GOSFORD CITY COUNCIL

COCKRONE LAGOON
FLOODPLAIN MANAGEMENT PLAN

FINAL

(Adopted by Council 27 May 2008)

May 2008

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Prepared By:

PATERSON CONSULTANTS PTY LTD
1/45 PRINCE STREET
GRAFTON NSW 2460

P O BOX 596
GRAFTON NSW 2460

Tel: (02) 6643 1588
Fax: (02) 6642 7566
Email: patcon@nor.com.au

Version 8
Authorised For Release

Copy of

DOCUMENT CONTROL SHEET

Paterson Consultants Pty Ltd
Suite 1, 45 Prince Street
Grafton NSW 2460

P O Box 596
Grafton NSW 2460

Telephone: (02) 6643 1588

Facsimile: (02) 6642 7566

Email: patcon@nor.com.au

Job Name: Cockrone Lagoon

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

Original Date of Issue:

DOCUMENT DETAILS

Title:	Cockrone Lagoon Floodplain Management Plan
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	April 1995	KWP
2	Exhibition	August 1997	KWP
3	Exhibition	June 1999	KWP
4	Exhibition	September 1999	KWP
5	Exhibition	November 2007	KWP
6	Exhibition	December 2007	KWP
7	Exhibition	February 2008	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	1	
Department of Environment and Climate Change									
Paterson Consultants File Copy								1	
Paterson Consultants Library								1	

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POLICY BACKGROUND

NSW Government Policy

The New South Wales Government's Flood Policy (Reference 1) 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 Cockrone Lagoon Floodplain Management Plan constitutes completion of the third stage of the management process for Cockrone 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

Cockrone 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 in March 2005).

The work on the Cockrone 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, and 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:

- Cockrone Lagoon Flood Study (1994 and 2003);
- Cockrone Lagoon Floodplain Management Study (1995 and 2003);
- Cockrone 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.

Floodplain Management Principles

Gosford City Council has adopted the one percent annual exceedence probability event (1% AEP) as the Designated or Standard flood for consideration of floodplain management options throughout the council area. This standard was derived under the 1986 Floodplain Development Manual. The 2001 Floodplain Management Manual supersedes the 1986 version. The 2001 Manual moves from a Flood Standard approach to specification of Flood Planning Levels for various types of development. The 2001 Manual has been superseded by the 2005 Manual, which explicitly classifies flood liable land as the land inundated by the Probable Maximum Flood (PMF).

Thus, Council's adoption of the one percent flood plus freeboard is a defacto adoption of a Flood Planning Level.

Gosford City Council, in application of floodplain management plans in their administrative area identifies flood-liable land by hydraulic categories as "Floodway" or "Flood Storage".

In Cockrone Lagoon and its environs, the hydraulic categories of "Floodway" and "Flood Storage" are applicable to particular portions of land.

Floodways

Floodways are those areas where a significant volume of water flows during floods. They are often aligned with obvious naturally defined channels.

Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, which may, in time, affect other areas. They are often, but not necessarily, the areas with deeper flow or areas where higher velocities occur.

Land use in floodways must be carefully controlled to ensure that the conveyance of the floodway is not reduced. Neither buildings nor hazardous uses or obstruction operations likely to impede floodwaters should be permitted in floodways. Only land use that is flood compatible or likely to enhance floodway capacity should be allowed.

The provision of floodways has added benefits as follows:

- 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 to the stream conveyance if it is necessary following ongoing 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.

Flood Storage

Flood storage areas are not as sensitive to change as floodways. Essentially, flood storage provides ponding and temporary storage of floodwater. They are generally not categorised by high velocity flows but may involve significant flood depths. It is important to maintain flood storage as loss of such storage may create higher flood levels in the storage area and higher flood levels downstream of the storage area.

Ecologically Sustainable Development

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

This Plan seeks to promote the adoption of an integrated approach to the management of all lands within the Cockrone Lagoon catchment.

EXECUTIVE SUMMARY

Cockrone Lagoon has a catchment of 7.1 sq kilometres, while the surface area of the lagoon is some 43.8 hectares.

Cockrone Lagoon is a relatively small shallow lagoon, located behind MacMasters Beach. The entrance is normally closed due to the action of dynamic coastal processes that create a beach berm across the entrance. The lagoon is perched some 2.5 metres above mean sea level.

The Flood Study of the lagoon was completed essentially in 1995. The flood study indicated that flood levels in Cockrone Lagoon are essentially controlled by the beach berm and the break-out of the lagoon through the beach berm.

Gosford Council's existing floodplain management program in Cockrone Lagoon comprises essentially:

- to mechanically assist break-out through the beach berm once water levels reach RL 2.53 m AHD; and

- to require minimum building floor levels of RL 4.3 m AHD within the lagoon's storage area.

The Cockrone Lagoon Floodplain Management Study was conducted in 1996 and examined a range of structural and non-structural measures to limit and/or reduce existing and future damages from flooding.

The principal measures examined were:

- maintenance of the beach berm at various levels;
- levees;
- house raising;
- flood warning systems;
- voluntary acquisition; and
- channel improvements.

The Cockrone Floodplain Management Plan (the subject of this report) follows the Floodplain Management Study.

The Floodplain Management Plan divides the Cockrone Lagoon area into six precincts, as below and shown on Figure 2.

Floodplain Management Precincts

Precinct	Category
Cockrone Lagoon - Beach Berm	High Hazard Floodway/Investigation
Cockrone Lagoon - Entrance Area	High Hazard – Low Hazard Floodway/Investigation
Cockrone Lagoon - Storage Area	Low Hazard Flood storage
Cockrone Lagoon - Floodway Area	High Hazard Floodway
Merchants Creek - Floodway Area	High Hazard Floodway
Newell Road Floodway	High Hazard Floodway

Essentially, the Floodplain Management Plan involves:

- maintenance of Council's existing let-out policy;
- maintenance of the beach berms; and
- adoption of the design one percent AEP flood plus 0.5 m freeboard as the "Flood Planning Level" through the study area. This follows Council's existing practice.
- building and planning controls to set minimum floor levels and "allowable" building locations.

Construction of drainage works at Newell Road (cost $186,000, Benefit/Cost Ratio 1.57).

A summary of the measures is attached.

The Plan allows for a review of its contents every 5 years.

A timetable for implementation of the measures is seen as:

- High priority works and measures: 2007 to 2008 inclusive
- Medium priority works and measures: 2008 to 2009 inclusive
- Low priority works and measures: 2009 to 2012 inclusive

Summary of Measures
Cockrone Lagoon Floodplain Management Plan

Item	Comment	Cost to Council	Priority[1]
Works and Measures			
1. Maintenance of Council's current "let-out" policy	Maintain existing situation	Variable, depends on rainfall recorded	H
2. Maintain beach berm at RL 3.3 to 3.5 m AHD	Required to enhance break-out	Variable, allow $5,000 per annum	H
3. Installation of flood gauges to indicate "let-out" levels	Required to assist in public education	Allow $5,000 capital cost	H
4. Additional investigations of lagoon entrance	Required to define induced levels and forces	Allow $48,000 capital cost	H
5. Levee and channel improvement works (Newell Road Floodway)	Required to prevent flood breakout from drainage reserve	$186,000	H
6. Development Controls (See summary below)			H
7. Improved rainfall data collection	Required to give better correlation to Cockrone Lagoon water levels	$20,500 capital cost	M
8. Distribution of simple brochures on flood issues	Required for public education	Allow $5,000 per annum	M
9. Improved water level prediction	Required to reduce chance of unnecessary opening of lagoon	Allow $3,000 per annum	L
Development Control Measures			
1. Setting of minimum floor levels	Required to ensure that new buildings and additions are at least 0.5 metres above 1% AEP flood levels	None	H

Item	Comment	Cost to Council	Priority[1]
2. No new works or buildings to be permitted in floodways	Required to maintain capacity and/or prevent development in High Hazard Area	None	H
3. Raising of existing buildings to be encouraged	Required to provide all buildings to be above 1% AEP flood plus freeboard	None	H
4. Filling under floor plan of buildings to be permitted	Required to provide minimum floor levels, subject to adjoining properties not being adversely affected	None	H
5. No filling of environmentally sensitive areas or modification of foreshore	Required for environmental protection	None	H
6. Filling of properties to 200 millimetres above "let-out" level be permitted	Required to reduce regular inundation of properties	None	M

Note: 1. Priorities: H High Priority
M Medium Priority
L Low Priority

1. INTRODUCTION

Cockrone Lagoon is a coastal lagoon which is formed behind the beach dunes at MacMasters Beach, Gosford.

The lagoon, as illustrated on Figure 1, is a significant landscape and recreational resource in the Gosford area.

The catchment of Cockrone Lagoon is some 7.1 square kilometres. Ninety percent of the catchment is natural bushland or under rural development. Urban development is essentially confined to a strip within 500 metres of the beach front to the South Pacific Ocean.

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.

Flooding in the tributary creeks to Cockrone Lagoon occurs from short duration, intense storms (durations of 3 hours or less) while the lagoon itself floods in longer duration events (durations in the order of 12 hours). The magnitude of flood water level rises in the lagoon is determined by conditions at the beach front and beach berm levels.

Investigations in the Flood Study (Reference 2) and the Floodplain Management Study (Reference 3) indicate that the historical beach berm levels are variable (between 2.6 and 4.0 m AHD) and that design one percent AEP flood levels are some 300 millimetres above the beach berm level prevailing at the time of the flood.

Design one percent AEP flood levels within Cockrone Lagoon are RL 4.1 m AHD for a beach berm level of RL 3.8 m AHD. The berm level is some 0.5 metres above the average berm level deduced from Council records available since 1972 and represents a level that is reached or exceeded some 10 percent of the time.

At the upstream end of the study area, design one percent AEP flood levels reach RL 4.82 m AHD at The Scenic Road, although one percent flood levels reach RL 7.5 on Bounty Hill Road (on a tributary to Cockrone Lagoon).

Ocean wave levels at the lagoon entrance have been assessed to reach RL 4.0 m AHD at one percent AEP.

The foreshore vegetation of Cockrone Lagoon generally consists of Melaleuca fringes with pockets of mature eucalypts. A significant rainforest area exists along Merchants Creek, a northern tributary to Cockrone Lagoon.

Land use around Cockrone Lagoon is essentially Residential 2(a) zoning near the beachfront with Open Space 6(a) and Conservation 7(a) zoning west of the residential area. Virtually all the western foreshore of Cockrone Lagoon is a designated wetland area under SEPP 14.

Future development potential with the current zonings is essentially limited to re-development of existing building with the existing subdivisions.

2. SPECIFIC COMPONENTS

2.1 Overview

Six flooding precincts have been identified around the lagoon foreshore.

These precincts have been classified for flood hazard as:

High Hazard - Floodways

- Cockrone Lagoon beach berm;
- Cockrone Gully, from the upstream study boundary to its confluence with Cockrone Lagoon (identified as Cockrone Lagoon floodway);
- Merchants Creek floodway from the confluence of Merchants Creek with Cockrone Lagoon to the upstream study extent; and
- an existing open drain through the residential areas bounded by Newell Road and Three Points Avenue.

High Hazard – Low Hazard Floodway (Floodway Investigation area)

- Cockrone Lagoon at its entrance to the ocean (Floodway/Investigation Area);

Low Hazard - Flood Storage

- Cockrone Lagoon and foreshores excepting high hazard areas above.

These precincts are illustrated on Figures 2 and 3, while Figure 4 provides greater detail in the Cockrone Lagoon Entrance Area.

Council has adopted a policy of opening the lagoons when water level reaches RL 2.53 m AHD (identified as the let-out-level). Council has, in the past, also adopted a policy that requires new buildings to have floor levels above RL 4.3 m AHD. These two policies effectively constitute Council's current floodplain management practice around Cockrone Lagoon.

Specific components of the Floodplain Management Plan are outlined below.

2.2 Cockrone Lagoon Beach Berm

In this area, coastal and ocean processes dominate. Management of the beach berm is covered by a separate Council policy.

Essentially, Council's policy covers:

- management of the beach berm to maintain levels in the range 3.3 to 3.5 m AHD; and
- let out of the lagoon once water levels reach RL 2.53 m AHD.

The investigations in the Flood Study (Reference 2) showed that maintenance of the beach berm in the range of RL 3.3 to 3.5 m AHD will produce one percent AEP flood levels of RL 3.8 m AHD. The target range of berm level (RL 3.3) has been maintained over the past 20 years by Council's "let-out" policy.

The community should be aware that severe weather conditions may prevent the "let-out" process and these management provisions may have to be delayed until work conditions are safe.

Current practice is to initiate the lagoon "let-out" on the falling tide. However, members of the community have questioned if the degree of scour through the beach berm during "let-out" is mitigated during a rising tide. The effectiveness of "let-out" on a rising tide would be best evaluated by field testing.

The Management Plan in this area thus covers:

- maintenance of Council's current "let-out" policy;

- maintain the beach berm at a level between RL 3.3 to RL 3.5 m AHD to enhance let-out of the lagoon in accordance with Council's policy - "Opening of Coastal Lagoons";

- undertaking a series of measures to optimise the break-out process.

Measures to optimise the break out process are:

- improvement to rainfall data collection systems to allow an improved co-relation between catchment rainfall and lagoon water levels;

- development of improved water level prediction methods for Cockrone Lagoon to reduce the chance of unnecessary opening of the lagoon;

- development of an improved flood prediction method to assist timely opening of the beach berm; and

- field trials of opening the lagoon during rising tide conditions to confirm if this strategy effectively reduces the width and depth of scour through the beach berm.

2.3 Cockrone Lagoon Flood Storage Area

This precinct covers the bulk of Cockrone Lagoon and its environs, as outlined on Figure 2.

The Floodplain Management Plan allows for the Cockrone Lagoon beach berm to be maintained at about RL 3.5 m AHD and the current practice of assisting "let-out" once water levels reach RL 2.53 m AHD. However, the "let-out" process may be delayed by severe weather conditions.

Thus, the Plan provides for enforcement of minimum floor levels which assume the "let-out process" is effective and encourages higher floor levels as additional protection against uncertainty of the "let-out" process.

Specific provisions in this precinct are:

- all new buildings and major extensions in the flood storage area are to be encouraged to have floor levels above RL 4.6 m AHD (as protection against the possibility that the beach berm cannot be effectively managed or should the "let-out" process be prevented by prevailing weather conditions);

- all new buildings and major extensions are encouraged to be located outside the 1% AEP flood extent, where possible;

- all new buildings and major extensions in and adjacent to the flood storage area are to be above the minimum floor level of RL 4.3 m AHD;

- raising of existing buildings to above minimum floor levels is to be encouraged;

- filling will be considered under the footprint of buildings to achieve minimum floor levels, subject to the requirement that such filling has no adverse affects on overland flow on adjacent properties;

- filling of properties up to 200 millimetres above the "let-out" level will be considered to reduce nuisance flooding on individual blocks, provided side slopes do not exceed 1:6 (vertical to horizontal) and provided such filling does not affect overland flow on adjoining properties;

- filling of environmentally sensitive areas, or modification of the foreshore, will not be permitted;

- proposed large scale filling will be treated on its merits, including assessment of drainage of overland flow patterns. Fill batters should not exceed 1:6 (vertical to horizontal).

- developments below the PMF level should have purposes that are compatible with the extreme flood risk and developments that are not compatible with flood recovery planning should be excluded (eg schools, hospitals, aged care facilities).

2.4 Cockrone Lagoon Floodway Area

This precinct represents the major tributary inflow into Cockrone Lagoon as outlined on Figure 2.

Specific provisions in this precinct are:

- floodway to be maintained in perpetuity for the passage of floodwaters;
- no works that impede the passage of floodwaters along the floodway are permitted;
- no new construction of buildings in the floodway is permitted;
- filling is prohibited;
- all land use to be flood compatible;
- raising of existing buildings from below minimum floor levels is to be encouraged;
- fences and structures likely to collect debris and/or impede the floodway are not permitted;
- all new buildings and major extensions are to be constructed outside the 1% AEP floodway area and are to be constructed above the minimum floor level; and
- proposals to cross the floodway for services are permitted provided the proposals are adequately investigated and do not significantly affect flood capacity or flood levels.

2.5 Merchants Creek Floodway Area

This precinct covers the Merchants Creek tributary as the north-eastern corner of Cockrone Lagoon, as outlined on Figure 2.

Specific provisions in this precinct are:

- floodway to be maintained in perpetuity for the passage of floodwaters;
- no works that impede the passage of floodwaters along the floodway are permitted;
- no new construction of buildings in the floodway is permitted;
- filling is prohibited;
- all land use to be flood compatible;
- raising of existing buildings from below minimum floor levels is to be encouraged;
- fences and structures likely to collect debris and/or impede the floodway are not permitted;
- all new buildings and major extensions are to be constructed outside the 1% AEP floodway area and are to be constructed above the minimum floor level; and

- proposals to cross the floodway for services are permitted provided the proposals are adequately investigated and do not significantly affect flood capacity or flood levels.

2.6 Newell Road Floodway

This precinct covers a drainage reserve and trunk drainage works entering Cockrone Lagoon at its south-eastern corner, as outlined on Figure 2.

Addendum No. 1 to the Flood Study has identified levee works as an appropriate measure to confine flood flows up to the 1% AEP event to the drainage reserve. These works are recommended.

The Newell Road Floodway is also a significant flood storage area. Any loss of flood storage upstream of the proposed levee has the potential to reduce the effectiveness of the levee. Accordingly, further filling in the floodway or encroachment by buildings into the floodway should be prohibited.

Specific provisions in this precinct are:

- levee works and/or channel widening to be constructed as outlined by Addendum No. 1 of the Flood Study;
- floodway to be maintained in perpetuity for the passage of floodwaters;
- no works that impede the passage of floodwaters along the overflow floodway are permitted until channel and levee works are completed;
- no further encroachment into the floodway will be permitted;
- filling is prohibited on land inundated by the 1% AEP flood;
- all land use to be flood compatible within the 1% AEP extent;
- raising of existing buildings from below minimum floor levels is to be encouraged;
- fences and structures likely to collect debris and/or impede the floodway are not permitted;
- all new buildings and major extensions are to be constructed outside the floodway area and are to be constructed above the minimum floor level. Construction within the overflow channel will be permitted on piers prior to completion of the channel and levee works.
- proposals to cross the floodway for services are permitted provided the proposals are adequately investigated and do not significantly affect flood capacity or flood levels.

The flood details shown on Figure 2 represent conditions after construction of levee and associated widening of the channel. Figure 3 indicates flood conditions as applying prior to completion of those works.

2.7 Cockrone Lagoon Entrance Area

This area lies between the Cockrone Lagoon Flood storage area and the beach berm area, as shown on Figure 4.

This area is affected by both flooding and coastal processes (principally ocean waves overtopping the beach). Preliminary wave height information was derived for the Flood Study. It is accepted that additional investigation is required to more accurately quantify the coastal hazard. Such investigation will allow better definition of appropriate land use controls. In the interim, until such analysis is available, a "Floodway/Investigation area" has been used to describe the area with development conditions essentially based on "floodways".

Specific interim land use controls are:

- the area identified shall be treated as "Floodway";

- the areas within the lagoon have been classed as High Hazard Floodway, while the surrounding foreshore areas have been classified as Low Hazard – Floodway with regard to lagoon catchment flooding;

- all new buildings and major extensions to be encouraged to have floor levels above RL 4.5 m AHD (as protection against the possibility that the beach berm cannot be effectively managed or should the “let-out” process be prevented by prevailing weather conditions).

- raising of existing buildings from below minimum floor levels is to be encouraged;

- all buildings and major extensions are to be subject to special design provisions to dissipate forces from inundation by ocean waves in accordance with Council's "Coastal Frontage - Development and Building" Policy;

- all buildings and major extensions are to be subject to special design conditions to address flood flows and velocities. Such flood forces are expected to be less than those created by ocean waves.

- filling will be considered under the footprint of buildings to achieve minimum floor levels, subject to the requirement that such filling have no adverse affects on overland flow on adjacent properties.

- new buildings, re-development or extensions should not project into the floodway more than present buildings. This provision has been specifically addressed by Council’s DCP No. 155 – “Single Dwellings and Ancillary Structures”.

- no further sub-division within the area or development that increases the population density. This provision is intended to limit the population at risk and thus in need of evacuation should a major flood or ocean event occur.

2.8 General Provisions

Section 2.2, "Cockrone Lagoon Beach Berm", contains a number of general provisions relating to improved management of the beach berm.

These provisions, in summary, are:

- improved rainfall data collection;
- improved water level prediction; and
- improved flood prediction methods.

The object of the above is improvement of the prediction of lagoon levels to ensure that the beach berm is not opened unnecessarily.

Additional general provisions are proposed. They are:

- preparation and distribution of simple brochures outlining flood issues and the responses contained in this Plan;

- construction of a staff gauge at a convenient location to indicate "let-out levels", design 1% AEP flood levels and Council's "Let-out" Policy;

- review of the Floodplain Management Plan every 10 years to ensure the Plan remains current with conditions as they exist at the time of the review.

It is noted in the Floodplain Management Study that upstream development has the potential to impact on flood behaviour and thus impact on the provisions of this Plan.

Accordingly, development controls are required upstream of Cockrone Lagoon to:

- restrict flood flows to current levels (to prevent an increase in design flood levels);

- restrict the sediment generation and transport to Cockrone Lagoon as increases can increase siltation of the Lagoon and subsequently increase flood levels.

Additionally, for consistency for the specific areas, development controls included within the general provisions are:

- New developments and major extensions to have flood free access up to 1% AEP flood event; and

- All new developments and major extensions to be above minimum floor level.

The PMF flood extents define the areas that can be considered "flood liable". In a flood of this magnitude, there are a variety of public facilities that will be critical for flood emergency management procedures (such as hospitals, police stations, SES stations, ambulance stations, major telecommunication facilities). Ideally, these installations should be located beyond the PMF flood extents.

2.9 Review Process

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It is accepted that the Floodplain Management Process is not "fixed". The provisions of this Plan can be expected to change in response to:

- recorded flood occurrences;
- changes in community perceptions and requirements; and
- changes to Government legislative frameworks (for example, the introduction of new State Environment Planning Policies (SEPP).

Review Process should be triggered by either:

- flood reaching greater than RL 3.3 m AHD within the lagoon storage area; or
- passage of 10 years after adoption of the Plan.

Each review should identify:

- if catchment changes have modified runoff and flow volumes;
- the adequacy of the berm maintenance operations and any changes to the frequency of required operations;
- recorded rainfalls, flood levels and berm openings;
- the adequacy of public education and flood warning system;
- the adequacy of measures to deal with floods larger than the design one percent AEP flood level; and
- the magnitude of any ocean level rises or climate change that would affect the provisions of the Plan.

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 (i.e.) land susceptible to flooding by the probable maximum flood (PMF) event. Note that the term flood liable land now covers the whole of the floodplain, not just that part below the flood planning level, as indicated in the 1986 Floodplain Development Manual (Ref. 4) (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. 4).

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

1. "Floodplain Management Manual: The Management of Flood Liable Land", New South Wales Government, January 2001.

2. "Cockrone Lagoon Flood Study", Paterson Consultants Pty Limited, April 1994.

3. "Cockrone Lagoon Floodplain Management Study", Paterson Consultants Pty Limited, March 1995.

4. "Floodplain Development Manual", New South Wales Government, Public Works Department 86010, ISBN 724030115, Dec. 1986.

5. "Floodplain Development Manual, the Management of Flood Liable Land", New South Wales Government, Department of Infrastructure Planning and Natural Resources, ISBN 07347 5476 0, April 2005

FIGURES

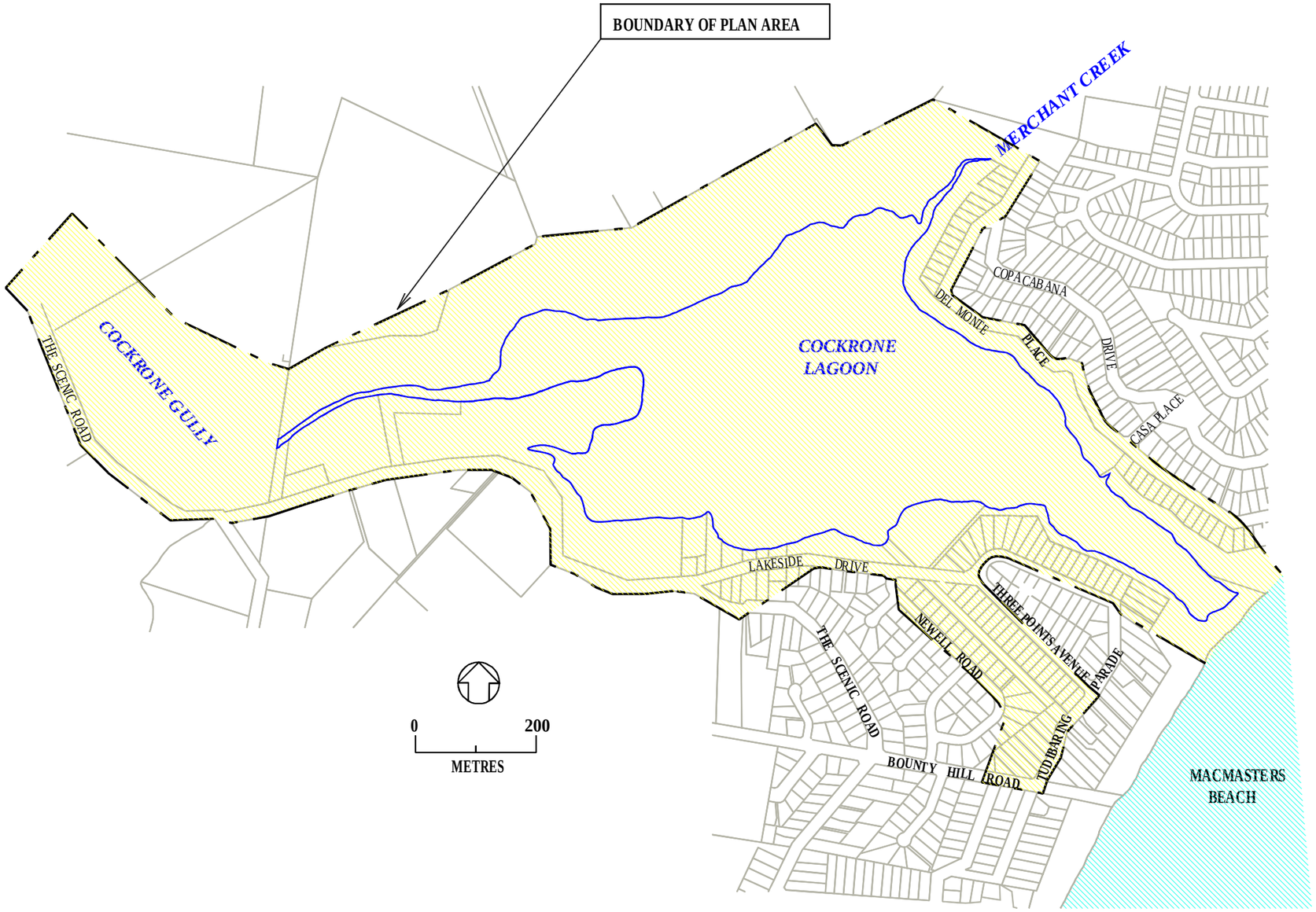

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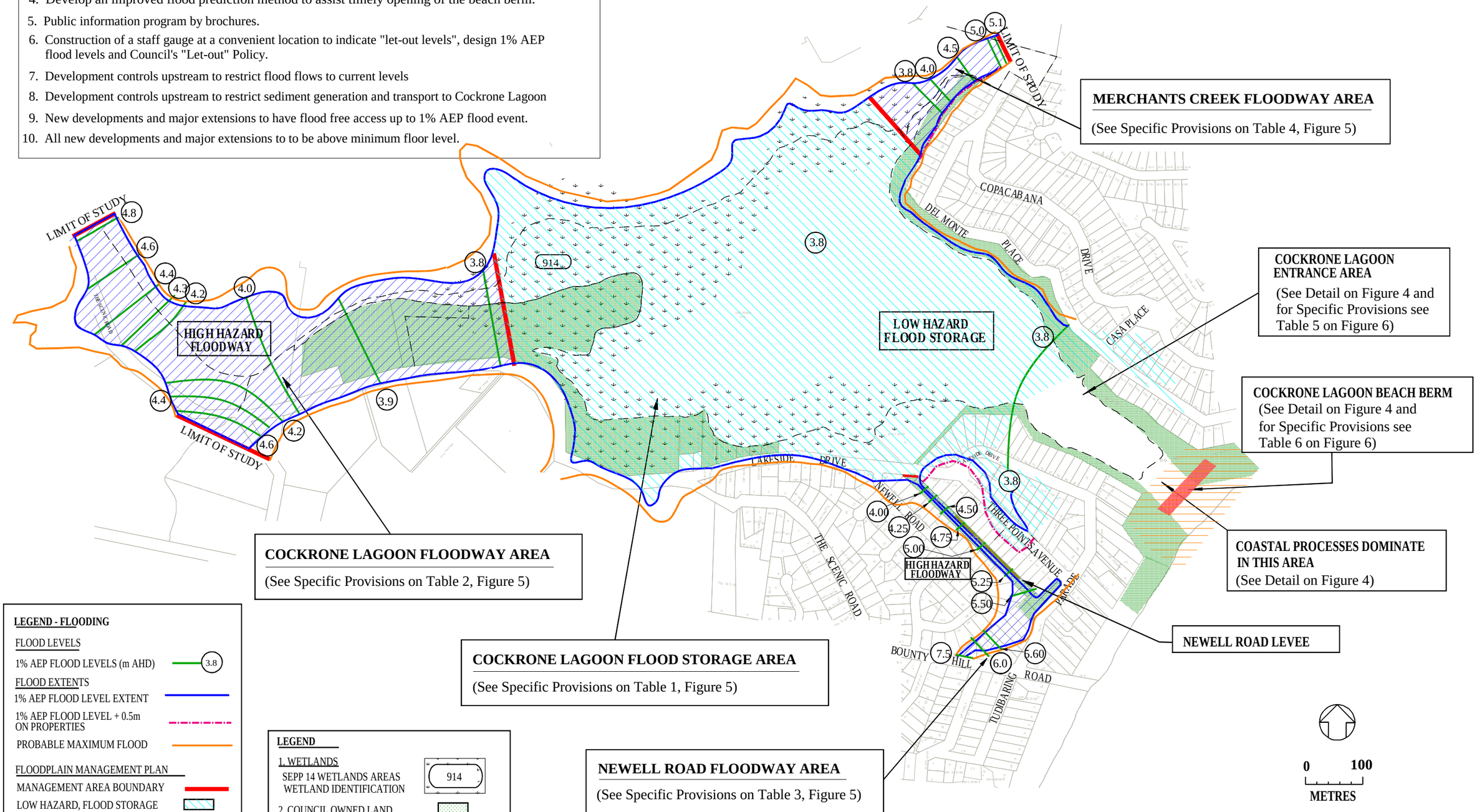
FIGURE 1
STUDY AREA

COCKRONE LAGOON
FLOODPLAIN MANAGEMENT PLAN

GENERAL MEASURES & GENERAL DEVELOPMENT CONTROLS

1. "Let-out Level" RL 2.53 m AHD
2. Develop an improved water level prediction method to reduce an unnecessary opening of the beach berm.
3. Improve rainfall data collection and improve correlation of rainfall to lagoon water level.
4. Develop an improved flood prediction method to assist timely opening of the beach berm.
5. Public information program by brochures.
6. Construction of a staff gauge at a convenient location to indicate "let-out levels", design 1% AEP flood levels and Council's "Let-out" Policy.
7. Development controls upstream to restrict flood flows to current levels
8. Development controls upstream to restrict sediment generation and transport to Cockrone Lagoon
9. New developments and major extensions to have flood free access up to 1% AEP flood event.
10. All new developments and major extensions to to be above minimum floor level.



MERCHANTS CREEK FLOODWAY AREA

(See Specific Provisions on Table 4, Figure 5)

COCKRONE LAGOON ENTRANCE AREA

(See Detail on Figure 4 and for Specific Provisions see Table 5 on Figure 6)

COCKRONE LAGOON BEACH BERM

(See Detail on Figure 4 and for Specific Provisions see Table 6 on Figure 6)

COASTAL PROCESSES DOMINATE IN THIS AREA

(See Detail on Figure 4)

NEWELL ROAD LEVEE

COCKRONE LAGOON FLOODWAY AREA

(See Specific Provisions on Table 2, Figure 5)

COCKRONE LAGOON FLOOD STORAGE AREA

(See Specific Provisions on Table 1, Figure 5)

NEWELL ROAD FLOODWAY AREA

(See Specific Provisions on Table 3, Figure 5)

LEGEND - FLOODING

FLOOD LEVELS

1% AEP FLOOD LEVELS (m AHD) — 3.8

FLOOD EXTENTS

1% AEP FLOOD LEVEL EXTENT

1% AEP FLOOD LEVEL + 0.5m ON PROPERTIES

PROBABLE MAXIMUM FLOOD

FLOODPLAIN MANAGEMENT PLAN

MANAGEMENT AREA BOUNDARY

LOW HAZARD, FLOOD STORAGE

HIGH HAZARD, FLOODWAY

LEGEND

1. WETLANDS

SEPP 14 WETLANDS AREAS WETLAND IDENTIFICATION — 914

2. COUNCIL OWNED LAND

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FIGURE 2
COCKRONE LAGOON MANAGEMENT PLAN
(AFTER NEWELL ROAD LEVEE CONSTRUCTION)

COCKRONE LAGOON
FLOODPLAIN MANAGEMENT PLAN

GENERAL MEASURES & GENERAL DEVELOPMENT CONTROLS

1. "Let-out Level" RL 2.53 m AHD
2. Develop an improved water level prediction method to reduce an unnecessary opening of the beach berm.
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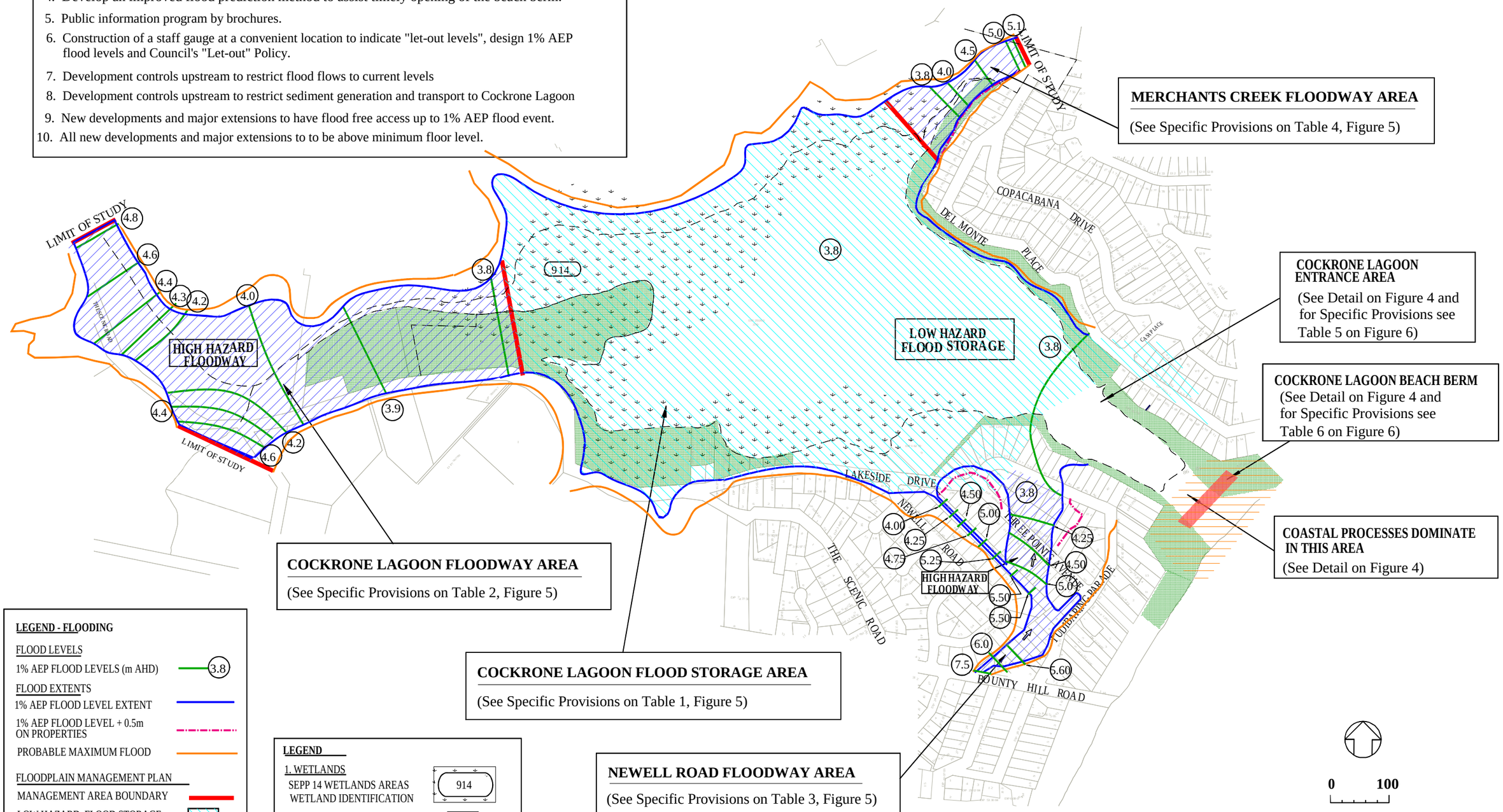

MERCHANTS CREEK FLOODWAY AREA
(See Specific Provisions on Table 4, Figure 5)

COCKRONE LAGOON ENTRANCE AREA
(See Detail on Figure 4 and for Specific Provisions see Table 5 on Figure 6)

COCKRONE LAGOON BEACH BERM
(See Detail on Figure 4 and for Specific Provisions see Table 6 on Figure 6)

COASTAL PROCESSES DOMINATE IN THIS AREA
(See Detail on Figure 4)

COCKRONE LAGOON FLOODWAY AREA
(See Specific Provisions on Table 2, Figure 5)

COCKRONE LAGOON FLOOD STORAGE AREA
(See Specific Provisions on Table 1, Figure 5)

NEWELL ROAD FLOODWAY AREA
(See Specific Provisions on Table 3, Figure 5)

LEGEND - FLOODING

FLOOD LEVELS
1% AEP FLOOD LEVELS (m AHD) — 3.8
FLOOD EXTENTS
1% AEP FLOOD LEVEL EXTENT
1% AEP FLOOD LEVEL + 0.5m ON PROPERTIES
PROBABLE MAXIMUM FLOOD

FLOODPLAIN MANAGEMENT PLAN
MANAGEMENT AREA BOUNDARY
LOW HAZARD, FLOOD STORAGE
HIGH HAZARD, FLOODWAY

LEGEND

1. WETLANDS
SEPP 14 WETLANDS AREAS
WETLAND IDENTIFICATION — 914
2. COUNCIL OWNED LAND

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FIGURE 3
COCKRONE LAGOON MANAGEMENT PLAN
(BEFORE NEWELL ROAD LEVEE CONSTRUCTION)

COCKRONE LAGOON
FLOODPLAIN MANAGEMENT PLAN

LEGEND - FLOODING

FLOOD LEVELS

1% AEP FLOOD LEVELS (m AHD) — 3.8

FLOOD EXTENTS

1% AEP FLOOD LEVEL EXTENT

1% AEP FLOOD LEVEL + 0.5m ON PROPERTIES

PROBABLE MAXIMUM FLOOD

FLOODPLAIN MANAGEMENT PLAN

MANAGEMENT AREA BOUNDARY

LOW HAZARD, FLOOD STORAGE

LOW HAZARD, FLOODWAY

HIGH HAZARD, FLOODWAY

LEGEND

1. WETLANDS
SEPP 14 WETLANDS AREAS
WETLAND IDENTIFICATION — 914

2. COUNCIL OWNED LAND

3. BUILDINGS (IF SHOWN)
EXISTING DEVELOPMENTS
BUILDING FOOTPRINT
IMPROVEMENTS FOOTPRINT

4. FORESHORE BUILDING LIMIT
FORESHORE BUILDING LIMIT LINE
(AS DEFINED BY COUNCIL'S DCP NO 155)

LOW HAZARD FLOOD STORAGE

Note: High Hazard / Low Hazard boundary defined by measurement along boundaries from Lakeside Drive to edge of existing grassed areas

FLOODWAY HIGH HAZARD
(DEFINED FROM LAGOON CATCHMENT FLOODING)

LOW HAZARD FLOODWAY
(DEFINED FROM LAGOON CATCHMENT FLOODING)

LOW HAZARD FLOODWAY
(DEFINED FROM LAGOON CATCHMENT FLOODING)

COCKRONE LAGOON ENTRANCE AREA
(For Specific Provisions, see Table 5 on Figure 6)

COCKRONE LAGOON BEACH BERM
(For Specific Provisions, see Table 6 on Figure 6)

COASTAL PROCESSES DOMINATE IN THIS AREA
For Development Controls, see
Coastal Management Plan and Associated Studies.

GENERAL MEASURES AND GENERAL DEVELOPMENT CONTROLS
(See Figures 2 or 3)

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FIGURE 4
COCKRONE ENTRANCE MANAGEMENT PLAN
(AFTER NEWELL ROAD LEVEE CONSTRUCTION)

TABLE 1

SPECIFIC PROVISIONS, COCKRONE LAGOON FLOOD STORAGE AREA

- all new buildings and major extensions are encouraged to have floor levels above RL 4.6 m AHD (as protection against the possibility that the beach berm cannot be effectively managed or should the "let-out" process be prevented by prevailing weather conditions);
- all new buildings and major extensions are encouraged to be located outside the 1% AEP flood extent where possible.
- all new buildings and major extensions in or adjacent to the flood storage area are to be above the minimum floor level of RL 4.3 m AHD;
- raising of existing buildings to above minimum floor levels is to be encouraged;
- filling will be considered under the footprint of buildings to achieve minimum floor levels, subject to the requirement that such filling has no adverse affects on overland flow on adjacent properties;
- filling of properties up to 200 millimetres above the "let-out" level will be considered to reduce nuisance flooding on individual blocks, provided side slopes do not exceed 1:6 (vertical to horizontal) and provided such filling does not affect overland flow on adjoining properties;
- filling of environmentally sensitive areas, or modification of the foreshore, will not be permitted;
- proposed large scale filling will be treated on its merits, including assessment of drainage of overland flow patterns. Fill batters should not exceed 1:6 (vertical to horizontal).
- developments below the PMF level should have purposes that are compatible with the extreme flood risk and developments that are not compatible with flood recovery planning should be excluded (eg schools, hospitals, aged care facilities).

TABLE 2

SPECIFIC PROVISIONS, COCKRONE LAGOON FLOODWAY AREA

- floodway to be maintained in perpetuity for the passage of floodwaters;
- no works that impede the passage of floodwaters along the floodway are permitted;
- no new construction of buildings in the floodway is permitted;
- filling is prohibited;
- all land use to be flood compatible;
- raising of existing buildings from below minimum floor levels is to be encouraged;
- fences and structures likely to collect debris and/or impede the floodway are not permitted;
- all new buildings and major extensions are to be constructed outside the 1% AEP floodway area and are to be constructed above the minimum floor level; and
- proposals to cross the floodway for services are permitted provided the proposals are adequately investigated and do not significantly affect flood capacity or flood levels.

TABLE 3

SPECIFIC PROVISIONS, NEWELL ROAD FLOODWAY AREA

- levee works and/or channel widening to be constructed as outlined by Addendum No. 1 of the Flood Study;
- floodway to be maintained in perpetuity for the passage of floodwaters;
- no works that impede the passage of floodwaters along the overflow floodway are permitted until channel and levee works are completed;
- no further encroachment into the channel floodway will be permitted;
- filling is prohibited on land inundated by the 1% AEP flood;
- all land use to be flood compatible within the 1% AEP extent;
- raising of existing buildings from below minimum floor levels is to be encouraged;
- fences and structures likely to collect debris and/or impede the floodway are not permitted;
- all new buildings and major extensions are to be constructed outside the floodway area and are to be constructed above the minimum floor level. Construction within the overflow channel will be permitted on piers prior to the completion of the channel and levee works.
- proposals to cross the floodway for services are permitted provided the proposals are adequately investigated and do not significantly affect flood capacity or flood levels.

TABLE 4

SPECIFIC PROVISIONS, MERCHANTS CREEK FLOODWAY AREA

- floodway to be maintained in perpetuity for the passage of floodwaters;
- no works that impede the passage of floodwaters along the floodway are permitted;
- no new construction of buildings in the floodway is permitted;
- filling is prohibited;
- all land use to be flood compatible;
- raising of existing buildings from below minimum floor levels is to be encouraged;
- fences and structures likely to collect debris and/or impede the floodway are not permitted;
- all new buildings and major extensions are to be constructed outside the 1% AEP floodway area and are to be constructed above the minimum floor level; and
- proposals to cross the floodway for services are permitted provided the proposals are adequately investigated and do not significantly affect flood capacity or flood levels.

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FIGURE 5
COCKRONE LAGOON MANAGEMENT PLAN, SPECIFIC PROVISIONS

TABLE 5

SPECIFIC PROVISIONS, COCKRONE LAGOON ENTRANCE AREA

- the area identified shall be treated as "Floodway";
- the areas within the lagoon have been classed as High Hazard Floodway, while the surrounding foreshore areas have been classified as Low Hazard - Floodway with regard to Lagoon Catchment flooding.
- all new buildings and major extensions to be encouraged to have floor levels above RL 4.6 m AHD (as protection against the possibility that the beach berm cannot be effectively managed or should the "let-out" process be prevented by prevailing weather conditions);
- raising of existing buildings from below minimum floor levels is to be encouraged;
- all buildings and major extensions are to be subject to special design provisions to dissipate forces from inundation by ocean waves in accordance with Council's "Coastal Frontage - Development and Building" Policy;
- all buildings and major extensions are to be subject to special design conditions to address flood flows and velocities. Such flood forces are expected to be less than those created by ocean waves.
- filling will be considered under the footprint of buildings to achieve minimum floor levels, subject to the requirement that such filling have no adverse affects on overland flow on adjacent properties.
- new buildings, re-development or extensions should not project into the floodway more than present buildings. This provision has been specifically addressed by Council's DCP No. 155 - "Single Dwellings and Ancillary Structures".
- no further sub-division within the area or development that increases the population density. This provision is intended to limit the population at risk and thus in need of evacuation should a major flood or ocean event occur.

TABLE 6

SPECIFIC PROVISIONS, COCKRONE LAGOON BEACH BERM

- maintenance of Council's current "let-out" policy;
- maintain the beach berm at a level between RL 3.3 to RL 3.5 m AHD to enhance let-out of the lagoon in accordance with Council's policy - "Opening of Coastal Lagoons";
- undertaking a series of measures to optimise the break-out process:
  - improvement to rainfall data collection systems to allow an improved co-relation between catchment rainfall and lagoon water levels;
  - development of improved water level prediction methods for Cockrone Lagoon to reduce the chance of unnecessary opening of the lagoon;
  - development of an improved flood prediction method to assist timely opening of the beach berm; and
  - field trials of opening the lagoon during rising tide conditions to confirm if this strategy effectively reduces the width and depth of scour through the beach berm.

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FIGURE 6
COCKRONE LAGOON MANAGEMENT PLAN, SPECIFIC PROVISIONS

GOSFORD CITY COUNCIL

COCKRONE LAGOON
FLOOD STUDY

ADDENDUM No. 1

MACMASTERS BEACH DRAIN

April 1997

(Amended December 2003, 2007)

GOSFORD CITY COUNCIL

COCKRONE LAGOON
FLOOD STUDY

ADDENDUM No. 1

MACMASTERS BEACH DRAIN

April 1997

(Amended December 2003, 2007)

Prepared By:

PATERSON CONSULTANTS PTY LIMITED
1/45 PRINCE STREET
GRAFTON NSW 2460

P O BOX 596
GRAFTON NSW 2460

Tel: 066 431588
Fax: 066 427566
E-mail: patcon@nor.com.au

Version 3
Authorised for Release

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1. INTRODUCTION

This Addendum report outlines the investigation of the trunk drainage for the MacMasters Beach area.

The report addresses local flooding issues which were not identified in the Cockrone Lagoon Floodplain Management Study report (Ref.1).

The MacMasters Beach drain is located in a drainage reserve between Lakeside Drive and Tudibaring Parade. Runoff from a catchment area of some 19.5 ha discharges to a natural drainage path at Bounty Hill Road some 100 m to the west of Tudibaring Parade. The natural drainage path flows through a waterhole/wetland area and thence to the MacMasters Beach drain. The principal features of the drainage system are shown on Figure A-1.

The excavated drain is trapezoidal in cross-section with a top width of 5.5 m, bottom width 1.5 m and depth 1.2 to 1.8 m. The drain discharges to Cockrone Lagoon via a two-cell 1.5 m x 0.6 m culvert under Lakeside Drive.

Flood behaviour in the lower section of the drain is dependent on the behaviour of Cockrone Lagoon while local runoff controls the flood behaviour in the upper section.

The investigation of the trunk drainage was undertaken using the hydrologic and hydraulic models developed for the Cockrone Lagoon Flood Study (Ref.2) as discussed below.

2. HYDROLOGIC MODELLING

A RORB rainfall-runoff model of the Cockrone Lagoon catchment had been developed for the Cockrone Lagoon Flood Study. This model determined runoff hydrographs for a number of sub-catchments, including the MacMasters Beach sub-catchment.

The critical storm duration for lagoon flooding was found to be dependent on beach berm level and rainfall intensity. For the 1% AEP design flood event, the critical storm duration is 9 hours.

The MacMasters Beach sub-catchment is some 19.5 ha in area and thus responds rapidly to intense rainfall. A small ILSAX model was established for the MacMasters Beach Drain using a sub-catchment division as indicated on Figure A-2.

Table A1 shows the estimated peak discharge determined using the ILSAX model and design rainfall data in accordance with Australian Rainfall and Runoff (Ref.3)

Table A1 also includes a flow estimate derived from the catchment RORB model for comparative purposes.

The Probabalistic Rational Method provides an estimated 1% AEP peak flow at Lakeside Drive of 6.1 m^3/sec, some 22 percent less than the ILSAX model.

Table A1

1% AEP Peak Discharges

Storm Duration (mins)	100 ARI Rainfall (mm)	Peak Discharges (ILSAX)		Peak Discharges (RORB)
		Bounty Hill Road (m^3/sec)	Lakeview Drive (cu m/sec)	Lakeside Drive (cu m/sec)
10	43.1	2.77	6.33	NC
20	51.7	3.95	7.97	11.9
30	63.2	3.89	7.80	11.1
45	77.4	NC	NC	10.9
60	89.1	4.04	7.83	10.4
90	105.6	NC	NC	12.1
120	118.7	3.79	7.84	11.6
180	139.1	3.00	5.90	NC

Notes: NC - Not calculated

3. HYDRAULIC MODELLING

The MIKE-11 hydraulic model developed for the flood study was modified to incorporate additional surveyed cross-sections along the MacMasters Beach drain and to include the potential breakout overland flowpath near the top of the drainage easement. The additional cross-sections and overland flowpath are shown on Figure A-3.

Local runoff hydrographs for storm durations of 20, 45, 60, 90 and 120 minutes were routed through the hydraulic model in order to determine the critical 1% AEP flood levels along the MacMasters Beach drain. The peak flood levels were generally set by the 90 minute and 120 minute duration storm events.

The hydraulic modelling showed that the waterhole/wetland area provided a significant detention storage flow reduction. The results of the hydraulic modelling are summarised in Table A2.

The hydraulic modelling showed that floodwaters would break out of the drain immediately downstream of the of the waterhole/wetland area and flow along a natural drainage path between the residual dune formation. The breakout floodwaters would flow across at least six (6) properties in

Three Points Avenue which back onto the drainage reserve. The breakout flow is equal to the flow which would be conveyed in the drain downstream of the breakout.

It is estimated that the breakout floodwaters would then flow through an additional 20 properties between Three Points Avenue and Cockrone Lagoon.

Table A2

1% AEP Peak Flood Levels – Existing Conditions

Location	Model X-Section	Storm Duration (minutes)					Peak Flow in 60 min Storm (m^3/s)
		20	45	60	90	120	
d/s Bounty Hill Rd	X13A	7.46	7.45	7.46	7.47	7.46	3.9
Waterhole	X11	5.47	5.51	5.54	5.53	5.54	3.6
d/s Waterhole	X10	5.47	5.50	5.53	5.53	5.54	3.2
Top of Drain	X9	5.43	5.47	5.50	5.51	5.51	2.6
Middle of Drain	X6	4.64	4.70	4.74	4.75	4.75	4.0
u/s Lakeside Dr	X4	3.67	3.68	3.71	3.72	3.72	5.4
22 Three Points Ave	X15	4.51	5.09	5.18	5.17	5.17	0.6

The floor level survey data collected for the floodplain management study indicates that five (5) houses in Three Points Avenue would be inundated by floodwaters 0.2 to 0.5 m in depth in the 1% AEP local storm event.

These houses would be subjected to "flash" flooding with virtually no warning. The residents would have no time to carry out any measures to reduce the damages or the impact caused by the floodwaters.

An additional six (6) houses in Three Points Avenue and on the southern side of Lakeside Drive would have less than 0.1 m clearance above the 1% AEP local flood.

Floodwaters would also extend over the parkland near the intersection of Three Points Avenue and Tudibaring Parade. The road formation and adjacent higher land would confine the floodwaters to the parkland area.

The runoff would be contained within the excavated channel downstream of the sewer crossing approximately 100 m from the top end of the drainage reserve.

The estimated 1% AEP local flood levels and extent of floodwaters are shown on Figure A-4.

4. FLOOD MITIGATION WORKS OPTIONS

Four (4) of the houses in Three Points Avenue which would be flooded by local runoff in the 1% AEP event are of timber framed construction. However, all are lowset and would be difficult to raise. The fifth flood-liable house is of brick veneer construction and is thus unsuited to raising.

Therefore, it is considered that raising of the flood-liable houses is not an effective option for Three Points Avenue properties.

Flood mitigation works options which could prevent or greatly reduce the breakout of floodwaters from the drainage reserve include:

- construction of an earth levee some 100 m long with a maximum height of 1.2 m
- widening of the excavated drain

Several scenarios for improvement and flood mitigation works were tested with the hydraulic model comprising:

- only levee works;
- levee works plus widening the existing channel to a 3.6 metre base width; and
- levee works plus widening the existing channel to a 6 metre base width.

The calculated 1% AEP flood levels with the levee and widening of the upstream section of the channel is presented in Table A3.

The hydraulic modelling of the levee, but without the channel widening work, indicates that the 1% AEP local flood levels along the MacMasters Beach drain and in the waterhole/wetland would be increased by 0.10 m. There would be no increase in flood levels at Bounty Hill Road. Hence, some channel improvement work is required.

The resultant increase in flood levels caused by levee works, but without channel improvement works, would force floodwaters to encroach approximately 2 m farther onto three (3) properties in Newell Road.

The increase in flood levels produced by the levee only works scenario can be prevented by increasing the size of the open drain adjacent to the proposed levee. The 1% AEP peak flood levels could be reduced to at least 0.1 metres below existing flood levels by construction of the levee together with increasing the bottom width of the drain to 3.6 m with 1:1.5 side-slopes.

For the channel improvement works, it would be necessary to enlarge the upstream section of the drain between the waterhole wetland and cross-section X6 only. Downstream of cross-section X6, the floodwaters are contained within the existing drain.

Hydraulic modelling of a 5 m widening of the excavated drain over the full length of the drain indicates that 1% AEP flood levels at the breakout would be lowered by 0.25 m. It would be necessary to undertake limited filling to raise ground levels sufficiently to confine the runoff to within the drainage reserve.

The hydraulic modelling results for the 2 hour duration storm are summarised in Table A3.

There is a 300 mm dia trunk sewer main laid along the drainage reserve as shown on Figure A-1. The sewerage drawings show that the sewer is located 2 to 4 m from the drain and at a depth of 3 to 3.5 m. There are also two branch sewers which cross the drainage reserve. These branch sewers are 0.3 to 0.4 m below the invert of the existing drain.

Construction of the proposed levee would increase the depth of cover to the trunk sewer main to approximately 4.5 m and would require two junction pits to be extended to levee crest level.

The excavation required to widen the existing drain by 5 m would partially expose the junction pits along the trunk sewer. The trunk sewer main would be unaffected, being some 1.2 m below the invert of the channel.

There are two branch sewer lines across the rear of the properties in Newell Road, on the southern site of the drainage reserve. The flood mitigation works options do not affect these sewers.

On review of the works required, the disruption that will be caused and the reduction in flood levels resulting from the works, it is clear that:

- the levee only scenario, which increases flood levels slightly, would not be acceptable in a developed area;

- widening the channel to a 6 metre wide base width plus levee construction reduces flood levels to about 400 millimetres below existing levels, but with attendant more widespread disruption;

- widening the channel base width to 3.6 metres will reduce the existing flood levels without the need for significant channel works.

Given the above, the appropriate flood mitigation response is construction of a levee plus channel widening to create a 3.6 metre wide channel base.

Table A3

Comparison of Flood Mitigation Options

Location	Model X-Section	1% AEP Design Flood Levels (m AHD)			
		Existing	Levee Only	Levee + 3.6 m Channel Base	Levee + 6 m Wide Channel Base
d/s Bounty Hill Road	X13A	7.46	7.47	7.47	7.47
Waterhole	X11	5.54	5.57	5.37	5.23
d/s Waterhole	X10	5.54	5.54	5.36	5.21
Top of Drain	X9	5.51	5.54	5.29	5.10
Middle of Drain	X6	4.75	4.76	4.67	4.29
u/s Lakeside Drive	X4	3.61	3.61	3.64	3.65
22 Three Points Ave	X15	5.17	-	-	-

5. PREFERRED FLOOD MITIGATION OPTION

Construction of an earth levee across the break-out from the Newell Road drain to Three Points Road, together with widening the existing channel to a 3.6 metre wide base width is considered to be the most effective flood mitigation works option for the area.

This option generally confines floodwaters to within the drainage reserve and does not result in significant increase in flood damages to other properties. No houses are affected by the resultant increased flood levels which are confined to the waterhole/wetland and the excavated drain.

The suggested levee route is shown on Figure A-5. The levee would tie in with existing ground levels at both ends and would be contained within the drainage reserve.

A typical cross-section of the proposed levee and drain widening is shown on Figure A-6.

The estimated cost of the works is $186,000 derived as per the cost estimate, Table A4 below.

Table A4

Cost Estimate - Flood Mitigation Works - Three Points Avenue

Item	Quantity	Unit	Rate ($)	Cost ($)
1. Establishment		LS	5000	5,000
2. Retaining Wall	200 m	LS	12,000	12,000
3. Earthworks:				
3.1 Strip	1,800	sq m	5	9,000
3.2 Cut	500	cu m	15	7,500
3.3 Impact Fill	1,500	cu m	15	22,500
3.4 Compact Fill	1,500	cu m	10	15,000
3.5 Disposal	500	cu m	10	5,000
3.6 Spread Topsoil	1,800	cu m	5	9,000
3.7 Grass	1,800	sq m	5	9,000
4. Service Adjustments		LS	5,000	5,000
Sub-total				99,000
Survey Investigation Design @ 25%				25,000
Sub-total				124,000
Contingency @ 50%				62,000
TOTAL				**186,000**

REFERENCES

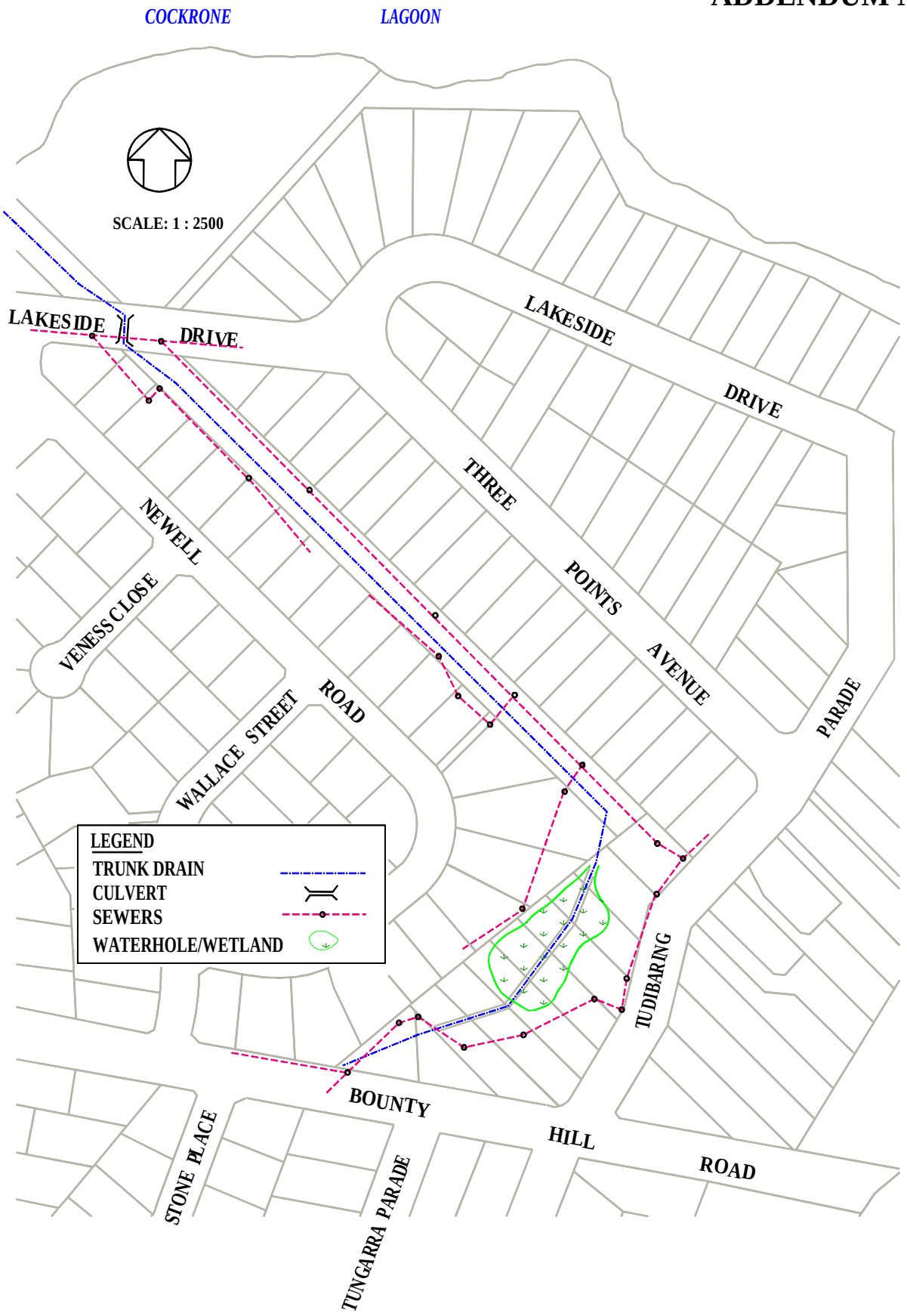
1. "*Cockrone Lagoon Floodplain Management Study*" Paterson Consultants, April 1995

2. "*Cockrone Lagoon Flood Study*" Paterson Consultants, April 1994

3. "*Australian Rainfall and Runoff*" Institution of Engineers, Australia, 1987 Edition

FIGURES

COCKRONE LAGOON
FLOOD STUDY
ADDENDUM NO.1



21 OCT 2007
DISK REF: 06033_CA
FIG REF: 06033_CA1_McM Bch Drn_V2

FIGURE A-1
MACMASTERS BEACH DRAIN

COCKRONE LAGOON
FLOOD STUDY
ADDENDUM NO.1

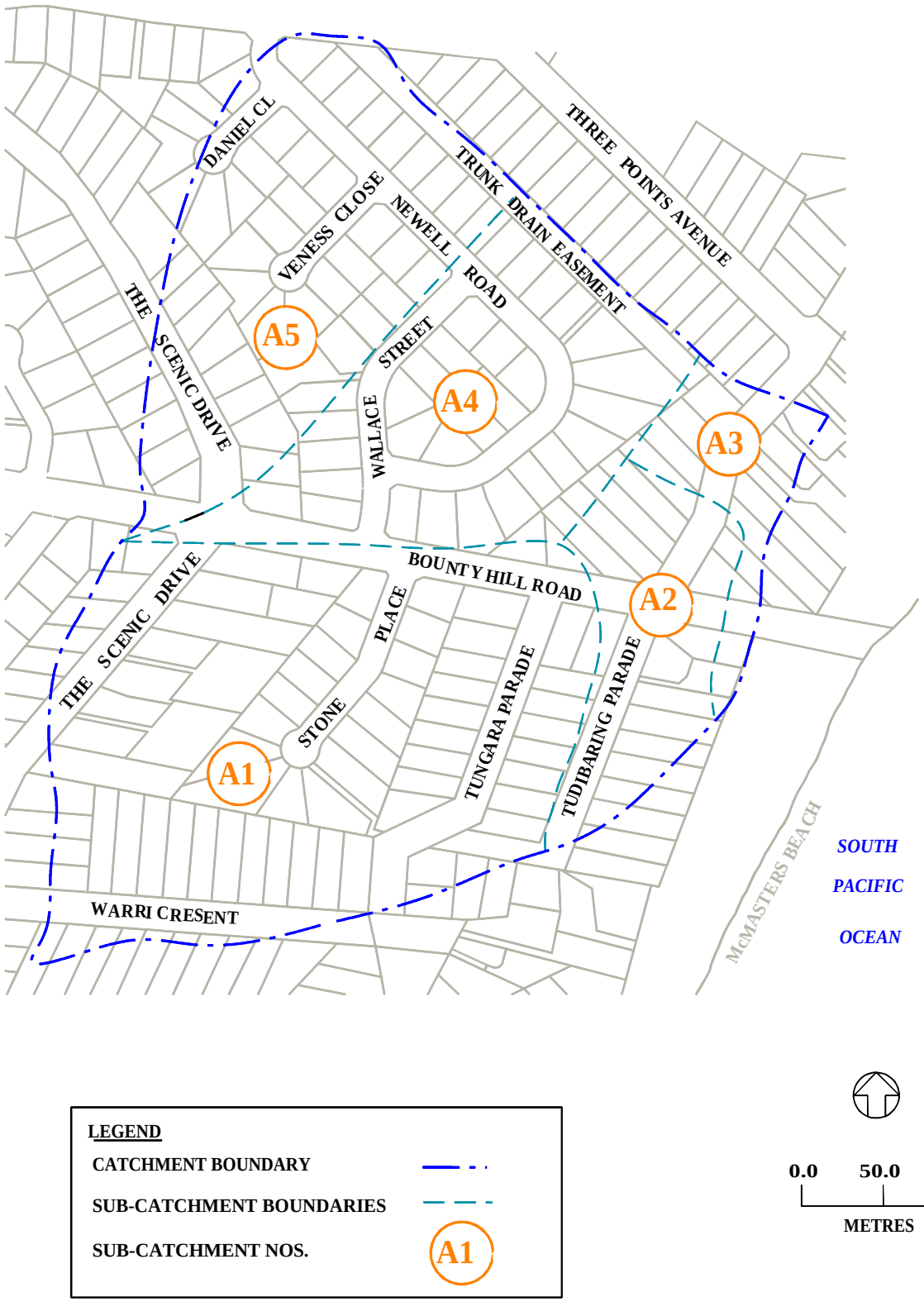
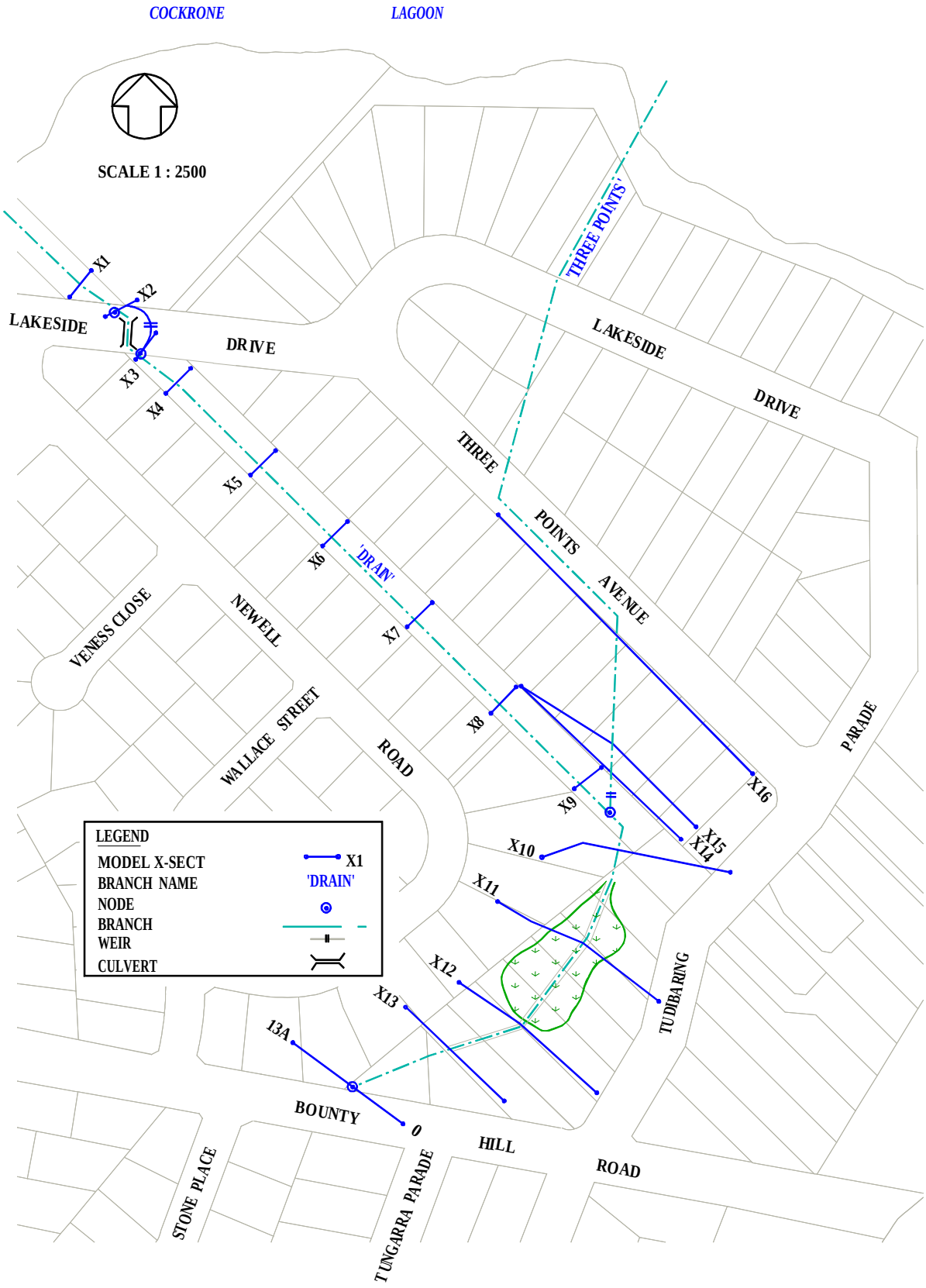


FIGURE A-2
SUB-CATCHMENT BOUNDARIES

5 DEC 2007
DISK REF: 06033_CA
FIG REF: 06033_CA2_Sub-C Bnd_V2



21 OCT 2007
DISK REF: 06033_CA
FIG REF: 06033_CA3_Hyd Model Exts_V2

FIGURE A-3
HYDRAULIC MODEL EXTENSIONS

COCKRONE LAGOON
FLOOD STUDY

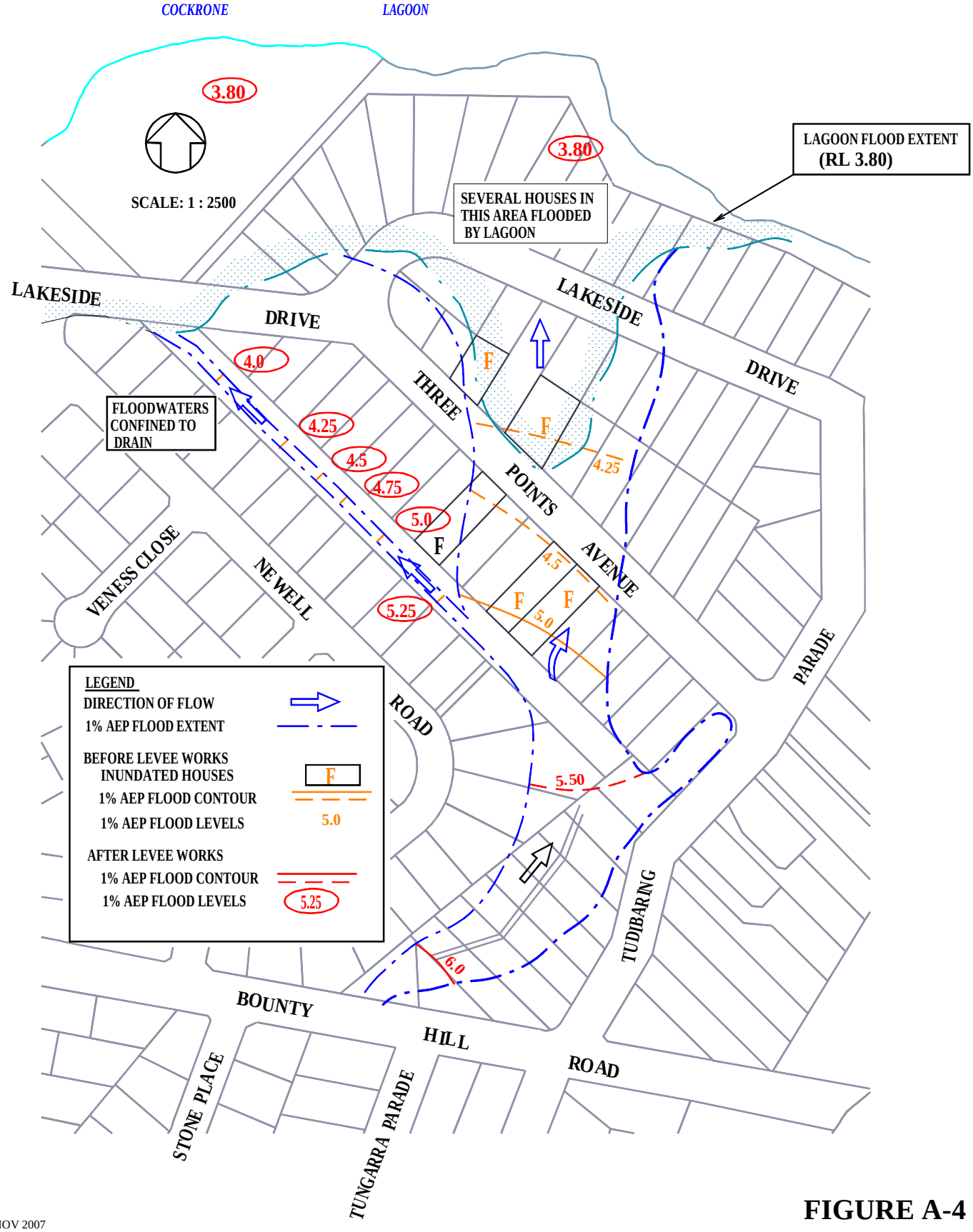
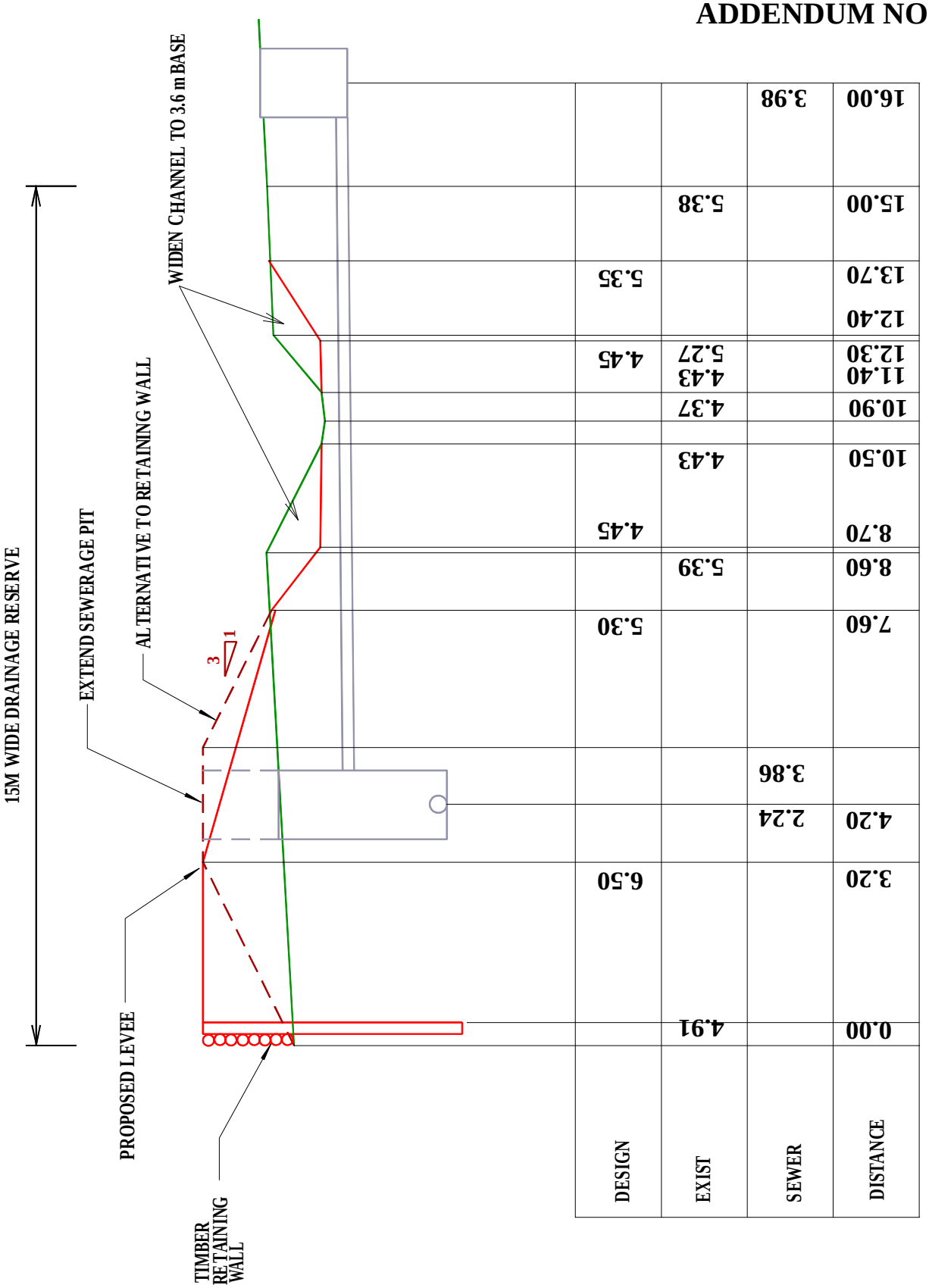


FIGURE A-4
1% AEP FLOOD LEVELS & EXTENTS

4 NOV 2007
DISK REF: 06033_CA
FIG REF: 06033_CA4_1%AEP_V2



DISTANCE	SEWER	EXIST	DESIGN
16.00	3.98		
15.00		5.38	
13.70			5.35
12.40			
12.30		5.27	4.45
11.40		4.43	
10.90		4.37	
10.50		4.43	
8.70			4.45
8.60		5.39	
7.60			5.30
	3.86		
4.20	2.24		
3.20			6.50
0.00		4.91	

21 OCT 2007
DISK REF: 06033_CA
FIG REF: 06033_CA_6_Prop Levee Widen

FIGURE A-6
PROPOSED LEVEE & CHANNEL WIDENING