CLARENCE VALLEY COUNCIL

ILUKA FLOODPLAIN RISK MANAGEMENT PLAN

MARCH 2007

WEBB, McKEOWN & ASSOCIATES PTY LTD

CLARENCE VALLEY COUNCIL

ILUKA FLOODPLAIN RISK MANAGEMENT PLAN

MARCH 2007

CLARENCE VALLEY COUNCIL

ILUKA FLOODPLAIN
RISK MANAGEMENT PLAN

MARCH 2007

Webb, McKeown & Associates Pty Ltd
Level 2, 160 Clarence Street, SYDNEY 2000
Telephone: (02) 9299 2855
Facsimile: (02) 9262 6208
25034:IlukaFRMP.wpd

Prepared by: ___________________________

Verified by: ___________________________

ILUKA FLOODPLAIN RISK MANAGEMENT PLAN

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOGRAPHS

LIST OF GRAPHS

FOREWORD

The State Government's Flood 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*
   - determine the nature and extent of the flood problem.
2. *Floodplain Risk Management Study*
   - evaluates management options for the floodplain in respect of both existing and proposed development.
3. *Floodplain Risk Management Plan*
   - involves formal adoption by Council of a plan of management for the floodplain.
4. *Implementation of the Plan*
   - construction of flood mitigation works to protect existing development,
   - use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

The Iluka Floodplain Risk Management Plan constitutes the third stage of the management process for the township of Iluka. It has been developed for Clarence Valley Council and prepared by Webb, McKeown & Associates for the future management of flood liable lands in the area.

This Plan should be reviewed every five years or following any significant flood.

SUMMARY

LOWER CLARENCE VALLEY

The Clarence River has a catchment area of some 21,900 km² to its mouth at Yamba, and some 19,800 km² to Grafton. Grafton is the main commercial centre in the region, downstream of Grafton the Clarence River meanders in a general north-east direction entering the Pacific Ocean through the training walls at Yamba. The township of Iluka lies on the northern bank of the river approximately 5 kilometres upstream of the mouth. The township of Iluka is predominantly a rural residential and tourist centre with a permanent population of approximately 2000 but this may double during the Christmas holiday period.

HISTORY OF FLOODING

There is a long flood history at Grafton and elsewhere on the lower Clarence River floodplain. At Iluka there is only a limited flood history as flooding has not caused the devastating damage that has occurred elsewhere on the floodplain upstream. The last significant flood was in March 2001 which did not cause any damage to the town.

Flood level at Iluka are available since 1998 from local residents. However there are no prior height data or records of properties being inundated.

LOWER CLARENCE RIVER FLOOD STUDY

The recently completed Lower Clarence River Flood Study Review (March 2004) established a 2D hydraulic model and determined design flood levels for the lower Clarence River floodplain from upstream of Grafton to the Pacific Ocean. This study supercedes a previous Public Works study, Clarence River Flood Study (December 1998).

The Lower Clarence River Flood Study Review determined design flood levels, depths and hazards for the 5y, 20y, 100y ARI and Extreme events. One notable feature of the study is that the construction of levees in the last 100+ years near Grafton have raised flood levels at Grafton by up to 0.9 m. However, any increase in flood level at Iluka is likely to be insignificant.

FLOOD HAZARD

Flooding at Iluka can occur as a result of a combination of high flows in the Clarence River, high ocean levels (storm surge), wave runup action along the foreshore or from intense rain over the local catchment. A survey of floor levels indicated that in a Clarence River flood, 5 floors would be inundated in a 20y ARI event and 45 floors in the 100y ARI event. The average annual damages are estimated at $55,000. The risk to life due to flooding as a result of high flows in the Clarence River is considered to be low as there is easy access to high ground and the inundation occurs gradually and with several hours (or days) warning.

Intense rain over the local catchment produces significant inconvenience to the community but negligible risk to life. Raised ocean levels due to storm surge/high tides and wave runup along the foreshore are generally less understood by the community than Clarence River flooding. For example, overtopping of the levee system and inundation of Iluka could occur in the absence of significant Clarence River flooding. The risk to life from ocean inundation is probably greater than for river flooding due to the relatively unexpected nature of the hazard and the likely short (if any) warning time.

RECOMMENDED FLOODPLAIN RISK MANAGEMENT MEASURES

A range of measures have been evaluated and the recommended measures for Iluka are provided in Table i). Measures within each priority class (high, medium or low) are not listed in any particular order, each measure in each class has the same level of priority.

PUBLIC EXHIBITION OF DRAFT PLAN

The Draft Plan was placed on public exhibition from 20th October to 24th November 2006. A public meeting was also held on 24th October 2006 at Iluka Community Hall.

Two responses to the Draft were obtained and both indicated that they objected to the possible raising of the Marandowie Drive concrete levee to 3 mAHD (Measure L2) for aesthetic and social reasons.

Table i): Recommended Floodplain Risk Management Measures for Iluka

Measure		Discussion	Recommendations	Indicative Cost and Benefit	Responsibility	Required Approvals
HIGH PRIORITY:						
H1:	Formalise a local drainage issues database.	Many residents of Iluka have highlighted the issue of runoff ponding in low lying areas or flowing at shallow depths across private property or roads. Council has in the past attempted to alleviate the problem by clearing pipe systems and installing new pipes or grading flow paths. However in many locations there are no simple solutions.	Local residents should ensure that all such issues are adequately documented (written and photographic) and reported to Council. Council will incorporate the information into a database and address these issues where appropriate.	The costs will depend on the nature of the problem. The benefits will be to obtain more accurate data and information regarding the types of issues and their occurrence so the best approach to remedying them can be developed.	Clarence Valley Council	None
H2:	Undertake levee Scenario 1 - filling the low spots in the Caravan Park levee and downstream of the Marandowie Drive concrete levee.	Filling the low spots to 2.4 mAHD would provide the same level of protection as the existing Marandowie Drive concrete levee (20y ARI) and complete the system.	The low spots in the Caravan Park levee and immediately downstream of the Marandowie Drive concrete levee should be filled to a minimum level of 2.4 mAHD. As there are no negative impacts (aesthetic, excessive additional cost, access) to elevating the existing levee, consideration should be given to possibly raising the levee within the Caravan Park to a higher level.	$10,000 Filling the low spots would prevent these areas from being the first place to overtop and would complete the Marandowie Drive and Caravan Park levee system.	Clarence Valley Council Department of Natural Resources	Clarence Valley Council Department of Natural Resources The Anchorage Caravan Park owner
H3:	Develop a Flood Evacuation Plan for Iluka.	During the March 2001 flood, floodwaters cut off the sole evacuation route from Iluka leaving the town isolated for four days until the waters receded. During this time the SES were stationed at Yamba and were ready to evacuate any persons if necessary. At present, there is no SES Flood Evacuation Plan specifically for Iluka, though it is considered under the Old Maclean Shire Flood Plan. This plan is currently being updated by the SES to include Evacuation Plans for all villages isolated during a flood, including Iluka.	An Evacuation Plan is necessary for the town of Iluka as it has been isolated in the past and will be isolated again in future floods. The Plan should give consideration to flood preparedness, response and recovery as well as SES access into Iluka when road routes are cut.	Nominal Cost. The benefits are that any future evacuations will be undertaken in a safe and efficient manner.	State Emergency Services	None

Measure	Discussion	Recommendations	Indicative Cost and Benefit	Responsibility	Required Approvals
H4: Update Flood Warning System.	Flood warning and the implementation of evacuation procedures by the SES are widely used throughout NSW to reduce flood damages and protect lives. The Bureau of Meteorology is responsible for flood warnings on major river systems such as the Clarence River. The flood warning system is based on stations which automatically record rainfall or river levels. Consideration is also given to ocean storm surge (where applicable). Analysis is then undertaken to determine the expected time and height of the flood peak.	The BOM already has a comprehensive flood warning system for the Clarence River, which has been tested in the 1996 and 2001 floods. Possible improvements include providing advice on the deadline when Iluka residents can evacuate the township and ensuring best practice is employed on providing advice on ocean storm surge and wave runup activity. The system should be reviewed after significant flood events.	Nominal Cost. The benefits are that in future floods the most accurate warnings possible, in terms of timing and peak level are available.	Bureau of Meteorology	None
H5: Prepare/update an Evacuation Plan for The Anchorage Caravan Park.	A comprehensive Evacuation Plan provides a means of minimising damages and the risk to life for all occupants. This is particularly important for tourists who may be unfamiliar with flooding.	An Evacuation Plan should be prepared/updated for The Anchorage Caravan Park and updated every two years or following any significant flood.	Nominal Cost. A comprehensive Evacuation Plan will ensure damages and the risk to life are minimised during future floods.	The Anchorage Caravan Park owner	None
MEDIUM PRIORITY:					
M1: Implement a Community Flood Awareness and Public Information Program.	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. Based on feedback from interviews and discussions, the residents of Iluka have a medium to high level of flood awareness and preparedness.	A flood awareness program should be implemented to maintain a high level of awareness amongst the Iluka residents. In particular awareness of evacuation, potential for the levee system to fail and what to do during a flood.	Nominal Cost. Flood awareness will help reduce flood damages and disruption during and after a flood.	State Emergency Services Clarence Valley Council Local Groups (Association of Iluka Residents (AIR), Rural Fire Service, etc)	None
M2: Undertake levee Scenario 2 - Fill and raise the low spots in the Duke Street mounds to 3.0 mAHD.	Filling and raising the Duke Street mounds to a level of 3 mAHD would provide protection greater than the 500y ARI event for properties in the areas. Consideration would need to be given to tying the Duke Street mounds into the high ground within the properties of Gundaroo Court to complete the system. There would be minimal impacts of this option as the majority of existing mounds are at, or higher, than this level.	This scenario should be investigated further to determine how the Duke Street mounds would be tied into the high ground behind properties on Gundaroo Court. Community acceptance would also need to be obtained. If these issues are resolved this measure should be pursued.	$40,000 with an indicative B/C ratio of 0.2 There will be additional costs to tie the levee into high ground near Angourie Street. Provide protection greater than the 500y ARI event for properties between Hickey Street and Angourie Street (and potentially those further downstream) as well as increase the time until overtopping for events greater than the 500y ARI.	Clarence Valley Council	Local Community Clarence Valley Council

Measure	Discussion	Recommendations	Indicative Cost and Benefit	Responsibility	Required Approvals
M3: Prepare a Development Control Plan for Iluka.	The strategic assessment of flood risk can prevent development occurring in areas with a high hazard and/or with the potential to have significant impacts upon flood behaviour in other areas. It can also reduce the potential damage to new developments likely to be affected by flooding to acceptable levels.	A Development Control Plan should be prepared for Iluka and give consideration to: • adequate access during floods, • the effects of fill/excavation, • building materials and structural soundness, • fencing, • public assets, • flood planning levels, • minimal floor level above natural surface.	Nominal Cost. Development control planning can reduce the effects of flooding on future development by minimising flood damages and managing risk.	Clarence Valley Council	Clarence Valley Council
LOW PRIORITY:					
L1: Undertake a study to quantify the effects of wave runup.	Wave runup is confined to the nearshore area and is dependant on a number of factors. Wave runup can produce flooding on the western foreshore of Iluka as well as foreshore erosion. The damages resulting from wave runup are difficult to accurately quantify as little data are available. A study into the effects of wave runup would quantify impacts on houses, foreshore stability and on possible mitigation measures.	A study into the effects of wave runup should be undertaken for the township of Iluka. Until such stage, the potential impacts should be incorporated into any possible mitigation measures which may be affected by wave runup (such as setting minimal floor levels and quantifying the level of protection provided by existing and future flood mitigation structures).	$10,000 A rigorous assessment of wave runup will ensure that the potential impacts are quantified and ultimately can be incorporated into development control planning.	Clarence Valley Council Department of Natural Resources	None
L2: Undertake levee Scenario 3 - Raise the Marandowie Drive and Caravan Park levees to 3.0 mAHD. Investigate additional levee around Cave and Spenser Streets.	Raising the Marandowie Drive and Caravan Park levees would provide protection greater than the 500y ARI event. To date the feedback from local residents along Marandowie Drive is that they are opposed to this measure for aesthetic and social reasons.	This scenario should be investigated further to ensure community acceptance and a preliminary design.	$200,000 with an indicative B/C ratio of 0.1. Provide protection greater than the 500y ARI event for properties upstream of Hickey Street as well as increase the time until overtopping for events greater than the 500y ARI.	Clarence Valley Council	Local Community Clarence Valley Council
L3: Voluntary House Raising	House raising is used to eliminate inundation from habitable floors. However it has limited application as it is not suitable for all building types and is more common in areas where there is a greater depth of inundation than at Iluka. Three properties on Marandowie Drive could potentially be raised although further investigations are required.	This scenario should be further investigated to ensure resident acceptance, property suitability and likelihood of funding. However, it should not be pursued if L2 is implemented.	$60,000 per house raised with an indicative B/C ratio of 0.3. Will eliminate inundation of habitable floors for three properties on Marandowie Drive in events up to the 100y ARI plus 0.5 m.	Clarence Valley Council Department of Natural Resources Owners of identified houses	Department of Natural Resources Owners of identified houses

1. INTRODUCTION

The Clarence River has a catchment area of some 21,900 km^2 to its mouth at the Pacific Ocean and some 19,800 km^2 to Grafton. The catchment is bounded to the west by the Great Dividing Range, by the Doughboy Range / Dorrigo Plateau to the south and the Great Dividing Range / McPherson Range to the north. The Richmond Range and the Coast Range separate the smaller coastal catchments from the Clarence River.

The City of Grafton is historically the regional centre servicing the Clarence Valley and its hinterland. It was founded in the mid 1800's as the port for the exporting of timber from the region. Further downstream there are several towns. At the mouth of the river on the south side is Yamba and on the north side is Iluka. Yamba has a population of approximately 6,000 and is a significant urban as well as tourist centre. Iluka has a population of 2,000 and is predominantly a residential and tourist centre with a small fishing co-operative and industrial estate.

Iluka (Figure 1) is approximately 5 kilometres upstream of the river's mouth and is partially separated from the main river by large breakwaters. The mouth of the Clarence River is restricted by a northern and southern breakwater which are up to 500 m in length and several metres high (refer Photograph 2).

Clarence Valley Council (CVC) engaged Webb, McKeown & Associates to prepare a Floodplain Risk Management Plan for Iluka. The objectives of this Plan are:

- to review the nature and extent of the flood hazard in light of the recently completed Lower Clarence River Flood Study Review (March 2004),
- to review the existing management measures aimed at reducing the impact of flooding on both existing and future development,
- to develop a Plan that addresses the current and future flooding issues for the township of Iluka.

A glossary of flood related terminology is provided in Appendix A.

1.1 Floodplain Risk Management Process

As described in the Floodplain Development Manual (Reference 1), the Floodplain Risk Management Process entails four sequential stages:

Stage 1: Flood Study.
Stage 2: Floodplain Risk Management Study.
Stage 3: Floodplain Risk Management Plan.
Stage 4: Implementation of the Plan.

The Flood Study stage was completed in March 2004 with publication of the Lower Clarence River Flood Study Review (Reference 2). In this study a two-dimensional hydraulic model was used to determine design flood levels for the lower Clarence River floodplain including Iluka. This study superceded a previous Flood Study (Reference 3) completed in 1998.

The Floodplain Management Study (Stage 2 - Reference 4) seeks to identify the nature of the flood problem in terms of risk to floodplain occupants and their assets, and then to canvass various management measures to mitigate the effects of flooding.

The end product is a Floodplain Risk Management Plan (Stage 3) which describes how flood prone lands in the township of Iluka are to be managed in the future.

A previous Management Plan for the Lower Clarence River, which included Iluka, was completed in 1999 (Reference 5). However, since the amalgamation of the local councils in early 2004 to form the Clarence Valley Council, the new council is developing consistent flood-related planning measures and policies throughout the Clarence Valley (Reference 6).

The measures recommended in this Plan recognises the work undertaken in Reference 6. Clarence Valley Council will complete the process through implementation of the actions (Stage 4) identified in this Plan depending upon financial and other constraints.

A rigorous public consultation program was carried out as part of this study. This included:

- an initial letter of introduction to local residents,
- follow up telephone calls to key respondents,
- floodplain management committee meetings,
- two workshops,
- public exhibition of material.

1.2 Iluka Township

The Clarence River valley was first explored by Europeans in the early 1830's with the first settlement near Grafton in 1837 on the south side of the Clarence River. Subsequently several small rural settlements developed, including the township of Iluka.

Iluka has developed on the northern bank of the Clarence River as a small tourist centre with a normal population of approximately 2000, however, this may double during the Christmas holiday period.

In recent years there has been significant pressures to develop new areas. These have arisen to accommodate increased tourist developments as well as for permanent residents, as a result of the so-called “sea change” phenomena. A sewerage system is proposed for the township and this may further increase the pressure for development.

A large part of the township is constructed on undulating sand hills which cause significant local drainage issues. These have been addressed in the past by CVC but due to the low lying nature of the topography cannot be completely eliminated. The flood prone areas of the township lie on the north-western side of the town fronting the Clarence River.

There are three caravan parks (The Anchorage, Iluka Riverside, Clarence Head) within Iluka with a small industrial estate to the north. The land to the east fronting the Pacific Ocean is part of the Iluka Nature Reserve and to the north is Bunjalong National Park.

Iluka Bay is protected by an extensive training wall system (Figure 1) and there is another wall on the southern side. The main area affected by flooding on the western side of the town from approximately Cave Street northwards. A levee bank has been constructed along Marandowie Drive and Duke Street to protect the houses to the east and The Anchorage Caravan Park.

1.3 Clarence River County Council (now Clarence Valley Council)

The Clarence River County Council (CRCC) was formed in 1959 to perform all the duties under Section 494 of the Local Government Act of 1919 relating to the prevention or mitigation of menace to the safety to life or property from floods. As a result of the amalgamation of local councils in early 2004 the CRCC has been renamed as the Clarence Valley Council (CVC).

Prior to formation of the CRCC, works were undertaken by the relevant Councils or by drainage unions. The majority of these works are now under the control of the CVC but some are still privately owned by landowners or drainage unions.

A summary of the activities undertaken by the CVC include:
- construction, management and maintenance of floodplain drainage and associated infrastructure,
- construction and maintenance of levees,
- provision of bank protection works, including quarrying,
- control of noxious weeds,
- voluntary purchase schemes,
- management of environmental, erosion and floodplain management projects.

1.4 Description of Flooding

1.4.1 Historical Events

Since the construction of the levee system in the 1970's, Iluka has not been inundated by floodwaters from the Clarence River. However, there are a number of recorded peak river levels for historical events taken near The Anchorage Caravan Park (Table 1). Each level was supplied by a local resident relative to the crest of the levee measured at 1.9 mAHD.

Table 1: Historical Flood Levels

Date	Level (mAHD)
09/04/1988	1.58
04/04/1989	1.33
28/04/1989	1.41
08/05/1996	1.59
11/03/2001	1.73

Note: Data supplied by local residents.

From Table 1 it can be seen that the largest recorded event was March 2001, where floodwaters came within 0.17 m of overtopping the levee. At Grafton, the March 2001 flood is considered to be approximately a 15y ARI event. Interviews with members of the community noted that during the 1988 flood, the pump within the Marandowie levee (Photograph 11) was used extensively, it has only been infrequently used since (in 2001 there was minimal internal floodwaters). Undoubtedly floods have occurred prior to those shown in Table 1, however no reliable flood height data are available or the number of building floors inundated.

The study area incorporates the entire township from Johnsons Lane in the north to Queen Street in the south. However the main areas subject to inundation are between Conrad Close in the north and Spenser Street in the south.

The following streets have properties affected by flooding from the Clarence River:

- Marandowie Drive,
- Conrad Close,
- Melville Street,
- Hemmingway Place,
- Loxton Avenue,
- Duke Street,
- Gundaroo Close,
- Riverview Street,
- Cave Street,
- Spenser Street.

The only caravan park affected by flooding is The Anchorage off Marandowie Drive.

1.4.2 Flooding Mechanisms

Flooding can occur as a result of four main mechanisms:

1. Inundation due to flooding in the Clarence River.
2. Inundation from high ocean levels (storm surge activity and/or high tides).
3. Wind/wave action along the eastern foreshore of the Clarence River.

4. Intense rain over the township of Iluka causing ponding in low lying areas as a result of inadequate local drainage. This mechanism is largely outside the scope of this present investigation.

1.4.3 Building Floors Inundated

Design flood levels for Iluka were derived in the Lower Clarence River Flood Study Review (Reference 2) taking into account the first two mechanisms described above and are provided in Table 2. A floor level survey was undertaken in May 2006 (Appendix B) and used to calculate the number of inundated buildings and associated damages for each design event (Table 2).

Table 2: Design Flood Levels

Event	Flood Level (mAHD)	Assumed Peak Ocean Level (mAHD)	Building Floors Inundated(1) (2)	Tangible Flood Damages (2) ($)
Extreme	3.65	2.6	225	$11,441,000
500y ARI	2.44	2.6	53	$1,444,000
100y ARI	2.38	2.6	45	$1,192,000
20y ARI	1.86	2.1	5	$81,000
5y ARI	1.13	0.8	0	$0

(1) Caravan park vans/units are not included in this total. Refer to Section 2.4.2

(2) The Marandowie Drive/Duke Street levees provide protection to approximately 1.9 mAHD and the Caravan Park levee provides protection to approximately 1.4 mAHD. As the crests of the Marandowie Drive and Duke Street levees are approximately at the 20y ARI level the damage assessment provided in Table 2 assumes full overtopping of the levee system in the 20y ARI and greater events. Figures 3 and 4 indicate the location of the buildings and the levees. Two of the five buildings inundated in the 20y ARI are behind levees.

Note: Figure 5.1 of Reference 2 indicates that the design flood profiles of the Clarence River are approximately flat over the final 10 kilometres to the Pacific Ocean. This indicates the significant influence of the high ocean levels in the lower reaches of the Clarence River.

A graph of the building floor levels and design flood levels is shown on Figure 2. Figure 3 is a plan showing the event that first inundates the main building on each property. Figure 4 provides the approximate flood extents and survey information.

1.4.4 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 3.

Table 3: Hazard Classification

Criteria	Weight [1]	Comment
Rate of Rise of Floodwaters	Low	Residents will generally be aware that the river is rising.
Duration of Flooding	Low	The duration of overtopping is less than 1 day with the floodplain slowly draining.
Effective Flood Access	Medium	The access routes are generally sealed roads and should present no unexpected hazard if used prior to overtopping.
Size of the Flood	Medium	Up to a 20y ARI event there is no direct inundation from the Clarence River. In the 20y ARI event and greater the majority of the floodplain is inundated.
Effective Warning and Evacuation Times	Medium	The existing BOM flood warning system should provide adequate warning for Clarence River flooding but the system for ocean effects and wave runup provides less warning.
Additional Concerns such as Bank Erosion, Debris, Wind Wave Action	Medium	There are likely to be a number of additional concerns which will increase the potential hazard. Probably the most significant is levee collapse and wind wave action. Debris and wind wave action may also cause damage to structures and increase the risk to life.
Evacuation Difficulties	High	These are likely to be low.
Flood Awareness of the Community	High	This is relatively high based upon the recent experience in the two floods in February and March 2001.
Depth and Velocity of Floodwaters	High	The depth of floodwaters is shallow compared to other areas on the Clarence River but still presents a risk to life. Of greater concern will be the velocity of floodwaters which presents a significant risk to life and property.

Note: (1) Relative weighting in assessing the hazard.

Based upon the above, the majority of the floodplain has a Low flood hazard classification for flood events up to a 20y ARI event. However the classification is High for a 100y ARI event.

1.5 Photographs

Photo 1: View across Clarence River to Iluka

Photo 2: Training walls at mouth of Clarence River


Photo 3: Concrete levee along Marandowie Drive - March 2001 flood


Photo 4: Concrete levee along Marandowie Drive - March 2001 flood


Photo 5: Marandowie Drive - March 2001 flood


Photo 6: Marandowie Drive - March 2001 flood


Photo 7: Cave Street - March 2001 flood


Photo 8: Cave Street - March 2001 flood

Photo 9: Concrete levee along Marandowie Drive

Photo 10: Start of concrete levee opposite The Anchorage Caravan Park

Photo 11: Pump within concrete levee system

Photo 12: The concrete levee is less than 1 m high

Photo 13: Flap gated culverts within concrete levee system

Photo 14: Duke Street earthen mound

Photo 15: Typical area where ponding of local runoff will occur

Photo 16: Typical area where ponding of local runoff will occur

Photo 17: Existing levee on access path to caravan park

Photo 18: Existing levee along northern boundary of caravan park

Photo 19: Existing low spots downstream of Marandowie Drive concrete levee

Photo 20: Potential location for new levee along Cave Street, Clarence River Bank on left

2. FLOODPLAIN RISK MANAGEMENT MEASURES

2.1 General

The NSW Government's Floodplain Development Manual (2005) separates floodplain management measures into three broad categories:

Flood modification measures modify the flood's physical behaviour (depth, velocity) and include flood mitigation dams, retarding basins and levees.

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 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 damages (benefit) compared 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.

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

2.2 Flood Modification Measures

Flood modification involves changing the behaviour of the flood itself, by reducing flood levels or velocities, or excluding floodwaters from areas under threat. This includes:
- dams,
- retarding basins,
- channel modifications,
- levees,
- flood gates,
- pumps

2.2.1 Dams and Retarding Basins

Flood mitigation dams and their smaller urban counterparts termed retarding basins have frequently been used in NSW to reduce peak flows downstream. Dams are rarely used as a flood mitigation measure for existing development on account of the:

- high cost of construction,
- high environmental damage caused by construction,
- possible sterilisation of land within the dam area,
- high cost of land purchase,
- risk of failure on the dam wall,
- likely low benefit cost ratio,
- lack of suitable sites. A considerable volume of water needs to be impounded by the dam in order to provide a significant reduction in flood level downstream. This is particularly true for large river systems, like the Clarence River,
- a dam would have minimal impact at Iluka where high ocean levels have a significant impact on flood levels.

This measure was not considered further for the above reasons.

2.2.2 Channel Modifications

This includes dredging and vegetation clearing to increase the waterway area, which in turn can reduce the flood levels. Channel modifications are rarely used today as a flood modification measure due to:

- the likely high environmental damage caused by the works,
- the subsequent possible change in ecology,
- the ongoing maintenance requirement,
- if maintenance is not undertaken and a flood occurs then there may be some liability issues for Council,
- there is no guarantee the works will be undertaken immediately prior to a flood. Also the early part of the flood or period of heavy rain prior to flooding may bring down sediments and debris,
- in large rivers the impacts of the channel modifications on flood levels is likely to be negligible.

This measure was not considered further for the above reasons.

2.2.3 Levees, Flood Gates and Pumps

DESCRIPTION

Levees are built to exclude previously inundated areas of the floodplain from the river up to a certain design event. Iluka currently has a concrete levee along Marandowie Drive (Photographs 3 and 12) and earthen levee mounds along Duke Street (Photograph 14) and on the northern side of The Anchorage Caravan Park (Photographs 17 and 18). Figure 4 provides crest levels along each part of the levee system. The Marandowie concrete levee was built in the 1970's to approximately the 20y ARI flood level (1.9 mAHD). Residents indicated that immediately downstream of the concrete levee the ground level is lower than 1.9 mAHD and floodwaters have entered Iluka in this area in the past (Photograph 19). The March 2001 flood came to within 0.17 m of the crest of the concrete levee. At Grafton, this was approximately a 15y ARI event. The Duke Street mounds are of varying levels with the lowest points at a similar level to the crest of the Marandowie concrete levee. The Caravan Park levee varies between 1.4 and 3.1 mAHD. Thus the first entry point for floodwaters is likely to be over the mounds in the caravan park as well as the low areas downstream of the Marandowie concrete levee.

Raising the Marandowie concrete levee to the 100y ARI flood level of 2.4 mAHD (increase of up to 0.5 m) was considered as part of the 1999 Lower Clarence River Floodplain Management Plan (Reference 5), but dismissed due to environmental and social reasons.

Flood gates can be considered as a separate modification measure or as part of the levee design. Flood gates allow local waters to be drained from the area when the level of the Clarence River is low, but when the river is elevated the gates prevent floodwaters from entering (or exiting) Iluka. There are currently a number of flood gates in Iluka however residents indicated that additional flood gates are required on the exit points which currently do not have them. Further discussion on local drainage issues is provided in Section 2.2.4.

Whilst flood gates have been used successfully at a number of locations throughout NSW over many years, they require ongoing maintenance to ensure their continued success. Vandalism, corrosion, damage or vegetation growth can all result in failure (either to release floodwaters from Iluka or prevent entry from the Clarence River) at critical times. Some form of ongoing maintenance program is therefore required.

Pumps are generally also associated with levee designs. They are installed to remove local floodwaters behind levees when flood gates are closed or there are no flood gates. There is an existing pump on Marandowie Drive which was installed for this purpose. It is understood that a maintenance program is undertaken to ensure that the pump is working. Additional pumps may be required if the levee is raised or even under the current configuration to assist in reducing local ponding cause by periods of high rainfall. A significant issue with pumps is the possible failure during a flood due to either inadequate maintenance, vandalism or power disruption. Possibly a 3-phase generator should be placed nearby in case of a power failure during a flood. According to residents the existing pump has probably not been used to reduce internal flood levels since 1988. It was in operation in 2001 but there was little internal water to remove.

DISCUSSION

There are three measures available involving some modification to the current levee system. These are:

Scenario 1: Fill the low spots in the Caravan Park levee to a minimum of 2.4 mAHD (100y ARI level). As there are no negative impacts (aesthetic, excessive additional cost, access) to elevating the existing levee, consideration should be given to possibly raising it to a higher level. A check should also be made to ensure that the ground at the downstream end of the Marandowie concrete levee is at or above 1.9 mAHD.

Scenario 2: Fill and raise the low spots in the Duke Street mounds to 3 mAHD (as a large portion of the mound is near, or higher than this level). Consideration would also need to be given to tying the Duke Street mounds into the high ground within the properties of Gundaroo Court to complete the system.

Scenario 3: Raise the Marandowie and Caravan Park levees to 3 mAHD. To provide a complete levee system at Iluka investigations into constructing a levee around Spenser and Cave Streets that ties into the Duke Street mounds should also be undertaken.

A crest level of 3 mAHD was chosen as the maximum level to raise the levee system as it equates to greater than the 500y ARI level. Residents of Iluka indicated that raising the Marandowie concrete levee to 3 mAHD was too high (for aesthetic reasons) and suggested an increase of just 0.3 m (new crest level of 2.2 mAHD). A comparison of three alternate height increases for the Marandowie concrete levee is shown in Table 4. For the purposes of evaluation, 3 mAHD was kept as the possible new level for Scenarios 2 and 3 but this could be altered.

Table 4: Comparison of Possible Increase in Crest of Marandowie Concrete Levee

Increase	Level of Protection	Impacts				
		Aesthetic	Access	Cost	AAD	Benefit/Cost
none (1.9 mAHD)	20y ARI	-	-	-	$55,000	-
+0.3 m (2.2 mAHD)	approximately the 50y ARI	minor	minor to nil impediment to existing level of access	$160,000	$54,000	<0.05
+0.5 m (2.4 mAHD)	100y ARI	moderate	significant as residents will not be able to "walk" over it	$170,000	$39,000	0.09
+1.1 m (3.0 mAHD)	>500y ARI	significant	significant	$200,000	$35,000	0.1

Note: There will also be some additional benefit to the sites in The Anchorage caravan park (refer Section 2.4.2). However this benefit cannot be readily quantified as it would depend on the usage at the time of the flood, also some caravans can easily be moved during a flood to minimise damages.

As well as providing an increased level of protection, raising the crest of the levee system has the additional advantage of increasing the time until overtopping for events greater than the levee design capacity. This may result in a reduction in flood damages in these events as there is more time to remove goods, cars, etc.

Whilst modification to the levee system would not exacerbate the existing local drainage issues, the installation of additional flood gates and/or pumps would help to manage these issues and should be considered as part of the overall design.

It is assumed that the Caravan Park and Duke Street levees would remain as earthen mounds. However it is possible that the Marandowie concrete levee could be re-constructed as either an earthen or concrete levee.

Benefits:

Scenario 1 - Filling the low spots in the Caravan Park levee to 2.4 mAHD and downstream of Marandowie concrete levee (to a minimum of 1.9 mAHD) would provide a standard level of protection (20y ARI) and complete the system, as at present these low spots would be the first places to be overtopped.

Scenario 2 - Filling and raising the Duke Street mounds to a level of 3 mAHD would provide greater than the 500y ARI event for properties between Hickey Street and Angourie Street, and potentially those further downstream if additional works are employed to tie the levee into high ground.

Scenario 3 - Increasing the crest of the Caravan Park and Marandowie concrete levees to 3 mAHD would provide protection greater than the 500y ARI event for properties upstream of Hickey Street. Providing an additional levee around Cave and Spenser Streets would provide protection for properties between Spenser and Angourie Streets.

Dis-benefits: Any levee modifications would not eliminate the problems associated with evacuation, isolation of the township and the risk to life during floods. In fact it may result in more people remaining in their houses when previously they would have left. Unless a levee is built to prevent inundation in the largest possible event (termed the Probable Maximum Flood or PMF), which would generally be unacceptable economically and socially, the levee system will eventually be overtopped in a very large event. Failure of the levee system may also occur during a flood event, prior to overtopping.

One of the major dis-benefits of levee raising is the negative aesthetic impact perceived by the local community. This is likely to be minimal for Scenarios 1 and 2 (as the mounds already exist, and are for the most part at 3 mAHD or higher), however it is likely to be significant for Scenario 3. Opinions from the community would need to be obtained to ensure that any modifications will be supported. To date feedback from local residents does not support Scenario 3.

It is possible to enhance the aesthetics of an earthen levee by planting vegetation or by landscaping. This is generally not possible for a concrete levee and there is the risk that graffiti may occur.

Levees may also exacerbate river bank erosion or collapse and this, as well as other potential environmental impacts, would require investigation. Preliminary investigations suggest that issues of this nature are likely to be manageable.

There may be some additional access issues with raising the levee system. These are considered to be minor and can be relatively easily addressed for Scenario 1, but could be of greater significance for Scenario 3 and potentially Scenario 2 (depending on how the Duke Street mound is tied into the high ground within properties on Gundaroo Court).

Costs: The costs associated with each of the Scenarios are shown in Table 5. These exclude costs associated with management of internal drainage, maintenance and land take.

The costing for Scenario 3 is based on replacing the existing concrete structure with an earth mound. There could be space constraints with an earthen levee along Marandowie Drive which will need to be resolved at the design stage. This was considered the most likely option as it would have less of an aesthetic imposition than raising the existing concrete levee. No consideration is given to removing the existing structure as it is assumed the mound could be constructed around it. The costing does not include the construction of an additional levee around Spenser and Cave Streets as this requires further investigation, particularly to determine if there is sufficient space between private properties and the river bank (refer Photograph 20).

Costings for Scenarios 1 and 2 assume that the small quantity of fill required is available on site. If this is not the case, costs would increase for transporting fill from elsewhere. Due to the larger volume of fill required, Scenario 3 costs include transporting fill into Iluka.

Table 5: Summary of Scenario Benefits and Costs

Measure	Floors Inundated				AAD	Cost (1)	B/C Ratio
	20y ARI	100y ARI	500y ARI	Extreme			
Existing	5	48	56	229	$55,000	-	-
Scenario 1	4	48	56	229	$54,000	$10,000	0.1
Scenario 2	4	38	41	229	$48,000	$40,000 (2)	0.2 (2)
Scenario 3 (3)	4	30	36	229	$35,000	$200,000	0.1

Notes:
(1) All costs are indicative only and are highly dependant upon the cost of importing fill.
(2) For Scenario 2 there will be additional costs to tie the levee into high ground near Angourie Street. These can only be determined following further survey and consultation with landowners.
(3) Assumes 3600 m^3 of fill at $50/$m^3$ plus additional costs for design. Does not include costs or benefits of additional Spenser/Cave Street levee.

OUTCOMES

Modifications to the existing levee system would provide a greater level of protection for some areas of Iluka. Any change to the levee height would also provide an opportunity to investigate whether "low points" in the system are required to ensure that overtopping occurs in a controlled manner and takes into account the evacuation routes.

ACTIONS

Scenario 1 should be undertaken as this involves low cost and results in minimal social and environmental impact. Scenario 2 should also be considered further but requires community acceptance due to the likely social impacts. Further detailed survey is also required to ensure that the levee can be tied into high ground. Scenario 3 is a relatively high cost measure with a low benefit cost ratio and a likely high adverse social impact. It can only be recommended if accepted by the majority of the community.

2.2.4 Local Drainage Issues

DESCRIPTION

Many residents have highlighted the issue of runoff within the Iluka township ponding in low lying areas or flowing at shallow depths across private property or roads (Photographs 15 and 16). The residents identified problems at Charles Street and Spenser Street, however it is likely that there are several other locations. For many residents this problem is of greater concern than flooding from the Clarence River, as it occurs relatively regularly (say a couple of times a year) and causes inconvenience. In some instances runoff has entered building floors. Residents consider that this issue can and should be resolved.

Residents have also indicated that several of the outlet pipes do not have flap gates.

DISCUSSION

Local drainage issues are found in all urban communities and generally occur as a result of historical circumstances (basic or no road and drainage system at the time of development, limited or no controls on minimum building floor levels, little or no kerb and guttering) and the nature of the topography (land never graded to form flow paths). Local drainage issues generally do not result in any significant damage to properties and there is minimal (if any) risk to life. However it does cause significant inconvenience to residents who take pride in the appearance of their community.

At Iluka there are many instances of these issues arising. Council has in the past attempted to alleviate the problem by clearing pipe systems and installing new pipes or grading flow paths. However in many locations there are no simple solutions to the problem. A house constructed as a "slab on ground" will experience water seepage under the door or ponding on the driveway if there is no grade. These problems have arisen due to poor building design and are generally not found in newer developments where overland flow is given greater consideration at the design stage. Council should confirm that all outlet pipes have fully functioning flap gates.

As a general guide a building floor should be constructed a minimum of 300 mm above the surrounding ground level, even in non-flood prone areas. This will generally ensure that these minor drainage issues do not inundate buildings floors.

It is possible that Council could undertake further minor clearing or construction works that would alleviate the problem. In the first instance a detailed record of the problem areas needs to be obtained to determine the scale and nature of the problem.

OUTCOMES

Local drainage issues are a significant issue in small towns such as Iluka which have developed over a period of years with limited development controls.

ACTIONS

Local residents should ensure that all such issues are adequately documented (written and photographic) and reported to Council. Council will address these issues where appropriate. Council will also prepare a drainage plan (if not already completed) showing the major drainage lines and pipe sizes, topography and the location of any flap gated culverts. This will assist in identifying problem areas.

2.2.5 Measures to Mitigate the Impact of Wave Runup

DESCRIPTION

Wave runup is confined to the nearshore area and is highly dependent on factors such as the wave height, wave length, water depth and embayment slope. The action of these waves may cause inundation of property and foreshore erosion. Wave runup effects will generally only occur over a small percentage of the foreshore in a given event (in the prevailing wind direction). The effects will vary in time and space as a result of changing foreshore profiles, which may occur naturally (sedimentation, erosion, vegetation growth) or as a result of human activities (construction of seawalls, levees or similar). There is no record of significant wave runup activity.

DISCUSSION

Wave runup effects can produce flooding on the western foreshore of Iluka as well as foreshore erosion. They also require that the structural integrity of any proposed structure be more closely examined, as in general no allowance is made for the structural impacts of these waves. To accommodate the effects of wave runup, it is becoming standard practice for Councils to adopt a 0.5 m freeboard (for setting floor levels of residential buildings) above the adopted design flood level, of which a significant component is to cater for the effects of wave runup. The damages resulting from wave runup are difficult to accurately quantify as little data are available.

Foreshore protection (using vegetation or seawalls) are measures which can be used to reduce the impacts of wave runup.

OUTCOMES

The effects of wave runup on the existing levee system, as well houses fronting on to the foreshore needs to be considered further. At present a study has not been undertaken which considers the effects of wave runup for the Iluka township, however this is recommended so as to quantify the impacts on houses, as well as on possible flood mitigation measures.

ACTIONS

A study into the effects of wave runup should be undertaken for the township of Iluka. Until such stage, the potential impacts should be incorporated into any possible mitigation measures which may be affected by wave runup (such as setting minimal floor levels and quantifying the level of protection provided by existing and future flood mitigation structures). The existing mangroves on the western foreshore of Iluka should be preserved so as to minimise the impacts of wave runup.

2.3 Response Modification Measures

2.3.1 Flood Warning

DESCRIPTION

It will be necessary for a number of residents in Iluka to evacuate their homes in a major flood. Whilst not all will have their house floors inundated, it is likely that their power, gas, water and sewerage systems will be affected.

Many residents may leave on their own accord with the State Emergency Services (SES) having the responsibility of evacuating people in a life threatening situation.

The amount of time for evacuation depends on the available warning time. This is critical for Iluka as access out of the township has been cut in the past due to flooding and in the March 2001 flood left residents isolated for four days. Providing sufficient warning time has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services.

Adequate flood warning gives residents time to move goods and vehicles above the reach of floodwaters and to evacuate from the immediate local area or even out of the town. 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.

At Iluka flooding is from a combination of runoff in the Clarence River and elevated ocean levels (high tide, ocean storm surge).

DISCUSSION

Flood warning, and the implementation of evacuation procedures by the 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 Clarence River. The flood warning system is based on stations which automatically record rainfall or river levels at upstream locations and telemeter the information to a central location. Consideration is also given to ocean storm surge (where applicable) by the use of a simple tidal algorithm. Analysis is then undertaken to determine the expected time and height of the flood peak.

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.

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.

At Iluka there are two critical stages for receiving flood warnings. The first is before the main access road into Iluka is cut and the second is before inundation of part of the township through overtopping of the levee system.

OUTCOMES

The BOM already has a comprehensive flood warning system for the Clarence River, which has been tested in the May 1996 and March 2001 floods. The reason behind Iluka being isolated during the March 2001 flood is due to the cutting of the main access road from the Pacific Highway. Residents did not leave in 2001 because either they had insufficient warning and they could not evacuate in time, or that the warning was given but residents chose not to leave. If it was the latter than there is no specific need for upgrades to the Clarence River Flood Warning System. However, if insufficient warning was given, a review of the current system should be undertaken to see if it can be improved. Unfortunately there is insufficient information available to be conclusive in this regard.

Similarly, a review of current practices involving estimating the impacts of ocean storm surge should be undertaken to ensure that current best practice is employed. Consideration may also be given to including advice on possible wave runup activity along the western foreshore of Iluka.

ACTIONS

The existing flood warning program for Iluka is considered to be sufficient. However possible improvements include providing advice on the deadline when Iluka residents can evacuate the township and ensuring best practice is employed on providing advice on ocean storm surge and wave runup activity. The program should be reviewed after every significant flood event so as to ensure it remains the best practice available.

2.3.2 Evacuation Planning

DESCRIPTION

During the March 2001 event floodwaters cut off the sole evacuation route from Iluka leaving the town isolated for four days until the waters receded. There is no permanent SES team located within Iluka however during this time they were stationed at Yamba and were ready to evacuate any persons if necessary. It is understood that two people were air lifted and one was taken out by boat.

An Evacuation Plan is therefore necessary for the town of Iluka as it has been isolated in the past and will be isolated again in future floods. Any plan should give consideration to flood preparedness, response and recovery as well as SES access into Iluka when road routes are cut.

DISCUSSION

At present, there is no SES Flood Evacuation Plan specifically for Iluka, though it is considered under the old Maclean Shire Flood Plan. This plan is currently being updated by the SES to include Evacuation Plans for all villages isolated during a flood, including Iluka.

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 their houses and people do not appreciate the dangers.

Fortunately there is abundant high ground within the township which will mean that (assuming all people move safely) there is no ongoing risk to life from floodwaters. There is also a Bowling club and other buildings (RSL club) which could safely house evacuees. In past floods the Rural Fire Services have assisted residents in raising furniture (etc) above the threat of floodwaters. If necessary, supplies could be provided by boat or by air, however we presume that there would already be sufficient supplies of food and water within the township for several days isolation.

The need for evacuation from the township is therefore only likely to be for medical reasons, related or not to the flood hazard. The SES would need to evaluate this risk within the proposed Flood Evacuation Plan and incorporate sufficient management measures.

OUTCOMES

The SES are currently preparing an Evacuation Plan for Iluka and other villages along the Clarence River. Consideration should be given to the additional floor level, flood level and flood related (levee crest level) data provided in this report. Priority should be given to the implementation of this plan once completed, which will involve ongoing community education and awareness.

ACTIONS

An Evacuation Plan for Iluka should be completed and made available to the residents of Iluka as well as local authorities (such as the Rural Fire Services).

2.3.3 Public Information and Raising Flood Awareness

DESCRIPTION

The success of any flood warning system and the evacuation process 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 residents 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 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 relatively recent times (previous few years) will increase flood awareness. 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. The recent floods of May 1996 and March 2001 means that the community generally has a medium to high level of awareness at this time. However they may incorrectly assume that flooding only impacts on cutting the main road and be unaware that in a major flood the levee system will be overtopped and building floors inundated.

- *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. It would appear that the majority of residents have lived in the area for several years and are familiar with flooding. However there are also a number of tourists in the town at any one time (many in The Anchorage Caravan Park) and they would not be familiar with the hazard. Furthermore, they are the people most likely to attempt to evacuate from the town in order to prevent being isolated.

- *Whether an effective public awareness program has been implemented.* It is understood that no large scale awareness program has been implemented, however the SES and Council have made available booklets on how to deal with flooding.

For floodplain risk management to be effective it must become the responsibility of the whole community. 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.

A major hurdle is often convincing residents that major floods (larger than March 2001) will occur in the future and will overtop the levee system.

OUTCOMES

Based on feedback from the interviews and general discussions, the residents of Iluka have a medium to high level of flood awareness and preparedness.

The SES also has a medium to high level of awareness of the problem and the requirements necessary to effect evacuations. As the time since the last significant flood (March 2001) increases, the direct experience of the SES units with historical floods will diminish. It is important that a high level of awareness is maintained through implementation of a suitable Flood Awareness Program. Table 6 provide examples of methods that can be used.

Table 6: Flood Awareness Methods

Method	Comment
Letter/Pamphlet from Council	These may be sent (annually or biannually) 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 topics relating to water quality, estuary management, etc.
Displays at Council Offices, Library, Schools, Shopping Centres, 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 hazards.

Method	Comment
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 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.
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.
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 helps to inform it of the problem and associated implications. 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 damages 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 or a flood gate that is jammed. This process can be linked to water quality or other water related issues including estuary management.

ACTIONS

A Flood Awareness Program should be implemented.

2.4 Property Modification Measures

2.4.1 Development Control Planning & Flood Planning Levels

DESCRIPTION

The strategic assessment of flood risk can prevent development occurring in areas with a high hazard and/or with the potential to have significant impacts upon flood behaviour in other areas. It can also reduce the potential damage to new developments likely to be affected by flooding to acceptable levels. Development control planning includes both zoning and development controls.

The division of flood prone land into appropriate land use zones can be an effective and long term means of limiting danger to personal safety and flood damage to future developments. Zoning of flood prone land should be based on an objective assessment of land suitability and capability, flood risk, environmental and other factors. In many cases it is possible to develop flood prone lands without resulting in undue risk to life and property.

DISCUSSION
The following issues need to be addressed when considering flood related development control policies.

Ensure Adequate Access: This issue needs to be addressed to ensure safe evacuation to high ground is possible in times of flood. Due to the nature of the terrain at Iluka this is unlikely to be a significant constraint.

Fill (or excavation) in the Floodplain: Filling of land for development can result in it no longer being flood liable. However, fill and excavation can have an affect on the flow patterns or even cause flood levels to rise. This is unlikely to be relevant at Iluka as it is situated at the mouth of a major river system with a large floodplain area and there are only limited areas for filling. Filling for building pads should therefore be permitted as long as it does not affect local drainage issues. The cumulative effects of filling should be monitored (i.e. collected in a database) but are unlikely to present a major concern in the future. Any proposed significant filling on the floodplain must be analysed with regard to its potential impacts on flooding.

Building Materials: Some building materials are less susceptible to damage by floodwaters, or are easier to clean after a flood. By using such materials, flood damages can be minimised.

Structural Soundness when Inundated: Floodwaters can impact upon the structural soundness of buildings in a number of ways relating to flow velocities, depths and associated debris loads. These should all be considered in relation to certification of the soundness of structures for the local hydraulic conditions.

Fencing: Fences, whether solid or open, can impact upon flood behaviour by altering flow paths. This impact will depend upon the type of fence and its location relative to the flow path. In Iluka this is unlikely to be a significant issue for Clarence River flooding but is of relevance for local catchment runoff.

Public Assets: It is essential that all public assets which may be damaged by floodwaters are located to minimise (or hopefully eliminate) such damage. Of particular concern is the proposed sewerage system for Iluka which is currently being designed. Council must ensure that adequate flood protection is provided.

Flood Planning Levels: The flood planning level (FPL) is used to define land subject to flood related development controls and is generally adopted as the minimum level to which floor levels in the flood affected areas must be built. The FPL includes a freeboard above the design flood level. It is common practice to set minimum floor levels for residential buildings as this reduces the frequency and extent of flood damage. Freeboards provide reasonable certainty that the reduced level of risk exposure selected (by deciding upon a particular event to provide flood protection for) is actually provided. It is common practice throughout NSW to use a FPL of the 100y ARI event plus a 0.5 m freeboard. At Iluka this would be a FPL of 2.9 mAHD (2.4 mAHD flood level plus 0.5 m freeboard).

Rezoning Land: In some flood prone areas rezoning of land has been undertaken to eliminate further development and/or to promote redevelopment at a higher level. This measure is not appropriate for Iluka due to the nature of development in the township.

OUTCOMES

In summary, development control planning can reduce the effects of flooding on future development by minimising flood damages and managing risk. In some areas where the FPL or other criteria can only be achieved at considerable additional cost, there is community resistance to implementing these measures. However at Iluka these measures are unlikely to involve such resistance.

ACTIONS

A Development Control Plan should be prepared for Iluka and give consideration to the measures mentioned. The Plan should also stipulate a minimum floor level (say 300 mm) above natural surface to minimise future problems with local drainage issues.

2.4.2 Controls on Caravan Parks in the Floodplain

DESCRIPTION

There are currently three caravan parks located at Iluka, of which only one is flood liable (The Anchorage Caravan Park). This site is likely to be the first place where the levee system will be overtopped. The floor level database indicates that there are some 61 caravans/units with floors below the 100y ARI flood level. It is likely that a number of these will experience minimal flood damage because the site is either vacant or the caravan floor is at a higher level. These were not included in the flood damages estimates in Table 2 because it is not possible to accurately estimate flood damages on caravan parks, due to the large variability in the number of vans at any point in time, as well as the potential for vans to be moved during times of flood.

Caravan parks within the floodplain present their own unique problems, these may include:

- there is generally poor access with a single entrance/exit which may be controlled by gates,
- only a poor (or no) site map is generally available to show the internal road system or the types of vans,
- fixed annexes which may contain high cost equipment such as freezers or stoves,
- there is poor internal lighting which may fail during a flood,
- there is generally no flood emergency plan or it has not been tested recently,
- there is a problem in communicating to the residents due to the lack of or failure of the public address system or telephone network,
- short term residents will have little flood awareness of the flood risk or damage minimisation measures,
- a large number of vans may be vacant thus increasing the workload and possible risk to life for the "rescuers" involved with removing the vans,
- there is the risk that vans may float and crash into each other or obstruct exit routes,
- caravans have little structural integrity and thus can easily be damaged by flowing water,

- the internal fittings (cupboards, fridges, beds) are usually non-removable and made from materials quickly damaged by floodwaters.

DISCUSSION

In theory caravans can be easily moved to high ground in a flood, particularly at Iluka where the high ground is relatively close . However, in practice experience has shown that this is unlikely to occur for some of the above reasons.

The Clarence River has a much slower rate of rise than a small river system and there is nearby high ground where vans could be moved. In events up to the 20y ARI the risk to life is low. However, in larger events the risk increases significantly as vans may “float” and crash into each other.

Some Councils have special provisions for caravan parks on the floodplain such as:

- rapid knock down annexes,
- quick release ties on the vans to prevent them floating away,
- an effective evacuation strategy documented in a Flood Action Plan,
- restrictions on the type of vans, e.g. untowable vans not permitted in certain areas, no rigid annexes,
- specific inclusion of caravan parks in the SES Local Flood Plan.

OUTCOMES

Caravan parks on the floodplain can represent a significant hazard during a flood. At The Anchorage Caravan Park the hazard is low because there is usually a long warning time, there is ready access to nearby high ground and the frequency of inundation is low.

This issue should be investigated further through a detailed inspection by the park manager and the SES to accurately assess the hazard. Following this, consideration should be given to implementing adequate safety provisions which would probably mean updating their existing flood evacuation plan. Consideration should be given to introducing some of the special provisions indicated above. At a minimum “at risk” parks should be clearly identified in the SES Local Flood Plan.

ACTIONS

The owner of The Anchorage Caravan Park should prepare/update an Evacuation Plan for the site and this should be reviewed every two years or after a significant flood.

2.4.3 House Raising

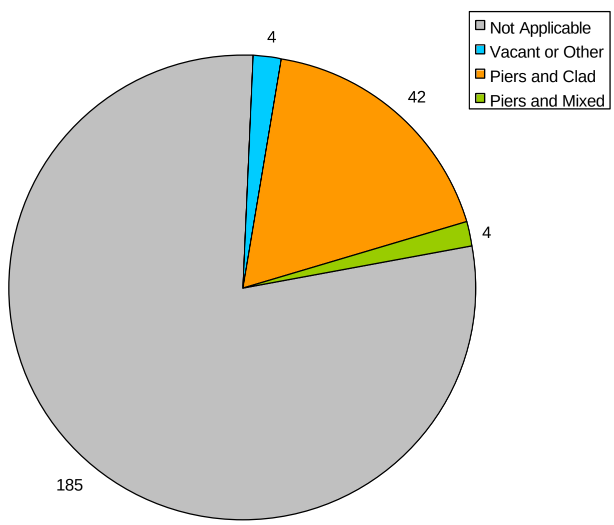
DESCRIPTION

House raising has been widely used throughout NSW to eliminate inundation from habitable floors. However it has limited application as it is not suitable for all building types. Also, it is more common in areas where there is a greater depth of inundation than at Iluka and raising the buildings allows creation of an underfloor garage or non-habitable room area.

DISCUSSION

House raising is suitable for most non-brick single storey buildings on piers and is particularly relevant to those situated in low hazard areas on the floodplain. The benefit of house raising is that it eliminates inundation to the height of the floor and consequently reduces the flood damages. At Iluka, house raising (to say the 100y ARI plus 0.5 m freeboard) would probably mean prevention of inundation to greater than a 1000y ARI event.

Graph 1 summarises the building floor type and house raising potential (based on building construction material) for those properties in Iluka which could be at risk of inundation.



Graph 1: Suitability for House Raising

Of the 42 potential properties however, only one is inundated in the 20y ARI event (and none in events smaller than this) but as it is a two-storey building it is not suitable for house raising. Three single storey buildings on Marandowie Drive (Numbers 20, 26 and 28) have ground floors between 1.9 mAHD and 2.0 mAHD (therefore inundated in an event greater than the 20y ARI but smaller than the 100y ARI) and are built from materials compatible for house raising. A benefit-cost analysis was undertaken based on raising these properties to the 100y ARI level plus 0.5 m (2.84 mAHD). The cost of house raising was assumed to be $60,000 per house. The benefits were measured as the reduction in the average annual damages as a result of raising the floors, converted to a net present worth (based on 6% over 50 years). The results of the analysis showed that each property had a B/C ratio of 0.3, and similarly to raise all three houses would provide a B/C ratio of 0.3.

An alternative to house raising for buildings that cannot be raised is flood proofing or sealing of the entry points to the buildings. This measure has the advantage that it is generally less expensive than house raising and causes less social disruption. However this measure is really only suitable for commercial and industrial buildings where there are only limited entry points and aesthetic considerations are less of an issue. Based upon our experience we do not consider flood proofing a viable measure for residential buildings in Iluka.

OUTCOMES

For the majority of flood affected properties in Iluka house raising is not a viable means of flood protection. For the three properties identified on Marandowie Drive, house raising should be investigated further to determine its viability (depending on resident acceptance, likelihood of funding, structural suitability, etc.).

ACTIONS

House raising should be considered further for the three properties on Marandowie Drive. If levee Scenario 3 is implemented however, raising of these houses will no longer be required.

3. ACKNOWLEDGEMENTS

This study was carried out by Webb, McKeown & Associates Pty Ltd and funded by Clarence Valley Council and the Department of Natural Resources. The assistance of the following in providing data and guidance to the study is gratefully acknowledged:

- Clarence Valley Council,
- Department of Natural Resources,
- Floodplain Management Committee,
- residents of Iluka.

4. REFERENCES

1. **Floodplain Development Manual**
   NSW Government, April 2005.

2. Clarence Valley Council
   Lower Clarence River Flood Study Review
   Volumes 1 and 2
   WBM Oceanics, March 2004.

3. Public Works
   Clarence River Flood Study
   December 1998.

4. Maclean Shire Council
   Lower Clarence River Floodplain Management Study
   Paterson Consultants Pty Ltd, August 1993.

5. Maclean Shire Council
   Lower Clarence River Floodplain Management Plan
   September 1999.

6. Clarence Valley Council
   Lower Clarence River Floodplain Management Plan Review (Draft)
   Bewsher Consultants Pty Ltd, December 2006.

FIGURE 1

AERIAL PHOTOGRAPH

FILE > J:\JOBS\25034\FIGURES\FIGURE01.cdr > MARCH 2007

FIGURE 2
BUILDINGS INUNDATED

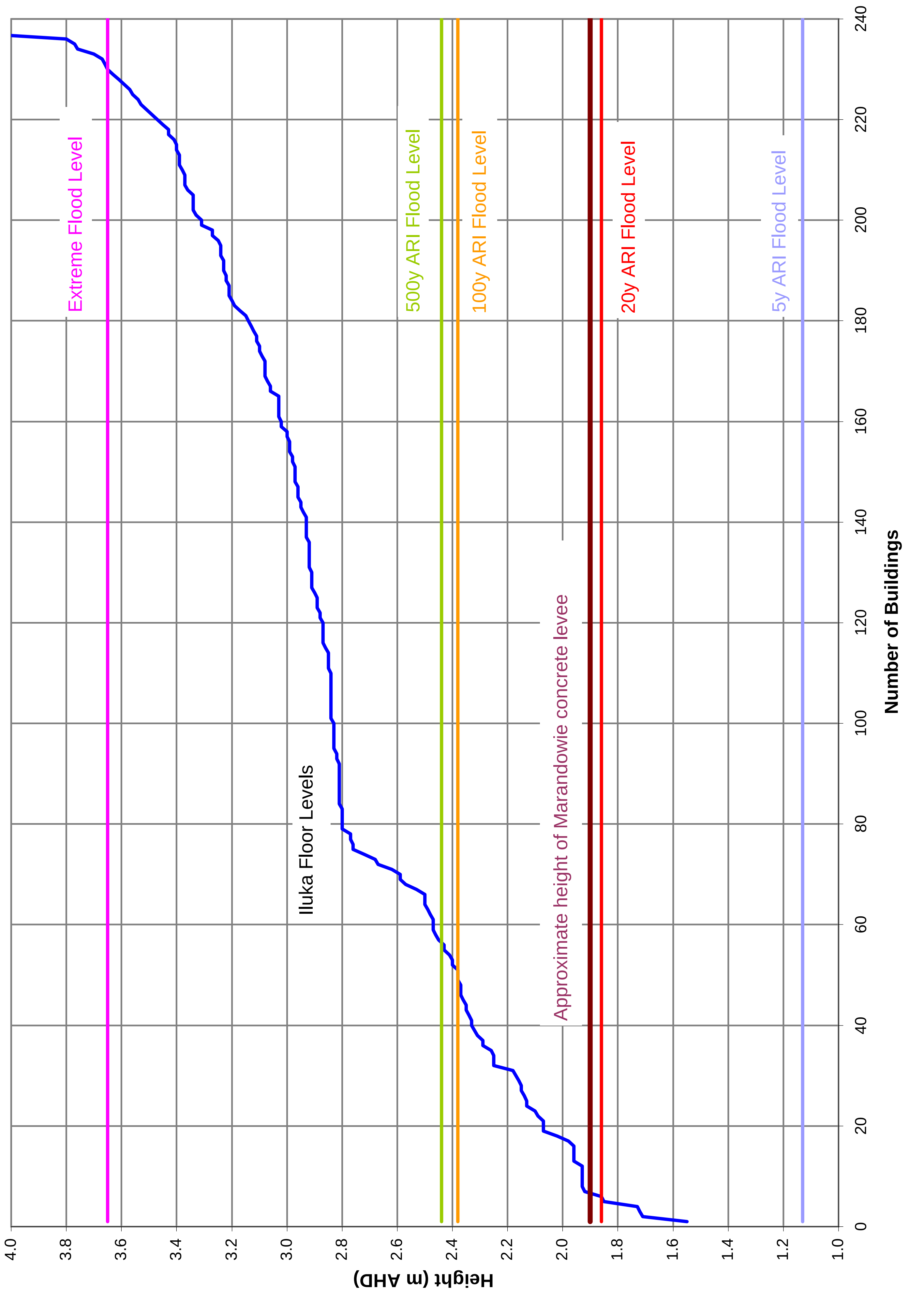
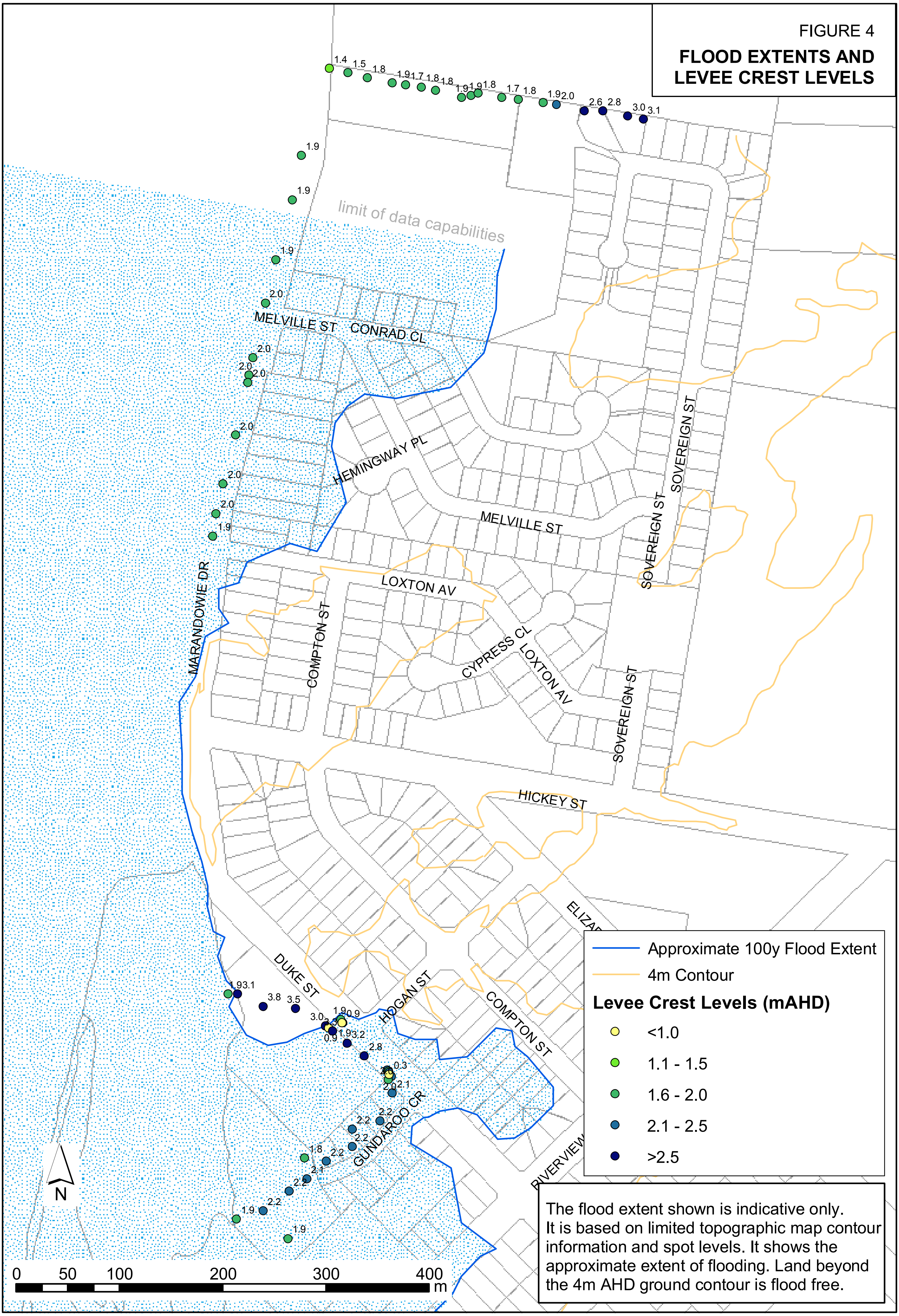


FIGURE 3
EVENT BUILDING FLOORS FIRST INUNDATED

FIGURE 4

FLOOD EXTENTS AND LEVEE CREST LEVELS



The flood extent shown is indicative only. It is based on limited topographic map contour information and spot levels. It shows the approximate extent of flooding. Land beyond the 4m AHD ground contour is flood free.

APPENDIX A: GLOSSARY OF TERMS

APPENDIX A: GLOSSARY OF TERMS

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.

disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.

flood plan (local)
A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.

flood planning area
The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the "flood liable land" concept in the 1986 Manual.

Flood Planning Levels (FPLs)
FPL's are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "standard flood event" in the 1986 manual.

flood proofing
A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.

flood prone land
Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.

flood readiness
Flood readiness is an ability to react within the effective warning time.

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

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

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

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

flood storage areas
Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.

floodway areas
Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.

freeboard
Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.

habitable room
in a residential situation: a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom.

in an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

hazard A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.

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

hydrograph A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.

hydrology Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.

local overland flooding Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.

local drainage Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.

mainstream flooding Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

major drainage Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves:

- the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or

- water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or

- major overland flow paths through developed areas outside of defined drainage reserves; and/or

- the potential to affect a number of buildings along the major flow path.

mathematical/computer models The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

merit approach The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.

minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: **minor flooding:** causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.
peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to “water level”. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

APPENDIX B: SURVEY OF PROPERTIES

APPENDIX B: SURVEY OF PROPERTIES

Street Number	Street Name	**Type of Property** Residential (R), Commercial (C), Industrial (I), Public (P)	Indicative ground level (to 1 dec pl)	RESIDENTIAL BUILDINGS					
				Lowest Habitable Floor Level (mAHD) **Note**: **All double storey floor levels taken on ground floor**	Single (S) or Double storey (D)	Do people live on the Ground Floor (Y or N)	**House Size** - Small (S), Medium (M), Large (L)	**Floor Construction** Pier (P) or Slab (S) Other - describe	**Wall Construction** Brick stone or rendered (B), Clad (C) , Mixed (M)
1	Conrad	Vacant	1.9	Vacant					
2	Conrad	R	2.0	2.25	S	Y	S	S	B
3	Conrad	R	2.4	2.83	S	Y	M	S	B
4	Conrad	Vacant		Vacant					
5	Conrad	Vacant	1.9	Vacant					
6	Conrad	R	2.3	2.49	S	Y	M	S	B
7	Conrad	R	1.9	2.80	S	Y	M	P	B
8	Conrad	R	2.3	2.82	S	Y	M	S	B
9	Conrad	R	2.0	2.18	S	N	S	S	C
10	Conrad	R	2.6	2.83	S	Y	L	S	B
Garage of 10 (12)	Conrad	R		2.92	S	N	M	S	B
14 Unit 1	Conrad	R	2.9	3.13	S	Y	S	S	B
14 Unit 2	Conrad	R	2.9	3.12	S	Y	S	S	B
16	Conrad	R	2.9	3.22	S	Y	M	S	B
1	Melville	R	2.0	2.10	S	Y	S	S	C
2	Melville	R	1.9	2.16	S	Y	M	S	B
3	Melville	Vacant	1.9	Vacant					
4	Melville	R	1.9	2.25	S	Y	M	S	B
5	Melville	R	2.1	2.89	S	Y	M	S	B
6	Melville	R	2.0	2.33	S	Y	M	S	B
7	Melville	R	2.4	2.86	S	Y	M	S	B
8 Unit 1	Melville	R	2.1	2.38	S	Y	M	S	B
8 Unit 2	Melville	R	2.2	2.38	S	Y	M	S	B
9	Melville	R	2.6	2.83	D	Y	L	S	B
10	Melville	Vacant	2.1	Vacant					
11	Melville	R	2.7	2.87	S	Y	M	S	B
12	Melville	Vacant	2.1	Vacant					
13	Melville	R	2.8	3.06	S	Y	M	S	B
14	Melville	R	2.5	2.91	S	Y	M	S	B
15	Melville	R	2.8	3.07	S	Y	M	S	B
16	Melville	R	2.5	2.84	S	Y	M	S	B
17	Melville	R	3.1	3.66	S	Y	M	P	B
18	Melville	R	2.8	3.27	S	Y	M	P	B
20	Melville	R	2.8	2.85	S	Y	M	S	B
22	Melville	R	3.1	3.37	S	Y	M	S	B
24 Unit 1	Melville	R	2.8	3.34	S	Y	S	S	B
24 Unit 2	Melville	R	3.0	3.34	S	Y	S	S	B
1	Hemingway	Vacant	2.1	Vacant					
3	Hemingway	Vacant		Vacant					
5	Hemingway	R	2.2	2.31	D	Y	L	S	B
7	Hemingway	R	2.3	2.97	S	Y	M	P	C
9 Unit 1	Hemingway	R	2.6	2.84	S	Y	S	S	B
9 Unit 2	Hemingway	R		2.84	S	Y	S	S	B
9 Unit 3	Hemingway	R		2.84	S	Y	S	S	B
40	Marandowie	R	1.7	1.85	D	Y	L	S	B
38 Unit 1	Marandowie	R	1.9	1.96	D	Y	M	S	M
38 Unit 2	Marandowie	R	1.9	1.96	D	Y	M	S	M
36	Marandowie	R	1.9	1.93	D	Y	L	S	B
34	Marandowie	R	1.5	2.07	S	Y	S	P	C
32	Marandowie	R	1.5	2.29	S	Y	M	P	C
30	Marandowie	R	1.1	2.02	D	Y	L	P	C
28	Marandowie	R	1.4	1.98	S	Y	S	P	C
26	Marandowie	R	1.5	1.92	S	Y	S	P	C
24B (rear)	Marandowie	R	1.7	1.86	S	Y	S	S	C
24A (front)	Marandowie	R	1.6	2.34	S	Y	S	P	C
22	Marandowie	R	1.7	2.81	S	Y	M	P	C
20	Marandowie	R	1.4	1.93	S	Y	S	P	C
18	Marandowie	R	1.1	1.93	S	Y	S	P	B
16	Marandowie	R	1.9	2.81	S	Y	L	S	B
14	Marandowie	R	2.0	2.13	D	N	M	S	M
12	Marandowie	R	2.7	3.70	S	Y	M	P	C
10	Marandowie	R	1.8	2.77	S	Y	S	P	C

Street Number	Street Name	**Type of Property** Residential (R), Commercial (C), Industrial (I), Public (P)	Indicative ground level (to 1 dec pl)	RESIDENTIAL BUILDINGS					
				Lowest Habitable Floor Level (mAHD) **Note**: **All double storey floor levels taken on ground floor**	Single (S) or Double storey (D)	Do people live on the Ground Floor (Y or N)	**House Size** - Small (S), Medium (M), Large (L)	**Floor Construction** Pier (P) or Slab (S) Other - describe	**Wall Construction** Brick stone or rendered (B), Clad (C) , Mixed (M)
8	Marandowie	R	3.7	4.49	D	N	M	P	C
1	Loxton	R	1.9	1.96	D	Y	M	S	B
3	Loxton	R	2.3	2.45	S	Y	S	S	B
5	Loxton	Vacant	3.0	Vacant					
7	Loxton	R	3.1	3.21	D	Y	M	S	M
9	Loxton	R	3.0	3.67	S	Y	M	P	C
11	Loxton	R	3.2	3.23	D	Y	M	S	C
16	Loxton	R	3.0	3.31					
23	Loxton	R		3.06	S	Y	M	S	B
1	Cypress	R	2.9	3.47	S	Y	M	S	B
2	Cypress	R	2.8	3.03	S	Y	S	S	B
3	Cypress	R	2.9	3.15	S	Y	M	S	B
4	Cypress	R	2.9	3.24	S	Y	S	S	B
5	Cypress	R	2.6	2.84	S	Y	M	S	B
7	Cypress	R	2.2	2.40	S	Y	M	S	B
9	Cypress	R	2.7	2.85	S	Y	M	S	B
2	Compton	R	2.4	3.27	S	Y	M	P	C
15	Compton	R	1.8	2.09	S	N	S	S	C
16	Compton	R	2.5	2.77	S	Y	M	S	B
17	Compton	R	2.2	2.47	S	Y	M	S	C
18	Compton	R	2.0	2.25	S	Y	M	S	B
19	Compton	R	2.4	2.67	S	Y	M	S	M
20	Compton	R	2.4	2.87	S	Y	M	S	B
21	Compton	R	2.7	2.87	S	Y	M	S	B
22	Compton	R	2.5	3.34	S	Y	M	P	B
24	Compton	R	2.8	3.24	S	Y	M	P	C
26	Compton	R	2.9	2.81	D	Y	M	S	M
28	Compton	R	2.9	2.96	D	Y	M	S	B
35	Compton	R	3.1	3.40	S	Y	M	S	B
40	Compton	R	2.7	2.89	D	N	S	S	C
42	Compton	R	3.1	3.33	S	Y	M	S	B
43	Compton	R	2.9	3.57	D	Y	L	S	M
44 Unit 1	Compton	R	2.9	3.02	S	Y	S	S	B
44 Unit 2	Compton	R		3.21	S	Y	S	S	B
45	Compton	R	2.7	2.80	S	Y	M	S	C
46	Compton	R	3.0	3.65	S	Y	S	P	C
47 Unit 1	Compton	R	2.7	2.91	S	Y	S	S	C
47 Unit 2	Compton	R		2.91	S	Y	S	S	C
48	Compton	R	2.4	2.57	S	Y	S	S	C
49	Compton	R	2.5	2.81	S	Y	M	S	B
50	Compton	R	2.3	2.62	S	Y	S	P	C
51	Compton	R	2.5	2.82	S	Y	S	S	B
52	Compton	R	2.2	2.48	D	Y	L	S	B
54	Compton	R	2.2	2.43	D	Y	M	S	M
56	Compton	R	2.3	2.46	S	Y	S	S	C
58	Compton	R	2.2	2.37	S	Y	S	S	B
60	Compton	R	2.4	2.98	S	Y	S	S	B
6	Sovereign	R	3.2	3.45	S	Y	S	S	C
Lot 3	Sovereign	R	3.0	3.31	S	Y	M	S	B
Lot 4	Sovereign	R	3.2	3.40	Under Construction			S	
78	Sovereign	R	2.8	3.00	S	Y	M	S	B
Lot 32	Sovereign	R	2.9	3.08	S	Y	M	S	B
Lot 30	Sovereign	R	2.9	3.23	S	Y	M	S	B
8	Hickey	R	1.8	2.36	S	Y	M	S	B
10	Hickey	R	1.9	2.26	S	Y	M	S	B
11	Hickey	R	3.0	3.77	S	Y	S	P	C
12	Hickey	R	2.5	2.99	S	Y	M	S	B
13	Hickey	R	2.5	2.97	S	Y	S	S	C
14	Hickey	R	2.9	3.11	S	Y	M	S	B
15	Hickey	R	1.9	2.32	S	Y	M	S	B
2	Elizabeth	R	2.9	3.10	D	Y	M	S	M
4 Unit 1	Elizabeth	R	2.8	2.93	S	Y	S	S	B
4 Unit 2	Elizabeth	R		2.93	S	Y	S	S	B
12	Elizabeth	R	2.8	3.03	S	Y	M	S	B
32	Elizabeth	R	2.5	2.99	S	Y	M	S	B
34 Unit 1	Elizabeth	R	2.7	2.97	S	Y	S	S	B
34 Unit 2	Elizabeth	R		2.98	S	Y	S	S	B

Street Number	Street Name	**Type of Property** Residential (R), Commercial (C), Industrial (I), Public (P)	Indicative ground level (to 1 dec pl)	RESIDENTIAL BUILDINGS					
				Lowest Habitable Floor Level (mAHD) **Note**: **All double storey floor levels taken on ground floor**	Single (S) or Double storey (D)	Do people live on the Ground Floor (Y or N)	**House Size** - Small (S), Medium (M), Large (L)	**Floor Construction** Pier (P) or Slab (S) Other - describe	**Wall Construction** Brick stone or rendered (B), Clad (C) , Mixed (M)
36	Elizabeth	R	3.2	3.43	S	Y	S	S	B
2	Duke	R	3.1	3.63	D	Y	L	P	M
7	Duke	R	2.4	2.53	D	Y	M	S	C
9	Duke	R	3.1	3.22	D	Y	L	S	B
11	Duke	R	3.0	3.11	D	Y	L	S	B
13	Duke	R	2.8	3.02	D	Y	L	S	B
15	Duke	R	3.3	4.58	S	Y	M	P	C
17	Duke	R	3.1	3.09	D	Y	L	S	B
19	Duke	R	3.1	3.39	S	Y	S	S	C
21	Duke	R	3.2	3.38	D	Y	L	S	B
23 Unit 1	Duke	R	3.1	3.56	S	Y	S	S	B
23 Unit 2	Duke	R		3.54	S	Y	S	S	B
25 Unit 1	Duke	R	3.4	3.51	S	Y	S	S	B
25 Unit 2	Duke	R		3.53	S	Y	S	S	B
26	Duke	R	2.1	2.81	S	Y	M	S	B
27	Duke	R (Garage)	3.1	3.34	S	Y	S	S	C
28	Duke	R	2.3	2.90	S	Y	M	S	B
29	Duke	R	3.1	3.76	S	Y	S	P	C
30	Duke	R	2.6	2.92	S	Y	M	S	B
31	Duke	R	3.0	3.43	S	Y	M	P	C
33	Duke	R	1.5	2.35	S	Y	M	P	M
35	Duke	R	1.6	4.09	D	N	M	S	C
36	Duke	R	1.8	2.14	S	Y	L	S	B
37	Duke	R	1.6	1.72	D	Y	M	S	M
38 Unit 1	Duke	R	2.6	2.83	S	Y	S	S	B
38 Unit 2	Duke	R		2.81	S	Y	S	S	B
39	Duke	R	1.7	3.03	S	Y	S	P	C
40	Duke	R	2.3	2.50	S	Y	M	S	B
41	Duke	R	1.8	2.17	S	Y	S	S	B
42	Duke	R	2.4	2.76	S	Y	M	S	B
43	Duke	R	1.8	2.13	S	Y	S	S	B
44	Duke	R	2.9	3.14	S	Y	M	S	B
45	Duke	R	1.7	2.88	S	Y	S	P	C
47	Duke	R	1.6	2.80	S	Y	S	P	B
49	Duke	R	2.0	2.15	D	Y	L	S	B
53	Duke	R	2.7	2.87	S	Y	M	S	B
55	Duke	R	2.3	2.43	S	Y	S	P	C
57	Duke	R	2.8	3.37	D	Y	L	S	B
1	Hogan	R	2.5	3.10	D	Y	M	P	C
2	Hogan	R	1.7	2.59	S	Y	S	S	C
7	Hogan	R	2.4	2.96	S	Y	S	P	C
1	Gundaroo	R	2.2	2.41	S	Y	S	S	B
2	Gundaroo	R	2.1	2.35	S	Y	M	S	B
3	Gundaroo	R	2.2	2.37	S	N	S	S	C
4	Gundaroo	R	2.2	2.84	S	Y	M	S	B
5	Gundaroo	R	2.2	3.00	S	Y	M	P	B
6	Gundaroo	R	2.2	2.38	S	Y	M	S	B
7	Gundaroo	R	2.2	3.03	S	Y	M	P	B
8	Gundaroo	R	2.3	2.97	S	Y	M	P	B
10	Gundaroo	R	2.3	3.08	S	Y	M	S	B
58	Riverview	R	3.0	3.39	S	Y	S	P	C
56	Riverview	R	3.3	3.49	D	Y	M	S	C
55	Riverview	R	2.4	2.50	D	Y	M	S	B
54	Riverview	R	2.7	2.84	S	Y	S	S	B
53 Unit 1	Riverview	R	2.7	2.81	D	Y	S	S	B
53 Unit 2	Riverview	R		2.81	D	Y	S	S	B
52	Riverview	R	2.6	2.72	D	Y	M	S	B
50	Riverview	R	2.6	2.89	S	Y	M	S	B
49	Riverview	R	3.2	3.19	D	Y	M	S	M
48	Riverview	R	2.5	2.68	S	Y	M	S	C
47 Unit 1	Riverview	R	3.2	3.24	D	Y	S	S	B
47 Unit 2	Riverview	R		3.23	D	Y	S	S	B
46	Riverview	R	2.3	2.40	D	Y	M	S	M
44	Riverview	Vacant	2.1	Vacant					
42	Riverview	R	2.6	2.85	S	Y	M	S	B
41	Riverview	R	2.3	2.47	S	Y	M	S	B
40	Riverview	R	2.1	3.08	S	Y	S	P	B

Street Number	Street Name	**Type of Property** Residential (R), Commercial (C), Industrial (I), Public (P)	Indicative ground level (to 1 dec pl)	RESIDENTIAL BUILDINGS					
				Lowest Habitable Floor Level (mAHD) **Note**: **All double storey floor levels taken on ground floor**	Single (S) or Double storey (D)	Do people live on the Ground Floor (Y or N)	**House Size** - Small (S), Medium (M), Large (L)	**Floor Construction** Pier (P) or Slab (S) Other - describe	**Wall Construction** Brick stone or rendered (B), Clad (C) , Mixed (M)
38	Riverview	R	2.1	2.80	S	Y	S	P	C
36	Riverview	R	2.1	2.37	S	Y	S	S	C
34	Riverview	R	1.9	2.93	S	Y	S	S	B
32	Riverview	R	2.0	2.84	S	Y	S	P	C
30	Riverview	R	2.2	2.76	S	Y	S	P	C
27	Riverview	R	1.7	2.83	D	Y	L	S	B
26	Riverview	R	2.6	2.95	S	Y	S	S	B
23	Riverview	R	2.5	2.84	S	Y	M	S	B
21	Riverview	R	2.0	2.84	S	Y	M	S	B
20	Riverview	R	3.0	3.80	S	Y	S	P	C
19	Riverview	R	2.8	3.36	S	Y	M	P	C
18	Riverview	R	3.0	3.08	D	Y	M	S	C
17	Riverview	R	3.2	3.39	S	Y	M	P	C
16	Riverview	R	2.4	2.93	S	Y	S	P	C
15	Riverview	R	3.2	3.21	S	Y	S	P	C
14A	Riverview	Vacant	3.1	Vacant					
14	Riverview	R	3.1	3.61	S	Y	S	P	C
13	Riverview	R	2.8	2.92	D	Y	M	S	B
12	Riverview	R	2.4	2.96	S	Y	S	S	C
11	Riverview	R	2.6	2.83	D	Y	M	S	B
10	Riverview	R	2.6	3.37	D	Y	M	S	B
8	Riverview	R	3.1	3.20	D	Y	M	S	M
7	Riverview	R	2.3	2.80	D	Y	M	S	C
6	Riverview	Vacant		Vacant					
3 - 5 Unit 1 Bld 1	Riverview	R	2.9	2.99	D	Y	S	S	B
4	Riverview	R	2.1	2.94	S	Y	M	P	C
2 Unit 4 of 4	Riverview	R	2.8	2.92	S	Y	S	S	B
2 Unit 1 of 4	Riverview	R	2.7	2.91	S	Y	S	S	B
2	Angourie	R	2.2	2.88	S	Y	S	P	C
4	Angourie	R	2.4	3.25	S	Y	S	P	C
6 Unit 2 of 6	Angourie	R	2.9	3.03	D	Y	S	S	B
8	Angourie	R	2.4	3.17	S	Y	L	S	B
15	Angourie	R	2.1	2.33	S	Y	M	S	B
1	Hammond	R	2.8	3.41	S	Y	M	P	B
2	Cave	R	1.8	1.93	S	Y	S	S	B
3	Cave	R	1.5	1.96	S	Y	S	S	C
4	Cave	R	1.5	1.93	S	Y	S	P	M
5	Cave	R	1.6	1.71	S	Y	S	S	B
6	Cave	R	1.4	2.07	S	Y	S	P	C
7	Cave	R	1.7	2.50	S	Y	M	P	B
8	Cave	R	1.5	1.55	D	N	M	P	M
9	Cave	R	1.7	1.73	D	Y	M	S	C
3	Spenser	R	1.3	2.47	S	Y	S	P	C
4 Unit 1 of 11	Spenser	R	2.6	2.59					
5	Spenser	R	1.7	2.29	S	Y	S	P	C
7	Spenser	R	2.0	2.15	D	Y	M	S	B
9a	Spenser	R	1.8	2.87	D	Y	M	P	C
9	Spenser	R	1.8	2.07	D	Y	M	S	M
10	Spenser	R	2.6	2.85					
11A	Spenser	R	2.6	2.93	S	Y	S	S	B
11B	Spenser	R	2.8	2.95	S	Y	S	S	B
13	Spenser	R	2.9	3.59	D	Y	M	S	B
14	Spenser	R	2.5	2.92	D	Y	L	S	B
16	Spenser	R	2.3	2.81	D	Y	L	S	B
18	Spenser	R	2.7	2.92	D	Y	M	S	B

Street Number	Street Name	**Type of Property** Residential (R), Commercial (C), Industrial (I), Public (P)	Indicative ground level (to 1 dec pl)	NON-RESIDENTIAL BUILDINGS				
				Name and Nature of Use/Business	Lowest Floor Level (mAHD)	Approximate Floor Area (m2)	**Floor Construction** Pier (P) or Slab (S) Other - describe	**Wall Construction** Brick stone or rendered (B), Clad (C) , Mixed (M)
2a	Charles	C	2.5	Iluka Boat Shed & Marine	2.61	360	S	C
2a	Charles	C	2.5	Makuli Restaurant & Cafe	2.61	72	S	C