GOSFORD CITY COUNCIL

AVOCA LAGOON
FLOODPLAIN MANAGEMENT STUDY

FINAL REPORT

May 2008

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Version 8
Authorised for Release

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DOCUMENT CONTROL SHEET

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Job Name: Avoca Lagoon FS, FMS & P

Job Nos.: 93-026, 02-017, 06-033

Original Date of Issue:

DOCUMENT DETAILS

Title:	Avoca Lagoon Floodplain Management Study – Final Report
Principal Author:	K W Paterson
Client:	Gosford City Council
Client Address:	P O Box 21, Gosford NSW 2250
Client Contact:	Mr Gary Poll

REVISION / CHECKING HISTORY

Version Number	Version Name	Date	Issued By
1	Draft	June 1994	
2	Exhibition	August 1997	
3			
4	Exhibition	September 1999	
5			
6			
7	Exhibition	November 2007	KWP
8	Final	May 2008	KWP

DISTRIBUTION RECORD

Destination	Version Number								
	1	2	3	4	5	6	7	8	9
Client (bound)								15	
Client (electronic)							1	1	
Department of Environment and Climate Change									
Paterson Consultants File Copy								1	
Paterson Consultants Library								1	

TABLE OF CONTENTS **PAGE NUMBER**

TABLE OF CONTENTS CONTINUED **PAGE NUMBER**

TABLE OF CONTENTS CONTINUED **PAGE NUMBER**

FIGURES

APPENDICES

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POLICY BACKGROUND

NSW Government Policy

The New South Wales Government's Flood Policy (Reference 2) is directed at providing solutions to existing flooding problems in developed areas as well as ensuring that new development is compatible with the flood hazard and that it does not create additional flooding problems in other areas.

Under the policy, the management of flood-prone land remains the responsibility of local government. The state government subsidises flood mitigation works to alleviate existing problems, providing specialist technical advice to assist councils in the discharge of their floodplain management responsibilities.

The flood policy provides for technical and financial support by the government through the following four sequential stages:

* *Stage 1 - Flood study:*

  Determines the nature and extent of the flood problem.

* *Stage 2 - Floodplain management study:*

  Evaluates management options for the floodplain in respect of both existing and proposed development.

* *Stage 3 - Floodplain management plan:*

  Involves formal adoption by council of a plan of management for the floodplain.

* *Stage 4 - Implementation of the plan:*

  Involves construction of flood mitigation works to protect existing development and includes use of local environmental plans to ensure new development is compatible with the flood hazard.

The Avoca Lagoon Floodplain Management Study constitutes completion of the second stage of the management process for Avoca Lagoon and its associated catchment and has been prepared for Gosford City Council to determine an appropriate floodplain risk management strategy.

Gosford City Council's Approach

Avoca Lagoon is one of the four major coastal lagoons in the Local Government area. The others are Wamberal, Terrigal, and Cockrone. All the lagoons face similar issues and are affected by:

- NSW Government Floodplain Management Policy;
- NSW Rivers and Estuaries Policy;
- NSW Coastal Policy.

The coastal, estuarine and floodplain management issues overlap to varying degrees in each lagoon.

Council established a Coastal Lagoons and Coastal Planning Committee, which concurrently undertook:

- floodplain management studies for Wamberal, Terrigal, Avoca and Cockrone Lagoons;
- estuarine and water quality investigations of the four lagoons;
- coastline management investigations for the coastline and beaches on the seaward sides of the four lagoons.

Council adopted:

- a Coastline Management Plan in 1995;
- a policy for opening of the various lagoons in 1999 (reviewed March 2005).

The work on the Avoca Flood Study, Floodplain Management Study and Plan were essentially completed over the period 1993 to 1995. However, their publication was delayed until similar projects at Terrigal and Wamberal were completed and the Coastline Management Plan was in place.

Publication Structure

The Floodplain Management Process comprises three stages (viz: Flood Study, Floodplain Management Study, Floodplain Management Plan). Each stage provides data for the Floodplain Management Plan. The most likely users of the reports on each stage are seen as differing. For example, the Plan will be of principal interest to Councillors, individual property owners and developers, while the Flood Study will be of principal interest to hydrologists, riverine and coastal engineers as providing the technical background to the Plan.

Accordingly, the Flood Study, Floodplain Management Study and Plan have been produced as three separate documents with the object of making the Plan as simple to use as possible.

The three stages of the floodplain management process have been completed (to "draft" stage) over a number of years as follows:

- Avoca Lagoon Flood Study (1994 and 2003);
- Avoca Lagoon Floodplain Management Study (1995 and 2003);
- Avoca Lagoon Floodplain Management Plan (1996 to 2007).

Thus, the monetary sums quoted in each report represent the Australian dollar values at the time of preparation of the report.

SUMMARY

This floodplain management study has been prepared by Paterson Consultants and follows on from the Avoca Lagoon Flood Study which was also carried out by Paterson Consultants.

The management study draws on the results of the flood study and uses this information, together with additional data collected for the management study to assess feasible floodplain management options for Avoca Lagoon foreshore area and floodplain within the study area.

Preferred management options have been recommended based on a comparative evaluation of each option and a range of relevant criteria. These evaluation criteria include indicators of flood mitigation performance, economic considerations, environmental impacts and social issues.

Three distinct modes of flooding occur in the study area:

- inundation by ocean storm waves near the lagoon entrance;
- inundation by floodwaters ponded in the lagoon around the lagoon foreshores; and
- inundation by local runoff on the floodplain upstream of the lagoon and adjacent to drainage flowpaths.

Ocean inundation levels adjacent to the lagoon entrance are higher than the equivalent lagoon flood levels. Thus management of the entrance area is considered to be a coastal management issue and is not related to lagoon flood management.

There are approximately 40 properties around the lagoon foreshore which have floor levels below the estimated one percent AEP design flood level. Two-thirds of these properties are also at risk from ocean storm wave action which poses a greater risk to life and property.

The estimated mean annual direct damage to public and private property is approximately $402,570.

A minimum floor level of RL 3.7 for new buildings around Avoca Lagoon is required under the current Flood Policy adopted by Council. This level provides minimal clearance above the estimated design flood level for Avoca Lagoon.

The preferred floodplain management option is improved management of the lagoon entrance. This would require periodic removal of sand from the entrance to limit the beach berm level to below RL 2.7 m AHD.

This option would reduce the design flood level for Avoca Lagoon by some 520 millimetres and provide the clearance above design flood level recommended in the Floodplain Development Manual (2005) (Ref. 12).

The preferred floodplain management option for future development incorporates the improved management of the beach berm at the lagoon entrance and the setting of minimum floor levels. The current minimum floor level is appropriate for the Avoca Lagoon foreshore.

However, it will be necessary to amend the minimum floor level for the floodplain upstream of the lagoon to ensure that the recommended clearance above design flood level is maintained. The recommended minimum floor level is RL 6.0 m AHD at Scenic Road, reducing to RL 3.7 m AHD at the upper limit of the lagoon 1.4 kilometres downstream.

1. INTRODUCTION

The New South Wales Floodplain Management Manual (Ref. 1) has been prepared to assist councils in the development of management plans for flood-liable lands. The principal objective of the floodplain management process is to reduce the impact of flooding and flood liability on individual owners and occupiers and to reduce private and public losses resulting from floods.

The floodplain management process comprises the following activities, as shown on Figure 1.1 which is derived from the Manual.

1. Establishment of a Floodplain Management Committee;
2. Development and implementation of an Interim Local Policy;
3. Completion of a Flood Study;
4. Selection of an appropriate Flood Standard;
5. Preparation of a Floodplain Management Study;
6. Adoption of a Floodplain Management Plan; and
7. Implementation of the Floodplain Management Plan.

The Avoca Lagoon Floodplain Management Study has been prepared by Paterson Consultants Pty Limited on behalf of Gosford City Council as part of the floodplain management process for Avoca Lagoon and other coastal lagoons within Gosford.

The floodplain management study follows on from the Avoca Lagoon Flood Study (Ref. 2) which was also prepared by Paterson Consultants with additional modelling of ocean flooding by Australian Water and Coastal Services (AWACS).

Gosford Council has adopted the one percent Annual Exceedence Probability (AEP) design flood as the Flood Standard for floodplain management. Gosford City Council currently uses a minimum floor level of RL 3.7 m AHD in accordance with the preliminary estimates from historical flood events in Avoca Lagoon..

Flooding of Avoca Lagoon can result from runoff from the lagoon catchment, ocean inundation or a combination of both. In order to limit the flooding of properties adjacent to the lagoon, Council has adopted a let-out-level of RL 2.09 m AHD for Avoca Lagoon. The lagoon entrance is opened when the water level in the lagoon rises to let-out-level.

The adoption of the let-out-level and the resultant practice of opening the lagoon entrance together with the minimum floor level requirements constitute the existing floodplain management for Avoca Lagoon.

Ecologically sustainable development (ESD) principles are now embodied through government policy (in particular the Environment, Planning and Assessment Act, Regulations 1994).

The floodplain management process seeks to satisfy ESD principles of:

* Intergenerational equity, that is the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations;

* Conservation of biological diversity and ecological integrity;

* Active and meaningful community participation in identifying issues, responses and strategies and decision making;

* Precautionary principle in that lack of scientific certainty is not a reason for the lack of amelioration measures to prevent environmental degradation where a threat of serious or irreversible environmental damage exists; and

* Inclusion of valuations of environmental costs of activities and the costs of changes to biodiversity, ecological and cultural values.

Thus, the floodplain management process seeks to promote the adoption of an integrated approach to the management of all lands within the Avoca Lagoon catchment.

This floodplain management study addresses the following issues:

- existing flood behaviour;
- environmental and planning considerations;
- future development;
- climatic change;
- flood damages;
- floodplain management options;
- floodplain management impacts;
- floodplain management economics;
- preferred floodplain management strategies.

The extent of lands included in the floodplain management study is shown on Figure 1.2.

2. EXISTING FLOOD BEHAVIOUR

2.1 Introduction

Avoca Lagoon is the largest of the four coastal lagoons within Gosford. The lagoon has a cruciform shape with a surface area of 97.5 hectares and average depth of 1.3 metres. The let-out-level is approximately 2 metres above mean sea level. The lagoon entrance is normally closed due to the action of coastal dynamic processes which result in the formation of a beach berm across the lagoon entrance, linking Avoca and North Avoca beaches.

Gosford City Council has records of openings of the Avoca Lagoon entrance commencing in 1972. These records show that the entrance has been opened 58 times over the period 1976 to 2003, primarily for flood control purposes. The entrance has broken out naturally on four other occasions when floodwaters caused the lagoon level to rise above the level of the beach berm.

Records of inundation of Avoca Lagoon by ocean storms are not as complete as those available for the opening of the entrance. Limited data are available for severe ocean storms in May 1974, June 1978 and August 1986 when waves overtopped the beach berm and entered the lagoon.

The available flood information obtained from Council records, Public Works Department (PWD) records and resident interviews is summarised in Table 1 below and on Figure 2.1.

2.2 Previous Studies

The recently completed Avoca Lagoon Flood Study details the investigations carried out to determine design flood levels for Avoca Lagoon and the adjacent floodplain. Hydrologic and hydraulic models were established and jointly calibrated using available rainfall and flood level data for three flood events. The calibrated models were then used with design rainfall data to determine design flood levels for Avoca Lagoon and the adjacent floodplain.

This floodplain management study draws on the results obtained in the Flood Study.

The investigation of ocean dynamic processes and overtopping of the beach berm by ocean storm induced wave action were carried out by Geomarine P/L and are described in the report "Avoca Lake and Cockrone Lake - Coastal Engineering Advice for Flood Studies" (Ref. 3). This report was prepared as a working paper for the Flood Study.

The ocean dynamic processes were also investigated by AWACS (Ref. 4). The report provides estimates of wave runup levels near the lagoon entrance and estimated peak lagoon flood levels resulting from overtopping of the beach berm by storm induced waves. The results of this study were similar to those obtained by Geomarine.

"A Position Statement of the Coastal Lagoons of Gosford City Council" (Ref. 5) was prepared by Gosford City Council in 1984. This paper discusses Council management of the lagoon entrances and proposes a minimum floor level of RL 3.7 m AHD for the Avoca Lagoon foreshore.

Data on the environment of Avoca Lagoon is discussed in the report "Gosford Lagoons Environmental Study" (Ref. 6) prepared by P A Management Consultants in 1975. Prof. Cheng completed an ecological assessment of the coastal lagoons in 1992 (Ref. 7).

TABLE 1

Summary of Available Flood Level Data For Avoca Lagoon

Flood Date	Flood Level (m AHD)	Location	Point*	Source
1963 (Highest recorded flood)	4.80	Avoca Beach Bowling Club	1	Greenkeeper
1988	2.046, 2.033	Maximum Height Recorders		DLWC Records
Jan 1989	2.42 (Peak)	7A Tramway Street North Avoca	2	Resident
	2.025 (1330 Hrs on 6/1/89)	Gauge# Beach = 2.3	3	Council Records
Feb 1990	1.45 (1715 Hrs on 2/2/90)	Gauge	3	Council Records
	2.43 (2345 Hrs on 2/2/90)	Gauge Beach = 2.65	4	Council Records
	2.483, 2.486	Maximum Height Recorders		DLWC Records
	4.8 (Peak)	Downstream of Scenic Highway	5	Resident (approx. only)
	2.10 (0900 Hrs on 9/2/92)	Gauge Beach = 2.8	3	Council Records
All Floods	<2.89	Scout Hall	6	Residents

Notes: * Refer to Figure 2.1 for locations.
"Gauge" refers to Gosford City Council gauge at the Avoca bridge which is used to "trigger" mechanically assisted break-outs.

2.3 Flood Behaviour

Avoca Lagoon has a catchment area of 11.4 square kilometres and drains to the Pacific Ocean via the entrance which separates Avoca and North Avoca Beaches. The lagoon entrance is normally closed as a result of coastal dynamic processes. The major drainage systems in the catchment are Saltwater Creek and an un-named creek draining the Picketts Valley area west of the Scenic Highway.

Approximately 30 percent of the catchment has been developed for residential purposes. The suburb of North Avoca is located on the slopes around the north arm of the lagoon and down to the ocean. The suburb of Avoca Beach is located on the slopes around the south arm of the southern shoreline of the main arm of the lagoon and down to the ocean.

The catchment topography is generally rough, with relatively steep slopes from the ridges down to the lagoon. Natural bushland and rural development cover some 60 percent of the catchment area.

Floods in the tributary creeks draining to the lagoon result from short duration storms, typically less than three hours. The steep terrain results in short catchment response time to rainfall. The short response time, coupled with the confined nature of the creek channels leads to spilling of floodwaters onto the floodplain prior to a significant rise in lagoon water levels.

Flooding around the lagoon foreshores results from rainfall of much longer durations, typically 12 hours or longer. The large surface area of the lagoon requires a considerable volume of runoff to raise the water level. The extent of water level rises in the lagoon is determined by conditions at the entrance.

With the entrance opened, floodwaters are able to discharge quickly with little resultant increase in lagoon water levels. On the other hand, with the entrance closed, floodwaters are ponded in the lagoon until the beach berm is overtopped or the lagoon entrance is artificially opened.

Thus, flood levels upstream of Townsend Avenue, near the junction of Saltwater Creek and the creek draining Picketts Valley are dependent on rainfall intensity and independent of the water level in Avoca Lagoon. Flood levels around the lagoon foreshores are dependent on the amount of rainfall and entrance conditions.

Properties adjacent to the lagoon entrance may also be inundated by high seas resulting from storms at sea. Overtopping of the beach berm by storm induced wave action and the propagation of these waves into the lagoon entrance may cause damage to properties which may be less susceptible to flooding by storm runoff.

The Avoca Lagoon Flood Study modelled both short and long duration rainfall events for 1, 2 and 20 percent AEP and PMP (Probable Maximum Precipitation). The Flood Study also investigated oceanic inundation of the lagoon as the result of an extreme storm at sea.

The Flood Study found that the critical rainfall duration for lagoon flooding is primarily dependent on the level of the beach berm across the lagoon entrance. The critical rainfall duration is also dependent on the intensity of rainfall, as reflected in the probability of exceedence.

Thus, the critical rainfall duration was found to be 2 hours for the entrance open or the beach berm at below let-out-level. The critical rainfall duration increases with beach berm level to exceed 12 hours at maximum beach berm level.

The intensity of rainfall in the PMP event is so great that the resultant runoff is much larger than the lagoon storage even at highest beach berm level. Thus, the critical rainfall duration for extreme rainfall events is 2 hours.

The one percent AEP design flood levels shown on Figure 2.2 have been determined from modelling results for short and medium duration rainfall events and a beach berm level of RL 3.3 m AHD. This beach berm level is some 400 millimetres above the average recorded beach level and has an estimated probability of exceedence of approximately 10 percent.

2.4 Ocean Inundation

Ocean waves may impact on Avoca Lagoon and the foreshore by overtopping of the beach berm when the entrance is closed or by entering the lagoon through the open entrance.

When the entrance is closed, ocean waves overtopping the beach berm can propagate within the lagoon. These conditions will persist for as long as the ocean waves overtop the beach berm.

The ocean dynamic processes were investigated in the Flood Study to determine:

- the increase in lagoon water level resulting from overtopping of the beach berm by ocean waves; and

- the maximum level reached by wave action in the lagoon entrance.

These analyses were based on data recorded during the ocean storm which occurred in May 1974. This is the most severe ocean storm recorded along the Central New South Wales Coast. The wave height history has an estimated recurrence interval of some 50 years. However, its coincidence with spring lunar tides increases this recurrence interval, when based on water level, to well in excess of 50 years.

Australian Water and Coastal Studies (AWACS) has estimated that the average recurrence interval governing lagoon inundation, inclusive of wave and surge water level conditions, for the May 1974 extreme ocean storm event is approximately 100 years, ie. equivalent to one percent AEP.

The estimated maximum inundation level in the lagoon entrance for this event is RL 3.8 m AHD. This inundation level includes:

- wave setup;
- wave transmission into the lagoon;
- wave runup at the shoreline;
- lagoon storage filling; and
- berm overtopping.

This peak level is applicable to the lagoon entrance area which extends some 250 metres behind the beach. Once the storm waves pass through this section, the waves quickly dissipate in the storage of the lagoon. Thus, the estimated peak flood level in the lagoon caused by inflow from the ocean for this event is RL 2.3 m AHD.

In response to a NSW Land and Environment Court action, it is apparent that more investigation work is required into the coastal hazard (that is, waves overtopping the beach and the area immediately behind the beach). However, the information above is sufficient for an interim assessment.

2.5 Design Flood Levels

The scenarios that can lead to flooding of the lagoon foreshores and upstream floodplain are:

- short duration rainfall events. These events determine peak flood levels on the floodplain upstream of the junction of Saltwater Creek and the Picketts Valley creek;

- medium duration rainfall events with lagoon entrance closed. These events determine peak flood levels in the lagoon in response to the volume of runoff entering the lagoon prior to breakout or opening of the entrance; and

- inundation by ocean storm induced wave action. The impact of ocean storm induced wave action is generally restricted to the lagoon entrance only, the volume of the water entering the lagoon being insufficient to produce a major increase in water level in the lagoon.

The estimated one percent AEP design flood levels for each of the above scenarios is presented in Table 2 below and shown on Figure 2.2.

TABLE 2

One Percent AEP Design Flood Levels
(m AHD)

Event	Avoca Dr/Townsend Ave	Lagoon	Entrance
2 Hour Storm	5.24	3.37	3.37
12 Hour Storm	4.98	3.60	3.60
Ocean Storm	2.30	2.30	3.80

2.6 Extent of Flooding

The approximate extent of lands inundated by the appropriate one percent AEP design flood event is also shown on Figure 2.2.

Specific areas or precincts affected by flooding are:

1. northern side of lagoon entrance - comprising seven properties in Bareena Avenue which are susceptible to inundation by wave action during ocean storms;

2. North Avoca - comprising nine properties in Lake Street and in Tramway Road which back onto the lagoon;

3. North Arm foreshore - comprising some eight properties in Leeside Road and three properties in Lake Shore Drive which are above lagoon flood levels but may suffer inundation due to blockages in the stormwater drainage systems. The properties in Lake Shore Drive experienced flooding due to blocked drainage in February 1989;

4. Saltwater Creek floodplain - comprising a small number of rural properties which may be isolated by lagoon floodwaters over access roads;

5. Avoca Drive/Scenic Highway intersection - unaffected by lagoon flooding but local runoff can cover Avoca Drive restricting access;

6. South Arm foreshore - comprising the caravan park and three adjacent properties in the Round Drive and Avoca Beach Primary School grounds; and

7. southern side of the lagoon entrance - comprising some 19 properties in Ficus Avenue and Avoca Drive which are susceptible to inundation by wave action during ocean storms.

There are additional open space areas bordering the lagoon which are flood-prone.

The locations of each of the above precinct areas are shown on Figure 2.3.

2.7 Flood Hazard Assessment

The New South Wales Floodplain Management Manual recognises three categories of flood-liable land:

* Floodways - those areas where a significant volume of water flows during floods, where flow velocities are generally high and deeper flow may occur.

* Flood Storage - those areas of the floodplain which provide temporary storage of floodwaters and flow velocities are generally low.

* Flood Fringe - those areas of the floodplain not included in floodways or flood storage areas.

The Manual also provides for two categories of flood hazard:

* High Hazard - where floodwaters could cause structural damage to buildings, there could be danger to life and limb and social disruption and financial losses could be high.

* Low Hazard - where potential damage and risk to life and limb would be low.

The flood hazard classification incorporates assessment of the depth and velocity of floodwaters, effective evacuation time and evacuation difficulties. The hazard classification is generally determined by assessment of the hydraulic variables - depth and velocity of floodwaters, as shown on Figure 2.4 which is reproduced from the Manual.

The preliminary hazard classification may be altered following a review of other significant factors including warning times, flood awareness, rate of rise of floodwaters and evacuation problems.

The Flood Study found that the depth of floodwaters in the one percent AEP flood adjacent to the lagoon shoreline and on the floodplain upstream of the lagoon would be generally in the range of 1 to 1.5 metres. The velocity of the floodwaters is generally less than 0.6 metres per second except at flow constrictions such as culverts.

Thus, the study concluded that the floodplain upstream of the lagoon and the lagoon foreshore area would be classified as "High Hazard" due to excessive depth of floodwaters. This classification is based on the assessment of hydraulic parameters only and the use of Figure 2.4.

The critical rainfall duration for flooding of the lagoon foreshore is relatively long (12 hours) due to the storage available in the lagoon. The rate of rise of the lagoon is relatively slow, taking over 10 hours to peak.

This relatively drawn out flood period, coupled with the low velocities of floodwaters along the lagoon foreshore area would enable evacuation of persons and belongings from flood affected properties to be carried out with only relatively minor difficulties.

Accordingly, it is considered that the flood-liable lands around the lagoon foreshore can be revised to "Low Hazard".

It is considered that the "High Hazard" classification should be retained for the floodplain upstream of the lagoon due to early flooding of access routes by local runoff.

The velocity of floodwaters flowing over the floodplain upstream of the lagoon is generally greater than 0.5 metres per second, while the depth is generally greater than 1.3 metres. Thus, flood-liable land upstream of the lagoon can be considered as being located in a floodway since little attenuation in peak discharge occurs due to storage routing.

On the other hand, flood-liable land around the lagoon foreshores can be considered to be located in flood storage. These areas are used for temporary storage of floodwaters and flow velocities are generally less than 0.2 metres per second.

The areas adjacent to the lagoon entrance (Precincts 1 and 7) present a number of difficulties in terms of flood hazard assessment. When the lagoon opens, the channel through the beach shows high velocities, instabilities and varies in its plan location.

It is clear from Land and Environment Court action in 1991 that additional investigation is required to better define the hazard from ocean wave overtopping. In this situation, it was seen as prudent to seek to classify the entrance areas under floodplain hazard classifications to inform the community of risks and to introduce an "Investigation" zone.

The areas adjacent to the lagoon entrance are susceptible to inundation by ocean waves. There is generally a prolonged establishment period for ocean storms. However, storm intensity and the resultant wave climate can vary more rapidly. The destructive force of the waves is much greater than that of the rising floodwaters in the lagoon.

Therefore, due to the uncertainty associated with ocean storms and the potential for greater damage, it is considered that the "High Hazard" classification should be retained for the lagoon entrance until further research is completed.

The concept of floodwaters, flood storage and flood fringe areas is not normally associated with oceanic inundation. Due to high damage potential within areas susceptible to ocean wave action, it is considered that these areas have similar characteristics to floodways. Therefore, the flood-liable areas adjacent to the lagoon entrance can be considered to be located in a floodway until further research is completed.

The proposed flood hazard classification for the lagoon foreshores and upstream floodplain is summarised in Table 3 below and presented in Figure 2.5.

TABLE 3

Flood Hazard Classification For Avoca Lagoon

Location	Precinct Areas*	Hazard Classification
Entrance	1, 7	High Hazard - Floodway/Investigation
Lagoon Foreshores	2, 3, 6	Low Hazard - Flood Storage
Upstream Floodplain	4, 5	High Hazard - Floodway

Notes: * Refer to Figure 2.3 for precinct locations.

3. ENVIRONMENTAL AND PLANNING CONSIDERATIONS

The Avoca Lagoon foreshores have been developed over a period in excess of 50 years. The area was originally developed with holiday housing in a beautiful and peaceful environment. More recently, the area has been developed for permanent residential purposes as part of the continuing urban development in Gosford.

The natural environment and urban planning considerations relevant to the lagoon foreshores and adjacent lands are discussed below.

3.1 Lagoon Environment

The foreshore along the northern side of the lagoon and Bareena Island is comprised of a melaleuca fringe forest with associated reedland/sedgeland. The vegetation occurs on mainly deep sands with muddy sediments present in some reedland areas. The vegetation requires infrequent flooding and inundation by lake waters for survival.

The vegetation on Bareena Island is virtually undisturbed, while clearing of the understorey in some sections of the lagoon foreshores has enabled exotic weeds and grasses to invade.

The area includes Sites 911 and 912 under the State Environmental Planning Policy (SEPP) 14 - Coastal Wetlands. The location of the SEPP 14 wetlands are shown on Figure 3.1. The threatened Green and Golden Bell frog has been found within a section of site 912.

The southern foreshores of the lagoon between the lagoon entrance and the Avoca Drive bridge across the entrance to the southern arm of the lagoon has been cleared for recreation purposes. The nearby Heazlett Park comprises a sporting oval, tennis courts and picnic area.

This is the only area in Gosford where remnants of littoral rainforest occur associated with melaleuca fringe forest. The area contains several large trees which have been included on the Significant Tree Register.

A grove of Swamp Oak is located between the Avoca Beach Public School and the caravan park at the southern end of the lagoon. This grove of trees is considered to be in a viable condition and worthy of conservation.

Small remnants of Swamp Mahogany occur within the caravan park area. Swamp Mahogany is a "keystone" species in the Central Coast region and is protected in Gosford. Infrequent flooding is required for Swamp Mahogany to survive.

The SEPP 14 wetland site 913 is located adjacent to the caravan park area (refer Figure 3.1).

The western foreshore of the southern arm of the lagoon comprises melaleuca fringe forest with understorey vegetation intact. A forest of Swamp Oak is present with reedland/sedgeland. This forest is relatively undisturbed near the Avoca Drive bridge with some selective clearing further south. The vegetation in this area requires inundation for survival.

The floodplain upstream of the lagoon comprises remnant forest of Bluegum and Turpentine with rainforest understorey vegetation. Some clearing has been carried out in the upper section of the floodplain upstream of the Public Reserve which is located at the western end of the lagoon.

In general, the lagoon foreshores away from the lagoon entrance area have relatively steep slopes above the lagoon water level with a drop of 500 millimetres or more at the waterline at some locations. The foreshores near the lagoon entrance are generally sandy with very mild slopes above the waterline. The northern shoreline of the entrance to the northern arm of the lake has a mild slope at the waterline with a sharp rise of approximately 500 millimetres height some 20 metres back from the waterline.

3.2 Landuse and Planning Controls

The flood-liable land around Avoca Lagoon is comprised of:

- open space, public reserve around the shoreline of the lagoon;
- residential development abutting the above open space public reserve; and
- rural development of the floodplain upstream of the lagoon.

The current zonings for the land around Avoca Lagoon are shown on Figure 3.2 and discussed below.

The land in Ficus Avenue, Avoca Beach and Bareena Avenue, North Avoca located immediately behind the beach berm is zoned Residential 2(f) - Beach Frontage. The construction of detached dwellings is permitted with consent but virtually all other forms of development are prohibited. Although lot sizes in Ficus Avenue are larger than normal, subdivision is restricted to amalgamation and minor boundary adjustments only for these lots.

The remaining land behind the beach between Ficus Avenue and Avoca Drive is zoned Residential 2(b) which permits construction of a variety of residential buildings including townhouses, motels etc in addition to detached dwellings. Land fronting to Avoca Drive is zoned Business 3(a) for retail and commercial buildings.

The land around the northern arm of the lagoon is zoned Residential 2(a) which permits construction of single dwellings. Dual occupancies are not permitted under Gosford Council's DCP No. 126.

The foreshore of the southern arm of the lagoon and the southern foreshore of the central lagoon along Avoca Drive is zoned Open Space - Recreation 6(a). The land beyond the immediate foreshore areas zoned Residential 2(a) with a small area of land zoned Business 3(a) adjacent to the caravan park.

The northern foreshore of the central lagoon is zoned Conservation and Scenic Protection 7(a).

The floodplain upstream of the lagoon is zoned Open Space - Recreation 6(a) Conservation and Scenic Protection 7(a) and Conservation and Scenic Protection - Tourism 7(c3).

Development within the Conservation and Scenic Protection zones is restricted to low intensity development i.e. single dwellings on large lots with tourist accommodation permitted on appropriately zoned land.

The housing on the southern side of Avoca Lagoon consist of a mixture of old holiday cottages, new permanent residences and a number of residential flats of variable age and standard. There is also a small commercial area in Avoca Drive to service the residential area.

The development on the northern side of the lagoon is comprised principally of single dwellings, many of which are of brick or brick veneer construction.

The more recent development on both sides of the lagoon has been carried out with flood heights in mind with building floor levels regulated through Council's flood policy.

Parts of the foreshore, as shown on Figure 3.1, are subject to the provisions of SEPP 14 - Coastal Wetlands.

3.3 Recreational Aspects

Avoca Lagoon provides significant visual and recreation resources for the coastal area of Gosford City. The resource value of the lake and foreshore areas varies. Areas adjacent to the beach tend to be used more for active recreation, particularly on the southern side of the lake near the beach. The remaining foreshore areas are significant in terms of landscape character and passive recreation such as walking and bird watching. Options to mitigate existing flooding around the foreshores may have potential impacts on these values.

The southern shore of Avoca Lagoon, east of the bridge, performs a number of recreation and landscape functions. Heazlett Park, immediately east of the bridge, is an important recreation reserve and a significant visual element at the entry to Avoca. Existing facilities include a small clubhouse/kiosk, tennis courts, carpark, picnic tables, toilet block and cricket ground and a concession hire for paddle boats.

The section of foreshore adjoining Heazlett Park contains the only remaining stand of littoral rainforest in Gosford. This part of the foreshore provides a very attractive picnic and walking area.

Avoca Drive, the main access road contains stands of large Norfolk Pines which are listed on the significant tree register.

The northern shore of the lake, near the beach, is not as heavily used for recreation as the southern shore. With population growth, the northern shores could experience increased pressure for recreation use. Parts of the foreshore have been cleared and are regularly mowed. This is done presumably on the basis of improving the amenity but has the effect of changing the natural character of the area. There is evidence of rubbish dumping along the foreshores and introduced weeds. On the north side of the lake, the reserve is used by local residents for access and parking.

Wetlands south of the bridge on the western approach and the existing foreshore vegetation are significant visual elements.

Lands in the southern most reaches of the lake are generally less accessible and, in terms of their recreation and landscape values, could be regarded as of local significance.

Extensive background information on recreation and landscape issues is provided in Gosford City Council's Avoca Lake Draft Development Control Plan, dated 1985. The Draft Development Control Plan proposes recreational uses based on the following criteria:

- uses which are compatible with the preservation of existing flora and fauna;
- uses that require minimal works and facilities;
- uses that can be enjoyed by participants but do not inconvenience other people;
- uses that will not conflict with the conservation objectives of the plan of management; and
- existing uses that can be managed so their environmental impact is minimal.

From this list, the following uses were deemed suitable:

- picnicking;
- fishing;
- water craft;
- swimming;
- photography;
- bird watching;
- walking, jogging and cycling;
- caravan and camping activities; and
- games.

The plan proposed an extensive foreshore broad walk and cycleway. Most active uses and water-based uses were focussed on the southern shore of the area immediately behind the lagoon entrance.

3.4 Future Development Potential

The catchment area of Avoca Lagoon is not developed to the capacity permitted under the current zonings. There are no known plans to intensify development densities permitted within the study area.

There is a significant area of land around the lagoon foreshore which is zoned for open space or public reserve.

Some redevelopment within the current urban areas is likely as holiday cottages are replaced by permanent residences and home unit blocks. There is some evidence of this redevelopment occurring at a number of locations around Avoca Lagoon.

It is also possible that some expansion of the existing urban areas may take place in the future in response to development pressures. However, the catchment characteristics are unlikely to change to a significant degree in the foreseeable future.

3.5 Climatic Change

The Greenhouse Effect is the term used to describe a postulated warming of the earth resulting from the accumulation in the atmosphere of certain gases, in particular carbon dioxide produced by the burning of fossil fuel.

The current consensus of scientific opinion is that a global warming of 1.5 to 4.5^0 C could occur over the next 30 to 50 years. Such a global warming could lead to changes in climate, rainfall and ocean levels.

A range of ocean level rise scenarios of between 0.13 and 0.32 metres over the next 50 years have been postulated. An allowance of 0.2 metres for ocean level rises over the next 50 years is seen as a reasonable design assumption.

The effect of a general increase in ocean levels will be to increase the level to which the beach berms will build up and to increase the tailwater control level for runout from the lagoon by an equivalent height.

It is also predicted that the severity of storms will increase, rainfall intensities could increase and there could be a more severe wave climate.

The hydraulic model results for the flood study show that the height of the peak lagoon flood level above the beach berm level decreases with increasing beach berm height. This is due to the increasing storage available within the lagoon as the lagoon water level rises.

The net result of higher ocean levels producing higher beach berms is that flood levels in the lagoon will be increased by a marginally lesser amount than the rise in ocean level produced by the Greenhouse Effect.

Therefore, it is considered appropriate to adopt an allowance of 0.2 metres for the potential rise in flood levels produced by the Greenhouse Effect.

4. FLOOD DAMAGES ASSESSMENT

4.1 Flood Damages

Flood damages are divided into categories as follows:

- direct damages - the effects of flood inundation on buildings and contents;
- indirect damages - the costs of evacuation, temporary accommodation, clean-up, loss of income etc; and
- intangible damages - the effect of floods on the health and psyche of the community.

Flood damages have been assessed using the ANUFLOOD (Ref. 8) flood damages model which was developed at the Centre for Resource and Environmental Studies at the Australian National University. The model is designed to assess potential direct damages resulting from flooding of urban areas. Estimates of indirect damage are not produced as outputs from the model. Intangible damages, which are also relevant in floodplain management, are not specifically considered in the model.

The model assesses the potential direct, tangible damage to property. The actual damages resulting from a flood may be less than the estimated potential damage if sufficient warning is given to evacuate and house contents can be removed or relocated above flood level.

The catchment response time for flooding of Avoca Lagoon is relatively short, therefore, it is considered that actual flood damages are unlikely to be significantly less than the estimated potential damages. Therefore, the assessment of flood damages was based on potential damage.

The ANUFLOOD model uses three sets of input data:

- a property database;
- a flood stage-frequency distribution for the study area; and
- stage-damage relationships specifying for different classes of property, the estimated potential direct damage to be sustained at differing depths of flooding.

The information for the property database was obtained as part of the floor level survey of properties which were located within the area inundated by the one percent AEP design flood, as determined in the flood study and shown on Figure 2.6. The floor level data appears as Appendix A.

The flood stage-frequency distribution was based on the results of the hydraulic modelling carried out for the flood study. The flood stage-frequency distribution adopted for the damages assessment is presented in Table 4.

TABLE 4

Avoca Lagoon Flood Stage-Frequency

AEP (%)	Lagoon Level (m AHD)	Entrance Level (m AHD)
50	2.8	2.8
20	3.1	3.1
10	3.3	3.3
5	3.45	3.5
2	3.56	3.7
1	3.60	3.8
0.1	3.70	4.0
PMF	4.45	4.45

The ANUFLOOD model contains stage height-damage relationships based on floods up to the mid 1980's.

More recent flood events, where flood damage data is available, occurred at Nyngan in 1990 and in Inverell in 1990. This flood damage information has been used after adjustment to 2003 dollar values for house contents and structural damage.

There has not been a significant recent flood in Avoca and it was thus considered that there was little value in attempting to estimate damages simply by resident interview.

The stage damage relationships were based on damages survey data collected for the 1990 flood at Nyngan. The damages estimates were corrected to 2003 dollar values.

The analysis of the information collected after the 1990 flood at Nyngan indicated that the indirect damages associated with flooding are:

- evacuation, temporary accommodation and loss of wages: $640/household/day.
- clean-up: $2,560 to $3,070/premises.
- loss of trade: $2,560/working day.

For a short duration flood, the indirect damages, based on the above figures, are equivalent to 15 percent of potential direct residential damage and 12 percent of potential direct damages for commercial properties.

Actual damage is defined as that damage which would occur after protective measures were undertaken. Protective measures include evacuation, raising or relocating contents to upper floors and removing vehicles to higher ground.

Considerable reduction in flood damages can be achieved with adequate warning and appropriate community response. The ratio of actual to potential damage depends primarily on flood magnitude, prior experience of flooding and warning times.

The hydraulic model results for the one percent AEP design flood show that the lagoon level rises approximately 600 millimetres to top-of-bank level over a period of 6 to 7 hours. This corresponds with the onset of higher intensity rainfall which produced a lagoon level rise of approximately 1 metre over a period of 4 hours.

Thus, the length of time available for mobilization and flood protection activities is unlikely to exceed 6 hours. This time may be significantly less if the flood occurs during the night, when darkness will restrict observation of flood levels and delay mobilisation and flood protection activities generally.

The highest recorded flood level for Avoca Lagoon occurred on 3 February 1990 when the lagoon level reached RL 2.43 metres before the entrance was opened by back-hoe. This highest recorded flood level is below the top-of-bank level for the lagoon.

The general community has no direct experience of major flooding from the lagoon. A small number of residents in Tramway Road would appear to be the only members of the community with direct experience of lagoon flooding.

It is considered that actual direct flood damages will be only slightly less than potential direct damages due to the relatively short warning time available and general absence of community experience with flooding.

It is unlikely that any reduction in direct damages can be achieved by residents adjacent to the entrance due to the uncertainties in forecasting ocean storm conditions.

4.2 Residential Properties

The floor level survey revealed that there are 35 residential properties adjacent to Avoca Lagoon with floor levels below the estimated one percent AEP flood level. This includes 21 residential properties adjacent to the lagoon entrance which are below the estimated level of inundation by ocean waves produced by an extreme storm at sea. Only a few properties in Ficus Avenue, Avoca Beach are above this level.

Ocean waves can cause structural damage to properties as well as water damage caused by inundation as shown on Figure 4.1. These photos of Ficus Avenue were taken after the extreme ocean storm events in June 1974.

There are nine (9) properties in Lake Street and Tramway Road, North Avoca with floor levels below the one percent AEP design flood level for Avoca Lagoon. The remaining four (4) properties are located in and adjacent to the caravan park at the southern end of the lagoon.

The floor levels of the properties are distributed over a range of levels, as indicated by Table 5 below.

TABLE 5

Distribution of Floor Levels

Floor Level Equal to or Less Than (m AHD)	Number of Dwellings Equal to or Below Floor Level Specified						
	Precinct						
	1	2	3	4	5	6	7
3.0	2	3	0	0	0	1	5
3.2	2	5	0	0	0	2	10
3.4	5	8	0	0	0	4	13
3.6	5	**9**	**0**	**0**	**0**	**5**	14
3.8	**7**	12	0	0	0	5	**14**
4.0	7	18	0	0	0	5	14
4.2	10	22	0	0	0	5	14
4.4	11	26	0	0	0	5	14
4.6	13	28	0	0	0	5	14
4.8	13	30	0	0	0	5	14
5.0	13	34	0	2	0	5	14

Note: **Underlined Bold** refer to 1% flood levels in each precinct

The estimated potential direct damages to residential properties for a range of probabilities are shown in Table 6 below.

TABLE 6

Potential Direct Damages to Residential Properties

AEP (%)	Damages (in thousands of dollars)		
	Lagoon ($)	Entrance ($)	Total ($)
10	138.4	211.8	350.2
5	217.3	358.6	575.9
2	259.1	481.2	740.3
1	273.9	615.7	889.6
PMF	880.6	550.3	1,430.9

Note: Dollar values based on assessment at Sep 2003

The estimated mean annual damage for residential properties around the foreshores of Avoca Lagoon is $155,280, equivalent to $3,980 per residential property.

4.3 Commercial Properties

The local business area is located in Avoca Drive between the south arm of the lagoon and the beach front. Only three commercial properties have floor levels which are below the one percent AEP design flood level.

The floor level of the Scout Hall located on the shoreline of the lagoon some 200 metres west of the bridge over the entrance to the southern arm of the lagoon is approximately 700 millimetres below design flood level.

The estimated potential direct damages to commercial properties for a range of flood probabilities are presented in Table 7 below.

TABLE 7

Potential Direct Damages to Commercial Properties

AEP (%)	Damages (in thousands of dollars)		
	Lagoon ($)	Entrance ($)	Total ($)
10	16.7	-	16.7
5	20.6	8.0	28.6
2	21.9	11.8	33.7
1	22.5	13.1	35.6
PMF	37.0	26.7	63.7

Note: Dollar values based on assessment at Sep 2003

The commercial properties included in the above analysis are located near the entrance to Avoca Lagoon and are affected by ocean storm waves. There are a number of adjacent commercial properties which are located above the estimated one percent AEP ocean wave action level. However, 11 of the properties are located below the estimated PMF level.

The estimated mean annual damage for commercial properties (including the Scout Hall) is $7,120, equivalent to $1,760 per property.

4.4 Public Utilities

The extent of land inundated in the one percent AEP design flood covers some 22 hectares of floodplain between The Scenic Highway and the upper limits of Avoca Lagoon and approximately five (5) hectares of land around the perimeter of the lagoon.

The inundated area comprises public reserve and open space areas, rural private property and urban development areas.

A number of public utility works are located within the inundated area including:

- sewerage pumping stations;
- roads and carparks;
- parkland and sporting complexes;
- school grounds; and
- underground water, sewerage, power and telephone services.

Public utility damages can involve the replacement or repair of assets which suffer damage as a result of inundation and clean-up of debris deposited by floodwaters.

The lack of a recent flood at Avoca limits the opportunity to obtain actual utility damages. A suitable approach was thus seen as using the Nyngan flood data (which is well-documented) to ascertain a damage per unit area of developed land to estimate the public utility damages.

An analysis of public utility damage estimates for the Nyngan flood indicate that public utility damages were approximately $8,180 per hectare of inundated land. This public utility damage estimate is similar to that derived for the Narrabeen Lagoon Floodplain Management Study (Ref. 10). On this basis, the estimated mean annual damage for public utilities within the Avoca study area is $150,040.

4.5 Avoca Caravan Park

The Avoca Caravan Park extends over an area of approximately 2.5 hectares adjacent to the end of the south arm of Avoca Lagoon. There are approximately 90 caravan sites in the park which are predominantly occupied by permanent residents. The entire site is located below the one percent AEP design flood level for Avoca Lagoon.

The hydraulic modelling carried out for the flood study shows that floodwaters from the lagoon begin to spill onto the caravan park approximately 7 hours after the commencement of runoff into the lagoon and coincident with the most intense rainfall period. Floodwaters then reach a peak depth of 700 millimetres some 3.5 hours later.

Thus, it would be necessary to evacuate the park and remove most of the caravans within a period of less than 3 hours in order to minimise the damage to caravans and contents.

It is unlikely that mobilization for evacuation would begin until the floodwaters from the lagoon begin to spread out over the caravan park.

The estimated mean annual damages for the caravan park, excluding the manager's residence, is $91,310, equivalent to $1,020 per site.

5. FLOODPLAIN MANAGEMENT OPTIONS

5.1 Overview

Gosford City Council has adopted the one percent AEP as its designated flood for the purposes of floodplain management throughout its administration area.

This report concentrates on feasible options for protection against the designated or design flood but includes considerations of floods up to the Probable Maximum Flood (PMF) magnitude.

The flood-liable land around Avoca Lagoon is comprised of:

- open space, public reserve around the shoreline of the lagoon;
- residential development abutting the above open space public reserve; and
- rural development of the floodplain upstream of the lagoon.

The Floodplain Management Manual lists a number of structural and non-structural flood mitigation measures with can reduce the impact of floods.

Structural flood mitigation measures control the extent and depth of floodwaters. These measures include:

- flood mitigation dams;
- levees;
- by-pass floodways;
- channel improvements; and
- detention basins.

Flood mitigation dams and by-pass floodways are not considered to be feasible options for Avoca Lagoon due to the topography and size of the catchment area.

It may be possible to construct a detention basin upstream of the Scenic Highway to reduce flood discharges between the basin and Avoca Lagoon. However, there are no properties within this area which are located below the one percent AEP design flood level.

A detention basin would reduce the rate of rise of floodwaters in Avoca Lagoon but would not reduce the volume of floodwaters entering the lagoon. It is the volume of runoff which is one of the primary factors which determine flood levels in the lagoon.

Therefore, it is considered that a detention basin option is not practicable for the Avoca Lagoon foreshore and floodplain.

The flood-liable properties around the foreshores of Avoca Lagoon are located in relatively compact areas which could be protected by foreshore levees.

The flood study concluded that the level of the beach berm across the lagoon entrance was the major control for flood levels in Avoca Lagoon.

Therefore, channel improvements, specifically at the lagoon entrance, and levees are considered to be feasible options and worthy of full investigation.

Dredging of Avoca Lagoon has been mooted for flood protection. The measure is not seen as a practical option. Achievement of flood level reduction would require increasing the storage available above the current let-out-level. Whilst dredging would increase the total lagoon volumes, it would not increase storage above let-out-level and, consequently, no significant flood mitigation benefit is achieved.

Provision of a permanent opening from the lagoon to the ocean was briefly examined and discarded as not practical for several reasons, as follows:

- the coastal processes move sand along the beach relatively quickly to close any opening of the lagoon through the beach. The historical opening and closure regime of the lagoon to the ocean indicates there is insufficient tidal flows to maintain an open entrance without a significant Council intervention;

- the lagoon in its present form provides an important visual and recreational resources within the Gosford area. A permanent entrance would imply lowering of normal water levels by about 2 metres with attendant exposure of large areas of the lagoon bed; and

- significant lowering of the lagoon water levels would cause a major adverse environmental impact to the flora and fauna in the foreshores surrounding the lagoons.

Non-structural flood management measures are designed to reduce the impact of flooding on lands within the flood-liable area. These measures include:

- flood proofing of buildings;
- land use zoning controls;
- building and development controls eg minimum floor levels;
- voluntary purchase of flood-liable properties;
- flood insurance;
- public education; and
- flood warning and disaster planning.

The commercial conditions of flood insurance have shown the insurance option to be almost impossible to implement with equity. All other non-structural options are feasible, though with different measures of effectiveness.

5.2 Lagoon Berm Management

The Avoca Lagoon Flood Study concluded that the level of the beach berm across the entrance was the primary control for flood levels in the lagoon. The hydraulic modelling results showed that the peak flood level in the lagoon is approximately 300 millimetres above beach berm level for natural breakouts.

Council has a management policy for Avoca Lagoon whereby the lagoon entrance is mechanically opened when the water level reaches let-out-level, RL 2.09 m AHD. This policy was developed to minimise the risk of flooding of properties around the lagoon foreshore.

Analysis of the lagoon opening records shows that the beach berm level at the time of opening varied between RL 2.0 m AHD and RL 3.5 m AHD with a median beach level at RL 2.65 m AHD.

A beach berm level of RL 3.3 m AHD was adopted for the determination of design flood levels for the lagoon. The beach berm level can be expected to be higher than the adopted design level for approximately 10 percent of flood events.

A preliminary analysis of the lagoon opening records indicates that the beach berm would build up to RL 3.3 m AHD over a period of 7 to 8 months after an opening of the lagoon entrance. This is slightly longer than the average interval between flood control openings of the lagoon entrance.

The relationships between peak lagoon flood level and beach berm level is demonstrated on Figure 5.1 which shows the design flood envelopes determined by hydraulic modelling carried out for the Flood Study. Figure 5.1 shows that the peak flood level in Avoca Lagoon in the one percent AEP flood is RL 3.6 m AHD for a beach berm level of RL 3.3 m AHD and is RL 3.36 m AHD for a beach berm level of RL 3.0 m AHD.

Thus, a 300 millimetre lowering of the beach berm produced a 240 millimetre lowering of the flood level in Avoca Lagoon.

It would be necessary to lower the beach berm over a minimum distance of 60 metres to achieve this reduction in flood level.

It is estimated that a cutting through the beach berm 60 metres wide and 300 millimetres deep would be filled by wind-blown sand over a period of 10 to 12 weeks.

The record of lagoon entrance openings shows that the beach berm has built up above RL 3.0 m AHD on eight occasions over the period 1977 to 1992. The maximum recorded beach berm level is RL 3.55 m AHD.

It is estimated that it would have been necessary to remove sand from the lagoon entrance nine times over this period in order to maintain an effective beach berm level at RL 3.0 m AHD.

Similarly, it is estimated that it would have been necessary to remove sand from the entrance 18 times to maintain an effective beach berm level at RL 2.7 m AHD. The estimated one percent AEP flood level for this beach berm level is RL 3.08 m AHD, some 0.52 metres lower than the design flood level.

The cost for the periodic removal of sand from the beach berm is quite small when compared to the potential reduction in flood damages of this practice.

The dynamics of the lagoon entrance opening are dependent on a number of factors, including:

- beach berm level and width of beach;
- lagoon water level;
- beach sand grading and compaction; and
- runoff entering the lagoon.

The ocean level has no impact on the initial stage of the opening process which is weir flow dependent on the lagoon water level. However, once the entrance channel has been scoured out and the weir collapses, the level difference between the lagoon and the ocean controls the flow of water out of the lagoon and the continuing rate of scour of the entrance.

The entrance and adjacent beach are extremely active areas with the result that there can be considerable variation in beach berm level and geometry depending on ocean conditions. The compaction of the beach sand is also variable, being fully compacted where saturated and of variable composition where dry.

There can be considerable variation in the time taken for the entrance channel to be formed and in the final width of the channel as a result of the velocity in each of the factors affecting the process. Review of the aerial photography taken over the past 40 years indicates that the entrance channel width can vary between 30 and 110 metres in width with a typical width of about 75 metres.

Similarly, there can be a wide variation in the time taken for the entrance to form. The entrance channel took some 5 to 8 hours to form when opened in September, 1993, compared with 1.5 hours when opened in January 1986.

It is considered unlikely that it is possible to alter the management of the entrance in order to effectively and reliably reduce the width of the channel and opening times.

5.3 Levees

There are nine (9) residential properties in Lake Street and Tramway Road, North Avoca which have floor levels below the design flood level. It would be possible to construct a low levee 600 metres long and up to 900 millimetres high to protect these properties.

The possible levee route is indicated on Figure 5.2. The levee would be located in public reserve land along the shoreline within SEPP 14 Wetland Site 911. There could be significant impact on the local environment as a result of this levee construction.

The Avoca Caravan Park and three (3) adjacent properties at the southern end of the lagoon are also located on flood-liable lands. The runoff from a catchment area of 93 hectares drains through the caravan park to Avoca Lagoon. It would not be possible to convey all the runoff from this sub-catchment to Avoca Lagoon within a piped drainage system. Therefore, a levee around the caravan park area to protect from lagoon flooding would tend to act more as a detention basin, causing water levels to rise more rapidly within the caravan park.

Therefore, it is considered that a levee around the caravan park area would exacerbate flooding in the area which was to be protected. A levee is considered inappropriate for this location.

5.4 Planning Controls

The Local Environmental Plan sets out the types of development permissible for land within each zone shown on Figure 3.2. The principal land zonings are summarised in Table 8 below.

TABLE 8

Principal Land Zonings
Avoca Lagoon Environs

Zone	Permitted Development
Residential 2(a)	Single dwellings
Residential 2(b)	Dwellings, townhouses, motels.
Residential 2(f) Beach frontage	Detached dwelling houses (with consent) amalgamation of lots, minor boundary changes.
Business 3(a)	Retail and commercial.
Open Space 6(a)	Recreation
Conservation and Scenic Protection 7(a) 7(c2) 7(c3)	 Dwelling houses, parks and gardens. Rural small holdings. Tourist development.

Building floor levels are regulated through Council's flood policy. This policy sets a minimum floor level for new development around Avoca Lagoon at RL 3.7 m AHD. This provides less than 0.1 metre clearance above the estimated one percent AEP design flood level for Avoca Lagoon.

Gosford Council has adopted a Coastal Lagoons Management Plan (1995), which seeks to manage land use within the Avoca Lagoon catchment plus other issues such as water quality, foreshore improvement, vegetation and fauna management, and fisheries and wetland management.

Parts of the lagoon foreshore are affected by SEPP 14 - Coastal Wetlands. The gazetted wetlands are shown on Figure 3.1.

Examination of the zonings on Figure 3.2 shows the lagoon foreshores as essentially residential 2(a), Open Space 6(a) and Conservation and Scenic Protection 7(a). Future development within the confines of the current zonings are thus seen as essentially single dwelling construction, as infill or redevelopment with the Residential 2(a) zone and single dwellings on large lots in the Conservation and Scenic Protection zone.

Gosford City Council, in the application of floodplain management plans throughout their administrative area, identifies flood-liable land by hydraulic categories. In this case, the categories of "Floodway" or "Flood Storage" apply.

The adopted definitions of "Floodway" and "Flood Storage" are:

> ***Floodways*** are those areas where a significant volume of water flows during floods. They are often aligned with obvious naturally-defined channels. Further, floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, which may, in time, affect other areas. They are often, but not necessarily, the areas with deep flow or areas where higher velocities occur.
>
> ***Flood Storage*** areas are areas which temporarily retain water during the passage of a flood. In these areas, the flow velocity, and therefore the flood hazard, is much less than the hazard within a Floodway.

The provision of Floodways has added benefits:

- floodways allow retention of the existing stream environment;
- they can accommodate floods larger than the designated flood; and
- a clearly visible Floodway constantly provides flood awareness to the local community.

In the distant future, the Floodway may provide the opportunity for improvement of the stream conveyance if it is necessary following on-going development. However, once defined, the Floodway should never be compromised. Small changes occurring progressively would, in time, cause a significant change to the flow capacity.

A concise description of the general requirements for **Floodways** is as follows:

- Floodways should be maintained in perpetuity for the passage of floodwaters;
- no landscape planting should be undertaken where it would hinder the conveyance of water;
- no work that would impede the passage of floodwaters should be permitted in a Floodway;
- no buildings should be permitted to be constructed in the Floodway;
- filling is prohibited in the Floodway;
- fences likely to collect debris and/or impede floodwaters are not permitted;
- all land uses should be flood-compatible; and

- proposals to cross the Floodway with services of major importance to the area could be permitted subject to conditions.

Floodways would need to be crossed by major service installations of importance to the area. These should be permitted in the Floodway provided they were investigated adequately and designed in a manner that did not significantly affect flood flow capacity or flood levels. They should also be designed so as to reduce damage potential to the services to the absolute minimum.

The requirements for Flood Storage areas should be less rigid than the Floodways. New buildings, desirably, should not be located within the Flood Storage area. If, however, exclusion of individual buildings is not practical, development will be considered, providing such development satisfies all constraints including the specified minimum floor levels and controls on any fill for buildings.

Application of Hazards to Avoca Lagoon and Environs

Flood hazard categories have been assigned in Chapter 2 and illustrated on Figure 2.5. The classifications adopted are consistent with the definitions above.

The bulk of the lagoon study area is classified as "Low Hazard, Flood Storage" with "High Hazard Floodways" at the upstream end (Precincts 4 and 5).

The High Hazard Floodway/Investigation at the lagoon entrance (Precincts 1 and 7) has been adopted due to the possible occurrence of ocean storms over-washing the beach. This area is considered best treated as a coastal hazard management process rather than a floodplain management process.

Within the **Flood Storage** areas (Precincts 2, 3 and 6), appropriate options are seen as:

- Council urge no further development within the floodplain areas;

- new buildings to be set with minimum floor levels of RL 3.7 m AHD (consistent with the current policy). Council strongly urge adoption of the higher levels given in the Flood Study;

- filling for new development in the Flood Storage areas would be restricted to the building footprint only, providing the drainage of adjacent blocks is not affected;

- new buildings should have some form of emergency access so that if flooding does occur, the occupants can reach flood-free ground along a route with gradually reducing flood depths; and

- permitting the filling of blocks to a limit of 0.2 metres above the "let-out-level" to provide some amenity to low lying parts of blocks.

Within the **Floodway** categories (Precincts 4 and 5), the most appropriate action is seen as:

- no new buildings be permitted in the Floodways;

- no further filling of the Floodway should be permitted;
- access bridges and roadways to be set nominally above existing floodplain levels such that flood levels are not increased by more than 0.01 metres in the design flood;
- fences on the floodplain to be of flood compatible variety such that their construction does not impede flood flows or debris;
- landscaping and planting should not increase the impedance to flow down the floodways; and
- proposals to cross the Floodway with services of major importance to the area would be permitted provided that the proposals are adequately investigated and designed in a manner that does not significantly affect flood-flow capacity and flood levels.

The aims of the above measures are seen as allowing limited works whilst retaining the Floodway status of the floodplain. Thus, landscaping and changes to the form of the floodway are possible, provided that flood flow capacity, and flood storage capacity are not reduced, nor flood flow velocities increased.

The measures above for both Flood Storage and Floodway areas are sufficiently general to enable site specific details to be determined at each block in the knowledge that the allowed developments will not aggravate flooding problems.

The minimum floor level recommendation option follows from the results of the Flood Study which indicated that flood levels within the lagoon are principally dependent on the beach berm level at the time of the flood. The Flood Study addressed the variable berm height by suggesting an appropriate berm height as one that was exceeded only 10 percent of the time, thus presenting a conservatively high flood level. An alternative argument is that the median level (that is the level which is exceeded 50 percent of the time) is appropriate. In the median berm level approach, the design one percent AEP flood level would fall to RL 3.05, where Council's current floor policy would provide 0.5 metres clearance to the design event.

The recommendation for limitation of the filling of the flood storage areas is derived from testing the impact of filling with the computer models developed in the Flood Study. This analysis showed that filling all the flood liable land that is currently zoned for "Residential uses" would cause an increase in flood levels of 20 millimetres in the design one percent AEP. This increase exceeds the Council's adopted standard of 10 millimetres for this flood event. Thus, filling of all sub-divided land would exceed Council's standard.

An equitable compromise is seen as allowing filling beneath building "footprints" which will produce some increase but not as significant as filling the whole site.

Given that the increase in flood levels is some 20 millimetres, it is anticipated that the filling will not create any measurable change in the rate of rise of floodwaters in Avoca Lagoon.

5.5 Floodproofing of Buildings

Floodproofing of buildings in flood-liable areas is an effective method of reducing flood damage to the structure and contents. One of the most effective means of floodproofing for residential buildings is to raise habitable floor levels above flood level. However, this is only feasible with timber-framed and clad construction or steel framed and clad construction.

Twelve (12) of the 39 residential properties affected by lagoon or ocean flooding within the study area are of brick or brick-veneer construction and cannot economically be raised above flood level.
There are only three (3) residential properties affected by lagoon flooding only which are unsuitable for raising. Voluntary purchase of these properties may be a suitable option for these landowners and is addressed in the next section.

There are nine (9) residential properties adjacent to the lagoon entrance which are unsuitable for raising above ocean storm wave heights. These houses and adjacent properties are prone to greater damage from ocean storm wave activity than from lagoon flooding. Protection for these and other beachfront properties is primarily a coastal management consideration.

5.6 Voluntary Acquisition

Voluntary acquisition of property is an option to virtually remove the flood damage potential.

However, the high cost of voluntary acquisition implies that it is generally only used in High Hazard Floodways where no other solution exists.

There are no residences in the upstream floodway (Precincts 4 and 5) that are below design flood level and thus this option is not applicable for these areas.

Property acquisition would be an option for the High Hazard Floodway near the lagoon outlet (Precincts 1 and 7) though this can be expected to attract very high costs and strong opposition from landowners. In this instance it has been assumed land acquisition costs between $447 300 and $511 200 per block would be involved.

5.7 Flood Warning and Public Education

The last significant flood occurred in February 1990 when the lagoon water level rose to 430 millimetres above let-out-level before the entrance was opened. The lagoon was well below let-out-level prior to the commencement of rainfall and rose 1 metre over a period of 6.5 hours before the entrance was opened.

It generally takes 3 hours to organise an emergency opening of the lagoon entrance. Hydraulic modelling results show that the water level in the lagoon can rise 700 millimetres during this time.

Council has recently installed automatic water level recorders on each of the coastal lagoons with telemetry to Erina Works Depot. This should enable improved monitoring of lagoon level rate of rise and enable earlier mobilization for opening of the lagoon entrance.

The earlier mobilisation and associated earlier opening of the lagoon outlet will achieve a reduction in flood levels and, consequently, flood damage. This occurs as earlier outflow from the lagoon on the rising limb of the flood prevents the lagoon rising as high.

A questionnaire was distributed to 80 properties within the study area seeking information on flooding around Avoca Lake. Of the 20 responses received, only 9 respondents had been affected by floodwaters on their property, while another 5 residents had some knowledge of lagoon floods.

Thus, there appears to be a general lack of community awareness of the possible extent of flooding from Avoca Lagoon. This is largely due to the effectiveness of Council's policy of opening the lagoon entrance when the level rises above the adopted let-out-level.

It is considered that public awareness of the potential flooding of the lagoon foreshores would be improved following a public education programme. A simple brochure outlining the relevant issues and distributed to all residents within the study area could be a satisfactory means of increasing the general awareness of the community.

The bulk of the flood liable properties in the Avoca Lagoon area are within "Low Hazard - Flood Storage" classifications. There are no flood liable buildings within the "High Hazard Floodways" entering the lagoon area. Thus, flooding is seen as a potential threat to property and possessions but not to human life.

It is thus considered that:

- the threat to life is not sufficient to justify flood warnings by sirens and the like;

- public acceptance and knowledge of flooding could be enhanced by provision of two staff gauges in Avoca Lagoon showing the "let-in-level" and design 1% AEP flood levels.

5.8 Future Upstream Development

There is the potential for future development in the catchment upstream of Avoca Lagoon.

In assessment of upstream development, it is useful to note:

- future development can be expected to conform with the existing planning controls and thus development in "Floodways" should not occur;

- the future development will affect run-off potential over the full range of rainfall events;

- mitigation measures against increased run-off are essentially forms of detention basins which delay and reduce peak flows but do not reduce run-off volumes;

- Avoca Lagoon essentially acts as a storage basin. The frequency of reaching its "let-out level" depends on the combination of rainfall and evaporation.

Thus, future upstream development can be expected to cause more frequent "let-out" of Avoca Lagoon, though without a long term simulation of Lagoon behaviour, the change cannot be exactly quantified. The increase in frequency in "let-out" is not expected to be significant.

Conversely, the change in runoff from future development and its impact on Avoca Lagoon itself (in a flooding sense) is unlikely to be mitigated by current technologies. Nonetheless, current technologies may need to be applied to protect the waterways reaching Avoca Lagoon.

Significant erosion of the catchment (either naturally occurring or following future development) will have a major impact on Avoca Lagoon.

The eroded material will be deposited in Avoca Lagoon, thereby:

- reducing the storage available below the "let-out level" and thus increasing the frequency of reaching the "let-out level"; and

- reducing the storage available above the "let-out level", thus potentially giving higher flood levels.

6. FLOODPLAIN MANAGEMENT OPTIONS IMPACTS

The aims of floodplain management are to reduce:

- personal and public losses;
- risk to the safety of residents in flood-liable areas;
- post flood trauma in the local community; and
- impact of floods and flood mitigation works on the environment.

6.1 Reduction in Damages

Flood damages to existing private and public property can be reduced by providing protection for flood-liable development or by relocating existing development above flood level or to flood-free areas. Flood damages to future development can be minimised by ensuring that such development does not occur in flood-liable areas or is located above flood level.

Thus, reduction in flood damages is achieved by structural and non-structural processes. The estimated reduction in direct flood damages for the various floodplain management options considered feasible for Avoca Lagoon are summarised in Table 9.

TABLE 9

Direct Flood Damages Reduction
For Existing Development

Option	Reduction in Mean Annual Damages ($)	Benefitting Areas (Precinct Numbers)
Maintain Beach Berm Level at RL 3.0 m AHD	13,670	2, 3, 4, 6
Maintain Beach Berm Level at RL 2.7 m AHD	37,190	2, 3, 4, 6
Lake Street Levee RL 3.6 m AHD	61,730	2
House Raising	108,120	1 to 7
Flood Warning	22,110	2, 3, 4, 6
Voluntary Acquisition	92,270	1, 7

The values in Table 9 represent a reduction in damage, a benefit accruing as a result of implementation of the option.

The benefits accruing thus apply to existing developments on the basis that new development will be essentially flood-free.

6.2 Environmental Effects

Improved management of the beach berm level at the entrance to Avoca Lagoon will not result in more frequent opening of the entrance but may result in a marginal increase in the volume of seawater entering the lagoon during ocean storm periods. This is expected to have a negligible impact on the water quality within the lagoon.

The established regime of the lagoon and foreshore areas will not be altered as a result of periodic lowering of a section of the beach berm. Therefore, this option is considered to have no impact on the lagoon environment.

The route of the proposed levee to protect development in Lake Street and Tramway Road lies partly in the gazetted wetland 911. It will be necessary to prepare and EIS as part of the approval process for this option. The route passes through a habitat area of the threatened Green and Golden Bell Frog.

The effects of constructing a levee would be to downgrade the visual amenity of the foreshore and adjoining properties. Construction of the levee could result in the loss of significant foreshore vegetation and loss of the habitat for a threatened frog species. The levee bank will have the effect of increasing the steepness of the foreshore and possibly making access to the lagoon more difficult.

Drainage of low-lying land behind the levee would require careful consideration to prevent flooding of properties by runoff ponded behind the levee.

The levee embankment could form part of a cycleway around the foreshore in accordance with Council's proposal in the Avoca Lake DCP. This would provide improved access to the foreshore area in general.

There is an existing rough track along part of the proposed levee route. This track provides rear access to a number of properties in Lake Street.

Raising floor levels as part of a co-ordinated programme will have negligible impact on the environment of the lagoon and foreshore areas. However, the general appearance of the residential development will be changed. Careful design of each house raising will be required in order to ensure minimal adverse visual impact on the streetscape. The implementation of such a programme will require the agreement of landowners.

The automatic water level recorders and telemetry installation have been installed adjacent to the Avoca Drive bridge over the entrance to the southern arm of the lagoon. This installation provides no visual or environmental impacts.

The more rapid response to rising lagoon water levels should result in a general lowering of floodwaters thus reducing the impact of debris around the foreshores and reduce the clean-up of the foreshore area.

6.3 Social Impacts

The options of beach berm management and improved entrance opening through flood warning are seen as having little social impact. In the main, these measures will be transported to the community and thus incur little social impact. The community acceptance of these measures is viewed as highly likely.

The levee construction would have an initial social impact during construction on the affected properties but this would diminish after construction completion. The affected landowners will probably feel a loss of amenity of their properties through the levee construction - their loss of views across the lagoon and its foreshores and their loss of access to the lagoon. The probable community acceptance of this measure is seen as low.

House raising, whilst providing flood benefits, can create a significant change to the lifestyle of the property owners.

The change flows from the raising of floors significantly with attendant access difficulties in reaching living areas from ground or street level. Such access difficulties are more acutely felt by the elderly and the disabled. The property owners may not see the benefit of flood protection as commensurate with the loss of access.

Similarly, the house raising will change the architectural style of the buildings and the general streetscape. Such changes may not be acceptable to all property owners.

The voluntary acquisition of houses near the beach front would provide greater community access to the lake foreshores and to the beach front. However, strong opposition could be expected from the landowners given the location in an area generally perceived by the community as a prime location.

One of the difficulties faced by floodplain and coastal management planning is the rarity of major events. The community acceptance of floodplain management plans can be expected to be high if instituted immediately after a significant flood event. However, community acceptance would diminish with increasing time after the event.

6.4 Floodplain Management Options Economic Evaluation

The economic evaluation of alternative floodplain management options is most easily carried out using a benefit-cost analysis.

The benefits derived from floodplain management include:

- tangible benefits: reduced direct and indirect damages; and
- intangible benefits: reduced stress, trauma and improvements in numerous social factors.

It was concluded in Chapter 4 that actual direct flood damages are unlikely to be significantly less than estimated potential direct damages due to the relatively short warning time available in major floods. Hence, all direct damage estimates have been prepared on the basis of potential direct damages.

Previous damages studies have concluded that indirect damages for predominantly residential development are equivalent to 15 percent of direct damages. This ratio has been adopted for the current study.

The economic evaluation of options has been based on mean annual damages and annual costs of the options. This approach is considered appropriate as none of the options under consideration involved staged construction which would affect the cash flow and "net present value" of future costs.

The annual costs of the various options comprise annual operating and maintenance costs and interest and redemption payments over the economic lifetime of the options. The annual costs were estimated for discount rates of 7.5 percent, equivalent to the current interest rate, net of inflation, and 12.5 percent to test the sensitivity of the results to changes in economic conditions.

The estimated capital costs of structural works has been based on current construction rates. Annual operation and maintenance cost have been assessed at 2 percent of capital cost.

The economic comparison of the floodplain management options is summarised in Table 10. The analysis has been based on an economic planning period of 50 years.

TABLE 10

Economic Comparison of Floodplain Management Options

Economic Parameter	Management Option					
	Lower Beach Berm		Lake Street Levee	House Raising	Flood Warning	Voluntary Acquisition
	RL 3.0	RL 2.7				
Capital Cost	-	-	269,500	862,700	12,800	14,058,000
Annual Interest and Redemption @ 7.5% Discount	-	-	16,290	66,460	1,850*	1,086,300
Annual Interest and Redemption @ 12.5% Discount	-	-	26,450	108,120	2,300*	1,763,640
Annual Operation and Maintenance	1,280	2,560	4,220	-	1,280	-
Total Annual Cost @ 7.5% ($)	1,280	2,560	20,510	66,460	3,130	1,086,300
Total Annual Cost @ 12.5% ($)	1,280	2,560	30,670	103,010	3,580	1,763,640
Reduction in Direct Residential Damages ($)	13,670	37,190	61,730	108,120	22,110	92,270
Reduction in Indirect Residential Damages ($)	2,040	5,580	7,400	16,230	3,250	13,840
Reduction in Direct Commercial Damages ($)	-	-	-	-	-	-
Reduction in Indirect Commercial Damages ($)	-	-	-	-	-	-
Reduction in Damages Public Utilities ($)	3,090	15,920	700	-	7,600	-
Total Reduction in Damages ($)	18,800	58,690	69,830	124,350	32,960	106,110
Benefit-Cost @ 7.5% pa	14.7	22.9	3.41	1.87	10.53	0.10
Benefit-Cost @ 12.5% pa	14.7	22.9	2.28	1.21	9.21	0.06

Notes: * 10 year replacement period adopted for instrumentation

The results presented in Table 10 show that house raising provides the greatest reduction in flood damages but also incurs the highest cost. The benefit-cost ratio is marginally greater than unity.

Lowering the beach berm at the entrance of Avoca Lagoon is the least cost option and yields a very high benefit-cost ratio, in excess of 14.

7. COMPARISON OF FLOODPLAIN MANAGEMENT OPTIONS

7.1 Comparison

The economic comparison of floodplain management options indicates that lowering the beach berm level and improved flood warning are options with very favourable benefit-cost ratios.

However, there are several other factors to be considered in the selection of the preferred management options. These factors include:

- environmental impacts;
- social impacts;
- effectiveness; and
- economic considerations.

One suitable method used to compare options is to prepare a comparison matrix. This enables direct comparison of all options against relevant criteria. The process can be carried out in stages, as follows:

- initial review of options to enable concentration on practical options;
- comparison of raw matrix data to determine options worthy of further consideration;
- applying weighting factors to evaluation criteria; and
- comparing weighted performance to select preferred option.

An initial review in Chapter 5 outlined several options that were discarded as not practical. These options were:

- retention/retarding basins in the catchment; and
- dredging of the lagoon.

These options have not been considered further.

The raw comparison matrix for feasible floodplain management options for Avoca Lagoon is shown on Table 11 which illustrates six options against 19 criteria.

The evaluation criteria in the comparison matrix are defined as follows.

Properties Protected in Design Flood - number of existing flood-liable properties which would not be flooded in Design Flood as a result of option.

Properties Protected in PMF - number of existing properties in study area which would not be flooded in PMF as a result of option.

Reduced Flood Risk - assumed to be equivalent to the percentage reduction in mean annual damages as a result of option.

Localised Adverse Hydraulic Impacts - defined as increases in depth, velocity or rate of rise of floodwaters in or adjacent to protected area.

Capital Cost - estimated cost of investigation, design and construction of works option.

Operating Cost - annual operating and maintenance costs.

Damage Reduction - reduction in mean annual damages due to option.

Benefit-Cost Ratio - ratio of reduction in mean annual damages (direct and indirect) to full annual cost of option.

Economic Sensitivity - ratio of change in benefit-cost ratio for 1 percent variation in discount rate.

Financial Staging - ratio of initial capital investment in option to total capital investment.

Affordability - ratio of least-cost option to cost of option.

Access - ratio measure of serviceability of road network during flood periods.

Utility Services - ratio measure of failure of utility services during flood periods compared to existing conditions.

Safety - ratio measure of the reduced risk to life within flood affected areas derived from the reduction in properties flooded.

Community Acceptance - perceived relative acceptance of option by the community in general and those directly affected by option.

Flora - impact on existing flora due to option.

Fauna - impact on fauna and habitat due to option.

Visual Impact - impact of option on local landscape.

Recreation - impact of option on recreation use of lagoon and foreshore areas.

TABLE 11
Comparison Matrix For Floodplain Management Options

Criteria		Management Option					
		Lower Beach Berm		Lake St Levee	House Raising	Flood Warning	Voluntary Acquisition
		RL 3.0	RL 2.7	RL 3.6			
1.	**Function**						
1.1	Reduction in Design Flood Level (m)	0.24	0.52	0	0	0	0
1.2	Properties Protected in Design Flood	1	6	9 (a)	27	3	26
1.3	Properties Protected in PMF	7	12	-	27	3	26
1.4	Reduced Flood Risk	9%	24%	32%	69%	14%	67%
1.5	Localised Adverse Hydraulic Impacts	No	No	Yes	No	No	No
2.	**Economics**						
2.1	Capital Cost ($)	-	-	140,580	862,650	12,780	14,058,000
2.2	Operating Cost ($)	1,280	2,560	2,810	-	1,280	-
2.3	Damage Reduction ($)	18,810	58,700	69,060	124,350	35,520	108,670
2.4	Benefit-Cost Ratio	14.7	22.9	3.41	1.87	10.53	0.1
2.5	Economic Sensitivity	0	0	0.3	0.13	0.16	0.008
2.6	Financial Staging	0	0	1.0	0.2 (b)	1.0	0.1 (c)
2.7	Affordability	1	0.5	0.09	0.02	0.41	0.001
3.	**Social Issues**						
3.1	Access	1.25	5	1.0	1.0	2.5	1.0
3.2	Utility Services	1.3	4.0	1.0	1.0	4.0	1.0
3.3	Safety	1.03	1.1	1.32	3.3	1.09	3.0
3.4	Community Acceptance	High	High	Low	Low	High	Very Low
4.	**Environmental Impact**						
4.1	Flora	No	No	Yes	No	No	No
4.2	Fauna	No	No	Yes	No	No	No
4.3	Visual Impact	No	No	Yes	Possible	No	Improve
4.4	Recreation	No	No	Yes	No	No	Improve

Notes: (a) flood-liable properties only.

(b) 5 year implementation program.
(c) 10 year implementation program.

The voluntary acquisition option is not seen as economically viable because of high cost and very low benefit/cost ratio. This option is unlikely to be acceptable to affected landowners or to the community at large. It has not been considered further.

The comparison matrix for feasible floodplain management options for Avoca Lagoon in Table 11 shows that house raising is the most effective option for reducing the impact of floods as measured by reduction in damages in the study area. It is also the most expensive feasible option and has a benefit-cost ratio a little greater than unity.

This option protects the majority of properties from lagoon flooding and ocean waves. The general appearance of the residential areas could be significantly altered as a result of raising numerous houses to a common floor level above flood height. There could also be some opposition to this option by the community due to the high cost. Some residents may also object to having their houses raised.

The remaining options are effective in reducing the impact of lagoon flooding to varying degrees. However, these options do not provide any protection against ocean storm waves. It is considered that protection of properties near the entrance to Avoca Lagoon should be included in a coastal management programme.

Construction of a levee to protect nine (9) properties in Lake Street and Tramway Road is an effective local option. However, the levee route passes through gazetted wetlands. This area provides a habitat for the threatened Green and Golden Bell Frog. Construction of this levee is likely to have significant impact on the vegetation along the route of the levee and on the habitat of this threatened frog species.

The environmental impacts of this option are unlikely to be acceptable to the community. The overall cost-effectiveness of this option is the second lowest of the options considered.

Improved management of the beach berm across the entrance to the lagoon is the most cost-effective option. This option has no adverse impacts on the lagoon environment. The option has the highest benefit-cost ratio and is likely to be widely accepted by the community.

Lowering the beach berm level to RL 2.7 m AHD was found to have the highest benefit-cost ratio and the very favourable benefits in the social issues. The option is considered to have no impact on the ecology, visual amenity or recreational use of the lagoon and foreshores.

The installation of a telemetry lagoon water level station will improve the flood control operations by enabling mobilization for mechanical opening of the entrance to begin earlier. The earlier opening of the entrance will result in lower flood levels in the lagoon.

7.2 Enhancements

The comparison in the previous section indicates the most attractive general floodplain management strategy is the management of the beach berms to RL 2.7 m AHD. The strategy effectively reduces the design 1% AEP flood level to RL 3.1 m AHD.

The proposed strategy, within the Avoca Lagoon area, will create a situation where:

- the existing "minimum floor level" will provide 600 millimetres of freeboard;
- five residences will remain at below the predicted 1% AEP flood level;
- seven residences will have freeboard at less than 300 millimetres above the 1% flood level;
- one residence will have freeboard of less than 500 millimetres but greater than 300 millimetres above the projected 1% AEP flood level;
- six residences out of the thirteen below the projected 1% AEP flood level or with less than 500 millimetres freeboard can be raised. The affected buildings are timber framed with "fibro" cladding.
- the remaining seven residences below the "cut-off" of the 1% AEP flood level plus 500 millimetres are brick veneer or double brick, which cannot practically be raised.

The above does not apply to the lagoon entrance area where coastal processes (principally wave action) dominate.

An enhancement of the proposed strategy would involve raising of the six residences currently classed as "below the projected 1% AEP flood level plus freeboard" and "practical to raise".

The incremental benefit-cost ratio of this "enhancement" work is 1.6, based on:

-	Works cost	$191,700
-	Annual works cost @ 7.5% discount rate	$ 14,820
-	Reduction in annual damage (6 houses at $3,980 each)	$ 23,880
-	Benefit-cost ratio	1.62

Whilst the benefit-cost analysis for this exercise is attractive, the cost per individual dwelling is high. The benefits for the work accrue principally to the land owner through reduced flood damages. Thus, the funding opportunities and relative contributions from government and individual land owners should be explored.

It is noted that the proposed strategy above was based on the 1994 floor level and building survey. However, inspection in 2002 has shown that five of the six buildings identified for raising have been re-developed. Presumably, the new floor levels have been set in accordance with Council's floor level

standard and thus comply with the provisions of this floodplain management study. The single property thus remaining to be raised is 7 Lake Street.

7.3 Extreme Floods

The floodplain management measures outlined earlier have been directed principally using the one percent AEP flood as the "benchmark". While floods of this magnitude are rare, larger floods can occur. Such extreme floods are represented by the Probable Maximum Flood (PMF).

The Avoca Lagoon Flood Study examined PMF flood levels, assuming a berm level of RL 3.3 m AHD. The PMF levels are generally 0.8 metres above the one percent AEP flood levels in the lagoon storage area. Along Saltwater Creek, the PMF flood levels are up to 2.2 metres above the design one percent flood levels. The PMF flood behaviour is expected, given the lagoon is surrounded by relatively steep slopes falling to the lagoon foreshores, while lagoon flood levels are principally controlled by the beach berm break-out process.

The most appropriate response at this stage is ensuring that future development has access to flood free land (viz: above the PMF flood level) via gradually rising routes, such that persons escaping the PMF event traverse areas of decreasing flood depth.

Due consideration should also be given to development in "Special Use" zonings. Such developments can include:

- hospitals;
- aged care facilities;
- police and emergency services; amd
- items of cultural significance.

Such developments should be considered on their merits, mindful of the actual development use, the number of people involved, the susceptability of such development to flooding and the contribution of such developments to flood recovery programs.

8. PREFERRED FLOODPLAIN MANAGEMENT STRATEGY

8.1 Existing Development

Analysis of the data presented in the comparison matrix for the floodplain management options investigated for Avoca Lagoon indicates that the preferred management option is the improved management of the beach berm at the lagoon entrance.

This option has a low cost, requiring only periodic removal of sand from the beach berm area after the beach has built up above a critical level.

Maintenance of a maximum beach berm level at RL 2.7 m AHD was found to be the most cost-effective option with favourable social benefits and no perceived environmental impacts.

It is considered that this option, in combination with improved warning provided by telemetry of lagoon water level, will be widely accepted by all parties involved in the flood management process.

A flood awareness program is required to increase the level of knowledge of flood issues around Avoca Lagoon. A single brochure outlining the issues and flood response is considered adequate in this case.

Flood awareness and flood warning can be improved by installation of two staff gauges in Avoca Lagoon indicating the "let-out level" and design 1% AEP flood levels. Such gauges need to be installed where easy public access is available.

The beach berm management option will provide increased protection for properties adjacent to the lagoon entrance against lagoon flooding only. However, these properties (in Precincts 1 and 7) will remain exposed to inundation by ocean storm waves. The protection of these properties and adjacent beachfront properties is an issue to be addressed in coastal management.

8.2 Future Development

Council's Flood Policy requires that new buildings constructed around the foreshores of Avoca Lagoon (that is, Precincts 2, 3 and 6) shall have a minimum floor level above RL 3.7 m AHD. This level is 100 millimetres above the estimated one percent AEP design flood level (assuming an "un-managed" beach berm).

The preferred floodplain management option to protect the existing development is to limit the beach berm level to below RL 2.7 m AHD. This option effectively reduces the one percent AEP flood level to RL 3.08 m AHD, thus providing more than 500 millimetres clearance to the adopted minimum floor level for the Avoca Lagoon foreshore.

The minimum floor level requirement contained in Council's current Flood Policy, in conjunction with adoption of the preferred management option, will provide a generally acceptable level of protection for future development around the Avoca Lagoon foreshore.

Filling around the lake foreshore should be permitted as a means to achieve the minimum floor level requirements. However, such filling should be under the building footprint only and should not adversely affect the drainage of the surrounding properties.

Similarly, filling of individual blocks to be not greater than 200 millimetres above the "let-out level" (RL 2.09 m AHD) would provide a reduction in the frequency of flooding on individual lots without significant impacts on flooding levels. Such filling, if undertaken, would require satisfaction of development consent conditions relating to fill batters, protection of environmentally sensitive areas and protection of existing foreshores.

The minimum floor level of RL 3.7 m AHD is not applicable to Precincts 4 and 5, which are located upstream of the lagoon. Flood levels in those areas are determined by local flood discharges, not lagoon flood levels.

Therefore, it will be necessary to amend the minimum floor level for these areas to provide a satisfactory clearance above the one percent AEP design flood.

The Floodplain Management Manual recommends that habitable floor levels should be a minimum of 500 millimetres above design flood level. Thus, the recommended minimum floor level varies from RL 6.1 m AHD at the Scenic Highway to RL 3.7 m AHD at the upper limit of Avoca Lagoon some 1.4 kilometres downstream.

New development within the catchment will require controls to ensure:

- flood flows into Avoca Lagoon through Precincts 4 and 5 should not be increased, which would increase flood levels, if it were to occur;

- soil erosion control is required to prevent increased siltation in Avoca Lagoon, which would reduce available storage and increase flood levels.

It should be noted that "greenhouse" changes could create a situation of increasing berm heights. Thus, Council will be required to maintain the beach berms more frequently or to accept a lower freeboard.

Whilst the minimum floor level can be set at RL 3.7 m AHD for consistency with current policy, it would be prudent for Council to urge property owners to set floor levels above RL 4.2 m AHD to allow for weather conditions or the like that may prevent Council opening the lagoon.

GLOSSARY

GLOSSARY - Terms and Abbreviations

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. Refer Appendix H of Floodplain Management Manual (Ref. 1).

Annual Exceedence Probability (AEP): the chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of *5%,* it means that there is a *5%* chance (that is one-in-20 chance) of a peak flood discharge of 500 m^3/s or larger occurring in any one year (see average recurrence interval).

Anti-dunes: erodible channels have bed forms. Anti-dunes are wave like bed forms which migrate upstream. They require high velocities to create the particular bed form.

Australian Height Datum (AHD): a common national surface level datum approximately corresponding to mean sea level.

Average Recurrence Interval: the long-term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.

Catchment: the land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.

Critical flow: flow lies between sub-critical and super-critical flow conditions. Critical flow usually occurs at flow controls eg. at a weir.

Development: is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act).

infill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development.

new development: refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.

redevelopment: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.

Direct Damage: damage caused by contact with flood water eg. structural damage to building, water damage to furniture or house contents or damage caused by silt and debris.

Discharge: the rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).

DST: Day Light Saving Time (East Coast).

Effective warning time: the time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.

EST: Eastern Standard Time.

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 education, awareness and readiness:

> *Flood education* seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
>
> *Flood awareness* is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
>
> *Flood readiness* is an ability to react within the effective warning time.

Flood fringe areas: the remaining area of flood prone land after floodway and flood storage areas have been defined.

Flood liable land: is synonymous with flood prone land (ie) 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, not just that part below the flood planning level, as indicated in the 1986 Floodplain Development Manual (Ref. 11) (see flood planning area).

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.

Flood planning area: the area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the "flood liable land" concept in the 1986 Floodplain Development Manual (Ref. 11).

Flood risk: potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in the Floodplain Management Manual is divided into 3 types, existing, future and continuing risks. They are described below.

existing flood risk: the risk a community is exposed to as a result of its location on the floodplain.

future flood risk: the risk a community may be exposed to as a result of new development on the floodplain.

continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.

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.

Hazard: a source of potential harm or a situation with a potential to cause loss. In relation to the Floodplain Management Manual (Ref. 1), the hazard is flooding which has the potential to cause damage to the community. (Definitions of high and low hazard categories are provided in Appendix G of Floodplain Management Manual).

Hydraulics: term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.

Indirect Damage: damage caused by flooding though not directly eg. loss of trade, cost of alternative accommodation or loss of wages.

Intangible Damage: damage that occurs but is difficult to quantify eg. increased ill-health in the community or disruption to community life.

Let-out-level: the water level in the lagoon used by Gosford City Council to initiate a mechanical break-out of the beach berm.

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.

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.

Phreatic Line: free water surface line reached within the beach berm.

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).

Reduced Level (RL): a measured height above Australian Height Datum.

Risk: chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the Floodplain Management 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 streamflow, also known as rainfall excess.

Sub-critical flow: flow in the channel is characterised by "mild" conditions featuring low velocities and reasonable depths.

Super-critical flow: flow in the channel is characterised by "unstable" conditions featuring high velocities and low depths.

Tangible Damage: damage that can be quantified in monetary terms.

Top Water Level (TWL): water level in the lagoon referenced by Council's opening records as existing prior to lagoon break-out.

REFERENCES

REFERENCES

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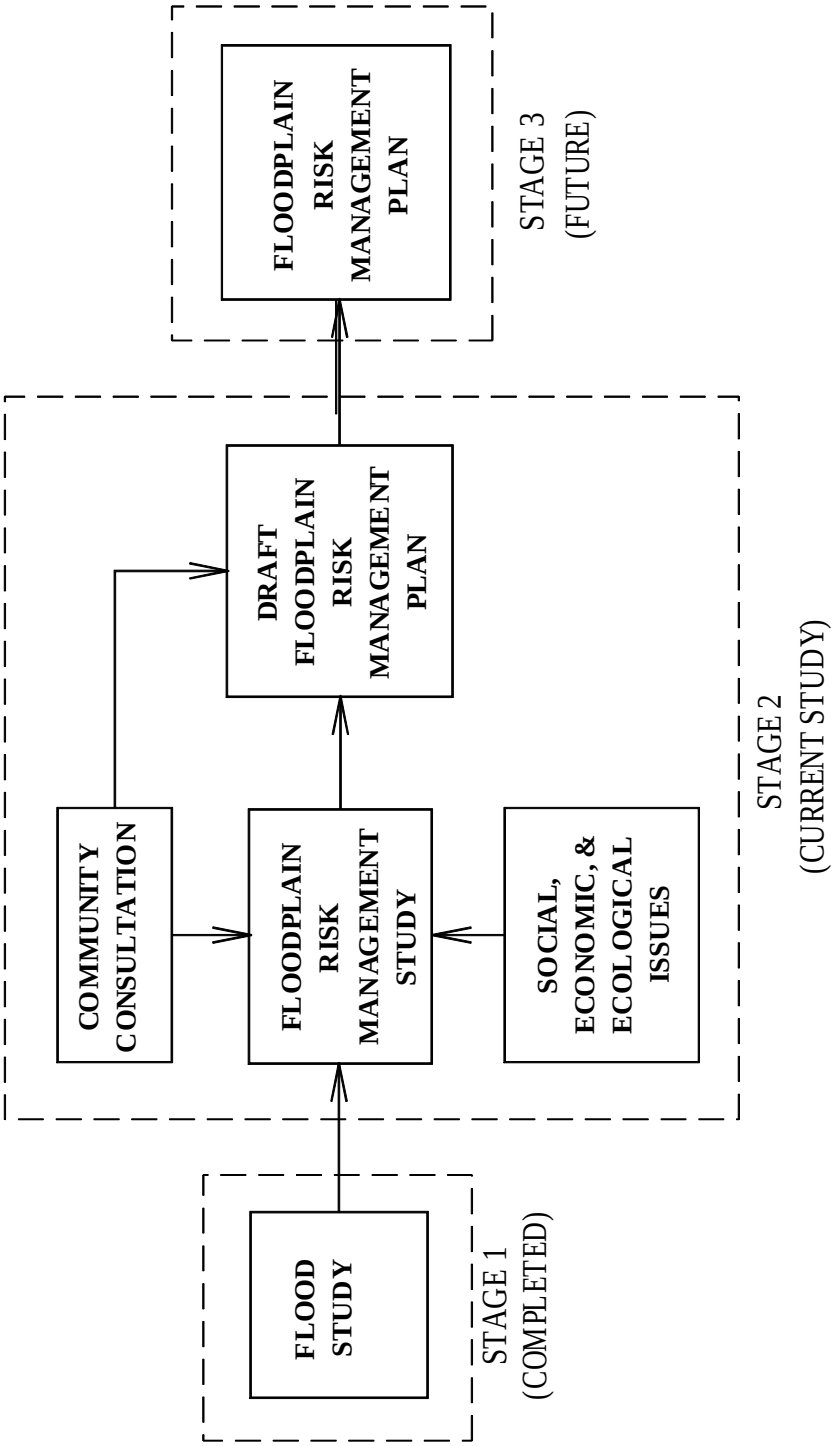
FIGURES



11 AUG 2003, KC
DISK REF: 93026_AFMS
FIG REF: 93026_AFMS_1-1_PROCESS

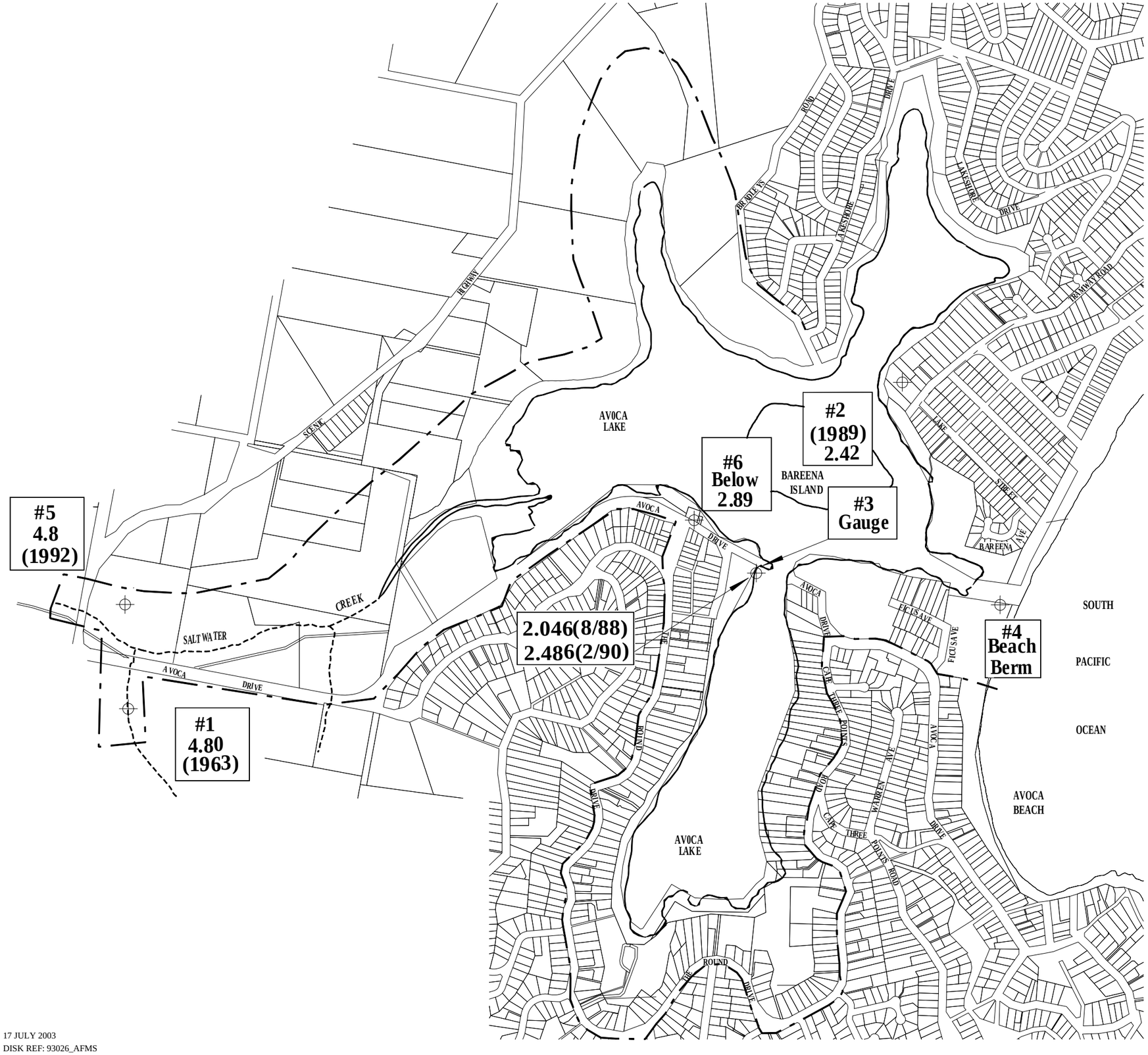
FIGURE 1.1
FLOODPLAIN MANAGEMENT PROCESS

AVOCA LAGOON
FLOODPLAIN MANAGEMENT STUDY

17 JULY 2003
DISK REF: 93026_AFMS
FIG REF: 93026_AFMS_1-2_SA

FIGURE 1.2
STUDY AREA

AVOCA LAGOON
FLOODPLAIN MANAGEMENT STUDY



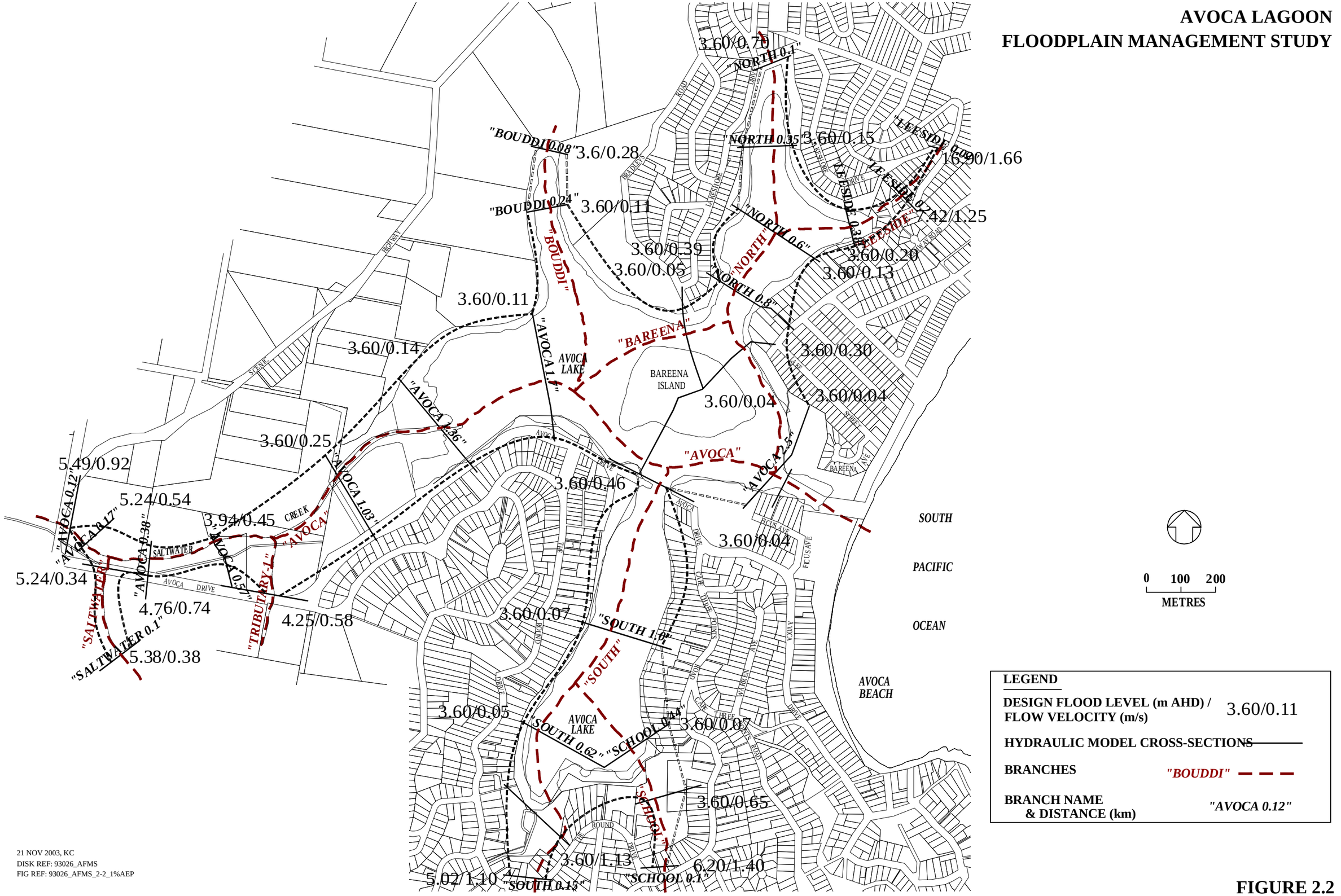
LEGEND

LOCATION	⊕
POINT NO.	#5
FLOOD LEVEL (m AHD)	4.80
YEAR	(1992)
BOUNDARY OF STUDY AREA	——— - ———

17 JULY 2003
DISK REF: 93026_AFMS
FIG REF: 93026_AFMS_2-1_REC FL LEVELS

FIGURE 2.1
RECORDED FLOOD LEVELS

AVOCA LAGOON
FLOODPLAIN MANAGEMENT STUDY



LEGEND

DESIGN FLOOD LEVEL (m AHD) / FLOW VELOCITY (m/s)	3.60/0.11
HYDRAULIC MODEL CROSS-SECTIONS	
BRANCHES	*"BOUDDI"*
BRANCH NAME & DISTANCE (km)	*"AVOCA 0.12"*

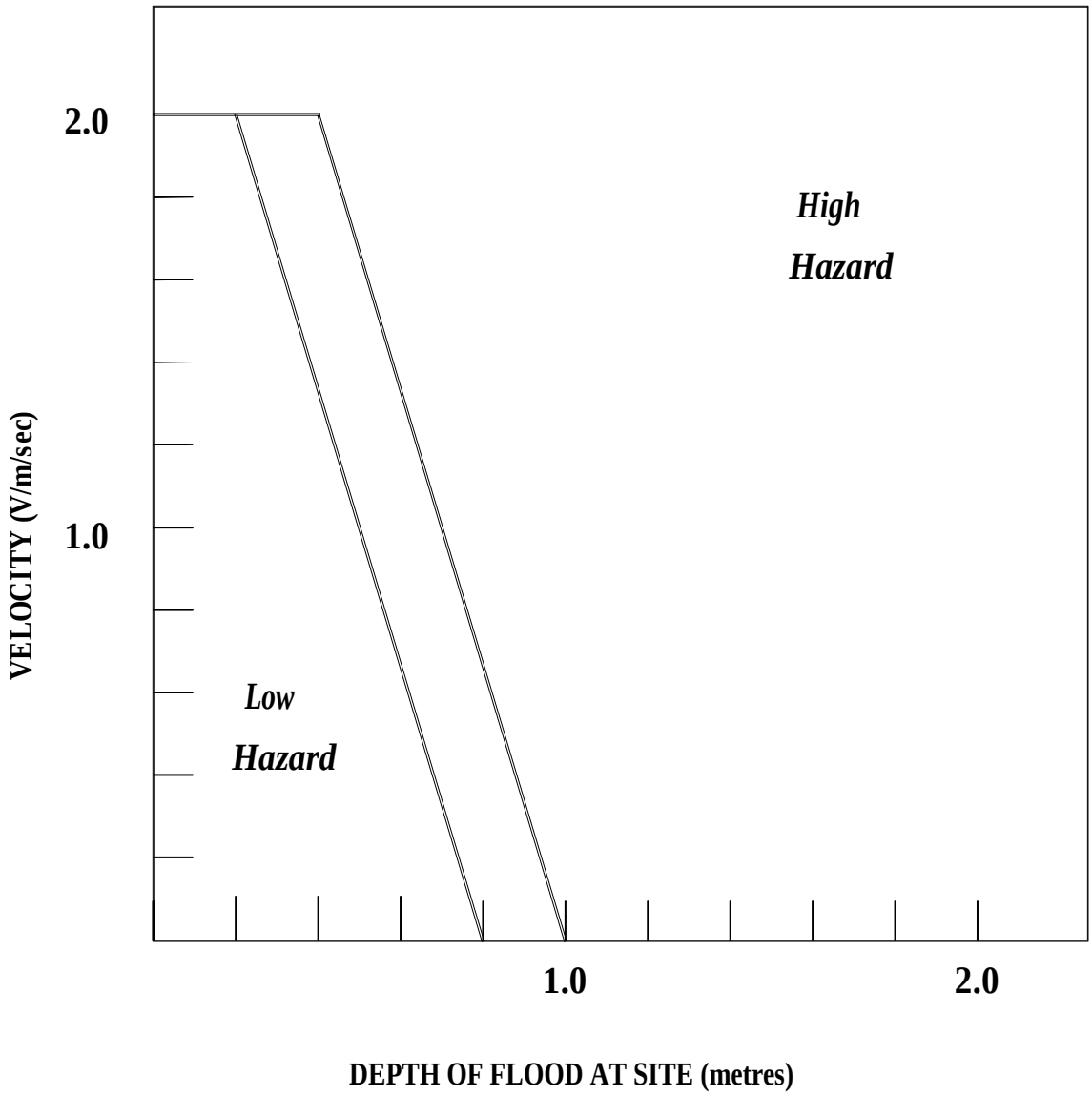
21 NOV 2003, KC
DISK REF: 93026_AFMS
FIG REF: 93026_AFMS_2-2_1%AEP

FIGURE 2.2
1% AEP DESIGN FLOOD LEVELS AND EXTENTS

AVOCA LAGOON
FLOODPLAIN MANAGEMENT STUDY

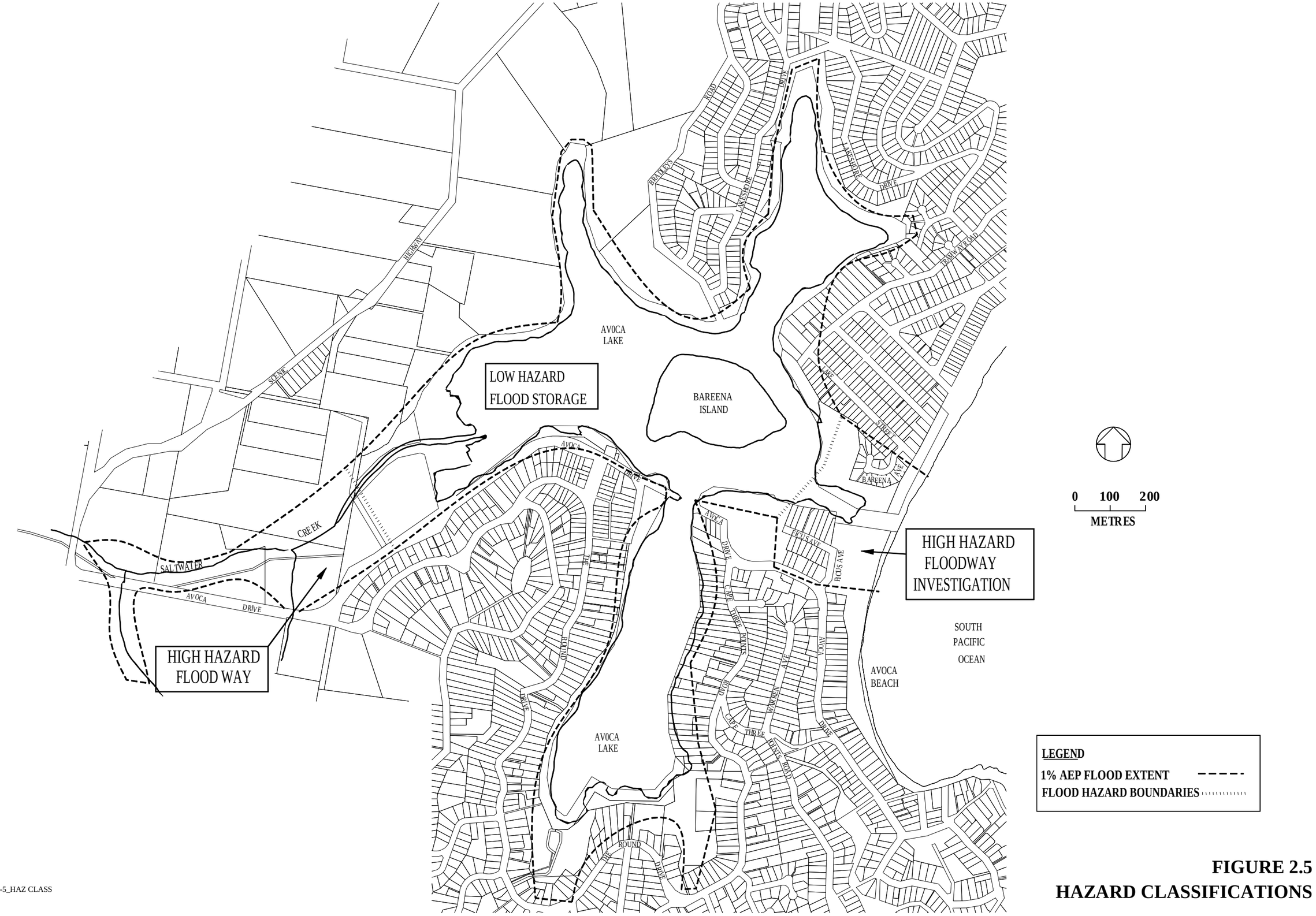
11 AUG 2003, KC
DISK REF: 93026_AFMS
FIG REF: 93026_AFMS_2-3_FL PRECINCTS

FIGURE 2.3
FLOOD AFFECTED PRECINCTS



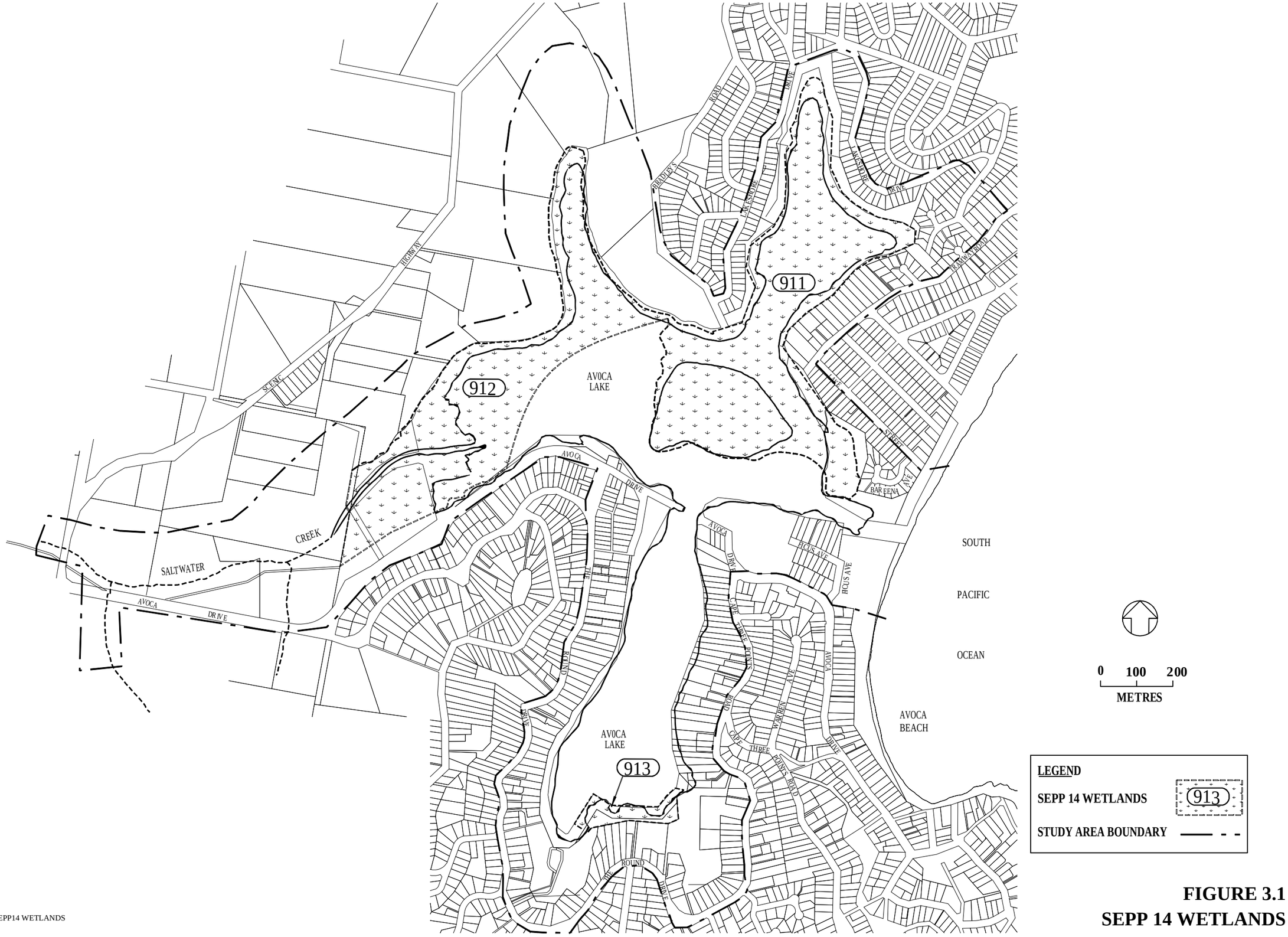
17 JULY 2003
DISK REF: 93026_AFMS
FIG REF: 93026_AFMS_2-4_HAZ

FIGURE 2.4
HAZARD DIAGRAM



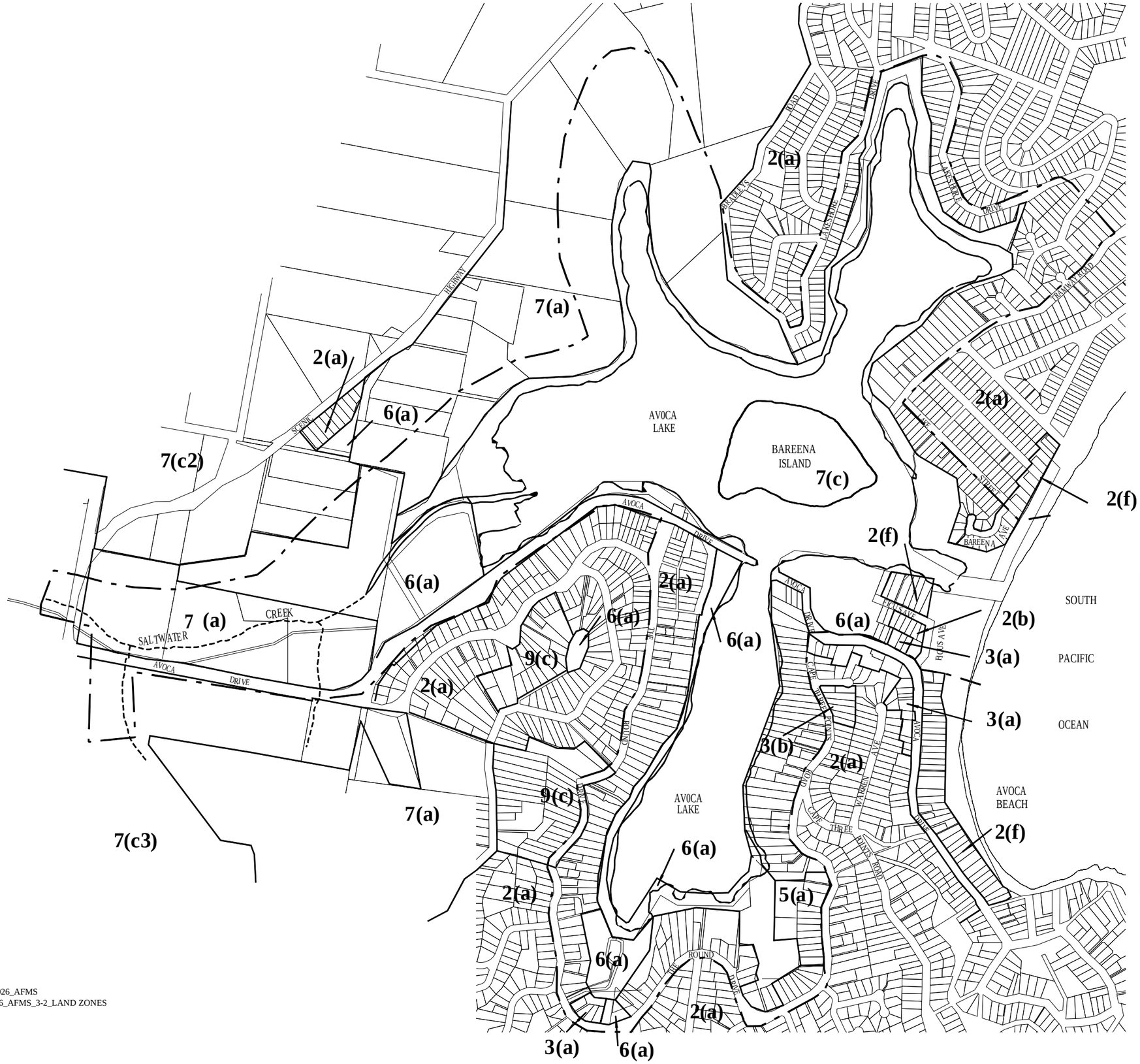
21 NOV 2003, KC
DISK REF: 93026_AFMS
FIG REF: 93026_AFMS_2-5_HAZ CLASS

FIGURE 2.5
HAZARD CLASSIFICATIONS



17 JULY 2003
DISK REF: 93026_AFMS
FIG REF: 93026_AFMS_3-1_SEPP14 WETLANDS

FIGURE 3.1
SEPP 14 WETLANDS



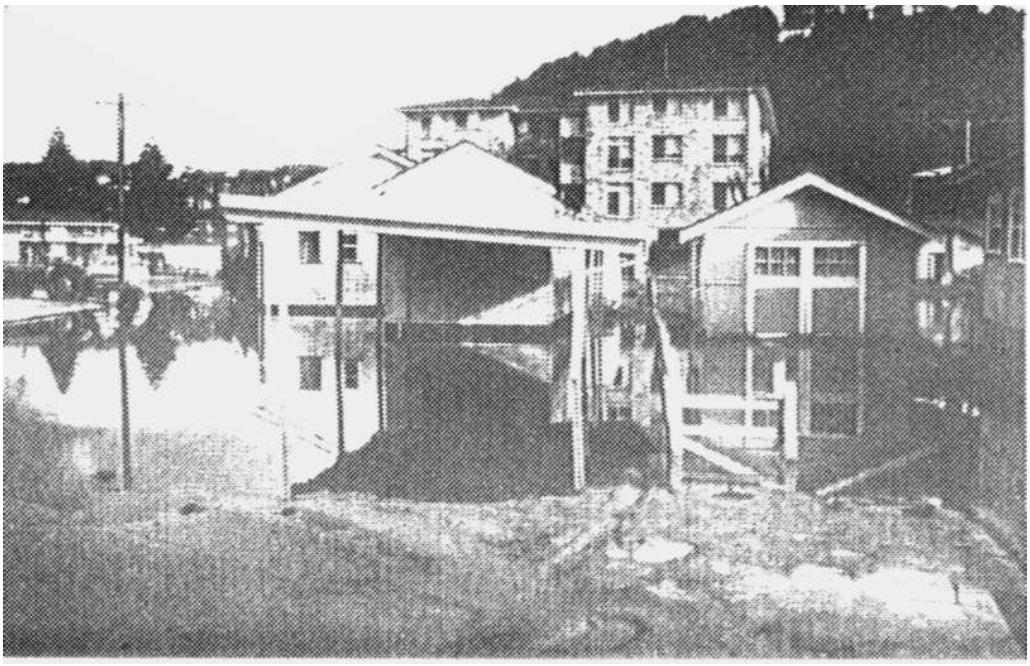
LAND ZONINGS

RESIDENTIAL	2(a)
RESIDENTIAL - BEACH FRONTAGE	2(f)
BUSINESS - GENERAL	3(a)
BUSINESS - SPECIAL	3(b)
OPEN SPACE - RECREATION	6(a)
CONSERVATION / SCENIC PROTECTION	7(a)
CONSERVATION / SCENIC PROTECTION TOURISM	7(c3)
STUDY AREA BOUNDARY	— -

17 JULY 2003
DISK REF: 93026_AFMS
FIG REF: 93026_AFMS_3-2_LAND ZONES

FIGURE 3.2
CURRENT LAND ZONING

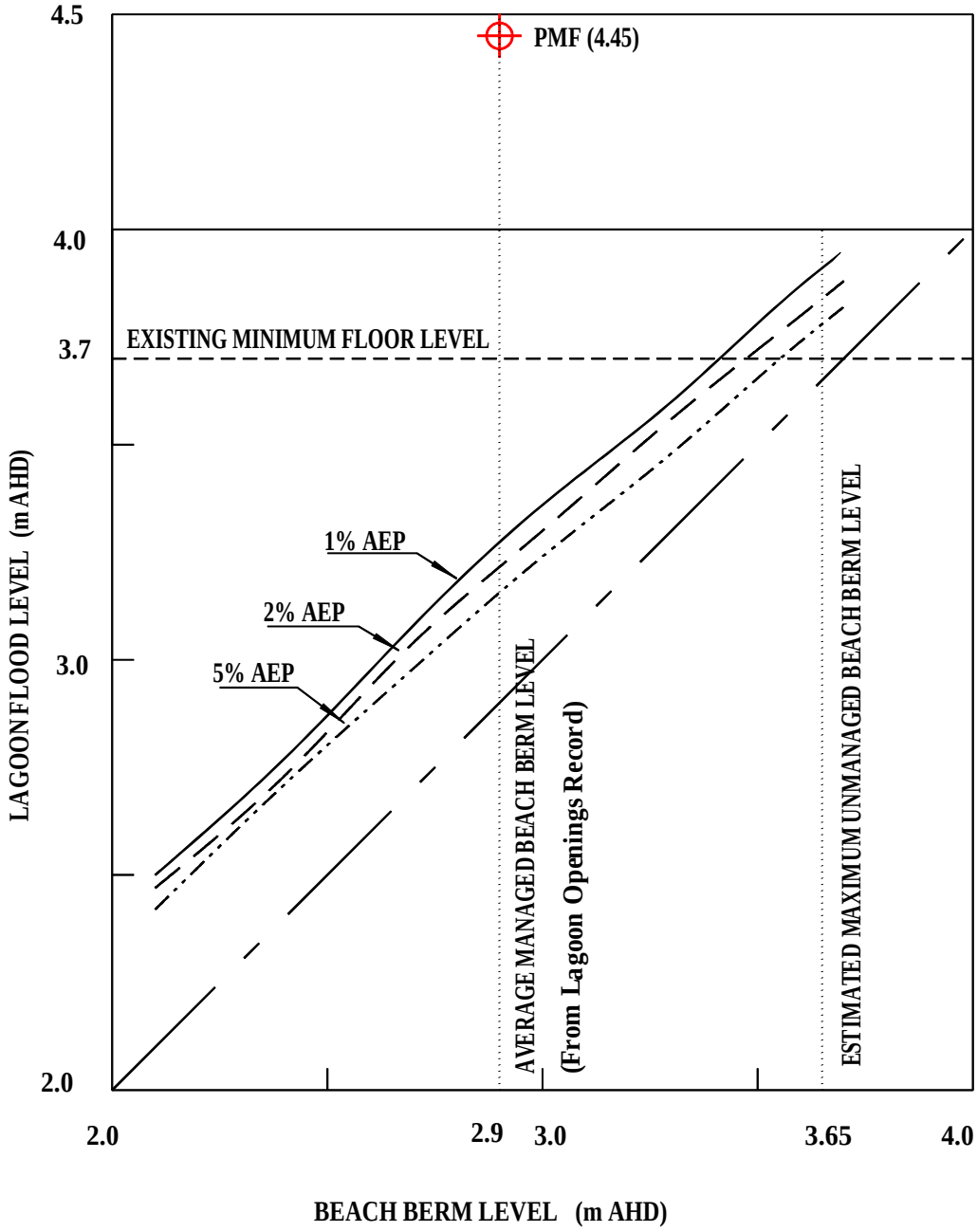
HOUSE IN FICUS AVE. LIFTED OFF FOUNDATIONS



PONDED SEAWATER AFTER STORM

18 JULY 2003
DISK REF: 93026_AFMS
FIEL REF: 93026_AFMS_4-1_STORM DMG

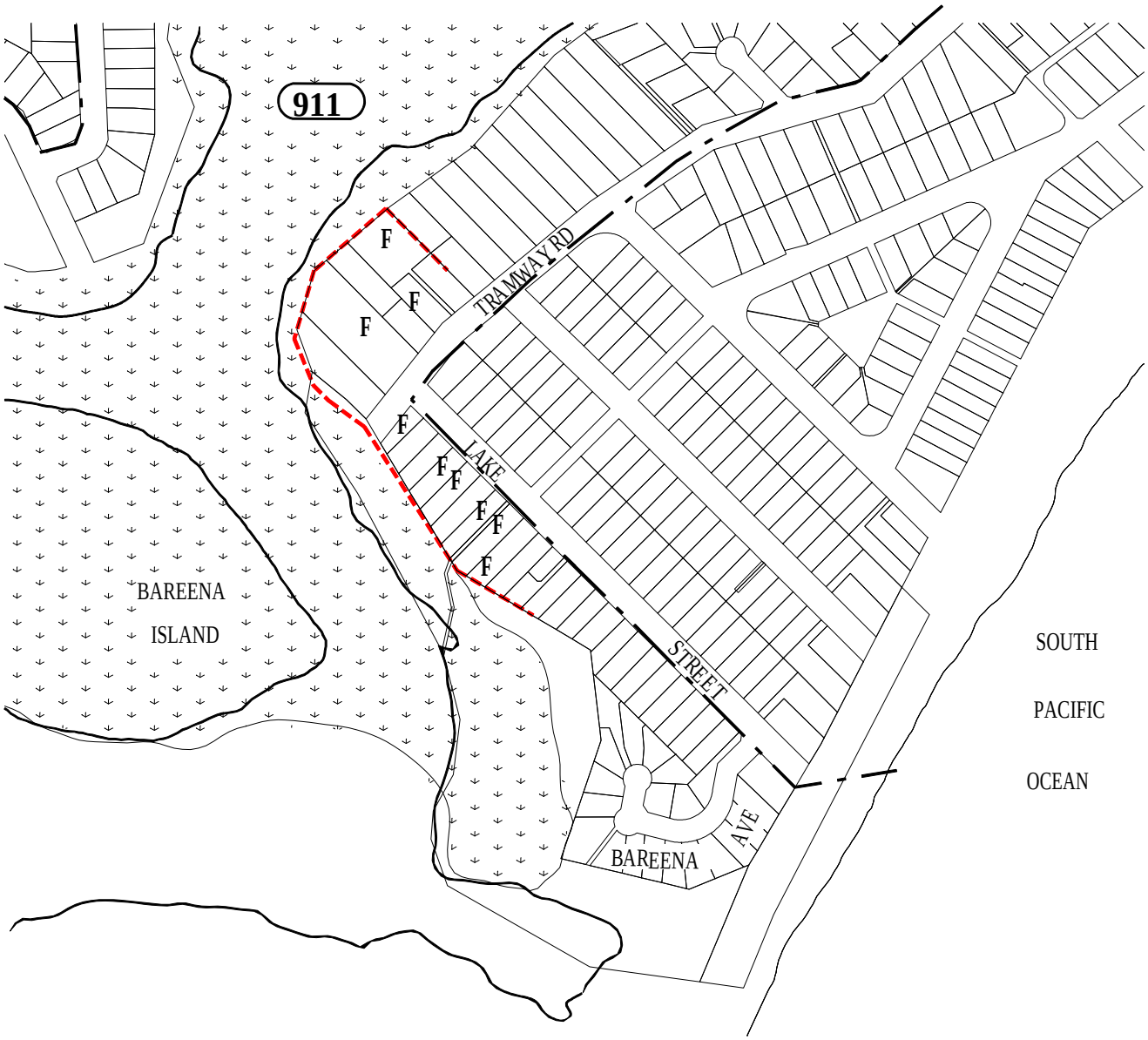
FIGURE 4.1
STORM DAMAGE

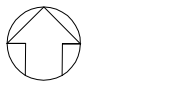


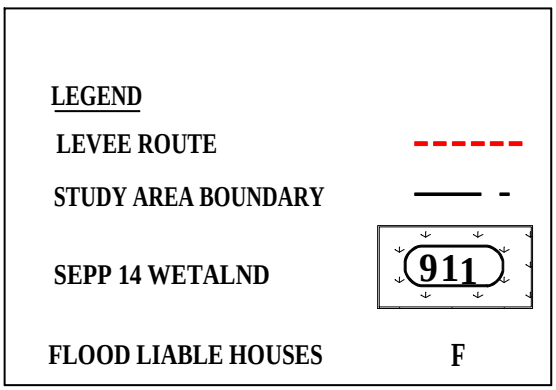
16 DEC 2003
DISK REF: 93026_AFMS
FIG REF: 93026_AFMS_5-1_DES FL LEVELS

FIGURE 5.1
DESIGN FLOOD ENVELOPES

AVOCA LAGOON
FLOODPLAIN MANAGEMENT STUDY







6 November 2007
DISK REF: 93026_AFMS
FIG REF: 93026_AFMS_5-2_LAKE ST LEVEE_V2

FIGURE 5.2
POTENTIAL LAKE ST LEVEE

APPENDICES

APPENDIX A

FLOOR LEVEL SURVEY FOR PROPERTIES

APPENDIX A - 1

NON-RESIDENTIAL PROPERTIES

Non-residential Properties
Survey Data

Variable	Description
1	Precinct
2	Business name and description
3	Street number
4	Street name
5	Code 4 = non-residential
6	Number of storeys
7	Building raised indicator
8	Height raised (m) (if indicator = 1)
10	Precinct, subarea
11	Construction material - 1 = N/A, 2 = Timber, 3 = Fibro, 4 = Brick, 5 = Steel, 6 = Stone, 7 = Other
12	Building age - 1 = pre-1940, 2 = post-1940
13	Building size - 4 = < 190 sq metres, 5 = 190 to 650 sq metres
14	Ground Level (m AHD)
15	Floor Level (m AHD)
16	Damage class - 1 = Low, 2 = Medium, 3 = High

Avoca Commercial Data

Variable Id

#1	#2	#3	#4	#5	#6	#7	#8	#11	#13	#14	#15	#16
16		352ROUND			2			4	1	4.70	4.98	2
16					1			4	1	4.30	4.35	2
16		AVOCA DR			1			3	2	2.80	2.89	1
17		210			2			4	2	4.60	4.63	2
17		212			1			2	1	4.00	4.65	2
17		170			4			4	1	3.23	3.29	2
18		170			4			4	1	3.27	3.33	2
18		170			4			4	1	3.36	3.42	2
18		172			4			4	1	3.64	3.84	2
18		174			4			4	1	3.90	4.07	2
18		174			4			4	1	4.06	4.26	2
18		173			2			4	1	3.73	3.83	2
18		173			2			4	1	3.74	3.97	2
18		177			1			3	1	4.00	4.22	2
18		179			1			4	1	4.06	4.14	2
18		179			1			4	1	4.06	4.11	2
18		179			1			4	1	4.06	4.11	2
18		179			1			4	1	4.06	4.11	2
18		179			1			4	1	4.06	4.11	2
18		179			1			4	1	4.06	4.11	2
18		179			1			4	1	4.06	4.11	2
18		179			1			4	1	4.06	4.11	2
18		180			2			4	1	4.48	4.53	2
18		180			2			4	1	4.49	4.54	2
18		180			2			4	1	4.52	4.57	2
18		180			2			4	1	4.52	4.62	2
18		180			2			4	1	4.52	4.62	2
18		168			1			3	1	3.44	4.09	2
18		168			1			4	1	3.78	3.98	2
18		164			1			4	1	3.75	3.95	2
18		164			3			4	1	3.96	4.11	2
18		162			2			4	1	4.05	4.19	2
18		162			2			4	1	4.20	4.28	2
15					1	1	0.88	4	2	5.00	5.88	2

APPENDIX A - 2

RESIDENTIAL PROPERTIES

Residential Properties
Survey Data

Variable ID	Description
1	Precinct
2	Street number
3	Street name
4	Code - 1 = Detached, 2 = Semi-detached, 3 = Flats/units
5	Number of storeys
6	Building raised indicator
7	Height raised (m) (if indicator = 1)
8, 9	Precinct, subarea
10	Construction material - 1 = N/A, 2 = Timber, 3 = Fibro, 4 = Brick, 5 = Steel, 6 = Stone, 7 = Other
11	House size - 1 = <80 sq metres, 2 = 80 to 140 sq metres, 3 = >140 sq metres
12	Property size - 1 = Small, 2 = Medium, 3 = Large
13	House condition - 1 = Poor, 2 = Medium/Good
14	Building age - 1 = pre-1940, 2 = post-1940
15	Ground Level (m AHD)
16	Lowest habitable floor level (m AHD)
17	Damage class - 1 = Low, 2 = Medium, 3 = High

Avoca Residential Data

Variable Id #1	#2	#3	#4	#5	#6	#7	#10	#11	#12	#13	#15	#16	#17
11	5	BAREENA ST	1	2			4	3	1	2	4.00	4.05	2
11	7		1	2			3	2	1	2	4.50	4.56	2
11	9		1	2			4	3	1	2	3.90	4.43	2
11	11		1	1			3	2	2	2	3.10	3.64	2
11	13		1	1			4	2	2	2	2.50	2.99	2
11	26		1	2			3	3	1	2	3.35	3.35	2
11	24		1	2			3	2	2	2	3.35	3.35	2
11	22		1	2			3	2	2	2	3.05	3.25	2
11	20		1	1			2	3	2	2	2.40	2.50	2
11	18		1	1			4	2	2	2	3.52	3.68	2
11	16		1	2			3	2	2	2	4.90	4.10	2
11	14		1	2			4	3	2	2	4.10	4.20	2
11	12		1	2			4	3	2	2	4.34	4.31	2
11	10		1	2			4	3	2	2	4.95	5.05	2
12	11	LAKE ST	1	1			4	2	2	2	3.60	3.99	2
12	12		1	1			4	2	2	2	4.35	4.55	2
12	14		1	2			3	2	2	2	4.44	4.84	2
12	19		1	1			3	1	2	2	3.75	4.25	2
12	21		1	1			3	1	2	2	3.90	4.40	2
12	20		1	1			3	1	2	2	4.62	5.12	2
12	18		1	1			3	1	2	1	4.55	4.57	2
12	16		1	1	1	1.00	3	1	2	2	4.12	5.12	2
12	8		1	1			3	1	2	2	4.75	4.99	2
12	9		1	1			3	1	2	2	3.60	4.11	2
12	7		1	1			2	1	2	2	2.90	3.08	2
12	5		1	1			4	2	2	2	3.30	3.79	2
12	6		1	2			1	2	2	2	4.09	4.09	2
12	3		1	1			4	2	2	2	3.50	3.75	2
12	1		1	1			4	2	2	2	3.15	3.60	2
12	13		1	2			3	2	2	2	2.90	2.94	2
12	15		1	1			3	1	2	2	3.35	3.35	2
12	17		1	1			4	2	2	2	3.20	3.25	2
12	21		1	1			4	2	2	2	3.37	4.07	2
12	41		1	1			4	3	2	2	3.87	4.32	2
12	39		1	1			4	2	2	2	4.28	4.88	2
12	37		1	2			4	3	2	2	4.00	4.40	2
12	33		1	1			3	1	2	2	3.18	3.18	2
12	3	TRAMWAY RD	3	2	1	1.06	4	2	1	2	2.75	3.81	2
12	3		3	2	1	1.07	4	2	1	2	2.75	3.82	2
12	3		3	2	1	1.08	4	2	1	2	2.75	3.83	2
12	3		3	2	1	1.09	4	2	1	2	2.75	3.84	2
12	3		3	2	1	1.06	4	2	1	2	2.75	3.81	2
12	5		1	2			3	2	2	2	2.64	2.74	2
12	9		1	1			4	2	2	2	3.23	3.33	2
12	7		1	1	1	1.30	4	2	2	2	2.45	3.75	2
12	9		1	2			3	2	2	2	2.20	2.22	2
12	11		3	2			4	3	1	2	4.46	4.66	2
12	11		3	2			4	3	1	2	3.90	4.09	2
12	15	OCEAN ST	1	2			2	1	2	2	4.75	4.80	2

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12  17                  1 1                   4 2 2 2   4.89 4.99  2
17 228 AVOCA            1 1                   3 2 2 2   5.08 5.58  2
17 220                  1 1                   2 2 2 2   4.95 4.97  2
17  13 FICUS AV         1 1                   3 1 2 2   2.47 3.17  2
17  11                  1 2                   3 3 2 2   2.90 3.00  2
17   9                  3 3                   4 1 1 2   2.70 3.15  2
17   9                  3 3                   4 2 1 2   2.70 3.15  2
17  12                  1 2                   4 3 2 2   3.47 3.57  2
17  10                  1 2                   4 3 2 2   3.91 4.11  2
17   7                  1 1 1                 3 1 2 2   2.36 3.11  2
17   8                  1 1 1                 3 1 2 2   2.84 4.34  2
17   6                  1 1                   4 1 2 2   2.51 3.11  2
17   5                  1 1                   7 1 2 2   2.53 3.23  2
17   3                  1 1 1                 3 2 2 2   2.70 3.85  2
17   4                  1 1                   3 1 2 2   2.79 3.29  2
17   4                  1 1 1 1.50            4 2 1 2   2.30 3.80  2
17   2                  3 1                   2 1 1 2   2.50 3.00  2
17   2                  3 1                   2 1 1 2   2.38 2.93  2
17   2                  3 1                   2 1 1 2   2.08 2.73  2
17   1                  1 2 0 1.50            4 3 2 2   2.54 2.59  2
17 171 AVOCA DR         3 4                   4 3 2 2   3.26 3.36  2
17 173                  2 2                   3 1 1 2   3.30 3.75  2
17 177                  3 1                   3 1 1 2   4.16 4.66  2
18 159                  3 2                   4 3 1 2   3.10 3.80  2
18 159                  3 2                   4 3 1 2   3.10 3.80  2
18 159                  3 2                   4 2 1 2   3.20 3.80  2
18 159                  3 2                   4 2 1 2   3.20 3.80  2
18 165                  1 2                   4 2 1 2   3.10 3.25  2
18 161                  3 2                   4 1 1 2   3.30 3.46  2
18 161                  3 2                   4 1 1 2   3.30 3.46  2
18 161                  3 2                   4 1 1 2   3.00 3.46  2
18 157                  3 2                   3 2 2 2   3.15 3.17  2
18 157                  3 1                   3 2 1 2   3.20 3.90  2
18 155                  1 1                   4 1 2 2   3.50 4.03  2
18 153                  3 2 1                 4 1 1 2   2.82 5.03  2
18 153                  3 2 1                 4 1 1 2   2.85 5.03  2
18 151                  1 1 1                 7 2 2 2   3.63 4.88  2
16 195 THE ROUND DR     3 2                   4 1 1 2   5.0  5.10  2
16 195                  3 2                   4 1 1 2   5.0  5.15  2
16 195                  3 2                   4 1 1 2   5.0  5.15  2
16 199                  3 1                   4 1 1 2   5.84 5.04  2
16                        2                   4 2 2 2   3.46 3.56  2
16                        1                   4 2 2 2   3.0  3.20  2
16                        2                   4 2 2 2   2.82 2.92  2
16 179                  1 2                   4 2 2 2   3.05 3.25  2
16 181                  1 3                   4 3 2 2   2.94 3.24  2
16 183                  1 1                   3 1 2 2   2.91 3.61  2
16 185                  1 1                   4 2 2 2   3.90 4.05  2
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