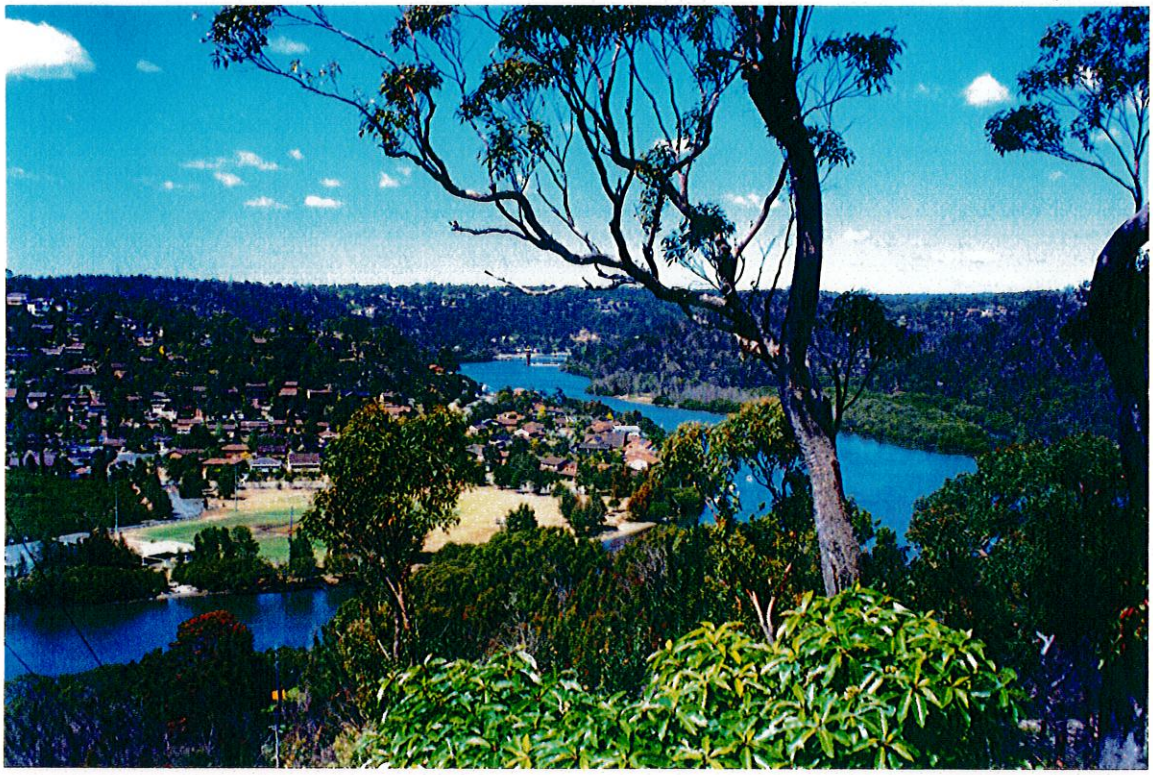
WORONORA RIVER
FLOODPLAIN MANAGEMENT STUDY



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SUTHERLAND SHIRE COUNCIL

WORONORA RIVER FLOODPLAIN MANAGEMENT STUDY

SEPTEMBER 1995

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FOREWORD

The State Government's Flood Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

The Policy provides for technical and financial support by the Government through the following four sequential stages:

1. Flood Study

   - determines the nature and extent of the flood problem.

2. Floodplain Management Study

   - evaluates management options for the floodplain in respect of both existing and proposed development

3. Floodplain Management Plan

   - involves formal adoption by Council of a plan of management for the floodplain.

4. Implementation of the Plan

   - construction of flood mitigation works as well as implementation of non-structural measures to protect existing development,
   - use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

A flood study was completed for the Woronora River in 1991. The present study includes evaluation of management options for the Woronora River floodplain in respect of both existing and proposed development. A Plan of Management will be prepared, based on the results of this study.

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GLOSSARY OF TERMS

Alert	a flood warning system involving the transmission of a radio signal from a field station to a "base" station computer each time a flood event occurs to allow for prediction of flood levels.
Annual Exceedance Probability (AEP)	refers to the chance or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high chance of occurring or being exceeded; it would occur quite often and would be relatively small. A 1% AEP flood has a low chance of occurrence or being exceeded; it would be fairly rare but it would be relatively large.
Australian Height Datum (AHD)	a common national plane of level corresponding approximately to mean sea level.
average annual damage	the average economic loss caused by flooding for a catchment, eg the Woronora valley, measured over a year.
catchment	the area draining to a site. Includes the catchments of tributary streams as well as the main stream.
compatible developments	developments appropriate to both the flood hazard at the development site and to the impact of the development on existing flood levels and flood flows.
conditional developments	developments likely to cause/suffer excessive flood damage or likely to have an unacceptable impact on flood levels and flood flows.
datum	specified reference level used in survey measurement (see Australian Height Datum).
designated flood	(see flood standard)
development	the erection of the building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.

discharge	the rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow which is a measure of how fast the water is moving rather than how much is moving.
extreme event	a large flood event substantially greater than the 1% AEP event.
flood	relatively high stream flow which overtops the natural or artificial banks in any part of a stream or river.
flood hazard	potential for damage to property or persons due to flooding.
flood liable land	land which would be covered with water as a result of a designated flood.
floodplain	the portion of a river valley, adjacent to the river channel, which is covered with water when the river overflows during floods.
floodplain management measures	the full range of techniques available of floodplain managers.
floodplain management options	the measures which might be feasible for the management of a particular area.
flood standard (or designated flood)	the flood selected for planning purposes. The selection should be based on an understanding of flood behaviour and the associated flood risk. It should also take into account social, economic and ecological considerations.
flood storages	those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
floodways	those areas where a significant volume of water flows during floods. They are often aligned with obvious naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, which may in turn adversely affect other areas. They are often, but not necessarily, the areas of deeper flow or the areas where higher velocities occur.

freeboard	a factor of safety usually expressed as a height above the designated flood. Freeboard tends to compensate for factors such as wave action, localised hydraulic effects etc.
high hazard	possible danger to life and limb; evacuation by trucks difficult; potential for structural damage; social disruption and financial losses could be high.
hydraulics	the term given to the study of water flow in a river, in particular, the evaluation of flow parameters such as stage and velocity.
hydrology	the term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
hydrograph	a graph which shows how the discharge changes with time at any particular location.
low hazard	should it be necessary, people and their possessions could be evacuated by trucks. Able-bodied adults would have little difficulty wading.
management plan	a document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, problems, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
mathematical/computer models	the mathematical representation of the physical processes involved in catchment runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff and stream flow eg MIKE 11 and RORB.

MIKE 11	a computer program developed by Danish Hydraulics Institute to determine flood hydraulic characteristics ie flood depth and velocities.
peak discharge	the maximum discharge occurring during a flood event.
probable maximum flood (PMF)	the flood calculated to be the maximum which is likely to occur.
probability	a statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedance Probability.
present worth	the present worth is taken as the equivalent value today of a future transaction eg. with a discount rate of 7%, $107 in one year's time has a present worth of $100.
RORB	a computer program developed by Laurenson and Mein to simulate hydrologic (flood volumes) characteristics of a catchment.
runoff	for the purposes of this study the amount of rainfall which actually ends up as stream flow, also known as rainfall excess.
stage	equivalent to 'water level'. Both are measured with reference to a specified datum.
stage hydrograph	a graph which shows how the water level changes with time. It must be referenced to a particular location and datum.
stormwater flooding	inundation resulting from the incapacity of an urban stormwater drainage system to handle runoff.
survey plan	a plan prepared by a registered surveyor.
telemetry	the transmission of information by radio waves.
water surface profile	a longitudinal plot showing the flood stage at any given location along a watercourse.

SUMMARY

INTRODUCTION

Sutherland Shire Council, through its Floodplain Management Committee, is developing a Floodplain Management Strategy for the Woronora River floodplain. The objective of this Floodplain Management Study is to define the nature of the flood hazards and identify, assess and optimise strategies and measures aimed at reducing the impact of flooding on both existing and future development. A preferred strategy comprising a range of flood mitigation options will be developed into a Floodplain Management Plan for the Woronora River catchment.

Woronora River has a total catchment area of about 174 km^2 and is situated approximately 22 km south of the Sydney Central Business District. The Woronora River drains from south to north with Heathcote Creek, Forbes Creek and Still Creek being the major tributaries. The catchment is reasonably urbanised with some areas prone to frequent mainstream flooding.

Woronora Dam is a major feature of the catchment area supplying water to the Sutherland district, Allawah and Penshurst.

The study area comprises the areas fringing the 10.8 km length of the river from The Needles downstream to the Como Railway bridge (located immediately downstream of the confluence of the Georges River). Areas potentially affected by flooding include principally low-lying areas of Woronora and Bonnet Bay, and also a smaller proportion of river frontage properties in Lucas Heights, Bangor, Illawong and Como.

PREVIOUS FLOOD STUDIES

A flood study was undertaken for the study area in 1991 for Sutherland Shire Council. Flood levels were determined for 1%, 2% and 5% AEP (Annual Exceedance Probability) events, and also for an extreme event using computer models. A review of the 1991 flood study, conducted as part of the present study, validated the results of the study for the 1%, 2% and 5% AEP events, however the extreme event was found to be substantially lower in magnitude than the estimated Probable Maximum Flood determined using recently updated rainfall figures from the Bureau of Meteorology. Increases in flood levels of 1.1 to 1.9 metres over the extreme event are predicted for the Probable Maximum Flood event (6 hour rainfall duration). Thus the revised figures for the Probable Maximum Flood have been used in determination of flood hazard and flood damage calculations in this report where floods of extremely low probability are considered.

Examination of a flood analysis for Forbes Creek, a tributary of the Woronora, undertaken by NSW Public Works indicates that the predominant flood effects for properties in Woronora from 5%, 2% and 1% AEP events occur due to backwater effects from flooding on the Woronora River.

Construction of a new high level bridge over the Woronora River, 120 m downstream of the existing, commenced in late 1994. It was found that the bridge caused a localised increase in the 5%, 2% and 1% AEP flood levels by up to 0.03 m at the bridge and diminishing to zero within a distance of approximately 200 m upstream from the bridge.

SOCIAL AND ECONOMIC CONSIDERATIONS

As part of the Floodplain Management Study a community workshop was held in Woronora. A range of possible flood mitigation options was discussed at the workshop with a clear objective expressed of ensuring that the high environmental amenity of the valley was maintained. Issues of local concern raised included water quality, localised stormwater flooding problems, perceived increase in siltation due to new urban developments, the effect of the new Woronora Bridge on flood levels and general environmental issues.

A flood hazard assessment was carried out examining the 5% and 1% AEP events, and the Probable Maximum Flood (PMF). Areas of most severe flood hazard occur on the western foreshore areas of Woronora, the eastern foreshore area of Woronora near Prince Edward Park and Deepwater Estate.

Prior to European settlement the area was occupied by Aboriginal people for many thousands of years. European occupation commenced before the middle of the nineteenth century with initial development concentrated around the suburb of Woronora. An acceleration of urban development, principally on the surrounding plateau areas commenced in the mid 1960's and continues to the present day with current development activity focused on the Menai and West Menai area. Predominant land uses within the study area are either residential or open space (a large proportion of which is natural bushland) for passive recreation. The Sutherland Shire Local Environmental Plan (LEP) indicates that flood mitigation works are allowable for all of the zonings present in the study area.

Examination of property levels obtained from a survey undertaken by Sutherland Council indicates that for the 1% AEP flood, 323 properties would be flooded including 289 houses which would experience flooding above floor level. Above floor flooding has a much greater social impact due to loss or damage to possessions and because the entry of water may be perceived to be like an invasion of the property. The community can be affected by psychological and sociological problems following property flooding.

The estimated economic impacts of flooding for the existing development conditions are:

Average Annual Flood Damage	$ 509,000
Present Worth (50 yrs @ 7%) (see glossary)	$7,000,000

Approximately 95% of the economic impacts relate to residential property. Flood insurance is not available to most residences in NSW. Information from 1991 Census data showed approximately 10% of the Woronora community to have incomes below the 'poverty level'.

Management of emergency procedures during flood events is the responsibility of the State Emergency Service. Existing rainfall gauges within the catchment provide 2 to 3 hours warning of flooding. The SES are able to mobilise within 1 hour of receiving a flood warning. Difficulties are encountered during evacuation due to the spread out nature of the urban development within narrow bands on each side of the river. A number of properties, in particular on the eastern shore upstream of Woronora are accessible by boat or foot only. Another problem relates to early flooding of access roads, in particular Menai Road (at the western approach to Woronora Bridge) which floods on a king tide.

The estimated level of community preparedness for the local community is 30%. Community preparedness tends to decrease with time as people tend to not appreciate the severity of a flood unless they have experienced one. Since the last flood occurred in 1988, people have moved away from the area and new residents are less aware of the potential risk of flooding.

The existing Council flood standard for new residences and extensions is set at 0.5 m above the 1% AEP flood level. An economic assessment of benefits versus costs for new residences suggests that maximum economic advantage could be gained by having floor levels at least 0.5 m above the 1% AEP flood level and preferably within a range of 1 to 2 m above. However, consideration must be given to Council height restrictions, visual amenity and privacy where house raising is considered.

EXISTING ENVIRONMENT

The local environment of the study area is characteristic of Hawkesbury sandstone areas of Sydney. The natural vegetation is dry sclerophyll woodland or open forest. Mean Annual Rainfall varies from 1000 mm to 1400 mm from north to south over the catchment, and is strongly influenced by local topography. Modifications to the natural environment since European settlement have resulted from urban development, reclamation of tidal flats and mangrove swamps and dredging. Residents perceive that water quality has decreased with the increase in urban development.

Maintenance of flooding frequency and intensity is important in maintaining the natural environment including channel morphology and replenishment of nutrients for aquatic ecosystems and floodplain areas. The 1991 flood study indicates that Woronora Reservoir does not appear to substantially affect the magnitude of larger flood events due to typically high storage levels.

The Greenhouse effect is predicted to cause a rise of 200 to 1000 mm in sea level over the next 50 years. This would lead to a similar increase in downstream flood levels, gradually diminishing to no impact upstream. It is recommended that flood levels be reviewed when greenhouse effects can be predicted with a greater degree of certainty.

POSSIBLE FLOODPLAIN MANAGEMENT OPTIONS

Preliminary assessment of the following floodplain management options was undertaken to assess suitability for application to the Woronora River valley:

Non-structural

- Flood Forecasting System
- Community Preparedness Campaign
- Planning and Building Controls
- Voluntary Purchase
- Voluntary House Raising
- Flood Insurance Scheme
- Access Road Improvements

Structural

- Flood Mitigation Dam
- Modification to Waterway at Woronora Bridge
- Levees
- Dredging

The floodplain management options were assembled into seven management strategies by the study team in association with the Woronora River Floodplain Management Committee as described below.

FLOODPLAIN MANAGEMENT STRATEGIES

Strategy 1 : Base Case

This strategy does not reduce flood levels. It consists of a series of non-structural options which are generally of low cost and minimal environmental impact.

The major feature is an improved flood forecasting system which utilises telemetered weather stations and stream gauges to provide input to a computer model located at Sutherland SES headquarters. Combined with an additional weather station in the upper catchment it is predicted that the improved system would provide 5 to 10 hours warning of the critical 36 hour storm. The system could also be used to improve the existing bush fire warning system.

The base option also includes planning and building controls to prevent the loss or reduction of flood storage and floodway capacity, and to constrain development growth in flood affected areas. An allowance for voluntary purchase of properties in high hazard areas was examined, however, it was found that there were no houses suitable for voluntary purchase.

All other strategies include the base case components in combination with other management options, as follows:

Strategy 2: Base Case and Voluntary House Raising

This strategy includes allowance for raising the 179 single storey houses which are affected by over floor flooding for the 1% AEP flood event. This may be achieved by either addition of a second storey or by elevating the existing residence. The lower storey or underhouse area would then be available for non-habitable uses such as storage or garage space.

Strategy 3: Base Case and Access Road Improvements

Two options were examined. The first involves access road improvements in Woronora comprising raising of the low lying areas of Prices Circuit between Manilla Place and Yanko Close to RL 2.0 m, and an emergency access from Nundah Place to Menai Road on the western approach to Woronora Bridge. The second option involves the emergency access from Nundah Place to Menai Road without the raising of Prices Circuit.

Strategy 4: Base Case and Levee at Bonnet Bay

A levee has been considered to protect a residential area in the southern part of Bonnet Bay comprising Harrison Avenue, McKinley Avenue and Washington Drive. The levee would extend for 400 m along the eastern foreshore and 250 m along the northern boundary of Jannali Park with an average height of 0.7 m. This would provide protection up to the 1% AEP flood.

Strategy 5: Base Case and Woronora Bridge Raising

An evaluation has been made of raising the Woronora Bridge by up to 1.2 m to reduce the effect of the bridge deck on upstream flood levels. A decrease in flood levels of up to 0.26 m for 5%, 2%, and 1% AEP events is expected to occur at the bridge diminishing to zero at a distance of 6 km upstream of the bridge.

Strategy 6: Base Case and Dredging

Dredging of a 50 m wide channel along the length of the river from Zone 2 to 500 m downstream from the Needles (Figure 3.1) has been evaluated. Two options were considered. For a quantity of 250,000 m^3 of material, reductions in flood levels of 0.15 to 0.2 m are predicted in the vicinity of Woronora. For a quantity of 580,000 m^3 the reduction would be 0.3 m.

Strategy 7: Base Case and Levee on Western Foreshore at Woronora

A levee extending 550 m along the Western Foreshore from the Woronora Caravan Park to 250 m south of Woronora Bridge would protect the caravan park, Menai Road and residential properties in Woronora in the vicinity of Woronora Bridge from flooding. The recommended height for the levee would be at the 5% AEP flood level to provide a reasonable level of protection whilst minimising impacts on views for residences adjacent to foreshore areas.

RESULTS

The results of the economic analysis of the strategies are presented in the table below.

SUMMARY OF BENEFIT-COST ANALYSES

Strategy		Benefits	Marginal Benefits	Costs	Marginal Costs	Benefit-Cost Ratio	Marginal Benefit-Cost Ratio
1.	Base Case	$1.3 million	N/A	$0.2 million	N/A	6.94	N/A
2.	Base Case plus voluntary house raising	$3.6 million	$2.3 million	$8.0 million	$7.8 million	0.45	0.29
3(a).	Base Case plus road raising and emergency access	$1.4 million	$58,000	$0.55 million	$0.35 million	2.5	0.15
3(b).	Base Case plus emergency access	$1.3 million	*	$0.20 million	$5,000	6.76	*
4.	Base Case plus levee for Bonnet Bay	$1.3 million	-	$0.43 million	$0.24 million	3.10	-
5.	Base Case plus raising bridge	$2.3 million	$0.99 million	$1.7 million	$1.5 million	1.37	0.66
6(1).	Base Case plus dredging to -4 m	$2.1 million	$0.80 million	$4.0 million	$3.8 million	0.53	0.21
6(2).	Base Case plus dredging to -5 m	$2.9 million	$1.6 million	$9.1 million	$8.9 million	0.32	0.18
7(a).	Base Case plus levee on western foreshore (1% AEP)	$1.9 million	$0.55 million	$1.0 million	$0.8 3 million	1.83	0.66
7(b).	Base Case plus levee on western foreshore (2% AEP)	$1.8 million	$0.43 million	$0.85 million	$0.65 million	2.08	0.65
7(c).	Base Case plus levee on western foreshore (5% AEP)	$1.7 million	$0.35 million	$0.73 million	$0.54 million	2.23	0.66

* Benefits are social rather than monetary

Following further assessment by the Woronora River Floodplain Management Committee the following measures are recommended for consideration by the community:

(i) Strategy 1, comprising an improved flood forecasting system, community preparedness campaign, and planning and building controls.

(ii) Strategy 2, voluntary house raising to be made available as a measure where properties are not proposed for protection by a levee.

(iii) Strategy 3b, re-establishment of an emergency access from Nundah Place to Menai Road.

(iv) Strategy 7, construction of a levee on the western foreshore at Woronora to the 5% AEP level to protect the Woronora Caravan Park, Menai Road and residential properties up to 250 m south of Woronora Bridge.

It should be noted that Strategy 7 was not favoured by community representatives on the Floodplain Management Committee but had to be considered by Council as a possible strategy. The costs for this strategy would be substantially reduced from those listed in the above table if Council is able to provide the fill for the levee as excess from its works program.

1.0 INTRODUCTION

Sutherland Shire Council, through its Floodplain Management Committee, is developing a Floodplain Management Strategy for the Woronora River floodplain in accordance with the New South Wales Government's Floodplain Development Manual (PWD, 1986).

The Woronora River catchment falls within the area administered by Sutherland Shire Council, Campbelltown City Council, Liverpool Council and Wollongong City Council. Woronora Dam, is a major feature of the catchment area.

The Woronora River drains from south to north with Heathcote Creek, Forbes Creek and Still Creek being the main tributaries. The majority of the drainage systems are natural channels. In tidal areas the catchment is reasonably urbanised and parts of the catchment are prone to frequent main stream flooding.

Significant floods since 1930 have occurred in 1933, 1943, 1949, 1952, 1956, 1961 and 1988.

The Woronora River Flood Study was completed in August 1991. The study provided a computer model to identify and define flooding behaviour in the Woronora River floodplain from The Needles to the Georges River confluence.

In February 1994 Acer Wargon Chapman was commissioned by Sutherland Shire Council to undertake preparation of a Floodplain Management Study and Floodplain Management Plan. The purpose of the Floodplain Management Study is to analyse data from the 1991 Flood Study with regard to the physical, social, economic and ecological aspects of the floodplain to facilitate the preparation of a Floodplain Management Plan.

The objective of the Floodplain Management Study is to define the nature of the flood hazards and identify, assess and optimise strategies and measures aimed at reducing the impact of flooding on both existing and future development. Such information will enable Sutherland Council to formulate a Floodplain Management Plan for the Woronora River catchment, having regard to both existing flooding problems and to potential future development.

The course of the Floodplain Management Study was directed through regular meetings with the Woronora River Floodplain Management Committee. The Committee consists of representatives from Sutherland Shire Council, the local community, NSW Public Works, the Environment Protection Authority, the Soil Conservation Service and the State Emergency Service. The Floodplain Management Strategies assessed in Section 5.0 of this report were selected by the Committee following examination of a range of possible mitigation options.

The contents of each section of this document are briefly described below.

Section 2.0, Background. A general description of the Woronora River Catchment and a review of the 1991 Flood Study is given. The results of Community Consultation process conducted during the study are discussed.

Section 3.0, Existing Flood Behaviour. Social, Economic, Physical and Ecological aspects of the existing flood behaviour are described. Existing warning and evacuation practices are outlined and the existing flood standard reviewed.

Section 4.0, Floodplain Management Options. Possible floodplain management options for the Woronora River valley are outlined and assessed.

Section 5.0, Floodplain Management Strategies. Floodplain management strategies comprising combinations of options are assessed in detail and a preferred strategy outlined.

Section 6.0, Floodplain Management Plan. The contents of the Floodplain Management Plan are summarised.

2.0 BACKGROUND

2.1 CATCHMENT DESCRIPTION

The Woronora River is the largest tributary of the Georges River located within the large structural geological formation termed the Sydney Basin. The river has a catchment area of approximately 174 km^2 and joins the Georges River 10 km upstream of its entrance to Botany Bay (refer Figure 2.1 Locality Plan). The topography of the Woronora Valley is characterised by steep slopes of Hawkesbury Sandstone. At Woronora the valley is approximately 900 m wide between ridges with a valley floor width of 250 m (RTA, 1990). Localised flood plain areas have formed in areas of the valley, in particular on river bends in the estuary. The lower estuary is characteristic of a drowned river valley with the previous valley floor now buried under sand and silt deposited during the rise in sea level associated with the end of the last ice age 15,000 to 30,000 years ago (Branagan, 1993). The estuary is very shallow in parts with tidal flats evident in areas downstream of Forbes Creek. In the upper catchment areas above the tidal limit the valley contracts into a narrow gorge.

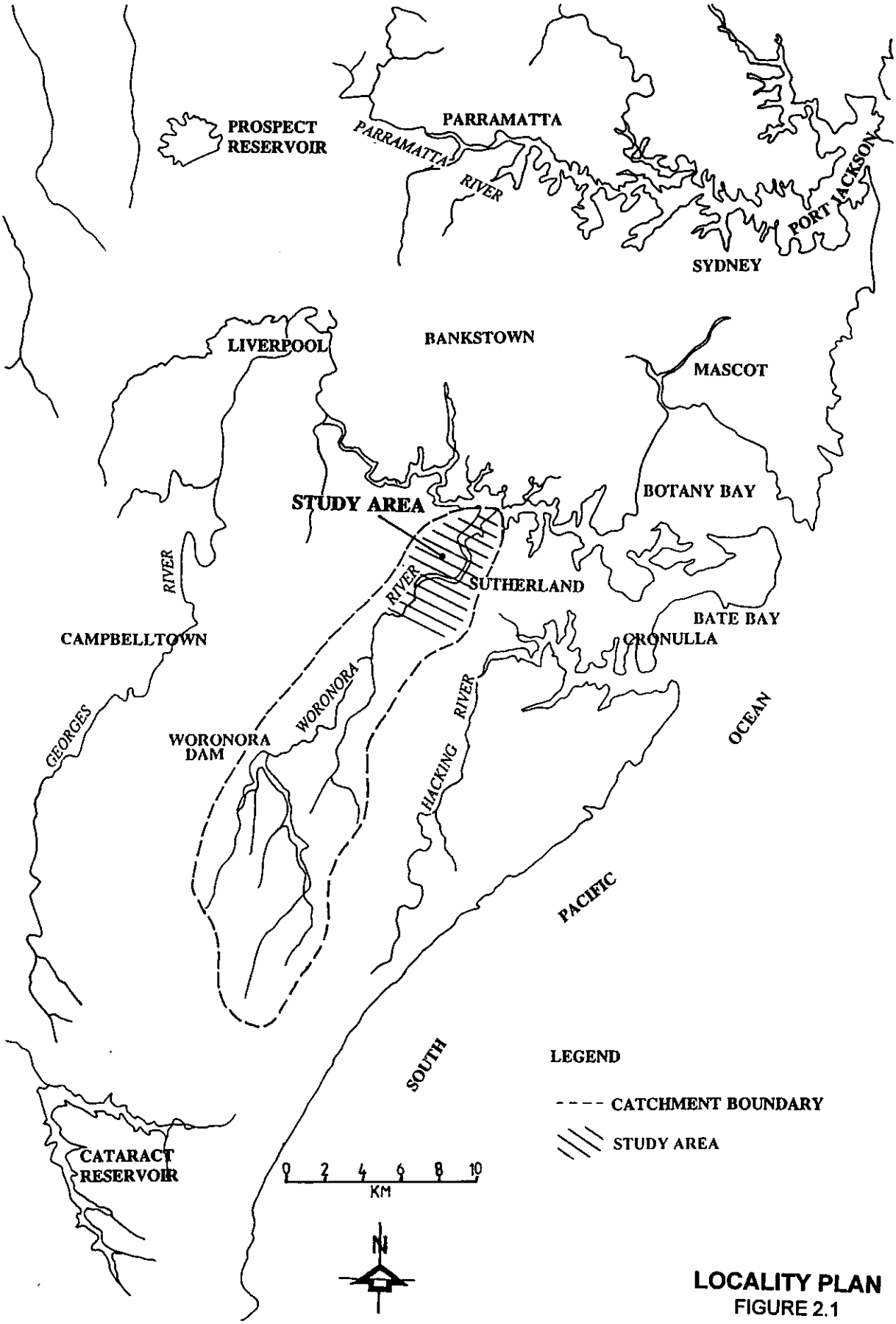
An important feature of the catchment is Woronora Dam which was completed in 1942. The dam is operated by the Sydney Water and supplies water to urban areas of Sutherland Shire, as well as Allawah and Penshurst located immediately north of the Georges River. The dam has a capacity of 71,790 ML with a maximum depth of 60 m. The catchment area controlled by the dam is 78.2 km^2 which represents 45% of the total catchment. The catchment area controlled by the dam represents the wetter portion of the catchment with mean annual rainfall varying between 1400 mm and 1200 mm compared to 1000 mm in the lower estuary.

A large proportion of the catchment is covered by natural bushland with urban areas restricted to the lower estuary either on plateau areas above the valley or floodplains and reclaimed land adjacent to the river. The study area comprises the areas fringing the 10.8 km length of the river from The Needles downstream to the Como Railway bridge (located immediately downstream of the confluence with the Georges River). Areas potentially affected by flooding include principally low-lying areas of Woronora and Bonnet Bay, and also a smaller proportion of river frontage properties in Lucas Heights, Bangor, Illawong and Como. Locations of features of interest within the study area are indicated in Figure 2.2.

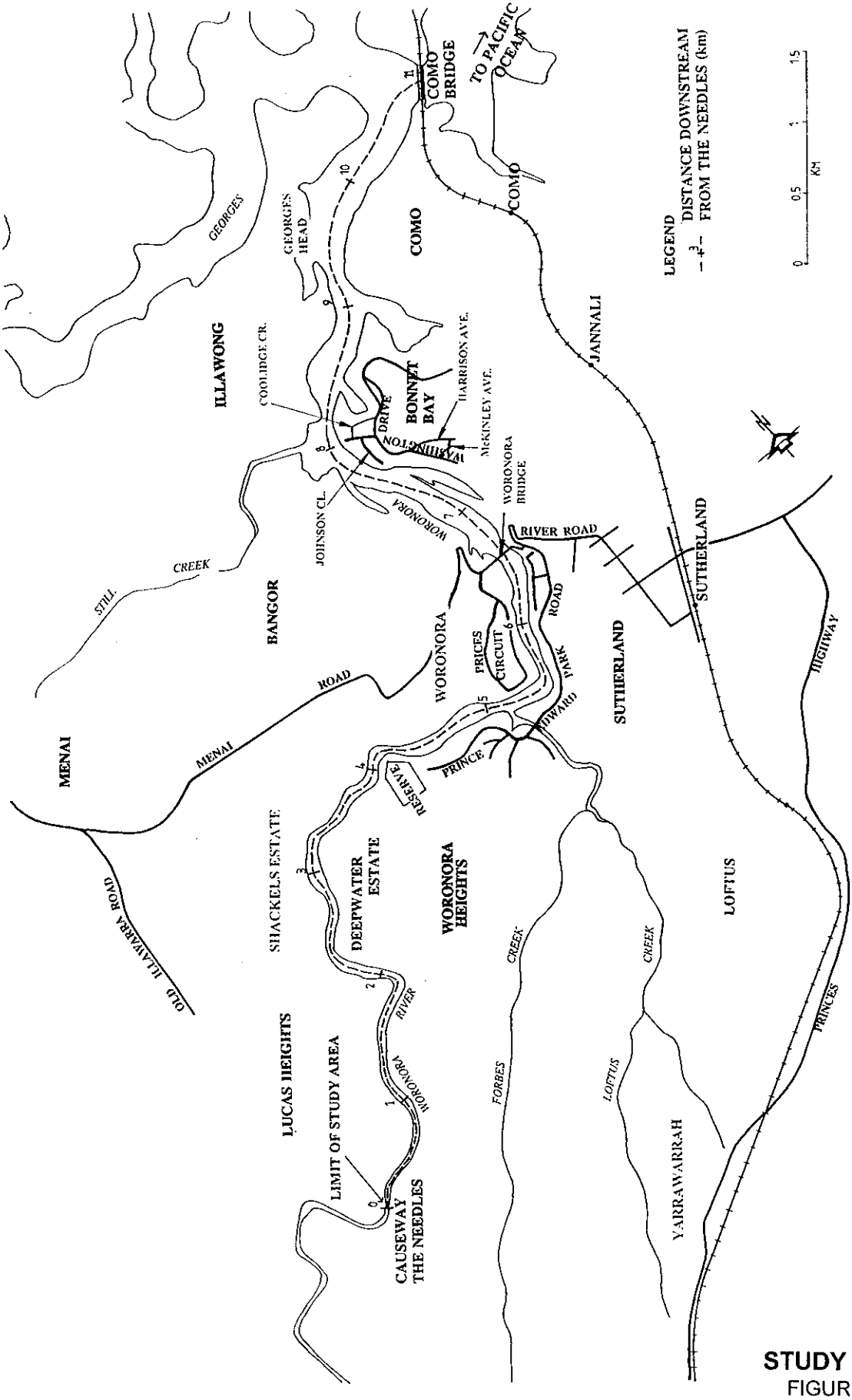
2.2 REVIEW OF PREVIOUS FLOOD STUDIES

2.2.1 Woronora River

A flood study of the Woronora River was undertaken by Sinclair Knight and Partners in 1991 on behalf of Sutherland Shire Council (Sinclair Knight, 1991). The study examined flooding along the 10.8 km stretch of the river from The Needles to Como Bridge considered in this report. Design levels were determined for 1%, 2% and 5% AEP (Annual Exceedance Probability) events, and also for an extreme event. A mathematical modelling approach was adopted using the computer programs RORB, for the hydrological analysis, and MIKE11 for the hydraulic analysis.



LOCALITY PLAN
FIGURE 2.1



STUDY AREA
FIGURE 2.2

Data sources used for the study included recorded flood levels, rainfall records, streamflow records, tidal measurements, and interviews with local residents. Nine historical rainfall-runoff events between 1933 and 1988 were simulated with the 1988 event used for calibration. The design flood levels are summarised in Table 2.1 below.

TABLE 2.1 WORONORA RIVER - DESIGN FLOOD LEVELS (Source: Sinclair Knight, 1991 and Tony Wong, 1994)

Location	1% AEP Flood Level (m AHD)	2% AEP Flood Level (m AHD)	5% AEP Flood Level (m AHD)	Extreme Flood Level (m AHD)	PMF Flood Level (m AHD)
Georges River (Como Bridge)	1.7	1.6	1.5	3.7	3.7
Bonnet Bay - Coolidge Crescent	2.8	2.6	2.3	5.2	6.0
Bonnet Bay - Harrison Avenue	3.0	2.8	2.5	5.5	6.5
Woronora Bridge - downstream	3.2	2.9	2.6	5.6	7.0
Woronora Bridge - upstream	3.4	3.1	2.8	5.9	7.0
Forbes Creek confluence	3.8	3.5	3.2	6.4	7.7
Shackles Estate	4.6	4.3	3.9	7.2	8.6
The Needles	6.7	6.3	5.8	10.1	12.0

It is noted that Woronora Dam was over 90% full for 18 of the 20 actual flood events considered in the report, and for the 1% AEP event a 10% depletion in capacity was found to cause a negligible reduction in peak streamflow. It was therefore concluded that flows for the 1% AEP event were generally not sensitive to variations in the water level for Woronora Dam.

Results of sensitivity analyses indicated a variation in flood levels of up to + or -0.5 m along the length of the river for changes in modelling parameters including channel roughness, higher Georges River flood levels, and higher bed levels.

A review of the 1991 flood study, conducted as part of the Floodplain Management Study, confirmed that the models used for the study were adequate and that the predictions made for flows, flood heights and velocities were reasonable.

A flood frequency analysis was carried out to check the statistical validity of the flood ranking adopted in the 1991 study. Flows for the 1% AEP flood were checked at two locations, being Woronora Dam and Engadine Weir.

Data at Engadine Weir are available for a 28 year period between 1924 and 1951. A flood frequency curve prepared using the 10 highest ranked floods indicated that the estimated 1% AEP discharge is 1000 m^3/s, which is consistent with the RORB predicted discharge of 974 m^3/s. A similar analysis for the period from 1933 to 1990

at Woronora Dam gave an estimated 1% AEP discharge of approximately 800 m^3/s, which is also consistent with the 820 m^3/s estimated by the RORB model.

The extreme flood event analysed in the 1991 flood study was based on a maximum 6 hour rainfall over the catchment of 447 mm as derived from Bureau of Meteorology Bulletin 51 (Bureau of Meteorology, 1984). This was reassessed in the present study using 1994 Probable Maximum Precipitation 6 hour rainfall figures of 600 mm supplied by the Bureau of Meteorology. The estimated flow at The Needles for the Probable Maximum Flood (PMF) based on these figures is 3940 m^3/s, which is substantially greater than the 2720 m^3/s calculated for the extreme event in the 1991 study. The increase in corresponding flood level over the extreme event is an average of 1.1 m with a maximum of 1.9 m in some areas (refer Table 2.1). The PMF has been adopted for use in the flood hazard and flood damage assessments in the present study (refer Sections 3.1 and 3.2) as its relatively larger value (compared with the previously assessed extreme event) would appear to provide a more reasonable assessment of the maximum flood event for the Woronora River (refer Figure 2.3).

2.2.2 Forbes Creek

Forbes Creek is a significant tributary of the Woronora River within the study area. The creek joins the Woronora River on the southern/eastern bank 5.7 km upstream of the Georges River.

A flood analysis was carried out in 1992 by NSW Public Works (PW, 1992) to compare the relative magnitudes and interaction between flood events on the Woronora River and flood events in the Forbes Creek catchment. The critical flood levels were found to occur from flooding on the Woronora River due to a 36 hour storm occurring over the entire catchment. The estimated flood levels 550 metres from the confluence (uppermost property on Thorp Road) with the Woronora River are:

1% AEP flood	3.9 m AHD
2% AEP flood	3.5 m AHD
5% AEP flood	3.2 m AHD

The critical storm duration for Forbes Creek catchment is only 2 hours. A 1% AEP two hour storm would give a flood level of 2.5 m AHD 550 m upstream from the Woronora River confluence assuming normal tidal levels. The coincidence of the peak from the two hour storm with a 36 hour 1% design flood on the Woronora River would give an estimated flood level of 4.0 m AHD at the same location.

It can therefore be seen that backwater effects from major floods on the Woronora River are the major influence for residential areas of Woronora adjoining Forbes Creek.

2.2.3 Effect of Proposed High Level Woronora Bridge

The Roads and Traffic Authority (RTA) proposes to construct a new high level bridge over the Woronora River at Woronora located approximately 120 m downstream of the existing bridge. The bridge would be approximately 32 m above water level supported on a total of seven piers located in the main channel and the floodway.

Concern has been expressed by a number of local residents that the bridge piers may substantially increase flood levels on the Woronora River.
To investigate the impact of the new bridge crossing, the bridge piers were incorporated into the original computer model used for the 1991 flood study and the model was re-run for the 5%, 2% and 1% AEP events. The new bridge piers were found to provide a localised increase in flood levels of up to 0.03 m. Predicted flood levels are therefore expected to be minimally affected by the construction of the new bridge.

Construction of the bridge pier caps is currently under way. A temporary rock fill causeway has been installed from the west bank to a distance of 110 m into the main channel to facilitate construction access. This has reduced the channel width to approximately 100 m in the vicinity of the bridge. At the request of the RTA, NSW Public Works assessed the effect of the temporary causeway on flood levels. It was found that the causeway caused a negligible increase in upstream flood levels. A culvert has been installed in the causeway to assist with local flow circulation. The causeway has been protected by geotextile fabric to minimise the possibility of erosion.

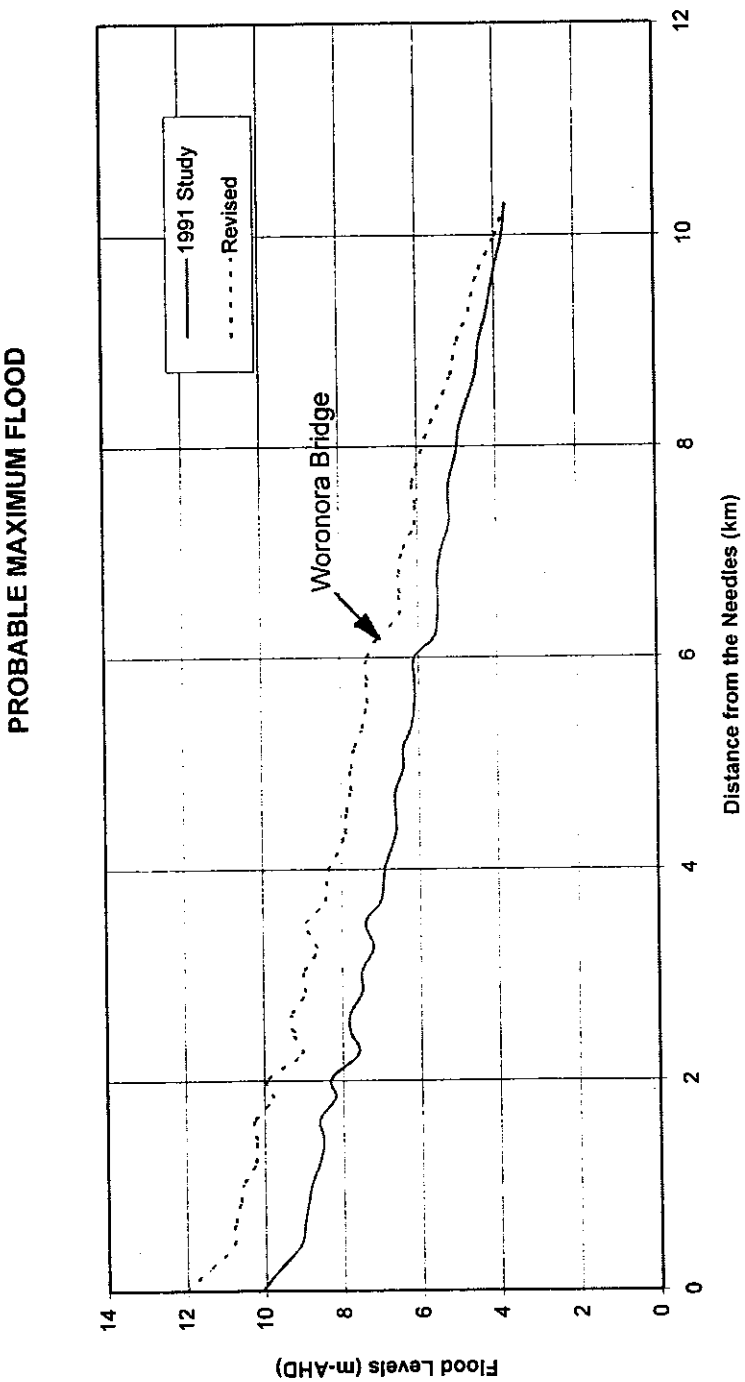
2.3 COMMUNITY CONSULTATION

Comments on floodplain management measures were sought from the local community in March - April 1994 through local newspaper advertisements and posters at public locations.

Relevant government agencies were contacted and comments sought regarding the study. A brief summary of the agencies consulted is included in Appendix A.

A community workshop was held at the Lifesavers Hall, Prince Edward Park, Woronora on 30 April, attended by 39 people including local residents, a Councillor, Council staff and representatives from local businesses. At the workshop members of the study team introduced the study and an interactive discussion was conducted to identify issues of concern and the attitude of the community to possible floodplain management measures.

A dedicated telephone line at Acer Wargon Chapman's Sydney office was arranged for other comments and queries in relation to the proposal. Comments from each caller were recorded. During the period of the study two telephone calls and four written submissions were received. Copies of the written submissions are reproduced in Appendix B.



FLOOD PROFILE FOR REVISED PMF
FIGURE 2.3

The response from the community indicated a generally low level of concern regarding possible flooding. As large floods have only occurred sporadically over the last 50 years many newer residents were surprised at the levels quoted in the 1991 flood study.

Specific matters on which concern was expressed were:

(i) Perceived poor water quality in the river. It was felt that floods assisted in flushing pollutants from the estuary.

(ii) Localised flooding problems from perceived inadequate stormwater drainage, and increased runoff from new urban areas on surrounding plateaus, eg Woronora Heights.

(iii) A perceived increase in siltation of the river and Forbes Creek in recent years. Navigation of the river upstream of Woronora was noted to be difficult at low tide. This had caused some problems with evacuation of residents during the January 1994 bushfires. Dredging was suggested as having a dual advantage in reducing flood levels and improving access.

(iv) The effect of the proposed new high level Woronora Bridge on existing flood levels.

(v) Erosion of river banks, thought to be caused by wash from motor boats.

(vi) Effect of proposed increase in draw off from Woronora Dam as discussed in the Sydney Water EIS for the Woronora Water Filtration Plant.

(vii) Suggestion of a flood mitigation dam to be incorporated into a possible future duplication of Heathcote Road.

(viii) Levees were not generally favoured in Woronora due to visual impact.

(ix) Access roads are often the first areas to be flooded, in particular Menai Road, Prices Circuit, Liffey Place at Woronora and Washington Drive at Bonnet Bay.

(x) Effects of flash flooding along Forbes Creek for residences in Thorp Road.

(xi) Dead or fallen trees should be removed from river banks to improve capacity of the river channel.

3.0 EXISTING FLOOD BEHAVIOUR

3.1 HAZARD ASSESSMENT

Flood hazard assessment has been carried out for properties affected by flooding of the Woronora River according to the provisional hazard categories contained in the NSW Government Floodplain Development Manual (PWD, 1986). In the provisional guidelines contained in the manual, flood hazard is categorised as either "Low" or "High" and is based on assessment of the combined effects of flow velocity and depth of inundation. Areas with flood depths as high as 0.8 m, in the absence of any significant flow velocity, are categorised as Low Hazard. Similarly, areas of flow velocities of up to 2 m/s but with minimal flood depth are also categorised as Low Hazard. In areas where flood depths exceed 1 m, they are categorised as High Hazard regardless of flow velocity. Some discretion is applied in the present assessment to take land use into account.

A total of 15 general locations were identified as subject to some degree of flood hazard and the assessment was based on the 5% and 1% Annual Exceedance Probability (AEP) and Probable Maximum Flood events. Table 3.1 lists the categories assigned to the 15 locations. For the 5% AEP event, 9 of the 15 locations were assigned a Low Hazard rating. The six areas assessed as being of High Hazard were located in Woronora (Caravan Park at Menai Road, Prices Ct, Thorp Road, Prince Edward Park Road, public reserve at Prince Edward Park Road and foreshore areas at the Deepwater Estate).

For the 1% AEP event, a further two areas were categorised into the High Hazard Category, ie. Wilson Place, Johnson Close and Washington Drive, Bonnet Bay, and Liffey Place, Thames Street and Prince Edward Park Road, Woronora.

For the Probable Maximum Flood, all areas except Illawong are categorised as High Hazard owing to excessively high flood depths and flow velocities.

Below is a provisional ranking, in order of flooding hazard, of the areas identified as subject to high hazard flooding for the 1% AEP event.

(i) Foreshore area along Thorp Road and Prince Edward Park Road, Woronora

(ii) Prices Circuit in the vicinity of Yanko Close, Boomi Place and Manilla Place, Woronora

(iii) Foreshore area at the Deepwater Estate, Woronora

(iv) Foreshore area at Menai Road (Caravan Park), Woronora

(v) Foreshore area along Prices Circuit in the vicinity of Woronora Bridge, Woronora

TABLE 3.1 PROVISIONAL FLOOD HAZARD ASSESSMENT

Location	5% AEP Event	1% AEP Event	PMF
Foreshore Areas in Como - Central Avenue, Bonnet Avenue, Wigens Avenue	**Low Hazard** Floodwater well confined in channel. Some possible damage to dwellings.	**Low Hazard** Floodwater well confined in channel. Some possible damage to dwellings.	**High Hazard** Floodwater well confined in channel but significant damage to some dwellings likely.
Foreshore Areas in Illawong - Bignell Street, Fowler Road, Kinsela Street, Sproule Road, Hector Street	**Low Hazard** Floodwater well confined in channel. Some possible damage to dwellings.	**Low Hazard** Floodwater well confined in channel. Some possible damage to dwellings.	**Low Hazard** Floodwater well confined in channel. Some possible damage to dwellings.
Foreshore Areas along Arthur Place and Lower Washington Drive - Bonnet Bay	**Low Hazard** Floodwater well confined in channel Some possible damage to dwellings.	**Low Hazard** Floodwater well confined in channel. Some possible damage to dwellings.	**High Hazard** Floodwater well confined in channel but significant damage to some dwellings likely.
Coolidge Cresc, Washington Drive - Bonnet Bay	**Low Hazard** Public reserve inundated up to 0.1 m with velocity of 0.1 m/s	**Low Hazard** Public reserve inundated up to 0.6 m with velocity of 0.3 m/s	**High Hazard** Flood inundation of properties between Coolidge Crescent and Washington Drive
Wilson Place, Johnson Close, Washington Drive - Bonnet Bay	**Low Hazard** Residential area inundated up to 0.4 m with velocity of up to 0.1 m/s	**High Hazard** Residential area inundated up to 0.9 m with velocity of up to 0.2 m/s	**High Hazard** Flood inundation of up to 4.1 m
Washington Drive, Harrison Avenue, McKinley Avenue - Bonnet Bay	**Low Hazard** Public reserve and properties along Washington Drive affected with flow depth of up to 0.1 m and velocity of up to 0.3 m/s	**Low Hazard** Public reserve and properties along Washington Drive affected with flow depth of up to 0.6 m and velocity of up to 0.3 m/s. Properties along Harrison Avenue and McKinley Avenue area less severely affected.	**High Hazard** Flood inundation of up to 4.0 m
Jannali Reserve	**Low Hazard** Recreation area inundated up to 0.3 m with velocity of up to 0.6 m/s	**Low Hazard** Public reserve inundated by up to 0.8 m with velocity of 0.7 m/s. Low Hazard assigned based on existing land use.	**High Hazard** Flood inundation of up to 4.1 m.

Location	5% AEP Event	1% AEP Event	PMF
Foreshore Areas at Menai Road (Caravan Park) - Woronora	**High Hazard** Residential area inundated by up to 0.9 m with velocity of up to 0.6 m/s.	**High Hazard** Residential area inundated by up to 1.5 m with velocity of up 0.9 m/s	**High Hazard** Flood inundation of up to 5.1 m.
Liffey Place, Thames Street, Prince Edward Park Road - Woronora	**Low Hazard** Residential area inundated up to 0.9 m with velocity of up to 0.2 m/s	**High Hazard** Residential area inundated up to 1.5 m with velocity of up to 0.2 m/s	**High Hazard** Flood inundation of up to 5.2 m.
Prince Edward Park Road in the vicinity of Forbes Creek (Life Saving Club & Public Reserve) - Woronora	**High Hazard** Public reserve inundated by up to 2.0 m with velocity of 0.7 m/s.	**High Hazard** Public reserve inundated by up to 2.7 m with velocity of 0.8 m/s.	**High Hazard** Flood inundation of up to 6.4 m.
Prices Circuit in the vicinity of Woronora Bridge - Woronora	**High Hazard** Residential area inundated up to 1.1 m with velocity of up to 0.2 m/s	**High Hazard** Residential area inundated up to 1.7 m with velocity of up to 0.3 m/s	**High Hazard** Flood inundation of up to 5.4 m.
Prices Circuit, Yanko Close, Boomi Place, Manila Place - Woronora	**High Hazard** Residential area inundated up to 1.6 m with velocity of up to 0.2 m/s	**High Hazard** Residential area inundated up to 2.2 m with velocity of up to 0.3 m/s	**High Hazard** Flood inundation of up to 6.0 m.
Foreshore Area along Thorp Road and Prince Edward Park Road - Woronora	**High Hazard** Residential area inundated up to 1.9 m with velocity of up to 0.4 m/s	**High Hazard** Residential area inundated up to 2.6 m with velocity of up to 0.4 m/s	**High Hazard** Flood inundation of up to 6.2 m.
Deepwater Estate	**High Hazard** Residential area inundated up to 1.7 m with velocity of up to 0.6 m/s	**High Hazard** Residential area inundated up to 2.4 m with velocity of up to 0.9 m/s	**High Hazard** Flood inundation of up to 6 m
Shackels Estate in Lucas Heights	**Low Hazard** Floodwater well confined in channel. Some possible damage to dwelling.	**Low Hazard** Floodwater well confined in channel Some possible damage to dwelling.	**High Hazard** Floodwater well confined in channel but significant damage to some dwellings likely.

(vi) Life saving club and public reserve in the vicinity of the Forbes Creek confluence, Woronora

(vii) Liffey Place, Thames Street and Prince Edward Park Road, Woronora.

(viii) Wilson Place, Johnson Close and Washington Drive, Bonnet Bay

3.2 SOCIAL IMPACTS

3.2.1 Preamble

The earliest inhabitants of the Woronora Valley were Aboriginal people who are believed to have inhabited the Sydney Basin for at least the last 50,000 years. An archaeological survey undertaken for the proposed high level road bridge at Woronora noted 38 archaeological sites in the Woronora area including open middens, shelters with art and axe grinding grooves (Navin and Dallas, 1990).

European settlement commenced prior to the middle of the nineteenth century. A farm was established on the western shore of the Woronora River in 1861 near to the present road bridge. In the late nineteenth and early twentieth centuries the valley became increasingly popular for day trippers from Sydney and the suburb of Woronora became established with many small weekenders built. The area was also popular with retirees at this time.

Residential development accelerated from the mid 1960's onwards with the development of plateau areas. This development is continuing today with a strong population growth and a high proportion of young families in the area. As land becomes increasingly valuable many older properties are being redeveloped, some of these as dual occupancies.

3.2.2 Zoning and Land Use

Urban development within the study area encompasses the suburbs of Lucas Heights, Menai, Bangor, Woronora Heights, Woronora, Bonnet Bay, Como and Illawong (refer Figure 2.2). Properties potentially affected by flooding are located predominantly in Woronora and Bonnet Bay with a smaller number of isolated foreshore properties along the length of the river.

The focus for current residential development is the Menai area on the plateau immediately west of Woronora. Future housing releases have been planned for the West Menai area located to the west of Old Illawarra Road. However, Council's position on this development is that it has been deferred due to environmental considerations.

Zonings and associated land uses in the study area are described below:

1(a) Rural

Applies to land fronting the western foreshore of the Woronora River upstream of Woronora. This area is generally only partially developed with a few older residences surrounded by native bushland. The remaining properties are gradually being acquired as Crown Land.

2(a1) Residential

Residential areas of Woronora generally away from foreshore area characterised by one or two storey detached dwellings. Also applies to waterfront properties in the area known as Deepwater Estate upstream of Forbes Creek.

2(e1) and 2(e2) Residential

Residential areas in environmentally sensitive localities. This applies to the majority of water frontage properties in the study area. These areas are characterised by large residential lots and remnant bushland. Zoning 2(e2) is restricted to Illawong off Fowler Road.

3(b) Neighbourhood Business

Applies to isolated business zones for local shops.

5(a) Special Uses

Woronora Public School, Scout Hall and Community Uses at Bonnet Bay.

5(c) and 5(d) Special Uses (Future Arterial Road)

Road reservation for new high level Woronora Bridge approaches.

6(a) Public Recreation

Passive recreation areas along much of river foreshore areas. Many areas contain natural bushland.

6(b) Private Recreation

RSL Club

7(a) Environmental Protection (Waterways)

Applies to the Woronora River. It should be noted that maintenance dredging of Maritime Services Board navigation channels does not require development consent in this zone.

7(b) Environmental Protection (Bushland)

Applies to natural bushland areas protected from development occurring on the eastern foreshore immediately downstream of the Needles, Jannali Reserve and much of the Still Creek and Forbes Creek catchment areas.

Foreshore building lines (measured from mean high water mark) of 10 m to 30 m have generally been adopted. Development is restricted in these areas to boat sheds, swimming pools/enclosures, landscaping and barbecue areas, jetties and boat launching facilities.

Residential height limitations are set at 7.2 m to any point of the uppermost ceiling and 9.0 m to the highest point on the roof.

Clause 35 of the Model Provisions, 1980 (Sutherland Council, 1993) indicates that nothing in the LEP can restrict the carrying out of various activities in the public interest including flood mitigation works.

Following from the 1991 flood study, flood affected properties are identified on S149 certificates available upon request from Council. An interim flood policy of 0.5 m minimum freeboard above the 1% AEP flood level for habitable floors and at the 5% AEP level for non-habitable areas has been adopted for new residences or alterations. This flood policy is reviewed in Section 3.6 of this document. Dual occupancies are currently discouraged on flood affected properties as is any other alteration or construction that may lead to a reduction in the capacity of the floodway. A sample of typical S149 certification is provided in Appendix C of this document.

3.2.3 Demographic Overview

Examination of 1991 census data for households near to the Woronora River indicates that there is a large proportion of traditional two parent families in the area. This is supported by the age profile statistics where there are peaks at 0-19 years of age (approximately 30% of total) and 30-49 years of age (approximately 35% of total). The large number of children has implications for the effect of flooding on the community (refer Section 3.2.4 for more detail).

The majority of households have an annual income in the $40,000-$50,000 range. The threshold incomes for the "poverty line" are around $21,000 for a family of 4 and $17,000 for a family of 3 which would represent approximately 10% of the Woronora community. This would indicate that a high proportion of the population could have sufficient resources to recover from a flood.

Families on low incomes would, subject to a means test, qualify for flood relief available from the NSW Department of Community Services. Relief may then be made available to enable the housing of victims affected by flooding to be restored to a basic level.

Flood insurance is not available to most residences in NSW.

3.2.4 Social Impacts of Flooding

In addition to economic losses flooding can lead to significant social impacts and disruption.

In two surveys of the social impacts of flooding (Lustig & Haeusler, 1989), it was found that householders suffered both physical (30% of households) and mental health problems (50% of households).

These physical effects were experienced especially when there was some pre-existing condition.

Other more psychological or sociological problems included irritability and nervousness. Alienation was also felt by some members of some families which had a further effect upon the household. There were also incidents of domestic violence directly attributable to flooding. The academic standard of some children decreased after flooding, and in one case this led to a child becoming argumentative and attempting to run away several times.

Obsessive behaviour was also shown by some individuals: in one instance a husband insisted on lifting the furniture during even the slightest storm. There was also strain placed upon family relationships through increased intolerance being experienced by some individuals and also through some parents feeling that they no longer had anything worthwhile to pass on to their children. Some people also felt guilty when engaging in enjoyable activities.

Many people who were flooded became very anxious when it rained, so much so that they could not enjoy holidays away from home for fear that it may flood while they were away. Also many young children continued to suffer anxiety whenever it rained and could not stand to be left alone during even minor storms.

From the studies of residents who were flooded in Sydney in 1986 and 1988, it was found that the residents were much worse affected when the floodwater entered the house, than when the flood only covered the ground outside, even when the damage to items outside the house was substantial. This is apparently in part because the entry of the water appears like an invasion of their property, and in part because personal items such as family photographs may be lost. Such losses are frequently regarded by the residents as being worse than the monetary ones. It is assumed from this that the number of households flooded can often be a useful index of the social impacts of flooding.

3.2.5 Properties Affected by Flooding

Floor levels of residences for properties affected by the 1% AEP flood were surveyed by Sutherland Council from February to March 1994. Table 3.2 sets out the number of houses which experience flooding over the ground and of those, the number that also experience flooding over the floor for different floods.

TABLE 3.2 PROPERTIES AFFECTED BY FLOODING

AEP Design flood	Houses with Flooded Yards	Houses Flooded Above Floor
5%	246	200
2%	283	254
1%	323	289
PMF	503	497

It should be noted that the number of properties which experience flooding over the ground may be greater than indicated in Table 3.2 because the surveyed ground heights at each house may not be the lowest point of the property.

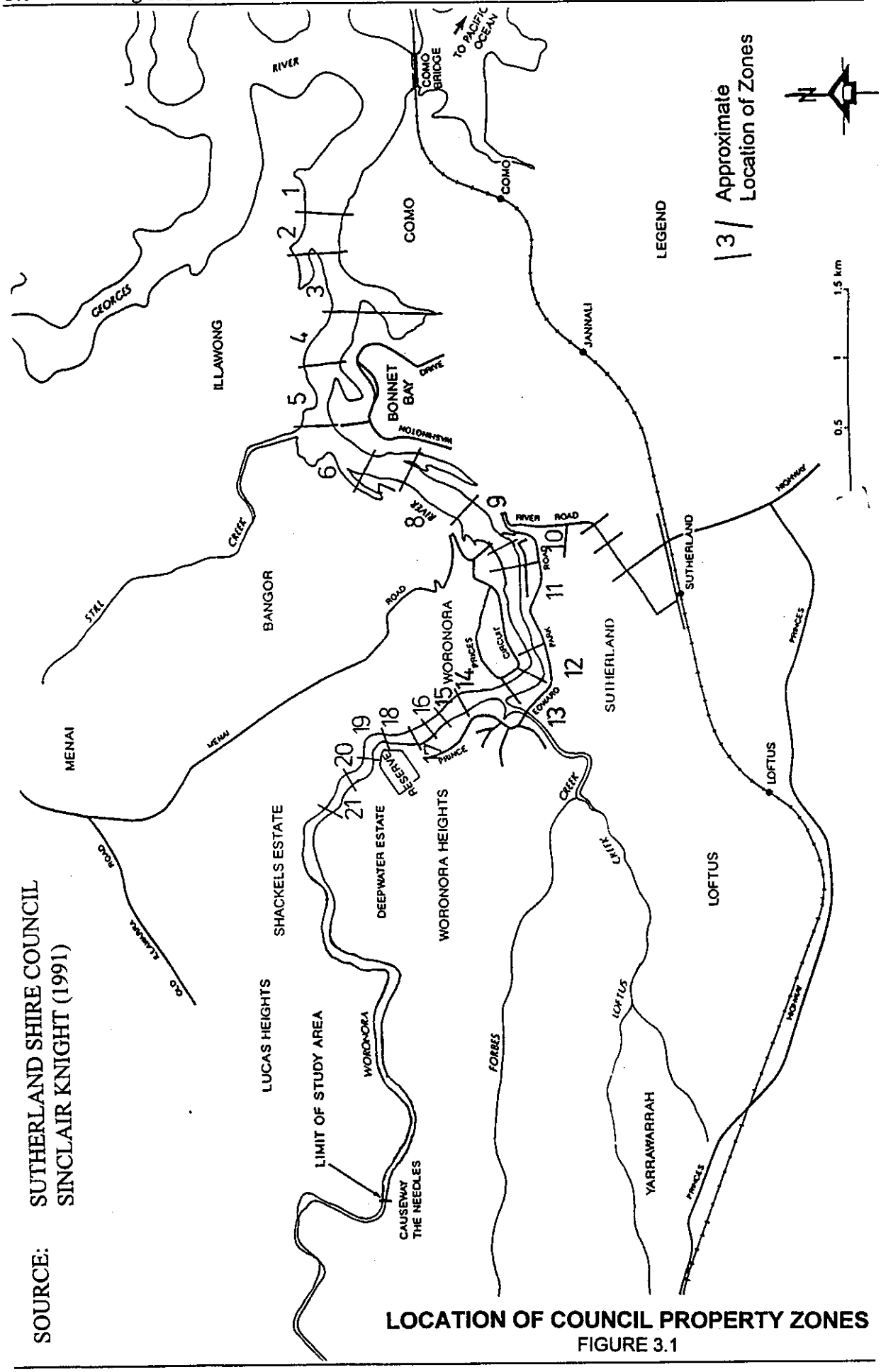
The properties in the Woronora floodplain have been allocated to 21 zones by Council as shown in Figure 3.1.

In order to determine appropriate strategies for the river, it is useful to consider these zones in small groups, since the range of flood levels varies substantially between the upstream and downstream zones as indicated in Figures D1 to D8 in Appendix D and Table 3.3.

TABLE 3.3 AVERAGE FLOOD LEVELS IN PROPERTY ZONES ALONG WORONORA RIVER (m AHD)

Zone	5% AEP Flood Level	2% AEP Flood Level	1% AEP Flood Level	Probable Maximum Flood
1-2	1.5	1.6	1.8	4.2
3-4	1.8	2.0	2.3	5.2
5-7	2.3	2.5	2.8	6.0
8-9	2.5	2.8	3.1	6.6
10-12	3.0	3.3	3.6	7.4
13-15	3.3	3.6	3.9	7.9
16-18	3.6	3.9	4.2	8.3
19-22	3.9	4.3	4.6	8.8
23-26	4.4	4.7	5.1	9.3
27-29	4.8	5.2	5.6	10.1

Note: Flood levels averaged over sets of zones to nearest 0.1 m.



LOCATION OF COUNCIL PROPERTY ZONES
FIGURE 3.1

Figure 3.2 shows the distribution of floor levels relative to the water levels for different floods. It can be seen that the major flooding problems are in Zones 10-15 (Prince Edward Drive and Prices Circuit area). A significant number of properties are marginally above the 1% AEP flood level in Zones (5-7) (Wilson Place, Washington Drive, Johnson Place, Bonnet Bay) and Zones (8-9) (Washington Drive, Harrison Avenue, McKinley Avenue, Bonnet Bay.

A majority of flood-prone houses in Zones 10-21 have floors below the 5% AEP flood level, and could normally be expected to be well aware of the flooding problem.

In general therefore, people around the Bonnet Bay and Woronora Bridge areas will be subject to reasonably frequent floods, and would normally be expected to be reasonably prepared for a flood. However, many residents have moved to these areas in the last 10 years and have not experienced a significant flood.

3.2.6 Woronora Caravan Park

The Woronora Caravan Park is located on the western foreshore of the river immediately north of the Woronora Bridge. There are presently 35 caravans and 5 cabins in the Woronora caravan park, all of which are occupied permanently.

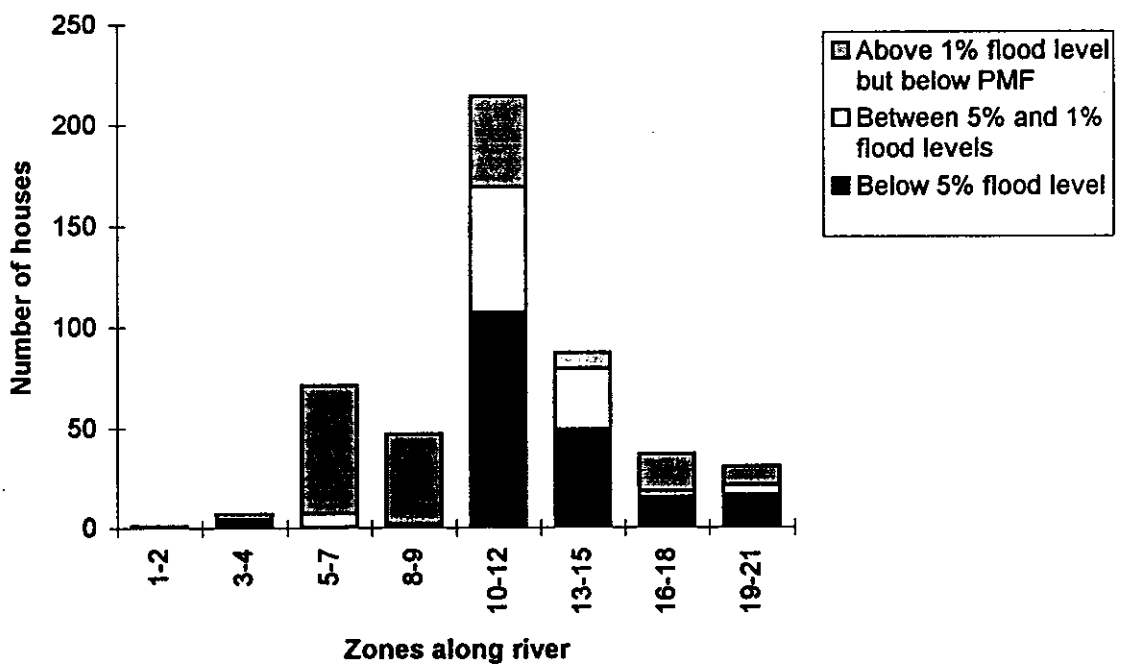
Some 82 people live on the caravan site on a permanent basis. Of the 35 caravans located on the site approximately 20 are tenanted with rents predominantly being between $78-$137 (1991 figures). It is reasonable to assume that many of the residents renting caravans are on lower than average incomes.

The site is extremely flood-prone, being even subject to flooding on king tides.

In the last flood, there was considerable difficulty in moving the caravans, and for this reason, the current plan of the SES for the caravan park is to evacuate only the people and not the caravans.

In a 5% AEP flood, it is likely that most caravans would be destroyed. Thus, practically all possessions would be lost. Given the susceptibility of the caravan site to flooding and the likely total loss to residents it can be forecast that the social impact of a flood on these residents would be substantial. It is also likely that, should severe flooding occur, residents would be unwilling and in many cases unable to move back to this site, resulting in further dislocation from social networks.

The NSW Department of Community Services assists those who have suffered damage or loss of accommodation in floods and other disasters. The assistance is however provided subject to a means test and consists of repairing what has been damaged or replacing what has been lost. In the instance where an entire caravan has been destroyed then they would replace the caravan with one of a similar age. It is possible that if there was a Public Appeal then that money may be available to those people affected, however this is not an event that can be generally expected.



DISTRIBUTION OF HOUSE FLOOR LEVELS
FIGURE 3.2

Department of Local Government Technical Bulletin No. 6 provides guidelines on the application of floodplain management practices to Caravan Parks. Relevant recommendations pertaining to the Woronora Caravan Park are:

(i) Preparation of a Flood Action Plan;

(ii) Installation of tie downs to prevent flotation of caravan and annexes during flooding.

3.3 ECONOMIC IMPACTS

3.3.1. Assumptions

The following assumptions have been made in estimating the economic impacts.

(i) The onset of significant flood damage is assumed to occur at the 20% AEP flood.

(ii) The ground levels for swimming pools were assumed to be the same as the ground levels of the residence in the same properties. However for steeply-sloping blocks, the ground levels were modified using orthophoto maps.

(iii) All of the items designated as "improvements" in the survey database were omitted, as they were all above the flood levels.

(iv) Ground levels were estimated from orthophoto maps, which have a 2 m contour resolution and can have errors of up to one metre. If ground level was not known then an underfloor space of 0.5 m was assumed for flood damage calculations. This is reasonable for houses which have no underfloor space (eg slab-on-ground construction) as the damage estimates account for losses on the property outside the house. The floor levels of a few residences which could not be surveyed were estimated from orthophoto maps as the surveyor was unable to obtain access.

(v) The data on houses which could not be surveyed contained no information on construction material or number of storeys. These houses were assumed to be of similar size and construction to neighbouring houses.

(vi) Damage classes were assigned to houses from field survey information where possible. Where no information was available, new housing developments and brick or stone houses were classed as having medium to high value. Fibro, wood and iron houses were classed as medium to low value.

(vii) Boat sheds were not included in the estimates, as anecdotal evidence indicates that the losses from boat sheds are normally small. Boats would generally be privately insured.

(viii) Flood damage to garages was assumed to be included in underfloor house damage, and allowance was made for this in the residential flood damage curve.

(ix) Based on local experience, the caravan park near Woronora Bridge was assumed to suffer flood damage from a 5% AEP flood event.

(x) Based on advice from the SES it was assumed that no caravans would be moved from the caravan park, even if a flood warning was received. The caravans are occupied permanently, and experience elsewhere indicates that many owners may not keep their caravans roadworthy.

(xi) Unless stated otherwise, strategies which included the Base Case assumed that the flood losses would be reduced by 20% because of the improved flood warning system. Consequently, any benefits, which were essentially reductions in damage, were also assumed to be reduced by 20%.

(xii) There were no benefits assumed for swimming pools or caravans for non-structural strategies.

The residential stage damage relationships used are given in Table 3.4 below and are reproduced in Appendix E. These have been derived from statistical analysis of damage given in previous studies.

Six major groups of stage-damage curves have been adopted. They consist of curves for both one-and two-storey houses.

Previous studies undertaken indicate that a two-storey house has of the order of 50% more possessions than a single storey house, and that these possessions are equally distributed between the two floors. It is also assumed that 1.8 m in a single storey house is the height to which most possessions would be raised in response to a flood warning. Once this level is exceeded most of the contents would be lost, therefore losses between 1.8 m and the ceiling (taken as 2.5 m above the floor) of a one-storey house represent the total value of house contents.

For two-storey houses it is assumed that the majority of possessions are moved to the upper floor and that once the water level reaches the second storey that losses are experienced, strictly speaking maximum losses should occur at this time however this study has adopted conservative estimates of damage.

It has also been assumed that the velocities of the flood flows will not be so high as to cause houses to be washed away.

There are three damage classes - low, medium and high. This subjective classification of damages is determined by the quality of the residence construction material, the level of building maintenance and the size of the residence. For example, a small unpainted fibro cottage would be a low damage class, while a large, well maintained brick house would be a high damage class.

TABLE 3.4 RESIDENTIAL STAGE - DAMAGE RELATIONSHIP (1991 DOLLARS)

	1 storey low	1 storey med	1 storey high	2 storey low	2 storey med	2 storey high
Maximum under house damage	$500	$1,500	$2,500	$500	$1,500	$2,500
Height of flooding above floor (m)						
0	$721	$2,038	$4,680	$541	$1,529	$3,510
0.1	$1,443	$4,076	$9,358	$1,082	$3,057	$7,019
0.6	$5,873	$11,140	$20,202	$4,405	$8,355	$15,152
1.5	$13,849	$14,810	$25,721	$10,387	$11,108	$19,291
1.8	$14,060	$15,036	$26,113	$10,545	$11,277	$19,584
2.5	$33,660	$36,000	$62,280	$25,245	$27,000	$46,710
2.6	$33,660	$36,000	$62,280	$26,327	$30,057	$53,729
2.8	$33,660	$36,000	$62,280	$27,658	$32,176	$58,982
3.1	$33,660	$36,000	$62,280	$29,850	$35,355	$81,862
4	$33,660	$36,000	$62,280	$35,632	$38,108	$88,001
4.3	$33,660	$36,000	$62,280	$35,790	$38,227	$88,294
5	$33,660	$36,000	$62,280	$50,490	$54,000	$93,420

3.3.2. Existing Losses

Table 3.5 shows the estimates of existing losses in the Woronora floodplain. It can be seen that a substantial proportion of the losses up to the 1% AEP level are incurred for floods below the 5% AEP level. This indicates that strategies to reduce damages for the most flood-prone properties may be economically justified.

TABLE 3.5 FLOOD LOSSES FOR EXISTING DEVELOPMENT CONDITIONS

Flood AEP	Residential losses	Commercial losses
20%	$0	$0
5%	$2,200,000	$160,000
2%	$3,100,000	$190,000
1%	$4,500,000	$220,000
PMF	$24,500,000	$980,000
Av. Annual Damage	$480,000	$29,000
Present Worth (50 yrs @ 7%)	$6,600,000	$400,000

Note: Table includes losses for indirect damage, at 5% for residential and 55% for commercial.

3.4 ENVIRONMENTAL IMPACTS

3.4.1 Existing Environment

As indicated in Section 2.1, the topography of the study area is characteristic of Hawkesbury Sandstone country found in much of Sydney comprising a steep sided gorge with a shallow cover of low nutrient highly erodible soils.

The Woronora valley experiences a temperate climate typical of the Sydney region. Topography exerts a strong influence on rainfall with mean annual rainfalls varying between 1,000 to 1,400 mm from north to south over the catchment.

A large proportion of the catchment is covered by natural vegetation. Vegetation form is typically woodland or open forest with dominant tree species Smooth-barked Apple *(Angophora Costata)*, Sydney Peppermint (*Eucalyptus piperita*), Scribbly Gum *(E. haemostoma)* and Red Bloodwood *(E. Gummifera)*. Vegetation along river banks in lower estuary areas is characterised by Grey Mangroves *(Avicennia marina)* with Swamp Oaks (*Casuarina glauca*) behind (National Trust, 1990). A saltmarsh area exists in the Still Creek estuary which is currently being regenerated with funding provided by the Water Board.

Mammal species common to the area include Echidna, Sugar Glider, Ring-tailed possum, Brush-tailed Possum, Brown Antechinus, Long-nosed Bandicoot and Koala. Twenty eight native bird species have been recorded as being present in the area. Common reptile species include Copper-tailed Skink, Lace monitor, and Eastern Blue-tongued Lizard (Gunninah Consultants, 1990).

Water quality has been noted by many residents as being an issue of concern. Sampling undertaken for the Woronora Bridge EIS (RTA, 1990) noted that turbidity levels were high in water samples tested in May 1990 following very high rainfall in that year. The EIS indicated that heavy metal concentrations (Zinc, Copper and Lead) generally complied with the Clean Waters Act regulations. Under the Clean Waters Regulation 1970 Woronora Dam is classified S - Specially Protected Waters and the Woronora River downstream of the dam P - Protected Waters.

Gunninah Consultants (1990) indicated that river fauna in the estuary is generally poorly developed, and proposed that this was due to fluctuations in salinity common to estuarine areas. The survey was conducted soon after flooding, and this may have affected the abundance and diversity of species present.

Estuaries are important biophysical systems supporting seagrasses, macroinvertebrates and other benthic communities. The shelter and food supply provided by estuarine habitats are important for juvenile fish survival, which are in turn important for commercial and recreational fishing. A number of long term local residents have indicated a decline in fish numbers over the last 50 years. Australian Bass *(Maquaria novemaculata)* is known to inhabit the Woronora River estuary and commercial oyster leases are operated in Bonnet Bay and Audrey Bay in the lower estuary.

Early European historical accounts indicate that the Woronora was a shallow estuary with extensive sand shoals, and which abounded with fish. These shoals appear to have prevented sharks from entering the estuary accounting for the local aboriginal name "Wooloonara" or "Place of No Sharks" later corrupted to Woronora (Burgess, 1994).

Modifications to the natural environment have occurred principally this century with the clearing of bushland and reclamation of floodplain and mangrove areas for residential development. Dredging of the river from the Forbes Creek confluence downstream to Georges Head was carried out from 1967 to 1976. The dredged material was used for reclamation works during the development of residential areas of Bonnet Bay. A smaller amount of dredging was also undertaken in Forbes Creek during this period. Warner and Pickup (1978) noted that some adjustment of the Woronora River channel morphology had occurred since dredging with erosion noted from Forbes Creek downstream to Bonnet Bay (suburb) and slight accretion in the vicinity of Georges Head.

A hydro-survey of the Woronora River estuary was carried out in 1984-85 by NSW Public Works. For this survey, cross-sections of the river channel and overbank areas were taken at 48 locations between the Georges River and The Needles. Sutherland Council re-surveyed 5 cross-sections in August 1990 and a different set of 5 cross-sections in June 1994. The results indicate that there has only been very minor changes to bed level over the last 10 years with no appreciable increase in siltation.

3.4.2 Effects of Flooding

Flow regimes in rivers on the east coast of Australia are generally characterised by low base flows punctuated by randomly spaced flood flows of much greater magnitude. Although there is no apparent temporal regularity for flood events, flooding has a significant role in maintenance of river ecology (Riding and Carter, 1992).

Flooding is also an important factor in maintaining channel morphological characteristics. It has been suggested that overall geomorphic form in rivers is largely determined by large flood events of low frequency (Nanson and Erskine, 1988). In the case of the Woronora River erosion of the existing gorge is likely to have occurred episodically due to individual flood events rather than gradual erosion by base flow. Construction of the Woronora Dam is likely to have changed flow regimes in the river for lower flows, however the 1991 flood study concludes that the dam is not a significant factor in retardation of larger flood events.

Accretion of the floodplain areas on the lower estuary would occur due to overbank flow. Deposition of alluvial material on the floodplain areas would also replenish nutrients to these areas. Flooding also replenishes nutrients important for the survival of aquatic ecosystems.

Floodplain and mangrove areas in the lower estuary have been utilised for development of Woronora and Bonnet Bay. The development of waterfront properties and reclamation has removed much of the riparian vegetation in these areas. This may be exacerbating erosion of river banks as vegetation provides resistance to flow (through vegetation increasing roughness) and bank strength (sediment binding of root systems).

3.5 FLOOD WARNING AND EVACUATION PRACTICE

3.5.1 Existing Situation

At present, there are about 2 to 3 hours warning before the onset of flooding. The main gauge in the catchment used for predicting floods at present measures the water level overtopping Woronora Dam. The time for a flood to reach The Needles from the dam could be about an hour, and another half an hour may be needed to reach the bridge.

There are 3 pluviometers (rain gauges) in the catchment, all owned by the Water Board. One is at the dam, another is about halfway between the dam and the upper extremity of the catchment, and one is in the vicinity of The Needles. These are not used for predicting floods. Other data used are the state of the tide, the barometric pressure, the height of flooding in the Georges River, the weather forecast and a manually read river gauge.

The Bureau of Meteorology does not at present issue specific flood level predictions for the Woronora River. The Bureau does, however provide general warnings for the area including:

(i) Confidential Flood Advices. Although targeted at the nearby Georges River, they can provide up to 24 to 36 hours advance warning of a large scale weather system that has the potential to cause flooding along the Woronora River.

(ii) Severe Thunderstorm Advices. An alerting forecast for 2-3 hours (up to 6 hours maximum) of weather forecast districts (eg Sydney Metropolitan Area) where severe thunderstorms are predicted to form. These Advises may precede a Severe Thunderstorm Warning.

(iii) Severe Thunderstorm Warnings. A short term (up to two hours maximum, but more likely only 30 minutes or so ahead) of thunderstorms that the Bureau is monitoring on radar and believes to be severe and could, amongst other effects, produce flash flooding. Warnings would target a more specific area than Advises, eg Southern Sydney or possibly a local government area eg Sutherland Shire.

The State Emergency Service (SES) is the designated combat agency in New South Wales for dealing with floods and co-ordinates the evacuation and welfare of affected communities.

The local SES is set up to mobilise and be on site within an hour. The main problem encountered is having sufficient time for warning the occupants before the floods come. The greatest difficulty with this is in warning those houses at the upstream end of the floodplain where there is no road access. SES personnel must either telephone individual properties or walk in or travel up-river by boat to give warnings. This can be a time-consuming and/or hazardous task.

Recent floods have only been small and only a few people have had to be physically evacuated. In a major flood it is expected that large number of people would need to be evacuated. One area of particular concern for evacuation is at the intersection of Prices Circuit and Menai Road. This is one of the first areas to flood and it restricts evacuation by all residents in the Prices Circuit area.

The Woronora caravan park is mostly permanently occupied. In the past removing caravans during floods has proved to be a time-consuming task, which diverts scarce resources from other activities.

3.5.2 Local Flood Plan

The State Emergency Service Act 1989 defines one of the functions of the Service as follows:

> "To act as the combat agency for dealing with floods (including the establishment of flood warning systems) and to co-ordinate the evacuation and welfare of affected communities".

The State Flood Plan recognises this function and directs that "each SES Local Controller in whose area there is a flood threat is to develop a Local Flood Plan". In doing so, SES Local Controllers act as agents for their communities in developing what are essentially community plans.

With the full support of the Sutherland Shire Council, the Sutherland SES Local Controller has begun the process of developing a Sutherland Local Flood Plan. This plan will:

(i) cover preparedness measures, the conduct of response operations and the co-ordination of immediate recovery measures for flooding within the Sutherland Local Council area;

(ii) use the work done for this Floodplain Management Study as the basis of understanding of the flood threat;

(iii) record the agreed responsibilities of agencies and individuals during flood response operations;

(iv) record arrangements for activation, collection of flood intelligence, development and distribution of effective warnings to the community, operational control, communications and liaison;

(v) indicate how the recovery process might be initiated.

The plan will be developed in conjunction with the Sutherland Local Emergency Management Committee and be formally presented to that Committee for acceptance as a sub-plan of the Sutherland Shire Local Disaster Plan. The Plan will then be printed and distributed as an "interim" document.

The Sutherland Shire Council will ensure that copies of the Local Flood Plan are made available through the Council Information Centre, Schools and Libraries. Comment and suggestions for improvement will be welcomed from members of the community and the plan will be regularly reviewed.

In addition a Flood Action Plan could be developed for the Woronora Caravan Park in accordance with Department of Local Government Technical Bulletin No. 6. Woronora River Public School currently has a flood plan. This would need to be reviewed for compatibility with the Local Flood Plan.

3.6 COMMUNITY PREPAREDNESS

Community preparedness is a measure of the flood-preparedness of a community. This is dependent on the following factors:

(i) population mobility
(ii) average life span
(iii) average recurrence of significant flood losses

As many residents are new to the study area and a major flood has not occurred for many years the current level of preparedness is estimated to be low.

The mobilities of the populations in each section of the Woronora River were calculated from the data on 'place of residence 5 years ago' for each Collector's District from the 1991 census. Only those Collector's Districts which included the residences affected by the floods were included. The mortality rate for the whole of the Sutherland Local Government area was used for each of the districts, as this information was not available by Collector's District.

Based on the above considerations a conservative estimated figure of 30% has been adopted for the economic evaluation in Section 5 of this report.

3.7 FLOOD STANDARD

The benefits of building at different floor levels were analysed for five sections of the floodplain, Zones 1-4, 5-9, 10-15, 16-22 and 23-29. For each level, the average annual damage was estimated for a typical house, and this was compared with the cost of building the house to that level. The level at which it is worthwhile to build the floor level depends upon the position of the vacant land on the floodplain. A lot which is lower in the floodplain will be flooded more often, therefore it is more beneficial on average, to build at a higher level. The cumulative benefits reduce the higher the level of the vacant land.

Figures 3.3 to 3.7 show the results of the analyses. Details of the calculations are set out in Appendix G.

Figure 3.3 indicates that a suitable level of the flood standard in Zones 1 to 4 could be between 3 and 4 m AHD. This is about 1 to 2 m higher than the 1% flood level. Figure 3.4 shows that the flood standard level for Zones 5-9 could be between 4 and 5 m AHD, again about 0.5 to 1.5 m higher than the 1% flood level.

It is therefore suggested that for all new residential properties, where the building foundations are subject to the 1% flood, Council inform the property owner it is advisable that all new dwellings have floor levels at least 0.5 m and preferably 1 to 2m above the 1% AEP flood level. In many cases, this could provide useful underfloor areas. As discussed in Appendix H, if the owner of a raised house uses the space underneath for facilities such as laundry, garage, rumpus room and workshop, the value of the house increases to reflect the cost of their installation. This would also require policing by Council to ensure that the underfloor areas are not converted to habitable living areas or for other inappropriate uses.

3.8 GREENHOUSE EFFECT

For many years scientists have speculated that a gradual warming of the earth's atmosphere has been occurring due to an increase in the concentration of so-called "greenhouse gases", principally carbon dioxide and methane. It is proposed that this warming began with the industrial revolution in Europe at the beginning of the nineteenth century, and has been accelerating ever since with increasing consumption of fossil fuels.

Many commentators believe that significant climatic change is inevitable over the next 30-50 years. One effect of global warming is to cause sea level to rise. Two processes are involved, with an increase in ocean volume due to thermal expansion and an increase in water quantity due to melting of polar ice caps.

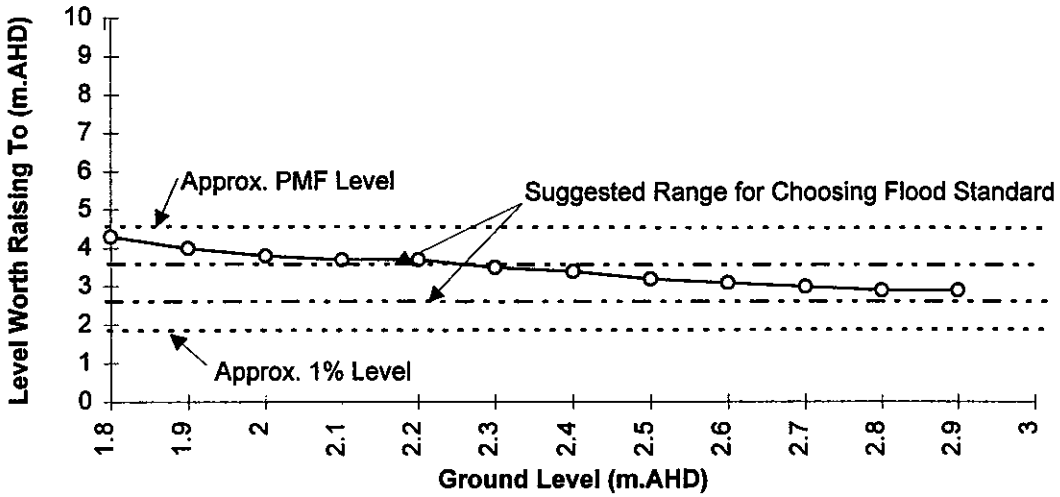
Another effect is to increase precipitation due to increased evaporation and the increased capacity of the atmosphere to hold water vapour. This is particularly relevant to the Sydney region which lies close to the boundary between climatic zones with summer and winter rainfall dominance. A southerly shift of this boundary due to

increased temperatures would cause an increase in both mean annual rainfall and rainfall intensities leading to an increased risk of flooding.

There is scientific evidence to suggest that the earth's surface has warmed by about 0.5°C since the start of this century with a corresponding rise in mean sea level of 100 mm. It is speculated that global temperatures may rise 1.5°C to 4.5°C over the next 50 years leading to sea level rises of 200-1000 mm (Bell, 1988).

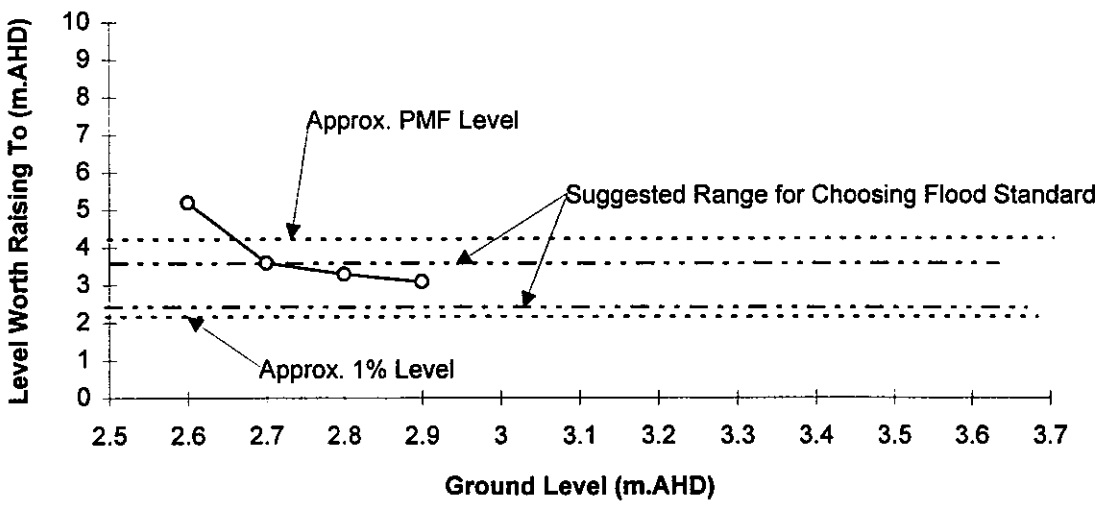
As flood levels in the lower estuary (north of Woronora Bridge) are principally controlled by the water level in Botany Bay it would be expected increases in flood levels of the order quoted above could occur with gradual attenuation upstream. In addition increased rainfall intensities could lead to further increases of flood levels. At this stage there is insufficient data to predict the increase in rainfall intensity, particularly as local topographic effects may have a major influence. It is therefore recommended that design flood levels be reviewed when predictions can be made with a greater degree of certainty.

It is important to note that there is considerable debate within the scientific community about greenhouse issues. Natural climatic variations, greater than the 0.5°C increase measured this century, have been recorded during historical times, and there have been many major climatic perturbations over geological time scales such as the ice ages the last of which ended approximately 15,000 years ago.



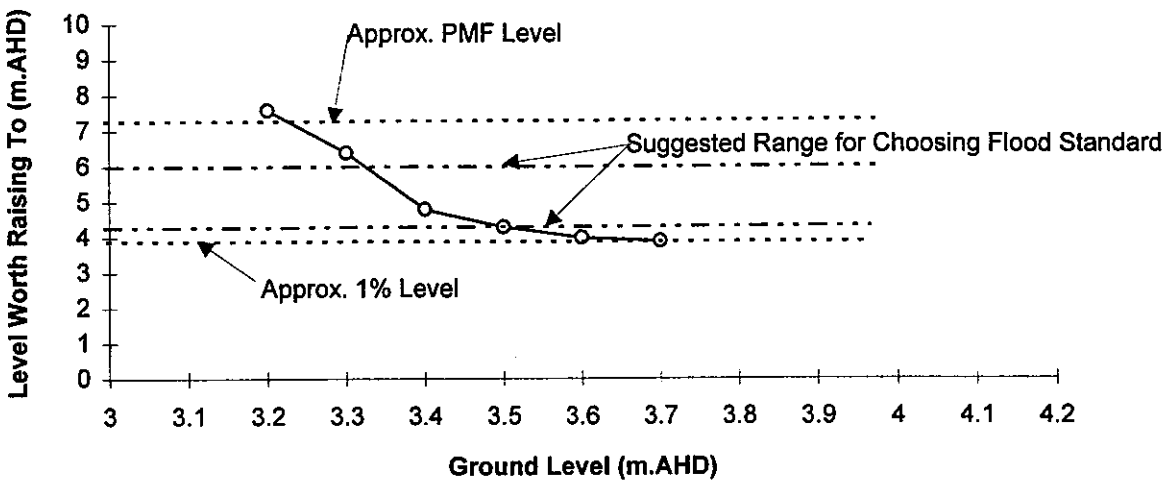
SUGGESTED RANGE FOR FLOOD STANDARD ZONES 1-4

FIGURE 3.3



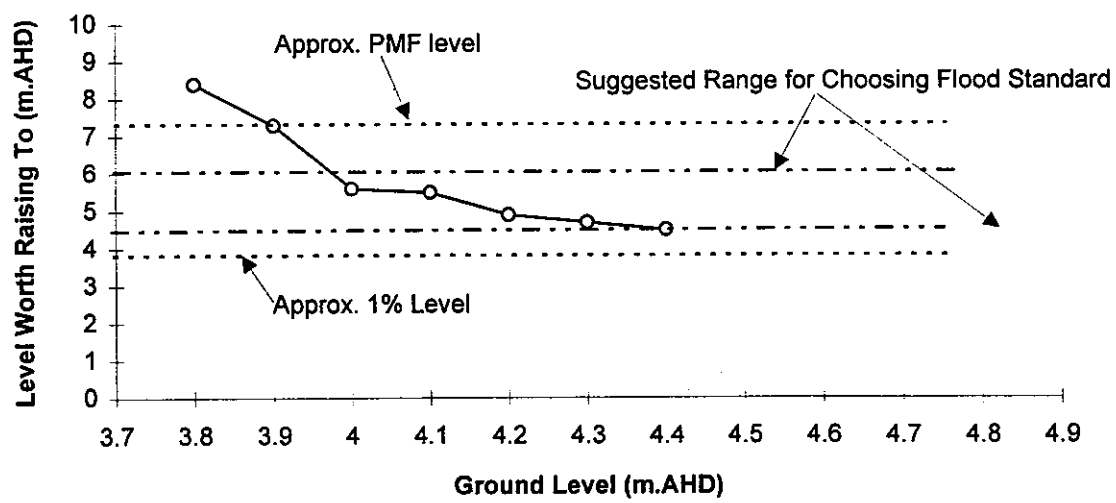
SUGGESTED RANGE FOR FLOOD STANDARD ZONES 5-9

FIGURE 3.4



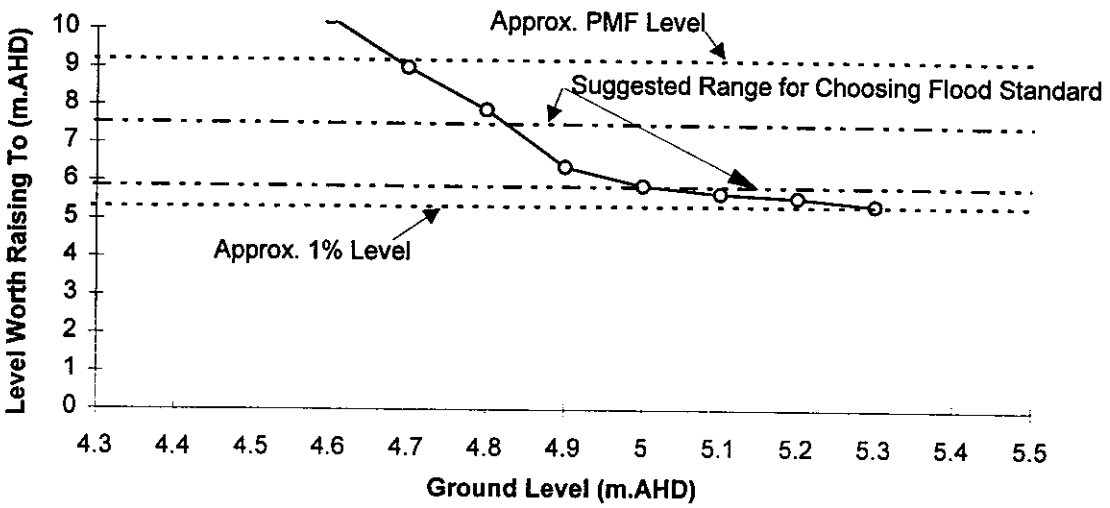
SUGGESTED RANGE FOR FLOOD STANDARD ZONES 10-15

FIGURE 3.5



SUGGESTED RANGE FOR FLOOD STANDARD ZONES 16-22

FIGURE 3.6



SUGGESTED RANGE FOR FLOOD STANDARD ZONES 23-29
FIGURE 3.7

4.0 FLOODPLAIN MANAGEMENT OPTIONS

4.1 INTRODUCTION

Floodplain management refers to measures that may be adopted to control the impacts of flooding. Such methods are generally categorised as either "structural" or "non-structural". Structural measures generally involve construction of major civil engineering works such as levees, retarding basins, flood control dams and dredging to control the behaviour of the river. Non-structural measures include improved warning and evacuation systems, community education programmes, flood-proofing of individual properties and planning and development controls. An explanation of some management measures that may be suitable for use within the Woronora River catchment is given below.

Combinations of options selected by the Floodplain Management Committee have been used as 'building blocks' for the Management Strategies detailed in Chapter 5 of this report.

4.2 NON-STRUCTURAL OPTIONS

4.2.1 Flood Forecasting System

Flood forecasting and warning can be an effective floodplain management measure if there is sufficient warning time for the community to react to the warning. An effective flood warning system involves flood forecasting, flood warning, evacuation planning, and most importantly an informed and prepared community.

Flood forecasting involves obtaining data from telemetered rainfall and flow gauges throughout the catchment to enable the size of the flood to be predicted rapidly. It is expected that such a system would provide an effective flood warning time of between 5 to 10 hours for the critical 36 hour storm, although shorter storm durations which may cause (less severe) flooding would have a shorter effective warning time.

Suitable gauges already exist within the Woronora River catchment. These would need to be upgraded to provide information for automatic input into a computer model. This would improve forecasting of flood levels allowing for assessment of flood severity and evacuation time available. Sutherland Shire Council would have the responsibility of maintaining the computer model.

The current warning system is not based on any technical advice on the hydraulic and hydrological characteristics of the catchment, and were this to be available, the warning time could be increased by another hour or so with little extra effort.

The cost of a computer and of setting up empirical charts to use the existing information more scientifically is estimated at $8,000.

If it were intended to increase the warning time by another hour, there would probably need to be an additional pluviometer in the upper catchment, costing about $7,000. As well, there may have to be a signal repeater station costing another $3,000, and a base station at the local SES (about $7,000).

The rainfall readings could be used by the SES to make coarse predictions of the scale of flooding. These predictions would be estimated using semi-empirical relationships developed by the Bureau of Meteorology using the existing hydrological and hydraulic models in the 1991 flood study (Sinclair Knight, 1991) for typical rainfall events.

This could extend the warning time by another 2 to 3 hours for small-scale storms. For very large events (which would be likely for the large, less frequent floods) there could be a 24 hour preliminary warning with a 70% chance of being correct. The reliability of the prediction would improve further as the storm approached.

In order to check on its predictions, it would be important for the SES to have access to river level information. There is a water level gauge at Woronora Dam which is already set up for an ALERT system. ALERT is a relatively inexpensive system for collecting and processing information used in the provision of an operational flood-warning system. In general terms ALERT involves the transmission of a radio signal from a field station to a base station each time an "event" occurs. An event is defined as a preset change in the parameter (ie. rainfall and river level) being measured. Once the data has been received at the base station it is stored for future use. The primary use of the data is for input to a hydrological model of the catchment that predicts future river levels.

To upgrade the gauge at the Needles could cost $7,000, and a new gauge (perhaps at Woronora Bridge) might cost $20,000. To improve telecommunications for warnings might cost another $10,000. Thus the total cost could be $62,000 plus operational costs at 10% per annum. Funding could be made available from the State Government for capital costs, however, operational costs would need to be borne by Sutherland Shire Council.

The Council would also be interested in using the pluviometer stations for predicting the movement of bushfires. The electronics would have to be augmented and gauges for measuring climatic variables such as wind speed, wind direction, temperature and humidity would need to be attached. This could cost another $4,000 per station and another $3,000 for an additional repeater station, or a total of $15,000. An allowance for setting up the empirical relationships is $5000.

Details of the costs for improving the flood-warning system are set out in Appendix H.

4.2.2 Community Preparedness Campaign

It must be recognised that there is an important difference between flood preparedness and flood awareness. One may be aware of a flood hazard, but one may not be prepared for it. Thus, while it is important to heighten awareness, it will be just as important, and far more difficult, to motivate people to start preparing.

It is recommended that Council conduct regular flood preparedness campaigns. It is suggested to initiate several strategies which are mutually reinforcing.

One strategy could be to incorporate the necessity for regular flood-preparedness campaigns into a Council policy

Awareness can be maintained in the community by:

(i) permanent marks showing the level reached by previous floods;

(ii) teaching about floods in schools;

(iii) sending out regular information with rate notices;

(iv) trial operations of a broadcasting voice mail system;

(v) SES displays and recruiting drives;

(vi) educational videos;

(vii) talks by SES officers.

A broadcasting voice mail system sends an automatic message to individual telephones. At present the available systems can only handle up to 50 lines and would cost approximately $1 million to install. It would be expected that with the advent of cable technology within 5 years the cost will be much less and it may then be practical to include this as a component of an early warning system.

The effectiveness of a flood warning system is also dependent on community awareness of the likely severity of flooding, the impact of flooding and the community's response to the flood warning issued.

Preparedness campaigns will need to be designed by professionals skilled in motivation on public health and safety issues. These designs will need to be based on market research and repeated at regular intervals to enable adjustment for demographic changes within the community.

The campaigns should preferably incorporate flood drills and community participation networks to enhance the pool of local knowledge concerning:

(i) what steps to take well in advance, eg. develop a procedure for collecting important documents, memorabilia, pets and treasured items for rapid evacuation;

(ii) precautions to take in light of an early, indefinite warning;

(iii) developing procedures for lifting and evacuation of property;

(iv) understanding the potential and limitations of the warning system.

The estimated costs involved would be $10,000 initially plus $2,500 per annum.

The benefits of a regular flood-preparedness campaign would extend to more than just reducing the monetary losses.

The campaign would also improve people's feeling of control, since they would have a better idea of how to respond to a flood warning. This improved sense of control would reduce the adverse social impact of the floods (of Slovic and others, 1984).

4.2.3 Planning and Building Controls

The use of planning controls as a floodplain management measure primarily involves adoption of appropriate zoning for land subject to flooding. Public reserves and land currently not developed, which are potentially affected by floods, would need to be examined to determine whether it is appropriate for these areas to remain undeveloped. If these areas are considered appropriate or necessary for future development, imposition of building and development controls would need to be considered.

One purpose of planning controls is to place restrictions on future development to prevent further constriction of the floodway. This is particularly significant for the Woronora River valley due to the narrow nature of the floodplain. For example at Woronora the floodplain is generally less than 900 metres in width.

Another purpose is to limit the number of residents at risk by restricting new development and increased development densities such as may arise from dual occupancies or medium density housing. This can be achieved by the preparation of Local Environmental Plans (LEPs) and Development Control Plans (DCPs) for flood liable areas.

Designation of an "environmentally sensitive" residential zone could be considered for those properties in the Woronora Valley that are affected by flooding. Such a zone would restrict development potential to single dwellings only. A Development Control Plan could be prepared to be used in dealing with Development/Building Applications within the study area covering issues such as floor heights, setbacks, building design and construction etc.

The impact on flood levels due to increased development in floodplain constricting the floodway would depend on the density and layout of future developments. It is expected that the impact on flood levels would be small and the maximum increase in flood levels would be in the order of 0.1 m to 0.2m. However, increased constriction of the floodway would lead to increased flow velocities which would further exacerbate the hazard rating of those areas already subject to flooding.

It is difficult to nominate a level of development at which a noticeable change in flood behaviour would occur. The layout of individual developments has a bearing on this.

For example, if a dense row of development was allowed to proceed along the foreshores of the river, it is likely that this would perform the function of a levee and flooding behaviour would change significantly regardless of the extent of development in the floodplain further away from the river.

There are opportunities for further development without affecting flood levels and if managed properly these could also have minimal impact on flow velocities in the floodplain and the hazard categories of these areas as they exist.

Building and development control involves flood proofing the developments in flood affected areas. Typical considerations include:

(i) setting minimum floor levels for habitable floors to the flood standard (see Section 3.7);

(ii) localised flood mitigation works including land fills, levee banks and flood walls;

(iii) appropriate construction methods and building materials; and

(iv) access to buildings for evacuation purposes.

Areas where these floodplain management measures would be most appropriate and cost effective are the foreshore areas currently subjected to low hazard flooding. Other areas which have well established developments would benefit less from such measures in the short term. However, new developments or additions to existing buildings in these areas would be subject to these building controls with the long term objective of reducing potential flood damages to all buildings in the area.

In all cases, building and development controls need to be imposed on a merit basis, balancing restrictive development conditions with the impact of development on flood behaviour in the floodplain.

Council's current policy is to set habitable floor levels for new residences and extensions to 0.5 metres above the 1% AEP flood level, with non-habitable areas set at the 5% AEP level. A number of residents who attended the community workshop advised that they were in the process of, or intending to, rebuild on their properties to

meet this standard. The high value of land in the area would make rebuilding economically viable in many cases.

4.2.4 Voluntary Purchase

There may be areas whereby the most cost effective flood mitigation measure would be the purchase of properties by Council for subsequent re-zoning for more appropriate landuse. If such a proposal were adopted by Council, properties in the Woronora River Floodplain potentially subject to high hazard flooding with a high risk of injury or death to the inhabitants may be considered for voluntary purchase.

Given the generally high property values in the Woronora Valley it would not be economically viable to purchase a large number of properties.

There do not appear to be any houses on the floodplain which would be inundated with floodwaters so rapidly to prevent escape. As such, it does not appear that there are any houses which would be suitable for voluntary purchase.

4.2.5 Voluntary House Raising

House raising involves elevating existing residences such that habitable floor levels conform with Council's flood standard. This has been undertaken successfully in parts of Sydney such as areas of Fairfield affected by flooding from the Georges River.

Houses most suitable for raising are typically timber framed residences with fibro or weatherboard cladding supported on piers. The house is jacked to the required position and the piers extended or replaced to support the elevated structure. Brick residences are often more economically raised by the addition of a second storey.

The cost of raising a weatherboard or fibro house in Fairfield has recently averaged approximately $35,000, while the cost of adding an extra storey to a brick house could be approximately $50,000.

Of the 179 single storey houses in the Woronora Valley which are flooded above the floor by the 1% flood, 77 are fibro or weatherboard and 102 are brick or other. The estimated cost of raising all of the 179 houses would be approximately $7,800,000.

Some property owners may object to the house raising option as they feel it would change the character of their houses. Adjacent owners may also object if their view was blocked. It is therefore suggested that some flexibility with regard to these matters and Council's height limitations be exercised.

There are also potential social implications for lower to middle income earners who may be unable to afford the cost of house raising should an owner contribution be required. This could adversely affect the resale potential and value of these properties. The same situation could be said to apply to owners of houses within the

floodplain which are unsuitable or too expensive to raise such as two storey houses or brick houses.

The principal environmental impact of this option would be a potential reduction in the visual amenity of the area with an increase in the number of two storey or substantially elevated single storey houses.

Government assistance may be available for houses designated as suitable for future raising.

4.2.6 Flood Insurance Scheme

At present household insurance against flooding is not readily available in New South Wales.

A possible means of overcoming this problem is for Sutherland Council to set up a flood insurance scheme for residents identified as being potentially affected. This would most readily be done by a system of special rate levies, with the money held in trust by Council for distribution to residents following a flood. A graded system of levies may be considered depending on the flood risk to individual property owners. A voluntary system could also be considered, however given the existing low level of concern generally shown by residents this may prove ineffective, and could lead to potential social division following a flood for residents who stand to benefit from the scheme.

The mid-rate for the levy would need to be set at the average annual flood damage for an individual property with an additional amount to cover administration costs. The estimated mid-rate levy for each household would need to be of the order of $1,100 per annum.

Council may feel that such a scheme would lead to a high financial risk particularly considering the random and unpredictable nature of flooding in the catchment. For example it is not unusual for two major flood events to occur within a short time frame. The fact that insurance companies have not undertaken this form of insurance previously would tend to indicate that the level of risk is seen to be high, particularly given the low level of predictive data available.

4.2.7 Access Road Improvements

Concern has been expressed by the SES that a major problem occurs due to early flooding of critical access roads at a number of locations. Roads identified as being affected include:

(i) Prince Edward Park Road, Woronora;
(ii) Prices Circuit, Woronora;
(iii) Menai Road, at the western approach to Woronora Bridge; and
(iv) Washington Drive, Bonnet Bay.

Localised raising of these roads at specific locations would improve accessibility as flood waters rise, providing increased time for evacuation.

Low points along the access roads are identified in Table 4.1 below.

TABLE 4.1 LOW POINTS ALONG ACCESS ROADS

Road	Location	Road Level (m AHD)	5% AEP Flood Level (m AHD)
Prince Edward Park Road	River Road to Forbes Creek Bridge	1.5 - 2.4	3.5 - 3.3
	South of Thames Street	2.5 - 3.0	3.0
Prices Circuit	Manilla Place to Yanko Close	1.4 - 2.2	3.0
	Near Menai Road	1.6 - 2.4	2.9
Menai Road	Western Approach Woronora Bridge	1.5 - 2.1	2.9
	Nundah Place	2.1 - 2.6	2.9
Washington Drive	Wilson Place to Coolidge Crescent	2.9 - 3.4	2.4

It can be seen that critical areas occur along Prince Edward Park Road, Prices Circuit and Menai Road. The following works are considered:

(i) Raising Prices Circuit in the vicinity of Manilla Place to Yanko Close to a minimum level of RL 2.0 m - estimated cost $350,000.

(ii) Providing an emergency access to Menai Road from Nundah Place - estimated cost $5,000.

Although Prince Edward Park Road between River Road and Forbes Creek is generally low lying this area is a cul-de-sac and the evacuation route to River Road is reasonably well elevated. Prices Circuit near Menai Road is the only present road access for properties on the western side of the river at Woronora. By providing an emergency access through to Menai Road from Nundah Place additional higher level emergency access is provided for minimal cost compared to an estimated $160,000 cost to raise Menai Road to a minimum level of RL 2.0 m at the western approach to Woronora Bridge.

Localised flooding of Prince Edward Park adjacent to the northern end of Liffey Place occasionally occurs due to the presence of a local stormwater floodway. This flooding is not related to water levels on the Woronora River and would need to be considered in a separate local drainage study.

4.3 STRUCTURAL OPTIONS

4.3.1 Flood Retarding Basin (20,000 ML)

Flood mitigation dams and retarding basins act as additional flood storage which can reduce the peak flood discharge and thus the peak flood levels along the river. It has been suggested that flood mitigation could be achieved by either construction of a flood mitigation dam or by a change to the operating regime of Woronora Reservoir to provide an available flood storage volume at the dam.

For the Woronora River catchment, the Woronora Reservoir has a storage capacity of 71,790 ML and serves as a water supply operated by Sydney Water. The 1% AEP flood at Woronora Dam has a peak discharge of 820 m^3/s and represents 65% of the peak discharge predicted at The Needles. The volume of the 1% AEP inflow at the reservoir is approximately 32,000 ML, 45% of the storage capacity of Woronora Reservoir. Thus for Woronora Reservoir to serve the dual functions of a water supply storage and a flood mitigation storage, it would be necessary for the full supply storage to be reduced from the current level and for an outlet structure to be constructed with the upper portion of the reservoir acting as a retarding basin.

A provision of 20,000 ML of flood storage would represent a drawdown of the reservoir of approximately 25%. The costs of this provision would include both the installation costs of drawdown facilities and the loss of opportunity cost with respect to water supply potential.

The social implications of this option relate to a comparison of the obvious benefits for the residents of the Woronora River valley against a reduction in water supply capacity. A reduction of 20,000 ML out of a total system capacity of 2,400,000 ML represents less than 1% which could be seen to be of minimal impact. However, if such a precedent were set the implications for larger storages with flood mitigation potential such as Warragamba Dam could be considerable. Sydney Water have advised that they have no specific legislative or business responsibilities associated with floodplain planning or flood mitigation.

There would be some environmental advantage in reducing the capacity of the dam in that the frequency of flows for riparian uses would increase. The advantage of this would be offset by a change in the flow regime with a substantial reduction in the size of flood flows.

It has been proposed that a flood retarding basin could be constructed at the Heathcote Road crossing over the Woronora River. This proposal is based on utilisation of fill from possible future duplication of Heathcote Road which currently comprises two lanes. A preliminary assessment indicates that a rock fill structure 45 metres high would be required to retain 20,000 ML. It is estimated that such a structure would require approximately 500,000 m^3 of rock fill. It is unlikely that major roadworks along Heathcote Road could provide this quantity of material and that it would be necessary to import rock fill.

It is estimated that the cost of the flood retarding basin structure would exceed $30 million.

Discussions with the RTA (Grant Eyre, 1994) indicate that there are no current plans to duplicate Heathcote Road and that the only works proposed would be localised improvements to the existing alignment.

There would be major environmental impacts associated with the construction of the basin with the site located on the boundary of Heathcote National Park.

There would also be environment impacts from outside the local area at the location where the rock fill would be quarried. The previous comments relating to flood frequency reduction also apply to this option.

4.3.2 Flood Retarding Basin (12,000 ML)

An alternative to the option presented above could be a smaller flood mitigation storage of 12,000 ML. This would represent 15% of the storage capacity of Woronora Dam.

This option could be seen as a means of controlling smaller floods with an acceptance of some damage from larger events.

The implications of this option utilising Woronora Reservoir are similar to those listed in Section 2.1 for the 20,000 ML scheme but would obviously be reduced due to the increased frequency of flooding below the dam.

Examining the option of a flood retarding basin at the Heathcote Road crossing indicates that a structure of 40 metres in height would be required. The structure would require approximately 275,000 m^3 of rock fill with the estimated cost exceeding $20 million.

As a modification to the above schemes it has been suggested that a retarding basin could be constructed to contain the 1% AEP flood whilst permitting a maximum discharge equivalent to the peak flow of the 10% AEP flood. The size and cost of such a structure would be expected to be of a similar order of magnitude to the 20,000 ML retarding basin.

4.3.3 Modification to Waterway at Woronora Bridge

The existing Woronora Bridge is estimated to cause a 0.2 metre upstream flood rise for the 1% AEP event. Predicted water levels in the vicinity of the bridge are above the underside of the bridge but below the top of the bridge deck. Works necessary to reduce the flood rise caused by the bridge could include the raising of the bridge deck or possible construction of a floodway on the western side of the bridge.

The existing two lane bridge was opened to traffic in May 1981. The structure is comprised of reinforced and prestressed concrete with a total length of 98.9 metres (five by 19.7 metre spans) and a width of 8.6 metres between kerbs. A 1.8 metre footpath is located on the upstream side of the bridge (RTA, 1990).

The existing bridge could be raised using lift slab techniques. A preliminary cost estimate for this work is $1.5 million. There is a possibility of a State Government funding subsidy for raising the bridge if Council decided to proceed with this option.

It is proposed to construct a new high level bridge downstream of the existing to carry arterial traffic currently using Woronora Bridge. The existing bridge would remain to provide for local traffic movements. The option of modifying road connections to the new bridge to allow for removal of the existing bridge was discussed with the RTA. Such an option was considered in the development of the design for the high level bridge but was found to be unacceptable due to potential hazards associated with traffic slowing to utilise right turn bays on either side of the bridge with steep uphill grades of up to 9% proposed (Greg Butler, 1994).

Another possible option is construction of a floodway on the western side of Woronora Bridge to improve channel capacity. A 50 m wide by 2 m deep floodway could be considered for this purpose. Preliminary analysis of this option found a reduction in upstream flood levels in the vicinity of 0.01 m which is not significant.

4.3.4 Levees

Among the most commonly used structural flood mitigation option are levees or flood walls. Levees serve to flood proof substantial areas in the floodplain but have the impact of either worsening flooding downstream, through the removal of important flood storage areas, or increasing flood levels upstream through the effect of increased downstream levels. Examination of the results presented in the 1991 Flood Study suggest that the construction of levee banks would not lead to any significant loss of flood storages. It is possible, however, that some increase in flood levels may result from such works.

Levee banks can often result in the community gaining a false sense of security regarding the level of flood protection offered by the works. It is important that the community be made aware of the selected design standard of the levee and that there is an associated risk of the levee bank being overtopped by an above-design event. The design of a levee system would also need to include subsequent discharge to the river by a pumping scheme or by gravity (via flap-gated outlets) as the flood in the river recedes.

The opportunity to use levee banks to prevent entry of floodwater into an area appears limited owing to the impact these may have on residential properties with river frontages. Flood levees could however be used to deflect floodwater away from designated areas to reduce flow velocities. Depending on the duration of a flood event, deflector levees can also reduce flood levels.

The use of levee banks was considered in the following areas:

(i) Along the foreshore area on the western bank from the northern end of the Woronora caravan park south along the foreshore reserve to up to 250 m south of Woronora Bridge.

(ii) Adjacent to Lakewood City reserve, Bonnet Bay;

(iii) The residential area in Washington Drive, Harrison Avenue and McKinley Avenue immediately north of Jannali Reserve.

Discussions with the Floodplain Management Committee indicated that the levee proposal (ii) did not merit further consideration as consideration was only given to construction of a deflector levee. Given the low flow velocities in this area during flooding this was not considered to be very effective in reducing flood depths.

For option (i) a levee approximately 550 m in length has been evaluated for 1%, 2% and 5% AEP floods. South of Woronora Bridge the levee would be located close to property boundaries to minimise impacts on views (refer Figure 5.12). The estimated cost for this option would be up to $350,000. At the caravan park site, the levee would block the residents' views of the river.

For option (iii) construction of a levee with an average height of 0.7 m has been evaluated. The levee would extend 450 m along the eastern shore of the Woronora River before heading inland over a distance of 250 m along the northern boundary of Jannali Reserve (refer Figure 5.3). The estimated cost for this option would be $100,000.

4.3.5 Dredging of Woronora River

Dredging of the Woronora River would reduce flood levels by enhancing channel capacity. Two possible scenarios would appear to be worth considering.

(i) Dredging of the full width of the river to between RL -5 m AHD and -4.5 m AHD between Bonnet Bay and The Needles. The volume of sediment to be dredged is estimated at approximately 2 million cubic metres.

(ii) Dredging of the river to provide a 50 m wide "deep" channel with a base level of between -5 m AHD and -4.5 m AHD between Bonnet Bay and Anzac Road. The volume of sediment to be dredged is estimated at approximately 500,000 m^3.

Dredging would have the additional advantage of improving river navigability which is often difficult during periods of low flow, and at also low tide. Such improvements would assist in evacuation of residents who rely on river access during emergency situations such as occurred during the January 1994 bushfires.

Large scale dredging of the river could have substantial environmental impacts. There would be direct impacts on benthic communities and the increased turbidity would affect fish and other marine organisms. There would be an increased risk of bank erosion which is already noted by local residents as an existing problem. This also would have implications for damage to properties if shoreline retaining walls were undermined. There could also be adverse environmental impacts if offshore dumping of spoil was adopted.

For these reasons the Floodplain Management Committee determined that limited dredging of a 50 m wide channel was the appropriate option for detailed analysis.

4.4 ASSESSMENT OF FLOODPLAIN MANAGEMENT OPTIONS

Evaluation of the suitability of the floodplain management strategies described in Sections 4.2 and 4.3 was carried out by the Study Team guided by consultation with local residents at the community workshop and the Floodplain Management Committee.

The environmental amenity of the river was felt by local residents to be very important. Non-structural options were seen to be preferable with apparent acceptance that flooding was a necessary natural phenomenon. To place this view in proper context many newer residents who attended the workshop had not experienced a major flood on the river and were apparently unaware or unconcerned of the potential hazard.

The results of a preliminary assessment of the options are presented in Table 4.2. Following consideration of the comments of local residents the following management options were felt to be appropriate for inclusion in management strategies.

Non-Structural Options

- Flood Forecasting System
- Planning and Building Controls
- House Raising
- Access Road Improvements

Structural Options

- Raising of Woronora Bridge
- Levee at Bonnet Bay north of Jannali Reserve
- Levee on Western Foreshore at Woronora
- Dredging of a 50 m wide channel along the length of the river.

Seven management strategies have been assessed in detail involving combinations of these options. The management strategies are detailed in the following chapter.

TABLE 4.2 SUMMARY OF POSSIBLE FLOODPLAIN MANAGEMENT OPTIONS

Management Option	Purpose	Comment
NON STRUCTURAL Flood Forecasting System	. Improves warning time . Improves evacuation plans . Prediction of flood magnitude improved . Reduces flood damage and loss of life	. Low cost option . Requires community preparedness campaign to be effective . Should be considered
Planning and Building Controls	. Restriction on development to minimise flood damage . Limit exposure to risk	. Low cost option . Some controls already present . May disadvantage existing property owners through reduction in land value or sale potential . Should be considered
Voluntary Purchase	. Purchase properties in high hazard areas to reduce risk of injury or loss of life during flooding	. Potentially high cost option due to high land values . Should not be considered
House Raising	. To reduce damages to existing properties	. High cost option . Should be considered
Flood Insurance Scheme	. Offset economic loss from flooding through a series of regular payments by local residents to be held in trust	. Not readily available through insurance companies . High risk for Council based scheme due to random nature of flooding . Does not reduce flood damages . Not practical for consideration
Access Road Improvements	. Increase evacuation time during flooding by reducing risk of flooding along initial access roads . Reduces flood damage and risk of loss of life	. Moderate cost option if adopted in selected areas . Should be considered for low lying areas of Prices Circuit, Menai Road, Prince Edward Park Road and Washington Drive

Management Option	Purpose	Comment
STRUCTURAL Flood Retarding Basin	. Reduce downstream flood levels . Reduce flood damages	. Very high cost for Heathcote Road dam . Woronora Reservoir unavailable for flood mitigation storage . Potential environmental impacts . Should not be considered
Modification to Waterway at Woronora Bridge	. Reduce flood levels upstream of Woronora Bridge . Reduce flood damages	. Floodway option of limited effectiveness and should not be considered . Bridge raising option has moderate cost and reasonable effectiveness and should be considered
Levees	. Prevent flooding of protected areas of the floodplain . Reduce flood damages . Improve evacuation time	. Moderate cost option . Only practical in limited areas . Internal drainage costs . Should be considered for residential area of Bonnet Bay immediately north of Jannali Reserve and western foreshore at Woronora
Dredging	. Reduce flood levels for whole of study area . Reduce flood damages	. High cost option . Potential environmental impacts . Substantial reduction in flood levels . Improved channel navigability is additional benefit . Dredging of a 50 m wide channel should be considered . need maintenance program and scour assessment study to determine costs.

5.0 FLOODPLAIN MANAGEMENT STRATEGIES

5.1 INTRODUCTION

The floodplain management options discussed in Chapter 4 have been assembled into seven management strategies. The management strategies were formulated by the study team in association with the Woronora River Floodplain Management Committee and were subsequently approved by the Committee for detailed analysis.

The composition of each strategy is summarised in Table 5.1, and is briefly discussed below.

Strategy 1: Base Case

This strategy consists of a set of non-structural options which are generally of low cost and minimal environmental impact. All strategies include these options.

Strategy 2: Base Case and Voluntary House Raising

This strategy also comprises non-structural options. However the cost implications of voluntary house raising are much more significant than for other non-structural options, and therefore it is considered separately.

Strategy 3: Base Case and Access Road Improvements

It has been noted that a problem exists with access roads in low lying areas of Woronora being flooded early. The possibility of raising selected areas of Prices Circuit and an additional access to Menai Road has been considered as a means of providing additional time for evacuation as flood waters rise.

Strategy 4: Base Case and Levee at Bonnet Bay

This strategy examines the option of providing a levee to protect the residential area of Washington Drive, McKinley Avenue and Harrison Avenue in Bonnet Bay.

Strategy 5: Base Case and Woronora Bridge Raising

Despite the possibility that the completion of the new high level bridge may be some years away, raising Woronora Bridge has been considered recognising the longer term timeframe for implementation.

Strategy 6: Base Case and Limited Dredging

A limited dredging option has been evaluated with removal of material to be carried out along a 50 m wide channel.

Strategy 7: Base Case and Levee on Western Foreshore at Woronora

This strategy examines the option of providing a levee to protect Woronora caravan park, Menai Road and residential properties adjacent to the foreshore reserve south of Woronora Bridge.

TABLE 5.1 FLOODPLAIN MANAGEMENT STRATEGIES

Management Option	Strategy 1	Strategy 2	Strategy 3	Strategy 4	Strategy 5	Strategy 6	Strategy 7
Flood Forecasting System	*	*	*	*	*	*	*
Community Preparedness Campaign	*	*	*	*	*	*	*
Planning and Building Controls	*	*	*	*	*	*	*
Voluntary House Raising		*					
Access Road Improvements - Prices Circuit Nundah Place			*				
Levee - Bonnet Bay				*			
Woronora Bridge Raising					*		
Dredging						*	
Levee - Woronora Western Foreshore							*

5.2 Evaluation of Strategies

The flood levels at cross-sections along the river were incorporated into the ANUGRID computer program (Taylor et al.), to produce a flood surface which takes account of changes in flood levels along the floodplain. For each of the strategies, this program was used to produce a flood surface for four different flood frequencies, the 20%, 5%, and 1% AEP floods, and the Probable Maximum Flood.

The flood surfaces produced by ANUGRID were then used in ANUFLOOD to apply the flood levels to house floor levels. The ANUFLOOD program (Taylor et al.) uses stage-damage curves to evaluate flood damages for different depths of flooding. The stage-damage relationships used in the damage calculations are formulated from recent flood events (Sydney 1986 and 1988), and are set out in Appendix E.

Both direct and indirect damages are included. Direct damages result from the physical action of the flood waters on property. Indirect damages are those losses which are not directly a result of floodwaters such as clean-up costs, loss of income of residents who take time off work, etc. For residential properties, the indirect damage has been found to approximate 5% of the direct damage. For commercial properties this is taken as 55% of the direct damage.

In the economic analysis the present worth of benefits and costs has been calculated for a 50 year period using a discount rate of 7%.

5.2.1 Strategy 1: Base Case - Flood Forecasting System, Community Preparedness Campaign, Planning and Building Controls

As discussed in Section 3.6, the average level of preparedness of Woronora valley residents is estimated to be 30%.

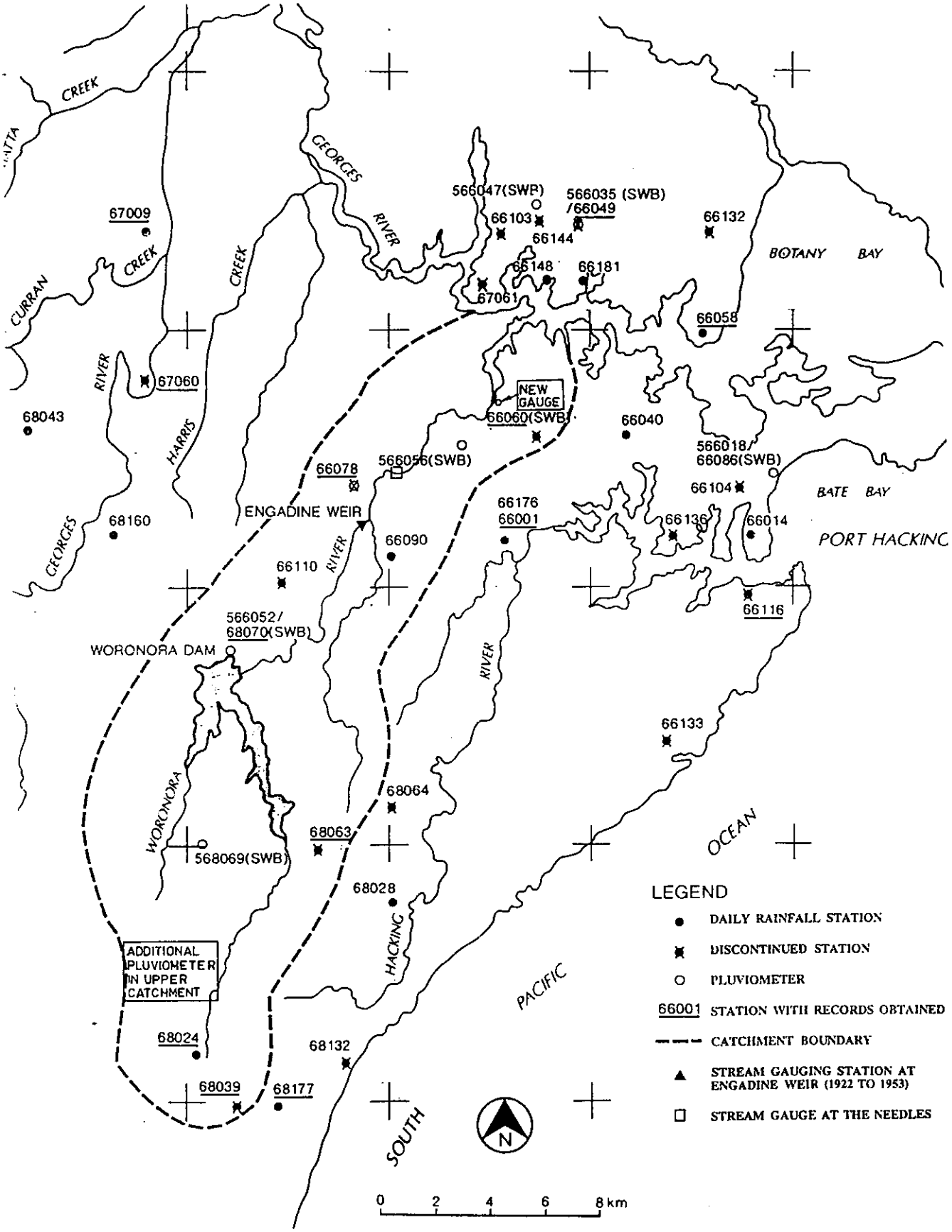
The flood warning time provided to residents by the current system is approximately 2 hours. An improved flood forecasting system could increase this time to 6 hours on average. The increased warning time can be used to remove valuable items to higher ground, resulting in a significant difference in the ratio of actual to potential damages.

The locations of existing stream gauges and pluviometers, and the proposed new stream gauge and pluviometer, are indicated in Figure 5.1.

The greater the preparedness of the community, the greater are the savings in damages achieved. Using graphs showing the ratio of actual to potential damage versus warning time from "Losses and Lessons from the Sydney Floods of August 1986" (Smith et al, 1990), and assuming that 30% of the population is prepared and 70% are unprepared, a saving of 20% of the potential damages could be achieved. As a preparedness campaign is an on-going feature of Strategy 1, the saving of potential damages could be expected to be even higher.

The benefits and costs of an improved flood-warning system, a regular preparedness campaign are summarised below. The details are set out in Appendix I.

Benefits:	
Residents	$1,252,802
Commercial	$ 79,696
Total	$1,332,498
Costs:	
Capital	$ 72,000
Maintenance	$120,066
Total	$192,066
Benefit Cost Ratio:	6.94



SOURCE: SINCLAIR KNIGHT (1991)

LOCATION OF GAUGING AND RAINFALL STATIONS
FIGURE 5.1

It can be seen that the benefit-cost ratio would be very high at about 6.94. Given that the calculations take no account of the considerable social benefits, the strategy would appear to be very worthwhile.

All subsequent strategies have been evaluated, assuming the benefits are reduced by 20% because of the savings from the Base Case.

This strategy has no effect on existing flood levels.

Recommended floor heights for new residences have been evaluated in Section 3.7 of this report, indicating that it is worthwhile constructing to 1-2 m above the 1% AEP flood level.

For further development in floodplain areas it is recommended that Council require the developer to demonstrate that significant negative impacts do not result with regard to the existing flood hazard as defined in Table 3.1 of this report. For substantial developments a two-dimensional flood model would be required. It is recommended that the hydraulic model used examines the effects for a distance of 100 m upstream and downstream of the development.

The "creeping" effect of piecemeal development should be considered in this regard.

5.2.2 Strategy 2: Base Case and Voluntary House Raising

The economic assessment of raising 179 houses with floor levels below the 1% AEP flood is summarised below:

Benefits:	
Residents	$3,548,073
Commercial	$ 79,696
Gross	$3,627,768
Marginal	$2,295,270
Costs:	
Capital	$7,987,066
Maintenance	0
Gross	$7,987,066
Marginal	$7,795,000
Benefit Cost Ratios:	
Gross	0.45
Marginal	0.29

The marginal benefits and costs consider the effect of house raising without the base case.

The benefits of house raising can be justified in certain circumstances, but not for all houses below the 1% level. The overall benefit-cost ratio of 0.45 is at the lower end of what may be economically worthwhile.

Nevertheless, if priority for house raising were to be given to those houses whose floors are most subject to inundation, the benefits would be very likely to exceed the costs. From the calculations in Appendix G, the maximum floor heights at which it could be justified to raise a timber or fibro house (costing $35,000) or to put a second storey on a non-raiseable house are given in Table 5.2 for the various zones of the floodplain. Table G2 (Appendix G) shows the costs and benefits of house raising, however, the benefits also can be applied to the construction of a new dwelling to a greater height.

TABLE 5.2 MAXIMUM FLOOR LEVELS TO QUALIFY FOR HOUSE RAISING

Zones	Maximum floor level to justify house raising	
	House raising	Second storey
1-4	no houses qualify	no houses qualify
5-9	no houses qualify	no houses qualify
10-15	2.6	2.1
16-22	3.0	2.5

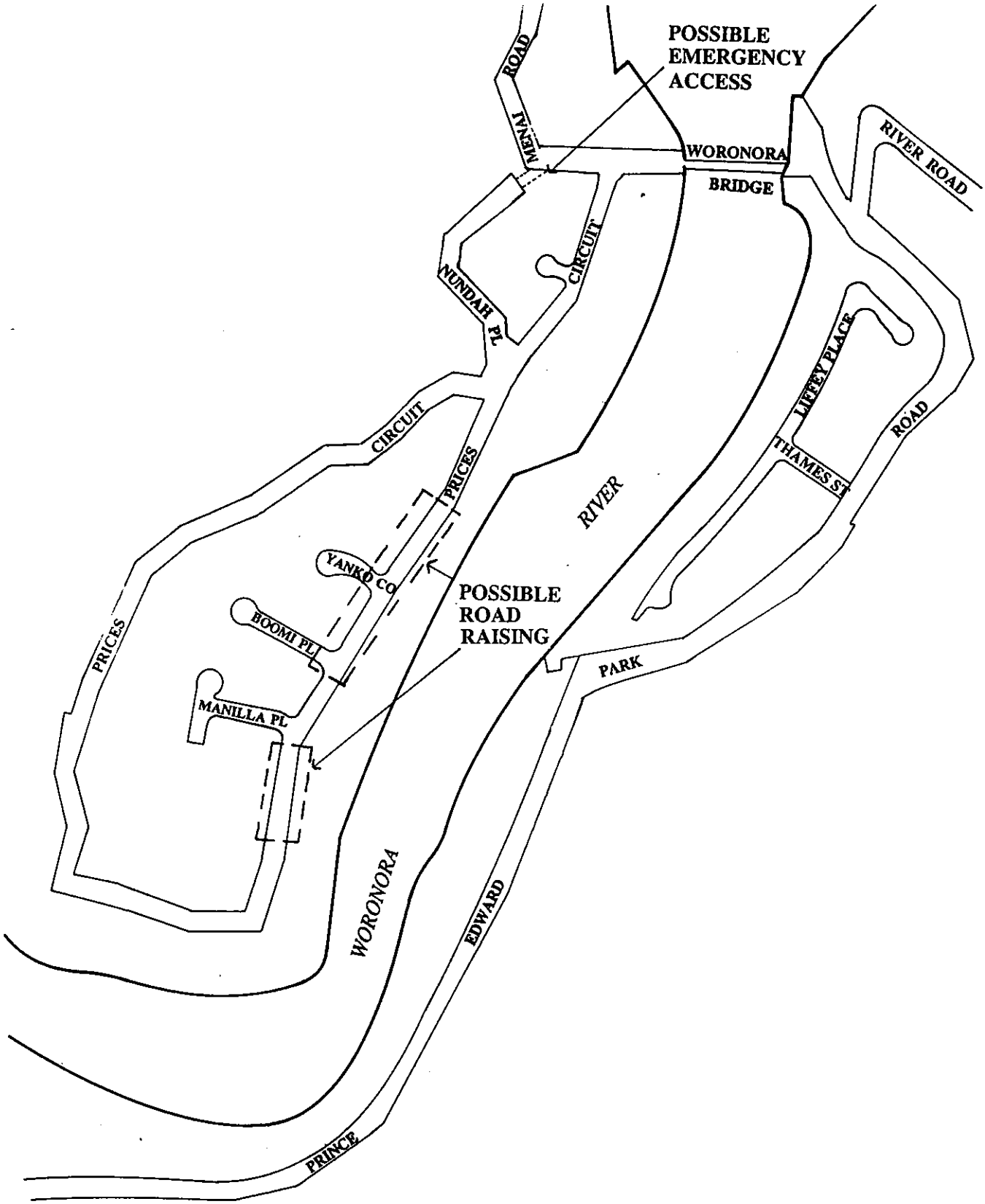
As for Strategy 1 this strategy would not be expected to affect existing flood levels.

5.2.3. Strategy 3: Base Case and Access Road Improvements

Option A

There are about 86 households which could experience difficulties in evacuating from their houses because the low section of Prices Circuit is cut off early by floodwaters. To raise this part of the street and provide an emergency access from Nundah Place to Menai Road is estimated to cost $355,000.

It is estimated that at most this might provide an extra hour for evacuation. Using the relationship for reduction of damages in Smith et al (1990), the average annual damage for these houses might reduce by about 5%. This works out to be approximately $4,000/a, equivalent to a present worth of $55,000. This is much less than the capital cost of $355,000. The locations of the proposed works are indicated in Figure 5.2.



PRINCE EDWARD PARK

STRATEGY 3: LOCATION OF POSSIBLE ROAD RAISING

FIGURE 5.2

When this is considered together with the Base Case, the benefit-cost ratio is reduced to 2.5. With the monetary benefits being relatively small, this strategy might be more appropriate for consideration to be undertaken in conjunction with other works such as the resurfacing of the road which is normally required every ten years - or more frequently in flood-prone areas.

The results of the economic assessment are summarised below:

Benefits:	
Gross	$1,390,461
Marginal	$ 57,963
Costs:	
Gross	$ 547,066
Marginal	$ 355,000
Benefit Cost Ratios:	
Gross	2.5
Marginal	0.152

Due to the limited extent of road raising involved (0.5 m maximum over a 300 m length) flood levels are not expected to be affected by this strategy.

Option B

The Menai Road at the intersection with Prices Circuit is cut off early by floodwaters. Nundah Place previously joined Menai Road, this intersection was closed off by kerb and gutter, wood posts and a grass verge.

The re-establishment of access from Nundah Place to Menai Road for emergency situations will allow residents of Nundah Place and Prices Circuit to evacuate the area at an intersection which is above the 5% AEP flood level.

The cost of a lockable gate and lay-by would be approximately $5,000. The benefits of this option will be primarily social rather than monetary. The low section of Prices Circuit at Boomi Place, Yanko Close and Manilla Place is cut off early by floodwater, and residents of this area will still need to evacuate as soon as possible to avoid the risk of being isolated.

Those residents who live in the remainder of Prices Circuit will be able to avail themselves of the extra time for evacuation provided by the access gate. However, it is possible that many residents will evacuate as soon as floodwaters begin to rise, while others will stay to save possessions until they are in danger of their car becoming marooned. The emergency access would not be expected to affect the amount of possessions which could be saved by these people.

There are many social benefits which would result from the emergency access. The access provides a route not only to higher ground, but also out of the area. Evacuating residents would be able to travel to stay with friends and relations, rather than staying in their car at the high point of Prices Circuit. Those resident where houses do not flood would still be able to access services such as shops, schools and medical facilities.

The access gate would also allow the SES and other emergency workers to enter and leave the area in order to assist in evacuation and advise residents on when it is best to leave the area.

These social benefits cannot be quantified in the benefit/cost model and will thus be noted to be registered as zero in the following analyses. However such benefits are clearly worthwhile, especially given the small investment required.

The results of the economic assessment are summarised below:

Benefits:

Gross (equals Base Case only)	$1,332,498
Marginal	0

Costs:

Gross	$197,066
Marginal	$ 5,000

Benefit Cost Ratios:

Gross	6.76
Marginal	0

5.2.4. Strategy 4: Base Case and Levee at Bonnet Bay

A flood protection levee along the foreshore reserves at Bonnet Bay parallel to Washington Drive in the vicinity of its intersections with Harrison Avenue and McKinley Avenue is considered. The area under existing conditions would be subjected to Low Hazard flooding during a 1% AEP event with expected flood depths of up to 0.6 m and flow velocities up to 0.3 m/s. This option involves the construction of a 650 m length levee of average height of 0.7 m to protect the area against flooding for events up to the 1% AEP flood. The levee would run along the eastern bank of the Woronora River for 400 m before heading inland over a distance of 250 m along the northern boundary of Jannali Park. The volume of earthworks involved is estimated to be about 1500 m^3. The location and details of the levee are shown in Figure 5.3.

Hydraulic simulations were carried out for the 5% and 1% AEP flood events with no significant increases in flood levels as a result of the construction of the levee. This would be expected as the reduction in floodplain flow area would be relatively small.

The economic benefits to the Bonnet Bay households would appear to be extremely small. Only two of the houses appear to have floors significantly below the 1% flood level, being only 0.2 m too low. The average annual benefit would be only about $400/a, of which half of the savings would come from the reduction of damages to swimming pools.

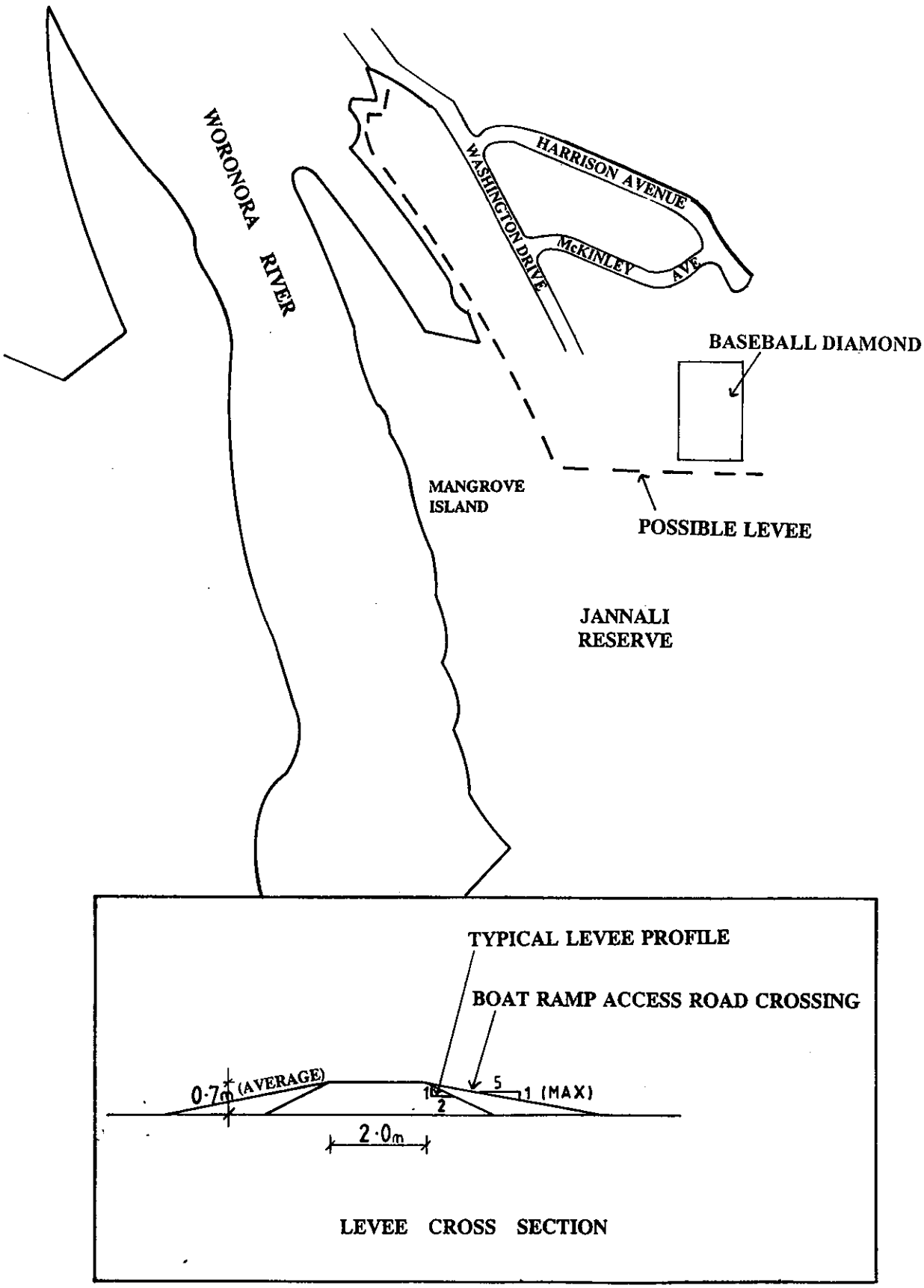
It is considered that the Bonnet Bay community is probably less prepared than the flood-prone community of the river as a whole, because the houses are relatively new and the occupants' experience of floods would be less.

If a levee were built for this area, it could be expected that the average preparedness of these householders could drop considerably, since the frequency of above ground flooding would reduce. People who are inexperienced will have a false sense of security and tend to believe that they will be protected by the levee. As a result, when the next overtopping flood came, the people would, on average, be less prepared than now.

This reduction in preparedness would, in effect, nullify the benefits to the people of Bonnet Bay of the increased warning time.

The overall benefits below are therefore identical to Strategy 1 with the extra cost of the levee of approximately $100,000.

Benefits:	
Residents	$1,252,802
Commercial	$ 79,696
Gross	$1,332,498
Marginal	-
Costs:	
Capital	$ 292,066
Maintenance	138,007
Gross	$ 430,073
Marginal	$ 238,007
Benefit Cost Ratios:	
Gross	3.10
Marginal	0



STRATEGY 4: LOCATION OF POSSIBLE LEVEE, BONNET BAY

FIGURE 5.3

5.2.5 Strategy 5: Base Case and Woronora Bridge Raising

Woronora Bridge is found to cause an increase in flood levels upstream due to flood waters being restricted by the underdeck of the bridge. Raising Woronora Bridge by 1.2 m has been considered ensuring that flood levels for events up to 1% AEP event are below the underdeck of the bridge.

Hydraulic analysis indicates that flood levels upstream of the bridge would decrease by between 0.2 m to 0.26 m along a 1.2 km section of the river. The effect of this option extends as far as 3.5 km upstream of the bridge where water levels were 0.1 m lower than for the existing conditions for the events simulated. Figures 5.5 - 5.7 compare the flood profiles resulting from this option with those for existing conditions for flood events of 5%, 2% and 1% AEP. Figure 5.4 indicates details of a possible raising procedure.

Raising Woronora Bridge could provide an average annual benefit of $66,000/a which equates to a present worth of nearly $1 million. This is not substantially less than the cost of raising, about $1.5 million. The results of the evaluation of bridge raising, together with the Base Case are summarised below.

Benefits:	
Residents	$2,208,087
Commercial	$ 111,837
Gross	$2,319,925
Marginal	$ 987,427
Costs:	
Capital	$1,692,066
Maintenance	$ 0
Gross	$1,692,066
Marginal	$1,500,000
Benefit Cost Ratios:	
Gross	1.37
Marginal	0.66

It should be noted that no allowance for bridge maintenance has been included as the increase on existing costs would be negligible.

Given that the social benefits have not been evaluated, and since the social benefits are often regarded as being at least as important as the monetary benefits to households, it would appear that this strategy could be justified.

The effect of raising the bridge in terms of reduction in the number of houses suffering above floor flooding is summarised in the table below:

TABLE 5.3 STRATEGY 5 - REDUCTION IN NUMBER OF HOUSES FLOODED ABOVE FLOOR LEVEL

AEP	Number of Houses flood above floor Base Case	Number of houses flooded above floor Strategy 5	Reduction in number of houses flooded above floor
5%	200	162	38
2%	254	221	33
1%	289	273	16

5.2.6 Strategy 6: Base Case and Dredging

River dredging would be effective in reducing the impact of flooding in most areas. This strategy involves the dredging of a 50 m wide "deep channel" along the Woronora River from the Needles to the Georges River confluence . Owing to the dominance of tidal and Georges River flows in the first kilometre of the river from the Georges River confluence, dredging of the channel was considered to only commence at Zone 2 (refer Figure 3.1) extending to 500 m downstream of The Needles. Two options were analysed, ie.

1 A trapezoidal channel of 1 in 3 side slope with a minimum invert ranging (linearly) from -4.3 m AHD at Zone 2 to -3.3 m AHD at 500 m downstream of The Needles.

2. A deeper trapezoidal channel of 1 in 3 side slope with a minimum invert ranging (linearly) from -5.3 m AHD at Zone 2 to -4.3 m AHD at 500 m downstream of The Needles.

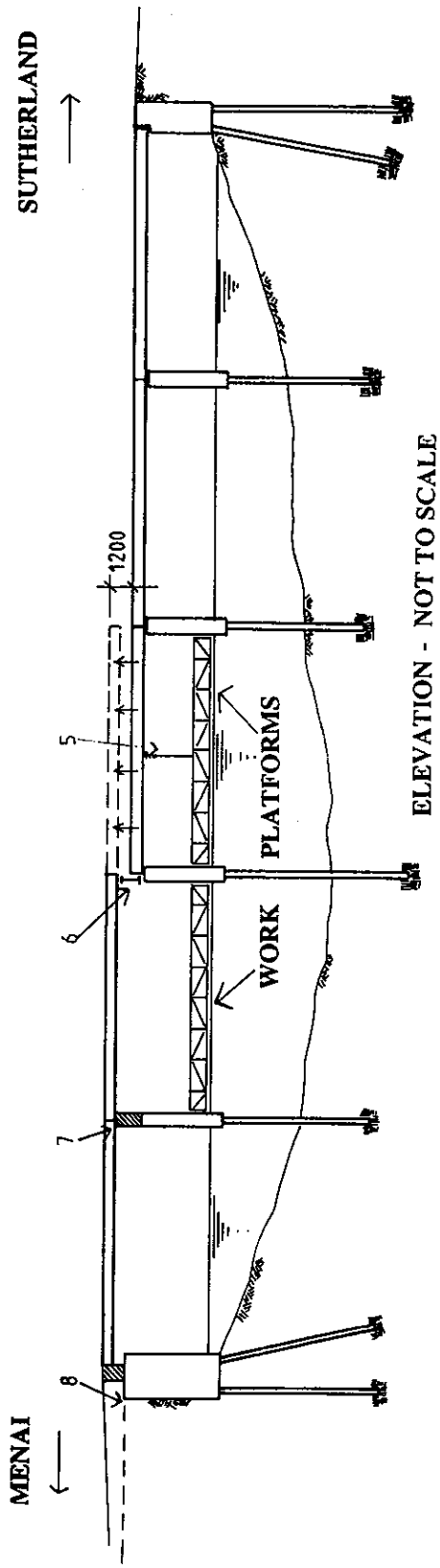
Typical dredging profiles are illustrated in Figure 5.8.

Option 1

The volume of dredged material for Option 1 is estimated to be approximately 250,000 m^3. Flood levels were found to be reduced by as much as 0.45 m (in the upper reaches of the river) with average reduction of about 0.15 to 0.2 m along the river section with the highest concentration of residential properties. The range of reduction applied for the 5%, 2% and 1% AEP events. For the PMF, the corresponding figures were 0.7 m and 0.3 m respectively.

Option 2

The volume of dredged material for Option 2 is estimated to be approximately 580,000 m^3. Reduction in flood levels was found to be as much as 0.9 m in the upper reaches with average reduction of about 0.3 m along the river section of most interest. For the PMF the corresponding flood level reductions were 1.2 m and 0.4 m respectively.

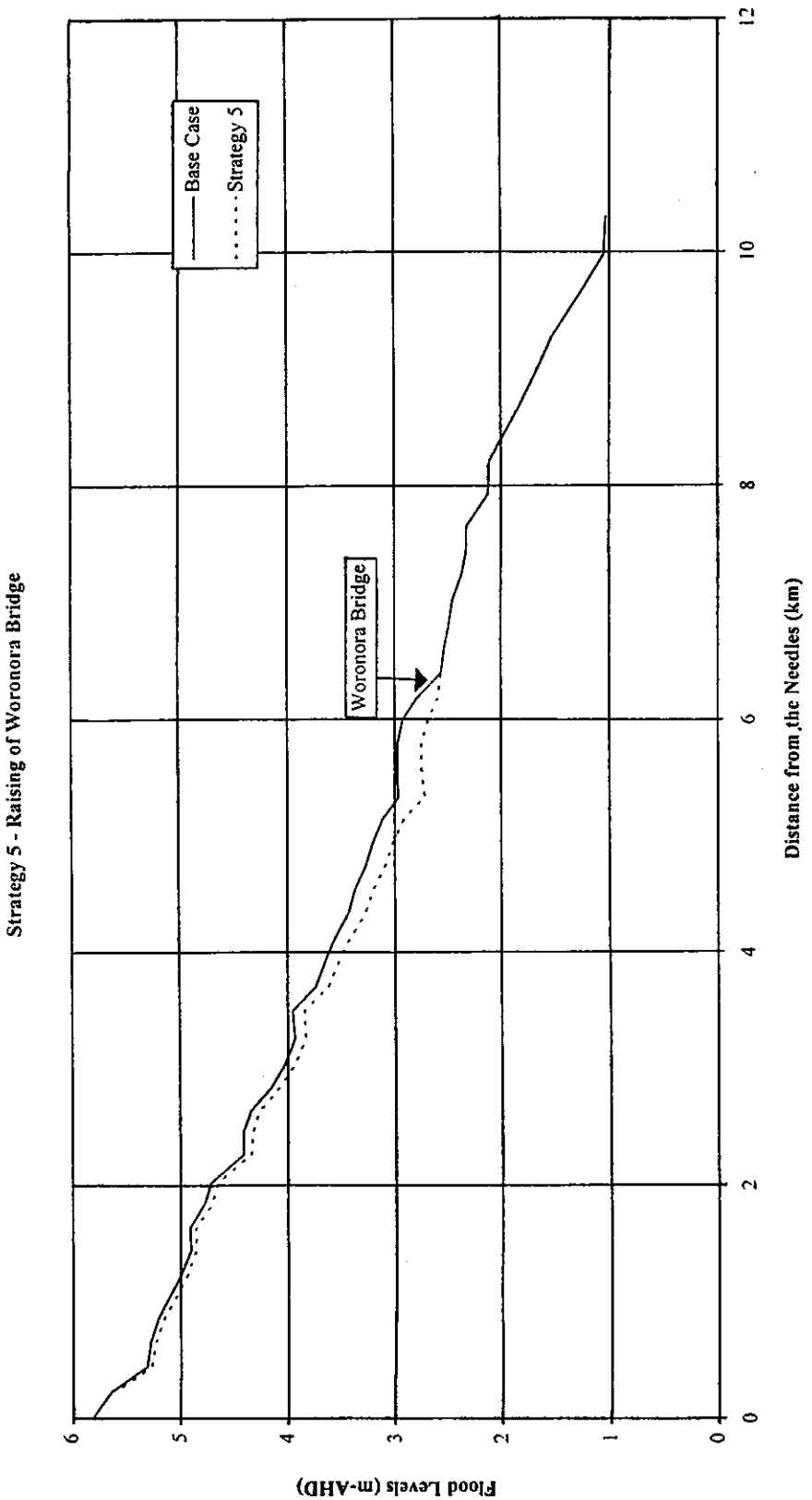


CONSTRUCTION SEQUENCE

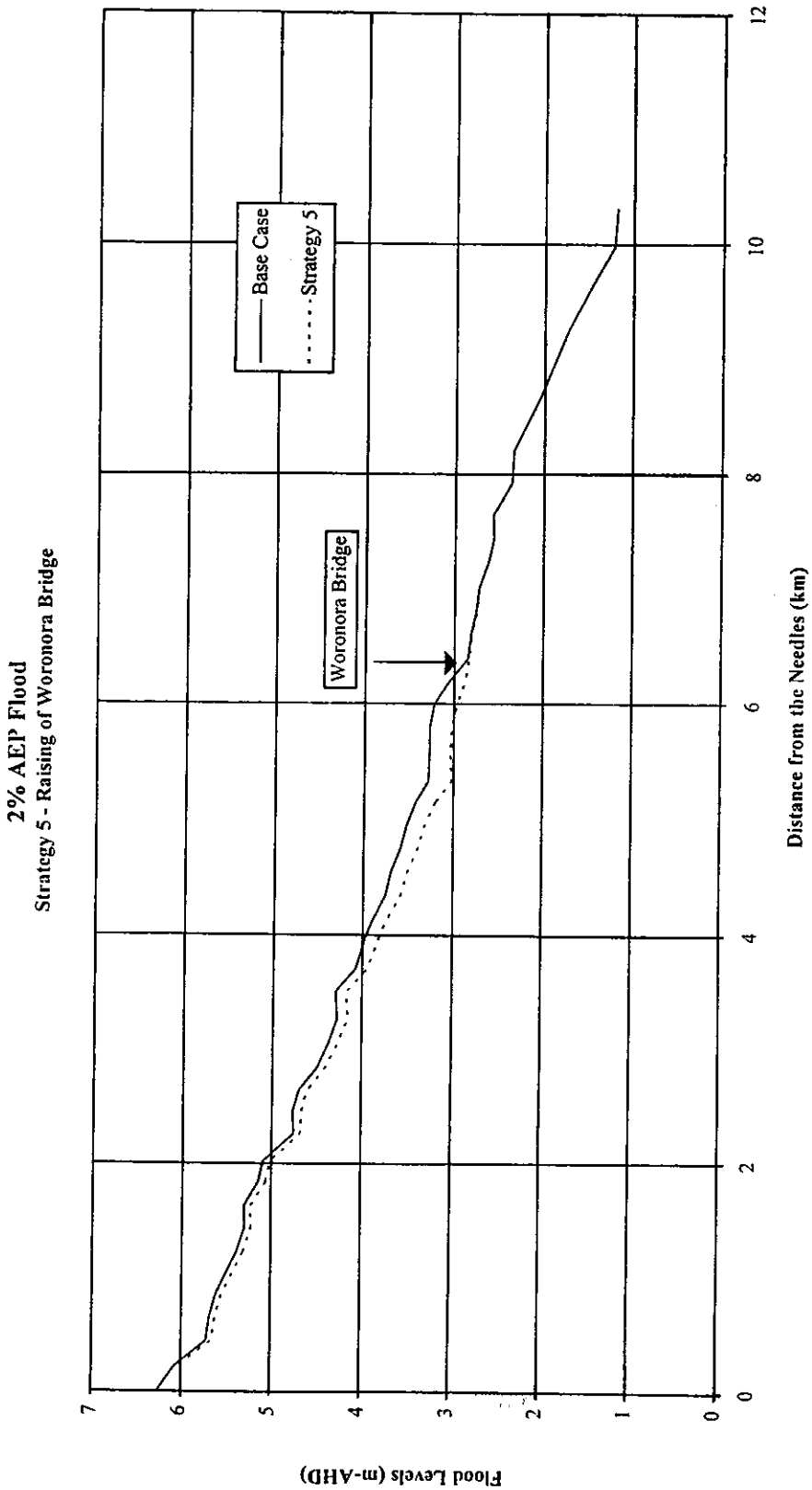
1. CLOSE ONE LANE OF BRIDGE AND APPROACHES
2. DEMOLISH/SAW CUT STRIP DOWN CENTRE LINE OF BRIDGE
3. SAW CUT THROUGH DECK AT EACH SUPPORT
4. INSTALL WORK PLATFORMS BY BARGE AND ATTACH TO PIERS
5. RAISE SPAN SECTION (HALF WIDTH) 1200 mm
6. TEMPORARILY PROP OFF PIERS
7. CONSTRUCT CONCRETE PIER EXTENSION AND REINSTATE BEARINGS
8. REPEAT 3 TO 8 FOR EACH SPAN
9. RECONSTRUCT ABUTMENTS AND APPROACHES
10. REPEAT FOR OTHER LANE

STRATEGY 5: DETAILS OF POSSIBLE WORONORA BRIDGE RAISING

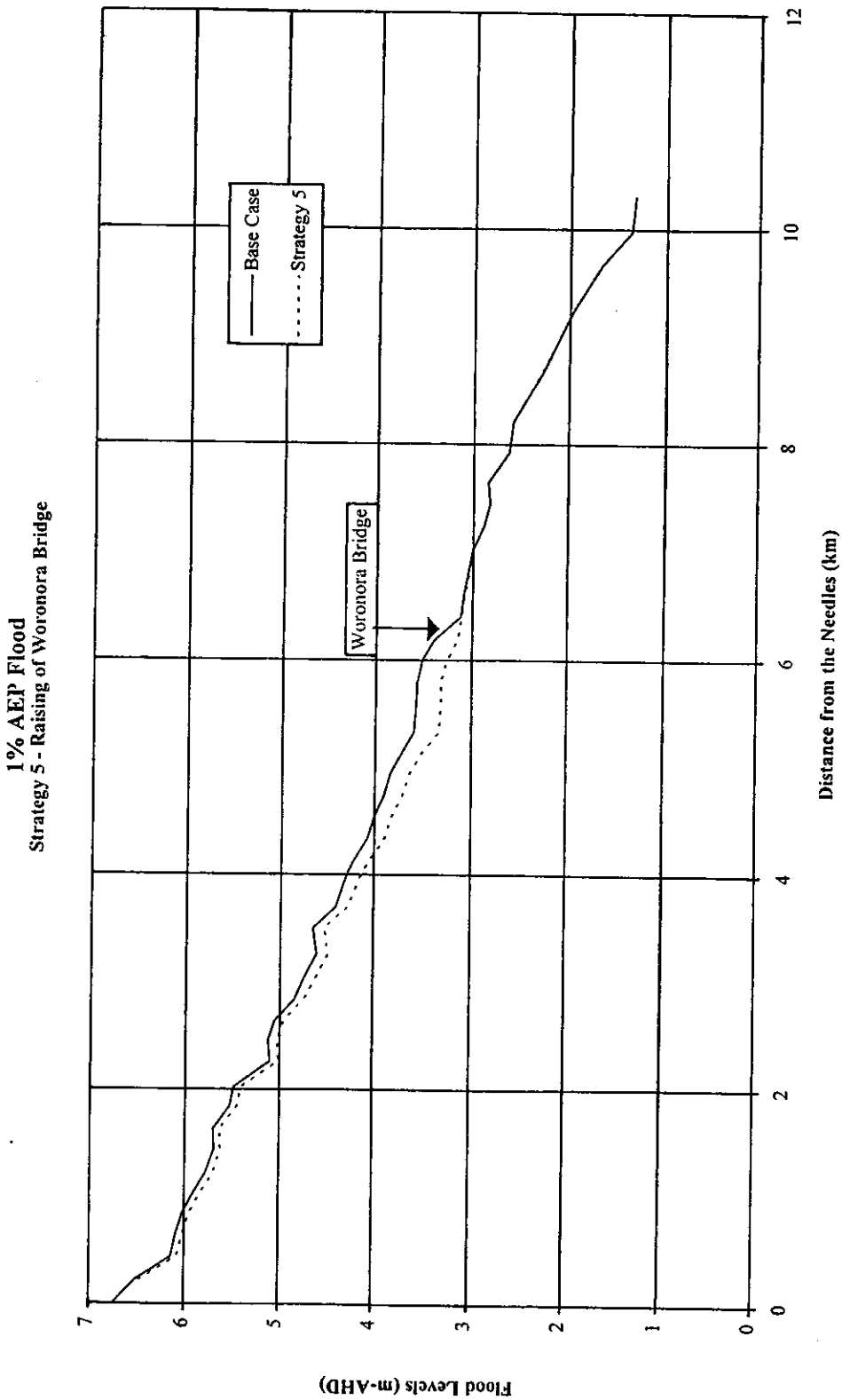
FIGURE 5.4



STRATEGY 5: FLOOD DEPTH PROFILE 5% AEP FLOOD
FIGURE 5.5



STRATEGY 5: FLOOD DEPTH PROFILE 2% AEP FLOOD
FIGURE 5.6



STRATEGY 5: FLOOD DEPTH PROFILE 1% AEP FLOOD
FIGURE 5.7

Figures 5.9 - 5.11 compare the water surface profile of the 5%, 2% and 1% AEP events for the options to existing flood levels.

The results of the economic evaluation of this strategy are summarised below. The analysis has allowed for maintenance dredging every 15 years. If this assumption is reasonable, Option 1 would appear to warrant further examination, since with a benefit-cost ratio of 0.51 dredging in selected locations may be justified.

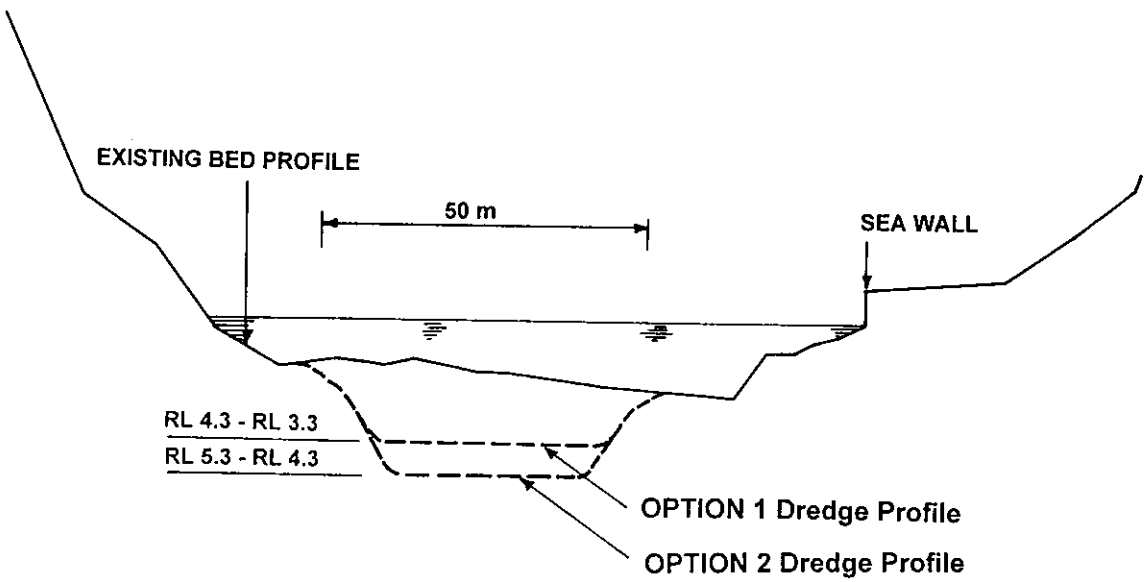
With an overall benefit-cost ratio of 0.3 Option 2 would appear to be difficult to justify.

Option 1

Benefits:	
Residents	$2,030,295
Commercial	$ 106,557
Gross	$2,136,852
Marginal	$ 804,354
Costs:	
Capital	$2,692,066
Maintenance	$1,353,567
Gross	$4,045,633
Marginal	$3,853,567
Benefit Cost Ratios:	
Gross	0.53
Marginal	0.21

Option 2

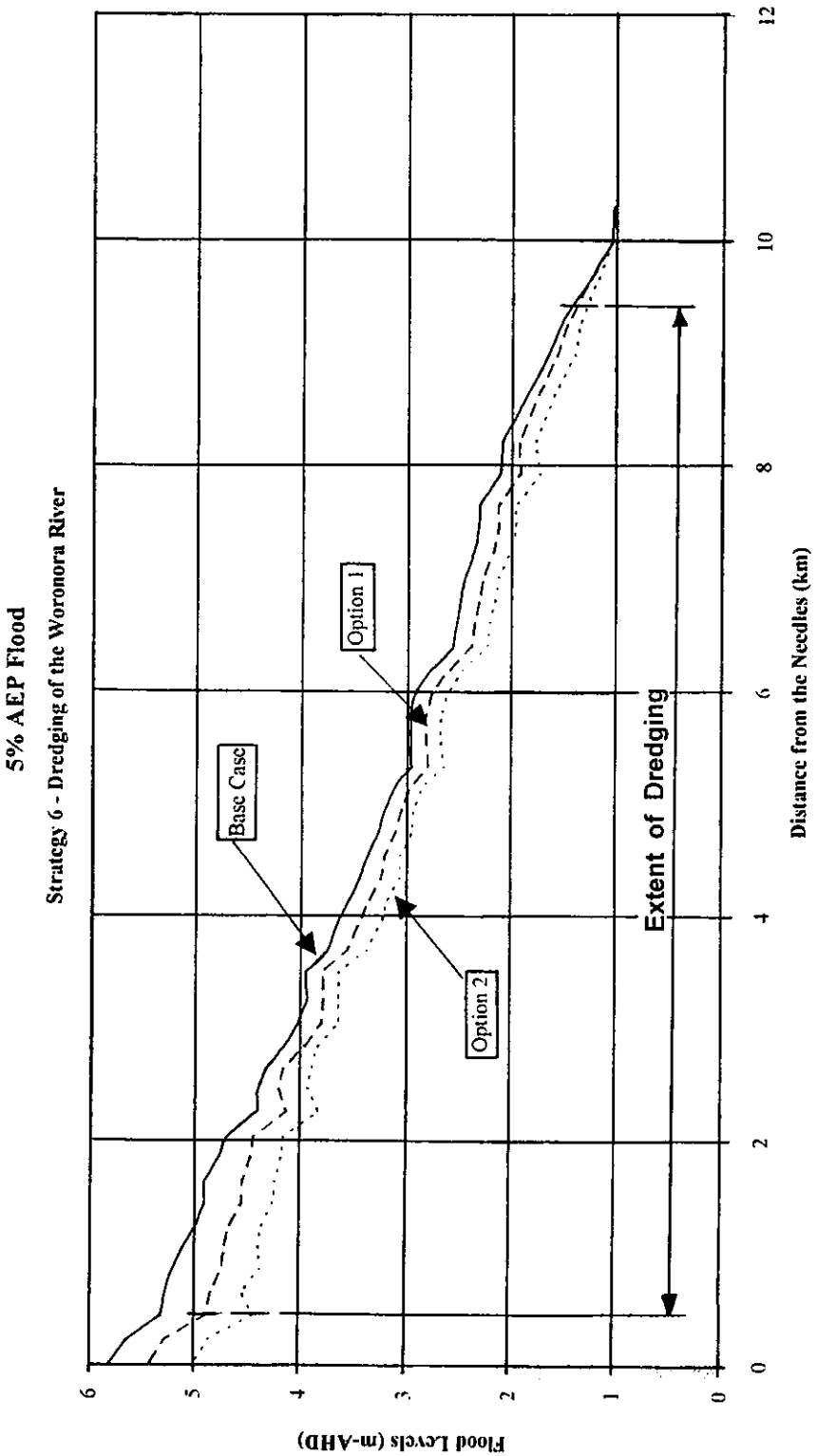
Benefits:	
Residents	$2,790,782
Commercial	$ 143,563
Gross	$2,934,344
Marginal	$1,601,846
Costs:	
Capital	$5,992,066
Maintenance	$3,140,274
Gross	$9,132,340
Marginal	$8,940,274
Benefit Cost Ratios:	
Gross	0.32
Marginal	0.18



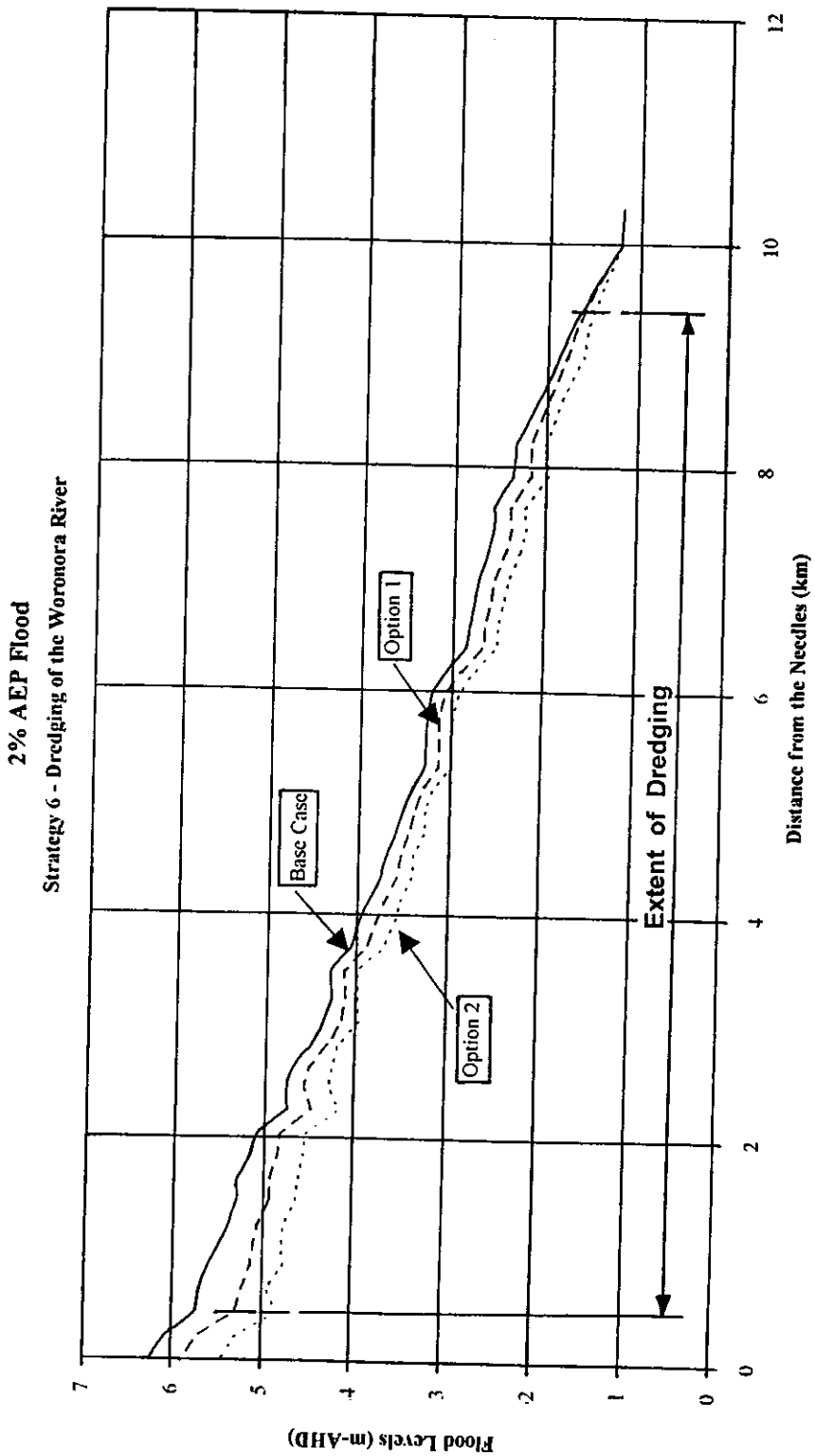
SCALES:

HORIZONTAL 1:1000
VERTICAL 1:200
Vertical Exaggeration 5:1

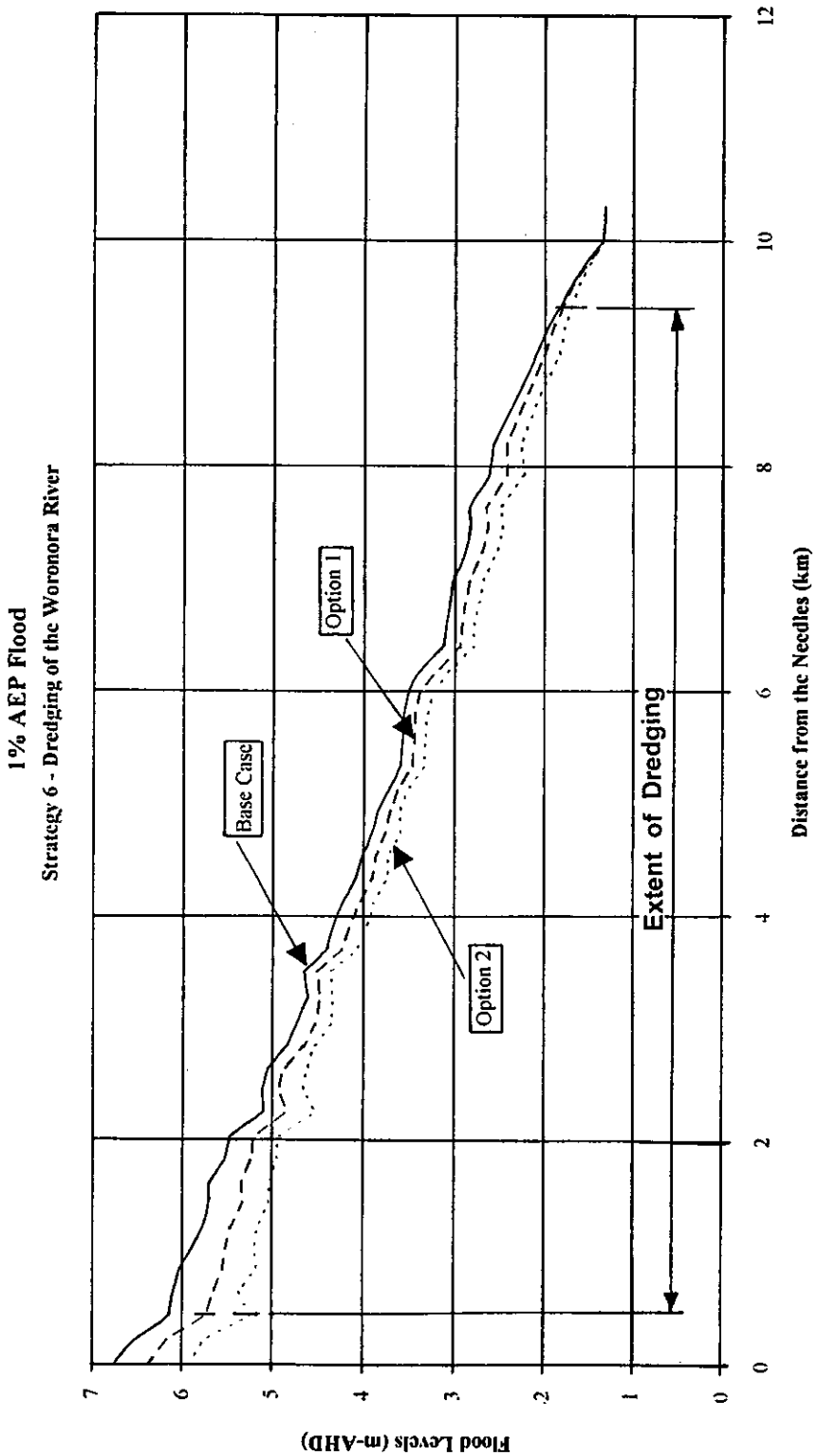
STRATEGY 6: POSSIBLE DREDGING PROFILES
FIGURE 5.8



STRATEGY 6: FLOOD DEPTH PROFILE 5% AEP FLOOD
FIGURE 5.9



STRATEGY 6: FLOOD DEPTH PROFILE 2% AEP FLOOD
FIGURE 5.10



STRATEGY 6: FLOOD DEPTH PROFILE 1% AEP FLOOD
FIGURE 5.11

5.2.7 Strategy 7: Base Case and Levee on Western Foreshore at Woronora

A levee approximately 550 m in length has been evaluated, extending along the western foreshore of Woronora River from the northern end of the caravan park south along the foreshore reserve to up to 250 m south of Woronora Bridge (see Figure 5.12). The levee would provide protection up to the 5% AEP flood level for the following areas:

(i) Woronora Caravan Park
(ii) Menai Road
(iii) Residential properties in Woronora (west) up to 250 m south of Woronora Bridge.

Woronora caravan park floods several times a year under high tide conditions. The presence of a levee would protect residents from this nuisance flooding and also allow protection for larger events up to the 5% AEP flood level. For events above the 5% AEP flood the levee would provide increased time for evacuation.

Woronora Bushfire Brigade station is located immediately south of the Caravan Park north of the approach to Woronora Bridge. For some years the Woronora Station has suffered water damage to equipment and the building as a result of flooding and king tides. During previous floods crews at the station assisted the SES with flood operations. On such occasions the station was used as a forward command even though power had been cut off and crews were working in the station in 0.5 m of water.

The Woronora Bushfire Brigade Station needs to be raised and/or relocated. Woronora River Bridge and the existing footbridge may impede access to the upstream section of the river during flooding and this should be considered in any relocation.

Menai Road is critical for access across the river. Until the new high level Woronora Bridge is completed this road will remain the only road crossing for developed areas in the valley. Maintenance of this access is important to assist with evacuation during flooding. As for the caravan park, the section of the road immediately west of the bridge floods under high tide conditions.

Provision of the levee would also enable protection of residential properties for floods up to the 5% AEP event. For flood events greater than this advantages would accrue from increased evacuation time. The levee would have the disadvantage of reducing views of the river from these residences. To minimise impacts it is suggested that the levee be located adjacent to the property boundary with the foreshore reserve.

The impact on views for a typical residence is shown in Figure 5.13. A typical floor level of RL 2.1 m has been selected for this evaluation. All but 2 of the houses in the area have levels at or above this level. For a view point of 1.5 m above floor level, corresponding to a person standing, approximately 70 m of the river width would be

visible compared to 90 m at present. For a view point of 1.1 m above floor level, corresponding to a person sitting, the river would not be visible compared to 85 m of the river width at present.

The levee would lead to only a marginal increase in flood levels. The average increase for the 2 km section upstream of Woronora Bridge would be 0.06 m for the 5% AEP event.

A possible disadvantage associated with the levee would be that surface runoff may pond behind the levee when river levels are elevated and water is unable to be discharged through the stormwater system. A preliminary flood analysis carried out indicates that if river levels were elevated and a 20% AEP event occurred over the catchment behind the levee localised flooding of the order of 0.5 m would result in low lying areas behind the levee. It should be noted that the combined probability of a 20% AEP storm event and elevated river levels is less than 20%. As the majority of houses are elevated more than 0.5 m above ground level significant over floor flooding is unlikely to result.

The results of the economic evaluation of the strategy are summarised below:

Benefits:

Residents	$1,597,746
Commercial	$ 88,960
Gross	$1,686,706
Marginal	$ 354,208

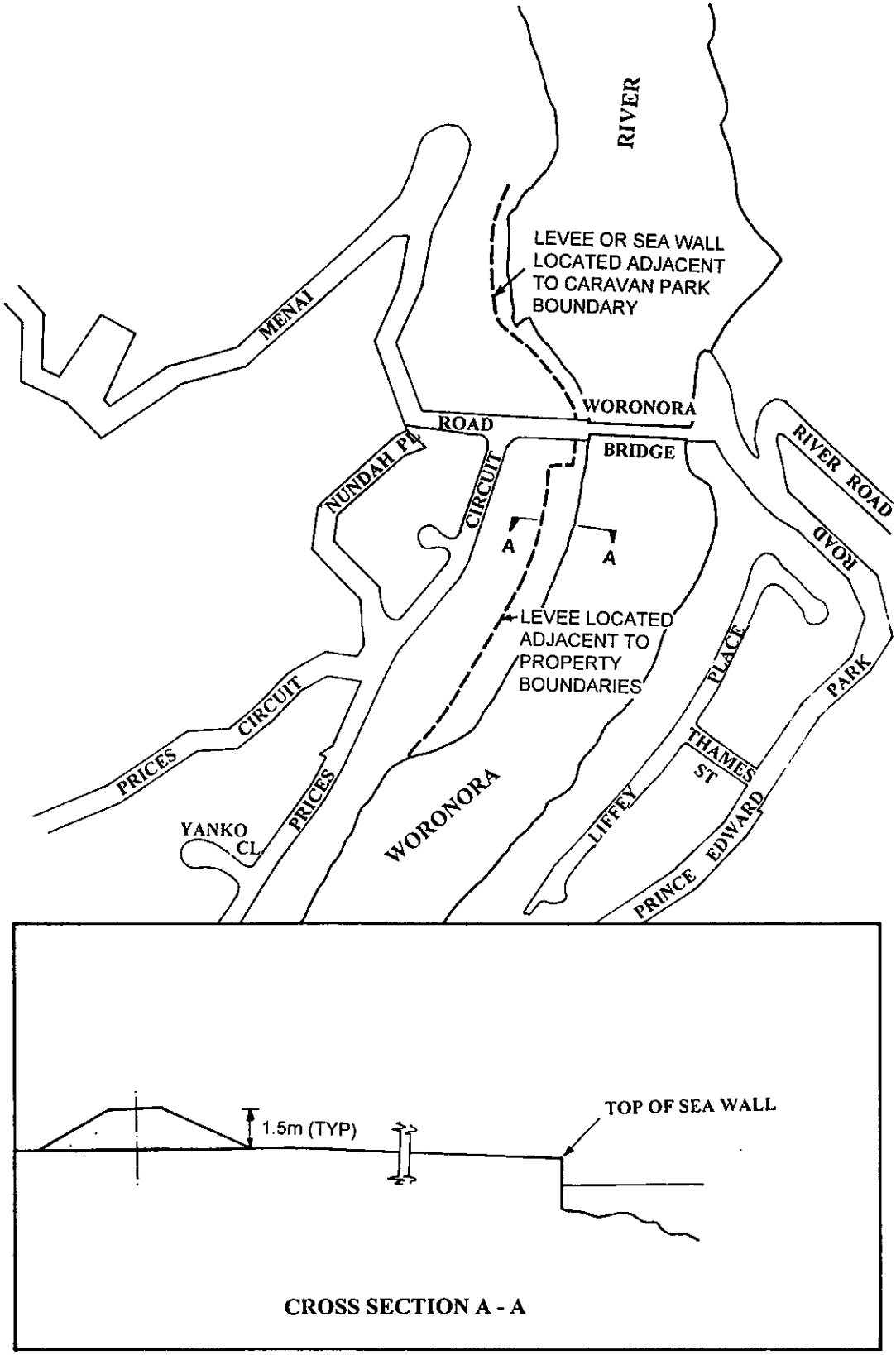
Costs:

Capital	$417,066
Maintenance	$310,517
Gross	$727,583
Marginal	$535,517

Benefit Cost Ratios:

Gross	2.32
Marginal	0.66

The marginal benefit-cost ratio for this strategy is 0.66 and given that the social benefits of this option have not been included, and are probably as least as high as the monetary benefits, the option of building a levee to the 5% AEP level, or higher, appears quite justifiable. Where the foreshore reserve is narrow between the river and the caravan park, a sea wall could be used in place of the levee. This option would increase the capital costs, the amount of increase dependent on the construction material used.

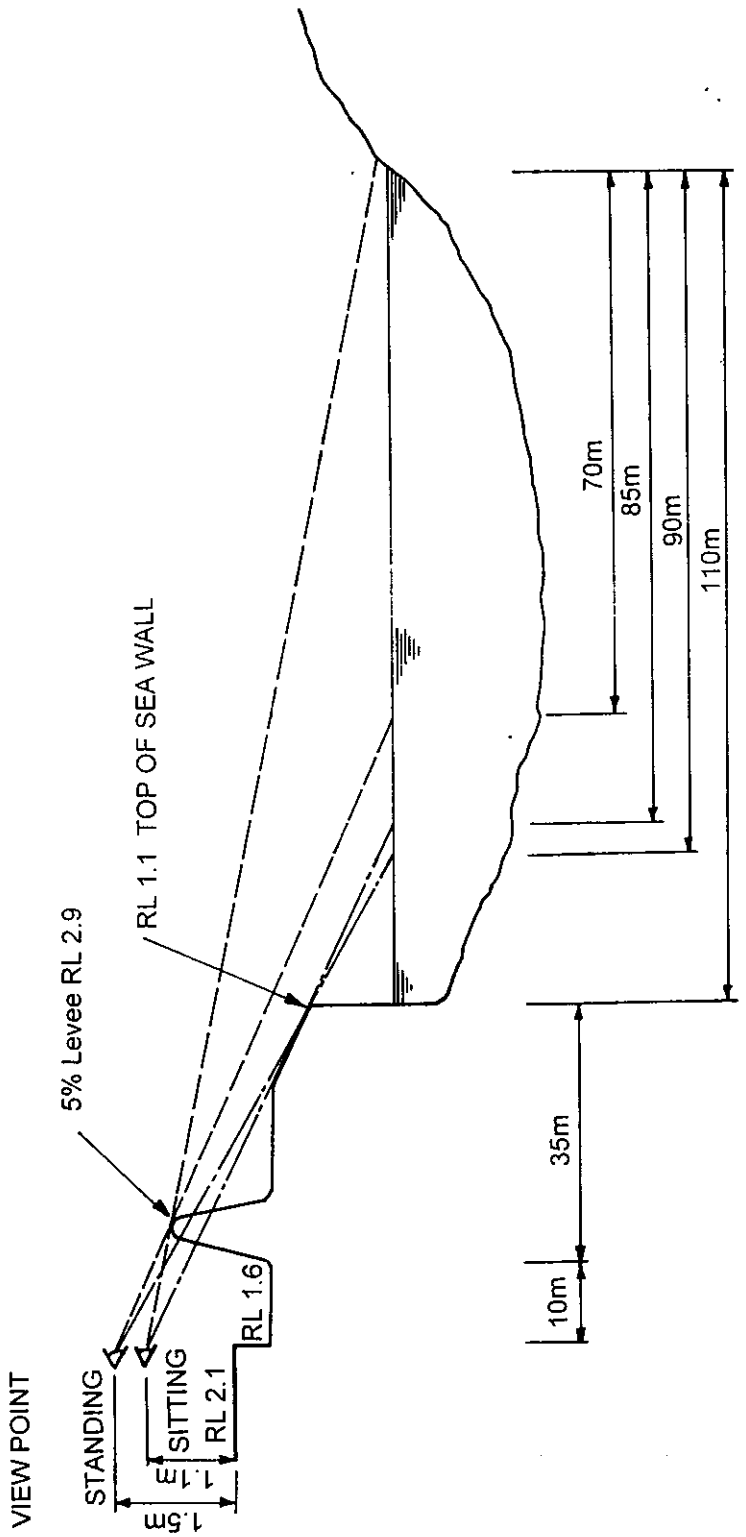


STRATEGY 7: LEVEE ON WESTERN FORESHORE, WORONORA

FIGURE 5.12

SCALES: VERTICAL 1:100
HORIZONTAL 1:1000

NB: THE LEVEE APPEARS TO BE TALL BY PROPORTION DUE TO THE DRAWING VERTICAL EXAGGERATION OF 10:1



EFFECT OF LEVEE ON RIVER VIEWS FROM RESIDENCES FACING FORESHORE RESERVE

FIGURE 5.13

Analyses were also carried out for levees at the 1% and 2% AEP levels. Figures for these have been summarised in Table 5.4. It is evident that, from an economic viewpoint, construction of a levee up to the 1% AEP level could be justified, however, the 5% AEP level is recommended to reduce impacts on views for residences adjacent to the foreshore reserve south of Woronora Bridge.

5.2.8 Summary of Results

The results of the evaluations of all the Strategies are summarised in Table 5.4 below.

TABLE 5.4 SUMMARY OF BENEFIT - COST ANALYSES

Strategy		Benefits	Marginal Benefits	Costs	Marginal Costs	Benefit-Cost Ratio	Marginal Benefit-Cost Ratio
1.	Base Case	$1.3 million	N/A	$0.2 million	N/A	6.94	N/A
2.	Base Case plus voluntary house raising	$3.6 million	$2.3 million	$8.0 million	$7.8 million	0.45	0.29
3(a).	Base Case plus road raising and emergency access	$1.4 million	$58,000	$0.55 million	$0.35 million	2.5	0.15
3(b).	Base Case plus emergency access	$1.3 million	*	$0.20 million	$5,000	6.76	*
4.	Base Case plus levee for Bonnet Bay	$1.3 million	-	$0.43 million	$0.24 million	3.10	-
5.	Base Case plus raising bridge	$2.3 million	$0.99 million	$1.7 million	$1.5 million	1.37	0.66
6(1).	Base Case plus dredging to -4 m	$2.1 million	$0.80 million	$4.0 million	$3.8 million	0.53	0.21
6(2).	Base Case plus dredging to -5 m	$2.9 million	$1.6 million	$9.1 million	$8.9 million	0.32	0.18
7(a).	Base Case plus levee on western foreshore (1% AEP)	$1.9 million	$0.55 million	$1.0 million	$0.83 million	1.83	0.66
7(b).	Base Case plus levee on western foreshore (2% AEP)	$1.8 million	$0.43 million	$0.85 million	$0.65 million	2.08	0.65
7(c).	Base Case plus levee on western foreshore (5% AEP)	$1.7 million	$0.35million	$0.73 million	$0.54 million	2.23	0.66

* Benefits are social rather than monetary

It can be seen that the Base Case produces a high level of benefits for low cost. Of the structural strategies the raising of Woronora Bridge and the levee on the western foreshore at Woronora produce a reasonable level of benefits given that social benefits, which have not been costed for these strategies, can be assumed to improve economic benefits by a factor of 2 to 2.5. The construction of an emergency access from Nundah Place to Menai Road produces no economic benefits but would provide significant social benefits for minimal cost .

Of the remaining strategies house raising, road raising and dredging perform poorly on an economic basis. Those may be some benefit in selective application of house raising for properties more suitable for raising in high hazard areas. The levee at Bonnet Bay produces no economic benefits as the marginal savings in flood damages (2 residences only) are cancelled out by an increase in damage due to a reduction in community preparedness behind the levee.

In addition to this Floodplain Management Study a Floodplain Management Plan has been prepared as a separate document. The purpose of the Floodplain Management Plan is to provide detailed information on how the measures listed above will be implemented.

6.0 FLOODPLAIN MANAGEMENT PLAN

Following further assessment by the Woronora River Floodplain Management Committee the following measures are recommended for consideration by the community:

(i) Strategy 1, comprising an improved flood forecasting system, community preparedness campaign, and planning and building controls.

(ii) Strategy 2, voluntary house raising to be made available as a measure where properties are not proposed for protection by a levee.

(iii) Strategy 3b, construction of an emergency access from Nundah Place to Menai Road.

(iv) Strategy 7, construction of a levee on the western foreshore at Woronora to the 5% AEP level to protect the Woronora Caravan Park, Menai Road and residential properties up to 250 m south of Woronora Bridge.

Estimated costs associated with the recommended measures are given in Table 6.1 below.

TABLE 6.1- COSTS OF RECOMMENDED FLOOD MITIGATION MEASURES

Flood Mitigation Measure	Costs	
	Capital	Maintenance p.a
Improved Flood Forecasting System	$62,000	$6,200
Community Preparedness Campaign	$10,000	$2,500
Planning and Building Controls	-	-
Improved Access	$5,000	-
Woronora West Levee	$225,000	$22,500
Voluntary House Raising	Fibro Weatherboard $35,000/house -	-
	Brick $50,000/house -	-

It should be noted that Strategy 7 was not favoured by community representatives on the Floodplain Management Committee but had to be considered by Council as a possible strategy. The costs for this strategy would be substantially reduced from those listed in the above table if Council is able to provide the fill for levee construction as excess from its works program.

7.0 ACKNOWLEDGEMENTS

This study has been prepared by Acer Wargon Chapman Pty Ltd, Environmental/Water division for Sutherland Shire Council.

The Consultant's study team members responsible for both inputs to and the preparation of this document were as follows:

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Ms E Brady - Study Assistant
Ms J Peters - Study Assistant
Ms Y Ali - Secretarial Support

Specialist input was provided by :

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Dr T L Lustig - Social and Economic Analysis
Ms F Watford - Study Assistant
Ms M Maher - Study Assistant

Tony Wong and Associates
Dr T Wong - Hydrology

Sutherland Shire Council officers who were involved in the co-ordination and management of the study included:

Mr M Rogers - Stormwater Management Engineer
Mr S Lee - Planner
Ms J Walker - Secretarial support
Ms L Crane - Secretarial support
Mr D Daly - Survey

NSW Public Works officers who were involved in the co-ordination and management of the study included.

Mr S Sarmed - Project Engineer
Mr G Bernard - Supervising Engineer

Members of the Woronora Floodplain Management Committee (not mentioned above).

Councillor D Emerson - Chairperson
Ms P Douglas - Environmental Protection Authority
Mr G Jones - State Emergency Services
Mr A Jenkins - State Emergency Services
Mr N Rendell - Soil Conservation Service
Mr J Cox - Community Representative

Mr N Farmer - Community Representative
Mrs D Noonan - Community Representative
Mr K Stedman - Community Representative
Mr A Mace - Community Representative
Mrs B Dixon - Community Representative
Mr R Zindler - Community Representative

Many others contributed to the study, including members of the public and all the agencies mentioned in Appendix A who provided information essential to the completion of the study. The assistance of all those who have contributed to this document is gratefully acknowledged.

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APPENDIX A LIAISON WITH GOVERNMENT AGENCIES

Letters of consultation were sent by Acer Wargon Chapman to a number of government agencies at Commonwealth, State and Local Government level and to certain non-government organisations in March 1994. The letters introduced the study and sought comments relating to areas of concern.

Comments received provided valuable assistance in the compilation for this document and where necessary adjustments were made to mitigation strategies to accommodate specific requests.

Listed below is a brief summary of the responses from the authorities consulted and where appropriate a review of their comments and concerns is provided.

Australian Gas Light Company

AGL indicated that the company had no gas mains located within the study area and that there were no current plans to provide services to the area.

Bureau of Meteorology

The Bureau indicated that it currently provides a flood warning service for the Georges River to Liverpool and Milperra, but that due to limited resources the service does not extend to the Woronora River. A study undertaken for the NSW Flash Flood Warning Consultative Committee identified the Woronora River as a "High Flash Flood Risk Catchment" that could be covered by a flash flood warning system.

Department of Conservation and Land Management - Crown Lands Service

The response from the Crown Lands Service noted that Crown land in the catchment includes a system of reserves managed by trusts. Most of the reserves are parks under the trusteeship of the Sutherland Shire Council, but others such as Woronora Cemetery are managed by private trusts. In addition, the zone beneath the tidal waters of the Woronora River is Crown land.

The Crown Lands Service requested to be kept informed of the progress of the study in relation to any proposals that may affect Crown land.

Department of Conservation and Land Management - Soil Conservation Service

The Soil Conservation Service advised that it is primarily concerned with the prevention and minimisation of land degradation associated with soil erosion and sedimentation in the catchment of the Woronora River. They recommend that government and community groups work together to manage land degradation through the concept of Total Catchment Management.

Department of Housing

The Department of Housing advised that it had no land holdings within the study area that are known to be affected by flooding.

Department of Planning - Heritage Council

The property list supplied for the Sutherland local government area indicated that there were no listed heritage items potentially affected by flooding within the study area. It was noted that should items of European heritage be identified during the course of the study these should be reported to the Heritage Council. Such items are defined as any relics more than 50 years old relating to the settlement of the area.

Department of Water Resources

The Department of Water Resources noted that due to the amount of clearing in the catchment in recent years it was considered essential to maintain vegetative buffer strips along the Woronora River and its tributaries. Such buffer strips would assist in providing habitat for flora and fauna, act as conservation corridors, reduce runoff velocity, reduce sediment load, and maintaining river bank stability.

It was advised that filling on the floodplain to meet the 1% AEP flood level is discouraged due to possible increases in flow velocities in the channel leading to potential erosion problems and increased flooding downstream. Also, any onsite detention ponds should be located away from the river/creekline. Any potential deepening, widening or lining of the Woronora River and its tributaries to improve flows should be referred to the Department for comment.

The Woronora River is noted as being gazetted and thus a 21D Permit (Soil Conservation Act) is required for any tree removal. The NSW State River and Estuaries Policy, adopted in 1993, has been formulated to provide management objectives and principles for rivers, estuaries and floodplains. The policy is based on the principle that government agencies, private landholders, resource users and the community must share responsibility for managing natural resources through a Total Catchment Management framework.

Note: tidal waters are administered by NSW Public Works.

Environment Protection Authority (EPA)

The EPA recommended that wherever practicable water quality controls should be integrated into flood management options. The following specific comments were given:

(i) Sewage overflow into the river may result from infiltration of floodwaters into the sewerage system.

(ii) Increased sedimentation has resulted from inadequate erosion controls on development, in particular in the Lucas Heights/Menai area. This has led to significant siltation in the Woronora River which will decrease channel capacity and thus may increase flood levels.

(iii) Post construction, additional sealed surfaces have the potential to increase runoff and therefore may affect flood peaks.

(iv) Developed areas can also contribute to the pollution load of the river from garden fertilisers, pesticides and detergents. Accordingly, flood detention basins ideally should have provisions for wet filtration ponds incorporated into their design.

(v) Any structural option proposed for flood mitigation should take into consideration all potential environmental impacts both at the site as well as up and down stream of it.

(vi) In a confined valley such as the Woronora, non structural options such as emergency response systems and evacuations procedures may be the least costly and most environmentally friendly options.

(vii) The potential effect on flood levels of the construction methods proposed for the new Woronora Bridge pylons should be discussed with the RTA.

(viii) Planning instruments can be used to prohibit further development in flood prone areas.

(ix) Community involvement in this study is applauded. However, it will be important for community members to be fully briefed on the environmental impacts of their proposed solutions.

Maritime Services Board (MSB)

The MSB noted that its management role included issuing of mooring licenses, controlling the placement of mooring apparatus in the Woronora River and provision and maintenance of navigation aids and advisory/regulatory signs in the waterway.

The MSB Waterways Authority requested an opportunity to comment on the draft Management Plan.

NSW National Parks and Wildlife Service (NPWS)

The NPWS South Metropolitan District indicated that at present all resources were concentrated on the assessment of the impact of the January 1994 bush fires, and did not have the resources available to provide a response at this time.

NSW Fisheries

The response from the NSW Fisheries noted that they have responsibility for the assessment, allocation, development, regulation and protection of fisheries resources and their habitats. It was noted that under Section 29 of the Fisheries and Oyster Farms Act it is an offence to impede the free passage of fish.

Optus

Optus Communications advised that they have no cable or plant in the area affected by the study.

Pacific Power

Pacific Power advised that they did not own any plant or equipment in the vicinity of the study area, nor were there any proposals to locate assets in the area in the future.

It was noted that the study area lies within an area over which Pacific Power holds a Petroleum Exploration Licence pursuant to the Petroleum (onshore) Act, 1991.

State Emergency Service - Sutherland Shire (SES)

The SES raised a number of points in their response:

(i) Introduction of an efficient early warning and flood height prediction system could include:

  (a) incorporating present methods of assessment with telemetry data transfer of this information to a predictive computer model located at the local emergency operations centre.

  (b) SES see a permanent tide/flood gauge on the river as a priority. They also see a need to update the current automatic gauge accessed by phone (with Sydney Water).

  (c) incorporation of existing meteorological stations into the warning system.

(ii) A reassessment of the stormwater drainage on both sides of the river needs to be completed. SES proposed placement of flapgates on river ends of the drains to prevent flooding of the roads without a breach of the bank. This would make evacuations quicker and safer.

(iii) Dredging of the channel should be investigated. Silting currently prevents access upstream from Como rail bridge during low tide (eg in response to fire calls). Locals feel the silting is the result of housing development at Engadine, Woronora Heights, Lucas Heights and Bangor. SES suggested a possible solution to the problem might be the construction of silt traps at the river end of the urban drainage systems.

(iv) Prohibit medium density development and restricting other development within the valley. It is suggested by SES that this would reduce the number of properties affected by a flood and therefore reduce numbers needing evacuation and risk to SES personnel.

Sydney Electricity

Sydney Electricity advised that they have diverse equipment installed within the area including distribution substations overhead high and low voltage aerials, underground high and low voltage mains, and sub transmission mains as well as the street lighting installation.

Telecom Australia

Telecom indicated that they have a number of submarine cable crossings in the area, (eg Illawong-Lugarno crossing, where Telecom plant such as manholes exist on both sides of the river bank, right down to the river bed at low tide).

It was advised that Telecom's External Plant Design and Construction group should be consulted prior to any aspects of the management study being finalised, which may potentially restrict Telecom access to its plant on its future operations in the area.

Sydney Water (formerly Water Board)

Sydney Water advised that while it has significant operational responsibilities associated with Woronora Dam and the proposed Water Treatment Works, it has no specific legislative or business responsibilities associated with floodplain planning or flood mitigation. Consequently the Sydney Water declined to participate directly in the planning study, however it would be prepared to respond on specific issues where relevant.

WORONORA RIVER FLOODPLAIN MANAGEMENT STUDY

SUBMISSION BY

JOHN WILLIAM COX MRAPI MHIA
DIRECTOR
J & R COX PLANNING & DESIGN SERVICES PTY LTD
61 PRINCE EDWARD PARK ROAD WORONORA

TO COMMUNITY WORKSHOP 30 APRIL 1994

INTRODUCTION :

The purpose of this brief submission is to explain the following;

A. the personal objective of being involved in the study and ongoing management

B. personal wish to provide the local community the benefit of personal experience and local knowledge through many years of direct involvement in local area planning, being a resident in the area and participating in the development of technical manual for use by local authorities in the control of the pollution of waterways and urban runoff;

C. to promote the establishment of a strategy which will prevent, within the limits of available information and projections, the general flooding and damage of any areas of existing development;

D. to assist the protection of the natural environment and general amenity of people living within the catchment;

E. to assist the maintenance of property value;

F. to assist identification of all organisations, authorities and community groups who have a role in some aspect of the total catchment management;

E. to assist in deciding the appropriate subdivision of responsibilities and allocation of all available resources into **geographical management units** within the framework of existing statutory controls, with or without amendment.

continued/...

GENERAL PERSPECTIVE :

There are a number of possible measures that could be undertaken now to secure existing development within the floodplain from any risk of being subjected to a general major flood in the predicted extreme event. This has particular regard to the Deepwater Estate, Woronora Village and Bonnet Bay Areas. Shackels Estate should remain a separate consideration having regard to its ultimate full acquisition and its own plan of management.

It is considered that there is a unique situation in this catchment distinct from the main Georges River Catchment. This is due to its strong topography, planned patterns of development and key access points where it would be convenient and relativelycost efficient to undertake flood mitigation works; ie. retention basins, wet and dry drainage detention areas, silt traps, up the length of the Woronora and it tributaries.

The latest Public Works Study identifies the possibility of there being a possibility that an extra 54.7 cubic million litres of water would need to be accommodated within the catchment. A check of the new flood levels on an individual property in Prices Circuit would mean that there would be about 3.65m of water over the Prince Edward Park picnic area in the vicinity of the clubhouse. The main flow of flood water would come from mainstream Woronora and Forbes Creek.

continued/...

From this information and the developed perspective it is considered one main structure could act to hold a large percentage of the main stream water. Such a main structure could only be recommended where it could be established that it would meet established demand and identified community objectives. The structure would need to take the form of a large retention reservoir which would receive funding not only for this purpose but for its dual role as a major road crossing of the Woronora. The material to build the structure would utilise materials won from the widening of the approaches to the river crossing. This would avoid the cost and problems associated with the cartage and disposal of overburden.

The recommended major structure would be at the Heathcote Road crossing of the Woronora, immediately downstream and adjacent the existing bridge. A lesser and similar structure is recommended at downstream Sabugal Pass. This structure would also serve as a road, upgrade of the existing Old Illawarra Road, Lucas Heights, causeway, Woronora Road, Engadine connection. Such a crossing would as access to existing and planned recreational and shopping facilities in both Engadine and Menai. Such a crossing would also alleviate any demand to link Woronora Heights to Woronora Village thence Sutherland or Menai.

RECOMMENDATION :

The first step in the study should involve allocation of resources to investigate a major structure with the objective of meeting dual demand and to secure existing existing and preposed development from any threat from major general flooding.

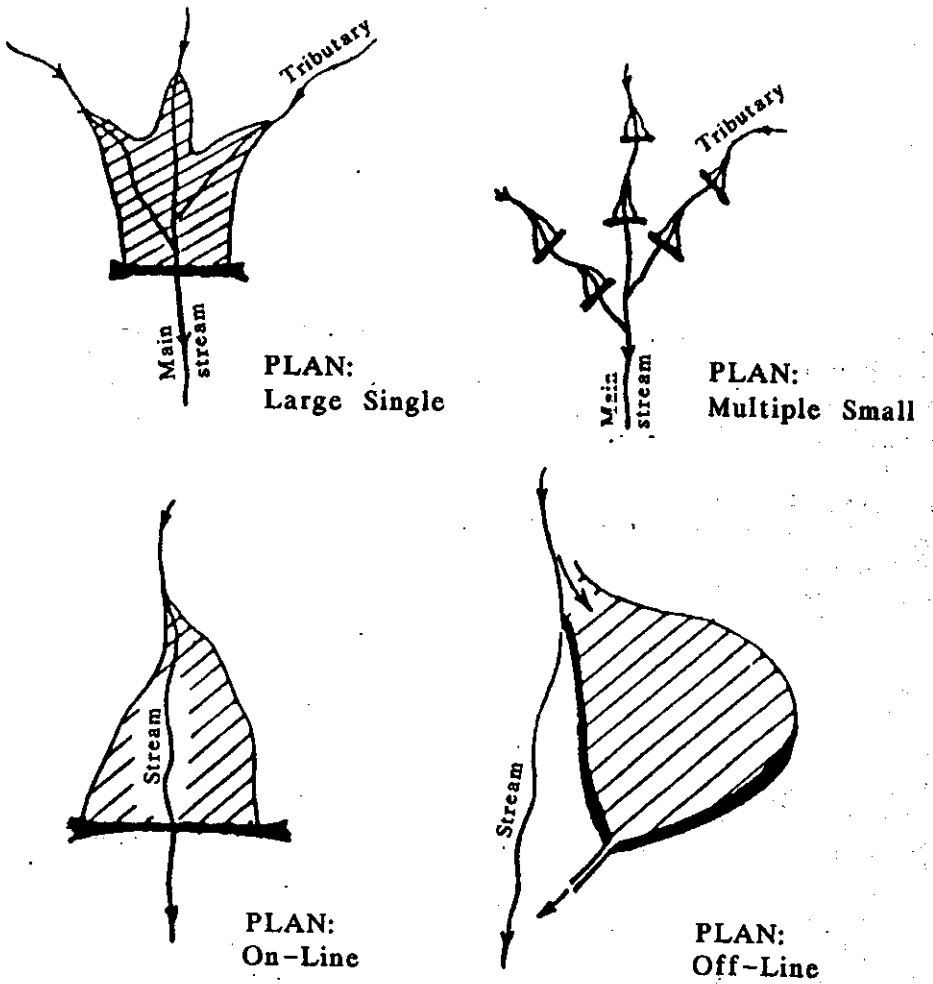
4/...

continued/...

Other aspects of the development of a total catchment management strategy could then proceed with any immediate threat to life or property or negative impact the environment and property values.

Signed,

John Cox



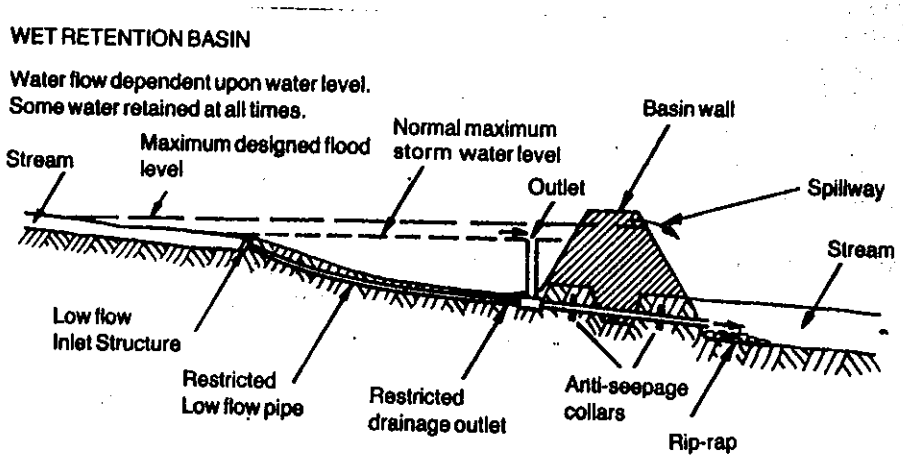


Figure 14: Design of wet retention basins

NEIL FARMER
18 THORP RD (ON FORBES CREEK)
WORONORA 2232

20.4.94

ACER WARGON CHAPMAN
21 APR 1994

MR HUGH SWINBOURNE
ACER WARGON CHAPMAN

WORONORA RIVER FLOOD PLAIN MANAGEMENT STUDY

Dear Sir

Thank you for your notes on Flood Mitigatia options. I will be unable to attend the community workshop on 30th April however I wish to make a few points which may be of relevance

1. The level of silt in Forbes creek and the main river has risen considerable over the past few years, (I estimate 0.2m in 4 years) as a consequence of development above the valley. A defined channel no longer exists in Forbes creek and other parts of the main river. This would cause flood levels to be higher and the rivers 'run' while in flood is not maintained in a defined channel.

While the level of flood waters ~~has~~ causes its obvious problems, the speed at which the water runs in the early stages of flooding can cause considerable damage.

2. As this silt builds up, the mangroves encroach further across the the creeks and river, growing and stabilising the silt at a higher level. This has a further damming effect on the river and concentrate the flood 'run' towards the developed side of the river which can cause damage to

property and undermine sea walls.

3. Fallen and dead trees on the river banks often break away at times of flo
and can cause damage to properties, jetty's and boats, they also become trapped on bridges and in mangroves having a further damming effect on the river. Regular removal of hazardous trees while being careful not to destablise river banks would be benificial.

I am pleased to see that the damming effect of the new and existing bridges is being concidered.

I hope your workshop is a success and I would be interested in receiving any further information on this matter

Yours faithfully

Neil

SUBMISSION

to

WORONORA RIVER FLOODPLAIN
MANAGEMENT COMMITTEE

PREPARED

by

COMMUNITY REPRESENTATIVE
ROBERT ZINDLER

February 1995

8 Thorp Road
Woronora Sutherland NSW
Telephone: 521-5212

SUMMARY

1. The Woronora River Valley has a long history of 10 yearly minor, as well as, major floods causing severe damage and financial loss. (Refer to Paragraphs 5,6,8,9,10 and 11 in the main body of this Submission).

2. The State Government has a Flood Policy to: (Par.1A+C).
   i) Solve flood problems.
   ii) Fund flood mitigation works.

3. The Sutherland Shire Council is responsible for: (Par.1B)
   i) Floodplain management.
   ii) The establishment of the Woronora River Floodplain Management Committee with community representatives.

4. The Floodplain Management Committee is to: (Par.4).
   i) Evaluate solutions to flood damage and losses.
   ii) Recommend appropriate solutions to the Sutherland Shire Council for approval by the State Government.

5. Damage done includes significant, up to catastrophic:
   i) Social, physical and emotional damage, incl. potential loss of life and limb. (Par.7)
   ii) Financial losses, including to 10% of the residents below the poverty line.(Par.10A).
   ii) Uninsurable damage to private homes. (Par.7, 8,9,10B+11-iv).
   iv) Uninsurable damage to commercial enterprises. (Par.8)
   v) Community, Local and State Government property.
   vi) Environment.

6. COMMENTS;
   FAILURE TO PROTECT THESE PARTICULARLY VULNERABLE PEOPLE FROM PREVENTABLE MAJOR DEVASTATION IS TANTAMOUNT TO SOCIAL DISCRIMINATION.

(Par.10)

7. 25% AEP floods are "once in 4 year" floods, which cause no damage. (Par.8).
20% AEP floods are "once in 5 year" floods, when some damage occurs. (Par.8).
5% AEP floods are "once in 20 year" floods, with high hazard damage. (Par.8).
2% AEP floods are "once in 50 year" floods,with very high hazard damage. (Par.8).
1% AEP floods are "once in 100 year" floods, with catastrophic "high hazard" damage. (Par.8).
PMF floods will wipe out the Woronora and Bonnet Bay communities. (Par.8).

8. On this scale, it may be possible for the community to accept the relatively lesser damage and losses of, say 15% AEP or "once in 7 year" floods. (Par.15+17).

9. Floods occur when stormwater inflow into an area is significantly greater than the outflow. (Par.12)

10. The outflow of floodwaters out of the Woronora River valley can be improved by some minor means: (Par.13+14)

    i) Reduce the river siltation by dredging.
    ii) Raise the Woronora Bridge by say 1 metre.

    Comment:
    Some other improvements can be made to reduce the effects of floods, but they do not materially reduce the flooding.

11. IN ORDER TO MINIMISE DAMAGE AND DEVASTATING LOSSES,IT IS ESSENTIAL TO RESTRICT THE INFLOW OF STORMWATER FLOODS TO 'ACCEPTABLE' LEVELS. (Par.15+17).

12. Inflow of excessive, i.e. above 'acceptable' level floodwaters, can be prevented by a Culvert Dam which could allow the passage of all stormwaters up to say, the 15% AEP discharge capacity. Anything worse than that will be held back until cleared at the end of the storm. (Par.18+20).

13. A suitable and very economical Culvert Dam can be constructed near the present Heathcote Bridge. (Par.21).

14. A SUITABLE CULVERT DAM WILL PERMANENTLY AND ECONOMICALLY REDUCE POTENTIALLY DEVASTATING AND CATASTROPHIC SIGNIFICANT FLOODS TO 'ACCEPTABLE LEVELS'. (Par.18+20).

ADDITIONAL BENEFITS OF A CULVERT DAM.

The cost of constructing of the Culvert Dam can be balanced against the savings of the considerable costs of: (Par.26).

i) Transporting and dumping rock waste from the excavation required for the widening of the approach roads to the present antiquated and dangerous Heathcote Bridge. (Par.22).

ii) The replacing the present Heathcote Bridge with a 4-lane wide top-deck of the Culvert Dam, avoiding the cost of building a new concrete or steel bridge. (Par.23).

THIS IS TRULY AN 'EVERYBODY WINS' SITUATION.

THE BALL IS NOW IN THE MANAGEMENT COMMITTEE'S AND SUTHERLAND SHIRE COUNCIL'S COURT.!!!!!

oOo

RECOMMENDATIONS

That: The Woronora River Floodplain Management Committee:

1 Adopts the concept of constructing a 15% AEP Maximum Release Capacity Culvert Dam in the Woronora River, near the present Heathcote Bridge, to permanently reduce the social and economic damage from significant floods in the Woronora River Valley.

2 Adopts Strategy 1: Improved flood forecasting system. (Ibid, Summary, page xiv).

3 Adopts Strategy 3: Access road improvements. (Ibid, Summary, page xiv).

4 Adopts Strategy 5: Raising the Woronora Bridge (Ibid, Summary, page xv).

5 Adopts Strategy 6: Dredging of the Woronora River. (Ibid, Summary, page xv).

and

6 Recommends to the Sutherland Shire Council, that the above proposed Culvert Dam be constructed.

REFERENCES

1 Woronora River Floodplain Management Study, (Draft) January 1995.

2 Woronora River Floodplain Management Plan, (Draft) January 1995.

THE WORONORA RIVER FLOOD PLAIN

Proposal for a permanent solution to significant flooding.

STATEMENTS

1. A. The State Government's Flood Policy is directed at providing SOLUTIONS (my emphasis here and elsewhere) to existing flooding problems in developed areas...". (Refer: Woronora Floodplain Management Plan (Draft), January 1995, page 1).

   B. Under the Policy the management of flood liable land remains the responsibility of local government. The State Government SUBSIDISES flood mitigation works TO ALLEVIATE existing problems and provides specialist technical advise to assist Councils in the discharge of their floodplain management responsibilities. (Ibid, page 1).

   C. The Policy provides for technical and FINANCIAL support by the Government through the following stages:

      i) Flood Study
      ii) Flood Plain Management Study
      iii) Flood Plain Management Plan
      iv) Implementation of the Plan which includes the construction of flood mitigation works subsidised by the State Government. (Ibid, page 1).

2. The Sutherland Shire Council,in February1994,commissioned the firm Acer Wargon Chapman, as expert consultants, to conduct the required studies, and to prepare a draft Plan with proposed 'solutions to existing flooding problems'. (See 1 A above and refer: Woronora River Floodplain Management Study. (Draft), January 1995, page 1).

3. "Floodplains..are developed for land uses such as housing ...and recreation". " Management of river floodplain areas can enable the land to be developed, while at the same time minimising the risk of damage caused by flooding". (Refer: Woronora River Floodplain Management Plan. (Draft), January 1995, page 1).

4. In line with recent Government policy to include community consultation, seven community representatives were subsequently 'invited to attend meetings' of the Woronora River Floodplain Management Committee. (Report and Minutes of the meeting on 24 November 1994 and Woronora River Floodplain Management Study (Draft) January 1995, page 53).

5. "...significant flooding occurs at least once every 10 years...". (Woronora River Floodplain Management Study,(Draft), January 1995, page 22).

6. "Significant floods...have occured in 1933, 1943, 1949, 1956, 1961 and 1988". (Ibid, page 1). One community representative has also reported a major flood in 1952.

Significant Floods Since 1930.

YEAR	INTERVALS BETWEEN FLOODS	
1933		)
1943	10 years	)
1949	6 years	)
(1952)	3 years	)
1956	4 years	) = 62 years
1961	5 years	)
1988	27 years	)
(to date-no flood)	(7 years)	)

7. All significant floods will cause "significant social, physical and emotional damage" to many Woronora and Bonnet Bay residents. (Ibid, page 12)

Table 3.2 Properties Affected By Flooding (Ibid,page 13)

A.E.P. Design flood	Houses with flooded yards	Houses flooded above floor
5%	246	200
2%	283	254
1%	323	289
P.M.F.	503	497

8. All significant floods will cause considerable damage and financial losses.

Table 3.5 Flood Losses For Existing Development Conditions (Ibid, page 18).

FLOOD A.E.P.	Residential Losses $	Commercial Losses $	Total * losses $
25%	nil	nil	nil
5%	2,000,000	160,000	2,160,000
2%	3,100,000	190,000	3,290,000
1%	4,500,000	220,000	4,720,000
P.M.F.	24,5000,000	980,000	25,480,000

* These estimated total losses are caused by ANY ONE of those floods. SUBSEQUENT FLOODS WILL CAUSE ADDITIONAL LOSSES.

"The onset of significant flood damage is assured to occur at the 20 AEP flood". (Ibid, page 15)

9. Table 3.4 Residential...Damage...(1991 dollars) (Ibid, page 17)

Losses from flooded houses range from:

$721 to $3,510 for floods, level with the floor

$13,849 to $19,291 for flood levels of 1.5m above the floor.

$33,660 to $46,710 for flood levels of 2.5m above the floor.

Up to $93,420 for flood levels of 5m above the floor.

Comments:
These are damage costs incurred per flooded house BY EVERY FLOOD. Several of these floods may occur within a few years of each other if the weather patterns in NSW change significantly. NSW experienced extended years of drought in recent years. However there are signs that the wheather may now become much wetter, with a greater potential for floods.

Comments:
5%, 2%, 1% are only theoretical mathetical calculations and can not be taken to truly represent actuality or reality.

10. A. "10% of the Woronora community (have) incomes BELOW the 'poverty level'" (Ibid, page xii)

B. "Flood insurance is not available to most residences in NSW." (Ibid, pages xii and 30).

Comments:

i) It is abundantly clear to any authority, responsable for the protection of the more vulnerable members of the community, that the loss of even $5,000 could be catastrophic for any person with an income 'below the poverty level'.

ii) It is likely that these people represent a disproprtionatly large percentage of the 200 houses which would be damaged by the 5% AEP floods and even more so in 1% AEP floods.

iii) FAILURE TO PROTECT THESE PARTICULARLY VULNERABLE PEOPLE FROM PREVENTABLE MAJOR DEVASTATION IS TANTAMOUNT TO SOCIAL DISCRIMINATION.

11. i) Figure 3.1 gives the "Location of Council Property Zones." (Ibid, after page 23)

ii) Table 3.3 Average Flood Levels in Property Zones Along Woronora River (in AHD) indicates flood levels at 5%, 2% and 1% AEP and at PMF flood levels in zones 8 to 21. (Ibid, page 13)

iii) Table 3.1 Provisional Flood Hazard Assessment (after page 8) indicates HIGH HAZARD IN ZONES 8 to 21, that means all the low lying areas in Bonnet Bay and Woronora. (Ibid, after page 8).

iv) High Hazard in the Glossary of Terms (Ibid, page viii) is defined as:
"POSSIBLE DANGER TO LIFE AND LIMB; EVACUATION BY TRUCKS DIFFICULT; POTENTIAL FOR STRUCTURAL DAMAGE; SOCIAL DISRUPTION AND FINANCIAL LOSSES COULD BE HIGH.

Comments:

i) As indicated above even 5% AEP floods can cause loss of life and devastating financial losses for every significant flood which may enter this valley from now on AND FOREVER, UNLESS appropriate and adequate flood mitigation measures are adopted and implemented by the Sutherland Shire Council and the NSW State Government.

ii) Strategies for flood mitigation which may be adopted on the basis of cost cutting measures which do not resolve the issue of minimising the costly high flood water levels, are a n unacceptable abbrogation of responsibility of the local and state governments and authorities.

12. Floods occur when the inflow of storm and rain water into a region is greater than the outflow of this water out of that region at any particular period of time.

13. Stormwater Outflow:
The Woronora River is a 'dogleg' river with almost right angled bends which impede the outflow of excess storm water.

Comment:
This configuration of the river cannot be changed. There are additional impediments to storm water out-flow such as:

i) Siltation of the Woronora and Georges Rivers.

ii) The bridge deck of the present low level Woronora Bridge when the river is in significant flood.

RECOMMENDATIONS

14 That: The Woronora River Floodplain Management Committee:

2 Adopts Strategy 1: Improved flood forecasting system. (Ibid, Summary, page xiv).

3 Adopts Strategy 3: Access road improvements. (Ibid, Summary, page xiv)

4 Adopts Strategy 5: Raising the Woronora Bridge. (Ibid, Summary, page xv).

5 Adopts Strategy 6: Dredging of the Woronora River. (Ibid, Summary, page xv).

Comments:

These solutions cannot improve the devastation, caused by significant floods, to any significant extent and can only be regarded as semi-cosmetic solutions.

15. Stormwater Inflow:

If flood damage is to be avoided or at least minimised and the outflow cannot be adequately improved, then the following will become important:

i) Determine the Maximum flood damage acceptable and economically justified for the effected community.

ii) Restrict the amount of stormwater inflow into the valey to a level commensurate with such acceptable flood levels and their corresponding social and economic damage.

Comment:

THIS PROPOSITION IS BOTH PRACTICALLY AND ECONOMICALLY FEASABLE.

16. Scale of Flood Damage:

Following is the scale of flood damage estimated in the study (Refer to paragraph 8 above)

25% AEP flood - No damage
20% AEP flood - Significant flood damage is assurred
5% AEP flood - High hazard and damage
Worse floods - Increasingly higher hazard and damage.

17. i) It is NOT feasable to eliminate all flood damage.

ii) IT IS feasable to adopt a flood level with levels of flood damage, which are both socially and financially 'acceptable'.

COMMENTS:

As the damage from 25% or 20% AEP floods could for practicle and economical purposes be regarded as too low and damage from 5% AEP floods are clearly too high, a level of 15% AEP flood damage could be 'acceptable'.

18. It is feasable to provide restrictions to the inflow of stormwater, with a permanent release capacity which corresponds to the adopted 'acceptable' flood levels. Any floodwater inflow greater than this 'maximum release capacity' can be temporarily retained until such retained waters have also been discharged by the automatic release discharge.

Comments:

THIS AUTOMATIC STORMWATER RELEASE SYSTEM CONTROLLED BY A PREDETERMINED 'MAXIMUM WATER RELEASE CAPACITY', WILL ENSURE THAT NO FLOOD DAMAGE IS EAXPERIENCED GREATER THAN WHAT IS "ACCEPTABLE" TO THE COMMUNITY.

19. By recognising pragmatic realities and the real issues, it has been possible to arrive at a solution to the inevitable damage caused by significant floods, which would provide safeguards for the greatest number of people, including the most vulnerable residents in the Woronora River Valley.

RECOMMENDATION

20 That: The Woronora River Floodplain Management Committee:

1 Adopts the concept of constructing a 15% AEP Maximum Release Capacity Culvert Dam in the Woronora River, near the present Heathcote Bridge, to permanently reduce the social and economic damage from significant floods in the Woronora River Valley.

Comments:

Such a Culvert Dam would not interfere with any river flushing requirements and would meet other environmental considerations.

21. A Culvert Dam could be constructed from rock waste generated by the construction of five-lane approach roads (2 lanes down, 2 lanes up and a climbing lane) on both sides of the Heathcote Bridge.

Comments:
The present major arterial rivercrossing near Heathcote is provided by the narrow and therefore dangerous Heathcote Bridge. Heathcote Road and Heathcote Bridge were built by the army during the Second World War. Heathcote Bridge is inadequate for the increasingly heavy traffic along that route and requires urgent replacement.

22. The cost of removal and dumping of the excavated rock for the construction of the approach roads will be significantly offset by the adjacent construction of the proposed Culvert Dam.

23. The Culvert Dam could be constructed with a four-lane wide top deck, adequate for motorway requirements.

i) The topography of the Woronora River gorge in that area is adequate and appropriate for the construction of the proposed Culvert Dam.

ii) However, the configuration of the eastern approach road with the Heathcote Creek running along side it and the western approach road with the Woronora River running along side it, would necessitate the Culvert Dam to be constructed at an angle of approximately 30 degrees to and accross the present Heathcote Bridge.

iii) The foundations and support piers of the present Heathcote Bridge could be incorporated in the proposed Woronora Culvert Dam. The entire bridge deck can then be removed permanently, saving the NSW Government the cost of constructing a new bridge.

24. The proposed integration of the construction of the flood mitigating Culvert Dam with the upgrading of the Heathcote Road in that area, providing a motorway-standard rivercrossing, would be eminently sensible and enormously cost saving. And, both are urgently needed.

25. Note: i) The Sutherland Shire Council is responsible for the floodplain management in the Woronora River Valley, but the NSW State Government will be essentially responsible for the funding of any major flood mitigation costs.

ii) The Road Transport Authority (RTA) is responsible for designing, constructing and maintaining NSW roads and bridges, but the NSW State Government will be responsible for the funding of all costs thereof.

COST SAVINGS

26. If the RTA upgrades the approach roads on both sides of the Woronora River at the Heathcote Bridge and constructs the Culvert Dam with the rock made available by the excavation then the NSW State Government:

i) Saves the enormous cost of carting way and dumping a significant proportion of the excavated rock.

ii) Saves the cost of a new expensive four-lane steel or concrete bridge.

iii) Saves most costs of the essential flood mitigation works, with the RTA- constructed Culvert Dam.

CONCLUTIONS

27. The integration of the two essential services outlined above:

i) Provides the Woronora Valley people with the flood protection they need at a very low cost.

ii) Provides the growing domestic, medium and heavy transport industries with first class road facilities.

iii) Saves the NSW Government millions of sparce dollars.

iv) Earns the Sutherland Shire Council the admiration and respect from everyone for dealing with major and costly issues in a far-sighted enlightened and courageous manner.

THIS IS TRULY AN 'EVERYBODY WINS' SITUATION.

THE BALL IS NOW IN THE MANAGEMENT COMMITTEE'S AND SUTHERLAND SHIRE COUNCIL'S COURT.

oOo

SUMMARY SUBMISSION
TO
WORONORA RIVER FLOOD PLAIN
MANAGEMENT COMMITTEE

PREPARED
BY
RESIDENT REPRESENTATIVE
JOHN WILLIAM COX
61 PRINCE EDWARD PARK ROAD
WORONORA NSW 2232

DATE
24 NOVEMBER 1994

1.0 INTRODUCTION

As a local representative of Woronora Village, I considered the level of information contained in the stated Flood Plain Management Strategies in insufficient and inconclusive. The Study document does not provide sufficient costs/benefits comparison between the options which would effectively reduce and manage flood levels against those which attempt to flood isolate or remedy on a lot by lot basis.

In this submission I would strongly recommend that the strategies be advertised in the local newspapers and other circulations such as the Woronora RSL & Citizen's News Letter.

2.0 SUMMARY

2.1 The 1.94 benefit-cost ratio, applied to the proposed levee does not take into account the potential for devaluing property value in the area on top of the $0.7m estimated cost. In this way considerable transfer costs would be involved.

2.2 The dredging proposal does not indicate the potential for private enterprise involvement as a commercial enterprise with possible sales of sand. There is a definite need based on a long observation of change in the morphology of the river and the expectations of negative impact of siltation on the river ecology and ongoing management, including the navigation of bush-fighting vessels.

2.3 There is no discussion or indication of any approach to the State about the the Heathcote Road, multi- purpose road/drainage retention option of similar retention in tributaries such as Forbes Creek below Wollybutt Road, Engadine or Still Creek, Menai.

2.3 The proposed use of Planning and Building Controls, outlined, (i) to (iv), is a recipe for ad hoc, visual degradation of the area and consequent devaluation of property in the Valley.

2.4 The option of a flood mitigation dam at Heathcote Road crossing discussed, in chapter 4.3.2, neglects to highlight the advantages of eliminating a number of downstream problems and rectification costs. This involves bank stabilisation, allowance for improvements and amenities to the Regional Park to be created from the former Shackel's and Deepwater Estates which have already involved an investment of public money in excess of $20m. A further $20m. multi-purpose, potential multi-sourced funding would be a step closer to a Corporate approach to planning and management.

2.5 The improvement to the approved access from the high level bridge to the Valley floor has important implications in times of emergency, especially that of a major flood. The local members of the District Chamber of Commerce and Industry, have already had meetings with the High Level Bridge, Project Engineer, Mr. Greg Buttler. He has shown plans which indicate a feasibility to provide direct access from Sutherland to the east side of the river. It was at the same time agreed direct access from Bangor to the west side of the river would be also feasible. The job before the community is now convince the State Government to change the current designs and funding.
In a major flood, under the current arrangement the east side of the river would be cut-off from vehicular access if the existing low level bridge or its western approach was flooded.

2.6 The proposed strategies if adopted would represent a further exercise in fragmented planning. The existing development should be the subject of an overall review such as the current Draft Local Environmental Plan and Housing Strategy, having regard to the threat of major flood and Total Catchment Management. Redevelopment to higher density and/or flexibility in housing form at existing density, coupled with innovation such as Land Pooling and Community Title redevelopment could potentially finance raising land levels and the replanning of roads. For example some roads could be eliminated in favour of a quay style development. Housing forms could be varied from attached to free-standing cluster houses. Urban Bushland could come under Community Association(s) control and Management.
The area could avoid the adverse impacts and environmental degradation currently being experienced with 25 weeks of subdivision works in Prince Edward Park Road with land being left unprotected from erosion and run-off, especially having regard to the ability to Hydra-seed and mulch the area many weeks ago.

There appears to have been no lessons learned from the subdivisions of Bonnet Bay, Menai, Woronora Heights and Lucas Heights, the run-off and bush-fire problems they have created.

3.0 CONCLUSION

It is my regretful conclusion that the Study and proposals lack vision and Corporate approach to planning. Instead of advantages to the residents and the suffering natural environment, there is disadvantages. Those disadvantages include, visual downgrading of the area, ad hoc planning and management, loss of property value and loss of opportunity to remove community anxiety about the potential of major flood and rising water levels due to Green House Effect.

There is a need for a Corporate approach and inclusion of such planning issues as Transport Infrastructure, (including all roads and bridges), , integrated public transport especially proposals for light rail or mono-rail linking Menai to Sutherland and other Centres, river hydrology and ecology.

It is considered necessary that the Committee should have representation from the Department of Planning Regional Office, Roads & Traffic Authority and the State Members Office if there is no such representation at present.

There is considered an urgent need for the Minister of Transport to review the adopted plan for approaches the high level bridge and the priorities for

In these circumstances, it is considered the estimated $29M plus cost of implementing the currently discussed strategies, Base Cases, 1 to 7, cannot be supported .

Signed,

John Cox MRAPI MHIA

SUTHERLAND SHIRE COUNCIL

Administration Centre, Eton Street, Sutherland *Ph 710 0333*
P.O. Box 17, Sutherland DX 4511

CERTIFICATE NUMBER : 7442 CERTIFICATE DATE : 16/06/94

YOUR REFERENCE : A[B 9746 TATE

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this property due to bushfire risk.

FLOODING

The property is affected by flooding.

Attention is drawn to the above reference to flooding. Please note the attached notation regarding flood levels affecting the property. For all other properties fronting Woronora River not shown on this plan, please contact Council's Technical Services Division for flood levels. (SEE PLAN NO. 12579 DATED 22/4/92 ATTACHED).
If landfill is required, due to flooding or tidal inundation , please contact Council's Engineering Division for details.

LANDSLIP
Development of this property is not restricted by the risk of land slip.

LAND SUBSIDENCE
Development of this property is not restricted by the risk of land subsidence.

PROXIMITY TO A.N.S.T.O.
The land is not within a 4.8km radius of the A.N.S.T.O. reactor at Lucas Heights.

TREE PRESERVATION ORDER

The land is affected by a tree preservation order. See Attachment 120.

SOIL CONSERVATION

The land is affected by Section 21 of the Soil Conservation (Further Amendment) Act.

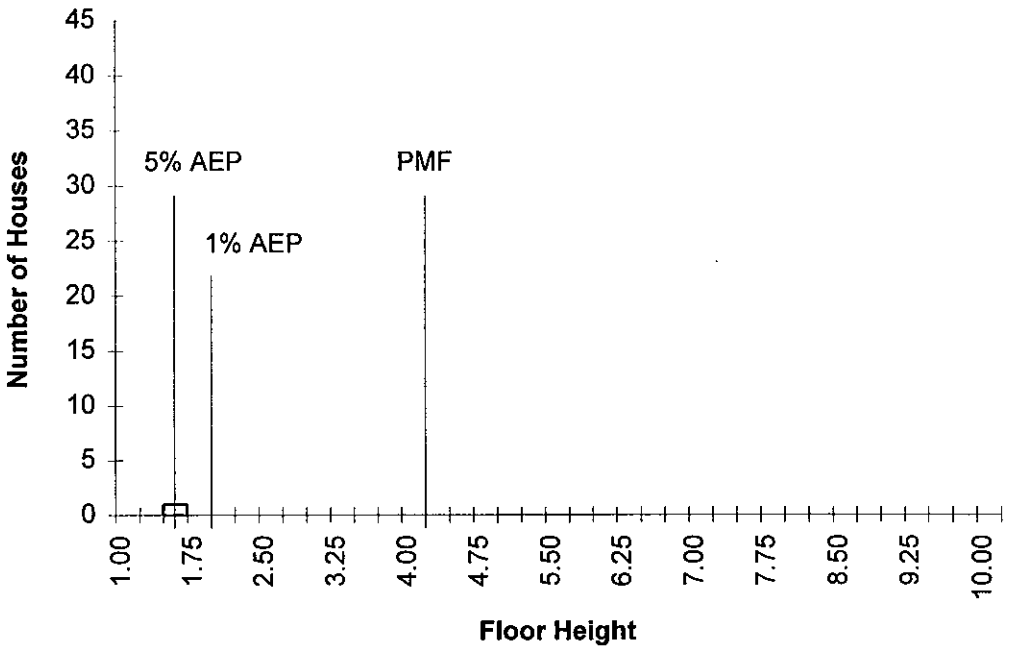
OTHER RISKS
Development of this property is not restricted due to any risk other than those detailed above.

NOTES TO INTENDING PURCHASERS/VENDORS :

1. Details of these matters are available for inspection at the Town Planning Department, Administration Centre, Sutherland.

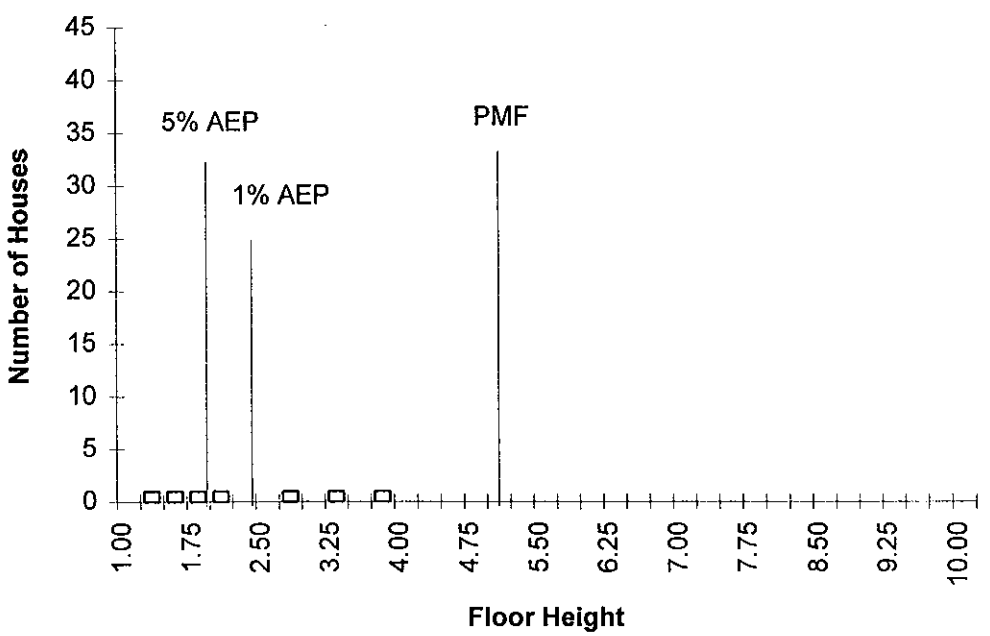
CONTINUED....

APPENDIX D DISTRIBUTION OF FLOOR HEIGHTS FOR DIFFERENT REACHES OF WORONORA RIVER



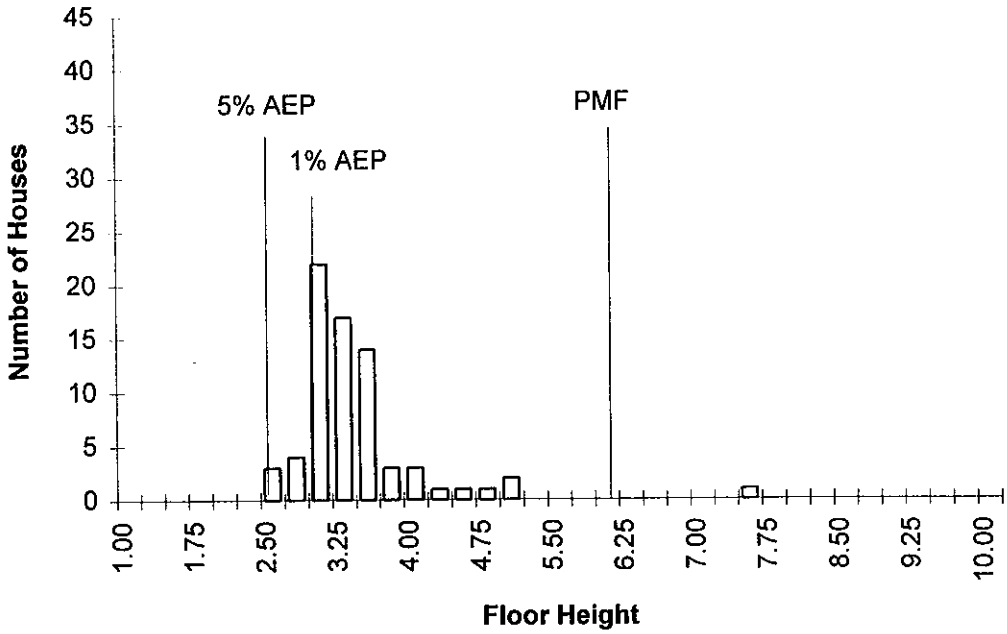
DISTRIBUTION OF FLOOR HEIGHTS IN ZONES 1-2

FIGURE D1



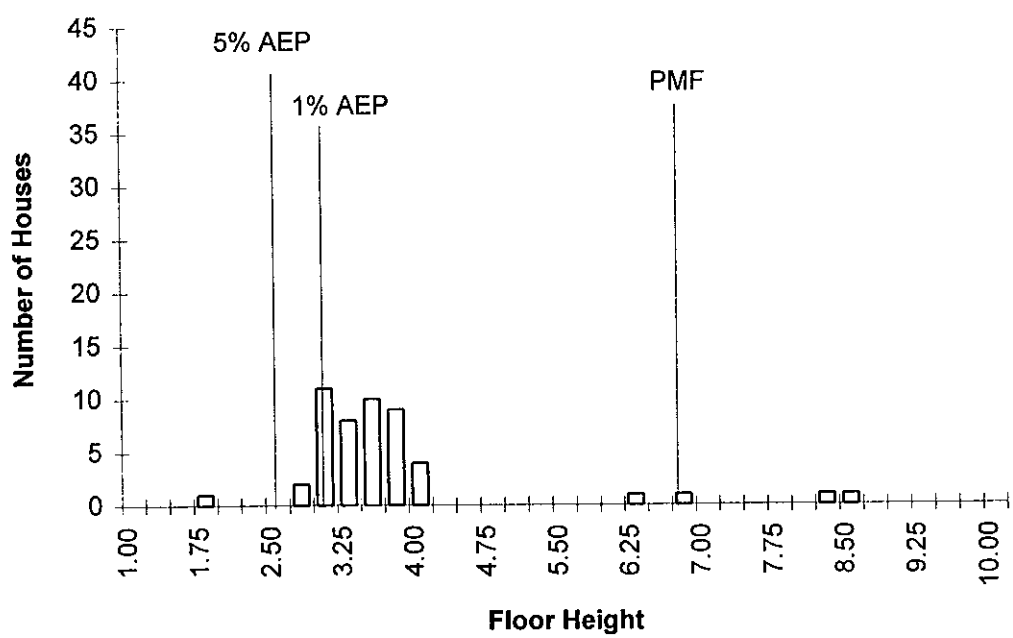
DISTRIBUTION OF FLOOR HEIGHTS IN ZONES 3-4

FIGURE D2



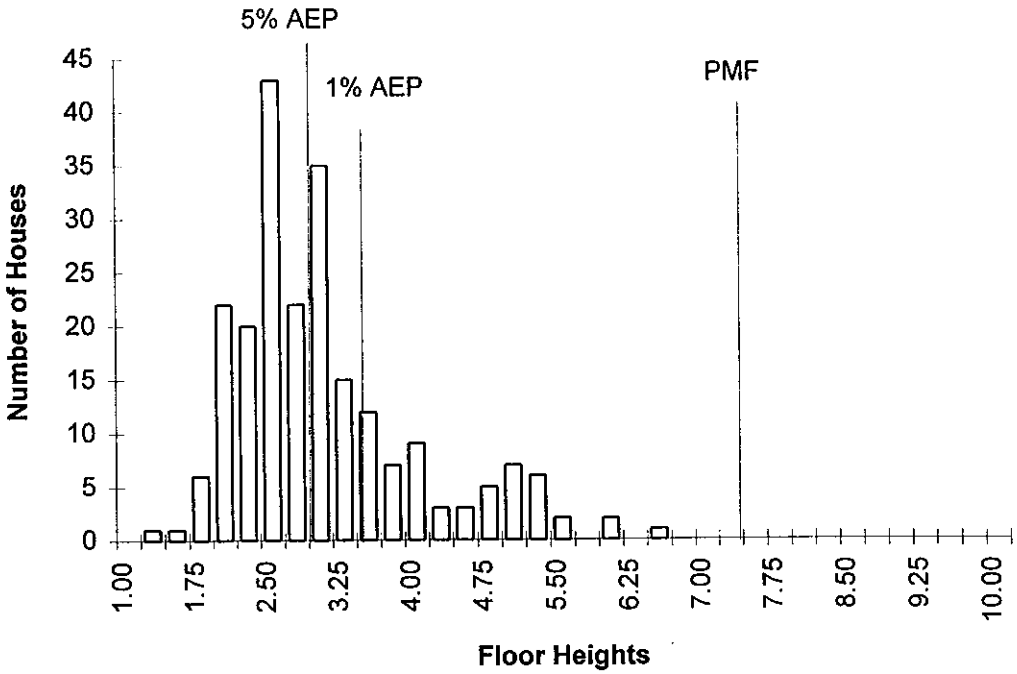
DISTRIBUTION OF FLOOR HEIGHTS IN ZONES 5-7

FIGURE D3



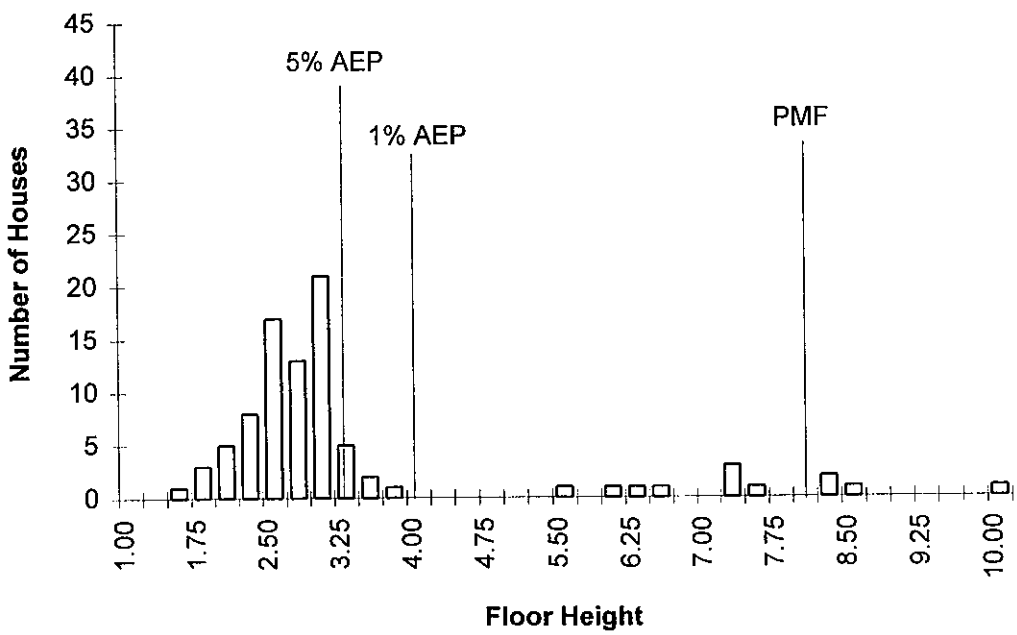
DISTRIBUTION OF FLOOR HEIGHTS IN ZONES 8-9

FIGURE D4



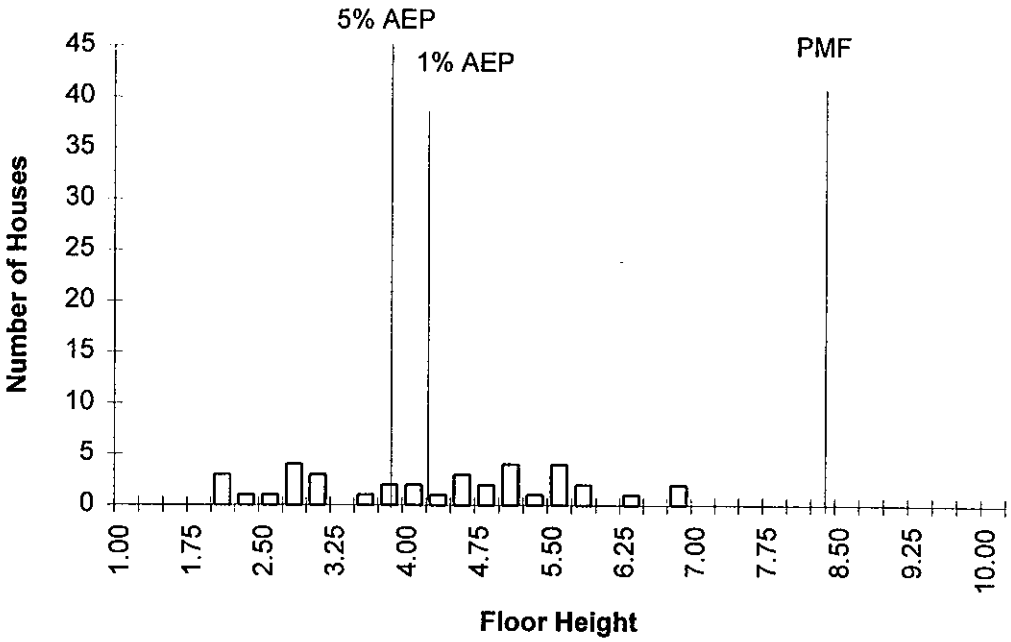
DISTRIBUTION OF FLOOR HEIGHTS IN ZONES 10-12

FIGURE D5



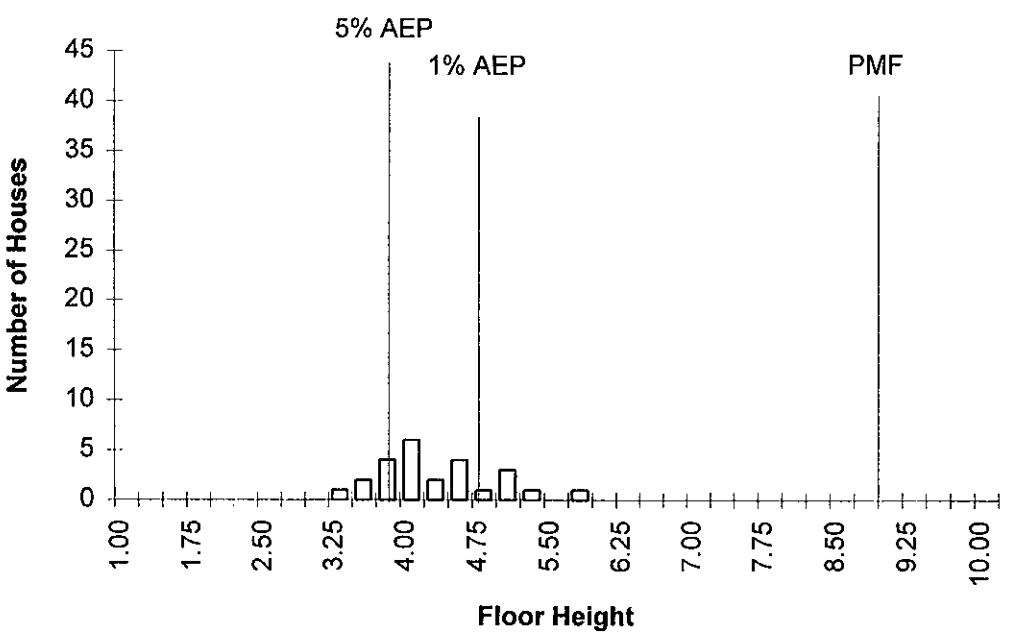
DISTRIBUTION OF FLOOR HEIGHTS IN ZONES 13-15

FIGURE D6



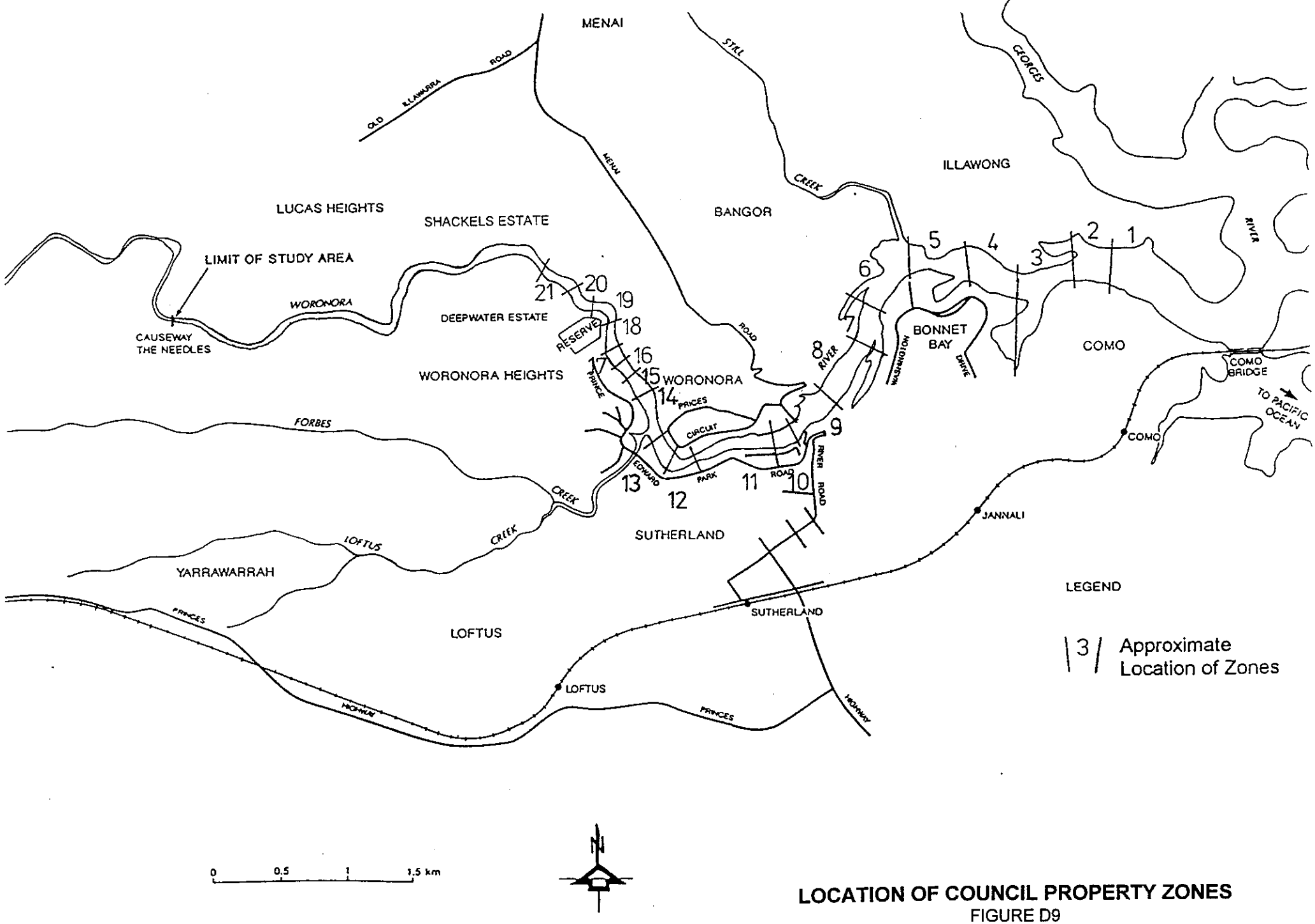
DISTRIBUTION OF FLOOR HEIGHTS IN ZONES 16-18

FIGURE D7



DISTRIBUTION OF FLOOR HEIGHTS IN ZONES 19-21

FIGURE D8



LOCATION OF COUNCIL PROPERTY ZONES

FIGURE D9

APPENDIX E STAGE -DAMAGE RELATIONSHIPS

The following stage-damage relationships were used to calculate the damages to residences, commerce, swimming pools and raised houses. The values for the residences and commercial establishments were in 1991 dollars and were converted to 1994 dollars using a Consumer Price Index (CPI) of 4.35% for the three year period obtained from the Australian Bureau of Statistics.

For residences, there is a maximum under-house damage for those houses that are raised off the ground 1 metre or above. For low quality houses this is estimated at $500, medium quality $1,500 and high quality $2,500. There are 6 stage damage relationships for low, medium and high quality 1 and 2 storey houses. Damages to three storey houses were assumed to be the same as for 2 storey houses.

Commercial damages were estimated using the procedures recommended in the ANUFLOOD manual.

For swimming pools, two sets of damage were used, one for in ground pools and the other for above ground pools.

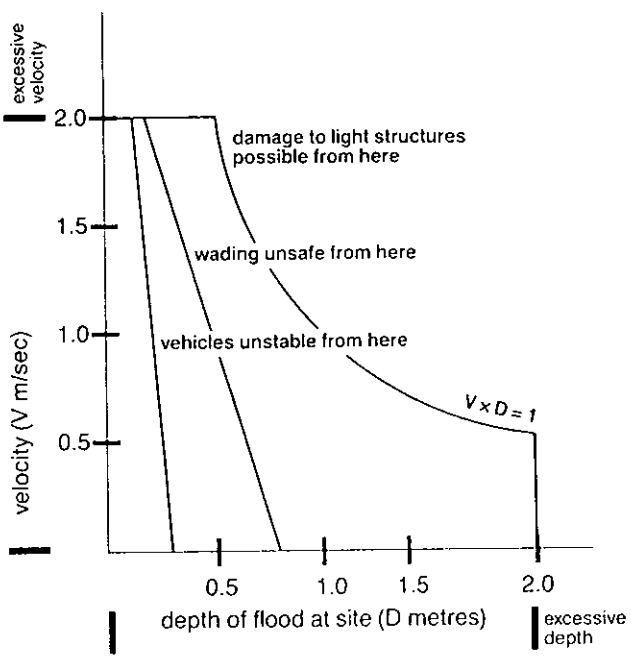
House raising was simulated by altering the stage-damage curve to simulate damages at a higher level than previously.

APPENDIX F FLOOD HAZARD CATEGORIES

(Courtesy - NSW Public Works, 1986)

Velocity and Depth Relationships

(Derived from laboratory testing and flood conditions which caused damage)



NOTES:

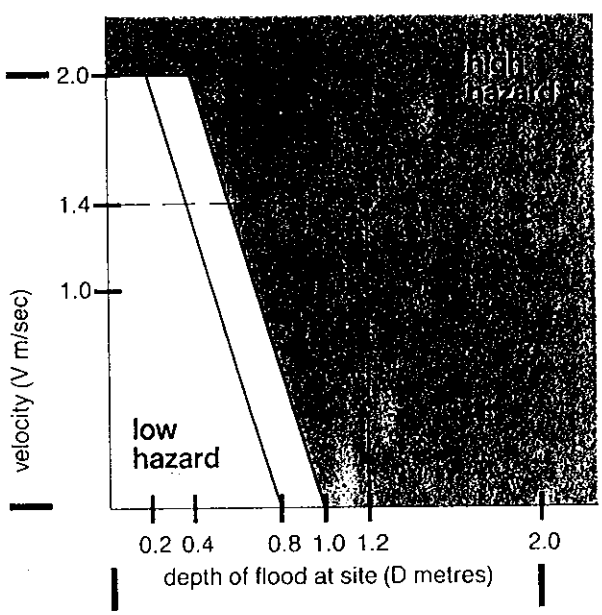
1. At velocities in excess of 2.0m/sec, the stability of foundations and poles can be affected by scour. Also, grass and earth surfaces begin to scour and can become rough and unstable.

2. The velocity of floodwaters passing between buildings can produce a hazard, which may not be apparent if only the average velocity is considered. For instance, the velocity of floodwaters in a model test has risen from an average of 1m/sec to 3m/sec between houses.

3. Vehicle instability is initiated by buoyancy.

4. At floodwater depths in excess of 2.0 metres and even at low velocities, there can be damage to light-framed buildings from water pressure, flotation and debris impact.

Provisional Hazard Categories



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**

APPENDIX G EVALUATION OF SUITABLE FLOOD LEVELS FOR DEVELOPMENT CONTROLS

For the purpose of this study, the river was divided into five reaches of the river, encompassing Council's Property Zones 1-4, 10-15, 16-22 and 23-29. The flood levels at each of the five zones were averaged for each flood frequency (Table G1.) and then used to calculate the average annual damage for a typical house with the floor built at different levels. These levels range form the lowest level of vacant land to the PMF level. An interval of 0.1m was used between the different floor levels.

Table G1 Flood levels used in the economic analysis of house raising

Property Zone	5% AEP Flood Level in (AHD)	2% AEP Flood Level	1% AEP Flood Level	Probable Maximum Flood
1-4	1.65	1.8	2.05	4.7
5-9	2.4	2.65	2.95	6.3
10-15	3.15	3.45	3.75	7.65
16-22	3.75	4.1	4.4	8.55
23-29	4.6	4.95	5.35	9.7

The benefits (ie. the reduction in average annual damage) of building at different levels were compared to the cost of building the house that much higher. Costs were based on building the house on brick piers or similar.

The social factors were incorporated into the evaluation by multiplying the damages by a factor of 2½. The reasoning for this was that during the social surveys after the Sydney floods of 1986 and 1988 (Smith and others, 1990; Lustig & Haeusler, 1988) the flood victims frequently commented that the social effects of the floods were worse that the financial losses.

If the social losses were deemed to be, let us say, equal to the financial losses, it would follow that the overall (ie. monetary and social) losses would be twice times the economic losses alone. If the social losses were double, the overall losses would be three times the financial losses. For this exercise it may be appropriate to consider the overall losses as being perhaps 2½ times as large as the financial losses.

In the first instance therefore, a factor of 2½ has been adopted for assessing the overall benefits. To test sensitivity, a very conservative factor of 2 was tested. The results on the attached Figures G1 to G5 indicate that the suggested range for choosing the flood standard is not greatly affected by the factor adopted for valuing social benefits.

Table G2 shows the benefits of costs resulting from these analyses for zones 1 to 4[1] for a social benefits factor of 2.5. The floor heights at which the benefits equalled or exceeded the costs were determined from these tables, and plotted relative to the ground height in Figures 3.3 to 3.7 in the main text. For example for a ground height of 2.5 m AHD the reduction in present

worth of damages (benefit) is equal to the cost of raising for a floor level located 0.8 m above ground level or 3.3 m AHD (ie 0.8 m + 2.5 m).

The benefits (ie. the reduction in average annual damage) of building at different levels were compared to the cost of building the house that much higher. Costs were based on building the house on brick piers.

It should be noted that the economic criterion chosen for assessing a flood standard has been that the total benefit to the householder of raising the house should not be less than the total costs. This differs from the standard normally used for arriving at an economically efficient design, namely that the marginal benefit should not be less than the marginal cost. That is for each additional dollar spent in building the house to a higher level, there should be at least a dollar's benefit in reduced losses.

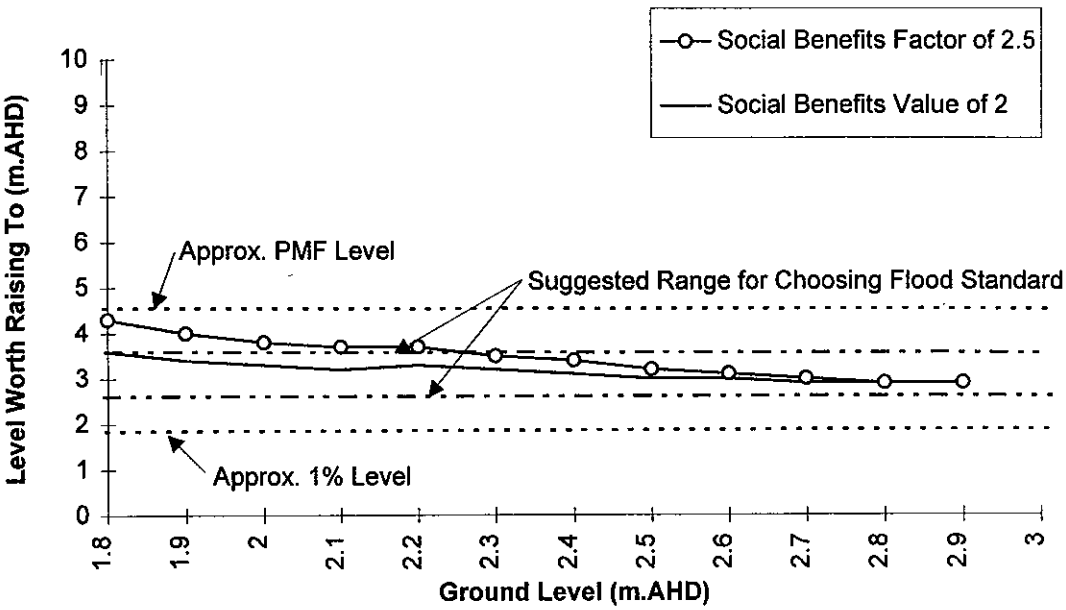
The former criterion has been adopted for this assessment. It is suggested that this would probably accord more with the way people tend to look on expenditures for securing their homes, particularly since the value of having non-habitable downstairs facilities covers the cost.

TABLE G2 BENEFITS AND COSTS OF ELEVATING FLOOR LEVELS (PAGE 1 OF 2)

COST OF RAISING			$330	$660	$990	$1,320	$1,650	$1,980	$2,310	$2,640	$2,970	$3,300	$3,630	$3,960	$4,290	$4,620	$4,950
Gnd.Ht	AAD	PW	Reduction in PW of damages by Height Raised			Reduction in PW of damages by Height Raised			Reduction in PW of damages by Height Raised			Reduction in PW of damages by Height Raised			Reduction in PW of damages by Height Raised		
mAHD	$	7%, 50yrs	0.1 m	0.2 m	0.3 m	0.4 m	0.5 m	0.6 m	0.7 m	0.8 m	0.9 m	1 m	1.1 m	1.2 m	1.3 m	1.4 m	1.5 m
1.2	$1,508	$52,029	$12,248	$22,288	$30,465	$38,021	$41,126	$43,403	$44,542	$45,266	$45,818	$46,060	$46,785	$47,440	$48,096	$48,682	$49,234
1.3	$1,153	$39,781	$10,040	$18,217	$25,773	$28,878	$31,155	$32,294	$33,018	$33,570	$33,812	$34,536	$35,192	$35,847	$36,434	$36,986	$37,504
1.4	$862	$29,741	$8,177	$15,733	$18,838	$21,115	$22,254	$22,978	$23,530	$23,772	$24,496	$25,152	$25,807	$26,394	$26,946	$27,463	$27,947
1.5	$625	$21,564	$7,556	$10,661	$12,938	$14,077	$14,801	$15,353	$15,595	$16,319	$16,975	$17,630	$18,217	$18,769	$19,287	$19,770	$19,873
1.6	$406	$14,008	$3,105	$5,382	$6,521	$7,245	$7,797	$8,039	$8,763	$9,419	$10,075	$10,661	$11,213	$11,731	$12,214	$12,317	$12,421
1.7	$316	$10,903	$2,277	$3,416	$4,140	$4,692	$4,934	$5,658	$6,314	$6,969	$7,556	$8,108	$8,625	$9,108	$9,212	$9,316	$9,419
1.8	$250	$8,625	$1,139	$1,863	$2,415	$2,657	$3,381	$4,037	$4,692	$5,279	$5,831	$6,348	$6,831	$6,935	$7,038	$7,142	$7,280
1.9	$217	$7,487	$725	$1,277	$1,518	$2,243	$2,898	$3,554	$4,140	$4,692	$5,210	$5,693	$5,796	$5,900	$6,003	$6,141	$6,279
2.0	$196	$6,762	$552	$794	$1,518	$2,174	$2,829	$3,416	$3,968	$4,485	$4,968	$5,072	$5,175	$5,279	$5,417	$5,555	$5,693
2.1	$180	$6,210	$242	$966	$1,622	$2,277	$2,864	$3,416	$3,933	$4,416	$4,520	$4,623	$4,727	$4,865	$5,003	$5,141	$5,244
2.2	$173	$5,969	$725	$1,380	$2,036	$2,622	$3,174	$3,692	$4,175	$4,278	$4,382	$4,485	$4,623	$4,761	$4,899	$5,003	$5,106
2.3	$152	$5,244	$656	$1,311	$1,898	$2,450	$2,967	$3,450	$3,554	$3,657	$3,761	$3,899	$4,037	$4,175	$4,278	$4,382	$4,520
2.4	$133	$4,589	$656	$1,242	$1,794	$2,312	$2,795	$2,898	$3,002	$3,105	$3,243	$3,381	$3,519	$3,623	$3,726	$3,864	$3,968
2.5	$114	$3,933	$587	$1,139	$1,656	$2,139	$2,243	$2,346	$2,450	$2,554	$2,726	$2,864	$2,967	$3,071	$3,209	$3,312	$3,381
2.6	$97	$3,347	$552	$1,070	$1,553	$1,656	$1,760	$1,863	$2,001	$2,139	$2,277	$2,381	$2,484	$2,622	$2,726	$2,795	$2,898
2.7	$81	$2,795	$518	$1,001	$1,104	$1,208	$1,311	$1,449	$1,587	$1,725	$1,829	$1,932	$2,070	$2,174	$2,243	$2,346	$2,484
2.8	$66	$2,277	$483	$587	$690	$794	$932	$1,070	$1,208	$1,311	$1,415	$1,553	$1,656	$1,725	$1,829	$1,967	$2,056
2.9	$52	$1,794	$104	$207	$311	$449	$587	$725	$828	$932	$1,070	$1,173	$1,242	$1,346	$1,484	$1,573	$1,691
3.0	$49	$1,691	$104	$207	$345	$483	$621	$725	$828	$966	$1,070	$1,139	$1,242	$1,380	$1,470	$1,587	$1,622
3.1	$46	$1,587	$104	$242	$380	$518	$621	$725	$863	$966	$1,035	$1,139	$1,277	$1,366	$1,484	$1,518	$1,553
3.2	$43	$1,484	$138	$276	$414	$518	$621	$759	$863	$932	$1,035	$1,173	$1,263	$1,380	$1,415	$1,449	$1,484
3.3	$39	$1,346	$138	$276	$380	$483	$621	$725	$794	$897	$1,035	$1,125	$1,242	$1,277	$1,311	$1,346	
3.4	$35	$1,208	$138	$242	$345	$483	$587	$656	$759	$897	$987	$1,104	$1,139	$1,173	$1,208		
3.5	$31	$1,070	$104	$207	$345	$449	$518	$621	$759	$849	$966	$1,001	$1,035	$1,070			
3.6	$28	$966	$104	$242	$345	$414	$518	$656	$745	$863	$897	$932	$966				
3.7	$25	$863	$138	$242	$311	$414	$552	$642	$759	$794	$828	$863					
3.8	$21	$725	$104	$173	$276	$414	$504	$621	$656	$690	$725						
3.9	$18	$621	$69	$173	$311	$400	$518	$552	$587	$621							
4.0	$16	$552	$104	$242	$331	$449	$483	$518	$552								
4.1	$13	$449	$138	$228	$345	$380	$414	$449									
4.2	$9	$311	$90	$207	$242	$276	$311										
4.3	$6	$221	$117	$152	$186	$221											
4.4	$3	$104	$35	$69	$104												
4.5	$2	$69	$35	$69													
4.6	$1	$35	$35														
4.7	$0	$0															

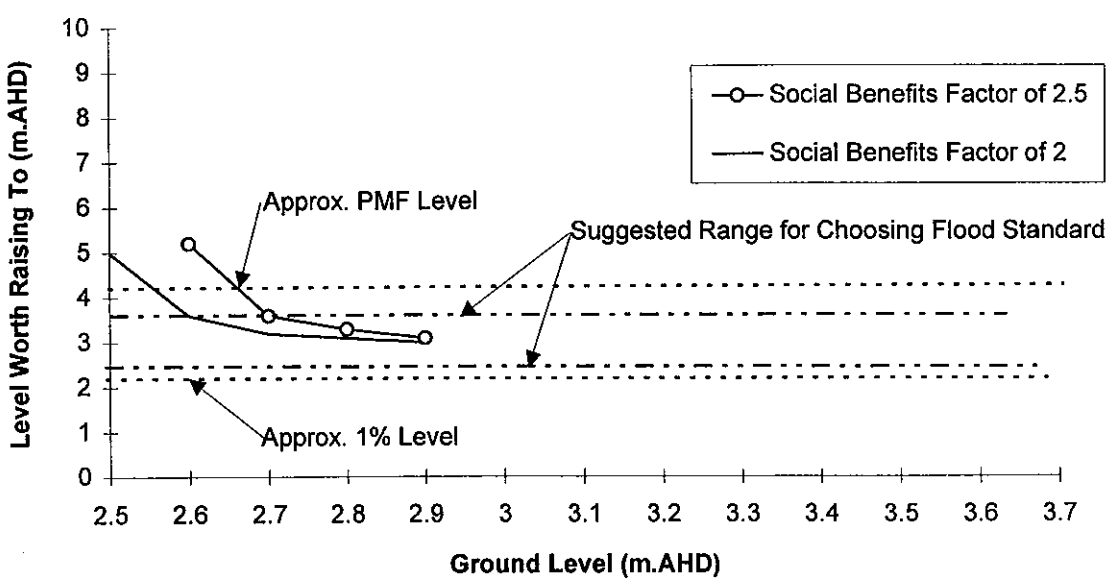
TABLE G2 BENEFITS AND COSTS OF ELEVATING FLOOR LEVELS (PAGE 2 OF 2)

COST OF RAISING			$5,280	$5,610	$5,940	$6,270	$6,600	$6,930	$7,260	$7,590	$7,920	$8,250	$8,580	$8,910	$9,240	$9,570	$9,900
Gnd.Ht	AAD	PW	Reduction in PW of damages by Height Raised			Reduction in PW of damages by Height Raised			Reduction in PW of damages by Height Raised			Reduction in PW of damages by Height Raised			Reduction in PW of damages by Height Raised		
mAHD	$	7%, 50yrs	1.6 m	1.7 m	1.8 m	1.9 m	2 m	2.1 m	2.2 m	2.3 m	2.4 m	2.5 m	2.6 m	2.7 m	2.8 m	2.9 m	3 m
1.2	$1,508	$52,029	$49,752	$50,235	$50,338	$50,442	$50,545	$50,683	$50,821	$50,959	$51,166	$51,166	$51,304	$51,408	$51,477	$51,580	$51,718
1.3	$1,153	$39,781	$37,987	$38,090	$38,194	$38,297	$38,435	$38,573	$38,711	$38,815	$39,056	$39,056	$39,160	$39,229	$39,332	$39,470	$39,560
1.4	$862	$29,741	$28,050	$28,154	$28,257	$28,395	$28,533	$28,671	$28,775	$28,878	$29,120	$29,120	$29,189	$29,292	$29,430	$29,520	$29,637
1.5	$625	$21,564	$19,977	$20,080	$20,218	$20,356	$20,494	$20,598	$20,701	$20,839	$21,012	$21,012	$21,115	$21,253	$21,343	$21,460	$21,495
1.6	$406	$14,008	$12,524	$12,662	$12,800	$12,938	$13,042	$13,145	$13,283	$13,387	$13,559	$13,559	$13,697	$13,787	$13,904	$13,939	$13,973
1.7	$316	$10,903	$9,557	$9,695	$9,833	$9,937	$10,040	$10,178	$10,282	$10,351	$10,592	$10,592	$10,682	$10,799	$10,834	$10,868	$10,903
1.8	$250	$8,625	$7,418	$7,556	$7,659	$7,763	$7,901	$8,004	$8,073	$8,177	$8,405	$8,405	$8,522	$8,556	$8,591	$8,625	
1.9	$217	$7,487	$6,417	$6,521	$6,624	$6,762	$6,866	$6,935	$7,038	$7,176	$7,383	$7,383	$7,418	$7,452	$7,487		
2.0	$196	$6,762	$5,796	$5,900	$6,038	$6,141	$6,210	$6,314	$6,452	$6,542	$6,693	$6,693	$6,728	$6,762			
2.1	$180	$6,210	$5,348	$5,486	$5,589	$5,658	$5,762	$5,900	$5,990	$6,107	$6,176	$6,176	$6,210				
2.2	$173	$5,969	$5,244	$5,348	$5,417	$5,520	$5,658	$5,748	$5,865	$5,900	$5,969	$5,969					
2.3	$152	$5,244	$4,623	$4,692	$4,796	$4,934	$5,023	$5,141	$5,175	$5,210	$5,244						
2.4	$133	$4,589	$4,037	$4,140	$4,278	$4,368	$4,485	$4,520	$4,554	$4,589							
2.5	$114	$3,933	$3,485	$3,623	$3,712	$3,830	$3,864	$3,899	$3,933								
2.6	$97	$3,347	$3,036	$3,126	$3,243	$3,278	$3,312	$3,347									
2.7	$81	$2,795	$2,574	$2,691	$2,726	$2,760	$2,795										
2.8	$66	$2,277	$2,174	$2,208	$2,243	$2,277											
2.9	$52	$1,794	$1,725	$1,760	$1,794												
3.0	$49	$1,691	$1,656	$1,691													
3.1	$46	$1,587	$1,587														
3.2	$43	$1,484															
3.3	$39	$1,346															
3.4	$35	$1,208															
3.5	$31	$1,070															
3.6	$28	$966															
3.7	$25	$863															
3.8	$21	$725															
3.9	$18	$621															
4.0	$16	$552															
4.1	$13	$449															
4.2	$9	$311															
4.3	$6	$221															
4.4	$3	$104															
4.5	$2	$69															
4.6	$1	$35															
4.7	$0	$0															



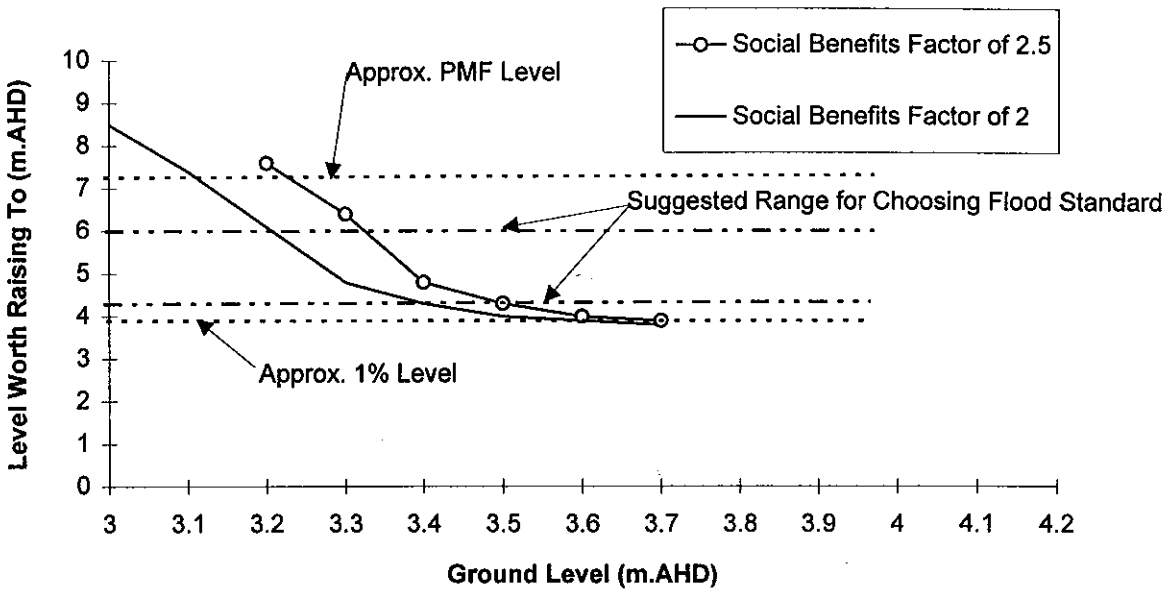
SUGGESTED RANGE FOR FLOOD STANDARD ZONES 1-4

FIGURE G1



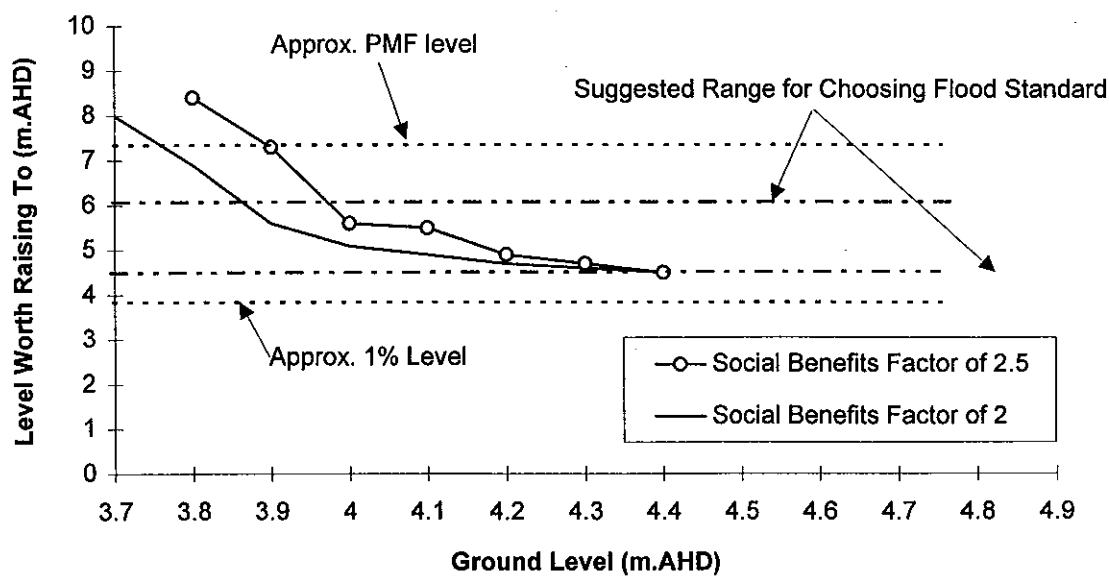
SUGGESTED RANGE FOR FLOOD STANDARD ZONES 5-9

FIGURE G2



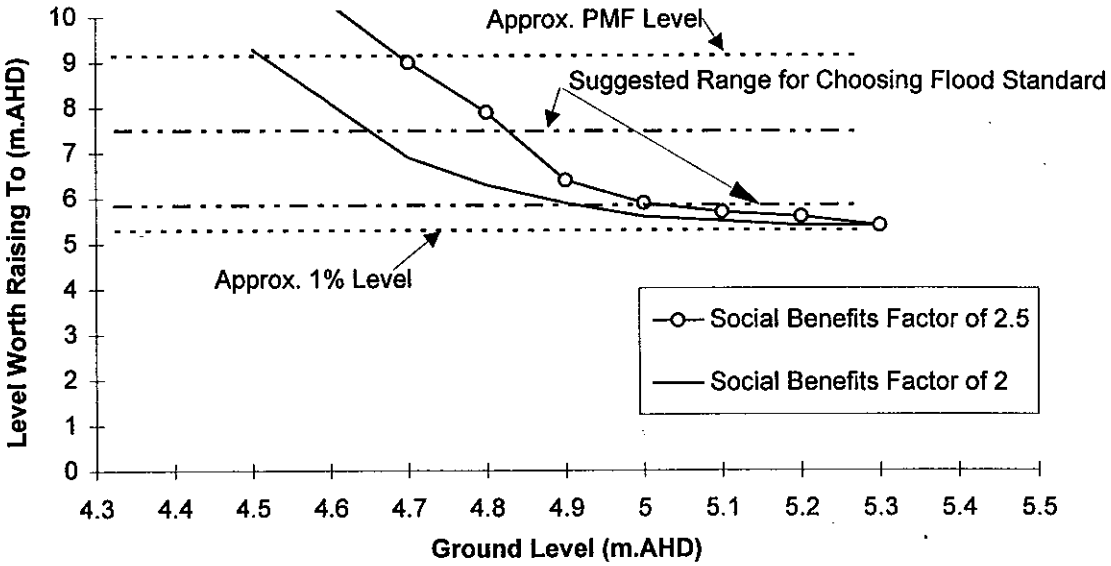
SUGGESTED RANGE FOR FLOOD STANDARD ZONES 10-15

FIGURE G3



SUGGESTED RANGE FOR FLOOD STANDARD ZONES 16-22

FIGURE G4



SUGGESTED RANGE FOR FLOOD STANDARD ZONES 23-29

FIGURE G5

APPENDIX H COSTS OF FLOOD FORECASTING SYSTEM

Costs of Flood Forecasting System	
Additional pluviometer	$ 7,000
Signal repeater station	$ 3,000
Base station	$ 7,000
Upgrade Needles river gauge	$ 7,000
New river gauge at Woronora Bridge	$ 20,000
Improved telecommunications for warnings	$ 10,000
Modelling and computer	$ 8,000
Sub Total	**$ 62,000**
Maintenance (15%)	$ 6,200
Present worth (50 yr) 7%	$ 86,000
Total	**$148,000**
Extra costs for bush fire warning	
3 stations @ $4,000	$12,000
Repeater station	$ 3,000
Total	**$15,000**

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APPENDIX I RESULTS OF BENEFIT-COST EVALUATIONS

Strategy 1 - base case : warning system, education, building control

Residential damage

ARI	Probability	do nothing	base case
4 YR	0.25	$0	$0
20 YR	0.05	$2,066,556	$1,671,665
50 YR	0.02	$2,981,075	$2,408,155
100 YR	0.01	$4,246,731	$3,537,187
PMF	0	$23,377,977	$18,880,229
Av. Annual Damage (AAD)		$456,633	$370,178
Present Worth (50yrs) 7%		$6,301,872	$5,108,727
Av. Annual Benefit (AAB)			$86,455
Present Worth (50yrs) 7%			$1,193,145

Commercial damage

ARI	Probability	do nothing	base case
4 YR	0.25	$0	$0
20 YR	0.05	$100,659	$80,527
50 YR	0.02	$123,382	$98,706
100 YR	0.01	$143,264	$114,611
PMF	0	$630,431	$504,344
Av. Annual Damage (AAD)		$18,628	$14,903
Present Worth (50yrs) 7%		$257,084	$205,667
Av. Annual Benefit (AAB)			$3,726
Present Worth (50yrs) 7%			$51,417

Cost of Base Case	flood warning system	$62,000
	preparedness campaign	$10,000
Total		**$72,000**

Annual costs	maintenance	@ 10%	$6,200
	preparedness campaign		$2,500
Total annual costs			$8,700
Present worth @	7%		**$120,066**

Summary of benefits

	Residents	Commercial	Total
Present Worth (50yrs) 7%, incl. indirect damage	$1,252,802	$79,696	$1,332,498

Summary of costs	Capital	Maintenance	Total
Present Worth (50yrs) 7%	$72,000	$120,066	$192,066

Comparison of benefits and costs	Benefits	Costs	Ratio
	$1,332,498	$192,066	6.94

Notes:

1. Probability is AEP (Annual Exceedance Probability) expressed in decimal form instead of a percentage eg. a probability of 0.01 is equivalent to 1% AEP.
2. ARI (Average Return Interval) $= \frac{1}{\text{Probability}}$

Strategy 2 - house raising + base case

Residential damage

ARI	Probability	do nothing	with raising
4 YR	0.25	$0	$0
20 YR	0.05	$2,066,556	$814,260
50 YR	0.02	$2,981,075	$1,148,020
100 YR	0.01	$4,246,731	$1,898,647
PMF	0	$23,377,977	$15,239,132
Av. Annual Damage (AAD)		$456,633	$211,782
Present Worth (50yrs) 7%		$6,301,872	$2,922,755
Av. Annual Benefit (AAB)			$244,850
Present Worth (50yrs) 7%			$3,379,117

Commercial damage

ARI	Probability	do nothing	with raising
4 YR	0.25	$0	$0
20 YR	0.05	$100,659	$80,527
50 YR	0.02	$123,382	$98,706
100 YR	0.01	$143,264	$114,611
PMF	0	$630,431	$504,344
Av. Annual Damage (AAD)		$18,628	$14,903
Present Worth (50yrs) 7%		$257,084	$205,667
Av. Annual Benefit (AAB)			$3,726
Present Worth (50yrs) 7%			$51,417

Cost of Base Case	$192,066
Cost of House Raising	$7,795,000
Total	**$7,987,066**

Summary of benefits

	Residents	Commercial	Total
Present Worth (50yrs) 7%, incl. indirect damage	$3,548,073	$79,696	$3,627,768

Summary of costs	Capital	Maintenance	Total
Present Worth (50yrs) 7%	$7,987,066	NA	$7,987,066

Comparison of benefits and costs	Benefits	Costs	Benefit/Cost Ratio
	$3,627,768	$7,987,066	0.45

Strategy 3: Base Case + Access Road Improvements at Prices Circuit

Residential damage

ARI	Probability	do nothing	base case
4 YR	0.25	$0	$0
20 YR	0.05	$2,066,556	$1,671,665
50 YR	0.02	$2,981,075	$2,408,155
100 YR	0.01	$4,246,731	$3,537,187
PMF	0	$23,377,977	$18,880,229
Av. Annual Damage (AAD)		$456,633	$370,178
Present Worth (50yrs) 7%		$6,301,872	$5,108,727
Av. Annual Benefit (AAB)			$86,455
Present Worth (50yrs) 7%			$1,193,145

Commercial damage

ARI	Probability	do nothing	base case
4 YR	0.25	$0	$0
20 YR	0.05	$100,659	$80,527
50 YR	0.02	$123,382	$98,706
100 YR	0.01	$143,264	$114,611
PMF	0	$630,431	$504,344
Av. Annual Damage (AAD)		$18,628	$14,903
Present Worth (50yrs) 7%		$257,084	$205,667
Av. Annual Benefit (AAB)			$3,726
Present Worth (50yrs) 7%			$51,417

Cost of Base Case	$192,066
Cost of Access	$355,000
Total	**$547,066**

Benefit of Access Road Improvements		
Saving time from road improvement		1.6 hours
% Savings for Inexperienced		4%
% Savings for Experienced		12%
Weighted Average Savings: 70% residents inexperienced + 30% residents experienced		6.4%
AAD attributable to houses affected by road improvements	$	62,930
Reduction in AAD from increased saving time	$	4,000
Av. Annual Benefit (AAB)	$	4,000
Present Worth (50yrs) 7%		**$55,203**

Summary of benefits

	Residents	Commercial	Total
Present Worth (50yrs) 7%, incl. indirect damage	$1,310,765	$79,696	$1,390,461

Summary of costs	Capital	Maintenance	Total
Present Worth (50yrs) 7%	$547,066	$0	$547,066

Comparison of benefits and costs	Benefits	Costs	Benefit/Cost Ratio
	$1,390,461	$547,066	2.5

Strategy 3b: The benefits of this strategy are social rather than monetary.
Refer text 5.3.2.

Strategy 4 - levee at Bonnet Bay + base case

Residential damage

ARI	Probability	do nothing	with levee
4 YR	0.25	$0	$0
20 YR	0.05	$2,066,556	$1,671,665
50 YR	0.02	$2,981,075	$2,408,155
100 YR	0.01	$4,246,731	$3,537,187
PMF	0	$23,377,977	$18,880,229
Av. Annual Damage (AAD)		$456,633	$370,178
Present Worth (50yrs) 7%		$6,301,872	$5,108,727
Av. Annual Benefit (AAB)			$86,455
Present Worth (50yrs) 7%			$1,193,145

Commercial damage

ARI	Probability	do nothing	with levee
4 YR	0.25	$0	$0
20 YR	0.05	$100,659	$80,527
50 YR	0.02	$123,382	$98,706
100 YR	0.01	$143,264	$114,611
PMF	0	$630,431	$504,344
Av. Annual Damage (AAD)		$18,628	$14,903
Present Worth (50yrs) 7%		$257,084	$205,667
Av. Annual Benefit (AAB)			$3,726
Present Worth (50yrs) 7%			$51,417

Cost of Base Case	$192,066
Cost of Levee	$100,000
Total	**$292,066**

Annual costs	maintenance	@	10%	$10,000
Total annual costs				$10,000
Present worth @	7%			**$138,007**

Summary of benefits

	Residents	Commercial	Total
Present Worth (50yrs) 7%, incl. indirect damage	$1,252,802	$79,696	$1,332,498

Summary of costs	Capital	Maintenance	Total
Present Worth (50yrs) 7%	$292,066	$138,007	$430,073

Comparison of benefits and costs	Benefits	Costs	Benefit/Cost Ratio
	$1,332,498	$430,073	3.10

NB -The reduction in preparedness of residents behind the levee cancels out the benefits of flood protection to two houses.

Strategy 5 - raising Woronora Bridge+ base case

Residential damage

ARI	Probability	do nothing	raise bridge
4 YR	0.25	$0	$0
20 YR	0.05	$2,066,556	$1,249,992
50 YR	0.02	$2,981,075	$1,962,357
100 YR	0.01	$4,246,731	$2,734,960
PMF	0	$23,377,977	$18,781,619
Av. Annual Damage (AAD)		$456,633	$304,254
Present Worth (50yrs) 7%		$6,301,872	$4,198,931
Av. Annual Benefit (AAB)			$152,379
Present Worth (50yrs) 7%			$2,102,940

Commercial damage

ARI	Probability	do nothing	raise bridge
4 YR	0.25	$0	$0
20 YR	0.05	$100,659	$69,414
50 YR	0.02	$123,382	$90,617
100 YR	0.01	$143,264	$108,332
PMF	0	$630,431	$504,344
Av. Annual Damage (AAD)		$18,628	$13,400
Present Worth (50yrs) 7%		$257,084	$184,931
Av. Annual Benefit (AAB)			$5,228
Present Worth (50yrs) 7%			$72,153

Cost of Base Case	$192,066
Cost of Raising Bridge	$1,500,000
Total	**$1,692,066**

Summary of benefits

	Residents	Commercial	Total
Present Worth (50yrs) 7%, incl. indirect damage	$2,208,087	$111,837	$2,319,925

Summary of costs	Capital	Maintenance	Total
Present Worth (50yrs) 7%	$1,692,066	$0	$1,692,066

Comparison of benefits and costs	Benefits	Costs	Benefit/Cost Ratio
	$2,319,925	$1,692,066	1.37

Strategy 6 (option 1) - dredging bed level between -4.3m and -3.3m AHD + base case

Residential damage

ARI	Probability	do nothing	dredging (1)
4 YR	0.25	$0	$0
20 YR	0.05	$2,066,556	$1,338,494
50 YR	0.02	$2,981,075	$2,066,097
100 YR	0.01	$4,246,731	$3,135,685
PMF	0	$23,377,977	$17,983,533
Av. Annual Damage (AAD)		$456,633	$316,523
Present Worth (50yrs) 7%		$6,301,872	$4,368,257
Av. Annual Benefit (AAB)			$140,109
Present Worth (50yrs) 7%			$1,933,614

Commercial damage

ARI	Probability	do nothing	dredging (1)
4 YR	0.25	$0	$0
20 YR	0.05	$100,659	$70,964
50 YR	0.02	$123,382	$92,442
100 YR	0.01	$143,264	$111,549
PMF	0	$630,431	$504,344
Av. Annual Damage (AAD)		$18,628	$13,647
Present Worth (50yrs) 7%		$257,084	$188,337
Av. Annual Benefit (AAB)			$4,981
Present Worth (50yrs) 7%			$68,746

Cost of Base Case						$192,066
Cost of Dredging	250,000 m3	@	$10	per m3	=	$2,500,000
Total						**$2,692,066**

Present Worth of maintenance every 15 ye	@	7%	$1,353,567

Summary of benefits

	Residents	Commercial	Total
Present Worth (50yrs) 7%, incl. indirect damage	$2,030,295	$106,557	$2,136,852

Summary of costs	Capital	Maintenance	Total
Present Worth (50yrs) 7%	$2,692,066	$1,353,567	$4,045,633

Comparison of benefits and costs	Benefits	Costs	Benefit/Cost Ratio
	$2,136,852	$4,045,633	0.53

Strategy 6 (option 2) - dredging bed level between -4.3m and -5.3m AHD + base case

Residential damage

ARI	Probability	do nothing	dredging (2)
4 YR	0.25	$0	$0
20 YR	0.05	$2,066,556	$1,013,832
50 YR	0.02	$2,981,075	$1,730,919
100 YR	0.01	$4,246,731	$2,491,190
PMF	0	$23,377,977	$17,584,332
Av. Annual Damage (AAD)		$456,633	$264,043
Present Worth (50yrs) 7%		$6,301,872	$3,643,985
Av. Annual Benefit (AAB)			$192,590
Present Worth (50yrs) 7%			$2,657,887

Commercial damage

ARI	Probability	do nothing	dredging (2)
4 YR	0.25	$0	$0
20 YR	0.05	$100,659	$57,697
50 YR	0.02	$123,382	$85,336
100 YR	0.01	$143,264	$105,332
PMF	0	$630,431	$504,344
Av. Annual Damage (AAD)		$18,628	$11,917
Present Worth (50yrs) 7%		$257,084	$164,463
Av. Annual Benefit (AAB)			$6,711
Present Worth (50yrs) 7%			$92,621

Cost of Base Case					$192,066
Cost of Dredging	580,000 m3	@	$10	per m3 =	$5,800,000
Total					**$5,992,066**

Present Worth of maintenance every 15 ye @	7%	$3,140,274

Summary of benefits

	Residents	Commercial	Total
Present Worth (50yrs) 7%, incl. indirect damage	$2,790,782	$143,563	$2,934,344

Summary of costs	Capital	Maintenance	Total
Present Worth (50yrs) 7%	$5,992,066	$3,140,274	$9,132,340

Comparison of benefits and costs	Benefits	Costs	Benefit/Cost Ratio
	$2,934,344	$9,132,340	0.32

Strategy 7 - levee of 5% AEP upstream of Bridge + base case

Residential damage

ARI	Probability	do nothing	with levee
4 YR	0.25	$0	$0
20 YR	0.05	$2,066,556	$1,466,941
50 YR	0.02	$2,981,075	$2,501,293
100 YR	0.01	$4,246,731	$3,124,106
PMF	0	$23,377,977	$18,781,619
Av. Annual Damage (AAD)		$456,633	$346,373
Present Worth (50yrs) 7%		$6,301,872	$4,780,209
Av. Annual Benefit (AAB)			$110,259
Present Worth (50yrs) 7%			$1,521,662

Commercial damage

ARI	Probability	do nothing	with levee
4 YR	0.25	$0	$0
20 YR	0.05	$100,659	$75,943
50 YR	0.02	$123,382	$102,583
100 YR	0.01	$143,264	$116,273
PMF	0	$630,431	$504,344
Av. Annual Damage (AAD)		$18,628	$14,470
Present Worth (50yrs) 7%		$257,084	$199,690
Av. Annual Benefit (AAB)			$4,159
Present Worth (50yrs) 7%			$57,394

Cost of Base Case	$192,066
Cost of Levee	$225,000
Total	**$417,066**

Annual costs	maintenance	@	10%	$22,500
Total annual costs				$22,500
Present worth @	7%			**$310,517**

Summary of benefits

	Residents	Commercial	Total
Present Worth (50yrs) 7%, incl. indirect damage	$1,597,745	$88,960	$1,686,706

Summary of costs	Capital	Maintenance	Total
Present Worth (50yrs) 7%	$417,066	$310,517	$727,583

Comparison of benefits and costs	Benefits	Costs	Benefit/Cost Ratio
	$1,686,706	$727,583	2.32

NB - Results take into account the reduction in preparedness of residents behind the levee.

Strategy 7 - levee of 2% AEP upstream of Bridge + base case

Residential damage

ARI	Probability	do nothing	with levee
4 YR	0.25	$0	$0
20 YR	0.05	$2,066,556	$1,466,941
50 YR	0.02	$2,981,075	$2,052,988
100 YR	0.01	$4,246,731	$3,547,850
PMF	0	$23,377,977	$18,781,619
Av. Annual Damage (AAD)		$456,633	$341,645
Present Worth (50yrs) 7%		$6,301,872	$4,714,950
Av. Annual Benefit (AAB)			$114,988
Present Worth (50yrs) 7%			$1,586,921

Commercial damage

ARI	Probability	do nothing	with levee
4 YR	0.25	$0	$0
20 YR	0.05	$100,659	$75,943
50 YR	0.02	$123,382	$93,815
100 YR	0.01	$143,264	$116,273
PMF	0	$630,431	$504,344
Av. Annual Damage (AAD)		$18,628	$14,294
Present Worth (50yrs) 7%		$257,084	$197,270
Av. Annual Benefit (AAB)			$4,334
Present Worth (50yrs) 7%			$59,814

Cost of Base Case	$192,066
Cost of Levee	$275,000
Total	**$467,066**

Annual costs	maintenance	@	10%	$27,500
Total annual costs				$27,500
Present worth @	7%			**$379,521**

Summary of benefits

	Residents	Commercial	Total
Present Worth (50yrs) 7%, incl. indirect damage	$1,666,267	$92,711	$1,758,979

Summary of costs	Capital	Maintenance	Total
Present Worth (50yrs) 7%	$467,066	$379,521	$846,587

Comparison of benefits and costs	Benefits	Costs	Benefit/Cost Ratio
	$1,758,979	$846,587	2.08

NB - Results take into account the reduction in preparedness of residents behind the levee.

Strategy 7 - levee of 1% AEP upstream of Bridge + base case

Residential damage

ARI	Probability	do nothing	with levee
4 YR	0.25	$0	$0
20 YR	0.05	$2,066,556	$1,466,941
50 YR	0.02	$2,981,075	$2,052,988
100 YR	0.01	$4,246,731	$2,735,034
PMF	0	$23,377,977	$18,781,619
Av. Annual Damage (AAD)		$456,633	$333,516
Present Worth (50yrs) 7%		$6,301,872	$4,602,776
Av. Annual Benefit (AAB)			$123,116
Present Worth (50yrs) 7%			$1,699,096

Commercial damage

ARI	Probability	do nothing	with levee
4 YR	0.25	$0	$0
20 YR	0.05	$100,659	$75,943
50 YR	0.02	$123,382	$93,815
100 YR	0.01	$143,264	$105,874
PMF	0	$630,431	$504,344
Av. Annual Damage (AAD)		$18,628	$14,190
Present Worth (50yrs) 7%		$257,084	$195,835
Av. Annual Benefit (AAB)			$4,438
Present Worth (50yrs) 7%			$61,249

Cost of Base Case	$192,066
Cost of Levee	$350,000
Total	**$542,066**

Annual costs	maintenance	@	10%	$35,000
Total annual costs				$35,000
Present worth @	7%			**$483,026**

Summary of benefits

	Residents	Commercial	Total
Present Worth (50yrs) 7%, incl. indirect damage	$1,784,051	$94,936	$1,878,987

Summary of costs	Capital	Maintenance	Total
Present Worth (50yrs) 7%	$542,066	$483,026	$1,025,092

Comparison of benefits and costs	Benefits	Costs	Benefit/Cost Ratio
	$1,878,987	$1,025,092	1.83

NB - Results take into account the reduction in preparedness of residents behind the levee.