DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT
STUDY AND APPENDICES

November 2005

FINAL REPORT

VOLUMES 1 AND 2
STUDY REPORT
AND APPENDICES

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TABLE OF CONTENTS

Page No

APPENDICES – BOUND IN VOLUME 2

LIST OF FIGURES

1 INTRODUCTION

1.1 Study Background

A comprehensive floodplain risk management plan (FRMP) has been prepared for the Dee Why and Curl Curl Lagoon catchments as part of a Government program to mitigate the impacts of major floods and reduce the hazards in the floodplain.

The first steps in the process of preparing the FRMP were the collection of Flood Data and the completion in November 2002 of detailed Flood Studies for the two lagoons and their main tributaries (LACE, 2002). The Flood Study report was later updated by Council in 2005 to incorporate revised flood extents on the Curl Curl Lagoon catchment following receipt of more recent survey information. The flood study is the formal starting process of defining management measures for flood liable land and represents a detailed technical investigation of flood behaviour.

Warringah Council subsequently commissioned Lyall & Associates Consulting Water Engineers (LACE) to prepare a Floodplain Risk Management Study and Plan for the Dee Why and Curl Curl Lagoon catchments and surrounding areas. The Brief for the study issued by Council generally follows the scope of work required for a Floodplain Management Study as identified in the Floodplain Development Manual (FDM, 2005).

The overall objective of the investigation was to assess the impacts of flooding, review policies and options for management of flood affected land and to develop a Floodplain Risk Management Plan which:

i) Sets out the recommended program of works and measures aimed at reducing over time, the social environmental and economic impacts of flooding.

ii) Proposes modifications to existing Council policies to ensure that the development of flood affected land is undertaken so as to be compatible with the flood hazard and risk.

iii) Reviews existing policies for managing the lagoon entrances and assesses their impacts on flooding.

In regard to the last objective, the need to promote periods of prolonged inundation within the lagoon systems needs to be balanced with the expectations of occupiers of low lying areas, who seek to have the lagoon entrances breached during periods of heavy rain or when berm heights build to excessive levels.

This investigation deals with the floodplain of Greendale Creek and Curl Curl Lagoon, as well as the floodplain of Dee Why Creek and Dee Why Lagoon. Dee Why Creek drains the Dee Why Lagoon North Catchment. The Dee Why Lagoon South Catchment which also drains to Dee Why Lagoon and includes the Dee Why Town Centre, is drained by a piped trunk stormwater system and does not form part of the present study.

In the preparation of this Study and Plan, LACE drew on the experience gained from several recent investigations on flooding in the study catchments, including:

- The Dee Why and Curl Curl Lagoon Flood Studies completed in November 2002
- The Dee Why and Curl Curl Catchments Property Survey Report
- The Dee Why Lagoon Estuary Management Study and Plan
- The Curl Curl Lagoon Estuary Management Plan

Throughout this study, LACE has been guided by the Floodplain Management Committee. The Committee has provided valuable direction, bringing together views from key Council staff, other departments and agencies, and importantly, the views of the community gained through the Community Consultation process carried out as part of the study.

1.2 Overview of Report

This report (**Volume 1**) sets out the findings of the *Floodplain Risk Management Study*.

Section 2 of the Report contains information on baseline flooding conditions on the catchments, including a review of existing planning policies, assessment of the impacts of flooding on the community, flood warning and preparedness and environmental considerations.

Section 3 is a review of possible Floodplain Management Measures which could be included in the Plan.

Section 4 details the selection of Floodplain Management Measures. Floodplain Management strategies comprising combinations of measures are assessed in detail and a preferred strategy outlined.

Section 5 contains a list of references.

The Study is supported by eight **Appendices** which provide additional details of the investigations undertaken for the preparation of the Study and Plan. These **Appendices** are bound in **Volume 2**.

Volume 3 presents the elements of the *draft Floodplain Risk Management Plan.*

2 BASELINE FLOODING CONDITIONS

2.1 Catchment Description

2.1.1 Dee Why Lagoon Catchment

Dee Why Lagoon is the second largest of four coastal lagoons located within the Warringah Local Government Area (LGA). The lagoon has a total surface area of approximately 30 ha and a total catchment contributing stormwater inflows to the lagoon of approximately 520 ha. Dee Why Creek catchment contributes 250 ha of this catchment.

The catchment of Dee Why Creek draining to Dee Why Lagoon is primarily urban with some light industry, open space and wetland areas. Pittwater Road, the main arterial road for the northern beaches, separates the lagoon and beach system from the urban development. As a result the lagoon still has many natural features and ecological processes.

For the purposes of this study, Pittwater Road defines the extent of the lagoon system (Dee Why Creek drains to the lagoon via the culvert beneath Pittwater Road).

The 80 m wide entrance to the lagoon is situated near Long Reef Beach, south of Long Reef Point, as shown on **Figure 2.1**.

Four culvert crossings of Dee Why Creek are located within the study area, which extends upstream to the commencement of the open channel section of creek at the intersection of South Creek Road and Fisher Road North in Cromer.

The most downstream culvert is located at the Pittwater Road crossing of Dee Why Creek and has an opening of 5.4 m width and 1.9 m height. The second is a bank of four 1800 mm diameter pipes which extend beneath both Campbell Avenue and a short width of grassed reserve located on the upstream side of the roadway. The third culvert is located downstream of the Cromer Park MW Soccer Grounds. The culvert is 2.7 m wide by 0.9 m high and discharges via a concrete lined channel to a wetland system, which is bordered by the playing fields to the north and a retirement village along its southern edge. The most upstream culvert comprises twin 900 mm diameter pipes which convey flows in the channel, which commences at South Creek Road - Fisher Road North, beneath the Dee Why Bowling Club.

The Time and Tide Hotel is located downstream of the wetland system. The northern bank of Dee Why Creek on which the hotel premises are located is lower than the right overbank, and the car park at the rear of the hotel is inundated during relatively minor flood events.

Downstream of Campbell Avenue, a trashrack captures vegetative debris and litter from stormwater prior to the creek discharging to the open section of channel which drains through Dee Why Park. The invert of the channel downstream of Campbell Avenue comprises a concrete half pipe, which continues downstream to a point adjacent to Billarong Avenue, where creek water levels are influenced by the height of the entrance berm of the lagoon and the culvert beneath Pittwater Road.

On the northern bank of the creek, in the vicinity of Billarong Avenue and Tarra Crescent, several residential properties are subject to inundation by floodwaters during heavy rainfall events which cause stormwater to bank up behind the Pittwater Road culvert. Parts of this area were flooded to depths over 500 mm in the storm of April 1998, which had a return period of approximately 10 years. Above-floor inundation was experienced at a number of residences in Tarra Crescent.

2.2 Curl Curl Lagoon Catchment

Curl Curl Lagoon is the smallest of the four coastal lagoons within the Warringah LGA. The lagoon has a total surface area of approximately 5.7 ha and a catchment area of approximately 440 ha which consists largely of residential and industrial land uses.

In the 1920s, the lagoon was reportedly surrounded by salt marsh and an extensive dune system which extended along Curl Curl Beach. The height of the dune system at that time was reportedly around 20 m, however, sand mining practices in the 1930s reduced their height to what is currently observed fronting Curl Curl Beach.

Prior to the 1950s, the foreshores of the lagoon were relatively low lying and land use in the area comprised a mixture of market gardens and natural vegetation. At the time, Greendale Creek, which is the main source of freshwater flow into the lagoon, meandered generally in an easterly direction from the culvert beneath Harbord Road to the lagoon, located approximately 1 km to the east of the road crossing. This meander pattern is evident in the 2 m contour base shown in Council's GIS (refer **Figure 2.2**).

Between 1951 and the mid 1970s, the northern and southern shores of the lagoon and creek were progressively filled with a variety of putrescible and non-putrescible waste to form the numerous sports fields which are present today. The meanders in the creek at that time were removed and the channel straightened so that it flowed due east to the lagoon.

Greendale Creek is enclosed between Pittwater Road and Harbord Road and consists of both piped and box sections of culvert of limited capacity, apart from a short length of open channel which is located on the southern side of Winbourne Road east of its intersection with Mitchell Road. A 1500 reinforced concrete pipe (RCP) which conveys runoff from the 0.9 km^2 catchment to the west discharges to the head of the channel which continues for a short distance to twin 1800 RCP's which convey flows to a junction pit near Sydenham Road. Downstream of the junction pit, flows are conveyed in twin 1200 RCP's to Harbord Road.

During storm events which surcharge the piped drainage system, stormwater traverses the street system between Pittwater Road and Harbord Road as overland flow. The path floodwaters take during such events is influenced by the varying road crossfalls and the presence of median islands in the road system. Some of the overland flow enters the commercial and industrial premises bordering the streets and also travels through the road system within the Winbourne Industrial Estate. During major flood events, the floors of some of the tenancies within the estate may be inundated.

East of Harbord Road, Greendale Creek has been subject to a rehabilitation works programme which has only recently been completed by Warringah Council. The works included the construction of a gross pollutant trap (GPT) on the downstream side of Harbord Road, a pedestrian footbridge at the end of Parkes Street (the Eastern Footbridge), revegetation of the banks of the creek and construction of a low rock weir with a fish ladder which signals the commencement of the salt marshes and flats of the lagoon. An older footbridge is also located to the north of the Bowling Club on Greendale Creek (the Western Footbridge).

For the purposes of this study, the recently constructed rock fish ladder, which is located a distance of approximately 50 m downstream of the Eastern Footbridge, defines the upstream extent of the lagoon system.

The entrance to the lagoon is located approximately 400 m east of Griffin Road, which crosses the lagoon via a piered bridge structure. Between Griffin Road and the lagoon entrance, the watercourse meanders to the north where it fronts low lying land at the southern end of Surf Road before reaching the North Curl Curl Surf Club car park, where ground levels rise steeply from the waters edge.

The entrance to the lagoon is situated at the northern end of Curl Curl Beach, near the Dee Why Heads. The throat of the entrance channel is approximately 70 m wide.

2.3 Flood Characteristics

The following discussion is drawn from the results of the Flood Study (LACE, 2002). The catchment models developed in that study have been demonstrated to replicate historic flood behaviour and consequently, may be used to describe the characteristics of “design” floods, over the full range of relevance to this study.

Floods which maximise water surface levels in the drainage systems result from intense short duration storms on the catchments. The flood study (LACE, 2002) showed that storms of 120 minutes duration were critical in terms of maximising peak discharges in the main streams.

In the lower reaches of the creeks, water levels are influenced by the storage in the lagoons, initial water levels and the prevailing entrance conditions prior to the commencement of surface runoff. Dee Why and Curl Curl Lagoons are examples of Intermittently Closed and Open Lakes and Lagoons (ICOLLS). On Dee Why Creek, the lagoon and the bridge over Pittwater Road influence flood levels for a distance of about 200 m upstream of Pittwater Road. Upstream of this location, flood levels are controlled by the hydraulic conveyance capacity of the channel and its overbank areas as well as the bed slope of the stream. On Greendale Creek, Curl Curl Lagoon influences levels as far as Harbord Road.

A review of available literature and recorded water level data for both lagoons, undertaken for the flood study showed that the berm height varies significantly over time, with an average of six breakouts occurring per year. As the primary breakout mechanism for an ICOLL is heavy rainfall, the adoption of appropriate entrance conditions for design flood estimation purposes was dependent on the conditional probability of local catchment conditions, entrance berm heights, lagoon water levels at the onset of rainfall and inshore ocean conditions.

Lagoon and Entrance Conditions

The following berm heights and lagoon levels were adopted for design purposes in conjunction with a storm tide of RL 1 m:

TABLE 2.1
BERM HEIGHT AND LAGOON LEVELS ADOPTED FOR DESIGN FLOOD ESTIMATION (LACE, 2002)

Location	Berm Height RL m	Lagoon Water Level RL m
Dee Why Lagoon	2.0	1.8
Curl Curl Lagoon	2.2	2.0

Peak Water Surface Profiles and Extents of Inundation

The extent of flooding and the boundary between high and low hazard areas for the 1% AEP flood on Dee Why Creek and Lagoon are shown on **Figure 2.3. Figure 2.4** shows water surface profiles for floods ranging between 20% AEP and the PMF. **Figure 2.5** shows the corresponding range of peak water surface levels at Billarong Avenue, just upstream of Pittwater Road.

Due to the storage effects of the lagoons and the steep bed slope of Dee Why Creek upstream of Pittwater Road, peak water levels do not increase greatly with increasing severity of flooding. The range of flood levels for various flood events is shown on **Table 2.2** below.

TABLE 2.2
PEAK FLOOD LEVELS
DEE WHY CREEK AND LAGOON
RL m

Flood Frequency % AEP	Lagoon	Billarong Ave	d/s Campbell Ave
20	2.3	3.3	4.52
1	2.55	3.59	4.91
PMF	3.41	4.35	5.71

Figures 2.6 and 2.7 show corresponding 1% AEP flood extent and peak water surface level information for Greendale Creek and Curl Curl Lagoon. **Figure 2.8** shows the range of peak water levels at Surf Road.

On Curl Curl Lagoon, there is a significant flood slope along the extent of the lagoon due to the higher flow velocities associated with the comparatively narrow width of the waterway. Velocities of flow in the Dee Why Lagoon are negligible and consequently this area functions hydraulically as a large, wide storage basin.

TABLE 2.3
PEAK FLOOD LEVELS
GREENDALE CREEK AND CURL CURL LAGOON
RL m

Flood Frequency % AEP	Lagoon Entrance	Griffin Rd Bridge	d/s Harbord Rd
20	2.59	3.15	5.19
1	2.81	3.63	5.69
PMF	3.87	5.68	6.11

Time of Rise of Floodwaters

Flooding on the two catchments is "flash flooding" in nature with a rapid rate of rise after the onset of heavy rainfall. On Dee Why Creek, the stream about 70 m downstream of Campbell Avenue would commence to rise about 20 minutes after the beginning of heavy rainfall and in the case of the 1% AEP flood would rapidly rise by 1.8 m to a peak level of RL 4.91 m over the following 30 minutes. Further downstream on Dee Why Lagoon, the rate of rise is somewhat slower due to the storage effects of the waterbody, with water levels rising from RL 1.8 m to 2.55 m over a period of 1.5 hours.

On Greendale Creek about 250 m downstream of Harbord Road, the stream commences to rise about 12 minutes after the commencement of heavy rainfall and rises by 3.6 m to a peak of RL 5.69 m over a further 24 minutes. At Curl Curl Lagoon, the level would commence to rise 18 minutes after the storm commences and would rise by 1.65 m to a peak of RL 3.63 m over the following 80 minutes.

2.4 Floodway and Flood Hazard Areas

2.4.1 Floodways

According to the Floodplain Development Manual (NSW Government, 2005), the floodplain may be subdivided into the following:

- Floodways;
- Flood storage; and
- Flood fringe

Floodways are those areas where a significant volume of water flows during floods and are often aligned with obvious natural channels. They are areas that, even if partially blocked, would cause a significant increase in flood level and/or a significant redistribution of flow, which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow of areas where higher velocities occur.

Flood storage areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.

Flood fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels (NSW Government, 2005).

The notion of hydraulic categories is subjective, and to a large degree can reflect the opinion of the assessor, particularly with what is considered to be a significant impact. In any case, the determination of hydraulic categories should take into account the cumulative impacts of developments within the floodplain. The hydraulic categories are not a tool to be used for the assessment of development proposals on an isolated or individual basis.

From a comparison of the diagrams in the flood study (LACE, 2002) showing the hydraulic categorisation and the hazard delineation, it was clear that the floodway zone closely corresponded with the high hazard areas. This simplified the wording of the *draft Local Flood Policy* presented in **Appendix D** in which the terms *"floodway"* and *"high hazard area"* have been used synonymously.

2.4.2 Flood Hazard

Flood hazard categories may be assigned to flood affected areas in accordance with the procedures outlined in the Floodplain Development Manual.

Flood prone areas may be provisionally categorised into *Low Hazard* and *High Hazard* areas depending on the depth of inundation and flow velocity. Flood depths as high as 0.8 m in the absence of any significant flow velocity represent *Low Hazard* conditions. Similarly, areas of flow velocities up to 2.0 m/s but with minimal flood depth also represent *Low Hazard* conditions.

Flood hazards categorised on the basis of depth and velocity are only provisional. They do not reflect the effects of other factors that influence hazard.

These other factors include:

- Size of flood – major floods though rare can cause extensive damage and disruption.
- Effective warning time – flood hazard and flood damage can be reduced by evacuation if adequate warning time is available.
- Flood awareness – flood awareness greatly influences the time taken by flood affected residents to respond effectively to flood warnings. The formulation and implementation of response plans for the evacuation of people and possessions promote flood awareness.
- Rate of rise of floodwaters – situations where floodwaters rise rapidly are potentially more dangerous and cause more damage than situations in which flood levels increase slowly.
- Duration of flooding – the duration of flooding (or length of time a community is cut off) can have a significant impact on costs associated with flooding. The duration is shorter in smaller, steeper catchments.
- Evacuation problems and access routes – the availability of effective access routes from flood prone areas directly influences flood hazard and potential damage reduction measures.

Hazard categories may be reduced or increased after consideration of the above factors.

A qualitative assessment of the influence of the above factors on the provisional flood hazard (based on velocity and depth considerations only) is presented in **Table 2.4**.

TABLE 2.4
INFLUENCE OF FLOOD RELATED PARAMETERS ON PROVISIONAL FLOOD HAZARD IN FLOODPLAINS OF DEE WHY AND CURL CURL LAGOONS

Parameter	Influence on Provisional Hazard	Flood Characteristics
Size of flood	0	Flooding is comparatively shallow, with no major increase in depth of flow with increasing severity of flooding.
Effective warning time	1	The warning time is short, which would tend to increase flood hazard.
Flood awareness	1	Flood awareness is likely to be low due to the comparatively long duration since the last flood and relatively isolated locations of flood damage. This would tend to increase the hazard when a flood eventually occurs.
Rate of rise of floodwaters	1	Flooding is of a “flash flooding” nature, which would tend to increase hazard.
Duration of flooding	– 1	The duration of the flood peak is quite short, less than 30 minutes.
Evacuation problems	– 1	The extent of inundation is confined to the vicinity of the central thread of the stream. There is easy evacuation out of the flooded area to higher ground bordering the creeks.

Legend 0 = neutral impact on provisional hazard
1 = tendency to increase provisional hazard
– 1 = tendency to reduce provisional hazard

After consideration of the above factors, it was considered that there was no reason to adjust the provisional flood hazard and that the final determination of hazard in the floodplains could be based on depth and velocity alone.

2.5 Economic Impacts of Flooding

The economic consequences of floods are discussed in detail in **Appendix B**. The economic assessment was required for two reasons; firstly to provide an assessment of the severity of flooding within the study area in terms of the number of properties flooded and the resulting flood damages; and secondly to allow an economic ranking of the competing flood management options in Chapter 3 of the study. The flood damages were assessed using techniques developed and tested in numerous urban and rural flood situations in NSW. Damages to residential, industrial, commercial and public buildings were estimated.

There are no data available on historic flood damages to the residential and commercial/industrial sectors in the study area. Accordingly it was necessary to use data on damages experienced as a result of historic flooding in other urban centres. These data were firstly converted to “potential” damages, which are the damages which would be experienced if no action were taken by residents such as raising goods above flood level or moving them from the floodplain.

As there is little warning time available for residents or commercial and industrial proprietors in the floodplains of Dee Why and Curl Curl Lagoons to take action, the estimated potential damages were reduced by only 10 per cent to convert to "actual" damages which would be expected to occur.

The numbers of flood affected properties are shown on **Tables 2.5 and 2.6**. These tables make the distinction between flood "affected" properties, where the water would be expected to be on the land around the house and flood "damaged" properties, where the flood waters would be above the floor of the property and cause some damage.

TABLE 2.5
TOTAL NUMBER OF PROPERTIES INUNDATED
DEE WHY CREEK AND LAGOON STUDY AREA

Flood Event % AEP	No. of Properties Flooded					
	Residential		Commercial/ Industrial		Public Buildings	
	A	D	A	D	A	D
20	47	9	4	0	1	0
10	53	12	4	0	2	0
2	67	14	4	2	2	0
1	73	17	6	2	3	0
PMF	143	67	12	6	4	3

TABLE 2.6
TOTAL NUMBER OF PROPERTIES INUNDATED
GREENDALE CREEK AND CURL CURL LAGOON

Flood Event % AEP	No. of Properties Flooded					
	Residential		Commercial/ Industrial		Public Buildings	
	A	D	A	D	A	D
20	8	2	20	10	1	0
10	16	3	24	13	2	0
2	56	9	29	24	2	0
1	74	23	35	24	2	0
PMF	153	104	49	40	3	2

Note: A - flood affected property (includes flooding in allotments and above floor flooding
D - flood damaged property (above floor flooding only)

Tables 2.7 and 2.8 show the damages experienced for each class of property. **Figures 2.8 and 2.9** show the relationship between flood damages and flood frequency on the two floodplains.

TABLE 2.7
FLOOD DAMAGES ON FLOODPLAIN OF DEE WHY CREEK AND LAGOON
$ x 10^3

Flood Event % AEP	Residential	Commercial/ Industrial	Public Buildings	Total
20	150	0	0	150
10	205	0	0	205
2	290	30	0	320
1	335	325	0	660
PMF	1,670	2,600	640	4,910

TABLE 2.8
FLOOD DAMAGES ON FLOODPLAIN OF GREENDALE CREEK AND CURL CURL LAGOON
$ x 10^3

Flood Event % AEP	Residential	Commercial/ Industrial	Public Buildings	Total
20	20	1,010	0	1,030
10	35	1,250	0	1,285
2	160	2,010	0	2,170
1	635	2,500	0	3,135
PMF	3,615	6,100	700	10,415

Damages on the Dee Why Lagoon catchment commence at the 20% AEP flood level when residences are inundated in the Tarra Crescent and Billarong Avenue area. Several properties are flood affected on the southern bank in the vicinity of Heron Place and Grafton Crescent, but the residences are not inundated. At the 1% AEP level, 17 residences are inundated in the above areas.

Several commercial properties located on the northern floodplain upstream of Pittwater Road and Campbell Parade are inundated at the 2% AEP level of flooding.

Damages on the Curl Curl Lagoon catchment commence at the 20% AEP level when 2 residences are inundated on the eastern side of Griffin Parade in Surf Road. Eleven commercial/industrial properties are inundated on the western side of Harbord Road and the Winbourne Industrial Estate area.

At the 2% AEP level of flooding, residences in the Holloway Place area are flooded. This area which includes the Bowling Club lies in a backwater of Curl Curl Lagoon and functions as a storage area. At the 1% AEP level, extensive flooding occurs in this area and additional commercial/industrial properties west of Harbord Road are also inundated. A total of 23 residential and 24 commercial/industrial properties are inundated on the Curl Curl Lagoon floodplain in the event of a 1% AEP flood.

At the 1% AEP level, considerable flood damages would be experienced on each floodplain. On the Dee Why Creek floodplain, total damages would amount to $660,000 equally divided between the residential and commercial/industrial categories.

On the Greendale Creek/Curl Curl Lagoon floodplain, the damages resulting from a 1% AEP flood would amount to $3,135,000 of which commercial/industrial would amount to $2,500,000 and residential $635,000.

Average annual damages for all floods up to the 1% AEP flood amount to $67,000 on Dee Why and $435,000 on Curl Curl Lagoon. Average annual damages represent the long term annual stream of damages resulting from flooding on the two catchments.

2.6 Flood Warning and Flood Preparedness

The Manly Warringah Pittwater Local Disaster Plan, March 2004 (DISPLAN) addresses all disasters, natural and man-made that may occur in the Manly, Warringah and Pittwater Council areas. The document covers planning, preparation, response and recovery aspects of dealing with disasters.

The DISPLAN does not have a specific focus on flooding although it does recognise that flooding is a general threat throughout the area. Floods are seen as having a high probability and major consequences.

The SES is nominated as the principal combat and response agency, however the DISPLAN does not contain the necessary storm/flooding Sub-Plan referred to in the document, as it is under review.

The DISPLAN clearly states the roles and responsibilities of all the agencies likely to be affected by or involved in the response to a disaster. For “Severe Storm” and “Flooding”, the three Councils are to:

- regulate property development and construction through LEPs and DCPs;
- provide and maintain appropriate drainage infrastructure; and
- implement Floodplain Management Plans.

At the same time, the SES is to prepare Storm and Tempest Sub-Plans and develop public education programs. The SES is responsible for the issuing of relevant warnings (in collaboration with the Bureau of Meteorology), as well as ensuring that the community is aware of the flood threat and how to mitigate its impact.

2.7 Existing Planning Instruments and Policies

Planning Instruments used by Warringah Council to manage development in the catchments draining to Dee Why and Curl Curl Lagoons comprise the following documents, which are reviewed in **Appendix C**:

- Warringah Local Environmental Plan 2000; and
- Warringah Design Guidelines, August 2001

A previous flood policy which was applied to both the Warringah and Pittwater LGA's, *"Interim Policy and Guidelines, 1990"* has been superseded by the August 2001 Guidelines. Flood related considerations for development are set out in Part C of the guidelines, dealing with General Principles of Development Control.

The guidelines as they relate to the development of flood affected land are quite short, being limited to two pages of discussion. The first page sets out three general principles for development:

- No reduction in flood storage or impact upon the existing flood regime.
- Habitable floor levels to be at least 500 mm above 1% AEP flood level.
- Building works affected by flooding are to be constructed of flood compatible materials.

The document then goes on to define the three hydraulic categories of flood liable land (floodways, flood storage and flood fringe) and briefly outlines the impacts of building in each zone. A list of flood compatible building materials is also presented.

The guidelines are embedded in a long list of other considerations for the control of development. They are also LGA wide guidelines and do not necessarily relate to the catchment specific issues in the Dee Why and Curl Curl Lagoon catchments.

They relate to residential categories of development, with no specific guidelines for development in industrial/commercial areas, or for essential services or SEPP 5 development.

In the Pittwater LGA, Council has proposed a local flood policy, Development Control Plan No. 30, entitled *"Pittwater Flood Risk Management",* December 2002.

That policy has adopted the 1% AEP flood with 500 mm of freeboard as the Flood Planning Level for residential and commercial development, with more stringent controls adopted for development in high hazard areas of the floodplain. A modified version of Pittwater Council's DCP 30 has been proposed as a Local Flood Policy for the Dee Why Curl Curl Lagoon study area.

A *draft Local Flood Policy* for the study area is attached as **Appendix D**. Features of the draft policy are as follows:

1) The *draft Local Flood Policy* relies upon the catchment specific flood data developed in the Flood Study (LACE, 2002).

2) The *Flood Policy* proposes the 1% AEP flood level plus 500 mm of freeboard as the Flood Planning Level for residential and commercial/industrial development. It proposes the Probable Maximum Flood level for essential services and SEPP 5 development.

3) The Flood Policy requires all future residential and commercial/industrial development which is located in the floodplain (i.e land inundated by the PMF) to comply with the Flood Planning Level requirements. This will ensure that no new properties located outside the extent of the 1% AEP flood have their floor levels set below the Flood Planning Level.

4) The *Flood Policy* discourages development in high hazard/floodway areas and sets out more stringent requirements for those areas, aimed at ensuring that the hydraulic conveyance capacity of the floodplain is not adversely affected by development.

5) The *Flood Policy* nominates the documentation required to be submitted with the Development Application. Procedures are aimed at maximising the use of existing flood data on the two catchments (LACE, 2002) and ensuring that developments in flood affected areas are evaluated in a cost effective manner, without imposing undue costs by way of privately commissioned flood study investigations.

2.8 Environmental and Ecological Considerations

The two main environmental issues are the management of the lagoon entrances and the related impact on upstream flood levels, and the rehabilitation of Dee Why Creek in the reach between Pittwater Road and Campbell avenue.

2.8.1 Entrance Management Considerations

As mentioned, both Dee Why and Curl Curl Lagoons are examples of Intermittently Closed and Open Lakes and Lagoons (ICOLLs). Many of the coastal estuaries of NSW fall into this category, where the coastal entrances to these estuaries experience a cyclical process of entrance infill and berm building due to wave action followed by breaching and entrance scour (Gordon, 1990).

The lagoon entrances are subject to a number of specific management issues as a result of their intermittent closure, such as:

- periodic flooding of low lying development or infrastructure, such as at the southern ends of Billarong Avenue on Dee Why Creek and Surf Road on Curl Curl Lagoon;
- water quality problems, algal blooms and odour.

The management of these issues presents a significant problem for Warringah Council where pressures from residents to interfere in the breaching process, particularly to reduce the perceived impacts of flooding, clash with the requirements of the lagoon ecosystems, which rely on extended periods of inundation to maintain biodiversity and overall aquatic health.

Hydraulic analyses have been undertaken to test the sensitivity of upstream flood levels to various berm heights at the lagoon entrances. The analyses have demonstrated that the water levels in the Dee Why Lagoon prior to the arrival of the flood wave from the catchment do not have a significant effect on peak flood levels. In the case of Curl Curl Lagoon medium flood levels would be slightly reduced by prior lowering of the level of the entrance berm, but there would be no significant reduction in levels for major flood events. The results are discussed in **Section 3.3.1** and details are presented in **Appendix E**.

2.8.2 Rehabilitation of Dee Why Creek

In the recent *Dee Why Lagoon Estuary Management Study*, it was proposed to rehabilitate Dee Why Creek in the reach between Campbell Parade and Pittwater Road. The proposal incorporates construction of a pool and riffle zone to replace the existing half-pipe concrete invert, in conjunction with an off line wetland. This reach of the creek includes the Billarong and Tarra Crescent areas on the northern floodplain, which are subject to inundation in the event of a minor 20% AEP flood, as well as flood prone developments on the southern floodplain in the Heron Place area.

It would be essential in any creek improvement scheme to ensure that flood impacts are not exacerbated.

Hydraulic analyses have been undertaken to test the impacts of the proposals on flood levels upstream of Pittwater Road. The analyses have shown that flood levels would be increased along Dee Why Creek if the proposal in the *Dee Why Lagoon Estuary Management Study* were to be implemented and that any wetland is too small in area to have a significant beneficial impact on water quality in the creek. An alternative creek rehabilitation scheme and wetland strategy is proposed. The results are discussed in **Section 3.3.3** and details are presented in **Appendix H**.

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3 POTENTIAL FLOODPLAIN MANAGEMENT MEASURES

3.1 Range of Available Measures

A variety of floodplain management measures can be implemented to reduce flood damages. **Figure 3.1** shows the classification of these measures into three categories: property modification, response modification and flood modification (AWRC, 1992).

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

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

Response modification refers to changing the response of flood affected communities to the flood risk by increasing flood awareness by the installation of flood warning systems and the development of emergency management plans for property evacuation. These options are wholly non-structural.

3.2 Respondent Views

Comments on potential flood management measures were sought mainly from the owners and occupiers of properties located on flood prone land by way of a Questionnaire. The responses are summarised in **Appendix A.** Question 12 in the Questionnaires for the two catchments outlined a range of potential measures. The responses are shown on **Table 3.1**, together with initial comments on the feasibility of the options, which are discussed in more detail in later sections of this chapter.

TABLE 3.1
RESPONSES TO QUESTIONNAIRE ON POTENTIAL FLOOD MANAGEMENT MEASURES

	Flood Management Option	Classification	Dee Why Lagoon		Curl Curl Lagoon		Comments
			Yes	No	Yes	No	
a)	Increase capacity of bridge crossings	FM	10	11	11	17	The bridge over Dee Why Creek at Pittwater Road acts as a constriction on flows and raises upstream flood levels (Tarra Crescent, Billarong Road). The option of increasing the bridge waterway to reduce upstream flood levels is reviewed in Section 3.3.2. This option is not relevant on the Greendale Creek/Curl Curl lagoon catchment.
b)	Increase creek capacity	FM	17	5	16	12	Increase in hydraulic capacity may be incorporated into proposals for rehabilitating Dee Why Creek downstream of Campbell Avenue, although any reduction in flood levels would be marginal. There are no opportunities on Greendale Creek for increases in hydraulic capacity.
c)	Maintenance programs to clear lagoon or creek of unnecessary vegetation	FM	28	0	29	1	Although strongly favoured by the respondents, the benefits of this option would be mainly environmental and would not result in reductions in flood levels along the two creek systems.
d)	Review/maintain existing flood mitigation works	FM	22	1	29	0	There are no existing flood mitigation works on the two creek systems. However, the implementation of structural flood mitigation works would clearly be favoured by the respondents.
e)	Construct upstream dams/basins to temporarily store floodwaters	FM	13	7	13	12	There are no opportunities for constructing detention basins on the two creek systems.
f)	Construct permanent levees	FM	7	12	9	13	Levees are not favoured by the respondents. However, for the sake of completeness, the feasibility of local levee schemes is reviewed in Section 3.3.4.
g)	Revise Lagoon Entrance Management	FM	21	1	21	3	This option is strongly favoured by the respondents. The sensitivity of lagoon entrance conditions to upstream flood levels was assessed by hydraulic modelling (Appendix E) and is discussed in Section 3.3.1.
h)	Voluntary property purchase scheme	PM	7	8	8	11	The respondents were evenly divided in their reaction to this option, which is often adopted to remove residential property in high hazard areas of the floodplain. This option is reviewed in Section 3.4.4.

TABLE 3.1
RESPONSES TO QUESTIONNAIRE ON POTENTIAL FLOOD MANAGEMENT MEASURES
(Continued)

i)	Provide funding or subsidies to raise houses above 1% AEP flood level	PM	4	12	11	13	This option is not favoured by the Dee Why Lagoon respondents, but the Curl Curl respondents has a neutral view. House raising is applicable to timber residences only, located in low hazard zones. This option is reviewed in Section 3.4.5.
j)	Flood proof individual properties	PM	3	12	10	12	Individual properties may be flood proofed by diversion banks (which may adversely affect flow patterns), water proofed doors and shutters across entrances. This option was not favoured by the Dee Why respondents. The Curl Curl respondents had a neutral view.
k)	Ensure controls on future development in flood-liable areas. (eg floor levels, etc)	PM	25	1	29	2	Controls over development in flood prone land are strongly supported by the respondents. This issue is covered in the *draft Local Flood Policy* in Section 3.4.3 and (Appendix D).
l)	Prohibit subdivision of properties within the floodplain	PM	22	4	24	5	This option would ensure that the existing flood risk is not increased by further development and is strongly supported by the respondents. This issue is covered in the *draft Local Flood Policy*.
m)	Prohibit rezoning for new development within floodplain	PM	23	3	27	5	This option is strongly favoured by the communities and would ensure that the existing flood risk is not increased by inappropriate land uses in flood prone areas.
n)	Improve flood warning	RM	24	0	27	0	There is presently no flood warning system for the two creek systems, where flooding is of a "flash flooding" nature, with sudden rises in water levels after the onset of heavy rainfall. Although such a system would be strongly favoured by the respondents it would not provide sufficient warning time for residents to take action.
o)	Improve evacuation and emergency assistance plans	RM	22	0	23	2	Emergency management in the study area is covered by the Manly Warringah Pittwater Local DISPLAN. Incorporation of specific evacuation procedures in the Storm and Tempest Sub-Plan would be strongly favoured by the respondents.

TABLE 3.1
RESPONSES TO QUESTIONNAIRE ON POTENTIAL FLOOD MANAGEMENT MEASURES
(Continued)

p)	Community education	RM	24	0	25	1	Promotion of awareness of the flood risk would be strongly favoured among the respondents. This option is reviewed below.
q)	Ensure all information about the potential risks of flooding is available to residents and business owners	RM	28	0	30	0	Dissemination of information on the nature of flood risk to property owners would be strongly favoured by the respondents. This option is reviewed below.
r)	Provide a certificate to all residents stating whether their property is flood affected and to what extent	RM	18	6	28	2	Provision of information on flood affection of properties would be favoured by the respondents. This could be achieved by appropriate notation on Section 149 Certificates. This option is reviewed below.
s)	Making sure residents and business owners have a Flood Action Plan	RM	20	1	23	4	Implementation of a formal Flood Action Plan for flood affected properties would be strongly favoured by the respondents. This option is applicable to commercial/industrial and apartment dwellings in flood affected areas.
t)	Install flood markers	RM	22	4	27	4	This option probably as part of an integrated flood awareness program combining options p) and q) above would be strongly favoured by the respondents.

Legend: FM = Flood Modification Option
PM = Property Modification Option
RM = Response Modification Option

3.3 Flood Modification Measures

3.3.1 Management of Lagoon Entrance Conditions

The responses to the Questionnaire showed that residents in the lower reaches of both catchments were strongly of the view that the elevation of the entrance berm had a considerable impact on flood levels. They considered that opening of the entrances prior to the occurrence of heavy rainfall was essential to mitigating upstream flooding.

The lagoons are typical of many coastal lagoons which are normally closed to the ocean as a result of the build up of a sand berm and then break out either naturally or due to human intervention. When the lagoons are closed, water levels are perched above ocean levels and when opened, drain to the ocean. Curl Curl Lagoon totally drains, exposing the bed.

Many of the entrance openings are not due to natural processes but are caused by people cutting a channel through the sand berm to start the water flowing out of the lagoon. The increased frequency of openings due to human intervention has a major impact on lagoon ecology by reducing the ability for fish and other organisms to establish in the lagoon. In addition, opening of the entrance may impact on the swimming water quality of the beach as the quality of the water discharging can be poor.

The lagoons are also occasionally opened mechanically as a flood mitigation procedure. During times of steady rainfall or when heavy rain occurs in the catchment in the preceding week, Council Officers monitor the water levels in the lagoon. The opening of the lagoon is achieved by using a bulldozer which excavates a pilot channel across the beach berm. The opening is timed to coincide with the receding ocean high tide to establish optimum hydraulic conditions for the opening flow.

Council has prepared Entrance Management Policies for each of the lagoons which recognise that there are a number of issues to be considered in addition to flood mitigation, including swimming water quality on the respective beaches after a lagoon opening has occurred and the impacts of openings, either by Council or unauthorised, on water quality and environmental conditions within the water bodies.

Dee Why Lagoon Entrance

The current practice is to open Dee Why Lagoon when the water level exceeds the obvert of the stormwater pipe draining into the channel at the end of Billarong Avenue. The elevation of the top of pipe is about RL 1.8 m. This elevation corresponds with the starting water surface elevation prior to the arrival of the flood wave on Dee Why Creek adopted in the flood study (LACE, 2002) and is about 1.4 m below the peak 20% AEP flood level in the Tarra Crescent/Billarong Avenue area (see **Table 3.2**).

**TABLE 3.2
DESIGN PEAK FLOOD LEVELS
DEE WHY LAGOON
(RL m AHD)**

Flood Event % AEP	Lagoon	u/s Pittwater Road Bridge
20	2.3	3.23
1	2.55	3.42

Source LACE, 2002

The water surface profile within the area of the lagoon is quite flat, consistent with the very low flow velocities within the waterway. However, there is a considerable increase in peak water levels across the bridge, indicative of the fact that the bridge imposes a constriction on the flow. As discussed later, the bridge constriction reduces the sensitivity of flood levels in this area to entrance conditions.

Curl Curl Lagoon Entrance

Curl Curl Lagoon is opened when the water level exceeds the obvert of the reinforced concrete pipe in the drainage pit at the end of Surf Road. The level of the pipe obvert is RL 2.08 m. As the pipe is not readily visible, the visual indicator adopted is when the lagoon water surface level reaches the underside of the cast iron grate over the pit, which corresponds to a level of RL 2.21 m.

The latter elevation is about 200 mm above the starting water surface elevation adopted in the flood study (LACE, 2002) and is about 700 mm below the 20% AEP flood level in the vicinity of the low lying property at the southern end of Surf Road (see **Table 3.3**).

There is a considerable flood slope within Curl Curl Lagoon due to the comparatively narrow extent of the waterway resulting in significant flow velocities. As discussed later, this feature reduces the sensitivity of flood levels to entrance conditions in this area.

**TABLE 3.3
DESIGN PEAK FLOOD LEVELS
CURL CURL LAGOON
(RL m AHD)**

Flood Event % AEP	Lagoon	Surf Road
20	2.59	2.92
1	2.81	3.33

Sensitivity of Upstream Flooding to Berm Levels

The impacts on upstream flood levels of varying the elevation of the entrance berms are evaluated in **Appendix E**. The hydraulic analysis demonstrated that flooding in the low lying residential sectors on Dee Why Creek is *not sensitive to variations in the berm level of Dee Why Lagoon*.

In the case of Curl Curl Lagoon, a minor reduction in peak water levels of around 200 mm could be achieved for a medium flood in the low lying Surf Road area by ensuring that the berm is no higher than RL 1.4 m prior to the occurrence of the flood. In Surf Road, there are several low lying properties which would be flooded in the event of minor (20% AEP) flooding with the berm at the RL 2.2 m level adopted for the Flood Study. Reducing the flood level by lowering the berm would be beneficial in this area.

Regardless of the hydraulic model results, however, residents on both lagoons are convinced that lowering the berm prior to the occurrence of a flood would have a beneficial impact and would support enforcement of such a policy, as outlined in the respective Entrance Management Policies.

Due to the "flash flooding" nature of the two catchments and the limited storage volumes contained in each lagoon, water levels in the potential damage centres respond quickly to heavy rainfall. A predictive flood warning model would have limited success in mitigating flooding. There would be insufficient time to interrogate mathematical models of the catchments and mobilise the forces necessary to effect an opening of the lagoons if the requirement for such action were "triggered" on the initiation of heavy rainfall over the catchment.

The approach outlined in the Entrance Management Policy, 1996 for initiating an opening, namely several days of prior rainfall resulting in a significant rise in lagoon levels, is appropriate, although there may be occasions when the lagoon is opened and the heavy rainfalls required to initiate flooding do not eventuate.

The reliability of the decision making process could be strengthened by linking the procedure to the prediction and monitoring of rainfall by the Bureau of Meteorology, which could be supplied on a customised website which could be set up by the BOM's Special Services Unit. The cost of such a service would be modest, amounting to an initial cost of around five to six thousand dollars and an annual cost of around three thousand dollars.

The BOM's Prediction and Monitoring service would comprise:

a) Daily monitoring of the weather situation by BOM and supply of information on the Customised Web page set up for Council.

b) Daily Forecast: The weather forecast is included on the Customised Web page and provides rainfall probabilities in the Sydney area for the next 4 days, including expected amounts, plus expert comment by a duty Meteorologist. The Web page also provides access to the latest rainfall, radar images and weather information.

c) In the event of expected rainfalls of significance in the vicinity of the Dee Why – Curl Curl catchments, the BOM would phone Council to advise. This advice would be forwarded when information becomes available to BOM of predicted heavy rainfall on the catchment.

It will in most cases provide a minimum of 3 hours warning time. However, a thunderstorm cell could develop within 30 minutes or directly over the catchment, in which case, warning times would be shorter.

d) During a flood emergency there would be telephone access to a BOM Meteorologist. This will allow Council to obtain a second opinion before initiating an opening.

e) In addition, Public Weather warnings would be directly faxed to Council after issue by BOM.

3.3.2 Enlargement of Bridge Opening on Dee Why Creek at Pittwater Road

The existing bridge over Dee Why Creek at Pittwater Road has a waterway opening 5 m wide by 1.9 m high. Hydraulic analyses undertaken in the flood study showed that there would be a difference in water elevations across the structure of 0.9 m in the event of a 20% AEP flood. The peak water level on the upstream side of the bridge would be RL 3.23 m for the 20% AEP flood, rising to RL 3.42 m for the 1% AEP event.

The bridge would be overtopped in the event of a 20% AEP flood. However, due to the small size of the catchment, the duration of interruption to traffic would be short, amounting to less than 1 hour for floods up to the 10% AEP magnitude and around 1.5 hours for the 1% AEP flood.

The low lying Tarra Crescent/Billarong Avenue area about 100 m upstream of the bridge is a centre of flood damages. Nine residential properties in this area would be flooded at the 20% AEP flood, with a maximum depth of inundation over floor level amounting to 0.45 m. In the event of a 1% AEP flood, 17 properties including several along Pittwater Road and in the Grafton Crescent area, would be inundated.

Widening the bridge openings would reduce the “afflux” caused by the structure and result in a reduction in peak water levels and consequent flood damages at Tarra Crescent/Billarong Avenue.

A 20 m wide structure would convey flows on Dee Why Creek up to the 2% AEP level without overtopping the road and would reduce upstream flood levels so that property inundation is eliminated for floods up to the 10% AEP magnitude.

Widening the opening to 40 m would allow the 1% AEP flood to be conveyed without overtopping Pittwater Road and would reduce upstream water levels so that properties are not flooded for events up to the 2% AEP.

A further increase in the waterway opening to 60 m would eliminate inundation in the Tarra Crescent/Billarong Avenue area for events up to the 1% AEP

Table 3.4 shows the results of an economic analysis of various bridge upgrading alternatives at the Pittwater Road crossing. Residential flood damages upstream of the crossing were converted into present worth values for three discount rates. The damages saved by reducing afflux represent the benefits of providing the width of bridge openings shown in column (3). The hydrologic design standards of the various bridge openings are shown in columns (1) and (2).

For example, in order to provide a 2% AEP design standard against overtopping Pittwater Road and at the same time prevent damages for floods up to the 10% AEP, it would be necessary to provide an opening 20 m wide, i.e. more than twice the existing width of opening, at an indicative cost of $1.4 million. The benefits of the scheme, as represented by the present worth value of flood damages saved, range between $0.56 million and $0.35 million depending on the discount rate adopted. For a best estimate discount rate of 7%, the benefit-cost ratio would be about 0.3.

For the purposes of this illustration, the simplifying assumption was made that the bridge would prevent damaging flooding for all flood events up to the design standard shown in column (2), but for larger events there would be no significant difference between pre- and post-bridge flood levels.

From site inspection, the maximum width of opening which could practically be provided is about 20 m. For the purpose of illustration the effects of larger openings have been shown in **Table 3.4**. These larger openings would require extensive excavations and training works on both the upstream and downstream sides of the road, and would impact on the playing fields and commercial development facing Pittwater Road. A 20 m wide opening would only provide a 10% AEP design standard for damage mitigation and cannot be justified economically. Consequently, upgrading the bridge for flood mitigation purposes is not likely to proceed.

Similarly the short duration of overtopping would not justify its upgrading on the grounds of disruption to traffic. Consequently, upgrading of the bridge is not likely to proceed for serviceability reasons.

TABLE 3.4
ECONOMIC ANALYSIS OF OPTIONS FOR UPGRADING BRIDGE OVER DEE WHY CREEK AT PITTWATER ROAD

Design Standard (Overtopping Roadway) % AEP	Design Standard (Upstream Flood Damages) % AEP	Required Width of Opening (m)	Indicative Cost $M	Benefits $M at Discount Rate Shown		
				4%	7%	10%
(1)	(2)	(3)	(4)	(5)	(6)	(7)
2	10	20	1.4	0.56	0.43	0.35
1	2	40	3.5	0.82	0.64	0.51
1	1	60	5.8	0.87	0.68	0.54

Notes: 1) The “Design Standard (Overtopping Roadway)” is the flood frequency at which overtopping commences.

2) The “Design Standard (Upstream Flood Damages)” is the flood frequency at which flood damages commence.

3) The assumed economic period of analysis is 20 years, in accordance with NSW Treasury Guidelines

3.3.3 Channel Works and Rehabilitation of Dee Why Creek

The hydraulic capacity of a stream may be increased by widening, deepening or straightening the channel and by clearing the banks of obstructions. The scope of such improvements can vary from minor works such as de-snagging and bank clearing, which do not increase the waterway area but reduce hydraulic roughness, to major channel excavations.

Careful attention to design is required to ensure stability of the channel is maintained and scour or sediment build up is minimised. A degree of sinuosity is often provided in the channel route for these and aesthetic reasons. The potential for channel improvements to increase downstream flood peaks also needs to be considered. In general, channel improvements need to be carried out over a substantial stream length to have any significant effect on flood levels.

In the recent *Dee Why Estuary Management Study (EMS)*, it was proposed to rehabilitate Dee Why Creek in the reach between Campbell Parade and Pittwater Road. The proposal, which was a development of a previous investigation by Panetta, 2000, involved the construction of a pool and riffle section of channel which would replace the existing half pipe concrete invert, in conjunction with an off-line wetland on the northern floodplain near the downstream section of this reach.

The proposal was not seen as fulfilling a flood mitigation role but was intended to improve the aesthetics of the existing channelised waterway, as well as providing water quality benefits. A key objective of the proposal was to ensure that any modification to the creek did not have an adverse impact on flooding, either by increasing flood levels or adversely re-directing flows.

Evaluation of the existing proposals, as well as the development of modifications which satisfy spatial, infrastructure and hydraulic constraints on the Dee Why Creek floodplain are discussed in more detail in **Appendix H**, which had the benefit of additional site surveys used in the Flood Study of the Dee Why Creek catchment prepared by LACE, 2002. The presence of existing sewer infrastructure and a wet weather overflow point into the creek system within the proposed wetland area were also found to have a significant adverse effect on the viability of the wetland project.

Further, there is insufficient land available at the site for construction of a wetland to result in significant water quality benefits. The area available for a wetland comprises about 0.36 ha, equivalent to only 0.13 per cent of the 2.6 km^2 Dee Why Creek catchment. In the *EMS*, an available area of 0.68 ha was suggested, but this is clearly an overestimate in view of the limitations on the available areal extent imposed by the sewer overflow. It would clearly not be advisable to bund the wetland so that it encloses the overflow, with the consequent impoundment of sewage after periods of heavy rainfall.

Hydraulic modelling of the wetland and riparian zone proposal was undertaken using the dynamic MIKE 11 model developed for the *Flood Study*. The results show that a project involving planting of the 20 m wide zone available along the line of the existing creek would have a significant adverse impact on flood levels and flow patterns along the reach which potentially extends upstream of Campbell Avenue. Flood levels would be increased over the range of flood magnitudes from a 20% AEP to a major 1% AEP flood.

As flooding of residential property in the Tarra Crescent/Billarong Avenue area would be experienced under present day conditions at the 20% AEP level, any increase in flood levels resulting from this project would increase the flood risk.

Consequently, it is recommended that the implementation, of the wetland and riparian zone not proceed in its currently proposed layout. Rehabilitation of this reach of the creek should be restricted to the replacement of the existing concrete pipe invert by a rock zone of roughly equivalent width and invert level, together with a narrow zone of low riparian plantings on each side, such that the overall conveyance capacity of the waterway is not reduced. A schematic layout is attached to **Appendix H** and an indicative budget cost of around $450,000 is included therein. Additional survey of the reach, including mapping the locations of significant trees to be retained, would be required to confirm the numbers and locations of the rock ramps and the degree of sinuousity that could be incorporated in the channel design.

In regard to the wetland proposal, it is to be noted that there are two existing remnant areas upstream of Campbell Avenue which have a sufficient surface area relative to the size of their upstream catchments to provide a beneficial effect on downstream water quality, if formalised into wetlands. These wetlands receive runoff from the Cromer Industrial Area. Further investigation would be required to confirm their suitability for incorporation in a wetland strategy, including an assessment of the flow paths through these areas and the potential impacts on adjacent developed areas.

However, as both of these measures are not seen as fulfilling a flood mitigation role they would be unlikely to attract funding from State and Commonwealth Government under the formers' Flood Mitigation Program. Hence, these two measures have not been included in the Floodplain Risk Management Plan for Dee Why Curl Curl Lagoons. Council is advised to seek funding through the State Government's Estuary Management Program.

Council has recently completed a staged program of channel and stream rehabilitation works for the reach of Greendale Creek downstream of Harbord Road to the lagoon proper. It is understood that the effect of the works was to reduce the frequency of inundation of the overbank areas of Greendale Creek by increasing the waterway area of the channel. (Note that the 2002 Flood Study for the lagoon incorporated survey which reflected the channel works program).

As this work has only recently been completed by Council, with vegetation along the stream banks now at a relatively mature stage in its development, there is considered to be limited opportunity/benefit in carrying out further works of a similar nature as part of a flood mitigation program.

3.3.4 Levees

Levees are an effective means of protecting flood affected properties up to the chosen design flood level. In designing a levee it is necessary to take account of potential redistribution of flood flows, the requirements for disposal of internal drainage from the protected area and the consequences of overtopping the levee in floods greater than the design event.

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

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

Reinforced concrete and concrete block walls are often used in situations where there is insufficient land available for earth banks. Such walls are provided with reinforced concrete footings of sufficient width to withstand overturning during flood events.
A major difficulty with levee schemes is the provision of facilities for the temporary storage and disposal of runoff derived from the local sub-catchments upstream of the protected area. In some situations, evacuation of runoff by pumping over the levee has been adopted where there is insufficient area available to store runoff for later disposal by gravity as the flood recedes.

Potential for Levees on Dee Why Creek Floodplain

The potential for protecting the residential development in the Billarong Avenue/Tarra Crescent area was examined. The present worth value of damages for flood events up to the 1% AEP magnitude in this area are quite significant, amounting to $0.55 million at a 7% discount rate. Consequently, development of a levee scheme with a 1% AEP hydrologic standard and costing up to $0.55 million could be justified on economic grounds.

However, the following technical factors militate against a levee scheme:

(1) There is a large local sub-catchment to the north which presently drains through this area en route to Dee Why Creek. Overland flows from this sub-catchment are conveyed with the prevailing grade along both Billarong Avenue and Tarra Crescent. It is not practicable to divert this runoff away from the area which would be protected by the levee. As there are no sites available for the temporary storage of surface runoff, water would pond behind the levee and would be unable to escape until floodwaters receded.

(2) There are no ridges of high ground available on the northern floodplain of Dee Why Creek to form the upstream and downstream limits of a levee scheme. The obvious route for a levee is along the grassed area between the creek and the boundaries of the allotments on the southern side of Tarra Crescent. Natural surface levels are in the range RL 3 to 3.5 m, compared with flood levels of RL 3.6 to 3.9 m in the Billarong Avenue area for the 1% AEP flood. However, unless the levee was constructed to the elevation of the PMF, there would always be the chance that it would be overtopped. On Dee Why Creek, flooding is of a “flash flooding” nature with a very short time of rise after the initiation of heavy rainfall. Consequently, sudden overtopping could take place with no time available for the evacuation of residents. These considerations would suggest that a flood greater than the 1% AEP event and possibly the PMF, should be adopted for design purposes.

(3) In the Billarong Avenue area, the PMF flood level is RL 4.35 m. A levee with a 500 mm freeboard would be around 1.5 to 1.8 m height and would detract from the amenity of the area. In the event of a flood of this magnitude, Pittwater Road would be surcharged by backwater influences from the lagoon and consequently the levee would need to be continued northwards, either by raising the road or continuing the levee as a block wall along the western side of the road.

From the above considerations, protection of the Tarra Crescent residential area by a levee is not considered technically feasible and has not been adopted for further consideration.

Potential for Levees on Greendale Creek/Curl Curl Lagoon

On Greendale Creek/Curl Curl Lagoon catchment, there are several flood liable residences at the southern end of Surf Road. In the event of a 20% AEP flood, the ground floors of two properties would be inundated to a maximum depth of 0.14 m. For the 1% AEP flood, four properties would be flooded to a maximum depth of 0.56 m.
Natural surface levels to the north of Surf Road rise quite steeply. There is a significant local catchment, runoff from which flows towards Surf Road in the event of intense rainfall and may flow across the allotments at the southern end of that street. Consequently, an area-wide scheme would not be feasible due to the likelihood of ponding behind the levee.

It may be practicable to protect one or more of the properties closer to the lagoon by low earth or block walls around the entrances. Such localised flood proofing measures would be of a private nature and outside the ambit of Council funded works discussed in this present study.

The other residential damage centre in the Curl Curl Lagoon catchment is situated on the southern floodplain in the Holloway Place area. Two low lying properties at the northern end of Holloway Place are flooded at the 2% AEP level. For the 1% AEP flood, there are 8 flooded residences in Holloway Place and two residences inundated in Manuela Place, which also runs northwards towards the creek and is located about 50 m to the west.

These residential areas are separated from the creek by Weldon Park which is located on filled ground considerably higher than natural surface levels at the ends of the streets. At the end of Manuela Place, the platform of Weldon Park is about 2 m above the street level.

The gully created between the park and the residences functions as a ponding area which is initially inundated by backwater flooding from Greendale Creek, which joins the gully near the Eastern Footbridge. For flood events up to the 2% AEP magnitude, the park is above the level of flooding in the creek adjacent to Holloway Place and Manuela Place. For larger flood events, the area would continue to function mainly as a flood storage area. However, some flow from Greendale Creek would enter the gully from upstream, due to overtopping of the creek bank via a low point located immediately downstream of Harbord Road. These flow paths and the extent of inundation are illustrated in **Figure 2.6**.

A levee protecting this area would be about 300 m long, extending from the eastern boundary of Freshwater High School to the western end of the Bowling Club. As for the situation on Dee Why Creek, however, there are several factors which would impact on the technical feasibility of a levee scheme.

1) At the end of Holloway Place, the natural surface level is RL 4.2 m and the peak flood levels are RL 5.7 m for the 1% AEP flood, increasing to RL 6.1 for the PMF. Allowing 500 mm freeboard, the height of a protective levee would range between 2 m and 2.4 m. Levees of these heights would occupy a large footprint if constructed of earth and would detract from the amenity of the area if constructed as a block wall.

2) The sub-catchment draining the area extends southwards beyond Wyadra Avenue and has a catchment area of 45 ha. It would not be economically feasible to divert the stormwater around the protected area and consequently it would be necessary to provide a facility for the temporary storage of up to 50,000 m^3 of runoff pending evacuation by gravity to the creek. It is not feasible to cater for such a large volume within the protected area.

From the above considerations, protection of the Holloway Place/Manuela Place residential area by a levee is not considered feasible and has not been adopted for further consideration.

3.3.5 Retarding Basins

Retarding basins provide additional flood storage which can reduce the flood peak in downstream reaches of the creek. Offline basins are preferred to maintain the continuity of the creek system.

Potential for Retarding Basins on Dee Why Creek Catchment

There is an existing wetland area upstream of the Time and Tide Hotel which could be adjusted to incorporate detention storage additional to the existing natural floodplain storage. However the wetland area controls only 0.75 km^2 of the total catchment area of 2.6 km^2 at Pittwater Road. There is a large urbanised catchment draining the southern portion of the catchment which joins the southern bank of Dee Why Creek opposite the Time and Tide Hotel. Runoff from this catchment would not be controlled by a retarding basin in the wetland and consequently, its impact on peak flows downstream of Campbell Avenue would be quite small.

Below Campbell Avenue, the creek traverses the open space area to Pittwater Road. There is a considerable volume of natural floodplain storage within this area which is mobilised during major flood events. However, there are no opportunities for adjusting natural surface levels to achieve greater storage volumes, in view of existing residential development on the southern bank in the Heron Place area and similar development further downstream in the Tarra Crescent area.

Potential for Retarding Basins on Curl Curl Lagoon Catchment

The major damage centres in the Curl Curl Lagoon catchment are situated in the Surf Road area and in the urban areas on the southern side of Weldon Park in Manuela Place, Holloway Place and Stirgess Avenue. There are no opportunities for the implementation of detention storage in these areas given the low lying nature of open space on which a basin could potentially be located.

On the western side of Harbord Road, considerable inundation would be experienced in the commercial and industrial areas. However, this area is completely built up and the original creek system has been piped and consequently, implementation of detention storage is not feasible.

From the above discussion, the provision of retarding basins in the two catchments is not considered feasible and this option has not been adopted for further consideration.

3.4 Property Modification Measures

3.4.1 Planning Controls and Flood Policy

NSW Flood Prone Lands Policy – The merit based approach to floodplain management in NSW was introduced in 1984 as an essential platform within the NSW Flood Prone Lands Policy. This approach, which is described in detail in the Floodplain Development Manual, 2005 involves consideration of local social, economic and environmental factors in selecting appropriate flood related planning controls rather than adopting a uniform state-wide standard.

Flood Planning Level – Selection of the Flood Planning Level (FPL) for an area is an important and fundamental decision as the standard is the reference point for the preparation of floodplain management plans. In effect it determines the area of land that should be subject to flood related development controls and building controls. The merit approach is inherent in the selection of the appropriate flood frequency. It involves balancing social, economic and ecological considerations against the consequences of flooding, with a view to minimising the potential for property damage and the risk to life and limb. If the adopted Flood Planning Level (FPL) is too low, new development in areas above the FPL (particularly where the difference in level is not great) may be inundated relatively frequently and damage to associated public services will be greater. Alternatively, adoption of an excessively high flood planning level will subject land that is rarely flooded to unwarranted controls.

All flood prone land needs to be considered and greater emphasis has been placed on defining the appropriate FPL standards to be applied to different land uses. This change reflects recognition that different land uses might warrant different levels of protection. For instance, a much higher level of flood protection would normally be warranted for essential services such as a hospital than, say, an industrial building. Current practice retains the merit based approach but focusses on defining appropriate planning flood levels for different land uses which reflect the needs of the local community.

Central to this approach is the recognition that there is a gradation of flood risk which decreases towards the boundary of the extent of the probable maximum flood (PMF). Within the boundary of this flood prone land, a range of different land uses are possible. For each land use, the social, economic and environmental factors need to be assessed separately and this may lead to different flood planning levels being adopted for different land uses.

The adoption of an FPL for any particular land use has wide implications, especially in planning matters. The adopted level will provide a basis for setting allowable floor levels for development. In addition, flood hazard zones will identify locations where different controls on future development may be applied. Therefore the selection of the FPL for different land uses should be given considerable attention and the 1% AEP flood should not just be adopted by default.

On the outer floodplain, there may be no formal controls and the residual flood risk will need to be managed by other means, principally by emergency management.

Council has a duty of care which requires it to take a responsible development decision in recognition of any potential hazard of which it should be aware. However, Council is indemnified in respect of floodplain management provided it follows the principles and procedures set down in the Floodplain Development Manual. By undertaking this Floodplain Management Study, giving due consideration to adopting planning flood levels and implementing a Floodplain Management Plan, Council will have taken steps to demonstrate due diligence.

Factors Influencing Flood Planning Levels – This section of the report sets out the factors that influence the selection of flood planning levels and recommends the appropriate standards for the Dee Why and Curl Curl Lagoon floodplains. The selection of appropriate flood levels for different land uses is a decision which must be made with a view to the long term future. The decision to set a particular level as the basis for control of development and building on the floodplain will only take effect as new buildings and developments are proposed or as existing buildings are redeveloped.

Whilst it is often difficult for a community to envisage a radical change from the current pattern of development within the area, it is necessary to look to the long term future in order to develop policies which will reduce the impact of floods on the community. The key to sensible floodplain management is to balance the need to reduce the impact of flooding against the social, economic and environmental factors of importance to the community.

While considering appropriate flood planning levels for adoption, it must be recognised that the associated controls will only apply to new developments, redevelopment or extensions to existing properties. The adopted controls must, therefore look to the future and must set appropriate standards for the long term development of the area. Adoption of a particular Flood Planning Level will have no effect on the existing building stock, and will only take effect as the current stock is redeveloped or upgraded.

3.4.2 Considerations for Setting Flood Planning Level

The key factors in selecting appropriate flood planning levels are:

- Topography
- Current Council policies
- Flood history and community perception
- Flood frequency-damages relationship
- Future development/available land
- Economic, environmental and social impact
- Implications of a flood greater than the planning level flood
- Flood warning, evacuation, response issues

In the Dee Why and Curl Curl Lagoon floodplains, there are a number of land use classes which need to be considered in terms of setting appropriate planning flood levels:

- Residential
- Commercial and industrial
- Essential services and uses which require special consideration, such as schools, hospitals, retirement homes and the like.

Table G.1 in **Appendix G** summarises the main issues which need to be taken into account in determining FPLs for planning controls for each of the land use classes. Consideration of the data set out in **Table G.1** supports retaining the 1% AEP flood as the basis for setting the FPL for residential, commercial and industrial development in the floodplain and for adoption of a higher FPL for essential services and retirement homes.

3.4.3 Building and Development Controls

Building and development controls involve the imposition of measures aimed at flood proofing developments in flood affected areas. These could include specifications of:

- Minimum floor levels for habitable floors (including appropriate freeboard provision);
- Localised flood mitigation works including land fills, levee banks and flood walls;
- Appropriate construction methods and building materials
- Egress routes from buildings.
- Provision of underfloor areas for the passage of floodwaters.

New buildings, or additions to existing buildings would be subjected to these building controls with the long term objective of having all buildings in the area ultimately flood proofed. Controls need to be imposed on a merit basis, balancing restrictive development conditions with the impact of development on flood behaviour in the floodplain.

For the Low Hazard flood prone areas in the catchments the setting of floor levels will, over time, reduce flood damages. In the Low Hazard areas the occurrence of above floor flooding is generally infrequent and the depth of flooding above floor level in a 1% AEP flood is less than in the High Hazard areas. Floor level provisions for new buildings are appropriate in these areas.

For the High Hazard areas identified in this study, floor levels clearly need to be set for any new buildings. This may not be sufficient where flood mitigation works are not proposed as, regardless of the house floor levels, the land use may not be compatible with the frequency, depth and velocity of flooding. Features of the proposed *Local Flood Policy* set out in preliminary draft form in **Appendix D** are:

(1) The proposed Flood Planning Level (FPL), which is defined as the minimum floor level for new residential, commercial and industrial development in the catchments, is based on the 1% AEP flood level plus an allowance of 500 mm for freeboard and applies for new development in the floodplain (i.e land inundated by the PMF).. For special uses and essential services, the proposed Flood Planning Level is based on the Probable Maximum Flood Level plus an allowance of 300 mm for freeboard.

(2) There is the requirement for no net displacement of flood storage resulting from proposed developments, regardless of their location in the flood affected area and in addition, no loss of floodway area in High Hazard areas. The boundary between the High Hazard and Low Hazard areas generally conforms with the extent of the 1% AEP floodway, except in the deeper areas of Dee Why Lagoon which mainly functions as a flood storage. Accordingly, the terms *"High Hazard"* and *"floodway"* are synonymous. That is, in these two catchments, floodways are High Hazard areas and within that zone, developments should not impact on the waterway cross sectional area available for the conveyance of flow (i.e. the floodway area). A preference is identified for suspended floors, allowing the flow of water and maintenance of flood storage in preference to compensatory excavation within the property to meet the requirements of the policy.

(3) In the case of car park areas, there is the requirement that all openings to basement car parks should be above the FPL in recognition of the "flash flooding" nature of the catchments and the hazardous nature of these facilities should their entrances be

surcharged. In the case of open car parks, a maximum permissible depth of inundation of 200 mm is nominated at the 1% AEP level of flooding. The draft policy does not permit car parks on High Hazard land.

(4) The draft policy does not permit subdivision in high hazard areas or where additional flood affected residential allotments will be created. This is in recognition of the NSW Government's Flood Policy to reduce the impacts of flooding over time.

(5) In regard to information to be submitted with the Development Application, the draft policy aims to balance the applicant's costs of preparing the submission with the flood risk. The information contained in the Floodplain Risk Management Study and Plan will provide Council with data on flood levels, extent of flooding and delineation of high and low hazards. Use of this data will allow applicants to categorise their site and identify flood constraints. In Low Hazard areas it is a relatively simple task to prepare the documentation, which requires presentation of the flood information on the site survey and demonstrated conformance with the requirements for no net displacement of flood storage and minimising inundation of car park areas. More detailed studies would only be required for developments in High Hazard areas and/or in situations where the applicant opts to seek independent advice on the Flood Planning Level and Hazard Classification. Experience with other floodplain management studies indicates that applicants sometimes challenge Council's flood information and that therefore, a procedure for dealing with this situation would be advisable.

3.4.4 Voluntary Purchase

This flood management measure involves the purchase of properties by Council for subsequent rezoning for more appropriate land use. These properties which are usually located in high hazard zones would be purchased at an equitable price and only where voluntarily offered.

There are no flood affected properties located in high hazard areas on the floodplain of the Dee Why study area. Consequently, if high hazard conditions are adopted as the governing criterion for this measure, then a voluntary purchase option would not be relevant.

On Dee Why Creek, the Tarra Crescent area is the principal damage centre. As discussed previously, significant flood damages are incurred at the 20% AEP level.

The present worth value of residential flood damages in the area is about $0.55 million at a 7% discount rate. The properties in the Tarra Crescent/Billarong Avenue area are two storey brick residences on attractively landscaped blocks, some with swimming pools and with ready access to the lagoon and beach. The purchase price of one property alone would more than match the total value of residential flood damages in the area. As the value of damages saved would equate to the benefits of the scheme, it is clear that a voluntary purchase scheme in the Dee Why study area would not be justified on economic grounds.

Although the area is subject to "flash flooding" with little warning time, flooding in the street system is relatively shallow and there is ready access to high ground. Consequently, there is little risk to life and limb resulting from continuing occupancy of the floodplain in this area. Accordingly, a voluntary purchase scheme could not be justified on social grounds.

A similar situation would occur in the two residential damage centres in the Curl Curl Lagoon catchment: Surf Road and the Holloway-Manuela Place-Stirgess Avenue areas. As discussed previously, the Surf Road area is subject to shallow flooding which commences at the 20% AEP level and at the 1% AEP level, 4 properties would be flooded to a maximum above floor depth of 0.56 m.

In the Holloway-Manuela Place Stirgess Avenue area, damaging flooding is initiated at around the 2% AEP level.

The two above areas are situated on the fringe of high hazard zones with ready access to high ground. Along Stirgess Avenue, ground levels fall relatively steeply towards the northern boundary of the properties and it is unclear whether the footprints of the residential homes fall within the high hazard zone. More detailed ground survey in the Stirgess Avenue properties would be needed to determine the actual extent of the high hazard zone in this area.

Of the 77 flood affected properties in the Curl Curl study area, there are 45 well established two storey properties of brick veneer type construction. The remaining 32 flood affected properties are of weatherboard or fibre type construction, 7 of which are located on the fringe of the high hazard zone near Stirgess Avenue. Again, given the value of property in this area, a voluntary purchase scheme could not be justified on economic grounds.

3.4.5 Flood Proofing by House Raising

This term refers to procedures undertaken, usually on a property by property basis, to protect structures from damage by floodwaters. The most common process is to raise the affected house so that the floor level is above (usually 0.5 m above) the FPL. For weatherboard and similar buildings this can be achieved by jacking up the house, constructing new supports, stairways and balconies and reconnecting services. Alternatively, where the house contains high ceilings, floor levels can be raised within rooms without actually raising the house. It is usually not practical to raise brick or masonry houses.

The State and Federal Governments have agreed that flood mitigation funds will be available for house raising, subject to the same economic evaluation and subsidy arrangements that apply to other structural and non-structural flood mitigation measures. State Government subsidy of $10,000 is available for house raising to owners of homes where habitable floors are just below the flood planning level. Such properties would not normally qualify for a house raising scheme on economic grounds.

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

- House raising should be part of an adopted Floodplain Management Plan
- The scheme should be administered by the local authority.

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

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

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

House raising is only appropriate for timber framed buildings and is usually implemented in low hazard areas, the cost of which is estimated at around $40,000 per property.

Of the 73 flood affected residences in the Dee Why Study Area at the 1% AEP flood level, only one residence is of fibro or weatherboard type construction. There are no damages incurred at the 1% AEP flood level, which is around 360 mm below the floor level of the residence. At an estimated cost of $40,000, the raising of this residence cannot be justified on economic grounds.

Of the 77 flood affected residence in the Curl Curl Study Area, only 9 are of fibro or weatherboard type construction. Of these, only two experience above floor inundation at the 1% AEP flood level. The present worth of damages saved by raising these two residences above the FPL is about $28,500 at a 7% discount rate. At an estimated cost of $80,000, the raising of these two residences cannot be justified on economic grounds.

This strategy is not feasible for the study area and has not been considered further.

3.5 Flood Response Modification Measures

3.5.1 Flood Forecasting, Warning and Evacuation Planning

Flood forecasting and warning can be an effective flood management measure if there is sufficient warning time for the community to react to the warning. An effective flood warning system has three key components, i.e. a flood forecasting system, a flood warning broadcast system and an evacuation plan.

A system has been implemented (Lagoonwatch) which monitors the Narrabeen Lagoon and entrance behaviour and is also capable of predicting flood behaviour in real time during intense storm conditions. It forms the first stage of the flood warning system for the Narrabeen Lagoon catchment.
The Lagoonwatch System is operated from Council's offices and can be accessed remotely outside office hours. It may be accessed on the internet by Council, SES, police and other emergency agencies responsible for dissemination of information and evacuation, using a personal computer and modem.

The Narrabeen Lagoonwatch System was commissioned as part of the Narrabeen Lagoon Floodplain Management Plan and comprises the following components:

1) Real time acquisition of environmental conditions for the previous 72 hours so that the current state of the catchment can be monitored. Data acquired include recorded catchment rainfalls, lagoon levels and offshore wave conditions.

2) Alarm facilities. Options are available which can awaken the Lagoonwatch System and issue synthesised voice messages to pre-determined personnel when monitored thresholds of environmental conditions are exceeded. Once alerted, Lagoonwatch can automatically commence facsimile transmissions of real time data and model results to pre-determined destinations at any required intervals.

3) Flood Level Prediction. Using recorded catchment rainfall a hydrologic model of the catchment is used to predict inflows to the lagoon arising from rainfall runoff. Predicted inflows from the creek system are added to the lagoon storage to predict changes in lagoon levels caused by rainfall. By adopting an entrance condition which is determined from an analysis of recorded data, the model is used to predict future lagoon levels for each of three possible scenarios of environmental conditions as follows:

   - Abating conditions: assumes no more rainfall and abating ocean conditions
   - Persisting conditions: assumes the average rainfall experienced for the previous three hours continues for the next three hours and recorded ocean conditions persist for the next 10 hours.
   - Extreme conditions: assumes 2% AEP rainfall for the next three hours and elevated ocean conditions for the next 10 hours.

Flood response to rainfall on the Dee Why and Curl Curl Lagoons is relatively short and is expected to be between around 30 minutes to 1 hour on both catchments (i.e. from the occurrence of the peak rainfall to the occurrence of the peak discharge in the catchment).

A flood warning system with such a short warning time is not likely to provide sufficient notice for the delivery of the warning to allow residents to evacuate valuable items prior to the arrival of the flood peak.

Consequently, implementation of a Lagoonwatch style flood forecasting system for the Dee Why and Curl Curl Lagoon catchments would not be effective in reducing the flood risk.

Response to flood warnings by SES and police follow procedures set out in the Manly Warringah Pittwater Local DISPLAN.

The Manly Warringah Pittwater DISPLAN was prepared by the Manly Warringah Pittwater Local Emergency Management Committee in accordance with the State Emergency Management Act. The plan aims to ensure co-ordinated and efficient management of the prevention, preparation of response and recovery arrangements for emergencies within the Manly, Warringah and Pittwater Local Government areas.

The Manly Warringah Pittwater Local Emergency Management Committee should review and update their procedures based on the information contained in this study. The latest information on design flood levels, extent of inundation and affected houses should be incorporated in their emergency management procedures.

3.5.2 Public Awareness

Community awareness and appreciation of the existing flood hazards in the floodplain would promote proper land use and development in flood affected areas. A well informed community would be more receptive to requirements for flood proofing of buildings and general building and development controls imposed by Council.

One aspect of a community's preparedness for flooding is the "flood awareness" of individuals. This includes awareness of the flood threat in their area and how to protect themselves against it. It is fair to assume that the level of awareness drops as individuals' memories of previous experience dim with time.

Means by which community awareness of flood risks can be maintained or may be increased include:

1. Permanent marks in the area showing the levels reached by previous floods (eg. the 1998 flood).
2. Teaching about floods in schools.
3. Sending out regular information with rates notices. The information contained in the flood information brochure prepared during the course of this present investigation could be edited and used for this purpose. Information on measures to improve water quality should be included.
4. Displays at Council offices using the information contained in the brochure.
5. Educational videos and photographs of historic flooding in the area.
6. Talks by SES officers with participation by Council and longstanding residents with first hand experience of flooding in the area.

Preparedness campaigns will need to be designed by professionals skilled in motivation on public health and safety issues. Their 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:

- What steps to take in advance.
- Developing procedures for lifting and evacuating property.

The benefits of a regular flood-preparedness campaign would extend to more than just reducing monetary losses. The campaign would also have social benefits by improving people's feeling of control, since they would have a better idea of how to respond to a flood emergency.
However, given the lack of significant flooding in the area in recent years, it may be difficult to generate the interest and co-operation required. These difficulties will need to be considered in planning any public awareness exercise.

3.6 Summary

This chapter has reviewed a number of potential floodplain management measures which are summarised on **Table 3.5**. Planning controls separately or in combination with the other measures are an essential component of floodplain management.

The response modification measures evaluated, which comprised planning controls and a flood awareness programme, are more justified than flood modification measures, which are in the main, not technically feasible on these two catchments.

A draft local flood policy has been developed in **Appendix D** aimed at ensuring that future development in the floodplain is compatible with the flood risk. For the purposes of administering this interim policy, the 1% AEP flood has been adopted, with 500 mm of freeboard adopted for the purposes of setting floor levels for residential and commercial/industrial development in the floodplain (i.e. land inundated by the PMF). This draft policy document is based on floodplain management policies set out in the NSW Government's *Floodplain Development Manual, 2005*.

TABLE 3.5
REVIEW OF POTENTIAL FLOOD MANAGEMENT MEASURES

Scheme	Comments
Levees	Not technically feasible on either Dee Why or Curl Curl Lagoon catchments.
Channel Improvements	There are no opportunities for significant channel improvement in the Curl Curl or Dee Why Lagoon catchments. Rehabilitation of Dee Why Creek between Campbell Avenue and Pittwater Road will not improve hydraulic capacity in this reach.
Enlargement of Bridge Waterways	Enlargement of the width of the existing bridge over Pittwater Road on Dee Why Creek to a maximum of 20 m is technically viable, but would not eliminate upstream flooding for events greater than 10% AEP and could not be justified on economic grounds. There are no opportunities for enlarging bridge openings on the Curl Curl Lagoon catchment.
Detention Basins	Not technically feasible on either Dee Why or Curl Curl Lagoon catchments.
Voluntary Purchase	Not economically viable or justifiable on social grounds on either Dee Why or Curl Curl Lagoon catchments.
House Raising	Not technically viable on either Dee Why or Curl Curl Lagoon catchments.
Planning Controls and Implementation of Local Flood Policy	This is a low cost and essential component of the Floodplain Management Plan and will over time reduce damages. Draft Local Flood Policy developed in **Appendix D** recommends 1% AEP plus 500 mm allowance for freeboard as Flood Planning Level for residential and commercial development and PMF for essential services, SEPP 5 development.
Flood Warning and Forecasting	Formal flood forecasting system not technically feasible due to "flash flooding" nature of catchment. However, SES and other emergency management authorities should use the flood information contained in this Study to update their procedures for flood response and evacuation.
Flood Awareness	Development of flood awareness campaign by Council is supported.

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4 SELECTION OF FLOODPLAIN MANAGEMENT MEASURES

4.1 Background

The Floodplain Development Manual requires a Council to develop a Floodplain Management Plan based on balancing the merits of social, economic and economic considerations which are relevant to the community. This chapter sets out a range of factors which need to be taken into consideration when selecting the mix of works and measures that should be included in the overall Floodplain Management Plan.

The community will have different priorities and, therefore, each needs to establish its own set of considerations used to assess the merits of different options. The considerations adopted by a community must, however, recognise the State Government requirements for floodplain management as set out in the Floodplain Development Manual and other relevant policies. A further consideration is that some elements of the Plan may be eligible for subsidy from State and Federal Government sources and the requirements for such funding must, therefore, be taken into account. Typically, State and Federal Government funding is given on the basis of merit as judged by a range of criteria:

- Degree of flood hazard and number of properties affected.
- Damage caused by flooding and the benefit/cost ratio of proposals.
- The importance given to strategic planning in the overall Plan.
- Compatibility of proposals with TCM and other government policies.
- Community involvement in Plan preparation.
- Availability of local funding for proposed works.

The issues which need to be considered in developing a Floodplain Management Plan typically fall under the following broad headings:

- Community Expectations and Social Impacts
- Natural Resource Management and Environmental Impact
- Economic and Financial Feasibility
- Technical Merit

The next section of this chapter presents a review of a range of considerations under the four headings listed above. An analysis is then presented which assesses the performance of the available options against the factors to be considered.

4.2 Community Expectations and Social Impacts

This heading encompasses all those issues which are not directly economic or environmental in character, such as:

- ➢ Community acceptance and expectations
- ➢ Public safety and welfare
- ➢ Compatibility with planning of objectives
- ➢ Administrative and political issues

4.2.1 Community Acceptance

Flood related works and measures can have a range of effects on the community and individuals. These effects, if strongly negative, are often enough to deter the implementation of a proposal which might otherwise have significant merit. The issues impacting upon acceptance of a proposed measure are likely to include:

- Potential for individual financial loss/gain
- Disruption to daily life during and after floods
- Perception of fair play
- Public safety and welfare

In the Dee Why and Curl Curl Lagoon floodplains, the respondents strongly supported property modification options such as controls on future development in flood liable areas and response modification options which would include community education and ensuring that all information about the potential risks of flooding is available to residents and building owners.

It is interesting to note that provision of a certificate to all residents stating whether their property is flood affected and to what extent was strongly supported in the Curl Curl Lagoon study area and to a lesser extent in the Dee Why Lagoon study area. This response would seem to indicate support for the provision of flood information on Section 149 Certificates. As a result of the recently completed flood study for the two catchments (LACE, 2002) and this present study, Council would be in a position to include such data.

4.2.2 Planning Objectives

Warringah Council has developed a set of planning policies for future development which reflects the long term goals of the community. These policies are embodied in the *Local Environmental Plan, 2000*. Planning controls will be a key element of the Floodplain Management Plan for the catchment. The draft Local Flood Policy presented in **Appendix D** is consistent with the *Floodplain Development Manual, 2005* and current government thinking.

Proposals for other works and measures to be included in the Floodplain Management Plan must be assessed for consistency with Council's overall planning policy relating to floodplain management.

4.2.3 Administrative/Political Issues

Effective floodplain management involves the co-ordinated action of the community, Council and State Government agencies. Clearly, any recommendation contained in the Floodplain Management Plan will have more chance of success if it fits within current administrative structures and allocation of responsibilities. On the other hand, should an alteration to the administrative system be clearly beneficial to the Plan, it should be so stated and the implications accepted.

The majority of the parties with responsibilities for floodplain management and emergency response in the event of a flood are represented on the Floodplain Management Committee and have been consulted in the course of this study. None of the options presented in **Chapter 3** involves any radical changes to the existing administrative structures and responsibilities.

4.3 Natural Resource Management and Environmental Impact

4.3.1 Total Catchment Management

Total Catchment Management (TCM) involves the co-ordinated and sustainable use and management of land, water, vegetation and other natural resources on a catchment basis. It allows for a co-operative forum where decisions may be made at both the community and government level. This is typically achieved through a Catchment Management Committee (in the present case Dee Why Curl Curl Lagoons Joint Estuary Floodplain Management Committee) which consists of both community and government representatives.

Aspects of a Floodplain Management Plan which could have implications for TCM include any proposals for flood mitigation storage basins, major levees or large scale channel modification works. As outlined in Chapter 3, such works are not technically viable and are therefore unlikely to be an issue, although rehabilitation of Dee Why Creek between Campbell Avenue and Pittwater Road, although not strictly speaking a flood mitigation option is technically feasible. Any rehabilitation activities undertaken to manage riparian vegetation in a way which maintains hydraulic capacity would be consistent with TCM objectives, provided they were planned with consideration to at least maintaining and preferably enhancing habitat values as well.

4.3.2 Other Relevant Government Policies

The NSW Government has developed a number of policies which are of direct relevance to floodplain management. The first of these are the policies enshrined in the Floodplain Development Manual which forms the basis for the formulation of Floodplain Management Plans. The second is the State Rivers and Estuaries Policies (NSW Water Resources Council, 1993) which is the umbrella policy for subsidiary policies including the Wetlands Policy; the Stream Management Policy; and the Riparian Zone Policy. The policy suggests that the overall objective should be to manage the estuarine and riparian zones of NSW in ways which:

- Slow, halt or reverse the overall rate of degradation.
- Ensure the long term sustainability of essential biophysical functions
- Maintain the beneficial use of these resources

For the purposes of floodplain management, these zones may be taken as the area above the tidal and low flow level to the inner edge of the floodplain. In practice, the riparian zone merges into the floodplain and any management policies or actions should not stop at artificially defined boundaries. Any activities to manage these zones within the study area would be consistent with this policy by improving:

- Stream stability
- Ecology and habitat
- Buffer strip functioning
- Scenic amenity
- Recreational amenity

4.3.3 Environmental Impact

Few floodplain management measures could be considered seriously if the impact on the environment were extremely adverse. On the other hand, there are also opportunities for environmental enhancement in association with floodplain management works or measures.

4.4 Economic and Financial Feasibility

4.4.1 Economic Feasibility

There is a range of procedures available to judge the economic worth of making an investment in floodplain management works and measures. The most common is the benefit/cost ratio (B/C) which has been used in this study. On a purely theoretical basis, no investment should be made in a measure if the benefits do not exceed the costs. However, many public projects are undertaken where this is not the case because the intangible benefits, which are not able to be quantified, are considered important.

The benefits of floodplain management measures are largely the savings in damages to existing properties or developments and the savings in damages achieved by preventing flood sensitive developments occurring in the future. The costs are primarily the capital and operating costs of flood modification works and of non structural (property modification or response modification) measures. Not all of the measures applicable to the study area lend themselves to meaningful B/C analysis.

The data presented in **Chapter 3** shows that:

- None of the flood modification measures are economically justified, that is, has a benefit/cost ratio greater than one. At a 7% discount rate, the benefit/cost ratio for enlarging the bridge waterway on Dee Why Creek at the Pittwater Road crossing from its present width of 5 m to a width of 20 m is about 0.3. This scheme would give only a 10% AEP level of protection against the incidence of damaging flooding in upstream urban areas and a 2% AEP level of protection against overtopping of the roadway. Wider bridges with larger waterway openings, aimed at providing a higher flood standard would not be viable on environmental and technical grounds.
- Other flood modification measures examined which included retarding basins and levee schemes are not technically viable.

Other measures which were considered included voluntary purchase schemes, house raising schemes, and other response modification (non-structural) methods such as flood preparedness, flood awareness and planning measures. Of these, only the response modification measures are considered justified.

4.4.2 Financial Feasibility

Measures proposed for the Floodplain Risk Management Plan must be capable of being funded over the proposed period of implementation. The sources of funding are traditionally:

- Council
- NSW Government
- Commonwealth Government

In the past, contributions from these three sources were such that, where the costs were attributable to approved floodplain management activities, Council would bear one-third of the overall cost with the balance being equally shared by NSW and Commonwealth Governments. However, the Commonwealth Government has indicated its intention to withdraw from funding flood mitigation projects. Therefore, the historic levels of Government contribution cannot be guaranteed.

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

Any State Government contribution is limited by the allocation to flood mitigation programs on an annual basis. The commencement/completion of flood mitigation projects would depend on the availability of Council's funds and/or limited Government funding. Flood mitigation projects can take anywhere from 5 to 15 years to complete because of funding considerations. Since Council has many demands for drainage/road works, the financial feasibility is likely to be a significant constraint to the rate at which works can be undertaken.

4.5 Technical Merit

4.5.1 Engineering Feasibility

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

4.5.2 Performance in Exceedance Floods

Any proposed floodplain management measures must be assessed assuming that at some future time they will be exposed to floods which exceed the FPL. It is imperative that, should an extreme flood occur, the works and measures under consideration do not expose the community to unacceptable risks far beyond those experienced without the work or measure.

A key consideration for extreme floods must be the provision of escape routes which allow for evacuation as a flood develops. The most important requirement for this is that islands surrounded by deeper floodwater should be avoided.

4.6 Ranking of Options

The considerations discussed above must be assessed in terms of their relative importance to the community as well as the likelihood of attracting government subsidy. Although multi-objective assessment methods are now well accepted by government for selecting from a range of options, the decision to provide State funds is still linked closely to economic and financial factors. The

Floodplain Management Committee and the community, however, have expectations which give more weight to social, environmental and planning issues.

A suggested approach to assessing the merits of various options is to use a subjective scoring system. The chief merits of such a system are that it allows comparisons to be made between alternatives using a common "currency". In addition it makes the assessment of alternatives "transparent" (i.e. all important factors are included in the analysis). The system does not, however, provide an absolute "right" answer as to what should be included in the plan and what should be left out. Rather, it provides a method by which the Council can re-examine its options and if necessary, debate the relative scoring given to aspects of the plan.

Each option is given a score according to how well the option meets the considerations discussed in **Section 4.2 – 4.5**. In order to keep the scoring simple the following system is proposed:

+2	Option rates very highly
+1	Option rates well
0	Option is neutral
-1	Option rates poorly
-2	Option rates very poorly

The scores are added to get a total for each option.

Based on considerations outlined in this chapter, **Table 4.1** presents a scoring matrix for the options reviewed in **Chapter 3**.

Implicit in the construction of the matrix is the a priori decision that no options which rates less than zero in terms of reduction in flood risk would be included in the assessment. This eliminates the likelihood of a project which has a negative impact on flooding, but scores well on other criteria, being selected in the Floodplain Management Plan.

This scoring has been used as the basis for prioritising the components of the draft Floodplain Management Plan. It must be emphasised however, that the scoring shown in **Table 4.1** is not "absolute" and ***Council should carefully review the proposed scoring and weighting as part of the process of finalising the overall Floodplain Management Plan***.

4.7 Summary

Table 4.1 indicates that there are good reasons to consider including the following elements into the Floodplain Management Plan:

- Planning Controls.
- Flood Awareness.
- Incorporation of the Catchment Specific information on flooding impacts contained in this Study in Emergency Management Procedures for the study area.

Property modification measures such as voluntary purchase or house raising schemes are not viable.

Flood modification measures such as levees, flood walls, retarding basins and channel improvements are technically infeasible.

Rehabilitation of Dee Why Creek to incorporate a more natural channel, whilst not a flood management measure, would be supported by the community on environmental grounds. However, careful attention in the design would be required to ensure that the works do not adversely affect flooding patterns.

Incorporation of a wetland at the downstream end of the creek rehabilitation project is not considered feasible for the reasons stated previously in **Section 3.2.3**. Investigation to assess the potential for achieving improvements in water quality from works in the existing wetland upstream of Campbell Parade are worthy of consideration.

However, as both of these measures are not seen as fulfilling a flood mitigation role they would be unlikely to attract funding from State and Commonwealth Government under the formers' Flood Mitigation Program. Hence, these two measures have not been included in the Floodplain Risk Management Plan for Dee Why Curl Curl Lagoons. Council is advised to seek funding through the State Government's Estuary Management Program.

TABLE 4.1
Floodplain Management Options Assessment

Option	Impact on Flooding/ Reduction in Flood Risk	Community Acceptance	Planning Objectives	Environ. Impacts	Economic Justification	Financial Feasibility	Extreme Flood	Government Policies	TCM Objectives	Administrative Arrangement	Score
Flood Modification											
Enlargement Culvert on Dee Why Creek at Pittwater Road	+1	0	0	0	-2	-2	0	0	0	0	-3
Rehabilitation of Dee Why Creek	0	+2	+1	+1	-2(1)	-2	0	+1	0	0	+1
Property Modification											
Planning Controls & Public Awareness	+2	+2	+2	0	+1	+1	+1	+1	+1	+1	+12
Revise Entrance Management Policy	+1	+2	+1	+1	0	0	0	0	0	0	+5
House Raising	+1	0	+1	+1	-2	-2	+1	+1	0	0	+1
Voluntary Purchase	+1	0	+1	+1	-2	-2	+1	+1	0	0	+1
Response Modification											
Flood Warning	0	+2	+1	0	-2	0	0	+1	0	0	+2
Flood Awareness Program	+1	+1	+1	0	0	0	0	+1	0	+1	+5

(1) Value represents the economic justification of this proposal as a flood management measure.

5 BACKGROUND INFORMATION IN RESPONSE TO THE COMMUNITY'S KEY CONCERNS

5.1 Australian Practice

Until 20 or 30 years ago the biggest recorded flood in a valley was the most commonly used for the basis of the FPL. The community accepted that anything below that level could expect to be flooded at some time in the foreseeable future, and anything higher than the flood-of-record was quite unlikely to be flooded.

The Australian Capital Territory, in the early 1970's, adopted the 1% AEP flood for derivation of the FPL. A major factor in this decision was the loss of seven lives during the 1971 Woden Valley flood, which had an AEP of about 1%.

In the mid-1970's, the Australian Water Resources Council proposed the adoption of the 1% AEP event as an appropriate standard for Australia. This preference was based on its widespread use in the United States of America. Also, a series of major floods with 1% and 2% AEP's occurred in Australia during the early to mid-1970's and caused considerable devastation. The 1% AEP flood event was therefore seen as being indicative of a big flood with potential disastrous consequences. Moreover, this flood was likely to be experienced at least once in a lifetime (eg there is a 50% chance that a 1% AEP flood will occur in a 70 year period).

Over the past 25 years it has become more common to adopt the 1% AEP flood to derive the FPL, particularly for residential development in urban areas, in communities all around Australia, as states have updated their floodplain risk management procedures.

The problem with adopting a standard level of risk, such as that embodied in the 1% AEP flood, is that it has tended to preclude investigation of risk levels that may be more critical to the community particularly in relation to evacuation and recovery strategies. It also led to minimal consideration or planning for larger floods, having provided a false sense of security that the 1% AEP flood event is the limit of flooding.

Since the release of the NSW Flood Prone Land Policy in December 1984 councils have been responsible for determining appropriate FPLs for their flood prone land. Whilst councils are encouraged to consider the full range of floods up to and including the PMF when determining FPLs, it is expected that the FPL for residential development will generally be based upon a 1% AEP flood event. FPLs are considered on the basis of social, economic, cultural and environmental factors, as well as flooding considerations.

The benefits from assessing the full range of floods up to the PMF is principally derived from a much greater understanding of continuing risk and the management measures needed to deal with it. As part of this, it provides key information on controls and consequences for emergency response and recovery planning, to input into local flood planning.

5.2 Hydrologic Analysis

The discharge of floodwaters past a given point on a river system is measured in volumetric terms and varies throughout the course of a flood event.

Flood frequency analysis and rainfall runoff routing (the latter was used for Dee Why and Curl Curl Lagoon studies) are the two most commonly used techniques for estimating peak flood discharges and hydrographs. Two approaches are made in undertaking these techniques with choice dependant on available data. The first approach involves the use of recorded flood and/or rainfall data near the point of interest and on the upstream catchment. In the absence of any recorded data a second approach using regional methods is adopted (this second approach was used for Dee Why and Curl Curl Lagoon studies).

A rainfall runoff routing model is a mathematical representation of the various catchment processes that transform rainfall into runoff (RORB was used for Dee Why and Curl Curl Lagoon studies). With these models, a rainfall event defined in space and time is used as input data to the model, which then simulates the associated discharge hydrograph at locations of interest in the catchment.

There are generally two methods for applying rainfall runoff routing models. The first involves a deterministic application and employs the use of recorded flood and rainfall event data. The second application is probabilistic and involves the use of design model parameters and design rainfall to simulate a design flood hydrograph at the catchment outlet or at nominated locations on the catchment (as was undertaken for Dee Why and Curl Curl Lagoon studies). It is used to determine flood hydrographs for different annual exceedance probabilities (AEPs).

It is generally accepted that the use of rainfall routing models in estimating design flood hydrographs involves a number of assumptions and a relatively large degree of uncertainty, especially in the absence of reliable recorded data. The implications of this uncertainty therefore need to be assessed by an experienced practitioner.

5.3 Probable Maximum Flood

The probable maximum precipitation (PMP) is the largest rainfall and the PMF the largest corresponding flood that could physically occur on the lagoon catchments. Storm events with rainfall of the order of the PMP, although extremely rare, do occur. An example was the 1984 storm at Dapto that approached this intensity.

The PMF is an extremely rare event and no AEP can be meaningfully attached to it. Nevertheless, to allow, for example, a computable flood damage estimate, the PMF event is generally given an AEP of between 0.01% and 0.0001%, an ARI of between 10,000 and 100,000 years.

The PMF event provides an upper limit of flooding and associated consequences for the problem being investigated. It is used for emergency response planning purposes to address the safety of people.

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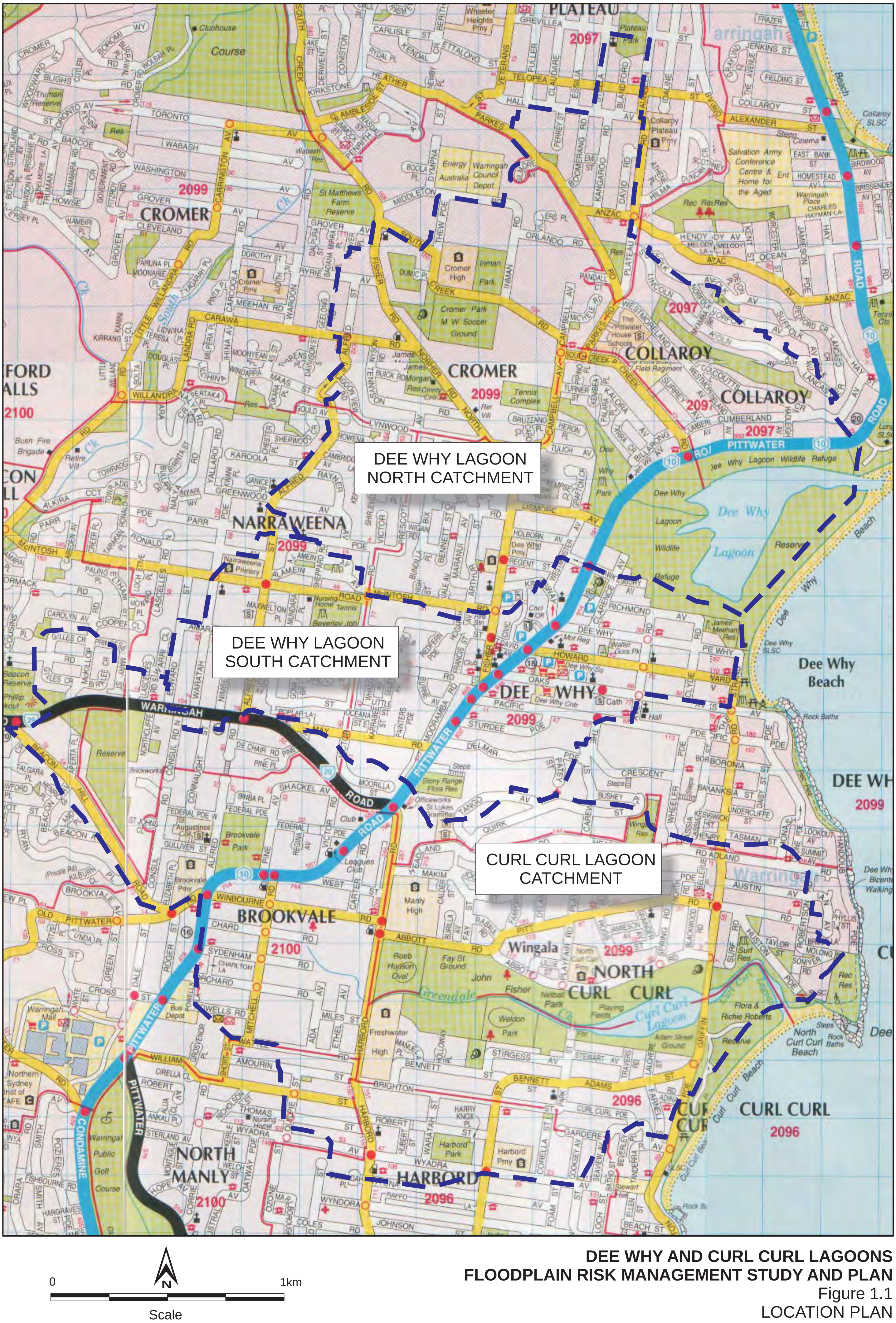
7 DEFINITIONS

The Floodplain Development Manual, 2005 contains a number of definitions which are relevant to the discussion of planning measures to assist in the management of development in the floodplain. These definitions include:

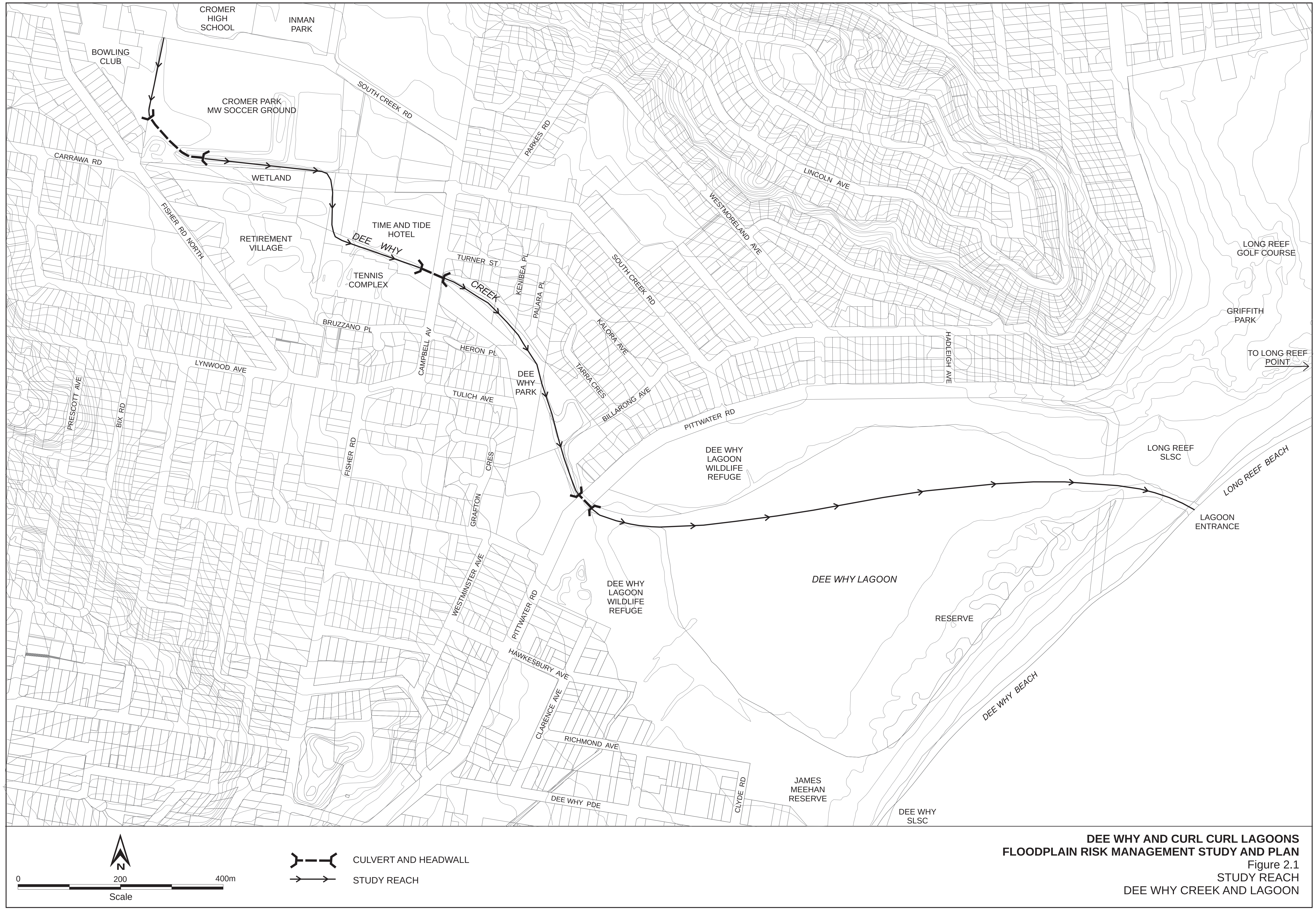
TERM	DEFINITION
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Annual Exceedence Probability (AEP))	The annual probability of occurrence of a flood of a particular magnitude or greater. For example, floods with a discharge as great as or greater than the 5% AEP event have a 5 % chance of occurrence in any one year. A 5% AEP flood is also equivalent to a 20 year Average Recurrence Interval (ARI) flood event which would occur on the average once in any 20 year period. AEP and ARI are ways of expressing the likelihood of occurrence of a flood event.
Flash Flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
Flood Liable Land	Is synonymous with flood prone land (i.e.) land susceptible to flooding by the probable maximum flood (PMF) event. Note that the term flood liable land now covers the whole of the floodplain.
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
Floodplain Risk Management Options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
Flood Risk Management Plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.

TERM	DEFINITION
Flood Planning Levels (FPLs)	Are the combinations of flood levels and freeboards selected for planning purposes, as determined in floodplain risk management studies and incorporated in floodplain risk management plans.
Flood Storage Areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
Floodway Areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Freeboard	A factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. It is usually expressed as the difference in height between the adopted flood planning level and the flood used to determine the flood planning level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such and wave action, localised hydraulic behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such as "greenhouse" and climate change. Freeboard is included in the flood planning level.
High Hazard	Where land in the event of a 1% AEP flood is subject to a combination of flood water velocities and depths greater than the following combinations: 2 metres per second with shallow depth of flood water depths greater than 0.8 metres in depth with low velocity. Damage to structures is possible and wading would be unsafe for able bodied adults.
Low Hazard	Where land may be affected by floodway or flood storage subject to a combination of floodwater velocities less than 2 metres per second with shallow depth or flood water depths less than 0.8 metres with low velocity. Nuisance damage to structures is possible and able bodied adults would have little difficulty wading.

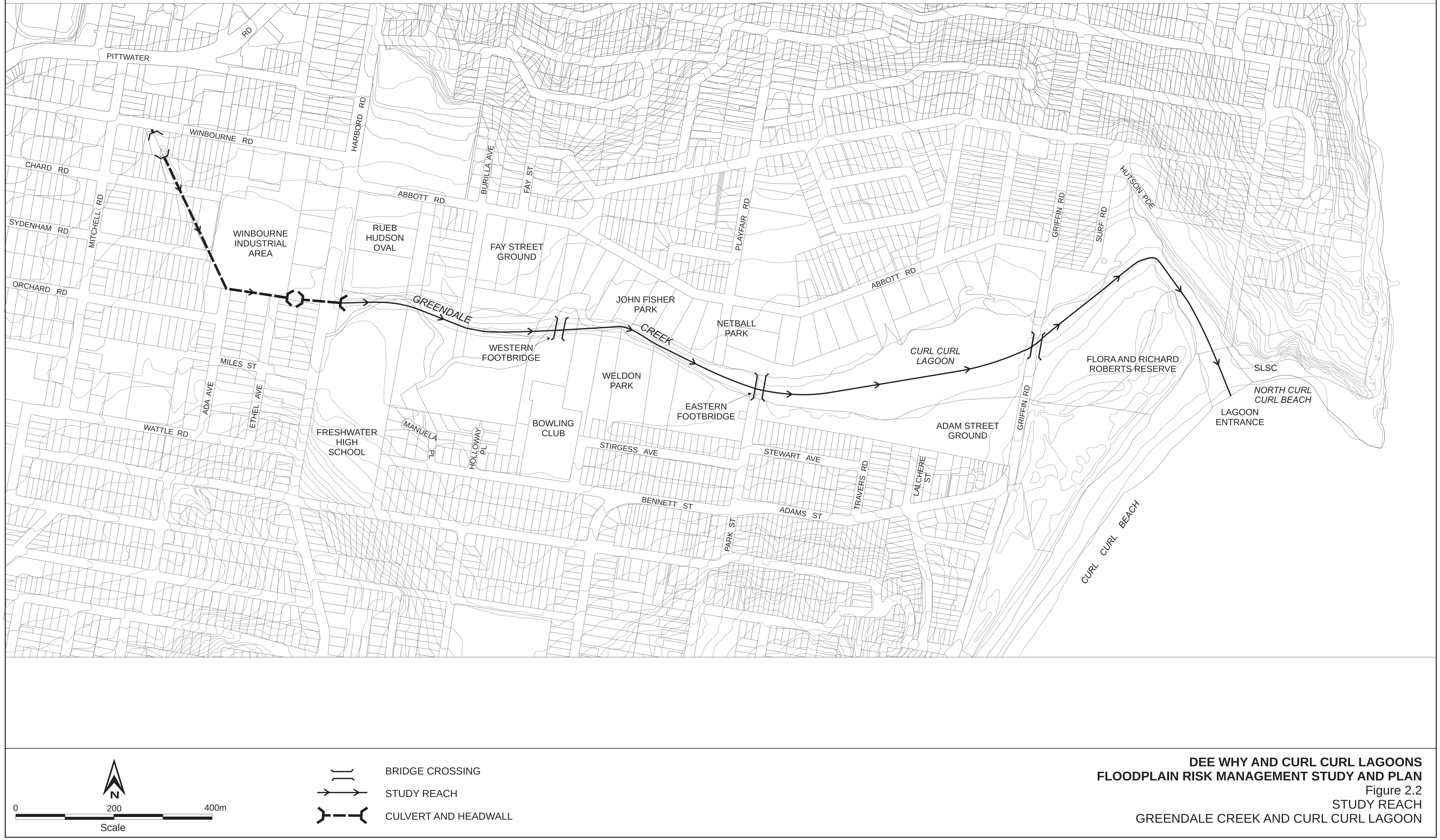
TERM	DEFINITION
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
Merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains.
Modification measures	Measures that modify either the flood, the property or the response to flooding.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with the PMF event should be addressed in a floodplain risk management study.
Probable maximum precipitation (PMP)	The greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to the estimation of the probable maximum flood.
Probability	A statistical measure of the expected chance of flooding (see annual exceedance probability).
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall which actually ends up as stream flow, also known as rainfall excess.



DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 1.1
LOCATION PLAN

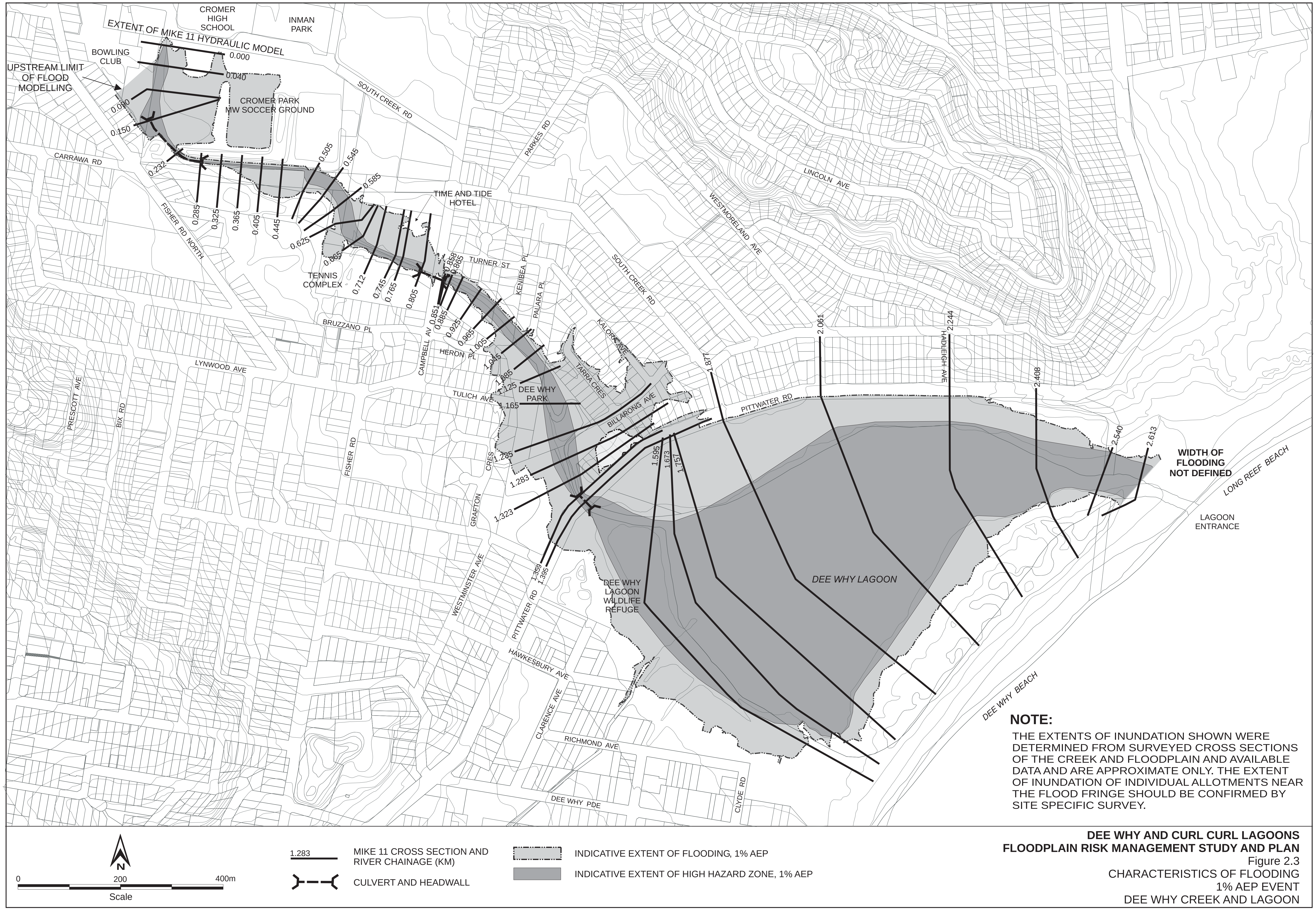


DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.1
STUDY REACH
DEE WHY CREEK AND LAGOON



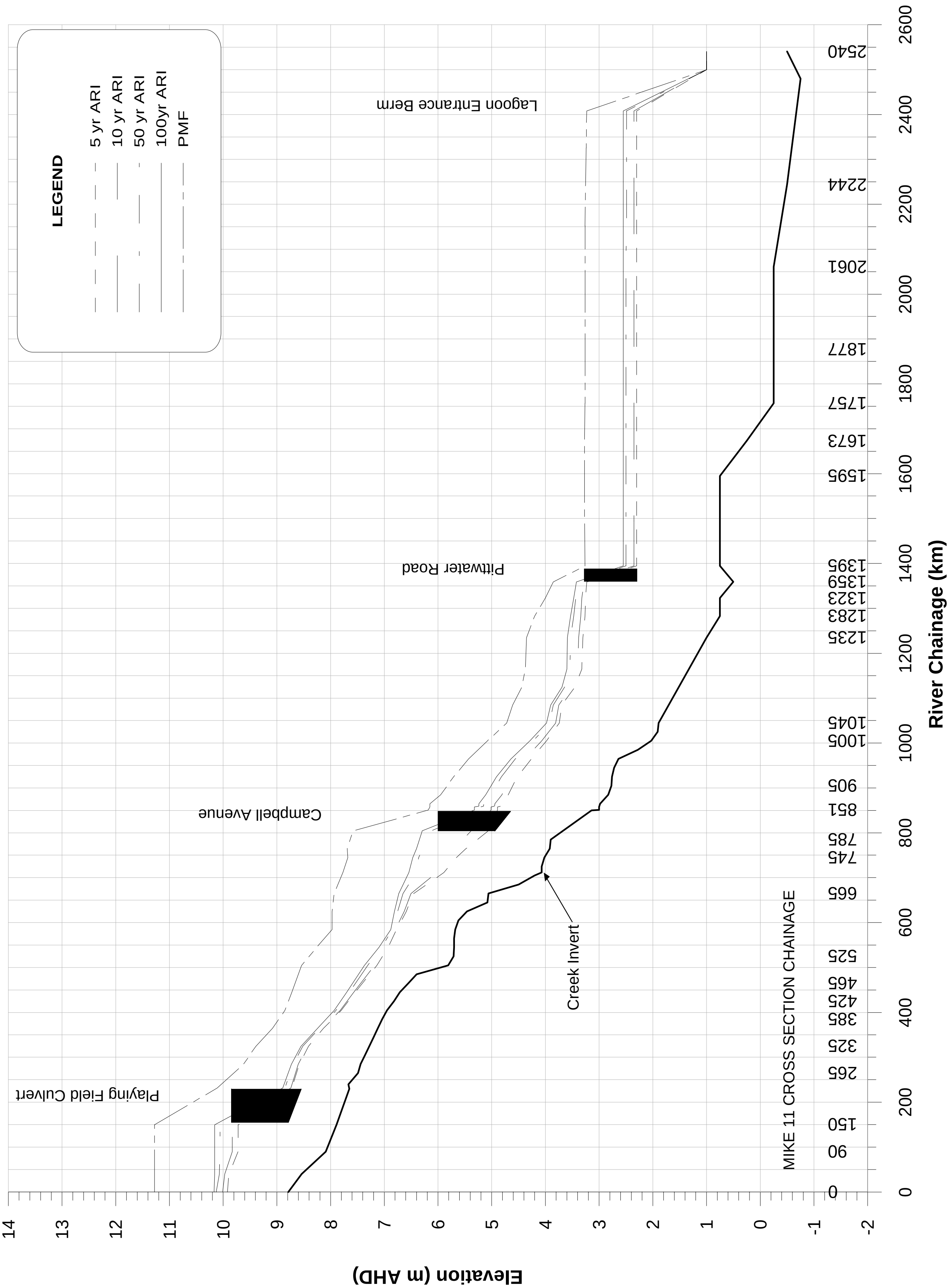
DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Figure 2.2
STUDY REACH
GREENDALE CREEK AND CURL CURL LAGOON



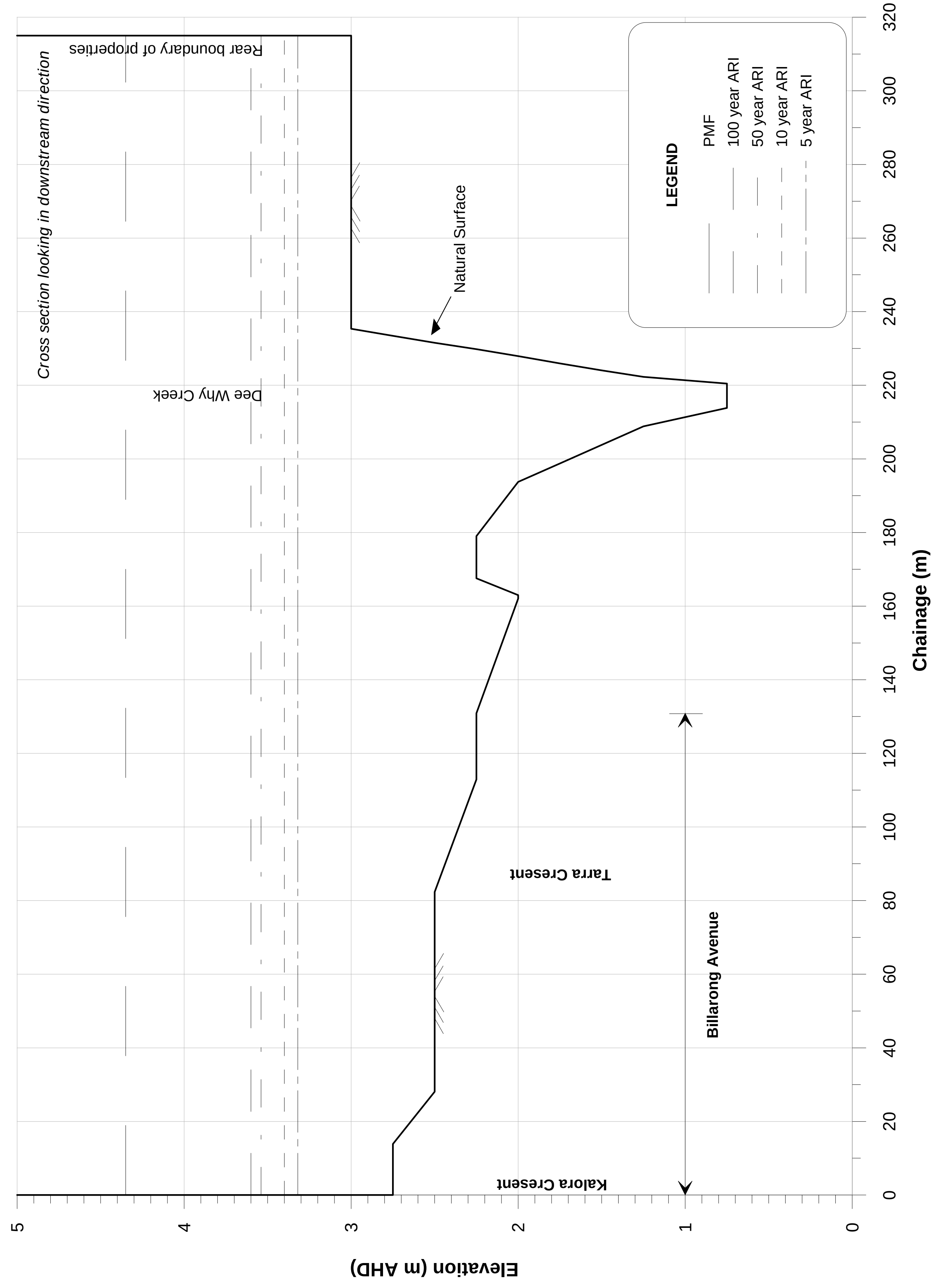
DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Figure 2.3
CHARACTERISTICS OF FLOODING
1% AEP EVENT
DEE WHY CREEK AND LAGOON



DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Figure 2.4
PEAK WATER SURFACE PROFILES
DEE WHY CREEK AND LAGOON

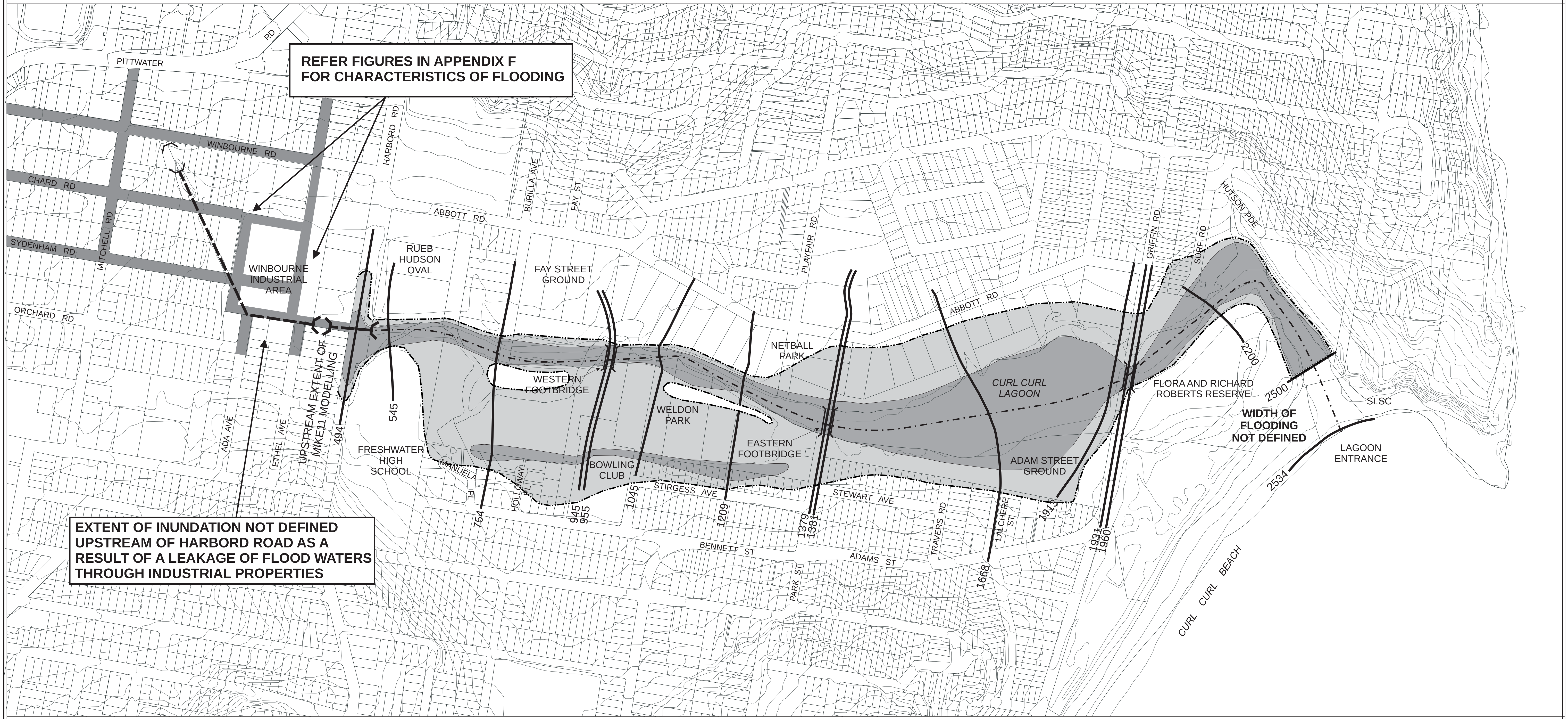


DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Figure 2.5
PEAK WATER SURFACE ELEVATIONS
CROSS SECTION CH 1235
DEE WHY CREEK UPSTREAM OF PITTWATER ROAD

NOTE:

THE EXTENTS OF INUNDATION SHOWN WERE DETERMINED FROM SURVEYED CROSS SECTIONS OF THE CREEK AND FLOODPLAIN AND AVAILABLE DATA AND ARE APPROXIMATE ONLY. THE EXTENT OF INUNDATION OF INDIVIDUAL ALLOTMENTS NEAR THE FLOOD FRINGE SHOULD BE CONFIRMED BY SITE SPECIFIC SURVEY.



N

0 200 400m

Scale

754 — MIKE 11 CROSS SECTION AND RIVER CHAINAGE (KM)

CULVERT AND HEADWALL

INDICATIVE EXTENT OF FLOODING, 1% AEP

INDICATIVE EXTENT OF HIGH HAZARD ZONE, 1% AEP

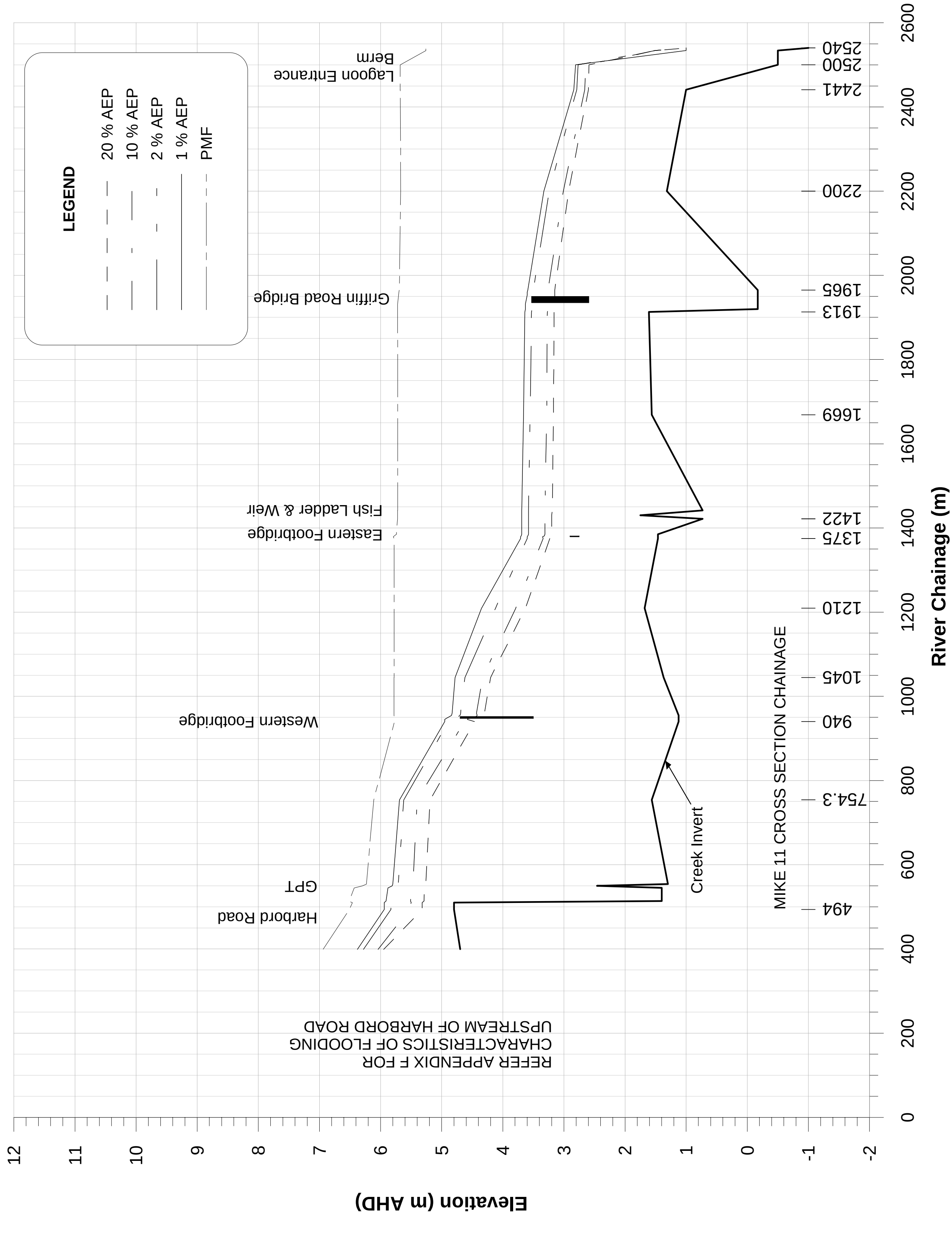
DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Figure 2.6

CHARACTERISTICS OF FLOODING

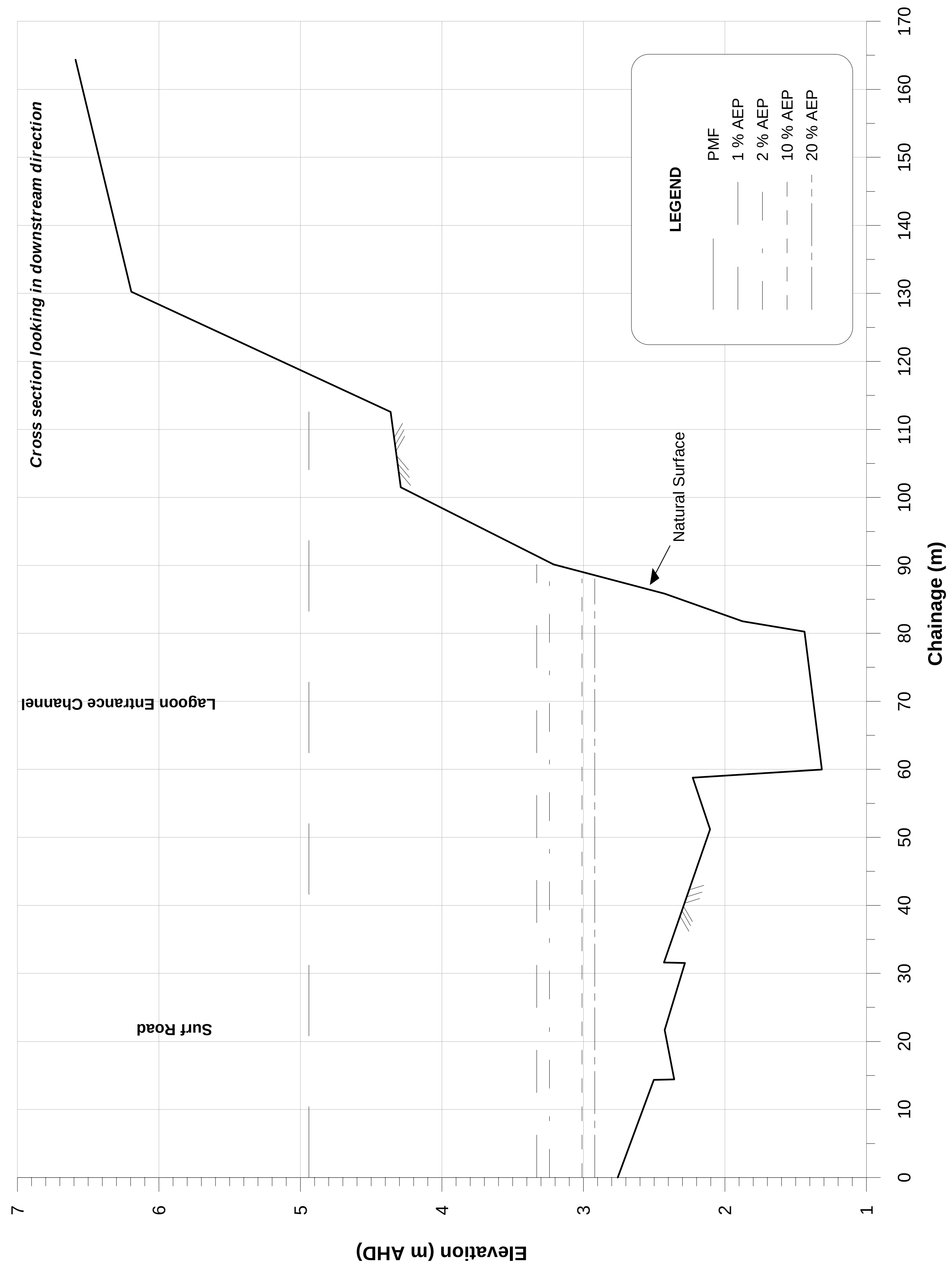
1 % AEP EVENT

GREENDALE CREEK AND CURL CURL LAGOON



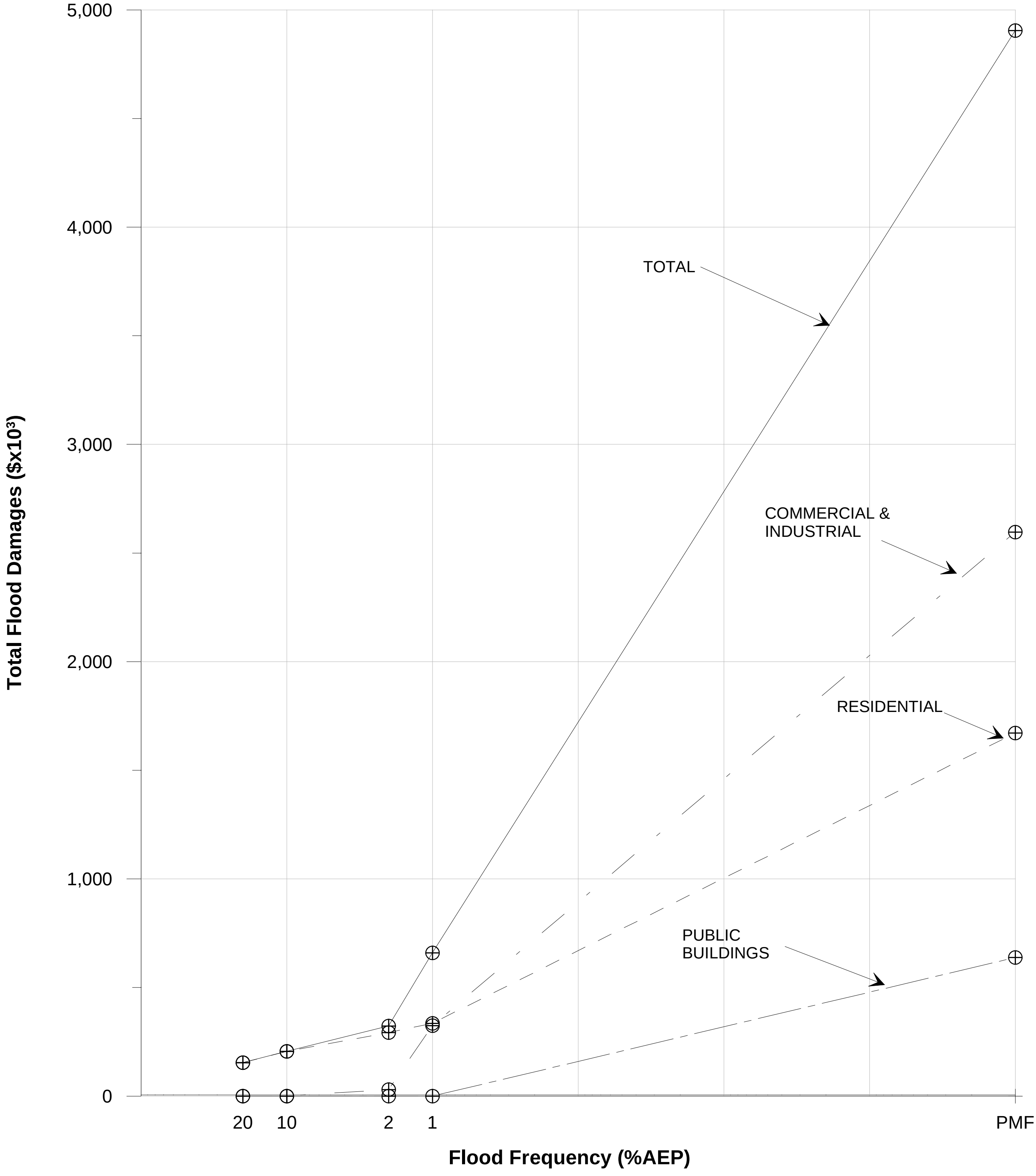
DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Figure 2.7
PEAK WATER SURFACE PROFILES
GREENDALE CREEK AND CURL CURL LAGOON



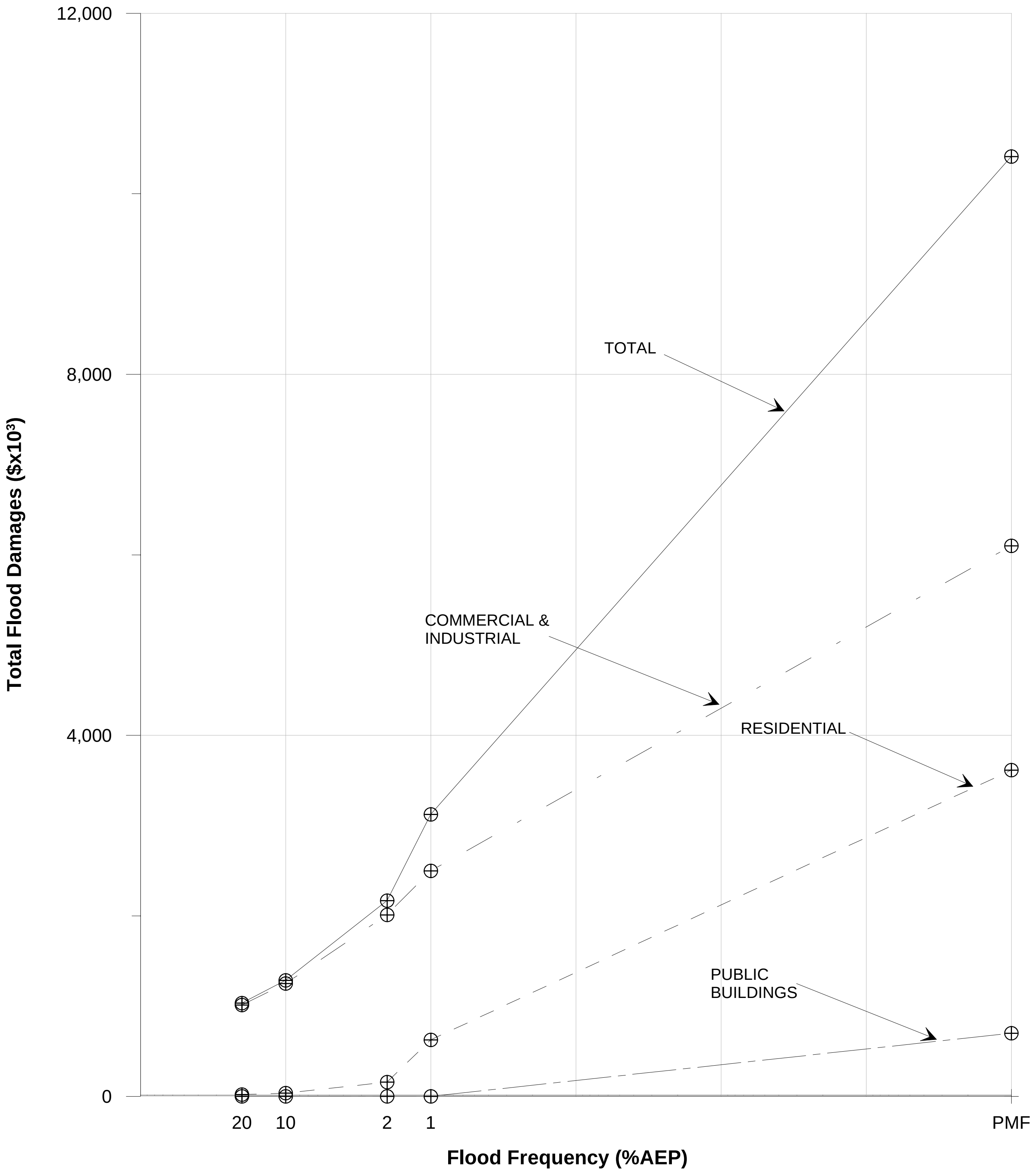
DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Figure 2.8
PEAK WATER SURFACE ELEVATIONS
CROSS SECTION CH 2200
CURL CURL LAGOON AT SURF ROAD



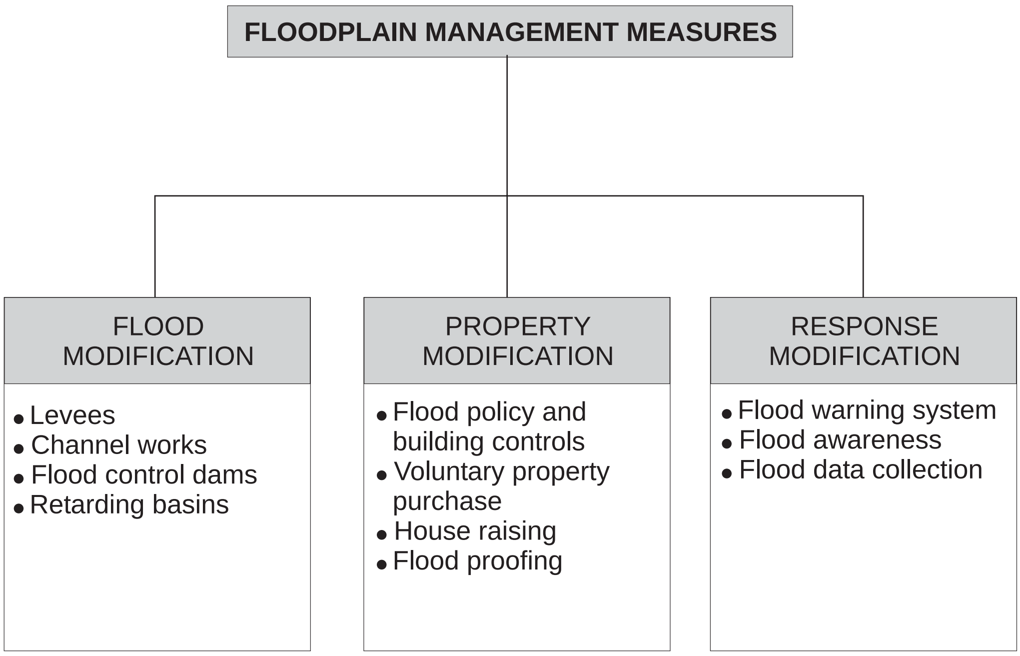
DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Figure 2.9
DAMAGE-FREQUENCY CURVES
DEE WHY LAGOON



DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDYAND PLAN

Figure 2.10
DAMAGE-FREQUENCY CURVES
CURL CURL LAGOON



DEE WHY AND CURL CURL LAGOONS
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 3.1
FLOODPLAIN MANAGEMENT MEASURES