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GOSFORD CITY COUNCIL

YATTALUNGA URBAN INVESTIGATION ZONE

TRUNK DRAINAGE STRATEGY STUDY

JANUARY, 1994

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EXECUTIVE SUMMARY

The Yattalunga Urban Investigation Zone is located approximately 6 kilometres south-east of Gosford, and stormwater runoff generated within the Zone drains to Brisbane Water in the west. The size of the catchment draining the area is approximately 2.5 square kilometres. There is pressure for further development within the catchment and in surrounding catchments.

To determine future land uses in consideration of the sensitive local environment, Gosford City Council resolved to carry out Urban Capability Studies for part of the catchment downstream of Avoca Drive and upstream of Davistown Road (approximately 35 hectares). This present study examines the trunk drainage issues and provides an assessment of the urban capability of the land within the Urban Investigation Area (UIA). A Flora and Fauna Survey and a Soil Survey have previously been undertaken.

All of the UIA study area presently consists of rural residential development and is zoned Urban Investigation Rural 1(d). This is an interim zoning which will be reviewed following completion of the Urban Capability Studies.

Hydrologic and hydraulic models were established to simulate the flood behaviour within the catchment. Calibration of the models was not possible because of the lack of available flood height data. It was therefore necessary to adopt recommended parameters which have been used successfully in other studies in the Gosford City area.

There is only one instance of a building being flooded during any of the known historical floods. This building is located downstream of Davistown Road. However, floodwaters have inundated property to just below floor level at all the other properties downstream of Davistown Road and at Kantara House located downstream of Avoca Drive.

The computer models were run to determine design flood levels within the study area. The results showed that the only significant flood problems under existing conditions for Council's adopted 1% design flood standard, are the overtopping of Davistown Road and Avoca Drive, and the inundation of 1 building. Flooding does occur to within 0.2m of existing floor levels at a number of properties downstream of Davistown Road. This is not normally regarded as a sufficient freeboard to allow for uncertainties such as wave action or local effects, the Greenhouse Effect, and the range of uncertainty around the calculated flood heights. Measures to reduce the depths of inundation across Davistown Road and Avoca Drive have been proposed as well as alternative solutions to alleviate flooding downstream of Davistown Road.

In accordance with Council's policy, floor levels for all future development should be set at a minimum of 500mm above the 1% design flood profile produced in this report. The order of accuracy of the design flood levels is ±0.4m.

Future development in the study area is constrained by a number of factors including:

- **Flooding:** Land filling within the UIA may only slightly increase upstream and downstream flood levels. Any potential increase in paved areas and urban drainage structures due to further development within the study area would be unlikely to affect flood levels. Nevertheless, because of other constraints, development within the existing 1% floodplain is not recommended.
- **Flora & Fauna:** Several areas of vegetation were identified as having particular environmental significance and being worthy of preservation. Development should not impact upon these areas.
- **Soil:** In some places the soil is waterlogged. The low lying area contains plastic clays and has the potential for the development of acid sulphate conditions. Development would therefore be difficult and would require careful management within these areas.

- **Water Quality:** If there is any reduction in the existing water quality, this may impact upon the existing vegetation and possibly Brisbane Water. Water quality control measures should be incorporated within any proposed developments.
- **Groundwater:** The existing flora and fauna would be sensitive to any changes in the groundwater regime. Given that there is only a relatively small potential for further development within the area, and development within the low lying plastic clay areas is not recommended, potential groundwater impact is unlikely to be a controlling factor.

Taking all of the above factors into account, it is recommended that development only proceed within the area designated on Figure 9 and be subjected to the guidelines provided in Section 7.3.

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1. INTRODUCTION

The Yattalunga Urban Investigation Zone is located at Yattalunga, approximately six kilometres south-east of Gosford on the New South Wales Central Coast (Figure 1).

There is pressure for further development within the catchment and in surrounding catchments. To determine future environmentally sensitive land uses, Gosford City Council resolved to carry out Urban Capability Studies for part of the catchment downstream of Avoca Drive and upstream of Davistown Road. To facilitate the preparation of this Plan, Gosford City Council commissioned Webb, McKeown & Associates to carry out a Trunk Drainage Strategy Study for the catchment and assess the urban capability of the land within the UIA. A Flora and Fauna Survey and a Soil Survey have previously been undertaken for the UIA.

The UIA is bounded generally by Avoca Drive to the north, Elvys Avenue to the east/south and Bourke Avenue/Davistown Road to the west. The unnamed creek draining the catchment discharges under Avoca Drive and Davistown Road and flows in a westerly direction into Brisbane Water (Figure 2).

The Trunk Drainage Strategy Study was required to examine:

- the existing problem,
- possible flood mitigation works,
- the potential for urban development within the study area,
- the hydrologic and hydraulic effects of possible further urban development of the catchment.

Existing conditions were taken as at February 1992. There is no intensive urban development within the catchment, although part of the township of Yattalunga lies in the south-west of the catchment. The upper catchment consists of heavily forested slopes, and on the lower slopes clearing has been undertaken in some areas and several houses have been constructed.

The Brief required that any future development in the UIA would be required to:

- provide protection for existing at risk development, or ensure that the flood risk to existing flood liable development would be no greater after further development than under existing catchment conditions,
- ensure that any new development would not be flood liable in Council's adopted designated flood (Flood Standard).

Achieving these objectives by means of compensatory works is considered acceptable as long as they are environmentally sensitive. Gosford City Council has adopted the 1% flood as the designated flood and requires floor levels to be a minimum of 500mm above that level. All levels are in metres to Australian Height Datum (0m AHD is approximately mean sea level).

2. CATCHMENT DESCRIPTION

The Urban Investigation Area is approximately 35 hectares (Figure 2) and the total catchment area to Davistown Road is approximately 2.5 square kilometres (250 hectares).

As at the date of the study (February 1992) all of the study area consisted of rural residential development zoned Urban Investigation Rural 1(d). This is an interim zoning which will be reviewed following completion of the Urban Capability Studies.

The trunk drainage is at present largely in a natural state. The only significant man-made drainage features are two road crossings at Avoca Drive and Davistown Road (Figure 2). The catchment upstream of Avoca Drive is heavily forested and predominantly in a natural state. Downstream of Avoca Drive the land has in parts been cleared of all vegetation. The land falls gradually to Davistown Road from Avoca Drive. Downstream of Davistown Road the land is heavily vegetated and subject to tidal inundation except for a small strip of land immediately adjoining the road.

The lower slopes of the UIA consist of poorly drained alluvial land with ill-defined drainage lines. The majority of the natural vegetation has been cleared and disturbed with some weed invasion. However there is a large remnant vegetation pocket consisting of a highly significant Swamp Palm Forest and surrounding Blackbutt forest on the lower slopes.

The majority of the land within the UIA is utilised by small rural holdings with some cattle grazing. The only commercial/social use is Kantara House which is used as a function centre. The properties immediately downstream of Davistown Road are a mixture of residential and light commercial premises. Downstream of Davistown Road a State Environmental Planning Policy No. 14 (SEPP 14) Wetland Site 935 has been delineated.

3. AVAILABLE DATA

3.1 Previous Studies

No previous drainage studies of this catchment have been undertaken. A Flora and Fauna survey by Andrews Neil (Reference 1) and a Soils and Drainage Limitations survey by the Soil Conservation Service of New South Wales (Reference 2) have been completed as part of the Urban Capability Studies. Summaries of each survey are attached as Appendices A and B respectively.

3.2 Flood Levels

A comprehensive investigation was undertaken to obtain historical flood height data. It concluded that there are no reliable flood height data within the catchment and no flood gauging instrumentation. The only flood data available are qualitative descriptions of floods and some photographs of a recent flood crossing Davistown Road.

Kantara House, located on the floodplain just downstream of Avoca Drive, reported that floodwaters have come to within 0.5m of the floor level, but never over the floor. This appears to be reasonably reliable data, although as the ownership of the building has changed recently, it is possible that earlier events could have reached higher levels.

Davistown Road has been overtopped on a number of occasions. In the 9 February, 1992 storm it was overtopped to a depth of up to 0.3m, although rainfall data indicate that this was only a minor event. Downstream of Davistown Road there are several houses affected by flooding, but the owners report that flooding has only occurred above floor level in one building (Lot 7, D.P. 24676 floor level = 1.86m AHD). Floodwaters have reached to within 0.2m of the floor level in other buildings. The residents also report that it is difficult to distinguish between historical events, as all floods reach approximately the same level at Davistown Road and immediately downstream.

Council records show that a number of properties in Bourke Avenue (Figure 2) have experienced flooding problems. There are no records of water inundating habitable floor levels and it appears that it is entirely backyard, garage and laundry damage and inconvenience. Flooding results from shallow overland flow rather than water flowing within a defined channel. Some residents have constructed fences or ditches to divert the water.

The isolated house in Bourke Avenue with a floor level of 3.12m (Figure 2) reported a flood level in 1989 of approximately 2.7m. It has been assumed that this level was from local runoff rather than being representative of the main creek water level. The ground level at this location is at approximately 2.7m.

3.3 Rainfall Data

Design rainfall data and temporal patterns were obtained from Australian Rainfall and Runoff, 1987 (AR&R) (Reference 3). A comparison of rainfall recorded at Kincumber (approximately 3kms away) during the storm of 7 February, 1990 and design rainfall data from AR&R, is presented in Table 1.

TABLE 1

Comparison of Peak Rainfalls at Kincumber Pluviograph during the Storm of 7 February 1990 and AR&R Design Rainfall Data (mm)

Duration (h)	Kincumber 7 February	Design				
		1%	2%	5%	10%	20%
0.5	62	63	57	49	42	37
1	100*	89	80	68	59	52
2	122*	117	105	90	78	68
3	132	137	123	105	91	80
6	134	178	160	136	118	104

Note: * Exceeds the 1% design rainfall intensity.

The storm of 7 February, 1990 caused severe flooding in the Gosford area which was well recorded in other catchments, e.g., Erina Creek and Narara Creek. Unfortunately the data search for this study produced no mention of this event. One possible explanation for this could be that as the peak occurred around 5.00am on 7 February, there were no eye-witnesses. Council's file shows no record of flooding for this event or any other historical flood within the UIA. Although there are records of local drainage problems.

3.4 Survey Data

A detailed field survey was carried out by Cahill and Cameron (Registered Surveyors) of Gosford as part of this study. The locations of surveyed cross-sections are shown on Figure 2. A set of survey plans has been provided under separate cover to Council.

4. APPROACH ADOPTED

4.1 General

The Watershed Bounded Network Model (WBNM) was used for the hydrologic modelling of the catchment and the RUBICON model for the hydraulic modelling. These models have the advantage that they have been used successfully in other studies within the Gosford City area and can be calibrated to historical data (if available).

4.2 Hydrologic Modelling

WBNM is a widely used model which was chosen for a number of reasons which included:

- its ability to be calibrated to historical data,
- its ability to simulate the impacts of future catchment development (further technical details on the WBNM model are given in Reference 4),
- the model has been used in other similar studies on the Central Coast and local model parameters have been derived,
- it provides runoff inputs at a number of locations which can then be input to the hydraulic model.

Estimates of design peak flows were also obtained from the Probabilistic Rational Method to provide a check on those derived using the WBNM model. Details of this method are provided in AR&R (Reference 3).

4.3 Hydraulic Modelling

The RUBICON model (Reference 5) was used to determine the hydraulic behaviour of the creek and overbank floodplain areas. RUBICON is a branched unsteady flow (or dynamic) model which was developed in the Netherlands by DELFT Engineering Software and Haskoning. Further technical details of the model are provided in

Appendix D. The model is well suited for simulating flood behaviour in complex floodplains, and can also replicate tidal behaviour in the lower reaches of creeks.

As it is a dynamic model and can simulate the full flood hydrograph over time (not just the peak), it has the advantage over steady state models of being able to accurately model the effects of floodplain storage, such as ponding behind roads, etc. This is particularly important if the effects of floodplain filling have to be simulated.

4.4 Practical Strategies

The methodology involved in developing a practical trunk drainage strategy for this UIA was as follows:

- determine the extent of the existing flooding problem,
- identify possible future development areas taking into account the following physical constraints:
  - extent of the 1% floodplain,
  - environmentally sensitive areas of vegetation requiring conservation,
  - unsuitable soil conditions,
  - sedimentation and water quality impacts,
  - groundwater impacts,
- investigate the impacts of developing these areas using various drainage strategies,
- propose a recommended drainage strategy and highlight matters which require further investigation.

5. HYDROLOGIC MODELLING

5.1 General

The catchment was subdivided into a total of 18 sub-catchments as shown on Figure 3. Routing the rainfall through the WBNM model provided flow hydrographs suitable for input to the RUBICON model at the locations shown on Figure 4.

5.2 Calibration

Calibration, or replication of a historical flood(s), is undertaken to ensure that the hydrologic model is accurately replicating existing conditions. Design flood levels can then be derived with more confidence. Ideally the WBNM model should be calibrated independently using recorded streamflow data. However, this was not possible in this case as there are no flow data available. An alternative is to calibrate the hydrologic and hydraulic models in tandem using historical rainfall and flood height data. Whilst there are good quality rainfall data for several storms available from the Kincumber pluviograph, there are no available flood height data. It was therefore not possible to calibrate the hydrologic model.

5.3 Design Runs

The development in the catchment (as at February 1992) was so sparse that it was assumed that the catchment was in a "rural state" under existing conditions. In the absence of calibration data, it was necessary to adopt the recommended default value for the WBNM model routing parameter "C" (C = 1.29) from AR&R. An initial loss of 0mm was adopted, together with a continuing loss of 2.5mm/h. Similar parameters were adopted in studies at Erina Creek, Worthing Road Creek and Nunns Creek, and were found to provide reasonable calibration and verification over a range of floods.

Design rainfalls and temporal patterns for durations from 0.5 to 6.0 hours were obtained from AR&R and input to the WBNM model to obtain design flows. These were then input to RUBICON to determine design flood levels. The 2h duration storm produced the highest flood levels and was adopted as the critical storm.

As a check on the validity of the design flow estimates, the Probabilistic Rational Method (PRM) was also used to calculate the peak flows at Davistown Road and at Avoca Drive. The results are compared in Table 2.

TABLE 2

Peak Flow Comparison
WBNM/RUBICON versus PRM

FLOOD	PEAK FLOW (m^3/s)			
	Davistown Road ($2.5km^2$)		Avoca Drive ($1.8km^2$)	
	WBNM	PRM	WBNM	PRM
1%	46	53	33	41
2%	40	43	29	33
5%	35	33	25	25
10%	29	25	21	20
20%	24	20	18	15

The results from the two methods compare favourably. The WBNM/RUBICON composite model provides a more sophisticated technique than the PRM approach, and for this reason, results from the WBNM/RUBICON model were adopted for design.

The peak flow of the Extreme flood was obtained by doubling the 1% peak flow. This approach is consistent with that adopted in Erina Creek, and other studies undertaken in the Gosford City area and provides an indication of the behaviour of a rare flood.

6. HYDRAULIC MODELLING

6.1 General

The RUBICON model was set up to model the creek from upstream of Avoca Drive to Brisbane Water (Figure 4). The layout incorporated all the available survey data (cross-sections) (Figure 2) and was established to ensure accurate representation of the flow patterns and hydraulic controls. Tributary inflows from the WBNM model were included where appropriate along the length of the creek.

6.2 Calibration

As noted previously, no flood height data were available for calibration of the model. Manning's 'n' values for each cross-section were therefore selected after a detailed field inspection, with the aid of photographs taken by the surveyors, and by considering recommendations in established references. A listing of the adopted Manning's 'n' values is provided in Appendix D.

6.3 Hydraulic Analyses

Preliminary investigations revealed that flood levels upstream of Davistown Road were largely insensitive to the level of Brisbane Water, this being the downstream boundary of the model. It was therefore decided to adopt a constant level of 0.5m AHD in Brisbane Water, but to examine as part of the sensitivity analyses changing this level to 0m or 2.0m AHD. The sensitivity results are discussed in Appendix C.

Maximum flood heights at each section for existing conditions were determined using RUBICON for each of the design flood events (2h critical duration). These levels are shown in Table 3 and also as peak height profiles on Figure 5. The 1% flood contours, and the extent of the 1% floodplain, are shown on Figure 6.

TABLE 3

Design Flood Levels (m AHD)
(assuming a Level of 0.5m AHD in Brisbane Water)

SECTIONS	DESIGN FLOODS					
	1%	2%	5%	10%	20%	Extreme
CS14	7.06	6.79	6.48	6.33	6.26	7.59
CS13	7.04	6.75	6.36	6.08	5.89	7.56
CS11	4.95	4.90	4.85	4.81	4.77	5.26
CS10	4.45	4.39	4.35	4.30	4.25	4.76
CS9	3.98	3.91	3.86	3.79	3.72	4.30
CS8	3.88	3.82	3.77	3.70	3.63	4.12
CS7	3.13	3.09	3.05	3.01	2.98	3.36
CS6	2.67	2.64	2.61	2.58	2.57	2.91
CS5	2.50	2.47	2.44	2.39	2.34	2.76
CS4	2.49	2.46	2.43	2.39	2.33	2.74
CS2*	1.80	1.76	1.71	1.66	1.59	2.14
CS1*	1.42	1.38	1.34	1.30	1.26	1.86

Note: * Refer to following text for data on design Brisbane Water Levels.

The flood levels at each cross-section indicate that Davistown Road (CS4) acts as a significant hydraulic control. It generates a difference in water level across the road of approximately 0.7m, behaving very much as a classical broad-crested weir, and causing the 1% and 20% floods to be within 0.2m of each other immediately upstream of Davistown Road. Since the road is relatively flat for a width of 100m to 200m, a small increase in depth produces a large increase in available waterway area. Thus flows from larger floods produce only a small increase in level at Davistown Road. The culverts have insufficient capacity by presently recognised standards, as floodwaters cross the road (lowest level 2.2m AHD) in 20% and greater floods.

These results are consistent with the limited available flood data, local observations, and flood photographs as described in Section 3.2. Upstream of Davistown Road, design flood profiles maintain approximately the same level until CS6 where the land starts to rise.

The results provided in Table 3 are for a constant 0.5m AHD level in Brisbane Water. This level approximates a high tide and could be expected to occur in conjunction with a flood producing storm. Elevated Brisbane Water levels occur due to a combination of factors including:

- spring tides,
- major rainfall,
- wind setup,
- wave setup,
- pressure setup.

The current design Brisbane Water levels (m AHD) as adopted in the Erina Creek Study (Reference 7) are:

1%	2.0m
2%	1.7m
5%	1.5m

The probability of a 1% Brisbane Water level occurring in conjunction with a 1% storm over the Yattalunga catchment is low. This is because the elevated Brisbane Water level is in response to a long duration storm, such as a decaying cyclone (say 2-3 days), while the critical storm duration for the catchment is much shorter (2h duration) and more likely to be associated with thunderstorm activity. The two flooding mechanisms (storm over the catchment and elevated Brisbane Water) can therefore be considered to be independent events. In a 1% elevated Brisbane Water the levels at sections CS1 and CS2 will exceed those shown in Table 3.

Local hydraulic structures such as fences, houses and vegetation, will have a significant influence upon flood levels immediately downstream of Davistown Road, particularly as this is an area of rapidly varying flow, with floodwaters cascading from the road and between these physical features. These effects cannot be accurately modelled within the scope of this study. Design flood levels derived in this study on the downstream side of Davistown Road are only indicative of flooding from the local catchment. Levels may well be higher if all the local factors are taken into account, particularly the level in Brisbane Water.

7. PRACTICAL STRATEGIES

7.1 Existing Flood Problem

7.1.1 Properties

The majority of the residents of the study area would have experienced the storm of 7 February, 1990 which produced rainfall intensities at Kincumber (which is only 3km from Yattalunga) in excess of the design 1% event. This could normally be expected to produce a flood equivalent in magnitude to a 1% flood. However, there is only one report of a building being flooded above floor level within the study area (historical flood data are discussed in detail in Section 3.2). This building is on Lot 7 and has a floor level of 1.86m AHD.

In the modelling of the 1% flood, the results show that this is the only building which would be flooded above floor level. Flooding would come within 0.3m of the floor level at Kantara House and between 0.2m and 0.5m of the other building floor levels downstream of Davistown Road. A 1% elevated Brisbane Water Level would inundate the floor level of Lot 7 and would be within 0.1m of a further two properties downstream of Davistown Road (Lots 8 and 10). All properties in this area would suffer backyard damage and inconvenience.

The methodology for determining flood damages is set out in Appendix E. It should be noted that Intangible Damages (stress, inconvenience) may equal or exceed the Tangible Damages (loss or damage to goods).

- **Lot 7 Davistown Road**

Lot 7 is a two storey dwelling. The ground floor is of brick constructed on slab-on-ground foundations and was built in the early 1980's. The second storey was built prior to 1980 and is of timber construction on galvanised iron poles.

The building is only inundated in floods larger than a 2% event (2% level in Brisbane Water is 1.7m) and the velocities are very low, so the flood hazard is also low.

No attempt was made to assess the most cost effective means of protecting the dwelling on Lot 7. In order to provide a measure of the flood damages which could be prevented at this location, an indicative value for the average annual flood damages for this property was assessed as $200. The Net Present Worth for the elimination of these damages (50 year period) is $3 000. It is therefore apparent that only works costing significantly less than $10 000 could be justified to rectify this problem. The only effective measure would appear to be flood proofing. This measure is discussed in further detail in the following section.

The best alternative may be to do nothing and wait until the site is re-developed.

- **General Flood Mitigation Measures**

Various measures which could be employed to protect all the buildings from flood damages along Davistown Road were evaluated.

The only viable measures for eliminating the flood hazard are:

- ***House Raising***: For all non-brick buildings. An indicative cost is $20 000 per building. This measure is now eligible for funding by State and Federal grants and is used widely throughout NSW. A disbenefit can be the alteration to the streetscape, however in this area this would not appear to be a major problem.
- ***Flood Proofing***: This is only viable for brick buildings. An indicative cost is $20 000 per building. Flood proofing is achieved by sealing all entrances to the building. The maximum depth of ponding outside before structural damage will occur is approximately 1m.
- ***Raising of Davistown Road and construction of a levee around the properties***: Construction of a levee would be relatively straightforward, but would involve acquisition of a 15m to 20m easement around the properties. Apart from the

visual impact of such a levee, this option may be unacceptable to the local residents. Preliminary indications are that it is unlikely to be cost effective, although no detailed costings have been undertaken.

Provision of the Flood Facts Brochure with Council's Rates Notice is an effective and cost effective procedure for heightening flood awareness within the community and minimising future flood damages. Council should also ensure that any construction works within the properties, e.g., paling fences, garages, etc., should be monitored to ensure that they do not unduly divert floodwaters to adjoining properties.

7.1.2 Roads

There are only two roads affected by flooding within the UIA - Avoca Drive and Davistown Road. The main creek crosses both these roads, which function as major arterial roads linking the Davistown Peninsula to Gosford. There have been no reports of overtopping at Avoca Drive, but there have been reports of reasonably frequent overtopping of Davistown Road by up to 0.3m.

Avoca Drive has twin 2.4m diameter culverts with the obvert of the culverts 0.7m below road level. Davistown Road has a bridge with a clear opening of 5.65m width and 1.75m height. As the lowest centreline level (2.2m AHD) along Davistown Road is approximately 0.2m below the obvert of the bridge, floodwaters overtop the road before the capacity of the bridge is exceeded (refer Figure 2).

In a 1% flood, Avoca Drive would be overtopped by up to 0.2m over a width of 80m in the vicinity of the culvert, and Davistown Road would be overtopped by up to 0.35m at the low point south of the bridge, and over a width of approximately 200m.

Both these overtoppings are relatively shallow, but still represent a possible threat to the safety of pedestrians. They also constitute a significant traffic hazard, particularly along Davistown Road.

The capacities of the waterway structures before road overtopping occurs are:

Avoca Drive	$30m^3/s$	(approximately a 2% event),
Davistown Road	$17m^3/s$	(less than a 20% event).

- **Avoca Drive**

Avoca Drive is an important arterial route from Kincumber and Copacabana to Gosford. Other routes are available if this route is cut during a flood. Since the capacity of the culverts is approximately a 2% event, there is no immediate requirement to upgrade them. When major road works are undertaken in the future, placement of an additional 2.4m diameter circular culvert would prevent overtopping of the road in a 1% flood. It is noted that the culverts are relatively free of vegetation and other obstructions, but it is still recommended that regular maintenance inspections be undertaken. On the downstream side, the efficiency of the culverts is reduced by an earthen mound. Consideration should be given to removing this obstruction.

- **Davistown Road**

Although the flood hazard at Davistown Road is not severe, the frequent overtopping of the road, and consequent traffic disruption, increases the importance of providing a flood free route. As this road is the only route from the urban areas of Davistown and Saratoga to Gosford, it is essential that access be available during floods. There is also further growth planned for these areas.

Two possible alternatives for remedying this problem are discussed below:

- raising Davistown Road and providing no additional waterway openings would increase the 1% flood level upstream by 0.8m. Two existing buildings would become flood liable and the additional flooding may affect the existing flora and fauna. In addition, this option would reduce the potential value of upstream land on the flood fringe. Due to these problems it has not been investigated further,

- raising Davistown Road and providing additional waterway openings under the road at the same time would eliminate the adverse upstream impacts described above. However, there is a potential for the flood liable properties on the downstream side of the road to be affected. Further, any works which may change the low flow regime of the upstream land have the potential to adversely affect the existing vegetation, particularly the Swamp Palm Forest. For these reasons it is essential that the low flow regime be maintained if this option is considered further.

It is therefore recommended, that if raising of the road is to be undertaken, additional waterway openings be provided. Maintaining the existing low flow regime can be achieved by ensuring that the inverts of the proposed openings are at the same level or higher than the existing waterway invert (0.6m AHD). Two locations for the openings are possible, either adjacent to the existing opening or near the low point in the road.

The former location is constrained by the following features:

- possible impact on the SEPP14 Wetlands immediately downstream,
- existing water main on the downstream side,
- the land rises rapidly to the north,
- a building is located immediately to the south.

It would therefore be preferable to locate the additional openings to the south of the bridge near the low point in the road, although this would require purchase of land on the downstream side. For the purpose of this report it was assumed that Council would purchase the large block in the middle (Lot 2, D.P. 703303) to enable this option to proceed. A grass lined channel would be needed to convey floodwaters across Lot 2. Downstream of Lot 2 no further works would be required as the land rapidly falls away to Brisbane Water.

The water exiting the channel would pass through approximately 100m of heavily vegetated terrain prior to entering the SEPP14 Wetlands. Overland flow follows this route under existing conditions. The proposed works would concentrate the flows and increase the frequency and volume of such flows. However, with the proposed water quality safeguards described in Section 7.2.4, and the filtering action of the 100m wide vegetated area prior to flows entering the Wetlands, there would be no significant impact from the further development.

Three 2.0m x 1.5m box culverts with an invert at 0.6m AHD would maintain the existing 1% flood level upstream of Davistown Road (2.5m AHD). In order to ensure that the existing low flow and groundwater regimes are not affected, it is proposed that a concrete or gabion drop structure be constructed immediately upstream of the culverts. This could be incorporated into a gross pollutant trap structure to improve water quality if so desired.

The benefits achieved by raising Davistown Road are largely "Intangible" in the terminology used in expressing flood damages costs, such as:

- reduction in stress and concern due to the road being cut,
- reduction in inconvenience caused by the road being cut, e.g. children late to school, late to work,
- provision of emergency services during a flood,
- reduction in traffic disruption and possibly accidents,
- water would not spread along the road and flow generally across the properties on the downstream side of Davistown Road.

It would take a detailed study in order to accurately evaluate the economic benefits of the road raising. However an indicative benefit would be $5 000 per annum (Net Present Value of $70 000 over 50 years).

The disbenefits of raising the road are:

- ***Environmental*** - the potential impact upon upstream flora could be minimised by the suggested drop structure. Downstream of the road, the concentrated flows exiting from the proposed channel through Lot 2 have the potential to impact upon the SEPP14 Wetland area located approximately 100m downstream of Lot 2. The impact is considered to be negligible for the following reasons:

- the proposed water quality structures within the developing areas (or at the drop structure) together with the length of the grass lined overland flow path, will minimise the residual pollutants in the runoff,
- the proposed works will not affect the low flow regime,
- the change in flow distribution during floods (from an opening at the north and overland flow across the road) to two openings under the road will only occur (say) once every year. It is unlikely therefore to cause a change in the vegetation pattern within the wetland. Velocities are also likely to be small. The impact will be further reduced if Brisbane Water is elevated at the time of the flood.

Because of the existence of the SEPP14 Wetland, Council may consider that this issue should be considered further by appropriate experts.

- ***Social*** - none, although the works may require the driveways of the properties downstream of Davistown Road to be re-constructed.

- ***Economic*** - the approximate cost to raise the road, and provide culverts, a drop structure, purchase Lot 2 and form a downstream channel, is $300 000. If the raising of the road was carried out at the same time as a general upgrading of the carriageway, the incremental cost of the works would be less.

A preliminary design for the works and a breakdown of the costs are provided in Appendix F.

7.2 Future Development Constraints

7.2.1 Flora and Fauna

A report on Flora and Fauna within the study area was prepared by Andrews Neil (Reference 1). The main stands of vegetation are shown on Figure 7. A summary of the recommendations of the report are included as Appendix A.

A number of different types of vegetation were identified to have particular environmental significance. These include the Swamp Mahogany Forests, the Swamp Oak Forests, and most importantly, the Swamp Palm Forests. The key issues which relate to the hydrologic regime of the area, particularly if the catchment was to be developed, are:

- changes in water quality may adversely affect the existing flora, particularly the Swamp Palm and Swamp Mahogany forests, and the designated SEPP14 Wetland downstream of Davistown Road, all of which are of high intrinsic value. Future development will therefore require rigorous controls on water quality,
- any changes to the low flow hydrologic regime upstream of Davistown Road may adversely affect the existing vegetation. Downstream of Davistown Road any changes in regime may impact upon the SEPP14 wetland, but unless there is a major change, the impact will be minor,
- changes to the groundwater table elsewhere could inadvertently impact upon groundwater levels within the area of high vegetation value. Such impacts could be caused by construction activities such as installation of services for water supply or sewerage to proposed developments. The degree of potential impact would depend on the distance of the activity from the sensitive area, and the type of work being carried out. An awareness of the potential problem, and proper controls, would eliminate any potential groundwater impacts.

7.2.2 Soils

A report on urban capability within the study area with respect to soils was prepared by the Soil Conservation Service (Reference 2). The results of this study are shown on Figure 8 and the conclusions of the report are included as Appendix B. The key issues are summarised below:

- in general the soil type away from the floodplain is suitable for development with appropriate erosion/sedimentation controls on the steeper slopes. In places the soil is waterlogged,
- most of the floodplain area contains plastic clays with possible acid sulphate potential. This area is also frequently waterlogged and unsuitable for development unless extensive engineering works are undertaken,
- marginal areas for development are on the boundaries of the floodplain to the north and on the high ground in the middle of the floodplain.

Urbanisation has the potential to involve significant disturbance to the land surface and generation of increased sediment loads in surface runoff. It is greatest during the construction phase and decreases thereafter. It is essential therefore that the Soil Conservation, RTA or other suitable guidelines be strictly enforced.

7.2.3 Flooding

The extent of the existing 1% floodplain is shown on Figure 6 together with flood contours at 0.1m increments. The extent of the 1% floodplain within the study area has been taken to the limit of the available survey data. Upstream of this limit the creeks become ill defined and flow is predominantly overland rather than confined to a defined channel. The 1% peak flows in these creeks are less than $5m^3/s$ and can therefore be contained within the normal drainage easements provided within a subdivision.

The potential impacts on flooding of future development within the UIA were represented in two ways:

- filling of the floodplain (loss of floodplain storage),
- urbanisation upstream of the floodplain (larger and more rapid flows).

The impacts of filling the floodplain upstream of Davistown Road were analysed for the 1% event by considering the following two alternatives:

- assumed 50m encroachment upon the floodplain from one side at cross-sections CS4, CS5 and CS6,
- assumed 100m encroachment upon the floodplain from one side at cross-sections CS4, CS5 and CS6.

The results are shown in Table 4.

TABLE 4

Impacts of Filling within the Floodplain Upstream of Davistown Road - 1% Flood

OPTION	BASE		50m		100m	
SECTION	m AHD	m^3/s	m	m^3/s	m	m^3/s
CS2	1.80	22	*	22	*	22
CS4	2.49	46	*	46	*	46
CS5	2.50	43	*	43	+.01	43
CS6	2.67	43	+.05	43	+.23	43
CS7	3.13	37	+.05	37	+.14	37

NOTE: The change in flood level compared to the base is shown for the 50m and 100m encroachments.
* change in flood level of less than ± 0.01m.

The results indicate that a 50m encroachment will raise 1% flood levels by up to 0.05m and a 100m encroachment by up to 0.23m. As there are no existing flood liable buildings upstream of Davistown Road, the affectation is only to existing rural lands. The increases are significant (particularly for the 100m encroachment) and would potentially reduce the value of the affected land.

Urbanisation of a catchment produces the following two major changes to the runoff characteristics:

- an increase in runoff volume due to an increase in impervious area,
- a decrease in the time of concentration of the runoff because of the construction of pipes, roadways, etc., which channelise and speed up the flow.

These effects were analysed using the hydrologic and hydraulic models. The results showed that the flood levels upstream of Davistown Road would be marginally decreased by urbanisation (by less than 0.01m). The reason for this is that urbanisation of the UIA "speeds up" the runoff from this area allowing the runoff to exit to Brisbane Water prior to the main flood flow from further upstream. The increase in runoff volume due to urbanisation has even less effect because of the relatively small size of the urbanised area compared to the total catchment area.

Retarding basins would therefore be counter-productive as a mitigation measure against urbanisation impacts in this locality. The relatively steep nature of the terrain (1 in 12 slope) and lack of suitable sites also makes them unsuitable. Nevertheless basins of some sort may be of value as water quality structures (refer Section 7.2.4). On-site detention is not recommended for this UIA as it would also be counter-productive.

Therefore, should future development be permitted within the UIA, no specific flood mitigation works are in fact necessary to compensate for the new development. Because of the importance of the existing flora and fauna it is essential that the pipe and trunk drainage systems be designed in an environmentally sympathetic manner whilst ensuring that no building (existing or future) will be inundated in a 1% flood event. The drainage design should be in accordance with guidelines provided in Australian Rainfall and Runoff. Particular emphasis should be given to the design of the overland flow paths.

As far as possible Council should provide controls on future subdivisions to ensure that:

- floor levels of all buildings are raised (say 0.3m) above the surrounding ground and at least 0.5m above the 1% flood level,

- fences or dense vegetation do not divert overland flow paths,
- properties on the low side of roads do not become major flow paths.

Of particular concern would be the future development of the land east of Bourke Avenue (Figure 2). Buildings along Bourke Avenue (Section 3.2) have been affected by floodwaters in the past which originate from this area. It is essential that any future drainage system not exacerbate the problem and in preference should be designed to reduce or eliminate future problems. The aim of the system should be to divert as much runoff as possible in a northerly direction away from Bourke Avenue. It may also be necessary to construct banks or roads which will divert overland flow northwards.

There would be minimal additional costs to implement the above concepts if they were incorporated at the design stage.

7.2.4 Water Quality

Any increase in development within the UIA has the potential to adversely affect the water quality within the UIA and downstream. The magnitude of any affectation would depend upon the scale of the development, the effectiveness of water quality controls, and the sensitivity of the area to be affected. At this stage the extent of any proposed development and likely water quality controls cannot be determined.

Because of the significance of the Swamp Palm Forest ecosystem and SEPP14 Wetland, it is imperative that any decrease in the existing water quality be minimised. This does not necessarily preclude further development of the UIA, but it does require that detailed consideration be given to water quality issues prior to permitting any further development. It is essential that any water quality structures be compatible with the urban environment.

Because of the sensitive nature of the environment it is recommended that a combined Water Quality and Drainage Master Plan Study be undertaken at the design stage prior to any development within the UIA. This study should encompass all of the proposed developments. It should form the basis for the integrated design of the drainage system. Further details of this approach are available in Reference 8.

This study should encourage the use of innovative techniques in the design such as:

- producing detailed guidelines for the construction phase of the sub-division to minimise erosion and adverse water quality impacts,
- recommending measures to enhance the infiltration of urban runoff, in particular the runoff from lawns and driveways. Such measures may include:
    - Dutch drains,
    - mini detention basins constructed in an easement or open space area,
    - porous pavements (lattice slabs, brick paving),
    - controls to limit runoff from driveways directly entering the stormwater system,
    - controls to ensure that there are no illegal drainage connections,
    - the use of grassed swales to facilitate infiltration and pollutant assimilation,
    - pollutant removal controls. These controls should include permanent and ongoing procedures. The permanent measures may include sediment traps in all gully pits, trash racks, Gross Pollutant Traps (GPT's) and/or macrophyte ponds at the downstream limit of drainage lines. Ongoing measures could include:
        - enforcement of controls on rubbish dumping,
        - regular cleaning of gully pits,
        - community awareness programs (through local groups).

The literature provides little guidance on the additional costs to implement an effective water quality management system at the design stage. Typically the information relates to structures within an existing urban environment (Reference 6). A preliminary cost estimate is $20 000 per hectare with an annual maintenance cost of 5%.

7.2.5 Groundwater

As has been discussed in several earlier Sections, any change to the position of the groundwater table could have adverse consequences on the environment. This would mainly apply in terms of potential effects on flora and fauna, but could also affect existing development by increasing damp or swampy areas if the water table was to rise, and potentially cause rising damp and other similar problems such as damage to the road base.

Given the other constraints which severely limit the potential for development within the UIA, and the fact that development is not recommended within the 1% floodplain or where unsuitable soil conditions exist, it is unlikely that groundwater will impose any additional constraints. Providing that there is no attempt to drain low lying areas by constructing open channels or tile drain sub-surface systems, and providing that the basic trunk drainage design relies on natural drainage paths, there is little chance of the water table being lowered significantly.

The other possible concern may be the potential raising of the groundwater table. This can occur due to increased watering of lawns in large scale urban areas or by construction of barriers to groundwater flow, such as construction of major roads across the floodplain. These are generally formed by excavation and backfilling, generally by relatively impervious materials. Since the scale of development is likely to be moderate, and the main roads are already in place, neither of these potential threats are likely to be realised.

The only potential threat to the groundwater level and its quality in the UIA, would appear to be from outside of the UIA, such as by large scale development of the upper catchment. It is understood that this is not a consideration at the present time. In summary, it can be concluded that there is no significant threat posed to the groundwater regime in this area by the scale of development envisaged at this time.

7.3 Conclusions and Recommendations

A number of possible constraints on the future development of the UIA at Yattalunga have been identified in this report and in studies carried out previously within the area.

These constraints include:

- flooding,
- water quality,
- acid sulphate soils,
- flora and fauna,
- groundwater table (soil waterlogging).

A development constraints plan has been prepared and is produced at Figure 9. It takes into account the abovementioned constraints and reflects the following key recommendations:

- development should not proceed on the low lying land as delineated on Figure 9,
- the potential areas for future development of the UIA are shown on Figure 9. It is estimated that the area near Avoca Drive may yield 60-80 residential lots and the area near Bourke Avenue 70-100 lots.
- development upon the upper slopes of the UIA can proceed in the manner indicated on Figure 9 subject to the inclusion of adequate water quality control measures during the construction and post-construction phases, and provision of a satisfactory geotechnical report prior to development,
- development outside the floodplain should be in accordance with Council's guidelines on flooding which are contained in the Flood Facts Brochure,
- the low lying lands should not be drained, but may be incorporated into a recreation area. Care should be taken to ensure that the integrity of the Swamp Palm Forest is not compromised,
- upgrading of Davistown Road should be considered by Council as a medium to high priority item,

- the upgrading of Avoca Drive should be considered by Council as a low to medium priority item, but maintenance works should be carried out as a high priority item,
- Council should closely monitor any construction works in the area immediately downstream of Davistown Road to ensure that new water quality and/or flood problems do not arise,
- no filling will be permitted downstream of Davistown Road until the proposed road upgrading works are undertaken. Following completion of these works Council should review this requirement,
- providing flood protection to the property on Lot 7 Davistown Road is a low to medium priority item,
- nuisance flooding of the properties along Bourke Avenue should not be exacerbated and the drainage design of the upstream subdivision should attempt to minimise this problem.

8. REFERENCES

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A Watershed Bounded Network Model for Flood Estimation Computer Programs and User Code
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RUBICON System Documentation
November, 1986.

6. State Pollution Control Commission
Pollution Control Manual for Urban Stormwater
August, 1989.

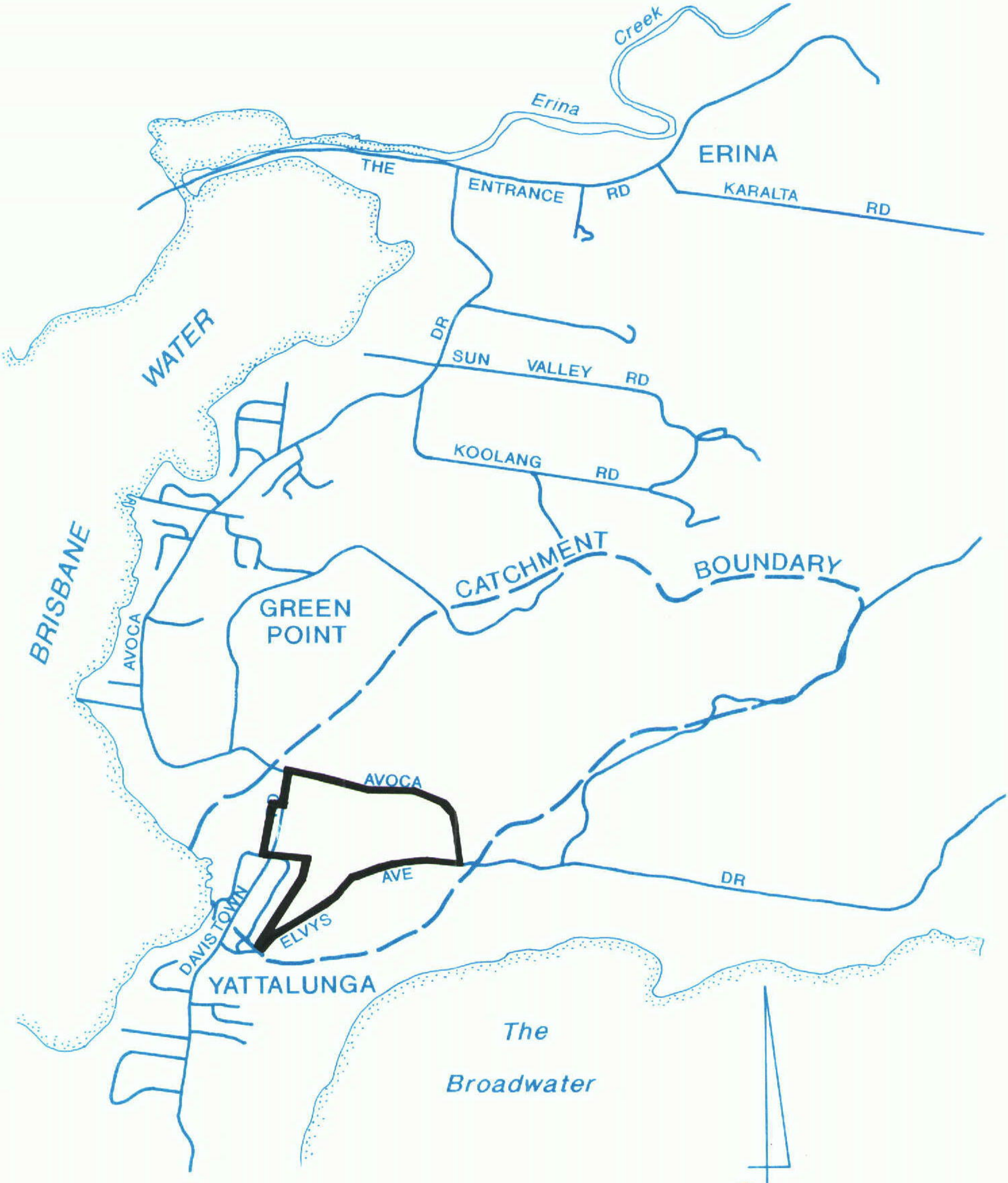
7. Gosford City Council
Erina Creek Flood Study Review 1990
Webb, McKeown & Associates, June 1991.

8. Department of Planning
Better Drainage - Guidelines for the Multiple Use of Drainage Systems
Land Systems EBC Pty Ltd, August 1993.

FIGURES

FIGURE 1

LOCALITY MAP



LEGEND

Study Area

SCALE

250 125 0 250 500 750 1000m

FIGURE 2

STUDY AREA AND SURVEY DATA

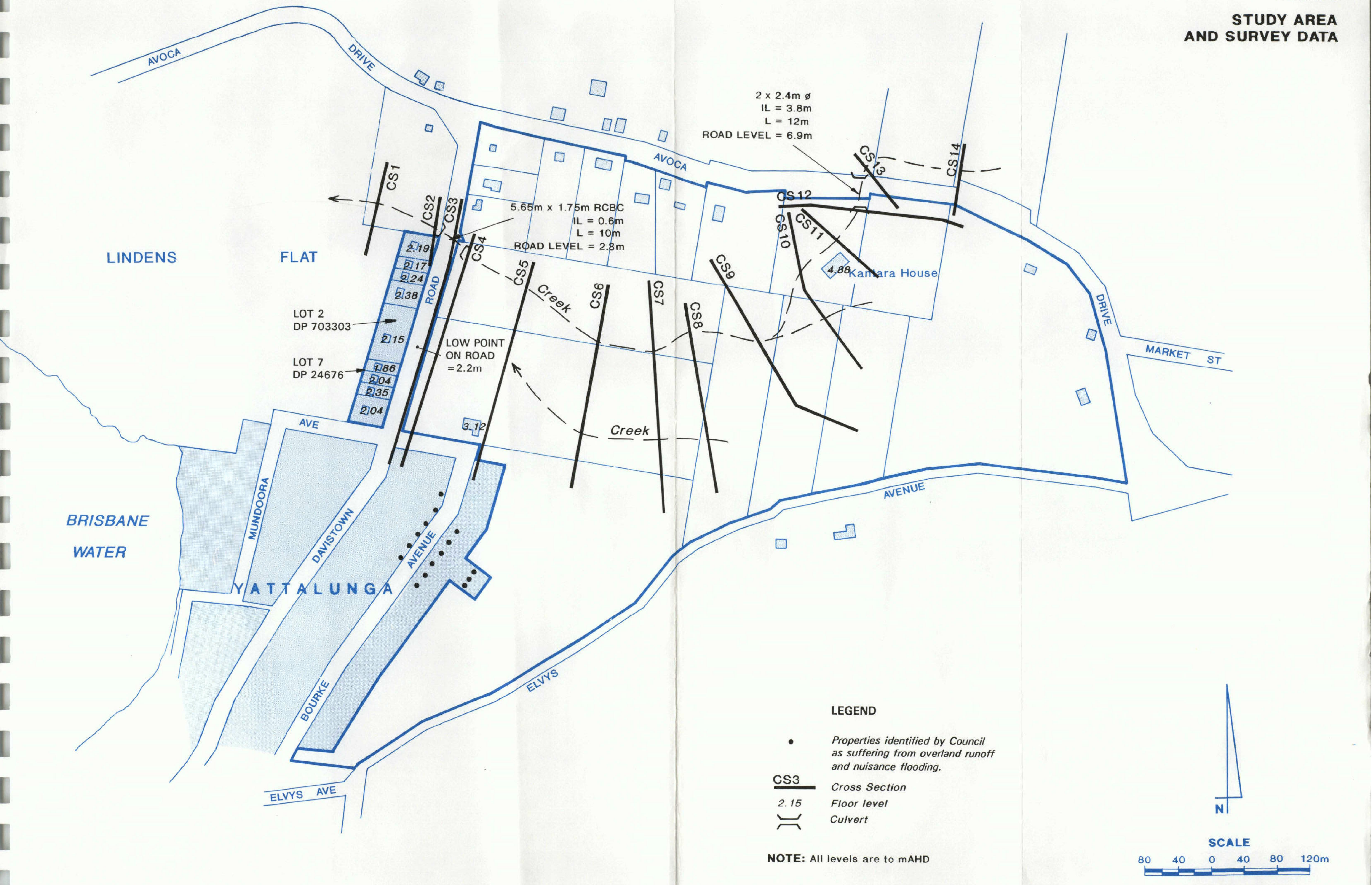


FIGURE 3

WBNM MODEL LAYOUT

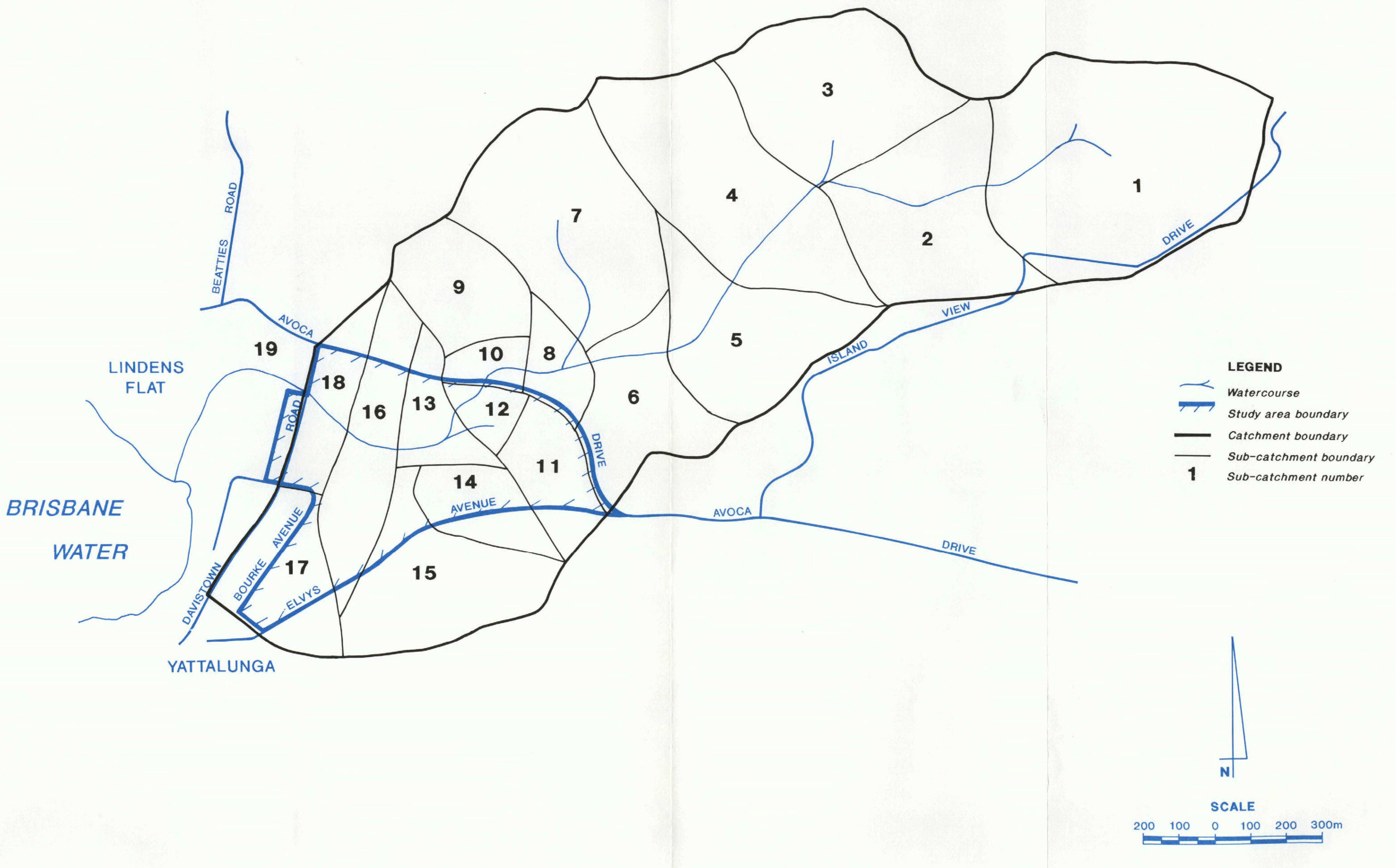


FIGURE 4

RUBICON MODEL LAYOUT

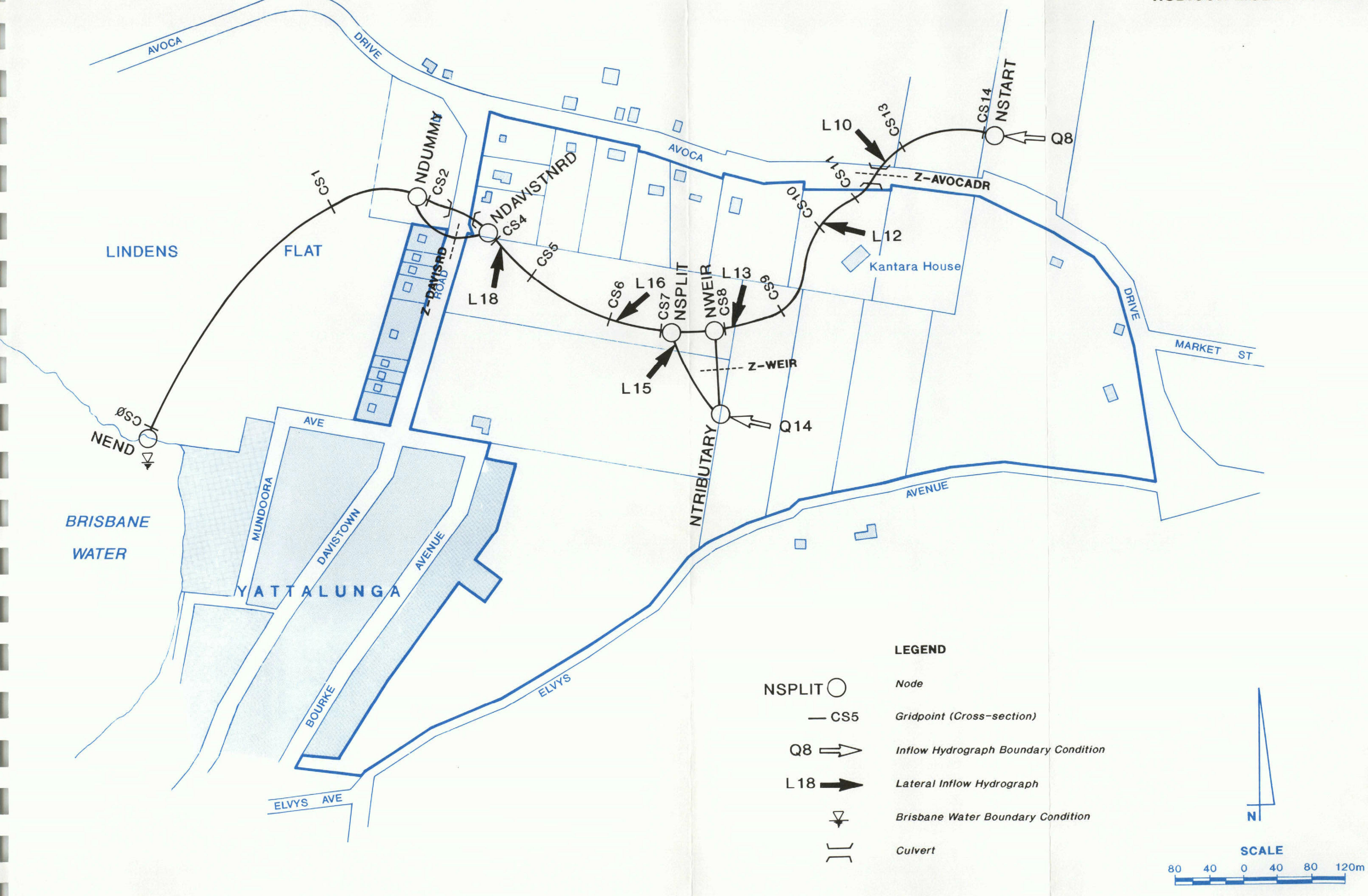


FIGURE 5

PEAK HEIGHT PROFILES
DESIGN FLOODS
EXISTING CONDITIONS

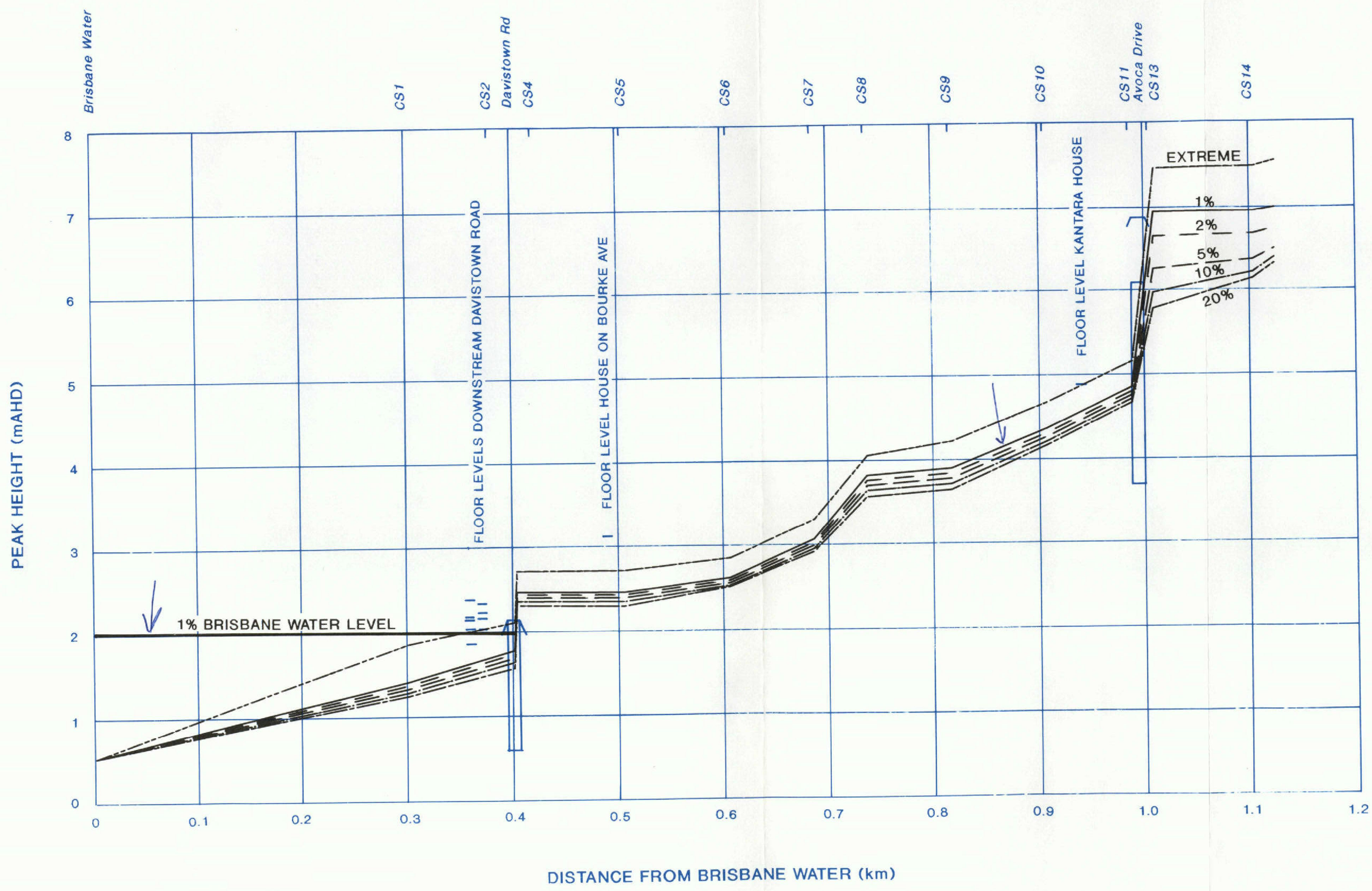


FIGURE 6

DEVELOPMENT CONSTRAINTS FLOODING 1% AEP FLOOD CONTOURS EXISTING CONDITIONS

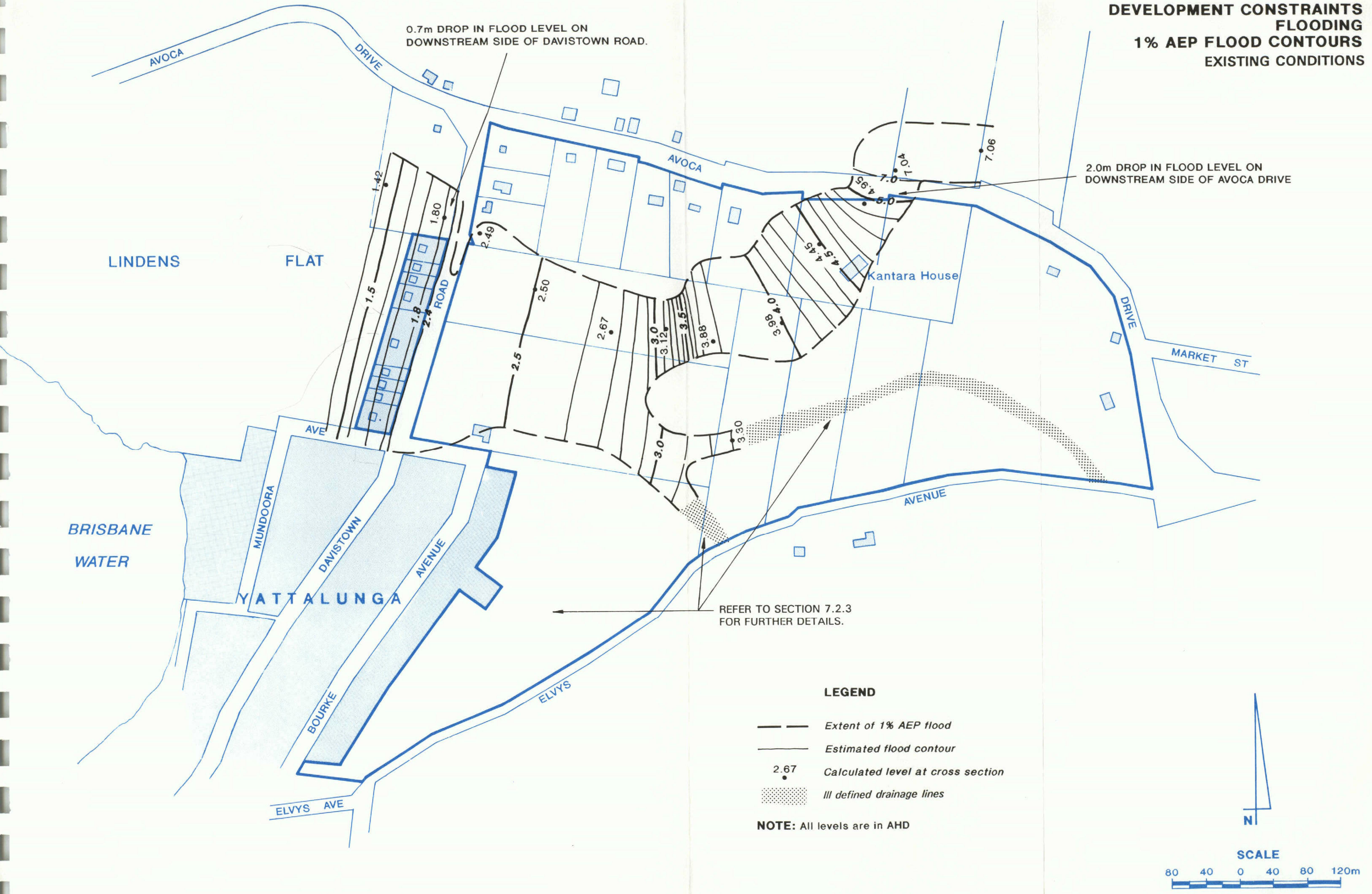
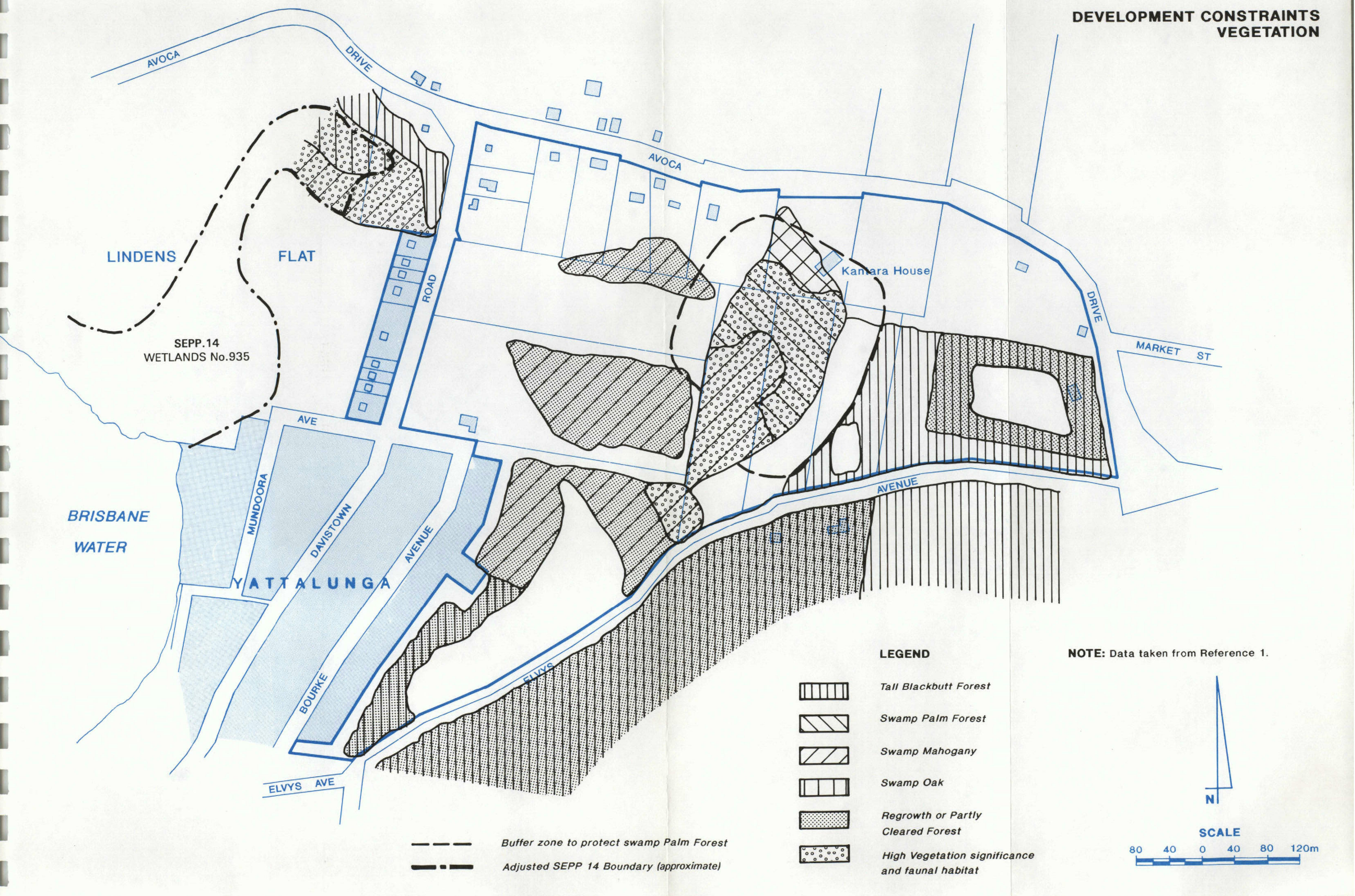


FIGURE 7

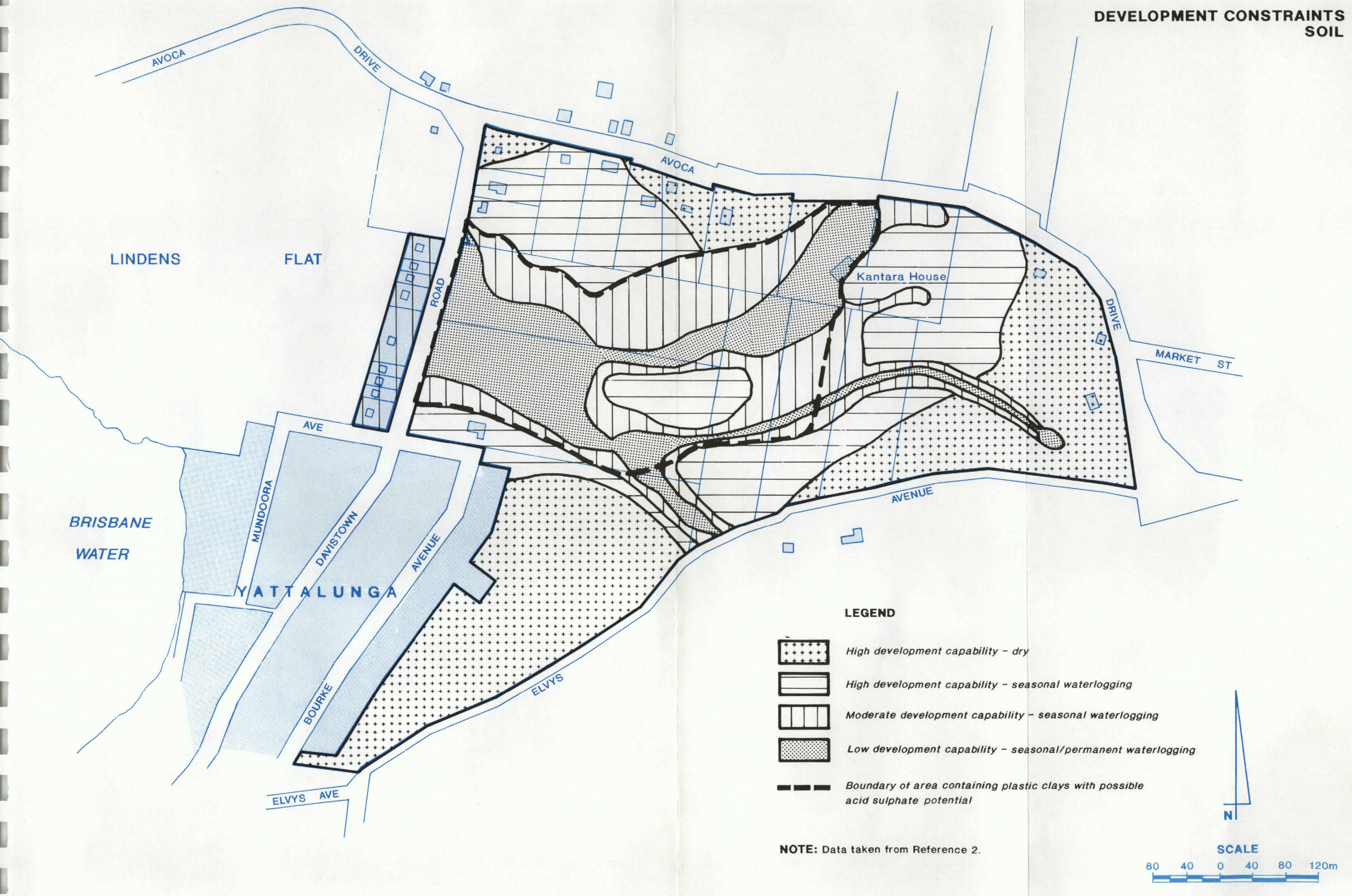
DEVELOPMENT CONSTRAINTS VEGETATION



NOTE: Data taken from Reference 1.

FIGURE 8

DEVELOPMENT CONSTRAINTS SOIL



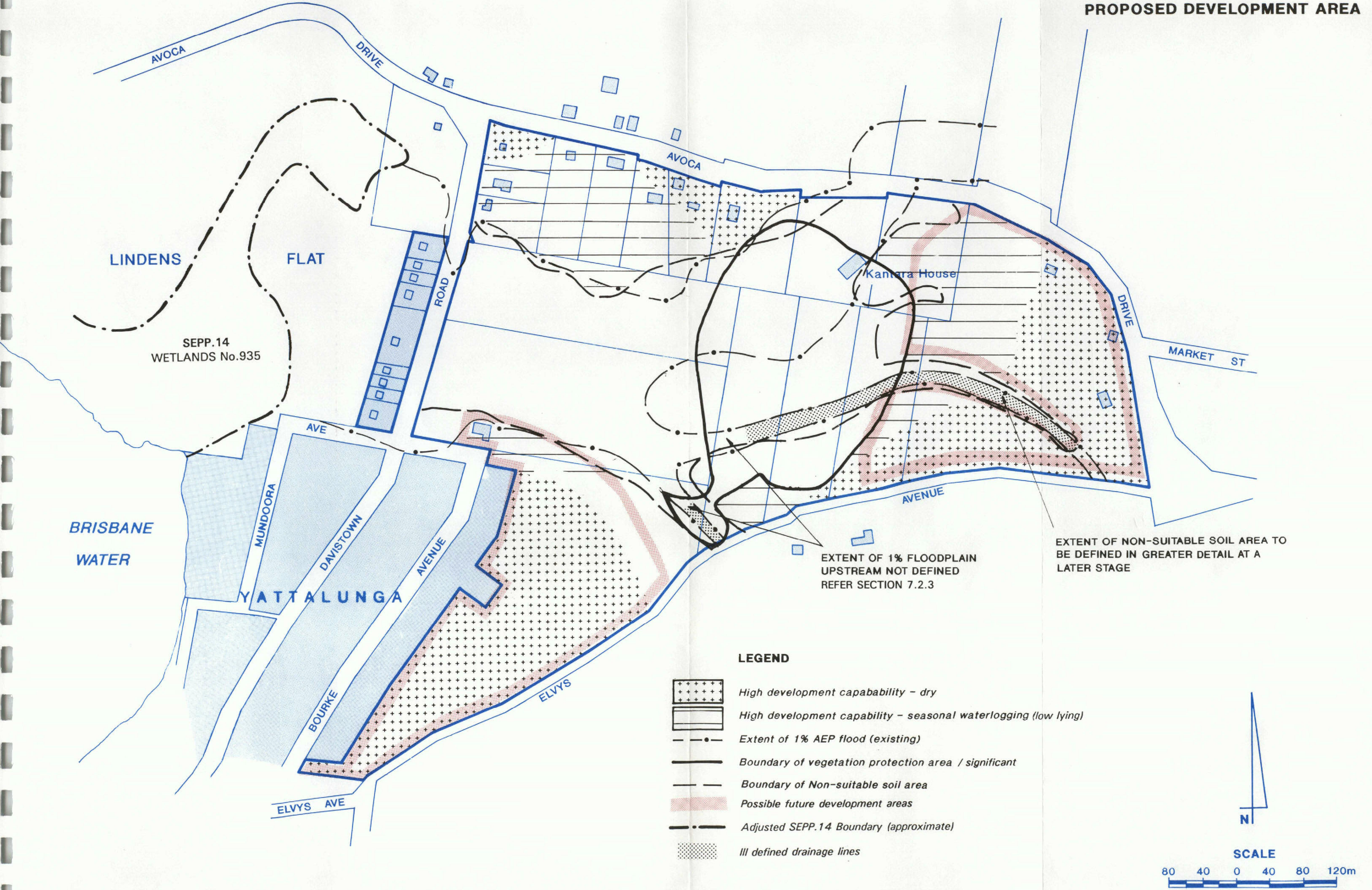
LEGEND

- *High development capability – dry*
- *High development capability – seasonal waterlogging*
- *Moderate development capability – seasonal waterlogging*
- *Low development capability – seasonal/permanent waterlogging*
- *Boundary of area containing plastic clays with possible acid sulphate potential*

NOTE: Data taken from Reference 2.

FIGURE 9

PROPOSED DEVELOPMENT AREA



APPENDIX A

APPENDIX A
FLORA AND FAUNA SURVEY

Gosford City Council commissioned Andrews Neil, Architects Planners and Landscape Consultants, to undertake a flora and fauna survey for the UIA at Yattalunga. The report was completed in June 1991.

The following recommendations were made relating to further development:

- the boundaries of State Environmental Planning Policy No. 14 site No. 935 be adjusted by field survey definition to include the Casuarina glauca forest with Baumea juncea meadows in Lot 43 Avoca Drive,
- that Council's Significant Tree Committee be informed that Portion 44 (Public Reserve) partly contains a significant stand of Eucalyptus robustus for its inventory and Council adopt the required management option for its conservation,
- that the Swamp Palm Forest boundaries be identified by field survey and a 50 metre buffer zone is added for their protection and this area be outlined for public reserve. These appear to occur partly on lots A and B, D.P.26044,
- that the presence of very large "Old Man" Eucalyptus with hollows in Community 1 be identified by field inspection and be excluded from any development proposal,
- that any hydrological and hydraulic design for the area cater for maintaining an overbank flooding regime for the Swamp Oak forest, the Swamp Mahogany forest and the Swamp Palm Forest. It is recommended that this be maintained for the vegetation to perpetuate,
- that a public reserve corridor be established between the Swamp Palm forest and Davistown Road along the creek line. A management plan be also prepared for this section and to include additional tree planting of Eucalyptus robusta and Eucalyptus saligna along a grassed floodway. Some understorey planting should be included,

- that a public reserve corridor be established along the remainder of the creek lines retaining an appropriate band of vegetation where possible,
- that a corridor from the Swamp Palm Forest to the Yattalunga ridge be established as the main wildlife corridor on to the ridge,
- that the vegetation on the slopes of Yattalunga Ridge on private property not be cleared to maintain habitat for fauna and to maintain a wildlife corridor,
- that Council plan for and recognise that the main wildlife corridor be seen as the slopes and plateau of Yattalunga Ridge connecting to Mount Kincumber and connecting Yattalunga Ridge to the lowland flat areas.

APPENDIX B

APPENDIX B
SOIL SURVEY

In June 1991 the Soil Conservation Service completed a soils urban capability study at Yattalunga. This was a refinement of another report in the same area for Gosford City Council which was completed in 1985.

The study concluded the following:

- approximately 60% of the survey area is suitable for medium to high density residential development,
- extensive building complexes should be avoided on the steeper slopes unless stringent erosion and sediment control measures are enforced,
- some areas with moderate subsoil drainage limitations can be corrected,
- the remaining 40% would experience seasonal waterlogging and would have subsoil drainage limitations which may require extensive engineering design to overcome if residential development is undertaken, although some of the area may be suitable if adequate groundwater drainage controls are implemented,
- the remaining area would be best used as public reserves or retarding basins,
- the floodplain area upstream of Davistown Road contains plastic clays with possible acid sulphate potential. However, this area experiences waterlogging and is not suitable for development,
- there is concern about increased runoff and flooding following development of the catchment.

APPENDIX C

APPENDIX C
SENSITIVITY ANALYSES - 1% FLOOD

C1. GENERAL

The lack of available streamflow or flood data for calibration of the hydrologic and hydraulic models necessitated the use of recommended or typical parameters for the design analysis. The sensitivity analysis described in this Appendix provides an insight into the likely changes to the 1% design flood levels for a range of parameters outside those adopted in the main body of the report.

C2. SENSITIVITY TO DESIGN RAINFALLS

In recent years the design rainfalls for the Gosford area have been questioned on a number of occasions by Engineering Consultants, Public Works and Council.

Therefore, in order to quantify the effects of varying the recommended AR&R information, a sensitivity analysis of the adopted 1% rainfall intensities was carried out. The 2 hour AR&R rainfall intensities were increased and decreased by 20%. A comparison of the resulting flood profiles is presented in Table C1.

TABLE C1

Sensitivity of Design 1% Flood Levels to Design Rainfall Changes

SECTIONS	RAINFALL CHANGE		
	BASE 1% (m AHD)	+20% (m)	-20% (m)
CS14	7.06	0.20	-0.55
CS13	7.04	0.20	-0.64
CS11	4.95	0.09	-0.09
CS10	4.45	0.09	-0.09
CS9	3.98	0.10	-0.12
CS8	3.88	0.07	-0.11
CS7	3.13	0.07	-0.07
CS6	2.67	0.07	-0.05
CS5	2.50	0.07	-0.06
CS4	2.49	0.07	-0.06
CS2	1.80	0.10	-0.08
CS1	1.42	0.09	-0.07

The results show that a significant variation in 1% flood levels (±0.08m on average) is caused by a ±20% change in rainfall intensity. There are insufficient data available to justify any change in the design rainfall information, but the sensitivity results provide a measure of the possible impacts if such changes were to be implemented in the future.

C3. SENSITIVITY TO BRISBANE WATER LEVEL

The starting water level in Brisbane Water can potentially affect flood levels upstream. In the study, a constant starting level in Brisbane Water of 0.5m AHD was adopted for all events. Table C2 shows sensitivity results for constant 1.0m and 2.0m AHD starting levels in Brisbane Water. It can be seen that upstream of Davistown Road the starting level in Brisbane Water has no impact on the adopted 1% flood levels.

TABLE C2

Sensitivity to Brisbane Water Levels

SECTIONS	CONSTANT LEVEL (m AHD)		
	Base (0.5m) (m AHD)	1.0m (m)	2.0m (m)
CS14	7.06	0.00	0.00
CS13	7.04	0.00	0.00
CS11	4.95	0.00	0.00
CS10	4.45	0.00	0.00
CS9	3.98	0.00	0.00
CS8	3.88	0.00	0.00
CS7	3.13	0.00	0.00
CS6	2.67	0.00	0.00
CS5	2.50	0.00	0.00
CS4	2.49	0.00	0.00
CS2	1.80	0.00	0.23
CS1	1.42	0.00	0.56

Note: The results are shown as a change in level in m compared to the base.

C4. SENSITIVITY TO MANNING'S 'n'

Manning's 'n' is the roughness parameter used in open channel friction calculations. The higher the value the less efficient is the channel. In the hydraulic model, Manning's 'n' values of between 0.050 and 0.080 were used to reflect the existing topography. These were considered to provide a reasonable representation of the roughness at each cross-section.

Two runs were undertaken to show the effect of varying Manning's 'n' between acceptable limits. In one run the Manning's 'n' was lowered by 20% for all natural sections and for the other it was raised by 20%. The results are shown in Table C3.

TABLE C3

Sensitivity to Manning's 'n'

SECTIONS	MANNING'S 'n'		
	BASE (m AHD)	+20% (m)	-20% (m)
CS14	7.06	+0.02	-0.02
CS13	7.04	*	*
CS11	4.95	+0.07	-0.09
CS10	4.45	+0.05	-0.08
CS9	3.98	+0.05	-0.03
CS8	3.88	+0.01	*
CS7	3.13	+0.06	-0.09
CS6	2.67	+0.04	-0.04
CS5	2.50	+0.01	*
CS4	2.49	+0.01	*
CS2	1.80	+0.32	+0.11

NOTE: * represents a change of less than ±0.01m.
The results are shown as change in level in m compared to the Base.

The results show that a maximum change in flood level of ±0.09m will result from a ±20% change in Manning's 'n'.

C5. CONCLUSIONS

The effects on adopted design 1% flood levels of changing the model and design parameters within reasonable limits was analysed. The results indicate that any likely change in flood levels can be safely accommodated within the nominated 0.5m freeboard allowance required between floor level and the 1% flood level.

APPENDIX D

APPENDIX D
THE RUBICON MODEL

D1. INTRODUCTION

HD-system RUBICON was developed by Haskoning BV and Delft Engineering Software. It can be used for studying a wide range of hydraulic engineering problems, such as:

- flood wave propagation through channels, rivers, floodplains and reservoirs,
- tidal flow in rivers and estuaries,
- effects of structures in channel systems,
- optimum design and operation of irrigation and drainage systems,
- wave propagation in hydropower systems,
- wave propagation resulting from dam failures,
- hydraulic parameters in water quality studies.

Modelling is based on the full de Saint-Venant equations solved with a highly accurate and efficient modification of Preissmann's implicit finite difference scheme. It is very flexible in specifying external and internal boundary conditions. The user can select from a number of system elements to simulate complex flow over floodplains or define structures at any point of the channel system, such as weirs, gates, culverts, siphons, spillways, sluices, storm surge barriers, dykes, etc.

Limitations are the accurate simulation of super-critical flow and two-dimensional flow situations where the convective momentum terms play a significant role.

Important objectives during the design of the program were to make it a user-friendly system, which would minimise the time required for data preparation, and formulate the system in a modular way to facilitate addition of enhancements.

This is exemplified by the following features:

- programs written in Fortran with the source code made available,
- separate processing for input, execution and output sub-systems,
- extended free format data input, including comments,
- possible to add user defined sub-routines and functions,
- all user-defined model elements (channels, structures, etc.) addressed by names,
- automatic generation of computational grid and element numbers following user's directives,
- use of special information symbols to minimise input effort,
- extensive checking of input data,
- continuation of input processing after detection of errors,
- restart facilities in model execution,
- possible generation of output at any point of the channel system.

The original suite of programs has been extensively modified by Webb, McKeown & Associates. A layout of the current RUBICON modelling system is given as Figure D1.

D2. SYSTEM ELEMENTS

The following range of model elements are available:

- branches,
- nodes,
- gridpoints,
- cross-sections,
- structures,
- lateral flows.

Branches are used as schematised elements for:

- rivers,
- channels,
- estuaries,
- connections between floodplain cells,
- closed conduits.

At the branch limits, nodes are included to provide for:

- free branch ends,
- branch connections,
- floodplain cells.

A single node can connect any number of branches. A boundary condition can be applied at a free branch as a function of:

- height,
- flow,
- critical outflow.

Gridpoints are located along branches and have an associated cross-section which defines the topography. Structures can be defined at any place along a branch and basically they provide a relationship between the discharge and upstream/downstream water levels. The definitions of structures are extremely flexible and culverts are modelled using the approach adopted by Boyd (Reference D1). Culverts are checked for outlet and inlet control and the lesser flow is adopted. Box or pipe culverts can be modelled as well as the shape of the wing-wall, Manning's 'n', slope and other culvert characteristics. Weirs are input as a weir type formulae and are generally represented as a series of horizontal steps with appropriate C values.

Inflows are generally input at the upstream nodes as a flow versus time function. However lateral inflows can also be included as a flow versus time function at any location along a branch.

The Manning's 'n' values for the cross-sections in the model are given in Table D1.

TABLE D1

Manning's 'n' Values
Yattalunga Urban Investigation Zone

SECTIONS	'n'	SECTIONS	'n'
CS14	0.060	CS7	0.050
CS13	0.060	CS6	0.050
CS11	0.070	CS5	0.050
CS10	0.080	CS4	0.050
CS9	0.070	CS2	0.080
CS8	0.060	CS1	0.080

D3. OUTPUT

Output from RUBICON is very comprehensive including:

- maximum profiles - height, flow or velocity,
- output at every time step of height, flow and velocity which can be represented as a dynamic profile,
- time functions of height, flow, velocity, area, width and a large number of other hydraulic parameters.

The output can be provided on a screen, disk or hard copy.

D4. REFERENCES

D1. Boyd M J, et al

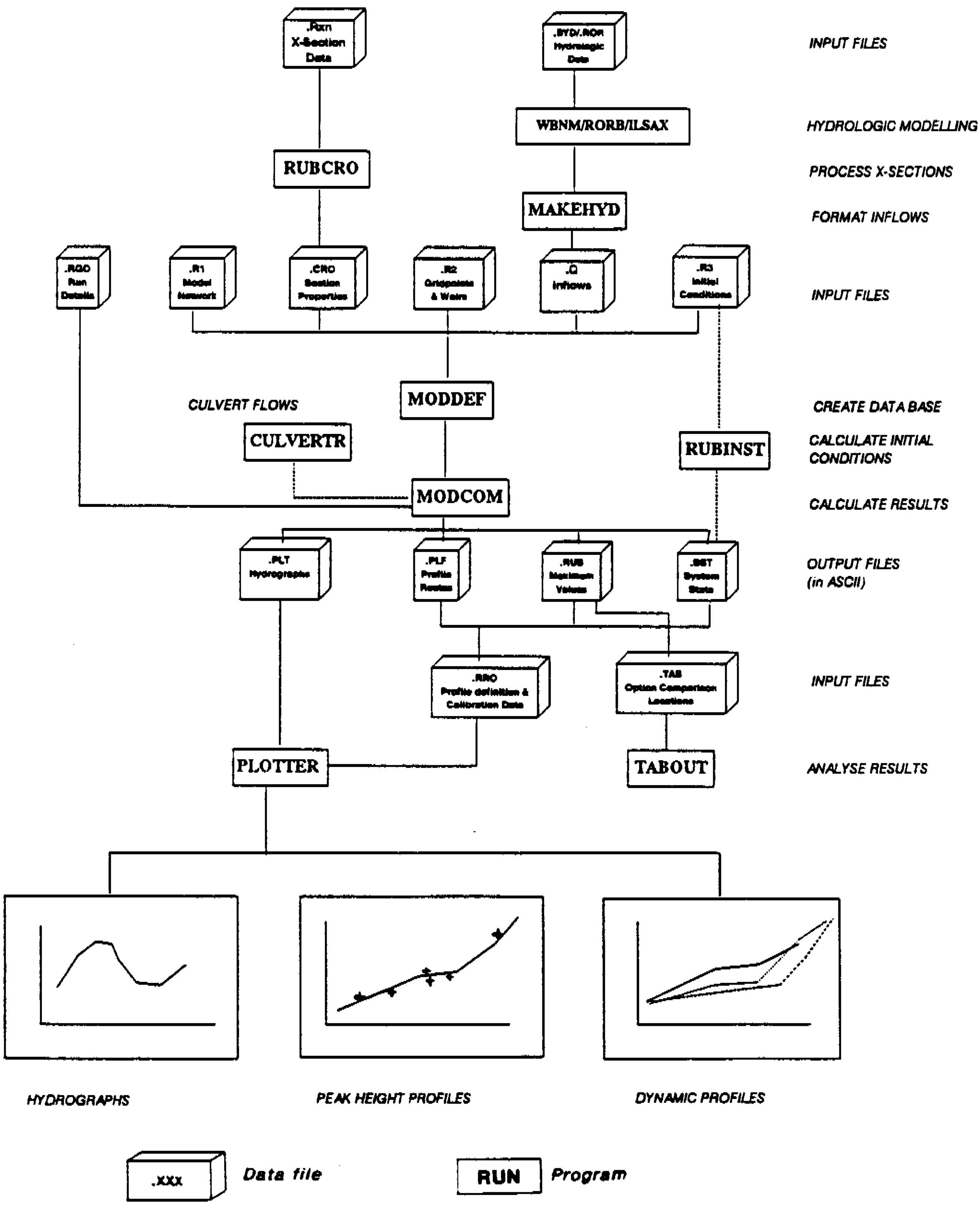
PC Programs for Flooding and Stormwater Drainage

Watercomp 1989, Institution of Engineers, May 1989.

FIGURE D1

RUBICON SYSTEM FLOW DIAGRAM

WEBB, McKEOWN & ASSOCIATES
RUBICON SYSTEM FLOW DIAGRAM



APPENDIX E

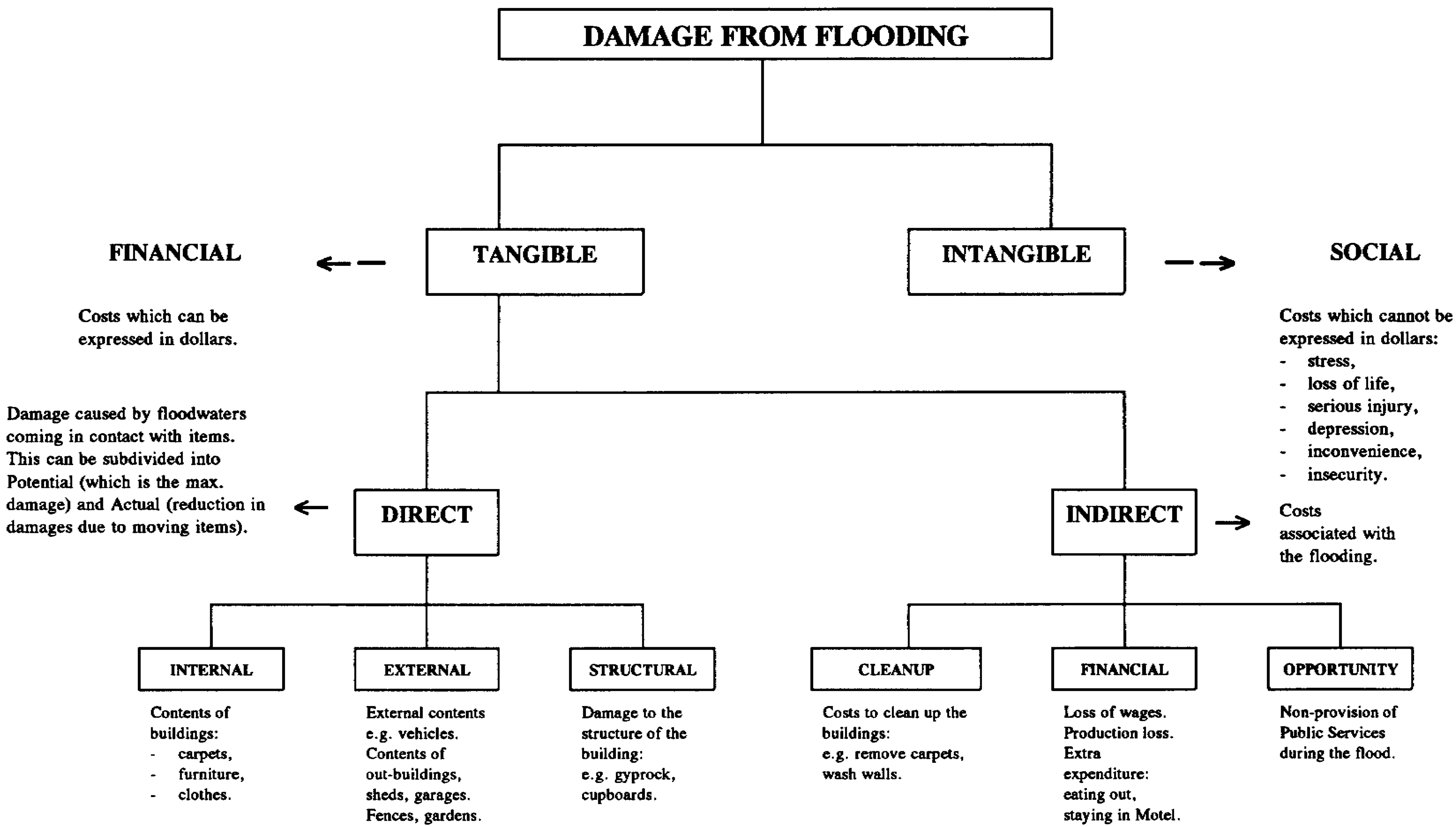
APPENDIX E
DERIVATION OF FLOOD DAMAGES

E1. GENERAL

Flood damages can be defined as being Tangible or Intangible. A schematic breakdown of the various damage categories is provided in Table E.1. *Tangible* damages are those for which a monetary value can be assigned, in contrast to *Intangible* damages, which cannot easily be assigned a monetary value.

TABLE E.1

FLOOD DAMAGE CATEGORIES



E2. TANGIBLE DAMAGES

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

- **Direct Damages**

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

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

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

As flood damages can vary greatly between houses and areas depending upon the type of building and contents, an average damage figure is estimated for each of the above categories following a flood. This is generally presented as a flood depth versus damage function. The size, building fabric, condition of the house and whether it is single or double storey are also taken into account.

- **Indirect Damages**

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

- *Clean-up* - clean carpets, furniture, refrigerator,
- *Financial* - loss of wages,
- *Opportunity* - non-provision of Public Services.

It would require an extensive survey to evaluate the costs of lost working hours, disruption to business and trade. Nevertheless an indication of the damages can be obtained from previous studies.

E3. INTANGIBLE DAMAGES

Intangible damages are those flood damages which by their nature are difficult to accurately quantify in monetary terms. Generally these damages are *indirect* damages and occur following a flood. An example of a *direct* intangible damage is the "loss of visual quality" of an area or "loss of a heritage item".

Intangible damages can be categorised as follows:

- **Residential**

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

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

  The most extreme consequence due to flooding is death and unfortunately this is not a rare occurrence. The literature provides many examples of deaths in Australia of local residents and rescue workers as a result of flooding.

- **Commercial/Industrial/Rural**

  Whilst a large number of businesses carry insurance for loss of trade during the period of the flood and until the clean-up is complete they may still suffer a financial loss. For example business confidence by the clients may be reduced permanently or the clients may have taken their business elsewhere during the flood/clean-up period and may not revert to the original supplier.

- **Services**

  The loss of services to customers, e.g., transport disruption, loss of education, loss of power, etc. will occur and these are generally not taken account of within the Tangible damage category.

- **Environmental**

  Environmental damage may occur as a result of flooding, for example flora and fauna may be lost. However as the riverine environment is a natural system it may be inappropriate to separate these effects of flooding. The loss of man-made structures which have a "heritage" or non-replaceable value are a real cost which cannot be quantified.

In summary there is a comprehensive body of available literature on Intangible Damages which provides many examples. However the costing of these damages in dollar terms is not accurately quantifiable. Nevertheless these "costs" should not be ignored when determining options. The literature suggests that the value of Intangible Damages may equal or exceed the Tangible Damages.

APPENDIX F

APPENDIX F
PRELIMINARY DESIGN OF PROPOSED WORKS

F1. RAISING OF DAVISTOWN ROAD (Section 7.1.2)

F1.1 Preliminary Design (Refer Figure F1)

- Design Flood - 1% Event - Peak Level at Road: 2.46m AHD,
- Peak Flow @ Upstream Section - 43m^3/s,
- Flow Distribution at Davistown Road:
  - Existing Bridge - 22m^3/s,
  - Proposed 3-2m * 1.5m RCBC - 21m^3/s.
- Culverts
  - Upstream Invert of Proposed Culverts: 0.6m AHD,
  - Downstream Invert of Proposed Culverts: 0.5m AHD,
  - Length of Proposed Culverts - 12m.
- Drop Structure
  - Crest of Inlet of Proposed Upstream Drop Structure: 1.3m AHD (existing ground level),
  - Length of Drop Structure Inlet - 12m.

    The drop structure should be constructed of concrete and would be in the form of a semi-circular weir around the entrance to the culverts. It should be constructed as unobtrusively as possible in order to blend in with the existing environment. Extensive landscaping may be required.
- Downstream Channel through Lot 2, D.P. 703303
  - Upstream Invert of Channel: 0.5m AHD,
  - Downstream Invert of Channel: 0.4m AHD,
  - Length of Channel - 40m,
  - Channel Dimensions - Trapezoidal grass lined channel with an invert width of 6m and 1:6 batters to existing ground level (1.2m AHD). The

channel should be constructed so as it can be maintained by Council's mechanical grass cutting equipment. Spoil from the excavated channel could be placed on the bank of the channel. This would increase the capacity of the channel and prevent overtopping onto adjoining properties.

- Gross Pollutant Trap or Other Water Quality Structures to be Constructed Upstream of the Drop Structure:
    - the requirement for such a structure depends on the nature of the upstream development and the water quality structures included within the subdivision drainage design. It is probable that there will be no requirement for an additional water quality structure further downstream. For aesthetic and environmental reasons it is preferable that water quality structures be included as near to the point source as possible (i.e. at the downstream limit of the proposed developments). At this stage it has been assumed that no water quality structure will need to be provided at the drop structure. However if it was found to be required at the time of construction of the drop structure an indicative additional cost would be $25 000.

F1.2 Approximate Costings

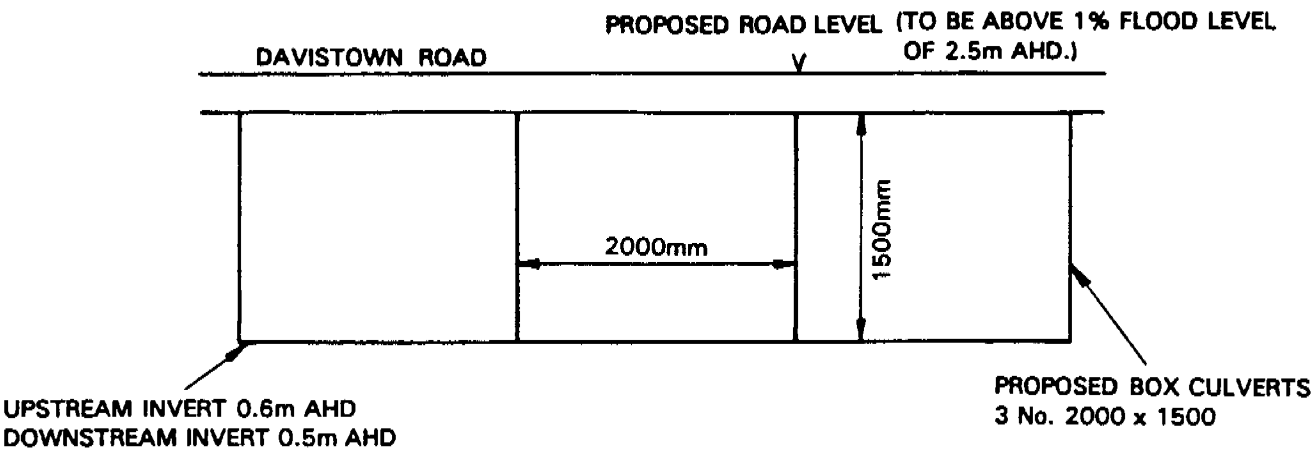
	$
Raising Davistown Road	110 000
Provision of Drop Structure	25 000
Provide and Install Culverts	45 000
Purchase of Lot 2, D.P.703303	100 000
Construct Downstream Channel	20 000
Total	300 000

FIGURE F1

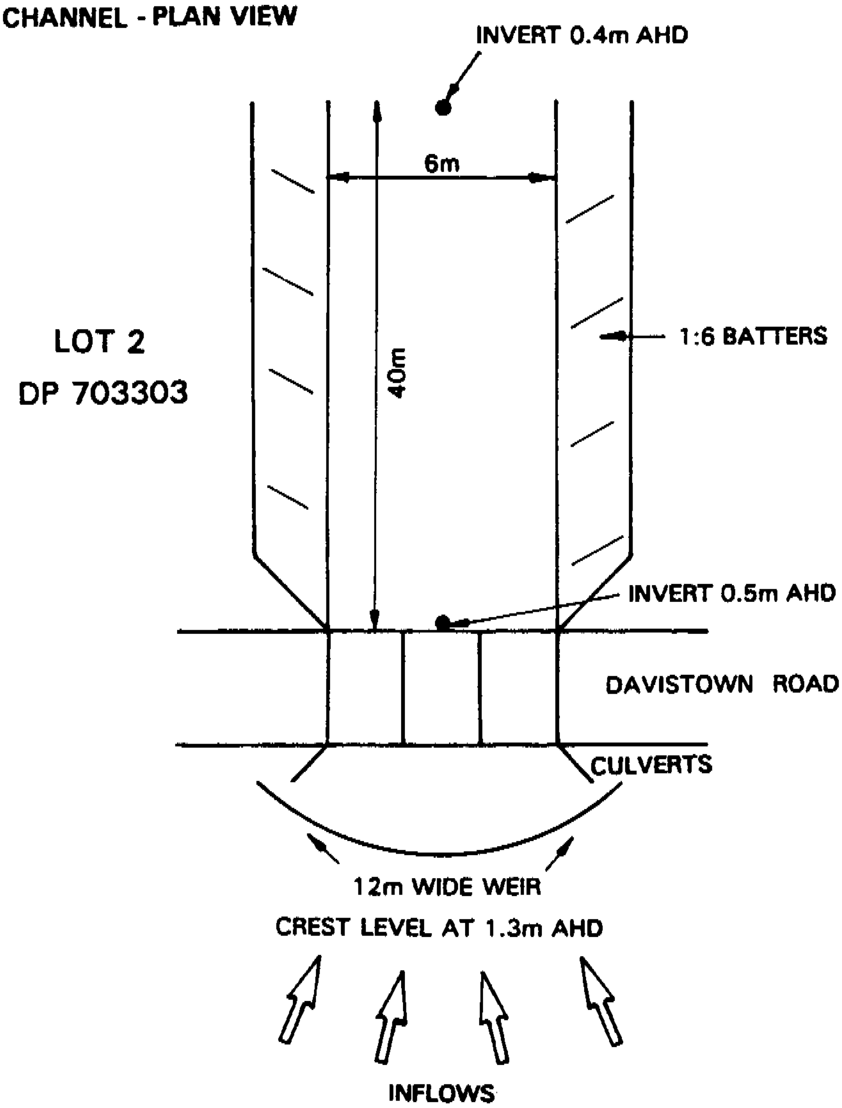
PRELIMINARY DESIGN OF WORKS

NOTE: NOT TO SCALE

CULVERTS - ELEVATION



DROP STRUCTURE AND DOWNSTREAM CHANNEL - PLAN VIEW



End of Report