

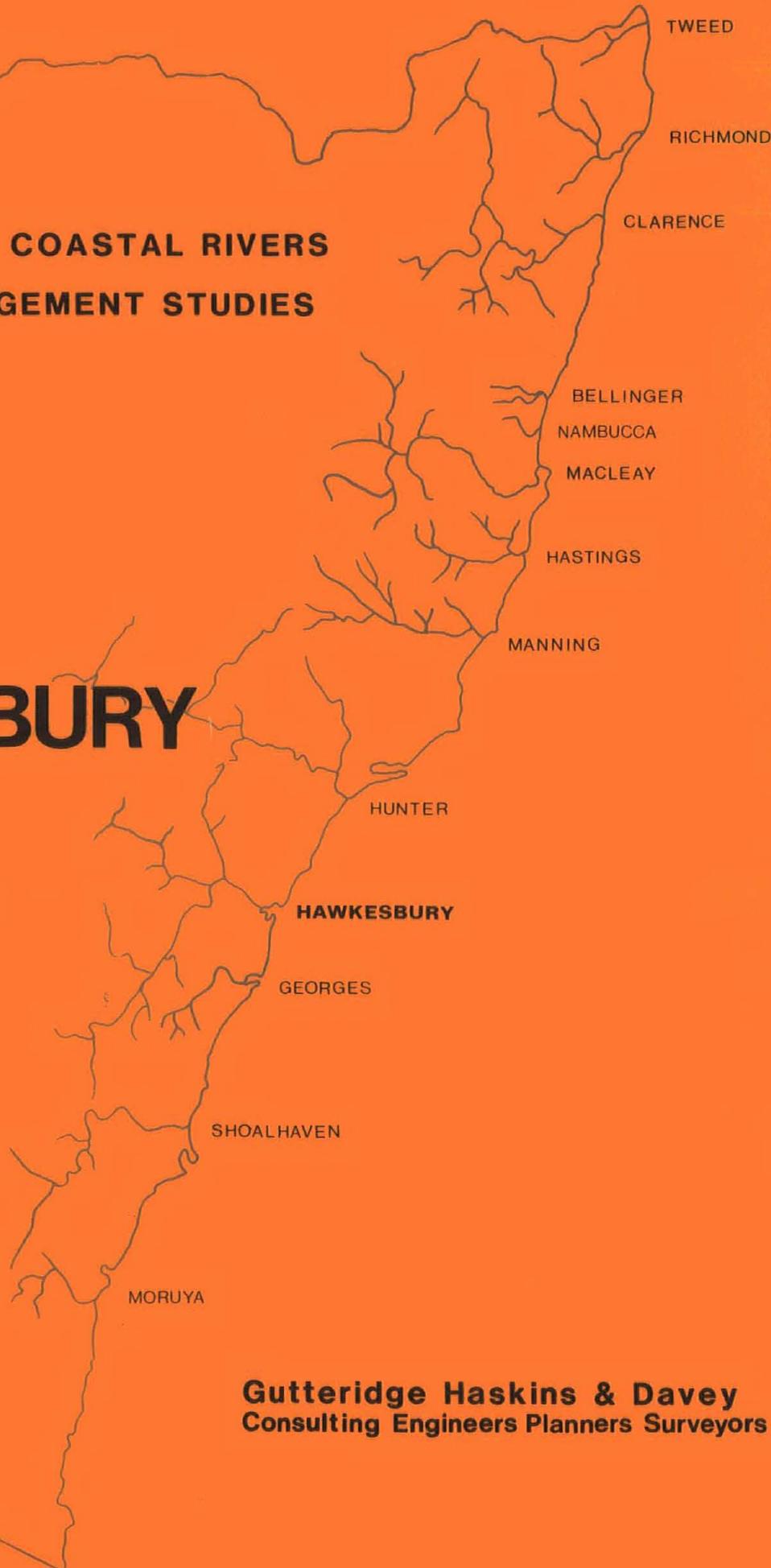
M. FITZGERALD

**NEW SOUTH WALES COASTAL RIVERS
FLOOD PLAIN MANAGEMENT STUDIES**

SUMMARY REPORT

**HAWKESBURY
VALLEY**

DECEMBER 1980



Gutteridge Haskins & Davey
Consulting Engineers Planners Surveyors

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THE HAWKESBURY VALLEY

DECEMBER 1980

FOREWORD

This study is one in a series of thirteen carried out on the major coastal river valleys of New South Wales. The studies were jointly funded by the N.S.W. and Commonwealth Governments. They were carried out by various consultants and were supervised by a Steering Committee comprised of representatives of the following bodies:

Public Works Department of N.S.W.
Water Resources Commission, N.S.W.
Dept of Environment & Planning, N.S.W.
Commonwealth Dept of National Development and Energy.
Commonwealth Dept of Housing and Construction.
Executive of Flood Mitigation Authorities of N.S.W.

The Committee was assisted by the Hunter Valley Conservation Trust in respect of the Hunter Valley study and by representatives from the relevant local government bodies in respect of the other studies.

The Chairman of the Steering Committee was provided by the Public Works Department, which also supplied administrative services and was responsible for liaison with the consultants on behalf of the Committee.

The studies were carried out within the following terms of reference:

- Report on flood plain management measures currently in operation in each of the river valleys including a summary of works completed or in progress and constraints on their effectiveness.
- Identify areas of continuing potential for flood losses, assess their significance and evaluate practical mitigation measures.
- Recommend a programme of short and long term proposals which conform to an overall flood plain management strategy with information as follows:
 - a brief description of measures and preliminary estimates of public capital and operating costs and private costs where applicable, and
 - estimates of economic, social and significant environmental benefits and costs and their distribution.
- Report on economic constraints to the implementation of the recommended flood plain management measures, including hydrological data.

Constraints due to time and cost limited the depth of study given to the various parts of the terms of reference. The degree to which the several requirements of the terms of reference have been answered was determined by the Committee in association with the consultants.

The studies are published on the authority of the Steering Committee and are recommended for consideration by Local, State and Commonwealth Governments. The views expressed in the studies are those of the respective consultants and do not necessarily represent the views of the authorities represented on the Steering Committee.

Each of the studies has been published in two volumes, a main report and a summary report. The main report contains detailed data, background information and comment on the findings of the studies, together with detailed appendices. It has been prepared for reference purposes and is intended for limited distribution, but will be generally available in the libraries of relevant councils and authorities. The summary report which contains the findings and pertinent background data and comments, has been prepared for general distribution.

The Steering Committee would like to acknowledge the assistance given in the studies by government departments, local government, local organisations and the public generally.



Chairman,
N.S.W. Coastal Rivers
Flood Plain Management Studies
Steering Committee.

NEW SOUTH WALES COASTAL RIVERS

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THE HAWKESBURY VALLEY

SUMMARY REPORT

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1.0 INTRODUCTION

1.1 OBJECTIVES

The objectives of floodplain management may be summarised as minimising economic and social loss and disruption from floods, the protection of life and property and the reduction of public and private losses while enhancing the economic, social and environmental value of floodplains.

The overall objective of the study has been the formulation of a plan for management of the Hawkesbury-Nepean floodplain from which a programme of works and other measures could flow to form the basis for continuing Commonwealth, State and Local Authority Involvement.

1.2 METHODOLOGY

Existing flood mitigation measures have been assessed. Options available for future implementation have been identified and recommendations made for works to be undertaken to decrease the present potential flood loss situation in the Hawkesbury-Nepean Valley.

The work involved:

- Collection and review of data available from rainfall records, stream gauges and flood records.
- A review of reports dealing with existing and proposed flood mitigation works in the Valley as well as numerous reports dealing with other matters relevant to floodplain management in the Valley.
- Preparation of an approximate inundation plan based on floodplain maps where these were available and otherwise on available topographical data and predicted or recorded flood levels.
- With the assistance of sub-consultants, consideration of agricultural, ecological and geomorphological aspects relative to floodplain management.
- Consideration of planning and socio-economic aspects to assess possible implications of floodplain management strategies.
- A review of existing statutory legislation to determine scope for enforcement of powers available to control development in the floodplain and also to detect areas where additional legislation could be beneficial.
- A review of current and past application of flood mitigation measures, structural and non-structural, and assessment of their effectiveness.
- Identification and assessment of future flood mitigation options, both structural and non-structural.
- Formulation of a floodplain management strategy for the Valley.

1.3 LIMITATIONS OF STUDY

Although floodplain management studies focus attention on the floodplain, the formulation of management strategies should entail valley-wide considerations. Because of time and funding constraints the Valley study was limited as follows:

- For the purposes of the study the floodplain was defined as that of the main Hawkesbury-Nepean River system downstream from Camden. (Figure 2)

- Activities in the Valley within the catchments of the Water Board storage dams were not considered. (Figure 1)

These limitations are considered acceptable since flooding problems in areas beyond the defined floodplain are relatively small, and also, because of the storage dams, activities within their catchments have little effect on flooding in the defined floodplain.

With the subject matter condensed to the degree necessary for the purposes of this summary report, there is a risk that some statements might appear incomplete, or even misleading, to the reader. Should such be the case, reference to the main report should provide clarification.

1.4 DEFINITIONS

The following definitions applicable to flooding have been used in this study:—

- **Flood Frequency**

The average interval of time which a flood of particular magnitude will be equalled or exceeded is known as the recurrence interval, the return period or the frequency.

- **Flood Prone Land**

Is defined as the area inundated by a flood of 100 year frequency.

- **Floodplain**

The term "floodplain" is synonymous with the term "flood prone land".

- **Floodway**

This term is used when referring to the high hazard zone, within the floodplain, where depths of flow and velocities are high. Definition of the floodway is important for floodplain management purposes as special consideration must be given to permissible land use. It is common to prohibit structural uses of land within the floodway. For preliminary purposes the 20 year flood line is commonly used to define the limits of the floodway but its final definition can be a complex matter.

2.0 THE VALLEY AND ITS CHARACTERISTICS

2.1 INTRODUCTION

The Hawkesbury-Nepean Valley (Figure 1) covers an area of approximately 22,000 square kilometres and has a population of about 500,000. The floodplain area of the main Hawkesbury-Nepean River system is estimated at 180 square kilometres and located within it are some 1,200 houses.

The Valley embraces about 75% of the Sydney Region and its resources are of great importance, not only to the Valley population, but also to adjoining urbanised areas of Sydney. Although comparatively small in area, when ranked according to population served by its resources the Hawkesbury-Nepean Valley must be regarded as amongst the most important in Australia.

2.2 ADMINISTRATION

The Valley embraces twenty-seven local government areas. The floodplain below Camden covers portions of ten of these areas.

Besides local government authorities, the following State Government bodies are amongst those concerned with activities in the floodplain:

- Department of Public Works
- Water Resources Commission
- Department of Environment and Planning
- Macarthur Development Board
- Heritage Council of N.S.W.
- Department of Mineral Resources
- Department of Lands
- State Pollution Control Commission
- Soil Conservation Service of N.S.W.
- Metropolitan Water Sewerage & Drainage Board

In addition, four "ad hoc" bodies have been formed to oversee specific aspects of river management in the floodplain and there are also numerous voluntary and other bodies with a specific field of interest in the floodplain.

This proliferation of bodies and authorities, each concentrating on its own particular field of interest and functioning without any degree of co-ordination, is seen as being counter-productive to effective floodplain management in the Valley.

2.3 PHYSIOGRAPHY

The Hawkesbury-Nepean River System discharges to the South Pacific Ocean at Broken Bay. Tidal effects extend upstream to about Richmond. The upstream section of the river is known as the Nepean while downstream of the confluence with the Grose River it is known as the Hawkesbury. Most of the southern and western portions of the Valley are comprised of heavily timbered, rugged and mountainous country and a salient feature is that approximately 45% of the Valley catchment drains into five water supply dams under the control of the Metropolitan Water Sewerage and Drainage Board.

2.4 GEOMORPHOLOGY

The Hawkesbury-Nepean River channel is, for much of its length, incised below sandstone plateaux. In the shale areas of the Cumberland Plains, the river course is influenced by rocky outcrops. Consequently, the plan form of the river is fairly stable. There is no evidence of meanders being cut off, although upstream of Freemans Reach the channel does appear to have migrated about 400 metres southwards since settlement.

Sediment transport into and along the lower Hawkesbury-Nepean has been affected by the construction of large dams, compensatory weirs and the activities of the extractive industries. It is evident that these man-induced alterations have changed both water and sediment discharges. Since 1949 there has been a period of increased precipitation and run-off which has also affected sediment transport. At this stage it seems that the storage and use of water has been more than compensated for by the increased precipitation. Only further study can confirm this and indicate how serious any resulting problems may be in the long-term.

Sanding problems have arisen in the Macdonald and Colo catchments. It is significant to note that these problems began to develop from about 1949, which was the start of the period of increased precipitation. As a result of the higher rainfall large volumes of sand have been mobilised and transported along the river to be deposited elsewhere. It is possible that damage and recovery is a cyclic phenomenon but there is no data available to check this hypothesis. In the Macdonald and Colo catchments, limited bank protection could be carried out to protect roads or high quality production land but before large scale work is undertaken the cost entailed must be balanced against the value of land and production, particularly if any natural recovery of the channel is in progress.

In the floodplain, the main geomorphological problems result from local channel instability and this is frequently associated with both naturally and artificially induced regime changes. Although problems of drainage of flooded areas are major considerations in flood management, it is the instability of banks, sedimentation and erosion which lead, in the long term, to more permanent and costly damage.

In order to assess the nature of channel changes and their likely impacts, it is necessary to carry out sufficient monitoring to obtain dimensional and process data. This information can be used in future planning work to predict likely developments and changes.

Some channel monitoring work has been carried out in the Valley by the Department of Public Works and it is recommended that a more intensive programme be implemented covering selected reaches of the Hawkesbury-Nepean, Macdonald and Colo Rivers.

2.5 ECOLOGY

Non-agricultural floras, mainly forest and scrub, occupy about 72% of the Valley. In the floodplain much of the tall open forest has been removed to make the land suitable for cultivation and grazing. Patches that remain have mostly been logged and are now being invaded by numerous exotic weed species. The degree to which clearing of native vegetation has been carried out, particularly in the vicinities of Richmond and Windsor is not immediately perceived by the non-botanist who sees a dense mass of vegetation along the river banks. However, this vegetation is almost all introduced and subsequently naturalised trees such as willows together with understory of exotic weeds.

Much of the area once covered by freshwater swamp has been completely partially drained and has been subjected to grazing and the introduction of weed species.

It is estimated that there are approximately 400 species of terrestrial vertebrates in the valley of which about 250 species are birds, the remainder being composed of approximately equal numbers of species of mammals, reptiles and amphibians. Very little is known of the ecology of invertebrates in the valley.

2.6 HYDROLOGY, WATER DEMANDS AND STREAM POLLUTION

The median annual rainfall in the Valley varies from about 1,500 millimetres near the headwaters of the Nepean to about 500 millimetres over rain-shadow areas near Goulburn and the headwaters of the Colo River.

The first stream gauging station was established in 1888 and currently there are 38 rated gauging stations in the Valley which measure run-off from approximately 80% of the Valley area. In addition there are numerous gauging stations in the valley which have not

been rated for the purpose of determining stream discharges but which are used to record flood heights.

The average annual run-off over the Valley has been estimated at about 3,000,000 megalitres. From the study it is clear that the water resources of the Valley are experiencing strain under increasing competition between present and potential water users. The main water user is the Metropolitan Water Sewerage & Drainage Board, and in the year ended 30th June, 1977, the volume of water delivered from the Board's dams in the Valley was 570,000 megalitres. Water demands for irrigation purposes are also significant and in 1977 usage for that purpose was 27,000 megalitres. The viability of the proposed Penrith Lakes Scheme depends on the location of a suitable source of fresh water for topping up and flushing and the estimated demand for that purpose is 30,000 megalitres per annum.

Linked with the reduced river flows caused by the demands of water user is the problem of stream pollution caused by stormwater runoff, uncontrolled sewer overflows that occur during storms and discharges from sewage treatment works. For example, in a study carried out by the State Pollution Control Commission in 1977 it was estimated that if the population of Penrith increases to 200,000, the section of river from Penrith to its confluence with Grose would be comprised of about 66% treated sewage effluent for 10% of the time and 16% for 30% of the time.

When formulating floodplain management strategies in the Valley, consideration must be given to the increasing demands on its limited water resources and to the deterioration of stream water quality that will tend to occur with increasing population. To protect and enhance the environment of the floodplain it seems that it will eventually be necessary to install nutrient - removal facilities at sewage treatment works and consideration will also need to be given to means of reducing stream pollution due to stormwater runoff and sewage overflow systems.

2.7 LAND USE

Most of the Valley is undeveloped virgin forest and extensive areas are occupied by proclaimed or proposed National Parks. In the central-eastern and southern sections rural usage dominates. Along the Nepean River between Richmond and Camden, extraction of sand and gravel from the bed, banks and floodplain of the River is a very important industry.

The population of the Valley is unevenly distributed with large areas uninhabited. West of Sydney, intensive urban and industrial development extends as far as Penrith. Population centres where residential development encroaches on the floodplain include Camden, Narellan, Penrith, Emu Plains, Richmond, Windsor, Riverstone and Wilberforce. Land use zonings along the floodplain along the Hawkesbury-Nepean River are shown in the Appendix.

2.8 INDUSTRIES

The principal industries in the Valley floodplain are agriculture and the extraction of sand, gravel and topsoil. Since the main sand and gravel deposits exist beneath fertile agricultural land the operations of the extractive industries are displacing agriculture and in place of farmland, lakes are being created. Lakes are advantageous to recreational pursuits and, in this regard are seen as an important resource for the western region of Sydney. Thus, agricultural and extractive industries and recreational activities in the floodplain are diverse pursuits competing for resources in the Valley.

(a) Agriculture

During the study, a survey of agricultural land was undertaken on the floodplains of the Hawkesbury-Nepean system extending from the rail bridge at Menangle on the Nepean to Gunderman School on the Hawkesbury. The area of agricultural land in this section of floodplain is 16,120 hectares, distributed in 11 local government areas. As can be seen from the following table, the most significant agricultural enterprise in this section of floodplain is grazing land devoted to beef and dry dairy stock.

Estimates indicate that there are about 700 individual holdings in the floodplain area varying in size from more than 200 hectares for some commercial grazing properties and dairies, to less than 10 hectares for many rural retreat blocks. Preliminary estimates indicate a gross annual value of production in the order of \$15m.

Increasing land prices, brought about by demand from those seeking rural retreats and hobby farms and from the extractive industries seeking deposits of sand and gravel, have placed pressure on the agricultural industry in the floodplain. Unless differential rating is provided for traditional grazing and dairying enterprise, it seems likely that farms will be further subdivided to the limits allowed by local government authorities.

**AGRICULTURAL ENTERPRISE AREAS
BY GEOGRAPHICAL AREA (Hectares)**

Enterprise	Lower Hawkesbury	Windsor	Penrith	Camden	Total
Dairying		751	1626	2174	4551
Grazing (improved pasture)	585	1982	1366	1341	5274
Grazing (local pasture)	443	733	903	851	2930
Vegetables		1279	324	119	1722
Turf	35	623	70	137	865
Poplars	49	26			75
Horticulture	228	150	277	48	703
Total	1340	5544	4566	4670	16120

(b) Extractive Industries

The extraction of soil, sand and gravel from the floodplain is a significant industry and one that will continue to meet the needs of Sydney for many years.

At present, the major activity of the industry is concentrated just north of Penrith where sand and gravel are being extracted from the river bed and floodplain. At Elderslie, in the Municipality of Camden, a large industry extracting sand and soil is evolving and elsewhere along the river there are many smaller enterprises that extract riverbank material for soil and also dredge the channel for sand. Extensive floodplain deposits of sand and gravel underlie farmlands downstream of Richmond and it is likely that the extractive industry will transfer its activities to these deposits as the Penrith resources become depleted. Large quantities of sand also exist in the Colo and Macdonald catchments but because of large haulage distances extractors have not been attracted to these areas.

The Penrith Lakes Development Corporation has been formed to implement planned extraction and rehabilitation of the areas being mined to the north of Penrith. As presently envisaged, this will provide a 2,500 hectare aquatic and sporting complex but as previously mentioned the final viability of the Penrith Lakes Scheme depends on locating a suitable source of fresh water. At Elderslie it is proposed to develop the worked out area into a suburban complex including a golf course and other recreational areas.

Many aspects associated with the operations of the extractive industries should receive consideration when formulating floodplain management strategies. These are listed in Table 3 and include the following important recommendations:—

- To reduce stream pollution problems, the activities of the extractive industries should be rationalised. Overall management of the extractive industries should be aimed at grouping operators in designated areas rather than a continuing

scatter of activities over a long length of river. It is recommended that, with this aim, a Regional Environment Plan be prepared under the provisions of the Environmental Planning and Assessment Act, 1979.

- There is a need for a study to examine the long term effects of the extractive industry on recreational and agricultural pursuits. Such a study should be made before any large scale extractive industry is allowed to develop in the Richmond Lowlands areas.

2.9 RECREATION

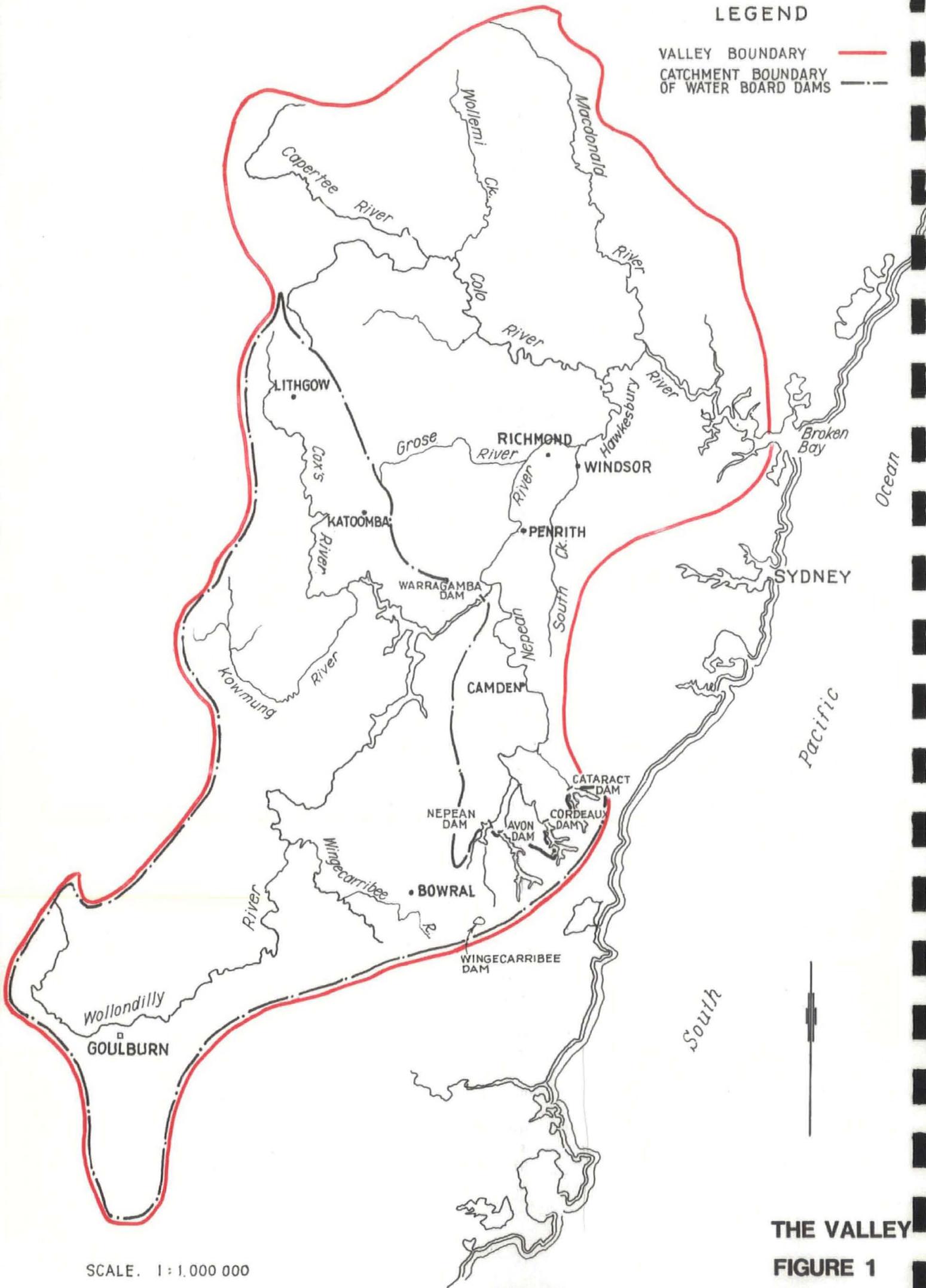
The Hawkesbury-Nepean River has been seen as a major recreational resource for the Western Suburbs of Sydney. Along the floodplain, recreation is mainly associated with water-based activities, and, at present, peak-day participation is estimated at about 10,000 persons. Implementation of the Penrith Lakes Scheme could raise peak-day participation to 30,000 persons.

The conservation of existing recreational facilities and the scope for development of further facilities must receive consideration when formulating floodplain management strategies. The following recommendations are made:—

- Encouragement should be given to the development of recreational facilities along river frontages, by private enterprise.
- Implementation of the Penrith Lakes Scheme should be fostered.
- Present methods of disposal of sewage from riverside caravan parks and recreational establishments should be investigated and, where necessary, upgraded to prevent stream pollution.
- Past workings of the extractive industries have left a heritage of unsightly areas in the floodplain. There is scope for rehabilitating such sites and developing worthwhile recreation areas. Action in this regard is recommended.

LEGEND

- VALLEY BOUNDARY ——— (solid red line)
- CATCHMENT BOUNDARY OF WATER BOARD DAMS - - - (dashed black line)



SCALE. 1 : 1,000 000

THE VALLEY
FIGURE 1

3.0 FLOODING

3.1 FLOOD RECORDS AND FLOOD PREDICTIONS

Since 1891, over sixty floods have occurred in the Valley. Peak flood levels have been recorded at different places in different years due to the varying centres of storm activity and the influence of a number of tributaries. The highest recorded floods have occurred at Camden in 1873, Penrith in 1900, Windsor in 1867 and on the Colo River in 1978.

Extensive investigations have previously been undertaken to derive stage-frequency curves at various locations in the river system and the results of those investigations were adopted for the purposes of the study. The adopted river levels for floods estimated to occur at frequencies of 100 years are given in the following Table. It is to be noted that the highest recorded flood levels at Camden, Penrith and upper Colo are very close to the adopted 100 year flood levels whereas at Windsor the 1867 recorded flood level is 3–4 metres higher than the 100 year adopted flood level.

ADOPTED 100 YEAR FLOOD LEVELS

River	Locality	Stage Height (AHD)*
Nepean	Camden at Cowpasture Bridge	72.2 metres
Nepean	Wallacia	44.5 metres
Nepean	Penrith at Victoria Bridge	25.4 metres
Hawkesbury	Windsor at Windsor Bridge	16.0 metres
Colo	Upper Colo at gauging station	21.0 metres

3.2 FLOODPLAIN

The valley floodplain (defined as the area inundated by a 100 year flood) is shown in Figure 2. As indicated on the map the floodplain may be considered as several large areas interconnected by narrow sections where the river is contained by gorges.

The uppermost floodplain area is around Camden where the town is often surrounded by floodwaters on three sides. Traffic on the Hume Highway can be interrupted at Camden but there is a high level bypass bridge above maximum flood level. Around Camden some residential land is affected by floods but the floodplain is mostly used for agriculture with dairying, grazing and vegetables predominating. Below Camden the Nepean River was congested with snags but a stream clearing programme has been in operation for some years and has considerably reduced the problem.

Further downstream, the Wallacia section is subject to some local flooding and has suffered from river bank erosion.

At Penrith the floodplain is quite extensive below the town, especially where sand and gravel extraction is taking place. Some residential land is affected but the main problems have been with bank slips and erosion along both sides of the river near the main rail and highway bridges. Further downstream between Penrith and Yarramundi the floodplain extends over agricultural land used for citrus, vegetables and grazing.

The floodplain widens between Richmond and Windsor to cover a large area known as Cornwallis Flats. This agricultural area has been extensively damaged in past floods with loss of agriculture, flooding of houses and interruption to communications and services. In addition the town of Windsor is affected by flooding of some residential areas and the blocking of roads to Wilberforce, M^CGraths Hill and Richmond. Floodwater may also back up South Creek to Riverstone where parts of the town are affected.

Below Windsor the town of Pit Town becomes isolated and the agricultural land around it is flooded. Floodwaters may also reach the periphery of Wilberforce across the river and cut the main road connection to Windsor and the metropolitan area.

Further North the Hawkesbury River is joined by the Colo River which has a comparatively large catchment area and, as in 1978, may experience big rises in river levels. Flooding may also occur along the other tributaries such as Cattai Creek, Webbs Creek and the Macdonald River. Below Wiseman's Ferry flooding effects on the Hawkesbury River become of minor significance.

3.3 PAST FLOOD DAMAGE

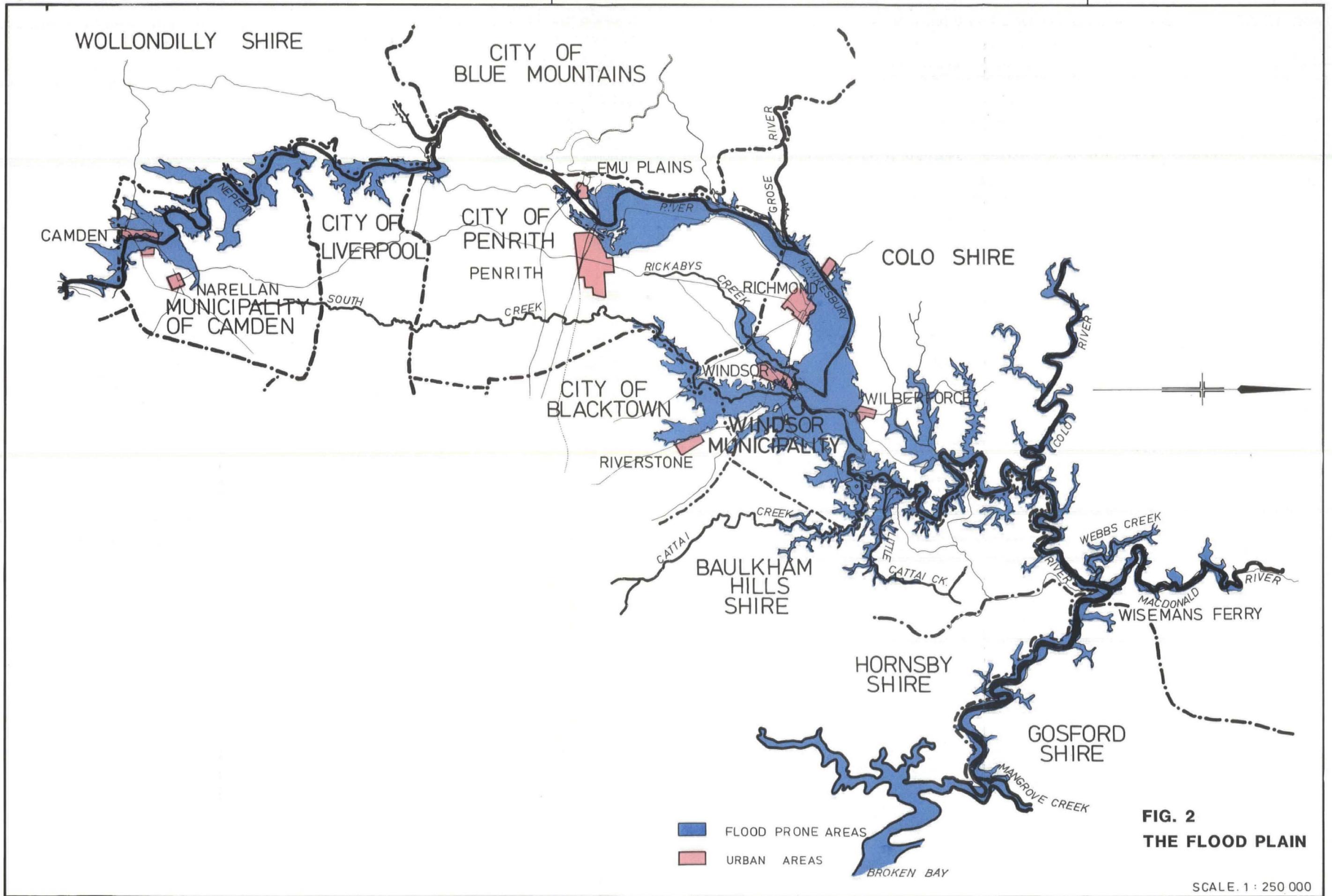
The main areas suffering flood losses are the floodplains downstream of Penrith, particularly in the Richmond, Windsor and Wilberforce Districts. Areas at Camden and river flats along the Colo, Macdonald and Lower Hawkesbury also frequently incur damage from flooding. Apart from the loss of one life during the 1978 flood, available records do not show any loss of life after 1925, but before that date the loss of 23 lives has been attributed to floods.

From an examination of available maps it has been estimated that there are 1,200 houses within the floodplain of which 950 are in residential areas and these may be subject to flood inundation in varying degrees of severity.

Floods in the Hawkesbury-Nepean Valley can cause disruption to industry, interruption of communications, crop losses to agriculture and structural damage to public utilities. Disruption may be caused to the extractive industries along the river, particularly below Penrith and at Richmond and Camden. On the falling river level after a flood, bank slumps and erosion frequently occur leading to loss of land and the threat of further damage to roads and nearby structures. The cost of stabilising these banks adds to the cost of flood damage. In addition the State Emergency Services are involved during the flood period and are a resource provided by the community generally.

To assess the order of magnitude of losses due to flooding, an examination has been made of damages incurred due to the 1978 flood. More severe floods have occurred in the past but the 1978 flood was selected for evaluation because details of damage are more readily available. The severity of the 1978 flood is ranked as approximately 1 in 20 years at Upper Colo. Direct and indirect losses evaluated during the study exceed \$5m but it is known that other substantial direct and indirect losses were also incurred. In addition, one life was lost and intangible losses would have been considerable.

For floodplain management purposes, the mean annual flood damage is an important parameter but its assessment is a task of considerable magnitude which is beyond the scope of the study. It is recommended that separate studies be undertaken to assess mean annual flood damages for both the rural and urban sectors of the Hawkesbury-Nepean floodplain as well as appropriate sectors of other floodplains in the State where considerable losses frequently occur. Data will then be available to decision makers enabling flood and costs of proposed mitigation works to be viewed with proper perspective in the Valley as well as on a State wide basis. A rational basis for allocation of available funds to cost-effective works will thus be promoted.



4.0 EXISTING FLOOD MITIGATION AND MEASURES

4.1 STRUCTURAL WORKS

The principal existing works related to flood mitigation are:—

- Water Board Storage Dams
- Stream Clearing and Dredging
- Bank Stabilisation Works
- Land Drainage Works

Water Board Storage Dams

Apart from Wingecarribee Dam, which is supplied principally from the adjoining Shoalhaven catchment, the Metropolitan Water, Sewerage & Drainage Board operates five water storage dams in the Valley, the main one being Warragamba and four smaller ones, Nepean, Avon, Cordeaux and Cataract. Warragamba Dam has a gated spillway but the four smaller dams have spillways with fixed crests.

Although none of the dams is intended to operate as a flood mitigation dam, fixed crest dams inevitably have the effect of reducing flood peaks simply because they impound water which would otherwise flow down the river. For dams with gated spillways, the effect on flooding depends on the mode of gate operation. A detailed study of the effect of the dams on past flooding has not been made but records kept during the 1978 flood show that the peak inflow to Warragamba Dam was 8,500 cubic metres per second and the peak outflow was only 6,100 cubic metres per second. Construction of the storage dams has vastly affected the environment in their course but geomorphological changes due to dam construction are probably still in progress.

Stream Clearing and Dredging

In 1972, stream clearing and snag removal over a 37 kilometre length of the Nepean River between Menangle and Bents Basin was commenced. Work is still in progress and to date stream clearing has been carried out over a length of approximately 20 kilometres. The current programme has been extended to cover 46 kilometres up to Wallacia Bridge.

In 1979 stream clearing work was commenced on a 5 kilometre length of the Colo River but was suspended pending environmental investigations. An environmental impact statement has been prepared and is currently (December 1980) under consideration.

Bank Stabilisation Works

In 1975 the eastern bank of the Nepean River upstream from Penrith Weir was stabilised by placement of rock fill over a length of about 670 metres and, in the same year, the bend in the river between Argyle and Windsor Reaches was similarly stabilised.

The bend in the Hawkesbury River, between Freemans and Argyle Reaches known as the "Breakaway" was stabilised after the 1956 flood using rock fill and further rock fill was placed during the period from 1964 to 1968.

After the 1978 flood, a section of the River bank at Regentville was stabilised by placement of rock fill and bank trimming.

Land Drainage Works

In the Richmond-Windsor area as well as further downstream, numerous land drainage schemes have been constructed to drain trapped floodwaters from agricultural land. By quickly draining floodwater from the land, after recession of river flooding, damage to crops is reduced, the water table lowered, and possible salt intrusion prevented.

Effectiveness and Comments

Flood mitigation works carried out to date have generally proved satisfactory but in the case of land drainage works and stream clearing works some adverse ecological effects have been identified. When designing land drainage works in the future, consideration should be given to possible siltation problems and reduction in wetland areas. Guidelines outlined in the Colo River environmental impact statement should be applied to any future stream clearing work.

It is noteworthy that most of the expenditure has been directed towards bank stabilisation work which, by its nature, is suitable for piecemeal implementation. Apart from bank stabilisation work, the construction of land drainage works at Bakers Lagoon at a cost of \$500,000 has been the largest project undertaken to date. It is recommended that the present method of funding be examined as it seems that this may have acted to constrain implementation of major flood mitigation schemes.

4.2 NON-STRUCTURAL MEASURES

In the Valley, Councils are well aware of losses that can be suffered due to flooding and non-structural measures such as control of development by means of planning schemes and the enforcement of building regulations requiring floor levels to be raised above flood levels, have been applied in the past.

The State Government has also implemented numerous non-structural measures aimed at mitigation of flood losses. These include enactments and the promulgation of policies which restrict or prohibit the construction of works on flood prone land or in the floodway, granting of low interest loans to encourage raising the floor level of homes and the preparation of floodplain maps. Through the Bureau of Meteorology, the Commonwealth Government provides a flood forecasting service and the Commonwealth and State Governments both make emergency services available during floods and grant relief funds after serious flooding. The Commonwealth and State Governments also provide subsidy funding for approved flood mitigation works.

Effectiveness and Comments

Although non-structural means of mitigating flood losses have been extensively applied in the past, some inadequacies in their past application as well as considerable scope for further application of such measures have been identified. The effectiveness of the reduction of damage potential and the risk to life in the past application of non-structural measures has been inhibited by the following factors:—

- (a) Varying policies of the Councils along the Valley.
- (b) The large difference between maximum recorded floods and the 1 in 100 year adopted flood levels.
- (c) The large number of blocks that could be built upon in the floodplain under existing zonings.
- (d) Developments approved in flood prone areas before a study of flood levels had been made.

These factors may delay the implementation of non-structural measures in the floodplain management plan proposed.

5.0 PROPOSED WORKS AND MEASURES

5.1 INTRODUCTION

This section presents structural and non-structural options recommended as a basis for a floodplain management plan in the Valley.

Structural options are listed in Table 1 and include works currently proposed by Councils as well as options identified during the study. Recommended non-structural options are listed in Table 2.

It needs to be recognised that the structural options identified during the study have only been subject to a limited "desk-type" assessment without benefit of field survey work or detailed site inspections. More detailed investigations are required to finally check their viability before consideration is given to implementation.

5.2 STRUCTURAL WORKS CURRENTLY PROPOSED BY COUNCILS

Flood mitigation works previously proposed by Councils are listed in Table 1. The proposed works estimated to cost \$1.25m are comprised of bank stabilisation works, construction of flood gates and levees, stream clearing work and land drainage works.

Apart from stream clearing work along the Macdonald River (Table 1 – Item 19) and the Clarendon levee proposal (Item 18), the proposals are generally commendable.

Work along the Macdonald River should be confined to limited reaches, such as where roads are endangered by erosion and guidelines from the Colo River environmental study followed. Since the Clarendon levee proposal was first evaluated, there has been a change in the agricultural usage of the land to be protected and the cost-effectiveness of this scheme should be reassessed.

Ecological aspects should receive consideration before any land drainage or bank stabilisation works are undertaken.

5.3 FURTHER STRUCTURAL OPTIONS

Apart from the works currently proposed by Councils, further structural options are listed in Table 1 and discussed below. Where available, estimated costs and approximate benefit/cost ratios are tabulated.

Camden Municipality

During the study, a scheme providing protection for 250 houses by means of levee banks was examined in a preliminary manner. As the height of the banks would be up to about 12 metres, the scheme was found to be environmentally and economically unattractive. However, with more detailed investigations it may be possible to develop an attractive levee scheme for protection of a limited number of houses. Detailed investigations are recommended to determine the location of smaller levees around the periphery of Camden and their cost effectiveness.

Blacktown City

From the study it appears that it could be feasible to construct a system of levees and flood gates at Riverstone to protect the meat works as well as some 120 houses in the floodplain, but data needed for a proper appraisal was not available. Detailed investigations are recommended to determine the cost-effectiveness of the proposal.

Penrith City

- Seventy-six dwellings in the Ladbury Avenue area south of the Great Western Highway and on the western side of Peach Tree Creek could be protected by a levee with flood gates. From a preliminary study it appears that such a scheme could be economically viable and detailed investigations are recommended to determine its cost effectiveness.
- Most of the western bank of the Nepean River between the Victoria Bridge and the Freeway Bridge, a length of about 3 kilometres, is inherently unstable. A length of 700 metres upstream from Victoria Bridge has been included in the current programme (Table 1 – Item 2) and the remainder of the bank should be stabilised as the need arises. Relatively low cost stabilisation measures have been implemented on the eastern bank and are now proposed for the western bank. Consideration should be given in the future to creating a more urban riverscape.

Windsor Municipality

- At Windsor approximately 60 houses in the floodplain could be protected by constructing levees and flood gates. From a preliminary examination such a scheme does not appear economically attractive. As in the case of the Camden levee scheme further investigations are recommended to identify sections around the town which may be more economically constructed.
- Raising of Windsor Road over South Creek between McGraths Hill and Fitzroy Bridge to provide flood-free access to Windsor from Parramatta and areas east of the town.
- Raising of the County Road or other roads to provide flood-free access to Pitt Town and prevent isolation of the town during times of flood.
- Other proposals which, from preliminary investigations do not appear economically attractive but which merit further consideration are:—
 - (a) Installation of flood gates at South Creek in conjunction with raising of Windsor Road.
 - (b) Construction of levees and flood gates at Rickabys Creek to protect agricultural land in the vicinity of Bakers Lagoon.
 - (c) Local raising of Windsor Road near Curtis Road.

Colo Shire

- From the study it appears that houses at Wilberforce could be protected by construction of levees and flood gates but inadequate data precluded a proper assessment. Further investigations are recommended.

Lower Hawkesbury Channel Improvements

Improvement of the conveyance of the Lower Hawkesbury Channel is an option identified during the study which could substantially reduce flood levels reached by the Hawkesbury River between North Richmond and its confluence with Cattai Creek. From a study of past floods, it appears that large areas of inundation are to some degree controlled by the hydraulic capacity of the Hawkesbury Channel downstream of Cattai Creek junction and that increasing the channel capacity could be a viable flood mitigation option. It is important to establish the feasibility of this option as its implementation could effect the need for consideration of other options. Priority investigation is therefore recommended.

5.4 RECOMMENDED NON-STRUCTURAL MEASURES

Non-structural measures generally have far less impact on the environment than structural works and are often more cost effective. Recommended measures are presented below and are listed with priority rankings in Table 2.

Environmental Planning

- It is recommended that the Director of Environment and Planning constitute a committee to advise the Minister for Planning and Environment on aspects related to floodplain management in the Valley and to co-ordinate the preparation of a Regional Environmental Plan.

Under the provisions of the Environmental Planning and Assessment Act, 1979, a Regional Environmental Plan should be prepared to examine and identify policies and actions for floodplain management.

This would be a long term plan for the various areas of the Valley and, in the interim, it is recommended that each Council should adopt an interim policy for the floodplain management of its own particular area as a short term strategy.

The Interim Policy should be uniform throughout the Valley and include the following recommendations:—

(a) Urban

- (i) No building in floodways.
- (ii) A minimum floor level of not less than 0.5 metres above the 1 in 100 year flood level for buildings to be specified in existing developing areas including provision for the land filling of building sites.
- (iii) No further subdivision of land below the 1 in 100 year flood line unless it can be filled to this level and access provided to higher ground subject to no adverse effects on flood levels or velocities.
- (iv) Floodplain management concepts should be incorporated in revised Local Environment Plans.

(b) Rural

- (i) No building to be permitted on floodways.
- (ii) No non-agricultural buildings to be permitted on land below the 1 in 100 year flood level for holdings below 40 ha in area.
- (iii) Buildings necessary for agricultural purposes to be placed on mounds at or above the 1 in 100 year flood level and be provided with a 4 metre wide strip surrounding them at this level.
- (iv) Further subdivision of rural holdings to be handled by amendments to the Local Environment Plan to prevent houses being built below the 1 in 100 year flood level.

- State Government policy now provides guidelines for the delineation of floodways and flood prone land as outlined by the N.S.W. Planning and Environment Commission Circulars 15 and 22 issued in 1977 and 1978 respectively. These are now administered by the Department of Environment and Planning. Existing land use zonings should be modified, as necessary, to prevent further structures from floodways. These areas would then become subject to open space planning in the future with the local Council acquiring properties as they become available. Any plan should take account of the flood of record.

Flood Forecasting and Flood Warning

- Flood predictions should be made and disseminated for Colo, Macdonald and Lower Hawkesbury Rivers.
- Besides forecasting peak flood heights, the Weather Bureau is prepared to make specific predictions, such as for flooding of bridges and caravan parks but has received no such requests in the past. As such predictions could help to mitigate losses, it is recommended that the Bureau make such predictions in future floods when requested.
- The adequacy of dissemination of flood warnings by the media should be investigated.

Emergency Services

- Duties of those involved in emergency operations should be clarified and special instructions issued.
- Possible consequences of the recurrence of maximum recorded floods at the major towns should be examined and brought to the attention of the State Emergency Services for contingency forward planning.
- Results of a current investigation into possible flooding of the Valley resulting from a catastrophic failure of Warragamba Dam should be brought to the attention of the State Emergency Service when available.

Flood Relief Schemes

An aim of floodplain management should be to reduce the need for reliance on relief funds. A separate study should be carried out to identify areas where phasing out of relief funds is practicable and desirable.

Public Awareness

- Floodplain maps should be widely distributed and displayed.
- Information regarding flood prone land should be shown on rate notices and on certificates issued under Section 149 of the Environmental Planning and Assessment Act, 1979.
- Should the Torrens Title Register System become computerised, details of flood prone land should be added to titles.
- Warning and information signs should be erected at bridges and caravan parks and flood heights should be marked on selected structures and public buildings.

Floodplain Mapping

- Completion of mapping over the floodplain as well as addition of floodway limits to maps should be expedited. Guidelines used to establish the floodway should be publicised.
- Consideration should be given to the standardisation of floodplain mapping procedures adopted by the Water Resources Commission and the Department of Public Works.
- Residential and other classes of buildings on flood prone land should be shown on floodplain maps.

Encouragement of Implementation of Non-Structural Strategies

A prerequisite to the granting of subsidy funds to a Council for implementation of structural options should be that the Council satisfies the Government that it has pursued available planning measures in a manner consistent with State Government Policy.

Data Collection and Investigation

- During the study it was found that lack of data precluded proper assessment of some important options and possibly masked the existence of some available options. Data collection and investigations recommended to provide information needed for proper floodplain management are listed under Items 21 – 25 in Table 2.
- One of the items included under this heading is investigation of the use of Warragamba Dam for flood mitigation purposes. It would be possible to substantially reduce flooding in the Hawkesbury-Nepean River by allocating part of the dam storage capacity to flood mitigation purposes. Priority should be given to investigation of the feasibility of this proposal. If found viable, it seems that this option could be implemented immediately.
- During this study numerous matters which have a bearing on floodplain management were identified but not pursued. These are listed in Table 3 and are recommended for consideration when formulation floodplain management strategies in the Valley.

6.0 THE RECOMMENDED FLOODPLAIN MANAGEMENT POLICY

6.1 GENERAL

An overall floodplain management plan for the Hawkesbury River Valley comprises both structural and non-structural measures which will reduce the impact of future floods on the communities living along the Valley and minimise damage and inconvenience that has occurred in the past. Structural flood mitigation options are usually costly to construct, require future maintenance and are generally applicable to existing developments. However, some structural measures are recommended where it appears that they will be cost-effective and provide needed flood mitigation.

In order to provide for future floodplain management non-structural options have been recommended for implementation and to control development. The recent proclamation of the Environmental Planning and Assessment Act and the statement of Government policy given in the Planning and Environment Commission's Circulars 15 and 22 provide a basis from which local authorities can now work.

The objectives of the plan will be:—

1. Protection of the developed urban areas from frequent floods and provision of flood-free access to residential settlements.
2. Rezoning of flood-prone undeveloped residential areas to rural use or open space and encouragement for resettlement of present residents from these areas to higher ground.
3. Zoning provisions to ensure that development and expansion occurs only on flood-free land.
4. Preservation of natural floodways and restriction by rezoning of further residential development on the floodplain.
5. Development of a valley wide flood warning system in association with the Bureau of Meteorology and State Emergency Services.
6. River bank stabilisation at various locations along the Nepean and Hawkesbury Rivers where a threat has been identified with possible damage to existing structures and roads and/or loss of valuable land.
7. Development of co-operation and co-ordination between relevant authorities for flood mitigation planning of the whole valley and allocation of costs to give equitable distribution over all communities of the valley.
8. Consideration of tax relief by Governments to encourage actions which may reduce the effects of flooding and minimise flood damage.

6.2 RECOMMENDED STRATEGY

In the past efforts at flood mitigation in the Hawkesbury-Nepean Valley have been piecemeal and have involved many statutory and non-statutory bodies. In order to provide a co-ordinated approach to floodplain management in the Valley, it is recommended that a co-ordinating body be established with policies aimed at:—

- Reduction of flood losses.
- Reduction of Government expenditure on relief payments.
- Improvement of floodplain environment.
- Implementation of policies which ensure that non-structural flood mitigation measures receive due attention.

- Collection of data and promotion of research to give a better understanding of river behaviour and effects of flood mitigation works and other works in the Valley.

The co-ordinating body could take the form of a Valley Authority or a Co-ordinating Committee. The latter could come under the provision of the Environmental Planning and Assessment Act, 1979.

When formed, the co-ordinating body should pursue the various options listed in Tables 1 and 2, taking into account the priorities allocated. Matters listed in Table 3 should also receive consideration.

There would be a decided advantage in setting up a flood mitigation co-ordinating body with responsibility for the entire catchment. The present break up of responsibility for mitigation planning, especially coinciding with relatively arbitrary boundaries such as the tidal limit or local government boundaries may result in a distortion of the priorities for flood mitigation works.

6.3 IMPLEMENTATION OF THE PLAN

In Tables 1 and 2 the components of the recommended floodplain management plan are ranked in the order of priority seen for their implementation. This order of priority reflects the relative need or urgency for their implementation, as perceived by the consultants, and, in some cases, the necessary sequencing of those proposals which are dependent upon the earlier completion of other proposals. It need not determine however, the order in which all the proposals should be implemented.

Various aspects relating to the implementation of each proposal are also summarised in Tables 1 and 2 together with consultants' perception of merit (or justification) of each proposal.

Table 3 lists other matters identified as relevant to flood mitigation in the Hawkesbury-Nepean Valley and which require further consideration. These are of a more general nature and of lesser importance than the items listed in Tables 1 and 2.

Priority ratings shown in the tables were allocated using the following criteria:—

- | | |
|--------------------------------------|--|
| No. 1 Priority:
(Urgent) | (a) Schemes which appear to have a capacity to significantly reduce potential flood damage, particularly loss of life, and which can be readily implemented. |
| | (b) Investigations of major schemes which, if implemented, could affect the need for implementation of other options. |
| | (c) Collection of data considered necessary for proper floodplain management. |
| No. 2 Priority
(Highly Desirable) | Schemes not qualifying as urgent for No. 1 Priority but more attractive than those ranked No. 3 Priority. |
| No. 3 Priority
(Desirable) | This Priority has been allocated to those schemes which, from limited investigations made during the study, do not appear attractive due to low benefit/cost ratios and/or difficulties in implementation under present circumstances. |

It is not intended that schemes placed in No. 3 category be left in abeyance until those in categories 1 and 2 have been implemented. Indeed, it is recommended that action be taken to further examine the merits of these schemes and to keep them under review as circumstances change.

The priorities shown in the tables are those allocated by the consultants after preliminary scheme assessments. They are not intended as a rigid guide as it is likely that, in some cases, fresh priorities will arise to suit changed circumstances as well as additional information obtained from more detailed assessments.

Pending formation of the co-ordinating body the following action is recommended to implement the floodplain management plan.

- Councils should carry out structural options numbered 1 to 6 in Table 1.
- Councils should carry out all non-structural options listed in Table 2 that are appropriate to their province and within their resources, particularly with regard to development controls (Items numbered 1 to 3) and the adoption of interim policies.
- High priority is recommended for the investigation of the proposal for improvement of the channel capacity of the Lower Hawkesbury (Table 1 – Item 7) and the use of Warragamba Dam for flood mitigation purposes (Table 2 – Item 25). Both these options could have vast effects on flooding and their implementation could affect the need for other available options.
- The State Government should pursue non-structural options listed in Table 2 that are beyond the scope of local government. Items numbered 17 to 24 are recommended for special priority.
- Councils should exercise responsibility for the proposed works and strategies under the guidance of the relevant State and Commonwealth Governmental Authorities. An outline of the floodplain management plan for the Valley is shown on Figure's 3,4,5, viz. existing works, currently proposed works and future options.

**TABLE 1 HAWKESBURY RIVER VALLEY
STRUCTURAL OPTIONS RECOMMENDED FOR INVESTIGATION/IMPLEMENTATION**

Order of Priority	Stat.	Proposal (and order of cost, and benefit where available)	Distribut. of Benefit		Aspects that could benefit or will require consideration					Consultant's perception of need or merit and remarks	
			Extensive	Local	Rural Economy	Urban Economy	Environmental	Access	Public Safety		Floodplain Hydraulics
1	P	1. Stream clearing programme along Nepean River between Menangle and Wallacia Bridge (\$40,000 per year)	✓		✓		✓			✓	Present programme should proceed but ecological aspects should receive more attention
1	C	2. Bank stabilisation of western bank of Nepean River over 700 m length upstream from Victoria Bridge (\$500,000).		✓		✓	✓	✓			Protection of park, recreation area and western abutment of road and rail bridges
1	C	3. Bank protection work along Argyle Reach of Hawkesbury River		✓	✓		✓				Protection of agricultural land
1	C	4. Bank protection work along Hawkesbury River at Howes Park (\$310,000)		✓		✓	✓	✓	✓	✓	Protection of parkland, urbanised area including residential streets.
1	C	5. Installation of flood gates at George Street, Windsor (\$30,000. Benefit/Cost:>1)		✓		✓	✓				Flood protection of residential area.
1	C	6. Drainage Works and levees at Dunstons Lagoon (\$100,000. Benefit/Cost: approx 2.5)		✓	✓		✓			✓	Mitigation of agricultural losses.
Ref. last col.	F	7. Improvement of conveyance of Lower Hawkesbury River Channel (cost not available).	✓		✓	✓	✓		✓	✓	Implementation of this scheme could reduce flood levels between North Richmond and Cattai Creek. Investigations are required to assess feasibility. Assessment should be given high priority and implementation could affect the need for other options
1	F	8. Raising of road McGraths Hill to Windsor and possible installation of flood gates (cost not available).		✓		✓	✓	✓	✓	✓	Road raising is recommended to provide flood-free access to Windsor. Flood gates would protect land south-west of Windsor but further investigations are needed before gates are installed.
1	F	9. Levees and flood gates at Riverstone (cost not available)		✓		✓		✓	✓		Protection of meat works as well as approx 120 houses. Recommended for more detailed investigation.
1	F	10. Levees and flood gates at Peach Tree Creek Penrith (\$300,000. Benefit/Cost: probably approx. 1.0)		✓		✓	✓	✓	✓		Protection of about 76 dwellings Detailed investigation required.

1	F	11. Raising of County Road – Windsor (cost not available)		✓		✓		✓	✓		Flood-free access to Pitt Town Further study required.
1	F	12. Levees and flood gates at Wilberforce (cost not available)		✓		✓		✓	✓		Number of houses which could be protected not assessed. Further investigations warranted.
1 (for study of limited scheme)	F	13. Levees and flood gates at Camden (\$7M, Benefit/Cost: probably <0.5 for complete scheme)		✓		✓	✓	✓	✓	✓	Scheme would protect approx. 600 residential lots containing 250 houses. Visual aspects need assessment. More detailed investigations are recommended for limited scheme.
1 (for study of limited scheme)	F	14. Levees and flood gates at Windsor (\$2.5M. Benefit/Cost: probably <0.1 for complete scheme)		✓		✓	✓	✓	✓	✓	Protection of approx. 60 houses at Windsor and local roads. Recommended for further investigation of limited scheme.
2	C	15. Stream clearing along Colo River over 5 km length upstream from Central Colo.		✓	✓		✓	✓		✓	Scheme should proceed subject to recommended guidelines.
2	C	16. Removal of sand at Cordners Corner (cost not available)		✓		✓					Scheme could provide revenue from sale of sand extracted and protect bank from flood damage. Further study is recommended to assess benefits as well as geomorphological effects.
2	C	17. Bank protection work along Freemans Reach of Hawkesbury River (\$30,000)		✓				✓		✓	Protection of river bank and main road.
2	C	18. Construction of levee at Clarendon along northern bank of Rickabys Creek (\$250,000. Benefit/Cost: >3 with vegetables).		✓	✓		✓	✓	✓	✓	Farmers changing from vegetables to turf. Scheme should be reassessed.
3	C	19. Stream clearing and bank protection work along Macdonald River (cost not available).		✓	✓		✓	✓	✓	✓	Bank stabilisation to protect roadworks is recommended. Stream clearing should be selective and subject to Colo River guidelines.
3	F	20. Bank protection work along Nepean River between Victoria Bridge and Freeway Bridge (cost not available)		✓		✓	✓	✓	✓		Proposed that this work be carried out section by section as need arises.
3	F	21. Local raising of Windsor Road near Curtis Road (cost not available)		✓		✓		✓			Requires raising of McGraths Hill – Windsor Road to be effective.
3	F	22. Levees and flood gates at Rickabys Creek – Windsor (cost not available).		✓	✓		✓			✓	Agricultural land around Bakers Lagoon could be protected but loss of scheme unattractive.

Status – P : Work in progress.

C : Currently proposed by Councils for inclusion in subsidy programme.

F : Other future option.

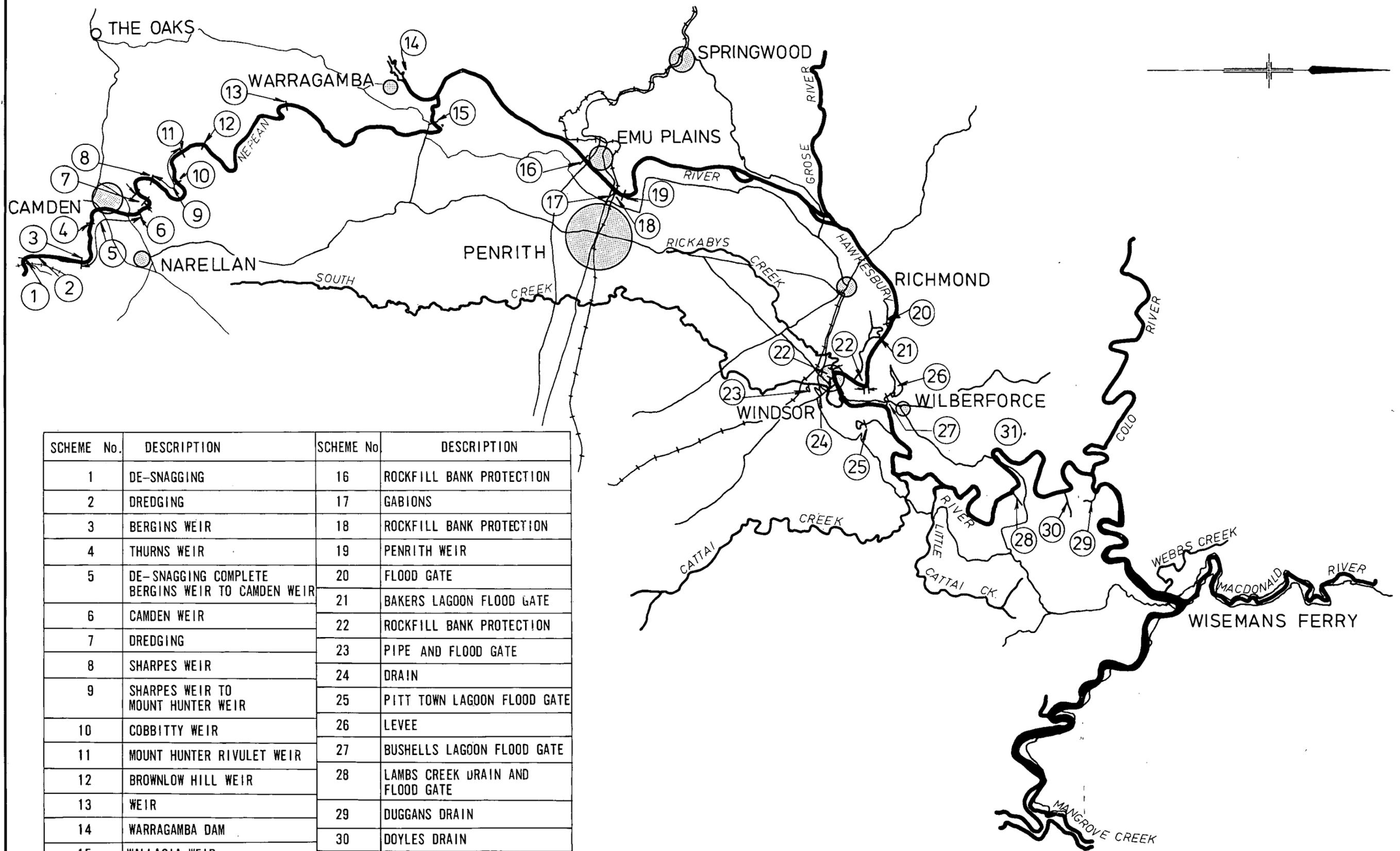
TABLE 2 HAWKESBURY RIVER VALLEY
RECOMMENDED NON-STRUCTURAL MEASURES

Order of Prior.	Title	Distribut. of Benefit		Aspects that could benefit or will require consideration						Consultant's perception of need or merit
		Local	Extensive	Rural Economy	Urban Economy	Environmental	Access	Public Safety	Floodplain Hydraulics	
1	Development Controls under Environmental Planning and Assessment Act, 1979 and Coastal Protection Act, 1979 1. Prepare Local Environmental Plans for individual Council areas and adopt as an Interim policy		✓		✓	✓		✓		Control local development on flood plain
1	2. Prepare Regional Environmental Plan to detail planning strategies for the future management of the valley and amend existing planning instruments as necessary.	✓		✓	✓	✓		✓		Planning and management of the flood plain.
1	3. Prepare State Environmental Planning Policy on flood plain management to outline guidelines for floodway areas and flood prone lands.	✓		✓	✓	✓		✓		To supersede P.E.C. Circulars 15 & 22
1	Promotion of Non-structural Options 4. State Government to take measures which will encourage Councils to pursue non-structural options.	✓		✓	✓	✓	✓	✓		In the past there appears to have been a tendency to pursue structural rather than non-structural options.
1	Flood Forecasting and Flood Warning 5. Issue separate flood warnings for Colo, MacDonald and Lower Hawkesbury Rivers	✓		✓	✓		✓	✓	✓	Difficulties arose during 1978 flood due to absence of warnings.
1	6. Bureau to make specific predictions for future floods, when requested.	✓					✓	✓	✓	Reduce flood losses by the issue of flood warning bulletins.
1	7 Investigate complaints regarding adequacy of dissemination of warnings by media.	✓						✓		Reduce flood losses.
1	Emergency Services 8. Investigate instances of alleged uncoordinated services.	✓						✓		Public Safety
1	9. Examine effect of floods of magnitude of maximum recorded events.	✓						✓	✓	Public Safety
2	10. Examine flooding from failure of Warragamba Dam.	✓						✓	✓	Public Safety
1	Public Awareness 11. Display flood plain maps.	✓						✓		Awareness promotes action taken to mitigate losses due to flooding.
1	12. Mark flood heights on structures.	✓						✓	✓	Awareness promotes action taken to mitigate losses due to flooding.

1	13. Display information regarding flood prone land on rate notices and Section 149 certificates.	✓						✓		Awareness promotes action taken to mitigate losses due to flooding.
3	14. When Title Register System becomes computerised, add details of flood prone land titles.	✓						✓		Awareness promotes action taken to mitigate losses due to flooding.
1	15. Display flood levels at caravan parks.	✓						✓		Awareness promotes action taken to mitigate losses due to flooding.
1	16. Erect warning and information signs at flood prone bridges.	✓						✓		Awareness promotes action taken to mitigate losses due to flooding.
1	Flood Plain Mapping 17. Expedite completion of mapping programme.	✓		✓	✓				✓	Improved management
1	18. Consider standardisation of mapping carried out by WRC and PWD.	✓		✓	✓				✓	Avoid possible anomalies.
1	19. Expedite addition of floodway limits to maps and publicise guidelines used to establish floodway.	✓		✓	✓				✓	Definition of floodway is important for planning and other purposes.
1	20. Show dwellings and other buildings on flood plain maps.	✓						✓		Useful for planning purposes, scheme evaluations and SES operations.
1	Data Collection and Major Investigations 21. Monitor river morphology.	✓		✓	✓	✓			✓	Data needed for identification and evaluation of options.
1	22. Establish register of houses and other buildings in flood plain.	✓						✓		Useful for planning purposes, scheme evaluations and SES operations.
1	23. Develop decision matrix.	✓		✓	✓	✓				Assist management body to evaluate options.
1	24. Assess mean annual flood damage for selected sectors of the flood plain.	✓		✓	✓					Assist in formulation of management strategies.
1	25. Investigate use of Warragamba Dam for flood mitigation purposes.	✓		✓	✓	✓	✓	✓	✓	Implementation would have vast flood mitigation effects. Early assessment is required because implementation of this option could affect the need for other options
2	Relief Schemes 26. Undertake study to examine effectiveness of present relief policies and to identify any areas where it could be practicable and desirable to phase out relief payments.	✓		✓	✓					An aim of flood plain management should be to reduce need for reliance on flood relief.

**TABLE 3 HAWKESBURY RIVER VALLEY
MISCELLANEOUS MATTERS FOR CONSIDERATION**

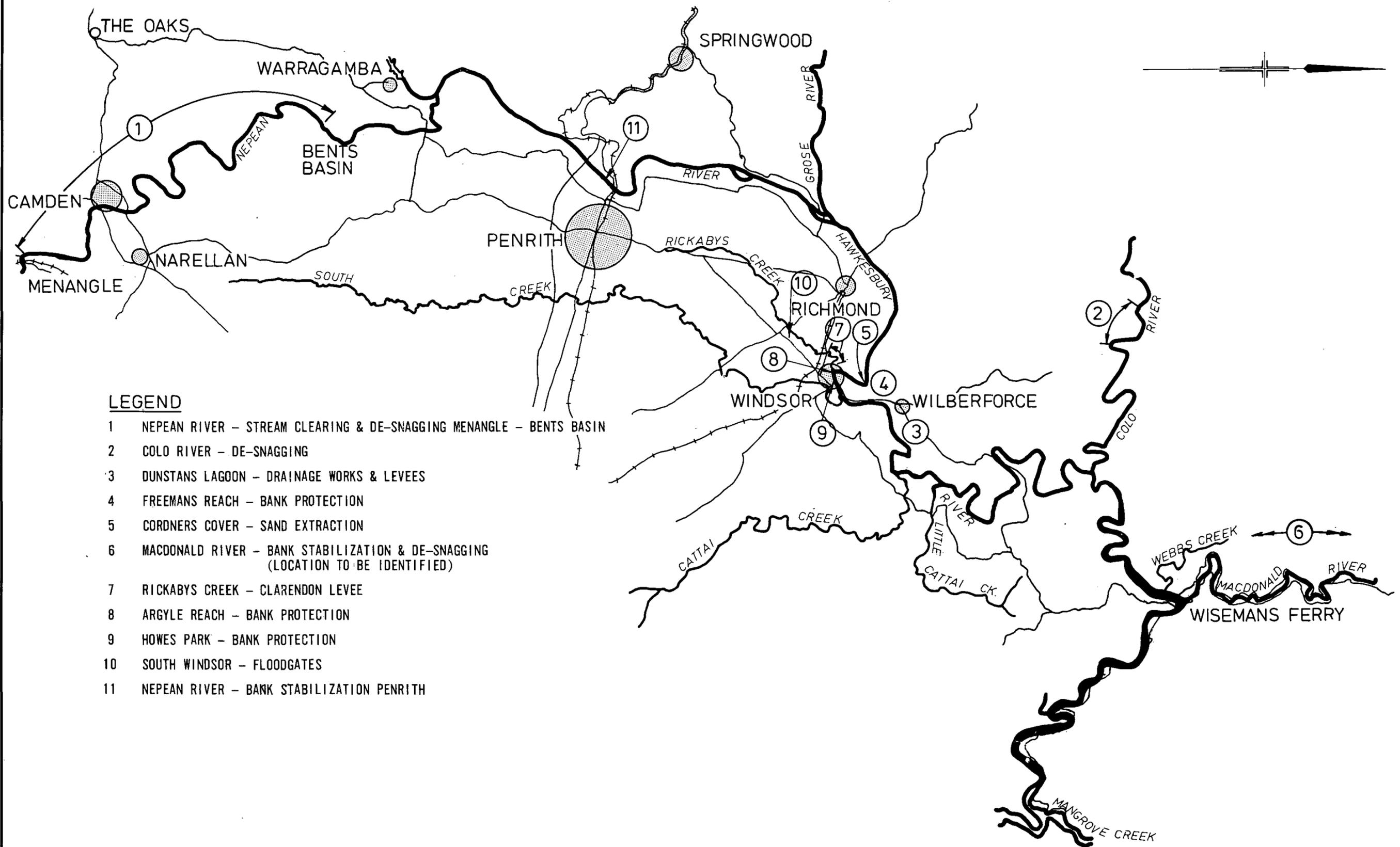
Item	Description	Benefit
1	Rationalise operations of extractive industries	Stream pollution, recreation.
2	Restore past working of extractive industries.	Environment, recreation.
3	Plant trees to obscure dredging operations.	Environment.
4	Before permitting extractive industries to develop in Richmond lowlands area study long-term effects on agriculture and recreation.	Provide data for proper flood plain management.
5	Develop athletic fields, picnic areas, lakes and other recreational facilities in flood plain.	Recreation, stream pollution.
6	Take into consideration principles and policies given in Sydney Regional Outline Plan.	Promotion of Government Policies.
7	Take into consideration conservation orders and registers compiled by Australian Heritage Commission and National Trust of Australia (NSW).	Raising and relocation of homes – scheme evaluation.
8	Recognise disadvantages of levees.	Scheme evaluation.
9	Ensure adequacy of toe where rockfill bank protection is used.	Bank stability.
10	Maintain gates at South Creek near McGraths Flats.	Functioning of scheme.
11	Recognise temporary nature of structural works on land that will be mined for sand and gravel.	Proper scheme appraisal.
12	Permit public access along river banks.	Recreation.
13	Encourage development of recreational facilities along river frontages by private enterprise.	Recreation.
14	When investigating scheme for lakes at Richmond, consider effects of tidal prism.	Scour prevention.
15	Consider desirability of making National Parks and Wildlife Service responsible for management of all wet land areas in flood plain.	Ecological.
16	Foster proposed Penrith Lake Scheme.	Recreation.
17	Foster preservation of rural character of flood plain.	Recreation, agriculture.
18	Identify and correct sources of stormwater infiltration into waste water sewers.	Reduce stream pollution.
19	Keep under review efficiency of septic tanks in flood plain.	Reduce stream pollution.
20	Locate or relocate, package sewage treatment plants to be clear of flood plain.	Reduce stream pollution.
21	Protect roads against flood damage along Colo and Macdonald Rivers.	Communications.
22	Take measures to reduce urban and rural erosion.	Reduce sedimentation and flooding.
23	Investigate agricultural economics.	To assist in land use planning.
24	Seek ecological advice on bank restoration after stream clearing or dredging work.	Improved habitat.
25	Make funds available for regular river maintenance.	Prevent deterioration of works and river banks.
26	Before commencing further major stream clearing programmes undertake environmental impact study.	Proper scheme assessment.
27	For proper formulation of management strategies an understanding of long-term river regime and ecological trends is required. A study should be carried out to examine the combined ecological and geomorphological impacts of the Water Board Dams, the compensatory weirs and the activities of the extractive industries and to determine whether there are any long-term trends towards aggregation or degradation or adverse ecological trends.	Assist formulation of strategies.
28	Encourage research into design of fish ladders.	Ecological.
29	When rockfill bank protection is used consider planting of eucalypts she-oaks and various understorey species high on bank. Under some circumstances planting of casuarinas along the banks and keeping these pruned to about 2 m high could be appropriate.	Bird habitat and recreation.
30	Consider construction of concrete sill at Bakers Lagoon.	Ecological.
31	When designing land drainage works for lagoon areas take into consideration possible adverse affects due to siltation.	Ecological.
32	Instruct Council workmen in proper techniques of stream clearing.	Reduce environmental damage and public criticism.
33	When investigating flooding take into account ponding over lake areas.	Proper assessment of flood levels.



SCHEME No.	DESCRIPTION	SCHEME No.	DESCRIPTION
1	DE-SNAGGING	16	ROCKFILL BANK PROTECTION
2	DREDGING	17	GABIONS
3	BERGINS WEIR	18	ROCKFILL BANK PROTECTION
4	THURNS WEIR	19	PENRITH WEIR
5	DE-SNAGGING COMPLETE BERGINS WEIR TO CAMDEN WEIR	20	FLOOD GATE
6	CAMDEN WEIR	21	BAKERS LAGOON FLOOD GATE
7	DREDGING	22	ROCKFILL BANK PROTECTION
8	SHARPES WEIR	23	PIPE AND FLOOD GATE
9	SHARPES WEIR TO MOUNT HUNTER WEIR	24	DRAIN
10	COBBITTY WEIR	25	PITT TOWN LAGOON FLOOD GATE
11	MOUNT HUNTER RIVULET WEIR	26	LEVEE
12	BROWNLOW HILL WEIR	27	BUSHELLS LAGOON FLOOD GATE
13	WEIR	28	LAMBS CREEK DRAIN AND FLOOD GATE
14	WARRAGAMBA DAM	29	DUGGANS DRAIN
15	WALLACIA WEIR	30	DOYLES DRAIN
		31	VARIOUS DRAINS & FLOOD GATES

FIGURE 3
EXISTING WORKS AND
WORKS IN PROGRESS

SCALE 1 : 250,000



LEGEND

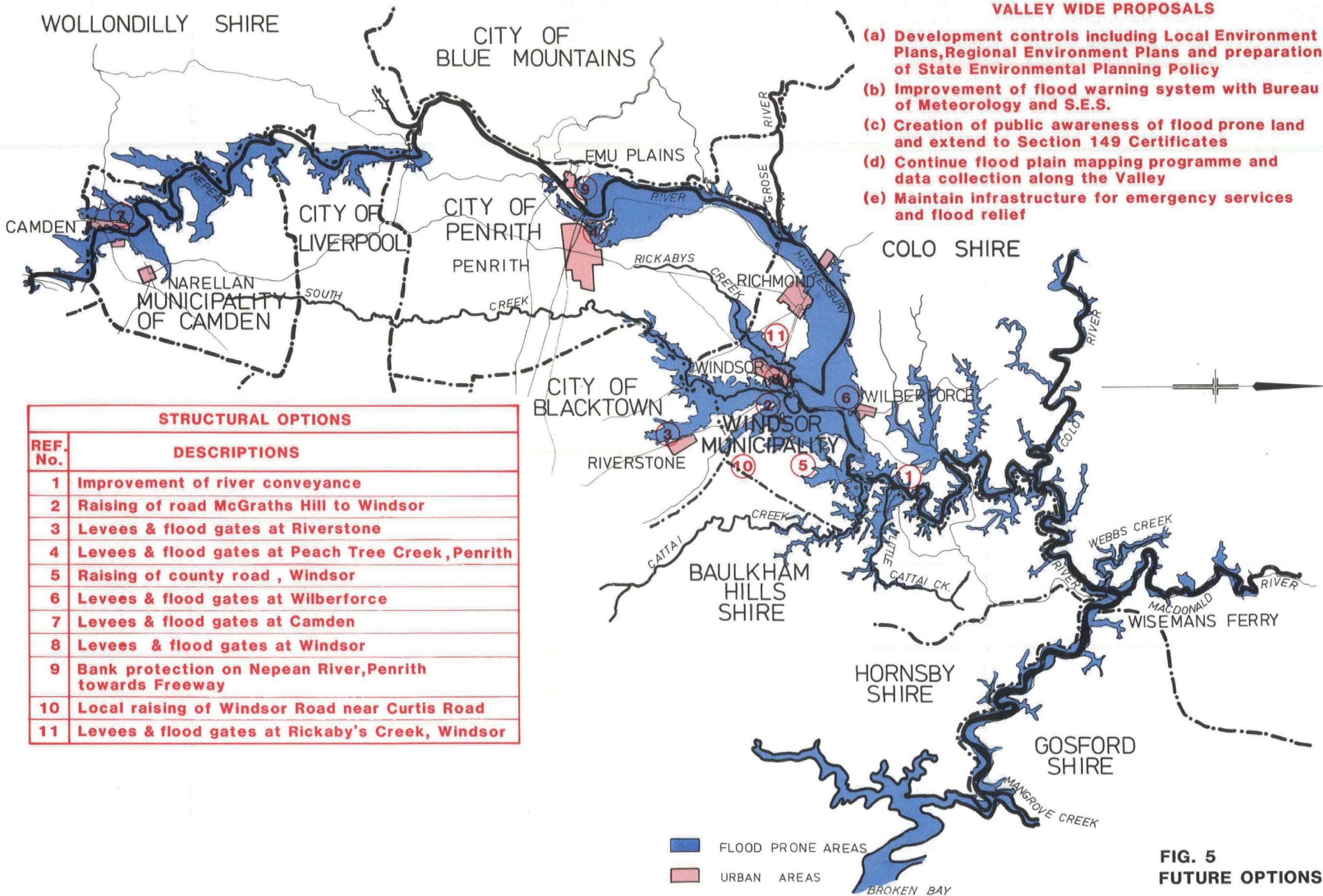
- 1 NEPEAN RIVER - STREAM CLEARING & DE-SNAGGING MENANGLE - BENTS BASIN
- 2 COLO RIVER - DE-SNAGGING
- 3 DUNSTANS LAGOON - DRAINAGE WORKS & LEVEES
- 4 FREEMANS REACH - BANK PROTECTION
- 5 CORDNERS COVER - SAND EXTRACTION
- 6 MACDONALD RIVER - BANK STABILIZATION & DE-SNAGGING (LOCATION TO BE IDENTIFIED)
- 7 RICKABYS CREEK - CLARENDON LEVEE
- 8 ARGYLE REACH - BANK PROTECTION
- 9 HOWES PARK - BANK PROTECTION
- 10 SOUTH WINDSOR - FLOODGATES
- 11 NEPEAN RIVER - BANK STABILIZATION PENRITH

FIGURE 4
CURRENTLY
PROPOSED WORKS

SCALE 1 : 250,000

VALLEY WIDE PROPOSALS

- (a) Development controls including Local Environment Plans, Regional Environment Plans and preparation of State Environmental Planning Policy
- (b) Improvement of flood warning system with Bureau of Meteorology and S.E.S.
- (c) Creation of public awareness of flood prone land and extend to Section 149 Certificates
- (d) Continue flood plain mapping programme and data collection along the Valley
- (e) Maintain infrastructure for emergency services and flood relief



STRUCTURAL OPTIONS

REF. No.	DESCRIPTIONS
1	Improvement of river conveyance
2	Raising of road McGraths Hill to Windsor
3	Levees & flood gates at Riverstone
4	Levees & flood gates at Peach Tree Creek, Penrith
5	Raising of county road, Windsor
6	Levees & flood gates at Wilberforce
7	Levees & flood gates at Camden
8	Levees & flood gates at Windsor
9	Bank protection on Nepean River, Penrith towards Freeway
10	Local raising of Windsor Road near Curtis Road
11	Levees & flood gates at Rickaby's Creek, Windsor

**FIG. 5
FUTURE OPTIONS**

SCALE. 1 : 250 000

PHOTOGRAPHS



REACH NEAR MENANGLE BEFORE STREAM CLEARING



BANK TRIMMED AND RE-GRASSED NEAR COBBITY BRIDGE



GABION RETAINING WALL TO PROTECT BANK AT PENRITH



EAST BANK OF RIVER AT PENRITH AFTER FLOOD



CORNWALLIS FLATS IN FLOOD ; HAWKESBURY RIVER IN FOREGROUND



OUTLET DISCHARGE AT
BAKER'S LAGOON FOLLOWING
FLOOD RECESSION



ARGYLE REACH, WINDSOR,
SHOWING BANK STABILISATION IN FOREGROUND



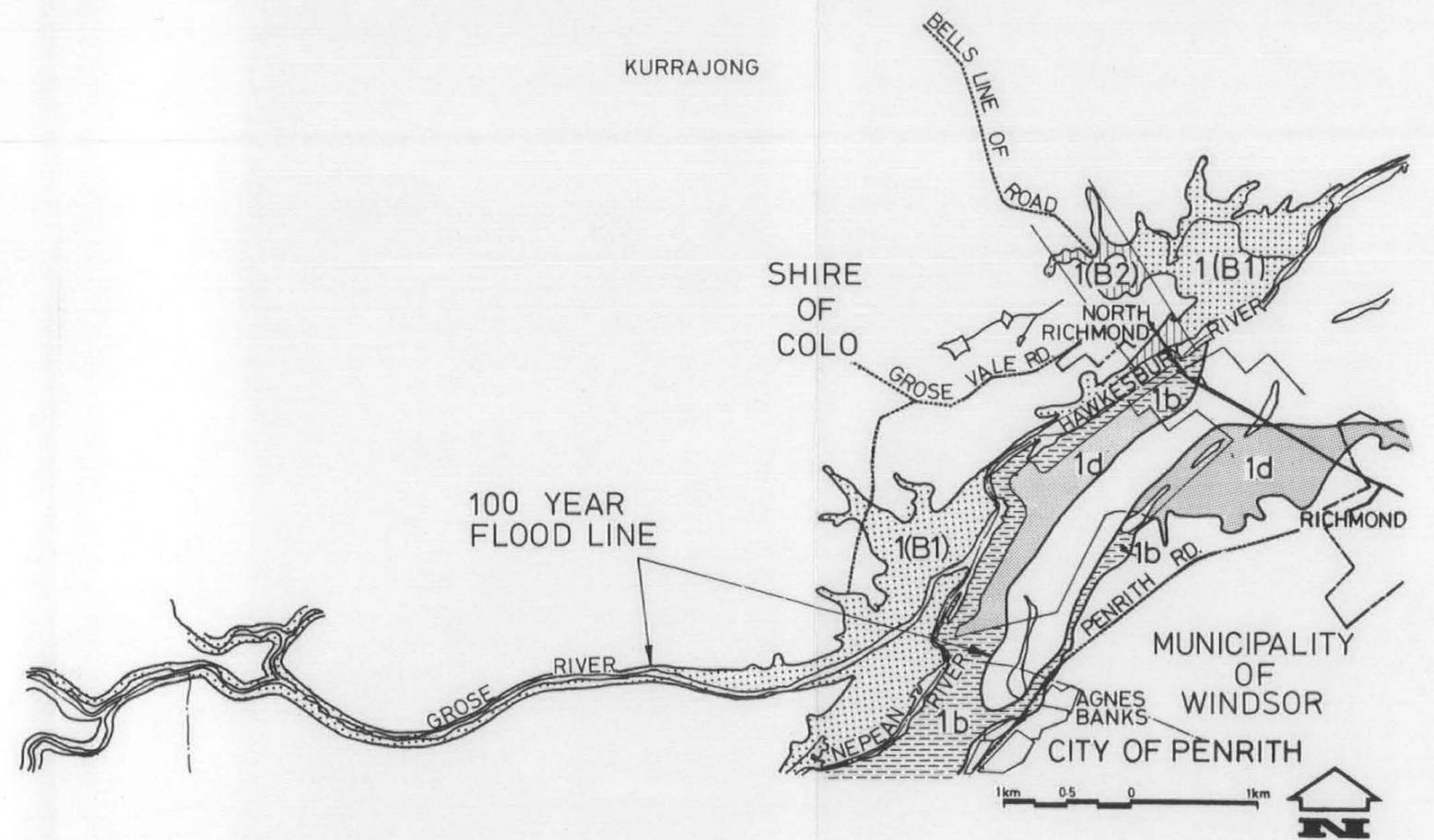
PORTLAND REACH – LOWER HAWKESBURY RIVER
– SHOWING AREAS USED FOR CARAVAN PARKS

APPENDIX

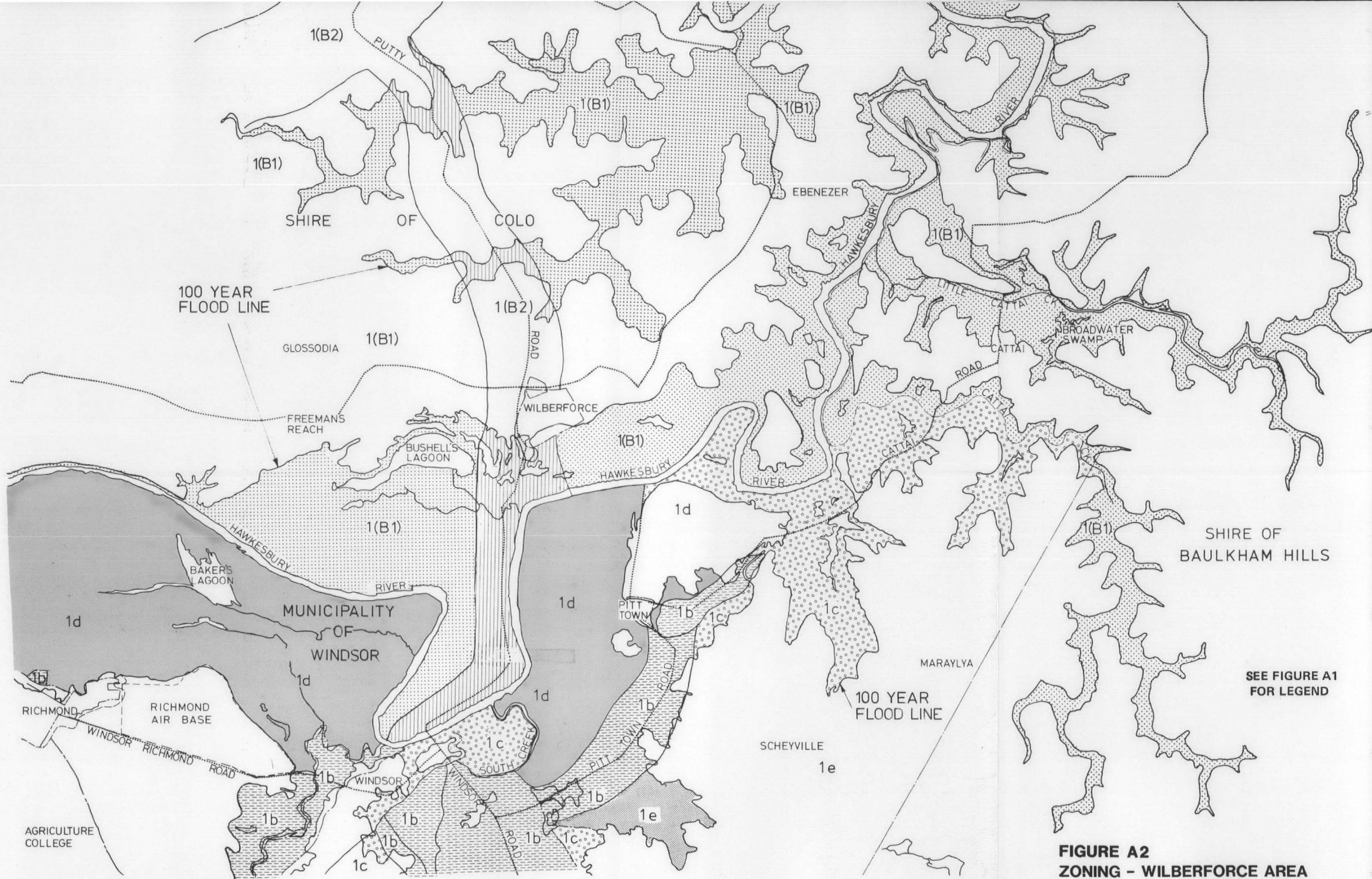
**LAND USE ZONINGS
WITHIN FLOOD PLAIN**

LEGEND

	Non-Urban A
	" B, 1b
	" C 2 h.a. min. 1c
	" D 8 h.a. min. 1d
	" E 20h.a. min. 1e
	" A1 40 h.a. min. 1(A1)
	" A2 40h.a. min. 1(A2) Arterial Road
	" B1 10 h.a. min. 1(B1)
	" B2 10ha. min. 1(B2) Arterial Road.
	" Special Uses



**FIGURE A1
ZONING - KURRAJONG AREA**



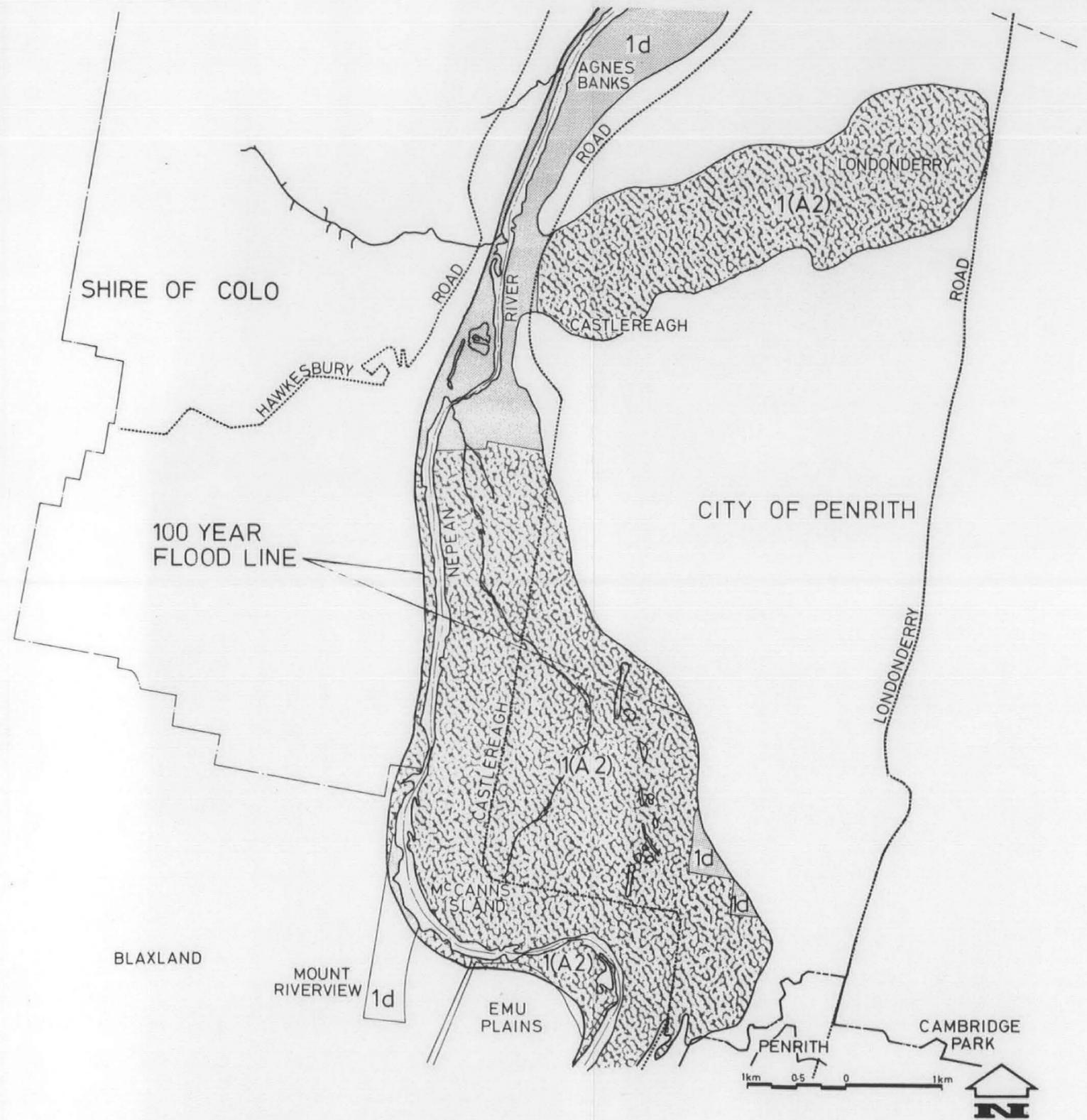
SHIRE OF BAULKHAM HILLS

SEE FIGURE A1 FOR LEGEND

FIGURE A2
ZONING - WILBERFORCE AREA

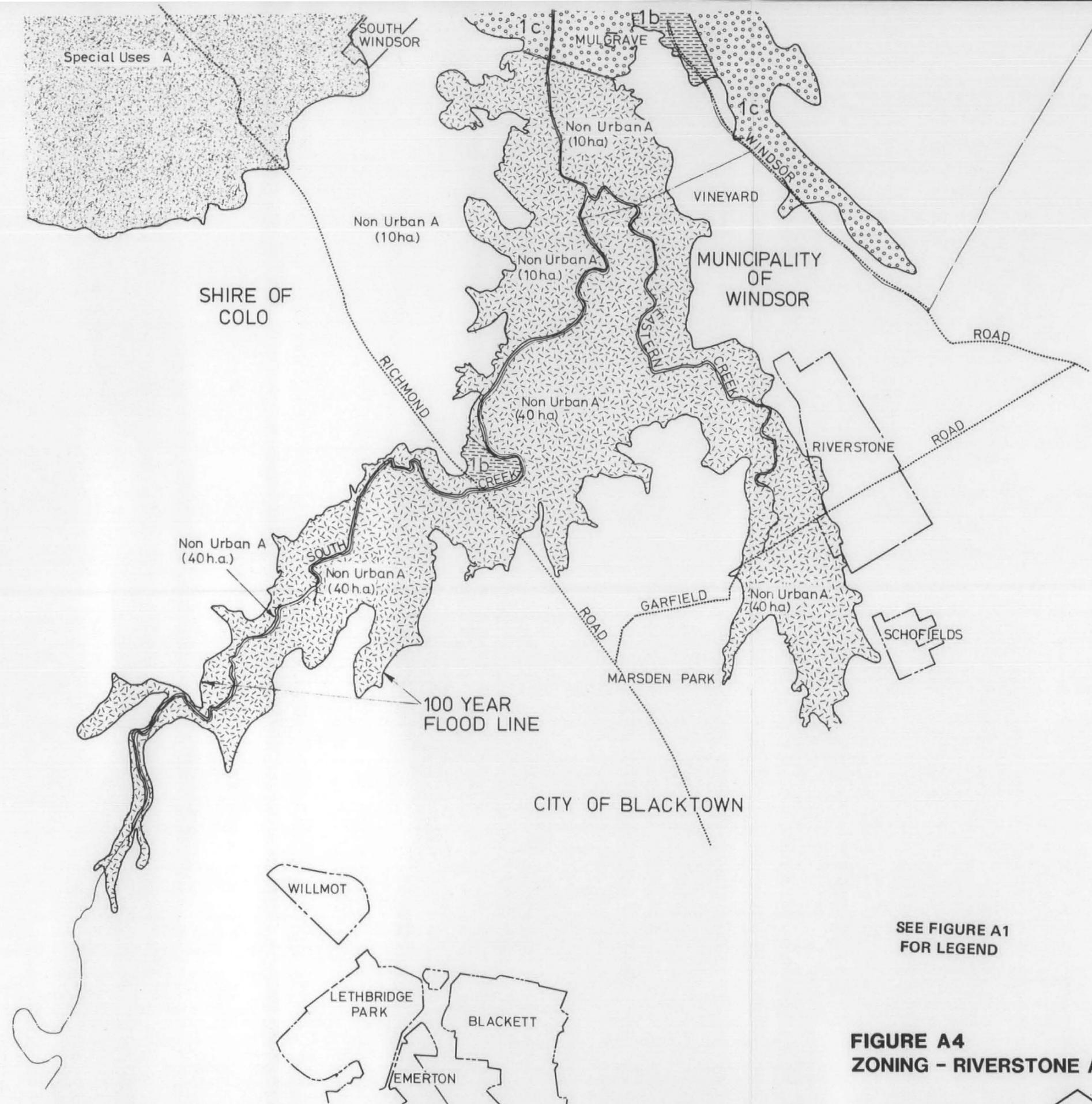


CITY OF BLUE MOUNTAINS



SEE FIGURE A1
FOR LEGEND

FIGURE A3
ZONING - SPRINGWOOD AREA

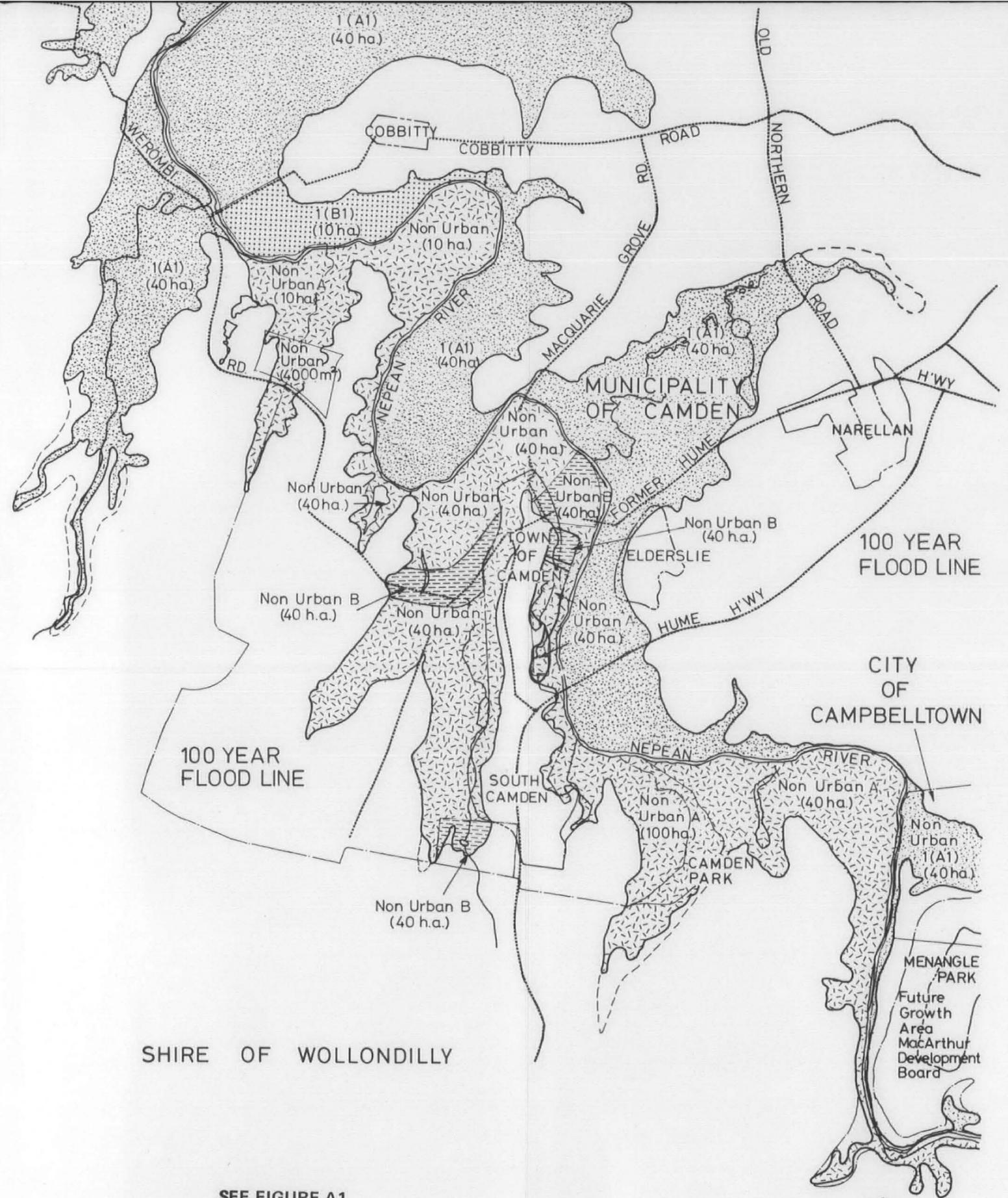


SEE FIGURE A1 FOR LEGEND

FIGURE A4
ZONING - RIVERSTONE AREA



SHIRE OF WOLLONDILLY



SHIRE OF WOLLONDILLY

SEE FIGURE A1
FOR LEGEND

FIGURE A6
ZONING - CAMDEN AREA

