SUTHERLAND SHIRE COUNCIL

BUNDEENA

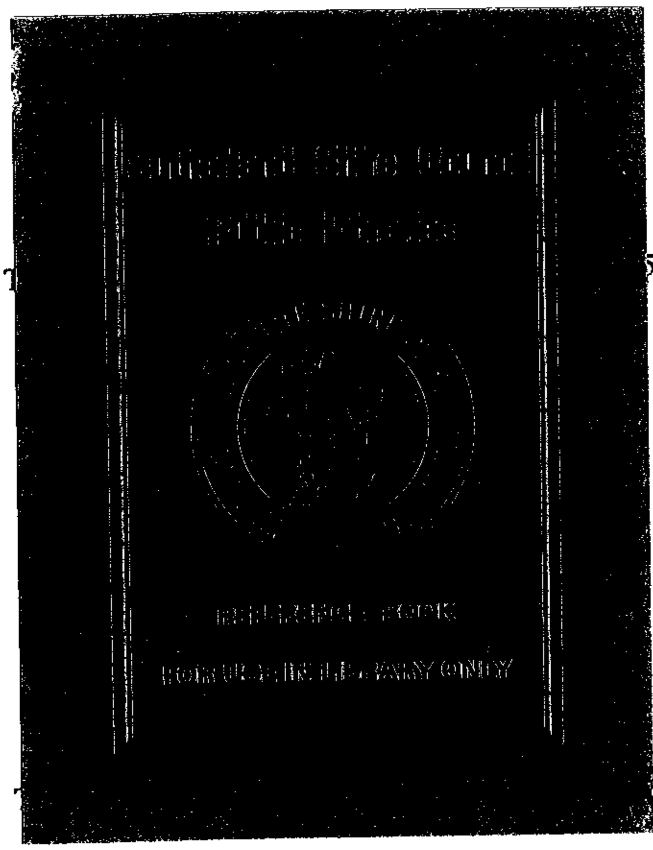
FLOOD MANAGEMENT STUDY

KINHILL

AUGUST 1993

BUNDEENA FLOOD MANAGEMENT STUDY

FINAL REPORT



August 1993
SE2155/001 Rev B

The sole purpose of the services performed by Kinhill and of this report is to estimate flood levels and prepare a flood management plan at a conceptual level for the township of Bundeena New South Wales in accordance with the scope of services set out in the contract between Kinhill Engineers Pty Ltd ("Kinhill") and Sutherland Shire Council ("the Client"). That scope of services was defined by the requests of the Client, the time and budgetary constraints imposed by the Client, and the availability of access to the site.

Kinhill derived the data in this report primarily from the survey provided by the Client, available mapping, visual inspections of the site, and recommended methods and techniques provided in *Australian Rainfall and Runoff—A guide to flood estimation* (Institution of Engineers, Australia 1987). The passage of time, manifestation of latent conditions or occurrence of future events may require further exploration at the site, analysis of the data, and re-evaluation of the findings, observations and conclusions expressed in the report.

In preparing this report, Kinhill has relied upon and presumed accurate certain information (or the absence thereof) about existing site survey, proposed building and facility layouts, and information provided by governmental officials and authorities, the Client and others identified herein. Except as otherwise stated in the report, Kinhill has not attempted to verify the accuracy or completeness of any such information. No warranty or guarantee, whether express or implied, is made with respect to the data reported or findings, observations and conclusions based on information not verified.

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INTRODUCTION

Bundeena is a township of just over 2,000 people located on the southern shore of Port Hacking in Sydney's south. The township is located within the Sutherland Shire Council area, and is bordered by the Royal National Park on all sides other than its shore with Port Hacking. The majority of the town drains into Bundeena Creek before the creek enters Port Hacking at Horderns Beach. The lower areas of the town have been constructed on an infilled ancient coastal lagoon located behind higher coastal dunes at Horderns Beach. As a result of the residential areas being built on such low and flat land, there has been a history of flooding and local drainage problems in this area of Bundeena.

In November 1992, Sutherland Shire Council engaged Kinhill Engineers Pty Ltd to take a fresh look at the flooding problems in Bundeena; consolidating past studies and incorporating new information into the flood management plan. Recent information included the following:

- the need to address stormwater quality in flood management issues;
- the need to address the feasibility of the potential to use stormwater to supplement the town water supply;
- the requirement that the impact of any works on the Royal National Park be kept to a minimum.

PREFERRED FLOOD MANAGEMENT PLAN

A combination of flood management measures have been assessed with the MIKE-11 model to provide a workable solution to the majority of the flood problems in Bundeena. In particular, no house floor levels would be flood liable in a 100-year ARI event and flood-free access would be available all along Bundeena Drive and to all properties in Liverpool and Scarborough Streets. Inundation of properties would be prevented in Bundeena Drive and in most properties in Scarborough and Liverpool Streets.

The preferred flood management plan and preliminary cost estimates are summarized in Table 1. Total costs of the preferred flood management plan has been estimated to be $384,000.

Table 1 **Preferred flood management plan**

Description	Estimated costs ($)
Construction of a low-level earthen levee at a level of 2.2 m AHD, as close as possible to the existing residential area with minimal impact on the Royal National Park. Concrete-block walls would be constructed at some locations to minimize impact on the park and private property. Alignment includes protection of permanent building in the caravan park (Options 4(a) and 4(b)).	145,000
Construction of a grass-lined channel with 4 m base and 1:6 side slope, for a distance of about 100 m downstream of Scarborough Street. (Option 3).	11,000
Removal of 600 mm high concrete-block wall that surrounds No 67–73 Scarborough Street. (Option 2).	1,000
Construction of 4 x 3.0 m wide x 0.75 m high concrete box culvert at the Scarborough Street crossing including raising the road to 1.6 m AHD to act as an overflow spillway. Safety signs at the new crossing are also recommended. Local drainage problems would have to be solved in at least four locations. This could involve pumping, connection to street drainage or pipes with one-way flap valves. (Option 4(a)).	144,000
Raising of Liverpool Street to 2.0 m AHD from Bundeena Drive to Scarborough Street, and Scarborough Street from Liverpool Street to the creek crossing. These works help prevent back flooding into the southern end of Liverpool Street and generally improve local access. (Option 10(b)).	83,000
Creation of drainage easement 20–40 m wide between Scarborough Street and Horderns Beach—wide enough for the access of maintenance vehicles and monitoring of any illegal private works in or adjacent to the creek. (Option 13).	–
Improved monitoring in Bundeena Creek catchment to help establish a data base suitable for the verification of hydrologic and hydraulic models. Components would include pluviograph(s) and maximum height recorders. (Option 12).	–
Public and council education about the requirements of the New South Wales Rivers and Foreshores Improvement Act, as amended in April 1992.	–
Review of relevant sections of Sutherland Shire Council's Section 149 Certificate Notations for Bundeena in light of the results of the current study.	–
Total cost for preferred flood management plan	**384,000**

– *No cost has been assigned to this option.*

STORMWATER QUALITY CONTROL

A preliminary investigation has been undertaken for a water quality control strategy for the Bundeena Creek catchment. At present, the most notable source of pollution in stormwater drains and the creek is a result of seepage and overflowing from septic tanks. When the sewer is ultimately connected, the water quality in Bundeena Creek is likely to improve significantly. However, the water of Bundeena Creek is still likely to suffer some pollution from the normal processes of urbanization.

The 'natural' wetland, with a volume of about 5,000 m^3, between Scarborough Street and Horderns Beach is currently acting as an adequate means of removing some suspended sediments and nutrients from the water. This would be significantly more effective when the sewer is connected. It is recommended that this natural wetland be formalized and planted with macrophytes to further improve the quality of water entering Port Hacking. Assuming a total wetland volume of 7,500 m^3, total costs would be about $40,000.

Gross pollutant traps and trash racks are not recommended for the Bundeena Creek catchment. Rather, it is recommended that pollutants be treated at the source. This would involve:

- an on-site erosion and sediment control strategy applicable to all construction sites;
- community awareness programme on stormwater pollution issues.

STORMWATER REUSE

The preliminary investigation conducted for this study has shown that the use of stormwater to supplement the Bundeena town water supply is a feasible option worthy of further consideration. Diversion works, involving about 200 m of open channel leading from the western catchment of Bundeena Creek, could gravity feed to an open storage pond of about 80 m wide by 80 m long, located on council-owned land behind Bundeena Oval. The stormwater could then be used either to supplement the existing potable supply after suitable treatment, or could be used to provide a new non-potable supply via a secondary reticulation system. Total capital costs for each of the systems have been estimated to be:

- potable supply—$2,140,000
- non-potable supply—$1,860, 000.

RAINFALL, STREAMFLOWS AND FLOOD LEVELS

Computer modelling

Design flows for 100-year and 20-year average recurrence interval (ARI) storm events over the Bundeena Creek catchment have been calculated using design rainfalls together with the RAFTS-XP hydrological model and the MIKE-11 hydraulic model. The MIKE-11 two-dimensional flow model was established to simulate the combined flood behaviour of tide levels at Horderns Beach, flood levels in the channel up to

Scarborough Street and flood levels in the swamp up stream of Scarborough Street. These design events have been assumed to occur when there is a mean astronomical tide in Port Hacking.

Flood standard

Sutherland Shire Council has adopted the 100-year ARI as their flood standard. Therefore, the aim of this study is to determine flood levels in Bundeena Creek that would occur with a probability of 'once-in-100-years'. The flood levels in Bundeena Creek, below about Scarborough Street, can result from either, or a combination of:

- runoff from the Bundeena Creek catchment
- high water levels in Port Hacking.

The number of combinations of rainfall events and tidal effects is infinite. In this study, it has been assumed that a 100-year (or 20-year) ARI design flow in Bundeena Creek does not occur at the same time as a 100-year ARI (or 20-year) water level in Port Hacking at Horderns Beach.

Existing flood behaviour

The following values from the Public Works Department have been adopted for use in the current study as the design flood levels in Bundeena Creek resulting from tidal levels (still water levels) in Port Hacking:

- 100-year ARI—1.50 m AHD
- 20-year ARI—1.43 m AHD.

The results of the MIKE-11 modelling show that generally, flooding is contained within the main creek banks upstream as far as about Scarborough Street. Bundeena Drive at the Bundeena Creek crossing would be flood free in a 100-year ARI event.

Upstream of Scarborough Street, the floodplain becomes very wide as this area is part of the Bundeena Creek swamp system. The outflows from this large storage area are generally controlled by the road profile of Bundeena Drive–Liverpool Street–Scarborough Street up to about 2.0 m AHD, while the Scarborough Street culvert crossing provides the main control on flows. Scarborough Street would not be trafficable in a 20-year ARI flood event.

Access to the southern end of Liverpool Street would be a problem even in a 20-year ARI event, when up to 0.5 m of water would cover the road. Trafficable access is available in and out of Bundeena in a 100-year ARI event.

There are two main constrictions to flow that were identified in the hydraulic modelling exercise:

- a natural steep-sided narrow section of channel downstream of Bundeena Drive adjacent to the Christian Centre (CS1018 to CS1061);

- a man-made constriction caused by filling of land, relocation of the channel and construction of a 600 mm high concrete-block wall just downstream of Scarborough Street.

The following design flood levels have been calculated for the area upstream of the Bundeena Drive–Liverpool Street–Scarborough Street road profile and in Bundeena Oval:

- 100-year ARI—1.96 m AHD
- 20-year ARI—1.88 m AHD.
- probable maximum flood—2.97 m AHD.

The corresponding levels with implementation of the flood management plan would be:

- 100-year ARI—1.82 m AHD
- 20-year ARI—1.64 m AHD
- probable maximum flood—2.97 m AHD.

A sensitivity test was carried out using the MIKE-11 model assuming the Council's one year/storm surge level of 1.28 m AHD as the water level in Port Hacking. An additional allowance for 'greenhouse' levels has not been included.

Inundation of properties and floors

Table 1 provides a summary of frequency of house floor inundation in Bundeena. These results show that the most significant flood problems in Bundeena are access and property inundation rather than above-floor flooding of houses. Most property owners would suffer the inconvenience of gardens being underwater and the inability of gaining access to their houses, rather than sustaining significant amounts of flood damage to the insides of their homes. Table 1 also provides an estimate of the number of properties that would suffer such inconvenience.

Table 1 **Frequency of property inundation**

Flood event (ARI years)	No. houses with flood-liable floors	No. houses with floors with less than 300 mm freeboard	Approximate number of houses suffering inconvenience from flooding
100	3	25	45
20	1	19	45

1 INTRODUCTION

Bundeena is a township of just over 2,000 people located on the southern shore of Port Hacking in Sydney's south. The township is located within the Sutherland Shire Council area, and is bordered by the Royal National Park on all sides other than its shore with Port Hacking. The majority of the town drains into Bundeena Creek before the creek enters Port Hacking at Horderns Beach. The lower areas of the town have been constructed on an infilled ancient coastal lagoon located behind higher coastal dunes at Horderns Beach. As a result of the residential areas being built on such low and flat land, there has been a history of flooding and local drainage problems in this area of Bundeena.

An investigation into flooding at Bundeena was carried out by Sutherland Shire Council in 1976 (Cooper 1976) and council adopted, in principle, a flood relief scheme for the town in 1978. Following exhibition of a Draft Development Control Plan for Bundeena Creek in 1983, Council resolved in 1984 to undertake more detailed hydraulic and floodplain analysis. The consultant's report was completed in 1985 (Cameron McNamara 1985) and recommended the construction of a large retarding basin, overflow spillway and associated channel works upstream of the town. Sutherland Shire Council formally adopted the Cameron McNamara Study in late 1986 and subsequently advertised its intention to prepare a further draft Development Control Plan. The majority of the large detention basin was to be located within the Royal National Park. Consequently there was opposition to its construction until all the environmental impacts had been addressed. Because of lack of resources, no further action took place on the issue.

In November 1992, Sutherland Shire Council engaged Kinhill Engineers Pty Ltd (Kinhill) to take a fresh look at the flooding problems in Bundeena; consolidating past studies and incorporating new information into the flood management plan. Recent information included the following:

- a new version of *Australian Rainfall and Runoff—A guide to flood estimation* (Institution of Engineers, Australia 1987) which provides new design rainfall intensities;
- completion of road and drainage works in the flood-liable area;
- development and filling activities in the catchment and the floodplain;
- a new detailed survey of the floodplain area;

- the need to address stormwater quality in flood management issues;
- the need to address the feasibility of the potential to use stormwater to supplement the town water supply;
- the requirement that the impact of any works on the Royal National Park be kept to a minimum.

The Bundeena Creek catchment is described in more detail in Chapter 2 which includes topography, the creek system and land-use. Chapter 3 discusses the background information available for the study including mapping and previous reports.

Rainfall, streamflows and flood levels are discussed in detail in Chapter 4. This chapter outlines the hydrologic and hydraulic investigation and provides the new adopted streamflows and flood levels for the existing catchment. A description of flood behaviour is also presented.

Available management options relating to flooding are put forward, discussed, and evaluated in Chapter 5. Preliminary cost estimates are provided for options adopted for further consideration. A preferred flood management plan for the Bundeena Creek catchment is presented at the end of Chapter 5.

Chapter 6 discusses stormwater quality in the Bundeena Creek catchment and discusses options available for reducing the amount of pollutants entering Port Hacking. A summary of the water quality control investigation is provided at the end of Chapter 6.

Chapter 7 assesses the feasibility of reusing stormwater to supplement the Bundeena town water supply. This includes the need for additional water supply, demand and available flow volumes, potential storage areas, treatment and reticulation requirements, together with preliminary cost estimates. A summary of the stormwater reuse strategy is presented at the end of Chapter 7.

2 STUDY AREA

2.1 LOCATION

The town of Bundeena has a population of just over 2,000 people and is situated on the southern shore of Port Hacking in Sydney's south. The residential area is under the jurisdiction of Sutherland Shire Council. The town in bordered by the Royal National Park on all sides other than its shore with Port Hacking. Bundeena Creek enters Port Hacking at the eastern end of Horderns Beach. A locality plan is shown in Figure 2.1.

The majority of the residential area of Bundeena is located in the Bundeena Creek catchment. Flooding directly associated with the rising waters of Bundeena Creek and the tidal influences from Port Hacking are the subject of this report.

2.2 CATCHMENT DESCRIPTION

2.2.1 TOPOGRAPHY AND THE CREEK SYSTEM

Bundeena Creek has a total catchment area of about 250 ha. About 193 ha of the catchment area are located within the Royal National Park while the other 57 ha have been urbanized.

The creek system flows through three distinct topographical features before entering Port Hacking at Horderns Beach. The ridgelines of the catchment are dominated by large plateaus. Creeks then drop quickly down steep-sided cliffs before entering a large low-lying swamp system. Bundeena Creek has two main arms, originating from the eastern and western sides of the catchment. Both flow generally in a northern direction before flowing into the eastern and western swamps respectively (refer Figure 2.1).

The lower areas of Bundeena, which are the subject of this report, have been constructed on an infilled section of this swamp system, referred to as an ancient coastal lagoon. The coastal lagoon is a typical feature of coastal river systems in eastern New South Wales where a lagoon has formed behind the higher coastal sand dunes adjacent to the ocean. Many such coastal lagoons have been filled or developed in the last 200 years to permit urbanization adjacent to the coast, and suffer similar flooding and drainage problems to Bundeena.

About 200 m upstream of Scarborough Street (refer Figure 2.1), the eastern and western arms of Bundeena Creek combine. Between Scarborough Street and Horderns Beach the channel is more defined. It appears that the outlet of Bundeena Creek is only open

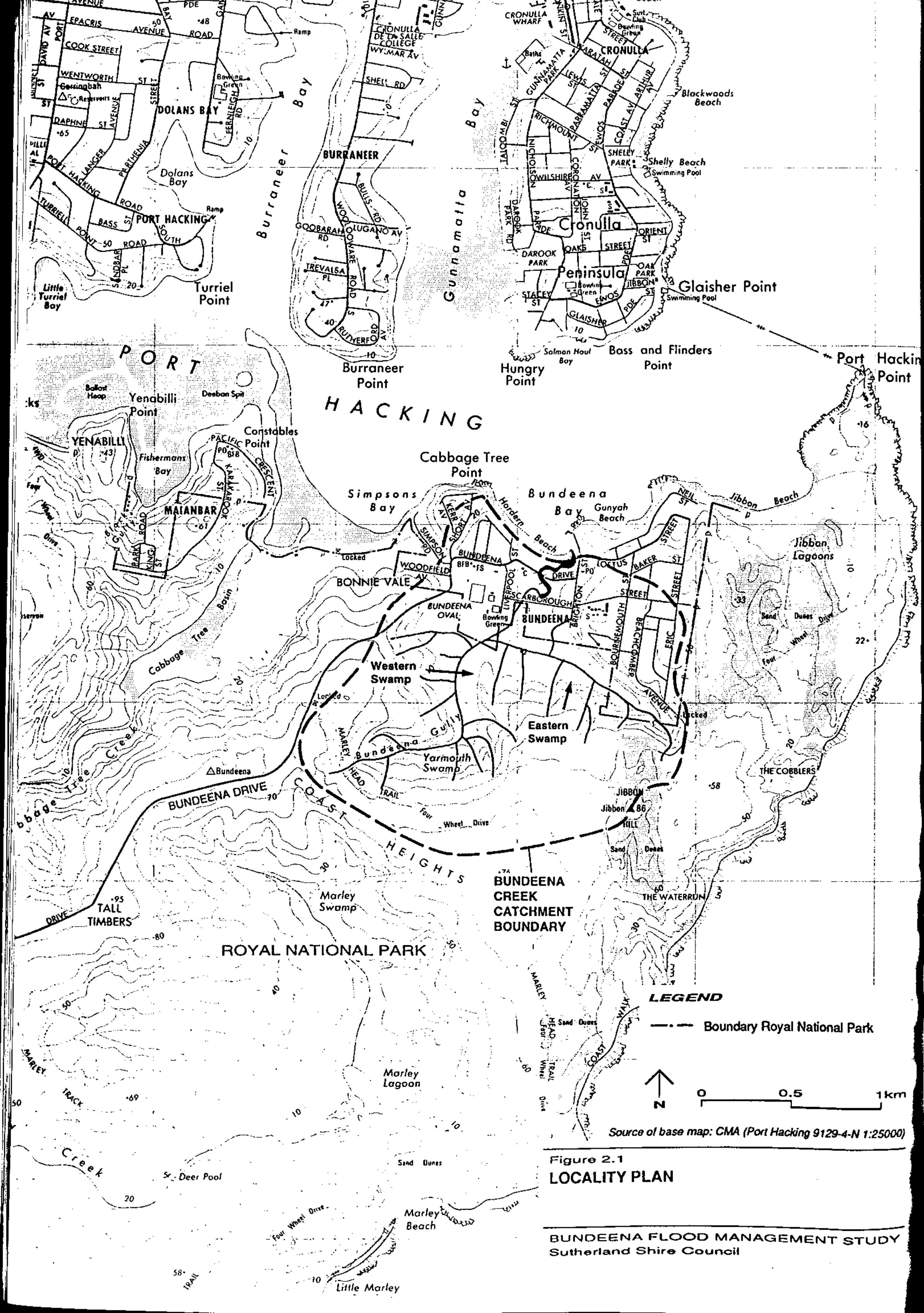

Figure 2.1
LOCALITY PLAN

BUNDEENA FLOOD MANAGEMENT STUDY
Sutherland Shire Council

to Port Hacking in large storm events, or in the event of very high tides, because of the presence of a sand dune at about 0.85 m AHD (Australian Height Datum) at the southern end of Horderns Beach. This dune causes the lower end of Bundeena Creek to remain as a stagnant pool under normal flow conditions with a water level of between 0.55 m AHD and 0.70 m AHD.

2.2.2 LAND USE

About 57 ha of the Bundeena Creek catchment have been developed for residential purposes. It is unlikely that the areas of urbanization would greatly increase in the future because current development borders the Royal National Park boundary. Current landuse zonings from the Sutherland Local Environmental Plan (Water Board 1992a) show that future development could occur:

- from redevelopment in existing residential areas particularly and in the area Zoned 9(a) (Mixed Residential/Business) between Bundeena Drive, Scarborough Street, Liverpool Street and Brighton Street;

- in the area zoned for Community Uses (Special Uses Zone 5[a]) which already includes a sports field, community centre, pre-school, bowling club and tennis courts;

- in the area zoned for a Boy Scout Camp at the southern end of Bournemouth Street (Special Uses Zone 6[a]);

- in the land zoned for a Sewage Treatment Plant south of the potential Boy Scout Camp land (Special Uses Zone 5[a]).

3 DATA BASE

3.1 MAPPING

3.1.1 CENTRAL MAPPING AUTHORITY

The following maps were available from the Central Mapping Authority:

- 1:25,000 topographical map (Port Hacking 9129-4-N) with 10 m contour intervals;
- 1:4,000 Bundeena U0922–5 orthophoto map with 2 m contour intervals. This map was used for definition of subcatchments and the areas of residential development for the hydrological modelling component of the study (refer Section 4.5.1).

3.1.2 COUNCIL SURVEY

A detailed topographical and land-use survey for the low lying areas of Bundeena was completed by Sutherland Shire Council in late 1992. The survey has been completed to Australian Height Datum (AHD) and it contains the following information:

- spot levels and 0.2 m contour intervals;
- roads and bridges;
- cadastral information;
- all buildings and floor levels of habitable areas;
- location of Bundeena Creek;
- locations of cross sections of Bundeena Creek for use in the hydraulic modelling component of the study.

This survey has been used as the base map for this report. Flood behaviour, flood extents, management options and quantities for costing purposes have been based on the information supplied in this survey.

3.1.3 COUNCIL DIGITAL TERRAIN MODEL

Sutherland Shire Council has recently acquired a digital terrain model for its local government area. The information supplied from the model is a digitized version of the

Central Mapping Authorities' Orthophoto map series which provides 2 m contour intervals and cadastral information. The equivalent area of the Central Mapping Authority map Bundeena U0922–5 (1:4,000) has also been used as a base map in this study.

3.2 PREVIOUS STUDIES

3.2.1 BUNDEENA CREEK FLOOD INVESTIGATION

Sutherland Shire Council carried out an investigation into flooding of Bundeena Creek in 1976 (Cooper 1976). The Rational Method and the Unit Hydrograph Procedure (from the 1958 version of *Australian Rainfall and Runoff* [Institution of Engineers, Australia 1958]) were used to calculate peak flow rates while Manning's Equation was used to determine flood levels in Bundeena Creek.

A flood mitigation scheme was proposed which involved the construction of a levee to a level of about 2.8 m AHD to the south of the township generally on land within the Royal National Park. This would involve the swamp being used as a retarding basin and an outlet structure being constructed just upstream of Scarborough Street. Local drainage problems that would result from the construction of the levee were addressed, with a system of wide open channels being proposed to convey water from the lowest lying areas to the main creek. The total cost of the scheme was estimated to be $72,000 (in 1992 dollar values).

3.2.2 BUNDEENA FLOOD MANAGEMENT STUDY

The Bundeena Flood Management Study (Cameron McNamara 1985) was a more detailed study than that of Cooper (1976) and involved the development of the first computer models of the Bundeena Creek catchment. The hydrologic computer model RORB was used to estimate flow rates, while a HEC-2 hydraulic model was established to calculate flood levels and to model the various flood mitigation options that were proposed. Historical flood levels were gathered for the Cameron McNamara study by means of resident interviews, discussions with Council officers and perusal of newspapers and public records. These levels were used to calibrate the HEC-2 hydraulic model.

The five flood mitigation options that were examined as part of the Cameron McNamara study were as follows:

- a retarding basin at the same height and generally along the lines of that proposed by Cooper (1976) with an outlet just upstream of Scarborough Street;
- a retarding basin on the western tributary to Bundeena Creek;
- channel improvement works downstream of Scarborough Street;
- an outlet structure at Horderns Beach;
- floor raising of flood-affected houses.

Central Mapping Authorities' Orthophoto map series which provides 2 m contour intervals and cadastral information. The equivalent area of the Central Mapping Authority map Bundeena U0922–5 (1:4,000) has also been used as a base map in this study.

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- channel improvement works downstream of Scarborough Street;
- an outlet structure at Horderns Beach;
- floor raising of flood-affected houses.

The Scarborough Street retarding basin, slightly modified from the 1976 proposal was recommended as the most effective means of reducing flood levels through the developed areas of the Bundeena Creek floodplain. This option would reduce flood levels sufficiently to contain the 100-year ARI flood within the main channel downstream of Scarborough Street. With an estimated cost of $440,000 (1992 dollar values) the recommended works involved:

- enlargement of 60 m of the existing channel downstream of Scarborough Street to 3.0 m base width and 1(vertical[V]):4(horizontal[H]) side slopes, creating a total channel width of about 11 m;

- realignment of the existing culvert of Scarborough Street;

- construction of a levee (with top width of 3 m and 1(V):4(H) side slopes) upstream of Scarborough Street to a level of 2.85 m AHD with a total length of 1,100 m generally through Royal National Park land to the south of Bundeena;

- construction of an overflow spillway 3 m wide at 1.25 m AHD with 2 x 500 mm diameter low flow pipes just upstream of Scarborough Street.

Floor raising was viewed as a viable option to provide freeboard against the 100-year ARI flood event. However it was recognized that, access to most properties would still be a problem.

One of the aims of the current study is to re-assess the mitigation options proposed by Cameron McNamara using the most up-to-date information together with any new options that may be appropriate. Computer models developed for the Cameron McNamara study were not available for use in the current study.

4 RAINFALL, STREAMFLOWS AND FLOOD LEVELS

4.1 BACKGROUND AND METHODOLOGY

Sutherland Shire Council has adopted the 100-year ARI as their flood standard. The flood standard is the reference point for preparation of floodplain management plans, and in effect, determines the area of land that should be addressed in flood-related issues. This does not mean, however, that floods with different recurrence intervals may not be used as criteria for the design and investigation of particular flood mitigation measures.

Therefore, the aim of this study is to determine flood levels in Bundeena Creek that would occur with a probability of 'once-in-100-years'. The flood levels in Bundeena Creek, below about Scarborough Street, can result from either, or a combination of:

- runoff from the Bundeena Creek catchment
- high water levels in Port Hacking.

The number of combinations of rainfall events and tidal effects is infinite. In this study, it has been assumed that a 100-year ARI design flow in Bundeena Creek does not occur at the same time as a 100-year ARI water level in Port Hacking at Hordems Beach. To assume that the two events occurred at the same time would statistically result in a probability of much less than 'once-in-100-years' and thus a conservative set of flood levels and mitigation works would result. Rather, the profiles of these two flooding conditions have been superimposed over one another to provide a adopted flood profile for Bundeena Creek.

This chapter outlines the hydrologic and hydraulic investigation carried out for the Bundeena Creek catchment used to determine design flows and flood levels within the study area.

Design flows for 100-year and 20-year ARI storm events over the Bundeena Creek catchment have been calculated using design rainfalls together with recognized hydrological and hydraulic computer models. These design events have been assumed to occur when there is a mean astronomical tide in Port Hacking (refer Sections 4.4.1 and 4.5.3).

Design levels in Port Hacking are available that correspond to probabilities equivalent to a 100-year and 20-year ARI condition. At these times, it has been assumed that there would be minimal flow in Bundeena Creek.

The methodology used for the hydrologic and hydraulic investigation is summarized below:

- review historical rainfall and flood level information used in the Cameron McNamara study (1985) and incorporate any, more recent, information;

- calculate design rainfalls using the techniques outlined in the 1987 version of *Australian Rainfall and Runoff—A guide to flood estimation* (Institution of Engineers, Australia 1987);

- determine design tide levels for Port Hacking at Horderns Beach;

- establish a Runoff Analysis and Flow Training Simulation (RAFTS) model for the Bundeena Creek catchment and calculate 20-year and 100-year ARI design flow rates;

- establish a MIKE-11 two-dimensional flow model to simulate the combined flood behaviour of tide levels at Horderns Beach, flood levels in the channel up to Scarborough Street and flood levels in the swamp upstream of Scarborough Street;

- adopt design flow rates and flood levels for 20-year and 100-year ARI flood events for the study area;

- describe the existing flood behaviour of Bundeena Creek.

4.2 HISTORICAL FLOOD EVENTS

There are no water level or flow recorders on Bundeena Creek and so any historical flood level information has been obtained from resident interviews and the local press. A large amount of flood level information was collected for the Cameron McNamara Study (1985). Five significant flood events were identified as a result of the survey:

- 14 November 1969
- 11 March 1975
- 23 February 1977
- 4 March 1977
- 8 November 1984.

The floods of November 1969 are generally accepted as the highest in memory of residents in Bundeena. Residents commented that Scarborough Street was raised and the property north of Scarborough Street was extensively filled with coal waste after the flood (Cooper 1976).

Daily rainfall records for Bundeena were available for the Cameron McNamara Study (1985) for the period from 1964 to 1978 from the Bureau of Meteorology's Gauge No.66116 (Bundeena Composite). The rainfall for the November 1984 storm at Bundeena was measured by the Bowling Club's green keeper. The nearest pluviograph (continuous rainfall measuring device) is about 2.5 km from Bundeena, at Cronulla, and is operated by the Water Board.

Table 4.1 summarizes the historical flood information available for Bundeena and includes corresponding rainfalls measured at Bundeena and Cronulla.

As shown in Table 4.1, high rainfalls in Cronulla in August 1986 and April 1988, indicate that flooding may have occurred in Bundeena during these events. A perusal of local press clippings collected after the August 1986 event (Public Works Department 1986 a) was made for the current study. No mention was made regarding flooding in Bundeena, however this does not mean to say that flooding did not occur (many areas of the east coast of New South Wales experienced flooding during this event). No further information was collected for either of these events for the current study.

Table 4.2 summarizes some of the rainfall statistics obtained from the daily rainfall records measured at Bundeena during the operation of the gauge between 1964 and 1978. During this period there were only four occurrences where less than 10 mm was recorded in a particular month. These dry months occurred in isolation—indicating that Bundeena receives, on average, quite a substantial amount of rain each year when compared to other areas of Sydney.

4.3 DESIGN RAINFALLS

Design rainfalls and temporal patterns were extracted using the techniques and data provided in *Australian Rainfall and Runoff—A guide to flood estimation Volumes 1 & 2* (Institution of Engineers, Australia 1987). Probable maximum precipitation values were calculated using the methods outlined in *Bulletin 51* (Bureau of Meteorology 1984). Table 4.3 provides a summary of results as well as a comparison of design rainfall intensities from previous studies. This table shows that design rainfall intensities for Bundeena have not changed significantly over time, with the changes in calculation techniques and available data.

Appendix A presents the adopted design rainfall intensities for storm events of various recurrence intervals.

4.4 DESIGN WATER LEVELS IN PORT HACKING

The water level at the outlet of Bundeena Creek at Horderns Beach in Port Hacking can be considered to be made up of three components:

- astronomical tide
- storm surge
- wave set-up.

These three components are discussed below.

Table 4.1 **Historical flood events in Bundeena**

Flood event	Design rainfalls		Observed flood levels			
	Bundeena (mm)	Cronulla (mm)	Downstream Bundeena Drive (m AHD)	Upstream Bundeena Drive (m AHD)	Downstream Scarborough Street (m AHD)	Upstream Scarborough Street (m AHD)
14 November 1969	290	–	2.0[2]	1.94, 2.06[2]	2.01–2.20[1]	–
11 March 1975	175	100	1.32	–	–	–
23 February 1977	189	88	–	–	–	1.91–2.01[4]
4 March 1977	93	55	–	–	1.83	1.77
8 November 1984	125	122[5]	1.11, 1.23	1.20	1.55, <1.90	1.71–1.78[3]
6 August 1986	–	214[6]	–	–	–	–
30 April 1988	–	205[7]	–	–	–	–

Note: *Source: Cameron McNamara (1985) unless shown otherwise*

(1) *Five values: 2.01, 2.03, 2.04, 2.07, 2.20 m AHD*
(2) *At Bundeena Drive*
(3) *Eight values between 1.71 and 1.78 m AHD*
(4) *Three values: 1.91, 2.00, 2.01 m AHD*
(5) *Source: Public Works Department (1985)*
(6) *Source: Public Works Department (1987)*
(7) *Source: Public Works Department (1989)*

Table 4.2 **Rainfall statistics at Bundeena**

Month	Average rainfall (mm)	Average number of raindays
January	159	13
February	129	13
March	180	14
April	89	10
May	77	9
June	170	12
July	49	7
August	82	10
September	84	11
October	101	13
November	100	13
December	70	10
Totals per annum	**1,290**	**135**
Average per month	**108**	**12**

Table 4.3 **Summary of design rainfall intensities**

Average recurrence interval (years)	Duration (hours)	Design rainfall intensities		
		Adopted for this study (1993)* (mm/h)	Cameron McNamara (1985)** (mm/h)	Cooper (1976)*** (mm/h)
PMP	2.0	210	–	–
100	0.5	133	139	–
	1.0	94	92	91
	2.0	60	58	–
50	0.5	119	124	104
	1.0	84	82	78
	2.0	53	52	52
20	0.5	101	105	–
	1.0	71	70	–
	2.0	45	44	–

* *Reference: Australian Rainfall and Runoff—A guide to flood estimation (Institution of Engineers, Australia 1987).*

** *Reference: Australian Rainfall and Runoff—Flood analysis and design (Institution of Engineers, Australia 1977).*

*** *use of Sydney (Station No.66062) as a representative station for design rainfall intensities.*

PMP Probable maximum precipitation. Reference: Bureau of Meteorology (1984).

4.4.1 ASTRONOMIC TIDES

Astronomical tides are caused by the relative motions and gravitation attraction of the earth, moon and sun. The tidal records for Sydney Harbour provide the longest continual tide record available in Australia. The station, located at Fort Denison, was commissioned in 1872. As Port Hacking is so close to Sydney Harbour, the tidal information applicable to Fort Denison has been used in this study.

Tidal information is generally quoted to Indian Spring Low Water (ISLW) datum. This can be related to Australian Height Datum (AHD) by subtracting 0.925 m from the ISLW level. Mean tide level is equivalent to about 0.0 m AHD (0.9 m ISLW) while the largest high tide is generally about 1.2 m AHD (2.1 m ISLW).

The sand dune at the exit of Bundeena Creek at Horderns Beach has been surveyed to be at a level of about 0.85 m AHD. This would correspond to about a 1.8 m ISLW tide. Such a tide level is considered to be quite high. This confirms that the outlet of Bundeena Creek would only be open to Port Hacking in a very high tide if there were no rainfall in the catchment.

4.4.2 STORM SURGE

Storm surge is caused by a combination of wind effects and barometric conditions. When wind blows over an open body of water, drag forces develop between the air and the water surface. This has the effect of increasing the water level along the shore face of the down wind direction.

Storm systems over the east coast of Australia usually are accompanied by low pressure meteorological systems. This drop in atmospheric pressure results in an increase in water level of about 10 mm for each millibar below the average sea level pressure for the area. Storm surge does not depend on rainfall nor the size of waves. The value for storm surge in the Sydney region has been estimated to be about 0.3 m above the astronomical tide level (Public Works Department 1991).

4.4.3 STILL WATER LEVEL

The still water level is the combined effect of the astronomical tide and the storm surge. Extensive studies have been undertaken to derive design still water levels from the Fort Denison data base. The following values (Public Works Department 1991) have been adopted for use in the current study as the design still water levels in Bundeena Creek resulting from tidal levels in Port Hacking:

- 100-year ARI—1.50 m AHD
- 20-year ARI—1.43 m AHD.

4.4.4 WAVE SET-UP AND RUN-UP

Wave set-up is the measure of the wave component of the water level in areas subject to oceanic conditions. It is likely to form a significant part of the total stormwater ocean level at shoreline sites. Its value is much smaller in harbours, estuaries and lagoons. Wave set-up is site specific, dependent on location, aspect and wave characteristics. Studies by the Public Works Department have estimated that wave set-up is likely to be 0.0–1.0 m above the still water level.

It is acknowledged that such an increase in downstream water levels would have a significant impact on Bundeena, and so the wave component of potential flood levels should not be overlooked. A wave analysis has not been undertaken for this study. However, as discussed in Section 4.5.4, the November 1969 flood level in Bundeena was caused mainly as a result of very high water levels in Port Hacking. The reported level near Bundeena Drive was about 2.0 m AHD which can be considered to be a combination of:

- 1.2 m AHD astronomical tide (100-year ARI Port Hacking level)
- plus 0.3 m storm surge
- plus 0.5 m wave set-up.

Therefore it would be reasonable to assume that a wave set-up for Port Hacking in the vicinity of Horderns Beach would be 0.5 m. This value has been taken into consideration in formulation of the preferred management plan discussed in Chapter 5.

4.5 HYDROLOGICAL AND HYDRAULIC INVESTIGATION

4.5.1 ESTABLISHMENT OF RAFTS MODEL

To determine the design flow rates at locations upstream of Scarborough Road, the computer program RAFTS-XP Version 2.72 (WP Software 1991) was used. The following assumptions were made for the modelling of the Bundeena Creek catchment:

- The most detailed available plan (Bundeena U0922–5) only provided contours at 2 m intervals and so an accurate definition of the swamp system of Bundeena Creek was difficult. It was assumed that the swamp system (both eastern and western swamps) operates as one large storage area generally controlled by the road profile of Bundeena Drive–Liverpool Street–Scarborough Street (refer Figure 4.1), up to about 2.0 m AHD. Up to this level, a large proportion of the outflows from the storage would be controlled by the Scarborough Street culvert and overflow of Scarborough Street itself. The RAFTS program would only allow a free outflow (that is, not controlled by backwater) from this storage. Stage versus volume relationships for the swamp storage are provided in Appendix B.

- Catchment areas, average catchment slopes and land use were determined using the 1:4,000 orthophoto (Bundeena U0922–5) and the 2 m contour map depicting natural contours supplied by council. The catchment boundaries for the residential areas south of Scarborough Street have not taken into account the local drainage system. This is considered to have a minimal impact on design flow rates because:

  – the total catchment area would still be the same;

– these areas drain directly into the swamp system and therefore the total flow at Scarborough Street would essentially be the same.

If a more detailed analysis of the local drainage system was required in a future study then the catchment boundaries should be more accurately assessed. Subcatchment definitions are presented in Figure 4.1.

- Using the newly surveyed Council plan, it was estimated that an average percentage of impervious area for residential areas of Bundeena would be about 30%. This value was used in the RAFTS model.
- Simple channel lagging was used, which allows hydrographs to be simply lagged by time, from one end of the subcatchment to the other, with no attenuation in peak discharge. This was considered to be an appropriate simplification because storage and attenuation effects of the Bundeena swamp system were modelled using the detention basin formulae available in RAFTS. Attenuation at other locations was considered to have comparatively little impact on the overall RAFTS results.
- Subcatchments were not divided into pervious and impervious subcatchments; rather, a percentage of impervious areas was applied to each subcatchment.

Manning 'n' for pervious areas

Table 4.4 provides the guidelines used for the assigning of Manning 'n' values to the pervious areas of subcatchments, based on information provided in the RAFTS-XP manual (WP Software 1991).

Table 4.4 **Manning 'n' for pervious areas used in the RAFTS-XP model**

Mannings 'n'	Description
0.100	Forested and densely vegetated catchments
0.050–0.070	Rural pastures
0.030–0.040	Rural and small rural living lots
0.025	Urban pervious areas

Rainfall losses

Table 4.5 shows the initial and continuing rainfall losses used for this study. These values are based on guidelines set out in *Australian Rainfall and Runoff—A guide to flood estimation* (Institution of Engineers, Australia 1987), and experience from previous studies. The percentage impervious for each subcatchment was calculated first, in order to assign the RAFTS loss index number.

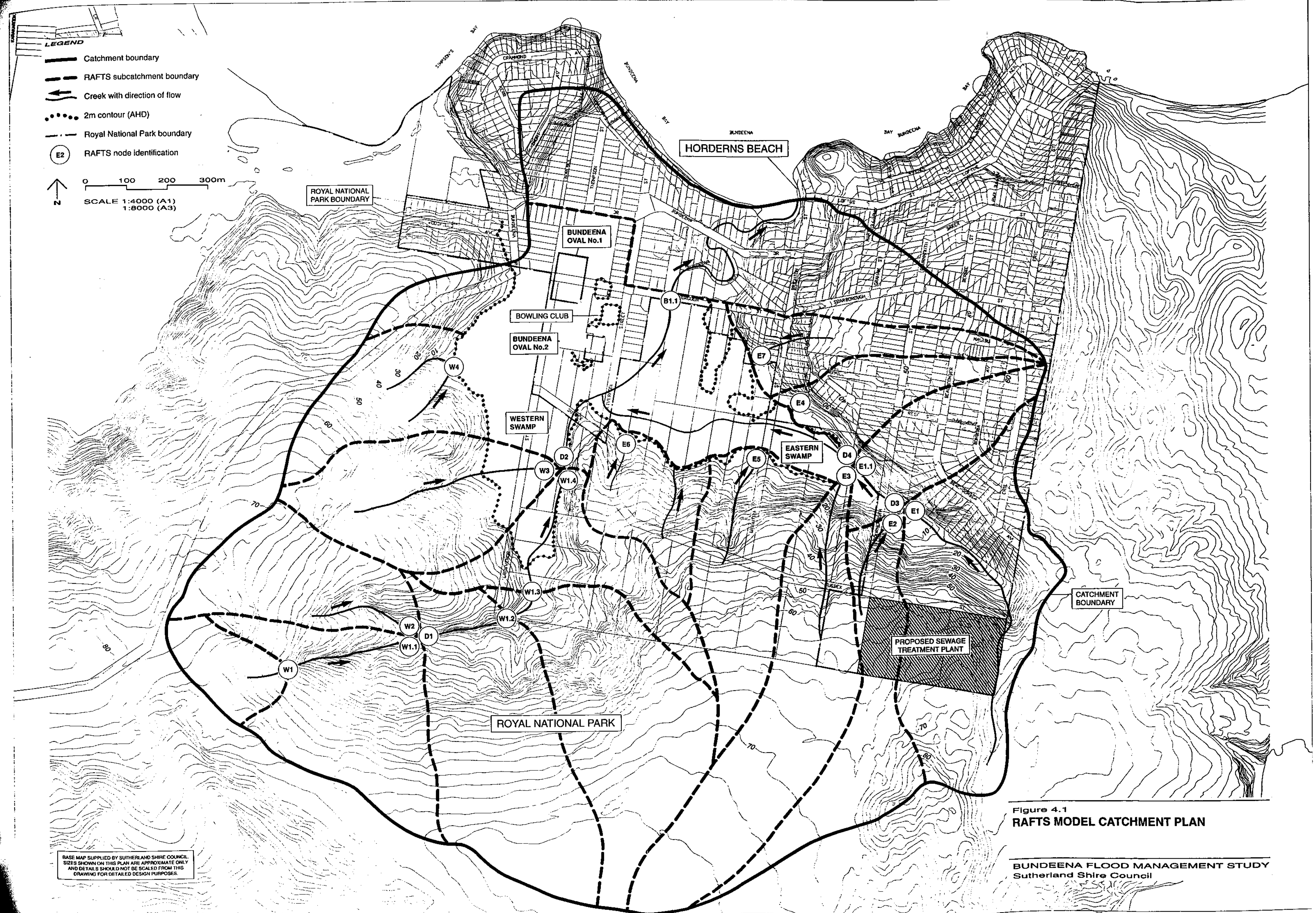

Figure 4.1
RAFTS MODEL CATCHMENT PLAN

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Table 4.5 **Rainfall losses**

RAFTS Index no.	Calculated impervious percentage of subcatchment	Initial loss (mm)	Continuing loss (mm/h)
1	0%–5%	10	2.5
2	6%–25%	5	1.0
3	>25%	1.5	0.0

4.5.2 PRELIMINARY RAFTS RESULTS

The ideal situation with any hydrological modelling is that actual streamflows are available from gauging stations (with corresponding rainfall data) at various locations throughout the catchment. The actual rainfalls can be entered into a mathematical model, such as RAFTS, and the model then calibrated by the adjustment of parameters until the design flows calculated by the model correspond to the actual flows measured at the gauging station.

Comparison of results from different methods

In the Bundeena Creek catchment, like many catchments of comparable size, no gauging data were available to calibrate the RAFTS model. Therefore, independent checks and comparisons were carried out to gain confidence in the results obtained from the computer model. Three sources were used:

- Cooper (1976) estimated peak flow rates at Scarborough Street and at the outlet to catchment using the Rational Method and a Unit Hydrograph Method described in the 1958 version of *Australian Rainfall and Runoff* (Institution of Engineers, Australia 1958). The calculation method used to determine these flows assumed no attenuation effects from the swamp system and so they have been compared to the total peak discharge, as calculated by RAFTS, that would enter the swamp system.

- The results of the RORB modelling carried out by Cameron McNamara (1985) are not presented in their report and so were not available for comparison. However outflows from the swamp system (that is, the flow at Scarborough Street) were available.

- The Probabilistic Rational Method outlined in Chapter 5 of *Australian Rainfall and Runoff—A guide to flood estimation* (Institution of Engineers, Australia 1987) was also used to calculate flows at selected locations. This method assumes a fully rural catchment with no attenuation effects and was applied accordingly.

Table 4.6 summarizes the comparisons of design flow rates calculated for the Bundeena Creek catchment including those calculated from the RAFTS modelling undertaken for the current study.

Table 4.6 **Comparison of design flow rates for 100-year ARI flood event**

Location	RAFTS subarea	Design flow rates for 100-year ARI flood event: Cooper (1976) (m³/s)	Cameron McNamara (1985) (m³/s)	RAFTS (1993) (m³/s)	Probabilistic Rational Method (1993) (m³/s)
Inflow to western swamp	D2	–	–	14	40
Inflow to eastern swamp	D4	–	–	10	28
Scarborough Street	B1.1				
• no basin effects		48	–	33	72
• with basin effects		–	24	28*	–
Horderns Beach	–				
• no basin effects		51	–	–	82
• with basin effects		–	24	28*	–

* *From MIKE-11 modelling (refer Section 4.5.3).*

From Table 4.6, it is shown that Cooper's values are higher than both the Cameron McNamara (1985) and RAFTS (1993) results. This is understandable, as the 1976 methodology did not include any attenuation of flows. The RAFTS (and MIKE-11) results are comparable with those of the Cameron McNamara Study. The Probabilistic Rational Method gave much higher results than the other three sources, with reasons for this including:

- no attenuation of flows is assumed in the Probablistic Rational Method;
- the Probabilistic Rational Method assumes, that at the time of the peak flow rate, the entire catchment is contributing to the flow;
- the only catchment parameter considered in the Probablisitic Rational Method is catchment area.

Despite all three reasons being applicable in the Bundeena Creek catchment, the Probabilistic Rational Method still provided a useful 'broad-scale' value of flow rate for this study.

From the values shown in Table 4.6 it was considered that results from the RAFTS modelling appeared reasonable and could be applied to the Bundeena Creek catchment.

The need for further modelling

As discussed in Section 4.5.1, detention basins modelled by the RAFTS program are assumed to have a free outlet. This means that the outlet can not be affected significantly by backwater from the creek downstream, and the ponding level of the basin must be independent of the downstream creek level. The outflow from the swamp system in the Bundeena Creek catchment and hence the flood level at Scarborough Street was found to be directly related to the flood level in Bundeena Creek downstream of the road. This meant that the design flow rate at Scarborough Street calculated by the RAFTS model would be conservative as the backwater effects were not being taken into account. Therefore, the RAFTS model results could not be used directly in the hydraulic modelling exercise. Rather, an unsteady flow model, namely MIKE-11, had to be used to simulate the interactions between the flood levels in the swamp system and those in the creek downstream of Scarborough Street.

4.5.3 ESTABLISHMENT OF MIKE-11 MODEL

MIKE-11 (Danish Hydraulic Institute 1990) is an unsteady flow analysis program that allows for interactions from upstream and downstream directions, such as runoff from a catchment combined with downstream tidal influences. Therefore, MIKE-11 was used in the current study to model the combined flood behaviour of the swamp system, the Scarborough Street culvert, the main channel downstream of Scarborough Street and tidal levels in Port Hacking.

The MIKE-11 program requires input of the following information:

- cross-section information
- roughness coefficients
- inflow hydrographs
- downstream conditions.

These inputs are discussed in more detail below. Many of the parameters used in the HEC-2 modelling exercise undertaken by Cameron McNamara could have been used in the MIKE-11, however they were not available for the current study.

Cross-section information

Cross-sections of Bundeena Creek between Horderns Beach and southern end of Liverpool Street were surveyed by Sutherland Shire Council at the end 1992. Spacing between cross-sections varied from between about 20 m and 50 m. These cross-sections were generally in the same locations as those surveyed for the Cameron McNamara Study (1985).

The MIKE-11 program requires that cross-sections extend to at least the maximum width of the floodplain. The council cross-sections were therefore extended accordingly using the detailed topographical and land use plan discussed in Section 3.1.2 and the flood extents provided in the Cameron McNamara Study (1985). Very wide cross-sections were extracted from the council survey plan to depict the swamp system upstream of Scarborough Street.

Figure 4.2 shows the locations of the creek cross-sections used in the MIKE-11 model.

Roughness coefficients

One of the main calibration parameters used in hydraulic modelling is the Manning 'n' value of roughness. At each cross-section the Manning 'n' values were determined using the following sources:

- a detailed field inspection of Bundeena Creek and its floodplain;
- using recognized references such as *Open Channel Hydraulics* (Ven te Chow 1959);
- using experience from previous studies.

Table 4.7 gives typical values of Manning 'n' adopted for use in the MIKE-11 hydraulic model.

Table 4.7 **Typical Manning 'n' values used in the MIKE-11 model**

Description	Adopted value
Concrete	0.015–0.020
Beach, sand dunes	0.030
Lawns	0.035
Long grass, paddocks	0.040–0.050
Marshed areas, mangroves	0.060–0.080
Thick creek-side vegetation	0.100–0.120
Areas within the Royal National Park	0.100–0.120

Inflow hydrographs

One inflow hydrograph was used in the MIKE-11 model, which was taken directly from the RAFTS model. This inflow hydrograph represented a combination of all inflows into the Bundeena Creek swamp system.

The RAFTS program calculated that a 9-hour storm would give the highest total inflow into the swamp system in a 100-year and 20-year ARI flood event. A probable maximum precipitation storm of two hours duration was also modelled using the MIKE-11 program.

Downstream conditions

As discussed previously, the aim of this study is to determine flood levels in Bundeena Creek that would occur with a probability of 'once-in-100-years'. This could result

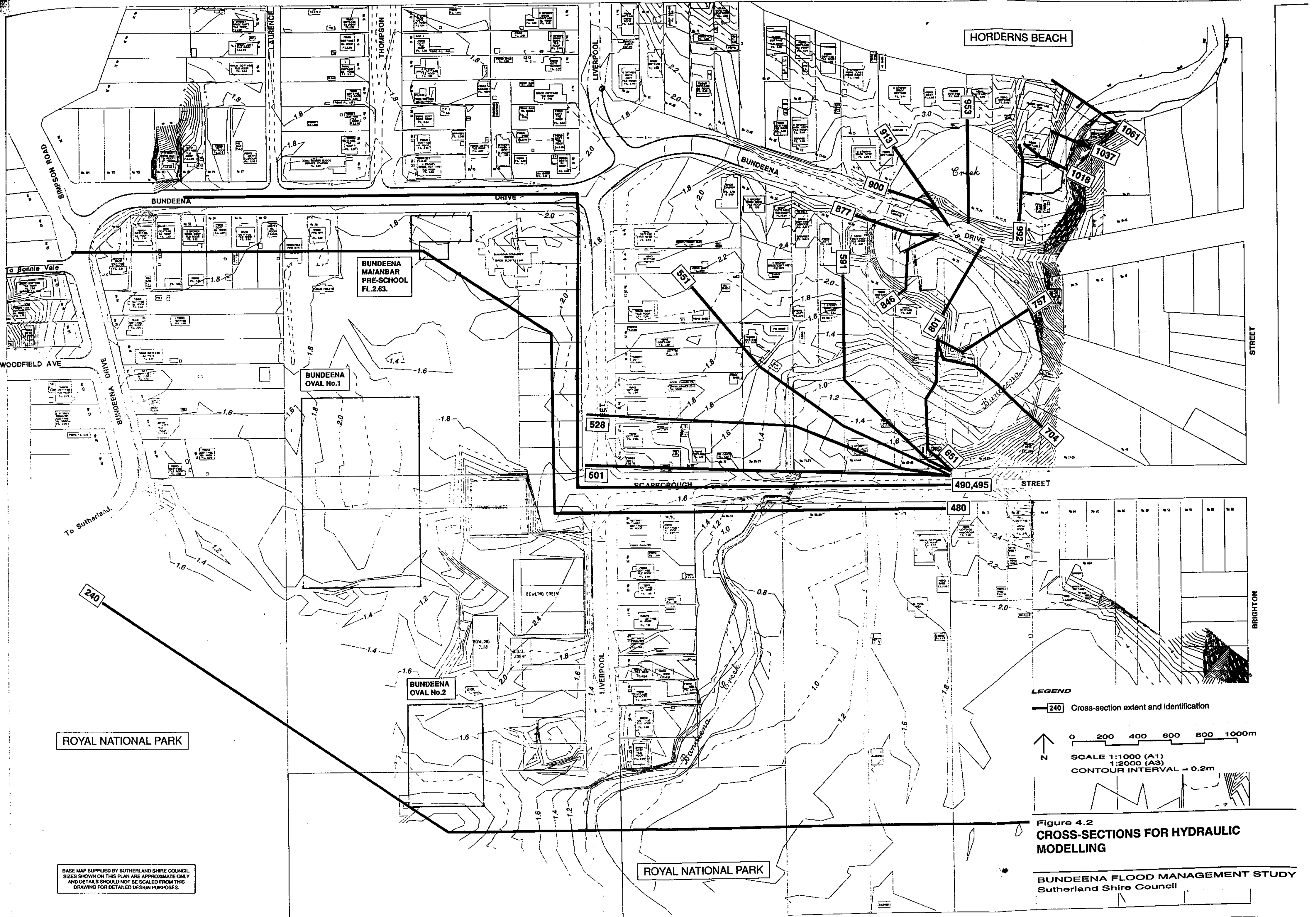

Figure 4.2
CROSS-SECTIONS FOR HYDRAULIC MODELLING

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from an infinite combination of rainfall events in Bundeena Creek catchment and tidal effects in Port Hacking. To maintain a probability of 'once-in-100-years', it has been assume that a 100-year ARI design rainfall event would occur at the same time as the 'average yearly astronomical tide'. This mean tide level is equivalent to about 0.0 m AHD. It has also been assumed that a storm surge of 0.3 m would be likely to occur during a 100-year ARI rainfall event because such an event is usually accompanied by a low pressure meteorological system (Public Works Department 1991). This combination of 'average yearly astronomical tide' with storm surge would result in a water level in Port Hacking of 0.3 m AHD.

Similarly for a probability of 'once-in-20-years', it has been assume that a 20-year ARI design rainfall would occur at the same as the 'average yearly astronomical tide'.

The sand dune at the exit of Bundeena Creek has been surveyed to be at a minimum level of about 0.85 m AHD. Therefore, this sand dune would act as the hydraulic control in Bundeena Creek up to a flood level of 0.85 m AHD. By assuming a Port Hacking level of 0.85 m AHD for the hydraulic modelling exercise, this would represent an astronomical tide level of 0.55 m AHD (that is allowing for 0.30 m storm surge) which represents a reasonably high tide level of 1.48 m ISLW.

This Port Hacking level of 0.85 m AHD, assumed to occur during both a 100-year ARI and 20-year ARI rainfall events, is therefore somewhat conservative and would take into account the perception that 'floods always occur at high tide'.

A sensitivity test was carried out using the MIKE-11 model assuming the Council's one year/storm surge level of 1.28 m AHD as the water level in Port Hacking (as discussed with Council, to add a greenhouse level of 0.2 m to this level would not maintain the probability of 'once-in-100-years'). The results of this sensitivity test, comparing the different Port Hacking water levels of 1.28 m AHD and 0.85 m AHD, are summarized below:

- at Hordems Beach, levels would be about 0.3-0.4 m higher;
- at Bundeena Drive, levels would be about 0.2 m higher;
- between CS704 and Scarborough Street, levels would be about 0.1–0.15 m higher;
- upstream of Scarborough Street, increases in flood levels would be neglible.

This sensitivity test highlights how tidal effects are dissipated in the more upstream areas of Bundeena Creek. If a high tide should occur during a 100-year ARI rainfall event, levels upstream of Scarborough Street would only suffer marginal increases. This would also apply to the flood management options discussed in Chapter 5.

When modelling the probable maximum flood with MIKE-11, the 100-year ARI still water level of 1.50 m AHD was adopted as the downstream water level. The mechanisms of the washing away of the sand dune during large storms was beyond the scope of this study.

4.5.4 VERIFICATION OF HYDRAULIC MODEL

As with hydrologic modelling, the ideal situation with any hydraulic modelling exercise is that actual flood levels are available at various locations within the floodplain. These historical flood levels can then be compared to the levels calculated by the hydraulic model.

Cameron McNamara (1985) conducted an extensive resident survey in order to obtain historical flood levels for the November 1969, March 1975, February 1977, March 1977 and November 1984 events (summarized in Table 4.1). However with only sketchy rainfall data available for these events, it was difficult to estimate historical flow rates with the RAFTS model. Therefore, a complete calibration exercise was not possible.

In such instances, where calibration of the hydraulic model is not feasible (this is common in many catchments of comparable size to Bundeena Creek), a series of comparisons and sensitivity checks are carried out to help verify the results of the hydraulic modelling.

Figure 4.3 shows a comparison of the following flood profiles:

- 100-year ARI flood event as calculated by MIKE-11
- 100-year ARI flood event from the Cameron McNamara Study (1985)
- 100-year still water level in Port Hacking
- historical flood levels from Table 4.1.

The comparisons and sensitivity checks for Bundeena Creek that were undertaken for this study are discussed below:

- The results from MIKE-11 show generally lower flood levels than those presented by Cameron McNamara (1985). A combination of the following explanations are offered for this difference:

  - HEC-2 can only calculate flood levels that are subcritical. Just downstream of Bundeena Drive and just downstream of Scarborough Street, there are relatively steep sections of channel where the HEC-2 model indicated that super critical flow would result. Consequently a flood depth corresponding to the critical depth was assumed. Therefore the depth adopted by HEC-2 would be somewhat higher than the actual depth. By calculating an artificially high flood depth, cross-sections further upstream also tend to have artificially high levels.

  - With artificially high calculated flood levels, constrictions all along the creek have been accentuated, especially just downstream of Bundeena Drive and in the swamp system upstream of Scarborough Street.

  - From the Cameron McNamara report (1985), it appears that some HEC-2 cross-section may not have been wide enough to cover the entire width of the

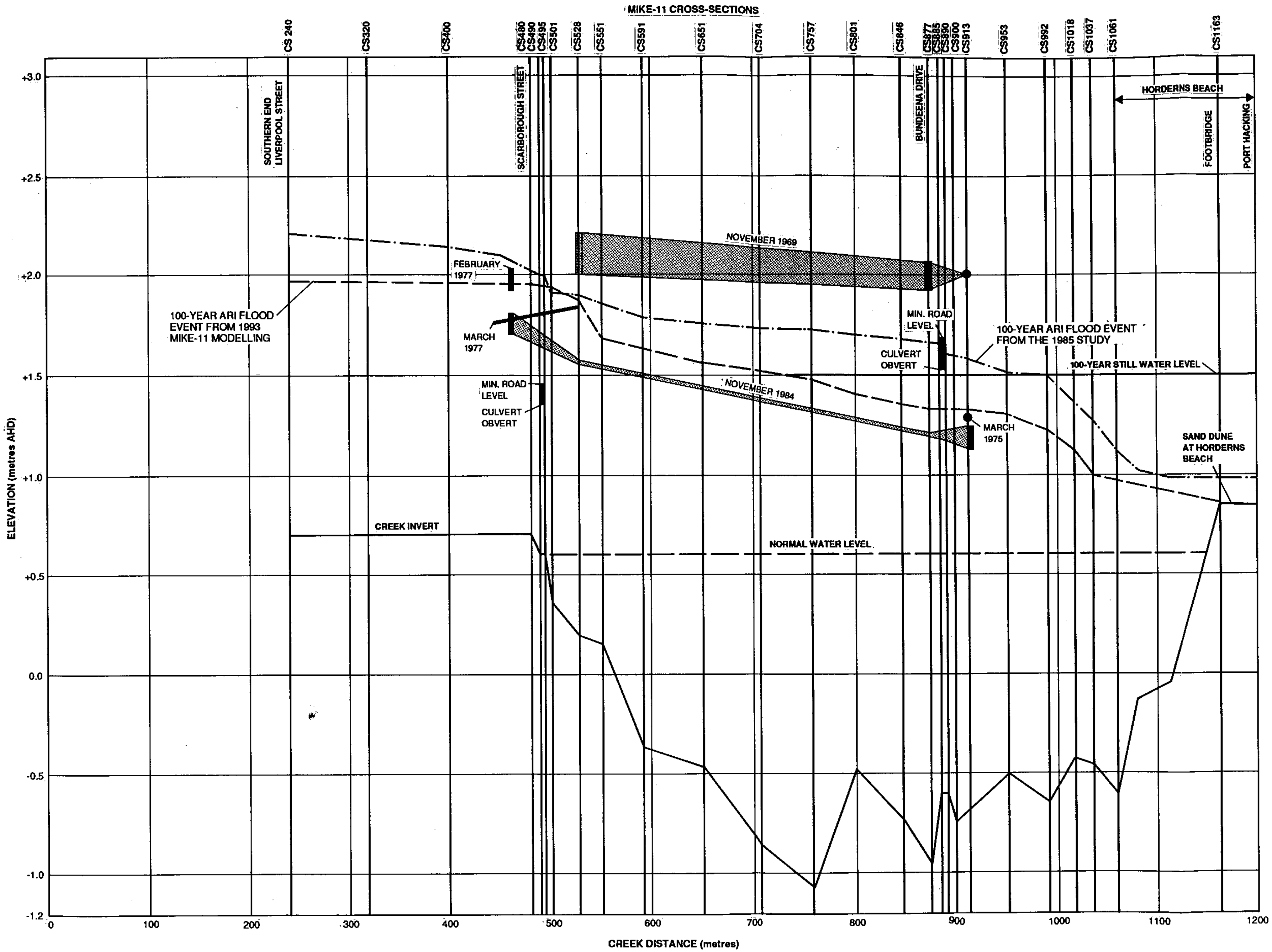

Figure 4.3
COMPARISON OF HISTORICAL & MODELLED FLOOD LEVELS IN BUNDEENA CREEK

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floodplain. This would also artificially increase flood levels in areas further upstream.

- The Manning 'n' values adopted for the Cameron McNamara report could have been excessively high.
- The expected order of accuracy of most hydraulic modelling is ±0.2 m. As the difference between these two profiles is generally in the expected range, it may be the different mathematical formulae of the two programs that have resulted in two different profiles.

- The results from MIKE-11 shows that flood levels in Bundeena Creek are quite insensitive to changes in flow rate. A 50% increase in flow rate between the 20-year ARI and 100-year ARI flood events would result in only a 110 mm difference in flood level in most locations along the creek.
- Historical flood levels collected for the November 1984 event produce a profile that is similar in shape to those design flood profiles calculated by both computer models.
- All the information collected for the historical events, except those for November 1969, are below the calculated 100-year ARI flood profiles.
- Figure 4.3 shows that the November 1969 storm was a somewhat different event to the others. It can be seen that within the vicinity of Bundeena Drive, three separate interviews reported a flood level in the order of 2.0 m AHD for this event. Modelling showed that a flow of two to three times the calculated 100-year ARI flow would be necessary to cause such a flood level. This provides two possibilities for the November 1969 event:
  - rainfalls in the Bundeena Creek catchment were well in excess of a 100-year ARI event.
  - wave set-up from Port Hacking exacerbated the flooding.

From the design rainfall intensities provided in Appendix B, a 100-year ARI storm of 24-hours duration would result in about 280 mm of rain. This is comparable with the 290 mm measured at the daily read gauge. Therefore, it is likely that a 100-year ARI rainfall fell on the catchment and this was combined with a Port Hacking water level of about 2.0 m AHD (which can be considered to be 1.5 m AHD still water level plus 0.5 m of wave set-up). From this analysis, the recurrence interval that should be assigned to the November 1969 event in Bundeena would be well in excess of 100 years. Also, as Port Hacking levels had a significant impact on the flood levels, it is not correct to try to calibrate the hydraulic model to these levels.

It was concluded from the above comparisons and verifications that the MIKE-11 model represented a reasonable simulation of flood levels in Bundeena Creek between the southern end of Liverpool Street and Horderns Beach.

4.6 ADOPTED STREAMFLOWS AND FLOOD LEVELS

From the discussions presented in Sections 4.5.2 and 4.5.4, the results from the RAFTS and MIKE-11 models were adopted as being able to reasonably model streamflow and flood levels, respectively, in the Bundeena Creek catchment resulting from storm runoff. As discussed in Section 4.1, these results should then be superimposed over the design still water levels in Port Hacking. Figures 4.4 and 4.5 provide flood contours and extents for the 100-year and 20-year ARI flood events respectively assuming a combination (at separate times) of the two sources of flooding. Figure 4.6 provides flood profiles for the probable maximum flood, 100-year and 20-year ARI flood events, together with the corresponding still water levels in Port Hacking. The flood levels at particular cross-sections for existing channel conditions are tabulated in Appendix C.

4.7 DESCRIPTION OF EXISTING FLOOD BEHAVIOUR

4.7.1 EXTENT OF INUNDATION

Figures 4.4 and 4.5 provide an overall picture of flooding from Bundeena Creek for storms in the catchment, combined (separately) with still water levels in Port Hacking for 100-year ARI and 20-year ARI events. Generally, flooding is contained within the main creek banks upstream as far as about Scarborough Street. Bundeena Drive at the Bundeena Creek crossing would be flood free in a 100-year ARI event.

Upstream of Scarborough Street, the floodplain becomes very wide as this area is part of the Bundeena Creek swamp system. As discussed in Section 4.5.1, the outflows from this large storage area are generally controlled by the road profile of Bundeena Drive–Liverpool Street–Scarborough Street up to about 2.0 m AHD. While the Scarborough Street culvert crossing provides the main control on flows, the corner of Scarborough Street and Liverpool Street provides a route for the breakout of higher level flows at about 1.8 m AHD.

In a 100-year ARI event there would be a maximum of about 0.45 m of water over the road at the Scarborough Street crossing. In a 20-year ARI event this depth would still be about 0.35 m, making this access impassable in both events.

Access to the southern end of Liverpool Street would be a problem even in a 20-year ARI event, when up to 0.5 m of water would cover the road. Although the last four houses in Liverpool Street are well above the flood level, it may be difficult to actually gain access to the properties.

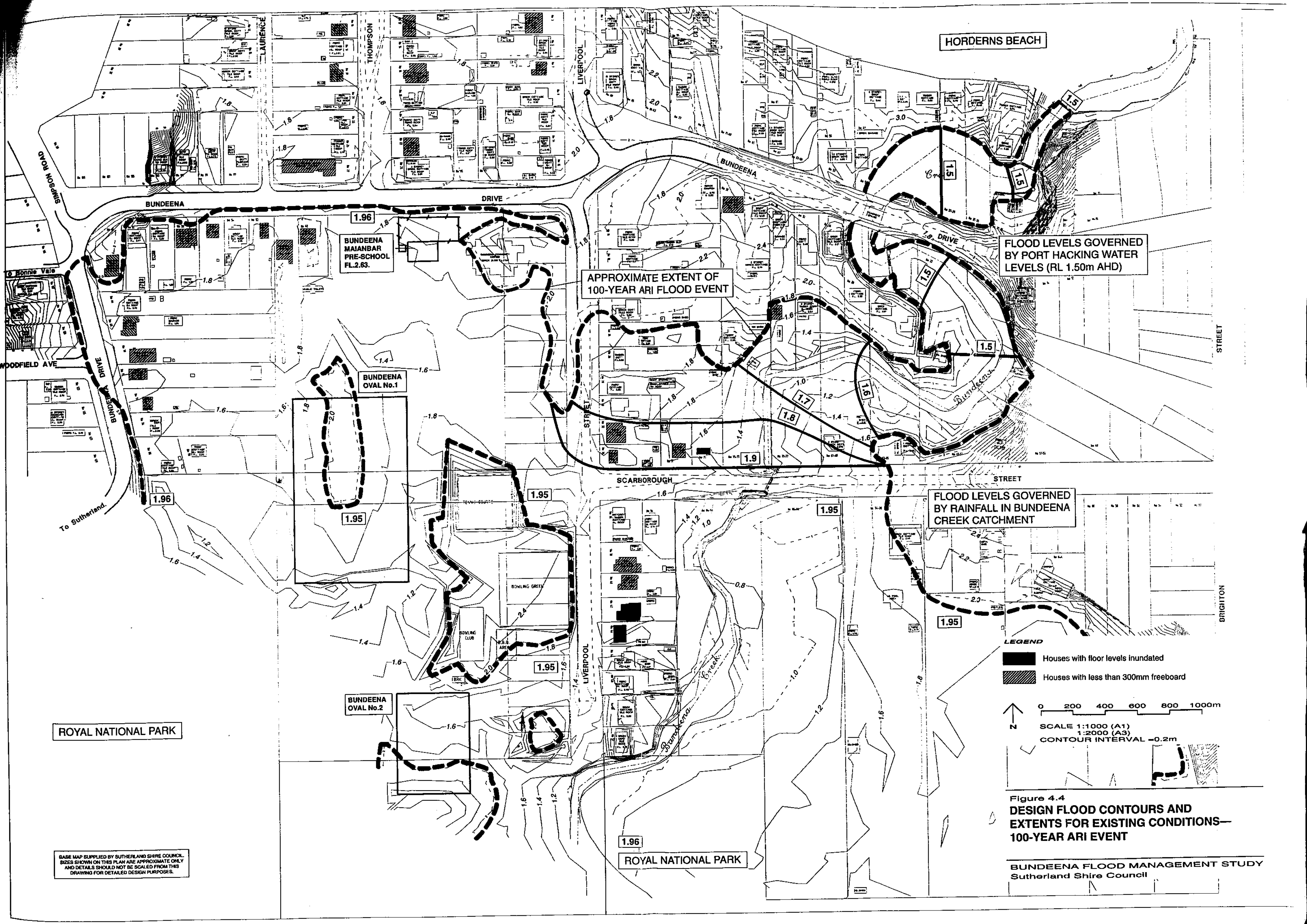

Figure 4.4
DESIGN FLOOD CONTOURS AND EXTENTS FOR EXISTING CONDITIONS—100-YEAR ARI EVENT

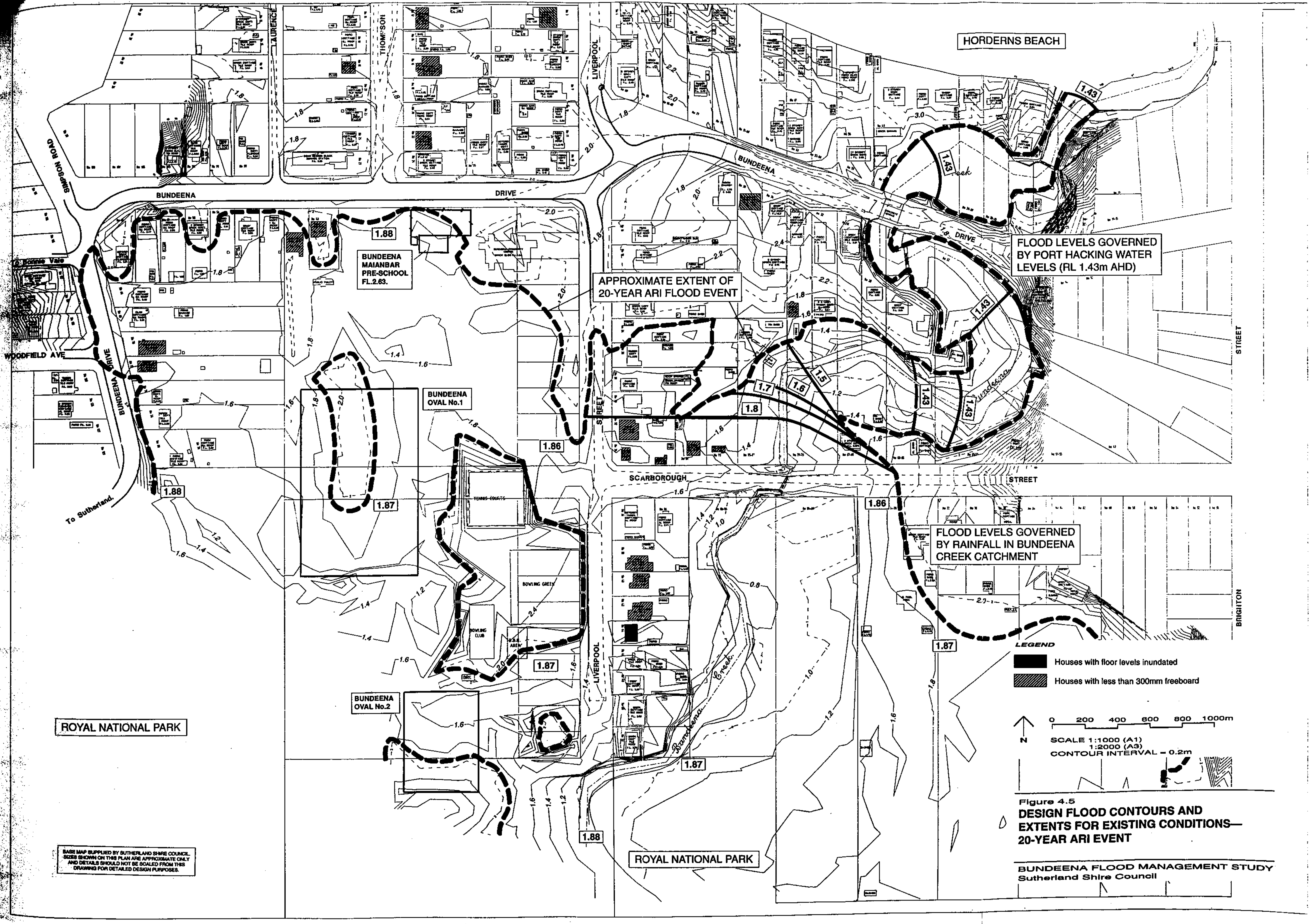

Figure 4.5
DESIGN FLOOD CONTOURS AND EXTENTS FOR EXISTING CONDITIONS— 20-YEAR ARI EVENT

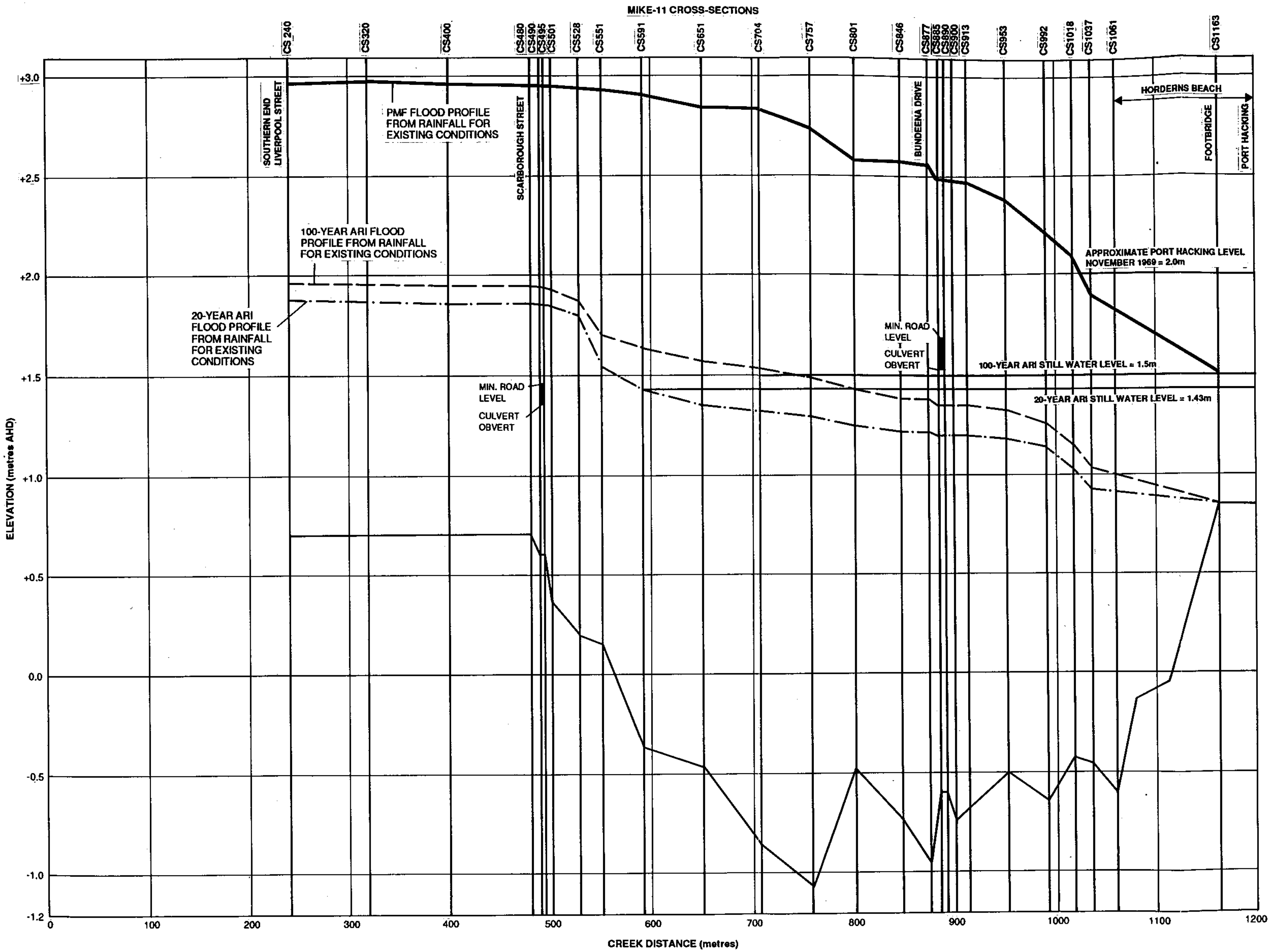

Figure 4.6
ADOPTED FLOOD PROFILES FOR EXISTING CONDITIONS

Figure 4.5 shows that trafficable access is available in and out of Bundeena in a 100-year ARI event. Although a short section of Bundeena Drive would be subject to inundation near the corner of Woodfield Avenue, flood depths would be less than 150 mm. This depth is considered to be acceptable and safe to vehicular traffic (Public Works Department 1986b).

The predicted depth of flooding at any other location can be calculated using Figures 4.4 and 4.5, by subtracting the ground level from the flood contour level at a particular location.

4.7.2 CONSTRICTIONS TO FLOWS

There are two main constrictions to flow that were identified in the hydraulic modelling exercise:

- a natural steep-sided narrow section of channel downstream of Bundeena Drive adjacent to the Christian Centre (CS1018 to CS1061);
- a man-made constriction caused by filling of land, relocation of the channel and construction of a 600 mm high concrete-block wall just downstream of Scarborough Street.

The natural constriction downstream of Bundeena Drive would only have an effect on flood levels at times when water levels in Port Hacking were not affecting water levels in Bundeena Creek. The right hand side of the creek at this location is very steep and densely vegetated.

The man-made constriction just downstream of Scarborough Street is believed to have been constructed after the November 1969 flood (Cooper 1976) when the property north of Scarborough Street was extensively filled with coal waste. Photographs of flooding taken in 1977 show that these works were in place at that time.

It appears that, at the time of filling, the natural course of the channel was altered, with a significantly smaller channel being constructed on the adjacent property. The alignment of the culvert under Scarborough Street was not altered. During a field inspection it was noted that erosion at the outlet of this culvert is a particular problem because flows are not directed into the channel. The council's survey plan (refer Figure 4.5) clearly shows the alignment problem.

In an attempt to prevent flood waters from entering the filled property, a 600 mm high concrete-block wall has been constructed parallel to Scarborough Street and for about 30 m along the western bank of the relocated channel. It appears that corrugated iron has been used further north along this western bank to try to achieve the same result.

From the flood profiles presented in Figure 4.6, the change in flood levels in the vicinity of CS 551 clearly shows the impact of this constriction just downstream of Scarborough Street.

4.7.3 PERIOD OF INUNDATION

From the RAFTS modelling, a 9-hour storm was calculated as causing the highest total inflow into the swamp system for both the 100-year and 20-year ARI flood events. The MIKE-11 modelling estimated that, for existing conditions, the 100-year ARI flood level on Bundeena Oval would be 1.96 m AHD and the period of time when flood levels would be greater than 1.6 m AHD would be 6–6.5 hours. Downstream of Scarborough Street to about CS 757, the period of time when 100-year ARI flood levels would be greater than 1.5 m AHD has been calculated by MIKE-11 to be 2–3 hours. Downstream of CS757, the period of time when flooding was higher than 1.5 m AHD would only be very short, as flooding would be governed by tide levels in Port Hacking.

4.7.4 INUNDATION OF PROPERTIES AND FLOORS

Table 4.8 provides a summary of frequency of house floor inundation in Bundeena. Sheds and garages have not been included in these numbers. These results show that the most significant flood problems in Bundeena are access and property inundation rather than above-floor flooding of houses. Most property owners would suffer the inconvenience of gardens being underwater and the inability of gaining access to their houses, rather than sustaining significant amounts of flood damage to the insides of their homes. Table 4.8 also provides an estimate of the number of properties that would suffer such inconvenience.

Table 4.8 **Frequency of property inundation**

Flood event (ARI years)	No. houses with flood-liable floors	No. houses with floors with less than 300 mm freeboard	Approximate number of houses suffering inconvenience from flooding
100	3	25	45
20	1	19	45

Also included in Figures 4.4 and 4.5 are those houses whose floor levels are below the calculated flood levels and those houses with floor levels with less than 300 mm freeboard above the calculated flood levels. Bundeena Drive between Simpson Road and Liverpool Street has been built across the natural Bundeena Creek floodplain at a level of about 2.0 m AHD. Some house to the north of Bundeena Drive have floor levels which are actually lower than the calculated flood levels in Bundeena Oval. Bundeena Drive acts as a type of levee that (just) protects these houses up to a 100-year ARI event—the calculated 100-year ARI is essentially at centreline of Bundeena Drive. Therefore, even a minimal increase in flood level south of Bundeena Drive could cause overtopping of the 'levee' and flood a number of houses.

To give an indication of those house which could be flooded if there was an increase of (say) 0.3 m, Figures 4.4 and 4.5 depict those houses that would have floors inundated in

5 FLOOD MANAGEMENT MEASURES

5.1 METHOD OF ASSESSMENT

This chapter examines a variety of measures that may be appropriate to reduce the impact of flooding in the low-lying areas of Bundeena. As many options as possible have been put foreward and considered qualitatively using the following criteria:

- cost effectiveness
- social effects and impacts
- environmental effects, particularly with regard to the Royal National Park
- hydraulic performance
- construction requirements
- maintenance requirements
- water quality impacts
- land use and property ownership
- effects on local drainage
- safety
- reduction of flood impact and damage.

Options have then been either:

- not adopted for further consideration
- recommended for further consideration.

Preliminary cost estimates have been carried out for those options recommended for further consideration.

In order to estimate the size or extent of the flood management options, selection of an appropriate flood standard is an essential part of the flood management process (Public Works Department 1986b). Sutherland Shire Council has adopted the 100-year ARI flood event as their standard and hence the management plan formulated in the current study is based on this design event.

The results from the MIKE-11 modelling have shown that generally the 20-year ARI flood level is only about 0.1 m lower than the 100-year ARI flood level. Table 4.8 shows that about forty-five houses would be inconvenienced by access and/or property flooding in both the 20-year and 100-year ARI events. Because the effects of the two events are so similar, the cost of solutions would only be marginally less if the 20-year ARI event was used as the design standard. Also, it is usually normal practice to only address Council's adopted flood standard (in this case the 100-year ARI flood event) because government funding assistance is not normally available for designs for less than the adopted flood standard.

A preferred flood management plan is presented at the end of this chapter.

5.2 OPTIONS FOR FLOOD MANAGEMENT

Table 5.1 provides details of the options for flood management examined for Bundeena. The options are not presented in order of importance. In Table 5.1 each option is briefly described, including its aim. Advantages and positive impacts are then listed together with any disadvantages and problems that may be apparent. Following the qualitative assessment of the option, it is noted whether or not the option is adopted for further consideration. Preliminary cost estimates are provided where appropriate. Figure 5.1 provides a pictorial representation and summary of each of the options.

The flood management options can be summarized as follows:

- Option 1—Enlargement of culvert at Bundeena Drive crossing of Bundeena Creek;
- Option 2—Removal of wall downstream of Scarborough Street;
- Option 3—Removal of wall and channel works downstream of Scarborough Street;
- Option 4—Low level levee upstream of Scarborough Street;
- Option 5—High level levee in the Royal National Park (proposed by Cameron McNamara [1985]);
- Option 6—Redirection of flows to Bonnie Vale and/or Horderns Beach;
- Option 7—Provision of a retarding basin in Bundeena Reserve;
- Option 8—Voluntary purchase and/or raising of flood-affected houses;
- Option 9—Individual flood proofing of flood-affected houses;
- Option 10—Road raising and improved local access;
- Option 11—Opening up of outlet at Horderns Beach;
- Option 12—Improved monitoring in Bundeena Creek catchment;
- Option 13—Creation of drainage easement.

Table 5.1 **Flood management options**

Option	Aim and description of option	Advantages and positive impacts	Disadvantages and problems	Conclusion
Option 1. Enlargement of culverts Bundeena Drive crossing of Bundeena Creek	**Option 1(a)** – Additional culvert at Bundeena Drive crossing of Bundeena Creek. **Option 1(b)** – Additional crossing of Bundeena Drive about 40m east of existing crossing. Aim: to try to reduce flood levels upstream of Bundeena Drive; to maintain access in 100–year ARI event.	* Flood levels at the Bundeena Drive culverts would be governed by Port Hacking water levels. However, if only a rainfall event in the catchment is considered, hydraulic modelling indicates that there would be negligible afflux caused by these culverts. Hence they do not act as a constriction to flows and it would appear uneconomic to enlarge the waterway area at this location. * As Bundeena Drive would not be overtopped in a 100–year ARI event in the vicinity of the creek crossing, this option would not be appropriate to improve access. * Nevertheless, Option 1 was modelled with MIKE–11 and the results are presented in Appendix C.		**Option 1.** Not adopted for further consideration because works would have minimal impact on solving flood probelems.
Option 2. Removal of wall downstream of Scarborough Street	Removal of 600mm high concrete block wall that surrounds No.67–73 Scarborough Street. Aim: to try to reduce flood levels upstream of Scarborough Street by removing the apparent consriction to flows; to improve the hydraulics through the culvert at Scarborough Street during low flows.	* Hydraulic modelling indicates that 100–year ARI flood level upstream of Scarborough Street would be reduced by about 120mm, however road would still be overtopped by a maximum of 400mm. Results of MIKE–11 modelling presented in Appendix C. * Hydraulics through the culvert would be improved at time of low flow. * Erosion would be reduced at No.77 Scarborough Street.	* Wall is located on private property and has been constructed since about 1975. * Who should pay for the work needs to be considered. * Because of the extensive filling of the property at No.69–73, erosion of the lawn area may result as the creek attempts to re-establish its natural course.	**Option 2.** Adopted for further consideration but problem of work on private property needs to be addressed. **Cost: $1,000**
Option 3. Removal of wall and channel enlargement works downstream of Scarborough Street	Option 2 plus construction of a grass lined channel with approx. 4m base width and 1:6 side slopes. Aim: to try to further reduce flood levels and to improve the hydraulics through the culvert upstream of Scarborough Street; to enlarge the channel to its original size.	* Hydraulic modelling indicates that 100–year ARI flood level upstream of Scarborough Street would be reduced by a further 130mm, allowing one house floor to be now above the 100–year ARI level, however road would still be overtopped by a max. of 250mm.—refer Appendix C. * Hydraulics through the culvert would be improved at times of low flow. * Work would make this section of creek more suitable as a 'natural' wetland area.	* All work would be on private property, and so who would pay for the work. * Filling of No.69–73 and altering the natural creek alignment occurred in about 1975, when the creek was moved from No.69–73 to the adjacent property No.77.	**Option 3.** Adopted for further consideration but problem of work on private property needs to be addressed. **Cost: $11,000 for channel works**

Table 5.1 **Flood management options (cont.)**

Option	Aim and description of option	Advantages and positive impacts	Disadvantages and problems	Conclusion
Option 4(a) Construction of low-level levee upstream of Scarborough Street–Alignment A: includes removal of wall and channel enlargement works described in Option 3.	Option 3 plus construction of a low-level levee and concrete- block walls where appropriate as close as possible to the existing residential areas. Works would also involve construction of a new culvert — 4 x 3.0m wide x 0.75m high — under Scarborough Street and raising of the road to a minimum level of RL1.6m AHD to form a controlled outlet to the 'basin'. See Figure 5.1. Aim: to provide protection of as much private property as possible from flooding from Bundeena Creek in a 100-year ARI event upstream of Scarborough Street.	* Hydraulic modelling indicates only minimal increase in 100-year ARI flood level—about 60mm—as a result of the works. Refer Appendix C. * Flooding of property from Bundeena Creek would be contained to outside of residential areas upstream of Scarborough Street. * In most areas the low-level levee would be less than 0.5m high, and visual impact would be low. * There would be minimal impact on the Royal National Park, in terms of removal of vegeation and changing of characteristics of flooding. * Cost would be significantly lower than Option 5.	* Local drainage/ponding problems would have to be addressed in at least four locations—refer to Figure 5.1: Solution could involve: –pumping of ponded water. –connection into street drainage. –drainage to creek via pipes with one-way flap valves. * Levee would have to be constructed on at least two private properties at the southern end of Liverpool Street. * Levee would be located on the border of Royal National Park. * Flood levels downstream of Scarborough Street would not be reduced. * Careful hydraulic design would be required for the raising of Scarborough Street and the new culverts under the road. * Levee would be overtopped in a probable maximum flood event. However, because the wall would be quite low and flow velocities quite slow, overtopping is not likely to be a catastrophic event.	Option 4(a) Adopted for further consideration Local drainge problems specifically would need to be addressed. **Costs:** *** low-level levee and concrete block walls: $109,000** ***culvert enlargement and road works: $135,000** ***localized drainage problems: $9,000**
Option 4(b) Construction of low-level levee upstream of Scarborough Street–Alignment B	This option is exactly the same as **Option 4(a)** with a variation of the alignment of the levee on the eastern side of Bundeena Creek, in order to protect the caravan park. The location of the levee in the caravan park should be as far north as possible, but could be located to just south of the two small buildings if required.	* as for Option 4(a).	* as for Option 4(b). This alignment would involve an additional local drainage problem to be addressed, and construction on at least one other privately owned property.	Option 4(b) Adopted for further consideration. Local drainge problems specifically would need to be addressed. **Additional costs to Option 4(a)** ***levee to protect caravan park: $33,000** ***localized drainage**

Table 5.1 **Flood management options (cont.)**

Option	Aim and description of option	Advantages and positive impacts	Disadvantages and problems	Conclusion
Option 4(c) Construction of low-level levee upstream of Scarborough Street–Alignment C–and construction of a local drainage collection area in the vicinity of Bundeena Oval.	Same as **Option 4(a)** with the construction of the low-level levee generally along the boundary between Bundeena and Royal National Park. The temporary storage area could be in the form of a grassed depression—about 100m by 300m maximum size—formed by reconstruction of Bundeena Oval. Drainage of the storage could be by gravity to the creek or to Bonnie Vale, or by pumping to either of these locations. The pumping option would allow more storage in the pond. Aim: to provide protection of as much private property as possible from flooding from Bundeena Creek in a 100-year ARI event upstream of Scarborough Street, and in addition, to provide a temporary storage area for local runoff in times of flood.	* as for Option 4(a). * Local drainage problems from most areas west of Bundeena Creek would be improved, including some areas north of Bundeena Drive.	* Low-level levee would have to be constructed on at least two private properties as in **Option 4(a),4(b)**. * Levee would be constructed through areas of thick vegetation, closer to the Royal National Park than **Option 4(a),4(b)**. * Flood levels downstream of Scarborough Street would not be reduced. * Playing surface of Bundeena Oval would suffer from more frequent inundation that may affect its availability and increase maintenance costs. * If the storage were to be emptied by pumping, maintenance costs would be higher than if gravity were used.	Option 4(c) Not adopted for further consideration (the social impacts of lowering Bundeena Oval would need to be addressed)

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Table 5.1 **Flood management options (cont.)**

Option	Aim and description of option	Advantages and positive impacts	Disadvantages and problems	Conclusion
Option 5. High level levee proposed by Cameron-McNamara in 1985 study	Construction of levee at RL2.85m AHD upstream of Bundeena township that would protect all areas from flooding from Bundeena Creek in 100-year ARI event. Outlet structure would be designed to restrict flows such that flood levels would be significanly reduced downstream of Scarborough Street. Aim: to protect all properties—not just houses — in Bundeena from inudation from Bundeena Creek in a 100-year ARI flood event.	* Flooding of the low lying areas of Bundeena would be limited to those relating to local drainage only, as flood waters from Bundeena Creek would be retarded sufficiently to remain in the main creek downstream of Scarborough Street.	* The levee would be located entirely in the Royal National Park, and, being 0.6m higher than the low-level levee proposed in **Options 4(a),(b) and (c)** would have environmental and visual impacts that would need to be carefully addressed. * The large outlet structure would be located entirely on National Park land. * As with Option 4, local drainage within the township—that is, north of the levee—would have to be carefully addressed. * Cost would be much higher than **Option 4(a).** * Levee would be overtopped in a probable maximum flood event. This is likely to be a more catastrophic event than if the low-level levee proposed in **Option 4(a)** were overtopped. * Need to the question the amount of land protected by this option, ie. is this extent of protection really necessary. * About 200m of Bundeena Creek near the southern end of Liverpool Street — located within the national park—would have to be diverted.	Option 5 Not adopted for further consideration because of adverse environmental impacts in the Royal National Park. **Cost: $624,000 (including creek diversion and outlet structure)**

Table 5.1 **Flood management options (cont.)**

Option	Aim and description of option	Advantages and positive impacts	Disadvantages and problems	Conclusion
Option 8. Voluntary purchase and/or house raising of flood–affected houses **Option 8(a):** Raise houses that would suffer inundation of floors **Option 8(b):** Purchase houses that would suffer inudation of floors. **Option 8(c):** Purchase all houses inconvenienced by flooding	Three properties would have their floors inundated in a 100–year ARI flood event. As shown in Figure 4.8, the most significant flood problems in Bundeena are related to access and property inundation rather than above–floor flooding of houses. In both the 100–year and 20–year ARI flood events, about forty–five properties would suffer inconvenience from flooding. Aim: to remove flood–liable houses from the floodplain and convert the property into open space: and/or to protect the habitable floor areas of flood–liable houses.	General: * Flood damage and the social impacts of flooding can be significanlty reduced by removal of houses from flood–prone areas. * House raising has proved to be a successful flood–proofing measure in other flood–liable areas in NSW.	General: * Government assistance is generally only available where floors would be actually inundated by the 100–year ARI event. * Social impacts of relocation of people are generally high and should be considered carefully. * Access to raised houses can be a problem especially during floods. * With all works described in **Options 2, 3, 4(a) and 10(b)** in place, all habitable floors would be protected from a 100–year ARI flood in Bundeena Creek. * **Option 8(a)**: Only timber, weatherboard or hardiplank houses are suitable for house raising. Therefore there would only be two houses that would be suitable for raising. This would not solve the flood problem in Bundeena. * **Option 8(b)**: There are three houses whose floors would be below the 100–year ARI flood level. Again, this would not solve the flood problem in Bundeena. * **Option 8(c)**: If the average cost to purchase and remove a house in Bundeena is assumed to be $200,000, then the cost of this option would be $9 million. Economics are likely to preclude this option.	**Option 8(a)** Not adopted for further consideration because would not solve the flooding problem in Bundeena. **Cost: $25,000–$40,000 per house for house raising** **Option 8(b)** Not adopted for further consideration because would not solve the flooding problem in Bundeena. **Cost: $600,000 (assuming an average of $200,000 for each house)** **Option 8(c)** Not adopted for further consideration for economic and social reasons. **Cost: $9 million (assumong an average of $200,000 for each house)**

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Table 5.1 **Flood management options (cont.)**

Option	Aim and description of option	Advantages and positive impacts	Disadvantages and problems	Conclusion
Option 9. Individual flood–proofing of flood liable houses without house raising.	This option would involve the construction of small walls — usually concrete block construction — around the perimeter of a flood–liable house. Flood gates or simply sandbags are used for protection of the access area or driveway. In the case of the two storey house at No.44 Liverpool Street, flood–proofing may take the form of flood–compatable uses only for the ground floor. Aim: to protect the habitable floor areas of flood–liable houses without raising the house.	* Small flood walls are generally found to be inexpensive and usually have minimal hydraulic impact on neighbouring properties. However this should always be checked. * Walls generally have low environmental and visual impact.	* Should always be checked to ensure minimal hydraulic impact on adjacent properties. * Flooding via the access to the property can be a problem because it often involves the manual installation of flood gates or sandbags. * In Bundeena, the main flooding problems are property and road inundation. Individual flood–proofing does not improve either of these situations.	**Option 9.** Adopted for further consideration for those properties whose floors would be inundated in a 100–year ARI event, in lieu of construction of the larger scale works. Hydraulic impacts need to be carefully assessed for flood–walls.
Option 10. Road raising and improved local access.	Aim: to provide flood free access in a 100–year ARI event to as many areas as possible in Bundeena. **Option 10(a)**: Raise Bundeena Drive near Woodfield Avenue to RL2.0m AHD. **Option 10(b)**: Raise Liverpool Street south of Bundeena Drive together with Scarborough Street to spillway/creek crossing to a level of RL2.0m AHD. **Option 10(c)**: Raise all Scarborough Street to a minimum of RL2.0m AHD.	* **Options 10(a), 10(b)** and only a short section of **10(c)** would provide flood–free access to all but about four houses in Bundeena. Scarborough Street would remain flood–liable in **Options 10(a) and 10(b)**, but alternative access would be avaiable. Right of way through neighbouring properties for those houses unable to have flood–free access may be a solution to this problem. * Refer to Section 5.4 for the possible ways that levees and road raising could be integrated.	* **Option 10(a)** is not likely to be necessary as Bundeena Drive would still be trafficable in a 100–year ARI event. * for all options local drainage would have to assessed. * local access to residential properties, especially in Liverpool Street, would have to be addressed in the detailed design stage. * flood–liable houses would remain flood–liable with these options. * to minimize increases in flood levels upstream of Scarborough Street, raising of Scarborough Street was found to be only feasible with the construction of the following works: –Option 3. – construction of new culverts similar in size to those needed for Option 4; –maximum road level of 1.6m AHD.	**Option 10(a).** Not adopted for further consideration as road would still be trafficable **Option 10(b).** Adopted for further consideration combined with **Options 2, 3** and **4(a)** but still need to address local access and drainage. **Cost: $83,000** **Option 10(c).** Not adopted for further consideration for hydraulic reasons

Table 5.1 **Flood management options (cont.)**

Option	Aim and description of option	Advantages and positive impacts	Disadvantages and problems	Conclusion
Option 11. Open up outlet at Horderns Beach.	This option would involve large scale excavation and/or property acquisition to try to open up the outlet of Bundeena Creek to allow the flood flows to get away more quickly. Aim: to try to reduce flood levels upstream of Horderns Beach during times of Bundeena Creek flood flows.		* Works could be carried out that would reduce 100-year ARI flood levels by about 250mm upstream as far as Scarborough Street, if only levels in Bundeena Creek are taken into consideration. However, the 100-year ARI flood level at this location of 1.5m AHD results from still water level in Port Hacking, hence reduction of flood levels would not be possible. * Any works would involve significant amounts of excavation and probably property acquisition.	**Option 11.** Not adopted for further consideration for hydraulic and economic reasons
Option 12. Improved monitoring in Bundeena Creek catchment.	This option involves the installation of: – pluviograph for the continuous measurement of rainfall. – maximum height recorders for the accurate measurement of flood heights. Aim: to establish a data base suitable for the verification of hydrologic and hydraulic models.	* Important for the verification of future hydrologic and hydraulic models.	* Vandalism, maintenance, dissemination of results are all operating costs that should be addressed prior to installation. * Installation of a gauging station is not likely to be feasible in the low-lying area of Bundeena because of the lack of a suitable control area with stable channel base unaffected by backwater.	**Option 12** Adopted for further consideration
Option 13. Creation of a drainage easement for Bundeena Creek.	Aim: to provide an easement for Bundeena Creek where the creek currently is located entirely on private property. This should enable council access for maintenance of the creek, and the monitoring of any private works in or adjacent to the creek. Such an easement would be necessary if the creek downstream of Scarborough Street were to be formalized as a 'natural' wetland — refer to Capter 6.	* Important for maintenance of the creek, and the monitoring of any private works in or adjacent to the creek.	* Problems may exist with education of those people who 'own' the creek and have done so for a number of years.	**Option 13** Adopted for further consideration

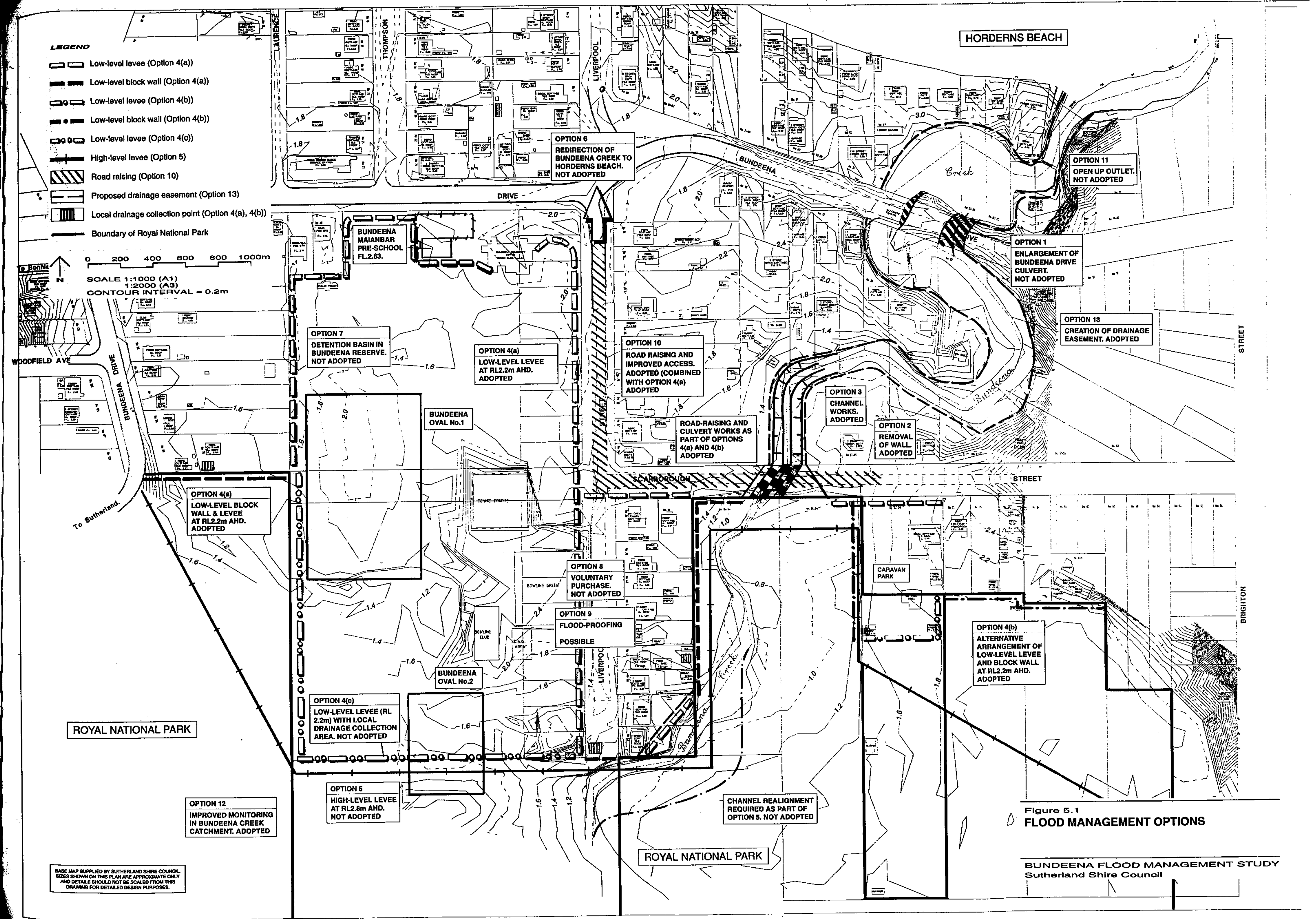


Figure 5.1
FLOOD MANAGEMENT OPTIONS

5.3 PLANNING AND DEVELOPMENT CONSIDERATIONS

This section briefly examines some of the planning and development issues that would be relevant to the Bundeena Creek floodplain.

5.3.1 NEW SOUTH WALES RIVERS AND FORESHORES IMPROVEMENT ACT

The New South Wales Rivers and Foreshores Improvement Act was amended in April 1992 to more effectively control activities in or near rivers, estuaries and lakes (New South Wales Government 1992). Excavations, fill and other works are recognized as having potentially detrimental effects on the environment. They can destroy habitats, decrease water quality, increase the effects of floods and cause erosion.

The Act requires that a '3A permit' is required for any activities on private land in or near rivers, estuaries and lakes. The permit is required for:

- any excavation within 40 m of the water or water course;
- construction of any structure including erosion control works, retaining walls causeways and bridges;
- placement of any fill material in or adjacent to the water or watercourse.

The requirement of this Act are particularly relevant to Bundeena Creek where much of the creek flows through private land (they have powers to do works under their own legislation). Residents should be made aware of their responsibilities under the Act to help protect the creek from further filling and illegal structures.

Local councils and other government authorities do not require 3A permits for works under their direct supervision (they have powers to do works under their own legislation). However, they should seek advice from the Public Works Department in the case of Bundeena, as the creek is under tidal influence, before proceeding with any activities.

5.3.2 SECTION 149 CERTIFICATES

Appendix D provides the relevant extracts from Sutherland Shire Council's Section 149 Certificate Notations for Bundeena. Most of the Bundeena Creek floodplain is included in an area where 'Attachment D1' is applicable. The restrictions placed on the construction of dwellings in Area D1 include:

- construction should be outside the 20-year ARI flood extent
- minimum habitable floor levels should be 2.7 m AHD
- minimum non-habitable floor levels should be 2.3 m AHD
- all other improvements should be located at or above 2.0 m AHD.

Attachment D1 also requires that any filling activities require consent from the council and that all fences are open type to allow free flow of any surface runoff.

The minimum habitable floor level of 2.7 m AHD in areas near the Bundeena Drive creek crossing represents 1.2 m freeboard above the 100-year ARI flood level. In the Liverpool Street area, this would represent 0.7 m of freeboard. It may be more appropriate to amend the requirements of this attachment to, say, 0.5 m above the 100-year ARI flood level. This is the freeboard adopted by many councils in their flood-liable areas. Such a requirement allows different minimum habitable floor levels, depending on the location along the creek rather than a single level applicable to all areas. The minimum levels of non-habitable floor levels could also be reduced accordingly.

The area where Attachment D2 is applicable (the area behind Rymill Place adjacent to the Royal National Park) has minimum habitable floor level requirement of 3.5 mAHD. This value appears conservative, as the 100-year ARI flood level in this area is in the order of 2.0 mAHD.

Council could also include the possible wave set-up levels (see Section 4.4.4) to determine minimum habitable floor levels in the Bundeena Creek floodplain.

5.4 PREFERRED FLOOD MANAGEMENT PLAN

Figure 5.2 presents the preferred flood management plan for Bundeena, and includes flood contours for the 100-year ARI event. Figure 5.3 depicts the flood contours for the 20-year ARI event with the preferred management plan in place. The preferred flood management plan involves a combination of the following works:

- *Options 2 and 3*—removal of wall and channel works downstream of Scarborough Street;
- *Option 4*—low-level levee upstream of Scarborough Street and around Bundeena Reserve;
- *Option 10*—road raising and improved local access;
- *Option 12*—improved monitoring in the Bundeena Creek catchment;
- *Option 13*—creation of a drainage easement;
- review of Section 149 certificate notations.

Table 5.2 summarizes the costs for the preferred flood management plan which have been estimated to total $384,000. The costs include mobilization and associated costs, assuming each of the items is constructed as a separate item. No allowance has been made for design or construction supervision, but a contingency of 15% has been included. Unit rates have been based on information provided in Cordell (1992) and the Rawlinson Group (1992).

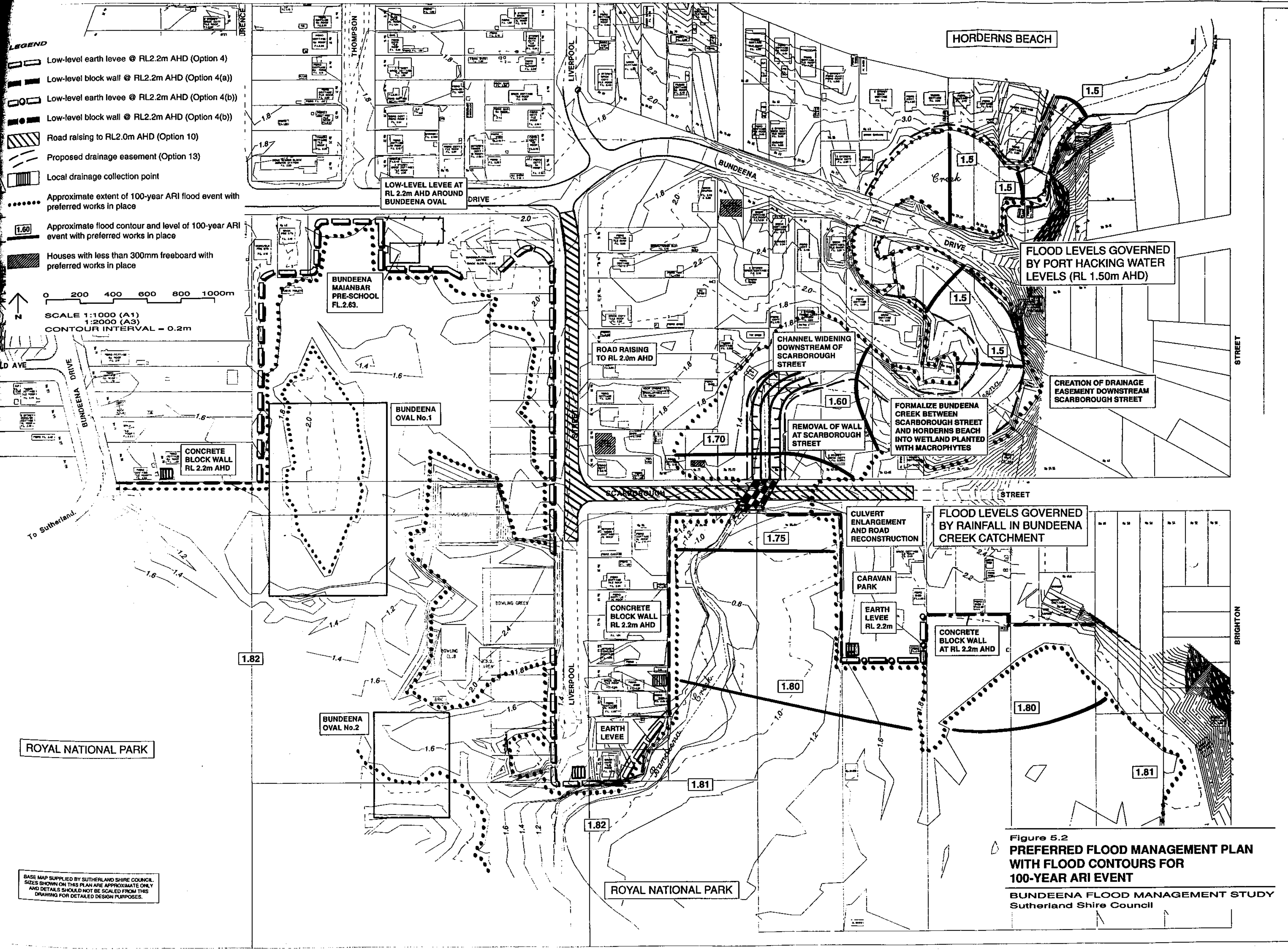


Figure 5.2
PREFERRED FLOOD MANAGEMENT PLAN WITH FLOOD CONTOURS FOR 100-YEAR ARI EVENT

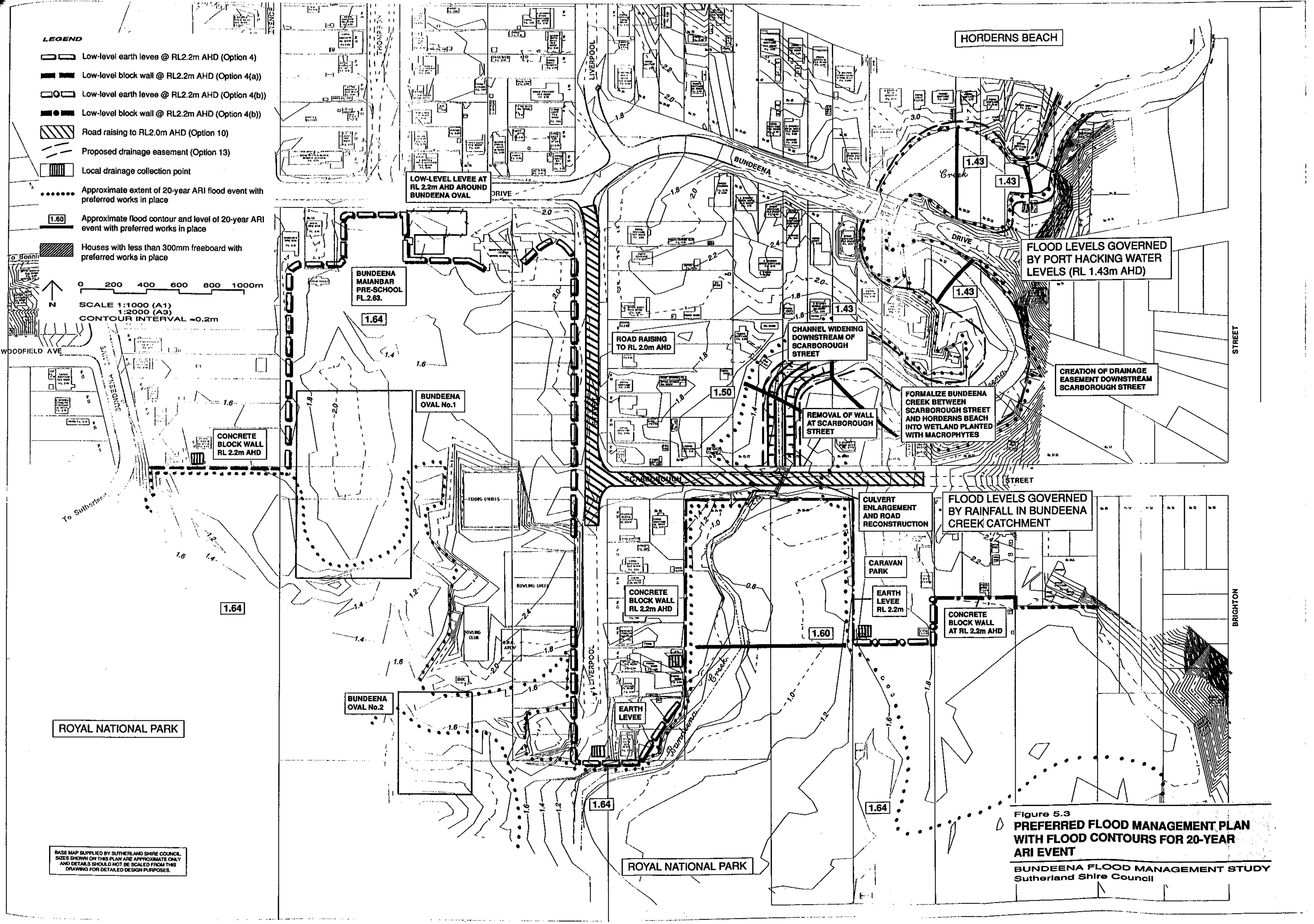


Figure 5.3
PREFERRED FLOOD MANAGEMENT PLAN WITH FLOOD CONTOURS FOR 20-YEAR ARI EVENT
BUNDEENA FLOOD MANAGEMENT STUDY
Sutherland Shire Council

Table 5.2 **Summary of costs for preferred flood management plan**

Item	Cost ($)
Removal of wall at Scarborough Street (*Option 2*)	1,000
Channel downstream of Scarborough Street (*Option 3*)	11,000
Concrete-block wall (RL2.2 mAHD) adjacent to Nos 78–80 Bundeena Drive (part *Option 4 [a]*)	12,000
Low-level levee (RL2.2 mAHD) around Bundeena Oval to the southern end of Liverpool Street (part *Option 4 [a]*)	54,000
Low-level levee (RL2.2 mAHD) in backyards of Nos. 50–52 Liverpool Street (part *Option 4[a]*)	6,000
Concrete-block wall behind Nos 38–48 Liverpool Street and adjacent to No 36 Scarborough Street (part *Option 4 [a]*)	37,000
Low-level levee and concrete-block wall to protect caravan park (*Option 4 [b]*)	33,000
Culvert enlargement (4 x 3.0 m wide x 0.75 m high) and road reconstruction at Scarborough Street crossing (part *Option 4 [a]*)	135,000
Road raising to RL2.0 mAHD in Liverpool Street from Bundeena Drive to Scarborough Street, and in Scarborough Street from Liverpool Street to the creek crossing (*Option 10 [b]*)	83,000
Solution to localized drainage problems: • backyards in Bundeena Drive (part *Option 4 [a]*) • southern end Liverpool Street (part *Option 4 [a]*) • backyards in Liverpool Street (part *Option 4 [a]*) • in caravan park (part *Option 4 [b]*)	12,000
Improved monitoring in Bundeena Creek catchment (*Option 12*)	–
Creation of drainage easement (*Option 13*)	–
Review of Section 149 Certificate notations	–
Total	**384,000**

– *no cost has been assigned to this item.*

5.4.1 OPTIONS 2 AND 3—STRUCTURAL WORKS DOWNSTREAM OF SCARBOROUGH STREET

Options 2 and 3 involve the removal of the concrete block wall that currently surrounds No 67–73 Scarborough Street, together with construction of a grass-lined channel for about 70 m downstream of Scarborough Street. Total cost for the works would be $12,000.

There are several problems that would need to be solved in order to carry out these works. All the works would have to be carried out on private property. Material would have to be removed from one property in order to construct the channel to the approximate size and location of its original course.

Liaison between property owners, the council and the Public Works Department in accordance with the New South Wales Rivers and Foreshores Improvements Act (see Section 5.3.1) is likely to be necessary, so that a workable solution can be achieved.

5.4.2 OPTIONS 4(A), 4(B) AND 10(B)—LOW-LEVEE, ROAD RAISING AND IMPROVED ACCESS

The combination of *Options 2, 3, 4(a), 4 (b) and 10(b)* would provide a workable solution to the majority of the flooding problems in Bundeena:

- no house floor levels would be flood-liable in a 100-year ARI event;
- flood-free access would be available all along Bundeena Drive;
- flood-free access would be available to all properties in Liverpool Street;
- inundation of properties would be prevented in Bundeena Drive and in most properties in Scarborough and Liverpool Streets;
- flood levels would be reduced in the vicinity of the Scarborough Street crossing and upstream;
- the breakout near the corner of Liverpool Street and Scarborough Street would be prevented.

Table 5.2 summarizes one combination of works and the associated costs. The costs include mobilization, demobilization and associated costs assuming each of the items is constructed as a separate item. No allowance has been made for design or construction supervision, but a contingency of 15% has been included.

It should be noted that the channel works and wall removal included in *Options 2 and 3* would be an integral part to the success of the low-level levee option. These works would reduce flood levels sufficiently so that flood levels would not be increased in the swamp system and upstream wetlands as a result of the low-level levee.

Concrete block walls

Where the low-level levee is proposed adjacent to the boundary of the Royal National Park, or where space is a problem, a concrete-block wall has been proposed in lieu of an earth levee, to minimize the impact on the park and private property. It is likely that this would become an integral part of the existing fences at some of these locations.

Concrete block walls would need to be designed as retaining walls and would be up to 1.0 m high. Based on Rawlinsons (1992) the following unit costs were assumed:

- \$117/m^2 for hollow concrete blocks 400 mm x 200 mm x 200 mm including core filling and bar reinforcement;
- \$355/m^3 for the reinforced concrete footing supporting the wall.

Scarborough Street crossing

A causeway with a low flow culvert has not been recommended at the Scarborough Street crossing for the following reasons:

- The hydraulic analysis has shown that a large waterway area is required at a low level to minimize the afflux that would otherwise be caused from the proposed levee. Hence 4 x 3 m wide x 0.75 m high box culverts have been recommended (Table 5.2).

- With construction of the levee and associated road raising, flows from Bundeena Creek would be concentrated at the Scarborough Street crossing. This is likely to increase flow velocities and so the safety of a causeway crossing would have to be addressed.

The proposed roadworks in Scarborough Street can be considered to be for 'hydraulic' purposes rather than to improve access. Safety signs at the new crossing are recommended.

Levees versus road raising

To assist with 'blending-in' the roadworks with the surrounding residential properties, as well as drainage, the increased level of the road has been minimized (assumed to be at about 2.0 m AHD). Road raising has been included, as shown on Figure 5.2 to help prevent back flooding into the lower areas of south Liverpool Street and to generally improve access in the area. The levee has been assumed to be at 2.2 m AHD to provide additional freeboard. During the detailed design stage the following options could be addressed by Council:

- whether it is feasible to raise the roads to a minimum 2.2 m AHD and omit adjacent levees;

- how to minimize the road raising in Scarborough Street so that:

  - the hydraulics of the creek crossing remain adequate
  - the chance of back flooding into lower lying areas is minimized
  - safety is not compromised.

The preferred management plan shown on Figure 5.2 indicates that protection of the southern end of Liverpool Street from inundation could be achieved with levees and road raising without actually raising the road in front of houses south of Scarborough Street. However, the option also exists for Council to raise Liverpool Street all the way south from Bundeena Drive. For some properties this would cause the road to be higher than the house. The other consideration is the provision of temporary storage of water during periods of high creek levels. This could also be addressed during the detailed design stage.

Levee freeboard

The proposed levee has been recommended to be at 2.2 m AHD which was about the reported flood level at Scarborough Street in the November 1969 event (Table 4.1). With a levee height assumed to be at 2.2 m AHD and a post-works 100-year ARI flood level upstream of Scarborough Street of 1.82 m AHD, the minimum freeboard of the low-level levee would be 0.38 m. This is considered appropriate in Bundeena for the following reasons:

- The November 1969 flood level, the highest recorded in Bundeena, was reported to be between 2.0–2.2 m AHD. Analysis has shown this event to be well in excess of the 100-year ARI event.

- A 1.0 m freeboard (that is, a levee height of 2.8 m) would be the same height as the levee recommended in the Cameron McNamara study (1985). It has been concluded that such a levee height would have adverse visual and environment impacts.

If, to receive government funding assistance, the levee is required to have a freeboard of 0.5 m, then Council could adopt a levee height of 2.32 m without having an impact on the hydraulic analysis.

Impact of wave set-up

As discussed in Section 4.5.3, a sensitivity analysis has been undertaken to assess the impact of the Council's one-year high tide level of 1.28 m AHD combined with a 100-year ARI rainfall event both with and without the proposed levee. The analysis showed that this tide level would only impact on areas downstream of Scarborough Street. Flood levels upstream of the levee would only increase marginally.

Depth and period of inundation

For existing conditions the 100-year ARI flood level in Bundeena Oval would be 1.96 m AHD and the period of time when flood levels would be greater than 1.6 m AHD would be 6–6.5 hours. With the recommended works in place, the 100-year ARI flood level in Bundeena Oval would be 1.82 m AHD and the period of time when flood levels would be greater than 1.6 m AHD would be 2.5–3 hours. The period of ponding would be shorter because the new larger culverts at Scarborough Street have a much greater low-level capacity than the existing culvert. Any future problems, as a result of the works, with water draining away on Bundeena Oval are likely to be in similar locations as existing problem areas. As part of the construction for the levee, small localized filling may improve some of these problems.

Downstream of Scarborough Street to about CS757, the period of time when 100-year ARI flood levels would be greater than 1.5 m AHD has been calculated by MIKE-11 to be 2–3 hours. The corresponding time with the preferred management plan in place would be 1.5–2.5 hours. Downstream of CS757 the period of time when flooding would be higher than 1.5 m AHD would be only very short, as flooding is governed by tide levels in Port Hacking.

The low-level levee would have minimum impact on the frequency and time of inundation of the upstream wetlands. The maximum flood level in a 100-year ARI event would only be 150 mm lower than the current situation. This amount is likely to be less in areas further upstream in the wetland system.

Particular issues necessary for detailed design

The issues that still need to be addressed with these works include the following:

- The hydraulics of the proposed Scarborough Street crossing is an integral component of the works and should be carefully assessed at the detailed design stage.

- There are four locations shown on Figure 5.2 where localized ponding is likely to occur. Solutions could involve:

  - pumping of ponded water
  - a drainage system connected to the street drainage
  - drainage through the low-level levee via very small pipes or pipes with one-way flap valves.

- The low-level levee would still be overtopped in a probable maximum flood;

- It should be noted that inundation of some properties downstream of Scarborough Street would still occur. However all floors would be protected from the 100-year ARI event.

- Construction of the low-level levee would be required on at least two private properties.

5.4.3 MONITORING IN THE BUNDEENA CREEK CATCHMENT

To improve hydrologic and hydraulic analysis in the Bundeena Creek catchment in the future the following installations are recommended as part of *Option 12*:

- at least one pluviograph for the continuous measurement of rainfall
- maximum flood height recorders.

No cost value has been assigned to this item.

5.4.4 CREATION OF DRAINAGE EASEMENT

Option 13 suggests the creation of a drainage easement between Scarborough Street and Horderns Beach. The easement would be about 20–40 m wide, encompassing the main channel and enough space for access of maintenance vehicles along the creek (estimated to be about 4 m wide adjacent to the top of each creek bank). Such an easement should enable Council access for maintenance of the creek, and the monitoring of any illegal private works in or adjacent to the creek. An easement would be necessary if this section of creek were to be formalized into a 'natural' wetland (see Section 6.4.1).

No cost value has been assigned to this item.

5.4.5 PLANNING AND DEVELOPMENT ISSUES

As discussed in Section 5.3, a public awareness programme is recommended to highlight the requirements of the New South Wales Rivers and Foreshores Improvement Act. Also Council may wish to update Attachments D1 and D2 of their Section 149 Certificate notations in light of the current study.

No cost values have been assigned to these items.

6 STORMWATER QUALITY IN THE BUNDEENA CREEK CATCHMENT

6.1 GENERAL

The urbanization of a catchment can produce many new sources of pollution which ultimately end up in the natural creeks and waterways. These pollutants include:

- higher input of sediments from increases in peak discharges and flow velocities
- increases in surface runoff from increased impervious areas
- sewer surcharges and overflows
- septic tank seepage and overflows
- litter from general human activity
- nutrients from fertilizers, detergents and animal wastes
- heavy metals and oils.

These factors result in urban stormwater runoff of poor quality, which ultimately pollutes downstream creeks, rivers and the ocean.

The pollutants which provide the best indicators of overall water quality include:

- suspended solids
- nutrients—nitrogen and phosphorus
- dissolved oxygen and oxygen-demanding materials
- micro-organisms—bacteria, viruses and faecal coliforms
- pH
- conductivity
- heavy metals and toxic organic materials
- oils and surfactants
- litter.

This chapter discusses the most important of these pollutants in terms of the results of the Water Board monitoring programme conducted in 1991–1992 (Water Board 1992a) together with field inspections carried out in late 1992.

Options for improving stormwater quality in the Bundeena Creek catchment are also presented in this chapter including a summary of preferred stormwater quality control measures.

6.2 WATER BOARD MONITORING PROGRAMME

6.2.1 BACKGROUND

Bundeena is not connected to the main trunk sewerage and disposal system operated by the Sydney Water Board. Existing sewage disposal methods used by the residents of Bundeena include:

- septic tanks
- pump-out of sewage
- individual household treatment systems.

The Water Board is currently undertaking a comprehensive study into the options available for watercycle management in Bundeena and Maianbar. The three main options outlined in the Bundeena/Maianbar Water-cycle Management—Options Report (Water Board 1992a) and the Bundeena/Maianbar Water Cycle Project—Value Management Study (Water Board 1992b) are:

- sewerage reticulation system, with a small treatment plant in the south-east corner of the Bundeena township and the reuse of effluent via a secondary water supply system for the town;

- sewerage reticulation system, with a main carrier transporting raw sewage under Port Hacking before linking into the existing sewage treatment plant at Cronulla;

- individual household treatment systems for the entire town.

For more details on the investigation, the reader is referred to the Options Report.

As part of the Options Report, the Water Board carried out a water quality monitoring programme in order to determine the existing level of pollutants in the creeks and stormwater drains in Bundeena and Maianbar. The results of this programme are discussed briefly below.

6.2.2 FAECAL COLIFORM BACTERIA

Faecal coliform bacteria is an important pollutant that is often measured in water courses because its presence indicates sewage contamination, and therefore the possible presence of bacteria and viruses. Recommended maximum values for the mean density of faecal coliforms (Water Board 1992c) are:

- for primary contact recreation (that is, swimming and boating): 150–200 colony forming units (CFU) per 100 mL;

- for secondary contact recreation (that is, wading only): 1,000 CFU/100 mL.

The results from the Water Board study showed faecal coliform bacteria to be present in high concentrations in most areas of Bundeena and Maianbar. Stormwater drains in the Bundeena Creek catchment were measured to have a mean density of

14,900 CFU/100 mL in dry weather and 22,900 CFU/100 mL in wet weather. Bundeena Creek was measured to have a mean density of 470 CFU/100 mL in dry weather and 22,900 CFU/100 mL in wet weather.

These high counts of faecal coliforms are likely to be directly associated with the overflowing of septic tanks and pump-out systems in Bundeena (Water Board 1992a). The results of the monitoring also showed that faecal coliform counts were always much higher than faecal streptococci, which is another faecal bacteria. This indicates that the origin of the bacteria is human rather than from animal wastes. Whichever option for sewage disposal is eventually implemented, faecal coliforms are likely to significantly decrease.

6.2.3 NUTRIENTS—NITROGEN AND PHOSPHORUS

The plant nutrients phosphorus and nitrogen are often used as indicators of overall water quality (Water Board 1992c). Their main sources are from garden fertilizers, detergents, pesticides and animal wastes. They are generally non-toxic but in excess, promote rapid growth of aquatic plants including algae and floating macrophytes that often clog the waterway with weeds.

High levels of both nitrogen and phosphorus were found in the stormwater drains of the Bundeena Creek catchment, even in dry weather. These results indicated that urban seepage and runoff were the main contributors to the nutrient loadings in the creek. Septic tanks, pump-out systems and the Royal National Park would be contributing much smaller amounts.

6.2.4 HEAVY METALS

Heavy metals and toxic organic chemicals are generally only found as trace concentrations in urban runoff. Concentrations are generally not sufficiently high to have toxic effects on aquatic life but they may lead to long-term ecological damage (State Pollution Control Commission 1989). Heavy metals, particularly lead and zinc, can emanate from:

- atmospheric fallout
- vehicle wear-and-tear and exhaust emissions
- runoff from galvanized iron roofs
- runoff from industrial areas.

The presence of high concentrations of iron in stormwater drains in Bundeena, even during dry weather, indicated the presence of raw sewage from the urban area. Trace metals are found in generally small concentrations in the Bundeena Creek catchment and include aluminium, zinc, maganese, copper, lead, chromium, nickel, cobalt and cadmium.

6.3 VISUAL OBSERVATIONS

During a field inspection of the Bundeena Creek catchment in late 1992, the following observations were made:

- There is not a great deal of urban litter present in the creek. While the pollutants discussed in Section 6.1 generally affect the actual quality of water in the creek, litter or gross pollutants are largely an aesthetic problem resulting in unsightly residues in the water. The absence of urban litter in Bundeena Creek could be a result of very little accessible open space in the catchment. Some litter was present near the outlet of the creek at Horderns Beach.

- The boundary between Bundeena and the Royal National Park near the Bowling Club appears to have been used as a dumping ground for many years. Building materials, garden refuse and household waste are common.

- Bundeena Creek forms a stagnant pool (estimated to be at a level of about 0.6 m AHD) between Horderns Beach and Scarborough Street. The water in this pool is turbid and an oil layer appears on the surface in some locations.

- Although there appears to be some flow in Bundeena Creek upstream of Scarborough Street, the water quality is still visibly poor. It is likely the pollutants are emanating from upstream urban areas including Brighton Street, Rymill Place, Bournemouth Street, Reef Street, Beachcomber Avenue, Bombora Avenue and Eric Street.

6.4 OPTIONS FOR IMPROVING WATER QUALITY

This section presents the methodology used to determine a water quality control strategy for the Bundeena Creek catchment. Capital and maintenance costs are also provided. The options available for improving water quality both in the construction phase and after development include:

- wetlands—to control nutrients (phosphorus and nitrogen) and suspended sediments
- gross pollutant traps—to remove coarse sediments such as sand and grit
- trash racks and litter control devices—to trap litter and other visible pollutants
- temporary measures for use in the construction phase of the development
- permanent on-site works for larger developments and industrial areas
- stormwater pollution education.

Each of these measures, including specific options relevant in the Bundeena Creek catchment, is discussed in the subsequent sections.

6.4.1 WETLANDS

Extensive research has been undertaken in Australia and overseas in recent years into the effective control of stormwater pollution by passing flows through permanent pools of water. It has been found that water pollution control ponds (known as wetlands or wet detention basins) are effective in removing suspended solids, nutrients (particularly phosphorus) and other pollutants from urban runoff. Designed as permanent lakes, wetlands also provide a low maintenance ecosystem, creating suitable habitat for birds and aquatic life.

Volumes of wetlands have a typical range of between 100–1,600 m³ per developed hectare, and depend on a range of variables including:

- existing land-use
- soil type
- topography
- average annual rainfall
- net increase of the catchment that is urbanized.

The longer the water is retained in the wetland (measured as a 'hydraulic residence time'), the greater is its efficiency in the removal of sediments, phosphorus and other pollutants. Lawrence (1986) developed relationships between hydraulic residence time and the amount of pollutant that could be expected to be removed. These relationships have been reproduced in Appendix E. These relationships show that phosphorus is the critical pollutant in the design of the wetland.

Options within Bundeena Creek catchment

Two locations were examined as wetland sites in the Bundeena Creek catchment:

- upstream of Scarborough Street;
- between Scarborough Street and Horderns Beach.

A wetland upstream of Scarborough Street would be located within the Royal National Park. Because a large number of trees would have to be cleared to create the wetland, the impact on the national park was considered to be too great to consider this option further.

The stagnant pool of water between Scarborough Street and Horderns Beach is already functioning a low-efficiency wetland. Formalizing this reach of creek as a wetland was considered to be a feasible option for reducing nutrients entering Port Hacking. The existing volume of wetland was estimated to be about 5,000 m³. This reach of creek could be formalized into a successful wetland by:

- deepening the existing pool to provide more volume in the wetland;

- planting reeds or macrophytes around the edge of the pool to provide an efficient mechanism by which nutrients and other pollutants could be removed from the water;

- creating an easement 20–40 m wide between Scarborough Street and Horderns Beach to ensure council have access for maintenance of the wetland and adjacent land (refer to Section 5.4.4).

The wetland would be designed to criteria outlined in documents such as *Water Pollution Control Pond Design Guidelines* (Australian Capital Territory Administration 1990) or the proceeding of recent seminars on the subject (for example, Phillips 1991, Institution of Engineers, Australia 1992 and Australian Water and Wastewater Association et. al. 1992).

Preliminary analysis of wetland downstream of Scarborough Street

Using an average annual rainfall at Bundeena of 1,290 mm, the curves developed by Lawrence (1986) and reproduced in Appendix E, show that the existing wetland downstream of Scarborough Street would have the ability to remove about 16% of total phosphorus and about 39% of suspended sediment. This assumes that the wetland currently acts as a sedimentation system rather than a system planted with macrophytes. If the wetland volume could be increased to 7,500 m^3, and it were planted with macrophytes, it would be able to remove about 32% of total phosphorus and 45% of suspended sediment. Note that by increasing the volume of the wetland by 50% and planting macrophytes, the wetland would become twice as efficient at removing phosphorus.

To determine the ideal percentage reduction of phosphorus and suspended sediment for the wetland as recommended by the Environment Protection Authority (EPA), typical export rates developed by the CSIRO were used (Kinhill 1993). Table 6.1 summarizes the pre-development and existing phosphorus loads estimated to emanate from the Bundeena Creek catchment. From Table 6.1, the efficiency of the wetland required to reduce phosphorus levels from existing (87.7 kg/a) to pre-development (29.5 kg/a) catchment conditions would need to be 66%. Using the curves developed by Lawrence (1986), this would require a wetland planted with macrophytes with a volume of about 25,000 m^3. It is unlikely that this volume would be available downstream of Scarborough Street.

To reduce phosphorus levels from existing levels of 87.7 kg/a to the generally accepted standard (by the EPA) of 0.3 kg/ha/a (that is, a total of 75 kg/a), the efficiency of the wetland would have to be only 14%. From the curves developed by Lawrence (1986) this would equate to a wetland volume of only about 4,000 m^3 if it were planted with macrophytes or 5,000 m^3 if no macrophytes were planted. It has been estimated that the existing wetland downstream of Scarborough Street would have a volume of about 5,000 m^3.

In summary, the results of the preliminary analysis of the 'natural' wetland downstream of Scarborough Street are as follows:

- Once the sewer is connected in Bundeena, the water quality in the existing wetland is likely to become an effective natural means of reducing pollutants entering Port Hacking.

Table 6.1 **Estimates of phosphorus exports from the Bundeena Creek catchment**

Land-use	Adopted export rate of phosphorus kg/ha/a	Pre-development catchment conditions		Existing catchment conditions		Typical rural catchment	
		Area (ha)	Phosphorus export (kg/a)	Area (ha)	Phosphorus export (kg/a)	Area (ha)	Phosphorus export (kg/a)
Forest/native*	0.10	220	22.0	193	19.3	–	–
Rural low export *	0.25	30	7.5	–	–	–	–
Urban	1.2	–	–	57	68.4	–	–
Typical rural	0.30	–	–	–	–	250	75.0
Totals		**250**	**29.5**	**250**	**87.7**	**250**	**75.0**
Average phosphorus exports			**0.12kg/ha/a**		**0.35kg/ha/a**		**0.30kg/ha/a**

* *Upstream Scarborough Street assumed to be all forest/native, downstream assumed to be originally 'rural-low export'.*

- The existing natural wetland with a volume of about 5,000 m^3 would act as a sedimentation nutrient removal system. It would have a phosphorus removal efficiency of about 15%, which is sufficient to reduce existing phosphorus levels in Bundeena Creek to generally accepted levels by the EPA (that is 0.3 kg/ha/a).

- It appears that there would be sufficient land area to formalize the existing wetland to provide a volume of 7,500 m^3 and be planted with macrophytes. About 32% of phosphorus could be removed prior to flows discharging into Port Hacking with such works. This could reduce the existing phosphorous export rate of 0.35 kg/ha/a to about 0.24 kg/ha/a which would be less than the generally accepted level of 0.3 kg/ha/a for 'rural' catchments (Refer Table 6.1). Such works have been estimated to cost about $29,000 and are included in the preferred management in strategy provided in Section 6.4.

- To reduce phosphorus levels to pre-development Bundeena Creek catchment conditions of 0.12 kg/ha/a, a wetland with a volume of about 25,000 m^3 would be required. As there is clearly insufficient area for such a wetland downstream of Scarborough Street (about 1.7 ha would be required) this option has not been considered further.

- It is recommended that more detailed water quality modelling be undertaken as part of the next stage of design. An allowance for a cost of $10,000 has been included for such a study which would also include design of the wetland.

6.4.2 GROSS POLLUTANT TRAPS AND TRASH RACKS

Gross pollutant traps usually take the form of a large open or closed concrete-lined basins designed to intercept litter, debris and coarse sediment during storm flows from urban catchments. Usually gross pollutant-traps are located where there is a need to:

- protect the aesthetic and environmental quality of downstream wetlands, open drainage channels or open water;

- to protect the macrophytes and faunal habitats at the upstream end of wetlands.

In order to trap litter in the gross pollutant trap structure, trash racks usually take the form of a series of vertical bars that form a grill across the flow path. They are usually designed to intercept debris and litter larger than a standard size 375 mL drink-can in storms up to a one year ARI event. They should be designed to be stable if they are totally blocked and overtopped in larger storm events. The trash rack may be either upstream or downstream of the gross pollutant trap structure with provision being made for bypassing or overtopping should blockage occur. Frequent surface cleaning of the trash screens for removal of litter and debris is usually necessary with these structures. Experience has shown this to be between five and ten times per annum. Removal of sediment is usually required 2–3 times per annum.

The possible installation of gross pollutant traps was examined in the Bundeena Creek catchment to protect:

- Bundeena Creek downstream of Scarborough Street
- Hordens Beach and Port Hacking.

Using *Major and Minor Gross Pollutant Traps* (WP Research 1988), which is based on Canberra catchments for sediment loads, possible gross pollutant traps were sized at the following locations:

- near Brighton Street, just downstream of the influence of the residential area;
- just upstream of Scarborough Street;
- downstream of Bundeena Drive, near the outlet at Hordens Beach.

The design document uses the criteria that 70% of material with a grain size greater than 0.04 mm (that is, equivalent to coarse silt) would be retained annually and deposited sediment would be removed every six months. Table 6.2 summarizes the results.

Table 6.2 **Gross pollutant traps**

Location	Catchment area (ha)	Residential area (ha)	Gross pollutant trap size			Estimated cost ($)	Recommended
			Length (m)	Width (m)	Depth (m)		
Near Brighton Street	77	17	12	2	0.5	40,000	No
Upstream of Scarborough Street	221	27	12	5	0.3	110,000	No
Downstream of Bundeena Drive	250	27	14	5	0.5	130,000	No

From this preliminary analysis, gross pollutant traps have not been recommended in the Bundeena Creek catchment for the following reasons:

- Both traps upstream of Scarborough Street would involve the construction of large concrete structures in the Royal National Park. It is likely that such structures would cause more environmental impact than they would be designed to prevent.

- The total catchment is less than 15% urbanized and so it is likely that such large traps are neither cost effective or warranted.

- From visual observations, there is not a great deal of urban litter in the creek and so trash racks may not be really warranted.

- The natural wetland downstream of Scarborough Street currently removes about 39% of suspended sediment and could remove up to 45% with the works described in Section 6.4.1.

- Further reductions in sediment in the creek system could be achieved with on-site erosion and sediment control together with community awareness programmes (see Sections 6.4.3 and 6.4.4).

- Maintenance of gross pollutant traps and trash rack is costly, yet imperative, for their effective performance. Current Water Board estimates show that the annual operating cost for a major gross pollutant trap and trash rack would be in the order of $17,500 (Kinhill 1993).

Another type of trash rack that is now gaining wider acceptance is the use of small litter control pits. These usually consist of baskets located at the outlet of stormwater pipes discharging into the natural creek or waterway. The baskets are usually contained within a pit, which acts as a small sediment trap, as well as protecting the basket itself. Litter control pits are gaining popularity in existing urban areas that have many discharge points into creeks and waterways, and insufficient land and funds available to build large gross pollutant traps. Capital cost of the structures have been estimated to be about $10,000. Similar to the larger trash racks, these litter control devices would require cleaning between five and ten times per annum. Operating costs have been estimated at about $7,400 per trap per annum. It would be the operating cost that is likely to preclude litter control devices as being suitable for the Bundeena Creek catchment and so they have not been recommended in the management plan. However, they may be deemed by Council in the future to be suitable for particular locations in the catchment.

6.4.3 ON-SITE EROSION AND SEDIMENT CONTROL

As shown in Table 6.2, the cost of removal of sediments from Bundeena Creek is quite high when compared with simple preventative on-site erosion and sediment control measures that could be applied at any construction site in the catchment. Particular measures include:

- the aim to minimize the amount of exposed surface at any one time, with controlled clearing, progressive revegetation and retention of topsoil;

- the diversion of runoff away from developing sites by use of catch drains and diversion drains;

- the use of energy dissipators and level spreaders;

- the construction of temporary sedimentation basins;

- the provision of hay bales and filter fences downstream of the site;

- the use of sediment barriers to protect existing kerb-side inlets, grated pits or road culverts.

One difficulty with the implementation of erosion and sediment control measures is that they place additional requirements on council staff to ensure that the devices are properly installed and adequately maintained. Despite this, an on-site erosion and sediment control strategy is recommended for the Bundeena Creek catchment.

6.4.4 STORMWATER POLLUTION EDUCATION

The water quality control measures such as gross pollutant traps and trash racks are expensive devices that have become necessary to protect waterways from a source of pollution that could be significantly reduced through council requirements and, especially, public education.

Just as developers are encouraged to treat potential water pollution at the source by using on-site erosion and sediment control measures, public education is needed to encourage the community to control the amount of pollution they are adding to the waterways.

Education and awareness programmes could include the following information:

- Investigations into the public's perception of flooding and stormwater pollution should be undertaken to determine whether people know where stormwater actually ends up. It should be emphasized that:
  - stormwater does not go into the sewerage system and it is not screened before it enters the creek system;
  - pipe systems, roads, and kerbed and guttered streets actually accelerate movement of the stormwater (and all it contains) towards the waterways;
  - it is not only industries and sewer overflows that pollute the waterways, although many campaigns seem to concentrate on only these aspects of stormwater pollution.
- When the sewerage system is connected to households in Bundeena, the water quality of the creek will improve significantly. However, there is still likely to be some pollution of Bundeena Creek resulting from the current level of residential development.
- There are many everyday things that people can do to control their pollution at the source, by:
  - washing cars on grassed surfaces, not on streets and driveways;
  - not washing garden refuse down stormwater drains, especially grass clippings;

- not dumping garden refuse or household waste near creeks;
- not using excessive amounts of fertilizer on gardens;
- continuing to be responsible with regard to litter reduction;
- providing some kind of erosion control if carrying out any outside building or renovation work;
- not allowing waste materials from their workplaces to escape into public areas.

Councils can also contribute to the control of pollution, before it enters waterways, in a number of ways:

- Street sweeping, if carried out frequently enough, can effectively prevent particulate matter from entering the creek system. However, in many cases street cleaning is only undertaken once or twice a month, or less. This is estimated to remove less than 5% of total solid and heavy metals (State Pollution Control Commission 1989). Although labour costs for street sweeping are high, it is a desirable measure to improve the aesthetics of the streetscape.

- Street washing is not a recommended practice because it only transfers accumulated pollutants directly into stormwater systems and receiving waters.

- Regular maintenance of outdoor bins is important in improving aesthetics and reducing the entry of visible pollutants to waterways. Regular cleaning of street gully pits should also be undertaken. An analysis of the composition of the rubbish may help focus the emphasis of future public education schemes.

- Instigation (and/or the support) of creek clean-up days is important for increasing community awareness and enthusiasm for the control of pollution.

The Upper Parramatta River Catchment Trust produces a regular newsletter, called *Streamline,* which outlines current projects being carried out by the Trust. It also contains articles relating to the community awareness of flooding and stormwater pollution. Appendix F gives some examples of relevant articles.

Sutherland Shire Council has recently started a public education campaign concerned with the residential component of stormwater pollution. Appendix F also provides their hand-out produced in 1992.

6.5 SUMMARY OF STORMWATER QUALITY CONTROL INVESTIGATION

A preliminary investigation has been undertaken for a water quality control strategy for the Bundeena Creek catchment. At present, the most notable source of pollution in stormwater drains and the creek is a result of seepage and overflowing from septic tanks. The Water Board is currently undertaking a comprehensive study into a sewerage scheme for Bundeena. When the sewer is ultimately connected, the water quality in Bundeena Creek is likely to improve significantly. However, the water of Bundeena Creek is still likely to suffer some pollution from the normal processes of urbanized areas including:

- sediments
- litter
- nutrients such as nitrogen and phosphorus.

The natural wetland between Scarborough Street and Horderns Beach is currently acting as an adequate means of removing some suspended sediments and nutrients from the water. This would be significantly more effective when the sewer is connected. It is recommended that this natural wetland be formalized and planted with macrophytes to further improve the quality of water entering Port Hacking. Assuming a total wetland volume of 7,500 m^3, total costs would be about $40,000. This cost would include water quality modelling, detailed design and construction of the wetland.

Gross pollutant traps and trash racks are not recommended for the Bundeena Creek catchment. Rather, it is recommended that pollutant be treated at the source. This would involve:

- an on-site erosion and sediment control strategy applicable to all construction sites;
- community awareness programme on stormwater pollution issues.

7 USE OF STORMWATER TO SUPPLEMENT TOWN WATER SUPPLY

7.1 THE NEED FOR ADDITIONAL WATER SUPPLY

Bundeena and Maianbar are currently provided with town water from Maianbar Reservoir, which has a capacity of 2.2 ML, of which only 1.1 ML is available for operational storage. Maianbar Reservoir is supplied by a single 200 mm main through the Royal National Park from Loftus Reservoir. This main is currently in need of remedial maintenance, however renewal is not yet necessary (Water Board 1992a).

The current peak daily demand from Maianbar Reservoir is 1.5 ML/d. However, as the inlet main is only capable of supplying 1.6 ML/d, any additional demand for water supply would require an increase in water supply to the area. It has been estimated that the introduction of a sewerage system to the area would increase water usage by 30% (from an average daily demand of 0.9 ML/d to 1.2 ML/d). (Water Board 1992a).

Several options for increasing water supply to the area are discussed in the Water Board's Bundeena/Maianbar Water Cycle Management Options Report (1992a), and include the following:

- reuse of tertiary treated effluent from a new sewage treatment plant at Bundeena via a secondary reticulation system;
- amplification of mains from Loftus Reservoir to Maianbar via a number of different routes;
- changing the source of supply from Loftus Reservoir to Engadine Reservoir, or the Sutherland Reservoir zone, via a number of different routes;
- construction of a larger reservoir at the existing Maianbar site;
- drawing water from local aquifers to supplement potable or non-potable supply;
- collection of stormwater at individual households in disused (and disinfected) septic tanks;
- collection of stormwater in the low lying areas of Bundeena to supplement the town water supply.

A preliminary investigation has been undertaken as part of this flood management study to examine the feasibility of the last water supply option listed above.

7.2 SUPPLY AND DEMAND

7.2.1 DEMAND FOR WATER

As discussed above, the average daily demand for water supply in Bundeena/Maianbar is currently 0.9 ML/d. With the introduction of the sewerage system, this is likely to increase to 1.2 ML/d (Water Board 1992a).

The options report states that the existing Maianbar Reservoir is, effectively, already at capacity. In order to supplement the existing water supply with potable water, it would be desirable to be able to provide an additional 0.5 ML/d from the collection of stormwater. This would increase the current supply capacity of Maianbar Reservoir from 1.6 ML/d to 2.1 ML/d.

The Water Board's options report also estimates that the average daily demand for non-potable water would be 0.23 ML/d after connection to the sewerage system. If the effluent reuse option is recommended, then a demand of 0.23 ML/d would constitute only about 40% of the available effluent from the new treatment plant and additional disposal facilities will be required. However, if effluent reuse is not available in the preferred sewerage option, the collection of stormwater could be used to supply the 0.23 ML/d of non-potable water.

In summary, two values of demand have been used in the current study:

- potable water demand—0.5 ML/d
- non-potable water demand—0.23 ML/d.

7.2.2 AVAILABLE SUPPLY OF STORMWATER

Only a preliminary water balance analysis has been undertaken for this study and it is recommended that a more detailed yield analysis be undertaken at the next stage of investigations.

It has been assumed that if stormwater were to be collected to supplement the townwater supply, then diversion from Bundeena Creek would be via an open gravity channel from the western swamp catchment, just upstream of its confluence with the eastern swamp. The runoff from the western catchment is likely to have significantly better water quality than that of the eastern catchment because the land use is solely national park. The diversion would involve a channel about 200 m long generally through the land Zoned 5(a) Community Uses south of the southern end of Liverpool Street. The catchment area of the stormwater collection facility would therefore be in the order of 115 ha.

As discussed in Section 4.2, the only collection of official rainfall data at Bundeena took place between 1964 and 1978, when the average annual rainfall was recorded to be 1290 mm. Assuming a typical annual runoff coefficient of 0.3 (also used in the wetland analysis described in Section 6.4.1), Table 7.1 summarizes the average available volumes of stormwater that could be expected from the western catchment.

Table 7.1 **Typical average volumes of stormwater runoff**

Typical month	Rainfall (mm/month)	Average volumes (ML)		
		per annum	per month	per day
Average month	108	447	37.3	1.2
Wettest month	180	745	62.1	2.0
Driest month	49	203	16.9	0.6

From Table 7.1, it can be seen that in an average month, more than double the required potable demand would be available, but in the driest month, nearly all the natural runoff would be required to meet the potable demand. The environmental consequences of extracting such large proportions of runoff from the natural ecosystem will need to be examined carefully in the next stage of investigations.

7.3 STORAGE POND

7.3.1 POSSIBLE STORAGE SITES

As discussed in previous sections of this report, there are very few areas of open space in Bundeena that would be low enough to be suitable for collection and storage of stormwater. The impact of a stormwater collection facility on national park land was considered to be too great and therefore not examined further. The construction of an underground storage facility below Bundeena Oval was considered, but the size of such a covered concrete structure would be extremely expensive. This option was therefore not examined further for economic reasons.

The only feasible site would be within the area Zoned 5(a) Community Uses which currently contains Bundeena Oval, Bundeena Community Centre, Bundeena Bowling Club, tennis courts and a large area of uncleared land with vegetation similarly to that of the adjoining Royal National Park. The most feasible option was considered to be an open storage pond constructed on this council land behind Bundeena Oval and the bowling club.

The site of the pond could either replace the existing sports field or be constructed on the uncleared land south of the southern end of Liverpool Street. The environmental impact of clearing a large tract of land that appears to part of the national park (although it is actually Council land) would need to be addressed in the next stage of investigations. The dense vegetation could also be an advantage—offering instant screening for the proposed works.

7.3.2 POND SIZE

A storage pond size of about 80 m by 80 m could be reasonably accommodated on the Council land behind Bundeena Oval and the bowling club. Table 7.2 summarizes the number of days storage that would be available for varying operating depths for a pond of this size.

Table 7.2 **Number of days of storage for varying depth of 80 m by 80 m pond**

Operating depth (m)	Volume (ML)	No. days storage for potable supply*	No. days storage for non-potable supply**
1.2	7.7	15	33
1.6	10.2	20	44
2.0	12.8	26	56
2.4	15.4	31	67

* *Based on demand of 0.5 ML/d*
** *Based on demand of 0.23 ML/d*

The selected operating depth of the pond and hence the operating volume would be dependent on a number of factors. These are summarized below:

- It can be seen from Table 7.2 that if stormwater were used to provide only non-potable water then a much more reliable supply would be available. Based on the preliminary water balance analysis carried out for this study, it appears that the supply would be less than 100% reliable if a one-month storage was available. A two-month storage would provide a reliability much closer to 100%.
- A deeper pond has the following advantages:
  - it allows more settling of solids;
  - there is generally less turbulence in the pond such that waters in the pond are less likely to be 'stirred up';
  - it allows for a more flexible operation because pumping can take place from varying depths.
- A shallower pond has the advantage of more natural disinfection from sunlight, however this is limited to a maximum depth of about 1.5 m.
- The depth of the proposed storage pond may be limited by ground conditions at the site. Design of the pond would have to ensure that the amount of seepage is minimized both into and out of the pond. A detailed groundwater study is recommended in the next stage of investigation in order to determine whether groundwater intrusion into the pond would be a problem. Costs may become excessive if the storage pond has to be concrete-lined. At this stage, however, it has been assumed that clay-lining or plastic-lining would be adequate.

7.3.3 POND LAYOUT

The proposed storage pond would be gravity-fed by an open channel that would offtake from the main channel of the western swamp just upstream of the confluence with the eastern swamp. A trash rack, typically consisting of rectangular bars with 20 mm spacings, would be located near the entry point into the pond.

In order to achieve a gravity-fed pond, the maximum operating level of the pond would have to be about 0.4 m AHD. The ground level in the area proposed for the pond is variable, but is in the order of 1.6 m AHD. This area is also flood-prone with the existing 100-year ARI flood level having been calculated to be 1.96 m AHD. In order to prevent unscreened stormwater flows from entering the pond, it would be desirable to construct embankments around the pond above the 100-year ARI flood level. A level of 2.2 m AHD (the same as the low-level levee described in Chapter 5) has been assumed for the top of embankments around the pond.

7.4 TREATMENT AND RETICULATION

7.4.1 NON-POTABLE SUPPLY

Figure 7.1 provides a process flow chart for the components involved in the collection, treatment and reticulation of a non-potable water supply from runoff from the Bundeena Creek catchment. Table 7.3 summarizes these components and provides broad-scale cost estimates where appropriate.

7.4.2 POTABLE SUPPLY

Figure 7.2 provides a process flow chart for the components involved in the collection, treatment and reticulation of a potable water supply that could be used to supplement the existing town water supply. Table 7.4 summarizes each of the components and includes broad-scale cost estimates where appropriate.

7.5 SUMMARY OF STORMWATER REUSE STRATEGY

The preliminary investigation conducted for this study has shown that the use of stormwater to supplement the Bundeena town water supply is a feasible option worthy of further consideration. Diversion works, involving about 200 m of open channel leading from the western catchment of Bundeena Creek, could gravity feed to an open storage pond of about 80 m wide by 80 m long located on council-owned land behind Bundeena Oval. The stormwater could then be used either to supplement the existing potable supply after suitable treatment or could be used to provide a new non-potable supply via a secondary reticulation system. Total capital costs (including 15% contingency) for each of the systems have been estimated to be:

- potable supply—$2,140,000
- non-potable supply—$1,860, 000.

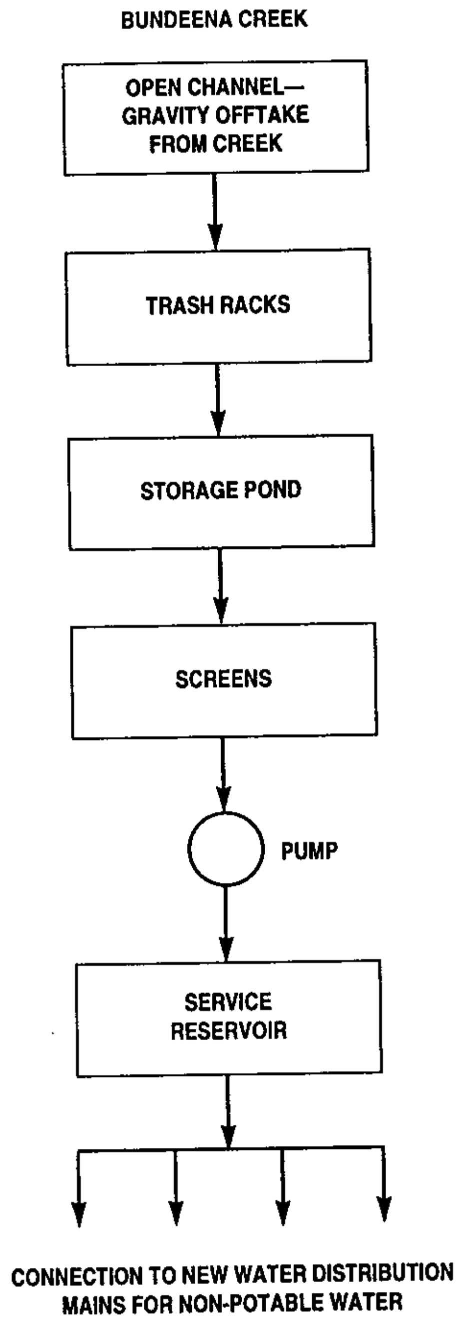


Figure 7.1

FLOW CHART FOR REUSE OF STORMWATE[R] FOR NON-POTABLE PURPOSES

Table 7.3 **Non-potable water supply — collection, treatment and reticulation**

Item	Description and assumptions	Cost ($)
Water quality criteria	* total coliforms — nil (95 percentile) * E coli — nil * turbidity — 10-20 NTU * colour — 10-15 Pt-Co-TCU	na
Offtake channel and diversion works	* earthen channel approximately 200m long, with say 3m base width and 1(V):4(H) side slopes. * diversion from western catchment to ensure better water quality.	20,000
Storage pond	* earthen pond approximately 80m by 80m. * located on Council owned land behind Bundeena Oval and bowling club. * assume operating level at 0.4m AHD. * assume top of embankment at 2.2m AHD. * depth dependent on various factors (refer Section 7.3.2) but likely to range between 1.2m and 2.4m — therefore overall depth would be between 3.0m and 4.2m. * coarse bar screen would be installed on the inlet to the pond and would consist of rectangular bars with 20mm spacings. * same for both non-potable and potable purposes.	590,000
Water treatment plant	* screening only would be carried out for non-potable supply using 3mm aperture wedge wire screen.	65,000
Pumping station	* intake pumpwell to be located in storage pond area. * pumps would be 20kW motor rating, submersible/ wet well type (one duty pump and one standby pump).	75,000
Rising main	* 100mm diameter ductile-iron-concrete-lined pipe required from the pump well up to the service reservoir. * assumes route would be along Scarborough Street, along the southern section of Eric Street, and up to the proposed sewage treatment site — total distance would be about 3,000m.	155,000
Service reservoir	* most appropriate location assumed to be on the land Zoned 5(a) proposed to be used for the new Sewage Treatment Works. * reservoir would be roofed steel construction with 1ML capacity.	345,000
Reticulation pipework	* separate reticulation system would be required to deliver non-potable supply to all properties in Bundeena. * 150mm diameter UPVC (plastic) pipes have been assumed — total length would be about 8,500m. * this system could not be constructed in the same trenches as the new sewer because the sewer would be located at the back of some properties whereas the water supply would have to be located at the front of all properties.	365,000
Exclusions	* land acquisition * geotechnical and/or hydrogeological investigations * survey	– – –
Total		**1,620,000**
Total with 15% contingencies		**1,860,000**

Notes:

NTU – national turbidity units; Pt–Co–TCU – platinum cobalt true colour units

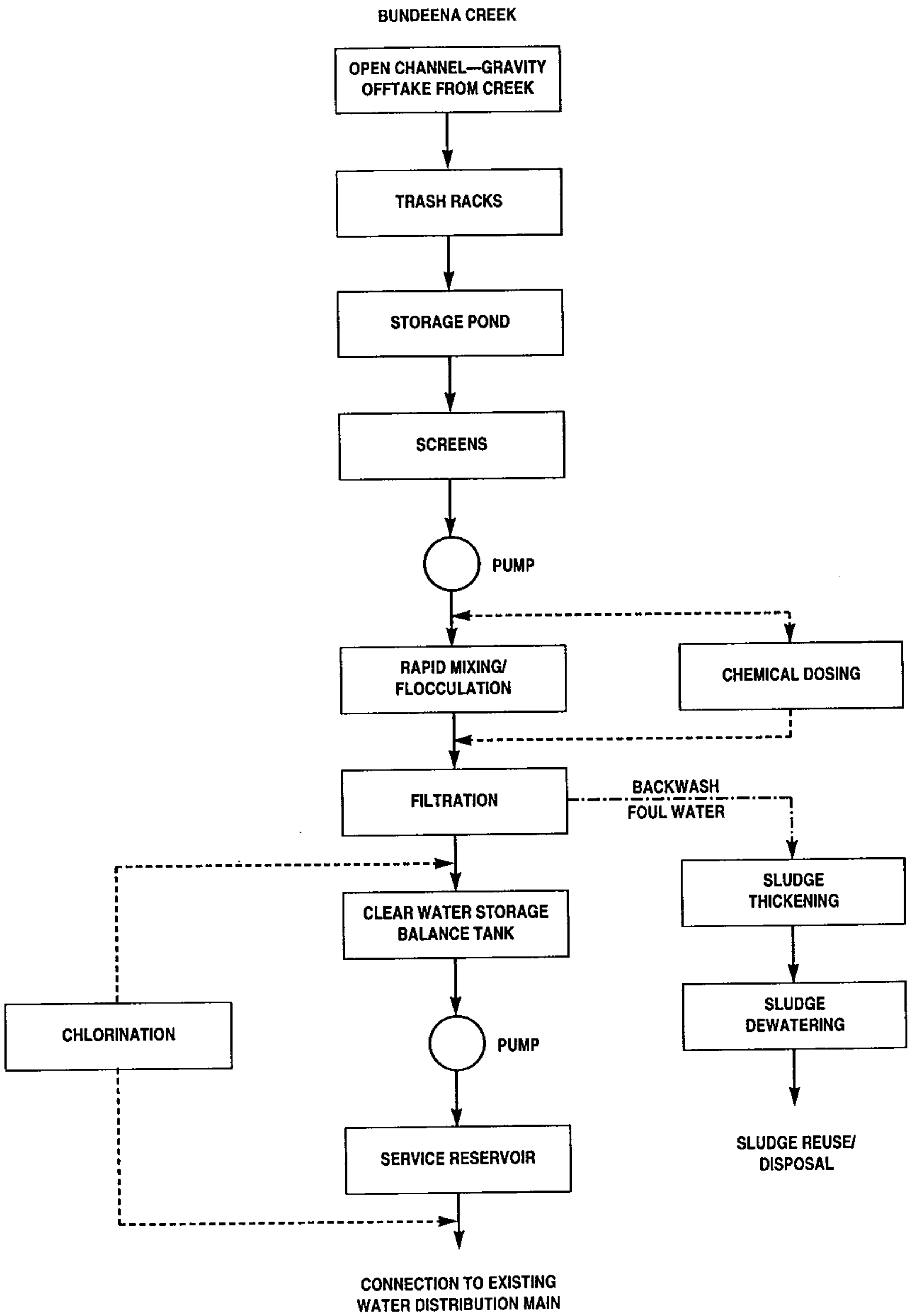


Figure 7.2
FLOW CHART FOR REUSE OF STORMWATE[R] FOR POTABLE PURPOSES

Table 7.4 **Potable water supply—collection, treatment and reticulation**

Item	Description and assumptions	Cost ($)
Water quality criteria	* total coliforms—nil (95 percentile) * E coli—nil * turbidity—< 1 NTU * colour—< 5 Pt-Co-TCU	na
Offtake channel and diversion works	* earthen channel approximately 200m long, with say 3m base width and 1(V):4(H) side slopes. * diversion from western catchment to ensure better water quality.	20,000
Storage pond	* earthen pond approximately 80m by 80m. * located on Council owned land behind Bundeena Oval and bowling club. * assume operating level at 0.4m AHD. * assume top of embankment at 2.2m AHD. * depth dependent on various factors (refer Section 7.3.2) but likely to range between 1.2m and 2.4m— therefore overall depth would be between 3.0m and 4.2m. * coarse bar screen would be installed on the inlet to the pond and would consist of rectangular bars with 20mm spacings. * same for both non-potable and potable purposes.	590,000
Water treatment plant	* a package direct filtration plant, with disinfection facilities (chlorination) has been assumed with a capacity of 0.5ML/d.	520,000
Pumping station	* intake pumpwell to be located in storage pond area. * pumps would be 20kW motor rating, centrifugal type (one duty pump and one standby pump).	100,000
Balance tank	* reservoir would be roofed steel construction with 0.1ML capacity (approximately four hours storage of filtered water).	60,000
Rising main	* 100mm diameter ductile-iron-concrete-lined pipe required from the pump well up to the service reservoir. * assumes route would be along Scarborough Street, along the southern section of Eric Street, and up to the proposed sewage treatment site—total distance would be about 3,000m.	155,000
Service reservoir	* most appropriate location assumed to be on the land Zoned 5(a) proposed to be used for the new Sewage Treatment Works. * reservoir would be roofed steel construction with 1ML capacity.	345,000
Reticulation pipework	* pipework would be required to connect new service reservoir to existing reticulation system. * 150mm diameter UPVC (plastic) pipes have been assumed—total length would be about 1,000m.	65,000
Exclusions	* land acquisition * geotechnical and/or hydrogeological investigations * survey	– – –
Total		**1,860,000**
Total with 15% contingencies		**2,140,000**

Notes:
NTU – national turbidity units; Pt–Co–TCU – platinum cobalt true colour units

Operating and maintenance costs for the potable supply would be considerably higher than for the non-potable supply. For the same size pond, the non-potable supply would have a much higher reliability.

There are a number of issues that would need to be addressed when further investigations are carried out regarding the reuse of stormwater in Bundeena. It is recommended that these investigations be carried out in conjunction with studies on both the introduction of the sewer and the augmentation of water supply in Bundeena/Maianbar. The issues that would need to be addressed in the near future are summarized below:

- If the preferred sewer option is to locally treat the effluent and reuse it via a secondary reticulation system, then the supplement of town water supply with stormwater would not be necessary.

- Supplement of the town water supply with stormwater may preclude the need for augmentation of the existing water supply if the transfer to Cronulla option (Water Board 1992a) is recommended.

- A decision needs to be made as to whether a potable or non-potable supply should be provided from the collection of stormwater, together with the required reliability of supply.

- A full water balance analysis should be undertaken into the reuse of stormwater to supplement the townwater supply.

- The environmental implications of extracting large proportions of the runoff from the natural catchment should be addressed in detail, including the impacts of alterations to flow regimes in the wetlands upstream of Bundeena in the Royal National Park.

- Diversion works would generally be located on council land Zoned 5(a) Community Uses to the south of the southern end of Liverpool Street. Some works are likely to be necessary on national park land and so liaison with the National Parks and Wildlife Service is important in the early investigation stages. This could also involve the impacts of clearing a large area of natural bushland on council-owned land.

- Geotechnical investigations would be important in the next stages to:

  - determine the impacts of groundwater intrusion into the pond
  - ascertain the maximum recommended depth of excavation in the pond
  - determine how seepage could be minimized in and out of the pond
  - provide more accurate capital cost estimates for the construction of the pond.

- More accurate locations of the various components of the scheme should be determined in the next stages of the investigation.

Appendix A

DESIGN RAINFALL INTENSITIES

```
*****************************************************************
*                              I F D                            *
*                                                               *
* Intensity - Frequency - Duration Design Rainfall Program     *
*                         (Version 2.0)                         *
*                                                               *
*     This software determines IFD design rainfall in           *
*    accordance  with the algebraic procedures presented        *
*       in Chapter 2 (Author : R.P. Canterford) of              *
*           Australian Rainfall & Runoff(1987)                  *
*                                                               *
*              ****************************                     *
*                                                               *
*      This software is supplied as is and without any          *
*    warranties as to performance or any other warranties       *
*                   expressed or implied.                       *
*                                                               *
*                  (C) WP SOFTWARE 1988                         *
*                   Ph. (062) 815811                            *
*****************************************************************
```

*** INPUT DATA ECHO ***

```
BUNDEENA (Sutherland Shire Council)
 2 year,  1 hour intensity:   40.00 mm/hr
 2 year, 12 hour intensity:    8.00 mm/hr
 2 year, 72 hour intensity:    2.50 mm/hr
50 year,  1 hour intensity:   84.00 mm/hr
50 year, 12 hour intensity:   16.00 mm/hr
50 year, 72 hour intensity:    5.00 mm/hr
Skewness:      .00
Geographical factor for 6 minute,  2 yr storm:    4.29
Geographical factor for 6 minute, 50 yr storm:   15.95
Latitude :      .0000
Longitude:      .0000
```

*** OUTPUT IFD TABLE ***

Rainfall Intensity (mm/h) for BUNDEENA (Sutherland Shire Council)

Duration	Average Storm Recurrence Interval (years)						
	1	2	5	10	20	50	100
5m	98.49	126.34	161.83	180.73	207.10	241.40	267.37
6	92.34	118.55	152.18	170.15	195.16	227.71	252.38
7	87.21	112.05	144.10	161.28	185.14	216.22	239.79
8	82.83	106.49	137.19	153.68	176.54	206.36	228.98
9	79.03	101.66	131.17	147.06	169.05	197.75	219.53
10	75.68	97.40	125.85	141.20	162.42	190.13	211.17
11	72.69	93.60	121.11	135.98	156.50	183.32	203.70
12	70.01	90.19	116.84	131.27	151.17	177.18	196.95
13	67.58	87.10	112.97	127.00	146.32	171.60	190.83
14	65.37	84.28	109.44	123.10	141.90	166.50	185.22
15	63.34	81.70	106.20	119.52	137.84	161.81	180.07
16	61.48	79.32	103.21	116.22	134.08	157.49	175.31
17	59.75	77.12	100.45	113.16	130.61	153.47	170.90
18	58.15	75.08	97.87	110.31	127.37	149.74	166.78
20	55.26	71.40	93.23	105.17	121.52	142.98	159.34
25	49.43	63.96	83.83	94.75	109.66	129.25	144.22
30	44.98	58.27	76.61	86.74	100.52	118.66	132.54
35	41.45	53.75	70.86	80.34	93.21	110.18	123.17
40	38.56	50.04	66.13	75.07	87.19	103.19	115.44
45	36.14	46.94	62.16	70.65	82.13	97.30	108.93
50	34.07	44.29	58.77	66.86	77.80	92.25	103.35
55	32.29	42.00	55.84	63.58	74.04	87.87	98.49
60	30.73	40.00	53.26	60.70	70.73	84.01	94.22
75	26.74	34.78	46.23	52.64	61.29	72.74	81.53
90	23.82	30.97	41.11	46.77	54.43	64.55	72.32
2.0h	19.81	25.74	34.08	38.73	45.02	53.34	59.71
3.0	15.23	19.76	26.09	29.59	34.36	40.63	45.44
4.0	12.63	16.37	21.56	24.43	28.33	33.47	37.40
4.5	11.70	15.16	19.94	22.59	26.18	30.92	34.54
5.0	10.92	14.15	18.60	21.05	24.40	28.80	32.16
6.0	9.70	12.56	16.49	18.65	21.60	25.47	28.43
8.0	8.05	10.41	13.64	15.41	17.82	21.00	23.42
9.0	7.46	9.65	12.62	14.25	16.48	19.40	21.64
10.0	6.97	9.01	11.77	13.29	15.36	18.08	20.16
12.0	6.19	8.00	10.44	11.78	13.60	16.00	17.83
14.0	5.64	7.28	9.51	10.72	12.39	14.57	16.24
16.0	5.20	6.71	8.76	9.88	11.42	13.43	14.97
18.0	4.84	6.25	8.15	9.20	10.62	12.50	13.93
20.0	4.53	5.86	7.64	8.62	9.96	11.71	13.05
22.0	4.27	5.52	7.21	8.13	9.39	11.04	12.31
24.0	4.05	5.23	6.83	7.70	8.89	10.46	11.66
36.0	3.13	4.04	5.28	5.95	6.87	8.09	9.01
48.0	2.58	3.34	4.36	4.91	5.68	6.68	7.44
60.0	2.21	2.86	3.73	4.20	4.86	5.71	6.37
72.0	1.94	2.50	3.26	3.68	4.25	5.00	5.57

Appendix B
DETAILS OF HYDROLOGIC MODELLING

Table B.1 **Stage versus storage relationship assumed for Bundeena Creek catchment swamp system**

Stage (mAHD)	Storage (m^3)
0.43	0
1.00	34,300
1.40	98,200
1.80	199,200
2.00	265,000
4.00	1,052,000

Table B.2 **RAFTS subcatchment areas and flows**

Subcatchment name	Subcatchment area (ha)	Total catchment area (ha)	Residential area (ha)	20–year ARI flow (m^3/s)	100–year ARI flow (m^3/s)
W1	4.5	4.5	0.0	0.6	0.7
W1.1	17.4	21.9	0.0	2.4	3.0
W2	11.6	11.6	0.0	1.3	1.7
D1	0.0	33.5	0.0	3.7	4.7
W1.2	23.4	56.9	0.0	6.2	7.9
W1.3	21.4	78.3	0.0	8.3	10.6
W1.4	10.8	89.1	0.0	9.4	12.1
W3	15.8	15.8	0.0	1.6	2.1
D2	0.0	104.9	0.0	11.0	14.1
W4	10.1	10.1	0.0	1.3	1.7
E1	25.2	25.2	4.4	3.1	3.9
E2	13.6	13.6	0.0	1.6	2.0
D3	0.0	38.8	0.0	4.7	6.0
E1.1	8.9	47.7	6.3	5.7	7.2
E3	21.9	21.9	0.0	1.9	2.4
D4	0.0	69.6	0.0	7.4	9.5
E4	7.0	7.0	5.8	1.2	1.5
E5	14.1	14.1	0.0	1.7	2.2
E6	7.9	7.9	0.0	1.0	1.3
E7	7.1	7.1	6.1	1.2	1.5
B1.1	39.4	220.7	4.6	24.8	33.0
B1.4	29.8	250.0	29.8	19.6*	27.7*

* *from Mike-11*

Appendix C

DESIGN FLOOD LEVELS

Table C.1 **Design flood levels for Bundeena Creek — Existing channel conditions and preferred management plan**

Cross-section number	Existing channel conditions: PMF event Creek(1),(3) (m AHD)	Existing: PMF event Tide(2) (m AHD)	Existing: 20-year ARI event Creek(1),(4) (m AHD)	Existing: 20-year ARI event Tide(5) (m AHD)	Existing: 100-year ARI event Creek(1),(4) (m AHD)	Existing: 100-year ARI event Tide(6) (m AHD)	Preferred management plan (Option 4): 20-year ARI event Creek(1),(4) (m AHD)	Preferred: 20-year ARI event Tide(5) (m AHD)	Preferred: 100-year ARI event Creek(1),(4) (m AHD)	Preferred: 100-year ARI event Tide(6) (m AHD)	Comments
240	2.97 *		1.88 *	1.43	1.96 *	1.50	1.64 *	1.43	1.82 *	1.50	
400	2.96 *		1.87 *	1.43	1.95 *	1.50	1.61 *	1.43	1.78 *	1.50	
480	2.96 *		1.86 *	1.43	1.95 *	1.50	1.56 *	1.43	1.74 *	1.50	just upstream Scarborough Street
490	2.95 *		1.86 *	1.43	1.94 *	1.50	1.56 *	1.43	1.69 *	1.50	Scarborough Street
495	2.95 *		1.86 *	1.43	1.94 *	1.50	1.56 *	1.43	1.69 *	1.50	Scarborough Street
501	2.95 *		1.85 *	1.43	1.93 *	1.50	1.56 *	1.43	1.69 *	1.50	just downstream Scarborough Street
528	2.94 *	2.20	1.80 *	1.43	1.87 *	1.50	1.51 *	1.43	1.69 *	1.50	
551	2.93 *		1.55 *	1.43	1.70 *	1.50	1.48 *	1.43	1.66 *	1.50	
591	2.91 *		1.43 *	1.43 *	1.64 *	1.50	1.47 *	1.43	1.65 *	1.50	
651	2.85 *		1.36	1.43 *	1.57 *	1.50	1.41	1.43 *	1.58 *	1.50	
704	2.85 *		1.33	1.43 *	1.53 *	1.50	1.37	1.43 *	1.54 *	1.50	
757	2.74 *		1.30	1.43 *	1.50 *	1.50 *	1.34	1.43 *	1.50 *	1.50 *	
801	2.60 *		1.25	1.43 *	1.43	1.50 *	1.29	1.43 *	1.43	1.50 *	
846	2.60 *		1.22	1.43 *	1.39	1.50 *	1.26	1.43 *	1.39	1.50 *	
877	2.57 *		1.22	1.43 *	1.38	1.50 *	1.26	1.43 *	1.39	1.50 *	just upstream Bundeena Drive
885	2.49 *		1.20	1.43 *	1.35	1.50 *	1.24	1.43 *	1.36	1.50 *	Bundeena Drive
890	2.48 *		1.20	1.43 *	1.35	1.50 *	1.24	1.43 *	1.36	1.50 *	Bundeena Drive
900	2.48 *		1.20	1.43 *	1.35	1.50 *	1.24	1.43 *	1.36	1.50 *	just downstream Bundeena Drive
913	2.48 *	2.00	1.20	1.43 *	1.35	1.50 *	1.24	1.43 *	1.36	1.50 *	
953	2.39 *		1.18	1.43 *	1.33	1.50 *	1.21	1.43 *	1.33	1.50 *	
992	2.21 *		1.14	1.43 *	1.26	1.50 *	1.17	1.43 *	1.27	1.50 *	
1018	2.10 *	2.00	1.03	1.43 *	1.15	1.50 *	1.06	1.43 *	1.16	1.50 *	
1037	1.91	2.00 *	0.93	1.43 *	1.03	1.50 *	0.96	1.43 *	1.03	1.50 *	
1163	1.50	2.00 *	0.85	1.43 *	0.85	1.50 *	0.85	1.43 *	0.85	1.50 *	Horderns Beach

** -- indicates the governing flood level to be adopted*

PMF -- probable maximum flood

Notes

(1) Flood levels calculated from MIKE-11 modelling

(2) November 1969 flood levels

(3) Assumed starting water level -- 100-year ARI Port Hacking water level (1.5 mAHD)

(4) Assumed starting water level -- dune level at Horderns Beach (0.85 mAHD)

(5) 20-year ARI Port Hacking water level (1.43 mAHD)

(6) 100-year ARI Port Hacking water level (1.5 mAHD)

Table C.2 **Design flood levels for Bundeena Creek—Existing channel conditions and proposed management options**

Cross-section number	Existing conditions 100-year ARI event		Proposed management options—100-year ARI event: Option 1 Enlarge culvert at Bundeena Drive		Option 2 Remove wall at Scarborough Street		Option 3 Option 2 plus channel works		Option 4 Option 3 plus low-level levee		Comments
	Creek(1),(4) (m AHD)	Tide(6) (m AHD)	Creek(1),(4) (m AHD)	Tide(6) (m AHD)	Creek(1),(4) (m AHD)	Tide(6) (m AHD)	Creek(1),(4) (m AHD)	Tide(5) (m AHD)	Creek(1),(4) (m AHD)	Tide(6) (m AHD)	
240	1.96*	1.50	1.96*	1.50	1.86*	1.50	1.76*	1.50	1.82*	1.50	
400	1.95*	1.50	1.95*	1.50	1.84*	1.50	1.73*	1.50	1.78*	1.50	
480	1.95*	1.50	1.95*	1.50	1.83*	1.50	1.70*	1.50	1.74*	1.50	just upstream Scarborough Street
490	1.94*	1.50	1.94*	1.50	–	1.50	–*	1.50	1.69*	1.50	Scarborough Street
495	1.94*	1.50	1.94*	1.50	1.82*	1.50	1.69*	1.50	1.69*	1.50	Scarborough Street
501	1.93*	1.50	1.93*	1.50	1.81*	1.50	1.69*	1.50	1.69*	1.50	just downstream Scarborough Street
528	1.87*	1.50	1.88*	1.50	1.74*	1.50	1.65*	1.50	1.69*	1.50	
551	1.70*	1.50	1.70*	1.50	1.66*	1.50	1.62*	1.50	1.66*	1.50	
591	1.64*	1.50	1.64*	1.50	1.62*	1.50	1.61*	1.50	1.65*	1.50	
651	1.57*	1.50	1.57*	1.50	1.56*	1.50	1.55*	1.50	1.58*	1.50	
704	1.53*	1.50	1.53*	1.50	1.52*	1.50	1.51*	1.50	1.54*	1.50	
757	1.50*	1.50*	1.49	1.50*	1.48	1.50*	1.47	1.50*	1.50*	1.50*	
801	1.43	1.50*	1.42	1.50*	1.41	1.50*	1.40	1.50*	1.43	1.50*	
846	1.39	1.50*	1.38	1.50*	1.37	1.50*	1.37	1.50*	1.39	1.50*	just upstream Bundeena Drive
877	1.38	1.50*	1.38	1.50*	1.37	1.50*	1.36	1.50*	1.39	1.50*	Bundeena Drive
885	1.35	1.50*	1.37	1.50*	1.35	1.50*	1.34	1.50*	1.36	1.50*	Bundeena Drive
890	1.35	1.50*	1.37	1.50*	1.35	1.50*	1.34	1.50*	1.36	1.50*	just downstream Bundeena Drive
900	1.35	1.50*	1.36	1.50*	1.35	1.50*	1.34	1.50*	1.36	1.50*	
913	1.35	1.50*	1.35	1.50*	1.35	1.50*	1.34	1.50*	1.36	1.50*	
953	1.33	1.50*	1.33	1.50*	1.32	1.50*	1.31	1.50*	1.33	1.50*	
992	1.26	1.50*	1.27	1.50*	1.26	1.50*	1.25	1.50*	1.27	1.50*	
1018	1.15	1.50*	1.15	1.50*	1.14	1.50*	1.14	1.50*	1.16	1.50*	
1037	1.03	1.50*	1.03	1.50*	1.02	1.50*	1.02	1.50*	1.03	1.50*	
1163	0.85	1.50*	0.85	1.50*	0.85	1.50*	0.85	1.50*	0.85	1.50*	Horderns Beach
			Not adopted		Adopted		Adopted		Adopted		

* -- indicates the governing flood level to be adopted

PMF -- probable maximum flood

Notes
(1) Flood levels calculated from MIKE-11 modelling
(2) November 1969 flood levels
(3) Assumed starting water level -- 100-year ARI Port Hacking water level (1.5 mAHD)
(4) Assumed starting water level -- dune level at Horderns Beach (0.85 mAHD)
(5) 20-year ARI Port Hacking water level (1.43 mAHD)
(6) 100-year ARI Port Hacking water level (1.5 mAHD)

Appendix D

SECTION 149 CERTIFICATE NOTATIONS

SECTION 149 CERTIFICATE NOTATIONS

BUNDEENA (SHEETS 9 & 10)

ATTACHMENT "D1"

1. The construction of dwellings on existing residential allotments be allowed subject to the following restrictions until such time as the retarding basin scheme is implemented:-

(i) Where practicable, structures should be located clear of the 1 in 20 year flood limit as defined in the Bundeena Creek Flood Management Study Report. Where this requirement cannot be met, structures are to be located as near as practicable to the edge of the floodway.

(ii) The minimum floor level of habitable structures within the area subject to these restrictions is to be 2.7 m above Australian Height Datum.

(iii) The minimum floor level of permanent non-habitable structures and the coping of swimming pools within the area subject to these restrictions is to be 2.3 m above Australian Height Datum.

(iv) All other improvements, including courtyard and landscaped areas, patios and the like, are to provide for future filling to a level of 2.0 m above Australian Height Datum.

(v) The area of any filling associated with slab-on-ground construction at or above the prescribed levels is to be kept to a minimum.

(vi) No filling is to be placed within the area subject to these restrictions without the written consent of Council.

(vii) Any fencing to be erected within the 20 year floodway is to be of an open type to allow the free flow of floodwaters through the fence during periods of intense rainfall.

2. Subdivision of land affected by the 1 in 20 year flood prior to implementation of the drainage scheme be restricted by imposing the condition that all new residential allotments must contain an area of 325 m^2 without filling clear of the 1 in 20 year flood as defined in the Bundeena Creek Flood Management Study Report dated May 1985, prepared by Consultants, Cameron McNamara Pty. Ltd.

SECTION 149 CERTIFICATE NOTATIONS

BUNDEENA (SHEET 10)

ATTACHMENT "D2"

1. Information available to Council indicates that part of the property may be affected by flooding, due to a rise in the water level of Bundeena Creek, in times of intense rainfall.

2. The floor level of any major habitable structure built on the site will be required to be fixed at or above RL 3.5 m on Australian Height Datum.

3. The property being filled to a minimum level of RL 3.0 m on Australian Height Datum.

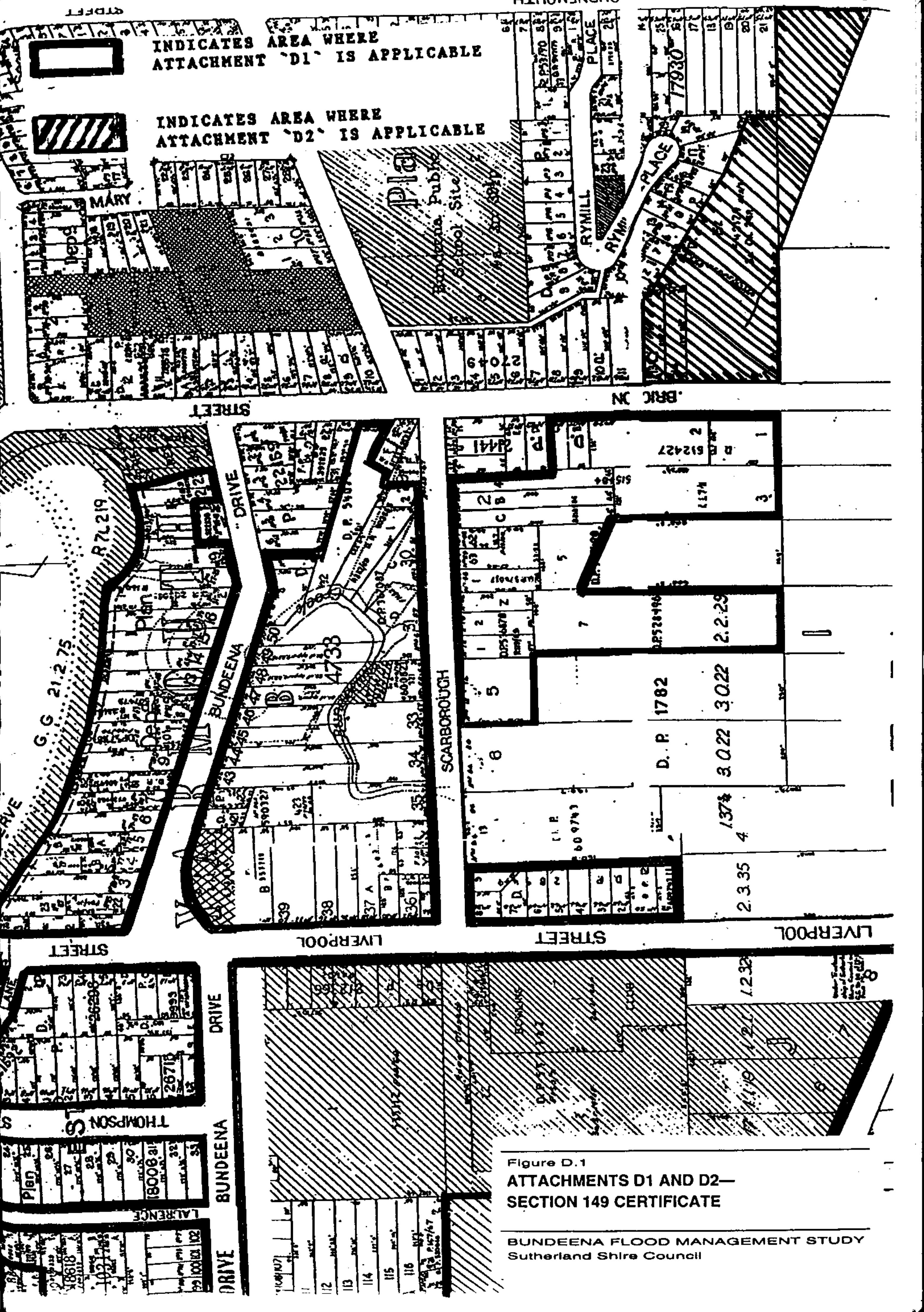
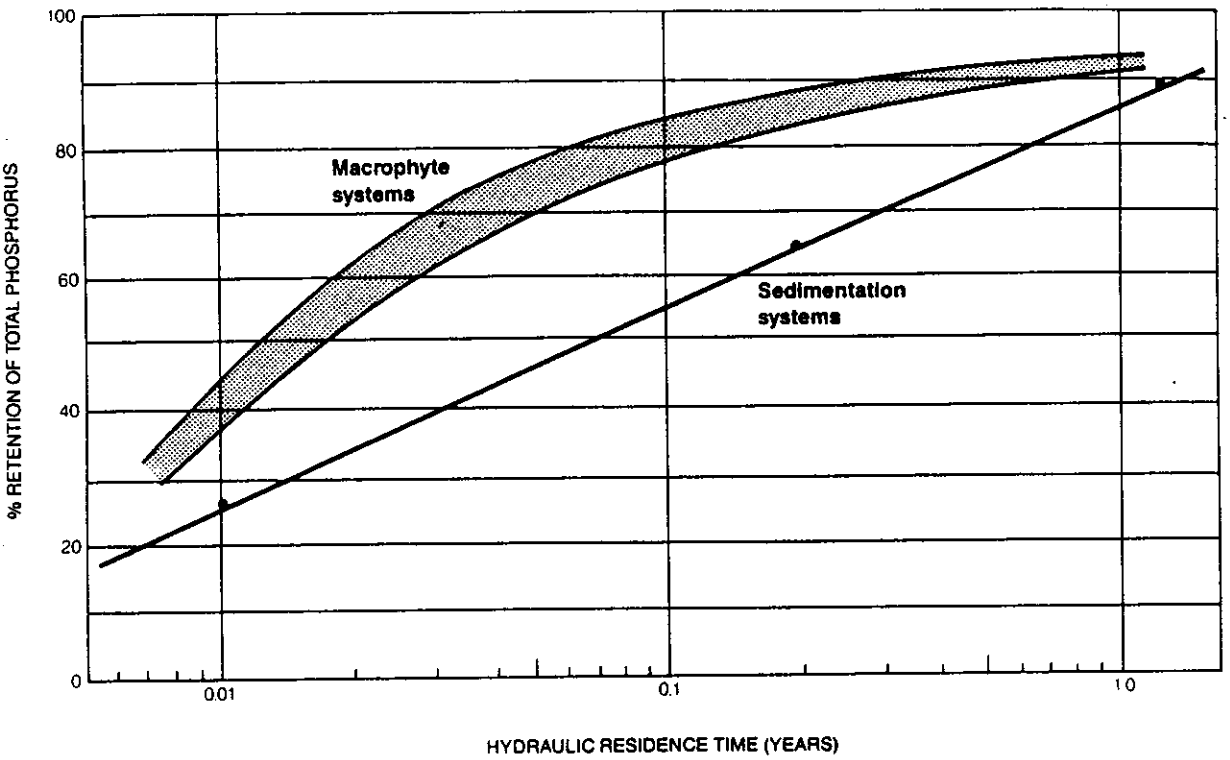


Figure D.1
ATTACHMENTS D1 AND D2—SECTION 149 CERTIFICATE

BUNDEENA FLOOD MANAGEMENT STUDY
Sutherland Shire Council

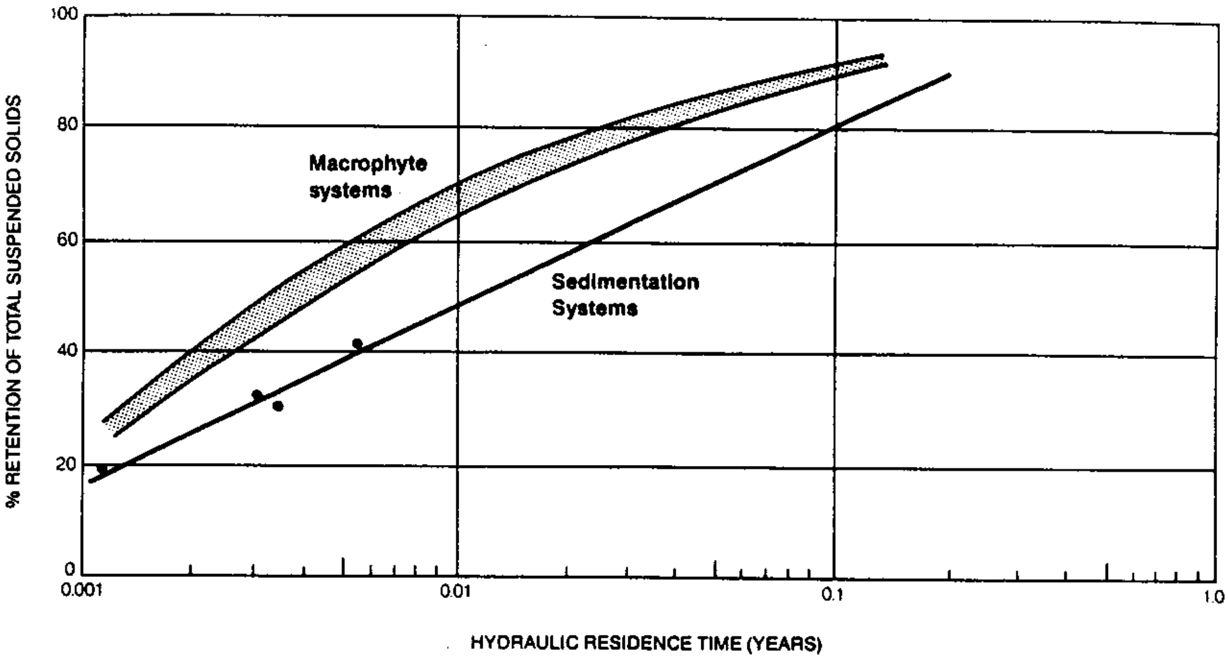
Appendix E

POLLUTION RETENTION CURVES FOR WETLANDS



Source: Lawrence (1986)

Figure E.1
PHOSPHORUS REMOVAL IN WATER BODIES



Source: Lawrence (1986)

Figure E.2

SUSPENDED SOLIDS REMOVAL IN WATER BODIES

Appendix F

STORMWATER POLLUTION EDUCATION

Stormwater
Everyone's concern

SUTHERLAND SHIRE COUNCIL

DO YOU	YOU SHOULD

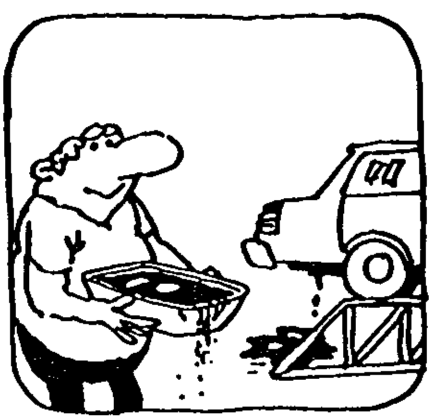
1 Wash your car where the suds will run onto the lawn not the gutter. The phosphate in detergents and solvents in car cleaners are no good for the creek, river or ocean.
Wash your car without detergents to remove light grime.

2 Put grass cuttings, leaves and other garden refuse on the compost, this way you return nutrients and organic matter to the soil.

3 Go easy on fertilisers, pesticides and herbicides excess will wash into the stormwater when it rains or if you overwater.

For all enquiries on safe disposal of pesticides, engine oil, etc. phone the Pollution Line on: 525 5555 for advice.

4 Dispose of engine oil at recycling outlets or leave in container for kerbside collection with your bottles, cans and papers.
Don't tip paint or turps down the drain. Wash paint brushes and rollers (water based paint) onto the grass.



STREAMLINE

MARCH 1991

UPPER PARRAMATTA RIVER
CATCHMENT TRUST

Published by the
Upper Parramatta River Catchment Trust
Level 1, 10 Valentine Avenue, Parramatta, NSW, 2150

COME TO THE CATCHMENT CREEK CLEAN-UP!

CLEAN UP AUSTRALIA DAY SUNDAY, MARCH 24

That unsightly rubbish in your local creek could soon be a thing of the past. Clean Up Day on Sunday 24 March 1991 is your chance to help improve your local creek or creek bank reserve.

The Catchment Clean Up effort is part of the nation-wide Clean Up Australia campaign. In previous years, the clean-up has been confined to a few areas in the catchment. But this year it is hoped to have all local creeks cleaned.

Two Catchment Co-ordinators are working closely with the Trust and the local councils to make Clean Up Day 1991 a great success. Already many individuals and community groups have offered to supervise particular sections of a creek. The main need now is for people like yourself to turn up and help on the day!

You may have already received a leaflet in your letterbox telling you the nearest clean-up site. If not, you can find out by ringing the co-ordinators - Jill Reardon (Baulkham Hills and Parramatta areas) on 871 8506 or Helmut Fetzer (Blacktown and Holroyd areas) on 871 5052 .

Helpers are asked to wear strong shoes (or gumboots) and gardening gloves. Thongs are not acceptable. In most areas the Catchment Clean-Up will start at 11 am and conclude by 2 pm, but you are only asked to give what time you can.

By removing the rubbish from creeks and creek banks, we lessen the risk of drains and culverts being blocked during storms. It will also make these areas safer, more attractive and more usable for relaxation and recreation.

This is a great opportunity to transform these neglected and abused areas into real community assets. **Be in it!**

IS YOUR GARDENING FLOOD FRIENDLY?

One of the pleasant aspects of our catchment is the attractive home gardens that will soon burst into spring colour.

Most of the proud owners of these gardens are community minded and the sort of people who are at peace with the world.

Never for a minute would you consider that amongst all these nice people lurk those who have unwittingly become 'flood fiends'.

These 'nasties', in green disguise, proudly cut the edges of their nature strip, mow it and then sweep or – even worse – hose the clippings down the gutter where they end up in the closest stormwater drain.

Just as bad is the owner of one of these new fangled path blowers who blows all the rubbish off his paths, into the street. If you must blow, blow it into a corner of your yard where it can be gathered up and put into the compost, a boon for all avid gardeners.

Another 'nasty' is the one who tippy–toes across the road to the local reserve to empty the mower's grass catcher. Equally guilty is the one who empties it over the back fence into the reserve. Even if contained in plastic bags it still presents a flood threat. The bag will eventually split and the clippings will wash into a drain or creek.

Another community enemy takes garden prunings and drops them onto reserves and creek banks. A wide range of noxious and unwanted vegetation can rapidly choke water–ways.

We are happy to report that most of our catch–ment gardeners are far more responsible and make a point of disposing of unwanted garden debris through the weekly Council rubbish bins or the regular 'clean up' days.

What type of gardener are you?

A 'nasty'

CREEK CLEAN UP BRINGS PRAISE

Take a bow all those who took part in the Creek Clean Up as part of the March 24 CleanUp Day.

About 500 tonnes of rubbish, plus 30 cars, was removed by the 1500 volunteers. We are pleased to report that on the following day the creeks were clean.

While most of the media attention was else–where, the catchment had the highest concen–tration of sites with over 50 in our 110 square kilometres.

Ian Kiernan, Chairman of Clean Up Australia, highly praised the organisation of our effort and the results which you achieved, citing it as an example for others to follow.

The challenge is now to continue the good work through the year and make sure no one rubbishes our catchment.

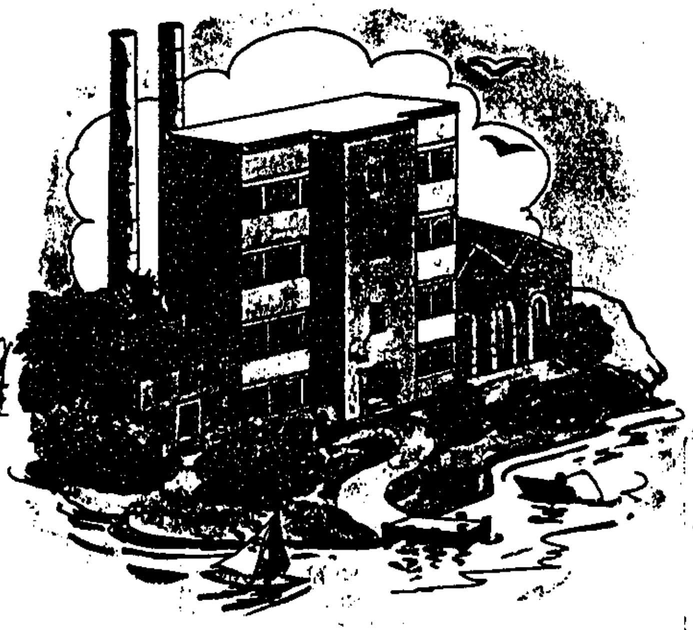
• The "Dob in a Dumper" campaign encourages people to report any illegal dumping of wastes (into the sewer or waterway).

What Can Companies Do?

* use different raw materials or systems that produce less or safer waste
* have a policy to reduce and prevent waste
* recycle where possible e.g. some cooking oil from fast food outlets, engine oils and some chemical wastes can be sold and reused
* install plants to treat waste at the work site, thus reducing disposal charges
* obtain approval to put acceptable waste into the sewer

What Can We All Do?

* be responsible: don't put chemicals, fats or oils into the sewerage or stormwater system — at work or at home
* participate in chemical collection and local recycling campaigns (watch local papers for details)
* Dob-in a Dumper — report people dumping industrial or commercial waste. Phone: (02) 269 5678



More Information

Water Board (including Trade Waste Offices)
(02) 269 6969
Waste Management Authority of NSW (02) 412 1388
Hunter Water Board (049) 26 7267
State Pollution Control Commission (02) 265 8888

or Regional Offices:	Grafton (066) 42 0535
Albury (060) 23 0911	Newcastle (049) 26 9971
Armidale (067) 73 7133	Queanbeyan (06) 299 3330
Bathurst (063) 33 4396	Wollongong (042) 26 8100

WATER BOARD
SYDNEY – ILLAWARRA – BLUE MOUNTAINS

THE NEW SOUTH WALES GOVERNMENT
Putting people first by managing better

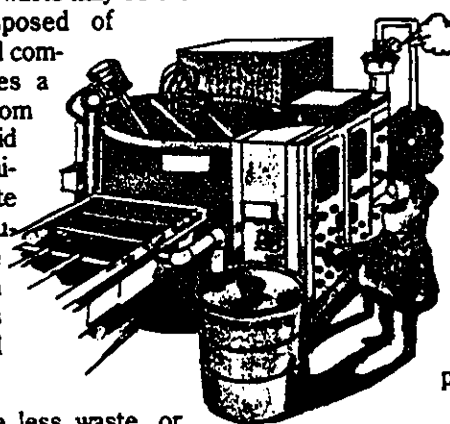
100% AUSTRALIAN RECYCLED PAPER

Know Where it Goes

Protect Your Environment

What is Industrial and Commercial Waste?

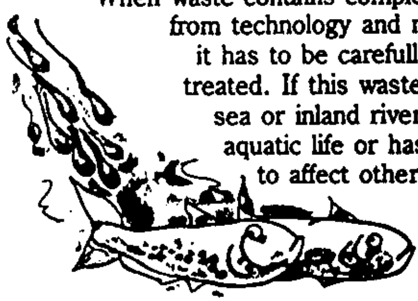
Every day there seems to be a new product on the supermarket shelf or a new technology for doing something. We all use these things. When industry manufactures products for us, waste may be created which must be recycled or disposed of properly. Industrial and commercial waste includes a range of garbage: from liquids, sludges and solid wastes from the chemicals and industrial waste water used in big manufacturing plants, to the oils and fats used in fast food shops. This waste is often called Trade Waste.



If we can produce less waste, or recycle it, so much the better. To keep our environment healthy we need to make sure, however, that when we dispose of this industrial and commercial waste, it does not pollute the environment.

How Does it Affect the Environment?

When waste contains complex by-products from technology and manufacturing, it has to be carefully handled and treated. If this waste gets into the sea or inland rivers it can affect aquatic life or has the potential to affect other life, including humans.



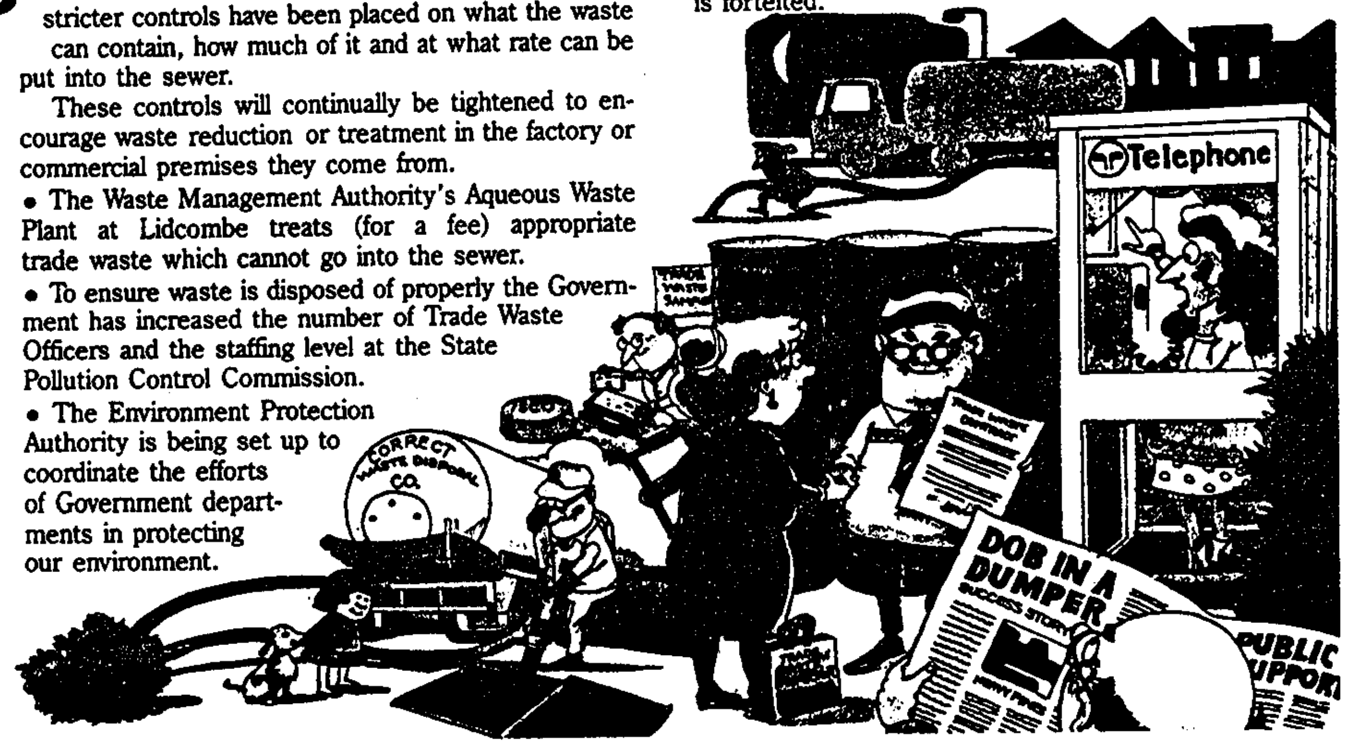
What is the N.S.W. Government Doing?

There is a worldwide move to regulate non-domestic wastes. The NSW Government has introduced a range of initiatives to better manage industrial and commercial wastes (often called Trade Waste).

- Many wastes can be treated through the sewerage system. However, industry and commerce must pay for the amount it discharges to the sewer, and for the amount of treatment required.
- The trade waste charges have been increased and stricter controls have been placed on what the waste can contain, how much of it and at what rate can be put into the sewer.

These controls will continually be tightened to encourage waste reduction or treatment in the factory or commercial premises they come from.

- The Waste Management Authority's Aqueous Waste Plant at Lidcombe treats (for a fee) appropriate trade waste which cannot go into the sewer.
- To ensure waste is disposed of properly the Government has increased the number of Trade Waste Officers and the staffing level at the State Pollution Control Commission.
- The Environment Protection Authority is being set up to coordinate the efforts of Government departments in protecting our environment.
- These efforts are now supported by tough new legislation — the Environmental Offences & Penalties Act. Penalties for not meeting requirements of the Act can be very severe. It applies to public authorities as well as private companies. It is now an offence to dispose of waste without a licence or equivalent. On-the-spot pollution fines should be introduced later this year.
- Charges are levied on industry and commerce in relation to the quality of their liquid waste going to the sewer. This Trade Waste money will be set aside in Trusts for the Environment. Money from interest on the Trust Funds will be spent on rehabilitation and restoration of the environment, environmental research and environmental education.
- Companies may agree to improve the quality of their waste and so reduce their waste charges in the interim. If they choose to do this they must lodge a bond (or security). If the company fails to fulfil their promises the bond is forteited.



Appendix G

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Appendix G
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