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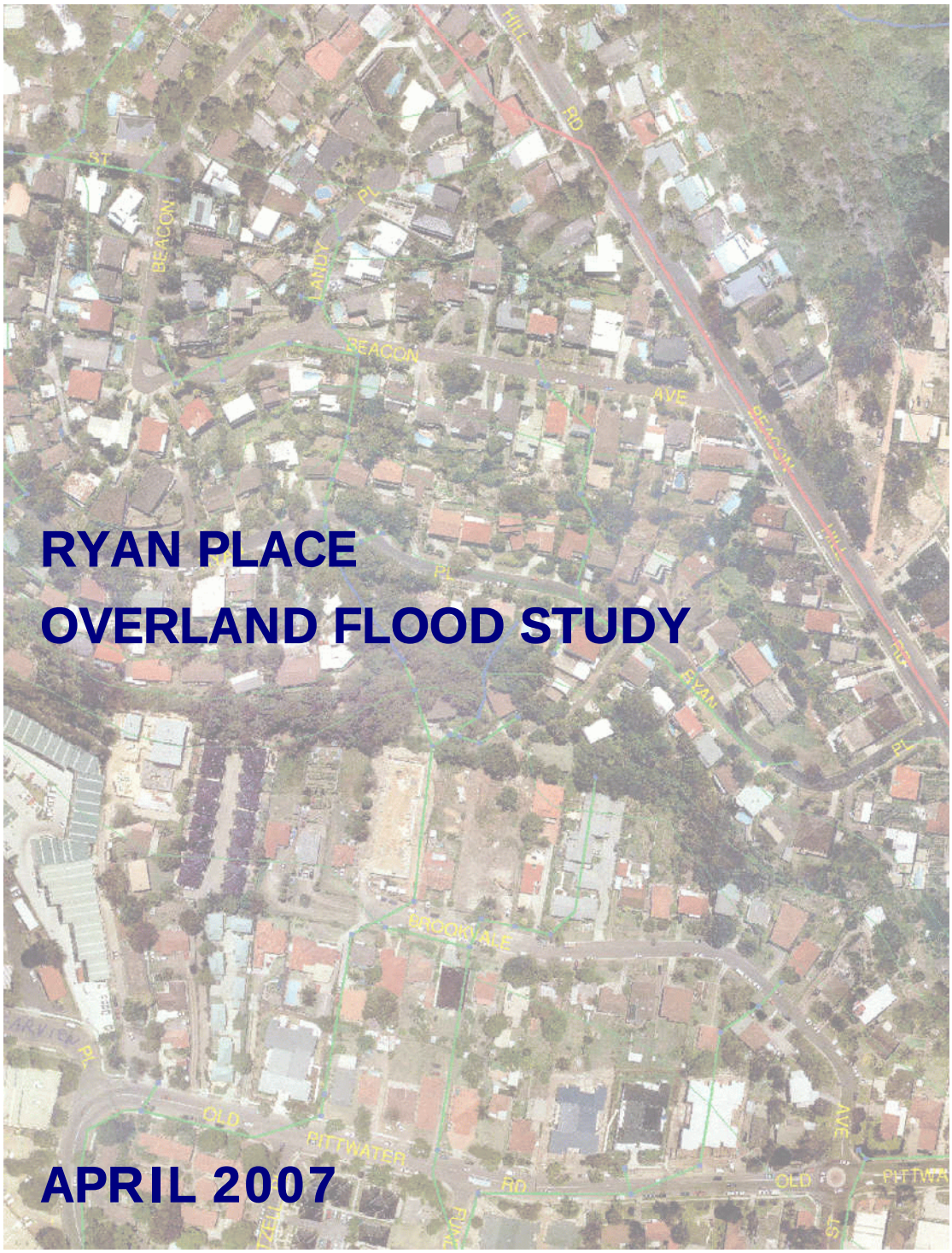

RYAN PLACE
OVERLAND FLOOD STUDY

APRIL 2007

WEBB, McKEOWN & ASSOCIATES PTY LTD

WARRINGAH COUNCIL

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OVERLAND FLOOD STUDY

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RYAN PLACE OVERLAND FLOOD STUDY

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FOREWORD

The NSW State Government's Flood Policy provides a framework to ensure the sustainable use of floodplain environments. The policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any 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 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 Ryan Place Overland Flood Study constitutes the first stage of the management process for the Ryan Place catchment area. Webb, McKeown & Associates were commissioned by Warringah Council to prepare this overland flood study. The following report documents the work undertaken in accordance with the Flood Policy (as detailed in the Floodplain Management Manual 2001, later revised after the completion of this report to be the Floodplain Development Manual 2005) and presents outcomes that define flood behaviour for existing catchment conditions. The report also provides an outline of possible management measures to mitigate the continuing flood hazard.

EXECUTIVE SUMMARY

The NSW Government's Flood Policy provides:

- a framework to ensure the sustainable use of floodplain environments,
- solutions to flooding problems,
- a means of ensuring new development is compatible with the flood hazard.

Implementation of the Policy requires a four stage approach, as detailed in the Floodplain Management Manual 2001, the first of which is preparation of a Flood Study to determine the nature and extent of the flood problem.

The Ryan Place Overland Flood Study was initiated as a result of overland flow problems being reported within surrounding residential areas, most recently in March 2003. This report has been prepared by Webb, McKeown & Associates for Warringah Council in 2004/2005.

The specific aims of the Ryan Place Overland Flood Study are to:

- define flood behaviour in the catchment,
- prepare flood hazard and flood extent mapping,
- prepare suitable models of the catchment for use in subsequent Floodplain Risk Management Studies and Plans,
- make preliminary recommendations of possible floodplain management/mitigation measures.

Description of Catchment: Ryan Place has a catchment area of approximately 11.9 hectares to Old Pittwater Road and lies entirely within the boundaries of Warringah Council. Runoff from the catchment drains into Brookvale Creek and ultimately Manly Lagoon and then the Pacific Ocean.

There is an extensive piped drainage system within the catchment comprising two branches which both start on Beacon Avenue, cross Ryan Place and join within No. 21 Ryan Place. This line then travels southwards to Old Pittwater Road. A further drainage line collects runoff on the eastern side of Brookvale Avenue and also drains to Old Pittwater Road. Overflows from these two systems would join at Brookvale Avenue and within the properties downstream.

The catchment has been developed for residential purposes entirely. Predominantly these are single dwellings constructed over the last 30 years. However, since 2000, several unit developments have been constructed on Brookvale Avenue and there is pressure for further medium density developments in this area. The only remaining significant area of semi-natural bushland is immediately downstream of Ryan Place where the two drainage paths join.

The key phases of the Ryan Place Overland Flood Study that have been undertaken are summarised below:

Review all available data, namely:

- reports, photographs, Council records,
- questionnaire survey of residents, interviews,
- rainfall data from the Bureau of Meteorology and Manly Laboratory,
- survey data - a limited cross-section survey was undertaken as part of this study by QASCO surveyors,
- identification of historical flood levels and the extent of flooding.

Determine Approach: A rainfall-runoff approach was adopted due to the absence of historical flood data. This approach involved the setting up of a MIKE-Storm computer model. This model comprises a hydrologic model to convert rainfall to runoff and a hydraulic model to simulate flow within the piped and overland systems.

Calibration to Historical Flood Levels: The lack of suitable flood height data meant that it was not possible to calibrate the MIKE-Storm model.

Determination of Design Flood Levels: Design rainfall data were obtained from Australian Rainfall and Runoff (1987). These data were input to the MIKE-Storm model to determine design flood behaviour including the estimation of design flood levels. The design analysis assumed that the kerb inlet pits were 50% blocked by debris. This approach is consistent with current best management practice. Sensitivity analyses were also undertaken. Due to the limited amount of calibration data available and in view of the sensitivity analyses, it is estimated that the order of accuracy of flood levels is up to ±0.5 m. This order of accuracy is typical of such studies and can only be improved with the availability of additional observed flood data to undertake a model calibration and delineation of an unobstructed overland flow path through the properties.

Flood Problem Areas: The study has indicated that Brookvale Avenue and Old Pittwater Road will be crossed by floodwaters in the 100y ARI event. The yards of many properties along these roads will also be inundated.

Outcomes: The main outcomes of this study are as follows:

- full documentation of the methodology and results,
- preparation of flood contour, hazard and extent maps for the catchment,
- establishment of a MIKE-Storm model which will form the basis for a subsequent Floodplain Risk Management Study and Plan,
- preliminary review of possible floodplain management/mitigation measures.

1. INTRODUCTION

The catchment area to Old Pittwater Road is 11.9 hectares (Figure 1). Downstream of Old Pittwater Road runoff flows through the Warringah Mall Shopping Centre and into Brookvale Creek through Warringah Golf Course. Ultimately the runoff enters Manly Lagoon and discharges into the Pacific Ocean. The catchment area to Old Pittwater Road is entirely comprised of residential urban development, there are no non-residential developments. The catchment has two main tributary branches entering from Ryan Place which join upstream of Brookvale Avenue within No. 21 Ryan Place.

In view of the increasing urban development and the need to accurately define the nature and extent of the flood problem, Warringah Council engaged Webb, McKeown & Associates to undertake an Overland Flood Study. The term overland has been used to signify that flooding results from runoff exceeding the capacity of the piped drainage system and/or is of sufficient magnitude to represent a hazard, as opposed to flooding from the overtopping of a natural or artificial defined creek system. The only area where there is some form of defined creek system is immediately downstream of Ryan Place. The remainder of the natural system has been destroyed over time by urban development. Today overland flow resulting from heavy rainfall does not generally follow a defined path but travels between buildings, under or through fences, along driveways, roads, etc., until it reaches Old Pittwater Road. The route may vary depending upon the size of the rainfall event and may change as residents construct fences or buildings.

The primary objectives of this Overland Flood Study are:

- to define the flood behaviour of the catchment by quantifying flood levels, velocities and flows for a range of design flood events under existing catchment conditions,
- to assess the hydraulic categories and undertake provisional flood hazard mapping in accordance with the NSW Floodplain Management Manual (2001) (Reference 5),
- to formulate a suitable hydraulic model that can be used in a subsequent Floodplain Risk Management Study,
- to provide a preliminary assessment of floodplain management measures.

As directed by Council, the scope of this study is such that the extent of the MIKE-Storm model covers the entire Ryan Place catchment draining to Old Pittwater Road.

This report details the results and findings of the Overland Flood Study investigations.

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

2. BACKGROUND

2.1 Catchment Description

As noted previously, the catchment has been developed for residential purposes entirely. The only remaining areas of semi-natural bushland remaining are the areas immediately downstream of Ryan Place to the southern boundary of No. 21 Ryan Place. In terms of local drainage, the roads in the catchment have been formed with kerb and gutter draining to an underground pipe system which eventually discharges to Brookvale Creek. There is no piped system within the heavily vegetated areas downstream of Ryan Place and upstream of the southern boundary of No. 21 Ryan Place. This reach has the remnants of a natural system comprising several small waterfalls and rock overhangs.

The urban development upstream of No. 21 Ryan Place comprises entirely single residential dwellings constructed over the last 30 years. The majority are of brick construction and roof runoff will drain to the streets. More recently, since approximately 2000, medium density unit developments have been constructed on the north side of Brookvale Avenue. Unit developments have also been constructed on the northern side of Old Pittwater Road.

The piped drainage system was installed at the time of the original subdivision. Subsequently minor modifications have been undertaken. Construction of the unit developments on Brookvale Avenue (particularly No's 34-36) has resulted in significant changes to the overland flow paths.

Photographs 1 to 23 included on the following pages illustrate some significant features of the drainage system.

Photograph 1: Headwall of eastern tributary within No. 21 Ryan Place.

Photograph 2: Eastern tributary upstream of headwall within No. 21 Ryan Place.

Photograph 3: Upstream of Photograph 2.

Photograph 4: View looking down private road to No. 21 Ryan Place.

Photograph 5: Ryan Place looking west.

Photograph 6: Runoff will enter Ryan Place from Beacon Hill Road.

Photograph 7: Western branch upstream of No. 21 Ryan Place.

Photograph 8: View to downstream of No. 21 Ryan Place.

Photograph 9: Stormwater pits in rear of No's 22-24 Brookvale Avenue.

Photograph 10: Driveway of No. 21 Ryan Place.

Photograph 11: Overland flow path through No's 22-24 Brookvale Avenue.

Photograph 12: 2.7 m wide overland flow path through No's 34-36 Brookvale Avenue.

Photograph 13: Stormwater inlet pit in rear of No's 34-36 Brookvale Avenue.

Photograph 14: Small "levee" preventing overland flow travelling to the western side of No's 34-36 Brookvale Avenue.

Photograph 15: View to western limit of Brookvale Avenue.

Photograph 16: View north through No's 34-36 Brookvale Avenue.

Photograph 17: Brookvale Avenue looking west.

Photograph 18: Southern side of Brookvale Avenue showing "raised footpath".

Photograph 19: Entrance to car park of No's 34-36 Brookvale Avenue.

Photograph 20: Possible overland route through No. 42 Brookvale Avenue.

Photograph 21: Driveway of No. 25A Brookvale Avenue.

Photograph 22: No's 34-36 Brookvale Avenue prior to redevelopment. Note overland flow path heavily restricted (photo courtesy of Owner of No. 21 Ryan Place).

Photograph 23: No's 34-36 Brookvale Avenue - March 2003 flood (photo courtesy of Owner of No. 21 Ryan Place).

2.2 Description of Drainage System

Details of the pit and pipe dimensions were obtained from Council's stormwater assets inventory database. The physical geometric details including pit numbers, type, size, depth, lintel size and pipe diameter were provided in a spreadsheet file. Kerb levels (in mAHD) and co-ordinates of each pit were also provided.

Field inspection of the system as part of this study indicated several minor discrepancies with the database. Missing kerb height data and pit depth data were derived either from field survey as part of the study or estimated from available information.

A summary of the pit and pipe system details is provided in Table 1 and the overall layout is indicated on Figure 1. A full listing of the data is provided in Appendix B.

Table 1: Pit and Pipe Details

PITS										
		Kerb Inlet		Junction			DGGP		Headwall	Total
Number		9		18			31		4	62
PIPE DIAMETER (mm)										
	375	450	525	600	675	750	900	Box Culvert		Total
Number	27	9	11	1	1	4	2	2		57

2.3 Previous Studies

2.3.1 Warringah Council Creek Management Study, 2003 (Reference 1)

This comprehensive Creek Management Study provides a detailed review of all creek systems within the local government area, including an overview of the hydraulic, sedimentary, water quality and ecological processes of the creeks, as well as the relationships with human development of the catchment. The outcomes are a series of both short and long term management options.

No specific work (as far as we can tell) was specifically undertaken on the Ryan Place catchment. However, Brookvale Creek was investigated and recommendations made which would apply to the Ryan Place catchment.

One key recommendation of the study is the need for modifications to Council's planning instruments. This proposed measure will ensure that a more ecologically sustainable creek system will be developed in the future. The report identified that even modest increases in development are likely to lead to a substantial decline in creek values.

2.3.2 Council Reports

No comprehensive flood study of the Ryan Place catchment has previously been undertaken. However a limited amount of information is available from Council files and this is summarised below:

- There are only 2 records on Council's stormwater database for the catchment. No. 34 Ryan Place indicated water in the garage in 1992 and No. 21 Ryan Place indicated flooding in the yard on several occasions.

- An inspection of No. 21 Ryan Place was undertaken by Council officers on 16th September 2003. A detailed report was prepared. The main issues being:
  1. Frequent flooding of property.
  2. Erosion of yard and of shared private driveway.
  3. Listing of possible mitigation measures.
  4. Structural faults on surrounding properties.
  5. The resident believes that there have been changes to the groundwater regime.
  6. Concerns with drainage through the downstream unit development at No's 34-36 Brookvale Avenue.

- Complaints from No. 32 Ryan Place in 1995 regarding leakage from stormwater pipes. These claims were subsequently investigated by Council and no evidence was found.

- Overland flow problems through No. 20 Ryan Place.

- Council memo on stormwater design for the proposed unit development at No's 34-36 Brookvale Avenue indicated:
  - assumed catchment area to No. 21 Ryan Place is 8.4 hectares,
  - analysis assumed 50% blockage for sag pits and 30% for on-grade pits,
  - 100y ARI peak flow = 5.9 m^3/s, 10y ARI = 4.7 m^3/s at No. 21 Ryan Place,
  - floor levels of proposed units set at 500 mm above the 100y ARI level,
  - OSD was to be incorporated in the development,
  - the assumed capacity of the inlet pit immediately downstream of No. 21 Ryan Place was calculated as 9 m^3/s but was taken as 4.5 m^3/s assuming 50% blockage,
  - 0.9 m^3/s (unclear why not 1.4 m^3/s (5.9-4.5)) was assumed to flow down the overland flow path at a depth of 200 mm. A surcharge pit was created in Brookvale Avenue to cater for the 2.3 m^3/s which cannot be conveyed by the downstream pipe system.

A further condition of consent was that the vehicle crossings of No's 21, 23, 30, 40 and 42 Brookvale Avenue must have a minimum freeboard of 200 mm above the gutter and the basement car park entry must be protected to 300 mm above the top of kerb. We understand that the footpath on the southern side of Brookvale Avenue was subsequently raised (refer Photograph 18).

- A 2002 survey plan of No's 34-36 Brookvale Avenue (i.e. before construction of the units) indicates a 2.44 m wide drainage easement through the property. The overland flow path would appear to have been partially restricted by the presence of a shed and carport (refer Photograph 22).

3. DATA

The first stage in the investigation of flooding and drainage matters is to establish the nature, size and frequency of the problem. On a large river system there are generally stream height and historical records dating back to the early 1900's, or in some cases even further. However, in small urban catchments there are generally no stream gauges or official historical records available. A general picture of flooding must therefore be obtained from an examination of rainfall records and local knowledge. For this reason, a comprehensive data collection exercise was undertaken.

3.1 Rainfall

3.1.1 Overview

Rainfall data is recorded either daily (24hr rainfall totals to 9:00am) or continuously (pluviometers measuring depths within small time periods of typically 2 to 5 mins). Daily rainfall data have been recorded for over 100 years at many locations within the Sydney basin. In general, pluviometers have only been installed since the 1970's. Together these records provide a picture of when and how often large rainfall events have occurred in the past.

However, care must be taken when interpreting historical rainfall measurements. Rainfall records may not provide an accurate representation of past events due to a combination of factors including local site conditions, human error or limitations inherent to the type of recording instrument used. Examples of limitations that may impact the quality of data used for the present study are highlighted in the following:

- Rainfall gauges frequently fail to accurately record the total amount of rainfall. This can occur for a range of reasons including operator error, instrument failure, overtopping and vandalism. In particular, many gauges fail during periods of heavy rainfall and records of large events are often lost or misrepresented.

- Daily read information is usually obtained at 9:00am in the morning. Thus if the storm encompasses this period it becomes “split” between two days of record and a large single day total cannot be identified.

- In the past, rainfall over weekends was often erroneously accumulated and recorded as a combined Monday 9:00am reading.

- The duration of intense rainfall required to produce flooding in the Ryan Place catchment is typically of the order of 30 minutes. This is termed the “critical storm duration”. For a much larger catchment (such as Brookvale Creek or Manly Lagoon) the critical storm duration may be several hours. For the Ryan Creek catchment a short intense rainfall can produce

flooding but if the rain stops quickly (as would be typical of a thunderstorm), the daily rainfall total may not necessarily reflect the magnitude of the intensity and subsequent flooding.

- Pluviometer records provide a much greater insight into the intensity (depth vs time) of rainfall events and have the advantage that the data can generally be analysed electronically. These data have much fewer limitations than daily read data. The main drawback is that a number of relevant gauges have only been installed since 1990 and hence have a very short period of record compared to the daily read data.

- Rainfall events which cause flooding in the Ryan Place catchment are usually very localised and as such only accurately "registered" by a nearby rainfall gauge. Rainfall gauges sited only a kilometre away can show very different intensities.

3.1.2 Available Rainfall Data

The South Creek Flood Study (Reference 2) undertook a detailed review of available daily and pluviometer records. The following provides a summary relevant to the Ryan Place catchment.

- Flooding will undoubtedly have occurred in the past. Possible dates include March 1942, January 1968, March 1975, August 1986, February 1990, April 1998 and March 2003.

- The daily read information provides only a guide to the likely intensity of flooding. This information is best obtained from pluviometers.

- Pluviometers have only been installed in the area since the mid 1980 's. The nearest of these is Allambie Heights which is approximately 1 kilometre to the west of Ryan Place. This pluviometer was installed in June 1999.

- Examination of pluviometer records for six gauges surrounding the South Creek catchment was undertaken in Reference 2. This revealed a wide variation in rainfall intensities for a given event (up to 15% difference between gauges less than 1200 m apart).

- The largest events in the last 10 years were on 10th April 1998 and 10th March 2003. The March 2003 event exceeded the 100y ARI design rainfall at the Middle Creek gauge but was only a maximum of 20y ARI elsewhere. The April 1998 event approached a 50y ARI event at Belrose but was generally a 20y ARI or less elsewhere.

- The March 2003 event at the Allambie Heights pluviometer was a 10y ARI event for a 30 minute duration and a 5y ARI for a 60 minute duration.

3.1.3 Design Data

Design rainfall data were calculated in accordance with Australian Rainfall and Runoff (Reference 3) and are listed in Table 2.

Table 2: Design Rainfall Data

Duration		Average Recurrence Interval (y)									PMP
		1	2	5	10	20	50	100	200	500	
5 minutes	intensity in mm/h	98	126	160	180	206	240	265	291	326	
	depth in mm	*(8.2)*	*(10)*	*(13)*	*(15)*	*(17)*	*(20)*	*(22)*	*(24)*	*(27)*	
10 minutes	intensity in mm/h	75	97	125	140	161	189	210	231	259	
	depth in mm	*(13)*	*(16)*	*(21)*	*(23)*	*(27)*	*(31)*	*(35)*	*(38)*	*(43)*	
15 minutes	intensity in mm/h	63	81	105	119	137	161	179	197	222	720
	depth in mm	*(16)*	*(20)*	*(26)*	*(30)*	*(34)*	*(40)*	*(45)*	*(49)*	*(56)*	*(180)*
20 minutes	intensity in mm/h	55	71	92	105	121	142	158	175	197	
	depth in mm	*(18)*	*(24)*	*(31)*	*(35)*	*(40)*	*(47)*	*(53)*	*(58)*	*(66)*	
25 minutes	intensity in mm/h	49.2	64	83	94	109	129	143	159	179	
	depth in mm	*(21)*	*(27)*	*(35)*	*(39)*	*(45)*	*(54)*	*(60)*	*(66)*	*(75)*	
30 minutes	intensity in mm/h	44.8	58	76	86	100	118	132	146	165	520
	depth in mm	*(22)*	*(29)*	*(38)*	*(43)*	*(50)*	*(59)*	*(66)*	*(73)*	*(83)*	*(260)*
45 minutes	intensity in mm/h	36	46.7	62	70	82	97	109	120	136	440
	depth in mm	*(27)*	*(35)*	*(46)*	*(53)*	*(61)*	*(73)*	*(81)*	*(90)*	*(102)*	*(330)*
1 hour	intensity in mm/h	30.6	39.8	53	60	70	84	94	104	119	400
	depth in mm	*(31)*	*(40)*	*(53)*	*(60)*	*(70)*	*(84)*	*(94)*	*(104)*	*(119)*	*(400)*
1.5 hours	intensity in mm/h	24.2	31.4	41.5	47.5	55	66	73	81	92	346
	depth in mm	*(36)*	*(47)*	*(62)*	*(71)*	*(83)*	*(98)*	*(110)*	*(122)*	*(139)*	*(520)*
2 hours	intensity in mm/h	20.4	26.5	34.9	39.8	46.3	55	61	68	77	305
	depth in mm	*(41)*	*(53)*	*(70)*	*(80)*	*(93)*	*(110)*	*(123)*	*(136)*	*(154)*	*(610)*
3 hours	intensity in mm/h	16	20.7	27.2	31	36	42.5	47.6	53	60	253
	depth in mm	*(48)*	*(62)*	*(82)*	*(93)*	*(108)*	*(128)*	*(143)*	*(158)*	*(179)*	*(760)*
4.5 hours	intensity in mm/h	12.5	16.2	21.2	24.1	27.9	33	36.8	40.7	46.1	
	depth in mm	*(56)*	*(73)*	*(95)*	*(109)*	*(126)*	*(148)*	*(166)*	*(183)*	*(207)*	
6 hours	intensity in mm/h	10.5	13.6	17.8	20.2	23.4	27.5	30.7	34	38.3	167
	depth in mm	*(63)*	*(82)*	*(107)*	*(121)*	*(140)*	*(165)*	*(184)*	*(204)*	*(230)*	*(1000)*
9 hours	intensity in mm/h	8.26	10.7	13.9	15.7	18.2	21.4	23.8	26.3	29.6	
	depth in mm	*(74)*	*(96)*	*(125)*	*(141)*	*(163)*	*(192)*	*(214)*	*(237)*	*(267)*	
12 hours	intensity in mm/h	6.96	8.98	11.6	13.2	15.2	17.9	19.9	21.9	24.7	
	depth in mm	*(83)*	*(108)*	*(140)*	*(158)*	*(182)*	*(214)*	*(238)*	*(263)*	*(296)*	

Notes: PMP = Probable Maximum Precipitation (only relevant durations shown)

3.2 Historical Flood Information

A data search was carried out to identify the dates and magnitudes of historical floods. The search concentrated on the period since approximately 1970 as it was considered that data prior to this date would generally be of insufficient quality and quantity for model calibration. The following sources of data were investigated:

- Warringah Council,
- newspaper articles,
- previous reports,
- local residents,
- rainfall records.

Unfortunately there is no stream height gauge in the catchment or other means of reliably determining the level of past flood events. Reliance must therefore be made on photographs, interviews with residents or other sources. Council records make no mention of significant flooding or drainage problems within the catchment. A detailed review of rainfall records (Section 3.1) was undertaken to establish the likely dates of flooding and together with resident interviews this provided the best source of flood data. The only flood photographs available are the March 2003 photographs taken by the Owner of No. 21 Ryan Place (refer Photograph 23). However, these photographs are of only limited value as they do not indicate a sufficiently precise level of floodwaters or timing that can be used for model calibration purposes.

3.3 Survey

Survey information of the creek and overland flow paths was provided by QASCO Surveyors. The base data included individual spot heights, road crossing details, cross-sections and other similar data (refer Figure 2).

3.4 Local Resident Survey

3.4.1 General

As part of this study an extensive community survey was carried out consisting of:

- advertisements in the local papers,
- a notice on Council's web site,
- a combined newsletter and questionnaire,
- follow up phone calls and interviews with selected respondents.

The questionnaire (refer Appendix D) was sent to those residents who lived within close proximity of the main drainage paths. The questionnaire was used to obtain information from residents about historical flood events, however it did not ask for suggestions for potential flood management measures. Follow up telephone calls and interviews were made to those respondents who advised that their property had been inundated in the past or those who indicated that they knew levels of previous floods.

3.4.2 Results

The results of the questionnaire are summarised in Table 3.

Table 3: Questionnaire Survey

Number sent out	Approx. 130
Number returned	27 (20%)
Number of flood affected properties:	12
Consisting of:	
Inundated land	11
Inundated houses	1
Source of Flood Damage:	
From failure of local drainage system	12
From the main creek	0

The flood affected areas highlighted by the survey are:

- No. 21 Ryan Place,
- No's 34-36 Brookvale Avenue,
- No. 25A Brookvale Avenue.

Other issues raised were:

- flooding/groundwater flows have worsened due to property modifications and development in the catchment,
- ponding of water during non-flood periods become breeding grounds for mosquitos,
- changes to groundwater flow regimes causing collapse of minor structures (brick fences).

The survey also highlighted the presence of groundwater flows in the catchment. Several residents believe that groundwater flows are significant contributors to their damage problems. This may be the case but it is unlikely that groundwater flows, due to their relatively slow rate of travel, make a significant contribution to the peak overland flows. The investigation into the presence and depth of groundwater as a source of seepage or drainage problems in the area is outside the scope of this study.

Residents have indicated that overland flooding has occurred at least once along the driveway of 22-24 Brookvale Avenue with associated inundation of floor levels. This drainage path was not investigated in this study as (we understand) the drainage pipe under the driveway is a private connection and is not identified on Council's pit/pipe database.

Runoff down Beacon Hill Road has been observed to enter Ryan Place and ultimately flow to Brookvale Avenue. One suggestion to prevent this from occurring is to reconfigure the intersection at Beacon Hill Road and Ryan Place. This issue was not investigated further as it is outside the scope of this investigation.

The Owner of No. 21 Ryan Place has indicated that runoff from Ryan Place enters the sealed access road leading to his property and has damaged the surface. There is also a drainage pit midway along the access road which is not indicated in Council's pit/pipe database.

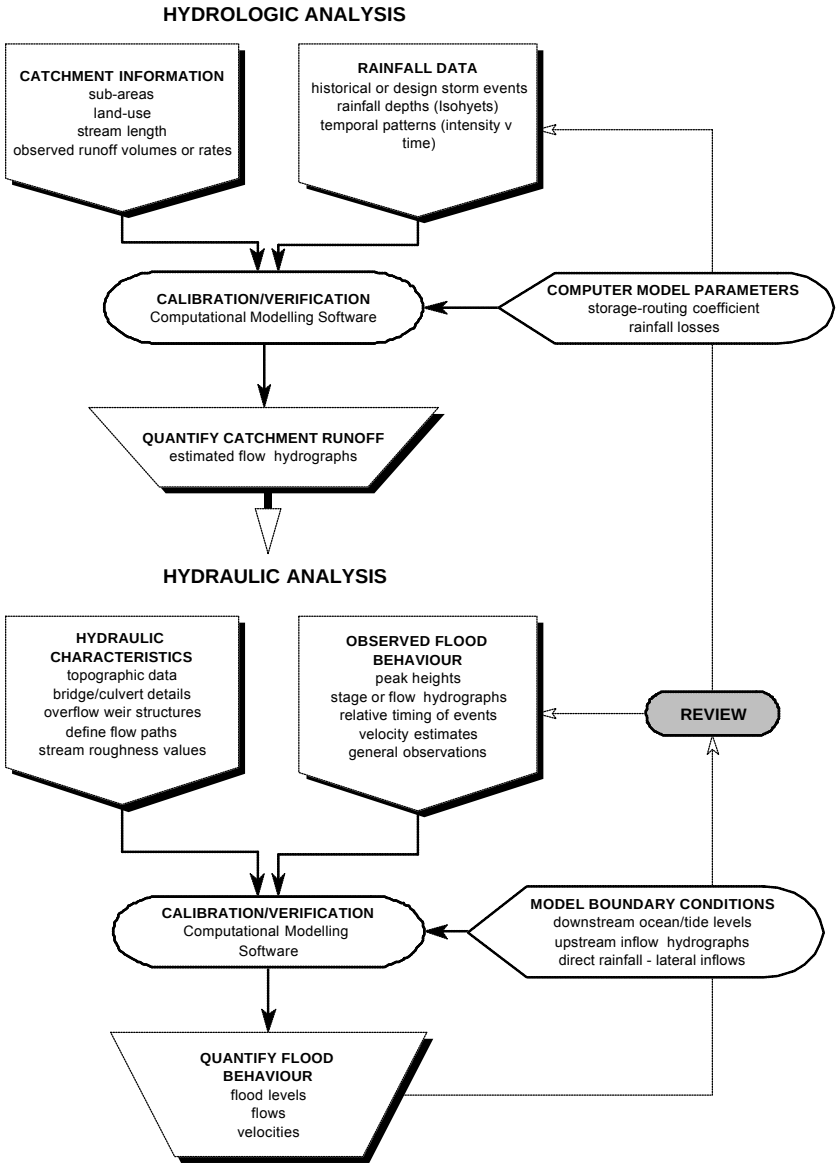
There have been various reports that sewage enters the stormwater system on the western branch through No. 21 Ryan Place. It is unclear whether this issue is ongoing or has been resolved.

Within No. 21 Ryan Place, the Owner has indicated that there is no drainage easement through his property. He contends that one or both of the drainage pipes through his property is broken causing damage to his building foundations. The Owner also states that erosion has occurred at his rear fence, immediately upstream of the large drainage pit within 34-36 Brookvale Avenue. Both these issues are outside the scope of the present investigation.

4. APPROACH ADOPTED

A diagrammatic representation of the Flood Study process is shown in Diagram 1. A combined hydrologic/hydraulic model (MIKE-Storm) was established for the entire catchment (Figure 1) and used to convert rainfall data into streamflow. The hydraulic component of the model simulated the pit and pipe network as well as the overland flow paths. The extent of the hydraulic model was taken from the start of the piped system in Landy Place and Beacon Avenue down to Old Pittwater Road. To ensure confidence in the results, the model requires calibration and verification against observed historical events. With the limited amount of rainfall and flood data available and given the lack of any stream gaugings, the model calibration process could not be undertaken. The model was then used to quantify the design flood behaviour for a range of design storm events up to and including the Probable Maximum Flood (PMF).

Diagram 1: Flood Study Process



5. HYDROLOGIC AND HYDRAULIC MODELLING

5.1 General

AR&R 1987 (Reference 3) provides a listing of models suitable for design flood estimation in urban catchments. However, the list has been superceded with the advent of more recent sophisticated computer models which combine the hydrologic and hydraulic components into one model.

The ILSAX model was the most widely used model for urban drainage in the 1980 and early 1990's but has since been superceded by the DRAINS, XP-RAFTS and MIKE-Storm models which provide more sophisticated pipe and overland flow hydraulics.

5.2 MIKE-Storm

The MIKE-Storm package was adopted for use in this study for the following reasons:

- MIKE-Storm is a stormwater specific adaption of the industry standard DHI MOUSE software widely used for pipe and open channel hydraulic simulation of unsteady flow conditions in network systems. It has been combined with ILSAX style hydrologic modelling to define the surface runoff from the catchment area.

- In comparison to DRAINS and XP-Storm, MIKE-Storm provides several key advantages including:
  - fully dynamic 1D and quasi-2D flow modelling allowing the proper distribution of pipe and overland flows to be simulated depending on backwater conditions, storage, downstream controls, etc.,
  - the inclusion of more definitive headloss formulations (at pits and along pipes) for both free surface and pressurised flow for dynamic conditions,
  - true, dedicated links to GIS and database software as standard capabilities simplifying manual handling of data and facilitating the interpretation of model results,
  - facilities for both design mode modelling or continuous simulation modelling to better assess the impacts of management strategies based on Water Sensitive Urban Design, on-site stormwater detention or rainwater interception principles.

- Importantly for the present study, MIKE-Storm offers a single modelling platform that dynamically simulates the interactions between pipe flow and surface flow. Unlike XP-Storm, the MIKE-Storm package provides inherently compatible representations of the pipe and overland flow components. The result is a fully featured modelling tool that is based on more realistic model assumptions.

- Being a 1D model, the base MIKE-Storm software offers similar features to the industry standard MIKE-11 package in terms of the use of cross-sections, definition of flow paths and the ability to simulate both super-critical and sub-critical flow conditions. MIKE-Storm solves the fully dynamic flow equations based on a robust and well-established numerical solution technique. Importantly, the MIKE-Storm package dynamically simulates the links between the surface flow and the piped network for steep and flat terrain with or without tidal influences. Hence, it offers a solid platform for 1D modelling of unsteady open channel flow throughout the catchment.

- The overland flow capabilities of MIKE-Storm include a number of advanced control structure formulations. It can accurately model headloss through a variety of structures for the full range of hydraulic control conditions including orifice flow and deck-overtopping situations. In addition, the in-built linkages between the pipe flow and overland flow components allows the impacts of inlet blockages to be better assessed.

- Results from the MIKE-Storm package can be directly integrated with GIS to facilitate easy development of the model (e.g. using a DTM) and to allow the geo-referencing of model results for interpretation and mapping purposes. The flood information (levels, inundation depths, etc.) can also be viewed as a series of map overlays or as an animation. Time-series information can be directly exported to commonly used desktop applications such as MSWord or Excel.

5.3 Hydrologic Modelling

The hydrologic models suitable for design flood estimation in an urban environment are described in Australian Rainfall and Runoff (Reference 3). The models range from simple procedures (e.g. Rational Method) which produce only peak flows, to more complex runoff routing models which estimate complete flow hydrographs and can be calibrated to recorded flow data.

For the present study, a runoff routing formulation based on methodology contained in the ILSAX/DRAINS model was adopted. The ILSAX/DRAINS type method is widely recognised and adopted for use in Australian catchments.

5.4 Hydraulic Modelling

The MIKE-Storm model established for the present study makes use of existing drainage information as well as additional topographic data collected as part of this study.

5.5 Model Calibration and Verification

It is preferable that hydrologic and hydraulic models used for design flood estimation are calibrated to historical flood data. This process ensures that the model replicates the recorded data collected from a historical flood. Therefore it can be reliably used to determine design flood levels by adopting the same model set and parameters derived during the calibration process.

Unfortunately, there is insufficient historical data available at Ryan Place to undertake model calibration or verification. The only data that does exist (photographs and recollections by resident at No. 21 Ryan Place) are for the March 2003 event but these data are not precise enough to be of value in calibration. However this information has been used to assist in model set up and derivation of overland flow paths.

6. MIKE-STORM MODEL CONFIGURATION

6.1 Sub-catchment Layout

A detailed MIKE-Storm model representing the overall drainage system network within the study catchment was established. A total catchment area of 11.9ha comprising 27 sub-catchments was analysed using the MIKE-Storm model. The extent of the catchment and drainage network is shown on Figure 1.

The reaches which do not have an associated sub-area correspond to junction pits, pipe bends or otherwise inlet pits which receive bypass flows from a nearby pit without being attributed a separate sub-area (this is a reasonable simplification of the system because these surface inlet pits have a very small immediate catchment). Allowances were made in the model for overland (bypass) flow paths between reaches.

Sub-catchment boundaries were manually delineated based on interpolation of the available topographic data, aerial photography and other similar information. The portion of impervious area was determined for each sub-catchment based on an inspection of the aerial photographs supply by Council. Since the only land use types occurring in the catchment are residential and road reserve, the percentage perviousness was estimated as 40% and the remaining 60% as impervious.

Overland (bypass) flow paths between the various reaches and/or systems were also incorporated as outlined in the following sections.

6.2 Drainage Network and Catchment Definition

The representation of the drainage system elements and overland flow paths in the MIKE-Storm model is discussed in the following sections.

6.2.1 Drainage System Elements

Figure 1 shows the location and extent of branches within the study catchment which have been included in the MIKE-Storm model. The drainage system defined in the model comprises:

- 62 pits and nodes, including surface inlets, junctions, headwall inlets and outlets,
- 98 links representing underground conduits (circular pipe or box) or channel lengths between nodes.

The pits and nodes modelled in MIKE-Storm can be classified as being surface inlet pits (on-grade or sag) or otherwise junctions, bends and outlets.

Surface inlets located at low points are termed *sag inlets*. It should be noted that MIKE-Storm does not require a distinction between sag or ongrade inlet pits. Rather each inlet behaves as a sag or ongrade pit based on the height of overland flows relative to the height of the inlet pit. Approximately 30% of all the pits in MIKE-Storm were modelled as *junction pits*. A junction pit is defined where there is no inlet to allow surface or bypass inflow (e.g. where two upstream branches combine, where two different sized conduits join, or where there is a significant bend in the alignment).

Being a fully dynamic model, MIKE-Storm calculates the headloss at pits for each time step. The total energy loss calculated is based on the sum of losses due to change in flow direction, change in elevation and losses associated with the expansion and contraction of flow as it passes through the pit.

Direct private property connections into Council's pipe system were not taken into account (due to the lack of information). Hence, the present model configuration only allows runoff to enter the drainage system via surface inlets in the street with the exception of the pit at the upstream boundary within No's 34-36 Brookvale Avenue. For the purposes of design flood estimation, this assumption is considered to be conservative given that a proportion of the runoff would enter the system via direct pipe connections from private properties.

The downstream point of the model was adopted as Old Pittwater Road where two "dummy" outlets were modelled. This is the extent of the agreed study area and was the most convenient place to terminate the model because several other larger catchments join downstream of this point before the system continues into Brookvale Creek.

6.2.2 Definition of Overland Flow Paths

The definition of overland flow paths within the MIKE-Storm model was based on the locations of pits as well as the layout of roads, drainage reserves and other potential flow paths, identified from site inspections and available survey data (Figure 2).

In the absence of detailed survey throughout the catchment, formal flow paths such as roads, footpaths and drainage reserves were defined based on "typical" cross-sections representing standard sections as per the following:

- full road,
- half road,
- footpath alone,
- road less footpath,
- drainage reserve (of varying width),
- flow path through private property.

In most cases, the particular flow path was modelled as a single branch (extending from pit to pit) that was linked into the overall network. The length and grade of each branch was based on the topographic data available in each location.

Specific survey by QASCO Surveyors (refer Figure 2) was obtained to define the overland flow path through No. 21 Ryan Place, No's 34-36 Brookvale Avenue and between Brookvale Avenue through to Old Pittwater Road.

6.2.3 Blockage

The potential for pit blockages within the system was accounted for by adopting a 50% blockage factor for all pits. This blockage factor is typical of the value commonly adopted for these types of studies in other similar urban catchments. However there are no technical studies (as far as we are aware) that confirm that this value is typical for the Ryan Place catchment.

An exception to this is the large pit (refer Photographs 13 and 14) within No's 34-36 Brookvale Avenue and immediately downstream of No. 21 Ryan Place, which was modelled assuming 100% blockage. This pit is intended to capture the overland flow from upstream and allow it to enter the culvert constructed under the passageway in No's 34-36 Brookvale Avenue. Without this pit the only runoff entering this culvert would be from the two small upstream pipes. As this pit is situated immediately downstream of the paling fence there is the potential that it may become blocked by vegetative debris or from the paling fence collapsing. This issue is discussed further in Sections 8.2.1 and 8.3.1. A note indicating that 100% blockage was assumed at this pit is shown on the relevant figures.

7. DESIGN EVENT MODELLING

7.1 Overview

As discussed in Section 5.2, the MIKE-Storm software models both the hydrology and hydraulics of the catchment drainage system. The model established was used to provide estimates of the design flood behaviour across the study catchment under existing conditions. The key model parameters and boundary conditions adopted for the design event modelling are summarised in the following sections.

7.2 Key Model Parameters

7.2.1 Rainfall Losses and Soil Type (Hydrologic Component)

Losses from paved areas are considered to comprise only of an initial loss (an amount sufficient to wet the pavement and fill minor surface depressions). Losses from grassed areas are more complex. They are made up of both an initial loss and a continuing loss. The continuing loss was calculated within the model using Horton's infiltration relationship which is based on the estimated representative soil type and antecedent moisture condition. A Soil Type of 2 and an Antecedent Moisture Condition of 4 was adopted. It was assumed that the soil in the sub-catchments has a moderate rate of infiltration potential and the antecedent moisture condition was considered to be saturated. The latter was justified by the fact that the peak rainfall burst can typically occur within a longer storm event that possibly has a duration of a few days. The adopted parameters are summarised in Table 4.

Table 4: Adopted Hydrologic Model Parameters

RAINFALL LOSSES	
Paved Area Depression Storage (Initial Loss)	1 mm
Grassed Area Depression Storage (Initial Loss)	5 mm
SOIL TYPE	2
Moderate infiltration rates and moderately well-drained. This parameter, in conjunction with the Antecedent Moisture Condition, determines the continuing loss (defined by Horton's infiltration equation).	
ANTECEDENT MOISTURE CONDITIONS (AMC)	4
Description	Saturated
Total Rainfall in 5 Days Preceding the Storm	Over 25 mm

7.2.2 Time of Concentration (Hydrologic Component)

Overland travel times for surface runoff within a sub-catchment were calculated using the kinematic wave equation. This relationship is based on the nature of the sub-catchment and accounts for different travel times with varying rainfall intensities.

7.2.3 Manning's Roughness for Overland Flow Paths (Hydraulic Component)

Roughness parameters adopted for the overland flow paths (Manning's 'n' values which represent the friction resistance) were based on previous investigations and experience. In general, the adopted values applied to the standard cross-sections used to represent overland flow paths in the model were between 0.015 for roads and 0.035 for grassed areas.

7.3 Boundary Conditions

7.3.1 Design Rainfalls and Runoff (Hydrologic Component)

Rainfall hyetographs were derived based on design rainfall intensities and design temporal patterns obtained from AR&R for events up to and including the 100y ARI event (Reference 3). The corresponding data for Probable Maximum Precipitation (PMP) was based on the current BOM GSDM guidelines (Reference 4). These were converted by the model into paved and grassed area runoff hydrographs as a function of the contributing surface area and rainfall losses. The paved and pervious area hydrographs are then superimposed to give total runoff hydrographs for each sub-catchment.

These runoff hydrographs are then input to the hydraulic model to be routed through the drainage (pit, pipe and overland) network.

7.3.2 Catchment Outlet (Hydraulic Component)

As no historical flood levels were available for the downstream boundary, a tailwater level was set at 150 mm above the respective pit surface level. The 150 mm represents the depth of the gutter and assumes the gutter is full. The steepness of the catchment down to Old Pittwater Road also means that the level at Old Pittwater Road will be governed by the flows arriving from upstream and the depth of ponding in Old Pittwater Road should not have any significant influence on upstream flood levels.

8. DESIGN FLOOD RESULTS

8.1 Overview

There are two basic approaches to determining design flood levels, namely:

- *flood frequency analysis* - based upon a statistical analysis of the flood events, and
- *rainfall/runoff routing* - design rainfalls are processed by a suite of computer models to produce estimates of design flood behaviour.

A *rainfall/runoff routing* approach using the MIKE-Storm model was adopted for this study. This approach reflects current engineering practice and is consistent with the quality and quantity of available data. The *flood frequency* approach requires a reasonably complete homogeneous record of flood levels/flows over a number of decades to give satisfactory results. No such records were available within the catchment.

8.2 Peak Design Flows

Design rainfall intensities and temporal patterns were derived from AR&R (Reference 3) and used as input to the MIKE-Storm model. Uniform depths of rainfall with zero areal-reduction factor were applied across the entire catchment.

Design inflow hydrographs for a range of durations (ranging from 15 minutes to 2 hours) for the 100y ARI event were run through the model to determine the "critical storm duration" or the design storm that produces the highest peak flood levels. The 25 minute duration storm was found to be critical. This particular duration was then adopted for all other design event frequencies. In a similar manner, the 15 minute storm duration was found to be the critical duration for the PMF event. Identical model parameters (refer Section 7) were used for all simulations.

The resulting peak flows at key locations are shown in Table 5.

Table 5: Peak Design Flows at Key Locations

Location (refer Figure 1)	Pit	Peak Flow (m^3/s)				
		5y ARI	10y ARI	50y ARI	100y ARI	PMF
Ryan Place Western Branch	30268-1	1.5	1.7	2.2	2.4	9.4
Ryan Place Eastern Branch	30272-2	1.5	1.7	2.2	2.4	9.5
Rear of 21 Ryan Place	30284-5	3.2	3.7	4.9	5.4	19.5
Cul-de-sac Brookvale Avenue	30285-0	3.2	3.8	5.0	5.6	20.3

Note: Results shown represent the total flow at the point (including pipe and overland).

The MIKE-Storm model results are presented in Appendix C. The results show pipe and overland flows for the entire catchment for the 5y, 10y, 50y and 100y ARI design and PMF rainfall events. An assessment of the pipe network is outside the scope of this investigation but the results would indicate that by assuming 50% blockage of the surface inlet pits the underground drainage network is under capacity. This is evident from the occurrence of significant overflows in the 5y ARI event.

The MIKE-Storm 100y ARI combined peak flow of 5.5 m^3/s at the rear of No. 21 Ryan Place is similar to that calculated by Council for the same location (Council estimated 5.9 m^3/s - refer Section 2.3.2).

Figures 3 through to 7 indicate the magnitude of pipe and overland peak flows across the entire study area for the various design storm events.

8.2.1 Overland Flow Path Assessment

There is a drainage easement from the downstream boundary of No. 21 Ryan Place through No's 34-36 Brookvale Avenue to Brookvale Avenue itself. The underground pipe within this easement was recently upgraded as part of the unit development to a 1500 mm x 900 mm box culvert with a large open pit (refer to Photograph 13) at the upstream point. In line with assessment of blockage of the entire drainage network this pit was assumed to be 50% blocked by debris. Following a site inspection it was also considered that 100% blockage could occur in a large storm event as the fence at the rear of No. 21 Ryan Place could fall and subsequently block this pit. Presently there are small flap gates (Photograph 14) at the base of the fence but these are likely to fail or become blocked in a large event.

Figures 3 to 7 indicate the peak overland flows assuming 100% blockage of this pit at the rear of No's 34-36 Brookvale Avenue as well as the 50% blockage scenario for the remaining pits.

8.3 Flood Contour and Hydraulic/Hazard Categorisation

Estimation of design flood levels at each node is provided in the output from the MIKE-Storm model and are shown on Figures 8 to 13 together with the interpolated flood contours and hydraulic/hazard categorisation. The categorisation was depth based and defined as either floodways or flood fringe (refer glossary for definitions). It was considered that no area within the study area can be categorised as flood storage due to the relatively shallow depths of flow. As detailed in the Floodplain Management Manual 2001, high hazard is defined as being areas where there is possible danger to personal safety, evacuation is difficult and there is potential for significant structural damage to buildings. Low hazard are areas where evacuation is possible and able bodied adults would have little difficulty in wading to safety. This assessment takes no account of the effect of fences or such like (these are not explicitly simulated in the computer model) which could have a significant affect on the distribution of overland flows and resulting design flood levels. Due to the lack of detailed survey all floodways areas are assumed to be high hazard and all flood fringe areas are assumed to be low hazard.

8.3.1 No. 21 Ryan Place/No's 34-36 Brookvale Avenue

Of particular importance is the potential affect that the fence separating No. 21 Ryan Place and No's 34-36 Brookvale Avenue could have on flow distribution and flood levels. As noted in Section 8.2.1 there is a possibility that this fence could collapse due to the build up of water pressure, scouring or being hit by debris (car) from upstream. Under such circumstances this would effectively block the inlet pit within No's 34-36 Brookvale Avenue (refer Photograph 14) which would have the beneficial effect of reducing upstream flood levels but increasing flows and flood levels in the downstream easement through No's 34-36 Brookvale Avenue.

An alternative possibility is that the flap gates at the base of the fence become blocked by debris and the fence does not fail but rather acts as a dam wall. In theory, upstream floodwaters could pond to the height of the fence (say 1.8 m). Whilst this scenario is unlikely (it is likely that the fence would collapse before this time) there is no reliable quantitative information available which would indicate at what upstream water level the fence would fail.

In order to account for the above, two scenarios were considered:

- fence fails and blocks inlet (downstream impact),
- fence does not fail but floodwaters pond to height of fence (upstream impact).

The design flood levels and contours are based on the worst case of the two scenarios, i.e., upstream the fence is assumed not to fail but downstream the fence fails.

8.3.2 Rear of Properties between Brookvale Avenue and Old Pittwater Road

A similar scenario to that mentioned in Section 8.3.1 exists at the rear fence boundary for those properties located between Brookvale Avenue and Old Pittwater Road. The only exception is that if the fences along the rear boundary fail there is little disbenefit downstream as these failures would not block an inlet pit.

The design flood levels shown on Figures 8 to 13 are based on assuming that the rear boundary fence provides little impediment to flow. This is considered reasonable as the likelihood of blockage over its entire length is small. However if blockage occurs and the fence does not fail, floodwaters might pond to the height of the fence (say 1.8 m).

8.4 Sensitivity Analysis

The MIKE-Storm model applies the same basic ILSAX hydrological model parameters which are considered to be the most appropriate for urban catchments based upon experience and use in other studies. As there are no calibration data available for the study area, sensitivity analyses were undertaken to determine the potential variation in results (flows and flood levels) which might occur if different parameters were adopted.

The following scenarios were considered to represent the outer limits of likely variations in parameter values:

- ±20% change in design rainfall,
- increase amount of rainfall losses (low runoff potential)
  Initial Loss: paved = 2 mm, grassed = 5 mm, AMC = 1,
- decrease amount of rainfall losses (high runoff potential)
  Initial Loss: paved = 0 mm, grassed = 0 mm, AMC 4 (unchanged),
- Soil type = 1 (high infiltration, low runoff potential).

Undertaking sensitivity analyses for the drainage system may not always result in a change in peak flow downstream, if for instance the size of the pipe or pit is the control, as there may be no change in the flow conveyed in the pipe. Alternatively there may be a change in the overland flow but the effect further downstream will depend on the particular characteristics of the pit and pipe network. At some locations the change in upstream flow is not reflected downstream due to the effects of ponding at sag pits or the relative timing of overland flows.

The model was re-run for the 25 minute 100y ARI design storm and a relative comparison of the resultant changes in peak overland flows at various locations are summarised below:

- a ± 20% change in the rainfall produces a corresponding 0% to 30% (approximate) change in peak overland flow,
- increasing the amount of rainfall losses and changing the AMC to 1 reduces the peak overland flows by up to 40%,
- decreasing the amount of rainfall losses and maintaining the AMC at 4 results in little change to peak overland flows,
- changing the soil type to 1 results in up to a 1% change in the peak overland flows.

The peak flood levels vary little between design events. This is because the flow path was assumed to be unrestricted by fences or buildings and extends across a considerable width. Thus for larger events (greater flow) the flood level increases only slightly (0.1 m difference between 5y ARI and 100y ARI events). Thus for the sensitivity scenarios tested there was little difference in peak flood levels or velocities.

9. PRELIMINARY REVIEW OF FLOODPLAIN MANAGEMENT MEASURES

9.1 General

Whilst this Ryan Place Overland Flood Study covers only an 11.9 hectare urban catchment within Warringah Council's local government area, the approaches proposed to mitigate the existing problem or ensure that future problems do not occur have a wider application for the local government area.

9.2 Understanding of the Problem

There are a large number of competing issues/problems within an urban catchment, such as Ryan Place, that have contributed to the existing problem. The main issues include:

- historical development in the area over 30 years ago occurred in a time when little was understood about urban drainage and the potential for large storms to cause significant flood damage through overland flow,
- increasing use of solid fences (brick, colourbond) rather than the more traditional paling or no fence,
- alterations to existing buildings or yards have been undertaken with no significant examination of overland flow issues,
- the existing pipe system probably has a capacity of a 2y ARI event, or less. The capacity is further reduced by blockage of pits or by the fact that in many places overland flow cannot successfully enter the pit (alignment of flow path, high velocity, vehicles parked),
- whilst there are easements over sub-surface drainage lines, generally the above ground path is obstructed,
- as redevelopment occurs there is increased pressure to maximise the use of the land and consequently further restrict an already limited overland flow path,
- implementation of Water Sensitive Urban Design (WSUD) encourages greater use of overland flow paths rather than containing the runoff underground,
- greater urban densities will increase the volume and peak flow from a site. Council's on-site detention policy (OSD) is intended to nullify these increases. How successful is the policy? There are many examples in other local Council areas where OSD structures are not constructed to design or subsequently have been modified and/or poor maintenance means they do not perform as intended,
- overland flow problems in the Ryan Place catchment have occurred relatively infrequently in recent times (due to a period of low rainfalls). When they have occurred (March 2003) the problems/issues that have arisen have probably not been fully documented at the time. The key to managing the problem is to understand how it has happened in the past and this can be difficult if only limited data are available. Also many affected residents choose to sell and move elsewhere, in the process they are unlikely to fully document the problem as that may influence a prospective purchaser. In this regard it is essential that full details of all future flood events are collected immediately (within 1 day),

- no designated overland flow path,
- a relatively steep upper catchment where the overland flows are generally confined and of high velocity and a relatively flatter lower catchment where the overland flow paths are ill-defined and minor topographic changes can easily divert runoff elsewhere.

9.3 Review of Floodplain Management Measures

9.3.1 Flood Modification Measures

The purpose of Flood Modification Measures is to modify the behaviour of the flood itself by reducing flood levels or velocities or by excluding floodwaters from areas under threat (Floodplain Management Manual).

Included under this classification are:

- dams, retarding basins,
- levees,
- bypass floodways,
- channel modifications - dredging, stream clearing,
- flood gates,
- constructing additional pit/pipe networks,
- on-site stormwater detention,
- dedication of an overland flow path.

Of the above list only the latter three (additional pipes, OSD and dedication of an overland flow path) are likely to be practical in this situation.

- **Additional pit/pipe network -** this is a costly solution that is contrary to WSUD practice. Also, it requires the system to be upgraded to its outlet in Brookvale Creek.
- **OSD -** Council should review their policy to see whether it is successful. Consideration might be given to developers being allowed to construct other drainage works which would have a greater hydraulic benefit (greater overland flow path) in lieu of OSD. This would be on the proviso that it did not exacerbate problems for other (downstream) areas.
- **Dedicated Overland Flow Path -** this measure is probably the most cost-effective solution but is difficult to enforce as Councils have little control over the type of fencing or such like that generally obstructs flow paths.

9.3.2 Property Modification Measures

Property Modification Measures refer to modifications to existing developments and/or development controls on property and community infrastructure for future development (Floodplain Management Manual).

These measures include:

- voluntary purchase,
- house raising,
- flood proofing of buildings,
- zonings,
- flood access,
- development controls.

For urban catchments with overland flow problems, such as Ryan Place, it is unlikely that voluntary purchase, house raising or flood proofing can be economically justified to negate an existing problem.

Probably the most cost-effective and productive measure is for Council to implement sufficient development controls to ensure future development is protected and does not exacerbate the existing problem. Preferably the controls should be such that they improve the existing situation.

The policy document should be written in a clear and unambiguous manner. Several Councils have recently undertaken such tasks (Woollahra, Ku-ring-gai) with implementation of DCPs. The main points that should be included are:

- a range of flood planning levels (building floors, basement car parks, above ground car parks),
- dedication of an unobstructed overland flow path, preferably with an easement,
- greater controls on buildings and fencing across overland flow paths,
- implementation of a Council wide system for "tagging" properties subject to overland flow,
- identification of tasks that must be undertaken by a prospective developer to ensure that the development complies with Council's policy (details of plans, calculations, etc.).

9.3.3 Response Modification Measures

Response Modification Measures encompass various means of modifying the response of the population to the flood threat (Floodplain Management Manual).

Such measures include plans for:

- flood warning,
- protection/evacuation of the area,
- relief of evacuees,
- recovery of the area once the flood subsides.

Flood warning and subsequent evacuation is clearly impossible on such a small sized catchment with a very short warning time. Nevertheless, it is appropriate that Council undertakes programs to educate and inform the community of the risks and how damages can be mitigated. There are a variety of means available but probably the most cost-effective is likely to be a brochure enclosed with Council's rates notice, or similar.

9.4 No. 21 Ryan Place

9.4.1 Site Description

No. 21 Ryan Place is a residential property located at the confluence of the west and east branches (Figure 1) and immediately upstream of No.'s 34-36 Brookvale Avenue. Two 525 mm diameter pipes lying on either side of the existing house convey the low flows across the property. The pipes join to the recently installed (2003) 1.5 m x 0.9 m box culvert downstream of the boundary. Across this boundary is a paling fence, separating No. 21 Ryan Place from No.'s 34-36 Brookvale Avenue.

9.4.2 Existing Issues

The two pipes direct floodwaters from the upstream catchment through No. 21 Ryan Place and into the box culvert. They are relatively small sized and there is significant potential for the pipe capacity to be exceeded and/or for the pipes to be blocked by debris. There is a history of overland flow crossing No. 21 Ryan Place and ponding behind the fence, causing some erosion to the yard and driveway.

The house floor is not at risk of inundation, however there is a risk to life associated with access and ground inundation, as well as potential damage to the garage and cars on the property.

In February 2006, Council surveyed the pipes on the property to assess their condition and it was revealed that both pipes were damaged. Leakage from these pipes could possibly affect the foundations of the house.

The resident of No. 21 Ryan Place has previously voiced complaints regarding the overland flow and pipe damage issues.

9.4.3 Design Flood Issues

During the determination of design flood levels a number of issues were raised:

- Due to the small size of the pipes the potential for blockage had to be considered in the analysis and 50% blockage was adopted for design.

- The pit immediately downstream of the property (within No.'s 34-36 Brookvale Avenue), which primarily collects overland flow from No. 21 Ryan Place, was also assumed to be restricted by blockage for the design events. In this case, 50% and 100% blockage scenarios were tested as there was the potential for blockage by vegetative debris and/or the paling fence collapsing and covering the pit.

- The paling fence, even if it remained standing, exacerbates the flood situation as it acts as a barrier to overland flow, resulting in ponding of floodwaters in No. 21 Ryan Place.

9.4.4 Possible Floodplain Management Measures

a) Repair damaged pipes within No. 21 Ryan Place

There are essentially three options:

- the existing pipes can be sleeved providing a new lining,
- replace the damaged pipes with new 525 mm diameter pipes,
- replace the damaged pipes with new larger capacity pipes.

The advantages and disadvantages of these options are summarised in Table 6.

Table 6: Comparison of Pipe Repair Options

Option	Advantages	Disadvantages
Pipe Sleeve	• Cheapest option. • Prevents leakage which eliminates possibility of foundation damage to building on No. 21 Ryan Place.	• Temporary solution which would only be effective for the life of the sleeve material (which is considerably less than the life of a concrete pipe). • Would slightly reduce the pipe capacity. • Does not address the other flood issues, such as blockage of downstream pit and overland flow associated with blockage of pipes (or inadequate capacity).
Replacing pipes with new 525 mm pipes	• Addresses leakage issue. • Longer term solution than sleeve.	• More expensive than sleeving, though providing essentially the same pipe capacity. • Does not address the other issues associated with this site (downstream pit blockage and overland flow). • Disruptive to resident.

Replacing pipes with new larger pipes	• Addresses leakage issue. • Longer term solution than sleeve. • Depending on the size, has the potential to completely alleviate the overland flooding problem across No. 21 Ryan Place as well as problems with blockage of downstream inlet (and thus reducing downstream flood levels through No.'s 34-36 Brookvale Avenue). • Only marginally more expensive than replacing with same sized 525 mm diameter pipe, though would provide a far greater benefit.	• Most expensive option though the majority of the construction cost (excavation, reinstatement) would be similar to the 525 mm diameter pipe replacement option. • Disruptive to resident. • Would require design to determine optimal pipe size.

Ideally, the existing damaged pipes should be replaced with new larger sized pipes. Most of the cost of replacing pipes is associated with the excavation and placement of the new pipes (including reinstatement), thus for a marginally greater expense (to purchase the larger pipes and excavate a slightly greater area) a much greater benefit could be achieved. Increasing the pipe diameter greatly increases the flow area (for example, tripling the size of the existing pipe results in a capacity nine times greater). Having a larger sized pipe would also reduce the likelihood of blockage or full capacity being reached. This means overland flow through No. 21 Ryan Place would be eliminated (up to the design capacity - assuming no blockage) and the floodwaters would directly enter the box culvert downstream. In turn, this would mean that downstream flood levels would be reduced as even if the inlet pit was 100% blocked, the water would already be in the pipe network and could flow directly into the box culvert.

The size of the new pipe would need to be investigated during the design process but our recommendation is that it should have a minimum 20y ARI capacity.

b) Reducing Flood Risk within the Property

As previously mentioned, the flood risk at No. 21 Ryan Place is limited to problems with access, risk to life and potential damages to cars and garage. There is no viable structural solution to these issues. Raising the garage or filling land would reduce damages and problems with access but are not viable from an economic or social perspective.

However, the flood risk could be addressed by:

- *The installation of larger pipes:* As previously mentioned installing larger pipes would eliminate overland flow across No. 21 Ryan Place (up to the design capacity - assuming no blockage) and reduce the possibility of blockage. In turn this would eliminate blockage concerns at the inlet pit downstream of No. 21 Ryan Place as floodwaters would flow directly into the box culvert. This not only reduces flood levels and the risk to life on No. 21 Ryan

Place but also within No.'s 34-36 Brookvale Avenue. There are no disadvantages of this option , apart from those listed in Table 6 though possible construction issues would need to be addressed.

- *Voluntary Purchase:* Alternatively, voluntary purchase (VP) of the property would eliminate the flood risk. At present Warringah Council has no existing VP scheme, but it would be possible to create one. Whilst voluntary purchase of No. 21 Ryan Place wold remove the flood risk to that property, it would not aid the flooding problem downstream (as there would still be overland flow and potential blockage issues). Voluntary purchase is an expensive management measure that is usually only considered cost effective in high hazard areas where building floors are frequently inundated (which is not the case at No. 21 Ryan Place). There are also other issues associated with voluntary purchase, particularly that it is only effective once accepted - i.e., once funding is approved and the house is purchased. There is also a history of the price offered by Council (as determined by the Valuer General) being less than that which the resident feels is reasonable so the scheme may not be accepted, in which case the flood risk remains.

We recommend that the installation of larger pipes be investigated first as potentially this measure can provide greater social, economic and hydraulic benefits.

10. ACKNOWLEDGEMENTS

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

- Warringah Council,
- residents of Ryan Place and Brookvale Avenue, particularly the Owner of No. 21 Ryan Place.

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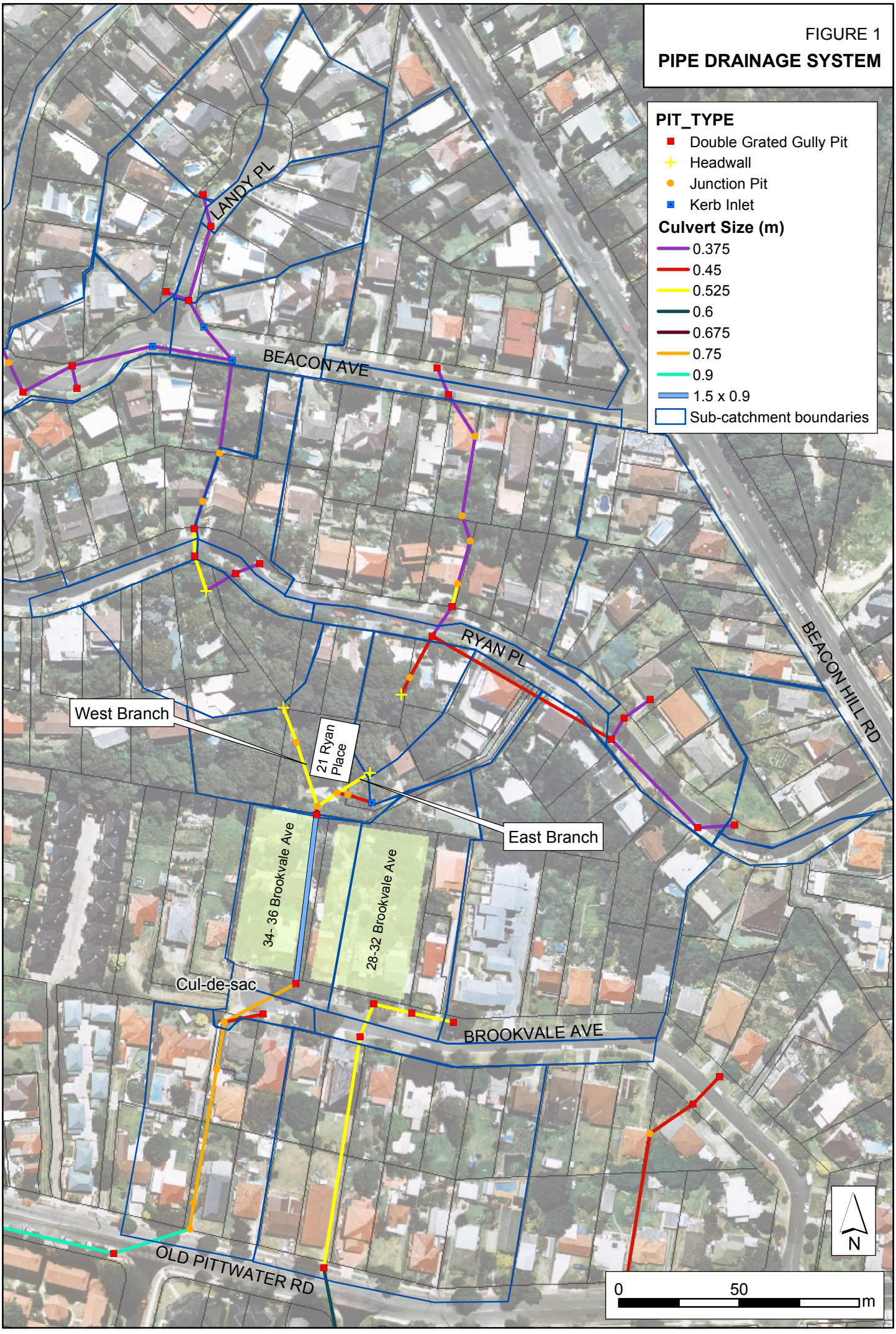
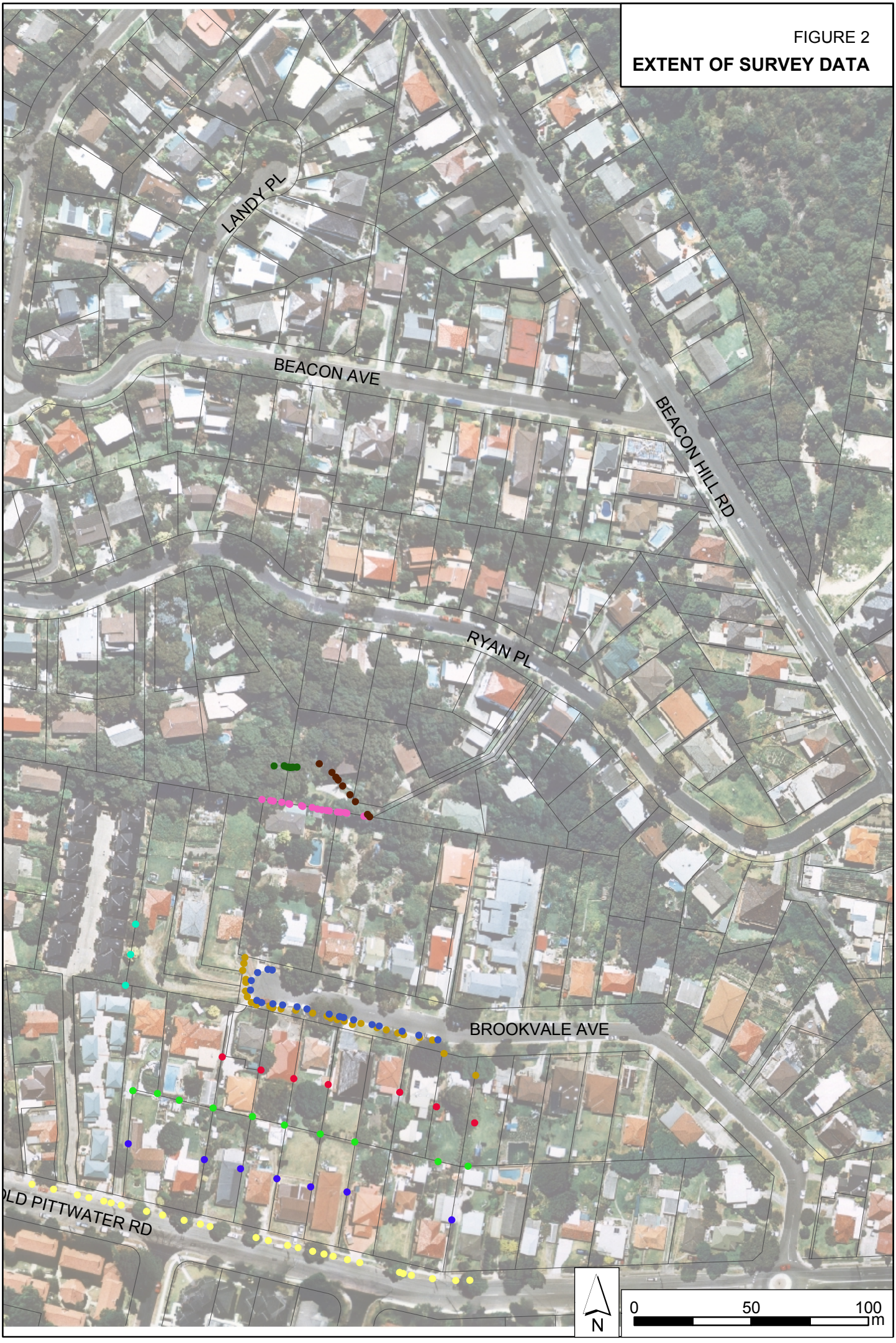


Note: Aerial Photograph Date 2000, Source: Warringah Shire Council

FIGURE 2

EXTENT OF SURVEY DATA



Note: Survey undertaken by Qasco, December 2004

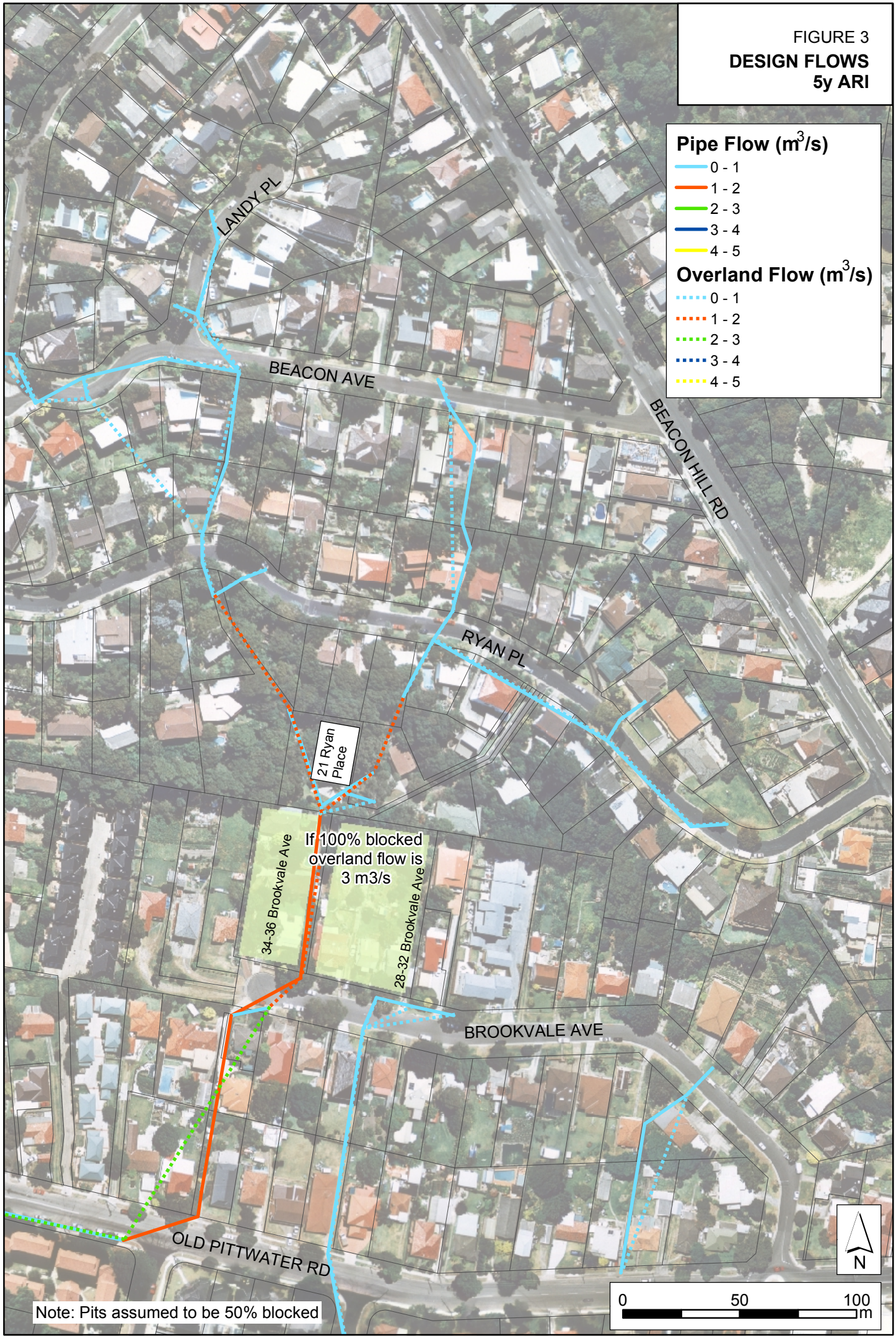


FIGURE 3
DESIGN FLOWS
5y ARI
Pipe Flow (m3/s)
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
Overland Flow (m3/s)
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
LANDY PL
BEACON AVE
BEACON HILL RD
RYAN PL
21 Ryan Place
If 100% blocked overland flow is 3 m3/s
34-36 Brookvale Ave
28-32 Brookvale Ave
BROOKVALE AVE
OLD PITTWATER RD
N
0
50
100
m
Note: Pits assumed to be 50% blocked

FIGURE 4
DESIGN FLOWS
10y ARI
Pipe Flow (m3/s)
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
Overland Flow (m3/s)
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
LANDY PL
BEACON AVE
BEACON HILL RD
RYAN PL
21 Ryan Place
If 100% blocked overland flow is 3.5m3/s
34-36 Brookvale Ave
28-32 Brookvale Ave
BROOKVALE AVE
OLD PITTWATER RD
N
0
50
100
m
Note: Pits assumed to be 50% blocked

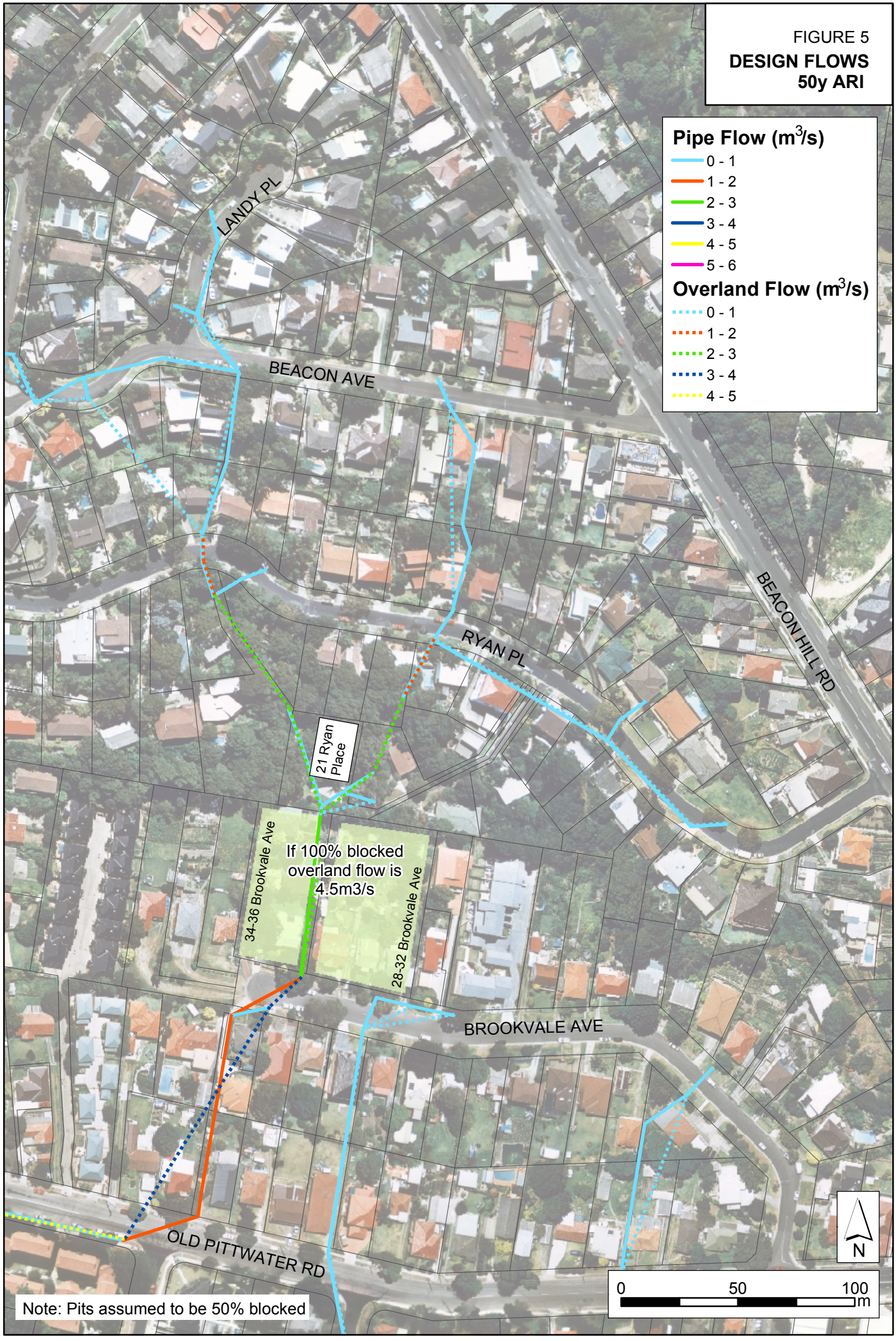


FIGURE 5
DESIGN FLOWS
50y ARI
Pipe Flow (m3/s)
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
Overland Flow (m3/s)
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
LANDY PL
BEACON AVE
BEACON HILL RD
RYAN PL
21 Ryan Place
34-36 Brookvale Ave
If 100% blocked overland flow is 4.5m3/s
28-32 Brookvale Ave
BROOKVALE AVE
OLD PITTWATER RD
N
0
50
100
m
Note: Pits assumed to be 50% blocked

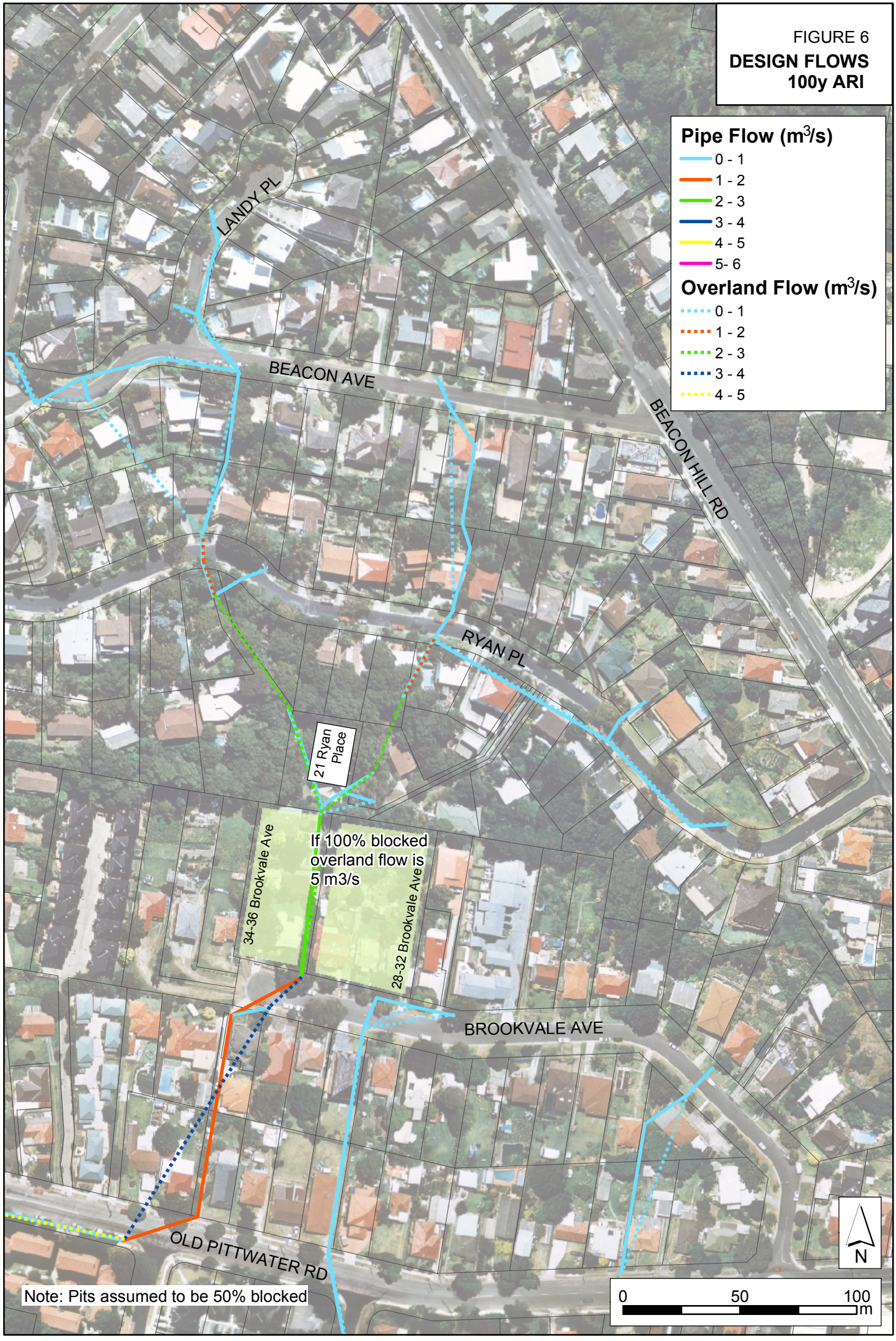


FIGURE 6
DESIGN FLOWS
100y ARI
Pipe Flow (m3/s)
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5- 6
Overland Flow (m3/s)
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
LANDY PL
BEACON AVE
BEACON HILL RD
RYAN PL
21 Ryan Place
If 100% blocked overland flow is 5 m3/s
34-36 Brookvale Ave
28-32 Brookvale Ave
BROOKVALE AVE
OLD PITTWATER RD
Note: Pits assumed to be 50% blocked
N
0
50
100
m

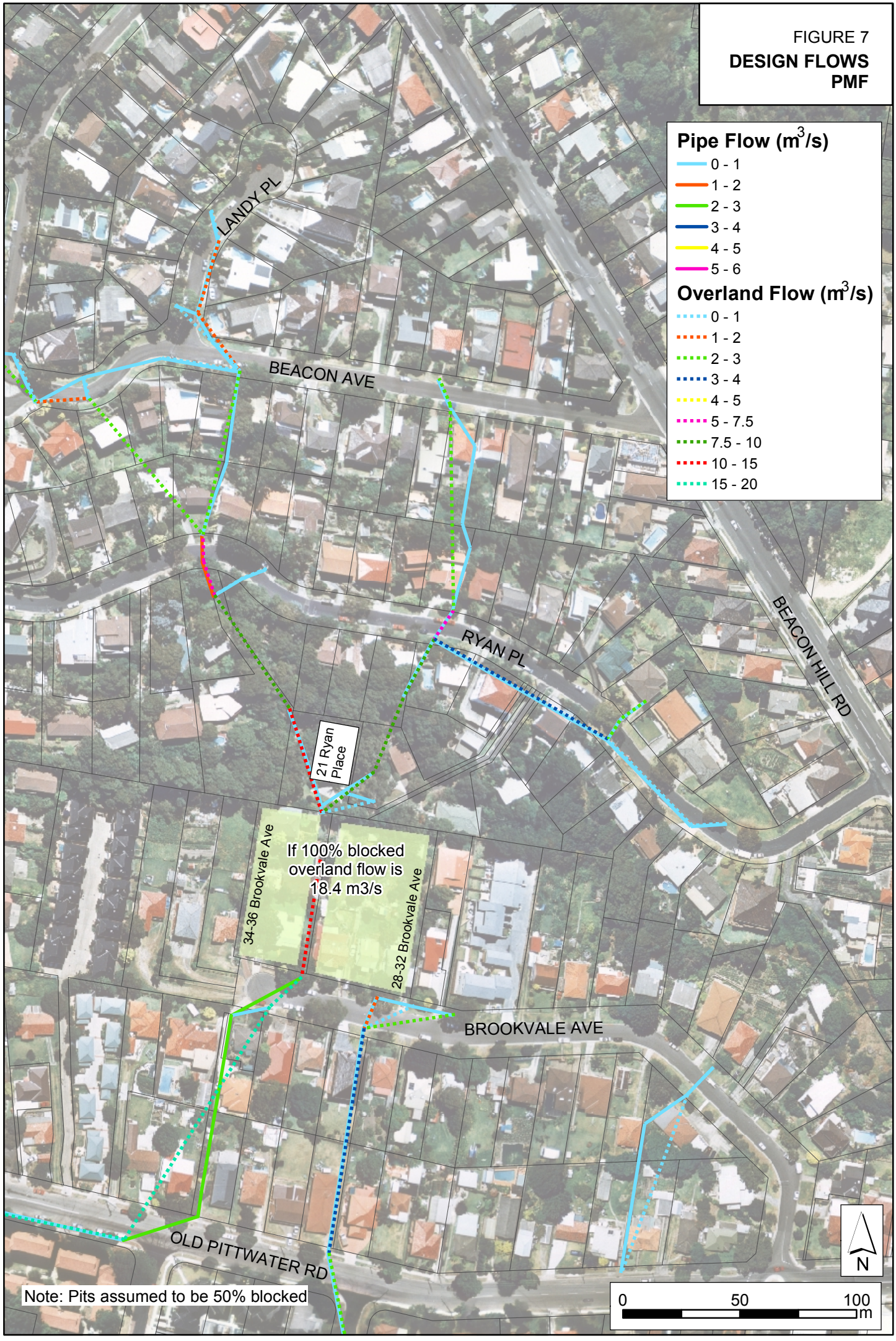


FIGURE 7
DESIGN FLOWS
PMF
Pipe Flow (m3/s)
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
Overland Flow (m3/s)
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 7.5
7.5 - 10
10 - 15
15 - 20
LANDY PL
BEACON AVE
RYAN PL
BEACON HILL RD
21 Ryan Place
If 100% blocked overland flow is 18.4 m3/s
34-36 Brookvale Ave
28-32 Brookvale Ave
BROOKVALE AVE
OLD PITTWATER RD
Note: Pits assumed to be 50% blocked
N
0
50
100
m

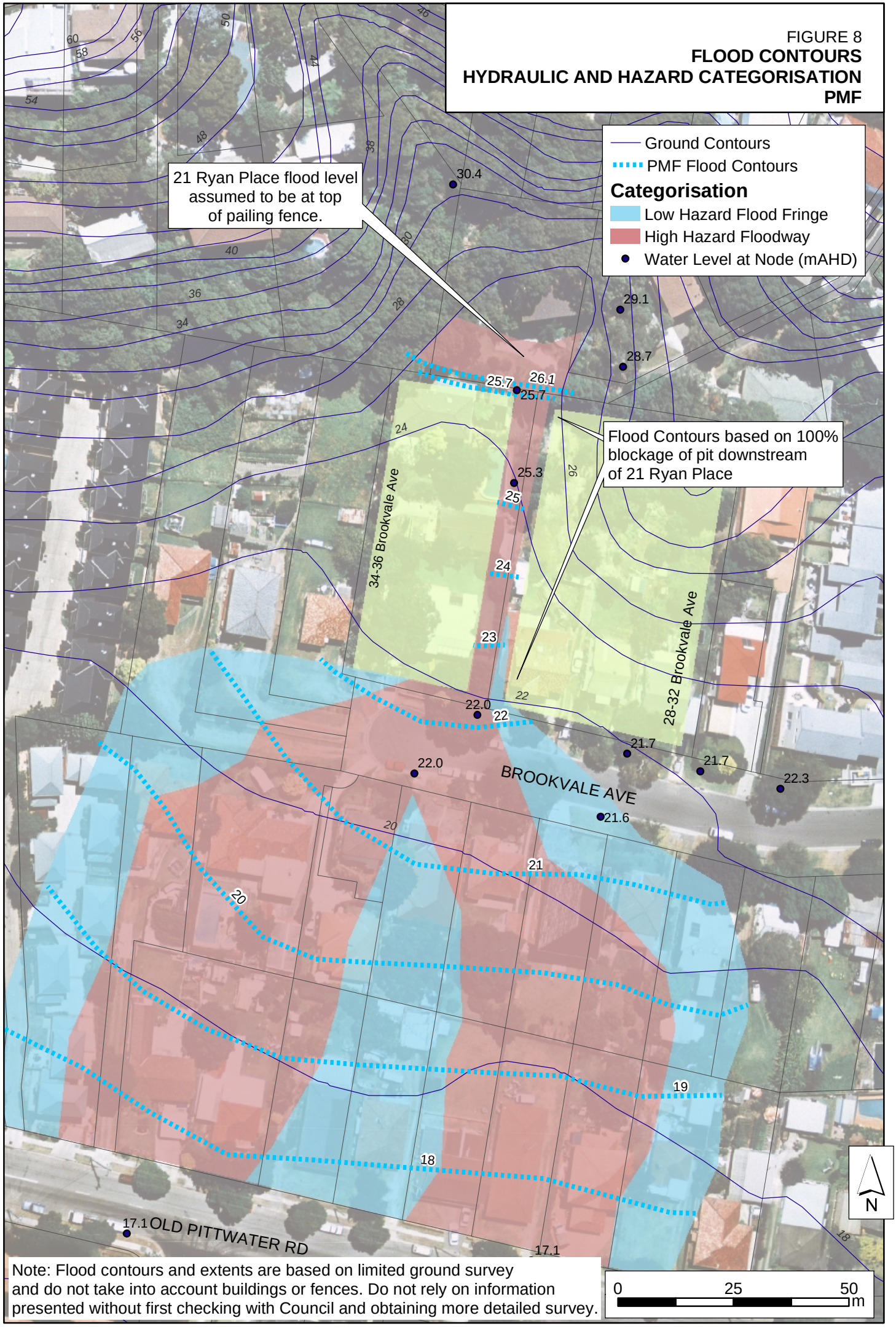


FIGURE 8
FLOOD CONTOURS
HYDRAULIC AND HAZARD CATEGORISATION
PMF
Ground Contours
PMF Flood Contours
Categorisation
Low Hazard Flood Fringe
High Hazard Floodway
Water Level at Node (mAHD)
21 Ryan Place flood level assumed to be at top of pailing fence.
Flood Contours based on 100% blockage of pit downstream of 21 Ryan Place
34-36 Brookvale Ave
28-32 Brookvale Ave
BROOKVALE AVE
OLD PITTWATER RD
30.4
29.1
28.7
25.7
26.1
25.7
25.3
25
24
22.0
22
22.0
21.7
21.7
22.3
21.6
17.1
17.1
N
0
25
50
m
Note: Flood contours and extents are based on limited ground survey and do not take into account buildings or fences. Do not rely on information presented without first checking with Council and obtaining more detailed survey.

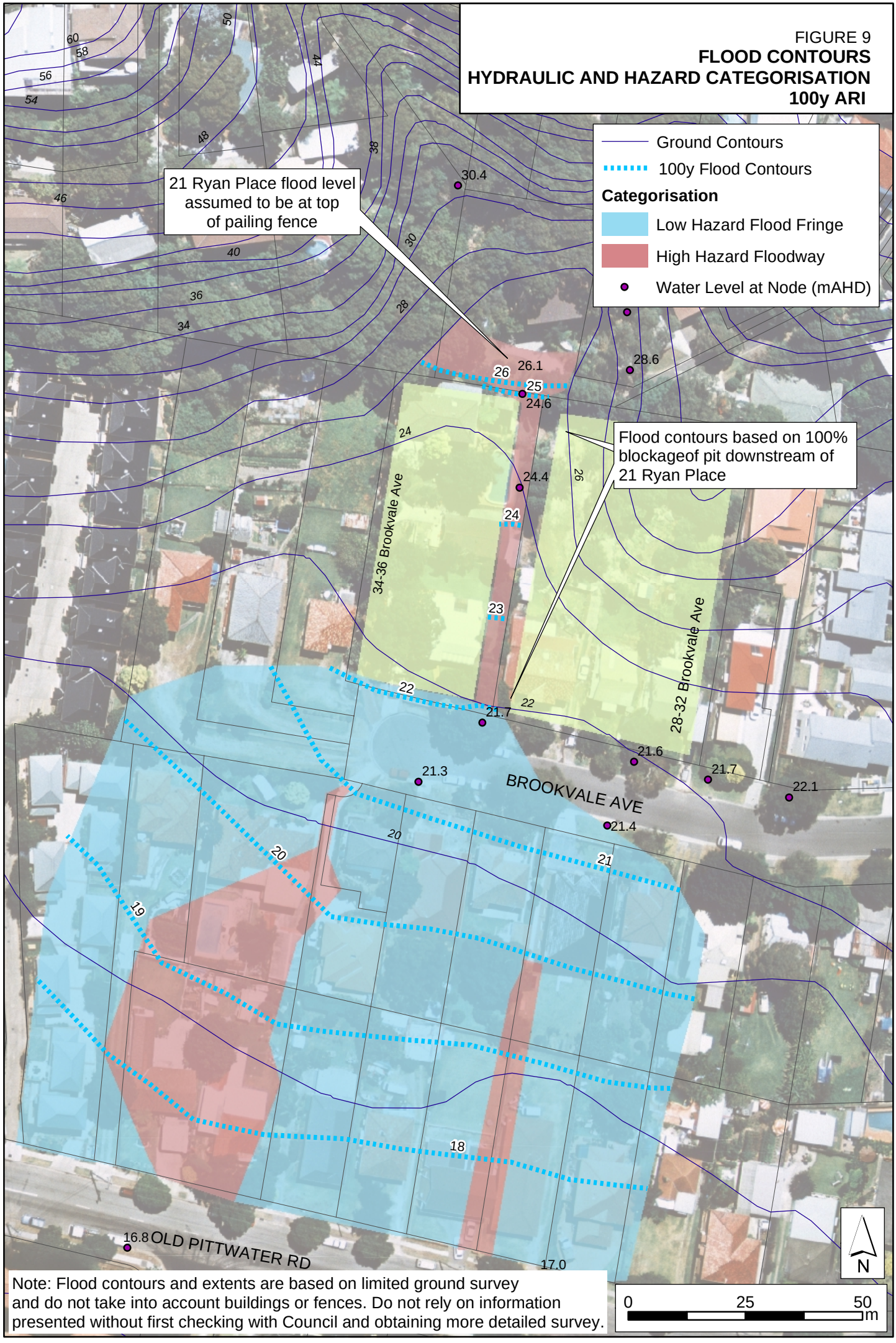


FIGURE 9
FLOOD CONTOURS
HYDRAULIC AND HAZARD CATEGORISATION
100y ARI
Ground Contours
100y Flood Contours
Categorisation
Low Hazard Flood Fringe
High Hazard Floodway
Water Level at Node (mAHD)
21 Ryan Place flood level assumed to be at top of pailing fence
Flood contours based on 100% blockageof pit downstream of 21 Ryan Place
34-36 Brookvale Ave
28-32 Brookvale Ave
BROOKVALE AVE
OLD PITTWATER RD
30.4
26.1
28.6
24.6
24.4
21.7
21.6
21.3
21.7
22.1
21.4
16.8
17.0
N
0
25
50
m
Note: Flood contours and extents are based on limited ground survey and do not take into account buildings or fences. Do not rely on information presented without first checking with Council and obtaining more detailed survey.

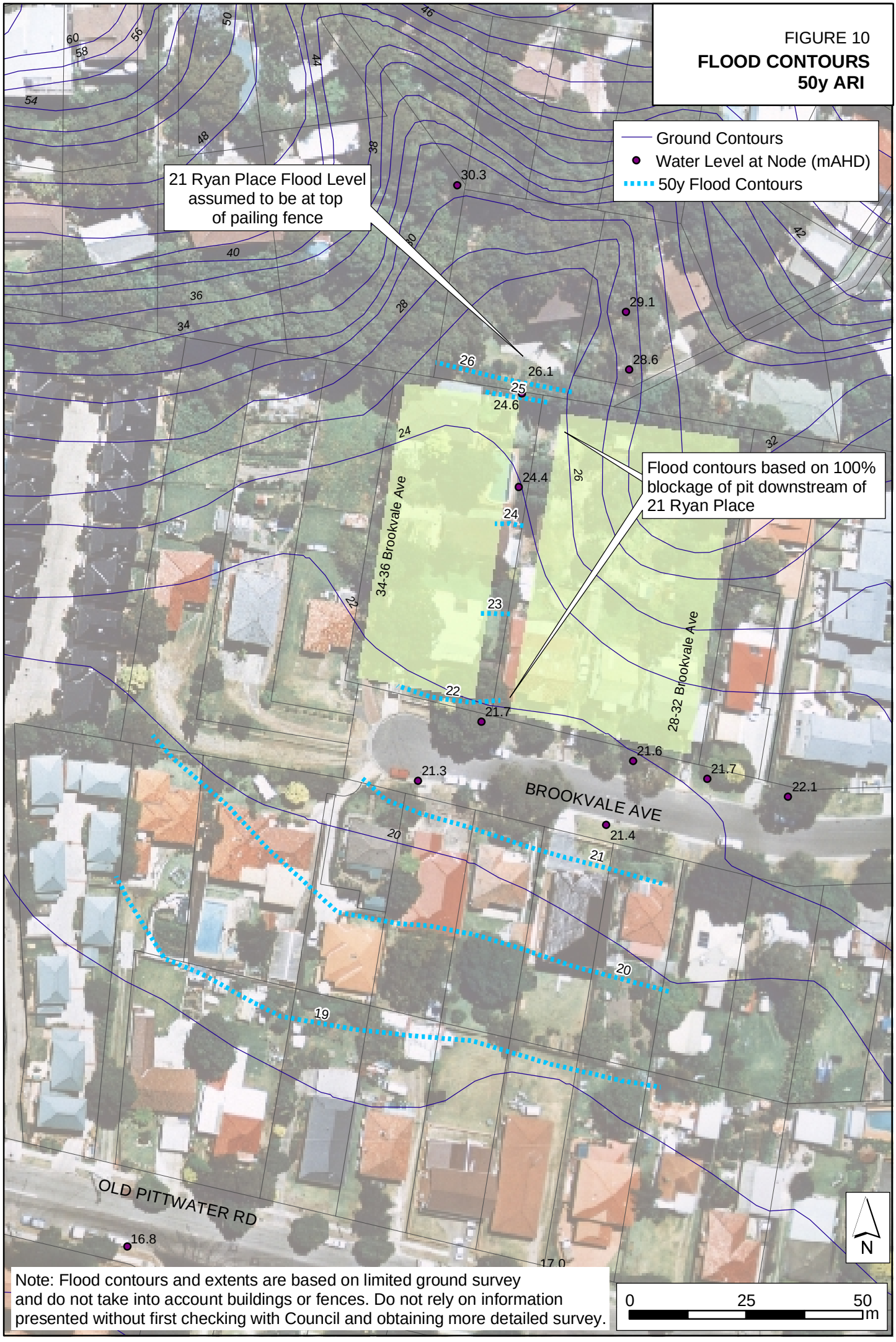


FIGURE 10
FLOOD CONTOURS
50y ARI
Ground Contours
Water Level at Node (mAHD)
50y Flood Contours
21 Ryan Place Flood Level assumed to be at top of pailing fence
Flood contours based on 100% blockage of pit downstream of 21 Ryan Place
34-36 Brookvale Ave
28-32 Brookvale Ave
BROOKVALE AVE
OLD PITTWATER RD
30.3
29.1
28.6
26.1
24.6
24.4
21.7
21.6
21.3
21.7
22.1
21.4
16.8
17.0
N
0
25
50
m
Note: Flood contours and extents are based on limited ground survey and do not take into account buildings or fences. Do not rely on information presented without first checking with Council and obtaining more detailed survey.

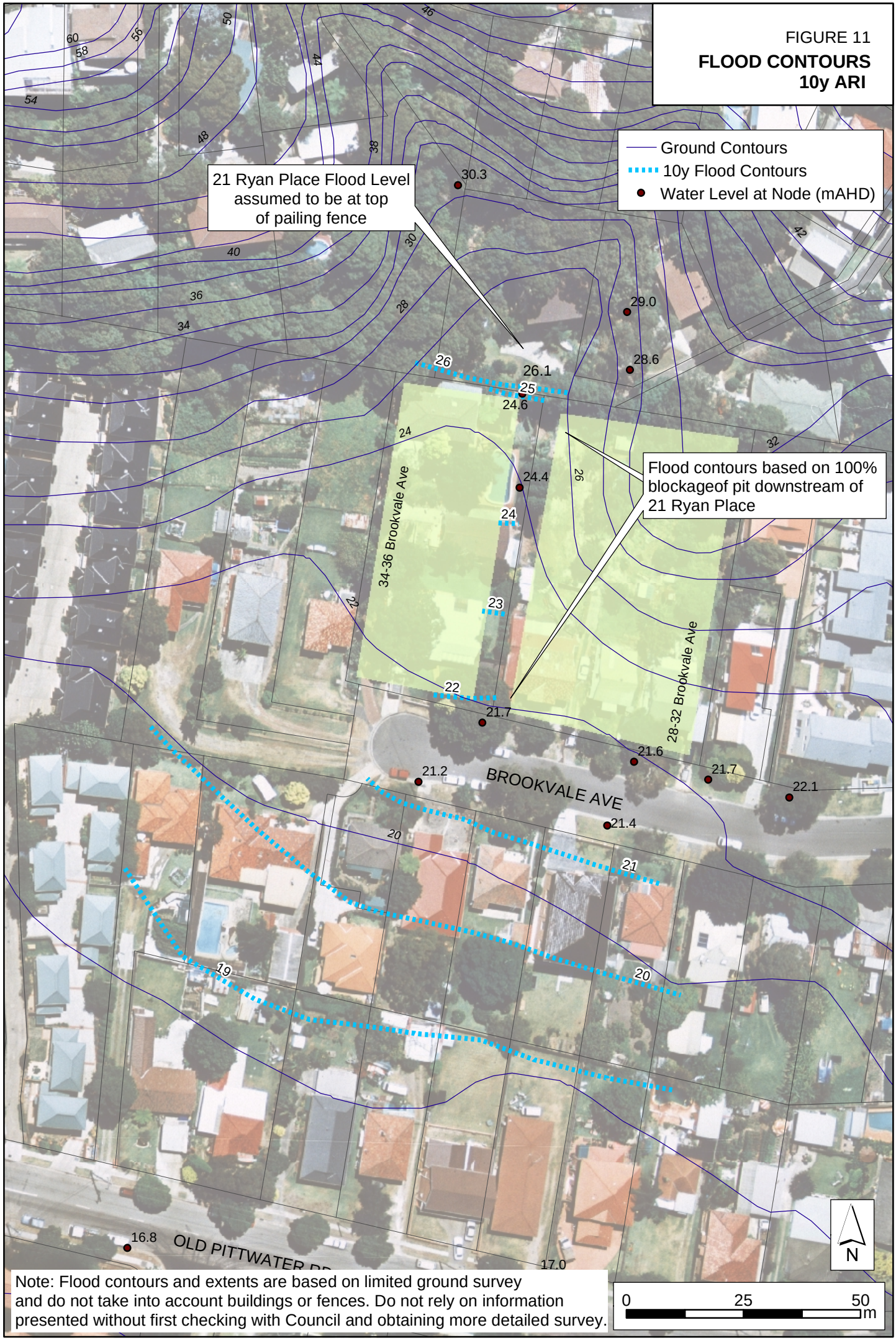


FIGURE 11
FLOOD CONTOURS
10y ARI
Ground Contours
10y Flood Contours
Water Level at Node (mAHD)
21 Ryan Place Flood Level assumed to be at top of pailing fence
Flood contours based on 100% blockageof pit downstream of 21 Ryan Place
34-36 Brookvale Ave
28-32 Brookvale Ave
BROOKVALE AVE
OLD PITTWATER RD
30.3
29.0
28.6
26.1
24.6
24.4
21.7
21.6
21.7
22.1
21.2
21.4
16.8
17.0
N
0
25
50
m
Note: Flood contours and extents are based on limited ground survey and do not take into account buildings or fences. Do not rely on information presented without first checking with Council and obtaining more detailed survey.

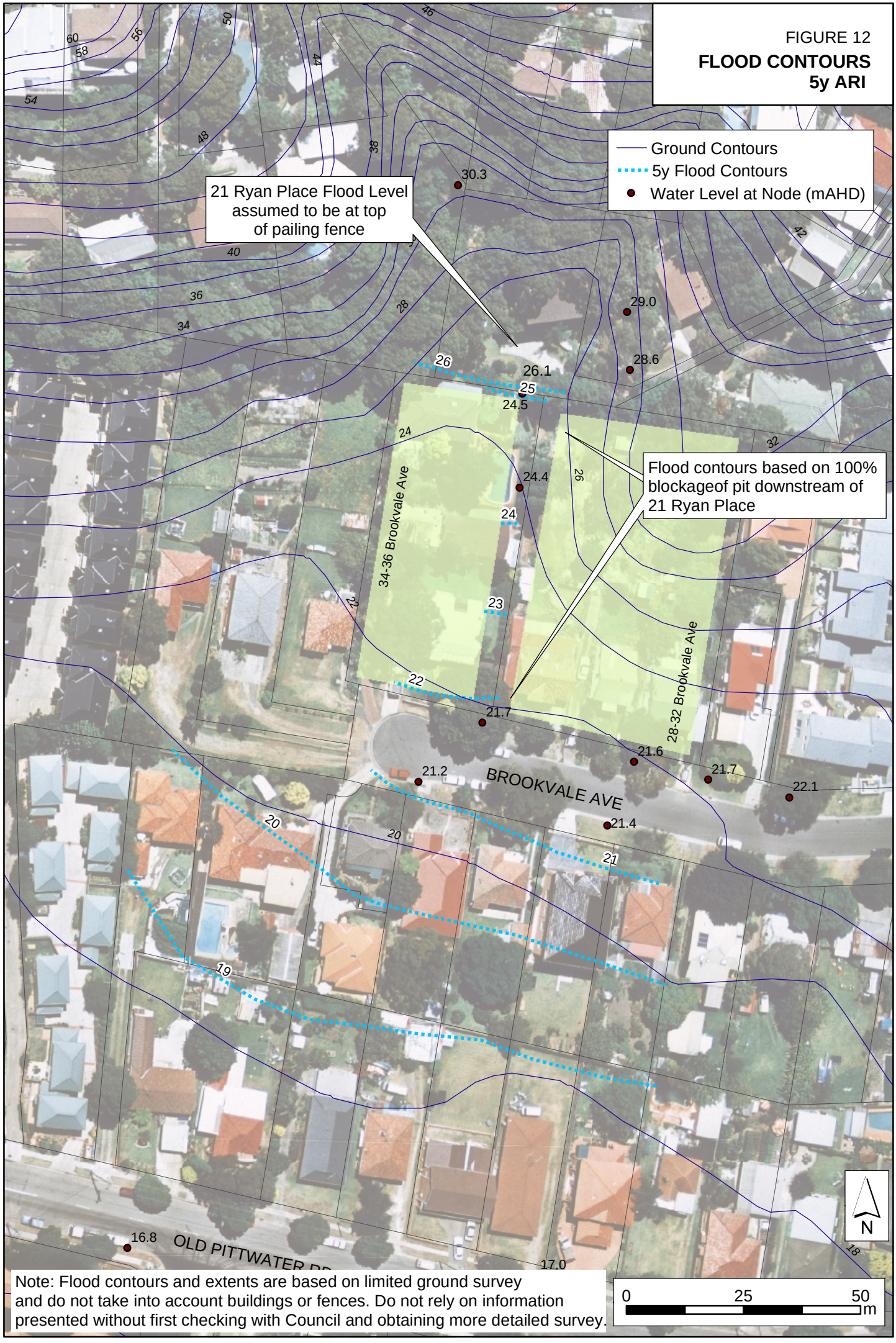
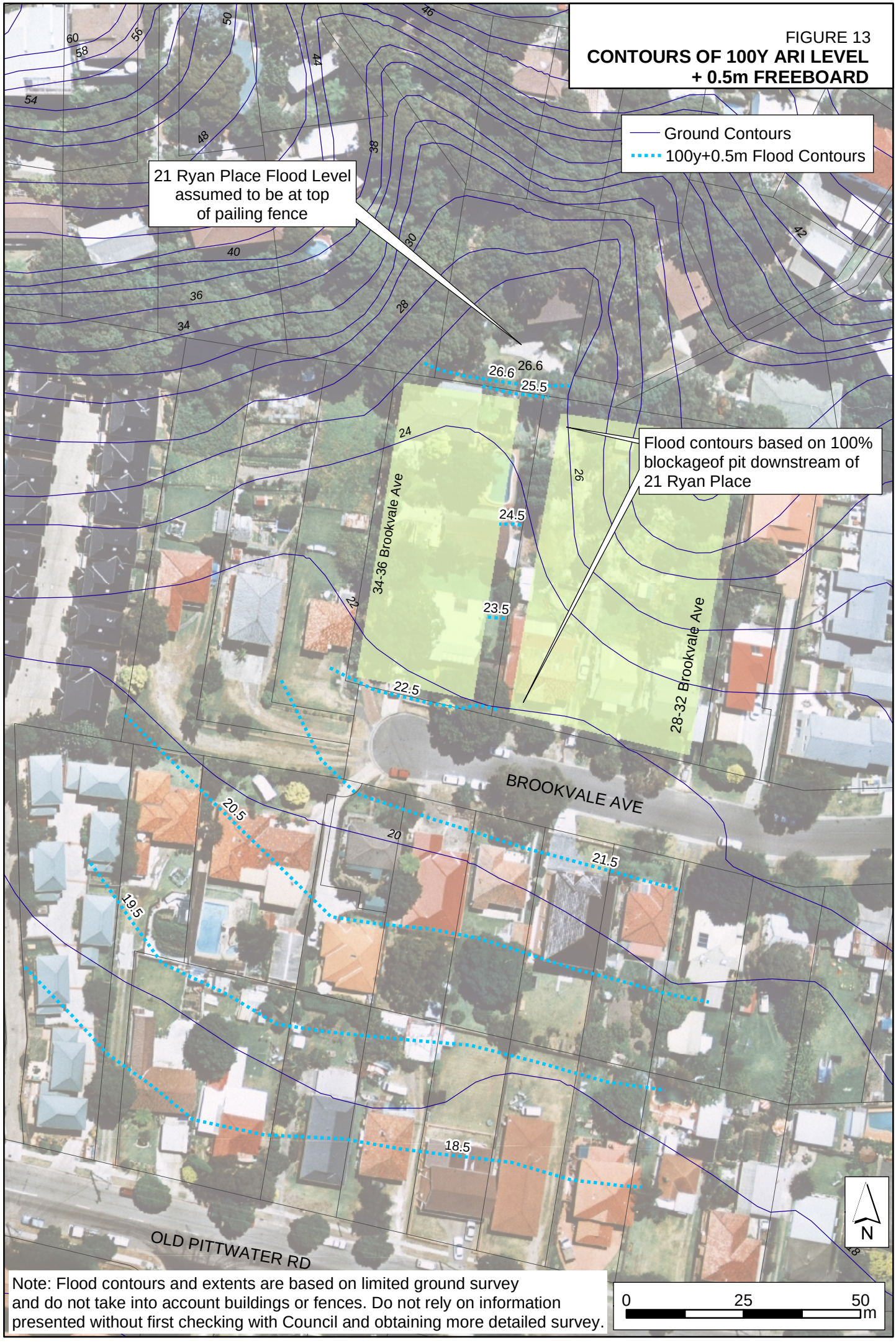


FIGURE 12
FLOOD CONTOURS
5y ARI
Ground Contours
5y Flood Contours
Water Level at Node (mAHD)
21 Ryan Place Flood Level assumed to be at top of pailing fence
Flood contours based on 100% blockageof pit downstream of 21 Ryan Place
34-36 Brookvale Ave
28-32 Brookvale Ave
BROOKVALE AVE
OLD PITTWATER RD
30.3
29.0
28.6
26.1
24.5
24.4
21.7
21.6
21.7
22.1
21.2
21.4
16.8
17.0
N
0
25
50
m
Note: Flood contours and extents are based on limited ground survey and do not take into account buildings or fences. Do not rely on information presented without first checking with Council and obtaining more detailed survey.



Note: Flood contours and extents are based on limited ground survey and do not take into account buildings or fences. Do not rely on information presented without first checking with Council and obtaining more detailed survey.

APPENDIX A: GLOSSARY OF TERMS

APPENDIX A: GLOSSARY OF FLOOD RELATED TERMS

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 peak flood discharge of 500 m^3/s or larger occurring in any one year (see average recurrence interval).

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.

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.

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.

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).

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 fringe areas The remaining area of flood prone land after floodway and flood storage areas have been defined.

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

floodplain Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.

Flood Planning Levels (FPLs) The combination of flood levels and freeboards selected for planning purposes, as determined in floodplain risk management studies and incorporated in floodplain risk management plans. The concept of flood planning levels supersedes the “standard flood event” of the first edition of this manual.

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 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.

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 Floodplain Management Manual.

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

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.
peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with the PMF event should be addressed in a Floodplain Risk Management study.
Probable Maximum Precipitation (PMP)	The greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to the estimation of the probable maximum flood.
probability	A statistical measure of the expected chance of flooding (see annual exceedance probability).
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: PIT AND PIPE DETAILS

Appendix B Table B1

IDENTIFIER AND LOCATION			INLET DETAILS		SUBCATCHMENT DETAILS			REACH DETAILS		
ID	PIT NUMBE	LOCATION	PIT TYPE	LINTEL	SUBAREA (ha)	D/S PIT	OVERFLOW TO	LENGTH (m)	PIPE DIAMETER	CULVERT WIDTH X
1655	30262-0	BEACON AVENUE	KI	1.9	0.84	30261-0	30266-0	7	375	
1654	30261-0	BEACON AVENUE	KI	1.85		30260-0	30266-0	7	375	
1691	30260-0	BEACON AVENUE	JP	1		30266-0		12	375	
1659	30266-0	BEACON AVENUE	DGGP	1.8		30258-0	30259-0	19	375	
1481	30258-0	BEACON AVENUE	DGGP	2.03		30257-0	30259-0	39	375	
1690	30259-0	BEACON AVENUE	DGGP	2.04	0.29	30258-0	30267-0	6	375	
1689	30257-0	BEACON AVENUE	KI	1.96		30256-0	30256-0	27	375	
1686	30254-0	LANDY PLACE	DGGP	2.64	0.21	30253-0	30256-0	8	375	
1685	30253-0	LANDY PLACE	DGGP	3.2	0.29	30255-0	30256-0	14	375	
1660	30267-0	RYAN PLACE	DGGP	4.86	0.87	30268-0	30268-0	6	525	
1661	30268-0	RYAN PLACE	DGGP	4.08	0.06	30268-1	30268-1	21.3	525	
1606	30256-2	BEACON AVENUE	JP	1		30267-0		4	375	
1683	30251-0	LANDY PLACE	DGGP	3.2	0.30	30252-0	30252-0	6	375	
1687	30255-0	LANDY PLACE	KI	2.62		30256-0	30256-0	11	375	
1060	30268-1	RYAN PLACE	HEADWALL	1		30284-1	30284-1	30	0	
1684	30252-0	LANDY PLACE	DGGP	3.2	0.25	30253-0	30253-0	35	375	
1493	30256-1	BEACON AVENUE	JP	1		30256-2		14	375	
1688	30256-0	BEACON AVENUE	KI	1.02	0.27	30256-1	30267-0	36	375	
1662	30269-0	RYAN PLACE	DGGP	3.15	0.05	30268-1	30268-1	21.9	375	
1663	30270-0	RYAN PLACE	DGGP	2.03	0.19	30269-0	30269-0	8	375	
1613	30284-1	RYAN PLACE	HEADWALL	1	0.40	30284-4	30284-5	19.8	525	
1579	30284-4	RYAN PLACE	JP	1		30284-0		12.2	525	
1650	30297-0	OLD PITTWATER ROAD	DGGP	2.7		30295-0	30295-0	45	600	
1614	30284-2	RYAN PLACE	JP	1		30284-0		21.3	525	
1641	30288-0	BROOKVALE AVENUE	DGGP	2.69	0.14	30297-0	30297-0	96	525	
1615	30284-3	RYAN PLACE	HEADWALL	1	0.18	30284-2	30284-5	15.2	525	
1640	30287-0	BROOKVALE AVENUE	DGGP	2.66	0.47	30288-0	30288-0	9	525	
1430	30287-1	BROOKVALE AVENUE	DGGP	0.86		30287-0	30288-0	17.2	525	
1671	30279-0	BEACON AVENUE	DGGP	2.76	0.92	30278-0	30278-0	7	375	
1670	30278-0	BEACON AVENUE	DGGP	2.98	0.09	30278-1	30271-0	18	375	
1642	30289-0	BROOKVALE AVENUE	DGGP	2.06	0.85	30287-1	30288-0	28	525	
1612	30272-2	RYAN PLACE	HEADWALL	1		30284-3	30284-3	46	0	
1611	30272-1	RYAN PLACE	JP	1		30272-2		15.2	450	
1664	30271-0	RYAN PLACE	DGGP	3.31	1.17	30272-0	30272-0	7.9	375	
1608	30278-2	BEACON AVENUE	JP	1		30278-3		10.7	375	
1610	30278-4	BEACON AVENUE	JP	1		30271-0		18	525	
1665	30272-0	RYAN PLACE	DGGP	3.29	0.12	30272-1	30272-2	8	450	
1607	30278-1	BEACON AVENUE	JP	1		30278-2		0	375	
1609	30278-3	BEACON AVENUE	JP	1		30278-4		14.3	375	
1666	30273-0	RYAN PLACE	DGGP	2.06		30272-0	30272-0	56	450	
1667	30274-0	RYAN PLACE	DGGP	2.69		30273-0	30273-0	8	375	
1150	30291-1	BROOKVALE AVENUE	JP	1		30292-0		58.4	450	
1668	30275-0	RYAN PLACE	DGGP	2.06	0.98	30274-0	30274-0	6	375	
1644	30291-0	BROOKVALE AVENUE	DGGP	2.7		30291-1	30292-0	80	450	
1496	30276-0	RYAN PLACE	DGGP	2.03	0.05	30273-0	30273-0	66	375	
1643	30290-0	BROOKVALE AVENUE	DGGP	2.7		30291-0	30291-0	6	450	
1669	30277-0	RYAN PLACE	DGGP	2	0.35	30276-0	30276-0	10	375	
1652	30299-0	OLD PITTWATER ROAD	DGGP	2.07		30299-1	30300-0	3	900	
1580	30286-1	BROOKVALE AVENUE	JP	1		30286-2		0	750	
1639	30286-0	BROOKVALE AVENUE	DGGP	4.43	0.05	30285-1	30299-0	12	450	
1638	30285-0	BROOKVALE AVENUE	DGGP	1.03	0.35	30285-1	30286-0	18	750	
1149	30286-2	BROOKVALE AVENUE	JP	1		30286-3		0	750	
1527	30285-1	BROOKVALE AVENUE	JP	1		30286-1		6	750	
1205	30286-3	BROOKVALE AVENUE	JP	1		30299-0		7.2	900	
1206	30299-1	OLD PITTWATER ROAD	JP	1		30300-0	30300-0	85	BC60120	BC60120
9000	30284-0	RYAN PLACE	JP	1		30284-5		2	675	
9001	30284-5	RYAN PLACE	DGGP	6.7	0.37	30285-0		72.3	1500*900	1500*900
9002	30282-0	RYAN PLACE	KI	1	0.18	30283-0		10.3	450	
9003	30283-0	RYAN PLACE	JP	1		30284-2		4.5	450	
9004	30300-0	OLD PITTWATER ROAD	KI	1					outlet	
9005	30292-0	OLD PITTWATER ROAD	KI	1					outlet	
9006	30295-0	OLD PITTWATER ROAD	KI	1					outlet	

APPENDIX C: DESIGN FLOOD RESULTS

LOCATION			5y ARI FLOWS (m^3/s)				10y ARI FLOWS (m^3/s)			
ID	PIT NUMBER	LOCATION	Sub-catchment	PIPE	D/S OVERLAND	TOTAL (pipe + d/s overland)	Sub-catchment	PIPE	D/S OVERLAND	TOTAL (pipe + d/s overland)
1655	30262-0	BEACON AVENUE	0.35	0.01	0.33	0.35	0.40	0.02	0.39	0.40
1654	30261-0	BEACON AVENUE		0.01	0.01	0.03		0.02	0.01	0.03
1691	30260-0	BEACON AVENUE		0.01		0.01		0.02	#N/A	0.02
1659	30266-0	BEACON AVENUE		0.05	0.30	0.35		0.06	0.35	0.41
1481	30258-0	BEACON AVENUE		0.12	0.00	0.12		0.13	0.00	0.13
1690	30259-0	BEACON AVENUE	0.12	0.02	0.36	0.38	0.14	0.03	0.41	0.44
1689	30257-0	BEACON AVENUE		0.12	0.00	0.12		0.13	0.00	0.13
1686	30254-0	LANDY PLACE	0.09	0.02	0.07	0.09	0.10	0.02	0.08	0.10
1685	30253-0	LANDY PLACE	0.12	0.14	0.23	0.37	0.14	0.15	0.27	0.42
1660	30267-0	RYAN PLACE	0.36	0.45	0.93	1.38	0.42	0.51	1.08	1.59
1661	30268-0	RYAN PLACE	0.03	0.52	0.89	1.41	0.03	0.59	1.04	1.62
1606	30256-2	BEACON AVENUE		0.26		0.26		0.29		0.29
1683	30251-0	LANDY PLACE	0.13	0.03	0.09	0.13	0.14	0.04	0.11	0.14
1687	30255-0	LANDY PLACE		0.14	0.00	0.14		0.15	0.00	0.16
1060	30268-1	RYAN PLACE			1.51	1.51			1.74	1.74
1684	30252-0	LANDY PLACE	0.10	0.05	0.18	0.23	0.12	0.06	0.20	0.26
1493	30256-1	BEACON AVENUE		0.26		0.26		0.29		0.29
1688	30256-0	BEACON AVENUE	0.11	0.26	0.41	0.67	0.13	0.29	0.47	0.77
1662	30269-0	RYAN PLACE	0.02	0.05	0.06	0.10	0.02	0.05	0.07	0.12
1663	30270-0	RYAN PLACE	0.08	0.04	0.04	0.08	0.09	0.04	0.06	0.10
1613	30284-1	RYAN PLACE	0.17	0.01	1.66	1.68	0.19	0.01	1.91	1.93
1579	30284-4	RYAN PLACE		0.01		0.01		0.01		0.01
1650	30297-0	OLD PITTWATER ROAD		0.18	0.42	0.60		0.20	0.49	0.69
1614	30284-2	RYAN PLACE		0.02		0.02		0.03		0.03
1641	30288-0	BROOKVALE AVENUE	0.06	0.13	0.47	0.60	0.07	0.15	0.54	0.69
1615	30284-3	RYAN PLACE	0.08	0.02	1.56	1.58	0.09	0.02	1.81	1.82
1640	30287-0	BROOKVALE AVENUE	0.20	0.07	0.16	0.23	0.22	0.08	0.19	0.27
1430	30287-1	BROOKVALE AVENUE		0.04	0.00	0.04		0.04	0.00	0.04
1671	30279-0	BEACON AVENUE	0.38	0.12	0.26	0.38	0.44	0.13	0.30	0.44
1670	30278-0	BEACON AVENUE	0.04	0.14	0.28	0.42	0.05	0.16	0.32	0.48
1642	30289-0	BROOKVALE AVENUE	0.35	0.04	0.31	0.35	0.41	0.04	0.36	0.40
1612	30272-2	RYAN PLACE			1.51	1.51			1.74	1.74
1611	30272-1	RYAN PLACE		0.59		0.59		0.68		0.68
1664	30271-0	RYAN PLACE	0.48	0.30	0.59	0.89	0.56	0.34	0.69	1.03
1608	30278-2	BEACON AVENUE		0.14		0.14		0.16		0.16
1610	30278-4	BEACON AVENUE		0.14		0.14		0.16		0.16
1665	30272-0	RYAN PLACE	0.05	0.59	0.91	1.51	0.06	0.68	1.06	1.74
1607	30278-1	BEACON AVENUE		0.14		0.14		0.16		0.16
1609	30278-3	BEACON AVENUE		0.14		0.14		0.16		0.16
1666	30273-0	RYAN PLACE		0.22	0.35	0.57		0.25	0.40	0.65
1667	30274-0	RYAN PLACE		0.12	0.29	0.41		0.13	0.33	0.47
1150	30291-1	BROOKVALE AVENUE		0.00		0.00		0.00		0.00
1668	30275-0	RYAN PLACE	0.41	0.03	0.38	0.41	0.47	0.03	0.44	0.47
1644	30291-0	BROOKVALE AVENUE		0.00	0.01	0.01		0.00	0.01	0.01
1496	30276-0	RYAN PLACE	0.02	0.04	0.13	0.17	0.03	0.04	0.15	0.19
1643	30290-0	BROOKVALE AVENUE		0.00	0.00	0.00		0.00	0.00	0.00
1669	30277-0	RYAN PLACE	0.15	0.02	0.13	0.15	0.17	0.02	0.15	0.17
1652	30299-0	OLD PITTWATER ROAD		0.67	2.52	3.19		0.70	3.10	3.80
1580	30286-1	BROOKVALE AVENUE		1.14		1.14		1.32		1.32
1639	30286-0	BROOKVALE AVENUE	0.02	0.01	2.06	2.06	0.02	0.01	2.48	2.49
1638	30285-0	BROOKVALE AVENUE	0.15	1.34	1.85	3.19	0.17	1.44	2.34	3.78
1149	30286-2	BROOKVALE AVENUE		1.14		1.14		1.32		1.32
1527	30285-1	BROOKVALE AVENUE		1.14		1.14		1.32		1.32
1205	30286-3	BROOKVALE AVENUE		1.14		1.14		1.32		1.32
1206	30299-1	OLD PITTWATER ROAD		0.67		0.67		0.70		0.70
9000	30284-0	RYAN PLACE		0.03		0.03		0.04		0.04
9001	30284-5	RYAN PLACE	0.16	1.98	1.17	3.15	0.18	2.19	1.50	3.69
9002	30282-0	RYAN PLACE	0.08	0.01	0.07	0.08	0.09	0.01	0.08	0.09
9003	30283-0	RYAN PLACE		0.01		0.01		0.01		0.01
9004	30300-0	OLD PITTWATER ROAD								
9005	30292-0	OLD PITTWATER ROAD								
9006	30295-0	OLD PITTWATER ROAD								

Note: Inlet pits assumed to be 50% blocked.

LOCATION			50y ARI FLOWS (m^3/s)				100y ARI FLOWS (m^3/s)			
ID	PIT NUMBER	LOCATION	Sub-catchment	PIPE	D/S OVERLAND	TOTAL (pipe + d/s overland)	Sub-catchment	PIPE	D/S OVERLAND	TOTAL (pipe + d/s overland)
1655	30262-0	BEACON AVENUE	0.50	0.02	0.48	0.50	0.56	0.02	0.54	0.56
1654	30261-0	BEACON AVENUE		0.02	0.01	0.03		0.02	0.01	0.03
1691	30260-0	BEACON AVENUE		0.02		0.02		0.02		0.02
1659	30266-0	BEACON AVENUE		0.07	0.43	0.50		0.08	0.49	0.57
1481	30258-0	BEACON AVENUE		0.16	0.00	0.16		0.17	0.00	0.17
1690	30259-0	BEACON AVENUE	0.18	0.03	0.52	0.55	0.20	0.04	0.59	0.62
1689	30257-0	BEACON AVENUE		0.16	0.00	0.16		0.17	0.00	0.18
1686	30254-0	LANDY PLACE	0.13	0.02	0.10	0.13	0.14	0.03	0.11	0.14
1685	30253-0	LANDY PLACE	0.17	0.19	0.33	0.52	0.19	0.21	0.37	0.58
1660	30267-0	RYAN PLACE	0.52	0.63	1.35	1.98	0.58	0.70	1.52	2.22
1661	30268-0	RYAN PLACE	0.04	0.72	1.30	2.01	0.04	0.80	1.46	2.26
1606	30256-2	BEACON AVENUE		0.36		0.36		0.40		0.40
1683	30251-0	LANDY PLACE	0.18	0.05	0.13	0.18	0.20	0.05	0.15	0.20
1687	30255-0	LANDY PLACE		0.19	0.00	0.19		0.21	0.00	0.21
1060	30268-1	RYAN PLACE			2.16	2.16			2.43	2.43
1684	30252-0	LANDY PLACE	0.15	0.07	0.25	0.33	0.17	0.08	0.29	0.37
1493	30256-1	BEACON AVENUE		0.36		0.36		0.40		0.40
1688	30256-0	BEACON AVENUE	0.16	0.36	0.59	0.94	0.18	0.40	0.66	1.06
1662	30269-0	RYAN PLACE	0.03	0.05	0.09	0.15	0.03	0.06	0.11	0.17
1663	30270-0	RYAN PLACE	0.11	0.05	0.08	0.13	0.13	0.05	0.09	0.14
1613	30284-1	RYAN PLACE	0.24	0.02	2.38	2.39	0.27	0.02	2.67	2.69
1579	30284-4	RYAN PLACE		0.02		0.02		0.02		0.02
1650	30297-0	OLD PITTWATER ROAD		0.25	0.61	0.86		0.28	0.69	0.97
1614	30284-2	RYAN PLACE		0.03		0.03		0.03		0.03
1641	30288-0	BROOKVALE AVENUE	0.08	0.18	0.68	0.86	0.09	0.20	0.76	0.97
1615	30284-3	RYAN PLACE	0.11	0.02	2.25	2.27	0.12	0.02	2.50	2.52
1640	30287-0	BROOKVALE AVENUE	0.28	0.10	0.23	0.33	0.31	0.11	0.26	0.37
1430	30287-1	BROOKVALE AVENUE		0.05	0.00	0.05		0.06	0.00	0.06
1671	30279-0	BEACON AVENUE	0.54	0.16	0.39	0.54	0.61	0.17	0.44	0.61
1670	30278-0	BEACON AVENUE	0.06	0.18	0.41	0.60	0.06	0.20	0.47	0.67
1642	30289-0	BROOKVALE AVENUE	0.50	0.05	0.45	0.50	0.57	0.06	0.51	0.56
1612	30272-2	RYAN PLACE			2.16	2.16			2.40	2.40
1611	30272-1	RYAN PLACE		0.82		0.82		0.88		0.88
1664	30271-0	RYAN PLACE	0.69	0.41	0.87	1.29	0.78	0.44	0.99	1.43
1608	30278-2	BEACON AVENUE		0.18		0.18		0.20		0.20
1610	30278-4	BEACON AVENUE		0.18		0.18		0.20		0.20
1665	30272-0	RYAN PLACE	0.07	0.82	1.34	2.16	0.08	0.88	1.52	2.40
1607	30278-1	BEACON AVENUE		0.18		0.18		0.20		0.20
1609	30278-3	BEACON AVENUE		0.18		0.18		0.20		0.20
1666	30273-0	RYAN PLACE		0.30	0.51	0.81		0.34	0.57	0.91
1667	30274-0	RYAN PLACE		0.16	0.42	0.58		0.18	0.47	0.65
1150	30291-1	BROOKVALE AVENUE		0.00		0.00		0.00		0.00
1668	30275-0	RYAN PLACE	0.58	0.04	0.55	0.58	0.66	0.04	0.61	0.66
1644	30291-0	BROOKVALE AVENUE		0.00	0.01	0.01		0.00	0.01	0.01
1496	30276-0	RYAN PLACE	0.03	0.05	0.18	0.24	0.03	0.06	0.20	0.26
1643	30290-0	BROOKVALE AVENUE		0.00	0.00	0.00		0.00	0.00	0.00
1669	30277-0	RYAN PLACE	0.21	0.03	0.18	0.21	0.23	0.03	0.20	0.23
1652	30299-0	OLD PITTWATER ROAD		0.74	4.28	5.02		0.75	4.85	5.60
1580	30286-1	BROOKVALE AVENUE		1.62		1.62		1.71		1.71
1639	30286-0	BROOKVALE AVENUE	0.03	0.05	3.41	3.47	0.03	0.08	3.90	3.98
1638	30285-0	BROOKVALE AVENUE	0.21	1.57	3.45	5.02	0.24	1.63	3.96	5.60
1149	30286-2	BROOKVALE AVENUE		1.62		1.62		1.71		1.71
1527	30285-1	BROOKVALE AVENUE		1.62		1.62		1.71		1.71
1205	30286-3	BROOKVALE AVENUE		1.62		1.62		1.71		1.71
1206	30299-1	OLD PITTWATER ROAD		0.74		0.74		0.75		0.75
9000	30284-0	RYAN PLACE		0.05		0.05		0.05		0.05
9001	30284-5	RYAN PLACE	0.22	2.57	2.31	4.88	0.25	2.80	2.63	5.43
9002	30282-0	RYAN PLACE	0.11	0.01	0.10	0.11	0.12	0.01	0.11	0.12
9003	30283-0	RYAN PLACE		0.01		0.01		0.01		0.01
9004	30300-0	OLD PITTWATER ROAD								
9005	30292-0	OLD PITTWATER ROAD								
9006	30295-0	OLD PITTWATER ROAD								

Note: Inlet pits assumed to be 50% blocked.

LOCATION			PMF FLOWS (m^3/s)			
ID	PIT NUMBER	LOCATION	Sub-catchment	PIPE	D/S OVERLAND	TOTAL (pipe + d/s overland)
1655	30262-0	BEACON AVENUE	2.19	0.08	2.11	2.18
1654	30261-0	BEACON AVENUE		0.08	0.01	0.09
1691	30260-0	BEACON AVENUE		0.08		0.08
1659	30266-0	BEACON AVENUE		0.19	2.00	2.19
1481	30258-0	BEACON AVENUE		0.27	0.01	0.27
1690	30259-0	BEACON AVENUE	0.76	0.05	2.69	2.74
1689	30257-0	BEACON AVENUE		0.26	0.00	0.26
1686	30254-0	LANDY PLACE	0.55	0.09	0.46	0.55
1685	30253-0	LANDY PLACE	0.75	0.66	1.59	2.26
1660	30267-0	RYAN PLACE	2.28	1.57	7.07	8.64
1661	30268-0	RYAN PLACE	0.17	2.00	6.81	8.80
1606	30256-2	BEACON AVENUE		0.97		0.97
1683	30251-0	LANDY PLACE	0.78	0.18	0.60	0.78
1687	30255-0	LANDY PLACE		0.66	0.00	0.67
1060	30268-1	RYAN PLACE			9.42	9.42
1684	30252-0	LANDY PLACE	0.64	0.27	1.14	1.42
1493	30256-1	BEACON AVENUE		0.97		0.97
1688	30256-0	BEACON AVENUE	0.71	0.97	2.71	3.69
1662	30269-0	RYAN PLACE	0.12	0.14	0.48	0.62
1663	30270-0	RYAN PLACE	0.50	0.11	0.38	0.50
1613	30284-1	RYAN PLACE	1.05	0.07	10.39	10.46
1579	30284-4	RYAN PLACE		0.07		0.07
1650	30297-0	OLD PITTWATER ROAD		0.96	2.79	3.75
1614	30284-2	RYAN PLACE		0.13		0.13
1641	30288-0	BROOKVALE AVENUE	0.36	0.73	3.03	3.75
1615	30284-3	RYAN PLACE	0.47	0.09	9.87	9.96
1640	30287-0	BROOKVALE AVENUE	1.21	0.39	1.00	1.39
1430	30287-1	BROOKVALE AVENUE		0.18	0.00	0.18
1671	30279-0	BEACON AVENUE	2.38	0.32	2.11	2.44
1670	30278-0	BEACON AVENUE	0.24	0.39	2.23	2.62
1642	30289-0	BROOKVALE AVENUE	2.20	0.18	2.02	2.20
1612	30272-2	RYAN PLACE			9.51	9.51
1611	30272-1	RYAN PLACE		0.98		0.98
1664	30271-0	RYAN PLACE	3.03	0.53	5.40	5.92
1608	30278-2	BEACON AVENUE		0.39		0.39
1610	30278-4	BEACON AVENUE		0.39		0.39
1665	30272-0	RYAN PLACE	0.31	0.98	8.53	9.51
1607	30278-1	BEACON AVENUE		0.39		0.39
1609	30278-3	BEACON AVENUE		0.39		0.39
1666	30273-0	RYAN PLACE		0.42	3.21	3.63
1667	30274-0	RYAN PLACE		0.24	2.42	2.65
1150	30291-1	BROOKVALE AVENUE		0.00		0.00
1668	30275-0	RYAN PLACE	2.55	0.14	2.41	2.55
1644	30291-0	BROOKVALE AVENUE		0.00	0.01	0.01
1496	30276-0	RYAN PLACE	0.13	0.21	0.82	1.03
1643	30290-0	BROOKVALE AVENUE		0.00	0.00	0.00
1669	30277-0	RYAN PLACE	0.90	0.10	0.80	0.90
1652	30299-0	OLD PITTWATER ROAD		0.88	19.50	20.37
1580	30286-1	BROOKVALE AVENUE		2.61		2.61
1639	30286-0	BROOKVALE AVENUE	0.13	0.38	17.78	18.16
1638	30285-0	BROOKVALE AVENUE	0.92	2.24	18.05	20.28
1149	30286-2	BROOKVALE AVENUE		2.61		2.61
1527	30285-1	BROOKVALE AVENUE		2.61		2.61
1205	30286-3	BROOKVALE AVENUE		2.61		2.61
1206	30299-1	OLD PITTWATER ROAD		0.88		0.88
9000	30284-0	RYAN PLACE		0.20		0.20
9001	30284-5	RYAN PLACE	0.98	4.86	14.68	19.54
9002	30282-0	RYAN PLACE	0.48	0.04	0.44	0.48
9003	30283-0	RYAN PLACE		0.04		0.04
9004	30300-0	OLD PITTWATER ROAD				
9005	30292-0	OLD PITTWATER ROAD				
9006	30295-0	OLD PITTWATER ROAD				

Note: Inlet pits assumed to be 50% blocked.

APPENDIX D: SAMPLE COMMUNITY QUESTIONNAIRE

RYAN PLACE OVERLAND FLOOD STUDY

for Warringah Council

COMMUNITY SURVEY – NOVEMBER 2004

Dear Resident,

Council is currently undertaking engineering studies of flooding in the area downstream of Ryan Place to Old Pittwater Road and we are seeking your input. It would be appreciated if you could take the time to read the following information. Your knowledge and assistance will serve to improve the quality and reliability of the outcomes from this study.

Thankyou!

BACKGROUND

The State Government's Flood Policy aims to reduce the impacts of flooding and flood liability on individual owners and occupiers, and to reduce private and public losses resulting from flooding. The Policy encourages the development of:

- solutions to existing flood problems in developed areas and
- strategies for ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in developed areas.

Under the Policy, Warringah Council has the responsibility for managing flood liable land in this study area.

THE PRESENT STUDY

Warringah Council has commissioned **Webb, McKeown & Associates Pty Ltd**, (the Consultant), to undertake the Ryan Place Overland Flood Study. The study is funded by Warringah Council.

The Study includes the entire catchment area from the top of the hill near Henricks Place to Old Pittwater Road. However flood level information will only be determined downstream of Ryan Place (refer figure).

The Study will define the nature of the flood risk by providing information on the extent, level and velocity of floodwaters for a range of flood events up to and including the probable maximum flood (PMF).

Survey Questions Overleaf….

WE NEED YOUR HELP

Recently, you may have seen notices placed in the Manly Daily and on Council's Internet site (www.warringah.nsw.gov.au/notices.htm) regarding the commencement of this Study. As part of the initial phases of the project, the Consultant is seeking to collect any available information regarding flooding in the catchment. The Consultant has already spoken to Mr Williams of 21 Kilburn Close but hopes that other residents may be able to help.

We have prepared a brief set of questions to help us identify potential sources of flood related information (see below). If you (or anyone that you may know) can assist us, please fill out the details below and return them using the reply-paid envelope enclosed (no stamp required). The Consultant may then contact you to discuss your information and to arrange for a resident interview if appropriate. Alternatively, you can contact the Consultant directly using the details provided below:

Consultant Contact

Karen Lancaster - Environmental Engineer, Webb McKeown & Associates Pty Ltd
Tel: 9299 2855: Fax: 9262 6208: E-mail: lancaster@webbmckeown.com.au

Should you require further information from Council in regard to the above please contact either:

Valerie Tulk
Environmental Projects Officer
Tel: 9942 2359
E-mail: tulkv@warringah.nsw.gov.au

OR

Katrina Brown,
Team Leader - Catchment Management
Tel: 9942 2911
E-mail: katrina.brown@warringah.nsw.gov.au

Thankyou for your time!

Contact name: _____ Date: _____

Address: _____ Telephone No: _____

_____ E-mail: _____

When did you first live in the area or become familiar with this property? _____ *(year approximately)*

Do you have photographs of floods or a diary describing floods or any other flood related information, (e.g. newspaper cuttings, written records, personal knowledge) which may assist us?

" Yes " No

To the best of your knowledge, has your house or yard been inundated by floodwaters in the past?

" Yes " No

If so, would you be able to identify levels on your property where any past flooding came to?

" Yes " No

Please use the remainder of this sheet to provide any further information. Your assistance will shape the future of flood management within this catchment and we welcome your input.

_____

_____

_____

_____

_____

NOTE: This information will be held by Council and only used for the purposes of this study.