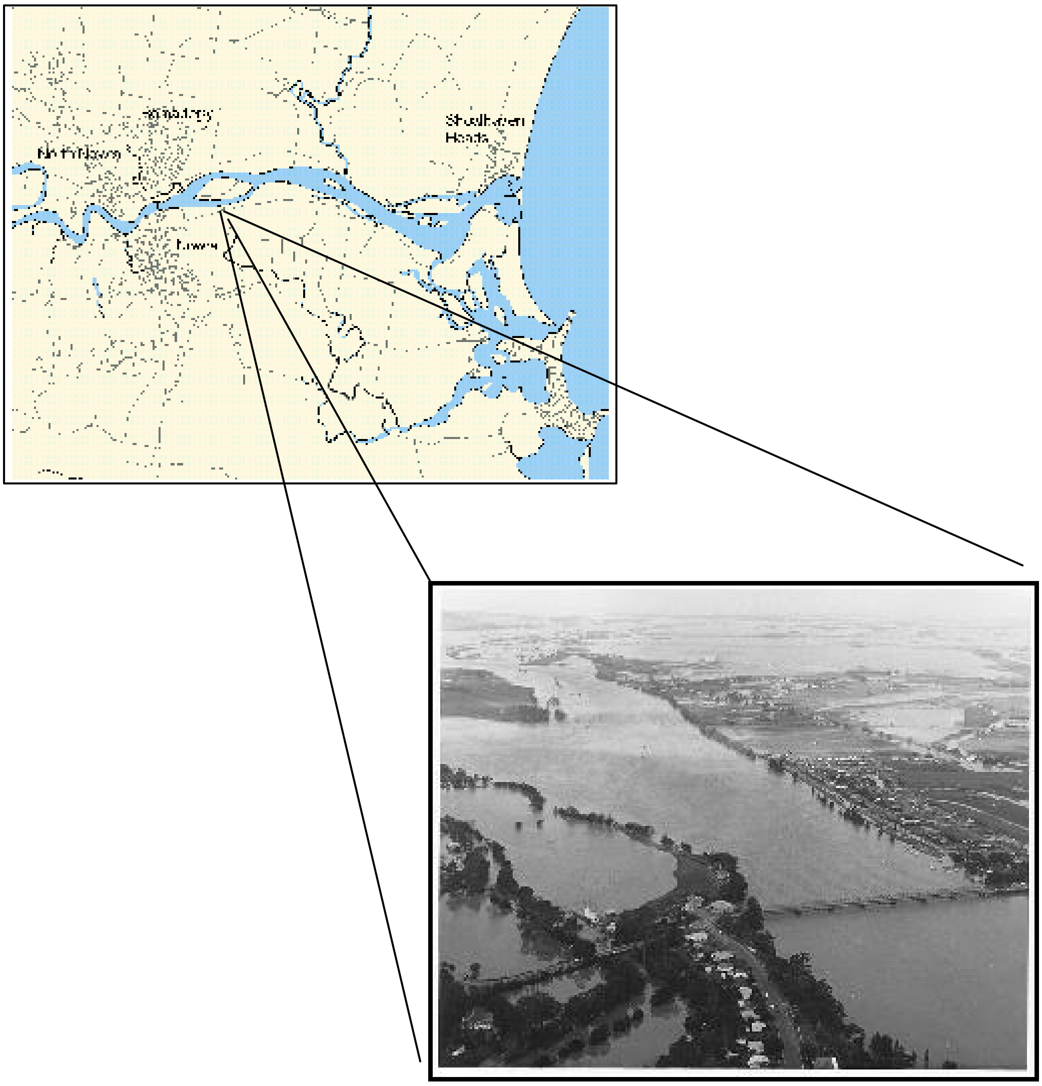
TERARA VILLAGE

FLOODPLAIN MANAGEMENT STUDY



Shoalhaven River, 1978 Flood

FEBRUARY 2002

SHOALHAVEN CITY COUNCIL

TERARA VILLAGE
FLOODPLAIN MANAGEMENT STUDY

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FOREWORD

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

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

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

1. *Flood Study*
   - determines the nature and extent of the flood problem.

2. *Floodplain Management Study*
   - evaluates management options for the floodplain in respect of both existing and proposed development.

3. *Floodplain Management Plan*
   - involves formal adoption by Council of a plan of management for the floodplain.

4. *Implementation of the Plan*
   - construction or implementation of floodplain management measures to protect existing development,
   - use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

The Terara Village Floodplain Management Study constitutes the second stage of the management process and has been developed by the Shoalhaven Floodplain Management Committee. It was prepared for the Committee by Webb, McKeown & Associates and provides the basis for the future management of flood liable lands at Terara.

The terminology used in this report is in accordance with the NSW Government's Floodplain Development Manual (1986 edition) and draft Floodplain Manual (1999 edition). Subsequently the final Floodplain Management Manual was released in January 2001. This latter document provided several changes in terminology which have not been included in this report.

SUMMARY

This Floodplain Management Study examines flooding issues relating to the village of Terara (Figures 1 and 2) and adjoining properties which are located on the south bank of the Shoalhaven River approximately 2.5 kilometres east of Nowra Bridge. Terara has a population of approximately 150 and has experienced major flooding in 1860, 1870, 1974 and 1978.

The study was initiated by Shoalhaven City Council to address the management of the flood problem of Terara. The primary objectives of the Study were to define the nature and extent of the hazard; to identify, assess and optimise measures aimed at reducing the impact of flooding on both existing and future development; and to make recommendations for the future management of the study area.

This Floodplain Management Study builds on the Lower Shoalhaven River Flood Study, which was completed in April 1990 and defines design flood levels within the Lower Shoalhaven floodplain, including Terara. Once a preferred scheme is adopted, an overall Floodplain Management Plan can be prepared.

A summary of the measures considered in the course of the study is provided in Table i).

Table i): Summary of Floodplain Management Measures

MEASURE	PURPOSE	COMMENT
FLOOD MODIFICATION:		
FLOOD MITIGATION DAMS (Section 4.2.1)	Reduce flooding downstream.	Not viable on economic grounds. Must be considered on a catchment wide basis.
FLOODWAYS (Section 4.2.2)	Provide a defined overbank area where a significant volume of water flows during floods.	Not applicable due to the size of the floodplain, the lack of a suitable location and the volume of water involved.
CATCHMENT TREATMENT (Section 4.2.3)	Reduce runoff from catchment.	Negligible impact on a large catchment but the general principles should still be applied.
RIVER IMPROVEMENT WORKS (Section 4.3.1) • Desnagging • Dredging • Realignment • Reconstruction • Remove hydraulic restrictions	Increase hydraulic capacity of the Shoalhaven River to reduce flood levels.	More applicable on smaller rivers. For the Shoalhaven River these measures provide only marginal hydraulic benefit, are not economically viable, and would raise significant environmental concerns. • Not applicable. • Limited benefit and high cost. • Not applicable. • Environmental concerns. • Not applicable. - high cost, - environmental impacts, - limited benefit.
SHOALHAVEN HEADS ENTRANCE WORKS (Section 4.3.2)	Permit floodwaters to exit to the ocean through Shoalhaven Heads and so reduce flood levels upstream.	May lower levels for runoff dominated events but may raise them for ocean dominated events. Any changes resulting from entrance works would be insignificant at the study area. Previous studies have shown that it is not viable to maintain a permanent entrance.
IMPROVED LOCAL DRAINAGE (Section 4.3.3)	To reduce the incidence of local runoff ponding.	Flooding in this manner does not inundate buildings. Further investigation is a matter for Council and the local residents.
LEVEES (Section 4.3.4)	Prevent or reduce the frequency of flooding of protected areas.	A number of levee options were considered but most involve a high economic cost and significant social and environmental consequences.
PROPERTY MODIFICATION:		
VOLUNTARY PURCHASE (Sections 4.4.1)	Purchase of the most hazardous flood liable properties.	High cost per property. Applicable for isolated high hazard residential buildings but cannot be economically justified to purchase all buildings. It could be considered as a long term means of reducing the number of flood liable buildings.

MEASURE	PURPOSE	COMMENT
PLANNING REGULATIONS (Sections 4.4.4)	Reduce potential hazard and losses.	Already in place. Can be updated to clarify outstanding issues.
HOUSE RAISING/FLOOD PROOFING (Sections 4.4.2 & 4.4.3)	Prevent flooding of existing buildings.	All flood damages cannot be prevented using these measures. House raising may not be practical for social and heritage reasons. House proofing should be considered.
RESPONSE MODIFICATION:		
FLOOD INSURANCE (Section 4.2.4)	Offset a random cost with a series of payments.	Not readily available at the present time for residential buildings.
FLOOD WARNING (Section 4.5.1)	Enable people to evacuate and reduce actual flood damages.	System currently in place but could be enhanced.
EVACUATION PLANNING (Section 4.5.2)	To ensure that evacuation can be undertaken in a safe and efficient manner.	The SES has a Local Flood Plan. This could be enhanced to provide more detail on the particular problems at Terara.
AWARENESS AND PREPAREDNESS PROGRAM (Section 4.5.3)	Educate people to minimise flood damages and reduce the flood problem.	A cheap effective method but requires continued effort. Examples of methods are provided.
OTHER MEASURES:		
BANK EROSION/COLLAPSE (Section 4.6.1)	To prevent further collapse of the river bank currently occurring during non-flood times.	Should be considered as part of the Estuary Management Program.
RAISING OF TERARA ROAD (Section 4.6.2)	Assist in evacuation.	Should be considered as part of any road upgrading program.
DEVELOPMENT MEASURES:		
CONTROL OF DEVELOPMENT OUTSIDE THE STUDY AREA (Section 5.1)	To ensure that the flood hazard is not increased.	Should be adequately addressed under Council's existing development controls.
DEPOSITION OF SILT ON PIG ISLAND (Section 5.2)	To assess whether the deposition is affecting the flood hazard at Terara.	A review should be undertaken.
GREENHOUSE EFFECT (Section 5.3)	May increase design flood levels.	The effect is likely to be minor within the normal planning timeframe but must be closely monitored.

1. INTRODUCTION

The Shoalhaven River catchment (Figure 1) covers an area of 7000 square kilometres with approximately 120 square kilometres of floodplain downstream of Nowra. The village of Terara (Figure 2) is located on the floodplain approximately 2.5 kilometres downstream of Nowra Bridge.

Terara was the original settlement on the south bank. The devastation of the 1860 and 1870 floods caused most of the population to move to the higher ground at Nowra with the subsequent decline of Terara.

The village has continued to be flooded periodically, but people are still attracted to the area as a place to live. The population is now housed in a collection of heritage listed buildings and more modern premises, and there is some pressure for further development.

1.1 The Flood Problem

Historical flood records are available since 1860 and Table 1 lists floods for which some information is available.

Table 1: Flood Events

Month	Year	Month	Year
February	1860	February	1934
June	1864	September	1938
April	1867	April	1945
June	1867	May	1948
March	1870	June	1949
April	1870	June	1951
May	1871	May	1955
February	1873	February	1956
June	1891	July	1956
February	1898	October	1959
July	1899	March	1961
July	1900	November	1961
July	1904	June	1964
January	1911	September	1967
October	1916	August	1974
December	1920	June	1975
July	1922	October	1976
11 May	1925	March	1978
27 May	1925	April	1988
April	1927	August	1990
January	1934		

Note: Data prior to 1988 were obtained from the *Lower Shoalhaven River Flood History at Nowra Bridge 1860-1980* (Reference 1).

The local newspaper, the "Shoalhaven News", was produced in Terara in the period 1860-1873 and a good description is available of the eight major floods which occurred in that time. The flood of April 1870 was probably greater than a 1% AEP event. It inundated the township by over a metre and swept away approximately one third of the village. Five lives were lost in rural areas along the Shoalhaven River.

> *".....The spot where once stood the post office, the telegraph office, the steam company's store and wharf, where all was life, business and activity, is now one vast vacant blanket and forms part of the Shoalhaven River. The streets turned into innumerable fullies, sand banks and creeks, fences were washed away and the whole formation of the town completely destroyed....."* Quotation taken from Shoalhaven - History of the Shire of Shoalhaven by W A Bailey.

According to some accounts the earlier 1860 flood was even more devastating and carried away over 50 buildings. Several lives were lost (reportedly none were residents of Terara) as well as some 79 acres (32 hectares) of land.

A major feature of both these floods was erosion of the river bank. Historical plans indicate the bank may have migrated south by up to 400 m (Reference 4). None of the floods since 1870 have matched these two events for destruction of property or loss of land.

More recent significant floods occurred in August 1974, June 1975, October 1976 and March 1978. The August 1974 flood covered the ground over the entire village causing significant disruption and inconvenience, although the majority of buildings were not inundated. The March 1978 flood was slightly higher than August 1974, (by 0.2 m at Hyams Hotel - refer Table 2) and caused similar flooding problems in the village.

Flood levels have been recorded intermittently since 1860 at Terara and regularly at Nowra Bridge since approximately 1960, however, despite a rigorous investigation of all available data, the peak levels of many historical events are not precisely known. A series of eight automatic water level recorders have now been installed along the river and all future events should be accurately recorded.

Table 2 lists the known or estimated heights of the major historical events and compares them with the design flood levels derived in the Flood Study (Reference 2).

Table 2: Peak Levels of Major Floods (mAHD)

	Historical Events				Design Events				
	1860	**1870**	**1974**	**1978**	**5%**	**2%**	**1%**	**0.5%**	**Extreme**
Nowra Bridge	5.5E	6.55E	4.9*	5.3*	5.3	5.8	6.3	6.8	8.9
Shoalhaven River at Terara	4.8E	5.7E	4.4*	4.7*	4.7	5.0	5.4	5.7	7.4
Terara (Hyams Hotel - at the intersection of Forsyth and South Streets)	4.6*	5.5*	3.7*	3.9*	3.6	3.9	4.7	5.1	7.2
Vacant Land/Moss Street	U	U	2.8#	4.3#	LR	3.7	4.5	5.1	8.0
Estimated AEP at Nowra Bridge	3%	0.7%	8%	5%					
Estimated Average Recurrence Interval at Nowra Bridge	30 years	150 years	12 years	20 years					

NOTES:

* * Recorded level taken from the Lower Shoalhaven River Flood History at Nowra Bridge 1860-1980.
* E Estimated level based on other historical flood data taken from the Lower Shoalhaven River Flood History at Nowra Bridge 1860-1980.
* U Unknown
* LR Subject to inundation from local runoff which has not been accurately determined.
* # Taken from Reference 2.
* Note 1: The more recent floods show a much greater difference in level between Terara (Hyams Hotel) and the river at Terara than the 1860 and 1870 events. This is due to the different heights of the river bank levee.
* Note 2: The design levels at Ferry Lane near Terara Road for floods smaller than a 0.5% AEP event reflect the benefit provided by the Riverview Road levee and are the result of backwater flooding.
* Note 3: The levels for the 1860 and 1870 floods at Nowra Bridge and in the Shoalhaven River at Terara are estimated as no actual levels were recorded.
* Note 4: Residents on the riverbank at Terara have provided levels of 4.3mAHD and 4.6mAHD for the 1974 and 1978 floods respectively.

1.2 Floodplain Management Process

Shoalhaven City Council has commissioned the following studies in accordance with the guidelines of the Floodplain Development Manual (Reference 3):

Stage 1: Flood Study - completed in April 1990

Stage 2: Floodplain Management Study - initiated 1992 and re-activated in June 1998

Stage 3: Floodplain Management Plan - initiated June 1998

The Flood Study (Stage 1 of the process) established the design flood levels, as shown in Table 2. The “1% AEP” or “1 in 100" flood has a 1 in 100 chance of being equalled or exceeded in any year. On a LONG TERM average it will happen once in every 100 years, but it is wrong to think it can only happen once in a century. Because floods are random events, there is still a 1 in 100 chance of the flood occurring next year no matter what happens this year.

The Floodplain Management Study (Stage 2) seeks to fully identify the flood problem and canvass various measures to mitigate the effects of flooding. The end product is the Floodplain Management Plan (Stage 3) which will describe how flood liable lands are to be managed in the future. This process requires community interaction to ensure that the proposals are fully understood and supported.

1.3 Council's Interim Flood Policy

Council adopted an interim flood policy in September 1987 which was last revised in August 1996. The main points are:

- the 1% AEP flood is the Standard Flood,
- the freeboard to the floor levels of habitable rooms of commercial and residential developments is 0.5 m in a floodway and 0.3 m elsewhere. Local rules may apply in some areas,
- where the proposed development could be damaged by flooding, the structure is to be suitably designed to meet the guidelines,
- materials used in construction below the minimum floor level are to be compatible with immersion in floodwaters,
- for proposed dwelling extensions, where it is impractical to raise the floor level, the minimum floor level requirement will be treated on its merits,
- creation of new residential lots by subdivision will not be permitted in floodways.

Further discussion on Council's flood policy is provided in Section 4.4.4.

2. BACKGROUND

2.1 Catchment Description

The Shoalhaven River rises approximately 50km inland of Moruya and follows a northerly direction for 170km before turning east for a further 90km to reach the Pacific Ocean at Crookhaven Heads. Two hundred years ago the main entrance was at Shoalhaven Heads. This entrance is now intermittent following the construction of the Berry's Canal link to the Crookhaven River in 1822.

The valley can be categorised into three broad regions:

- upstream of Welcome Reef where the terrain is rolling plateau,
- between Welcome Reef and Nowra where the catchment consists of steep forested country with the main streams entrenched in deep gorges,
- downstream of Nowra where an expansive floodplain has developed.

The floodplain area was formed by the infilling of an old coastal lagoon. The southern part of the floodplain is drained by the Crookhaven River, which rises near Nowra, while the northern section is drained by Broughton Creek, which rises upstream of Berry. Flood behaviour in the area has been extensively modified since European settlement through the construction of flood mitigation and bank protection works. The excavation of Berry's Canal has also had a major impact by opening up a second entrance at Crookhaven Heads.

2.2 Terara Village

2.2.1 Description

The village of Terara (Figures 1 and 2) was the site of the original European settlement on the southern bank of the Shoalhaven River. In the early and middle part of the nineteenth century it was a thriving centre for commerce and agriculture. It was the major trading centre of the district and ocean going vessels berthed at the Illawarra Steam Navigation Company (ISN) wharf. In 1870 the population of Terara was almost 1000 whilst the township of Nowra had barely been formed. As discussed in Section 1.1, the village was extensively damaged in the floods of 1860 and 1870 and consequently the population centre moved to Nowra.

Today the village of Terara and adjoining properties consist of approximately 60 residential buildings and a school. The houses are a mixture of modern brick buildings and historic timber or stone buildings.

The village is currently protected (to the height of the levee bank) from direct inundation from the Shoalhaven River by an earthen grassed levee which is generally up to 1 m above natural surface. There is considerable vegetation along the river bank and on the levee. The bank is extensively eroded in parts posing a clear threat to the levee by undermining. The levee crest is at approximately 4.4 mAHD to 4.7 mAHD along West Berry Street and will not be overtopped until approximately a 10% AEP event. It is understood that the levee was raised to its present height following the 1978 flood. A longitudinal profile from Nowra Bridge to Terara (1992/93 survey) together with the design flood profiles determined in the Flood Study are shown on Figure 4.

The average ground level within the village is approximately 3.4 mAHD and the majority of the ground in the village will be inundated by backwater from the floodplain in a 5% AEP event. The lowest floor level within the village is at 3.4 mAHD and details of the number of buildings flooded in different events are given in Section 3.4.

2.2.2 Zoning

The village of Terara (bounded by Nobblers Lane, Terara Road/South Street, Southern Road and West Berry Street) was originally zoned Village. The Local Environmental Plan (LEP) of May 1985 changed the zoning to 1(g) Rural. The existing lots containing a dwelling house retain existing use rights. The remaining, vacant lots cannot be developed for residential buildings under the 1(g) zoning unless, among other considerations, Council is satisfied that the dwelling house is essential for the proper and efficient use of the land for agriculture or turf farming. The size of the lot is a major factor in this consideration. Three of these vacant lots are presently for sale (August 1999).

There is no industrial/commercial or proposed industrial/commercial zoning at Terara.

A Rural Environmental Plan was gazetted in July 1999. This plan amends the 1985 LEP. The main features of the Rural Environmental Plan as they relate to flooding are:

> *The policy position of minimising development and settlement in flood prone areas has been retained..... The 1(g) zone remains the principal control in conjunction with Clauses 29 and 30. Zone objectives and provisions have been redrafted as a result of Council's 1993 working party debate.*

Clause 29 states:

Development of flood liable land:

29. (1) Subject to subclause (2), the Council must not consent to the carrying out of development on land which, in its opinion, is flood liable.

(2) The Council may consent to the carrying out of development on flood liable land if:

a) the development is for a purpose ancillary or incidental to the use of land for the purpose of agriculture; or

b) *the development comprises the extension or alteration of an existing dwelling house; or*

c) *the land is in any urban zone under this plan; or*

d) *the Council has received a flood assessment report, in relation to the land, that addresses each of the matters referred to in subclause (3), and the Council is of the opinion that the development is feasible despite the land being flood liable.*

(3) In considering an application to which subclause (2) applies, the Council must make an assessment of:

a) *the likely levels, velocity, sedimentation and debris carrying effects of flooding;*

b) *the structural sufficiency of any building the subject of the application and its ability to withstand flooding;*

c) *the effect which the development, if carried out, will or is likely to have on the flow characteristics of floodwaters;*

d) *whether or not access to the site will be possible during a flood; and*

e) *the likely increased demand for assistance from emergency services during a flood.*

(4) In granting consent to a development application made pursuant to subclause (2), the Council may impose conditions that set floor levels, require filling, structural changes or additions or require other measures to mitigate the effects of flooding or assist in emergency situations.

The objectives of the 1(g) Rural zone are:

- *to limit the erection of structures on land subject to periodic inundation,*
- *to ensure that dwelling houses are erected on land subject to periodic inundation only in conjunction with agricultural use,*
- *to ensure that the effect of inundation is not increased through development,*
- *to restrict development and how it is carried out so that its potential to have an adverse impact on site and off site on acid sulfate soils is reduced or eliminated; and*
- *to conserve and maintain the productive potential of prime crop and pasture land.*

The only development permitted without development consent in the 1(g) Rural zone is agriculture.

2.2.3 Heritage

Items of Environmental Heritage were identified both in the LEP 1985 (2 items) and the Illawarra REP 1986 (2 items). Since then, Terara Village has been identified as a heritage conservation area under a Draft Heritage LEP (9 items identified) and the associated floodplain is also identified as a pastoral landscape in the Shoalhaven Heritage Study. These documents now identify thirteen heritage buildings in total: five within the “township” area between Nobblers Lane and Bryant Street; four near the school on Millbank Road; and four west along Terara Road. These are shown on Figure 2.

Any flood mitigation works which may affect these buildings (e.g. house raising, flood proofing, voluntary purchase, works or trees) will require detailed consideration of the impacts on heritage quality.

There are no identified Aboriginal sites within the study area.

2.2.4 Environmental

A preliminary review of the environmental qualities of the area has indicated that:

- the presence of acid sulfate soils and the release of acid into the river system is becoming of increasing importance and is currently being investigated. Some floodplain management measures (levees, drains) may upset the existing regime.
- at this point of time, no record of threatened or endangered species of flora or fauna has been identified within the study area.

2.3 Lower Shoalhaven River Flood Study

2.3.1 Review

The Lower Shoalhaven River Flood Study (Reference 3) was completed in 1990. The draft Compendium of Data (Reference 4) documented the data used in the Flood Study.

In the Flood Study a computer based hydrologic model, termed the Watershed Bounded Network Model, was established. This model converted rainfall data to estimates of streamflow which were input to the hydraulic model, called the Cell Model. This model covered the area from a point approximately 12 kilometres upstream of Nowra Bridge to the Pacific Ocean at both Shoalhaven Heads and Crookhaven Heads and produced information on flood levels, velocities and flows for the river and floodplain. The Cell Model layout for the study area is shown on Figure 3.

Both models were calibrated and verified to data recorded for the floods of August 1974, June 1975, October 1976, March 1978 and April 1988.

Design rainfall data were obtained from Australian Rainfall and Runoff (1987 edition) and input to the models to produce design flood information for the extreme, 1%, 2% and 5% AEP floods. The extreme flood provides an indication of the likely effects of the Probable Maximum Flood (PMF).

The Flood Study also considered:

- appropriate design ocean levels,
- the effects of the relative timing of the ocean peak and flood peak discharge,
- the effect of closure of the Shoalhaven Heads Entrance and subsequent scouring during the flood,
- variation in adopted width and friction values at the Shoalhaven Heads entrance.

The study concluded that, for a 1% AEP flood, the peak level at Shoalhaven Heads would be 0.75 m higher if the entrance was closed rather than open at the beginning of the flood. The difference would reduce to 0.01 m at Nowra Bridge.

The models used in the Flood Study were "state of the art" at the time of the study (1986 to 1988). Little has changed in hydrologic modelling since that time, but a new generation of hydraulic models has appeared. These new models still rely on calibration against historical flood levels to produce accurate replication of flood events. Given the amount of historical data used to calibrate and verify the Cell Model (and the lack of recent major floods) it is considered that the use of an "up to date" hydraulic model would not significantly alter the design flood levels at locations where historical levels are available. The results from the Flood Study are thus considered suitable for use in the Floodplain Management Study.

2.3.2 Design Flood Levels

Design flood levels were established in the Flood Study for the 1%, 2% and 5% AEP events and the extreme event. As part of the present study levels for the 0.2%, 0.5% and 10% AEP design floods were also established using the same procedure as in the Flood Study. Peak design levels are shown in Table 3 and on Figure 4.

Table 3: Design Flood Levels (mAHD)

Flood (AEP) Location	Extreme	0.2%	0.5%	1%	2%	5%	10%
Nowra Bridge	8.9	7.3	6.8	6.3	5.8	5.3	4.8
Sailing Club	8.8	7.2	6.7	6.3	5.7	5.2	4.8
Riverview Rd West (River)	8.5	7.0	6.5	6.1	5.6	5.1	4.7
Riverview Rd East (River)	8.2	6.8	6.3	6.0	5.5	5.1	4.6
Pig Is West	7.4	6.1	5.7	5.4	5.0	4.7	4.4
Pig Is East	6.9	5.7	5.3	5.0	4.6	4.3	4.0
Willows Caravan Park	8.7	6.8	5.5	LR	LR	LR	LR
Riverview Rd West (land)	8.4	6.6	5.2	4.4	LR	LR	LR
Riverview Rd East (land)	8.2	6.5	5.2	4.6	4.4	LR	LR
Vacant Land/Moss St	8.0	6.2	5.1	4.5	3.7	LR	LR
Shoalhaven Caravan Pk	7.5	6.0	5.2	4.9	4.8	3.7	LR
Terara	7.2	5.8	5.1	4.7	3.9	3.6	LR
Worrigee Swamp	7.0	5.6	5.0	4.5	3.8	LR	LR

Note: LR Subject to inundation from local runoff which is not accurately simulated in the Cell Model.

As the design flows were determined using a runoff routing approach, as opposed to frequency analysis of historical flood records, any change in the estimates of the 1860 and 1870 flood levels at Nowra Bridge, or elsewhere, will not alter the design flood results.

Appendix E provides a post flood evaluation and review program which should be undertaken following each flood.

2.4 Stream Morphology

The Shoalhaven River channel below Nowra Bridge has experienced major changes in the period since European settlement. These include:

- the construction of Berry's Cut in 1822 and the scouring of Berry's Canal. This has resulted in shoaling of the Shoalhaven Heads entrance and subsequent periodic closure as the main river entrance has shifted to Crookhaven Heads,
- bank recession of up to 700 m has occurred over 150 years in the vicinity of the confluence of Berry's Canal and the Shoalhaven River,
- from 1822 to the early 1900's the river was dredged to maintain navigability. Over 1.1 million tons were removed in the period 1893 to 1911. The dredged material was either dumped on Old Man Island or taken out to sea,
- there has been a major retreat of the northern river bank (except near the downstream end of Pig Island) with maximum erosion near Broughton Creek,
- Pig Island has increased in width (650 m to 850 m) and in length (1680 m to 2400 m),
- the south channel around Pig Island has migrated to the south-east causing retreat of the Terara foreshore by up to 400 m,
- Numbaa Island may possibly not have existed prior to 1800,
- an 1822 survey plan indicates that the southern bank at Riverview Road has moved northwards by up to 150 m.

A study by the Public Works in 1988 (Reference 5) could not establish the fundamental reasons why the river morphology in the vicinity of Terara has changed since European settlement. Further downstream, much of the change can be attributed to Berry's Cut and the diversion of flow to Crookhaven Heads.

The main agents of erosion are flood scour, tidal scour and wind waves. To some extent the natural processes have been countered by scour protection works, but these works are under increasing pressure as the banks on which they rest are undercut. In places there has been a total loss of some protection works.

Overall the Public Works study concluded that the rate of river bank erosion is not slowing (except locally where protection works have been employed) and states:

> *"There is no end in sight to the erosion pattern in the study area, necessitating further understanding of the processes and leading to a management strategy that will combine remedial measures (where economically justifiable) with appropriate land use planning. The results of this report should be used in determining set back distances for all developments near river banks (including levees) in the interim period pending the devising of a management strategy."*

2.5 Public Consultation Program

2.5.1 Components

A rigorous public consultation program (Appendix B) was carried out as part of this study and included:

- a letter of introduction and questionnaire,
- floodplain management committee meetings which included public representatives,
- newsletters,
- public meetings,
- public exhibition of material.

The direction of the study, and the degree of emphasis placed upon the various management measures, was influenced by feedback from the public consultation program. A summary of the responses to the program is given below.

2.5.2 Terara Flood Awareness Survey (1993)

There was a good response from residents (42 responses out of approximately 50 households) and the following information was obtained:

- The length of residence in Terara varied from one year to 83 years, with an average of 24 years.

- Most residents receive flood warnings from the radio or television with a smaller number from friends and neighbours (Riverwatch).

- Respondents were divided as to whether the warnings were accurate, with roughly equal numbers considering the warnings good, fair and bad.

- Approximately half the respondents have been offered flood assistance in the past. In half those instances the offer was made by the SES or Council. The remainder were from friends, Police and the Navy.

- Only two respondents said that water had entered their houses and it did so in both the 1974 and 1975 events. Others reported that water entered their houses but only as a result of wash from vehicles being driven along flooded streets.

- Approximately 75% of respondents had experienced yard flooding in at least one of the floods in the 1970's.

- Approximately 25% said they experienced post-flood trauma. Many claimed to have experienced trauma after all of the 1970's floods. The remainder said it occurred only after the 1974 and 1975 events (the 1975 event was less than a 5% AEP).

- Approximately 75% of respondents had some sort of personal flood action plan which reflects the reasonably high flood awareness of Terara residents.

- Although the majority of residents were concerned about flooding, most did not think there was a risk to life.

- When questioned about the influence of flooding in their decision to move to Terara only two respondents claimed <u>not to know</u> about flooding in the area prior to moving.

- Under the “further comments” heading most concern was regarding flooding from local runoff and blocked drains (8 comments), filling of Pig Island (5), bank erosion (5) and closure of Terara Road during floods (5).

- Almost all residents of Terara consider themselves to have at least a medium level of flood awareness.

2.5.3 Terara Questionnaire (July 1998)

There were 32 responses from approximately 60 landowners.

- The average length of residency was 19 years (ranging from 50 to one year).
- Only four houses had experienced above floor inundation but 75% had experienced above yard inundation.
- Previous floods had caused residents to leave their houses (25%), move their car (34%), and miss work (31%).
- Only 19% had experienced a financial loss.
- 53% had received a flood warning, of these 82% considered the warning useful.
- Only 6% (2 respondents) felt that they suffered trauma resulting from flooding.
- All residents considered themselves flood aware with 56% having an action plan and 22% considering there was a risk to life.
- When asked to estimate the amount of warning time for a flood, 22% had no idea, 34% said 1 day, 9% said 12 hours, 13% estimated 6 hours and 19% less than 6 hours.

- 63% considered flooding was of concern and 25% considered it was not a concern (12% did not respond).
- All respondents considered some form of flood mitigation measures should be carried out. 69% saw dredging or enlarging Shoalhaven Heads as a priority and 66% favoured maintaining or raising the existing levee. Other measures suggested were better flood warning (41%), flood insurance (34%) and dredging of the river (31%).
- Nobody suggested raising their houses, with only one considering voluntary purchase and a few (13%) sealing of buildings. 16% suggested more flood information.
- Answers from the question concerning how deep the water would be in major floods is not reported as the majority of respondents did not answer.
- A number of additional comments were made including:
  - maintain/stabilise the river banks,
  - provide speed control for boats,
  - wave lap and wind action are more important factors contributing to erosion of the river bank than overtopping,
  - concern about dredging activities and the deposition of tailings on Pig Island,
  - clearing of local drains/Crookhaven River,
  - control sightseers during floods,
  - hydraulic impacts of raising the existing levee.

2.5.4 Public Meeting (October 1998)

The following issues (in no particular order) were raised by the residents during the course of the meeting (30 attendees).

- Trees on the river bank have fallen over as a result of being used to anchor the rope from the dredge, rather than undermining from wind/wave action.
- Local drainage problems in August 1998 resulted from failure (sticking open) of a non return valve on a pipe exiting to the river.
- More consideration should be given to try and prevent “sightseers” driving through inundated roads and causing excessive “wash” from their vehicles.
- Flood depth markers should be installed on Terara Road to assist in evacuation.
- Some form of temporary bank erosion works must be implemented, as soon as possible, to prevent further bank collapse and possible loss of the levee and houses. This situation is critical near the corner of West Berry Street and Southern Road.
- The SES should be provided with levels/times, etc., to assist with flood evacuation.
- More investigation should be undertaken on evacuation planning.
- The August 1998 flood reached 3.3m at the Nowra Bridge gauge.
- Would more trees on the river bank help?
- What is the hydraulic effect of the hole excavated by the existing dredge?
- Council has a policy of maintaining a “low” spot at the mouth to ensure that a flood can “blow” it out. Council has also sent bulldozers to open the mouth prior to the flood peak.
- What about closing Berry’s Canal so as to try and divert water through Shoalhaven Heads?

- By how much should houses be raised?
- What are the solutions for local drainage?

All of these comments, and others not listed, have been considered in developing management strategies.

3. EXISTING FLOOD PROBLEM

3.1 Flooding Mechanism

Flooding in Terara can result from one or both of:

- flow from the Shoalhaven River over the levee,
- backwater flooding from the floodplain (Worrigee Swamp) which initially occurs as a result of local runoff but in larger events is augmented by flow over the river bank elsewhere.

The relative significance of the two mechanisms depends on flow in the river, local rainfall and the height of the river bank levees.

3.2 Hydraulic Classification

The Floodplain Development Manual defines three hydraulic categories which can be applied to areas of the floodplain.

> "*Floodways* are those areas where a significant volume of water flows during floods. They are often aligned with obvious naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood flow, which may in turn adversely affect other areas. They are often, but not necessarily, the areas with deeper flow or areas where the higher velocities occur.
>
> *"Flood storage* areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas will rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.
>
> *"Flood fringe* is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels."

The hydraulic classification for the Terara area varies depending upon the distance from the river bank. Flood levels generally decrease from the river towards the south and velocities also decrease the further away from the river as shown in Table 4.

Table 4: Depths and Velocities

Flood Levels		River	Terara Village [1]	Worrigee Swamp [1]
5% AEP event	RL(mAHD)	4.7	3.6	LR
	depth (m)	n/a	0.2	LR
2% AEP event	RL(mAHD)	5.0	3.9	3.8
	depth (m)	n/a	0.5	1.3
1% AEP event	RL(mAHD)	5.4	4.7	4.5
	depth (m)	n/a	1.3	2.0
0.2% AEP event	RL(mAHD)	6.1	5.8	5.6
	depth (m)	n/a	2.4	3.1
Extreme event	RL(mAHD)	7.4	7.2	7.0
	depth (m)	n/a	3.8	4.5

(1) Depths at Terara and Worrigee Swamp are calculated for a typical ground levels of 3.4 mAHD and 2.5 mAHD respectively. The lowest level on Terara Road is 2.7mAHD.

LR Subject to inundation from local runoff which is not accurately simulated in the Cell Model.

n/a Not applicable.

Velocities (m/s)	River	Terara Road
5% AEP event	2.1	0.9
2% AEP event	2.4	0.7
1% AEP event	2.7	0.4
0.2% AEP event	3.0	0.6
Extreme event	3.0	0.8

Note: Velocities are the section average velocity at the peak level. Local velocities may be higher by up to three times.

There is no clear cut division between each category but land adjacent to the bank of the river is clearly floodway while further away, Worrigee Swamp is flood storage. On the basis of these results all land within the study area was considered to be floodway.

3.3 Flood Hazard Classification

Flood hazard is a measure of the overall adverse effects of flooding. It incorporates threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production.

Land is classified as either *low* or *high* hazard for a range of flood events. The classification is a qualitative assessment based on a number of factors as listed in Table 5.

Table 5: Hazard Classification

Criteria	Weight [1]	Comment
Size of the Flood	Medium	Up to a 10% AEP event there is no direct inundation from the Shoalhaven River. In the 5% AEP event the majority of the floodplain is inundated.
Flood Awareness of the Community	High	Based upon the results of the questionnaire.
Depth and Velocity of Floodwaters	High	Velocities will be high (over 2 m/s) near the river bank but will reduce to approximately 1 m/s across the floodplain. The depth of floodwaters is the main concern (refer Table 4).
Effective Warning and Evacuation Times	Medium	The existing ALERT system should provide adequate warning (Section 4.5.1).
Rate of Rise of Floodwaters	Low	Residents will be aware that the river is rising but may be surprised at how rapidly the floodplain becomes inundated following overtopping of the levee.
Duration of Flooding	Low	The duration of overtopping is of the order of 20 hours and the flood will generally have receded in approximately two days.
Evacuation Difficulties	High	These are likely to be high on account of: • the distance to high ground (two kilometres to Nowra), • there is only one evacuation route along Terara Road, • Terara Road is inundated by up to 0.9 m in a 5% AEP event and 2 m in a 1% AEP event with peak velocities of up to 1 m/s, • the emergency services (SES, Police) will be “stretched” answering calls throughout the area.
Effective Flood Access	High	The access route (Terara Road) is a sealed road and presents no unexpected hazard but it will only be passable for vehicular traffic up to approximately a 10% AEP event and there is no pedestrian access route.
Additional Concerns such as Bank Erosion, Debris, Wind Wave Action	High	There are likely to be a number of additional concerns which will increase the potential hazard. Probably the most significant is bank collapse, as occurred in the floods of 1860 and 1870. Debris and wind wave action will also cause damage to structures and increase the risk to life.

Note 1: Relative weighting.

Based upon the above, the flood hazard classification is low for flood events less than a 5% AEP event and high for larger events.

3.4 Flood Damages

The cost of flood damages and the extent of the disruption to the community depends upon many factors including:

- the magnitude (depth, velocity and duration) of the flood,
- land usage and susceptibility to damage,
- awareness of the community to flooding,
- effective warning time,
- the availability of an evacuation plan or damage minimisation program,
- physical factors such as erosion of the river bank, flood borne debris, sedimentation.

Flood damages can be defined as being "tangible" or "intangible". Tangible damages are those for which a monetary value can be assigned, in contrast to intangible damages, which cannot easily be attributed a monetary value. A summary of the types of damages with details of how the costs were calculated for this study is provided in Appendix A.

Table 6 indicates the number of residential buildings likely to be flooded in various events and shows the corresponding tangible damages. Likely damages to public utilities are provided in Appendix A. No allowance has been made for losses through bank collapse or complete destruction of buildings.

Table 6: Terara Village - Damage to Residential Buildings

Flood	Buildings Inundated	Tangible Damages ($1999)
Extreme	55	2 000 000 *
0.2%	52	1 800 000 *
0.5%	51	1 500 000 *
1%	44	1 000 000 *
2%	13	200 000
5%	1	20 000
10%	Nil	Nil

Note: * Damages will be higher if buildings are completely destroyed.

While the total likely damages figure in a given flood (as shown on Table 6) is useful to get a "feel" for the magnitude of the flood problem, it is of little value for economic evaluation. When considering the economic effectiveness of a proposed mitigation option, the key question is what are the total damages prevented over the life of the option? This is a function not only of the high damages which occur in large floods but also of the lesser but more frequent damages which occur in small floods.

The standard way of expressing flood damages is in terms of average annual damages. These are calculated by multiplying the damages that can occur in a given flood by the probability of the flood occurring in a given year and summing across the range of floods. By this means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods.

Based on Table 6, the average annual tangible damages (AAD) for Terara are estimated to be approximately $25 000 ($1999). This figure excludes damages to public property and intangible damages.

4. FLOODPLAIN MANAGEMENT MEASURES

4.1 Introduction

Measures which can be employed to mitigate flooding and reduce flood damages can be separated into three broad categories:

Flood modification measures modify the flood's physical behaviour (depth, velocity) and include flood mitigation dams, retarding basins, on-site detention, channel improvements, levees, floodways or catchment treatment.

Property modification measures modify land use including development controls. This is generally accomplished through such means as flood proofing (house raising or sealing entrances), planning and building regulations (zoning) or voluntary purchase.

Response modification measures modify the community's response to flood hazard by informing flood-affected property owners about the nature of flooding so that they can make informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

A number of the measures mentioned above were clearly not applicable to the situation at Terara and were deleted from consideration at an early stage of the study process. Section 4.2 briefly canvasses these. Measures which were subjected to more detailed consideration are discussed in Sections 4.3 to 4.5.

A number of methods are available for judging the relative merits of competing measures. The benefit/cost (B/C) approach has long been used to quantify the economic worth of each option on a relative basis enabling ranking against similar projects in other areas. The benefit/cost ratio is the ratio of the Net Present Worth of the reduction in flood damage (benefit) to the cost of the works. Generally the ratio expresses only the reduction in tangible damages as it is difficult to accurately include intangibles such as anxiety, risk to life, ill health and other social and environmental effects. In this study the reduction in tangible damages to public utilities has not been included.

The potential environmental or social impacts of any proposed flood mitigation works are of great concern to society and these cannot be evaluated using the classical benefit/cost approach. The public consultation program (Appendix B) has ensured that all identifiable social and environmental factors were considered in the decision making process.

4.2 Measures Not Considered Further

Early in the study a report was provided to the Floodplain Management Committee with a list of all possible floodplain management measures which could conceivably be applied in the study area. The measures were classified with regard to reduction in flood level, social effect, environmental impact, cost to implement and benefit/cost ratio.

The Committee identified a number of measures that were not worthy of further consideration. These are summarised in Table 7 and the following sections.

Table 7: Floodplain Management Measures Not Considered Further

Measure	Impact				
	Reduction in Flood Level	**Social Effect**	**Environ-mental Impact**	**Cost to Implement**	**Benefit/ Cost Ratio**
FLOOD MODIFICATION MEASURES:					
Flood Mitigation Dams etc.	Yes	Nil	Very High	Very High	Low
Floodways	Non Applicable	-	-	-	-
Catchment Treatment	Minimal	Nil	Low	Low	Nil
RESPONSE MODIFICATION MEASURES:					
Flood Insurance	Nil	Some	Nil	Not Available for Residential	

4.2.1 Flood Mitigation Dams, Retarding Basins, On-Site Detention

Special purpose flood mitigation dams, or dams which have significant flood storage capability, such as Burrendong Dam (approximately 1 million megalitres of flood storage), can significantly reduce downstream peak flood levels. However dams are extremely expensive and can generally only be justified for flood mitigation in economic terms if combined with a water supply or power generation capacity. Construction of large dams will also have a significant environmental effect and should be evaluated on a catchment wide basis.

Tallowa Dam was constructed in the early 1970's downstream of the Shoalhaven River/Kangaroo River confluence as part of the Shoalhaven Water Supply Scheme. The dam was constructed to maintain a water supply for Bendela Pumping Station and has an active storage capacity of approximately 36 000 megalitres. As the volumes of each of the 1974, 1975 and 1978 floods were in excess of 1 million megalitres, the mitigating capacity of the dam is negligible.

Stage 2 of the Water Supply Scheme would involve construction of a major dam at Welcome Reef, which could have a capacity in excess of 2 million megalitres. At this time there is no certainty that Welcome Reef Dam will be constructed, and even if it were built, it would only control 50% of the catchment to Nowra. Floods originating in the Kangaroo Valley or Yalwal Creek would be unaffected.

There is little opportunity for reducing flood peaks at Nowra or downstream by constructing new dams or upgrading existing dams. The flood mitigation benefits of Welcome Reef should be considered when evaluating the viability of the dam, but would be a minor component of the decision making process given its primary function.

Retarding basins and on-site stormwater detention systems are increasingly being used in developing catchments. Both these measures are appropriate for controlling flooding in small catchments (say up to 20 km^2) or to mitigate the effects of increased runoff caused by development. However, they would have a negligible impact on flood levels in the Shoalhaven River and are not appropriate for flood mitigation at Terara.

4.2.2 Floodways

Floodways are lower overbank areas which can carry significant flow in times of flood. In some instances, on smaller streams, an artificial floodway can be created in an environmentally sensitive manner to achieve reductions in upstream levels. However, given the size of the Shoalhaven floodplain, and the lack of a suitable location and the volume of water involved, artificial floodways are not viable here.

4.2.3 Catchment Treatment

Catchment treatment modifies the characteristics of the catchment to reduce runoff to the river. For an urban catchment, this involves planning to maximise the amount of pervious area, maintaining natural channels where practical and the use of on-site detention. For a rural catchment, this involves limiting deforestation or contour ploughing of hill slopes.

Again it is a measure which can be effective on small catchments but has negligible impact on the volumes of water involved in a Shoalhaven River flood. As a general concept, catchment treatment techniques should be encouraged along with water quality and erosion/sedimentation controls but these will not affect flooding at Terara.

4.2.4 Flood Insurance

Flood insurance (Reference 6) does not reduce flood damages but transforms the random sequence of losses into a regular series of payments. Many residents regard flood insurance as a preferred flood mitigation measure. At present, flood insurance is not readily available for houses, although it is available for some commercial and industrial properties. There are a number of potential implications with flood insurance, such as rebuilding in a floodway and these need to be addressed.

4.3 Flood Modification Measures

4.3.1 River Improvement Works

Description

River improvement works, such as desnagging or removal of hydraulic restrictions, reduce flood levels by increasing the hydraulic capacity of the river. Dredging could also improve the hydraulic capacity by increasing the inbank flow area.

Discussion

Desnagging and removal of vegetation may reduce flood levels on small creeks but would provide negligible benefit on the Shoalhaven. Vegetation removal is likely to destabilise the banks. Realignment or reconstruction of the channel and removal of hydraulic restrictions such as the islands (Pig, Numbaa, Old Man) were considered but rejected due to:

- high cost,
- land ownership and compensation issues,
- likely impact on the erosional and sedimentation regime,
- unlikely to be sustainable (i.e. will require ongoing maintenance dredging),
- environmental concerns,
- bank stability concerns,
- loss of agricultural land.

"Terara Sand and Gravel" has operated a dredge since 1992 to extract approximately 35 000 m^3 (or 50 000 tonnes) per annum. Currently the dredge only works within a limited area upstream of the village and provides minimal hydraulic benefit as it creates localised holes rather than reducing the bed level by a uniform amount over a large distance.

The hydraulic model was used to evaluate the effect of increasing the dredged area to enable a reduction in the general bed level. Three scenarios were analysed for both the 5% and the 1% AEP events.

Scenario A - 260 000 m^3 removed,
Scenario B - 550 000 m^3 removed,
Scenario C - 1 000 000 m^3 removed.

Dredging was assumed to extend over a 4.5 km length of the river from approximately midway along the Riverview Road levee to approximately midway between Pig Island and Numbaa Island. The resulting changes in peak flood level are shown in Table 8. The indicated reductions in flood level will have an insignificant effect on the flood hazard at Terara. Dredging further upstream or downstream would have no additional benefit.

Table 8: Dredging - Reduction in Flood Level (m)

Dredging Scenario	A		B		C	
Location/Flood	**1%**	**5%**	**1%**	**5%**	**1%**	**5%**
Terara	0.02	*	0.03	*	0.07	*
Pig Island	0.02	0.02	0.04	0.04	0.07	0.08
Ferry Lane	0.03	0.03	0.06	0.06	0.11	0.12

NOTE: * values are not provided for the 5% AEP event at Terara as the land is only just inundated at this level and the peak levels relate more to local drainage, or backwater levels in the swamp than the river levels.

The cost of dredging largely depends on the size of the dredge and the land-based operation. An indicative range is $8/m^3 to $10/m^3. Assuming $9/m^3 the scenario costs would be:

- Scenario A - $2.3 million,
- Scenario B - $5.0 million,
- Scenario C - $9.0 million.

On top of these costs there is currently a royalty of $1.20/m^3, although this might be renegotiated if the work was solely for flood mitigation purposes with no financial gain.

A preliminary estimate of the present worth of the reduction in annual average damages for Scenario B is only $1 600, which implies a very low B/C ratio unless the material removed has commercial value.

Potential use of the extracted material depends on the quality of the material and the local market. The existing dredge operation provides sand for local concrete manufacturing and filling at approximately $12/m^3 to $20/m^3. Preliminary investigation suggests that decreasing the price will not significantly increase demand. In fact the current operator adjusts the extraction rate to meet the demand and could easily produce up to twice the current volume of material. Most of the material removed in the three scenarios would, therefore, not find a market and disposal sites would need to be found. This would add to the economic cost and also have significant environmental implications.

A dredging operation normally extracts approximately 30% solids and 70% liquid, and legislation requires that the liquid be settled before returning to the river. The present operator uses a trench on Pig Island for settling but this is already a source of contention and preliminary investigations suggest that this issue will be a significant problem for a larger operator.

Dredging is an extractive industry and requires an EIS to be prepared as part of the approval process. An EIS would cost of the order of $100 000 and would require an evaluation of a range of environmental and social issues.

Further investigation would also be required to determine the long term effectiveness of dredging. It is possible that a subsequent flood would simply deposit material in the dredged area, thus negating the benefit. There is also the possibility that large scale dredging may induce local bank failure as a result of affecting the sedimentation/erosional regime of the area.

Conclusions

Large scale dredging will marginally reduce flood levels but will not greatly affect the inundation of buildings in large floods. It is not an effective floodplain management measure as it provides only marginal hydraulic benefit, is not economically viable and would raise significant environmental concerns.

4.3.2 Shoalhaven Heads Entrance

Description

The entrance at Shoalhaven Heads has closed on a number of occasions since the construction of Berry's Cut in 1822. It experiences rapid closure between flood events by shoaling of the entrance due to coastal processes. More recently the entrance was closed from late 1980 until it opened during the April 1988 flood. The entrance closed again in September 1989 and subsequently opened during the August 1990 flood (possibly it opened again between 1990 and 1998). The entrance opened in August 1998, closed in January 1999 and opened again in October 1999.

Floods are the only mechanism which open the entrance and the length of opening is related to the subsequent river flow and coastal and estuarine processes. Not all floods result in the entrance opening.

Some residents believe that providing a permanently open entrance will lead to significant reductions in flood levels in the vicinity of Terara.

Discussion

In the Flood Study (Reference 2) two entrance scenarios were examined for the design floods:

- *Closed* - as existed prior to the April 1988 flood with a beach dune at 2 mAHD and the flats behind the dune at 0 mAHD. This dune scoured during the passage of the flood.
- *Open* - the entrance was assumed to be a rectangular opening 400 m wide with an invert at -2 mAHD. This is the likely maximum size of channel and would only occur following a major flood.

The Flood Study adopted the *entrance closed* scenario for design but also considered the impacts on flood behaviour of assuming an *entrance open* condition. The scenarios were modelled for the 1% and 5% AEP floods and various ocean levels. The results are reproduced in Table 9:

Table 9: Impacts of Entrance Conditions at Shoalhaven Heads (mAHD)

Condition	**Shoalhaven River at Terara**		**Shoalhaven Heads**	
	5% AEP	**1% AEP**	**5% AEP**	**1% AEP**
Entrance Closed with Elevated Ocean	4.68	5.43	2.60	3.23
Entrance Open with Elevated Ocean	4.67	5.41	2.18	2.65

The table indicates that an open entrance will slightly decrease the 5% and 1% AEP levels adjoining Terara (by up to 0.02 m).

A number of other investigations (References 7 to 12) have examined the feasibility of a permanent ocean entrance at Shoalhaven Heads. Overall it would appear that the disadvantages of having a permanent entrance outweigh the advantages. Council has a policy of maintaining a low level beach berm at the Shoalhaven Heads entrance. When a flood occurs in future the beach berm will be quickly overtopped and the floodwaters will scour out the entrance. Council has also provided equipment in the past to "open" the dunes if sufficient warning is available and unsuccessfully trialed a "wet notch" in 1995/96.

Conclusions

Maintenance of an open entrance at Shoalhaven Heads would marginally reduce 1% AEP flood levels in the vicinity of Terara. The impacts would be small, and a permanent open entrance cannot be justified solely on the grounds of reducing flood levels at Terara.

4.3.3 Local Drainage

Description

Both residents and the SES have reported that on several occasions roads, in particular Terara Road, and (possibly) buildings have been flooded by local runoff without the river bank being overtopped.

The catchment area of the Worrigee Swamp to Millbank Road and Greenwell Point Road is approximately eight square kilometres and drains to Crookhaven Creek. The channel of Crookhaven Creek is not well defined in parts and consists of shallow overgrown depressions. A major flood mitigation drain with a flap gated culvert is located immediately east of the Shoalhaven Caravan Park and will remove water from Worrigee Swamp behind the village. Intense rainfall over the area causes ponding in the low areas and consequently inundation of the roads. This can occur on average twice a year.

Discussion

Flooding from local drainage occurs more frequently than overbank flooding but it is not a significant threat as:

- the floodwaters only pond to a low level before they "escape" to Crookhaven Creek across Millbank Road,
- the depth and velocity are low,
- it is caused by relatively short duration intense rainfall over the Nowra/Terara districts. Inhabitants would generally be aware that significant rainfall has occurred and should not be "caught unaware",
- the roads are generally still trafficable to most vehicles under these conditions.

Some residents believe that installation of flap gated culverts within the township of Terara would ensure that local runoff quickly drains away. The estimated cost to construct these culverts ranges from $2 000 to $10 000 per culvert depending upon the type of flap gate. The main problems with providing flap gates are:

- they are difficult to maintain and may get “stuck” open. The risk is reduced if the more expensive “duck bill” type flap gates are installed,
- they represent a breach in the river bank levee and may be points of scour during a flood.

Cleaning out of the local drains has also been suggested as a possible solution.

Conclusions

Local flooding is not a threat to property or lives but causes inconvenience and disruption in the area. The drains are maintained by Council and their effectiveness is largely determined by the operation of the floodgates and downstream river levels. Consideration could be given to undertaking a review of drainage from the Swamp taking into account the acid sulfate soil potential. Input from the residents, the SES and Council officers, the Department of Agriculture, Fisheries and Land and Water Conservation would be required to identify the problem areas and the solutions. An indicative cost for these works would be up to $10 000 per annum. Low points in Terara Road could also be raised to improve access during local flood events. As the benefits are largely intangible a benefit cost ratio has not been determined.

This is a local drainage issue rather than flooding from the Shoalhaven River. Further investigation is a matter for Council and the local community.

4.3.4 Levees

Description

A levee was built along the southern bank of the Shoalhaven River from Nowra Bridge to Terara in the mid 1970's. Following the floods in the 1970's, the height of the levee at Terara was increased to its present level. Previously the crest was probably only 0.5 m above the adjacent natural ground surface. In 1986 the levee from Nowra Bridge to Ferry Lane (the Riverview Road Levee) was increased to the 1% AEP flood level, approximately 2 m above the adjacent natural ground surface. The adequacy of the present levee, and possible measures to upgrade protection to Terara, were considered as part of this study.

Discussion

The benefits of levees in floodplain management have long been recognised, however in recent years a number of significant disbenefits have also become apparent.

They are expensive, for example the Riverview Road Levee cost approximately $600/m length in 1986. A levee to exclude large floods from Terara would need to be up to 2 m high and would effectively visually separate the village from the river. It would also require a large "footprint" of land (up to 20 m wide) which is not available in some places. An alternative structure, such as a concrete wall, would be even more visually intrusive. As an additional issue, the stability of the river bank poses a serious concern for the stability of any structure that might be built along it.

Increasing flood protection for Terara would marginally increase levels in the river and may deflect flows towards the north bank near the Paper Mill.

Unless the levee was raised to the PMF level, which would be unacceptable both economically and socially, it would eventually be overtopped in a very large flood event. When this inevitably happened, initial velocities would be high and substantial flood damages would occur. Failure of the levee may also occur during a flood event, prior to overtopping. The situation would probably be exacerbated if the levee engendered a false sense of security in the local population and substantially lowered flood awareness. This was one of the contributing factors to the flood damages in Nyngan in 1990.

Raising of the levee may also lead to pressure to alter Council's Flood Policy and allow further development. Previous reports on flooding at Riverview Road considered that levees should only be used to protect existing dwellings and should not be promoted to facilitate further development on the floodplain.

With these reservations in mind, three possible levee upgrades were considered.

Levee Linking Riverview Road to Terara

A levee on the southern bank of the Shoalhaven River to the 0.5% AEP flood level from Ferry Lane to downstream of Terara would cost approximately $2 million, giving an indicative B/C ratio of less than 0.1 (not including the benefit to agricultural users). It would prevent overbank flooding up to the design level but would not prevent backwater flooding from the swamp or from local rainfall. There would be concerns about the environmental impact, the loss of river views and the potential hydraulic impacts elsewhere on the floodplain.

Ring Levee

A ring levee around the majority of the buildings in Terara could be used to enclose the area generally bounded by West Berry Street, Bryant Street, Terara Road and Nobblers Lane. It could be extended to include the building to the east of Bryant Street, the three buildings at the corner of Millbank Road and Terara Road, and the two buildings west of Nobblers Lane.

The proposed route would enclose 34 buildings out of 55 in the local area and the embankment would need to be up to 2m high and approximately 1800 m long. An indicative material and construction cost would be $0.9 million (assuming a cost of $500/metre length) but the cost could increase significantly depending on the availability of fill material. There would be additional costs for internal drainage works, landtake, roadworks and provision of road access across the levee and possible resumption of buildings. An indicative cost for these items would be $0.5 million giving a total cost of $1.4 million giving a B/C ratio of 0.13.

Again there would be significant environmental issues to be resolved and the fragile nature of the riverbank foundations to be overcome.

Terara - Upgrade and Maintain Existing Levee

The existing levee has a number of low points (Figure 4) and is of doubtful structural stability as it was not designed to a high engineering standard. In parts the levee is narrow and built of unsuitable material which may lead to failure. It is also threatened by collapse of the river bank (Section 4.6.1).

Raising the levee above the general bank level elsewhere would provide no additional benefit as Terara would be outflanked by the floodwaters. However, there would be some benefit in the levee being slightly higher than elsewhere to reduce the high velocities which occur during overtopping. The village would then be inundated first by low velocity water from Worrigee Swamp. This would provide no significant reduction in tangible flood damages but would reduce the risk to life at the time of overtopping.

The levee presently prevents flooding from the river up to approximately a 10% AEP event (4.4 mAHD). The 5% AEP flood level is 4.7 mAHD and the 2% AEP is 5.0 mAHD. Raising the embankment to the 2% AEP level may be achievable without introducing significant social, economic and hydraulic concerns. An indicative cost would be $50 000.

The existing levee should be examined for structural integrity, any defects rectified, and any low points filled in to provide a consistent level of protection and limit the possibility of localised scouring. Because of the relatively small scale of upgrading works, they should not affect the hydraulic impacts, or present serious social or environmental consequences. An essential component of any levee raising/upgrading work would be to consider the threat to the levee from bank erosion.

Conclusions
A number of levee options were considered for Terara but most involve high economic cost and significant environmental and social concerns. The most viable option is to upgrade the existing levee to ensure its structural integrity and remove any low points. This could also involve a modest increase in height. Any work would need to take account of the present state of the riverbank and funding issues would need to be resolved. In the first instance detailed survey would be required, as well as a geotechnical assessment of the existing embankment/river bank and consideration of the bank erosion/collapse issues discussed in Section 4.6.1.

4.4 Property Modification Measures

4.4.1 Voluntary Purchase

Description
Voluntary purchase of the entire village cannot be economically or socially justified but could be used as a long term strategy to reduce the number of flood liable properties.

Discussion
Voluntary purchase is not favoured by a large part of the community. Among their concerns are:
- it can be difficult to establish a fair market value,
- in many cases residents may not wish to move for a reasonable purchase price,
- progressive removal of properties may impose stress on the social fabric of the area,
- it may be difficult to find alternative equivalent priced housing in the nearby area with similar aesthetic values.

The special heritage status of Terara also needs to be considered. Purchased buildings could not be demolished and it would be impractical to leave them unoccupied as they would steadily deteriorate over time.

Conclusions
Despite the reservations listed above, voluntary purchase could be considered as a long term means of reducing the number of flood liable buildings in Terara. This may be appropriate when buildings reach the end of their useful life or for heritage listed buildings when their heritage qualities are lost or cannot be maintained (fire, storm damage). A detailed strategy would be required to reduce social disruption and recognise the special heritage status of the village.

4.4.2 House Raising

Description

House raising costs approximately $40 000 per house and is suitable for most non-brick single storey buildings on piers.

Discussion

This measure could be applicable to approximately 20 buildings in the study area. The benefit/cost ratio varies for each building depending on the floor level and the relative height of flooding, but a typical ratio is 0.4. This is relatively low because buildings in Terara are not generally flooded until a 5% AEP event.

The questionnaire showed a low level of acceptance for house raising. Again the heritage status of Terara is an issue as the general nature of the village and individual streetscapes would be significantly impacted. House raising would not significantly reduce the flood hazard in the area, and may in fact encourage residents to stay with their house rather than be evacuated when a major flood is predicted.

Conclusions

This measure could be considered further but social and heritage issues would seem to make it unacceptable.

4.4.3 Flood Proofing

Description

Flood proofing involves the sealing of entrances, windows, vents, etc., to prevent or limit the ingress of floodwaters. It is only suitable for brick buildings with concrete floors and can prevent ingress for outside depths up to approximately one metre. Greater depths may cause collapse of the structure unless water is allowed to enter. An existing house could be sealed for approximately $10 000 while the cost for new houses or extensions would be much less. Approximately eight buildings in Terara may be suitable for flood proofing.

Discussion

This measure is rarely used in NSW for residential buildings and is more suited to commercial premises where there are only one or two entrances and maintenance and operation procedures can be better enforced.

Flood proofing requires sealing of doors (new frame, seal and door); sealing and re-routing of ventilation gaps in brickwork; sealing of all underfloor entrances and checking of brickwork to ensure that there are no gaps or weaknesses in the mortar.

It will not reduce the flood hazard and may increase the hazard if residents stay in their houses and a large flood eventually inundates the building. A typical benefit/cost ratio is 1.3 and there are no significant environmental or social problems.

Conclusions

This measure has a higher B/C ratio than house raising and should be investigated further. Preliminary work would include detailed inspection of buildings and interviews with the residents.

4.4.4 Planning Considerations

Description

Terara is categorised as a high hazard floodway with the May 1985 LEP restricting further development through the application of a Rural 1(g) zone. Any further residential development (where not assessed with agriculture) within this area is not permitted as:

- it will provide an unacceptable level of risk to life and property,
- it will increase the burden on the rescue services (more equipment and personnel required and increase in their level of risk),
- there is building land nearby which provides a similar level of amenity without the risk of flooding,
- evacuation from the area is hazardous and there are no means of significantly reducing the level of risk,
- bank erosion has occurred in the past and may occur in the future.

Extension and improvements to the existing buildings are currently permitted if the floor levels of habitable rooms are above the Minimum Floor Level (1% AEP level + freeboard). Extensions where the floor level is below the MFL are permitted up to 50 m^2.

Property owners have existing use rights which allow them to carry out reasonable extensions to their houses as well as replacement of their houses. These rights are attached to the properties and automatically transferred to any new owner.

New development, where assessed with agriculture, is permitted as long as it meets the necessary requirements. This can be justified as:

- it is necessary to support agricultural development on the floodplain,
- the agricultural sector is likely to be more aware of a developing flood situation than the urban sector,
- tractors and other vehicles (four wheel drives) are generally available for flood evacuation.

Development associated with the local school is permitted, however in the long term the school should be relocated.

Discussion

Appropriate planning restrictions involve consideration of the social, economic, environmental and risk to life and limb consequences associated with the occurrence and mitigation of floods of various sizes. This involves trading off the various benefits of reducing the impact of flooding on development against the costs of restricting land use in flood prone areas and of implementing management measures.

Issues to be considered in planning are shown in Table10.

Table 10: Flood Related Issues Considered in Planning

ISSUE	COMMENT
Flood Behaviour up to the PMF	Depth, velocity. Change in behaviour over the full range of events.
Existing Flood Standard	Is it accepted by the community? How significant will any change be?
Land Use	Existing and potential. How will this be affected?
Availability of Land	Is there other land suitable for development in the area?
Impact of Floodplain Management Strategies	How will these impact upon existing and future development?
Land Values and Social Equity	Will changes affect other land owners?
Impact of Future Flooding	On existing and future development.
Impact of Future Development	On flood behaviour.
Resulting Change in Flood Damages	Percentage and absolute change.
Consequences of Larger Floods	Up to the PMF.
Flood Awareness and Preparedness of the Community	Present community. In the future.
False Sense of Security	Will this be created?
Flood Warning/Flood Evacuation	Effectiveness of emergency response.
Environmental and Ecological Issues	Will these be affected? Streetscape.
Duty of Care	How has this been taken into account?

The primary objective of the NSW Government Flood Policy is *to reduce the impact of flooding and flood liability on individual owners and occupiers, and to reduce private and public losses resulting from flooding*.

This present study has identified the study area as high hazard area and has examined a range of floodplain management measures to reduce the hazard. No viable flood modification measures are available, and whilst the response modification measures will reduce flood damages, they do not provide a long term solution to the problem. Voluntary purchase of the entire area cannot be socially or environmentally justified (Section 4.4.1).

Planning regulations offer the only long term solution by prohibiting further residential development unless assessed with agriculture and encouraging the gradual reduction in the residential population.

Conclusions

A review of the above considerations supports the present zoning and development restrictions. Wording on the 149 Certificate adequately conveys the policies of Council. The issues for the entire study area could be formalised in Council's Flood Policy as set out below.

- **Future Development**

Council has rejected all applications for new residential buildings (where not assessed with agriculture) on vacant lots within the study area since introduction of the LEP in May 1985 in accordance with the restrictions of use within the 1(g) zone. Prior to the LEP Council also rejected new dwelling applications as far back as 1978 on flooding grounds.

Currently (1999) there are five lots where the owners have made an enquiry with Council regarding an application for residential development. Council has advised that there is no information (existing uses right, provisional approval, etc.) which in Council's opinion makes these lots different to any other lots within the village. The results of this study support the objectives of the 1(g) zone including that there should be no further residential development.

- **Existing Development**

Continuation of the existing use right provision means that the number of buildings and residents (and level of damage and hazard) within the study area will probably not reduce under the existing planning framework. However, it is possible that this will occur through natural attrition in the medium to long term. Council should ensure that, as far as possible, any gradual reduction in the population occurs in a manner which takes into account the social and heritage values of the residents and the area as well as the flood hazard.

Table 11 indicates the proposed changes to Council's Flood Policy.

Table 11: Proposed Changes to Council Flood Policy

REQUIREMENTS	EXTENSIONS/ALTERATIONS TO EXISTING RESIDENTIAL DEVELOPMENT
Floor Level	To be considered on its merits to a maximum of 50 m^2 if the floor is below the 1% AEP + 0.5 m level or 100 m^2 if above. This is to include the total area of extensions since March 1999.
Building Components	To be considered on its merits.
Structural Soundness	To be considered on its merits.
Impact upon Others	Not to be considered unless the works are greater than 100 m^2 in area.
Flood Evacuation	No additional works required.
Flood Awareness	Approval will only be provided if the owners have measures in place which demonstrate their commitment to increased flood awareness (signs, literature available, evacuation plan).
REQUIREMENTS	**NEW RESIDENTIAL BUILDINGS WHERE ASSESSED WITH AGRICULTURE**
Floor Level	1% AEP level plus a 0.5 m freeboard
Location	Development in a Floodway will only be permitted if it can be shown that there is no other viable alternative. Further consideration would then need to be made regarding the specific location of the development.
Building Components	The proponent should demonstrate that where possible all building components are designed to withstand inundation up to the 1% AEP +0.5 m level with minimal affectation.
Structural Soundness	The structural integrity of the completed works to withstand water and debris damage up to the 0.2% AEP (1 in 500y) is to be certified by a professional structural engineer.
Impact upon Others	Not to be considered unless the works are greater than 250 m^2 in area.
Flood Evacuation	Any new development will require that the owners advise the SES of their development and evacuation requirements.
Flood Awareness	Approval will only be provided if the owners have measures in place which demonstrate their commitment to increased flood awareness (signs, literature available, preparation of an Evacuation Plan).
Other Issues	A report is required from the Department of Agriculture to confirm the economic viability of the agricultural enterprise. A number of other planning issues are required to be addressed including the relationship of the dwelling to the agricultural activity.
REQUIREMENTS	**COMMUNITY SERVICES (schools)**
Floor Level	To be considered on its merits, preferably at the 1% AEP level plus a 0.5 m freeboard
Location	Not to be located in a Floodway.
Building Components	The proponent should demonstrate that where possible all building components are designed to withstand inundation up to the 1% AEP +0.5 m level with minimal affectation.
Structural Soundness	The structural integrity of the completed works to withstand water and debris damage up to the 0.2% AEP (1 in 500y) is to be certified by a professional structural engineer.
Impact upon Others	Not to be considered unless the works are greater than 250 m^2 in area.
Flood Evacuation	Any new development will require that the owners advise the SES of their development and evacuation requirements.
Flood Awareness	A Flood Awareness Plan must be prepared by the developer to the satisfaction of the Floodplain Management Committee. This will document what actions are to be taken in a flood (Evacuation Plan) and what measures have been adopted to heighten flood awareness (Awareness Plan).

4.5 Response Modification Measures

4.5.1 Flood Warning

Description

Flood warning, and the implementation of evacuation procedures by the State Emergency Services (SES), are widely used throughout NSW to reduce flood damages and protect lives. The Bureau of Meteorology (BOM) is responsible for flood warnings on major river systems such as the Shoalhaven River. A flood warning system is usually based on stations which automatically record rainfall or river levels at upstream locations and telemeter the information to a central location. Alternatively this type of information can be relayed manually.

Adequate flood warning gives residents time to move goods, stock and vehicles above the reach of floodwaters and to evacuate from the area. The effectiveness of a flood warning scheme depends on:

- the maximum potential warning time before the onset of flooding.
- the actual warning time provided before the onset of flooding. This depends on the adequacy of the information gathering network and the skill and knowledge of the operators.
- the flood awareness of the community responding to a warning.

Studies have shown that flood warning systems generally have high benefit/cost ratios if sufficient warning time is provided. Even with an effective flood warning system, some tangible and intangible flood damages will still occur.

Discussion

An ALERT system (Automated Local Evaluation in Real Time) has been operated in the catchment by Shoalhaven City Council and the BOM since 1989. It cost $120 000 to install which was shared between the two authorities. It consists of 15 rain and eight stream sensor stations and a number of repeater stations. The system has not been tested in a large flood but performed successfully in smaller events in the 1990's. Some operational problems (radio interference, battery life, software problems) have occurred but these have now been resolved.

Although Council monitors the situation during flood events the responsibility for preparing regional flood warning rests with the BOM. Based on this information the SES issues community level warnings. Council does not issue warnings but assists the SES with road closures and evacuations. Council uses the ALERT system to provide information to the SES for events below the minimum level at which the BOM issues warnings.

Council does not have a facility to forecast flood levels but is currently investigating this matter. If Council had its own forecasting model it would provide additional benefits such as:

- it would act as a fall back system if the BOM system failed,
- it may assist in minor and local flooding situations not monitored by the BOM,
- Council may wish to take action to protect its assets based upon its own forecasting rather than waiting for the official BOM warning.

The main improvement that could be made to the existing system is the use of computer based models to generate real time flow estimates and (ultimately) flood levels. Installation of an automatic gauge at Terara would also improve forecasting as well as a staff gauge at Grassy Gully.

Conclusions

The ALERT system is a suitable approach for providing flood warning advice for the Shoalhaven River. The system should be continually monitored and upgraded as required. More sophisticated computer modelling, installation of gauges at Terara and Grassy Gully and rectification of the minor existing system problems are the main limitations of the present system. Council should also prepare a Flood Warning Manual to ensure that the existing knowledge held by current Council and SES staff is adequately documented.

4.5.2 Evacuation Planning

Description

A comprehensive Local Flood Plan was prepared by the SES in November 1996. It includes sections on:

- Flood preparedness, including:
    - public education,
    - activation,
    - flood intelligence,
    - warnings.

- Response, including:
    - control,
    - operations centre,
    - liaison,
    - communications,
    - information,
    - road control,
    - flood rescue,
    - evacuation,
    - logistics and re-supply,
    - stranded travellers.
- Recovery, including:

- welfare,
- registration and inquiry,
- all clear,
- recovery co-ordination,
- debrief.

Discussion

The effectiveness of the Plan to evacuate Terara has not been tested. The main problems with all flood evacuations are:

- they must be carried out quickly and efficiently,
- they are hazardous for both the rescuers and the evacuees,
- residents are generally reluctant to leave their homes, causing delays and placing more stress on the rescuers,
- evacuation routes may be cut some distance from the village and people do not appreciate the danger.

At Terara the last point is critical as shown on Table 12 and the present Plan should specifically address the issue.

Table 12: Rates of Rise - 1% AEP Design Flood

Elapsed Time from Start of Levee Overtopping (h)	Levels (mAHD)			Comment
	Nowra Bridge	River at Terara	Terara Village	
-3.0	3.0	2.9	-	Local rain may have already inundated parts of Terara Road.
-1.5	4.0	3.6	-	
-1.0	4.5	4.0	-	
0.0	4.9	4.4	-	Start of overtopping of river bank.
1.5	5.6	4.8	3.6	Parts of Terara Road are up to 1m deep.
4.0	6.2	5.3	4.0	Majority of Terara Road over 0.8m deep.
8.0	6.3	5.4	4.6	Peak.
20.0	4.7	4.4	3.6	End of overtopping of river bank.

Table 12 is based on an idealised design flood hydrograph. The times may vary considerably in practice.

As part of this study, discussions were held with the SES and Council to review the effectiveness of the Flood Plan and to provide recommendations for further enhancement. Key areas where improvements are possible include details on:

- when and where evacuation routes are cut,
- the number of buildings affected at various flood heights,
- road closures,
- the potential for bank erosion/collapse.

Another issue of concern to many residents is damage caused by the wash from sightseer's vehicles travelling along the roads. This is alleged to have flooded some houses in the 1970's which would otherwise have remained dry.

At present the Plan only covers floods up to the 1% AEP event. Larger events up to the extreme or Probable Maximum Flood must be considered as these pose the greatest risk to life.
There is no section of the Plan dealing specifically with Terara and its environs. Possibly a section should be included detailing the particular requirements of the village.

Conclusions

The Plan should be updated to provide information on the extreme flood as provided in the 1990 Flood Study and the 0.2% and 0.5% AEP events. The Plan states that *no urban community is likely to require complete evacuation*. This is untrue in an extreme flood (or even a 1% AEP event) at Terara.

Floor level data contained in this Floodplain Management Study (Appendix D) should be provided to the SES to enable officers to accurately determine which houses require evacuation. These details can be linked to Council's GIS database to provide a map of the affected properties.

A special section on Terara should be included in the Plan. This would clearly identify the flood hazard, the potential for bank erosion and the need for early evacuation. The need to control sightseers would also be noted. (Council staff could be provided to direct traffic.) Proposed improvements to the evacuation route (Terara Road) are provided in Section 4.6.2.

Appendices A, B and C of the Flood Plan should be upgraded to include the current maps and data sheets.

4.5.3 Flood Awareness and Preparedness

Description

The success of any flood warning system depends on:

Flood Awareness: How aware is the community to the threat of flooding? Has it been adequately informed and educated?

Flood Preparedness: How prepared is the community to react to the threat? Do they (or the SES) have damage minimisation strategies (such as sand bags, raising possessions) which can be implemented?

Flood Evacuation: How prepared are the authorities and the evacuees to evacuate households to minimise damages and the potential risk to life? How will the evacuation be done, where will the evacuees be moved to?

Discussion

A community with high flood awareness will suffer less damage and disruption during and after a flood because people are aware of the potential of the situation and listen to official warnings on the radio and television. There is often a large, local, unofficial warning network which has developed over the years and residents know how to effectively respond to the warnings by raising goods, moving cars, lifting carpets, etc. Photographs and other non-replaceable items are generally put in safe places. Often residents have developed storage facilities, buildings, etc., which are flood compatible. The level of trauma or anxiety may be reduced as people have "survived" previous floods and know how to handle both the immediate emergency and the post flood rehabilitation phase in a calm and efficient manner.

The level of flood awareness within a community is difficult to evaluate. It will vary over time and depends on a number of factors including:

- *Frequency and impact of previous floods.* A major flood causing a high degree of flood damage in the previous few years will increase flood awareness. However if no floods have occurred, or there have been a number of small floods which cause little damage or inconvenience, then the level of flood awareness may be low.

- *History of residence.* Families who have owned properties for generations will have established a considerable depth of knowledge regarding flooding and a high level of flood awareness. A community which predominantly rents homes and stays for a short time will have a low level of flood awareness.

- *Whether an effective public awareness program has been implemented.*

For floodplain management to be effective it must become the responsibility of the whole community. A public consultation program was incorporated into this present study to involve the public and various organisations in the decision making process. An important part of the program was simply to inform the community that there is a flood problem. It is difficult to accurately assess the benefits of an awareness program but it is generally considered that the benefits far outweigh the costs. The perceived value of the information and level of awareness, diminishes as the time since the last flood increases. Some residents may oppose an awareness program because they consider it reduces the value of their properties.

A major hurdle is often convincing residents that large floods will occur in the future. At Terara this is made easier by reference to the large historical events of last century.

Conclusions

Based on feedback from the questionnaire, public meetings and general discussions, the residents of Terara have a medium to high level of flood awareness. Their level of preparedness is probably low to medium.

The SES has a medium to high level of awareness of the problem and the requirements necessary to effect evacuations. As the time since the last major flood (1978) increases, the direct experience of the SES units with historical floods will diminish. More consideration should be given to the problems of evacuating Terara, especially the need for early evacuation due to access problems.

A suitable Flood Awareness Program should be implemented using appropriate elements from Table 13. The details of the program and necessary follow up should be properly documented to ensure that they do not lapse with time.

Table 13: Flood Education Methods

Method	Comment
Letter/Pamphlet from Council	These may be sent (annually or bi-annually) with the rate notice or separately. A Council database of flood liable properties/addresses makes this a relatively inexpensive and effective measure. The pamphlet can inform residents of subsidies, changes to flood levels or any other relevant information.
School Project or Local Historical Society	This provides an excellent means of informing the younger generation about flooding. It may involve talks from various authorities and can be combined with water quality, estuary management, etc.
Displays at Council Offices, Library, Schools, Local Fairs	This is an inexpensive way of informing the community and may be combined with related displays.
Historical Flood Markers or Depth Indicators on Roads	Signs or marks can be prominently displayed in parks, on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators on roads advise drivers of potential hazard.
Articles in Local Newspapers	Ongoing articles in the newspapers will ensure that the problem is not forgotten. Historical features and remembrance of the anniversary of past events (1860, 1870) make good copy.
Collection of Data from Future Floods	Collection of data assists in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible. A Post-Flood Evaluation Program (Appendix E) documents the steps to be taken following a flood.
Notification of 149 Certificate Details	All property owners were notified that they were flood affected as part of the public consultation program. Future owners are advised during the property searches at the time of purchase through a 149 Part 5 Certificate.
Types of Information Available	A recurring problem is that new owners consider they were not adequately advised that their property was flood affected on the 149 Certificate during the purchase process. Council may wish to advise interested parties, when they inquire during the property purchase process, regarding flood information currently available, how it can be obtained and the cost.

Method	Comment
Establishment of a Flood Affectation Database	A database would provide information on (say) which houses require evacuation, which roads will be affected (or damaged) and cannot be used for rescue vehicles, which public structures will be affected (e.g. sewage pumps to be switched off, telephone or power cuts). This database should be reviewed after each flood event. It could be developed by various authorities (SES, Police, Council).
Flood Preparedness Program	Providing information to the community regarding flooding informs it of the problem. However, it does not necessarily adequately prepare people to react effectively to the problem. A Flood Preparedness Program would ensure that the community is adequately prepared. The SES would take a lead role in this.
Foster Community Ownership of the Problem	Flood damage in future events can be minimised if the community is aware of the problem and takes steps to find solutions. For example, Council should have a maintenance program to ensure that its drainage systems are regularly maintained. Residents have a responsibility to advise Council if they see a maintenance problem such as a blocked drain. This process can be linked to water quality or other water related issues including estuary management.

4.6 Other Issues

4.6.1 Bank Erosion

Description

The channel morphology study (Reference 5) describes historical erosion rates along the river based on surveys and aerial photographs. Terara itself has a history of bank erosion (see Appendix C). In the 1860 and 1870 floods over 50 hectares of land were lost near the village. In each of these floods the bank receded by 50 m to 100 m and a number of buildings were lost. Subsequently there has only been a minor retreat of the river bank in this vicinity.

Bank protection works have probably been in place at Terara since the last century. Currently there is a small, partial rock revetment wall which provides light to moderate protection. However, the river bank is extremely steep and potentially unstable. In areas the bank is heavily vegetated whilst in others it has been cleared to provide an uninhibited view across the river.

The possibility of further significant bank erosion cannot be dismissed and the potential impact on the village in future major floods needs to be carefully considered.

Discussion

The cost of bank erosion to the Terara community is impossible to accurately quantify. In the 1860 and 1870 floods, bank erosion, as opposed to inundation by floodwaters, was probably the most significant factor contributing to damage. In subsequent floods bank erosion would appear not to have been a major factor.

The extent of bank erosion is not necessarily linked to the magnitude of the flood and may even occur at non-flood times. The 1860 and 1978 floods appear to have reached similar levels at

Terara and Nowra Bridge yet there was no significant damage to the bank in 1978. While 1860 and 1870 were both large events, serious erosion could still occur in a quite small flood given appropriate conditions.

The estimate of average annual damages (Section 3.4) has not taken account of the effects of bank erosion, and a rigorous analysis of this problem is outside the scope of this study. Nevertheless it is reasonable to infer that in moderate to large floods, bank erosion could be a significant problem. If it does occur during a flood there will be a significant increase in the risk to life, particularly if residents remain with their properties.

Inspections of the river bank at Terara in 1993 and 1998 revealed that:

- there is evidence of recent slumping outside No. 1 Nobblers Lane, and the bank is now within 15m of the house,
- in places the stone revetment wall, probably constructed over 50 years ago, is a pile of rocks some 10 m away from the present river bank,
- the bank has been “protected” on many occasions by local residents using building rubble and vehicle tyres,
- in parts, large trees on the bank have fallen into the river (or may have been pulled out as a result of being used as an anchor point) causing localised areas of erosion,
- in other places large trees are perched precariously on top of near vertical banks. If these trees fall their root system may take a considerable section of land with them,
- in many places the bank is being undercut producing a near vertical bank which ultimately will slump. This is due to ongoing tidal and wind and wave action not as a result of recent floods,
- near the end of Southern Road a fairly recent slump has removed part of the levee bank.

Conclusions

Bank erosion can be controlled to some extent by extensive and costly river bank works and many small scale attempts at this have been made over the years at Terara. From an economic viewpoint major works are unlikely to be cost effective and could ultimately be ineffective. It would appear that there is a high likelihood that bank retreat may cause the loss of significant areas either over a period of years through tidal wind and wave action, or quite rapidly as a result of a major flood.

There is little that can be done to prevent erosion during a flood, but the impacts of tidal wind and wave action can be reduced by rock protection or re-vegetation in the inter-tidal zone. This issue should be considered further by Council’s Estuary Management Committee and should include the possibility of a set back for development from the river bank. A consistent treatment for the bank should also be incorporated in any assessment. It is essential that some physical measures be implemented as soon as possible to minimise further bank loss.

4.6.2 Raising Terara Road

Description

The sole evacuation route from Terara is along Terara Road to Nowra. The road can be flooded by local rainfall and will be quickly inundated in a flood which overtops the river bank (about a 10% AEP or greater event). Survey of the road indicates that the lowest point is at 2.7 mAHD approximately 300 m east of Ferry Lane and the remainder is generally at 3.0 mAHD or above.

Discussion

Raising the low spots on Terara Road to a general level of 3.0mAHD would ensure that vehicles leaving Terara should be able to reach high ground at Ferry Lane. This would assist in flood evacuation by increasing the time available to move people. Raising the road above 3.0mAHD probably cannot be justified as it would affect the streetscape and property access and increase flood levels north of the road (at the village itself).

Conclusions

Terara Road should be raised to a consistent level of at least 3.0 mAHD between the village and Nowra. The work could be carried out as part of road upgrading work. This should also include installation of depth indicators.

5. DEVELOPMENT MEASURES

This chapter discusses measures to deal with future development within or near the study area to ensure that it will not significantly affect the flooding regime, or if it does, that the impacts are addressed.

5.1 Control of Development Outside the Study Area

Developments outside of the study area have not been examined unless they were raised as part of the community consultation program, i.e. Pig Island. It is possible that developments outside the area may affect the erosional and sedimentational regime of the river, cause adverse hydraulic impacts or increase the amount of pollutants and sediments. However, it is Council's responsibility to ensure that any development applications adequately address these issues and that the flood hazard at Terara is not adversely affected.

5.2 Deposition of Silt on Pig Island

Description

Since approximately 1968 a dredge has been operating in the Shoalhaven River, approximately 500 m upstream of Terara. Currently the operators, Terara Sand and Gravel, pump slurry to a land based operation upstream of the village where it is screened. The waste is then pumped to Pig Island where it is settled in a 4 m wide drain running along the southern bank of the island. At regular intervals the drain is cleared and the sediment re-used on Pig Island.

Originally the sediment was being used to construct a levee on the south-west bank of the island opposite Terara. In May 1993 the levee was up to 3 m high, with a base width of 8 m, and over 300 m in length. In 1992 and 1993 a number of studies were carried out into the likely effects of the levee (References 13 and 14) and in August 1993 Council determined not to approve the existing work as it could have a detrimental effect on the flow of waters within the River and could adversely affect the stability of the southern foreshores. Council approved the settlement drain and required that the levee be removed over a period of three months. This was done by the land owner and the silt is now used for fill for a building pad and possibly a stock flood refuge. It is understood that a small amount of silt has been removed from Pig Island to be sold as landscaping mulch.

The residents of Terara have been concerned since 1992 that they were adversely affected by the work on Pig Island. They still hold this view. This is probably the most significant issue of concern to the residents, together with bank erosion/collapse.

Discussion

Issues raised by residents include:

1. What are the approximate quantities of sediment being deposited on Pig Island?
2. Where has the sediment been deposited and where will it be placed in the future?
3. How long will the dredge work in the river?
4. Do the present or future deposits impact on others elsewhere?
5. The residents of Terara need to be assured that the existing placement of silt has been adequately addressed by Council and controls are in place to regulate future deposits. This may require visits to the island, survey and interpretation of aerial photographs.
6. Discussion of the relative merits of the present arrangements versus the possible adverse impacts elsewhere.
7. Re-survey of the southern bank of Pig Island and comparison with the pre-levee survey of March 1992.

Conclusions

The deposition of silt on Pig Island is of major concern to the residents of Terara. This situation needs to be resolved by:

- a review of available reports, survey and aerial photographs,
- discussions with the proponents regarding future proposals,
- discussions with the residents of Terara to outline the agreed proposals.

5.3 The Greenhouse Effect

Description

The Greenhouse Effect results from the presence of certain gases in the atmosphere which allow the sun’s rays to penetrate to the earth but reduce the amount of energy being radiated back. It is this trapping of reflected heat which has enabled life to exist on earth.

Recently, there has been concern that increasing amounts of greenhouse gases resulting from human activity may be raising the average surface temperature. As a consequence, this may affect the climate and sea level. The extent of any permanent climatic or sea level change can only be established through scientific observations over several decades. Nevertheless, it is prudent to consider the possible range of impacts with regard to flooding and the level of flood protection provided by any mitigation works.

Discussion

The Bureau of Meteorology has indicated that there is no intention at present to revise design rainfalls to take account of the Greenhouse Effect, as the possible mechanisms are far from clear and there is no indication that the changes would in fact increase rainfalls in major storms. Even if an increase in total annual rainfall does occur, the impact on storm rainfalls may not be adverse.

It has also been suggested that the cyclone belt may move further southwards. The possible impacts of this on design rainfalls cannot be ascertained at this time as little is known about the mechanisms that determine the movement of cyclones under existing conditions.

Another possible consequence of the Greenhouse Effect could be a rise in sea level. This issue is complicated by other long term influences on mean sea level changes. The available literature suggests that a gradual increase in sea level is likely to occur with a rise of perhaps 0.3 m to 0.5 m within the next 50 years. This will have a significant impact at Shoalhaven Heads if it equates to a similar increase in the design ocean level, but modelling results demonstrate that any change in ocean levels will have minimal impact on flood levels at Terara.

Of more significance would be any impact on the erosional and sedimentation regime at Shoalhaven Heads. The Greenhouse Effect may vary the frequency and length of closures but, at this stage, there is not enough information to allow any definite conclusions on this.

Conclusions

The Greenhouse Effect may affect design flood levels in the Lower Shoalhaven River, however, preliminary investigation demonstrates that the impact in the study area will be minor. The impact on the Shoalhaven Heads entrance may be more significant but there is no definitive information at this stage. Council should continue to monitor the available literature and reassess Council's Flood Policy as appropriate.

6. ACKNOWLEDGMENTS

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- Shoalhaven Floodplain Management Advisory Committee,
- Shoalhaven City Council,
- Department of Land and Water Conservation,
- State Emergency Services,
- Local residents of Terara.

7. REFERENCES

1. Public Works Department
Lower Shoalhaven River Flood History at Nowra Bridge 1860-1980
Draft Report, July 1981.

2. Public Works Department
Lower Shoalhaven River Flood Study
Webb, McKeown & Associates Pty Ltd, April 1990.

3. New South Wales Government
Floodplain Development Manual
December, 1986.

4. Public Works Department
Lower Shoalhaven River Flood Study - Compendium of Data
Webb, McKeown & Associates Pty Ltd, Draft Report, April 1990.

5. Public Works
Shoalhaven River Bank Erosion Study - Phase 1
Channel Morphology 1805-1985
December, 1988.

6. Irish, J
Flood Insurance
28th Annual Flood Mitigation Conference, Nowra, May 1988.

7. Public Works Department
Engineering Studies of the Shoalhaven - Crookhaven Estuary: Vol I, Shoalhaven River Entrance Study
Posford, Pavry, Sinclair & Knight, 1977a.

8. Public Works Department
Engineering Studies of the Shoalhaven - Crookhaven Estuary: Vol III, Shoalhaven Waterway Planning Study
Posford, Pavry, Sinclair & Knight, 1977b.

9. Public Works Department
Shoalhaven River Entrance Management
PWD Report No. 83038, 1984.

10. Shoalhaven Shire Council
Engineering Studies of the Shoalhaven - Crookhaven Estuary: Vol II, Lower Shoalhaven River Flood Study
Sinclair Knight and Partners Pty Ltd, 1977.

11. Public Works Department
Shoalhaven Valley Floodplain Management Study
Sinclair Knight and Partners Pty Ltd, 1981.

12. Public Works Department
Shoalhaven River Entrance Study
University of New South Wales, Water Research Laboratory
Report No. 86/09, 1986.

13. Forbes Rigby
A Report on the Impact of Construction of a Levee on Pig Island on Flooding in the Lower Shoalhaven
September 1992.

14. University of New South Wales, Water Research Laboratory
Bank Erosion of Terara, Effect of the Pig Island Levee
Technical Report No. 93/02, April 1993.

FIGURE 1
CATCHMENT MAP

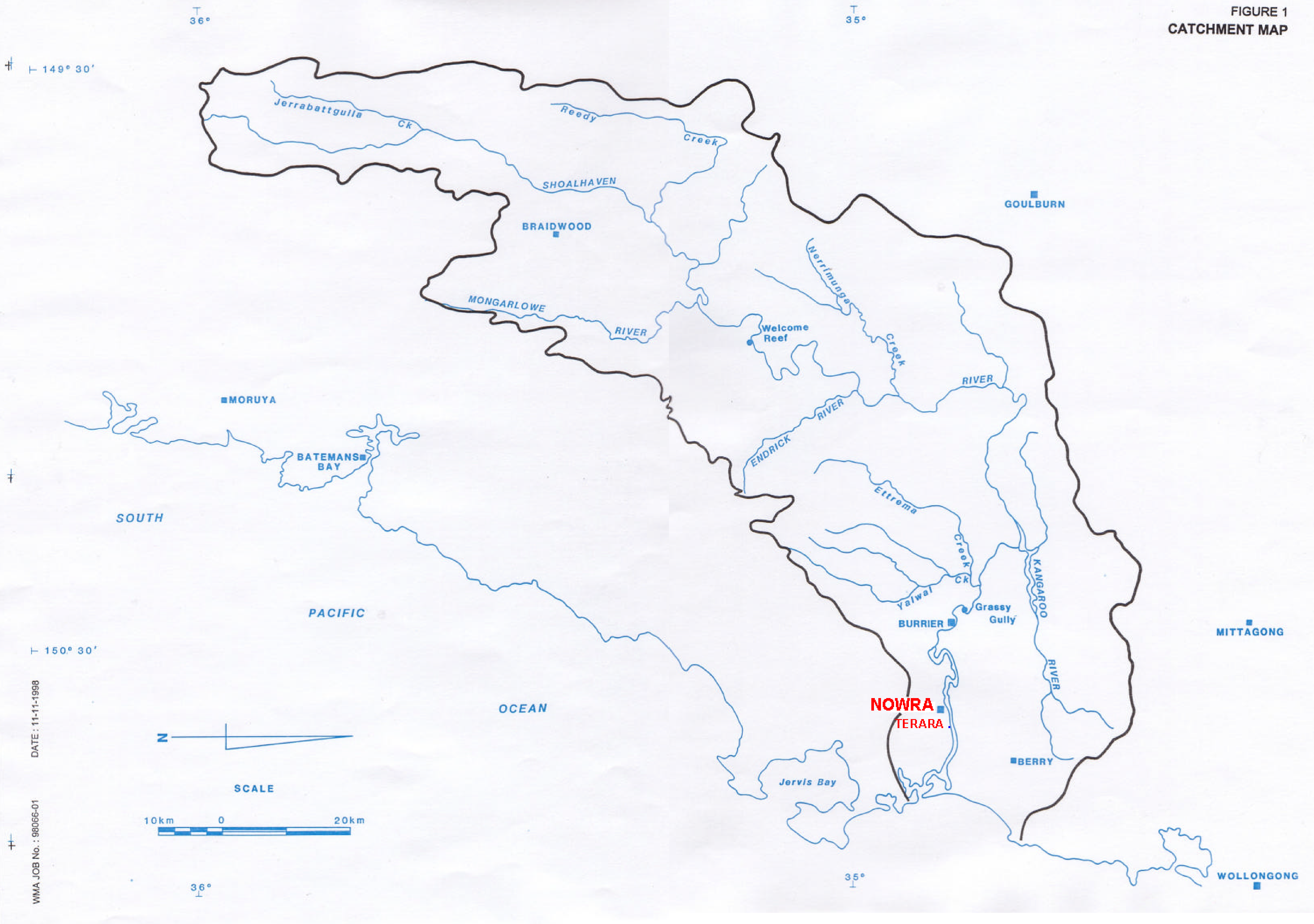


FIGURE 2
LOCALITY PLAN

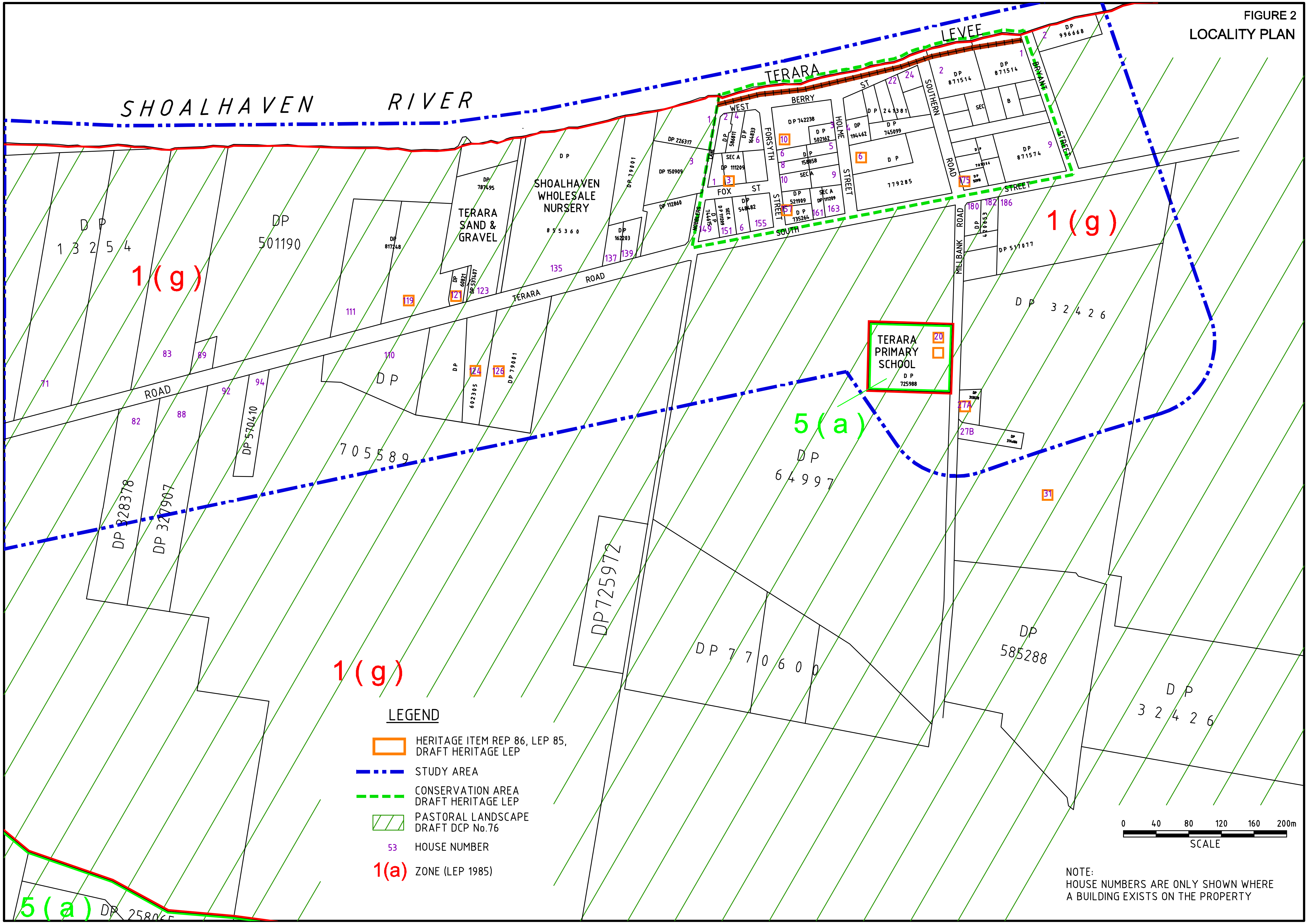


FIGURE 3
CELL MODEL LAYOUT

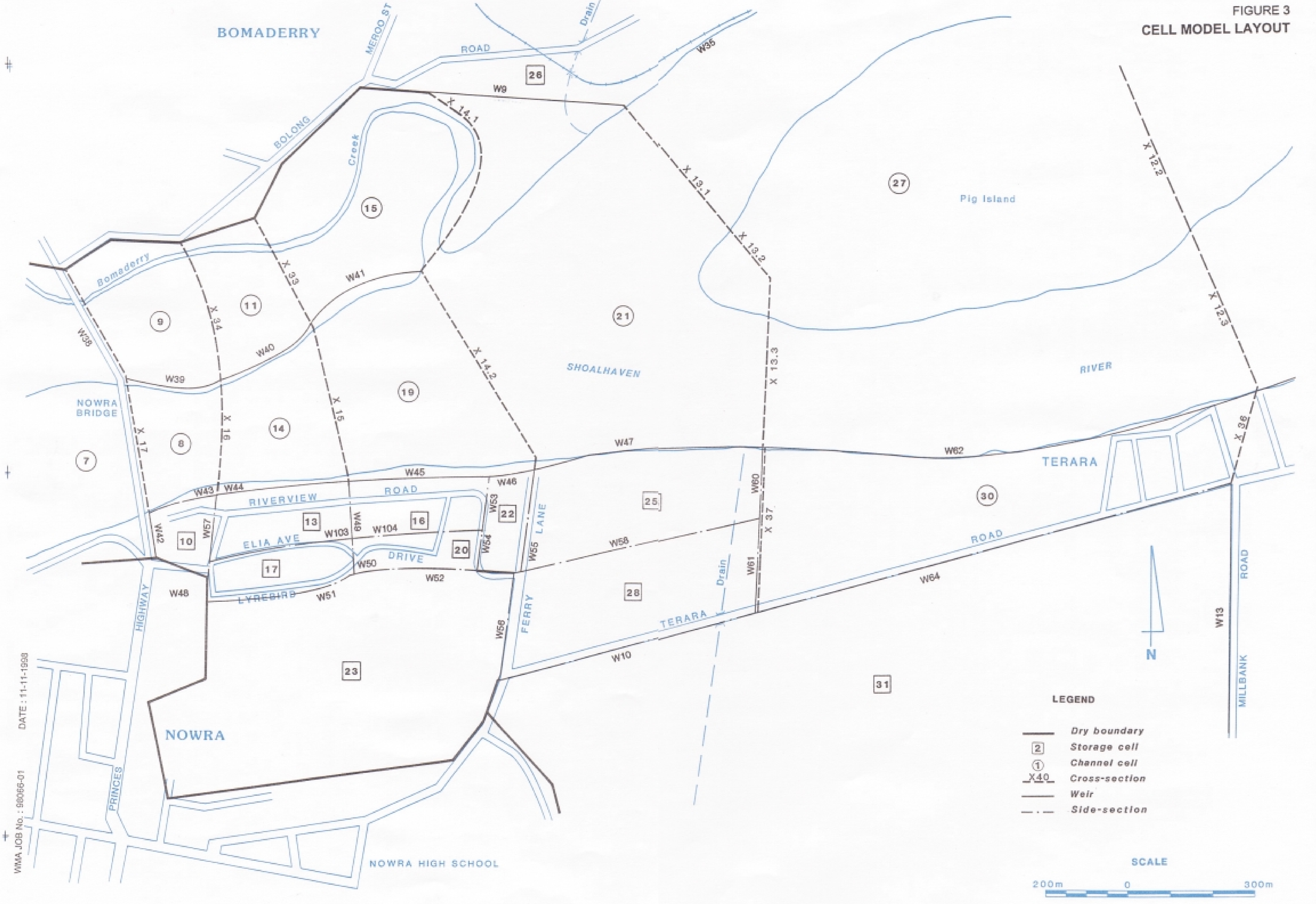
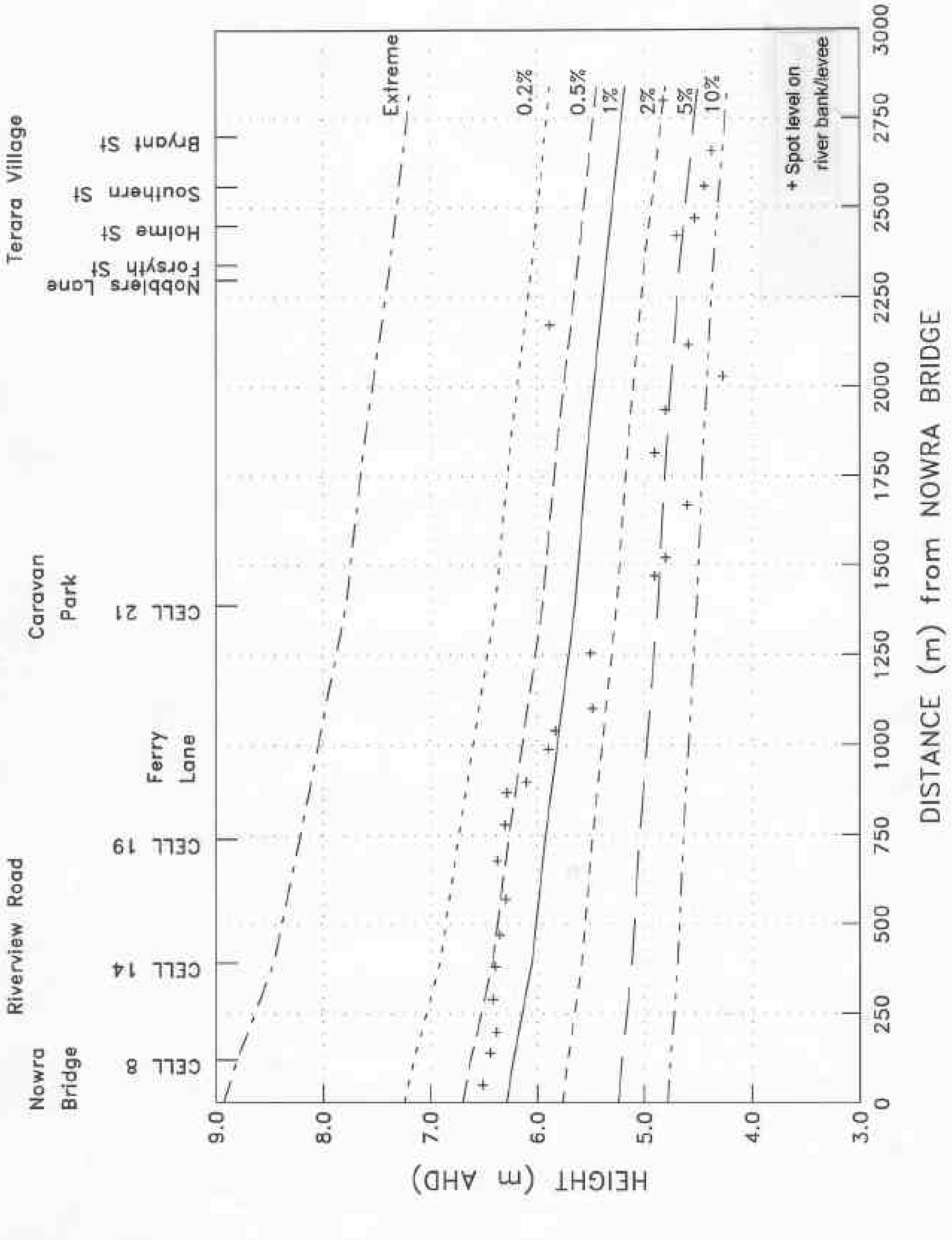


FIGURE 4

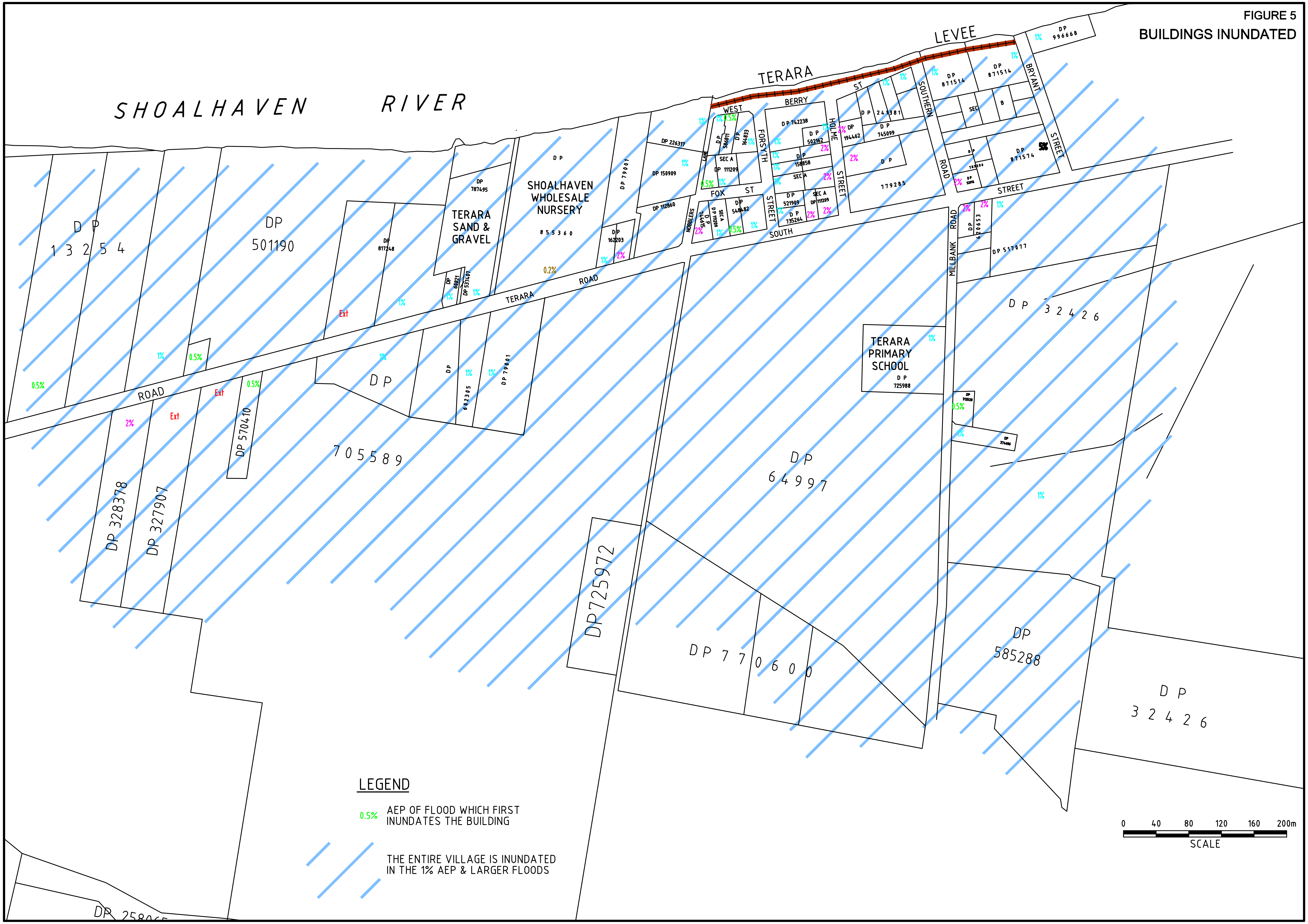
DESIGN FLOOD PROFILES



WMA JOB No. : 98066-01 DATE : 11-11-1998 15:00

FIGURE 5

BUILDINGS INUNDATED



APPENDIX A: DESCRIPTION AND ASSESSMENT OF FLOOD DAMAGES

APPENDIX A: DESCRIPTION AND ASSESSMENT OF FLOOD DAMAGES

A1. DESCRIPTION OF FLOOD DAMAGES

A1.1 General

A database provided by Shoalhaven Council (Appendix D) has been used to identify the number of buildings inundated above floor level for various design events. For each property a habitable floor level (or work floor level for non-residential buildings) and a typical ground level were obtained. The ground level reflects yard damages to the grounds, garage, etc.

Flood damages can be defined as being *tangible* or *intangible* and a schematic breakdown of the damages categories is provided as Table A1. Tangible damages are those for which a monetary value can be assigned, in contrast to intangible damages, which cannot easily be attributed a monetary value.

There are few records of actual flood damages to buildings or private property although these undoubtedly occurred in the floods in the 1970's. A draft 1979 report into the feasibility of constructing the Riverview Road levee provided the following information.

August 1974 Flood

Riverview Road Area: No homes were flooded. Flooding was mainly confined to roads. The river broke its banks near the Nowra Sailing Club and the water was channelled along Hawthorn Avenue into Worrigee Swamp.

Terara: Four out of 21 owners interviewed indicated their homes were flooded.

June 1975 Flood

No indication of the number of homes inundated.

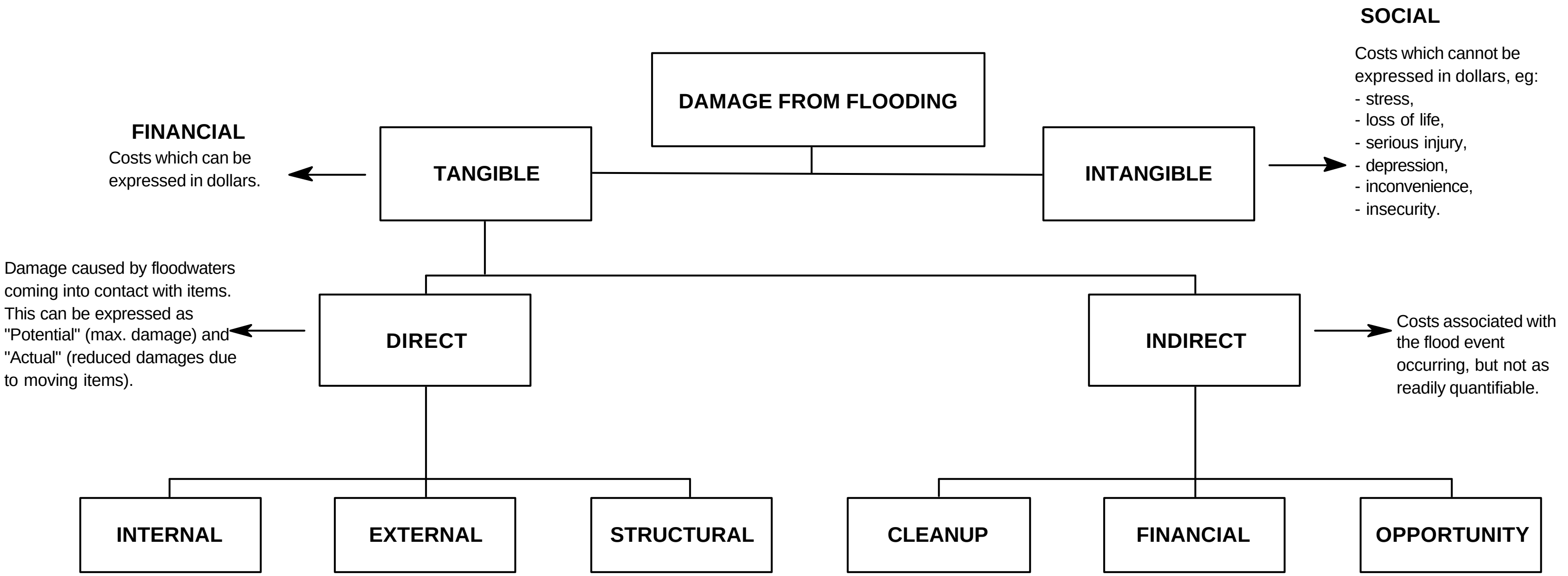
March 1978 Flood

Riverview Road Area: The river broke its banks at a number of places. The main area was opposite Hawthorn Avenue. The Willows Caravan Park was inundated as well as most of the surrounding land. Approximately 10 out of 94 homes were inundated.

Terara: Water flowed through the whole of the village. It was estimated that up to 10 buildings were inundated (probably an over-estimate).

Flood Damages:	Residential	$10,640	Nowra Boat Hire	$500
	Council	$2,800	Schadel's Sand	$17,000
	Telecom	$350	Market Gardening	$11,300
	Electricity	$670	Swimming Pool	$650
	Willow Caravan Park	$6,000	Sailing Club	$2,150
	Riverhaven Motel	$28,000	**Total**	**$80,060**

Table A1: Flood Damages Categories



	INTERNAL	EXTERNAL	STRUCTURAL	CLEANUP	FINANCIAL	OPPORTUNITY
RESIDENTIAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Laundries, Caravans, Sheds, Tools, Gardens, Fences	Physical Damage to Buildings: Gyprock, Cupboards, Scour of Footings, Houses becoming buoyant (floating off footings)	Clean Carpets, Walls, Clothes; Re-instate Furniture; Remove Mud and Debris	Loss of wages, Living costs (temporary accomodation and food), Time to repair/replace damaged items	Not Applicable
RURAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Sheds (stables/barns), Machinery, Tools, Fences, Feed storage, Saddles, Crops &/or Stock, Irrigation Systems	Physical Damage to Structures: Damage to Homestead, Sheds, Access tracks, Protection levees	Clean Homestead and Out-buildings; Remove Debris; Dispose of affected crops &/or stock	Loss of Farm Production and Income, Re-instatement of Pastures, Supplementary feeding of stock (by hand or outside agistment), Stock movement/ transport, Living costs (temporary accomodation and food)	Sowing or harvesting of Crops, Sale of Stock (at depreciated value or dependent on market influences)
COMMERCIAL	Contents of Buildings: Products, Stock, Fittings, Tools, Machinery, Raw Materials	External Items: Vehicles, Machinery, Display, Raw Materials/Stockpiles, Fences	Physical Damage to Buildings	Dispose of damaged products, stock, materials; Cleaning and Re-instatement	Loss of Productivity and Income, Bank Interest Charges	Loss of existing &/or Potential Trade
PUBLIC AUTHORITIES	Contents of Public Buildings and Facilities	Public Property and Facilities: Parks, Signs, Machinery, Equipment	Physical Damage to Infrastructure: Electricity, Water, Telephone, Gas, Road & Rail Transport Links	Remove Mud & Debris from Facilities, Public & Private Property Repairs (temporary & permanent)	Disruption of Services, Community Service Relief Grants	Provision of Public Service

A1.2 Tangible Damages

Tangible damages can be sub-divided into *direct* damages, which occur due to physical contact with the floodwaters, and *indirect* damages which occur as a result of the disruption of business, trade and other activities. Direct and indirect damages may be referred to as *Potential* or *Actual* damages. Potential damages are the assumed damages if no damage reduction measures are employed and are thus greater than the actual damages. The ratio of actual to potential damages depends upon a number of factors including:

- magnitude of the flood,
- prior flood experience of the community,
- length of warning time.

Direct Damages

Direct damages can be sub-divided between the rural and urban sector. Under direct urban damages there are three broad categories: *Residential, Commercial* and *Public Sector*.

The direct damages under these categories can be grouped under the following headings:

- *Internal* - building contents,
- *Structural* - structure and building fabric,
- *External* - yard, garage, vehicle and other machinery (air conditioning).

Damages to commercial and industrial buildings are much more difficult to quantify for two reasons:

- damages to a given property vary much more than with houses, as they are heavily influenced by the type of business being carried out and the amount of stock carried. This will also vary over time as different businesses use the building,
- industrial enterprises in particular cannot simply be averaged out. Where large factories or warehouses are involved, the only way to get a good estimate of potential damages is to do a site specific survey of the enterprise.

As flood damages can vary greatly between areas depending upon the type of buildings and contents, an average damages figure is estimated for each of the above categories (residential, commercial and public sector) following a flood. This is generally presented as a flood depth versus flood damages function.

Public sector (non-building) damages include:

- recreational/tourist facilities,
- water and sewerage supply,
- gas supply,
- telephone supply,
- electricity supply including transmission poles/lines, sub-stations and underground cables,
- roads and bridges including traffic lights/signs,

- railway line and associated structures,
- costs to employ the emergency services.

Damages to the public sector can contribute a significant proportion of the total flood costs. In the Inverell flood of February 1991, direct costs to the local Council accounted for 10% of the total direct damages. A single item such as a bridge or a sub-station may account for a large proportion of the damages bill in a particular flood.

Indirect Damages

Indirect damages are more difficult to quantify. They can be sub-divided into three broad cost categories:

- *Clean-up* - clean carpets, furniture, refrigerator, etc. It also includes the cost of alternative accommodation,
- *Financial* - loss of wages, loss of trade for the commercial/industrial sector,
- *Opportunity* - non-provision of commercial and public services.

In a particular locality it would require an extensive survey to evaluate the costs of lost working hours, disruption to business and trade. Nevertheless an indication of the damages can be obtained from previous studies. Generally the indirect damages have been expressed as a percentage of the direct damages. The figure varies greatly depending upon a number of factors including:

- magnitude of flood,
- time away from home/work,
- category (residential, commercial, industrial).

An average percentage (indirect as a percentage of direct) from a number of post flood surveys is:

- Residential - 15%,
- Commercial - 30%,
- Industrial - 50%.

It should be noted that there can be a considerable range (± 100%) around the above figures for commercial and industrial properties in different locations.

A1.3 Intangible Damages

Intangible damages are those flood damages which by their nature are difficult to quantify in monetary terms. An example of a *direct* intangible damage is the "loss of visual quality" of an area or the "loss of a heritage item". Most intangible damages are *indirect* and commonly occur after the flood peak has passed.

Intangible damages can be categorised as follows:

- **Residential**

  Post flood damages surveys have linked flooding to stress, ill-health and trauma in the residents. For example the loss of memorabilia, pets, insurance papers, etc., may cause stress and subsequent ill-health. In addition, flooding may affect personal relationships by contributing to marriage breakdowns and lead to stress in domestic/work situations. Residents may worry each time heavy rain occurs and there is a threat of flooding. This may be reflected in increased sickness or depression requiring psychiatric help. These effects can induce a lowering in the quality of life of the flood victims.

  Flood victims may also suffer injuries during a flood or during the clean-up process. Whilst the direct costs of the injuries may be accounted for in the flood damages survey, the physiological effect or discomfort may last for a long time.

  The most extreme "intangible damage" that can arise from flooding is death, and unfortunately this is not a rare occurrence. There are many examples of deaths of local residents and rescue workers during floods.

- **Commercial/Industrial/Rural**

  Whilst a large number of businesses carry insurance for loss of trade during and following a flood until the clean-up is complete, they may still suffer a financial loss. For example the confidence in the business of regular clients may be reduced permanently. Clients may take their business elsewhere during the flood/clean-up period and may never revert to the original supplier.

- **Services**

  The loss of services to customers, e.g., transport disruption, loss of education, loss of power, etc., occur as a result of floods and these are generally not costed within the tangible damages category.

- **Environmental**

  Environmental damage may occur as a result of flooding, for example flora and fauna may be lost. However the riverine environment is a natural system and it is difficult to quantify the effects of flooding on natural processes. Some flora and fauna can in fact benefit from flooding. Also in the short term there may be a deterioration in water quality or vegetation, which may recover in the long term. Wetlands develop over time as a result of flooding and require periodic flooding for their long term survival.

Probably the most significant potential environmental impact is the release of pollutants as a result of flooding. Generally this is as a result of flooding of commercial/industrial establishments.

The loss of man-made structures which have a "heritage" or non-replaceable value are a real cost which cannot be quantified. Modifications to the pattern of flooding through flood mitigation works may change the existing ecosystem. Although the changes can be beneficial or adverse.

In summary, there is a comprehensive body of available literature on intangible damages which provides many examples. However the costing of such damages in dollar terms is often not possible. These "costs" must not be ignored when determining floodplain management options. The literature suggests that the value of intangible damages may equal or exceed tangible damages. It is therefore often necessary to imply a value to the intangible damages to achieve a proper appreciation of proposed works and measures.

A2. ASSESSMENT OF FLOOD DAMAGES

A2.1 General

A2.1.1 Introduction

Quantification of flood damages is generally based upon post-flood damage surveys. An alternative procedure is to undertake a self-assessment survey of the flood liable residents. This latter approach is more expensive and may not accurately reflect what actually occurs in a flood. Floods by their nature are unpredictable and it is unlikely that a self-assessment survey would have predicted the scale of the damages which occurred in Nyngan in 1990. For this reason it was decided to use the post-flood damage approach in assessing flood damages. More recent information will become available from the November 1996 flood at Coffs Harbour. A listing of the most widely known post flood damage surveys is shown in Table A2.

Table A2: Residential Flood Damage Surveys

Location	Year of Flood	Comments
Brisbane	1974	400 residential properties.
Lismore	1974	100 properties. The data were obtained several years after the last major flood.
Forbes	1974	35 properties. The data were obtained several years after the latest major flood.
Sydney (Georges River)	1986	96 properties (2 studies undertaken)
Nyngan	1990	24 residential, 14 commercial and 6 public properties, 4-5 weeks after the flood.
Inverell	1991	4 residential, 20 commercial and 10 public properties, 2-3 weeks after the flood.

The most comprehensive surveys are those carried out for Sydney (Georges River), Nyngan and Inverell. Some of the problems in applying data from these studies to other areas can be summarised as follows:

- varying building construction methods, e.g. slab on ground, pier, brick, timber,
- different average age of the buildings in the area,
- the quality of buildings may differ greatly,
- inflation must be taken in account,
- different fixtures within buildings, e.g. air-conditioning units,
- change in internal fit out of buildings over the years or in different areas, e.g. more carpets and less linoleum or change in kitchen/bathroom cupboard material,
- external (yard) damages can vary greatly. For example in some areas vehicles can be readily moved whilst in other areas it is not possible,
- different approaches in assessing flood damages. Are the damages assessed on a "replacement" or a "repair and reinstate where possible" basis? Some surveys include structural damage within internal damage whilst others do not,

- varying warning times between communities means that the potential to actual damage ratio may change,
- variations in flood awareness of the community.

A2.1.2 Summary of Survey Data

Flood damages data from the following surveys are provided in Table A3:
- Inverell 1991 - Reference A1,
- Nyngan 1990 - Reference A2,
- Sydney (Georges River) 1986 - Reference A3.

References A1 and A2 were undertaken by Water Studies Pty Ltd and Reference A3 by the Centre for Resource and Environmental Studies (CRES) at the Australian National University, Canberra.

Table A3: Summary of Post Flood Damage Surveys
(Note: Costs quoted at the time of the flood)

	Nyngan	**Inverell**	**Georges River**
TOTAL FLOOD DAMAGES	$47 Million	$20.6 Million	$17 Million
Year	**1990**	**1991**	**1986**
Flooded Premises and Total Cost per section in $M (in brackets):			
Residences	717 ($18.9)	126 ($2.3)	1000
Commercial/Industrial Premises	98 ($11.3)	264 ($14.9)	215
Public Authorities/Utilities	42 ($17.0)	36 ($3.4)	Not Known
Total	857	426	
Damage ($M) per Category and % of Total Flood Damages (in brackets):			
Direct	28.6 (60%)	10.7 (52%)	16.9 (89%)
Indirect	18.7 (40%)	9.8 (48%)	2.1(11%)
Average Damages per Premise and % of Total Flood Damages (in brackets):			
Average Residential	$26 400(40%)	$18 000(11%)	$8 000(48%)
Average Commercial/Industrial	$117 000(24%)	$54 000(72%)	$40 000(52%)
Average Public	$400 000(36%)	$93 000(17%)	Not Known
Average Residential Damages by Category and % of Total Residential Damages (in brackets):			
Direct - Internal	$8 900(34%)	$8 100(42%)	Not Known
Direct - External	$4 500(19%)	$2 500(19%)	$3 500 (44%)
Direct - Structural	$5 200(20%)	$5 000(27%)	Not Known
Indirect - Financial	$4 800(20%)	$300(1%)	Assumed as 15%
Indirect - Clean Up	$2 200(7%)	$2 100(11%)	of Direct
Average depth of inundation above floor	0.8m	0.6m	Not Known
Average Commercial Damages by Category and % of Total Commercial Damages (in brackets):			
Direct - Internal	$28 600 (25%)	$17 100 (33%)	Not Known
Direct - External	$1 100 (1%)	$5 500 (12%)	Not Known
Direct - Structural	$3 000(3%)	$750 (1%)	Not Known
Indirect - Financial	$79 500 (70%)	$23 000 (45%)	Assumed as 55%
Indirect - Clean Up	$2 000 (1%)	$4 900 (9%)	of Direct
Average Annual Damage	$0.63M	Unknown	$14.4M

NOTES:

- 93% of all properties in Nyngan were flooded above floor level.
- The AAD figure for Sydney (Georges River) is $0.88M for residential and $13.5M for commercial/industrial.

A2.2 Tangible Damages - Residential Properties

Tangible direct damages are generally calculated under the following components:

- Internal,
- Structural,
- External.

Tangible indirect damages can be subdivided into the following groups:

- accommodation and living expenses,
- loss of income,
- clean up activities.

Damages may be calculated as either estimated actual damages or estimated potential damages. If potential damages are calculated an Actual/Potential (A/P) ratio is estimated based upon (as well as other factors) the likely flood awareness of the community and the available warning time.

The flood awareness of the community is likely to be high with the available flood warning time medium. For these reasons the A/P ratio will be relatively high (say 80%). At Nyngan (February 1990) the A/P ratio for average residential damages was 77%. It should be remembered that not all items can necessarily be saved (kitchen cupboards, carpets) and that many residents may be away. Based upon the available data it is considered that the A/P ratio for the study area will be similar to that at Nyngan or Inverell.

A2.2.1 Direct Internal Damages

- **Water Studies**

In the Water Studies approach internal damages are based upon the following formulae provided in Reference A1.

$$\frac{D}{D_2} \quad 0.06 \; 1.42H \; 0.61H^2 \qquad \text{for } H < 1.0m$$

$$\frac{D}{D_2} \quad 0.75 \; 0.12H \qquad \text{for } H > 1.0m$$

where,

H	=	height of flooding above floor level (m)
D	=	damage at height (H) above floor level
D_2	=	damage at height of 2m above floor level

At Nyngan and Inverell D_2 was $12 500 for small houses and $14 500 for medium/large houses. These values are in $1991's. The reference states that *"Damages to individual properties scatter widely around the relationship, which can only be used to reliably estimate the aggregated damage to a collection of flood prone dwellings and not the damage to a single dwelling."*. Structural damages are not included in the above figures.

- **CRES**

In the CRES approach (Reference A3) internal and structural damages are combined. Data are provided for three groups of buildings, namely Poor, Medium and Good. The data are shown in $1986's in Table A4.

Table A4: Residential Stage-Damage for Actual Direct Damage to Structure and Contents ($1986's)
(Taken from the Georges River Study: Reference A3 - Table A2.2.7)

Over floor Depth	Poor	Medium	Good	Average
0.0m	370	1045	2400	1270
0.1m	740	2090	4799	2540
0.6m	3012	5713	10360	6360
1.5m	7102	7595	13190	9300
1.8m	7210	7711	13391	9440

A2.2.2 Direct Structural Damages

In the CRES approach internal and structural damages are combined. In the Water Studies approach structural damage was adopted as approximately $5 000 at both Nyngan and Inverell.

A2.2.3 Direct External Damages

The majority of external damages is attributable to vehicles. However there is a high likelihood that a significant percentage of the vehicles can be moved to high ground even with minimal flood warning.

At Nyngan external damages were estimated as $4 500, mostly for vehicles, and at Inverell at $2 500 of which $1 500 was for vehicles. In the Sydney 1986 data obtained by CRES an external damages figure of $600 was adopted per property experiencing over ground flooding. In addition a sum of $2 000 per property experiencing over ground flooding in excess of 0.6m was included.

A2.2.4 Indirect Damages

In the Inverell study the indirect damages were taken as $200 for accommodation, $100 for loss of income and $2 100 for clean up activities. The total indirect damages ($2 400) therefore, represented approximately 20% of the direct damages. At Nyngan indirect damages were high due to the extended period residents were away from their homes and were estimated at $7 700 per dwelling flooded above floor level. In this case the indirect damages amounted to approximately 40% of the direct damages. CRES adopted a figure for indirect damages of 15% of the direct damages (Georges River Study).

A2.3 Adopted Tangible Damages - Residential Properties

The adopted values used in this study are provided in Table A5 and documented in the following sections.

Table A5: Adopted Residential Depth/Damage Data ($1998)

Depth over Floor/Yard (m)	Total	Internal Damages	Structural Damages	External Damages	Indirect Damages
0.1	7018	3918	2000	300	800
0.3	17922	8622	6000	900	2400
0.5	27850	12350	10000	1500	4000
1.0	32900	17400	10000	1500	4000
1.5	34100	18600	10000	1500	4000
2.0	35300	19800	10000	1500	4000

A2.3.1 Direct Internal Damages

The Water Studies approach to the determination of internal damages was adopted for use in this study. As noted previously the A/P ratio for Nyngan is likely to be similar to that for the study area. A single D_2 value of $20 000 was adopted for all residential buildings regardless of the type of the building.

A2.3.2 Direct Structural Damages

Structural damages were assumed to be a linear relationship from $0 at 0 m to $10 000 at 0.5 m. Above this value it was considered that there would be no additional structural damages.

In floods larger than a 1% AEP event there is the possibility that some buildings may collapse or have to be destroyed. The cost of these damages have not been included in the analysis.

A2.3.3 Direct External Damages

External damages (laundry/garage/yard/vehicle) were assumed to be a linear relationship from $0 at 0 m above ground level to $1 500 at 0.5 m.

A2.3.4 Indirect Damages

Indirect damages were assumed to be a linear relationship from $0 at 0 m above floor level to a maximum of $4 000 at 0.5 m.

A2.4 Tangible Damages - Public Utilities

The damages to public utilities include:

- water and sewerage supply,
- telecommunications,
- road/rail transport,
- other public assets.

Little data are available for establishing costs to public utilities, and the data from Nyngan and Inverell show that it can vary from 17% to 36% of the total damages bill.

The following is a summary of the likely damages to public property.

Sewerage

There is no public sewer system at Terara. Flooding will cause inundation of the septic tanks and possible release of sewerage.

There are very little tangible damages to the systems. The damages are largely intangible through the loss of supply of the system, such as inconvenience, disruption and health risk.

Recreational Facilities/Roads

There will be some direct tangible damages but the major factors are intangible damages to the community through the loss of use of the facilities.

Telephone, Electricity, Water Supply

These facilities should experience only minor (if any) flood damages. Telephone and electricity supplies may be severed at the time of the flood for other reasons (lightning).

Evacuation and Clean-Up Costs

It is estimated that the evacuation and clean-up costs to Council for each event is $40 000.

In this study damages to public utilities were not estimated.

A2.5 Annual Average Damages

It should be emphasised that these **figures include only tangible (direct or indirect) damages to buildings and residents, the cost of intangible damages has not been evaluated**. Available literature suggests that the extent of **intangible damages may equal or exceed the tangible damages. Damages to the public sector have not been accurately assessed in this study**. Recent studies show that **damages to public property can vary significantly but may comprise 50% of the private tangible flood damages**.

A3. REFERENCES

A1. NSW Department of Water Resources
Inverell Flood Damage Survey February 1991 Flood
Water Studies Pty Ltd - November 1991.

A2. NSW Department of Water Resources
Nyngan 1990 Flood Investigation - Chapter 9
October 1990.

A3. Public Works, Department of Water Resources
Losses and Lessons from the Sydney Floods of August 1986 Vol. 1 and Vol. 2
Centre for Resource and Environmental Studies, Australian National University, and Environmental Management Pty Ltd Sydney - September 1990.

APPENDIX B: PUBLIC CONSULTATION PROGRAM

APPENDIX B: PUBLIC CONSULTATION PROGRAM

The following text was provided to the Floodplain Management Committee at the start of the study.

Council has requested that the community be involved in the preparation of the Floodplain Management Studies (FMS) and Floodplain Management Plans (FMP) for the village of Terara and the Riverview Road area to ensure that affected persons are aware of the study and to ensure that the consultants have considered and reported on suggestions raised by the community.

To meet the requirements of the consultant's brief in this regard a public consultation program has been prepared for implementation during all stages of the study process.

B1. OBJECTIVES

The consultation program seeks to:

- increase community awareness of the findings of the 1990 Flood Study and of the ongoing process of preparing the FMS and FMP,
- encourage community participation in the FMS and FMP preparation,
- encourage feedback on the draft FMP document to assist Council in their consideration of the final outcomes.

B2. KEY CONSIDERATIONS

In developing the consultation program, the following considerations were regarded as important:

- The expected role of the community needs to be clearly established. This means that the ground rules for community involvement need to be clearly set out so that the community knows what is expected of them. In general a wide range of community views will be sought and discussed. Final decision making will rest with the Floodplain Management Committee (FMC) and Council.

- The program will focus on residents and property owners of the flood liable areas although advertisements in the local press will make the general community aware of the study.

- The consultation program closely follows the study work program and will be seen as an important element of that process. However it is not seen as an end in itself but rather as a means of ensuring that the final product has been prepared in full consideration of all issues raised by the community.

- The consultation program will be carried out by the consultants and thus will be seen to be somewhat independent of any vested interests in the area. An alternative is to engage an independent facilitator to conduct the meetings.

- Consultation methods will seek to provide an independent and impartial forum to ensure that the community fully understands the proposals being considered for inclusion in the study, and can exchange ideas and discuss the full implications of proposals with relevant technical experts in a friendly and non-intimidatory environment. It is not intended that the program be a forum for debate or argument, rather one for the exchange of ideas and the recording of community views.

B3. PROPOSED PROGRAM

The proposed consultation program has three distinct phases:

- **Phase 1** is a short inception period during which broad agreement to the details of the study are to be resolved including matters such as:
  - means of disseminating information,
  - determining the format of the newsletter, questionnaire and advertisements,
  - identifying the community to be consulted,
  - details of the dates and agendas and participants for public meetings.

- **Phase 2** includes the range of activities during the preparation of the FMS.

- **Phase 3** includes the range of activities associated with the exhibition of the draft FMP and the review of submissions.

The following main elements of the program are presented for consideration.

B3.1 Phase 1 - Inception

Means of Disseminating Information: It is proposed that the community be consulted initially via a Letter of Introduction and a Questionnaire which will be distributed by mail to the approximately 460 homes and businesses which occupy or own land within the study area. If people wish to respond or provide comment they will be asked to write to a Reply Paid Number at Webb McKeown's office. Subsequently two A4 newsletters will be provided.

The above material will be mailed to any other interested party nominated by the Committee. Council will distribute material to members of the Floodplain Management Committee.

Council will display the various material in local libraries, Council Offices, community centres and any other appropriate locations.

Advertisements will be placed by Council in the local and national papers at the time of distribution of the newsletter. Council will also issue press releases to local radio, television, and newspapers. These will also announce the dates of the public meetings.

The exact format of the newsletter and advertisements will be the subject of discussion but the broad issues to be covered are set out under Phase 2.

Agenda: The following dates are to be determined:

- 1st Floodplain Management Committee Meeting, 23 July 1998,
- Period of Investigation of Strategies by Consultant,
- Date of Distribution of 1st Newsletter,
- Date of 1st Public Meetings,
- Period for Preparation of Draft FMS and FMP by Consultant,
- Date of Distribution of 2nd Newsletter,
- Date of 2nd Public Meetings,
- Date of Draft FMP submitted to Council.

Other FMC meetings will occur at regular intervals.

Community to be Involved: Any residents occupying land (within the study area) which is below 8.0 mAHD will be invited to be involved in the process. Material will be provided to resident owners, non-resident owners and tenants. The advertisements will capture residents who have involvement in the area but do not occupy low lying land. All government and local progress associations will be contacted by direct mail.

Identification of Stakeholders: Any body which has a significant interest in the study should be identified and included in the mailing list. Depending on the number of groups they could be asked to attend the FMC meetings, attend meetings with the project group, or be talked to individually by the consultant.

How Public Interest will be Generated: The success of the study can be measured by how the outcomes of the study are supported by the community. To achieve a high level of support the community needs to be involved in the decision making process. The proposed program aims to generate public interest in the following ways:

- advertisements in local newspapers and press releases provided to local radio, television and newspapers,
- distribution of the letter of introduction and two newsletters,
- two public meetings,
- displays at Council,
- local progress associations and/or representatives on the Floodplain Management Committee should advise their members.

B3.2 Phase 2 - Preparation of the FMS

Preparation and Release of Newsletter: The newsletter will seek to:

- advise the community of the study, its purpose, timetable and expected outcomes,
- summarise the findings of the Flood Study,
- provide concise representations of the strategies proposed in the FMS,
- outline the consultation program and inform the community on how to become involved in the process,
- invite a submission on the draft FMS,
- advise of the forthcoming public meetings to discuss the findings of the FMS.

Discussions with Stakeholder Groups: It is expected that representatives of these groups will attend the FMC meetings. Alternatively it may be possible to meet with these groups prior to or following the FMC meetings.

Public Meetings: Two meetings will be held with residents (one for each area). Invitations to attend the meetings would be included in the newsletter and public advertisement. It is anticipated that both meetings will be held on the same day in Council Offices.

It is expected that the meetings would run for approximately 2 hours and be chaired by a Councillor. Each will be attended by Mr R Dewar. The meetings would address the following issues:

- a presentation of the study process,
- an outline of the flooding characteristics of the area,
- a presentation of the strategies,
- community response to those strategies,
- discussion of other strategies to be considered,
- where to from here?

The meeting will include display of graphical material including aerial photos, maps and the proposed strategies.

Technical Workshop: A technical workshop would be held with relevant officers of Council (from a range of relevant disciplines such as engineering, planning and recreation), and State Government departments with an interest in the outcome of the FMS. This workshop would discuss the strategies presented in the FMS and any others nominated by the group. This workshop may form part of a FMC meeting and should occur after the public meetings.

The results of the workshop, discussions and submissions will be reported to the Council and will be presented to the FMC for consideration and recommendation prior to proceeding with the completion of the draft FMP.

B3.3 Phase 3 - Preparation of the Draft FMP

Once a draft FMP has been prepared and approved for exhibition by the committee the following activities will occur:

- An exhibition of the draft FMS and FMP will be prepared by Council and exhibited at Council Chambers and major libraries. It is not expected that the exhibitions will be elaborate or space consuming. The consultants would provide maps, plans, etc.

- Advertisements will be placed in the state (SMH) and local newspapers advising of the availability of the draft FMS and FMP for comment. The advertisements will advise on where the draft study is exhibited and how comments can be made. The consultants would prepare the advertisements which would be placed by Council. Local radio, television stations and newspapers would also be issued with a press release from Council.

- A second newsletter will be prepared and circulated in a similar manner to the first newsletter with the addition of those who expressed an interest during the study process.

- Public meeting(s) will be held to discuss the draft and to hear comments of the community.

- Council and the consultants will review submissions on the Draft Reports and report to the FMC.

B3.4 Role of the Consultants

Webb, McKeown & Associates: Webb, McKeown & Associates (R Dewar) would participate in the meetings and workshop. He would provide technical support and present the findings of the study in a manner understandable by non-technical members of the public. WM would prepare the newsletters and format of the consultation program.

TERARA VILLAGE/RIVERVIEW ROAD AREA FLOODPLAIN MANAGEMENT STUDIES QUESTIONNAIRE

No. 1
3 July, 1998
Distribution Area: All Residents

Your response to this questionnaire will help Council in its investigation of the flooding issues along the south bank of the Shoalhaven River (Nowra Bridge to Terara). Please tick a box where requested.

1. Please provide your name and address details below.
   Name: ________________________________ Telephone: _______________
   Address: ____

2. How long have you been at this address? __________ Years

3. Type of development?
   - House
   - Residential Units
   - Commercial (specify) ____________
   - Agricultural

4. Your status with regard to this property?
   - Owner residing or conducting business at property.
   - Tenant
   - Owner not residing or conducting business at property.
   - Other (please specify) ____

5. Have you ever experienced? Please tick more than one box.

	Yes	**No**	**Not Applicable**
Have floodwaters ever entered your house?			
Have floodwaters ever entered your yard?			
Has flooding ever caused you to leave your house?			
Has flooding ever caused you to move your car?			
Have you ever incurred a financial loss from flooding?			
If YES provide approximate amount (in $'s). _____________			
Have you ever missed work during a flood?			
Have you ever received a flood warning?			
If YES was the warning useful?			
Have you ever received assistance during a flood?			
From whom - specify? _______________________________			
Have you ever experienced any post flood emotional trauma?			
Do you have a flood action or emergency plan?			
Do you think there is a risk to life in your area from flooding?			
Do you think that you are flood aware?			

6. How deep (in centimetres) do you think the water would be above your lowest habitable (or work) floor level in the following events?

In a flood which occurs on average once in every 20 years __________ cms

In a flood which occurs on average once in every 100 years __________ cms

In the largest possible flood event __________ cms

7. How much time do you think you would have in a major flood to undertake emergency measures?

no idea 1 day 12 hours 6 hours less than 6 hours

8. Is the inundation of your land and/or building caused by flooding (from severe rain and ocean conditions) of concern to you? Yes No

If Yes indicate the means by which you would like the problem to be addressed.

Yes

do nothing

dredge, enlarge or maintain the Shoalhaven Heads entrance channel

better flood warning information

more information regarding damage minimisation or evacuation procedures

house raising

flood insurance

dredge the Shoalhaven River

voluntary purchase of building/land

sealing the entrances to the building

maintain or raise the levee on the southern bank from Nowra bridge to Terara

Other - specify: ____

____

9. Please provide any further comments that you think appropriate.

____

____

After completing this questionnaire please check that you have answered every question. Put the completed questionnaire into an envelope and mail (no stamp required) within 7 days to:

REPLY PAID 1752

Webb, McKeown & Associates Pty Ltd

Level 2, 160 Clarence Street

SYDNEY NSW 2000

Attention: Mr Richard Dewar

Thank you for your assistance

TERARA VILLAGE FLOODPLAIN MANAGEMENT STUDY

COMMUNITY INFORMATION SHEET OCTOBER 1998

INTRODUCTION

This Community Information Sheet has been issued to inform you of the Floodplain Management Studies (FMS) being prepared for the village of Terara and the Riverview Road area.

Shoalhaven City Council has appointed Webb, McKeown & Associates Pty Ltd (Consulting Engineers) to develop a sustainable plan for floodplain management of these two areas.

An integral part of the study process is the implementation of a community consultation program and this newsletter constitutes part of this process. Previously a questionnaire and a letter of introduction were provided by Council in July 1998.

Your questions and/or comments are welcome at any time during the course of the study. Details on how to contact the study team are provided on the back of this sheet as well as details of the upcoming public meeting.

FLOODPLAIN MANAGEMENT PROCESS

The implementation of sound floodplain management practice is an important process which can be used to optimise development potential, and to obtain social and economic benefits from the reduction in tangible and intangible flood damages.

The **first step** in the process is preparation of a Flood Study to establish design flood levels. (Design flood levels are levels which have a known likelihood of occurrence. For example the 1% annual exceedance probability event (AEP) has a 1% or 1 in 100 chance of being equalled or exceeded in any year.) This study was completed in 1990. The results indicate that a number of buildings would be inundated above floor level.

Event	Buildings Inundated above floor
Extreme	55
0.5% (AEP)	51
1% (AEP)	44
2% (AEP)	13
5% (AEP)	1

The **second step** is preparation of this FMS which identifies various floodplain management measures.

The **third stage** is preparation of a Plan which documents how the works identified in the FMS are to be implemented. The **final stage** is the undertaking of the works.

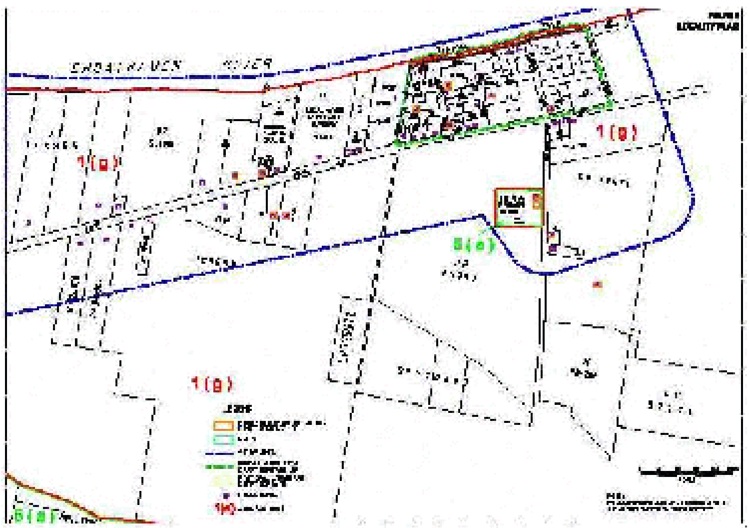
OBJECTIVES OF THE STUDY

The objectives for this FMS are as follows:

- to manage flooding as an integral part of the planning and development process,
- to systematically identify and address flooding problems,
- to prepare a schedule of works to manage the existing flood problem and reduce future flood damages,
- to implement a unified approach,
- to ensure sustainable development principles are achieved,
- to maintain and enhance the quality of the Shoalhaven River.

THE STUDY AREA

The study area (Figure 1) incorporates the village of Terara from the drainage easement (west) to Bryant Street (east).



THE FLOOD PROBLEM

Runoff from the 7000 square kilometre catchment of the Shoalhaven River enters the lower floodplain area at Nowra bridge, and enters the Pacific Ocean through Shoalhaven Heads or the Crookhaven entrance. Tidal conditions, wind wave activity and the build up of sand may restrict these outlets.

As the water level rises floodwaters overtop the river banks and inundates the floodplain. Flooding in the past (1860, 1870, 1974, 1978) has caused considerable damage and hardship to the community. A levee has been constructed from Nowra Bridge to Terara (it is at various levels) and provides protection up to the 10% AEP level at Terara and the 1% AEP level at Riverview Road.

The study area is designated as **High Hazard Floodway** and a summary of possible floodplain management measures is shown in the accompanying table and below.

Flood Modification - modifies flood behaviour.

Property Modification - modifies land use and development controls.

Response Modification - modifies the communities response to flood hazard.

HOW DO I GET INVOLVED?

Community input to the FMS is essential and a range of consultation activities are planned to coincide with the various stages of the study. Activities have or will include:

- your direct feedback to the project team or Shoalhaven City Council,
- individual discussions with residents, businesses and other stakeholders,
- input from your local representatives on the Floodplain Management Committee,
- questionnaire,
- public meetings,
- public exhibition of the draft FMS and Plan.

Submissions are welcome at any stage of the study process. Any interested party is invited to attend the first public meeting. It will be followed by the Riverview Road area public meeting (7 30 pm till 9 30 pm).

FIRST PUBLIC MEETING
For the TERARA STUDY

5 30pm till 7 30 pm
Monday 26 October 1998
Training Room No 1
Shoalhaven City Council Offices
Bridge Road, Nowra
(You are requested to meet the security personnel at the southern entrance to gain access to the building)

WHO TO SPEAK TO?

The Project Manager is:
Mr Richard Dewar,
Reply Paid 1752
Webb, McKeown & Associates
Level 2, 160 Clarence Street
SYDNEY NSW 2000
Telephone: (02) 9299 2855
Facsimile: (02) 9262 6208
Email:Shoalhaven@webbmckeown.com.au

You may also wish to contact Mr Ajith Goonatilleke, Strategic Drainage Engineer, Shoalhaven City Council on (02) 44 293238 to discuss any aspects of the project.

Should you only wish to make a brief comment or seek clarification on any issue, or have any comments on the proposal, please respond in the format as shown below and return to the free Reply Paid address.

NAME: ________________________________

ADDRESS: ______________________
____

TELEPHONE: ________________________________

COMMENT:
____
____
____
____
____

PLEASE ATTACH A LONGER SUBMISSION IF THERE IS INSUFFICIENT ROOM ABOVE.

APPENDIX C: BANK EROSION AND FAILURE

APPENDIX C: BANK EROSION AND FAILURE

C1. GENERAL

The terms bank erosion and bank failure are often used interchangeably. However, the two terms have different specific meanings. *Erosion* occurs when individual soil particles of the bank's surface material are removed. *Failure* occurs when a relatively large section of the bank fails and slides into the channel.

The major factors contributing to river bank erosion are:
- altered flow patterns, tidal currents and/or velocities,
- wave attack (from boats and wind waves),
- rainfall,
- seepage,
- overbank drainage,
- changes in land use (e.g. removal of native vegetation, introduction of livestock).

The major causes of river bank failure can generally be categorised as either an increase in the shear stresses in the bank or a decrease in the shear strength of the soil. These causes, which can individually or in combination lead to bank failure, are:
- increase in shear stress within the bank:
  - changes in channel shape due to bed scour or erosion of the bank face,
  - increase of load at the top of the bank,
  - rapid drawdown of water against the bank face,
- decrease in shear strength of soil:
  - swelling of clays due to absorption of water,
  - pressure of groundwater from within the bank,
  - creep, or minor movements of the soil,
  - removal of vegetation from banks.

C2. BANK EROSION

Soil particles carried away from a bank by flowing water are removed by a tractive force which tends to pull particles along with the flow. An *alteration in flow patterns, tidal currents and/or velocities*, whether natural (e.g. flooding) or caused by man (e.g. excavation) can increase the tractive force. The potential for erosion depends on the resistance of the river bank's soil particles, which is based on particle size and cohesive properties. Larger particles weigh more and are harder to move, thus gravel is more resistant to erosion than sand. Highly cohesive particles such as clay are more resistant.

Flow patterns vary across the width of a river, particularly at bends. The velocity (and correspondingly the tractive force) significantly increases towards the outside of a bend, causing a greater erosion potential on the outside bank. On the inside of a bend the velocity decreases allowing suspended sediments to deposit and build a point bar.

Local scour around obstacles in the bed or banks of the channel is caused by the turbulence of eddies and velocity concentrations in the flow generated by the obstacle. The extent of scour is related to the size and streamlining of the obstacle. Typical obstacles which cause scour are irregular bank lines, bridge piers, weirs, boat docks, rubble, and trees.

When *waves* set up by passing boats or wind reach the river bank, the repeated agitation caused by the waves can dislodge soil particles. Waves will alter the exposed bank wherever the energy cannot be dissipated in non-destructive hydrodynamic turbulence, such as progressive breaking on a stable beach, movement through the interstitial spaces of a rip rap slope, or diffraction and transfer of momentum through vegetation or other fixed or floating bodies. Additional damage can be caused by boats which moor.

Raindrops striking an exposed river bank tend to loosen soil particles and reduce the infiltration capacity of the soil. With the infiltration capacity reduced, more and more of the rainfall will run down the bank, increasing the tractive force of the runoff and thereby increasing the potential for erosion.

Seepage effects can be either steady or unsteady. Steady effects relate to discharge from, and recharge to, the regional groundwater regime through the channel bank. Pressure from groundwater movement inside the bank forces water on to the face of the bank, loosening soil particles at the bank's surface. The resulting downslope movement of seepage water and loosened soil particles can further erode the bank. Groundwater seepage can be observed as a wet bank face or as piping flow from small holes on the slope.

Unsteady seepage effects relate to changes in pore water pressure in the bank due to fluctuations in the water level in the channel, and are independent of the steady seepage into or out of the bank. These result from long-period changes such as flooding and tidal activity, or short-period changes such as water level drawdown due to boat and surface waves. The flow of pore water within the soil depends on the rate of change of the water level in the channel, the permeability, and the drawdown or wave height. Silty and sandy soils are most at risk as they cannot respond quickly enough to avoid relatively high pressure gradients, yet the seepage velocity may be significant.

Overbank drainage is closely related to the problem of river bank surface erosion due to rainfall and seepage, and can be responsible for severe sheet and rill erosion. Whilst erosion due to overbank drainage can occur naturally, it is more likely to occur when the land near the top of the bank has been disturbed by clearing and ploughing and no provisions have been made for surface drainage control.

Changes in land use which influence river flow past the bank and the amount of sediment in the flow can cause an otherwise erosion-free bank to suffer severe erosion. Three major changes in land use which can increase the potential for erosion are vegetation clearing (e.g. for agricultural purposes), allowing livestock to trample banks, and urbanisation. The inevitable results of removing vegetative cover, disturbing surface soils, and decreasing the area available for rainfall infiltration are downstream flooding and increased sediment loads. In addition to higher tractive forces during the flood, the sediment load deposited by the flood reduces the channel's flood-carrying capacity so that the river may attempt to widen itself to carry the flow, thus further eroding the banks.

C3. BANK FAILURE

Bank failure due to *changes in channel shape* such as toe scour is perhaps the most dramatic and serious cause of bank recession, resulting in sudden loss of the bank and its vegetation. Scour typically tends to occur at the toe of the bank, over steepening the slope and instigating collapse of the bank through slip circle failure or slumping. The resulting talus, which normally stabilises the toe is subsequently removed through sediment transport under strong river and/or tidal flows and the recession process is repeated.

An *increase in the load on top of the bank* causes an increase in shear stress within the bank, thereby increasing the potential for bank failure. Loads can be increased by man-made structures such as roads, bridges, buildings, etc., as well as by living things such as livestock.

Bank failure due to *rapid drawdown* (or a rapid drop in water surface elevation) is most likely to occur as floodwaters recede, or when the bank is subject to fluctuations in water surface elevations. During periods of high water, banks can become saturated by inflow from the river. When the bank face is covered by water, a pressure balance exists between the water in the channel and the weight of the saturated bank, helping to keep the bank in place. If the water elevation of the river is suddenly lowered and the soil cannot drain quickly, a pressure imbalance can develop (a pressure imbalance can also be caused by infiltration due to rainfall or runoff, or by groundwater sources deep within the bank). If the bank has insufficient shear strength to resist, the imbalance may cause bank failure.

The *swelling of clay materials* within banks due to the absorption of water can cause erosion by decreasing the shear strength of the bank. When the exposed wet clay and silt dry out, shrinkage and cracking can occur near the bank's surface, forming a layer of soil that can be easily eroded. The next time that water moves over the bank face, all or part of the layer may be removed. As the newly exposed material dries out, the cycle can repeat itself.

High *pore water pressure* in the bank material due to seepage or rapid lowering of the water level in the channel, will reduce the shear strength of the soil and can trigger a deep-seated rotational failure.

Soil creep can be observed as the development of bank cracks running generally parallel to a river. Wetting and drying cycles can cause swelling and shrinking of soils which contain clay. This encourages the generation of vertical fissures and the formation of soil blocks with desiccation cracks. This in turn encourages soil creep which can be responsible for bank failure.

The *root mat from vegetated banks* (mangroves have a particularly effective root mat) can modify the geotechnical properties of the soil, such that the shear strength of the bank can be increased and some tensile strength provided. Vegetation can therefore help to maintain the stability of river banks by helping prevent tension crack formation. Removal of the vegetation can cause the river bank to suffer mass failure.

APPENDIX D: FLOOR LEVEL DATABASE

APPENDIX D: FLOOR LEVEL DATABASE

No.	House No.	Street	Floor Level (mAHD)	Ground Level (mAHD)	Single Storey	Double Storey	Timber	Fibro	Mixed	Brick	Good	Poor	Large	Medium	Units	Comments	AEP which first Inundated the Floor
1	1	BRYANT ST	4.0	3.6	1				1		1			1	1		1%
2	2	BRYANT ST	4.0	3.8	1		1				1			1	1		1%
3	9	BRYANT ST	3.4	2.9	1		1					1		1	1		5%
4	186	SOUTH ST	4.4	2.9	1				1		1			1	1		1%
5	182	SOUTH ST	3.7	3.0	1				1		1			1	1		2%
6	180	SOUTH ST	3.8	3.0	1				1		1			1	1		2%
7	20	MILLBANK RD	4.2	3.8	1				1		1			1	1	school	1%
8	27A	MILLBANK RD	4.5	3.7	1				1		1			1	1		0.5%
9	27B	MILLBANK RD	4.2	3.7	1		1				1			1	1	house 'A'	1%
10	175	SOUTH ST	3.6	3.4		1				1	1		1		1		2%
11	2	SOUTHERN RD	4.2	4.0	1				1		1			1	1		1%
12	24	WEST BERRY ST	4.4	3.8	1		1				1			1	1		1%
13	22	WEST BERRY ST	4.6	3.8	1				1		1			1	1		1%
14	4	HOLME ST	3.7	3.6		1			1		1		1		1		2%
15	6	HOLME ST	3.9	3.6	1		1				1			1	1		2%
16	3	HOLME ST	4.1	3.6	1		1				1			1	1		1%
17	5	HOLME ST	3.9	3.6	1		1				1			1	1		2%
18	9	HOLME ST	3.7	3.2	1			1			1			1	1		2%
19	163	SOUTH ST	3.6	3.4	1		1				1			1	1		2%
20	161	SOUTH ST	3.9	3.7	1		1				1			1	1		2%
21	157	SOUTH ST	4.3	3.9		1	1				1			1	1		1%
22	10	FORSYTH ST	4.3	4.0	1				1		1			1	1		1%
23	8	FORSYTH ST	4.2	3.7	1		1				1			1	1		1%
24	6	FORSYTH ST	4.1	3.8	1			1			1			1	1		1%
25	10	WEST BERRY ST	4.4	3.8	1		1					1		1	1		1%
26	6	WEST BERRY ST	4.5	4.1		1				1	1			1	1		1%
27	4	WEST BERRY ST	5.0	4.0	1					1	1			1	1		0.5%
28	2	WEST BERRY ST	4.6	4.1	1					1	1			1	1		1%
29	1	FOX ST	4.7	4.2	1			1			1			1	1		0.5%
30	3	FOX ST	4.5	4.0	1		1				1			1	1		1%
31	6	FOX ST	4.7	4.2	1		1				1		1		1		0.5%
32	155	SOUTH ST	4.3	4.0	1					1	1			1	1		1%
33	151	SOUTH ST	4.2	3.5	1		1					1		1	1		1%
34	149	SOUTH ST	3.7	3.2	1					1	1			1	1		2%
35	31	MILLBANK ROAD	4.3	3.8	1				1		1			1	1	house 'B'	1%
36	1	NOBBLERS LANE	4.6	4.4	1					1	1		1		1		1%
37	3	NOBBLERS LANE	4.1	4.0	1					1	1		1		1		1%
38	139	TERARA RD	3.8	3.3	1		1				1			1	1		2%
39	137	TERARA RD	4.0	3.2	1		1				1			1	1		1%
40	126	TERARA RD	4.4	3.9		1			1		1			1	1		1%
41	123	TERARA RD	4.0	3.5		1			1		1		1		1		1%
42	121	TERARA RD	4.4	3.7	1				1		1			1	1		1%
43	119	TERARA RD	4.5	3.7	1		1				1			1	1	for sale at 12/92	1%
44	124	TERARA RD	4.4	3.9	1				1		1			1	1		1%
45	111	TERARA RD	6.1	3.4		1				1	1		1		1	t48 2nd floor	Ext
46	110	TERARA RD	4.4	4.0	1					1	1			1	1		1%
47	94	TERARA RD	5.1	4.4	1		1				1			1	1		0.5%
48	92	TERARA RD	7.0	4.5		1				1	1			1	1	t51 2nd floor	Ext
49	89	TERARA RD	5.0	4.3	1					1	1			1	1		0.5%
50	88	TERARA RD	6.4	3.7		1				1	1		1		1	t54 2nd floor	Ext
51	83	TERARA RD	4.6	4.1	1				1		1			1	1		1%
52	82	TERARA RD	3.6	3.4		1				1	1			1	1	living d/s	2%
53	71	TERARA RD	4.7	4.2	1				1		1			1	1	farmhouse	0.5%
54	135	TERARA RD	5.5	3.9		1				1	1		1		1	Plant nursery	0.2%
55	10	Berry St	4.4	3.8		1				1		1		1	1	Two storey	1%
			Totals		43	12	19	3	17	16	51	4	9	46	55		
			%		78	22	35	5	31	29	93	7	16	84			

Note: The data shown in the above Table was collected and used for the purpose of the assessment of flood damages in the study and internal use of Council. It should not be used for any other purpose. Council will not take any responsibility for any loss or damage suffered due to any errors in the above data.

APPENDIX E: POST FLOOD EVALUATION AND REVIEW

APPENDIX E: POST FLOOD EVALUATION AND REVIEW

E1. GENERAL

Design flood levels along the Shoalhaven River are provided in the *Lower Shoalhaven River Flood Study* - April 1990. Copies of this report are held by Shoalhaven City Council and the Department of Land and Water Conservation. The design levels were obtained from computer models of the catchment which were calibrated to five historical floods (August 1974, June 1975, October 1976, March 1978 and April 1988).

The accuracy of the design flood levels can be improved with further flood and rainfall data to confirm the calibration of the computer models. The following procedure has been developed to ensure that the information available from future floods is accurately obtained and analysed.

E2. PROCEDURE

Step 1 - Future Flood: If the river level exceeds (say) 4.8 m at Nowra Bridge data should be collected. The design flood levels at Nowra Bridge are shown in Table E1.

Step 2 - Collect Peak Levels: River levels and times should be recorded during the event if possible by SES, Council employees or local residents. It is imperative that the peak height of the flood be marked immediately following the event either from debris marks or eyewitness reports. Debris marks can be lost within hours of the peak as a result of wind, rain or human activities.

Council should despatch personnel to cover the length of the river (on both banks) to identify, mark and photograph debris. The levels can be picked up later by a surveyor. The data should be recorded in a report showing the photograph, time of recording (if during the flood) and level to AHD. Council should consider if a circular or notice in local papers is warranted to obtain further information.

If possible velocity measurements should be taken (by the DLWC or other authority) from Nowra Bridge.

Step 3 - Buildings Inundated: If floodwaters enter buildings, the occupier should be interviewed to provide a preliminary indication of the damages and peak level, and to obtain photographs. The floor level database used in the Floodplain Management Study indicates which buildings are likely to be flooded in a given event.

Step 4 - Reports from Authorities: Council should obtain written reports from various sections of Council, the SES and any other relevant public authority on the flood. Data should be obtained from the DLWC automatic water level recorders and Sydney Water and Bureau of Meteorology rain gauges. These data can be obtained at any time although if they are collected soon after the event they can be used to identify and correct any gross errors in other data.

Step 5 - Major Floods: Flood levels which indicate an AEP of greater than 5% should be used to re-examine the calibration of the hydrologic/hydraulic models. Data from any other floods which have not previously been analysed should be included in this re-examination.

Steps 6 and 7 only apply to floods with an AEP greater than 5%.

Step 6 - Rainfall Data: Rainfall data from Sydney Water and Bureau of Meteorology gauges is continuously recorded and can be readily obtained at any time. If warranted, additional rainfall information can be sought from residents at the same time as flood data are requested.

Step 7 - Hydrologic/Hydraulic Modelling: The new data should be run through the WBNM and CELL models. If the models do not produce satisfactory results then all available information (including that from floods used in the Flood Study) needs to be considered to see if the model parameters should be changed. Consideration should be given to upgrading the hydraulic model. This will require a considerable amount of additional survey. Any changes in calibration parameters may lead to revised design flood levels. A report should be produced documenting the results and any adjustments required to Council's Floodplain Management Plans and S149 Certificates.

Step 8 - Shoalhaven Entrance Survey: The amount of sand that accumulates between openings at the mouth of the Shoalhaven Heads entrance has a significant influence upon flood levels in the local area. It is essential that as much information as possible is obtained on the pre and post flood topography at the entrance. Generally this will only be possible from aerial photography, but a post flood survey may be warranted. Such a survey was undertaken following the April 1988 flood and this proved very useful in calibrating the hydraulic model. These data should be obtained as soon after the flood as possible.

Table E1: Design Flood Levels (mAHD)

Event (AEP)	Nowra Bridge	Shoalhaven River at Terara
Extreme	8.94	7.39
0.2%	7.28	6.08
0.5%	6.76	5.70
1%	6.34	5.43
2%	5.79	5.04
5%	5.25	4.68
10%	4.78	4.36