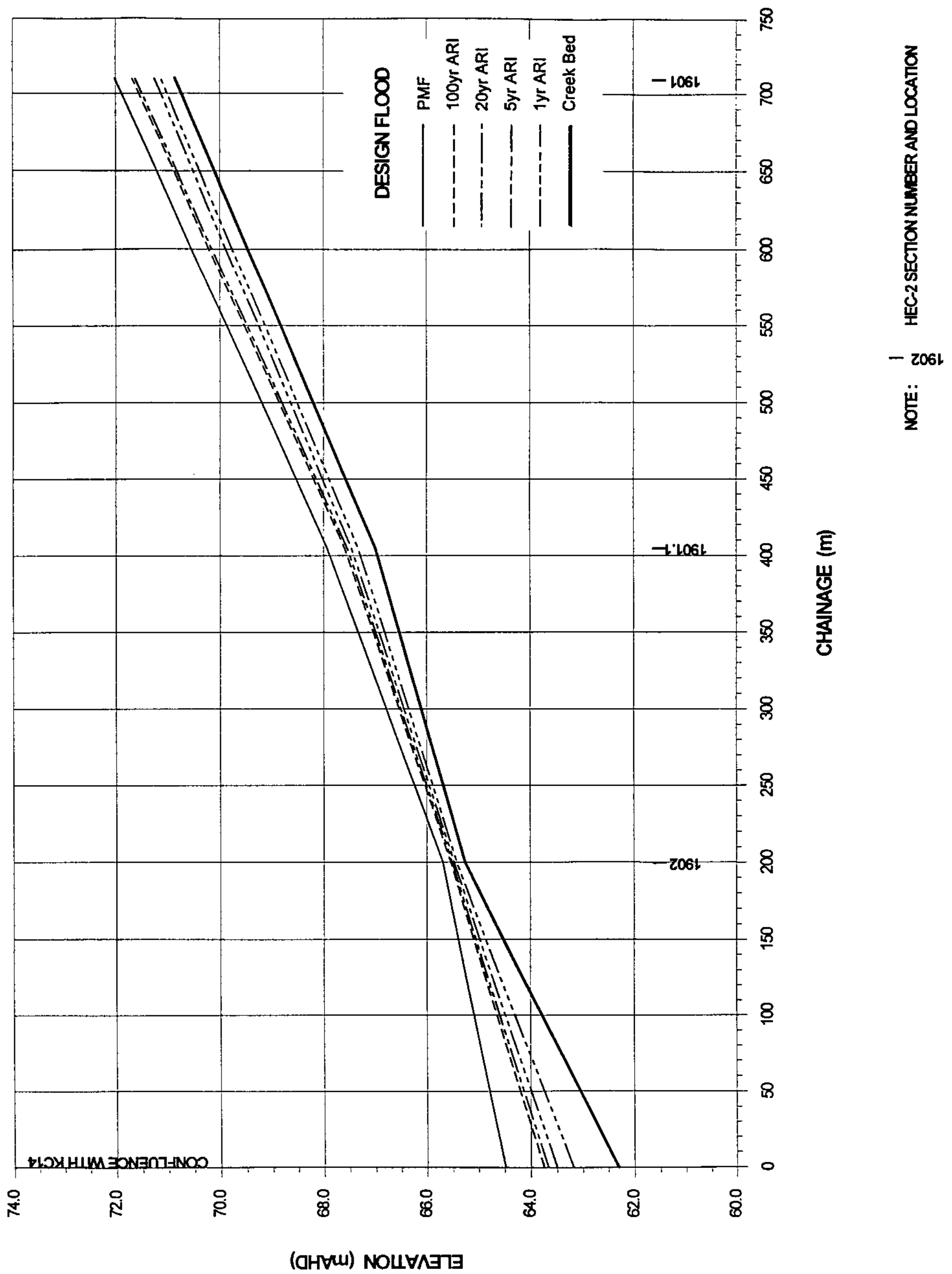
WATER SURFACE PROFILES - EXISTING CONDITIONS



AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.17

BRANCH KC17 OF TRIBUTARY 3
WATER SURFACE PROFILES - EXISTING CONDITIONS

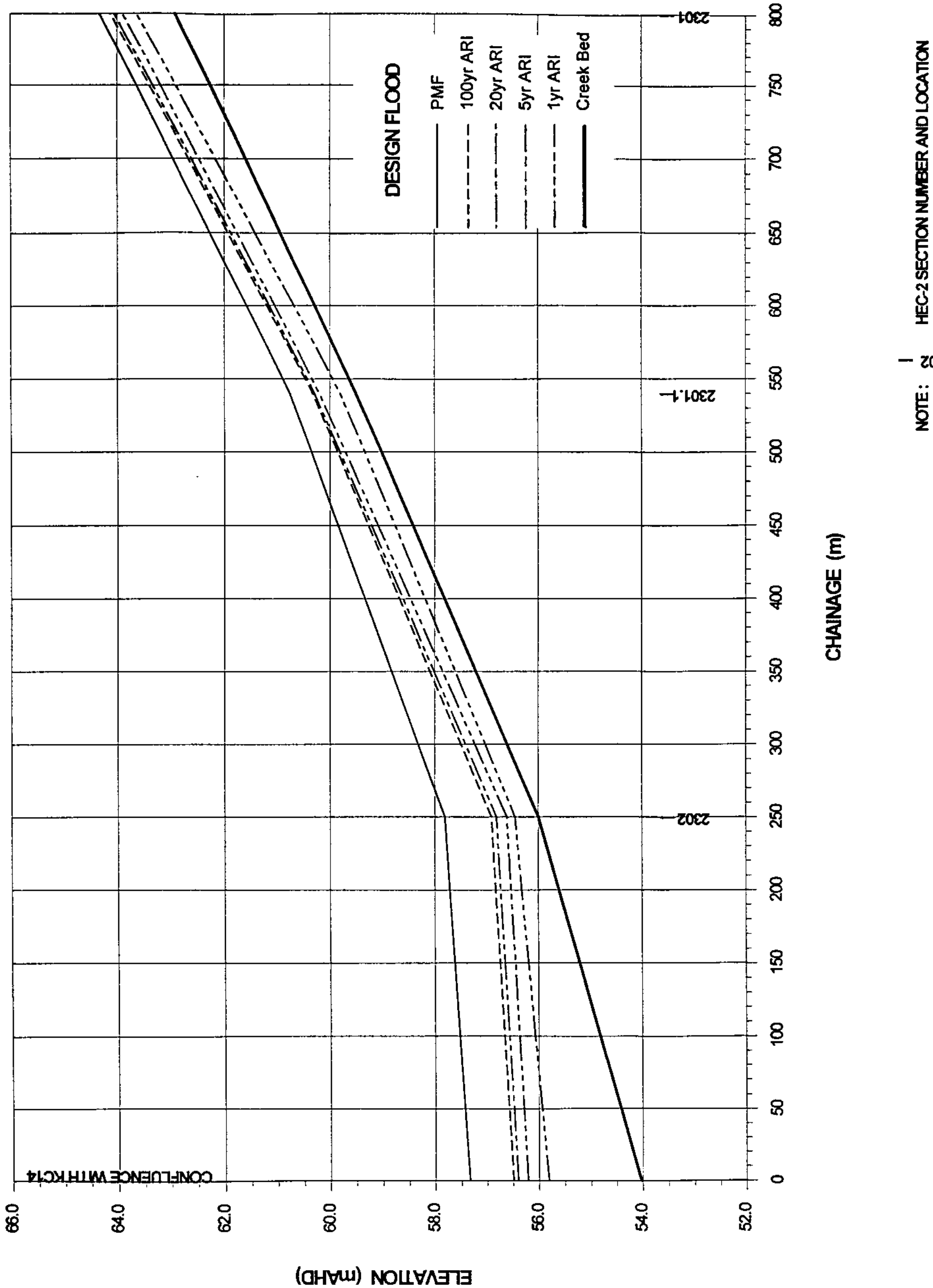


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.18

BRANCH KC19 OF TRIBUTARY 3

WATER SURFACE PROFILES - EXISTING CONDITIONS

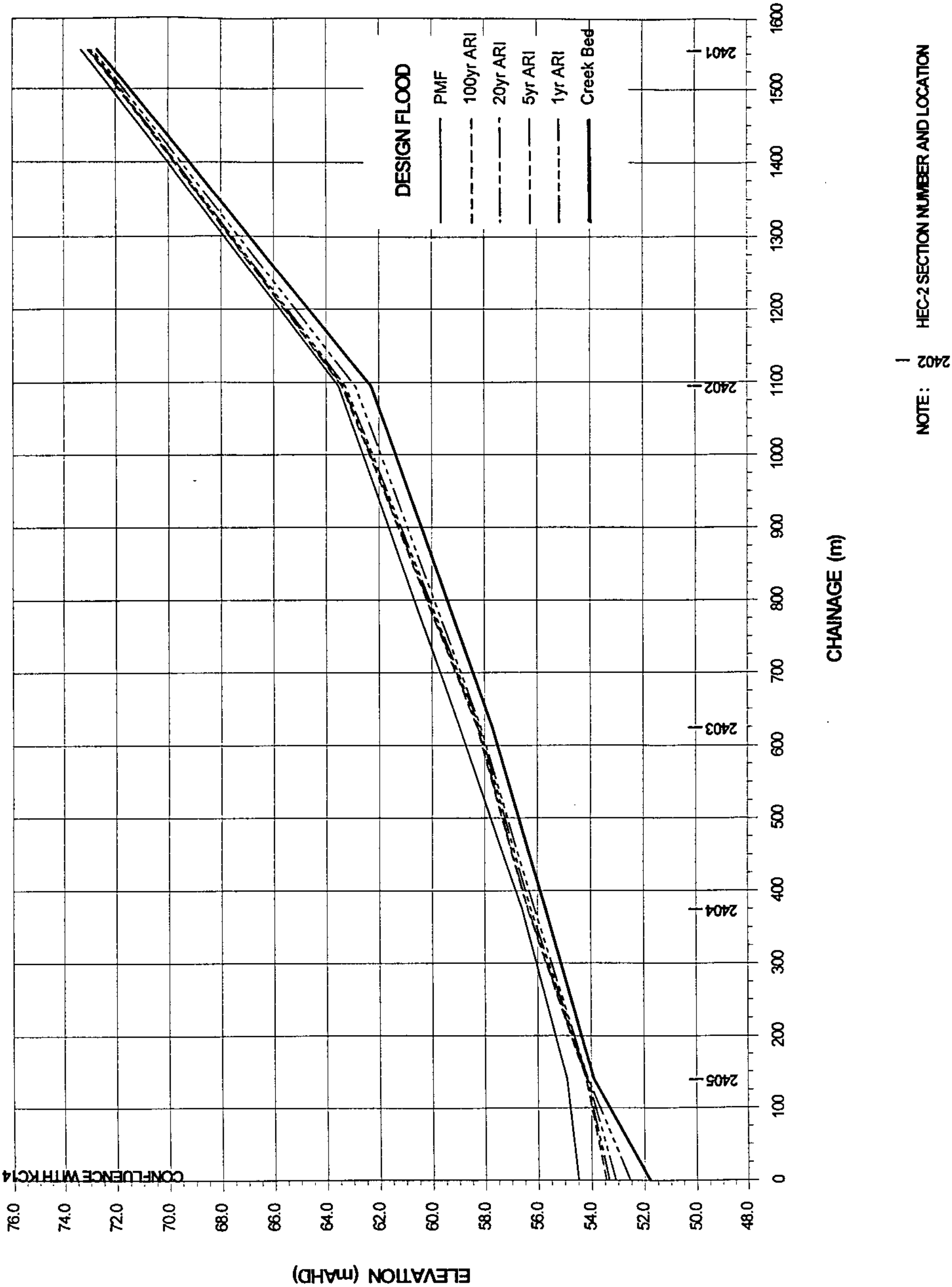


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.19

BRANCH KC23 OF TRIBUTARY 3

WATER SURFACE PROFILES - EXISTING CONDITIONS

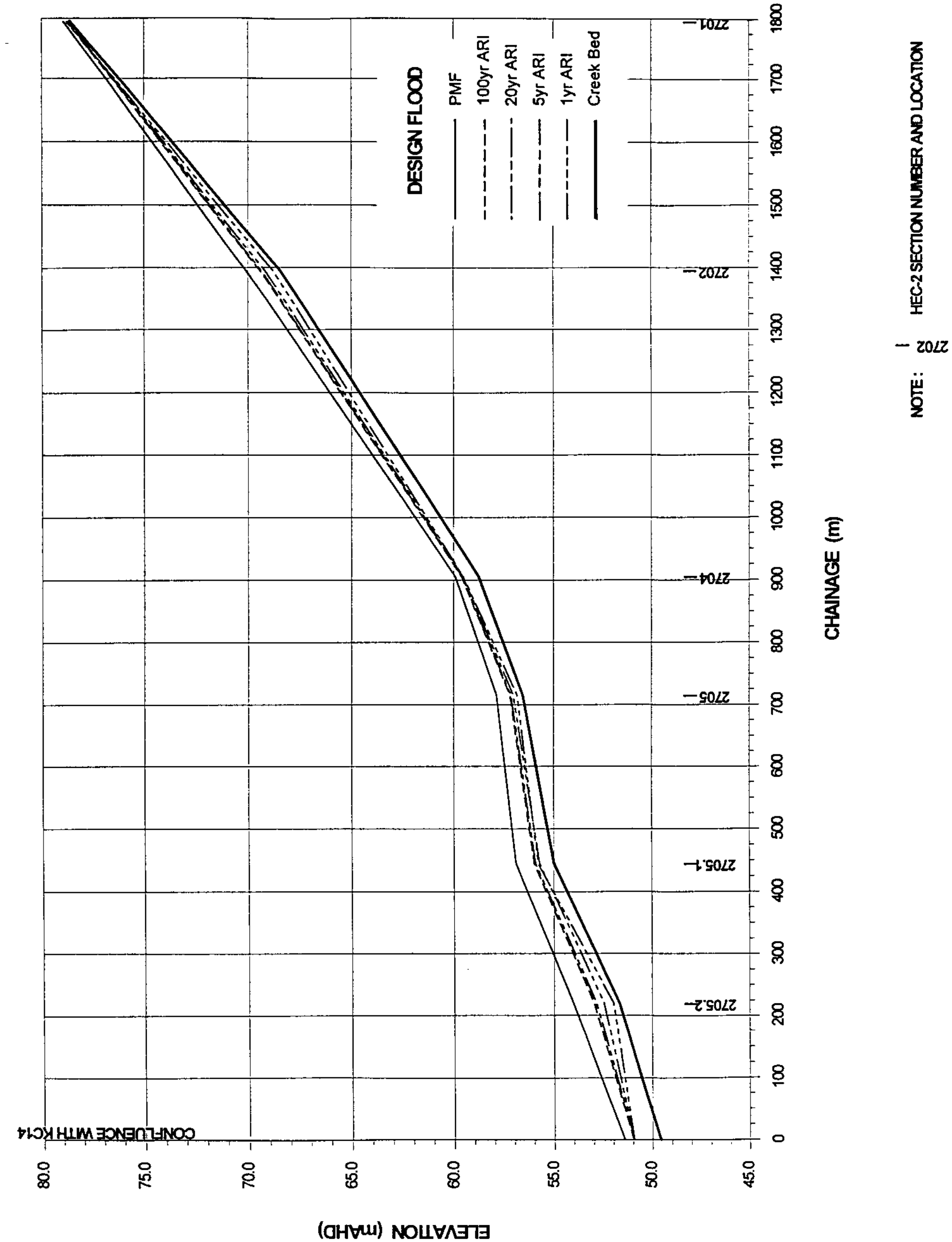


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.20

BRANCH KC24 OF TRIBUTARY 3

WATER SURFACE PROFILES - EXISTING CONDITIONS

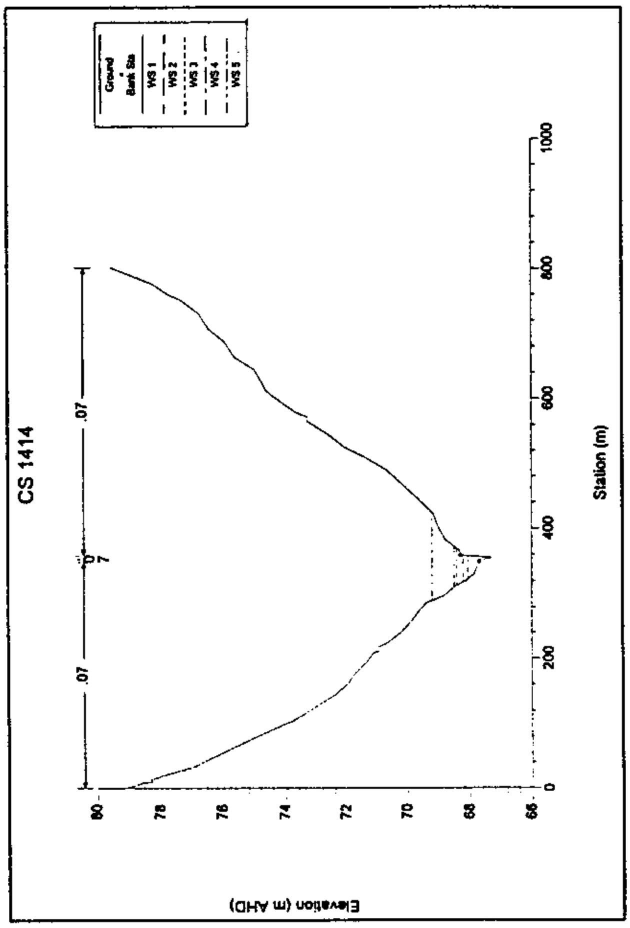


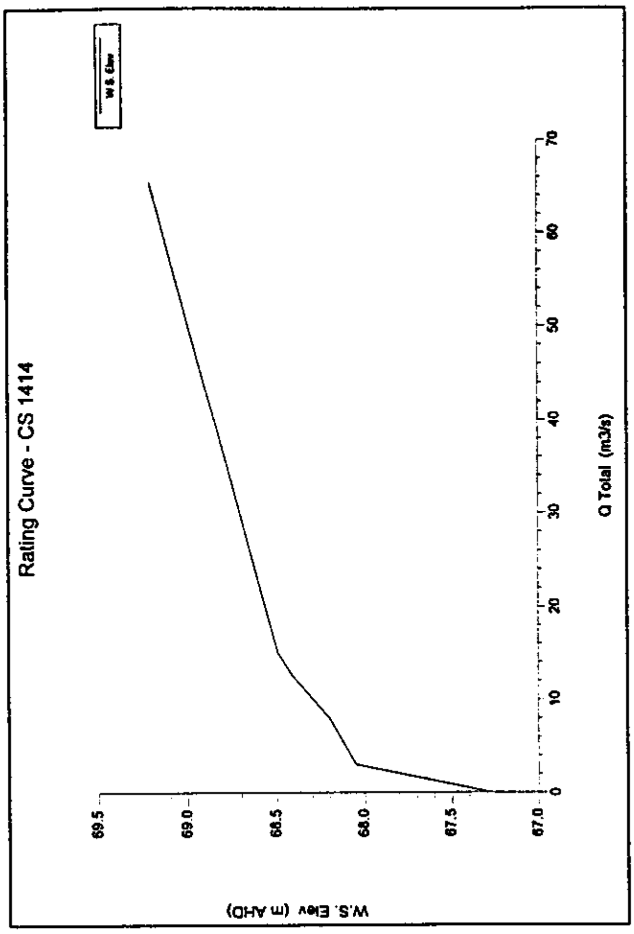
AUSTRAL FLOODPLAIN MANAGEMENT STUDY

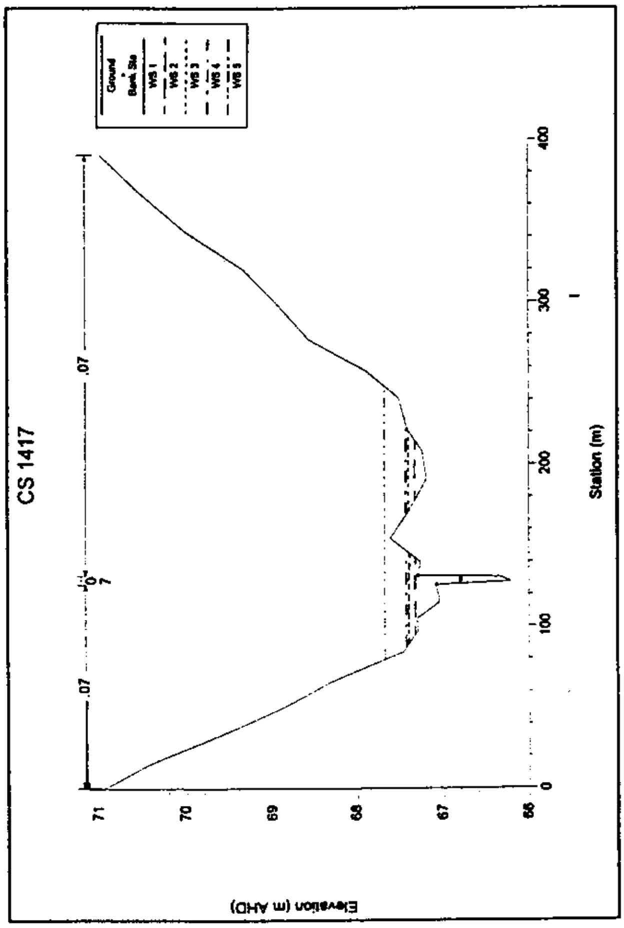
Figure B3.21

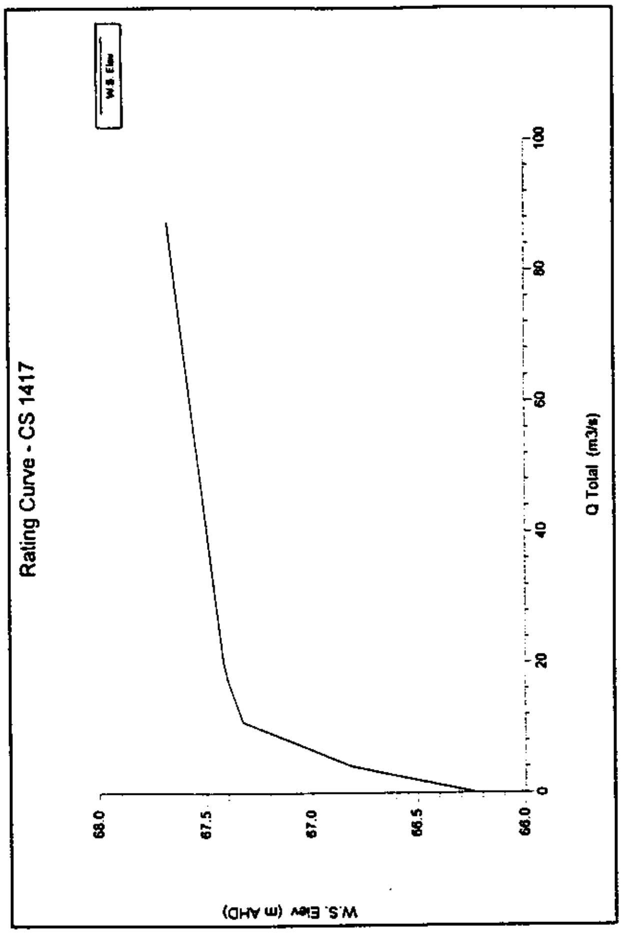
BRANCH KC27 OF TRIBUTARY 3

WATER SURFACE PROFILES - EXISTING CONDITIONS







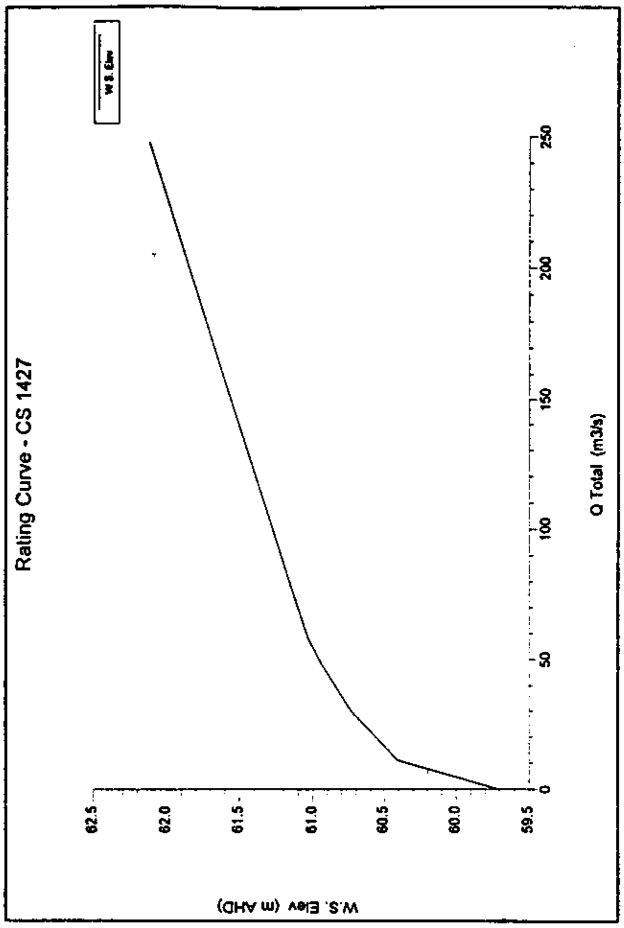


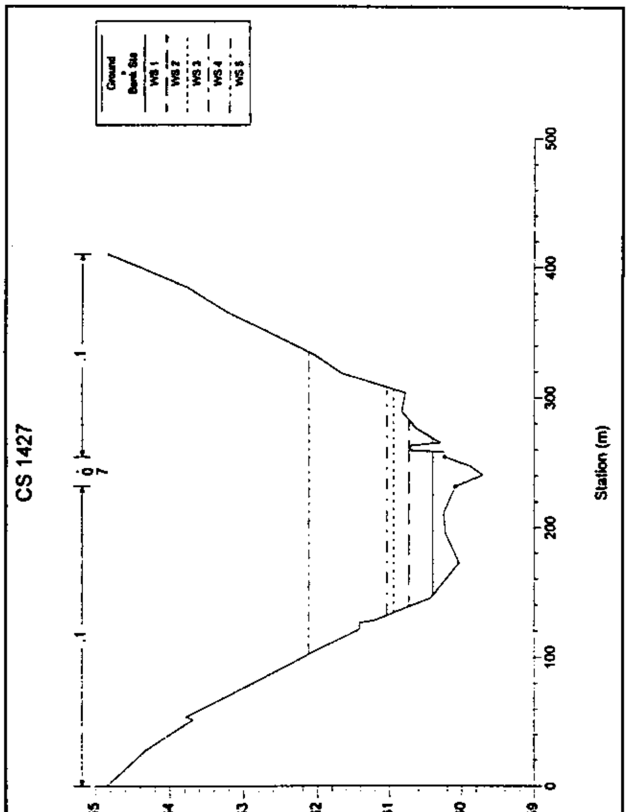
AUSTRAL FLOODPLAIN MANAGEMENT STUDY

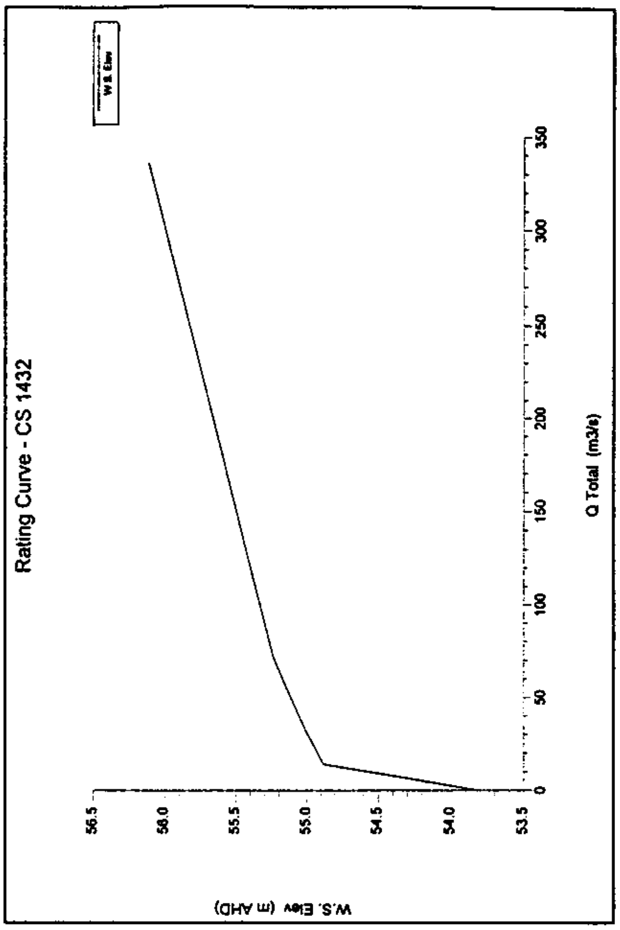
Figure B3.22

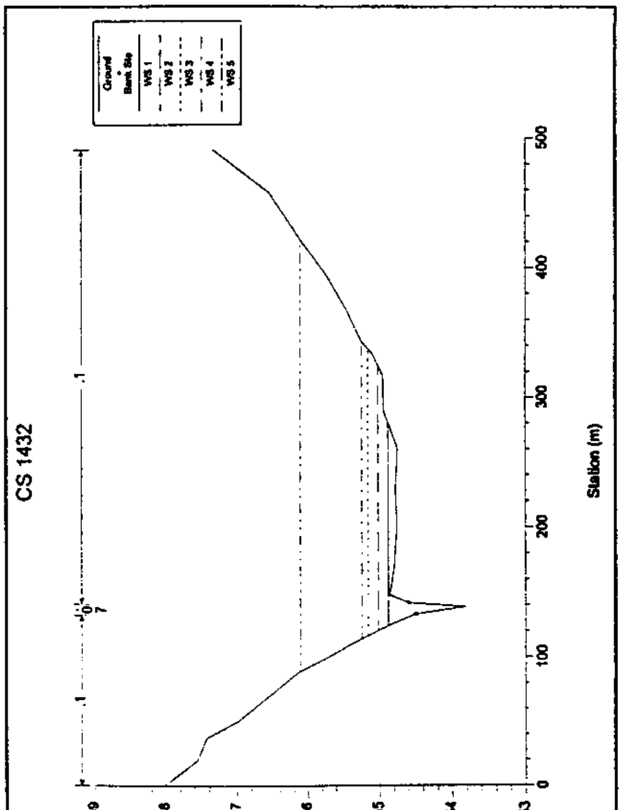
TRIBUTARY 3

TYPICAL CROSS SECTIONS AND RATING CURVES









AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B3.22 (cont.)

TRIBUTARY 3

TYPICAL CROSS SECTIONS AND RATING CURVES

B4. DISCUSSION

B4.1 General

Streams in the study area have a low capacity and generally overflow at about the 1 year ARI flood. Larger flows inundate a progressively larger area but with comparatively small increase in water level. Between the 5 year and 100 year ARI, the increase in level is around 200-400 mm.

Flow velocities on the floodplain are small, generally around 1-1.5 m/s, particularly in the downstream sections of the main streams. Velocities tend to be higher in the relatively steeper areas upstream where the flow profiles tend to converge.

High velocities are also experienced in the immediate vicinity of bridges, reflecting the constrictions on flow imposed by the contracted water way openings. Examples of this effect occur at Elizabeth Drive and Fifteenth Avenue on Kemps Creek (Table B3.5), Ninth Avenue and Cowpasture Road and Fourteenth Avenue on Tributary 3 (Table B3.36).

Backwater influences arising from flood levels in the main streams extend up the tributary streams for several hundred metres upstream of their confluences with the main streams. This effect results in a flat profile in the zone of influence of the main stream. Further upstream, water levels are controlled by the conveyance capacity of the waterway and the bridge/culvert crossings.

Due to the streams generally surcharging at around the 1 year ARI flood, nuisance flooding in many areas occurs on a regular basis. There are several instances where the lack of channel capacity results in flow on the floodplain being captured by the local street system. Two examples of this are:

- Tributary 1 (Scalabrini Creek) at Fifth Avenue
- Tributary 2 of Kemps Creek at Twelfth and Fourth Avenues.

Generally culvert crossings in the study area have a hydrologic capacity equal to or less than 2 year ARI. With the low level road crossings being surcharged during minor storm events road access to many areas in the Austral precinct is effectively stopped.

Five major bridge/culvert structures have hydrologic capacities equal to or greater than 10 year ARI. On Kemps Creek (Table B3.1) they are:

- Bridges at Elizabeth Drive and Fifteenth Avenue
- Culverts at Bringelly Road.

On Bonds Creek (Table B3.11):

- Culverts at Cowpasture Road and Bringelly Road.

All five structures cause a restriction to flood flows resulting in ponding upstream and a general reduction in flow velocities in the region of backwater. Flow profiles tend to be flat in the zone of influence of the bridge and steepen further upstream.

B4.2 Kemps Creek Main Arm and Branches

B4.2.1 Kemps Creek

General

The Kemps Creek hydraulic model extends from Bringelly Road to a point a short distance downstream of Elizabeth Drive, a distance of 9.1 km (Table B3.1 - B3.6 and Figure B3.1). Kemps Creek has its headwaters in the Leppington precinct which is under Camden City Council's jurisdiction. At Bringelly Road, where the creek crosses into Liverpool City Council's jurisdiction, and at the upstream end of the hydraulic model, approximately 6 km^2 of catchment is contributing to flows. Figure B3.6 shows typical cross-sections and rating curves.

Kemps Creek between Bringelly Road and Elizabeth Drive is in its natural state for the majority of its length with minor channel improvements in the following areas:

- Twelfth Avenue culvert crossing, extending for a length approximately 200 m upstream and downstream

- Between the confluence with Bonds Creek and Gurner Avenue.

Bringelly Road to Confluence with Bonds Creek (Cross-Section 1.43)

The reach of Kemps Creek between Bringelly Road and Twelfth Avenue has a bed slope of about 0.5% and flow velocities average around 1.4 m/s in the channel and 0.7 m/s on the floodplain. Downstream of Twelfth Avenue the bed slope flattens to around 0.3% and average velocities reduce slightly in the channel and on the floodplain to 1.0 m/s and 0.6 m/s respectively.

At Bringelly Road the box culverts cause a restriction to the flow which creates an increase in water levels across the roadway of approximately 0.5 m for events equal to or greater than the 5 year ARI flood and greater.

Small off-line storage dams have been constructed along the upstream reach of Kemps Creek between Bringelly Road and its confluence with Bonds Creek. These dams would not affect flood levels for events which surcharge the creek banks i.e. generally greater than the 2 year ARI event, as they are mainly excavated into the floodplain.

At Twelfth Avenue there are 4 x 1350 RCPs which have a hydrologic capacity of less than 1 year ARI. The surcharging of the Twelfth Avenue culverts causes water to spread out across the heavily wooded floodplain on the east bank where flood flows converge with flows which have surcharged Bonds Creek. The floodplain has a large conveyance capacity, thus there is only an increase in levels of approximately 400 mm between the 5 and 100 year ARI floods compared to an approximate 500 mm increase in levels between the 1 and 5 year ARI floods.

Bonds Creek Confluence to Gurner Avenue

Fifteenth Avenue crosses Kemps Creek approximately 400 m downstream of its confluence with Bonds Creek. The bridge has a waterway area of 122 m^2 and an approximate hydrologic capacity of 50 year ARI. The restriction to flows caused by the bridge creates an afflux across the bridge, which for 20 year ARI is approximately 300 mm. Between the 50 and 100 year ARI events, flows surcharge Fifteenth Avenue on the east bank while both banks are surcharged for flood events greater than the

100 year ARI. The bridge deck of Fifteenth Avenue is approximately 250 mm above the PMF flood level. In the case of the 100 year ARI event, backwater effects influence levels and reduce velocities for a distance of approximately 500 m upstream.

The balance of flows above the 50 year magnitude are conveyed over the roadway, resulting in the increase in levels shown on Figure B3.1 for the 100 year flood. For larger floods the bridge deck is submerged and has a progressively smaller effect on upstream flood levels.

Downstream of Fifteenth Avenue the creek has a very flat floodplain which is approximately 500 m wide. The excavated channel, which continues downstream to Gurner Avenue, has a hydrologic capacity of less than the 1 year ARI. Flood flows greater than the 1 year ARI extend across the floodplain where there is a general increase in levels of approximately 350 mm from the 5 to the 100 year ARI. PMF levels are generally 800 mm higher than the 100 year ARI.

<u>Gurner Avenue to Elizabeth Drive</u>

Gurner Avenue, approximately 700 m downstream of Fifteenth Avenue, has a low level road crossing with 2 x 900 RCPs conveying low flows beneath it. The hydraulic capacity of the pipes is less than a 1 year ARI flood and any larger flows quickly surcharge the roadway. Once surcharged, flows spread out across the floodplain and effectively cut access via Gurner Avenue.

Downstream of Gurner Avenue no channel excavation works have been carried out and the channel size is significantly less than upstream. The creek banks are heavily wooded as is its eastern floodplain. The western floodplain has been generally cleared a short distance from the creek.

The small hydrologic capacity of the creek, increased roughness due to the wooded areas and the presence of illegal fill in the creek bed cause a reduction in flow velocities and spreading out of flood flows in the area between Gurner Avenue and Elizabeth Drive. For flows greater than the 1 year ARI the banks of Kemps Creek are surcharged and the floodplain begins to fill. Progressively larger areas of land are flooded up to the 100 year ARI event, but there is comparatively little increase in the area flooded for larger floods. There is generally a range of only 1 m between 1 and 100 year ARI flows. The PMF profile is about 1 m higher still. However, because of the shape of the floodplain there is a comparatively narrow strip averaging about 50 m on the western side of the floodplain between these two flood events. Because of the flat topography of the eastern side of Kemps Creek between Gurner Avenue and Elizabeth Drive, the PMF extends as much as 200 m further than the 100 year ARI flood.

The inundation of a wide area of the floodplain causes problems on the branches draining to the main stream because of backwater effects which prevent the escape of local catchment flows. One such location is in the vicinity of Floribunda Road on the west bank of Kemps Creek. Nuisance flooding arises due to inadequacies in the local drainage system, coupled with coincident backwater flooding from Kemps Creek. Uncontrolled overland flows travel down Floribunda Road towards an escape channel which has been excavated to convey flows to the creek. Backwater effects from Kemps Creek prevent the local runoff from quickly exiting the channel thus producing extended periods where the channel flows full.

The bridge at Elizabeth Drive significantly restricts the flow and causes velocities in the bridge backwater to be reduced. The waterway area is sufficient to convey the 100 year ARI flood without surcharging the roadway but causes a significant rise in water levels across the bridge even for larger events. The 100 year flood ARI produces a head difference of 200 mm. The backwater effect created by the bridge constriction extends approximately 800 m upstream which exacerbates flooding problems in this area. The PMF surcharges the bridge deck and approach embankments and results in a rise in level across the structure of 1.3 m.

B4.2.2 Branch KC01

Branch KC01 has its confluence on the west bank of Kemps Creek approximately 450 m upstream of Twelfth Avenue's crossing of Kemps Creek. The hydraulic model of KC01 extends upstream approximately 1.9 km to Bellfield Avenue (Table B3.7 and Figure B3.2). The average bed slope of the branch is 1.0% which is considerably steeper than the main streams occupying the floodplain. Backwater flooding from Kemps Creek influences water surface levels to a point approximately 200 m downstream of King Street. Above the zone of influence of main stream flooding, the water surface profiles tend to converge showing only around 0.5 to 0.75 m range between 1 and 100 year ARI floods.

Flooding in the upper reaches of KC01 between Wynyard Avenue and Bellfield Avenue is influenced by two large storage dams. The first dam has been constructed so that flows enter and exit the dam near its upstream end. The embankment surrounding the dam is constructed to a level which would not be overtopped by the PMF. These conditions would force water out and around the dam so that flooding would occur over a larger area than under natural conditions. The second dam has been constructed on the east bank immediately upstream of Wynyard Avenue and in the event of a large storm would force flows over onto the western bank as it encroaches onto the floodplain.

There are 2 x 1050 RCPs under Wynyard Avenue which have a hydrologic capacity of approximately 2 year ARI. Due to the steepness of the creek, backwater effects caused by the road crossing are not experienced upstream.

Between Wynyard Avenue and Devonshire Road the creek is well defined and there is no floodplain as the surrounding landscape is relatively steep. The presence of a storage dam within the floodplain does not appear to exacerbate flooding as it has been excavated into the floodplain.

At Devonshire Road there are 2 x 3200 x 900 box culverts which have a hydrologic capacity of 20 year ARI. The road crossing causes a backwater effect which influences flood levels for approximately 100 m upstream. Downstream of Devonshire Road the creek is heavily wooded and has large amounts of reed growth in the channel. While the ground of the west bank rises quickly, the east bank downstream of Devonshire Road flattens out. In the event of a 100 year ARI flood the east bank of KC01 will surcharge and flow will move overland towards King Street.

Immediately upstream of King Street, branch KC01 has large amounts of growth in its channel and at present is completely blocked by a build-up of debris behind a boundary fence. King Street is an on-grade gravel road and the culvert at the branch crossing is an oval pipe 900 high by 1200 wide. The build up of silt due to the construction of a small embankment on the downstream side of the crossing prevents this pipe from operating effectively and it was assumed to be ineffective for conveying flow in the HEC-2 model. Therefore, most storm events would cause the inundation of King Street. Water that ponds on King Street is prevented from travelling downstream as overland flow by an embankment on the eastern floodplain and higher land on the west. For floods less than 100 year ARI, flows will be conveyed to Kemps Creek by the branch which has had its channel excavated to form a trapezoidal channel. In the event of a 100 year ARI flood the floodplain downstream of King Street will be inundated for a width of approximately 250 m.

B4.2.3 Branch KC02

Branch KC02 is located on the west bank of Kemps Creek between Twelfth and Fifteenth Avenues. The hydraulic model extends for about 500 m from its confluence with Kemps Creek to a point approximately 150 m upstream of Herley Avenue (Table B3.8 and Figure B3.3). Backwater flooding from Kemps Creek extends upstream to a point approximately 250 m downstream of Herley Avenue. The average bed slope of the creek is 1.5% and upstream of the influence of Kemps Creek, the water surface profiles show only around 0.5 to 1 m range between 1 and 100 year ARI floods.

The creek generally has a capacity to contain the 20 year ARI flow but the 2 x 600 RCPs under Herley Avenue have only a 2 year ARI capacity. For small to medium flood events, between the 2 and 20 year ARI that cause surcharging of Herley Avenue, flood flows would most likely re-enter the creek immediately downstream. Due to the steepness of the stream, backwater flooding due to the limited culvert capacity only extends 20-30 m upstream. For storm events greater than the 20 year ARI, flows will surcharge the west bank in the vicinity of Herley Road which is relatively flat and flow overland towards Kemps Creek. In the case of the PMF, flooding will extend approximately 270 m from the creek on the east bank.

Model results gave a “cross over” of water surface profiles at Herley Avenue, so that the computed 20 year level was higher than the 100 year value. This was an artefact of the model, resulting from the relatively coarse spacing of sections upstream of Herley Avenue. The water levels at sections 202 and 201.2 on Table B3.8 have been reduced to 61.5 m AHD for the 20 year flood (ie no higher than the computed 100 year flood).

B4.2.4 Branch KC03

Branch KC03 joins the west bank of Kemps Creek approximately 200 m upstream of Gurner Avenue. The hydraulic model extends upstream of the confluence for a distance of approximately 800 m (Table B3.9 and Figure B3.4). Backwater flooding from Kemps Creek extends approximately 270 m upstream. The creek has a bed slope of approximately 1% in its upper reaches but flattens out near Kemps Creek in the region affected by backwater flooding. Above the zone of influence of main stream flooding, the water surface profiles tend to converge showing only around 0.1 to 0.6 m range between 1 and 100 year ARI floods.

The natural course of the creek appears to have been significantly altered by the construction of a series of small storage dams interconnected by small excavated channels. The storage dams are mainly constructed by the excavation of the creek bed and thus would not have significant adverse effects on flood levels.

Approximately 270 m from Kemps Creek, a channel has been excavated perpendicular to the direction of KC03. This channel conveys flows approximately 130 m to the south (in the upstream direction with respect to Kemps Creek flows) to a small storage pond. Downstream of this pond there is no defined channel and any flood flows would be conveyed by numerous flood runners to Kemps Creek. The excavated channel which runs perpendicular to the existing creek direction would only contain minor flood flows and, once surcharged, flow would spread out over the floodplain and cause flooding problems to properties downstream.

B4.2.5 Branch KC07

Branch KC07 has its confluence immediately upstream of the bridge at Elizabeth Drive on Kemps Creek's west bank and extends for about 700 m to a point approximately 150 m upstream of the Cross Street road crossing (Table B3.10 and Figure B3.5). The average bed slope of the creek is 1.2% and, upstream of backwater effects from Kemps Creek flooding, the water surface profiles tend to converge showing only around 0.2 to 1.0 m range between 1 and 100 year ARI floods.

The culvert at Cross Street is a single 600 RCP which has an approximate 2 year ARI hydrologic capacity. The roadway results in an increase in flood levels across the culvert of approximately 1.2 m for the 1 year ARI flood. The limited capacity of the pipe causes ponding to occur upstream of the roadway and backwater effects extend approximately 150 m upstream.

A "crossover" of the water surface profiles occurs upstream of Cross Street, so the 20 year level is higher than the 100 year level. As discussed previously, this is an artefact of the model. Twenty year flood levels at sections 701.2 and 702.1 have been reduced to be no higher than 100 year values.

The creek is in the form of an excavated channel from Cross Street to a point approximately 250 m downstream. The creek has a bed slope of about 1% downstream of Cross Street which leads to a close spacing of the flood profiles between the 1 and 100 year ARI floods. The overbank area is fairly steep on both sides and therefore flows are constrained to a narrow flood extent which for the 100 year ARI storm event is only 60 m wide.

Near the downstream confluence with Kemps Creek an on-line storage dam has been constructed. This dam would cause some backwater effects for lesser floods but in the event of a 100 year ARI storm, flooding from Kemps Creek would inundate the dam and extend to a point approximately 50 m upstream.

B4.3 Bonds Creek Main Arm and Branches

B4.3.1 Bonds Creek

Denham Court Road to Bringelly Road

Bonds Creek has its headwaters in the Denham Court precinct which is under Camden City Council jurisdiction. Bonds Creek flows for a short distance in Liverpool City Council jurisdiction between Denham Court Road and Cowpasture Road where it then re-enters Camden City Council control for a short distance until it crosses under Bringelly Road and again re-enters Liverpool City Council control. The hydraulic model commences at Denham Court Road and continues to the confluence with Kemps Creek, a total distance of 6.4 km. (Table B3.12 - B3.16, Figure B3.7). Figure B3.9 shows typical cross sections and rating curves.

In its upper reaches Bonds Creek is in its natural state and contains large amounts of reed growth in its channel.

Downstream of Denham Court Road the creek has been diverted into 2 large storage dams which help to water a large agricultural establishment.

Between Denham Court Road and Cowpasture Road the creek waterway is small and has a less than 1 year ARI capacity. The surrounding topography is flat, leading to a wide floodplain which, in the event of a 100 year ARI storm, has a 300 m to 400 m wide flood extent. Due to the wide floodplain and its large capacity to convey flood flows, water surface levels only rise approximately 300 to 400 mm between the 5 to the 100 year ARI flood.

The 3 x 3300 x 1800 box culverts at Cowpasture Road and the 3 x 3000 x 1500 box culverts at Bringelly Road have an approximate hydrologic capacity of 10 year ARI. These two structures impose a considerable constriction on flows, which result in high velocities in their immediate vicinity. The culverts cause an increase in flood levels across the roadways, which for the 20 year ARI flood, are approximately 600 mm and 1.3 m respectively. For both road crossings backwater effects extend approximately 200 m upstream for events greater that the 1 year ARI flood. The backwater at Cowpasture Road extends to the Hume Highway.

Bringelly Road to Kemps Creek Confluence

Downstream of Bringelly Road the remaining road crossings are at a low level and generally have a hydrologic capacity around 2 year ARI, leading to frequent overtopping, which results in a large increase in overall hydraulic capacity for a comparatively small increase in upstream flood level. The channel is steeper than Kemps Creek and this results in generally higher flow velocities which average around 1.8 m/s. In the constricted areas near culverts, velocities are considerably higher (for example, at Ninth Avenue).

From Bringelly Road to its confluence with Kemps Creek, Bonds Creek has been excavated to form, what was originally, a regular trapezoidal channel. Over time, the banks of this channel have been eroded by flood flows due to the highly dispersive nature of the soil. The banks along the majority of its length have become close to vertical and in some locations the banks are collapsing into the creek bed.

Between Bringelly Road and Edmonson Avenue the creek bed contains amounts of reed growth which has been promoted by the erosion of the creek bed causing small depressions where standing water is present. The presence of the reeds increases the roughness characteristics of the creek and further reduces its capacity to convey flood flows.

The hydrologic capacity of the creek along this reach is between 1 and 2 year ARI, with flows from larger events surcharging the banks and flowing onto the floodplain. Between Bringelly Road and Fifth Avenue flood flows that surcharge the creek spread out across the low lying area on its east bank. At Fifth Avenue the creek is crossed by a footbridge which has no influence on flood levels. Downstream of Fifth Avenue the east bank has steeply rising ground which forces flood flows onto the west bank. Scalabrini Retirement Village is situated on the west bank between Fifth and Edmonson Avenues. There is a small levee constructed around the perimeter of the Village but a break in the levee of approximately 150 m along the west bank of Bonds Creek allows flood flow greater than 1 year ARI to enter the Village grounds.

The 4 x 3000 x 950 box culverts at Edmonson Avenue have a hydrologic capacity of approximately 2 year ARI. The road crossing causes ponding upstream for a distance of approximately 200 m.

Bonds Creek between Edmonson Avenue and its confluence with Kemps Creek has minimal reed growth in its invert, which reduces its hydraulic roughness. The creek crosses under a further four road crossings which have a hydrologic capacity of 2 year ARI or less.

Tributary 1 (Scalabrini Creek) joins Bonds Creek approximately 70 m upstream of Seventh Avenue. At this point Bonds Creek controls approximately 1000 ha of catchment while Tributary 1 contributes flow from approximately 580 ha of catchment.

Downstream of its confluence with Tributary 1, Bonds Creek has a capacity of 1 year ARI. Surcharging flows inundate the floodplain which is wide and has an elevation close to that of the creek banks. In the case of a 100 year ARI flood, water will inundate the floodplain for a width of 300 to 500 m. Velocities of flood flows on the floodplain are around 0.5 m/s. Due to the large conveyance capacity of the floodplain, flood levels between the 5 and 100 year ARI only increase by around 600 mm between Edmonson Avenue and Fourth Avenue and around 300 mm between Fourth Avenue and Tenth Avenue.

Downstream of Tenth Avenue, land on the east bank of Bonds Creek steepens, thus reducing the available area to convey flow. Water surface elevations in the reach of Bonds Creek from Tenth Avenue to a point approximately 800 m downstream, rise around 450 mm between the 5 and 100 year ARI floods.

At its confluence with Kemps Creek, flood flows which surcharge the creek inundate the heavily wooded western floodplain. In the event of a 100 year ARI storm, inundation of the western floodplain by both Bonds and Kemps Creek extends upstream of the confluence for about 900 m.

B4.3.2 Branch BC08

Bonds Creek has numerous small branch creeks which contribute flow but which do not exceed the trunk drainage limit of 5 m^3/s for the 100 year ARI event. Only one branch exceeds the above criterion. This branch is labelled BC08 and has its confluence with Bonds Creek on its western bank near Tenth Avenue.

A hydraulic model was constructed for BC08 from Tenth Avenue to a point approximately 800 m upstream. The HEC-2 model was used to ascertain flood levels in the upper reaches of the branch where the creek was well defined (Table B3.17 and Figure B3.8). The slope of the creek in this region is approximately 1.2% and water surface profiles tend to converge with a 0.1 to 0.2 m range between 1 and 100 year ARI floods.

The creek’s existing course has been altered by the excavation of a 130 m long channel running perpendicular to the natural creek direction, approximately 400 m upstream of Tenth Avenue. This channel conveys flows around a large building which has been constructed over the path of the natural creek. Levels in the vicinity of this building would be increased due to the reduction of flow area resulting from its construction. Due to the steepness of the channel upstream of this location, (approximately 1.2%), the influence of the increased levels does not extend far upstream.

Once past the end of the large building the bank of the excavated channel has numerous low spots which allow flows to escape and travel along flood runners which drain to small storage dams. In the event of a large flood, flows would be conveyed towards Tenth Avenue as shallow sheet flow. Bonds Creek surcharges for storm events greater than the 1 year ARI in this region, and resulting backwater effects will promote ponding behind Tenth Avenue.

B4.4 Tributary 1 (Scalabrini Creek)

Tributary 1 was modelled from Bringelly Road to its confluence with Bonds Creek upstream of Seventh Avenue, a distance of approximately 1.2 km (Tables B3.19 - B3.23 and Figure B3.10). Figure B3.11 shows typical cross-sections and rating curves.

At Bringelly Road approximately 470 ha of catchment contribute to flows with an additional 110 ha contributing at the confluence with Bonds Creek.

Between Bringelly Road and Fifth Avenue, Tributary 1 is in its natural state. The creek and its banks are heavily wooded and it has a flat low lying floodplain which is approximately 150 m wide. For storm events greater than 1 year ARI this floodplain becomes inundated. The bed slope in this region is approximately 0.3% and flow velocities are around 1-1.5 m/s.

At Fifth Avenue there is a 750 RCP which has a hydrologic capacity of less than 1 year ARI leading to frequent inundation of the roadway. Existing contouring of the roadway allows a major portion of the flow on the floodplain to move to the west away from the creek towards Fourth Avenue. Once flow has been conveyed away from the Fifth Avenue creek crossing it has no opportunity to re-enter the creek immediately downstream. Instead, it moves onto Fourth Avenue and is conveyed north where it may enter a recently excavated subsidiary channel along the eastern side of Fourth Avenue to the north of Sixth Avenue. This channel conveys flows back to Tributary 1 approximately 150 m downstream of Sixth Avenue.

The natural channel immediately downstream of Fifth Avenue is virtually non existent due to the major portion of the flow being conveyed away from the creek at Fifth Avenue. The natural creek continues for 150 m downstream of Fifth Avenue where it enters a large excavated trapezoidal channel.

The excavated channel on Tributary 1 has a hydrologic capacity of approximately 100 year ARI. Flow velocities in the channel are over 2 m/s and are dependent on the bed slope which averages about 0.55%. The channel was constructed to stop flooding of nearby properties but due to flows not being able to enter the channel at its upstream end, the two roads, Fifth Avenue and Fourth Avenue, are still being frequently inundated. The excavation of this channel has been undertaken more recently than that of the Bonds Creek channel. The first signs of bank erosion are present in the highly dispersive soil with numerous small rills forming in the banks where overland flow enters the channel. There has also been a large gully eroded adjacent to Sixth Avenue in the east bank which is approximately 2 m wide and conveys flows from the roadway.

Backwater effects from Bonds Creek extend upstream to a point 70 m downstream of Sixth Avenue on the Tributary's main drainage channel and extend back up the subsidiary channel to Fourth Avenue. Within this reach, the range between 1 and 100 year ARI peak flood levels is about 1.5 m with a further 1.2 m rise to the PMF. Flow velocities are reduced from 2 m/s to around 1 m/s in the channel and 0.3 m/s on the floodplain.

B4.5 Tributary 2 and Branches

B4.5.1 Tributary 2 (KC08)

Tributary 2 joins Kemps Creek on the upstream side of the bridge at Fifteenth Avenue on the eastern floodplain. The hydraulic model extends 3.1 km upstream through the Austral village area to Tenth Avenue (Tables B3.25 - B3.29 and Figure B3.12). Typical cross-sections and rating curves are shown on Figure B3.15. The creek is in its natural state for a majority of its length and generally has a hydrologic capacity less than 1 year ARI.

The average bed slope upstream of the influence of Kemps Creeks is around 0.8% and the water surface profiles converge with a range of 0.5 m between 1 and 100 year ARI floods.

Upstream of Eleventh Avenue, Tributary 2 has a fairly well defined creek and no floodplain. Flood flows up to the 100 year ARI event are contained in a narrow strip of land of average width 40 m. This may change in the future as construction is taking place downstream of Tenth Avenue which will pipe flood flows across a property.

Between Eleventh Avenue and Edmondson Avenue the construction of 2 driveways across the tributary with small culverts causes flood flows to surcharge the creek and spread out across the floodplain. These culverts have capacities less than 1 year ARI and, due to their location being in a wooded area, become readily blocked with organic litter.

Downstream of Edmondson Avenue flood flows greater than the 1 year ARI surcharge the banks of the tributary and inundate the flat, 150 m wide floodplain. At Twelfth Avenue the tributary follows beside the roadway before crossing under the road via a 2900 x 750 box culvert. The orientation of the culvert at right angles to the direction of flow greatly reduces its hydraulic efficiency. For this reason the culvert was assumed ineffective and was not included in the hydraulic model.

A large portion of the flows which surcharge the tributary at Twelfth Avenue are captured by the roadway and are convey west to the intersection of Twelfth Avenue and Fourth Avenue. At this point they turn north and head along Fourth Avenue where they join flood flows from Branch KC11 and that portion of flow which was not captured by Twelfth Avenue road reserve.

The orientation of the tributary, the size of the existing culverts and the nature of flooding at Fourth Avenue result in the roadway acting as a broad crested weir and cause ponding upstream. This ponding causes backwater effects to be experienced approximately 200 m upstream for all storm events. The culvert beneath Fourth Avenue was assumed ineffective and all of the flow was assumed to be conveyed over the roadway, which acts as a broad crested weir (Figure B3.12).

Immediately downstream of Fourth Avenue the presence of fill on the floodplain will further exacerbate flooding by reducing the area available for flow and flood storage, thus raising levels.

Between Thirteenth and Fourteenth Avenues flood flows that are larger than the 1 year ARI event inundate the floodplain for an approximate width of 200 m. The wide, flat floodplain has a large hydraulic capacity so that only a small increase occurs in levels of approximately 150 mm between the 5 to 100 year ARI events.

At Fourteenth Avenue the tributary follows the direction of the roadway inside the road reserve towards Kemps Creek. The hydrologic capacity of this channel again is around 1 year ARI. For events larger than 1 year ARI, flows cross the roadway and either travel overland to an excavated channel which conveys flows from branch KC13 and runs parallel with Fourteenth Avenue for smaller events or, in the case of the 100 year ARI, totally inundate the floodplain.

B4.5.2 Branch KC11

Branch KC11 has its confluence with Tributary 2 about 150 m downstream of Fourth Avenue. The hydraulic model has its downstream section immediately upstream of Fourth Avenue. The creek was modelled for a length of 1.1 km to a point approximately 300 m upstream of the intersection of Edmondson and Thirteenth Avenues (Table B3.30 and Figure B3.13). The branch has relatively steep rising land on both its banks which contain the full range of flood flows to a maximum width of approximately 100 m for the PMF event. The 600 RCP under the intersection of Edmondson and Thirteenth Avenues has a hydrologic capacity of less than 1 year ARI which leads to frequent inundation of the intersection.

Backwater influences caused by flooding at Fourth Avenue extend approximately 100 m upstream. The upper two-thirds of KC11 has an average bed slope of 1.5% and water surface profiles converge with a range of 0.1 to 0.5 m between the 1 and 100 year ARI floods. The PMF level is an additional 0.2 to 0.3 m above the 100 year ARI. Velocities in the channel are around 0.7 m/s.

B4.5.3 Branch KC13

Branch KC13 has its confluence with Tributary 2 near Kemps Creek. Due to the nature of flooding of Tributary 2, which was discussed earlier, flood flows from the KC13 catchment would be joined by those of Tributary 2 upstream of its confluence, at the location where Tributary 2 enters the Fourteenth Avenue Road Reserve. For this reason the hydraulic model of branch KC13 started at this location and continued for 1.1 km upstream to a point approximately 400 m upstream of the intersection Fourth and Fifteenth Avenues (Table B3.31 and Figure B3.14). Upstream of the intersection residences have been constructed on the creek's left bank, the elevation of which prevents any flooding problems up to the PMF. Four 525 mm diameter pipes convey flows underneath the intersection. The hydrologic capacity of these pipes is less than 1 year ARI, causing frequent inundation of the intersection.

Downstream of the intersection the creek follows Fifteenth Avenue for a distance of 150 m before heading across country. Land to the south of Fifteenth Avenue directly downstream of the intersection is flat, and surcharging of the intersection would cause flood flows to quickly inundate this land. Approximately 250 m downstream of the intersection the left floodplain steepens and flood flows are contained for a short distance before they spread out again prior to joining flood flows from Tributary 2.

KC13 has an average bed slope of 1.2% and water surface profiles differ by around 0.3 m between the 1 and 100 year ARI's. The PMF level is an additional 0.3 to 0.4 m above the 100 year ARI. Velocities in the channel average around 1 m/s.

B4.6 Tributary 3 and Branches

B4.6.1 Tributary 3 (KC14)

Tributary 3 joins Kemps Creek approximately 600 m upstream of Elizabeth Drive. The hydraulic model extends over 5 km from the junction with Kemps Creek to Fourteenth Avenue (Tables B3.33 - 3.37 and Figure B3.16). The tributary has its headwaters in the Austral village area and crosses five roadways before entering open land where it meanders through both cleared and heavily wooded areas.

In its upper reaches between Fourteenth Avenue and Eighteenth Avenue, the natural course of the tributary has been altered in many locations by land owners so that it follows property boundaries. At Fifteenth, Seventeenth and Eighteenth Avenues the northerly flowing creek crosses the east-west running road reserves offset to the east of the original route of the creek. The creek now makes two 90° turns so that flow can enter the culverts. These sharp directional changes greatly reduce the hydraulic capacity of the existing culverts. In the event of a large flood flow would not follow these bends and would pass directly over the roadway.

The culverts under Fourteenth, Fifteenth, Sixteenth and Eighteenth Avenues have hydrologic capacities equal to or less than 1 year ARI which leads to frequent inundation of the roadways (Table B3.32). At Seventeenth Avenue there are 2 x 3000 x 1200 box culverts which have a nominal hydrologic capacity greater than 100 year ARI. In practice, this large capacity would be greatly reduced due to the stream orientation upstream.

The creek bed between Fourteenth and Eighteenth Avenues has an average slope of over 1% and channel velocities are around 1.5-2 m/s except in the ponding areas upstream of the five road crossings. In this reach water surface profiles converge and have a range of less than 0.5 m between the 1 and 100 year ARI floods.

Between Fourteenth and Seventeenth Avenues there is no floodplain and flows are contained within a 50 to 100 m flood extent. Downstream of Seventeenth Avenue the land begins to flatten out and flood flows greater than 1 year ARI spread out across this low lying area.

Downstream of Eighteenth Avenue the tributary is joined by branch KC19 and heads across open land till it reaches Kemps Creek 3.5 km downstream. Along this 3.5 km reach of Tributary 3 the creek has a hydrologic capacity less than 1 year ARI. Flood flows spread out across the floodplain for a width of around 200 m which increases to around 400 m downstream of its confluence with branch KC24. The creek bed along this reach has an average bed slope of 0.6% and there is a range of about 1 m between 1 and 100 year ARI water surface levels. Flow velocities at the 100 year level are generally less than 1 m/s in the channel and 0.5 m/s on the floodplain.

B4.6.2 Branch KC17

Branch KC17 has its headwaters to the south of Gurner Avenue. The hydraulic model for KC17 starts at its confluence with Tributary 3 adjacent to Kemps Creek electrical substation and extends approximately 900 m upstream to a point 230 m to the north of Gurner Avenue (Table B3.38 and Figure B3.17). The creek is ill defined over its length and flood flows inundate the 150 m wide floodplain.

Upstream of the junction, KC17 has an average bed slope of around 0.8% for a distance of 500 m and the water surface profiles differ by 0.2 to 0.5 m between the 1 and 100 year ARI floods. In its upper reaches the bed slope increases to around 1.5% and water surface profiles converge to less than 0.2 m between the 1 and 100 year ARI floods.

B4.6.3 Branch KC19

Branch KC19 runs parallel to Eighteenth Avenue and has an average bed slope of approximately 1.2%. KC19 has its confluence with Tributary 3 approximately 100 m downstream of Eighteenth Avenue. The hydraulic model extends approximately 700 m to the east of its junction with Tributary 3 (Table B3.39 and Figure B3.18). KC19 has a catchment area of only 38 ha leading to a range of flows of 2 to 8 m^3/s and a difference in water surface levels of 0.1 to 0.6 m between the 1 and 100 year ARI floods respectively.

The branch has 4 access driveways constructed across it. These crossing were not included in the HEC-2 model but for major storm events they would surcharge. Due to these crossing being low-level structures they will not cause backwater effects for major storm events but may cause small ponding regions for floods which do not surcharge the driveways.

B4.6.4 Branch KC23

Branch KC23 has its confluence with Tributary 3 approximately 1.7 km downstream of Eighteenth Avenue. The HEC-2 model extends upstream for a distance of 800 m (Table B3.40 and Figure B3.19). KC23 catchment has been cleared for pastoral reasons except for a strip of land which extends 300 m upstream from its junction with Tributary 3. The creek bed has an average slope of 1.3% and a difference in water surface levels of 0.5 m between the 1 and 100 year ARI floods. The creek has formed a gully in the lower 500 m of its length.

B4.6.5 Branch KC24

Branch KC24 has its confluence with Tributary 3 approximately 1 km upstream of its confluence with Kemps Creek. The creek was modelled for a distance of 1.6 km and has an average bed slope of approximately 1.3% (Table B3.41 and Figure B3.20). The catchment of KC24, as with KC23, has been mainly cleared of trees. The construction of 5 small on-line storage dams has caused flood flows to skirt the embankments and push water out onto the floodplain. Fast moving flood flows re-entering the creek have caused large amounts of erosion in the highly dispersive soil. Due to the steepness of KC24 the water surface profiles between these dams varies by only 100 mm between the 1 and 100 year ARI floods.

B4.6.6 Branch KC27

Branch KC27 has its confluence with Tributary 3, to the south of the sandmining plant at Cecil Park, and approximately 700 m upstream of the confluence of Tributary 3 with Kemps Creek (Table B3.42 and Figure B3.21). The branch meanders through open country till it reaches the eastern boundary of the sandmining plant. The sandmining plant has been constructed over the existing creek, thus a channel has been excavated which conveys flows along its eastern boundary to the south. At the south eastern corner of the sandmining plant the creek turns north and joins Tributary 3.

In its upper reaches the creek is relatively steep with an average slope of 2.2% which decreases to around 1.5% approximately 300 m upstream of the eastern boundary of the sandmining plant. Water surface profiles converge showing only around 0.1 to 0.7 m range between the 1 and 100 year ARI flood.

B4.7 Floodway Zone

The floodway zone is delineated by the boundary between the floodway and flood storage areas on the floodplain. The 100 year ARI flood discharge was adopted as the basis for defining the floodway zone.

The floodway zone was assessed in Kemps and Bonds Creeks and its tributaries using the HEC-2 model. There are 5 encroachment methods built into the program from which methods 4 and 5 can be used to estimate the floodway zone within the floodplain. These methods calculate the floodway width by gradually reducing the area available for flow on the floodplain until water levels rise by a specified amount.

Method 4 was adopted for the analysis of the floodway zone. This method computes encroachment stations so that conveyance within the encroached cross section at the higher level is equal to the conveyance of the section under existing conditions. The target water level specified for the encroachments was 100 mm above the 100 year ARI water surface level as indicated in the NSW Floodplain Development Manual (1986). The encroachment stations are determined by the program so that equal loss of conveyance occurs on each overbank. If half of the loss can not be obtained in one overbank the difference is made up, if possible, in the other overbank, except that the encroachments are not allowed to fall within the main channel.

The floodway zone calculated with the HEC-2 model is shown in Figure B4.2. A set of plans at 1:2,000 scale, which show the boundary between the floodway and flood storage areas on the floodplain, have been supplied to Liverpool City Council.

The accuracy of the floodway extent is dependent on the accuracy of the HEC-2 model results. The floodway zone is calculated at each cross section in the HEC-2 model and the zone is interpolated in between sections. The floodway zones calculated at bridges were treated with caution and interpreted with the results at the sections upstream and downstream of the bridge to determine a realistic floodway zone. The floodway zone shown on the plans gives an approximate indication of land available for development and could be used for preliminary planning purposes.

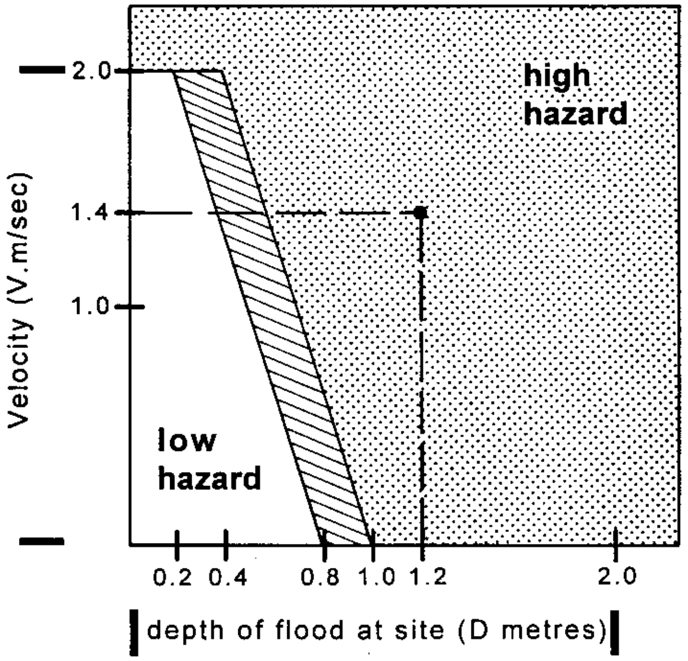
B4.8 Flood Hazard

The flood hazard zone is that region within which a flood may potentially cause damage to properties or persons. The 100 year ARI event was adopted as one criterion for defining the flood hazard zone.

A location may be considered hazardous due to the depth of flood water and/or its velocity. The definition of a hazardous region was adopted from the NSW Floodplain Development Manual (1986). Figure B4.1 (Figure 7 in the Manual) shows the relationship between the product of the water depth and the velocity which was used to define the hazardous regions. The outer line of Figure B4.1 was adopted.

At each section in the HEC-2 model, the west overbank, east overbank, and main channel velocities and the top water level are calculated The location on the west and east overbank of the boundary between the high and low hazard category was then determined using Figure B4.1.

By repeating this exercise for each section and interpolating between each section, the flood hazard boundary for the 100 year ARI was determined.



NOTE:
The degree of hazard may be either -

- reduced by the establishment of an effective flood evacuation procedure.
- increased if evacuation difficulties exist.

Within area the degree of hazard is dependent on site conditions and the nature of the proposed development.

EXAMPLE
If the depth of flood water is **1.2m**
and the velocity of floodwater is **1.4m/sec**

then the provisional flood hazard is **high**

(Source: NSW Floodplain Management Manual)

AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure B4.1

PROVISIONAL HAZARD CATEGORIES

B5. REFERENCES

Department of Water Resources (1990), "Flood Study Report - South Creek".

Department of Water Resources (1991), "South Creek Floodplain Management Study".

NSW Government (1986), "Floodplain Development Manual", PWD 86010.

US Army Corps of Engineers (1995), "HEC-RAS River Analysis System", Users Manual.

LIVERPOOL CITY COUNCIL

AUSTRAL FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

Review and Finalisation

APPENDIX C

ASSESSMENT OF FLOOD DAMAGES

September 2003

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Job No NC812 File: f:\documents\austral fms\construction files\appc.doc	Date: 18 September 2003 Rev: 5.0	Principal: SJP Reviewer: BWL

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FIGURES

SYNOPSIS

Estimation of flood damages was carried out to permit a "broad brush" economic assessment of various flood mitigation strategies and to provide input data to the selection of the flood standard. Damages from floods ranging between the 1 year ARI and probable maximum flood (PMF) events were assessed with the assistance of a numerical computer model and spread sheets. Data for the model comprised an estimate of the depths of inundation over the floodplain, as well as information on the value of damages to residential, commercial and industrial property.

The depth of inundation was determined from the results of the hydraulic modelling described in Appendix B. Property damage was estimated from site inspection, supplemented by the results of several investigations carried out for the Department of Water Resources (LMJ, 1985; LMCE, 1992; 1994; DWR, 1990).

There are no data available on historic flood damages in the Austral area. Accordingly, data on damages experienced during recent flooding in other centres of NSW were transposed and used in the assessment for Austral. To that extent the computed values are "potential" damages rather than actually experienced damages. A small percentage reduction has been made to allow for property evacuation which would reduce the damages actually experienced in future floods to values below these potential damages. The resulting damages are labelled "actual" damages in the tables.

Damages calculated in LMCE's 1995 study have been updated as part of the 2002 review. Damages have been converted to 2002 values by applying the CPI as supplied by the ABS (a rate of 1.18).

In addition residential, commercial and public damages have been increased by multiplying by a factor of 2, based on data obtained from more recent flooding events. Recent data presented by the Bureau of Transport and Regional Economics (2002) and R. Blong (2001) have indicated that residential damages should be increased by at least 2 x URBLOSS damages (approximately $70,000 at 2 m depth of inundation). We have also applied these findings to industrial/commercial and public properties, using the same line of reasoning.

Agricultural damages have been adjusted by applying the CPI rate only, as these damages were based on original Gresearch carried out in 1995.

C1. INTRODUCTION AND SCOPE

C1.1 Introduction

Damages from flooding belong to two categories:

- **Tangible Damages**
- **Intangible Damages**

Tangible damages are defined as those to which monetary values may be assigned, and may be subdivided into direct and indirect damages. Direct damages are those caused by physical contact of flood water with damageable property. They include damages to commercial and residential building structures and contents, and infrastructure such as electricity, gas, water supply and sewerage reticulation. Indirect damages result from the interruption of community activities, including traffic flows, trade, industrial production, costs to relief agencies, evacuation of people and contents and clean up after the flood.

Generally, tangible damages are measurable in dollar values using survey procedures, interpretation and research of government files.

The various factors included in the **intangible damages** category may be significant. However, these effects are difficult to quantify due to lack of data and the absence of an accepted method. Such factors may include:

- inconvenience
- isolation
- disruption of family and social activities
- anxiety, pain and suffering, trauma
- physical ill-health
- psychological ill-health.

C1.2 Scope of Investigation

In the following sections, damages to residential, commercial and industrial properties as well as public buildings in the Austral-Kemps Creek area have been estimated.

From site inspection, residences were classified into "low", "medium" and "high" value properties. Potential damages for each class were estimated from depth-damage functions which relate the direct potential damages caused to individual structures with the above-floor depth of inundation. The damage functions include damages to structures, building fabric and contents. From estimates of the depths of inundation for floods of various recurrence intervals, the individual damage functions have been integrated to give estimates of total direct damages. In this step, allowance has been made for some property evacuation which would reduce the damages actually experienced to values below the potential damages.

Commercial and public building damages may be computed via individual stage-damage relationships, or on the basis of damages per square metre of floor area for a range of depths of inundation. For this present investigation, they were estimated on an areal basis, with the properties categorised into "low", "medium" or "high" value enterprises.

Damages to agricultural enterprises such as market gardens have been assessed on the basis of the area of cultivated land, greenhouses and animal housing sheds within the area affected by flooding. For each enterprise the value of damage and lost production has been estimated from data provided by NSW Agriculture.

C2. DESCRIPTION OF NUMERICAL MODEL

The computer model URBLOSS was used to process the residential and commercial damages data. This program calculates the depth of inundation and associated losses for all kinds of properties in an urban setting. The program requires three input files which define property characteristics, water surface elevations and stage-damage relationships.

The program estimates residential damages on a property by property basis according to a probable damage category (high, medium or low value), the location of the property and the depth of inundation.

The model requires data describing the flood levels within the area of interest. This data is derived from hydraulic modelling as described in Appendix B. The flood liable area is subdivided into triangular cells in which the vertices of each triangle are located by coordinates at which water surface elevations are specified. The program then calculates a water surface plane which defines water surface elevations at all points within the triangle. The depth of flooding is computed as the difference between this plane and floor elevation at each property. Damage is estimated from depth-damage curves appropriate to each property type.

Included within the program is the ability to model the reduction in flood damages which result from flood awareness and flood warning. The reduced damages are denoted "actual" damages.

It should be understood that URBLOSS is not intended to identify individual properties liable to flood damages and individual values of damages, even though it appears to be capable of doing so. The reason for this caveat lies in the various assumptions used in the procedure, the main ones being:

- assumption that computed water levels are accurate and without any error;
- assumption that the water surfaces between computational points are planar, not curved;
- assumption that floor levels can be accurately determined on the basis of local ground levels shown on topographic plans together with visual estimates of floor height above ground level
- the use of "average" stage-damage relationships, rather than a relationship for each property
- the uncertainty associated with assessing an accurate factor to convert potential to actual flood damages for each property.

The consequence is that some individual properties may be inappropriately included as flood liable, while others may be excluded. Nevertheless, when applied over a broad area these effects will tend to cancel, and the resulting estimates of overall damages, both potential and actual, will be reasonably accurate.

C3. SOURCES OF DATA

To estimate average annual flood damages for a specific area it is necessary to estimate the damages for several floods of different magnitudes, ie of different frequencies, and then to integrate the damages over the whole range of frequencies. To do this is necessary to have data on the damages sustained by all types of property over the likely range of inundation. There are several ways of doing this, as follows:

- The ideal way would be to conduct specific surveys in the aftermath of a range of floods, preferably immediately after each. This has been done previously in the Forbes area, with details of 5 flood properties in Eugowra and 18 in Forbes obtained following the August 1990 flood. The results of that survey are contained in the Forbes Flood Damage Survey (Water Studies, 1992). Another example approaching this ideal is the case of Nyngan where surveys were conducted in May 1990 following the disastrous flood of a month earlier (DWR, 1990).

- The second best way is for experienced assessors to conduct a survey to estimate likely losses that would arise due to various depths of inundation. This approach is used from time to time, but it can add significantly to the cost of a floodplain management study (LMJ, 1985). It was not used for this current study.

- The third way is to adapt or transpose, data from another flood liable area. This was the approach used for this investigation. It involved use of the basic data collected for Forbes, Eugowra and Nyngan and making adjustments to account for changes in values due to inflation, and to account for differences in the nature of developments between those towns and the study area. This was assisted by conducting a drive-by survey in flood liable areas of the study area.

- The fourth way is to use generalised data such as that published by CRES (Centre for Resource & Economic Studies, Canberra) and used in the Floodplain Management Study for Forbes (SKM, 1994). This data is considered suitable for generalised studies, such as broad regional studies. It is not considered suitable for use in specific areas, unless none of the other approaches can be satisfactorily applied.

As indicated above an important source of data for this study was a drive-by inspection of all properties in the Austral area estimated to be affected by all flooding events up to and including the PMF, which was carried out as part of the 1995 study. The properties were divided into three categories: residential, commercial/industrial/agricultural and public buildings. The survey covered all of the creeks modelled in Appendix B. Data obtained from the drive-by inspection for residential properties, included:

- the location/address of each property
- a description of the residence
- an estimate of the residence's value class, age and size
- an estimation the construction type and foundations
- a description of any external buildings/structures
- an estimation of the height of floor level above the ground level.

For commercial/industrial properties and public buildings, information was recorded regarding:

- the location of each property
- the nature of each enterprise
- an estimation of the floor area
- an estimation the construction type and foundations of the property
- an estimation of the height of floor level above the ground level.

The property descriptions were used to classify the properties into categories according to the likely effect of flooding and likely extent of flood damages.

The photogrammetric mapping carried out for this study, provided spot levels on the ground adjacent to each building at which level, the property became flood affected. Following collation of the data obtained from the drive-by inspection, floor levels of flood prone properties were estimated. These floor levels were then inserted into input files for the URBLOSS model. A property is said to be flood affected when the water level is above the ground level of the building and flood damaged when the water level is above the floor level.

The drive-by inspection provided estimates of floor levels of all buildings located on any one property, including garages, laundries and granny flats. In general, where there was more than one structure on a property, the lowest floor level was adopted as the level at which damages would commence, for the purposes of the URBLOSS model. This was considered to be a valid approach because damageable items and property are frequently stored in these additional buildings.

Vacant blocks and carparks were not included in the model. No account was taken of vehicles remaining in carparks during a flood.

C4. RESIDENTIAL DAMAGES

C4.1 Direct Residential Damages

C4.1.1 Method

The study area was subdivided into damage cells, with the cell layout generally following the same orientation as that of the HEC-2 hydraulic model. Properties assessed as being flood prone at the PMF level were included in the damages model.

C4.1.2 Damage Functions

A depth-damage curve relates flood damage to depth of flooding above floor level for different property types. In this study, depth-damage curves were used to estimate:

- Direct internal damages
- Structural damages
- External damages

Previous studies have shown that residential depth-damage curves, both actual and potential, can be reduced to a generalised relationship of the following form (Water Studies, 1986):

$$\frac{D}{D_2} = 0.06 + 1.42H - 0.61H^2 \qquad \text{for } H < 1 \text{ metre}$$

and

$$\frac{D}{D_2} = 0.75 + 0.12H \qquad \text{for } H > 1 \text{ metre}$$

Where
D = potential damages ($)
H = depth of inundation above floor level (metres)
D_2 = potential damages ($) at 2 metres inundation

These equations provide an estimate of the potential damage to a property if no action is taken by the householder to reduce damage during a flood (such as removing valuable electronic equipment or lifting furniture onto a table). The ability of a resident to effectively reduce damage is closely related to the warning time.

In the case of Austral, even if an effective flood warning system were in place there would only be a few hours warning time. Flooding experience in the past 15 years is limited to relatively minor events, and because there is no recent experience of major flooding the degree of flood awareness in the area for such events is low. With low awareness and little warning time, residents would not be expected to take actions such as lifting and removing carpets, lifting some possessions to higher levels or evacuating them from the house, removing garden furniture, mowers, boats and trailers, etc. Accordingly, the potential internal and external damages were reduced by only 10% to give an estimate of actual internal and external damages.

No reduction was applied to potential structural damages when computing actual damage, as this damage category is not sensitive to flood warning time.

As part of the 2002 review, the damage values originally adopted were reviewed. Recent Australian and overseas flood damage data presented by the Bureau of Transport and Regional Economics

(2002) and R. Blong (2001) indicates that a medium potential damage value of around $70,000 at 2 m depth of inundation is recommended. This recent data suggests that the flood damages for residential damages are double those currently used previously in URBLOSS. Accordingly, the residential damages obtained in the 1995 study have been updated by multiplying the **total damages** (including direct and indirect damages) by the CPI rate from 1995 to 2002 (1.18) and then doubling them, according to the current practice. The revised D_2 values are given below.

Property Value Class	Internal	External	Structural	Total
Low	$34,000	$4,000	$20,000	**$58,000**
Medium	$40,000	$4,000	$25,000	**$69,000**
High	$47,000	$5,000	$32,000	**$84,000**

C4.2 Indirect Residential Damages

Indirect residential damages comprise the costs of evacuating people and contents, providing temporary accommodation, cash grants to welfare and relief agencies, clean-up costs after the flood and loss of wages.

Because of the lack of readily useable data on this subject, these costs are sometimes estimated as a percentage of the direct damages. Typically, a value of 15% of actual direct damages is adopted (LMJ, 1985; SKM, 1994).

In the Nyngan study, the average indirect cost was $7,700 ($18,200) per flooded property. Of this amount the cost of clean up was $2,400 ($5,700) and the remaining financial cost of $5,300 ($12,500) amounted to 28% of the total actual direct cost to surveyed properties. The Nyngan residents were away from their homes for a long period (21 - 28 days) and were accommodated at public expense. In other situations, eg Georges River in 1986 where the ratio to direct damage was 5%, the flooded individuals were away for a shorter duration, around 12 days, and found private accommodation. (Costs in brackets are the updated 2002 costs.)

For the present study clean up costs were estimated at $2,500 ($5,900) per dwelling, based on Nyngan and adjusted for inflation. Additional welfare and disaster relief costs were assessed at 15% of actual direct damages. This percentage value lies between the Nyngan and Georges River cases and appears reasonable for the Austral situation.

C4.3 Total Residential Damages

In order to estimate damages on individual creeks, the study area was divided up as follows (see Figure 4.1):

- Bonds Creek and Scalabrini Creek (Tributary 1)
- Kemps Creek main arm and branches on the west bank in the reach between Bringelly Road and Elizabeth Drive
- Tributary 2 of Kemps Creek
- Tributary 3 of Kemps Creek. This model includes Tributary KC07 which joins the left bank of Kemps Creek near Elizabeth Drive,

Three hundred and fifty nine residential dwellings were identified in the 1995 drive-by survey as being located in the floodplain and were included in the damages assessment. Of these, 68 residential dwellings are located within the extent of the 100 year ARI high hazard floodway.

Tables C4.1 to C4.4 summarise the estimated actual residential damages for a range of floods. The damage estimates were carried out for floods between the 1 year ARI flood level, which is approximately the threshold flood at which significant damages commence, and the PMF event.

Table C4.1
Bonds Creek and Scalabrini Creek (Tributary 1)
Estimated Actual Residential Damages

Flood Event	Number of Properties		Damages ($\$ \times 10^3$)		
ARI (years)	Flood Affected	Damaged	Direct	Indirect	Total
1	12	9	79	65	144
5	41	26	551	236	787
20	72	52	1,416	520	1,936
100	89	61	1,959	654	2,615
PMF	116	95	3,801	1,133	4,934

In this section of the creek system, flooding greater than 1 year ARI results in inundation over a wide area of the floodplain, particularly upstream of Tenth Avenue. This effect is responsible for the rapid increase in the number of flood damaged residences in the range of 5 to 20 year ARI floods. The damages curve tends to flatten out above the 20 year ARI flood, and from the 100 year ARI flood onwards there is a gradual increase in damages up to the PMF.

A total of 61 properties are flooded in the event of the 100 year ARI flood. This area is the most damage-liable in the Austral study area, with about 60% of the 102 residences liable to be damaged by the 100 year ARI flood. At the PMF level of flooding, the corresponding value is 55%.

Table C4.2
Kemps Creek Main Arm and Branches on West Bank (Elizabeth Drive to Bringelly Road)
Estimated Actual Residential Damages

Flood Event	Number of Properties		Damages ($\$ \times 10^3$)		
ARI (years)	Flood Affected	Damaged	Direct	Indirect	Total
1	11	4	73	35	107
5	22	16	222	128	350
20	25	20	404	179	583
100	38	29	695	276	971
PMF	65	51	1,914	589	2,503

Flood damage occurs at scattered locations as a result of a 1 year ARI flood. For larger floods, the increasing extent of inundation results in more concentrated damages in the vicinity of Gurner Avenue upstream as far as Thirteenth Avenue and between Elizabeth Drive and Pratten Street. However flood damages are only about half those experienced on Bonds - Scalabrini Creeks at the PMF event.

Table C4.3
Kemps Creek Tributary 2
Estimated Actual Residential Damages

Flood Event	Number of Properties		Damages ($ x 10 3)		
ARI(years)	Flood Affected	Damaged	Direct	Indirect	Total
1	10	8	159	71	230
5	13	8	228	82	309
20	15	9	276	95	371
100	17	10	318	107	425
PMF	27	17	591	189	781

Tributary 2 is relatively small in terms of catchment area and peak flows, but experiences considerable flood damage due to close settlement, the ill-defined nature of the creek, inadequate drainage capacity at road crossings and activities which have altered the natural overland flow paths.

Considerable damage occurs in the reach between Eleventh and Fourteenth Avenues. Flows travel down Twelfth Avenue to Fourth Avenue and along this road, to rejoin the creek downstream of the three small pipes (600 and 900 RCP's) which comprise the drainage system at the road crossing. Considerable ponding occurs upstream of Fourth Avenue due to inadequate capacity of these pipes.

Table C4.4
Kemps Creek Tributary 3 and Tributary KC07
Estimated Actual Residential Damages

Flood Event	Number of Properties		Damages ($ x 10^3)		
ARI (years)	Flood Affected	Damaged	Direct	Indirect	Total
1	3	0	0	0	0
5	4	0	0	0	0
20	6	1	0	6	6
100	7	2	29	16	45
PMF	14	10	255	97	252

Lesser damages are experienced than in the other creeks as there is less settlement in this catchment. Most of the damages occur in the reach between Eighteenth and Fourteenth Avenues.

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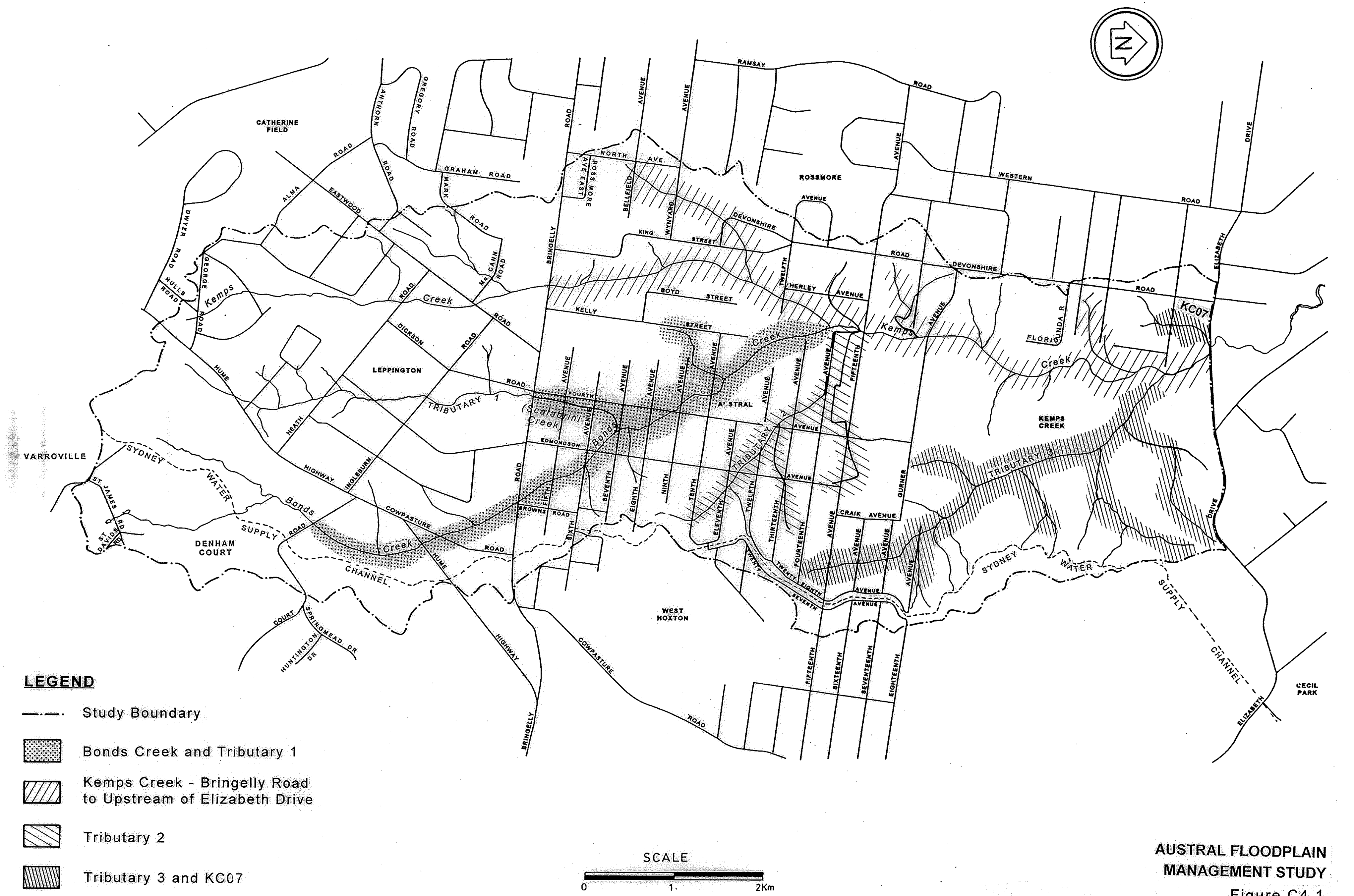


AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure C4.1

DAMAGE ASSESSMENT LOCATION PLAN

C5. COMMERCIAL/INDUSTRIAL AND AGRICULTURAL DAMAGES

Commercial/industrial and agricultural properties were assessed separately. Agricultural properties were subdivided into market gardens, green houses and poultry sheds. Caravans have also been included under this category.

C5.1 Commercial and Industrial Properties

C5.1.1 Method

Excluding agricultural enterprises, there are less than 20 commercial and industrial businesses in flood affected land within the study area. Direct damages up to the PMF event were estimated using a spreadsheet employing the same method to that used in the URBLOSS model. Each enterprise was included in the data base and flood levels were obtained from the HEC-2 model results.

Ground levels were obtained from spot levels from the photogrammetric mapping undertaken in the course of this study and the height of floor level above ground level for each property was estimated from a drive by survey.

C5.1.2 Damage Functions

Each property was categorised in terms of the following:

- damage category
- floor area
- floor level

The damage category assigned to each enterprise was "low", "medium" or "high", depending on the nature of the enterprise and the likely effects of flooding. Damages were then determined on the basis of floor area. Using the same approach adopted for increasing the residential damages, commercial damages have been updated to 2002 values by multiplying by 2 and the CPI rate (2 x 1.18). The following damage functions (2002 values) were adopted for potential internal damages for both commercial and industrial properties:

Low value enterprise	\$346/m^2
Medium value enterprise	\$890/m^2
High value enterprise	\$1,362/m^2

These values were based on selected results derived from the survey of flood affected properties and presented in the Nyngan Study (DWR, 1990) adjusted for inflation.

The above values are indexed to a depth of inundation of 2 m. At floor level and 1.2 m inundation, zero and 70% of these values respectively were assumed to occur. The resulting depth-damage relationship is rather similar to that used in the ANUFLOOD computer model (SKM, 1994).

The factor for converting potential to actual damages depends on a range of variables such as the available warning time, flood awareness and the depth of inundation. Given sufficient warning time a well prepared organisation will be able to temporarily lift property above floor level. However, unless property is actually moved to flood free areas, floods which result in a large depth of above floor inundation will result in considerable damage to stock and contents.
For the present study, the approach of relating the potential to actual conversion factors to the depth of inundation was adopted. The shape of the resulting relationship is related to the short warning time available and the low flood awareness.

Potential damages were converted to actual damages using percentages which were 14% at zero inundation, increasing to 36% for an inundation of 400 mm, and 90% at 1.6 m, at which depth it remained constant.

Other investigators have used similar approaches or have based the conversion factors on warning time and preparedness only, not depth. In the recent study for Forbes (SKM, 1994) a value of 0.15 was adopted to convert potential to actual damages. That community would have a high degree of preparedness given the history of flooding in the town and accordingly the conversion factor would be low.

External and structural damages were assessed as 1% and 3% of the actual internal damages respectively.

C5.2 Agricultural Properties

The cost for the flood damages (2002 values) to the other categories of commercial properties is as follows:

Markets Gardens	$2,650/ha
Green Houses	$9,500 each
Caravans	$16,500 each
Poultry Sheds	$50,000 each

These figures are based on 1995 average commercial values for each property indexed for inflation to 2002 and are independent of the depth of inundation. These figures **have not** been doubled, as they were based on original research and not on any data provided by ANUFLOOD.

External damages were assessed as 1% of internal damages (excluding market gardens for which no external damages occur).

C5.2.1 Market Gardens

Market gardens in the Austral-Kemps Creek area grow a wide variety of vegetables for the Sydney retail market. Most market garden operations are able to grow 3 - 4 crops per year and have a continual rotation of crops at various stages of growth.

Data available from NSW Agriculture (1993, 1995) presents gross margins for the production of a wide variety of vegetables including Asian vegetables which are increasingly grown in the Austral area. The gross margin data includes typical cost for all operations and inputs associated with vegetable growing. These data were analysed to determine the cumulative costs of cultivation, planting, fertilisers, sprays and irrigation for various stages of crop development up to but not including harvesting. The worst case for damages would be if a flood occurred just prior to harvest and that this was no residual value in the crop. By assuming that at any one time there would be a series of crops at various stages of development, the average damage from a single flood occurring at any time during the year was determined to be 70% of the average investment in growing a crop to the point of harvest. The average investment, based on the gross margin data ranges from $1,775/ha to $9,500/ha depending on the crop. The average investment is $3,800/ha which converts to an average potential loss of $2,650/ha (updated to 2002 values).

C5.2.2 Greenhouses

Two types of greenhouse operation are common in the Austral area:

- growing crops in the natural soil;
- growing crops under hydroponic conditions on raised trestles.

Most greenhouses which occupy an area of 500 m^2 are half round structures covered with plastic. These structures cost about $9,500 each (Lawrence Ullio-pers com) to replace. It has been assumed that a flood would destroy a greenhouse and ruin any crop grown on the ground within it. For hydroponic systems, it is assumed that, while the crop would be unaffected, damage to equipment would be $600 per greenhouse (updated to 2002 values).

C5.2.3 Poultry Sheds

There are a number of chicken rearing enterprises within the flood affected area of Austral. Flooding up to a depth of 1 m is not likely to affect the poultry cages but can be expected to cause damage to the structure and to equipment. The estimated damage for floods up to 1 m depth (about the maximum for the locations in Austral used for poultry sheds) is $50,000 per shed (updated to 2002 values).

C5.2.4 Caravans

Flood damages to caravans are considered to occur at a depth of 500 mm or greater above ground level. Caravans and mobile homes on the site have been categorised as small or large, with the larger ones being equivalent to two small. The damage value of $16,500 quoted above is for small caravans. Once damaged by flooding a caravan cannot be repaired. The flood damage cost per caravan therefore is the cost of replacement (updated to 2002 values).

C5.3 Indirect Damages

C5.3.1 Commercial and Industrial Businesses

Indirect commercial and industrial damages comprise clean-up costs, costs of removal of goods and storage, loss of trading profit and loss of business confidence.

Disruption to trade takes the following forms:

- The loss of trade during the time the business is closed as a result of the flood until reopening after clean-up and restocking. The total loss of trade is influenced by the opportunity for trade to divert to an alternative source. There may be significant local loss but due to the trade transfer this may be considerably reduced at the regional or state level.

- In the case of major flooding, a downturn in subsequent business can occur within the flood affected region due to the cancellation of contracts and loss of business confidence. This is in addition to the actual loss of trading caused by closure of the business by flooding.

Loss of trading profit is a difficult value to assess and the magnitude of damages can vary depending on whether the assessment is made at the local, regional or national level. Differences between regional and national economic effects arise because of transfers between the sectors, such as taxes, and subsidies such as flood relief returned to the region.

Some investigations have lumped this loss with indirect damages and have adopted the total damage to trading profit as a percentage of the direct damage. In other cases, loss of profit has been related to the gross margin of the business, ie turnover less average wages. The former approach has been adopted in this present study and the loss of trading profit has been taken as 15% of direct actual damages. The total indirect damages is then the sum of the clean up costs, a value of $36/m^2 was adopted and the loss of trading profit (updated to 2002 values).

C5.3.2 Agricultural Properties

Clean up costs for the other categories of commercial properties were estimated on a comparative basis to that adopted for the average residential property. The following values (updated to 2002 values) have been adopted:

Markets Gardens	$600/ha
Green Houses	$120 each
Caravans	$710 each
Poultry Sheds	$6,000 each

Loss of trading profit has been considered to be 15% of total direct damages as for commercial and industrial businesses. The loss of trading profit for caravans is estimated to be 3% of total direct damages, calculated at a loss of $180 per caravan per week of rental for 3 weeks.

Tables C5.1 and C5.2 summarises commercial/industrial and agricultural damages respectively.

Table C5.1
Actual Commercial and Industrial Damages

ARI (years)	Damages ($ x 10^3)		
	Direct	Indirect	Total
1	0	0	0
5	3	22	24
20	115	127	245
100	325	159	484
PMF	3,316	753	4,069

Table C5.2
Actual Agricultural Damages

ARI (years)	Direct Damages ($ x 10^3)			
	Market Gardens	Poultry Sheds	Greenhouses	Caravans
1	10	0	110	0
5	21	40	246	0
20	26	40	320	0
100	74	358	468	2,487
PMF	89	1,074	601	2,703
	Indirect Damages ($ x 10^3)			
1	4	0	23	0
5	8	11	52	0
20	10	11	68	0
100	28	96	100	181
PMF	33	289	127	197
	Total Damages ($ x 10^3)			
1	13	0	133	0
5	28	50	299	0
20	36	50	388	0
100	102	454	567	2,668
PMF	122	1,363	728	2,899

C5.4 Total Commercial and Agricultural Damages

Table C5.3 summarises total commercial and agricultural damages for the study area. The values shown on Table C5.2 have been rounded off to the nearest $5,000.

Table C5.3
Total Commercial and Agricultural Damages

Flood Event	Damage $ x 10^3		
ARI (years)	Direct	Indirect	Total
1	120	27	147
5	310	92	402
20	502	216	718
100	3,712	564	4,276
PMF	7,782	1,400	9,182

C6. DAMAGES TO PUBLIC BUILDINGS

C6.1 Direct Damages to Public Buildings

Included under this heading are government buildings, churches, swimming pools and parks. There are only two properties within the flood affected land classified as public buildings in the study area; St. Anthony's Catholic Church and the New South Wales Animal Welfare League. St. Anthony's church lies within the flood affected land, but is not itself subjected to flooding.

The Animal Welfare League would be subject to flooding. It comprises several buildings each of which fall under a different category for flood assessment purposes. The permanent building has been considered a medium value property for which potential internal damages are \$900 per m^2. The demountable building is considered a lower value property with internal damage costs of \$450 per m^2 and the kennels as a very low value property with damage costs of \$83 per m^2. These estimates are based on 2 m of inundation and were originally obtained from data contained in the Nyngan Study (DWR, 1990), then doubled and adjusted for inflation to update to 2002 values.

The above values were adjusted for depth of inundation in the same manner for the commercial and industrial businesses described in Section C5.1.2. Potential damages were converted to actual damages also using the methodology described in Section C5.1.2.

Structural damages were taken as 15% of internal damages. An allowance was also made for damages to external buildings, which were taken as 25% of internal damages to the main building.

C6.2 Indirect Damages to Public Buildings

A value of \$17,300 was adopted for the clean-up of the property, which is based on results presented in the Nyngan Study, doubled and adjusted for inflation to update to 2002 values.

Total "welfare and disaster" relief costs were assessed as 15% of the actual direct costs as for the residential properties.

C6.3 Total Damages to Public Buildings

Table C6.1 summarises damages to public buildings in the study area.

Table C6.1
Estimated Actual Damages to Public Buildings

Flood Event	Number of Properties		Damage $ x 10^3		
ARI year	Affected	Damaged	Direct	Indirect	TOTAL
1	0	0	0	0	0
5	0	0	0	0	0
20	1	1	11	19	30
100	1	1	12	19	31
PMF	1	1	13	19	32

The reduction in damages to the public building as a result of mitigation works is as for commercial and industrial businesses, described in Section C5.1.

C7. SUMMARY OF DAMAGES

Residential flood damages under existing conditions have been computed on the Bonds Creek and Kemps Creek catchments for a range of flood frequencies from the 1 year ARI to the PMF event. Commercial and industrial flood damages have also been computed for the catchment as a whole. The total damages for each flood event and the assessed average annual damages (AAD) are presented on Tables C7.1 and C7.2. Average annual damages are the average damages per year that wold occur over a very long period of time.

Sixty-eight residential dwellings are located within the extent of the high hazard floodway. Of these, 47 are "flood affected" in the 100 year ARI event. For the 20 year, 100 year and PMF events 23, 35 and 43 dwellings respectively within the floodway are "flooded damaged", ie flooded above floor level.

Total residential damages transferred from Tables C4.1 to C4.4 have been rounded off to the nearest $5,000.

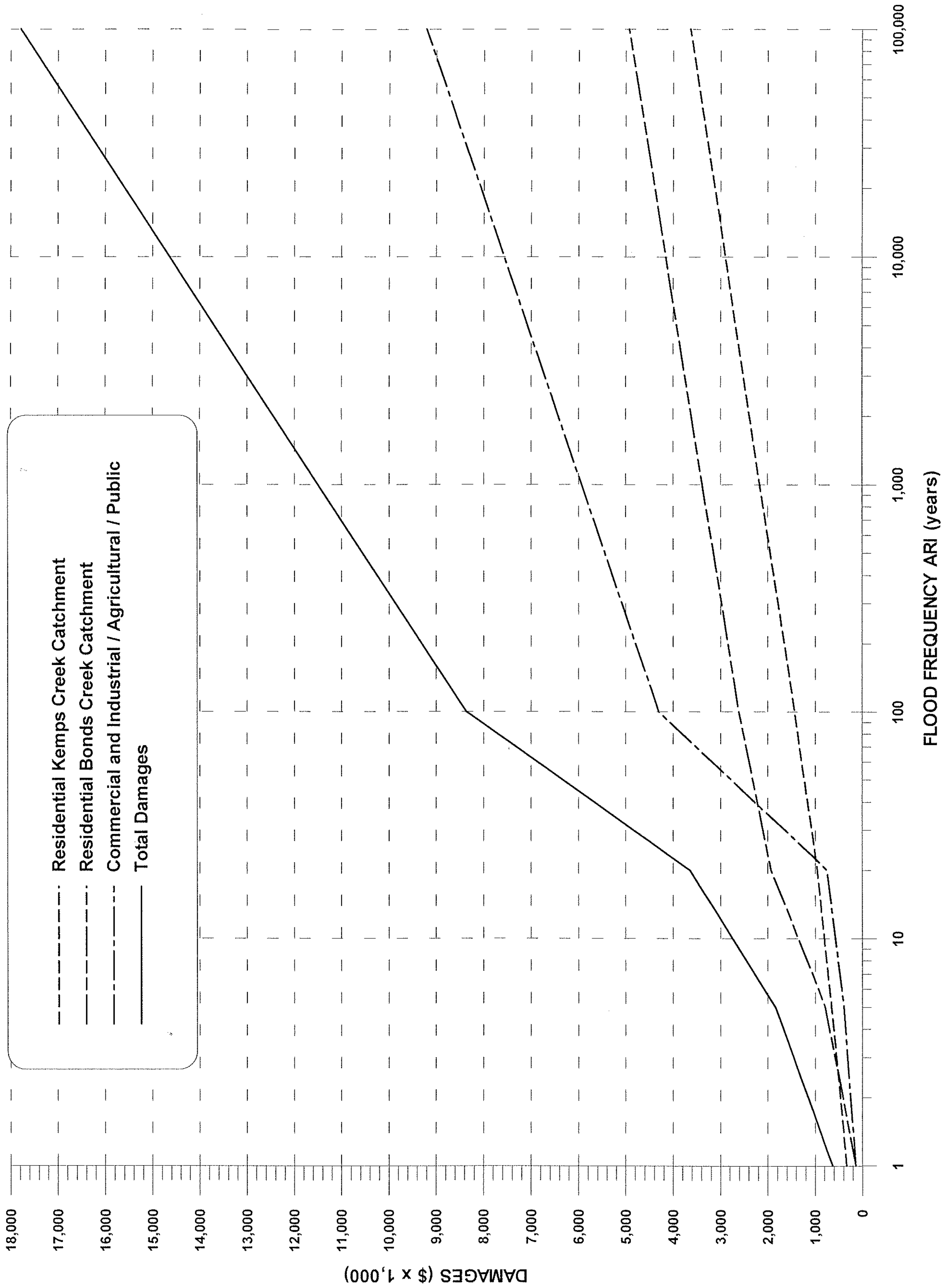
Table C7.1
Estimated Total Damages

Flood Event ARI years	Damages $ x 10^3			
	Residential		Commercial, Industrial, Agricultural and Public	Total
	Bonds Creek Catchment	Kemps Creek Catchment		
1	145	340	145	630
5	785	660	400	1,845
20	1,935	960	750	3,645
100	2,615	1,440	4,310	8,365
PMF	4,935	3,635	9,215	17,785

Table C7.2
Estimated Average Annual Damages

Location	Average Annual Damages $ x 10^3
Residential Bonds Creek Catchment	706
Residential Kemps Creek Catchment	591
Commercial and Industrial/Agricultural/Public	474
Total	**1,771**

Figure C7.1 shows the total damage-frequency curve.



Austral Floodplain Management Study

Figure C7.1

Damage-Frequency Curve

C8. DISCUSSION ON FLOOD DAMAGES

C8.1 General

The threshold of flood damage varied throughout the catchment tributaries although it generally commences at the 1 year ARI flood with significant damage occurring at the 5 year ARI flood. Damage for each flood event is distributed throughout the catchment, however localised areas of damage, where it may be possible to provide effective flood management schemes, are evident. Floodplain management options are considered in detail in Chapter 5 of the main report.

Although there are a considerable number of residential properties flooded within the study area, the commercial and agricultural damages (Table C5.3) far exceed the residential damages, comprising between 60% and 70% of the total damages for the 100 year ARI event.

C8.2 Bonds Creek and Scalabrini Creek

Residential properties located in the Bonds Creek and Scalabrini Creek catchments would suffer flooding at the 1 year ARI event, mainly resulting from flooding of Scalabrini Village by Bonds Creek. Flood damages increase significantly at the 5 year flood, with Scalabrini Village incurring the majority of the damage.

Flooding at the PMF event would generally be concentrated between Eleventh Avenue and Bringelly Road.

C8.3 Kemps Creek (Main Arm)

Residential flood damages to properties in the Kemps Creek catchment commence at the 1 year ARI flood and increase steadily up to the PMF event. Significant damages occur throughout the catchment and in particular between Elizabeth Drive and Gurner Avenue.

C8.4 Tributary 2

Properties on Tributary 2 would experience significant flood damage at the 1 year ARI event. The number of properties damaged increases by approximately 33% at the 100 year ARI and 100% at the PMF event compared to the 1 year ARI.

C8.5 Tributary 3

Flood damage to properties adjoining Tributary 3 commences at the 20 year ARI flood and increases significantly for the PMF event.

C8.6 Commercial and Industrial Properties

Commercial and industrial properties are for the most part concentrated between Gurner and Tenth Avenue on Kemps and Bonds Creek and Tributary 2. Flooding to these properties is described under the individual tributaries above. The damage-frequency curve, Figure C7.1, shows that commercial damages increase significantly for events greater than the 20 year ARI.

C8.7 Public Buildings

There is only one public building which experiences flooding in the Austral catchment. Flood damage to this building (Table C6.1) commences at the 20 year ARI and does not increase significantly for larger flood events.

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LIVERPOOL CITY COUNCIL

AUSTRAL FLOODPLAIN MANAGEMENT STUDY

APPENDIX D

FLORA AND FAUNA

September 2003

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LIST OF FIGURES

D1. INTRODUCTION

This study of the vegetation and fauna habitat in the Liverpool Council part of the Kemps Creek catchment was undertaken to assist in the preparation of a floodplain management plan.

The study aims are to provide information on:

- the distribution of vegetation communities and fauna habitats within the catchment and
- the conservation value of these areas including the presence of rare species

Assessment of the impact on flora and fauna of various flood mitigation measures will be reviewed in a subsequent report.

D2. METHODOLOGY

As the primary focus of the drainage study is the mitigation of flood problems in the study area, survey effort was concentrated along the main drainage lines.

D2.1 Vegetation

Aerial photographs specifically taken for the floodplain study were used to locate the remnant vegetation communities of the catchment. These are indicated on the accompanying map (Figure D2.1). Ground truthing was then done by inspections on foot of the major remnant communities. Notes were made of the species composition and structure of the canopy and understoreys, and disturbance at the sites visited.

D2.2 Fauna

The vegetation community descriptions were used to describe the different fauna habitats that occur on the site. The habitat surrounding the site was also investigated to gain an appreciation of the relative importance of the habitat that occurs on the site.

A search was undertaken for specific sources of native fauna food and shelter, such as dense shrubs, flowering trees, tree hollows and rock outcrops. The presence, or lack of particular fauna habitat requirements was noted to enable predictions of species that would be likely to utilise the site.

A list of species “likely to occur” has been added to those which were actually detected during the field inspection. This list was generated on the basis of species that are known to occur in similar habitat in the locality

D2.3 Conservation Significance

Literature pertaining to the flora and fauna of the Cumberland Plain (eg Mt King Ecological Surveys, 1990; Benson, 1992) was reviewed to assess the conservation value of the catchment. Staff of the National Parks and Wildlife Service and National Herbarium (Sydney) were also consulted for their comments.

AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure D2.1

REMNANT VEGETATION

D3. VEGETATION

Terrestrial Communities

The major remnant vegetation community of the catchment is open forest/woodland of cabbage gum (*Eucalyptus amplifolia*) with co-dominants forest red gum (*E.tereticornis*), broad-leaved apple (*Angophora subvelutina*), coast grey box (*E.bosistoana*) and swamp oak (*Casuarina glauca*). The canopy is generally 10-20m tall with 10-30% foliage cover. This community corresponds to Benson's river-flat forest.

Commonly occurring as a consistent understorey are paperbarks. In those parts of the catchment above the confluence of Bonds and Kemps Creeks *Melaleuca decora* is the common paperbark, whereas around the lower parts of Kemps Creek there are often pure stands of *M.lineariifolia* without a eucalypt canopy. Green wattle (*Acacia decurrens*) is another common understorey species.

The shrub layer in these woodlands and forests and woodlands is generally depauperate, probably due to grazing. The main shrub species is blackthorn (*Bursaria spinosa*). Where stock has been removed species such as *Hakea sericea* and *Daviesia ulicifolia* become more common.

Common couch (*Cynodon dactylon*) and wandering jew (*Tradescantia albiflora*) are the main groundcover species forming thick mats in many areas. Otherwise, the groundcover consists mostly of weeds such as paddy's lucerne (*Sida rhombifolia*) and fireweeds (*Senecio* spp). Native groundcovers include blue trumpet (*Brunoniella australis*), wallaby grasses (*Danthonia* spp) and kangaroo grass (*Themeda australis*).

Away from the drainage lines there are remnant forests or woodlands of spotted gum (*E.maculata*), grey box(*E.moluccana*) and broad-leaved ironbark (*E.fibrosa ssp fibrosa*). The best examples of these are in the proposed Kemps Creek nature reserve where there is also an intact shrub and groundcover layer. As these communities are unlikely to be affected by flood mitigation proposals they were not extensively surveyed.

In-stream Vegetation

Due to the occasional high flow rates along the creek lines there are only patches of aquatic vegetation in the creeks. Generally, the most common species is cumbungi (*Typha orientalis*) and barnyard grass (*Echinchloa crus-galli*) which can handle occasional flattening by floods. Where there is some ponding thick growth of knotweed (*Persicaria* sp) may occur. On Kemps Creek near Bringelly Road there is thick growth of the introduced weed water hyacinth (*Eichornia crassipes*). Thick growths of green algae indicating elevated nutrient levels are common.

D4. FAUNA HABITAT

Most of the catchment consists of areas cleared for market gardening or grazing. Some native bird species are advantaged or unaffected by clearing eg willie wagtail, peewee, magpie. Introduced predators such as foxes and cats are also advantaged.

Most native reptiles, mammals, frogs and a host of birds require greater cover and more varied habitat characteristics than represented in the cleared or fragmented areas. Habitat features represented in the remnant vegetation include:

- thick foliage cover
- tree hollows for shelter and nesting
- a shrub layer component for smaller birds
- thick groundcover, fallen logs etc
- a variety of flowering plants. Especially important are the Melaleucas and Acacias which provide pollen nectar and exudates.

The size and condition of the remnant areas is also important. The larger they are the less able aggressive and predatory edge species such as magpies and cats are able to penetrate them.

Therefore, those remnants of the original vegetation are of increased importance as habitat to fauna disadvantaged by clearing. During the field survey many bird species were observed in the cabbage gum forest, which do not occur in the more open areas. These include yellow robin varied sittella, grey fantail and rufous whistler.

D5. CONSERVATION SIGNIFICANCE

Most of the areas of remnant vegetation within the study area are too small and too heavily disturbed to be of conservation significance. However, there are two main sections along the drainage lines which should be considered when designing flood mitigation options.

One is the bushland beside Kemps Creek between Gurners Road and Elizabeth Drive. Most of this area has been proposed as a nature reserve since 1978 and has been identified by a number of authors (eg Benson, 1992; Mt King, 1991; Doherty 1987) as being of high regional conservation significance. The National Parks and Wildlife Service regards this area of being state significance due to the presence of three poorly reserved vegetation communities and two nationally listed rare plant species.

The other significant area is a triangular shaped alluvial fan above the confluence of Kemps and Bonds Creeks. Here as in the Kemps Creek section, there is a good stand of cabbage gum open forest. Due to past widespread clearing for agriculture, cabbage gum associations are regarded as vulnerable and inadequately conserved at a state level (Benson, 1987). Furthermore, three of the main canopy species cabbage gum, broad-leaved apple and coast grey box are considered vulnerable and of particular conservation significance in the western Sydney region (Benson & McDougall, 1991). The regional office of the National Parks and Wildlife Service advises that any bushland remnants on the Cumberland Plain over 2 ha in size should be conserved as they are of regional conservation importance (D. Stellar per comm).

Both areas discussed above are habitat for a range of fauna, mostly birds, not found in the surrounding cleared or fragmented habitats. They could also be habitat for rare and regionally significant birds such as turquoise parrot, swift parrot, glossy black cockatoo and red-capped robin.

The in-stream vegetation is not considered to be of significance as it is badly disturbed by previous drainage “improvements” and weed invasion. Two aquatic plants regarded as vulnerable in western Sydney, *Schoenoplectus mucronatus* and *Persicaria lapathifolia*, are quite common along the creeks. Unlike, the terrestrial vegetation these species are more amenable to translocation and replanting.

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LIVERPOOL CITY COUNCIL

AUSTRAL FLOODPLAIN MANAGEMENT STUDY

APPENDIX E

NOT USED

September 2003

LIVERPOOL CITY COUNCIL

AUSTRAL FLOODPLAIN MANAGEMENT STUDY

APPENDIX F

PLANNING ISSUES

September 2003

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F1. CURRENT PLANNING ISSUES AND CONTROLS

Both the current and possible future land use pattern within the Austral - Kemps Creek area are governed by both State and local planning instruments, policies and controls. Any discussion of the potential for development of the study site, and thus the impact of that development on the floodplain, must be considered within the context of those instruments and controls.

This report provides an overview of the planning instruments and controls which both apply to the study site and are relevant to the long term planning of the area.

F1.1 State Environmental Planning Policy (SEPP) No.19 - Bushland in Urban Areas

SEPP No.19 aims to protect and preserve bushland within the urban area because of:

"(a) its value to the community as part of the natural heritage;

(b) its aesthetic value; and

(c) its value as a recreational, educational and scientific resource."

The Liverpool City Council area forms part of the land to which the policy applies.

The specific aims of the policy are:

"(a) to protect the remnants of plant communities which were once characteristic of land now within an urban area;

(b) to retain bushland in parcels of a size and configuration which will enable the existing plant and animal communities to survive in the long term;

(c) to protect rare and endangered flora and fauna species;

(d) to protect habitats for native flora and fauna;

(e) to protect wildlife corridors and vegetation links with other nearby bushland;

(f) to protect bushland as a natural stabiliser of the soil surface;

(g) to protect bushland for its scenic values, and to retain the unique visual identity of the landscape;

(h) to protect significant geological features;

(i) to protect existing landforms, such as natural drainage lines, watercourses and foreshores;

(j) to protect archaeological relics;

(k) *to protect the recreational potential of bushland;*

(l) *to protect the educational potential of bushland;*

(m) *to maintain bushland in locations which are readily accessible to the community; and*

(n) *to promote the management of bushland in a manner which protects and enhances the quality of the bushland and facilitates public enjoyment of the bushland compatible with its conservation."*

Comment

The State Policy applies generally to development on land zoned or reserved for public open space, or development on land which is adjacent to such land. Part of the Austral - Kemps Creek study area is zoned for open space purposes and as such any development measures which are both proposed as part of the recommendations of the Austral - Kemps Creek Floodplain Management Study, and apply to land to which SEPP No.19 applies, must be assessed in terms of the impact on urban bushland in the area.

Areas identified as "urban bushland" are presented in Appendix D.

F1.2 Liverpool Local Environmental Plan 1997

Liverpool City Council has numerous planning instruments which collectively control land use development within the City. Council has prepared a planning instrument which aims to consolidate all existing planning instruments into a modern planning document. The consolidating instrument is Liverpool Local Environmental Plan 1997.

Following are suggested amendments to the plan, as prepared by Don Fox Planning:

DEFINITIONS

Flood liable land (being synonymous with ***flood prone land*** and ***floodplain***) is the area of land which is subject to inundation by floods up to and including an extreme flood such as a probable maximum flood (PMF).
Replace existing definition in clause 6

Probable maximum flood (PMF) is the largest flood that could conceivably occur at a particular location.
Add definition in clause 6

OBJECTIVES

(…) To minimise the risk to human life and damage to property caused by natural hazards such as bushfire, land instability and flooding and to allow for more detailed controls for development on flood prone land to be implemented within a Development Control Plan.
Probably not critical but could consider replacing objective at clause 2(g) with the above – to be recommended for other Councils.

STANDARD CLAUSE

… **Development in Flood Prone Land**

(1) Notwithstanding any other provisions of this Plan, the Council may refuse consent to the carrying out of any development on flood prone land where, in its opinion, the development may:

(a) be inconsistent with any floodplain risk management plan adopted by Council in accordance with the Manual entitled "*Floodplain Management Manual*" dated 2001 (as published by the State Government);

(b) detrimentally increase the potential flood affectation on other development or property;

(c) result, to a substantial degree, an increased risk to human life;

(d) be likely to result in additional economic and social cost which could not reasonably be managed by potentially affected persons and the general community; or

(e) adversely affect the environment of the floodplain by causing avoidable erosion, siltation, unnecessary destruction of river bank vegetation or a reduction in the stability of the river bank.

(2) When undertaking an assessment required by this clause, Council shall take into consideration the impact of the development in combination with the cumulative impact of development which is likely to occur within the future, within the same floodplain.

(3) For the purposes of this Plan, the Council may consult with and take into consideration, any advice of DIPNR, the Upper Parramatta River Catchment Trust (if the land is within that catchment), and the State Emergency Service in relation to the nature of the flood hazard, the necessity and capacity to evacuate persons, and the consequence and suitability of the development.

Could replace Clause 21 with the above – to be recommended for the other councils. Clause 21 is nonetheless comprehensive and it is not essential that it be changed. The above clause however is simpler, will be consistent with that recommended for many other councils and covers all relevant matters.

EXEMPT DEVELOPMENT

Amend exempt development provisions so as to exclude the following from being classed as exempt development:

"………..is within that part of the flood liable land that is affected by the 100 year average recurrence interval (ARI) flood………..."
Replace clause 6A (3) (f) with the above.

"……….that part of the flood liable land that is affected by the 100 year average recurrence interval *(ARI) flood……."*
Replace "flood liable" in clause 6B(3) (a) with the above.

Review DCP 33 to also achieve the objective of the above changes.

FORESHORE BUILDING LINES (FSBL)

Amend the map referred to in clause 23 to provide a FSBL along the Georges River which is a distance from the River equal to the extent of the High Flood Risk Precinct but need not be less than any existing FSBL. Clause 23(d) would need to be deleted also.

ALTERNATE APPROACH TO USE OF FORESHORE BUILDING LINE TO EXCLUDE DEVELOPMENT FROM HIGH FLOOD RISK PRECINCTS

Insert following definition in dictionary of LEP:

> ***High Flood Risk Precinct*** means:
>
> Those parts of flood liable land where the depth and velocity of flood waters and evacuation difficulties would pose an unacceptable risk to types of development and activity, as indicated by hatching on the map.

Insert following clause in LEP:

> **Development in a High Flood Risk Precinct**
>
> …….Notwithstanding any other provision of this plan, all development in a high flood risk precinct is prohibited, other than alterations and additions to existing buildings, agriculture, forestry, recreation areas, roads, utility installations (other than gas holders or generating works), extractive industries and mines.

F2. LAND USE IN THE AUSTRAL - KEMPS CREEK AREA

In May 1994, Liverpool City Council released its Liverpool Rural lands Study. That study, inter alia, provides comprehensive details of the land use pattern in the rural areas of the City. Within the Austral - Kemps Creek Floodplain Management Study area, the following land uses were identified:

- Schools
- Vacant land
- Agriculture including the following subcategories:
  - grazing
  - market gardens
  - green houses
  - poultry
- Rural Residential
- Extractive Industry
- Training Tracks (Horse/dogs)
- Electricity Substation
- Council Depot
- Showground
- Commercial Activities
- Residential
- Bowling Club

F3. PLANNING IN ADJOINING COUNCIL AREAS

The Austral - Kemps Creek Floodplain Management Study area is restricted to that land which is contained within Liverpool City. The total catchment of Kemps Creek, however, is not restricted to Liverpool City but encompasses land within both Camden City and Campbelltown City areas.

In order that a comprehensive study can be undertaken, details of the likely development in both the Camden and Campbelltown sections of the catchment must be addressed in order that the likely impact of that development on flooding can be determined.

In this regard, contact has been made with the Planning Sections of both councils with the following general conclusions:

F3.1 Camden Council

The majority of the land within both the Kemps Creek catchment and Camden City is zoned Rural 1(b) with a 2 hectare minimum lot size. Land use in the area consists largely of market gardens, rural residential development, some illegal uses such as junk yards and motor repair stations.

F3.2 Campbelltown Council

Only a small section of the Kemps Creek catchment falls within Campbelltown City. The land is zoned Environmental Protection 7(d1) with a 100 hectare minimum lot size requirement. A study of the area in recent years recommended that the 100 hectare minimum lot size remain. Council has adopted that recommendation.

There are currently some 2 hectare lots in the area.

In the interests of catchment management and planning, it may be prudent for Liverpool, Camden and Campbelltown City Councils to investigate the establishment of a Kemps Creek Planning Committee which would jointly oversee the long term planning of the total catchment.

LIVERPOOL CITY COUNCIL

AUSTRAL FLOODPLAIN MANAGEMENT STUDY

APPENDIX F

PLANNING ISSUES

September 2003

Prepared by:

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Don Fox Planning
11 Dartford Road
Thornleigh 2120

Tel: 9980 6933
Fax: 9980 6217

Job No NC812 File: f:\documents\austral fms\construction files\appf.doc	Date: 18 September 2003 Rev: 5.0	Authors: NK/DF Reviewer: SJP

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F1. CURRENT PLANNING ISSUES AND CONTROLS

Both the current and possible future land use pattern within the Austral - Kemps Creek area are governed by both State and local planning instruments, policies and controls. Any discussion of the potential for development of the study site, and thus the impact of that development on the floodplain, must be considered within the context of those instruments and controls.

This report provides an overview of the planning instruments and controls which both apply to the study site and are relevant to the long term planning of the area.

F1.1 State Environmental Planning Policy (SEPP) No.19 - Bushland in Urban Areas

SEPP No.19 aims to protect and preserve bushland within the urban area because of:

"(a) its value to the community as part of the natural heritage;

(b) its aesthetic value; and

(c) its value as a recreational, educational and scientific resource."

The Liverpool City Council area forms part of the land to which the policy applies.

The specific aims of the policy are:

"(a) to protect the remnants of plant communities which were once characteristic of land now within an urban area;

(b) to retain bushland in parcels of a size and configuration which will enable the existing plant and animal communities to survive in the long term;

(c) to protect rare and endangered flora and fauna species;

(d) to protect habitats for native flora and fauna;

(e) to protect wildlife corridors and vegetation links with other nearby bushland;

(f) to protect bushland as a natural stabiliser of the soil surface;

(g) to protect bushland for its scenic values, and to retain the unique visual identity of the landscape;

(h) to protect significant geological features;

(i) to protect existing landforms, such as natural drainage lines, watercourses and foreshores;

(j) to protect archaeological relics;

(k) to protect the recreational potential of bushland;

(l) to protect the educational potential of bushland;

(m) to maintain bushland in locations which are readily accessible to the community; and

(n) to promote the management of bushland in a manner which protects and enhances the quality of the bushland and facilitates public enjoyment of the bushland compatible with its conservation."

Comment

The State Policy applies generally to development on land zoned or reserved for public open space, or development on land which is adjacent to such land. Part of the Austral - Kemps Creek study area is zoned for open space purposes and as such any development measures which are both proposed as part of the recommendations of the Austral - Kemps Creek Floodplain Management Study, and apply to land to which SEPP No.19 applies, must be assessed in terms of the impact on urban bushland in the area.

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In the interests of catchment management and planning, it may be prudent for Liverpool, Camden and Campbelltown City Councils to investigate the establishment of a Kemps Creek Planning Committee which would jointly oversee the long term planning of the total catchment.

LIVERPOOL CITY COUNCIL

AUSTRAL FLOODPLAIN MANAGEMENT STUDY

APPENDIX G

COMMUNITY CONSULTATION

September 2003

Prepared by:

Perrens Consultants/
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Job No NC812 File: f:\documents\austral fms\construction files\appg.doc	Date: 18 September 2003 Rev: 5.0	Author: AAT Reviewer: SJP

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ATTACHMENTS

FIGURES

G1. BACKGROUND

This appendix highlights the flooding issues identified through the community consultation process. This process involved contact with local residents, relevant public utilities and the Council.

Two phases of consultation were carried out: one in 1995 and the other in 2003.

The consultation program was developed with the objectives of:

- obtaining local data on the frequency, extent and duration of flooding and possible mitigation measures
- obtaining feedback on community issues and concerns
- informing and educating the public about the nature of the flood threat and options for managing the threat
- resolving issues which are in dispute or conflict with the objectives of the draft Floodplain Management Plan
- encouraging future ownership of the Management Plan by local residents.

The 1995 consultation process involved:

- a resident questionnaire (108 respondents)
- resident interviews (12 interviewees)
- a council complaint database (44 pieces of correspondence collected)
- attendance at precinct committee meetings and Floodplain Management committee meetings
- presentation of a workshop to present the study findings and to obtain resident's views
- Public authority consultation.

The consultation process has enabled specific flooding locations to be identified and investigated and revealed a widespread and frequent flooding problem in the study area with a number of houses being flooded above floor level in the last 20 years. Severe rainstorms often affect road access, with the low lying area of Fourth Avenue being a particular source of complaint.

The types of solutions most favoured by the residents in the area included improving creek channels by removal of debris and vegetation in conjunction with upgrading of piped drainage both under and along the side of roads. Other suggestions involved the construction of levees and detention basins, protection of creek banks against erosion and the raising of road levels. Other issues identified included illegal filling and inappropriate land zoning in the area

Specific problem areas and possible mitigation measures were later investigated using the hydraulic model of the creek system discussed in Appendix B and Chapter 5 of the main report.

As a result of meetings with the Floodplain Management Committee, the relevant Precinct Committees and the community workshop, a set of criteria for assessing the possible flood management and drainage improvement measures was identified and an action plan proposed. Where suitable, items from this plan have been incorporated in the draft Floodplain Management Plan.

The 2003 consultation program was carried out as part of the review and finalisation of the Floodplain Management Study. The aims of this part of the consultation process were to provide stakeholders with information regarding the findings of the study and to give them an opportunity to provide feedback on these outcomes. This feedback has been incorporated into the final report and resulting Austral Floodplain Management Plan.

G2. THE 1995 CONSULTATION PROCESS

G2.1 The Resident Consultation Process

The resident consultation process was developed to allow an exchange of information between the community and the study team prior to the formulation of the draft Management Plan. The process contained three stages:

- Stage 1 Questionnaire, resident interviews and introductory newsletter
- Stage 2 Community meetings and quarterly newsletters
- Stage 3 Workshop

A further stage of public consultation will commence after the completion of this study and will involve a public display of the draft Floodplain Management Plan.

G2.1.1 Community Questionnaire

The questionnaire was developed in conjunction with the Council and distributed to all residents within the study area. Thirteen hundred questionnaires were distributed and 108 responses were received.

A copy of the questionnaire is contained in Attachment 1. The questionnaire requested information including:

- what years flooding had occurred
- height of flooding
- extent of flood damages
- specific flooding problems
- possible mitigation measures.

A detailed analysis of the results of the questionnaire is contained in Attachment 1 together with a list of respondents.

The residents who replied to the questionnaire have lived in the Austral - Kemps Creek area for between 2 weeks and 56 years, with an average residence time of 19 years. During this time 48% have experienced flooding from as far back as 1969 and up to 1993. Some form of flooding occurred almost every year during the 80's and 90's. The largest floods occurred in 1988, 1991 and 1989. Nine respondents (8% of the sample) experienced above floor flooding and 25 respondents (23% of the sample) had experienced flood damages in the time they have been living in the Austral - Kemps Creek area.

The responses were analysed for both specific flooding locations and possible causes/solutions/improvements. Figure G2.1 summarises the issues of concern and the locations where specific issues have been identified. Fourth Avenue was the most complained about location (18% of the sample), followed by the creek crossing at Fifteenth Avenue (7%). Other frequently complained about locations included creek crossings at Edmondson Avenue, Gurner Avenue, Tenth Avenue, Eighth Avenue and Thirteenth Avenue. In all there were about 28 different "trouble spots" (see Attachment 1 for a complete list).

Analysis of the questionnaire responses indicated that the general perception of residents was that flooding was caused by the build up of vegetation and pollution in the creek channels (29% of sample) and inadequate/undersized drainage pipes (25%). Other problems in the area are backflooding from major tributaries (eg South Creek and Kemps Creek) into the minor creeks so that water is unable to get away (4%), illegal fill (3%) and the effects of upstream development/drainage improvement works. Residents consider that flooding could be reduced by clearing the creek beds, providing adequate piped drainage, constructing detention basins and levee banks and by raising road levels.

G2.1.2 Resident Interviews

Analysis of the questionnaire responses identified a group of 12 residents who were able to contribute additional useful information to the study and who were subsequently interviewed. Residents were selected on the basis of the severity of flooding affecting their property or on the basis of the information they were able to provide about flooding in the Austral - Kemps Creek area. Interviews were conducted in December 1994 and January 1995.

Residents were able to highlight several flooding “hot spots” for further examination. Information regarding depths of flooding for particular flooding events assisted in the verification of the hydraulic model.

Other residents were able to provide information about flooding generally. These local experts confirmed and highlighted flooding problems revealed in the community questionnaire results.

The resident interviews confirmed the findings of the questionnaires regarding the flooding problems. More detail was obtained regarding the mechanism of flooding in the area and useful photographs were supplied by the residents. A summary of responses is contained in Attachment 2.

G2.1.3 Newsletters

A summary of the study progress was placed in relevant editions of Liverpool Council’s Precinct Committee Newsletters. The bulletin served two purposes:

- to maintain lines of communication between interested residents and the study team (LMCE and Council)
- to inform residents of the progress of the study.

These newsletters helped to prevent initial interest from waning and to retain awareness of the study progress to ensure active involvement in the workshop and in commenting on the draft Plan.

G2.1.4 Community Meetings

A representative of the study team was attended three meetings of both the Austral Progress Association and Kemps Creek Precinct Meetings in order to keep the community informed of the study progress.

A representative of the study team also attended three Floodplain Management Committee meetings. At these meetings the Committee was briefed on study progress. The Committee later made recommendations to Council on the designated flood and suitable planning controls for implementation in conjunction with the designated flood. Both the Precinct Committee and Floodplain Management Committee meetings were used as a forum for the selection and ranking of criteria for assessing flood management measures.

G2.1.5 Workshop

Following the completion of an interim report on the findings of the Floodplain Management Study, a workshop was held. Eight community representatives were invited and the workshop was open to all elected members of council, together with selected council staff. The workshop was run by an independent facilitator who provided a report on the proceedings.

The objectives of the workshop were to:

- Provide an opportunity for community representatives to appreciate the nature of flooding in the Austral - Kemps Creek area.

- To give the community a meaningful opportunity to participate in resolving current problems relating to flooding.

The outcomes of the workshops were:

- A list of key issues were identified by the Residents.

- Weighted selection criteria which the Residents would like to see used in evaluating floodplain management measures were determined. Table G2.1 below lists the ranking of possible selection criteria against which floodplain management measures could be assessed, as voted for in the meetings and workshop. In the table, a ranking of 1 corresponds to the most important criterion, while 10 is the least important. The criteria identified and their ranking were incorporated into the selection of measures outlined in Sections 6 and 7 of the main report.

- A list of opportunities that the Residents saw as capable and worthy of pursuing as a result of the implementation of the recommendations of the Study.

- A recommendation with regard to how the flood related matters affecting the area could be managed.

- An Action Plan that when executed, would lead to the satisfaction of the Resident's objectives with regard to the management of the flooding and associated problems in the area.

TABLE G2.1
RANKING OF SELECTION CRITERIA

Criterion	Floodplain Management Committee			Austral Precinct Committee	Kemps Creek Precinct Committee	Weighted Overall Ranking
	Community	Govt	Council Staff	Community	Community	
Economics and Finance						
Economically justified	8	4	5	6	2	6
Financially feasible	5	9	3	7	5	7
Social and Community						
Safe access	7	6	4	2	1	5
Performance in exceedance floods	4	10	8	1	3	8
Expectations	3	1	1	2	3	1
Planning objectives	1	2	5	5	8	2
Future development limits	1	5	5	4	7	4
Administrative/political	10	8	10	9	9	10
Environmental						
Environmental impacts	6	3	1	8	6	3
Government policies	9	7	8	10	9	9
No of respondents	7	3	6	13	10	

More detail of the outcomes is provided in Attachment 3.

G2.2 Public Utility Consultation

Local public authorities and relevant statutory authorities were contacted to obtain comments on the flooding situation in the area and/or the environmental effects of possible flood mitigation measures.

Authorities directly affected by flooding through impacts on infrastructure and facilities were asked to identify locations of flooding and possible flood mitigation measures. This group included bodies such as AGL.

A second group of authorities were requested to supply requirements/guidelines relating to the implementation of flood mitigation works ie creek clearing, construction of levees, detention basins etc. This group included bodies such as the EPA and DLWC.

A full list of the authorities contacted together with a copy of the responses received is contained in Attachment 4. The issues identified through this process have been included in the formulation of the draft Floodplain Management Plan.

Pacific Power advised that although no flooding has been experienced at their substation located near the corner of Gurner Avenue and Fourth Avenue, Kemps Creek, some difficulty has been experienced with access via Gurner Avenue. No other part of their infrastructure appears to be affected by flooding in the study area.

The EPA recommended that drainage management measures be considered in the context of the principles of Total Catchment Management and ecologically sustainable development and, where possible, integrate water quality control options.

CaLM requested that any measures that involve construction works be implemented in conjunction with a progressive erosion and sediment control program, with attention to:

- Control of surface drainage (especially in main watercourses).
- Early revegetation of competed development areas.
- The construction of sediment trapping structures.

Other issues which CaLM considers important are:

- Soil salinity and its impact on revegetation.
- Level of water tables and long term impact on these levels due to urbanisation, especially with tree loss and increased runoff.
- Increased potential stream bank erosion due to larger volumes of runoff from urbanised areas, especially in lower intensity, relatively frequent run levels.
- Potential decrease in water quality due to contamination of runoff from urban areas, including increased turbidity (soil loss) and nutrient enrichment.
- Decreased potential of wildlife corridors along riparian zones and potential loss of stream bank vegetation as a result of stream bank erosion.

The Department of Land and Water Conservation requested that the study consider the Government's Flood Policy and the State Rivers and Estuarine Policy. The key issues from the DLWC's perspective related to access during floods, the selection of an appropriate Designated Flood Level, selection of appropriate planning and development controls and control on illegal filling of land and loss of flood storage. The deteriorating water quality in the creeks resulting from a range of causes was also to be addressed.

AGL provided some general information regarding flood affectation.

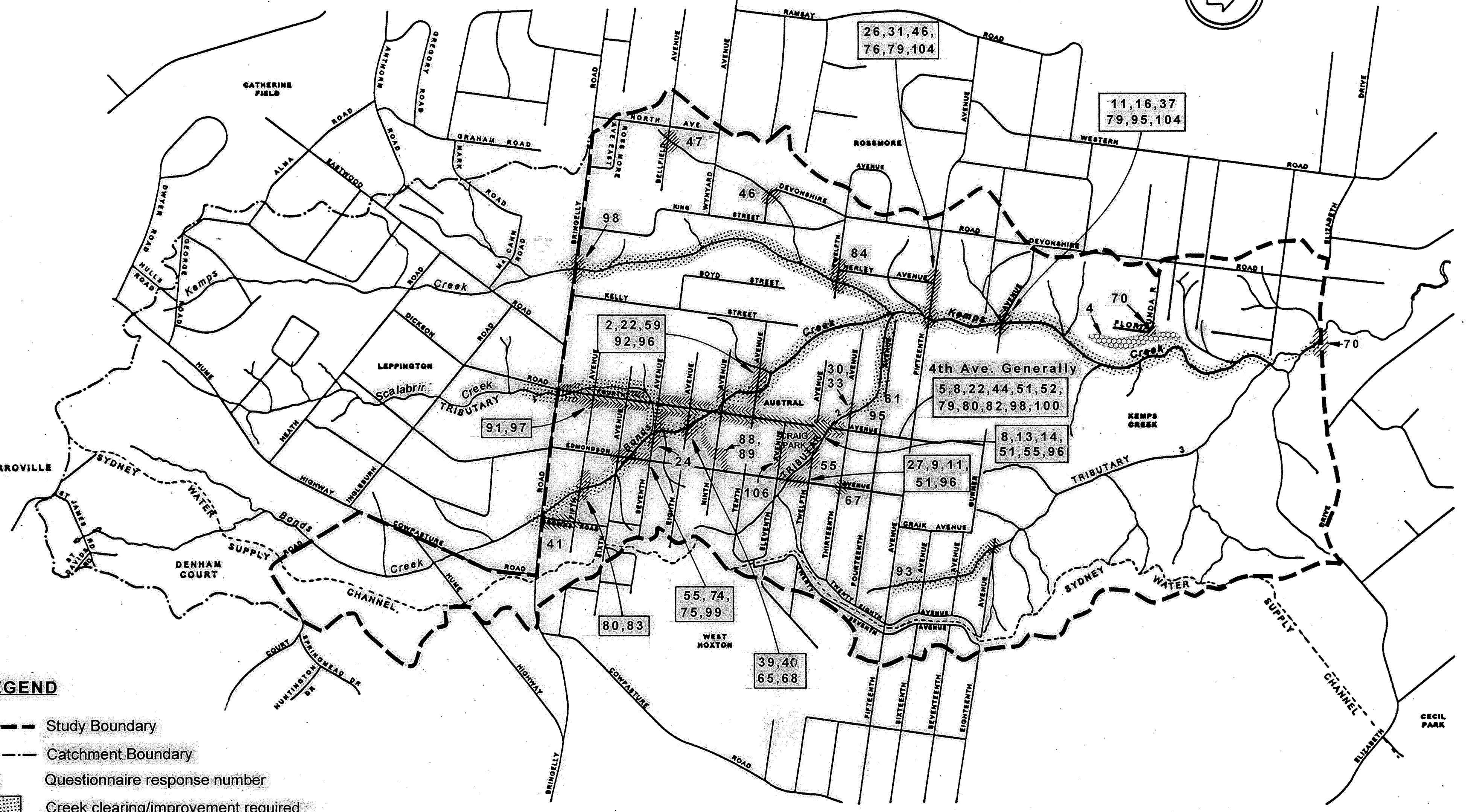
G2.3 Local Council Consultation and Council Database

Council has extensive files relating to specific flooding and drainage problems in the study area. These were inspected in order to identify any further flooding issues and a detailed database of complaints recorded by Council (both external and internal) was set up (Attachment 5). This database can be updated by Council as required in order to monitor the area in the future.

A total of 44 complaints/memos were identified from Council's files and included in the database. The complaints/suggestions were categorised according to the issue referred to, including channel bank erosion, creek clearing, potential easement, illegal fill, levees, zoning and miscellaneous.

Analysis of these issues indicated that the most common complaint was related to illegal fill (43% of the correspondence) followed by creek clearing.

Note:
This figure should be cross - referenced to the resident questionnaire response database.



LEGEND

Study Boundary

Catchment Boundary

93 Questionnaire response number

Creek clearing/improvement required

Illegal Fill

Flooding

Improved Drainage Required

SCALE

0 1 2Km

AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Figure G2.1

RESIDENT QUESTIONNAIRE FLOODING ISSUE LOCATIONS

G3. THE 2003 CONSULTATION PROCESS

The 2003 consultation program was developed in order to publicise the findings of the study and to obtain feedback from relevant government agencies and the community.

As part of the program a poster summarising the study background, findings and recommendations was prepared and exhibited at eight locations, as follows:

Liverpool City Council
Administration Centre
1 Hoxton Park Road
LIVERPOOL NSW 2170

Liverpool City Council
Customer Service Centre
193 Macquarie Mall
LIVERPOOL NSW 2170

Liverpool City Library
170 George Street
LIVERPOOL NSW 2170

Casula Library
Ingham Drive
CASULA NSW 2170

Miller Library
Woodward Crescent
MILLER NSW 2168

Green Valley Library
179-183 Wilson Road
GREEN VALLEY NSW 2168

Moorebank Library
Cnr Nuwarra Road & Maddecks Avenue
MOOREBANK NSW 2170

Austral Bowling Club
Cnr Eighth & Edmondson Avenues
AUSTRAL NSW 2171

As part of this exhibition the Austral Floodplain Management Study report was available for perusal and a take home brochure was offered to residents. A copy of the brochure is reproduced in Attachment 6.

Three hundred and fifty residents within the Austral area were notified about the exhibition and an information night via a letter box drop and through an advertisement in the local press (Liverpool Champion and the Liverpool Leader). The exhibition was displayed from 18th June to 16th August 2003.

The information session for the public was held in Austral on 23rd June 2003. Council officers and a representative from Perrens Consultants were available to address concerns and answer questions. Approximately 50 residents attended the meeting.

A copy of the draft report was sent to the following for review:

- Liverpool Council Floodplain Management Committee
- All Liverpool City Councillors
- Relevant Council staff
- The EPA, DIPNR (formerly PlanningNSW and DLWC), Sydney Water, NPWS, RTA, Penrith City Council, NSW Fisheries, Bankstown City Council, Camden Council, SES, Fairfield City Council.

In response to the 2003 consultation process, correspondence was received from EPA, DIPNR and Liverpool City Council's Stormwater Engineer (contained in Attachment 7). Where appropriate, these comments have been incorporated and addressed within the main report.

ATTACHMENT 1

RESIDENT QUESTIONNAIRES

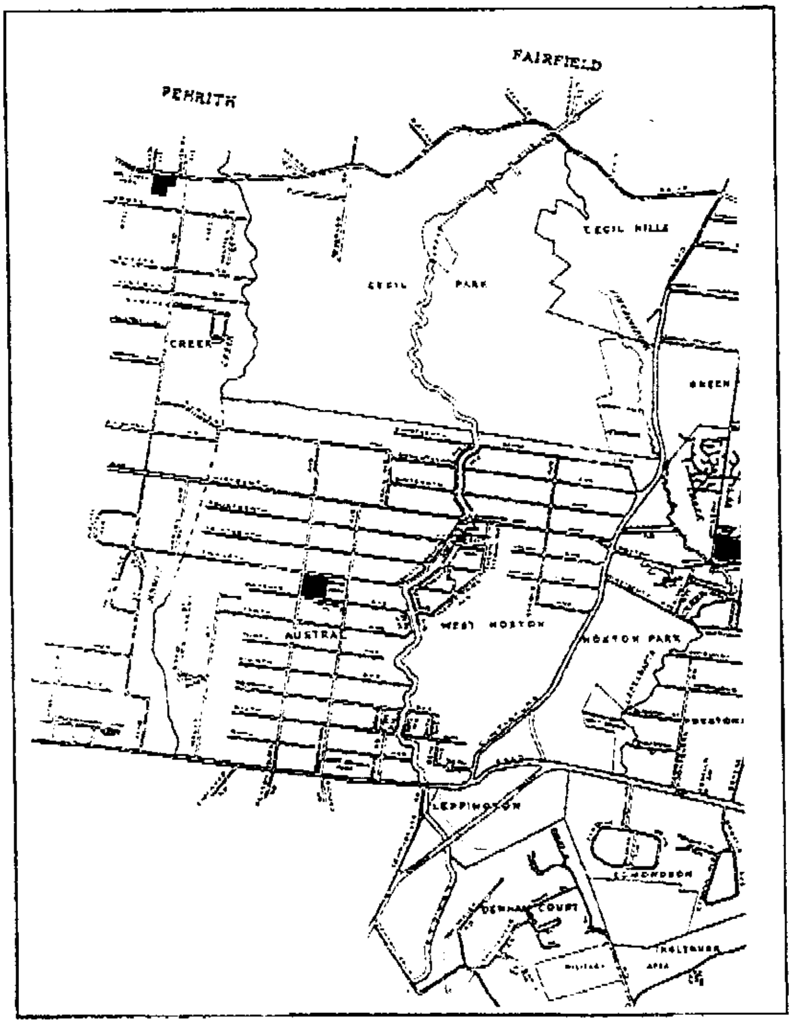
Liverpool City Council

Postage
paid
Australia

TO THE HOUSEHOLDER

Have your say

Austral Floodplain Management Study



Liverpool City Council
1 Hoxton Park Road
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4 Help Street
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November 1994

This is my city. This is your city.

LIVERPOOL
THIS IS OUR CITY NOW!

Austral Floodplain Management Study

Introduction

A drainage and floodplain management study has been commissioned by Liverpool City Council (LCC) for the Austral area (shown on the map on the front page). The area includes the two major creeks, Kemps Creek and Bonds Creek, as well as other tributaries.

The consultants, Lyall & Macoun Consulting Engineers (LMCE), will carry out the study. Lyall & Macoun are Water and Environmental Engineers with over 20 years experience in floodplain management studies. Liverpool Council staff from the engineering, environmental and planning departments will work with the consultants to complete the study.

The purpose of the study is to identify flooding problems and evaluate measures and strategies to lessen the impact of flooding in the Austral area. As part of the study, a Floodplain Management Plan will be developed listing a staged program of remedial actions to be undertaken by Council as funding permits. The study commenced in October 1994 and will be completed around mid-1995.

The Study Process

There are several steps involved in the study including:

- Detailed topographic mapping.
- Obtaining local resident knowledge of past flooding events and drainage problems through questionnaires, interviews and Precinct meetings.
- Computer modelling of the catchment to determine flood behaviour.
- Preparing the draft Flood Management Plan for community review.
- Finalising the Floodplain Management Plan.

The mapping will mainly be carried out by aerial survey but some ground surveying will be required, and therefore surveyors may need to enter some properties. Should this be necessary on your property the surveyors will be carrying a letter of authority from Liverpool City Council.

Community Consultation and Input

Local Residents

An important first step in the study will be to determine the nature and extent of flooding in the study area. We believe that the local residents will be able to contribute greatly to our knowledge of historic flood events, as well as identifying local flooding problems and possible solutions.

To commence the residents' input process, a mail back questionnaire has been prepared. We would appreciate your filling it in and returning it to the address shown by 15 of December 1994.

Community Input on Solutions

Throughout the study the local community and the Council will be consulted on an on-going basis. This will include discussion of the progress of the study, results of the information obtained and the development of option and alternatives to solve local problems. Discussions will be held mainly at Precinct Committee meetings in the study area.

Should you have any further questions, or require additional information, please call Steve Perrens at Lyall Macoun Consulting Engineers on 413 3411 or Ray Parsell at Liverpool City Council on 821 9257.

Austral Floodplain Management Study

Mail - Back Questionnaire

1. How long have you been
   (a) at this address? .... years
   (b) in the Austral area? .... years

2. Have you ever experienced flooding at this location? ❑YES ❑ NO
   If yes, what years?

3. Have floods ever entered the house? ❑YES ❑ NO
   If yes, what years?

4. Do you know where the highest flood came to? ❑YES ❑ NO
   If yes, please describe. (eg to the top step, over the floor)

   ....

   ....

5. How did you know about this flood level? *(Cross out if not applicable)*
   [present at the time / told by previous resident / told by neighbours]

6. Please provide a list of the dates of any major flood events which you can recall.

   ....

   ....

   ....

7. Has flooding damaged your house or property? ❑YES ❑ NO

8. Do you have any photographs of the creeks or flooding in the area? ❑YES ❑ NO

9. If you know of any specific flooding problems in the Austral area, please describe them.

   ....

   ....

   ....

   Please provide any suggestions about what could be done to reduce these problems

   ....

   ....

   ....

10. If you know of any other people in the area who may be able to help us with flood information from the past, could you please provide their name and phone number or ask them to contact us.

    Name:.. Phone:..

11. If you have answered *yes* to any of the questions above or have other detailed information, it may be helpful if we could interview you. Would you be available for an interview? ❑YES ❑ NO

THANK YOU FOR YOUR HELP
PLEASE RETURN YOUR QUESTIONNAIRE BY 15 DECEMBER 1994

More detailed written comments are welcome. Please staple any sheets with your comments to this questionnaire and fold them together for mailing.

Fold this section first before sealing

Name:...

Address:..

Phone Number:...

REPLY PAID No. 104
Lyall & Macoun
Consulting Engineers
Level 2, 4 Help Street
CHATSWOOD NSW 2067

Fold in 3 on the dotted lines
seal with clear sticky tape and post

Thank you for your assistance

SUMMARY OF RESIDENT QUESTIONNAIRE RESPONSES

Total number of respondents 108

Question 1 Duration of time at current address — 2 - 56 years, average 19 years

Question 2 Has flooding been experienced at this location? — YES 51 (48%)
Years flooded at that location:

Year	No respondents	Year	No respondents
1969	1	1987	4
1973	1	1988	9
1976	1	1989	6
1980	1	1990	3
1982	1	1991	7
1985	1	1992	3
1986	3	1993	3
		TOTAL	44

Question 3 Has flooding entered the house? — YES 9 (8%)

Question 4 Can flood levels be provided? — YES 39 (36.5%)

Question 6 Years of major flooding in the general area:

Year	No respondents	Year	No respondents
1974	1	1988	13
1978	1	1989	3
1983	1	1990	7
1985	1	1991	8
1986	4	1992	1
1987	2	1993	2
		TOTAL	44

Question 7 Flood damaged incurred — YES 23 (23%)

Question 8 Relates to requests for photographs of flooding.

Question 9 (a) Specific flooding problem locations:

Location	No.	%
Edmondson Avenue (between Eleventh and 12th Avenues)	6	(6%)
Gurner Avenue creek crossing	7	(6%)
Cnr 4th and 12th Avenues	5	(5%)
4th Avenue (generally)	14	(15%)
13th Avenue (near 4th Avenue)	4	(4%)
10th Avenue creek crossing	6	(6%)
15th Avenue creek crossing	6	(7%)
8th Avenue creek crossing	4	(4%)
Other:	25	(27%)

- bottom of Herley Avenue
-7th Avenue (between 4th and Edmondson)
- Fifth Avenue bridge
- Floribunda Road
- Cnr 4th and 5th Avenues
- Browns Road (between Bringelly and 5th Avenue)
- Devonshire Road (between Bringelly Road and 5th Avenue)
- Bellfield Avenue
- Craik Park
- Edmonson Avenue (near Bringelly Road)
- Cnr 13th Avenue and Edmondson Avenue
- footbridges over Edmondson Avenue
- Edmondson Avenue (between 6th and 7th Avenues)
- 12th Avenue
- Elizabeth Dr bridge
- Sixth Avenue crossing
- 9th Avenue (between Edmondson and 4th Avenues)
- 14th Avenue
- 18th Avenue crossing
- Bringelly Road (between Kelly and Kings)

Question 9 (b) Possible causes/solutions/improvements:

Cause/Solution/Improvement	No.	%
creek channel improvements required	31	(29%)
illegal fill exacerbating flooding	3	(3%)
drainage improvements required	27	(25%)
backflooding	4	(4%)
Other:	14	(13%)

- construct detention basins
- flooding exacerbated by upstream works
- channel erosion
- raise road levels
- construct levees

QUESTIONNAIRE RESPONDENTS

Number	Name		Address
1	D	Burley	278 Edmondson Avenue
2	E	Turner	42 Eleventh Avenue
3	B.C	Woodward	233 Eleventh Avenue
4	A	White	112-116 Floribunda Road
5	N	Van der Linden	215 Eighth Avenue
6		Haylock/Catanzoriti	70 Fifth Avenue
7	A	Belay	320 Edmondson Avenue
8	T	Gimellaro	180 Twelfth Avenue
9	S	Sampson	108 Eleventh Avenue
10	D&V	Hamone	45 Floribunda Road
11	G	Griffin	205 Lee & Clarke Road
12	H	Lo	590 Fifteenth Avenue
13	P	Shannon	Lot 85 Boyd Street
14	A	Segatto	225 Twelfth Avenue
15	C	Bianco	175 Thirteenth Avenue
16	F	Petulla	125 Gurner Avenue
17	G	Trautsell	203 Edmondson Avenue
18	C	Aquilina	Lot 1170 Bringelly Road
19	M	Cass	Lot 16 286 Fourteenth Avenue
20		Bonanno	175 Tavistock Road
21	S	Grima	30 Grant Close
22	M	Gauci	144 Tenth Avenue
23	S	Lichtenberger	195 Thirteenth Avenue
24	G	Holland	70 Seventh Avenue
25	A	Gorrell	Lot 132 Boyd Street
26	P	Holden/Boyd	575 Devonshire Road
27	J	Taylor	Lot 3 King Street
28	M	Greco	315 Sixth Avenue
29	V	Baird	400 Edmondson Avenue
30	G	Chan	288 Thirteenth Avenue
31	L	Taylor	Lot A King Street Rossmore
32	J	Cervelli	Lot 1 Cnr Exceter Road and Devonshire Road
33	M	Muscat	315 Thirteenth Avenue
34	R	Cicino	184 Fourteenth Avenue
35	J	Willis	140 Floribunda Road
36		Unknown	
37	M	Zerafa	Lot 655 Fifteenth Avenue
38	R	Bagnarol	55 Devonshire Road
39	P	Mitton	105 Eighth Avenue
40	P	Mitton	109 Eighth Avenue
41	J	Boyce	10 Fifth Avenue
42	N	Garvey	35 Seventeenth Avenue
43		Unknown	
44	J	Wilson	230 Seventh Avenue
45		Unknown	
46	G	Cardillo	35 Devonshire Road
47	D	Toohey	16 Bellfield Avenue Rossmore
48	M	Edwards	Lot 87/ 30 Boyd Street
49		Unknown	
50	B	Chesters	73 Ninth Avenue
51	R	Lee	330 Twelfth Avenue
52	A	Eason	105 Ninth Avenue
53	J	Azzopardi	Lot 1171 Bringelly Road
54		Napoleone	West Hoxton
55	G	Said	202 Twelfth Avenue

QUESTIONNAIRE RESPONDENTS

Number	Name		Address
56	B	Mills	60 Fourteenth Avenue
57	D	Atic	5 Browns Road
58	V	Camera	350 Edmondson Avenue
59	D	Pisani	205 Tenth Avenue
60	B	Gojnich	90 Gurner Avenue
61	B	Ferrington	235 Thirteenth Avenue
62	N	Dunn	23 Kelly Street
63	P	Bartuccio	160 Devonshire Road
64	M	Biscan	67 Kelly Street
65	J	Vitrone	163 Eighth Avenue
66	K	Pace	395 Devonshire Road
67	A	Demasi	100 Thirteenth Avenue
68	L	Dilario	167 Eighth Avenue
69	S	Cole	1 Bringelly Road
70	V	Marciano	110 Floribunda Road
71	C	Carrozzi	60 Sixteenth Avenue
72	A	Napoleone	164 Tenth Avenue
73	G	McFadyen	220 Thirteenth Avenue
74	J	Sharpe	140 Edmondson Avenue
75	G	Davis	225 Sixth Avenue
76	L	O'Dea	650 Fifteenth Avenue
77	M	Di Condio	85 Eleventh Avenue
78	A	Lipari	485 Fifteenth Avenue
79	T	Kane	635 Fifteenth Avenue
80	R&S	Hanson	184 Fifth Avenue
81	J&V	D'Emanuele	120 Devonshire Road
82	M	Metcalfe	110 Bringelly Road
83	J	Hanson	186 Fifth Avenue
84	G	Kopievsky	110 Herley Avenue
85	D	Knnjasich	Lot 54 Kelly Street
86	C	Wittwer	234 Fifth Avenue
87	M	Camera	245 Twelfth Avenue
88	B	Ghassibe	85 Ninth Avenue
89	W	Ghassibe	100 Ninth Avenue
90	M	Camera	180 - 190 Thirteenth Avenue
91	E	Germanos	180 Fifth Avenue
92	F	Madden	7 Kelly Street
93	G	Cascio	115 Elizabeth Dr
94	P	Damico	230 Eleventh Avenue
95		Habib	125 Fourth Avenue
96	R	Norris	210 Tenth Avenue
97	H	Xidias	45 Fourth Avenue
98	D	Jones	205 Eighth Avenue
99	P	Phillips	130 Seventh Avenue
100	I	Fear	170 Fourth Avenue
101	P	Melonas	665 Fifteenth Avenue
102	I	Wilson	150 Floribunda Road
103	K	Ferguson	480 Fifteenth Avenue
104	M	Meers	Lot 16 Gurner Avenue
105	J	Strasser	35 Herley Avenue
106	L	Stone	160 Eleventh Avenue
107	L	Hatem	315 Fourteenth Avenue

ATTACHMENT 2

RESIDENT INTERVIEWS

RESIDENTS INTERVIEWED

Questionnaire Number	Name	Address	Date Interviewed
99	P. Phillips	130 Seventh Avenue	17-1-95
51	R. Lee	330 Twelfth Avenue	17-1-95
16	F. Petulla	125 Gurner Avenue	17-1-95
68	L. Dilaro	167 Eighth Avenue	17-1-95
41	J. Boyce	10 Fifth Avenue	17-1-95
89	W. Ghassibe	100 Ninth Avenue	22-12-94
35	J. Willis	140 Floribunda Road	22-12-94
4	A. White	112-116 Floribunda Road	22-12-94
11	G. Griffin	205 Lee & Clarke Road	22-12-94
104	M. Meers	235 Gurner Avenue	22-12-94
12	H. Lo	590 Fifteenth Avenue	22-12-94
2	E. Turner	42 Eleventh Avenue	22-12-94

SUMMARY OF INTERVIEWS

Mr & Mrs Phillips

Mr and Mrs Phillips expressed concern about flooding of Kemps Creek along the back of their property. The creek swells during heavy rain and becomes a fast flowing river, spilling out across the floodplain. The most serious flood occurred in 1991 when flood waters reached an embankment 10 m from the rear of their house, approximately 100 m from the creek. The maximum water depth was 10 cm. Water recedes quickly after rain has ceased. Old photos of the floodplain were obtained.

Mr & Mrs Lee

Mr & Mrs Lee have been residents in the Austral - Kemps Creek area for 48 years. Their house has never been flooded or threatened by floods. Kemps Creek flows along the back of their property. During periods of heavy rainfall the creek swells to a rapid flowing river. Mr and Mrs Lee described seeing flood levels of 1.5 m at the corner of Fourth and Twelfth Avenue, Scalabrini Village under water and main roads being cut off and resident isolated. Fourth Avenue has been elevated recently, both Mr and Mrs Lee feel this has made the flooding worse. Floodwater has nowhere to drain and is forced into properties along Fourth Avenue. They also expressed concern that the council’s embankment along the banks of Kemps Creek was totally inadequate for major storms. The information provided by them helped confirm the location of major flooding hot spots identified by the respondents of the survey. Photos of flooding during the last five years at the intersections of Fourth and Twelfth Avenues, Eleventh and Fourth Avenues and along Fourth, Twelfth, Eleventh, Tenth Avenues were also obtained.

Mr Pettula

Mr Pettula's property has never been flooded. Mr Pettula confirmed information about the serious flooding at Gurner Avenue crossing. During periods of heavy rain water spills across Gurner Avenue and spreads out across the floodplain. Flood water was frequently fast flowing and often impassable.

Mr Dilaro

Kemps Creek runs directly adjacent to the Dilaro's property. The distance between the creek and the house is 4-5m. The Dilaro's have only recently purchased the property and are unaware of the consequences of a serious flood. They are very concerned about the erosion of the creek bank. At every storm the bank erodes closer to their house. Mr Dilaro would like council to take measures to stabilise the bank.

Ms Boyce

Ms Boyce's property has never been threatened by floods. Ms Boyce described the extent of flooding at the intersection of Bringelly and Browns Roads, and Fifth Avenue & Browns Road. The flooding at Bringelly and Browns Roads can be approximately 20-30 cm deep. In serious floods, water ponds at both intersections and flows along the edge of the road between both intersections.

Mr Ghassibe

Mr Ghassibe's property has never been flooded. His father's property (across the road) is frequently flooded. The channel that flows through Mr Pettula's fathers property passes under Ninth Avenue via a 1m pipe. The pipe is clogged by vegetation and debris, the water therefore spills over the road cutting the road in two. Flood water flowing across Ninth Avenue can be 1 m deep in heavy storms. The channel that carries water to Bonds Creek is shallow and overgrown. Mr Ghassibe indicated that all the property owners along the channel were prepared to accept any council improvements to alleviate further flooding of Ninth Avenue. The worst floods occurred in June 1991.

J Willis, A White, G Griffin, M Meers

The residents of Floribunda Road, Gurner Avenue and Lee and Clarke Road indicated that flooding was serious and extensive in that area. Ms Meers provided photographs that showed flooding at Gurner Avenue spreading over a distance of 100 m on either side of the crossing. The water moves very rapidly and can be as deep as 1.5 - 1.7 m based on observations of the flood markers adjacent to the creek. All four residents remembered 1988 as the most serious flood, and felt that the Council's channel excavations upstream (made in the early 1990's) had made the problem worse for less serious storms. All residents felt that water receded quickly once rainfall had ceased.

The residents also raised the issue of illegal / legal fill in the area. Fill has been placed by some residents to prevent flood waters rising onto their properties. The effects of the fill on flooding levels are unknown, there have been no major storms since the majority of the fill was placed.

Mrs Lo

Mrs Lo's property flooded in 1986. Water surrounded the house and began to rise up into the house. Water entered the house at 1 am in October 1986, rose to 150 mm above floor level and had receded from the house by morning.

The entire property except the north western corner was under water. Flooding occurs when water in the easement along the side and back of their property backs up and spills out across the floodplain. Flood damages were estimated at $10,000.

Mr E Turner

Mr Turner's house has never been flooded although his property is flooded after each major storm. There are no drainage channels along the sides of Eleventh Avenue, and Mr Turners house is lower than the road, consequently water flows off the road onto his property. The maximum water depth was 50 cm in 1988 (?). A channel exists opposite his property, however the pipe that channels water under Eleventh Avenue is blocked by vegetation and debris, causing water to spill over the road and onto his property. Photos of Mr Turner property in a flood were provided.

ATTACHMENT 3

WORKSHOP OUTCOMES

TOM DOMINY

SOLUTION FACILITATOR

AUSTRAL - KEMPS CREEK DRAINAGE STUDY

COMMUNITY PARTICIPATION WORKSHOPS

REPORT

WORKSHOP DATES - **September 19th & 26th**, 1995

PO BOX 482 CAMMERAY NSW 2062
TELEPHONE (02) 956 7804
FACSIMILE (02) 925 0319

Client

Lyall & Macoun Consulting Engineers
Level 2, 4 Help Street
CHATSWOOD NSW 2067

Telephone 02 413 3411

Study Conducted by

Tom Dominy Solution Facilitator
P.O. Box 482 *(Street-1/28 The Boulevarde)*
CAMMERAY NSW 2062

Telephone 02 9956 7804

CONTENTS

1. EXECUTIVE SUMMARY

The area known as the Austral - Kemps Creek flood plain has been the subject of ongoing drainage related problems for many years.

The Liverpool City Council recently engaged Lyall and Macoun Consulting Engineers, to analyse the flood plain's hydraulic behaviour and to prepare a Drainage Study for the area.

This report is nearing finalisation, due for presentation at the end of October, 1995. Lyall Macoun's brief required them to inform the Residents of their findings and to solicit Resident's opinions so that their study report could reflect community attitudes and expectations for the area.

These two workshops were part of that process and had the following objectives:

Provide an opportunity for community representatives to appreciate the nature of the flooding in the Austral - Kemps Creek area, and

To give the community a meaningful opportunity to participate in resolving current problems relating to flooding.

These workshops were conducted with the above objectives in mind and produced the following outcomes:

A list of key issues as identified by the Residents.

Weighted Selection Criteria that the Residents would like to see used in evaluating flood and warning management options.

A list of opportunities that the Residents saw as capable and worthy of pursuing as a result of the implementation of the recommendations of the Drainage Study.

A recommendation with regard to how the flood related matters affecting the area could be managed.

An Action Plan that, when executed, would lead to the satisfaction of the Resident's Objectives with regard to the management of the flooding and associated problems in the area.

2. BACKGROUND

Background work had been carried out for this project prior to the commencement of these Community Participation Workshops. This background work is represented by the following document:

Lyall Macoun Consulting Engineers "Invitation letter and Background Material"
dated 17th July, 1995

3. WORKSHOP OBJECTIVES

The following objectives had been set prior to the commencement of the Workshops in consultation with the Client:

Provide an opportunity for community representatives to appreciate the nature of flooding in the Austral - Kemps Creek area.

To give the community a meaningful opportunity to participate in resolving current problems relating to flooding.

4. WORKSHOP REPORT

This report has been developed by Tom Dominy Solution Facilitator. The Report seeks to provide an independent and objective overview of the Community Participation Workshop process and outcomes.

5. KEY ISSUES

The Workshop participants discussed and recorded those matters that they considered to be 'Key Issues' associated with the Project. These issues were:

(The numbers associated with the following Key Issues are those that were sequentially assigned during the Workshops. The groupings were allocated by the Facilitator subsequent to the Workshop)

Communication between Liverpool City Council and the Community

3 Concern over lack of funds and decision making.

5 Residents looking for consistency in the Council guidelines.

8 Community feed back required on the current flood drawings.

9 Council do not have access to inspect the creeks.

13 Strike an economic, social and environmental balance between land use and development, and cost to improve.

15 Tap into local knowledge and build up some data from residents at all levels of flooding 1:1 upwards.

19 Community feed back on development controls.

23 TRUTH in proposals - (Realistic)

Apparent Past Inappropriate actions by the Liverpool City Council

1 Inconsistency of Council's approvals, particularly with Health and Building Permits in flood prone areas.

2 Decisions have been made on political rather than technical grounds in the past.

11 Have a five year plan for implementing a practical solution.

14 Council look seriously at culvert upgrades and street closures.

17 Management of land fill and Council policy.

21 Recommendation of Plan to include what Council can do to prevent future development.

Relief for Affected Residents

6 Council should put in place an acquisition plan for those affected.

7 Council should put in place appropriate controls and provisions that exclude construction in flood areas.

12 State and Federal money may be available for works but the cost effective arguments are not available to support the funds.

20 Plan should address a 'buy back' scheme.

22 Council to commence an acquisition scheme.

Flood and Warning Management

4 Avoid property and stock damage.

18 Early warning flood system - computer as used at Georges River.

Communication between Liverpool City Council and other Councils

10 Penrith City Council be approached to assist in the problem due to work in their area.

16 Floods to be coordinated with upstream councils on their plan. Total catchment approach.

6. SELECTION CRITERIA

The Workshop participants discussed, recorded and evaluated the criteria by which they would judge the suitability, or otherwise of any proposals for improvement of the current situation. These criteria together with their scoring based on a maximum value of ten are:

Immediate and progressive improvement	10
Cost of restoration to the Owners	7
Lifestyle inconvenience	1
Environmental effectiveness	1

7. OPPORTUNITIES

The Workshop participants discussed and recorded those matters that they considered as opportunities that should or could be realised whilst the Drainage Study was being discussed or being put in place. These opportunities were:

(The numbers associated with the following Opportunities are those that were sequentially assigned during the Workshops. The groupings were allocated by the Facilitator subsequent to the Workshop)

Involve Other Bodies

3 To involve the RTA in bridge works while they are working on Elizabeth Drive.

4 Involve adjacent Councils

5 Involve people from Camden and Penrith that are affected by the flooding

11 Discuss the lowering of risks with the Insurance Council/Lending Authorities

12 Involve the Hawkesbury/Nepean Catchment Trust.

Potential Liverpool City Council Action

6 Realigning the creeks to their original positions

7 Improved development in improved areas

8 Improve decision making and approaches that can be made to strategic decision making

9 Improve road safety - less water on the roads and fewer people attempting to drive through water

10 To improve the definition of risk associated with flooding on their property

Of Benefit to other than the Local Residents

1 Potential to create employment

Environmental

2 Restore the environment, both creeks and wetlands

8. PRIORITIES

The Workshop participants discussed and recorded the following matters that they considered to be priorities. These were (not necessarily in priority order):

Carry out remedial works where the creek passes under Elizabeth Drive

Gurner Avenue - close road and/or enlarge the culvert, have the Consultant investigate the potential improvements - install gates across the road that can be closed by council officers

Tap into local knowledge in order to develop a plan (5Y), note that this has been substantially completed.

9. MANAGEMENT

The Workshop participants considered that the following Management Structure should be put in place in order that adequate Technical and Community resources were assembled to progress the implementation of any plans. The recommendation in this regard is:

"Establish a sub-committee (management committee) comprising of:

Council Officers
Councillors
Community representatives

with the power to make recommendations, on flood plain matters, to council for its implementation"

10. ACTION PLAN

The following actions were identified by the Workshop participants as being necessary to move the project forward in a timely manner:

NO.	ACTION	BY WHOM	BY WHEN
1	Develop a flood plain management plan (strategic), to set the framework for a five year plan	FPMC	June, 1996
2	Identify residents most at risk	L.M.C.E	Oct., 1995
3	Develop a plan of action to reduce the risk	L.M.C.	Oct., 1995
4	Council to initiate a regular program of stream cleaning, to remove those items of dumped rubbish, eg. old car bodies, not trees	Council	ongoing
5	Improve road drainage and upgrade culverts	Council	over 4 years
6	Prioritise options for all creek segments, including any of the above items, eg. 3, 4 & 5 not 1 & 2	S.P.	Oct., 1995
7	Recommend to Council that a "Neighbourhood Environment Watch" be set up	Council	Oct., 1995
8	Prepare a community information booklet and associated educational program	Council	June 1996
9	Install signs and boom gates strategically in the area, empower local people to operate them	Council & S.P.	2-3 year plan
10	Determine if land owners will allow Council access to maintain the creeks, or who would be willing to allow easements along the creeks allowing Council access, at no cost for acquisitions to Council	Council	June 1996

L.M.C.E. = Lyall and Macoun Consulting Engineers

11. FACILITATOR'S OBSERVATIONS

The Workshop participants, in particular the community representatives, were sceptical that anything tangible would be achieved by these workshops. This scepticism appeared to be based on previous lack of action on the matter of flooding over many years.

The Workshop participants, however did appear to respond favourably to the technical information presented by Dr. Stephen Perrens with regard to the flood plain characteristics and available options to alleviate flooding and its consequences.

The Community participants appeared to accept the reality of the situation and welcomed the frankness of presentation, even though it may not have been what they wanted to hear or consistent with their perception of the degree of relief that was possible.

This scepticism may be overcome if the community could see some real action on the matter. Of particular interest to me was their strong emphasis on the need for prompt action, as evidenced by the option judging criteria developed and scored during the Workshop.

12. APPENDICES

12.1 Project Brief

The project brief for Tom Dominy Solution Facilitator was to:

Become reasonably familiar with the project background information and the site.

Facilitate the Workshops.

Report on and make independent observations, if appropriate, with regard to the conduct and outcomes of the Workshop.

12.2 Available Information

The information available to all participants prior to the Workshop consisted of the following documents:

Lyall Macoun Consulting Engineers "Invitation letter and Background Material"

dated 17th July, 1995

12.3 Workshop Participants

The following individuals attended the Workshop on the days indicated in the table below:

Participant	Representing	Workshop 1	Workshop 2
Tom Glavich	Councillor, LCC	Y	N
Colin Harrington	Councillor, LCC	Y	N
Geoff Neville	Councillor, LCC	Y	Y
Tony Pascale	Councillor, LCC	Y	Y
Alison Megarrity	Councillor, LCC	N	Y
Arthur Baker	Community	Y	Y
David Edwards	Community	Y	Y

Matt Harris	Community	Y	Y
Ian Leeding	Community	Y	Y
Richard Millett	Community	Y	Y
Frank Oliveri	Community	Y	N
Alison White	Community	Y	N
Mary Willis	Community	Y	Y
Bill Witson	Community	N	Y
Angus Campbell	Community	N	Y
Ros Dent	Environment,LCC	Y	N
Steven Layman	Planning & Development	Y	Part
Pat Remano	Drainage Engineer, LCC	Y	Y
Ray Parsell	Drainage Engineer, LCC	Y	N
Stephen Perrens	Lyall Macoun	Y	Y
Neil Kennan	Lyall Macoun	Y	Y

ATTACHMENT 4

PUBLIC AUTHORITY CONSULTATION

LIST OF AUTHORITIES CONTACTED

Authority	Department	Contact	Address
Department of Land and Water Conservation (Now DIPNR)	Urban Floods	Neil Benning	PO Box 3720 Parramatta NSW 2124
Environmental Protection Agency	Regional Programs Unit Southern Sydney Region		Locked Bag 1502 Bankstown NSW 2200
Telecom Australia	Cable Locations	Cec Moore	PO Box 21 Miller NSW 2168
Department of Conservation and Land Management	District Soil Conservationist	Owen Graham	PO Box 1416 Parramatta NSW 2124
Prospect Electricity	Customer and Design Manager	Lyn Blaire-Hickman	Hoxton Park Road Hoxton NSW 2171
Pacific Power	Manager Central Region Pacific Grid	Bob Langdon	PO Box 87 Horsley Park NSW 2164
A.G.L.	Mains Liaison Officer	David Churchill	PO Box 35 Mortlake, NSW 2137

New South Wales Government

Water Resources

Lyall & Macoun Consulting Engineers
4 Help Street
CHATSWOOD NSW 2067

DX: 28360 Parramatta
Facsimile: (02) 895 7281
Telephone: (02) 895 6211
Ext: 7826
Contact Name: Mr M. Walsh
Our Reference: 0102723
[RML263]

Attention: Dr Stephen Perrens

Dear Sir,

Re: Austral Floodplain Management Study

Your Reference: Letter of 12 January 1995; NC407

The Department has the responsibility for administering two policies that are relevant to the Austral Floodplain Management Study. These are the Government's Flood Policy and the State Rivers and Estuaries Policy.

The Department would like to see the study consider both policies as they relate to flooding issues and the enhancement of the river and adjacent riverine environments. Whilst the focus of the Floodplain Management Study and resultant Plan should be on flood related issues, it should also provide a framework within which valuable ecological features are preserved; river and floodplain environment enhanced where appropriate; and, water quality issues are managed in an appropriate manner.

Under this framework it is hoped that the resultant Floodplain Management Plan will consist of a co-ordinated mix of measures that address the existing, future and residual flood and environmental problems in the Austral Study Area.

In relation to addressing flooding issues the study should follow the guidelines set out in the Floodplain Development Manual. The issues the Department considers relevant to the Study Area are presented in the South Creek Flood Study and Floodplain Management Study reports (1990, 1992). The range of likely mitigation options and measures suitable for the study area can be gleamed from the latter study. The key issues relate to access during floods, the selection of an appropriate Designated Flood Level(s), selection of appropriate planning and development controls, and control on the illegal filling of land and loss of flood storage.

In relation to environmental issues the Department would draw your attention to a number of modifications that have reportedly been made to the creeks within the study area and to the floodplain through illegal filling. The deteriorating water quality in the creeks resulting from a range of causes is also an issue that needs to be addressed.

0102723

The Department would also like to see the involvement of the adjoining Penrith and Camden Councils throughout the study and in the development of the Floodplain Management Plan.

Should you have any queries in relation to the flooding issues raised in this letter please contact Marcus Walsh on (02) 895 7826. For further information on the environment issues (and in particular the occurrence of filling of floodplain, creek modifications and deteriorating water quality) please contact Giselle Howard on (02) 895 7806.

Yours faithfully,

Neil Benning
Manager,
Urban Flood Management

21/2/95.

22-2-95

filename: 000268 Austral Floodplain Management Study

Environment
Protection
Authority
New South Wales

Civic Tower
Cnr of Jacobs Street
and Rickard Road
Locked Bag 1502
Bankstown
NSW 2200

Telephone .02. 795 5000
Facsimile .02. 795 5002

Dr Stephen J Perrens
Lyall and Macoun Consulting Engineers
35 Hume Street
CROWS NEST 2065

Our Reference: BA2904

Your Reference: NC407

Contact: John Goodwin

Dear Dr Perrens,

AUSTRAL FLOODPLAIN MANAGEMENT STUDY

Thank you for your letter dated 13 January 1995 requesting input from the Environment Protection Authority (EPA) to the above Study. The EPA is pleased to make the following recommendations.

1. Study Objectives

The prime objectives of controlling current flooding and drainage problems as well as amplifying the system to cater for future expansion of development, should be provided within the principles of Total Catchment Management and ecologically sustainable development. It is essential that the floodplain management plan for Kemps Creek integrates drainage and flood mitigation with water quality control options.

Planning controls and non-structural measures are the least cost options for flood protection. They also have the least impact on the environment. The EPA strongly recommends that planning instruments are used to prohibit development which may exacerbate flooding. Floodplains are ideal areas for public open space, recreation and/or wildlife corridors. The EPA will be happy to provide detailed advice to Liverpool Council in regard to planning instruments including other constraints to development (apart from flooding).

Structural measures have the greatest potential for adverse environmental impact and are usually the most costly. Not withstanding the above, it is recommended that any necessary flood detention basins, sediment control ponds and/or artificial wetlands, be constructed off-line.

2. Integrated Stormwater Management

Future development should be designed to facilitate retention of existing natural watercourses and riparian buffer strips. Past channelisation practices are not recommended as they form conduits for pollutants to be transported downstream. Natural channels allow assimilation of some nutrients; help to trap sediments; help maintain downstream water quality; and protect aquatic habitats and ecosystems. In this regard the following publications are recommended.

* "Better Drainage - Guidelines for the Multiple Use of Drainage Systems", Department of Planning
* "Preparing Soil and Water Management Plans for Urban, Industrial and Resort Developments", Lake Illawarra Catchment Management Committee
* "Management of Urban Watercourse Corridors", Lake Illawarra Catchment Management Committee
* DRAFT "Erosion and Sediment Control Policy", Hawkesbury-Nepean Catchment Management Trust

The above documents clearly show that the benefits of pollution control; stream bank stability; maintenance of biological diversity; and long term flood management, can be integrated with rehabilitation and maintenance of effective riparian corridors which maximise local biodiversity.

In addition, consideration should be given to the benefits of on-site stormwater re-use as a means of offsetting increased run-off associated with development as well as a means of conserving scarce water resources.

3. Sensitive Environments

The Floodplain Management Study should identify and provide protection for sensitive environments within and adjacent to the study area. Interrelationships between such areas and their surrounds should also be identified and essential buffer zones and linkages maintained. The 1993 State of the Environment Reports for Liverpool, Camden, Campbelltown, Fairfield and Penrith local government areas may be of assistance.

The EPA recommends that careful consideration be given to State environmental policies during the course of preparation of the Management Study. These include the State Soils Policy; State Trees Policy; and State Rivers and Estuaries Policy.

4. Existing Development

Existing development in the Kemps Creek catchment is comprised of intensive horticulture and rural residential. Diffuse run off from intensive agriculture such as market gardens and poultry farms is nutrient enriched and may contain other pollutants which could adversely impact on proposed residential areas. Planning for future development should also take into account a combined extractive industry/landfill depot operated by Brandown Pty Ltd located off Elizabeth Drive; the Sydney Water Supply canal; and a major transmission easement and substation towards the eastern side of the study area. An unauthorised landfill also exists in the Denham Court area of the floodplain catchment.

5. Total Catchment Management.

Kemps Creek is a tributary of South Creek which already contributes to water quality problems in the Nepean/Hawkesbury River. The EPA actively supports the integrated approach of Total Catchment Management in development of a floodplain management plan. In this regard, you are urged to contact the South Creek Catchment Management Committee co-ordinator on (045) 77 4243. In addition, the cumulative impacts of development on the catchment should be assessed in terms of both water quality and quantity, and habitat protection. The long term aim of developing water quality objectives for each stream within the floodplain catchment should also be considered.

I trust that you find the above comments useful. Should you wish to discuss any aspect in more detail, please do not hesitate to contact John Goodwin on 795 5252.

Yours Faithfully

22.2.95

CRAIG LAMBERTON
Regional Manager, Southern Sydney
for Director-General

Lyall and Macoun Consulting Engineers
Water and Environmental Engineers
35 Hume Street
CROWS NEST NSW 2065

RECEIVED 22 MAR 1995

SOIL CONSERVATION SERVICE

Neale Court
311 High St
Penrith NSW 2750
PO Box 651
Penrith NSW 2751

Phone (047) 21 0188
Fax (047) 21 0181

Contact: Neville Pavan

Our Ref: 20: P4/III (N:AUSTRAL.STU)

Your Ref: NC407

Attention: Dr S. Perrens

Dear Sir,

RE: AUSTRAL FLOODPLAIN MANAGEMENT STUDY

I refer to your letter of 12th January, 1995 seeking comment on matters relevant to this Department which should be addressed when considering the subject management study, and take this opportunity to apologise for the late response.

The Soil Conservation Act, 1938 makes provision for the conservation of soil and farm water resources and for the mitigation of erosion within New South Wales. Any activity which disturbs the natural ground surface or the protective vegetation cover constitutes an erosion hazard necessitating the adoption of adequate control measures to minimise environmental degradation.

As you are aware, erosion and sediment control is an important environmental consideration prior to and during any activity and/or development. It is essential to minimise on-site erosion, and offsite sedimentation of adjacent properties, streams, waterbodies and the like.

In this context, if construction works are proposed a progressive erosion and sediment control program should be implemented from the initial operation stage until the proposal has been completed and the site fully stabilised and/or landscaped.

Such a program should consider:

1. Control of surface drainage (especially in main watercourses)

2. Early revegetation of completed development areas

3. The construction of Sediment Trapping Structures (e.g., sediment basins, strawbale and geo-textile fences).

Other issues which are considered important and applicable to sound land management are:

1. Soil salinity and its impact on revegetation.

2. Level of water tables and long term impact on these levels due to urbanisation, especially with tree loss and increased runoff.

3. Decreased runoff response times and flood response times.

4. Increased potential stream bank erosion due to larger volumes of runoff from urbanised areas, especially in lower intensity, relatively frequent run levels.

5. Potential decrease in water quality due to contamination of runoff from urban areas, including increased turbidity (soil loss) and nutrient enrichment.

6. Decreased potential of wildlife corridors along riparian zones and potential loss of streambank vegetation as a result of streambank erosion.

If further information is required for the Liverpool City Council area in future, please contact me at the Department's Penrith Office.

Yours faithfully,

Neville Pavan.

NEVILLE PAVAN
District Soil Conservationist
PENRITH

7 March 1995

PacificGrid

GRID/C/MET/VC:MF

Lyall & Macoun Consulting Engineers
Water and Environmental Engineers
35 Hume Street
CROWS NEST NSW 2065

ATTN: Dr Stephen J Perrens

07 FEB 1995

25th January 1995

Dear Sir

RE: Austral Floodplain Management Study

We thank you for your letter of 13/01/95 on the above matter and appreciate your invitation for us to contribute to your Study. Our comments are as follows:

i) Within the area covered by your Study as indicated in your Figure A2.1 we have only one Electricity Substation which is called "Kemps Creek 500/330kV Substation". This Substation is located near the corner of Gurner Avenue and Fourth Avenue, Kemps Creek, and it has been there since early 1982.

ii) Since the Substation has been there we have not experienced or been advised of any problems with flooding. We have however had problems with access to the Substation via Gurner Avenue when it floods where it crosses Kemps Creek near the Devonshire Road end. Although Gurner Avenue then becomes inaccessible we have always gained access from Fifteenth Avenue and Fourth Avenue.

iii) Because the Substation is built up from the surrounding land we feel it is unlikely that flooding could ever impact on the Substation itself.

iv) For your information however, even if the Substation was affected by any incident such as floods, it would not necessarily affect the electricity power supply within the area of your study. Local electricity power supplies will be more affected by problems occurring to installations owned by Prospect Electricity, which we presume you have contacted yourself.

v) Outside Kemps Creek Substation itself we do not have or propose to have any underground cables or electrical services which need to be included within your Study.

vi) Within your Study Area we do also have a large number of high voltage transmission lines rated at 500kV and 330kV which are mounted on large steel lattice type structure. As you are aware these structures are very high and they are designed to maintain specified clearances between the electrical conductors and the ground. We believe that these installations will not be affected by normal flooding within your area of study.

We hope the above information is of use to you, but if you require any further details please do not hesitate to contact myself, Victor Galea at the above phone number.

Yours faithfully

V.C. Galea

V.GALEA FOR
MANAGER/CENTRAL REGION

AGL Gas Companies

RECEIVED

13 DEC 1995

Ans'd........

ENG:ML:JM:A2038

11 December 1995

Lyall & Macoun Consulting Engineers
Level 2
4 Help Street
CHATSWOOD NSW 2067

Attention: Ms A Tourle

Dear Madam,

RE: AUSTRAL FLOODPLAN MANAGEMENT STUDY.

In reply to your facsimile of 7th December 1995 concerning affectation to this Company's plant and apparatus and to review an assessment of the Company's operation system.

Please see attached document which has been reviewed by our Research, Development and Engineering Department and I trust will be adequate for your report.

I have also enclosed for you a copy of our mains plan for your area.

Should you have any further matters to discuss regarding this please contact me on 736 5764.

Yours faithfully,
AGL Gas Companies (NSW) Limited

James Madden

FOR **D. J. Churchill**
Mains Liaison Officer

mains20\jm.487

AGL Gas Company (NSW) Limited ACN 003 004 322 • Tennyson Road Mortlake NSW 2137
P.O. Box 35 Concord NSW 2137 Phone: (02) 922 0101 Fax: (02) 736 5755
THE AUSTRALIAN GAS LIGHT COMPANY SINCE 1837

GAS

4.1 SYSTEM OPERATION

The gas supply to Sydney, Wollongong, the Central Coast and Newcastle comes by transmission pipeline from South Australia via Wilton. The line then runs North-East from Wilton to Windsor before crossing the Hawkesbury River downstream of Wisemans Ferry.

The line operates at 4800 kPa and is constructed of mild steel. Automatic line break valves are fitted at intervals along the pipe and automatically shut off a damaged section of pipe should a leak be detected. This would result in a loss of supply to all consumers which draw their supply from upstream of the break.

Offtakes from this line feed into trunk receiving stations (TRS) which reduce the pressure for bulk distribution to regions.

Gas supplies to most of the Sydney region including regions West of the line such as St Marys, Penrith and Emu Plains are effected and controlled from three TRS's located between Horsley Park and Windsor and therefore in the study area. Failure at any of these stations would result in the particular region being without gas supply. Depending on which TRS is affected it may be possible to maintain continuity of supply to domestic consumers via the horsley Park TRS at the expense of reduced supply to the industrial consumers supplied from this station.

High pressure mains carry gas from the trunk receiving station to pressure mains supply to consumers.

Within the study area there are approximately 40 kilometres of high pressure mains and 200 kilometres of medium and low pressure mains supplying gas to approximately 24,400 customers. High pressure mains are constructed from high tensile steel pipe and medium and low pressure mains are constructed from lead jointed cast iron pipe or plastic pipe. The distribution network also includes line control valves, telemetry equipment and customer meter and regulator sets.

4.2 FLOOD EFFECTS

The transmission pipeline would be susceptible to flood damage at the crossing of the Hawkesbury River. Erosion of the river banks and/or the river bed itself could result in rapture of the pipe or even the loss of a 400-600 metre length.

This would result in a loss of supply to Newcastle and the Central Coast. Ninety percent of industrial enterprises in these area rely on natural gas although backup diesel is available.

The pipeline is buried two metres below the bed and covered by ballast. Monitoring of erosion since 1988 however, has revealed that the river bed has changed considerably and in some sections a significant amount of pipe cover has been depleted by scour during abnormally heavy flows. AGL are currently assessing means of improving the security of this river crossing and continuing with regular monitoring of depth of pipeline cover on this and other major creek crossings.

Trunk Receiving Stations consist of pressure reducing equipment, pipework and a control building. Flooding would damage electrical and mechanical equipment at each station and at greater flood depth, building.

High pressure mains would be subject to localised damage where the mains are exposed on river or creek crossings. A break in one of these would result in gas being released until valves were shut off. This requires the Mortlake control centre to detect the leak and then communicate by telemetry to remotely close the valve. If power supply is cut at this stage it will be necessary for the valves to be closed manually.

The pressure regulating stations are fitted with electric and pneumatic sensing devices which would shut off supply when floodwaters entered the regulators. These could be manually overridden providing there is no physical damage to the equipment.

Medium and low pressure pipes are susceptible to damage from erosion caused by flooding. Experience with previous minor flood events in the valley is that no major damages have been sustained to the pipelines. Again remote or manual closure of valves would be required when a leak is detected. Leaks in these pipes would be more difficult to detect remotely because of the smaller rates of leaking.

When flood waters reach the inlet of a consumer's meter, water will enter the pressure regulator, meter assembly, internal reticulation and appliances but is unlikely to cause any permanent damage.

4.3 EMERGENCY PROCEDURES

AGL have no specific emergency response plan for flooding but rely on remote sensing and control systems for the isolation of leaks. This system relies on electricity supply being available. Should power failure occur then valves would need to be closed manually.

4.4 RESTORATION

Restoration of gas supplies are likely to be inhibited by shortage of manpower and materials. There is no standardisation of gas supply in Australia and manpower and replacement parts would be available from other Australian gas supply authorities.

Should the high pressure transmission pipeline fail at the Hawkesbury River crossing, restoration could take some months. It could be two weeks before flood waters have subsided sufficiently for an assessment to be made of the damage. There is about 200 metres of replacement pipe in stock but should a greater length be damaged (and it could be as much as 600 metres), pipe would have to be manufactured in Western Australia or imported from overseas. This could take three months. A further month could be required for restoration of the line because of the access difficulties and the need to lay the pipe under water. This would mean that Newcastle and the Central Coast could be without gas for up to five months.

A break in the medium or low pressure pipes would be easier to repair and the time required to restore supply would depend largely on the number of customers affected. This is because the pilot light on every customer's hot water heater would have to be relit by AGL staff. A recent rupture in a line in Redfern affected 500 customers. Supply was restored within 24 hours but this required 200 staff and stretched to the limit AGL's manpower resources.

Restoration of each pressure regulation station is estimated to take only 1 day providing flooding debris has not caused any physical damage.

For houses where the gas meter has been inundated by floodwaters the regulator would need to be reconditioned, the pipes and appliances drained and cleaned. This is estimated to take four hours per household.

The priority of repairs would be to restore gas to customers outside of the flood affected area then to gradually restore supply to the flood zone.

Repair work does not require electricity or telephone services to be able to proceed. However, repair vehicles weigh about 20 tonnes and would need to use the road network to effect repairs.

ATTACHMENT 5

COUNCIL COMPLAINTS DATABASE

COUNCIL COMPLAINTS DATABASE
Summary of Complaints

CODE	COMPLAINT/ SUGGESTION	No. COMPLAINTS	PERCENTAGE
B	Channel bank erosion	2	4.5
C	Creek clearing required	7	16
E	Potential easement	2	4.5
F	Illegal fill	19	43
L	Levee	2	4.5
M	Miscellaneous	8	18
Z	Zoning	4	9
	TOTAL	44	100

Note: codes correspond to the `type of problem' listed in the attached database.

LIVERPOOL CITY COUNCIL - COMPLAINTS DATABASE

Type of document	Document From	Position	Document to	Position	Residents Name	Residential Address	File Number	Nature of Complaint	Location of Complaint	Type of problem	Documentation
Council Memo	Davidson, J	?	Stewart, R	Engineering Services Manager			E2.21100	Response to bank erosion at Lot 931 & lot 930 8th Ave. Mr Jaksic is concerned that erosion is threatening his property. The Austral Floodplain Management Study will (it is hoped) improve this situation.	Lot 931 & Loy 932 8th Ave	B_Ja	
Council Memo	Stewart, R	Engineering Services Manager	Walker, J	General Manager			E2.21100	Hollands filling of Lot 785 11th Avenue	Lot 785 11th Avenue	F_Ho	
Council Memo	Stewart, R	Engineering Services Manager	Bunch, M	Maintenance Engineer			E.1290/3E	Eleventh Ave Drainage problems re: Application for Easement clearing. Notice of proposed work		F_Di	
Council Memo	Stewart, R	Engineering Services Manager	Bunch, M	Maintenance Engineer			E2.21000	Application to obtain easement in Mr Di Condio's property	Lot 786 11th Ave	F_Di	
Council Memo	Stewart, R	Engineering Services Manager	Vell, A	Alderman			E.3605	Mr Strickland is informing Councillor Vella about proposed action at Lot 785 11th Ave (Hollands Property)		F_Ho	
Council Memo	Stewart, R	Engineering Services Manager	Charlton	Works Manager			E2.21000	Spreading Fill around Area re: 190 4th Ave. Technical Services is impressing upon works the need to avoid spreading fill on a flood plain.	190 4th Ave	F_Ka	
Council Memo	Stewart, R	Engineering Services Manager	Latham, M	Alderman			E.1290/3E	Further correspondence concerning the inaction by Mr Hollands at Lot 785 11th Ave re: Illegal filling and diversion of the natural water course.	Lot 785 11th Ave	F_Ho	
Council Memo	Nguyen, H	?	Webb, RW	Design Engineer				Update of Mark Brunch's Memo. Work scheduled for Lot 786 has been completed, accept for some repair. The total repairs will be completed in one month.	Lot 786 11th Ave	F_Di	
Council Memo	Carter, W	Director Technical Services	Harrington, C	Alderman			E2.21000	Further correspondence about flooding at Mr Vallentines property. Mr Carter advises that the flood mitigation works considered necessary to reduce flooding of the property cannot be justified economically. The DWR also advise that the dam Mr Burgess has constructed could not be causing significant flooding problems to Mr Valentine.	12th Ave	F_Va	
Council Memo	Webb, RW	Design Engineer	A/EMS	Design Engineer			E.1290/3E	Summary of Matters discussed at the Kemps Creek Precinct Meeting 4th September 1991		M_	
Council Memo	Stewart, R	Engineering Services Manager	Lynch, P	Alderman			E2.21000	Re: Flooding of Kemps Creek - Mrs Neale. Mr Strewart finds that Mrs Neales property is more likely to be at risk that any other property n the region. No flood mitigation works are possible. The property may have to be purchased.	Lot 31 Elizabeth Drive	Z_Ne	
Council Memo	Webb, RW	Design Engineer	Vell, A	Alderman			E.1290/3E	Eleventh Ave Drainage problems re: Easement clearing. Notice of intended work	Lot 786 11th Ave	F_Di	
Council Memo	Parsell, Ray	Drainage and Investigation Engineer	Strickland, N	Manager Engineering			E221000	Eleventh Avenue complaints re: Gimarello and Hollands(see above for details). Mr Parsell feels that the Gimarello issue is no longer in dispute.	11th Ave	F_Ho	
Council Memo	Parsell, Ray	Drainage and Investigation Engineer	Sargeant, Owen	Co-Ordinator Health and Building Surveying			E221100	A house has been sighted across a natural stormwater flow path. Piping work may now be necessary	Lot 805 11th Ave	Z_Za	
Council Memo	Stewart, R	Engineering Services Manager	Lynch, P	Alderman			E2.21000	Re: Clearing Kemps Creek and South Creek. Mr Stewart advises that the cost and benefits of clearing g the creek do not balance the enormous cost associated with the task.	Kemps Creek	C_	
Council Memo	Stewart, R	Engineering Services Manager	Kidd, PS	Director Public Services			?	A request by Mr Stewart to consider the political implications of Creek Clearing 600m downstream of Gurners Crossing. Mr Stewart express some reservations about the credibility of accusations that the drainage channel dug upstream of Gurners Crossing have made the problem significantly worse.	Kemps Creek	C_	
Council Memo	Parsell, Ray	Drainage and Investigation Engineer	Kellehear, T	Land and Development Engineer			P3850.190	Development application for fill. Application should be refused, fill inappropriate in Flood areas	Unknown	F_	
Council Memo	Whittle, K	Western Area Supervisor	Charlton	Works Manager			E2.21100	RE : Flooding Problems at Lot 163 8th Ave. Mrs Miles' property is subject to flooding due to fill placed on her neighbours land, and in a nearby dam.	Lot 163 8th Ave	F_	
Council Memo	Parsell, Ray	Drainage and Investigation Engineer	Peebles, B	Senior Engineer Assets			E.3605/3S	Ray Parsell's advice to management about the request by Mr Carrozzi to clear the fire hazard from his land. Some discussion of the misguidance of altering the flow of natural water.		C_Ca	
Residential Complaint					Bajic	277 Cabramatta Rd Cabramatta	E2.21100	A bank has been built along the edge of bonds creek by Mr Bajic's neighbour, this bank obstructs the flow of water and pushes water onto his property causing major flooding	Fourteenth Ave, 270	L_Ba	Letter: Bajicc to Walker 6 June 1994 Letter to Council (Bajic) 27 October 1994
Residential Complaint					Birch, K	440 12th Ave	E2. 2100	A levee bank has been constructed by Mr Birch around his property and Tennis Court to prevent flooding. Council have taken action to remove this bank Status of bank presently unknown	440 12th Ave	L_Bi	Letter: Birch Strickland 16 Sept 1994 Letter: Strickland to Birch 28 July 1994
Residential Complaint					Carrozzi	60 16th Avenue	E.3605/3S	Council have constructed a channel along the eastern boundary of Mr Carrozi's property. The spoil from the channel was left lying between the channel and Mr Carrozzis' Fence. The area has now become very overgrown with grass and Blackberries. Mr Carrozzi feel this is a potential fire hazard. Requests council clear overgrowth.	60 16th Avenue	CL_Ca	Memo form Ray Parsell to Brian Peebles, 8 Dec 1994

LIVERPOOL CITY COUNCIL - COMPLAINTS DATABASE

Type of document	Document From	Position	Document to	Position	Residents Name	Residential Address	File Number	Nature of Complaint	Location of Complaint	Type of problem	Documentation
Residential Complaint					Casico	115 18th Ave	E2.211000/P3	Council has taken action to remove fill on Mr Casicos' property, this action is being stalled by the results of LMCE's Austral Flood Study	115 & 95 18th Ave	F_Ca	Letter: Casico to City Council & Photographs
Residential Complaint					Dicondio	85 11th Ave	E2.2100	Di Condio and Hollands are having an ongoing battle about fill on Mr Hollands block that Mr Di Condio claims is causing flooding of his property - see Hollands	75 11th Ave	F_Di	See Hollands
Residential Complaint					Dimech, WP	128 - 130 Floribunda Rd	E2-21000	Illegal fill in Floribunda Ave has caused flooding for residents who have not filled	Floribunda Ave	F_Di	
Residential Complaint					Formica, S	Lot 1046 6th Ave	E2.21000	Council proposed and built a channel that runs through Mr Formica's property . the Formica's were compensated for the loss of the land occupied by this easement.	Lot 1046 6th Ave	E_Fo	Letter: Council to Formica explaining purchase of land and compensation
Residential Complaint					Gimellaro	60 11th Ave	E.1290/6E	Council ordered Mr Gimarello to remove fill obstructing the natural flood plain. This issue has been resolved (R. Parsell)	60 11th Ave	F_Gi	~~Letter: Council to Gimarello ordering fill~~ removal Memo: Ray Parsell to Neil Strickland 23 March 1994
Residential Complaint					Grima	240 13th Ave	E.3850/6T	Mr Grima requested the council to dredge the creek	Kemps Creek	C_Ha	Letter: Grima to Council 7 March 1994 Letter: Council to Grima 9 March 1994
Residential Complaint					Hanson R	184-186 5th Ave	E2.21000	Council proposed and built a channel that runs through Mr Hanson's property . The Hansons were compensated for the loss of the land occupied by this easement.	184-186 5th Ave	E_Hs	Letter: Council to Hanson 5 August 1991
Residential Complaint					Holland, E	75 11th Ave	E.1290/3E	Council ordered the removal of illegal fill in the Creek on Mr Hollands block, Mr Di Condio (Mr Hollands neighbour) has asked council to take action concerning the fill. Mr Hollands has also constructed a headwall that obstructs the flow of water and piped the water into the creek, altering the natural path of the water. Council have requested that this also be removed.	75 11th Ave	F_Ho	Letter: Strickland to Hollands, 13 July 1994 Letter :Strickland to Hollands, 13 April 1994 Memo: Ray Parsell to Neil Strickland 23 March 1994
Residential Complaint					Jaksic	Lot 931 8th Ave	E2.21100	Mr Jaksic is concerned about bank erosion that is occurring in the creek bed adjacent to his property. There is a distance of 4m approx between the bank and the property.	Lot 931 & 932 8th Ave	B_Ja	Council Memo
Residential Complaint					Kaiser	190 4th Ave	E.149513	Mr Kaiser's house has not previously been effected by flooding until after the council had widen the storm water drains in approx 1991-1992. Mr Kaiser feels this action has directly contributed to the flooding of his property. He also feels that raising the level of the crossing at 4th and 9th has contributed to the flooding of his property.	190 4th Ave	F_Ka	Letter: Kaiser to Council 2 April 1994 Letter: B. Peebles to Kaiser 12 July 1994
Residential Complaint					McFadden	220 13th Ave	E.3850/6T	Mrs McFadden requested council dredge the creek	Kemps Creek	C_Mc	Letter: Peebles to McFadden 11 August 1994
Residential Complaint					Meers, M	Lot 16 Gurners Ave	E2.21000	Mrs Meers is one of a group of concerned residence that have written to the council about the flooding that occurs between Gurners Crossing and Floribunda Ave. Mrs Meers lives directly adjacent to the Crossing and is very concerned about the flooding that totally obstructs Gurners Crossing and spreads out some 100m.	Gurners Crossing	M_Mc	Letter: Mrs Meers to Council March 1992 Letter: Council to Mrs Meers March 1992
Residential Complaint					Messina	Lot 150-151 18th Ave	E1280.3	Mr Messina approached Council about removing illegal fill on the property opposite his house in 18th Ave. Mr Messina claims that the fill has raised the height of the house opposite such that water no longer flows along the natural water way but across his block.	85 17th Ave & 150 18th Ave	F_Me	Letter: Macri Stathis & Co (solicitors representing Mr Messina) to Council on - 27 May 1994 - 3 March 1994
Residential Complaint					Muchmore	215 13th Ave	E2.21100	Mr Muchmore requested that the Council clean and straighten the creek that runs through his property.	Kemps Creek	C_Mu	Letter: Muchmore Council 5 Jul 1994 Letter: Council to Muchmore 7 Jul 1994
Residential Complaint					Neale	Lot 31, Elizabeth Drive Kemps Creek				Z_Ne	
Residential Complaint					Sharpe	140 Edmonson Ave	Request Number 58567	A fence has been built across the natural water course causing his property to flood. Mr Sharp also complains about the low bridge under the road that blocks and causes the water to flood across the road.	140 Edmonson Ave	M_Sh	Customer Request to Council - 16 November 1994
Residential Complaint					Vallentine, P	12th Ave	E2.21000	Mr Valentine has been having an ongoing argument with Council about flooding on his property since the early 90's. Mr Valentine complains that a) his neighbour has spread fill around a dam down stream causing the water to back up onto his property and flood, Mr Valentine also claims that council is using his property as a detention basin. Mr Valentine claims that Mr Burgess (his neighbour) has raised the level of the drainage channel bed flowing under 12th Ave. Mr Valentine asks Council to fix this	12th Ave	M_Va	See memo prepared by Ray Parsell 14 April 1994, memo contains copies of original documents and letters sent by Mr Vallentine.
Residential Complaint					Willis, J	140 Floribunda Ave	E2.21000	Mr Willis is part of the same group of residents as Mrs Meers that are concerned about flooding in Floribunda Ave.	Floribunda and Gurners Crossing	M_Wi	Various letters and petitions signed by the residents of Floribunda Rd and Grunners Crossing
Residential Complaint					Wilson, I	150 Floribunda Rd Kemps Creek	E2. 21000	Same as above	Same as above	M_Wi	Same as above

LIVERPOOL CITY COUNCIL - COMPLAINTS DATABASE

Type of document	Document From	Position	Document to	Position	Residents Name	Residential Address	File Number	Nature of Complaint	Location of Complaint	Type of problem	Documentation
Residential Complaint					Zahra, C	Lot 805 11th Avenue	E.2190/3	Council has approved the erection of a house in the middle of the natural water course	Lot 805 11th Avenue	Z_Za	Memo: Parsell, Ray Drainage and Investigation Engineer to Sargeant, Owen Co-Ordinator Health and Building Surveying
Council Report							E2 0000.1	Flooding February 1992 - record of road closures in Austral between the 5th & 10th of February, total of 256mm	Fourth Ave - 5th Ave and 12th Ave Camden Valley Way - Cowpasture Road and Casa Paloma Caravan Park	A_W	Report - 10/2/92
Council Memo	Findley, RT	Town Clerk	Whitlam, GE	MP, QC	Scalabrini Village	Scalabrini Village	E2.21100	Council is making representations to Mr Whitlam to approach the federal government about a special grant for flood mitigation works near the village	Scalabrini Village	M_Sc	Letter: Findley to Whitlam - 15th March 1976
Residential Complaint					Campbell, Clive	Loy 3 9th Ave	E2.21100	Flooding of 9th Ave- access to 9th Ave blocked. Some information about the natural water course pre 1950	9th Ave	M_Ca	Letter: Campbell to Council - 23rd June 1975

ATTACHMENT 6

RESIDENT BROCHURE

Draft Austral Floodplain Management Study and Plan

Liverpool City Council

COMMUNITY INFORMATION BROCHURE **June 2003**

The Austral - Kemps Creek area has experienced flooding problems for a long time and in response Liverpool City Council have commissioned a Floodplain Management Study. A draft Floodplain Management Plan with the aim of reducing the impact of flooding on the community has been prepared. The Plan is based on taking all feasible opportunities for managing the flooding problem whilst retaining the existing pattern of subdivision and land use. This brochure summarises the findings of the Study and outlines the key elements of the draft Plan. The brochure also provides information on how the community can obtain more information and provide feedback on the study findings

INTRODUCTION

Flooding is a natural feature of the Austral area. Floods are a problem in the area largely because the historical subdivision of the land and its subsequent development did not take account of the natural pattern of flooding. There is no point in "blaming" our great grandparents for the pattern of subdivision. The problems have to be faced by, and managed by, the community of Austral-Kemps Creek, with reasonable assistance from Council.

INFORMATION NIGHT!

Council will be holding a public information session for the draft Plan. The session is open to all interested members of the public. Dr Steve Perrens of Perrens Consultants and officers from Liverpool City Council will make a presentation and be available to answer your questions.

7 pm Monday 23rd June 2003

H.J. Starr Progress Hall, 264 Edmondson Avenue, Austral.

Please confirm your attendance by contacting Council officer Mr Robert Dinaro on 9821 7741.

All welcome!

WHAT ARE THE MAIN FINDINGS OF THE STUDY?

The Floodplain Management Study provides Council with a strategy to address flooding problems in the area.

SETTING THE SCENE

Flooding in the Austral - Kemps Creek area has a number characteristics:

- Flooding is a natural feature of the area.
- The area has wide floodplains which contain relatively small natural channels of limited capacity.
- Approximately 30% of the area is flood prone and 10% of the area acts as a floodway and conveys the majority of flood water.
- The original subdivision for the Austral area in 1887 was laid out as small rural land holdings covering the whole area. The subdivision layout paid no attention to topography and drainage patterns and no land was reserved for drainage purposes, according to the usual practice at that time.
- While some land is in public ownership, the majority of the natural creek and floodplain system remains in private ownership.
- It appears from Council's files that residents have unrealistic expectations of the level of service which can be provided by rural drainage schemes. This has resulted in considerable pressure on Council officers to deal with perceived flooding problems which are in fact part and parcel of the normal operation of the rural drainage system.
- Due to the topography and land ownership patterns in the area there are no opportunities to carry out works which would result in significant reductions in the impact of flooding. Any feasible flood mitigation works are only likely to result in minor reductions in the impact of flooding.

HOW FLOODING AFFECTS THE COMMUNITY

The draft Plan is based on significant consultation with the community which aimed to find out how people are affected by flooding and what they would like done about it.

The most common concern was the nuisance and inconvenience caused by floods which cut roads.

An assessment of the economic impact of flooding on the community indicates that there are a number of residential properties which would be affected by floods as summarised below.

ARI (years)	No. residential properties damaged	Damage to all classes of properties
1	21	630,000
5	50	1,845,000
20	82	3,645,000
100	102	8,365,000
PMF	173	17,785,000

The average annual damage (the average damage per year that would occur from flooding over a very long period) in the area is estimated to be about $1.8 million, of which about 25% is attributable to losses from rural industries.

At various meetings held during the course of the study the community was invited to contribute views about matters which should be included in the Plan and priorities for action. The issues considered important included:

- Improved safe transport access
- Proposed measures should be acceptable to, and meet the expectations of, the community
- Reduction of flood damage and hazard.

SOME DEFINITIONS:

Flood planning area	the area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels (FPL)	the combination of flood levels and freeboards selected for planning purposes, as determined in floodplain management studies.
Flood prone land	land susceptible to flooding by the probable maximum flood (PMF) event. This is defined as the floodplain.
Floodway	those areas where a significant volume of water flows during floods which, even if only partially blocked, would cause a significant redistribution of flood flow and affect flood levels
Average recurrence interval (ARI)	the long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 100 year ARI flood event will occur on average once every 100 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Probable maximum flood (PMF)	the largest flood that could conceivably occur at a particular location, usually estimated from the probable maximum precipitation. The PMF defines the extent of flood prone land.

WHAT ARE THE COMPONENTS OF THE DRAFT PLAN?

The recommended components for inclusion in the draft Plan are listed below and the location of the structural components are shown on the attached plan. These measures, if implemented, would result in improved road access during flooding and rectification of the worst problem areas. More details of all the recommendations can be found in the study report.

The community should not expect that the proposed works would solve all flooding problems, or that funding will be available for all proposed activities.

A. Improve road access during flooding

- Fourth Avenue culvert on Bonds Creek
- Fourth Avenue/Twelfth Avenue upgraded culverts and improved channel on Tributary 2
- Scalabrini Creek downstream of Fifth Avenue improved channel and upgraded culvert
- Edmondson Avenue upgraded culvert on Tributary 2
- Eighth Avenue upgraded culvert on Bonds Creek
- Edmondson Avenue upgraded culvert on Bonds Creek
- Fifteenth Avenue upgraded culvert on Tributary 3
- Gurner Avenue close road, remove existing culvert and reinstate creek

B. Stream clearing, vegetation management project

C. Bond Creek levee d/s Fifth Avenue to protect Scalabrini Village

D. Stabilisation/bank protection Bonds Creek d/s Eighth Avenue

E. Planning Measures

- Update Local Environment Plan (LEP) to incorporate definitions from Floodplain Management Manual (FMM)
- Review and update all Development Control Plans (DCPs) to ensure consistency of definitions with LEP & FMM.
- Prepare and adopt Austral Floodplain Management Study Draft DCP (including the Planning Matrix)
- Formally adopt the Landfill Policy
- Develop Rural Land Use Management for Flood Prone Land Guidelines

F. Response Modification Measures

- Flood Education and Readiness Campaign
- Flood Warning Scheme Investigation
- Recovery Planning Review and Update
- Section 149 Certificates Review

HOW CAN I FIND OUT MORE OR MAKE A COMMENT ON THE PROPOSED PLAN?

A public exhibition providing more detailed information (including a display and the study report) will be available from **Wednesday 18th June 2003** to **Saturday 16th August 2003** during normal business hours at Council's Administration Centre, Council's Customer Service Centre, all Council libraries and the Austral Bowling Club.

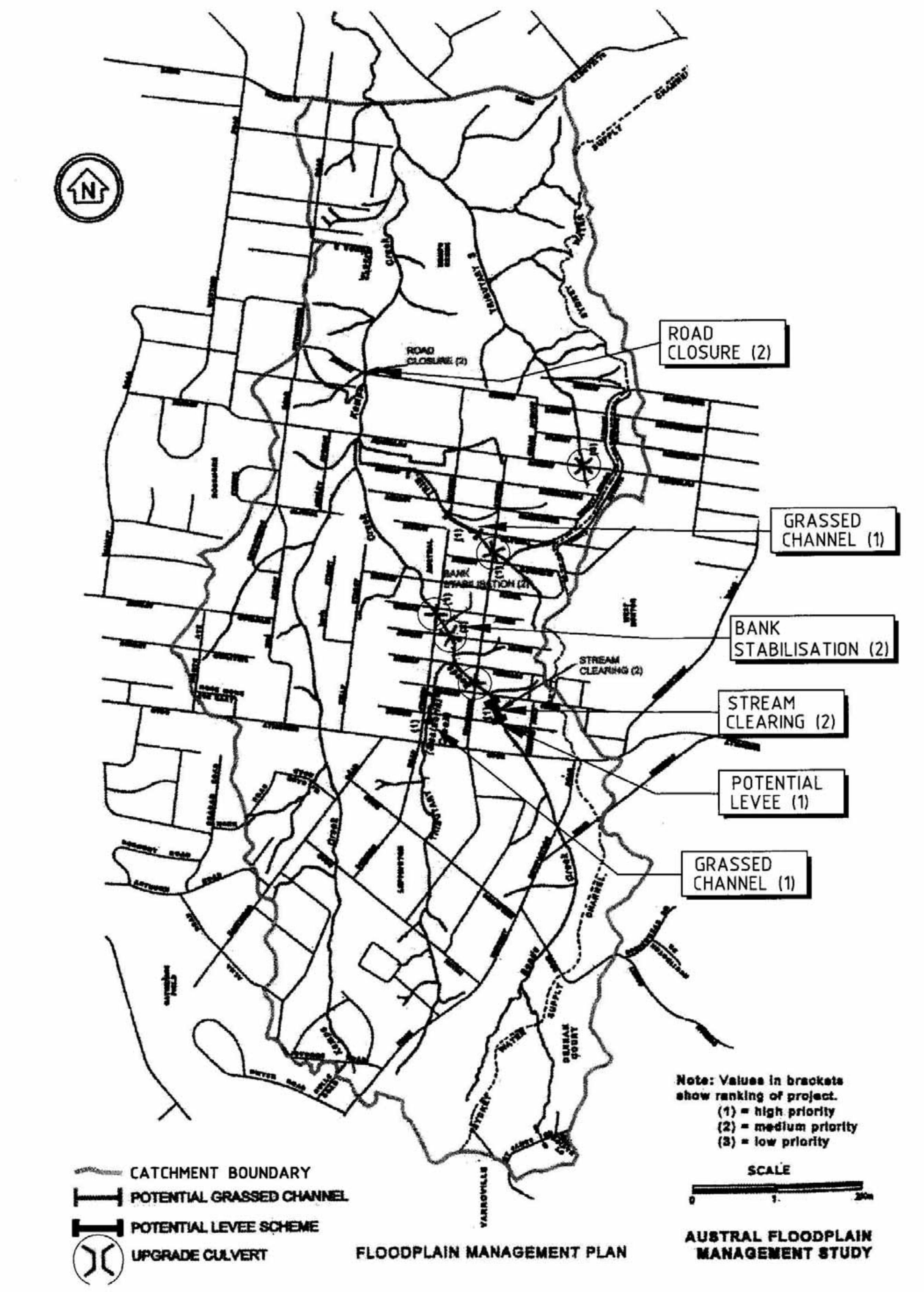
Written submissions regarding the Floodplain Management Study are invited from the public and should be received by the closing date of the exhibition period. If you would like to discuss any issues raised by the study, provide suggestions or input:

please phone:

Mr Robert Dinaro,
Liverpool City Council
☎ 9821 7741

or write to (quote File No. E2.40012):

The General Manager
Liverpool City Council
1 Hoxton Park Road
Liverpool NSW 2170
Att: Mr Robert Dinaro


ROAD CLOSURE (2)
GRASSED CHANNEL (1)
BANK STABILISATION (2)
STREAM CLEARING (2)
POTENTIAL LEVEE (1)
GRASSED CHANNEL (1)
Note: Values in brackets show ranking of project.
(1) = high priority
(2) = medium priority
(3) = low priority
SCALE
CATCHMENT BOUNDARY
POTENTIAL GRASSED CHANNEL
POTENTIAL LEVEE SCHEME
UPGRADE CULVERT
FLOODPLAIN MANAGEMENT PLAN
AUSTRAL FLOODPLAIN MANAGEMENT STUDY

ATTACHMENT 7

CORRESPONDENCE RECEIVED

Robert Dinaro
Env & Comm

Your reference : E2.40012
Our reference : SRF9220/SR520/06
Contact : Helen Laird, 9995 6844

NSW EPA
Sydney Region

Mr R Dinaro
Locked Bag 7064
Liverpool NSW 1871

LIVERPOOL CITY COUNCIL
a.m. 15 AUG 2003 p.m.
RECEIVED FAX/DX/AP Hand

Dear Mr Dinaro

Re: E2.40012 AUSTRAL FLOODPLAIN RISK AND MANAGEMENT STUDY AND PLAN

The EPA has reviewed the above document and makes the following comments.

To achieve the primary objective stated in the 2001 Floodplain Management Manual, that is "to reduce the impact of flooding utilising ecologically methods wherever possible" and also the objective to "increase the emphasis on the integrated and strategic management of floodplains" it is suggested that the scope of the management of flood waters be broadened to incorporate integrated water cycle management. Integrated water cycle management would allow an holistic review of the management of flooding and include such policies as Council's Stormwater Management Plan and the Government's commitment to the achievement of Water Quality and River Flow Objectives and investigate ways in which these strategies could be used to positively contribute towards the risk of flooding.

In taking such an approach to flooding alternative management strategies may become evident and more cost effective. The current matrix approach attempts to complete such an undertaking, however its focus remains solely upon the issue of flood management. In broadening the focus to ensure any assessment is part of an integrated approach to water management the costs and benefits to the community and environment may alter or become more evident. For example an integrated assessment of the proposal to grass and channelise stretches of creek would show the detrimental impact upon achieving the Government's Water Quality Objectives.

Also, it is noted that the study area forms part of the South West Sector Core Study area that is currently under investigation by the Department of Infrastructure, Planning and Natural Resources (DIPNR). Any flood mitigation measures should not jeopardise future land use planning decisions of the area.

15 AUG 2003
E2.40012.10
Dinaro

Yours sincerely

Juanita Croft
14/8/03

JUANITA CROFT
Principal Officer, Sydney Planning

2

Environment Protection Authority
PO Box 668 Parramatta NSW 2124 Australia
Level 7 79 George Street Parramatta NSW 2150
Telephone 61 2 9995 5000
Facsimile 61 2 9995 6900
ABN 43 692 285 758
www.epa.nsw.gov.au

LIVERPOOL CITY COUNCIL
a.m. 15 AUG 2003 p.m.
RECEIVED

Infrastructure, Planning and Natural Resources

Contact: Marcus Walsh
Phone: (02) 9895 7632
Fax: (02) 9895 6255
e-mail: marcus.walsh@dipnr.nsw.gov.au

Our Ref: 0434531

Your Ref: File No. E2.40012

The General Manager
Liverpool City Council
Locked Bag 7064
Liverpool BC NSW 1871

Attention: Mr Arvind Lal

13 August 2003

Dear Sir/Madam

Re: Draft Austral Floodplain Management Study and Plan

Thank you for the opportunity to comment on *the Draft Austral Floodplain Management Study and Plan, May 2003* prepared by Perrens Consultants on behalf of Council.

The Department has reviewed the draft Report and a copy of our comments is attached for your consideration.

The Department would be happy to meet and discuss the comments in more detail if warranted.

Should you have any queries or wish to seek further clarification please contact Mr Marcus Walsh on 9895 7632.

Yours faithfully

for Harry Panagopoulos
A/Team Leader, Sydney Flood Group
Sydney South Coast Region

15426.2007
E2.40012 A10
LAL

Austral Floodplain Risk Management Study & Plan, Draft Report, May 2003 -Comments

The *Draft Austral Floodplain Risk Management Study & Plan, Review and Finalisation, May 2003* prepared by Perrens Consultants for Liverpool City Council (Study & Plan) adequately addresses the identified existing, future and continuing flood risks in the Austral-Kemps Creek area.

The following general comments on the Study & Plan are presented for consideration:

<u>South West Sector Development</u>

Land within the Austral- Kemps Creek study area is included within the South West Sector Investigation Area which is currently being considered for large scale development (Area to house about 200,000 people) by the NSW Government (Attachment A). The investigations (housing, infrastructure, services, employment opportunities, biodiversity values, conservation, etc) are currently being fast tracked and an options paper is expected in September 2003.

The Study & Plan adequately addresses the range of flood risks associated with both the current level of development and likely future growth under the current landuse zoning's. However, the relevance/viability of the Study & Plan is questionable under the likely South West Sector planning options.

By way of example, all of the watercourses in the study area have been preliminary classified as "Category 1", the highest rating, as input to the South West Sector planning investigations. Category 1 watercourses require riparian zone setbacks greater than 40m wide on both sides, with additional width provided for a buffer zone. These types of corridors alone will have an impact on flood behaviour and associated flood risks within the study area.

The Study & Plan needs to consider the implications of the South West Sector planning options as part of the Review and Finalisation process.

<u>Existing Flood Risks</u>

The works recommended to address the existing flood risks are "hard" engineering solutions consisting of culvert amplifications, channelisation, levees, and stream clearing. These types of works were generally accepted in the early to mid 1990's when the Study was undertaken. In more recent times efforts have been undertaken to look at "softening" these types of works to minimise adverse environmental effects and incorporate improved local environmental outcomes.

The report notes that the capital costs of the recommended works do not include land acquisition, as reliable information is not presently available. In a majority of cases these costs are likely to be high and may affect their viability. Should this be the case then the quoted B/C ratios (>> 1.0) give the local community expectations that may not be warranted.

By way of example, LCC recently commissioned a Study to prepare concept designs for one of the recommended schemes on Tributary 2 at 4th Avenue between 12th and 13th Avenues. The Study only looked at the "hard" engineering solution as recommended in the Study & Plan that have adverse environmental effects.

The estimated capital cost of the works (Preferred Option 5) was approximately $2M of which land acquisition costs were estimated to cost approximately $500,000. The costs provided were construction costs only and the total project costs for the works would be expected to be higher. Hence the B/C ratio for the works is likely to be less than 1.0. These costs are considerably higher (approximately 10 times) than those quoted in the Study & Plan for the works. In addition, the B/C ratio for the works is considerably lower that that quoted in the Study & Plan (7.7).

A review of the proposed works ("softer" options), their costs and associated B/C ratio's is warranted.

In particular, the Department would like to see flood mitigation works undertaken in accordance with the Department's requirements regarding flood issues and environmental management (provision of ecological connectivity along bed and banks of a channel and under any road crossings via a Vegetation Management Plan).

It appears that environmental impacts associated with ranking of "hard" engineering works needs review in light higher expectations in terms of environmental management. It is difficult to believe that all works result in neutral environmental impacts.

Future Flood Risks

The flood related planning and development controls should adequately address the future flood risks based on current zoning's within the study area. However, the actual level of protection recommended is not provided by or reflected in the controls within the planning matrix.

The confusion rests with application of the terms "flood planning area" and "flood planning levels" and how they are applies across the floodplain. They have been correctly defined but incorrectly applied.

The Study & Plan recommends that the PMF be adopted as the "flood planning area" and a gradation of planning controls apply to land that falls within this area based on the hazard categorisation of the land and landuse.

However, based on the definitions within the Floodplain Management Manual, 2001 this would equate to one flood planning level equivalent to the PMF plus 0.5m freeboard. One level of protection for all development equivalent to PMF +0.5m freeboard. This is clearly not the intention in this case.

The intention is in fact to have a range of flood planning levels (and associated flood planning areas) across the entire floodplain (as defined by the PMF). For example, FPL's for residential development = 100 year ARI + 0.5m freeboard; critical utilities = PMF +0.5m freeboard; for flood awareness = PMF; etc

The text needs to be reworded to reflect the correct application of the terminology and the intended level of protection.

How is the control "*No net reduction in flood storage below the 100 year ARI level*" to be achieved? What is the intention?

The Study and Plan does little to justify the adoption of the three risk zones – hydraulic and hazard categories. For example, why was the 100 year ARI event adopted as the basis for defining the floodway (and high risk) zone? Was the floodway associated with the PMF assessed? If so, was there any significant variation in the nature and extent of the floodway? For the 100 year ARI event what was the difference between the nature and extent of the floodway and flood fringe areas? Was a majority of the existing high value riparian vegetation within the floodway (Figure D2.1)?

In more recent Studies, the 200 and 500 ARI flood events are also estimated and modelled to assist in the evaluation and adoption of risk zones.

The Study & Plan does not discuss the impact of the recommended flood related building and development controls on downstream development ie d/s Elizabeth Drive. The controls will essentially allow filling to the edge of the floodway (high risk zone). The cumulative loss of flood storage (flood fringe area) may result in an increase in d/s flood levels.

The steady state HEC-RAS model used in the Study and Plan could not assess this outcome at the time. Would need to run a series of hydrographs through a dynamic hydraulic model to assess the impacts of any storage effects. Provided that there is little difference between the floodway and flood fringe areas, the cumulative loss of storage is unlikely to result in adverse impacts d/s of the study area.

The Study & Plan does not discuss impacts of future riparian corridor enhancement on flood behaviour in general and flood risk zones in particular. There is a potential conflict in those areas where works are proposed to address the existing flood problems.

On balance, due to the very short flood warning times, the high existing risk exposure, the nature of the floodplain as reflected by the limited flood range and low velocities, it may have been more appropriate to adopt a more stringent set of flood related building and development controls for the floodplain. For example, a high risk (100 year ARI extent) and low risk zone, and adopt the PMF +0.5m freeboard as the FPL for all development. Was this outcome considered and or assessed?

Continuing (Residual) Flood Risk

Council should seek specific comments/advise from the SES (initially Head Office). Council may wish to contact Steve Opper, State Planning Coordinator, SES on (02) 4224 2279.

Administrative/Political Considerations

Need to update information in regard to changes in Department's names and responsibilities post State Election last March.

Also need to review sources of funding, and those agencies/local groups that have taken on responsibilities for Total Catchment Management and Rivercare activities ie reference to South Creek CMC.

Any liaison with SES needs to be undertaken initially at State level.

Hydrologic and Hydraulic Modelling

Was photogrammetric mapping referred to in the hydraulic modelling section used in the formulation of the RAFTS-XP model ie supplement 1:10000 and 1:4000 orthophoto in deriving subcatchment areas, slopes, cross sections etc? if not why not?

Need to show comparison of peak flows and flood levels derived with those from DWR/Willings model. Could compare at key locations. Need to explain/justify any differences.

How was the effects of urbanisation modelled subsequently used &/or reflected in the Study?

How were starting water levels in the hydraulic model derived?

Flood profiles => envelope of peak flood water levels based on critical duration's? Or other?

Hydraulic categories and hazards => referred to above.

Flora and Fauna => Needs to reflect recent developments and implications in terms of desktop watercourse categorisations (environmental values) within the study area undertaken by the Department as part of the South West Sector planning investigations as discussed above.

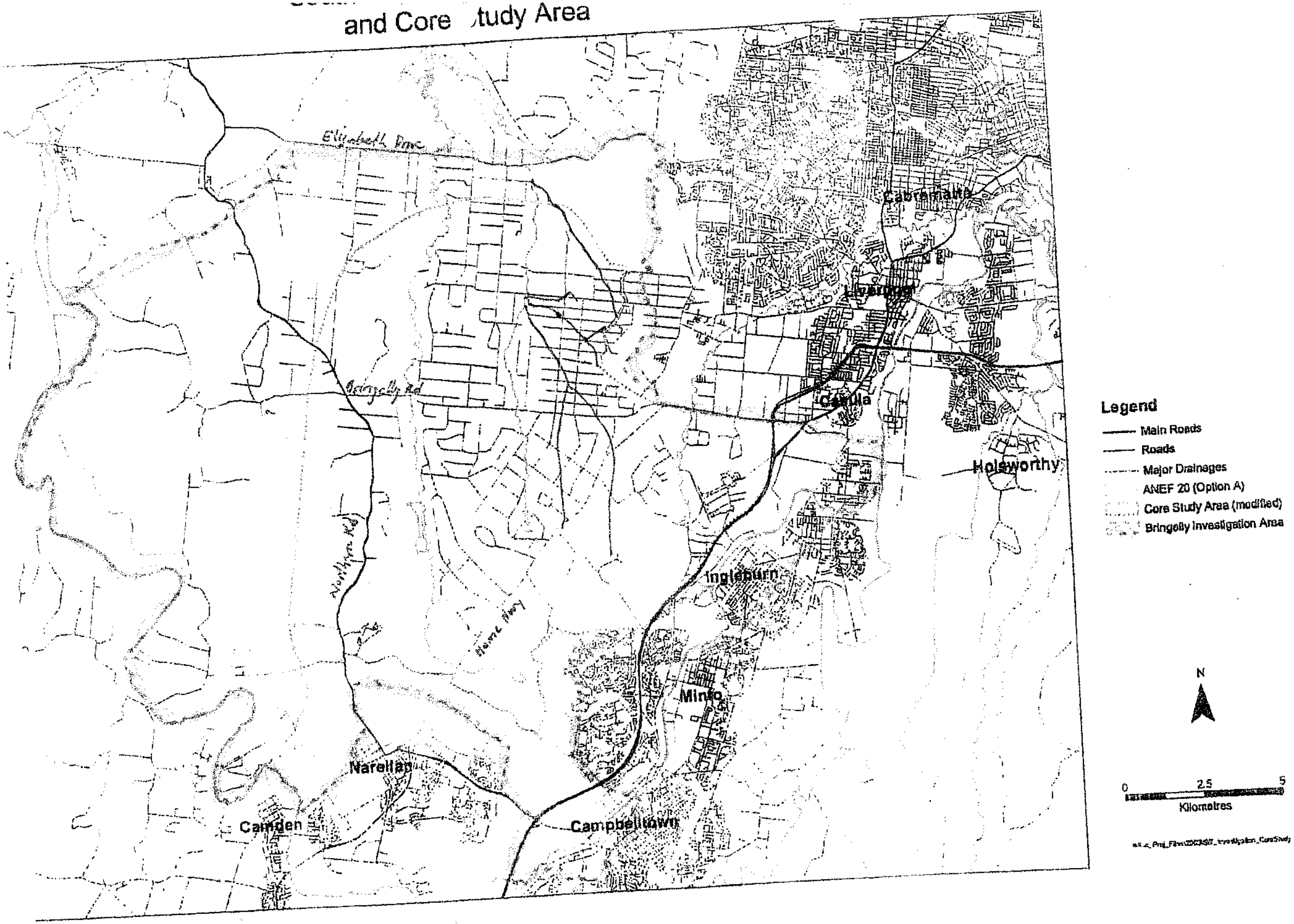
It is intended that "ground truthing" the environmental values of these watercourses will be undertaken shortly.

Draft DCP Landfill & Earth Dams => Relevance for the study area?

Community Consultation

Note that no additional consultation (post 1995) has been reported as part of the review process. Why?

and Core Study Area



Liverpool city council
creating our future together

Memo

To:	**Robert Dinaro**	**Date:**	**15 August 2003**
CC:		**From:**	**Terry Kefalianos**
Subject:	**Draft Austral FMS**	**Reference:**	**E2.40012**

Message:

Reference is made to the Draft Austral Floodplain Management Study and Plan recently placed on public exhibition. There are a number of issues that need to be considered as follows:

Restrictions on Property Titles

Council's current Floodplain Management Plan (Adopted December 1987 with subsequent amendments) requires all rural subdivisions to have a restriction placed on Section 88B of the property title. Please find attached sample of this restriction for your reference. This restriction significantly limits the development of land below the 100 year ARI and has been applied to a number of properties in the South Creek and Kemps Creek catchments.

There are a number of issues with this restriction as follows:

1. This restriction is excessively severe as it prohibits development that is permitted by the planning recommendations of the Draft Austral Floodplain Management Study and Plan.
2. Restrictions on property titles are placed as a condition of consent for development applications. The opportunity for land to be developed diminishes as flood risk increases. Therefore the opportunity for a development application to be approved and restrictions to be placed on the property titles diminishes as the flood risk increases. His creates a situation were title restrictions are placed on land least affected by flooding however no title restrictions are placed on the land most severely affected by flooding.
3. The time required to implement these restrictions or make any amendments recommended by future floodplain management studies.

Is it appropriate for item 1 in the Flood Awareness Category in Table 5.2 on page 31 to require restrictions on property titles given points 2 and 3 above?

It is suggested that property owners be permitted to extinguish current title restrictions at their own expense once the development controls recommended by the Draft Austral floodplain Management Study and Plan are implemented.

Gurner Avenue Bridge
Reference is made to section 7.1.1.5 on page 66. Given that the Gurner Avenue bridge has been recently replaced, is it still appropriate to recommend closure?

Filling Within The Floodway

Section 5.2.4 on page 32 indicates that land fill is permitted within the floodway provided that compensating works are undertaken to maintain flood conveyance. Is this accurate?

E Kefalianos

Terry Kefalianos
Stormwater Engineer

// 147370

INSTRUMENT SETTING OUT TERMS OF EASEMENTS AND RESTRICTIONS AS TO USER INTENDED TO BE CREATED PURSUANT TO SECTION 88B, CONVEYANCING ACT, 1919.

Lengths are in metres

Plan:

Subdivision covered by Council Clerk's Certificate No.
of

PART 1

Full name and address of proprietors of the land

Vincenzo Costa,
Lot 2 Western Road, Kemps Cre

Raffaele Bartholomew Iaconis
Lot 1 Western Road, Kemps Cree

Carmel Iaconis
Lot 1 Western Road, Kemps Cree

1. Identity of Easement firstly referred to in abovementioned plan.

Easement for batter 2 wide & variable

Schedule of Lots etc. Affected

Lots Burdened	Authority Benefited
20 21 22	The Council of the City of Liverpool

2. Identity of Easement Secondly referred to in abovementioned plan.

Easement to drain water 15 wide, 20 wide, 25 wide 40 wide & variable.

Schedule of Lots etc. Affected

Lots Burdened	Authority Benefited
2-12 inclusive 17 18 22	The Council of the City of Liverpool

3. Identity of restriction Thirdly referred to in abovementioned plan.

Restriction as to user

000166

Schedule of Lots etc. Affected

Lots Burdened	Authority Benefited
9-15 inclusive	The Council of the City of Liverpool

CERTIFIED TRUE & CORRECT COPY
Signed [signature] Date 29 APR 1987

INSTRUMENT SETTING OUT TERMS OF EASEMENTS AND RESTRICTIONS AS TO USER INTENDED TO BE CREATED PURSUANT TO SECTION 88B, CONVEYANCING ACT, 1919,

Lengths are in metres

(Sheet 2 of 4 Sheets)

Plan:

Subdivision covered by Council
Clerk's Certificate No.
of

PART 1

4. Identity of restriction fourthly referred to in abovementioned plan — Restriction as to user

Schedule of Lots etc. Affected

Lots Burdened	Authority Benefited
8, 9, 17, & 18	The Council of the City of Liverpool

5. Identity of restriction fifthly referred to in abovementionted plan

Schedule of Lots etc. affected

Lots burdened	Authority Benefited
3, 4, 5, 6 & 7	The Council of the City of Liverpool

PART 2

1. Terms of Easement for batter firstly referred to in abovementioned plan.

Full and free right for the body in whose favour this easement is created and its authorised agents and employees from time to time and all times hereafter to enter, go upon, return, pass and repass with or without vehicles in, through, along and over the servient tenements and to use the servient tenements for the purpose of placing thereon and/or excavating and removing therefrom all such earth, soil cement, sand, clay and other materials as shall in the opinion of the said body be necessary or desirable for the purpose of constructing, reconstructing and forever maintaining on the servient tenements a batter to serve as a support for the surface sub-soil and undersurface of any land adjoining or adjacent to the servient tenements or a cutting thereon and the said batter then so constructed to use at all times hereafter for the purpose of giving such support as aforesaid and the registered proprietor of the lots burdened which herein shall include his executors, administrators and assigns covenants that he will not use or permit to be used the servient tenements in any manner or for any purpose which may affect or have a tendency to affect the stability of the said batter as a support for any land as aforesaid and will not do or suffer to be done any act or thing which may injure or damage the said batter or in any way impair its efficiency and its efficiency and if he should do or suffer to be done any act or thing which may in any way injure, damage or impair the said batter he will at his own expense properly and substantially repair and make good all such injury and damage PROVIDED THAT if the said registered proprietor upon receipt of notice in writing from the said body requiring him properly and substantially to repair and make good all such damage or

CERTIFIED TRUE & CORRECT COPY

Signed *F.P.* Date 29 APR 1987

000165

INSTRUMENT SETTING OUT TERMS OF EASEMENTS AND RESTRICTIONS AS TO USER INTENDED TO BE CREATED PURSUANT TO SECTION 88B, CONVEYANCING ACT, 1919.

Plan:

Subdivision covered by Council Clerk's Certificate No. of

PART 2

injury shall fail to do so properly it shall be lawful for but not obligatory upon the said body to repair and make good all such injury or damage and all costs, damages, charges and expensed incurred by the said body in so doing shall be repayable by the said registered proprietor to the said body upon demand.

2. Terms of restricton as to user thirdly referred to in above-mentioned plan

No building or buildings or permanent structure or structuresare to be erected on the land hereby burdened between the Line of Limitation shown on plan and the eastern bank of South Creek or any variation to the Line of Limitation as may be determined by the Prescibed Authority.

3. Terms of restriction as to user fourthly referred to in above-mentioned plan

The cost of repair, replacement or removal of any fence erected within the easements to drain water over the lots hereby burdened shall in the event of council maintaining the said easements to drain water be borne by the proprietor of each lot burdened.

4. Terms of restriction as to user fifthy referred to in above mentioned plan

Any foundation of any building to be erected on the land hereby burdened shall be approved by a Certified structural engineer to Councils specifications and conditions.

CERTIFIED TRUE & CORRECT COPY

Signed Date 29 APR 1987

INSTRUMENT SETTING OUT TERMS OF EASEMENTS AND RESTRICTIONS AS TO USER INTENDED TO BE CREATED PURSUANT TO SECTION 88B, CONVEYANCING ACT, 1919.

(Sheet 4 of 4 Sheets)

Plan:

Subdivision covered by Council Clerk's Certificate No.
of

Signed in my presence by Vincenzo Costa who is personally known to me.

Signature of Witness

Proprietor

Signed in my presence by Raffaele Bartholomew Iaconis who is personally known to me.

Signature of Witness

Proprietor

Signed in my presence by Carmel Iaconis who is personally known to me.

Signature of Witness

Proprietor

CERTIFIED TRUE & CORRECT COPY
Signed Date 29 APR 1987

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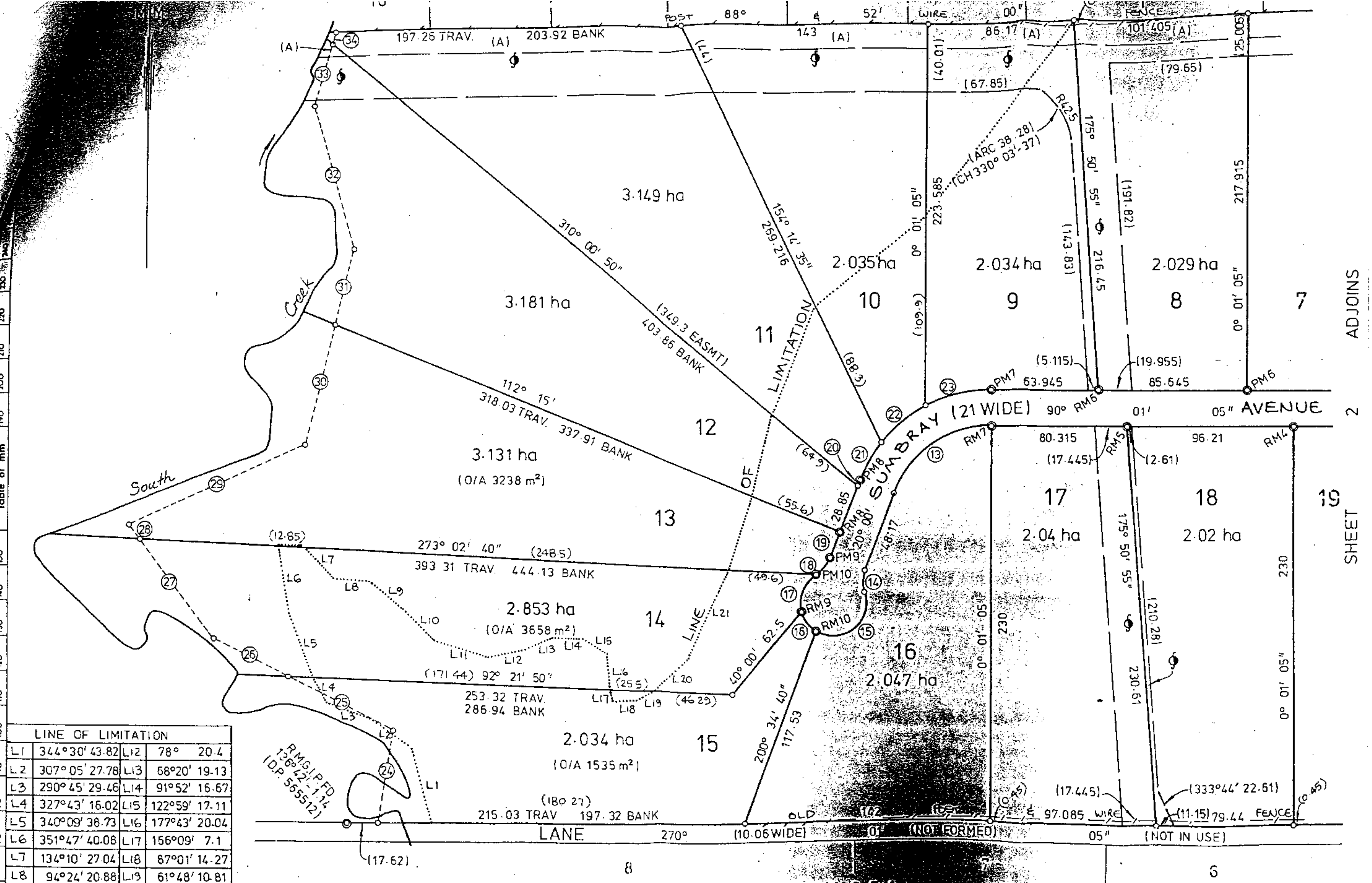

D. P. 739051

EASEMENT TO DRAIN WATER 15 WIDE, 20 WIDE, 25 WIDE, 40 WIDE & VARIABLE.

(A) EASEMENT FOR DRAINAGE 15 WIDE

LINE OF LIMITATION					
L1	344°30'	43.82	L12	78°	20.4
L2	307°05'	27.78	L13	68°20'	19.13
L3	290°45'	29.46	L14	91°52'	16.67
L4	327°43'	16.02	L15	122°59'	17.11
L5	340°09'	38.73	L16	177°43'	20.04
L6	351°47'	40.08	L17	156°09'	7.1
L7	134°10'	27.04	L18	87°01'	14.27
L8	94°24'	20.88	L19	61°48'	10.81
L9	128°38	25.78	L20	47°20'	27.9
L10	134°55'	25.04	L21	25°45'	57.11
L11	108°05'	31.26			

SCHEDULE OF CURVED AND SHORT BOUNDARIES

	RAD	ARC	CHORD		RAD	ARC	CHORD
13	60	73.325	235° 00'30" 68.845	19			20° 00' 15.895

SCHEDULE OF REFERENCE MARKS

4	R.M.D.H.&W. IN H'WALL	258°41' 5.09
5	R.M.D.H.&W. IN W'WALL	133°57' 5
6	R.M.D.H.&W. IN W'WALL	321°45' 5

SCHEDULE OF PERMANENT MARKS

[illegible]	0°01'	0.5
[illegible]	0°01'	0.5
[illegible]	290°00'	0.5

CREEK TRAVERSE SCHEDULE