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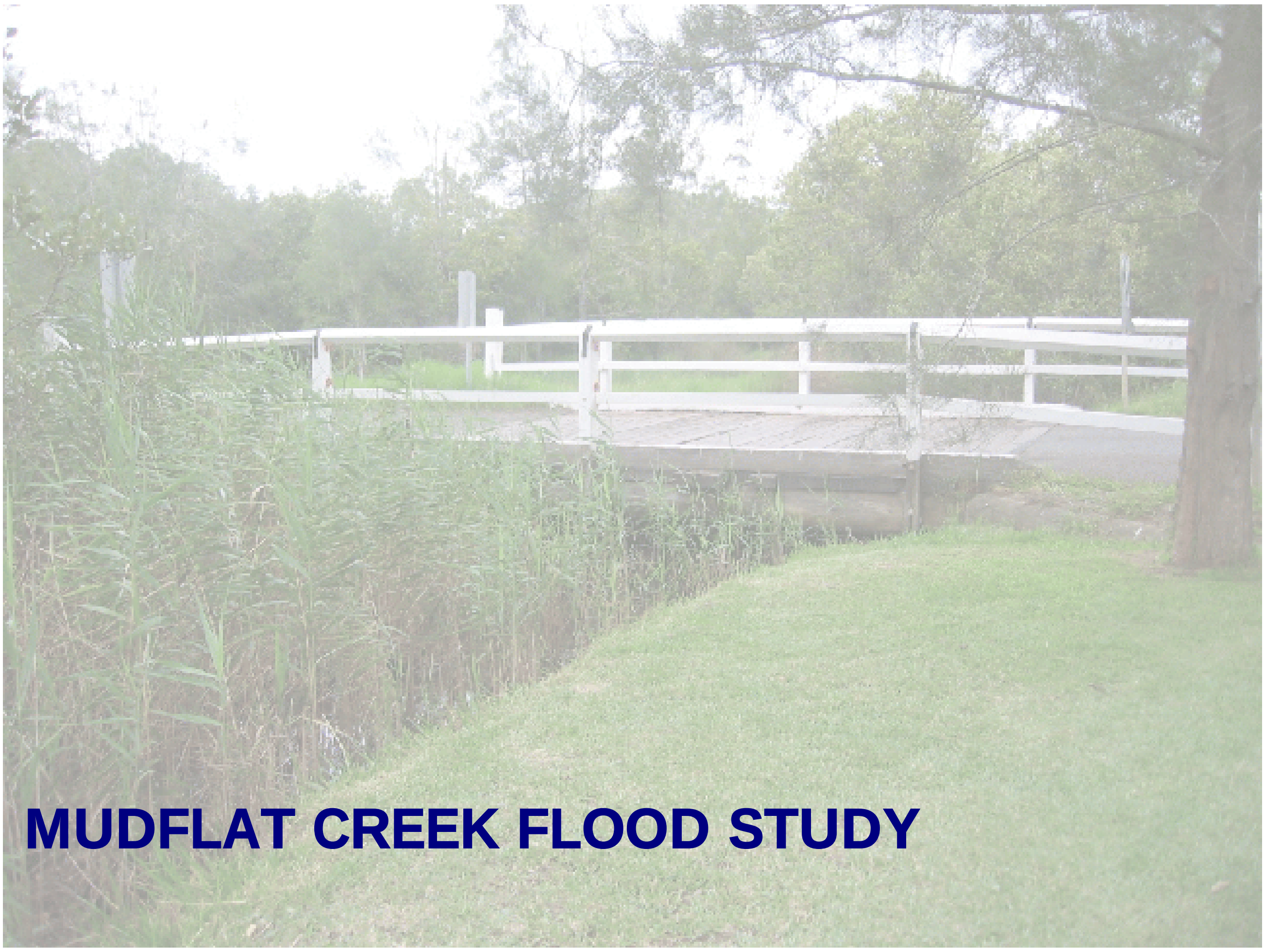
Adopted by Gosford Council on 10-Jan-06,
Minute Number 2006/15-A of FM05/4

NSW Government
DEPARTMENT OF NATURAL RESOURCES

GOSFORD CITY COUNCIL
CENTRAL COAST

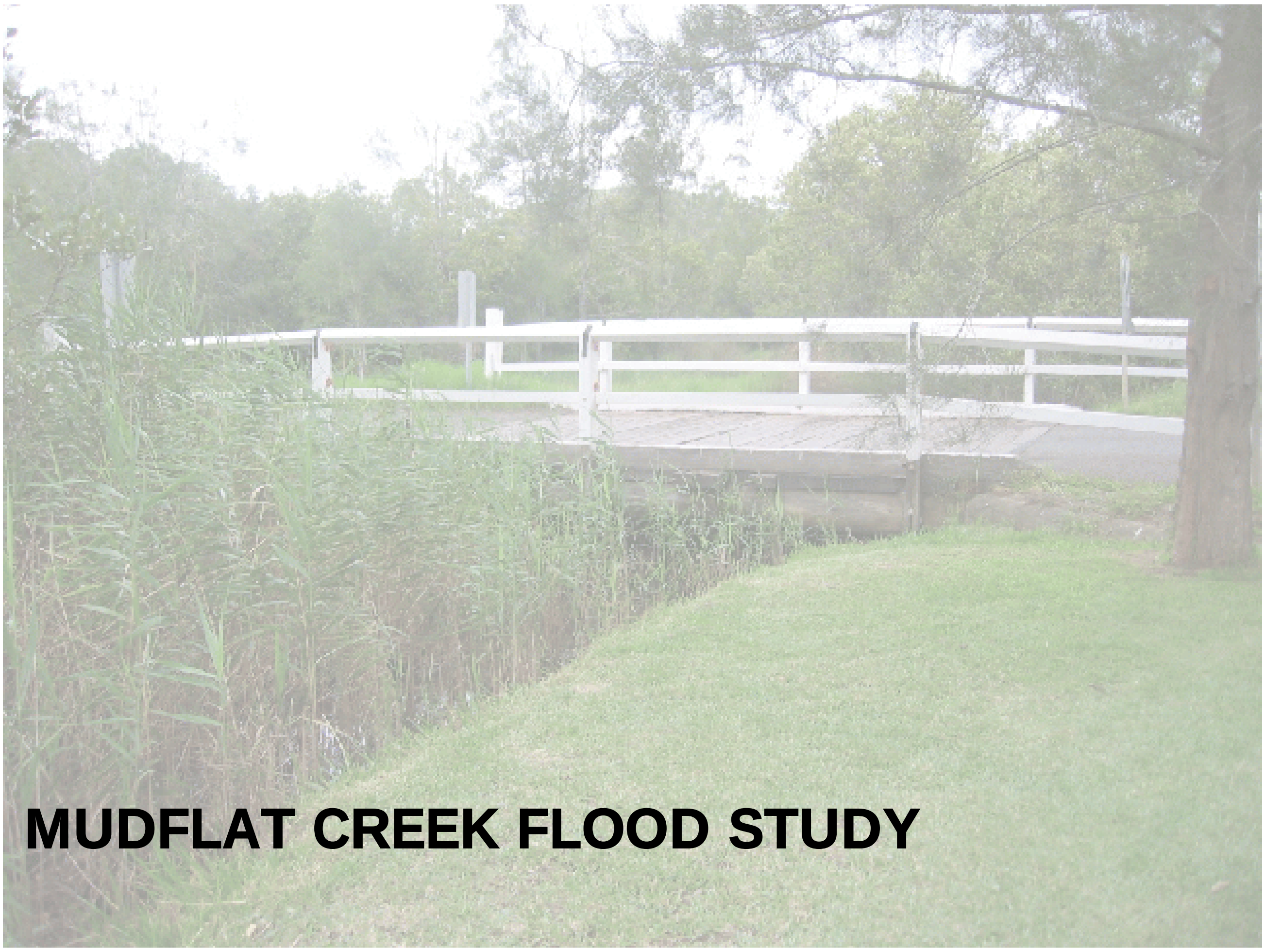


MUDFLAT CREEK FLOOD STUDY

NOVEMBER 2006

WEBB, McKEOWN & ASSOCIATES PTY LTD

GOSFORD CITY COUNCIL



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MUDFLAT CREEK FLOOD STUDY

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF DIAGRAMS

LIST OF TABLES

LIST OF PHOTOGRAPHS

LIST OF FIGURES

FOREWORD

The NSW State Government's Flood Prone Land 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 risk management responsibilities.

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

1. *Formation of a Floodplain Risk Management Committee*
   - an advisory committee of Council which includes representatives of relevant Government authorities and the community.
2. *Data Collection*
   - compilation of existing data and collection of additional data.
3. *Flood Study*
   - determine the nature and extent of the flood problem.
4. *Floodplain Risk Management Study*
   - evaluates management options for the floodplain in respect of both existing and proposed development.
5. *Floodplain Risk Management Plan*
   - involves formal adoption by Council of a plan of management for the floodplain.
6. *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 Mudflat Creek Flood Study constitutes the third stage of the management process for Mudflat Creek and its catchment area. Webb, McKeown & Associates were commissioned by Gosford City Council to prepare this flood study on behalf of Council's Floodplain Risk Management Committee. The study project was jointly funded by Gosford City Council and State and Federal Governments. The following report documents the work undertaken and presents outcomes that define flood behaviour for existing catchment conditions.

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EXECUTIVE SUMMARY

The NSW Government's Flood Prone Land Policy provides for:

- 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 staged approach, one of which is the preparation of a Flood Study to determine the nature and extent of the flood problem.

The Mudflat Creek Flood Study has been initiated as a result of flooding of local roads and residential areas, most recently in July 1988, January 1989, February 1990, February 1992 and February 2002. The study has been prepared by Webb, McKeown & Associates for Gosford City Council in 2004 and incorporates the floodplain between Fraser Road and Brisbane Water.

The specific aims of the Mudflat Creek Flood Study are to:

- define flood behaviour in the Mudflat Creek catchment,
- prepare flood hazard and flood extent mapping,
- prepare a suitable model of the floodplain that can be used in subsequent Floodplain Risk Management Studies and Creek Rehabilitation Studies and Plans.

Description of Creek Systems: Mudflat Creek has a catchment area of approximately 123 hectares and lies entirely within the boundaries of Gosford City Council. It drains into Brisbane Water through the lower area of Killcare.

A large portion of the lower section of the catchment has been developed for residential purposes. This takes in the area bounded by Fraser Road, Stanley Street and Hardys Bay. The upper section of the catchment largely comprises natural bushland or rural land type although there is some residential development predominantly around Stewart Street, The Scenic Road and Wards Hill Road.

Within the study area there are two road crossings over the creek at Fraser Road and Noble Road. Between these crossings the creek runs through the rear of residential properties. Overbank areas in many areas are confined due to the presence of fences, garden beds and sheds. Residents have also constructed footbridges to gain access over the creek. Upstream of Fraser Road the creek is confined to a relatively deep and narrow channel on a steep gradient.

The key phases of the Mudflat Creek Flood Study that have been undertaken are summarised below:

Review all Available Data, namely:
- reports, photographs, Council records,
- questionnaire survey of residents and interviews,
- rainfall data from the Bureau of Meteorology and Manly Hydraulics Laboratory,
- survey data - a comprehensive field survey was undertaken in 1998 and 2004,
- available peak flood level data for historic events.

Determine Approach: Due to the absence of long term historical flood data a rainfall-runoff computer modelling approach was adopted. This involved the setting up of two computer models - a hydrologic model to convert rainfall to runoff and a hydraulic model to convert the runoff to flows, levels and velocities.

Due to limited historical flood level information, it was not feasible to rigorously calibrate the hydrologic and hydraulic models against observed flood events. A limited model calibration was therefore carried out by:
- determining the order of magnitude of the observed storms for which limited historical flood level data were available,
- comparing historical flood level data with the corresponding design flood level data.

Determination of Design Flood Levels: Design rainfall data were obtained from Australian Rainfall and Runoff (1987). These data were input to the hydrologic model to produce inflows for the hydraulic model and the design levels subsequently calculated. The lower parts of the creek are influenced by a combination of flows entering from the Mudflat Creek catchment and elevated water levels in Brisbane Water. The design analysis assumed that both the Fraser Road and Noble Road culverts were blocked by vegetative debris. This approach is consistent with current best management practice following the August 1998 floods in North Wollongong. Sensitivity analyses of the parameters adopted for design modelling were also undertaken.

The full range of design events (20% AEP to PMF) was analysed. The Probable Maximum Flood (PMF) was undertaken to provide the full extent of the floodplain, the PMF levels are not used for normal residential development control purposes.

Building Floors Inundated and Tangible Flood Damages: The following table indicates the number of building floors inundated and the tangible flood damages.

Table i): Buildings Inundated and Tangible Damages

Design Flood	Building Floors Inundated	Tangible Damages
PMF	23	$930,000
0.5% AEP	7	$130,000
1% AEP	5	$100,000
2% AEP	4	$60,000
5% AEP	4	$60,000
10% AEP	3	$40,000
20% AEP	2	$20,000

Note: The values shown are assuming 100% blockage at Noble Road bridge and Fraser Road culverts.
All the buildings affected are Residential. There are no Commercial or Industrial buildings in the study area.

Based on the above values the average annual damages are $21,000.

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 Mudflat Creek floodplain,
- provision of a hydrologic/hydraulic modelling platform to form the basis for a subsequent Floodplain Risk Management Study and Plan,
- preliminary flood damages assessment.

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1. INTRODUCTION

Mudflat Creek is a 123 hectare catchment which drains to Hardys Bay through the lower Killcare district (refer Figures 1 and 2). The lower section of the catchment is predominantly occupied by urban residential development. A natural escarpment divides the lower section of the catchment from the upper plateau area. This upper plateau is predominantly natural or rural land type with some residential development around Stewart Street, The Scenic Road and Wards Hill Road (Figure 2).

In light of reported flooding incidents in the study area, and following on from the Killcare Catchment Drainage Investigation that was completed in 1999 (Reference 1), Gosford City Council engaged Webb, McKeown & Associates to undertake a Flood Study.

The primary objectives of this Flood Study are:

- to define the flood behaviour of the Mudflat Creek catchment by quantifying flood levels, velocities and flows for a range of design flood events under existing catchment and floodplain conditions,
- to assess the hydraulic categories and undertake provisional flood hazard mapping in accordance with the NSW Floodplain Development Manual 2005 (Reference 2),
- to assess the extent of the flooding problem by undertaking a flood damages assessment,
- to formulate suitable hydrologic and hydraulic models that can be used in a subsequent Floodplain Risk Management Study.

As directed by Council, the scope of this study is such that:

- the extent of the hydrologic model covers the entire Mudflat Creek catchment draining to Brisbane Water,
- the hydraulic model incorporates Mudflat Creek from Brisbane Water to a point approximately 100 m upstream of Fraser Road,
- in establishing the hydraulic model and appropriate boundary conditions, consideration has been made of the impacts of tides and Brisbane Water flooding on the Mudflat Creek catchment.

This report details the results and findings of the Flood Study investigations, the key elements of which include:

- a summary of available flood related data,
- calibration of the hydrologic and hydraulic models,
- definition of the design flood behaviour for existing conditions through the analysis and interpretation of model results.

This Flood Study does not consider flooding associated with local drainage issues which may result from inadequate urban drainage provisions. These issues were assessed in the Killcare Catchment Drainage Investigation that was completed in 1999 (Reference 1). However, comment has been provided on the behaviour of local overland flooding from the catchment area to the north of Fraser Road.

A glossary of flood related terms is provided in Appendix A. Appendix B provides a listing of the design flood data.

2. BACKGROUND

2.1 Catchment Description

The Mudflat Creek catchment is characterised by a distinct upper and lower section (refer Figure 2). The upper section of the catchment is located in the plateau area of Killcare Heights. This section of the catchment comprises of residential development around Wards Hill Road, The Scenic Road and Stewart Street together with a large proportion of natural bushland or rural type land. This plateau was assessed in a previous drainage study (Reference 1) with a number of options proposed to address its local drainage problems.

From the plateau the catchment slopes very steeply down undeveloped, densely forested slopes to the area bounded by Fraser Road and Hardys Bay. This lower section is relatively flat and low lying. Runoff from the plateau area drains to Fraser Road via two natural gullies. Pipe and overland flow systems convey flows from these natural gullies, through the residential areas to Mudflat Creek. Mudflat Creek then travels through the rear of properties 37-63 Fraser Road before reaching the bridge in Noble Road and its outlet to Hardys Bay.

2.2 Creek Description

The following provides a descriptive overview of the key characteristics of the Mudflat Creek floodplain. This overview is based on observations made from several site inspections during the course of the study. Information provided by Council and local residents has also been used where appropriate. There are two road crossings located within the floodplain (refer Table 1 and Photographs 1 and 10). A twin 900 mm diameter piped crossing is also located at No. 40 Fraser Road.

Table 1: Road Crossings

Location	Type of Structure	Invert Level (mAHD)	Waterway Area (m^2)	Road Level (mAHD)	Photograph
Noble Road	Road bridge	0.18	4.0 (approx)	1.20	1
Fraser Road	1950 mm diameter pipe	1.88	3.0	4.50	10

Some of the significant features of the creek are illustrated in Photographs 1 to 10 as shown on the following pages and are referred to in Tables 1 and 2.

Photograph 1: Noble Road Bridge looking upstream.

Photograph 2: Noble Road Bridge looking downstream. Note extent of reed and mangrove vegetation.

Photograph 3: Looking upstream from Noble Road Bridge. Note varying overbank area due to gardens, fences and sheds.

Photograph 4: Twin 900 mm diameter pipe outlet into Mudflat Creek at rear of 57 Fraser Road. Note siltation covering half of pipe at the outlet.

Photograph 5: Downstream of twin 900 mm diameter pipe outlet.

Photograph 6: Looking upstream at rear of 53, 55 and 57 Fraser Road.

Photograph 7: Example of a heavily vegetated section of the creek upstream of Noble Road.

Photograph 8: Mudflat Creek at 47 and 49 Fraser Road.

Photograph 9: Fraser Road culvert looking upstream.

Photograph 10: Looking upstream from the Fraser Road culvert.

The outlet of the creek into Brisbane Water is a wide mudflat that is dominated by mangroves. Immediately upstream of the outlet a bridge crosses the creek at Noble Road. The underside of this bridge is at approximately 0.8 mAHD and the creek immediately upstream is densely vegetated with reeds.

Between Noble Road and Fraser Road the creek runs through the rear of residential properties 37-63 Fraser Road and consequently the extent of the overbank area is variable with fences, gardens and sheds representing significant impediments to the overbank flow area. The degree of maintenance varies, with some sections of the creek heavily vegetated while other sections are mowed and maintained by residents. In many cases the same landholders own land on both sides of the creek and a number of footbridges have been constructed for access purposes (refer Photograph 6).

Runoff from the southern section of Wards Hill Road, Stewart Street and The Scenic Road in the plateau area of Killcare Heights (Figure 2) is conveyed via a natural gully which drains to Mudflat Creek via a twin 900 mm diameter stormwater pipe before ultimately discharging into the creek at the rear of 57 Fraser Road.

Flows along the main channel are conveyed under Fraser Road (north-south alignment) via a 1950 mm diameter pipe culvert. Immediately downstream of Fraser Road (north-south alignment) the creek is heavily vegetated with a variety of native and introduced plant species. Rock lining of the embankments upstream and downstream of the 1950 mm culvert has been carried out to reduce erosion.

Upstream of Fraser Road along the main channel the creek is markedly deeper and is fringed by natural bushland. The creek forms into a natural gully that drains the area referred to by local residents as "The Triangle". This is the area bounded by Maitland Bay Drive, Wards Hill Road (northern section) and The Scenic Road.

Table 2: Other Significant Features of the Creek System

Feature	Comments	Photograph
Dense channel vegetation	Most parts of catchment.	7, 9, 10
Encroachment of residential development	Footbridges, fences, garden beds and sheds all impact on the overbank area and flow capacity of the creek.	3
Siltation	Extent of siltation that has occurred is evident at the outlet of the twin 900 mm diameter pipeline.	4

2.3 Previous Studies

2.3.1 Killcare Catchment Drainage Investigation, 1999 (Reference 1)

The present study follows on from the Killcare Drainage Investigation (Reference 1) that was undertaken by Webb, McKeown and Associates for Gosford City Council in 1999. As the name would indicate, the Drainage Investigation dealt mainly with deficiencies in the drainage system. The investigation comprised three main stages:

- **Drainage Study:** which identified the causes and extent of existing drainage problems by estimating the catchment runoff and assessing the flow capacity of the existing drainage system.
- **Drainage Management Study:** to identify various drainage strategies or mitigation works to address the existing flood and drainage problems.
- **Drainage Management Plan:** to define the recommended plan of works best suited to resolve the flooding problems.

Flood and drainage problems were identified throughout the catchment and a set of recommended works were developed to address deficiencies in the drainage system. Recommended works included upgrading the piped drainage system in the upper reaches of the catchment in Stewart Street, The Scenic Road and Wards Hill Road. To address flooding of properties in Fraser Road it was recommended that the pipe system conveying flows from the Stewart Street catchment down to Mudflat Creek be upgraded. This pipeline runs along Fraser Road and through drainage easements in properties down to Mudflat Creek. Other works to address minor flooding problems throughout the catchment were also outlined.

During the course of the Drainage Investigation supplementary works were commissioned by Gosford City Council. These works included the detailed survey of Mudflat Creek and adjacent lands from Hardys Bay to Fraser Road. The additional survey data was utilised to establish a HEC-RAS hydraulic computer model to determine depths of flooding for the 10% AEP and 1% AEP storm events. The present study follows on from this preliminary work, providing a more comprehensive assessment of the Mudflat Creek flood behaviour in a framework that is compatible with the NSW State Government's Flood Prone Land Policy.

A detailed comparison between modelling results from the Drainage Investigation with those of the present study is provided in Section 7.8.

2.3.2 Killcare Drainage Design, 2001 (Reference 3)

Following on from recommendations in the Killcare Catchment Drainage Investigation, Gosford City Council commissioned Brown and Root to undertake a drainage design for Killcare. The design included the following works:

- upgrades to the street drainage system in Wards Hill Road, Scenic Road and Stewart Street,
- channel improvement works to Mudflat Creek including upgrading of the Noble Road bridge and Fraser Road culvert,
- amplification of the twin 900 mm diameter drainage line conveying flows from Stewart Street to the Mudflat Creek outlet at the rear of 57 Fraser Road,
- provision of a sedimentation basin at the corner of Blythe and Stanley Streets.

Reference 3 indicated that the proposed channel improvement works would have only a minor affect on reducing design flood levels along Mudflat Creek. However, there may be some associated benefits in terms of stabilising of the creek banks.

2.4 Causes of Flooding

Flooding within the Mudflat Creek catchment may occur due to a combination of factors including:

- an elevated water level in Brisbane Water due to tidal influences, rainfall and storm surge,
- elevated water levels within Mudflat Creek as a result of intense rain over the Mudflat Creek catchment. The levels in the creek may also be affected by constrictions along its length (e.g. culverts, blockages, vegetation),
- local runoff over a small area accumulating (ponding) in low spots. Generally this occurs in areas which are relatively flat with limited potential for drainage. This type of flooding may be exacerbated by inadequate local drainage provisions and elevated water levels at the downstream outlet of the urban drainage (pipe, road drainage) system. Detailed analysis of this type of flooding is outside the scope of the present study and has been investigated previously in the Killcare Catchment Drainage Investigation, 1999 (Reference 1).

These factors may occur in isolation or in combination with each other. Generally the peak water level in Brisbane Water will occur several hours after the flood peak in Mudflat Creek itself. This is because the peak levels in the Mudflat Creek catchment are typically the result of short duration storms of up to two hours duration. In contrast, the peak levels in Brisbane Water would typically result from longer duration storms of say 6 hours or longer.

3. DATA

The first stage in the investigation of flooding 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 such as Mudflat Creek there are no stream gauges or official historical records available. An indication of flood behaviour 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 Public Survey

3.1.1 General

As part of this study an extensive public survey was carried out consisting of:
- adverts in the local papers,
- notices in local shops,
- a combined newsletter and questionnaire,
- follow up phone calls and interviews with selected respondents.

The questionnaire was sent to the owners and residents of the properties located within the estimated extent of Mudflat Creek floodplain in Killcare (refer Figure 4) as well as to members of local community groups. Follow up telephone calls were made to those respondents who advised that their property had been inundated in the past or those who indicated that they had information (flood levels, etc.) pertaining to previous floods.

Representatives of the local community organisations provided valuable assistance.

3.1.2 Results

The results of the questionnaire are summarised in Table 3 and indicated on Figures 4 and 5.

Some historical flood levels were identified as a result of the questionnaire. This information is included in Table 10 (Section 3.3.3) with the locations shown on Figure 3a. It should be noted that these levels are based on anecdotal evidence only and therefore are not necessarily always reliable.

Table 3: Questionnaire Survey

Issue	No. of Responses
Number sent out	Approx. 190*
Number returned	17 (9%)
Number of flood affected properties	12
Consisting of:	
Inundated land	6
Inundated houses	3
Inundated but unable to contact to confirm extent	3
Source of Flood Damage:	
From failure of stormwater drainage system	8
From Mudflat Creek	4
some respondents affected on more than one occasion	
Dates of Key Flood Events	
1984	1
1985	1
July 1988	2
January 1989	2
February 1990	4
February 1992	2
February 2002	2
some respondents affected on more than one occasion	
Other Water Related Issues Noted	
Siltation/dredging suggested	8
Spread of mangroves and reeds	6
Mosquitos and stagnant water	2

* *Approximately 140 surveys were distributed to residents and property owners associated with approximately 100 properties in the immediate vicinity of Mudflat Creek. A further 50 surveys were distributed to residents in the broader catchment by local community groups.*

3.1.3 Discussion

Although it is outside the scope of the present study, many residents living near Mudflat Creek also raised several issues relating to the quality and maintenance of the creek. A key concern was the amount of siltation that has occurred in the creek. A number of respondents indicated that the creek was once deep enough to row a boat under Noble Road bridge at low tide. Some residents also felt that the siltation had encouraged the proliferation of mangroves at the outlet of the creek into Hardys Bay and Brisbane Water. Both of these issues have the potential to raise flood levels.

In light of the observed siltation some residents have suggested that dredging of the creek should be undertaken and the spread of mangroves controlled. Other respondents felt that anecdotal evidence of siltation in the creek should be augmented by a scientific study to establish the history of sedimentation and the sources.

Blockages of Council's stormwater drains were seen to be a contributing factor to drainage problems experienced on some properties. Some respondents mentioned the need for regular cleaning of the drains to reduce these problems.

3.2 Rainfall

3.2.1 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 a number of years at many locations within the Gosford region. 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 reading for Monday 9:00am.

- The duration of intense rainfall required to produce flooding in the Mudflat Creek catchment is typically less than two hours. This is termed the "critical storm duration". 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.

- Rainfall records can frequently have "gaps" ranging from a few days to several weeks or even years.

- 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 most of the relevant gauges were only installed in the 1980's and hence have a very short period of record compared to the daily read data. These types of gauges can also fail during storm events due to extreme conditions.

- Rainfall events which cause flooding in the Mudflat Creek catchment are usually very localised and as such only accurately "registered" by a nearby gauge. Gauges sited only a kilometre away can often show very different intensities. The nearest pluviometer station to the study area is approximately 6km away at Kincumber.

3.2.2 Available Rainfall Data

There are no official rainfall gauges located within the Mudflat Creek catchment. However, within 10km of the catchment, the Bureau of Meteorology (BOM) operates seven daily read gauges and the Manly Hydraulics Laboratory (MHL) has established three pluviometers (refer Table 4 and Figure 1).

Table 4: Rainfall Stations

Station	Start Date	Data available to	Operator
DAILY READ:			
North Gosford	December 1971	July 2004	BOM
Gosford	May 1877	August 1993	BOM
Woy Woy	December 1964	May 2004	BOM
Woy Woy South	April 1977	November 1979	BOM
Wamberal	March 1968	November 1988	BOM
Terrigal Memorial Country Club	August 1990	June 2004	BOM
Avoca Beach Bowling Club	May 1970	June 2004	BOM
Privately Read Gauge Killcare	1988	2004	L Walker
PLUVIOMETER:			
Kincumber	May 1987	August 2004	MHL
Mt Elliot	December 1985	August 2004	MHL
Wyoming	August 1988	August 2004	MHL

There are several other rainfall gauges located outside the catchment, particularly to the north near Wyong. Data were not collected for these gauges as they are considered to be too far from the catchment to be relevant.

As can be seen on Figure 1, the pluviometer at Kincumber is considerably closer to the study catchment than the other two pluviometers. A summary of data recorded at the Kincumber pluviometer for the known Mudflat Creek storm events is provided in Table 5. It should be noted that only the annual maximum intensities for each duration were collected. Thus in many cases there was a greater intensity during the year than in the event under consideration. This could be correct or it could be because the gauge failed during the storm event of interest.

Table 5: Annual Peak Rainfall Depths (mm) at Kincumber for Reported Storm Events

Reported Storm Event	6 January 1989			7 February 1990			9 February 1992			25 February 1999			3 February 2002		
Duration	**Depth (mm)**	**Date**	**Storm Frequency (AEP)**	**Depth (mm)**	**Date**	**Storm Frequency (AEP)**	**Depth (mm)**	**Date**	**Storm Frequency (AEP)**	**Depth (mm)**	**Date**	**Storm Frequency (AEP)**	**Depth (mm)**	**Date**	**Storm Frequency (AEP)**
30 minutes	31	6 Jan	50-20%	62	7 Feb	1%	42	9 Jan*	10-5%	17	25 Feb	<100%	24	23 Aug*	100-50%
60 minutes	37	6 Jan	100-50%	100	7 Feb	0.5%	72	9 Jan*	5-2%	33	4 Apr*	100%	28	23 Aug*	<100%
120 minutes	61	6 Jan	50-20%	122	7 Feb	1-0.5%	81	8 Jan*	10-5%	40.5	4 Apr*	100%	29	23 Aug*	<100%
180 minutes	71	6 Jan	50-20%	132	7 Feb	2-1%	87	9 Feb	20-10%	46.5	25 Feb	100%	33	3 Feb	<100%

Notes:

1. Only years where flooding was reported in Mudflat Creek are shown.
2. No data were available for 1988 due to technical problems with the pluviometer.
3. Date of peak recorded depth shown in brackets.
4. * denotes dates where the peak recorded annual depth did not correspond to the reported flood event (refer explanation above).

A private daily rainfall recorder at 14 Noble Road, Killcare (refer Figure 1) has also recorded useful rainfall information (Table 6). Limited rainfall data are also available from other local residents.

Table 6: Significant Daily Rainfall Events at 14 Noble Road, Killcare

Year	Day/Month	Daily Rainfall (mm)
1988	29th April	77
	30th April	78
	5th July	76
	6th July	116
1990	3rd February	270
	4th February	140
	7th February	165
	19th March	79
1991	10th June	146
	11th June	107
1992	9th January	116
	9th February	175
	10th February	133
1998	18th May	68
	19th May	68
	6th August	88
	7th August	79
	8th August	62
1999	25th February	107
	26th February	32
	2nd April	59
2002	4th February	52
	27th February	87
	28th February	72
2003	29th March	134
	14th March	84
	15th March	57

*Data provided by Les Walker.

3.2.3 Design Data

Design rainfall data were calculated in accordance with Australian Rainfall and Runoff (Reference 4) and are listed in Table 7. The calculated design rainfall values are marginally lower than those provided in Gosford City Council's design specification (Reference 5) which was taken at Terrigal. The Australian Rainfall and Runoff data should provide more appropriate site specific rainfall data.

Table 7: Design Rainfall Data

Duration		Annual Exceedance Probability (AEP)					
		20%	10%	5%	2%	1%	0.5%*
15 minutes	intensity in mm/h	111	123.4	140.3	162	178.5	188
	depth in mm	27.8	30.9	35.1	40.5	44.6	47
25 minutes	intensity in mm/h	88.1	98.4	112.4	130.3	144	150
	depth in mm	36.7	41	46.8	54.3	60	62.5
30 minutes	intensity in mm/h	80.5	90.1	103	119.6	132.3	137
	depth in mm	40.3	45.1	51.5	59.8	66.2	68.5
45 minutes	intensity in mm/h	64.9	72.9	83.6	97.4	107.9	113
	depth in mm	48.7	54.7	62.7	73.1	80.9	84.7
1 hour	intensity in mm/h	55.1	62	71.1	83	92.1	97
	depth in mm	55.1	62	71.1	83	92.1	97
2 hours	intensity in mm/h	35.8	40.4	46.5	54.4	60.5	64
	depth in mm	71.6	80.8	93	108.8	121	128
3 hours	intensity in mm/h	27.3	30.9	35.6	41.7	46.4	49.5
	depth in mm	81.9	92.7	106.8	125.1	139.2	148.5

*Calculated using Volume 2 of AR&R 1987.

Rainfall data for the Probable Maximum Precipitation (PMP) were calculated in accordance with the procedures of the Commonwealth Bureau of Meteorology (Reference 6) and are summarised in Table 8.

Table 8: PMP Rainfall Depths

Duration (mins)	Rainfall Depth (mm)
15	173
25	222
30	247
45	311
60	361
90	464
120	544
180	654

3.3 Historical Flood Information

3.3.1 Overview

A data search was undertaken to identify the dates and magnitudes of historical floods. The following sources of data were investigated:

- Gosford City Council,
- previous reports,
- local residents,
- rainfall records.

Unfortunately there is no stream height gauge or other means of reliably determining the level of past flood events in Mudflat Creek. Reliance must therefore be placed on photographic evidence, interviews with residents, previous reports or similar. A detailed review of rainfall records (Section 3.2) was also undertaken to establish the likely dates of flooding.

3.3.2 Flood Photographs

The following flood photographs were collected from reports and local residents. Photographs 27 to 29 are aerial photographs that illustrate the changes in the extent of development over the last 50 years.

Photograph 11: Looking north along open channel between 57 and 59 Fraser Road - February 1999.

Photograph 12: Rear of 57 Fraser Road looking upstream - February 1999.

Photograph 13: Rear of 57 Fraser Road looking downstream - February 2002.

Photograph 14: Rear of 45 Fraser Road - February 1990.

Photograph 15: Rear of 45 Fraser Road - February 1990.

Photograph 16: Upstream of Noble Road bridge - July 1988.

It is assumed that Photographs 17 to 26 were all taken during the April 1988 event, however it is possible that it was the July 1988 event.

Photograph 17: Floodwaters crossing Noble Road and entering Hardys Bay. View looking south.

Photograph 18: Noble Road crossing. View looking south.

Photograph 19: Noble Road crossing. View looking south.

Photograph 20: Floodwaters crossing the north-eastern corner of Fraser Road with No. 37 Fraser Road under renovations. View looking south to culvert.

Photograph 21: No's 47, 49 & 51 Fraser Road showing runoff entering from Photograph 20. View looking south.

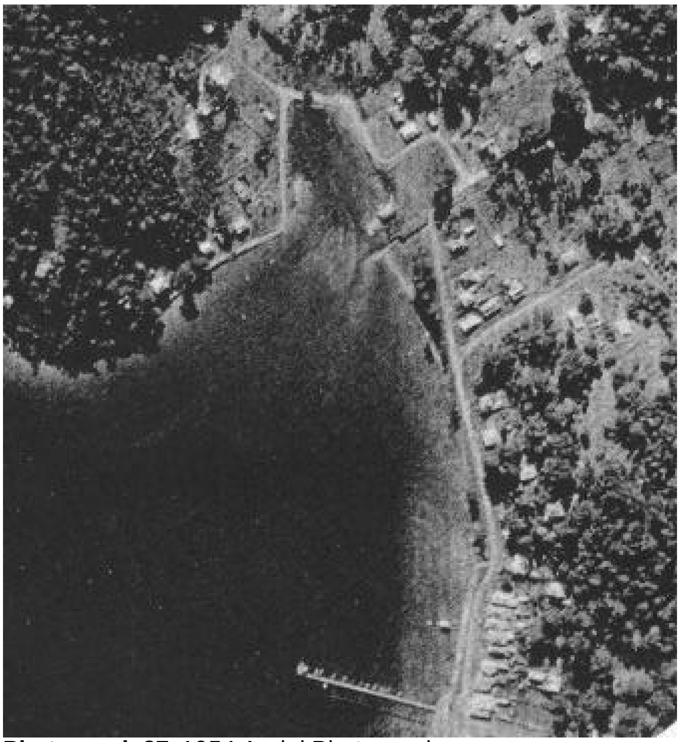
Photograph 22: Looking upstream to Photograph 21. View looking north-east.

Photograph 23: Hardys Bay Parade from corner of Noble Road. View looking south-west.

Photograph 24: Lot 54 (No. 63) Noble Road looking south.

Photograph 25: Looking upstream to Noble Road bridge.

Photograph 26: At Fraser Road culvert. View looking south.



Photograph 27: 1954 Aerial Photograph.

Photograph 28: 1957 Aerial Photograph

Photograph 29: 1999 Aerial Photograph

3.3.3 Summary

In terms of past flood events, the questionnaire survey (Section 3.1) found that a number of local residents identified January 1989, February 1990 and February 1992 as major flood events in recent times. There was also some anecdotal evidence of flooding occurring in April and/or July 1988, February 2002 as well as 1984 and 1985.

During the data search photographs that showed flooding occurring in April and/or July 1988, February 1999 and February 2002 were sourced from previous reports and residents.

Based on all available data sources the dates of known flood occurrences in Mudflat Creek are summarised in Table 9.

Table 9: Known Dates of Flooding in Mudflat Creek

Month	Year	Month	Year
unknown	1984	February	1990
unknown	1985	February	1992
April and July	1988	February	1999
January	1989	February	2002

In summary, whilst flooding of Mudflat Creek has undoubtedly occurred on many occasions in the past, there are few accurate records detailing exactly when flooding occurred and how high floods have reached. A summary of the location and description of available flood level information is provided on Figure 3a and Table 10.

Table 10: Historical Flood Level Information

Date of Flood	Ref. No. on Figure 3a	Location	Approx. Recorded Flood Level (mAHD)	Comments
Mid 1980's	1	14 Noble Road	Greater than 1.8	Located near the outlet to Hardys Bay.
Mid to late 1980's	2	10 Noble Road	Greater than 1.7	Located near the outlet to Hardys Bay. Exact year of flooding not known.
	3	10 Noble Road	1.5	Level from Photograph 16 (July 1988).
Feb 1990	4	33 Fraser Road	3.0 to 3.5	Most likely due to overland flow from Fraser Road rather than floodwaters rising from the creek. Occurred prior to the Fraser Road reconstruction and installation of twin 900 mm diameter pipes.
	5	37 Fraser Road	4.3	Reported flooding of house and yard, most likely caused by overland flow from Fraser Road rather than floodwaters rising from the creek (refer Photograph 20 - April 1988 event).
	6	45 Fraser Road	4.0	Flooding reported in front yard, 3 to 4 inches below house floor level. Cause is probably due to overland flow from Fraser Road rather than floodwaters rising from the creek.
	7	45 Fraser Road	2.8 to 3.2	Estimated level from photograph of debris mark. Current form of the channel is different today due to embankment collapse during the flood.
Around 1990	8	31 Fraser Road	2.1 to 2.3	Possibly occurred in February 1990, yard 200 mm under water. Due to overland flow from the Stewart Street catchment rather than rising floodwaters. Occurred prior to installation of twin 900 mm diameter pipes.
Feb 1999	9	57 Fraser Road	1.3	Estimated level from photograph of floodwaters in rear yard.
Feb 2002	10	51 Fraser Road	2.2	Estimated flood level from photograph of floodwaters in rear yard and anecdotal evidence. Rainfall records would suggest that this was only a relatively minor storm event of less than 50% AEP. Possibly the storm was localised and thus had a greater intensity than recorded at the Kincumber gauge.
Not known	11	26 Fraser Road	6.0 to 8.0	Sheet flow across front of property. Most likely due to overland flow from the Stewart Street catchment rather than floodwaters rising from the creek.
	12	35a Fraser Road	1.5 to 2.0	Reportedly due to overland flows rather than floodwaters rising from the creek.
	13	47 Fraser Road	3.6	Flooding reported in front yard. Up to level of cement slab. Cause is probably due to overland flow from Fraser Road rather than floodwaters rising from the creek.
	14	48 Fraser Road	6.0 to 8.0	Small stream of runoff observed. Most likely due to overland flow from upstream catchment rather than floodwaters rising from the creek.

Note: Photographs 17 to 26 were taken in the April or July 1988 event. Reference No's 5, 6, 7 and 13 reflect flood heights in Photographs 20 to 22. The remainder of the photographs are taken near Noble Road and indicate only a relatively shallow depth of floodwaters over the road.

3.4 Survey

Detailed survey information of the creek was obtained by Bissett and Wright in 1998 as part of the Killcare Catchment Drainage Investigation (Reference 1). In addition to this, Chase Burke and Harvey collected additional survey information for the detailed design of the pipe drainage system and channel upgrade investigation undertaken by Brown and Root in 2001 (Reference 3). These survey data were combined for use in the current study. The data included individual spot heights, road crossing details and other details. This information was assumed to be representative of existing creek conditions.

In addition, Bissett and Wright were commissioned to undertake survey of property boundaries and floor levels. The extent of survey data used in the present study are indicated on Figures 3b to 3e.

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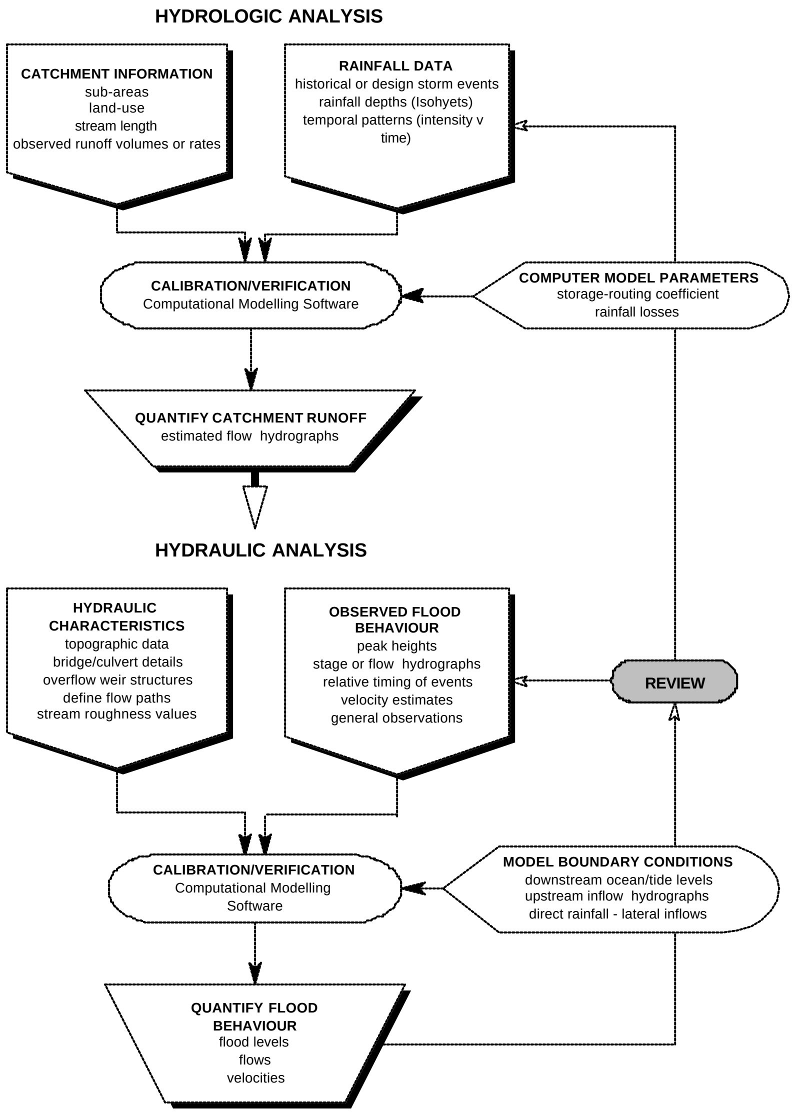
4. APPROACH ADOPTED

A diagrammatic representation of the Flood Study process is shown in Diagram 1. A hydrologic model (WBNM) was established for the entire catchment (Figure 6) and used to convert rainfall data into streamflow for input to a hydraulic (MIKE-11) model of both Mudflat Creek and flows down Stanley Street. The extents of the hydraulic model were determined following site inspection and discussion with Council and are indicated on Figure 7. To ensure confidence in the results, both models require calibration 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 focussed on comparing peak historical flood levels with the design flood level of the same corresponding frequency of rainfall. The MIKE-11 model was 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



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5. HYDROLOGIC MODELLING

5.1 General

The Mudflat Creek catchment was previously modelled using ILSAX as part of the Killcare Catchment Drainage Investigation (Reference 1). As described in AR&R 1987 (Reference 4), ILSAX is best suited to modelling small urban catchments. This was appropriate for modelling the piped drainage systems assessed in the previous drainage investigation. However, the main purpose of the hydrologic modelling in the present study is to establish design peak flows along Mudflat Creek itself. For this purpose a network model such as RORB, RAFTS or WBNM is more suited.

A comparison of RORB, RAFTS and WBNM is provided in AR&R 1987 (Reference 4). These models allow the rainfall depth to vary both spatially and temporally over the catchment and readily lend themselves to calibration against recorded data.

References 4 and 7 compare the merits of WBNM and RORB and conclude that there is little difference between them. Reference 7 suggests that WBNM should be preferred as it is easier to use and requires less data. It also has the capability to incorporate a wide variety of flow control structures including detention basins, pipes and culverts. A further advantage over RORB is the use of different approaches to modelling overland runoff and streamflow. WBNM was therefore adopted as the hydrologic model for this study.

5.2 Model Configuration

The WBNM model simulates a catchment and its tributaries as a series of sub-catchment areas based on watershed boundaries linked together to replicate the rainfall/runoff process through the natural stream network. The adopted sub-catchment division is shown on Figure 6. The model input data includes definition of physical characteristics such as:

- surface-area,
- proportion developed (imperviousness),
- stream shortening.

The model established for this study comprises a total of 19 sub-catchments and included all tributaries upstream of the Mudflat Creek confluence with Brisbane Water. The model also included the area draining to Stanley Street and discharging into Brisbane Water immediately south of the main Mudflat Creek channel. The layout of the sub-catchments was defined to provide a reasonable level of spatial detail within the catchment and to provide flow hydrographs at specific locations. For example, the model was structured to provide primary inflows at the upstream limits of the hydraulic model. Catchment areas were determined from 2 m topographic contours provided by Council in GIS format. Impervious percentages were defined in the WBNM model based on an analysis of existing development shown on the 1:4000 orthophotomap of the study area.

5.3 Calibration and Verification

5.3.1 Key Model Parameters

In calibrating the WBNM model, two main parameters can be varied to achieve a fit to observed data:

- *Rainfall losses*
  Two parameters, initial loss and continuing loss, modify the amount of rainfall excess to be routed through the model storages.
- *Lag parameter*
  The lag parameter affects the timing of the catchment response to the runoff process and is subject to catchment size, shape and slope.

5.3.2 WBNM Calibration

The WBNM model is calibrated by adjusting one or more of the model parameters in order to match observed streamflow hydrographs. However, as there were no observed flow data available within the Mudflat Creek catchment this process was not possible. Rather, the parameters adopted for this study were based on values recommended in AR&R, our own experience and previous results from the Killcare Catchment Drainage Investigation (Reference 1). In this present study, a lag parameter value of 1.29, an initial loss of 0 mm and continuing loss of 2.5 mm/h were adopted. AR&R suggests values for initial loss ranging from 0 mm to 35 mm for eastern NSW catchments. Although it is a conservative assumption, the use of zero initial loss for the present study was considered justified in that prior to the flood producing rains, the catchment is likely to be wet from preceding rain. The adopted value of 2.5 mm/h for continuing loss has been found to be applicable over a wide range of catchments in Eastern Australia.

Due to the lack of available flow data within the Mudflat Creek catchment, the process of model calibration was limited to comparing available flood level data with the design flood level data for the corresponding frequency of the historical rainfall data. No independent calibration of the WBNM model was possible.

6. HYDRAULIC MODELLING

6.1 General Approach

Given the objectives of the study, the available data and in view of the nature of the watercourse and potential flow paths within the study area, a one-dimensional (1D) flow representation provides the most efficient and effective assessment of flood behaviour. This is particularly so given that the overbank areas are limited and the flow width is relatively narrow.

The 1D hydraulic model of the floodplain was established using the MIKE-11 software package (Reference 8). The MIKE-11 model is widely used in flood engineering both within Australia and internationally. It is a proven tool for the dynamic modelling of branched networks comprising complex cross-sections and hydraulic control structures.

The MIKE-11 model layout of Mudflat Creek extends from a location approximately 100 m upstream of the Fraser Road culvert down to the confluence with Brisbane Water (Figure 7). The model cross-sections were derived from the detail survey information collected for the study (refer Section 3.4). Both the Fraser Road culvert and the culvert at No. 40 Fraser Road were defined in the model as a composite control structure with capacity for both culvert throughflow in combination with road overtopping. A different approach was used to represent the Noble Road bridge within the hydraulic model. The size of the waterway area in conjunction with the nature of the bridge, and the height of the bridge relative to design tailwater levels, is such that it is not expected to act as a significant hydraulic control. Therefore the in-channel roughness at this location was nominally increased to make some allowance for any localised hydraulic impacts. There are a number of minor footbridges along the creek that also have only minor effects as a hydraulic control. Again these were accounted for by adjusting the channel roughness values adopted for the cross-sections.

Flows that travel along Stanley Street discharge into Brisbane Water at a location immediately south of Mudflat Creek. Hence flows along Stanley Street were represented as a side branch in the MIKE-11 model with the connection point to the main (Mudflat Creek) branch being the point of discharge into Brisbane Water.

6.2 Model Calibration

A summary of reported historical flood level information is provided in Table 10 and on Figure 3a.
The quality of this information is low with:

- Photograph 14 being the only record for the July 1988 event. Unfortunately the Kincumber pluviometer was broken for this event and thus it cannot be used for calibration purposes,

- flood levels for the storm events of the mid to late 1980's and February 1990 are based on anecdotal evidence with limited photographic records,
- flood levels for the February 1999 event are based on photographic records (refer to Photographs 11 and 12),
- flood levels for the February 2002 event are based on both anecdotal and photographic records (refer to Photograph 13).

It should be noted that anecdotal reports of flood levels that occurred 10 to 20 years ago may be inaccurate. While photographs can be a more reliable source, it is inconclusive as to whether or not the flood levels shown in the February 1999 and February 2002 photographs are the highest levels reached during the actual storm event.

Details of how this information was used in calibration are provided in Section 7.4.

7. DESIGN FLOOD RESULTS

7.1 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 WBNM model was adopted to derive design inflow hydrographs for this study. These hydrographs then defined boundary conditions to produce corresponding design flood levels using the MIKE-11 hydraulic model. 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.

7.2 Hydrologic Modelling

Design rainfall intensities and temporal patterns were derived from AR&R (Reference 4) and input to the WBNM 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 3 hours) for the 1% AEP event were analysed to determine the “critical storm duration” or the design storm that produces the highest peak flood levels along the creek. The 2 hour duration storm was found to be critical. This particular duration was then adopted for all other design event frequencies. In a similar manner, the 45 minute storm duration was found to be the critical duration for the PMF event. For all simulations, the same WBNM model parameters were used.

For each event, the design flow hydrographs obtained from the WBNM model were input to the MIKE11 model at the corresponding locations along the creek. The peak design flows for key local sub-areas are shown in Table 11.

Table 11: Peak Design Discharges for Key WBNM Sub-Catchment

WBNM Sub-Catchment	Peak Discharge (m^3/s)						
	20% AEP	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**PMF***
S02	1.5	1.7	2.0	2.3	2.6	2.9	9.0
S01	1.9	2.2	2.6	3.0	3.4	3.8	12
M16	0.8	0.9	1.1	1.2	1.4	1.5	4.5
M09	4.7	5.4	6.4	7.3	8.2	9.2	32
M08	1.4	1.7	1.9	2.2	2.4	2.7	8.1
M07	0.8	0.9	1.0	1.2	1.3	1.5	4.3
M03	10	12	15	17	20	22	93
M02	12	14	17	20	22	25	104
M01	17	20	24	28	32	36	139

*45 minute storm duration for the PMF event.
Refer to Figure 6 for location of sub-catchments.

7.3 Hydraulic Modelling

7.3.1 Tailwater Conditions - Brisbane Water

In addition to runoff from the catchment, Mudflat Creek can also be influenced by high tailwater levels in Brisbane Water. As noted previously, these two distinct flooding mechanisms may or may not result from the same storm. The Mudflat Creek catchment is much smaller in size (1.3 km^2) compared to the total area draining to Brisbane Water (155 km^2). Hence, for a given flood event, it is more likely that the Brisbane Water level would peak after the corresponding flood peak occurs in Mudflat Creek. It is acknowledged however that this may not necessarily be the case. Consideration must therefore be given to accounting for the joint probability of coincident flooding from both catchment runoff and tailwater effects from Brisbane Water.

A full joint probability analysis is beyond the scope of the present study. Traditionally it is common practice to estimate design flood levels in these situations using a ‘peak envelope’ approach that adopts the highest of the predicted flood levels obtained from the two mechanisms.

There is no rigorous commonly adopted procedure for determining an appropriate tailwater level in Brisbane Water to be used in conjunction with design flows. Creek flooding is completely independent of tides and has an equal chance of occurring on high or low tide.

A constant level of 0.9 mAHD was adopted as the tailwater condition for design flows in Mudflat Creek. This level is exceeded for approximately 1% of the time in an average year.

Design flood levels due to Brisbane Water flooding were based on levels determined in the Erina Creek Flood Study, 1991 (Reference 9) as reproduced in Table 12. The design flood levels were determined as the maximum of the levels obtained from the two mechanisms. It should be noted that the design flood levels due to Brisbane Water flooding are subject to change following the completion of the Brisbane Water Flood Study.

Table 12: Design Flood Levels for Brisbane Water Flooding

Event	Design Flood Level (mAHD)
PMF	2.00*
0.5% AEP	2.00*
1% AEP	1.95#
2% AEP	1.7
5% AEP	1.48
10% AEP	1.48*
20% AEP	1.48*

*estimated for the purposes of this study.
Reference 9 indicates a level of 1.96 mAHD but this has been rounded to 1.95 mAHD.

A sensitivity analysis of the relative impacts of assuming different tailwater conditions is discussed in Section 7.7.

7.3.2 Blockage Assessment

Given the combination of urban development and natural bushland within the catchment, the potential for blockage of culverts and creek crossings by debris can increase the flood levels experienced along the creek. The role of blockages in exacerbating flood impacts during the August 1998 storm in North Wollongong has highlighted the importance of considering the implications for blockages in design flood analysis.

Evidence from the August 1998 North Wollongong storm indicates that there is the potential for culvert openings less than 6 m width to be blocked during a flood. For Mudflat Creek this would imply that the Fraser Road culvert and Noble Road bridge could be either partially or fully blocked.

To quantify the impacts of potential blockages on design flood behaviour, several different blockage scenarios (Table 13) were simulated using the MIKE-11 model for the 1% AEP event.

Table 13: Blockage Assessment Modelling Scenarios - 1% AEP Event

Scenario	Description
Base Case	No blockages
Scenario 1	Fraser Road culverts 100% blocked
Scenario 2	Noble Road bridge 100% blocked
Scenario 3	Noble Road bridge blocked and Fraser Road culverts 50% blocked
Scenario 4	Noble Road bridge and Fraser Road culvert 100% blocked

Note: Fraser Road culverts refers to the road crossing and the twin 900 mm piped crossing at No. 40 Fraser Road.

The modelling results indicate that blockage of the Noble Road bridge has virtually no impact on flood levels. This is to be expected since the bridge is completely drowned out as it is approximately 400 mm under water at the 1.6 mAHD tailwater level adopted for the analysis. The results also indicate that blockage at the Fraser Road culverts has only a localised impact on flood levels. The level of water over Fraser Road for the various blockage scenarios assessed is provided in Table 14.

Table 14: Flood Levels over Fraser Road - 1% AEP Event

Scenario	Flood Level (mAHD)
No blockage	4.59
50% blockage	4.63
100% blockage	4.69

The results in Table 14 indicate a relatively small difference in level for the NO blockage/blockage scenarios. There are two main reasons for this:

- the 1950 mm pipe under Fraser Road only carries a relatively small percentage of the total flow,
- as Fraser Road is relatively wide and at approximately a constant level a small increase in level represents a large increase in flow.

It is **recommended** that the results from Scenario 4 (100% blockage at the Fraser Road culvert and Noble Road bridge) be adopted for the establishment of design flood levels.

7.4 Model Calibration

Where there is a lack of streamflow data, as is the case in this study catchment, a common means of model calibration is to generate flow hydrographs using historical rainfall data input to the hydrologic model. The process of model calibration is then undertaken by ensuring the peak levels from the hydraulic model match the observed levels. However, this method has limited application on Mudflat Creek as:

- Heavy rainfall was recorded on 3, 4 and 7 February 1990. Since the exact date of the observed flooding in February 1990 is not known, it is inconclusive as to which storm burst is actually attributable to the reported flood levels.
- Only one historical flood level is available for the February 1999 and February 2002 events. Furthermore, both of these reported flood levels are located at the downstream end of the creek and so will be more influenced by tailwater levels in Brisbane Water than catchment runoff.
- Rainfall events which cause flooding in the Mudflat Creek catchment are typically very localised and as such only accurately "registered" by a nearby gauge. The nearest pluviometer is at Kincumber, approximately 6km from the edge of the study catchment. Gauges sited only a kilometre away can show very different intensities.

Consistent with the quality and quantity of historical flood information available, the adopted model calibration approach was as follows:

- for each of the events where flood level information was available, an assessment was made of the likely storm frequency based on the rainfall data,
- the historical flood levels were compared to flood levels for the corresponding design storm.

To assess the frequency of each reported storm, rainfall data for the Kincumber pluviometer were obtained. The Kincumber pluviometer is significantly closer to the study catchment than the other two stations located at Mt Elliot and Wyoming (Figure 1). Rainfall data were available for all the reported storm events of February 1990, February 1999 and February 2002.

Kincumber pluviometer data were not available for the April or July 1988 event (refer Photograph 16) as the data logger malfunctioned for the entire year. Table 6 indicates relatively large daily totals on 29/30 April 1988 and July 1988. However without pluviometer data the magnitude of the rainfall bursts cannot be accurately determined. Reference 9 obtained the data from the Kincumber gauge which indicates 24 hour totals of 87, 180 and 168 mm on 29, 30 April and 1 May 1988. These values are greater than those given in Table 6.

Following corrections for the data logger issues the peak intensities at Kincumber for the April 1988 event were estimated to be:

- 30 minutes: 35 mm (approximate AEP of <20%)
- 60 minutes: 53 mm (approximate AEP of <20%)
- 120 minutes: 87 mm (approximate AEP of 10% to 5%)

It should be noted that the daily totals suggest the storm was less intense over Mudflat Creek than at the Kincumber pluviometer.

7.4.1 February 1990 Storm

Heavy rain fell over the Central Coast of NSW on the 2-4 February. This was caused by a depression originating from tropical cyclone Nancy. Further heavy rain was experienced on the 7 February when an intense burst of rain fell over a four hour period. Based on rainfall data at Kincumber, the recorded 1 and 2 hour intensities for the 7 February storm were in excess of a 1% AEP design storm intensity.

While the exact date of reported flooding for Mudflat Creek in February 1990 was not known it is likely, based on rainfall data available, that it was 7 February. Three flood levels were obtained for the February 1990 storm, these are summarised in Table 15 along with the corresponding 1% AEP design flood levels.

Table 15: Comparison of February 1990 Flood Levels with 1% AEP Design Levels

Location	Reported Flood Level (mAHD)	1% AEP Design Flood Level (mAHD)
33 Fraser Road	3.0 to 3.5	3.2
37 Fraser Road	4.3	3.6
45 Fraser Road - front yard	4	3.2
45 Fraser Road - rear yard	2.8 to 3.2	3.2

Note: Refer to Table 10 for further details on the reported flood levels.

There is a reasonable correlation between the 1% AEP design flood level and the reported flood level at 33 Fraser Road and in the rear yard of 45 Fraser Road. However, the reported flood levels identified at 37 Fraser Road and in the front yard of 45 Fraser Road are significantly greater than the corresponding 1% AEP design flood levels. Based on accounts of the nature of the flooding that occurred, it is likely that these two flood levels were associated with overland flows rather than rising creek levels. Overland runoff was observed to come from the northeast corner of Fraser Road and travel through the front yards of 37, 39, 45 and 47 Fraser Road. It is likely that this overland flow contributed to flooding of 37 and 45 Fraser Road as the flow travelled towards the creek.

7.4.2 February 1999 Storm

Over 100 mm of rainfall was recorded at a private rain gauge at 14 Noble Road on 25 February 1999 (Table 6). The rainfall intensity recorded at the Kincumber pluviometer for this storm was less than the 50% AEP design rainfall intensity (17 mm in 30 minutes). It is possible that the storm experienced at Mudflat Creek was very localised and of a much greater intensity than that recorded at Kincumber. A flood level of 1.3 mAHD was obtained at 57 Fraser Road based on photographic evidence. This flood level corresponds to a design flood level of less than the 20% AEP. However, as it is located at the downstream end of the creek, this area is also influenced by tailwater levels from Brisbane Water.

7.4.3 February 2002 Storm

Significant rainfall was recorded at a private rain gauge at 14 Noble Road on the 4th, 27th and 28th February 2002 (Table 6). However, none of these dates corresponded to significant rainfall intensities at the Kincumber pluviometer. A three hour rainfall intensity was recorded at Kincumber on 3 February but this was less than a 50% AEP design intensity. It is possible that the storm experienced at Mudflat Creek was localised and of greater intensity than that recorded at Kincumber. A flood level of 2.2 mAHD was reported at 51 Fraser Road based on photographic evidence. This flood level corresponds to a design flood level of between a 10% and a 5% AEP event. However, as it is located at the downstream end of the creek, this area is also influenced by tailwater levels from Brisbane Water.

7.4.4 Summary

A comparison of the historical flood level data with the design results suggests a reasonable correlation. The only exception being two levels recorded in February 1990 which would appear to reflect overland flow rather than the main creek flow.

This validation procedure is very limited and it is essential that in future flood events a more robust procedure is undertaken for recording historical flood level data. Historical flood level data should be accurately recorded within 24 hours of an event as such information is crucial to the proper calibration and verification of the models and ultimately determining the accuracy of design flood levels.

7.5 Design Events

Peak height profiles for the 20%, 10%, 5%, 2%, 1%, 0.5% AEP events and the PMF assuming Scenario 4 blockage conditions (refer Table 13) are provided on Figures 8 and 9. A tabulation of the design flood results (peak flood levels and velocities) at each model cross-section location is provided in Appendix B.

For the purposes of floodplain risk management in NSW the floodplain is divided into one of three Hydraulic categories (floodway, flood storage or flood fringe) and two Hazard categories (Low or High). These terms are defined in Appendix A. Further details of this process are provided in the NSW Government's Floodplain Development Manual (April 2005 - Reference 2). The hydraulic and hazard categorisation in this study was determined qualitatively based upon the available hydraulic (depth and velocity information) and survey information together with our knowledge of the Mudflat Creek catchment and experience.

As indicated in the NSW Government's Floodplain Development Manual (Reference 2) this process of Hazard categorisation is **Provisional** and should be refined at a later date to reflect other factors that influence hazard (such as warning time, flood readiness, rate of rise, duration of flooding, evacuation problems, effective flood access and the type of development). These issues will be examined in the subsequent Floodplain Risk Management Study. The categorisation (after possible subsequent refinement) provides a tool to assist in the preparation of the Floodplain Risk Management Plan and is used for assessing the suitability of future types of land use and development activities.

Hydraulic and Hazard categorisation maps for the PMF, 0.5%, 1% and 5% AEP events are respectively provided on Figures 10 to 13. The floodplain was assumed to be represented by either Floodway or Flood Fringe areas with no significant Flood Storage areas. Design flood contours for the PMF, 0.5%, 1% and 5% AEP events are respectively provided on Figures 14 to 17. Design flood extents for the 1% AEP event plus 0.5 m is shown in Figure 18.

7.6 Flood Damages

The quantification of flood damages is an important part of the floodplain risk management process. By quantifying flood damages for a range of design events, appropriate cost effective management measures can be analysed in terms of their benefits (reduction in damages) versus the cost of implementation.

The extent of disruption to the community and overall cost of flood damages depend upon many factors which include:

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

The estimation of flood damages tends to focus on the physical impact for the human environment but there is also a need to consider the ecological costs and benefits associated with flooding of the floodplain. Flood damages are often defined as being "tangible" or "intangible". Tangible damages are those for which a monetary value can be assigned. This is in contrast to intangible damages (stress, injury and loss of life) which cannot easily be attributed a monetary value.

The number of buildings likely to be flooded and the corresponding tangible damages were estimated for a range of events and a summary of results for Mudflat Creek is provided in Table 16 with the buildings shown on Figure 19. Likely damages to public utilities were not considered. Additionally no allowance was made for potential losses associated with the complete destruction of buildings.

Table 16: Buildings Inundated and Tangible Damages

Design Flood	Building Floors Inundated	Tangible Damages
PMF	23	$930,000
0.5% AEP	7	$130,000
1% AEP	5	$100,000
2% AEP	4	$60,000
5% AEP	4	$60,000
10% AEP	3	$40,000
20% AEP	2	$20,000

Note: The values shown are assuming 100% blockage at Noble Road bridge and the Fraser Road culverts.
All the buildings affected are Residential. There are no Commercial or Industrial buildings in the study area.

The standard way of expressing flood damages is in terms of Average Annual Damages (AAD). These are calculated by multiplying the estimated damages that can occur for a given flood by the probability of the flood occurring in a given year and then summing across the range of floods. By this means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods. Based on the damages estimated for the different flood events as shown in Table 16, the average annual tangible damages (AAD) for the Mudflat Creek floodplain are estimated to be of the order of $21,000.

Given the variability of flooding and property values, etc., the total likely damages figure in any given flood event (as indicated in Table 16) is useful to get a “feel” for the relative order of magnitude of the overall flood problem, but is of only limited value for precise economic evaluation of actual event conditions. When considering the economic effectiveness of a proposed mitigation option, the key question is the relative difference in total damages prevented over the life of the option. This is a function of not only the high value damages which occur in the larger less frequent floods but also of the more frequent lesser damages which occur in small floods.

7.7 Sensitivity Analyses

7.7.1 Results

Given the lack of reliable historical flood level and streamflow data, only a limited calibration of the MIKE-11 model was possible. In view of this, sensitivity analyses were undertaken to determine the impacts of key model parameters on the simulated flood behaviour.

The following sensitivity analyses were carried out for the 1% AEP event (assuming NO blockage):

- ±25% variation in Manning's 'n' roughness values,
- ±10% change in rainfall,
- ±20% change in WBNM storage routing parameter,
- a tailwater level in Brisbane Water of 0.5 and 1.95 mAHD.

A summary of results for the above scenarios are provided at key locations in Table 17.

Table 17: Sensitivity Analyses - 1% AEP Event

Branch	Mike11 Model Chainage (m) (refer Figure 7)	Base Case	Manning's "n"		Rainfall		WBNM 'C' Value		Tailwater Level	
			+25%	-25%	+10%	-10%	+20%	-20%	0.5 mAHD	1.95 mAHD
Mudflat Ck	Fraser Road Culvert	4.59	0.00	0.00	0.03	-0.03	-0.03	0.04	0.00	0.00
Mudflat Ck	158	3.14	0.06	-0.06	0.05	-0.05	-0.06	0.09	0.00	0.00
Mudflat Ck	258	2.02	0.09	-0.02	0.05	-0.06	-0.06	0.07	0.00	0.12
Mudflat Ck	Noble Road Bridge	1.64	-0.01	-0.01	0.12	0.06	0.05	0.16	0.00	0.63
Stanley St	10	4.52	0.02	-0.03	0.01	-0.01	-0.01	0.00	0.00	0.00
Stanley St	79	2.49	0.02	-0.02	0.02	-0.02	-0.01	0.01	0.00	-0.02
Stanley St	126	1.72	0.08	-0.06	0.04	-0.04	-0.02	0.02	0.01	0.34

Note: Results provided as a relative change in level (in metres) compared to the 1% AEP base case event assuming NO blockage.

The results indicate that the peak levels are relatively insensitive to the adopted Manning's "n" roughness values, with the greatest impact only +0.09 m.

Changing the rainfall by ±10% would change the estimated design flood levels but again the impact is small, with only a maximum change of +0.12 m.

Changing the WBNM storage parameter produces a maximum change of ±0.07 m.

Lowering the tailwater to 0.5 mAHD have virtually no impact on peak flood levels upstream of Noble Road bridge. Raising the tailwater level in Brisbane Water to 1.95 mAHD is most significant for the lower reaches such as at the Noble Road bridge where the impact is +0.63 m, but this quickly dissipates to nil at Chainage 158, and is only +0.12 m at Chainage 258.

7.7.2 The Greenhouse Effect

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

Since the early 1980's there has been concern that increasing amounts of greenhouse gases resulting from human activity may be raising the average earth surface temperature. As a consequence, this may affect the climate and sea level. The extent of any permanent climatic or sea level change can only be established through scientific observations over several decades. Nevertheless, it is prudent to consider the possible range of impacts with regard to flooding and the level of flood protection provided by any mitigation works.

SEA LEVEL RISE

Based on the latest research by the United Nations Intergovernmental Panel on Climate Change (UNIPCC), evidence is emerging on the likelihood of climate change and sea level rise as a result of increasing “greenhouse” gasses. In this regard, the following points can be made:

- greenhouse gas concentrations continue to increase,
- the balance of evidence suggests human interference has resulted in climate change over the past century,
- global sea level has risen about 0.1 m to 0.25 m in the past century,
- many uncertainties limit the accuracy to which future climate change and sea level rises can be projected and predicted.

Any change in the sea level will have an immediate and significant impact. This issue is complicated by other long term influences on mean sea level changes. The available literature suggests that a gradual increase in sea level is likely to occur with a rise of perhaps 0.2 m to 0.4 m within the next 50 years. Results from Table 17 indicate that any increase to the tailwater level results in a similar change to the flood levels in the lower reaches with the effects dissipating further upstream.

INCREASE IN RAINFALL INTENSITIES

On a regional basis the CSIRO Climate Change Group predicted in 1995 increased air and water temperatures, and greater frequency and intensity of severe storms for the NSW coastline. According to these predictions, east coast lows, which are one of the main causes of storms and floods, would be more intense, leading to increased occurrence of gale force winds and flooding. However, further research still needs to be undertaken.

To date, the Bureau of Meteorology has indicated that there is no intention to revise design rainfalls to take account of the Greenhouse Effect, as the possible mechanisms are far from clear, and there is no indication that the changes would in fact increase design rainfalls for major storms. Even if an increase in total annual rainfall does occur, the impact on design rainfalls may not be adverse. Table 17 indicates the change in flood levels resulting from ±10% change in the 1% design rainfalls.

INCREASE IN CYCLONIC ACTIVITY

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

7.8 Comparison of Results with the Killcare Catchment Drainage Investigation (Reference 1)

A comparison of the peak flows and design flood levels from the present study with those of the previous Killcare Catchment Drainage Investigation (Reference 1) is provided in Table 18 for several key locations.

Table 18: Comparison of Design Results with Reference 1

Branch	**Mike11 Model Chainage (m) (refer Figure 7)**	**1% AEP Peak Discharge (m^3/s)**		**1% AEP Peak Flood Levels (mAHD)**	
		Killcare Catchment D.I. (Ref.1)	**Present Study**	**Killcare Catchment D.I. (Ref.1)**	**Present Study**
Mudflat Creek	Fraser Road culvert	19	20	4.1	4.7
Mudflat Creek	143	n/a	n/a	3.0	3.2
Mudflat Creek	168	n/a	n/a	2.6	3.0
Mudflat Creek	216	n/a	n/a	1.9	2.1
Mudflat Creek	282	n/a	n/a	1.8	2.0
Mudflat Creek	Noble Road	n/a	n/a	1.7	1.6
Mudflat Creek	393	n/a	n/a	1.6	1.6
Mudflat Creek	436	30	32	1.6	1.6

n/a - results not available for comparison.

The results shown in Table 18 indicate that there is a slight difference of approximately 6% between the adopted design discharges for the two studies. This is a relatively satisfactory correlation considering that two completely different hydrologic modelling approaches were used, ILSAX for the previous study and WBNM for the present study. However, there is a more significant variation in estimated 1% AEP flood levels between the two studies. It is likely that the discrepancies between the two studies can be attributed to one or more of the following factors:

- *Approach and Objectives*

It should be noted that the primary aim of the previous study was to investigate the performance of the drainage system and (understandably) hydraulic modelling of the creek was undertaken in less detail than in the present study.

- *Differences in Topographic Data Sets*

While the survey data used in the previous study was also used to define the creek in the present study, further detail survey was undertaken of the floodplain adjacent to the creek. This enabled better definition of overbank areas in the present study. In comparison to the previous study the current model has more confined overbank areas. This would contribute to the increase in flood levels estimated for the current study.

- *Incorporation of Control Structures*

The difference in design flood levels shown in Table 18 at the Fraser Road culvert can be attributed to the representations of the structure in the different models. In the previous HEC-RAS model the culvert was modelled as a narrow notch in the road level. In the present MIKE-11 model the culvert has been defined implicitly as a composite control structure with capacity for both culvert flow in combination with road overtopping.

- *Modelling Assumptions*

In the present model it is assumed that the Fraser Road culvert is fully blocked and hence all flow overtops the road. In the previous model no blockage was assumed. The two models also assumed slightly different Manning's 'n' roughness values. The previous model assumed channel Manning's 'n' values of 0.03 to 0.04 and overbank values of 0.035 to 0.08, whilst the present study used channel Manning's 'n' values of 0.04 to 0.065 and overbank values of 0.05 to 0.1. These Manning's 'n' values were based on experience and judgment and are considered to be representative of the vegetative condition at the time. The higher values used in the present study would contribute to the increase in flood levels estimated in the current study.

In summary, the current study uses a more rigorous, fully dynamic modelling approach that utilises more detailed survey data. These factors provide a greater degree of confidence in the simulated flood behaviour compared to that estimated for the earlier Killcare Catchment Drainage Investigation.

7.9 Overland Flooding in Fraser Road North

Reports of flooding by a number of residents fronting that part of Fraser Road aligned parallel to Mudflat Creek indicate that overland flooding is a significant problem in this area. Residents at 37, 45 and 47 Fraser Road all indicated that they have experienced flooding to either their yards or houses in the past (refer Photographs 21 and 22). Discussions with these residents indicate that this flooding is mainly due to overland flow coming from the north-east corner of Fraser Road, that, after overtopping into the front yard of 37 Fraser Road, flows through the yards of 37, 39, 45 and 47 Fraser Road. This is revealed in Photograph 20 taken during either the April or July 1988 event. Since that time there has been some changes to Fraser Road and to the yard of No. 37 (construction of an earthen and a concrete levee bank facing Fraser Road) as shown in Figure 20. The earthen levee runs on both sides (eastern and northern boundaries) of the property.

From Figure 20 it is also evident that Fraser Road rises from the sharp bend eastwards up to 51 Fraser Road before falling again. This grade coupled with the earth levee in 37 Fraser Road restrain floodwater from proceeding east by creating a pond right on the bend and further rise in water at this point creates a flow southwards on and along Fraser Road up to the culverts.

Further increase in the floodwater at this spot causes some of this southbound flow to overtop the levee and enter 37 Fraser Road, wherein a second concrete levee guides the overflow towards east into neighbouring properties. The front yards of all these properties are below the road level and slope backwards towards the creek. The overland flows through front yards of these properties reaches up to 47 Fraser Road while reducing in quantity as some part of this flow returns to the main creek through openings and walkways within these properties. This can be confirmed by the presence of a swale from 37 to 47 Fraser Road passing through the front yards.

After 47 Fraser Road the swale disappears and it is less likely for the remaining overland flow to pass by further downstream without substantially rising in level. Owner of this property has submitted this issue to Council in response to the public exhibition of this flood study report.

The majority of Killcare Heights, including the area referred to by residents as “the triangle” (refer to Section 2.2), drains to the Fraser Road culvert via a natural gully that connects the upper and lower sections of the catchment. During large storm events residents on both the western and eastern side of Fraser Road have observed that flows travelling down the natural gully have overtopped the banks and flowed across Fraser Road. Flows were observed to travel through the reserve adjacent to 44 and 48 Fraser Road, across the roadway and through the properties on the south side of the road (No’s 37 to 57) before joining the creek. Results from the flood modelling undertaken would suggest that overtopping of the natural gully would occur in the 20% AEP event and greater. In addition runoff from the heavily vegetated and relatively steep slopes on the north side of Fraser Road (refer catchment M08 on Figure 6) would enter the roadway at the sharp bend and add to the breakout flow.

The estimated design flows draining to the Fraser Road culvert together with the local catchment flows are summarised in Table 19. It should be noted that for design the culvert under Fraser Road was assumed to be 100% blocked, thus all the flow would pass over Fraser Road. Without blockage the culvert has a capacity of approximately 8 m^3/s before overtopping of the road. Thus overtopping will occur (assuming no blockage) in the 20% AEP event and greater. However it is possible that a breakout may occur further upstream before the capacity of the culvert is reached.

In case of a breakout of the floodwaters anywhere upstream of the Fraser Road culverts, water will flow away from the creek towards the northern sharp bend in the Fraser Road. This can be observed by looking at the three cross-sections of the creek in this area, as shown in Figure 3e. Cross-section FR3 is nearest to the Fraser Road. Ground levels in all the three cross-sections fall just right side of the right bank of the creek forming a wide swales that moves away from the creek towards the northern corner of Fraser Road. This also explains the source of floodwaters in the bend.

Table 19: Design Flows at Fraser Road

Flood Event	Peak Flow at Culvert * (m^3/s)	Peak Flow from Catchment M08 (m^3/s)
20% AEP	10	1.4
10% AEP	12	1.7
5% AEP	15	1.9
2% AEP	17	2.2
1% AEP	20	2.4
0.5% AEP	22	2.7
PMF	93	8.1

Notes: The hydraulic modelling does not simulate the actual flow paths taken by the overflow and runoff from the north side of Fraser Road. For this reason the modelling does not account for the difference in water level between the street front of No's 37 to 57 Fraser Road and the rear (i.e. in the creek).
* The design flood analysis assumes that the culvert is 100% blocked.

The amount of flow entering each property, the peak level attained and the flow path cannot be determined using the existing hydraulic model. The Mike-11 model only accounts for flow along the main creek line. Given the lack of street drainage provisions, any significant amount of flow travelling along Fraser Road could potentially cause significant flooding problems to these properties.

A qualitative assessment of overland flooding issues in Fraser Road has been undertaken and is summarised in Figure 20. These issues will need to be addressed at the Floodplain Risk Management Study phase.

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8. ACKNOWLEDGMENTS

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

- Gosford City Council,
- Department of Natural Resources,
- Killcare Wagstaffe Trust Inc.,
- Killcare, Pretty Beach, Wagstaffe Youth and Community Association,
- residents of the Mudflat Creek catchment.

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FIGURE 1

LOCALITY PLAN AND RAINFALL STATIONS

STUDY AREA
DAILY READ RAINFALL STATION
PLUVIOMETER RAINFALL STATION
PRIVATELY READ RAIN GAUGE

1 0 1 2 3 4 5km
SCALE

FILE > J:\JOBS\24016\FIGURES\FIGURE 1.CDR DATE > 24-09-2004 12:00

FIGURE 2

CATCHMENT MAP AND ROADCROSSINGS

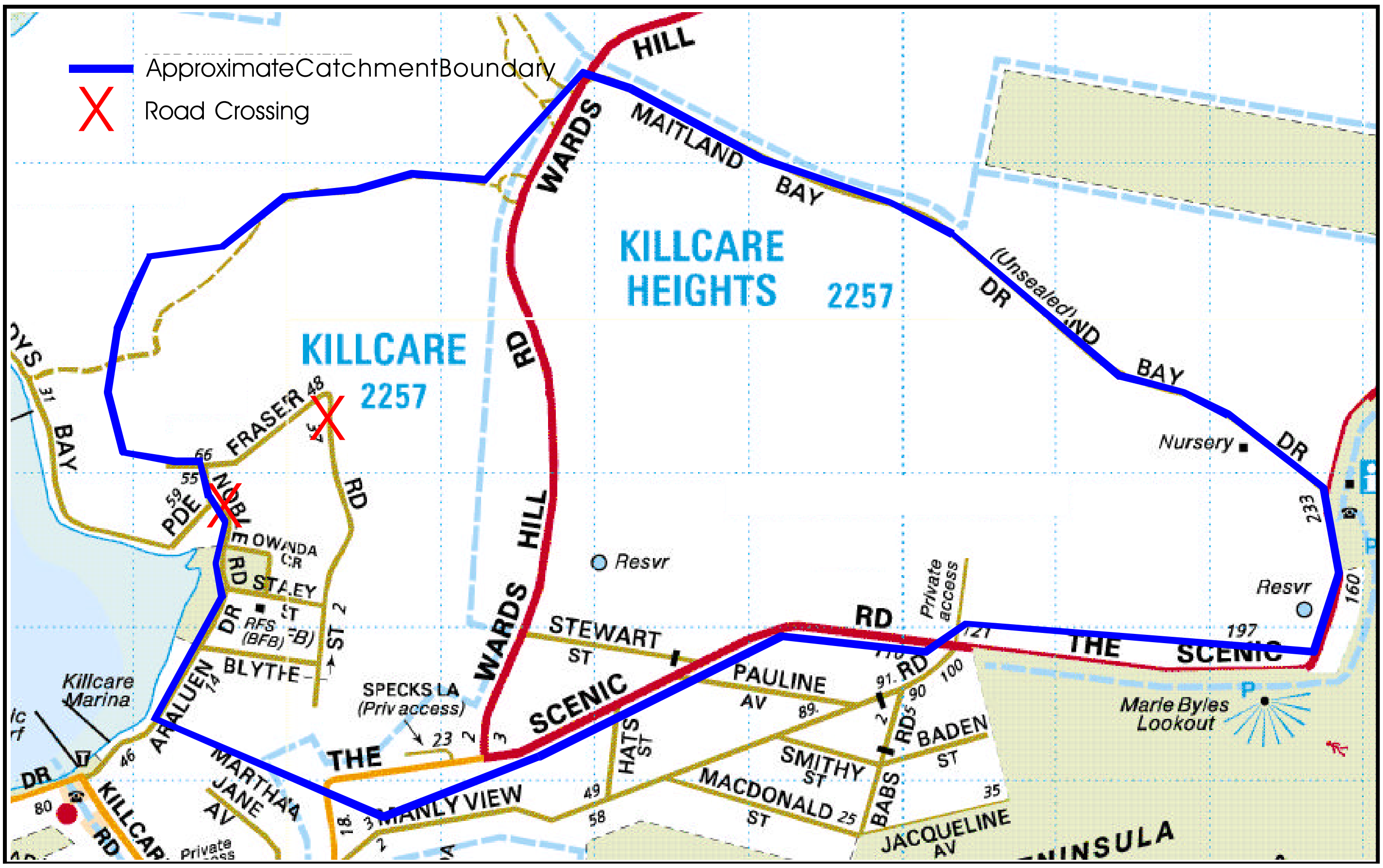


FIGURE 3a

SURVEY DATA
HISTORICAL FLOOD LEVELS

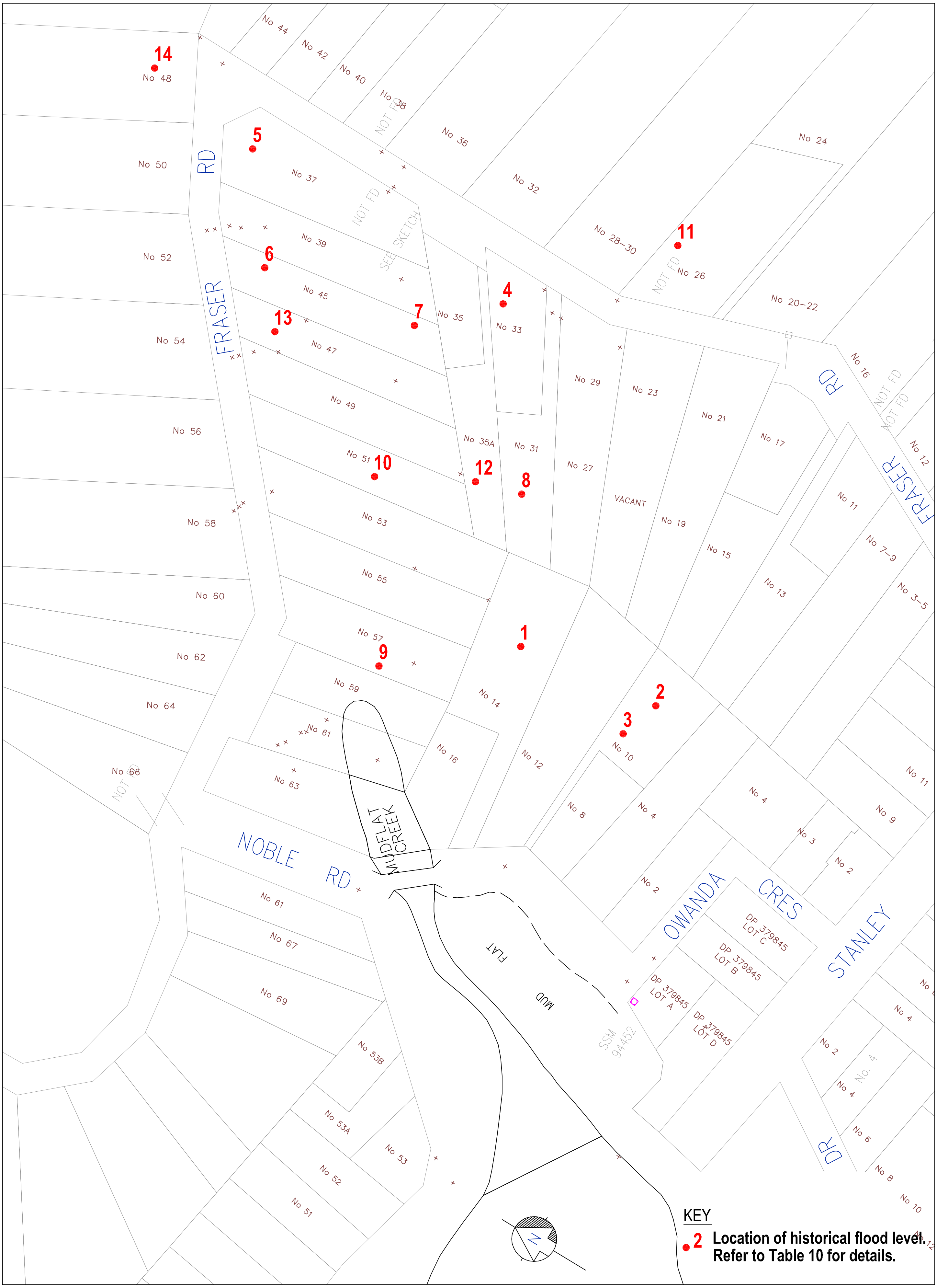


FIGURE 3b

SURVEY DATA
CREEK DEFINITION

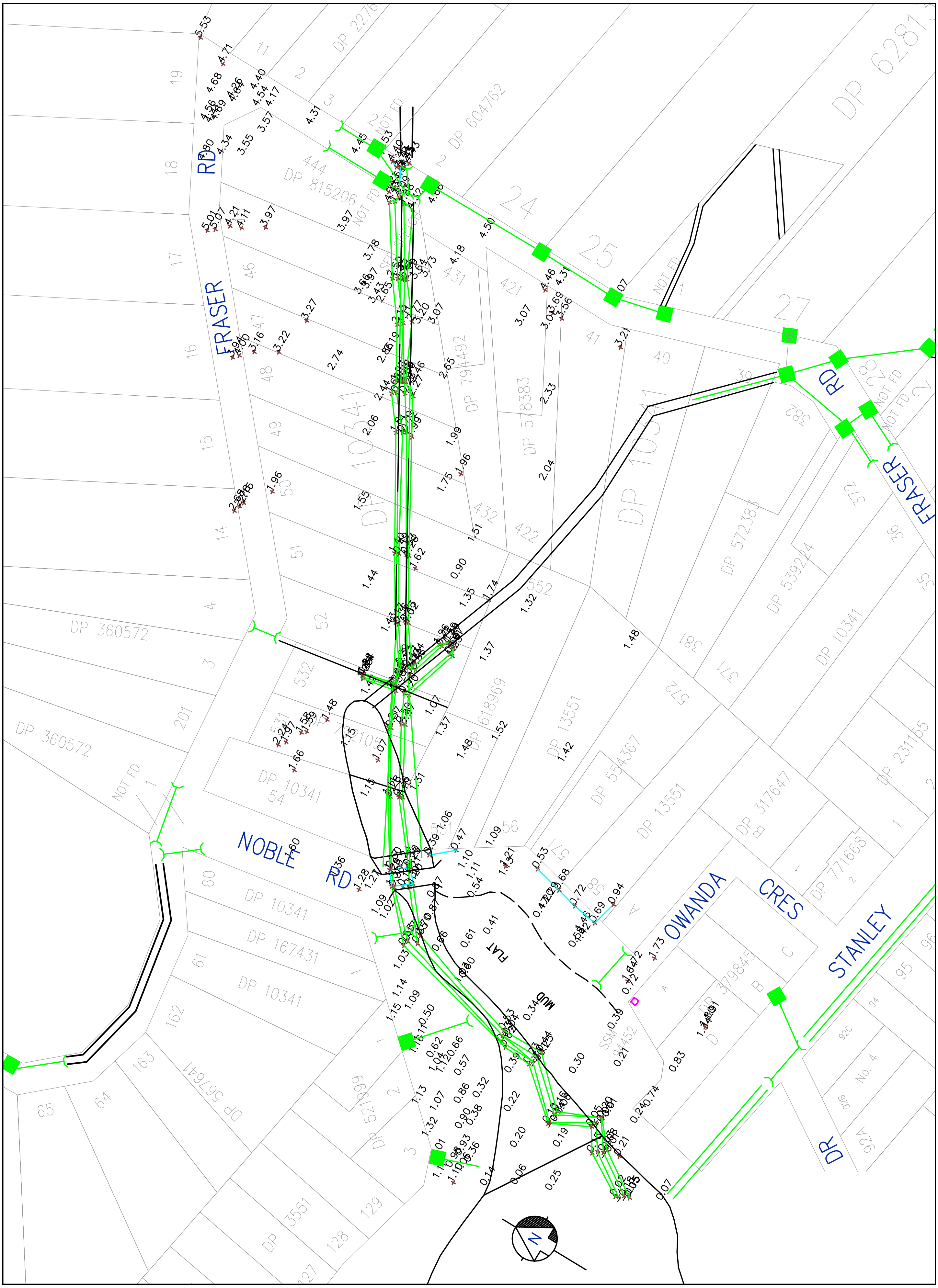


FIGURE 3c
SURVEY DATA
PROPERTY DEFINITION

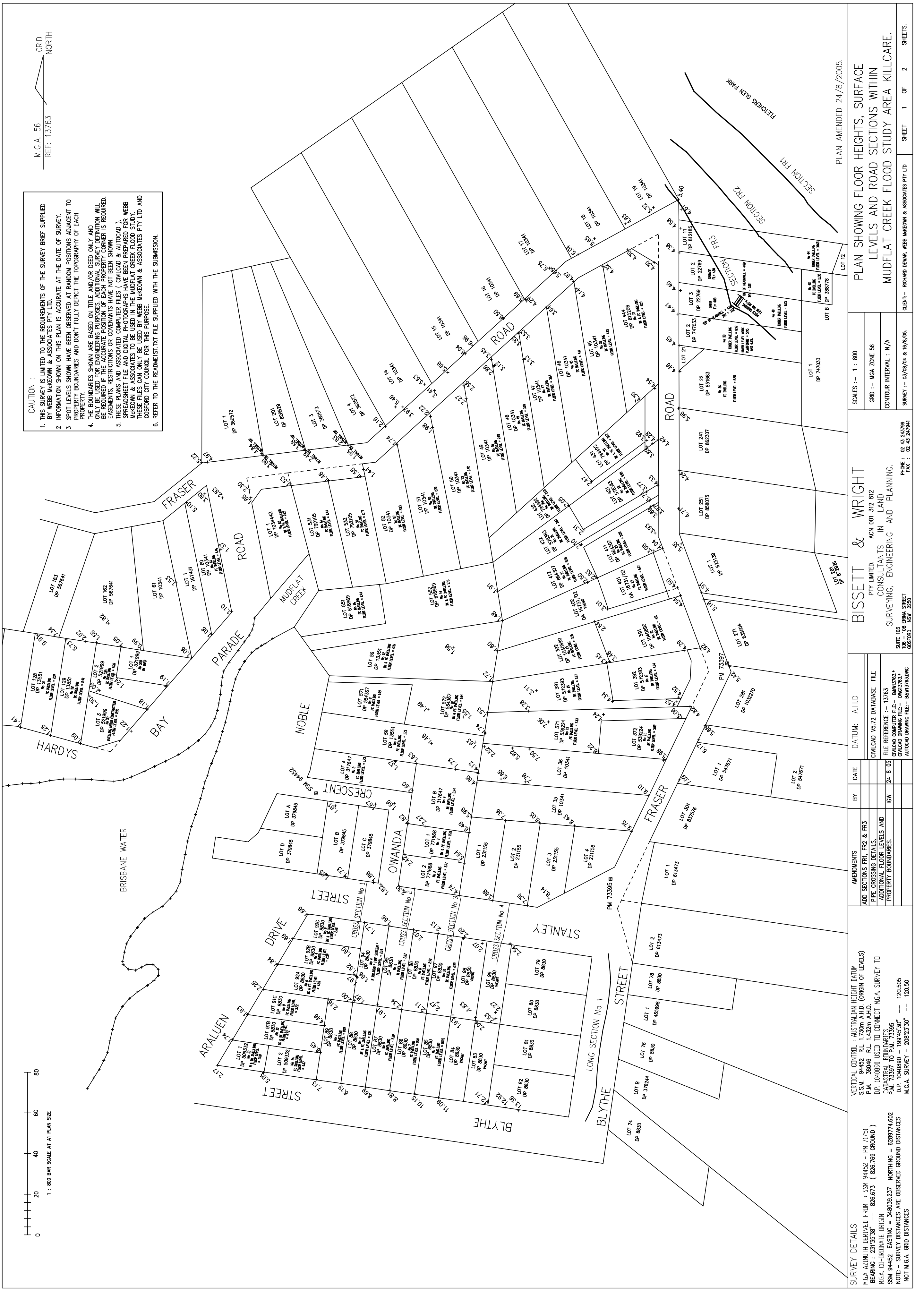


FIGURE 3d
SURVEY DATA
STANLEY STREET CROSS SECTIONS

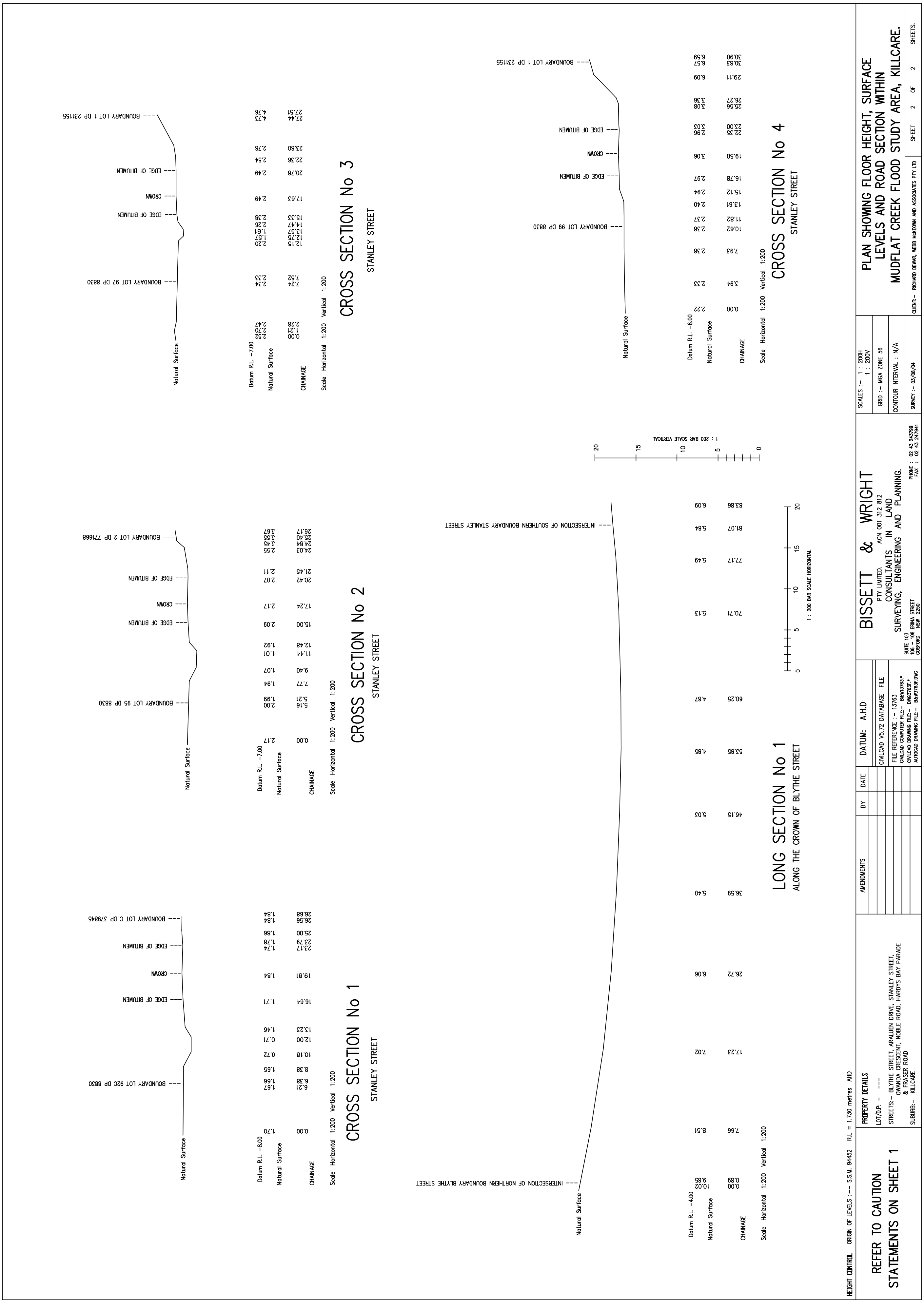


FIGURE 3e
SURVEY DATA
FRASER ROAD CROSS SECTIONS

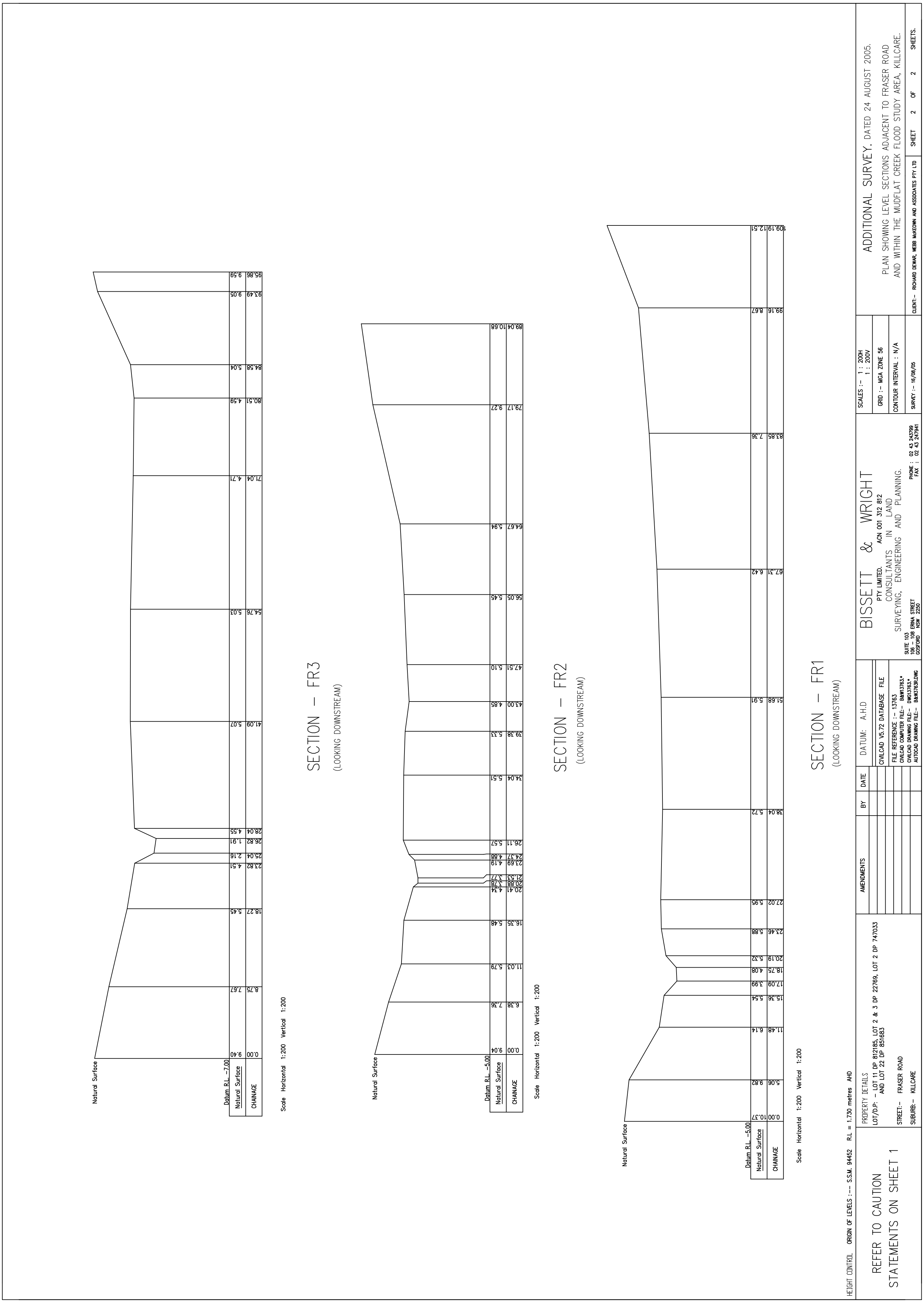
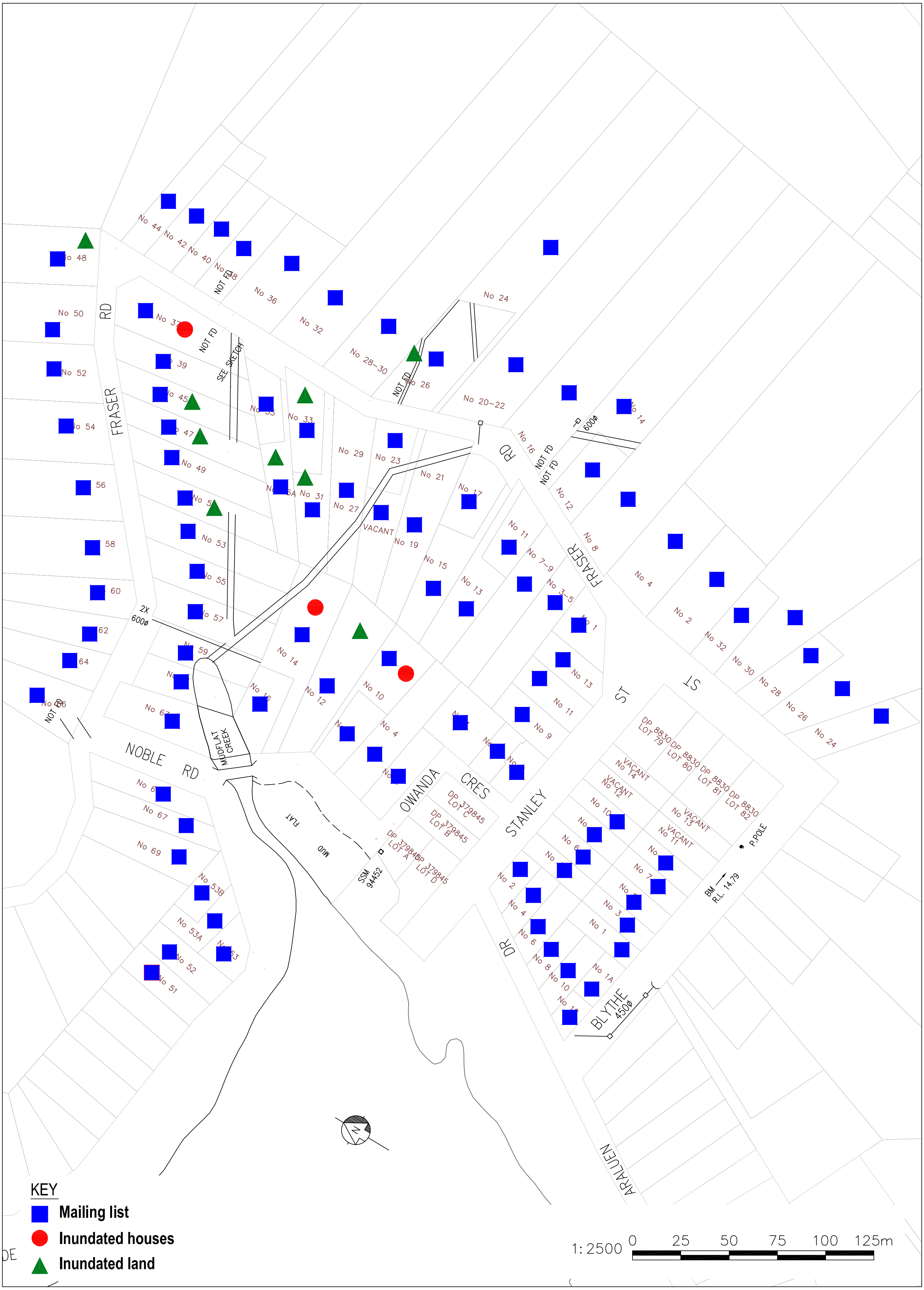


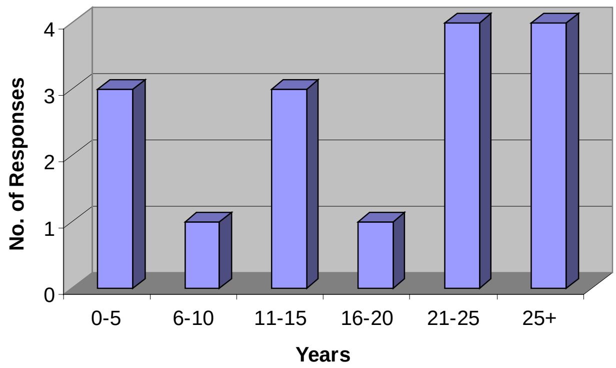
FIGURE 4

QUESTIONNAIRE SURVEY

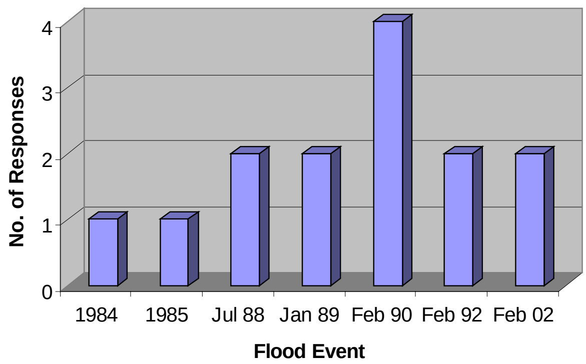


ANALYSIS OF QUESTIONNAIRE RESULTS

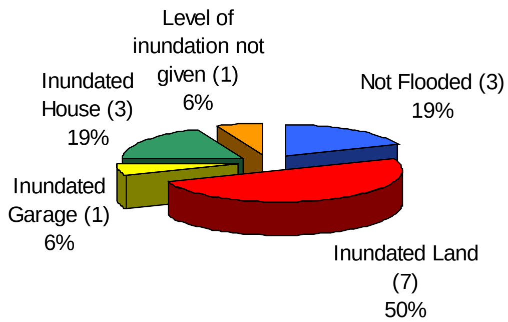
Years in Area



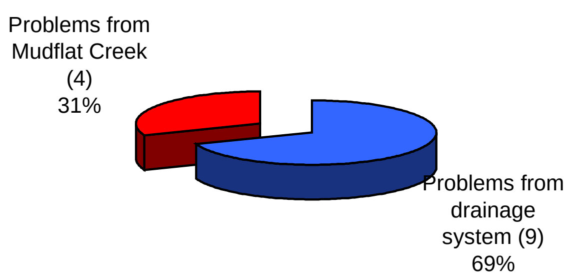
Flood Events Identified



Respondents Affected by Flooding



Source of Flooding



Other Water Related Issues Noted

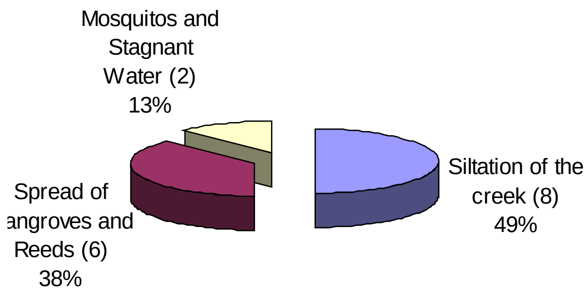


FIGURE 6

HYDROLOGIC MODEL LAYOUT

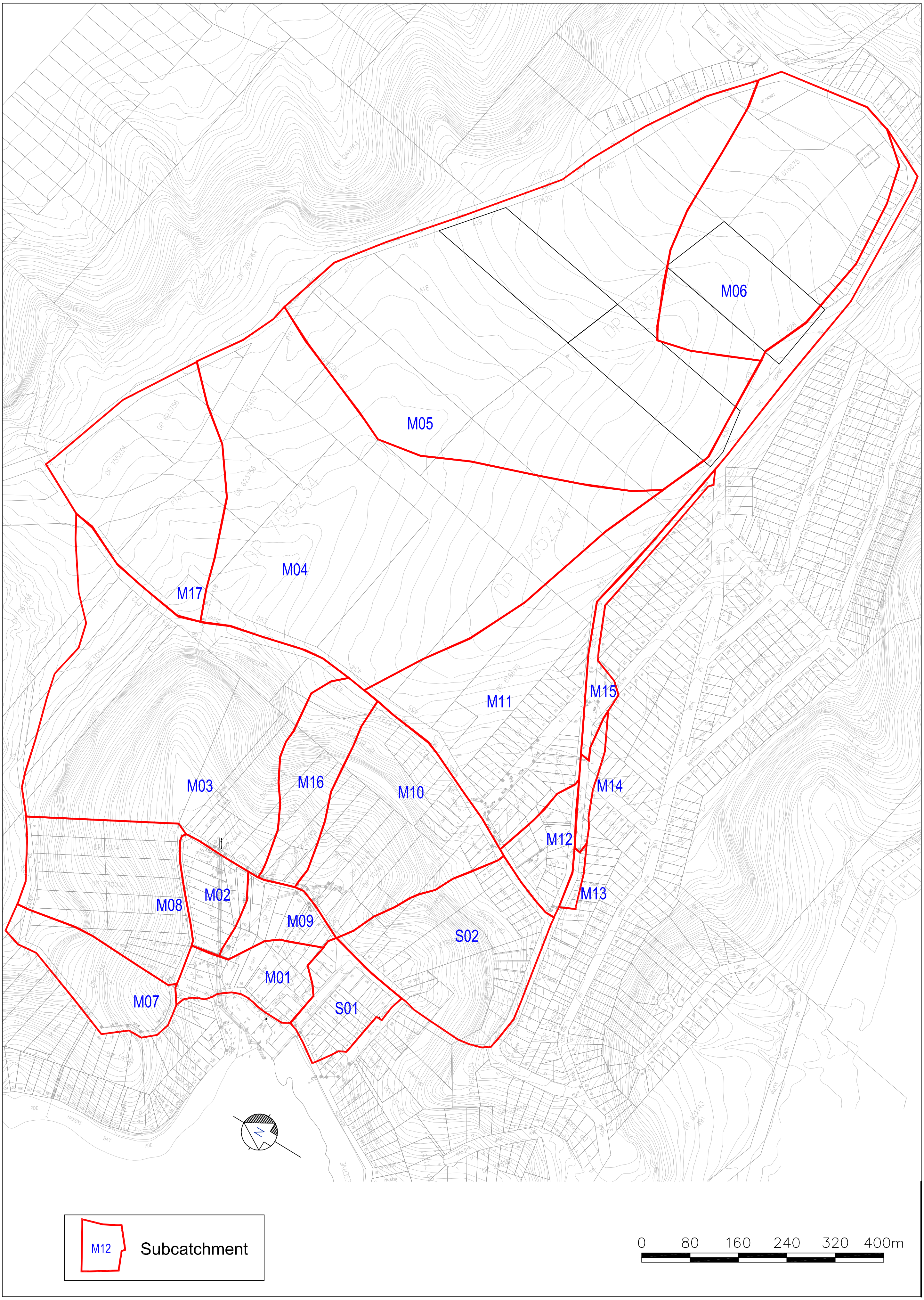


FIGURE 7

HYDRAULIC MODEL LAYOUT

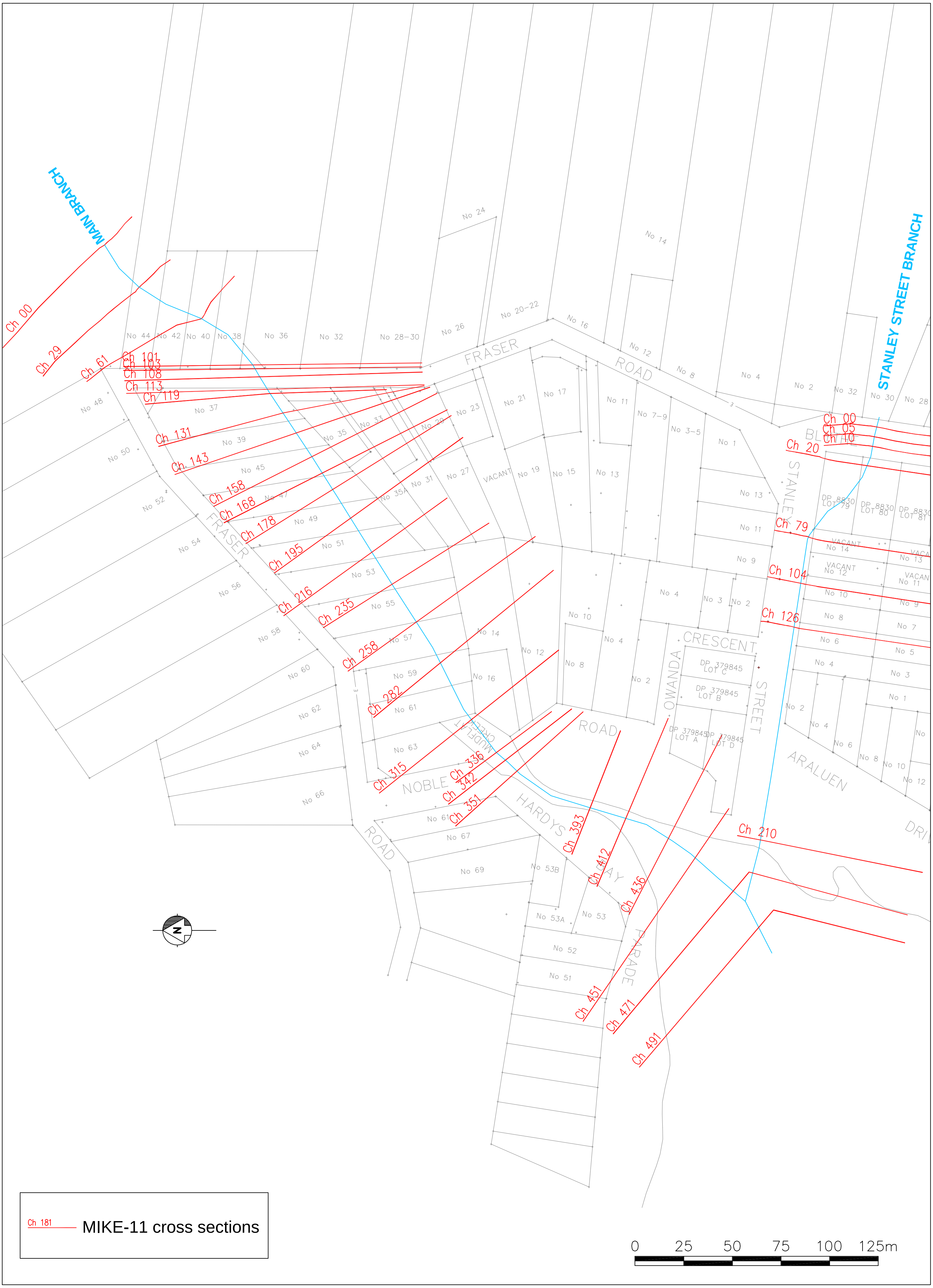


FIGURE 8
PEAK HEIGHT PROFILES
DESIGN FLOODS - MAIN BRANCH

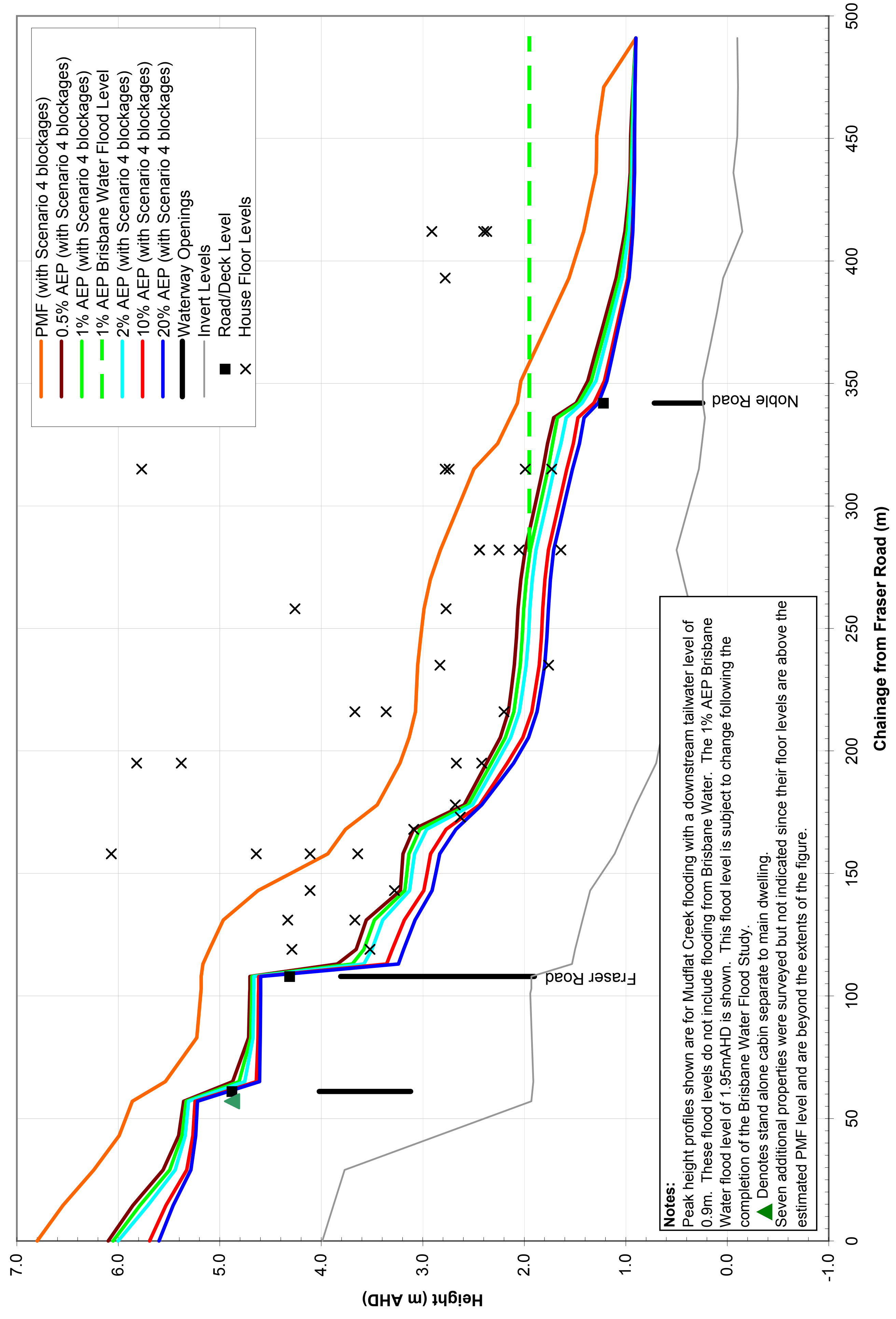


FIGURE 9

PEAK HEIGHT PROFILES

DESIGN FLOODS - STANLEY STREET BRANCH

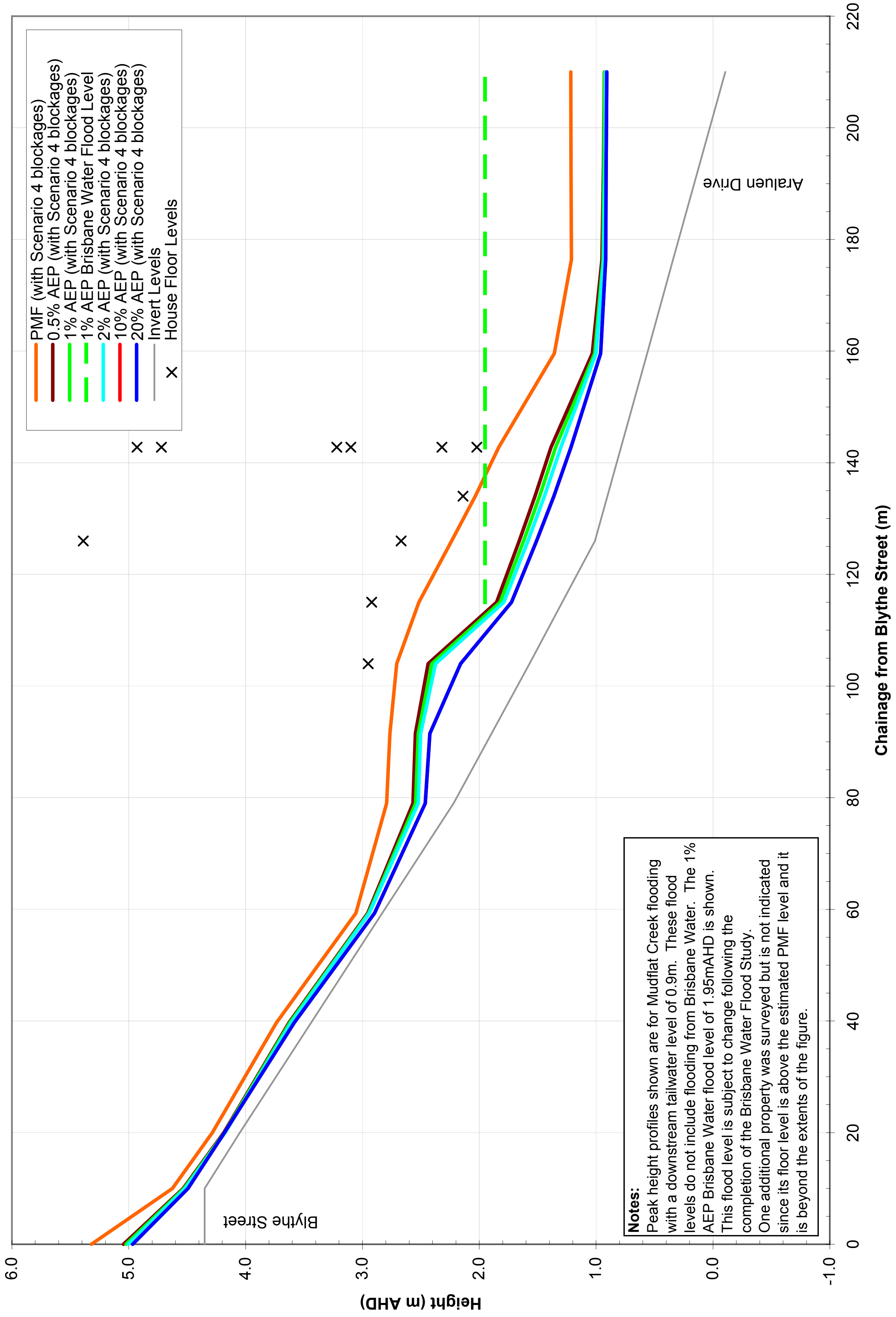
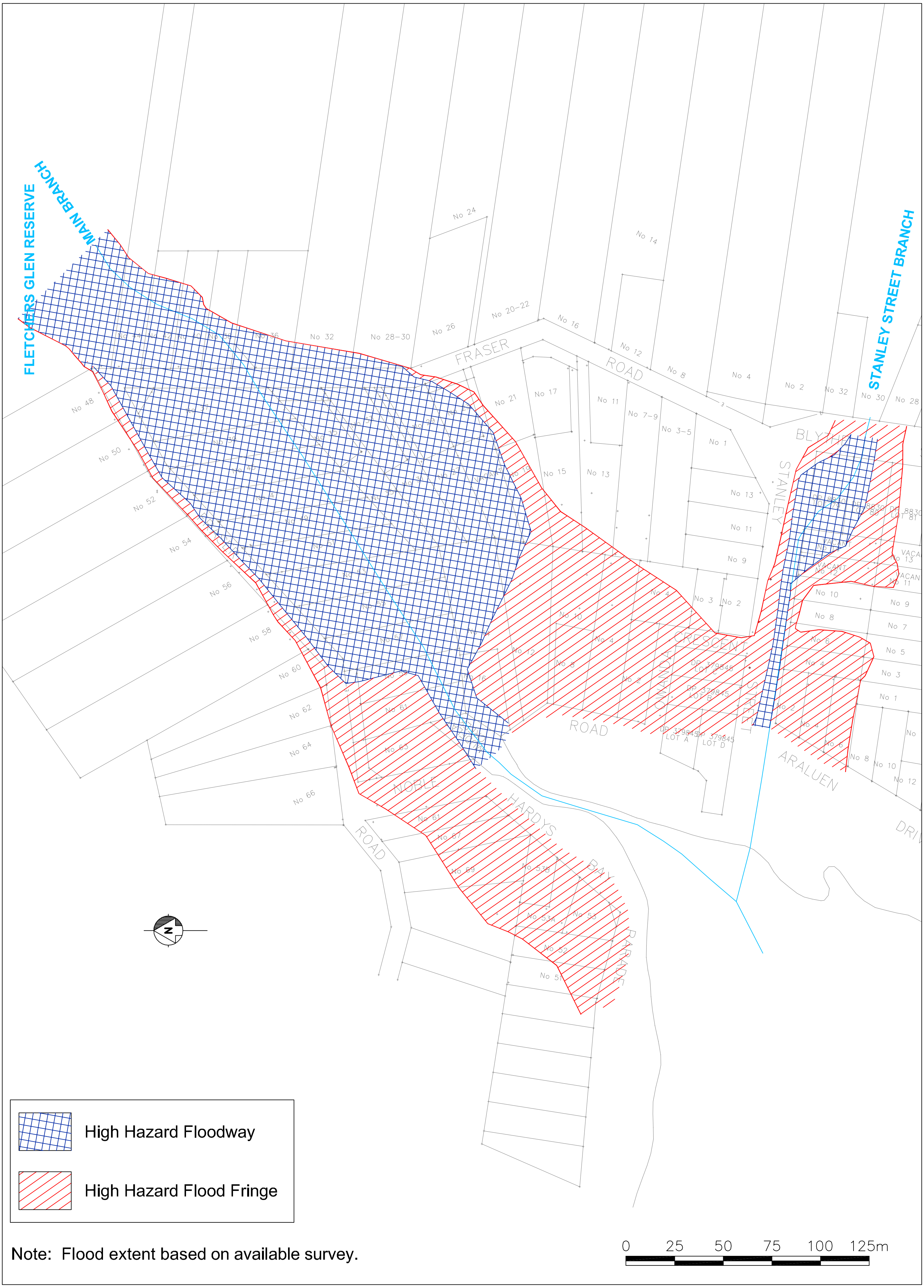


FIGURE 10

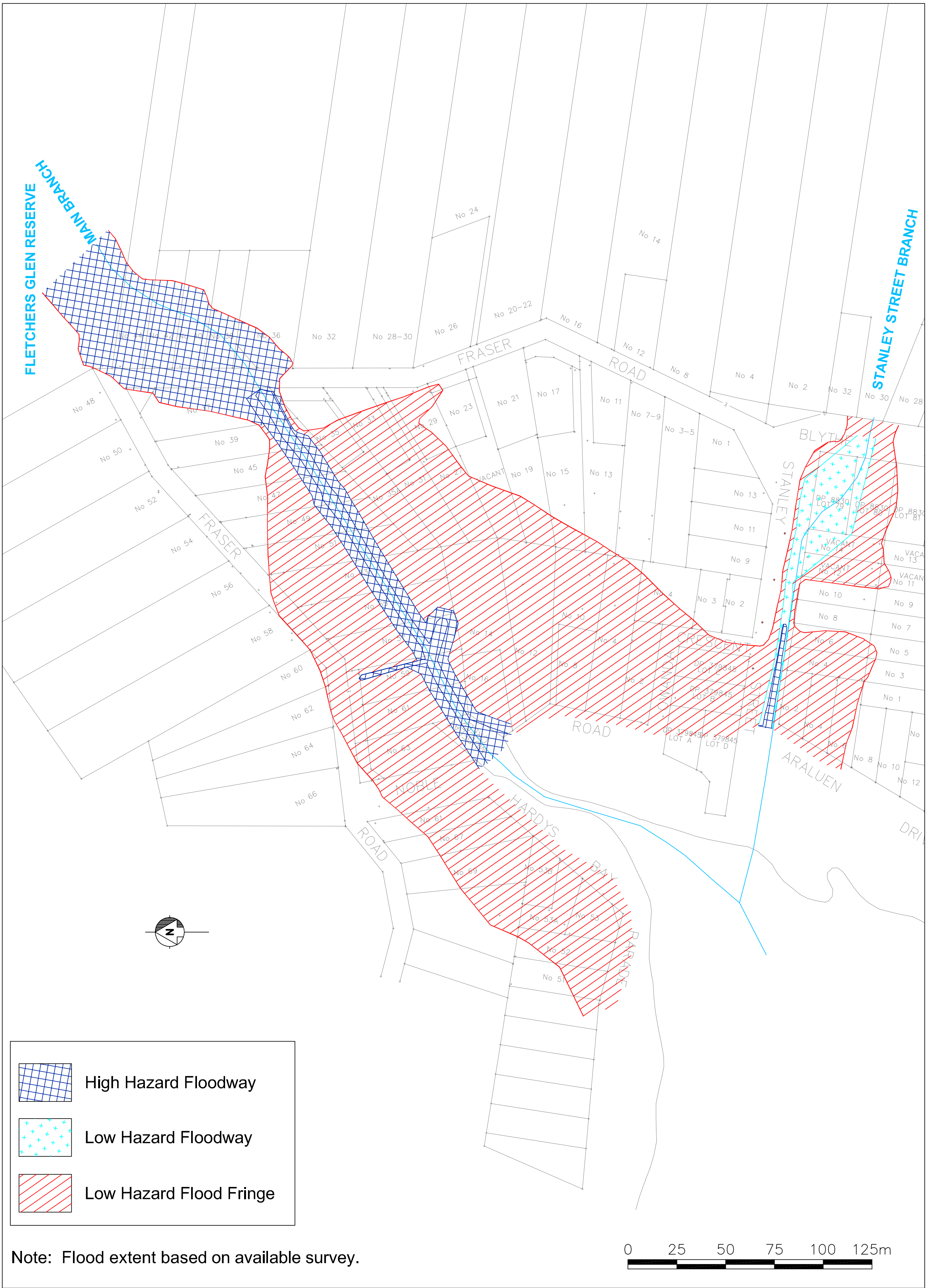
HYDRAULIC AND HAZARD CATEGORISATION - PMF DESIGN CONDITIONS



Note: Flood extent based on available survey.

FIGURE 11

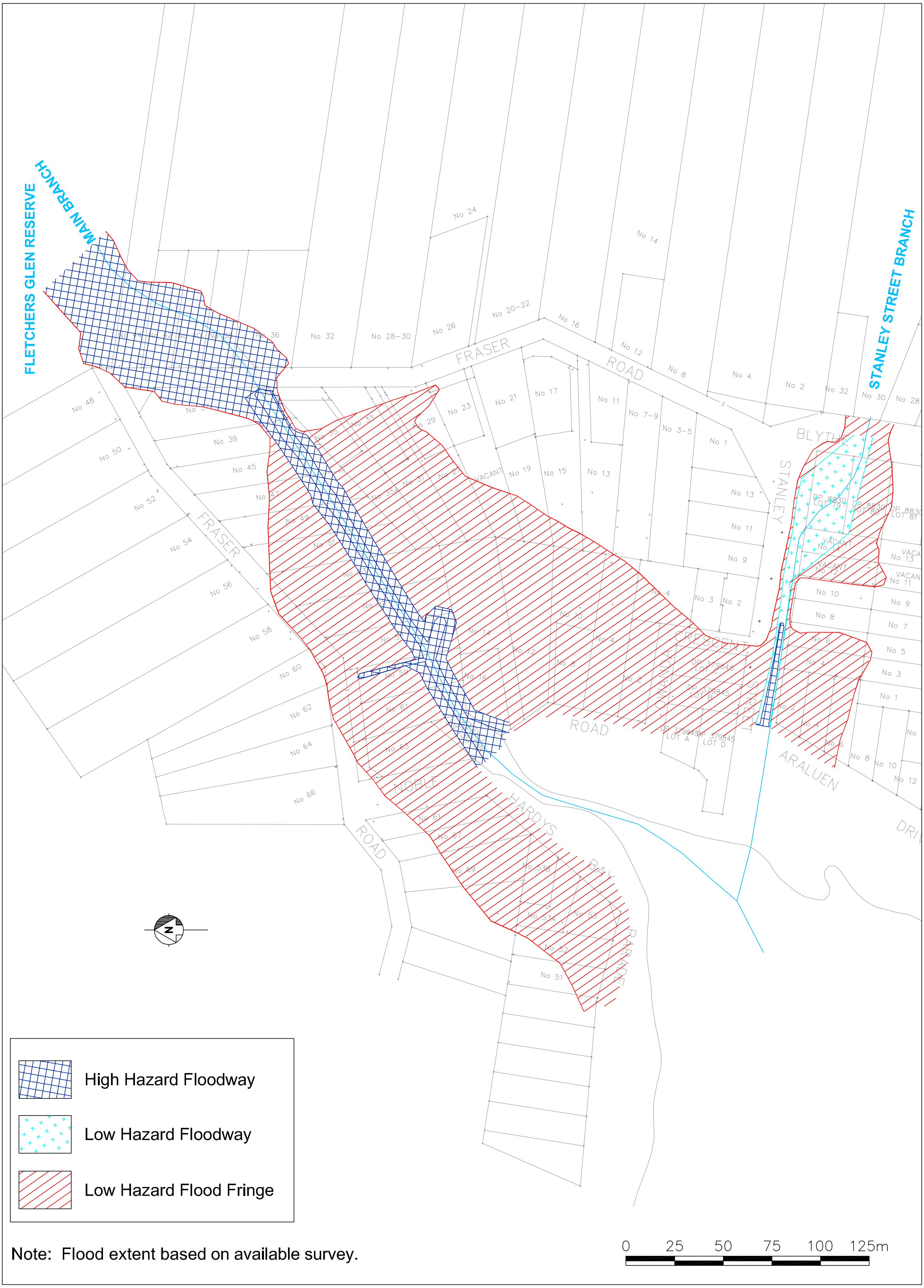
HYDRAULIC AND HAZARD CATEGORISATION - 0.5% AEP DESIGN CONDITIONS



Note: Flood extent based on available survey.

FIGURE 12

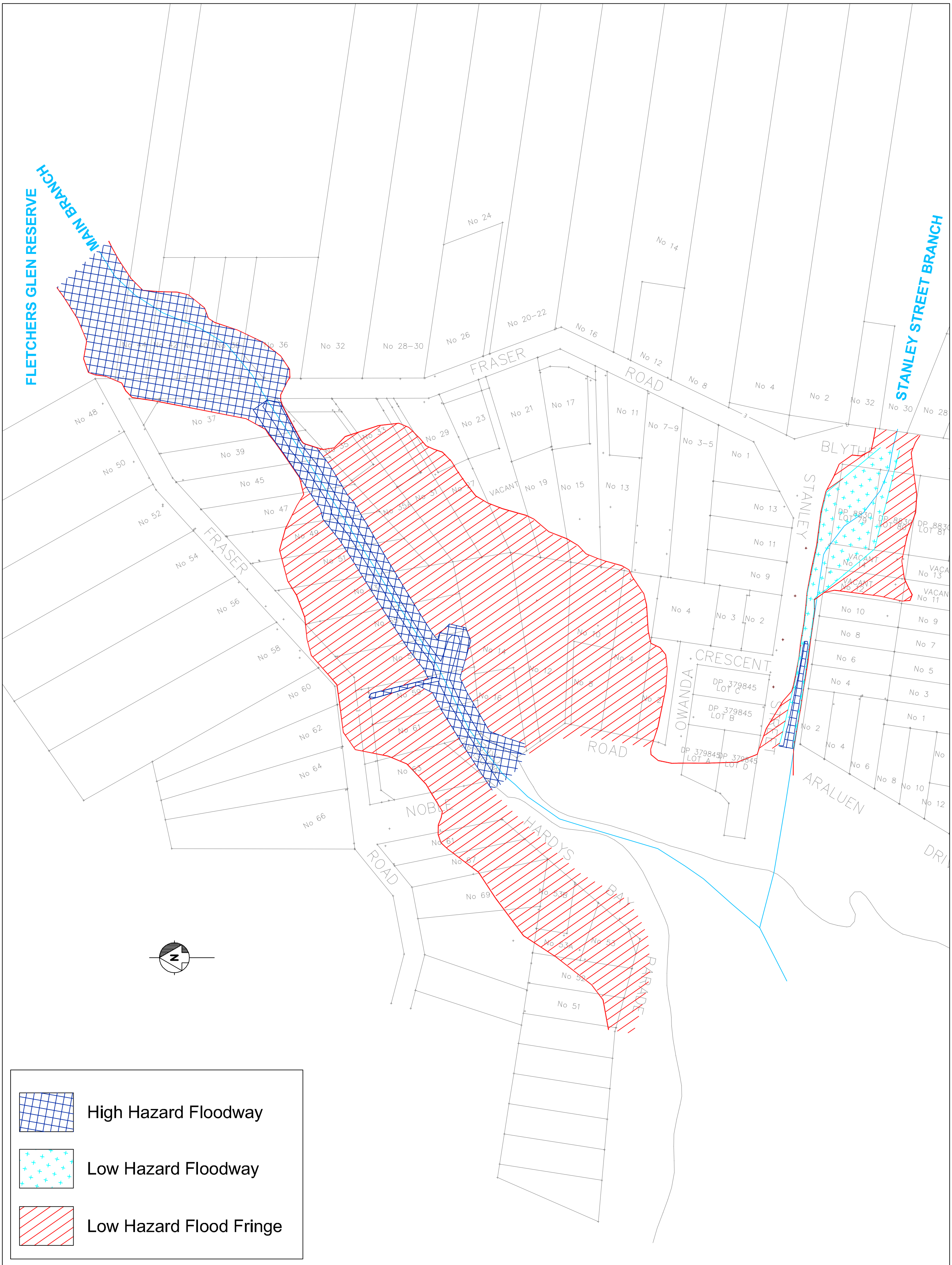
HYDRAULIC AND HAZARD CATEGORISATION - 1% AEP DESIGN CONDITIONS



Note: Flood extent based on available survey.

FIGURE 13

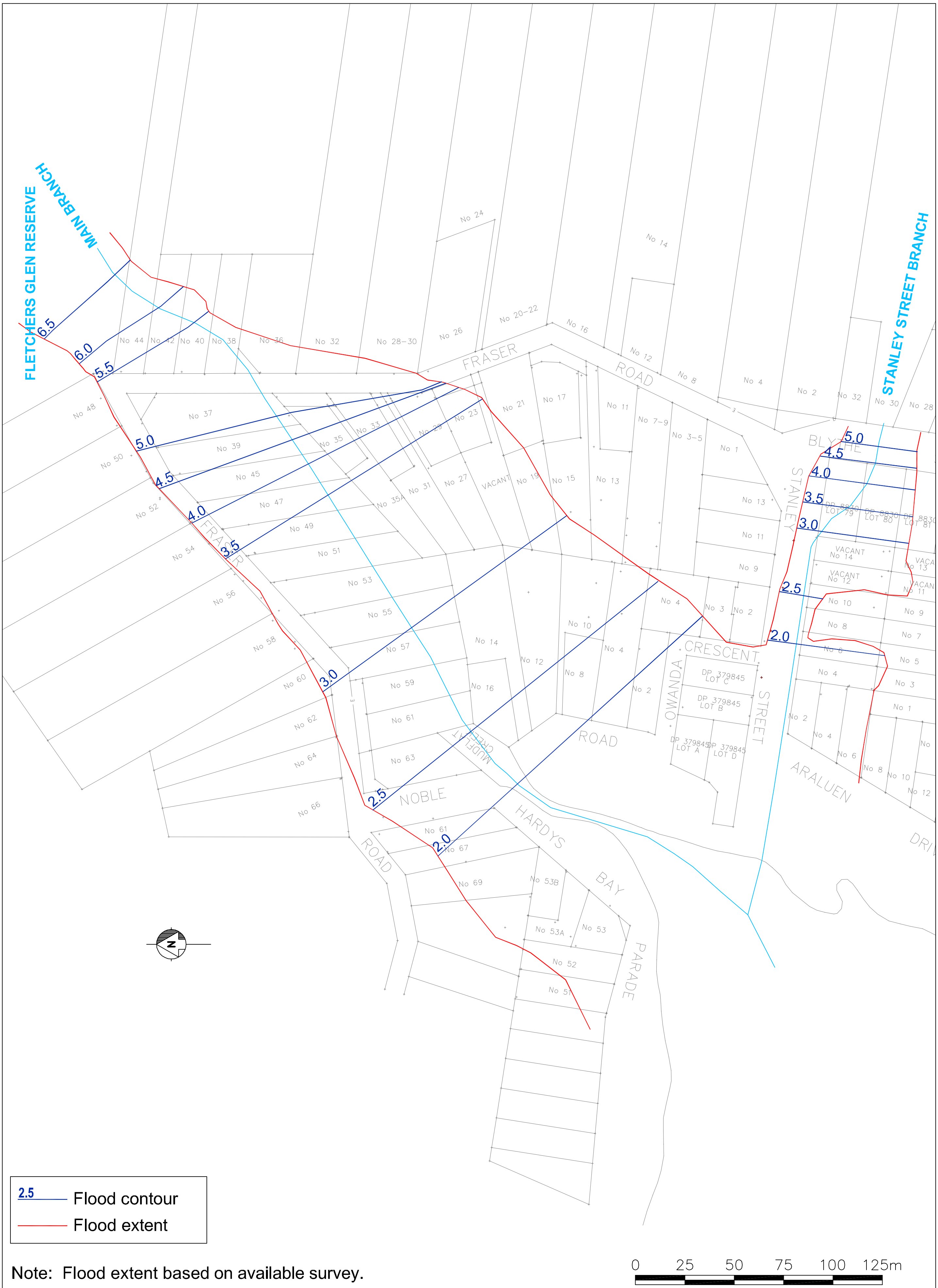
HYDRAULIC AND HAZARD CATEGORISATION - 5% AEP DESIGN CONDITIONS



Note: Flood extent based on available survey.

FIGURE 14

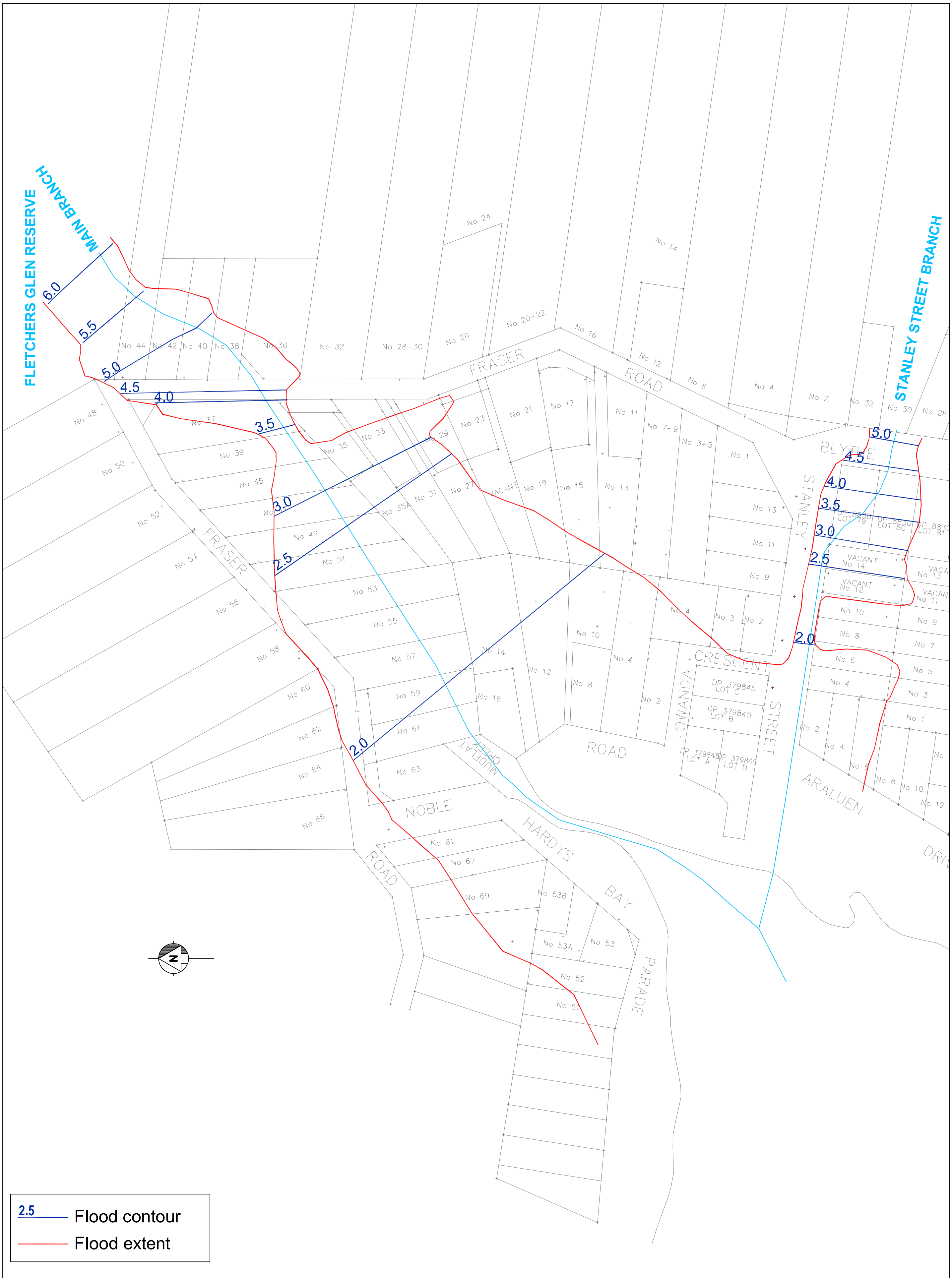
DESIGN FLOOD CONTOURS - PMF CONDITIONS



Note: Flood extent based on available survey.

FIGURE 15

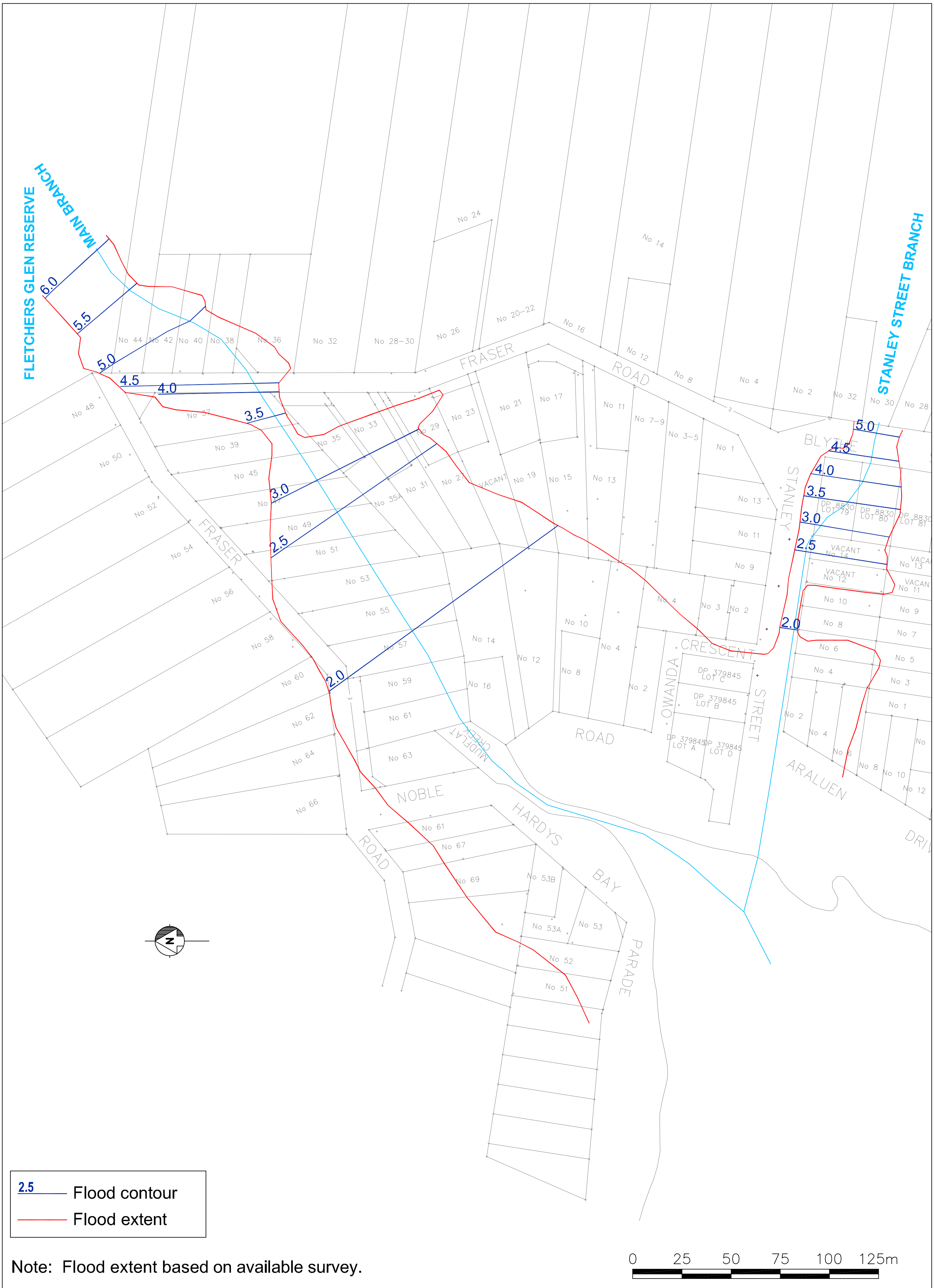
DESIGN FLOOD CONTOURS - 0.5% AEP CONDITIONS



Note: Flood extent based on available survey.

FIGURE 16

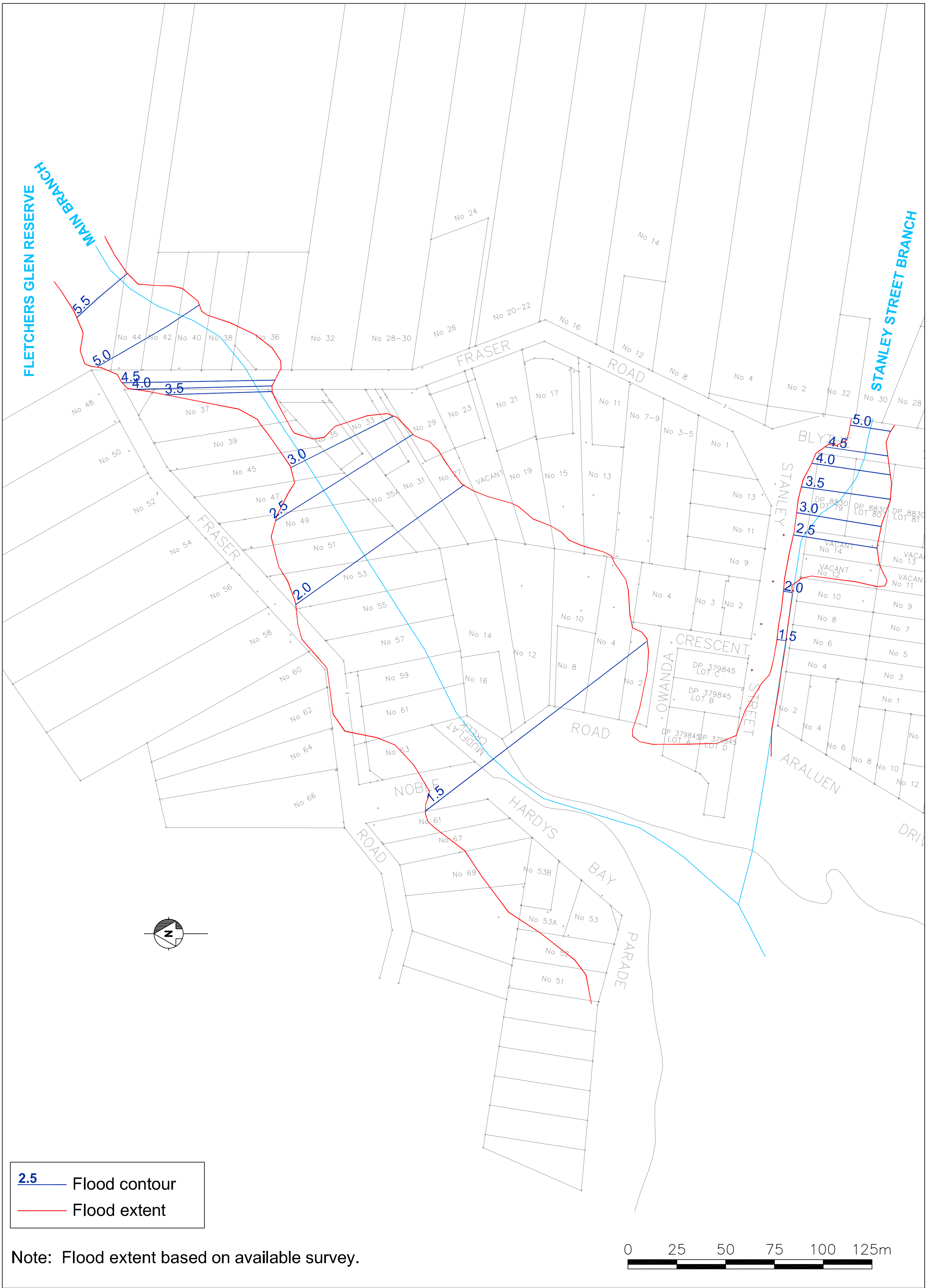
DESIGN FLOOD CONTOURS - 1% AEP CONDITIONS



Note: Flood extent based on available survey.

FIGURE 17

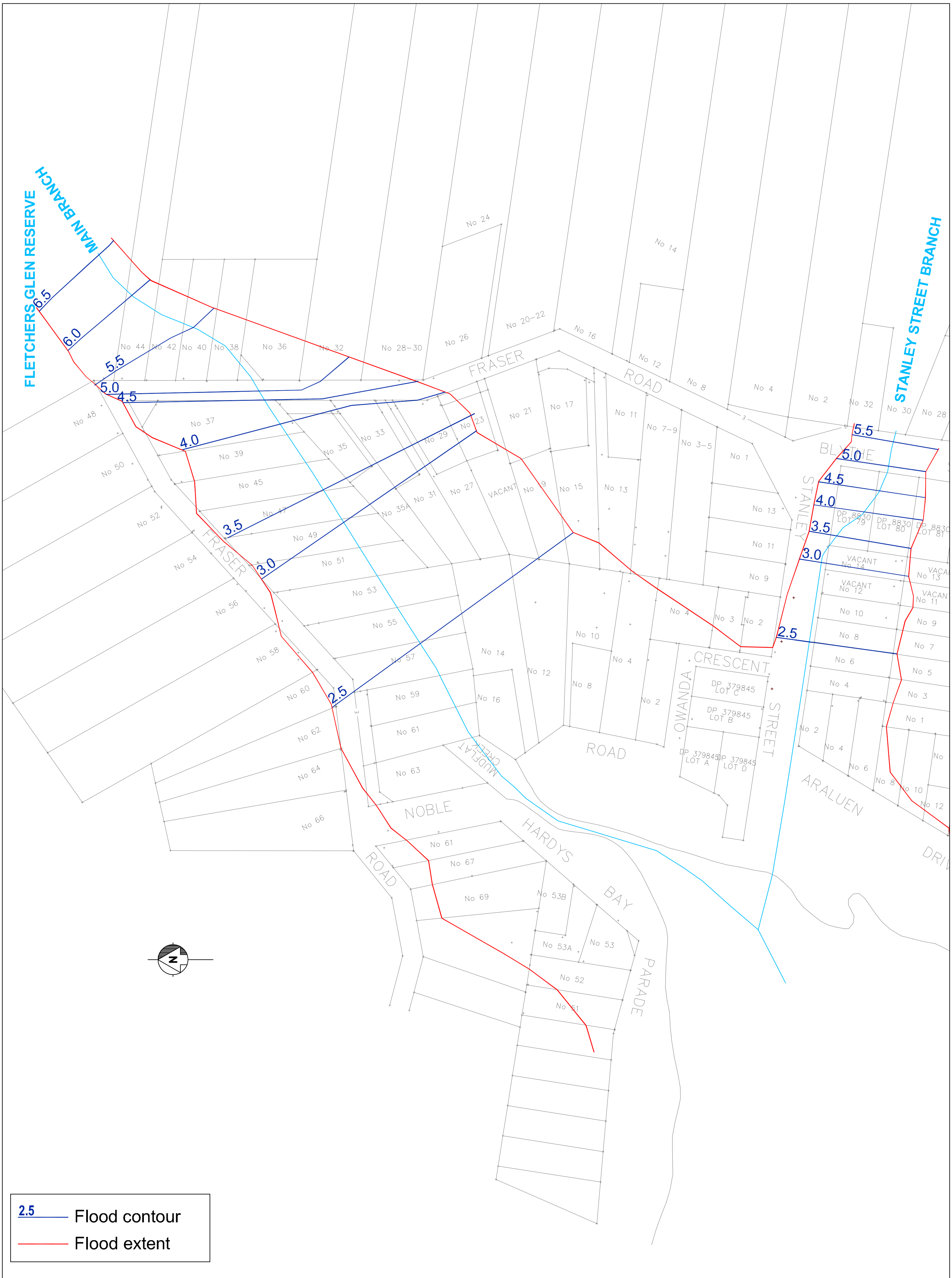
DESIGN FLOOD CONTOURS - 5% AEP CONDITIONS



Note: Flood extent based on available survey.

FIGURE 18

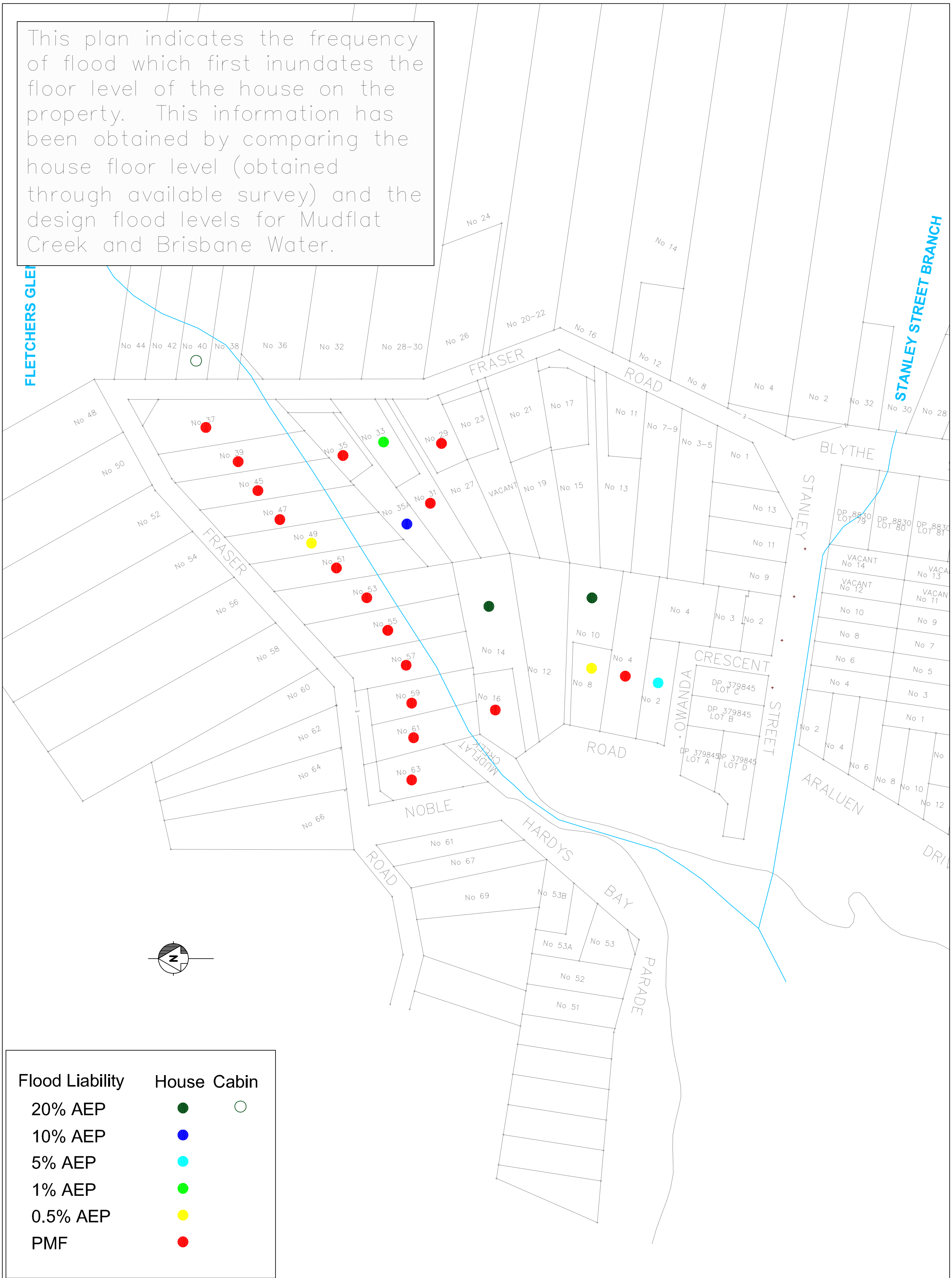
DESIGN FLOOD EXTENTS - 1% AEP + 0.5m FREEBOARD



Note: Flood extent based on available survey.

FIGURE 19

BUILDINGS INUNDATED



Note: Flood extent based on available survey.

FIGURE 20

OVERLAND FLOW DETAILS

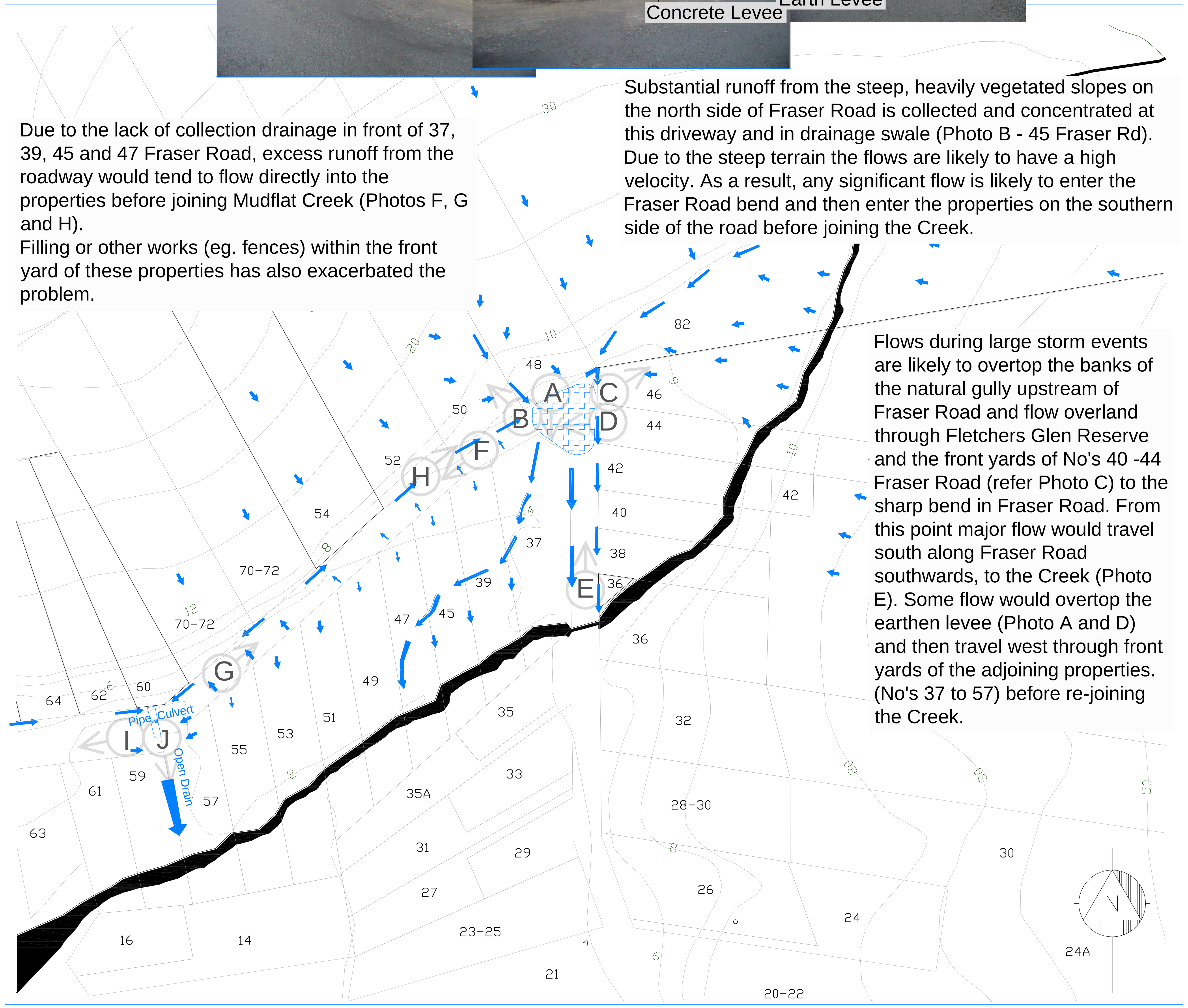

Photo E


Photo F


Photo G


Photo H

Photo A

Due to the lack of collection drainage in front of 37, 39, 45 and 47 Fraser Road, excess runoff from the roadway would tend to flow directly into the properties before joining Mudflat Creek (Photos F, G and H).
Filling or other works (eg. fences) within the front yard of these properties has also exacerbated the problem.

Substantial runoff from the steep, heavily vegetated slopes on the north side of Fraser Road is collected and concentrated at this driveway and in drainage swale (Photo B - 45 Fraser Rd). Due to the steep terrain the flows are likely to have a high velocity. As a result, any significant flow is likely to enter the Fraser Road bend and then enter the properties on the southern side of the road before joining the Creek.

Flows during large storm events are likely to overtop the banks of the natural gully upstream of Fraser Road and flow overland through Fletchers Glen Reserve and the front yards of No's 40 -44 Fraser Road (refer Photo C) to the sharp bend in Fraser Road. From this point major flow would travel south along Fraser Road southwards, to the Creek (Photo E). Some flow would overtop the earthen levee (Photo A and D) and then travel west through front yards of the adjoining properties. (No's 37 to 57) before re-joining the Creek.


Photo B


Photo C


Photo D

Flow in the western end of Fraser Road is collected by open drains that run along the side of the road (Photo I). At the low point in Fraser Road runoff is conveyed across the road by a pipe that discharges into an open drain that runs between 57 and 59 Fraser Road to the Creek (Photo J). Based on anecdotal information, flows regularly overtop this open channel. Maintenance of these open drains has been raised as a concern due to difficulties in mowing the sides.


Photo I


Photo J

LEGEND

- Existing Flow Path of Mudflat Creek (Approximate)
- Overland Flow Pattern (Concentrated Flow)
- Overland Flow Pattern (Starting/Sheet Flow)
- Ponding of Flood Water
- Photo No and Camera Projection

APPENDIX A: GLOSSARY OF 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 Development 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 change 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: DESIGN FLOOD RESULTS

				20% AEP Event			10% AEP Event			5% AEP Event			2% AEP Event			1% AEP Event			0.5% AEP Event			PMF Event		
Road Crossing	Branch	MIKE11 Chainage (m)	Chainage from Hardys Bay (m)	Flood Peak (mAHD)	Peak Discharge (m^3/s)	Peak Velocity (m/s)	Flood Peak (mAHD)	Peak Discharge (m^3/s)	Peak Velocity (m/s)	Flood Peak (mAHD)	Peak Discharge (m^3/s)	Peak Velocity (m/s)	Flood Peak (mAHD)	Peak Discharge (m^3/s)	Peak Velocity (m/s)	Flood Peak (mAHD)	Peak Discharge (m^3/s)	Peak Velocity (m/s)	Flood Peak (mAHD)	Peak Discharge (m^3/s)	Peak Velocity (m/s)	Flood Peak (mAHD)	Peak Discharge (m^3/s)	Peak Velocity (m/s)
	MUDFLAT CREEK	0	390	4.60	10.5	0.2	4.62	12.3	0.3	4.64	14.7	0.3	4.67	17.2	0.3	4.69	19.6	0.3	4.71	22.1	0.4	5.09	92.0	0.8
	MUDFLAT CREEK	2	388	4.60	10.5	0.2	4.62	12.3	0.2	4.64	14.7	0.3	4.67	17.2	0.3	4.68	19.6	0.3	4.70	22.1	0.4	5.08	91.9	0.8
Fraser Road	MUDFLAT CREEK	7	383	4.60	10.5	0.2	4.62	12.3	0.2	4.64	14.7	0.3	4.67	17.2	0.3	4.68	19.6	0.3	4.70	22.1	0.4	5.08	91.9	0.8
	MUDFLAT CREEK	12	378	3.26	10.7	1.3	3.37	12.5	1.4	3.49	15.0	1.6	3.59	17.5	1.7	3.71	20.1	1.7	3.86	22.7	1.7	5.07	94.1	1.8
	MUDFLAT CREEK	18	372	3.21	10.8	1.3	3.31	12.7	1.5	3.42	15.3	1.6	3.51	17.8	1.8	3.59	20.4	1.9	3.67	23.1	2.1	4.98	95.5	2.4
	MUDFLAT CREEK	30	360	3.10	10.9	1.3	3.20	12.8	1.4	3.32	15.4	1.4	3.41	17.9	1.5	3.49	20.5	1.6	3.57	23.2	1.7	4.80	96.0	1.9
	MUDFLAT CREEK	42	348	2.94	11.0	1.5	3.02	12.9	1.6	3.09	15.5	1.8	3.16	18.1	1.9	3.21	20.7	2.0	3.26	23.4	2.2	4.50	96.6	1.8
	MUDFLAT CREEK	50	341	2.86	11.0	1.3	2.95	12.9	1.4	3.03	15.5	1.4	3.09	18.1	1.5	3.14	20.8	1.6	3.18	23.5	1.7	4.31	96.9	1.8
	MUDFLAT CREEK	57	333	2.84	11.0	1.4	2.93	13.0	1.4	3.02	15.6	1.4	3.08	18.2	1.3	3.13	20.9	1.3	3.18	23.6	1.3	4.12	98.2	1.7
	MUDFLAT CREEK	67	323	2.68	11.1	1.5	2.78	13.1	1.5	2.88	15.7	1.5	2.96	18.3	1.5	3.02	21.0	1.5	3.07	23.7	1.5	4.04	103.4	2.1
	MUDFLAT CREEK	77	313	2.42	11.2	1.9	2.50	13.1	2.0	2.62	15.8	2.0	2.74	18.4	2.0	2.83	21.1	2.0	2.91	23.8	2.0	3.98	111.8	2.8
	MUDFLAT CREEK	86	305	2.25	11.2	1.7	2.26	13.2	2.0	2.28	15.9	2.3	2.29	18.5	2.6	2.31	21.2	2.9	2.33	23.9	3.2	3.33	110.1	10.8
	MUDFLAT CREEK	94	296	2.11	11.3	1.5	2.17	13.3	1.5	2.23	15.9	1.5	2.28	18.6	1.5	2.33	21.3	1.6	2.38	24.0	1.6	3.25	104.6	2.0
	MUDFLAT CREEK	105	286	1.97	11.4	1.4	2.02	13.4	1.4	2.09	16.0	1.4	2.14	18.7	1.4	2.19	21.4	1.4	2.24	24.2	1.4	3.16	104.6	1.8
	MUDFLAT CREEK	115	275	1.89	11.4	1.0	1.94	13.4	1.0	2.00	16.1	1.1	2.06	18.8	1.1	2.11	21.5	1.1	2.16	24.3	1.1	3.09	105.5	1.7
	MUDFLAT CREEK	125	266	1.82	11.5	1.0	1.88	13.5	1.0	1.94	16.3	1.0	2.01	19.0	1.0	2.06	21.7	1.0	2.11	24.5	1.0	3.07	106.5	1.4
	MUDFLAT CREEK	134	256	1.80	11.6	1.0	1.85	13.6	1.0	1.92	16.4	1.0	1.99	19.2	1.0	2.04	21.8	0.7	2.10	24.6	0.7	3.07	106.7	1.2
	MUDFLAT CREEK	146	245	1.78	11.7	0.6	1.83	13.7	0.6	1.90	16.6	0.6	1.96	19.4	0.6	2.02	21.9	0.6	2.07	24.8	0.7	3.04	106.6	1.2
	MUDFLAT CREEK	157	233	1.76	11.8	0.5	1.82	13.9	0.5	1.89	16.7	0.5	1.95	19.5	0.6	2.01	22.1	0.6	2.06	25.0	0.6	3.02	106.9	1.2
	MUDFLAT CREEK	169	221	1.75	11.9	0.5	1.81	14.0	0.5	1.88	16.9	0.5	1.94	19.7	0.6	2.00	22.3	0.6	2.05	25.2	0.6	3.00	107.1	1.2
	MUDFLAT CREEK	181	209	1.73	14.7	0.6	1.78	17.2	0.6	1.85	20.8	0.7	1.91	24.1	0.7	1.96	27.2	0.7	2.01	30.7	0.8	2.91	126.8	1.5
	MUDFLAT CREEK	192	198	1.68	17.3	0.7	1.73	20.2	0.8	1.80	24.4	0.9	1.85	28.2	0.9	1.95	32.0	0.9	2.00	36.0	1.0	2.76	144.5	1.9
	MUDFLAT CREEK	203	187	1.63	17.3	0.8	1.69	20.3	0.9	1.75	24.5	0.9	1.81	28.3	1.0	1.95	32.0	1.0	2.00	36.0	1.1	2.68	143.7	2.0
	MUDFLAT CREEK	214	176	1.53	17.4	1.2	1.59	20.4	1.2	1.66	24.9	1.2	1.72	28.7	1.2	1.95	32.0	1.2	2.00	36.0	1.2	2.52	142.6	2.1
	MUDFLAT CREEK	225	166	1.48	17.8	1.0	1.52	20.9	1.0	1.59	25.7	1.2	1.70	29.8	1.2	1.95	32.0	1.1	2.00	36.0	1.2	2.29	142.3	2.4
	MUDFLAT CREEK	235	155	1.48	19.2	1.0	1.48	23.0	1.1	1.55	28.9	1.2	1.70	33.4	1.3	1.95	32.0	1.0	2.00	36.0	1.1	2.17	142.3	2.1
Noble Road	MUDFLAT CREEK	241	149	1.48	19.0	2.9	1.48	22.7	3.4	1.48	28.8	4.0	1.70	34.4	4.5	1.95	32.0	0.9	2.00	36.0	0.9	2.11	142.0	1.9
	MUDFLAT CREEK	250	140	1.48	19.8	1.1	1.48	23.0	1.2	1.48	28.1	1.2	1.70	32.4	1.1	1.95	32.0	0.6	2.00	36.0	0.7	2.08	141.2	1.5
	MUDFLAT CREEK	261	130	1.48	18.2	1.0	1.48	21.4	1.1	1.48	27.3	1.1	1.70	31.9	1.0	1.95	32.0	0.6	2.00	36.0	0.6	2.00	140.4	1.6
	MUDFLAT CREEK	271	119	1.48	17.4	0.9	1.48	20.6	1.0	1.48	26.3	1.1	1.70	31.4	0.9	1.95	32.0	0.5	2.00	36.0	0.6	2.00	139.6	1.7
	MUDFLAT CREEK	282	109	1.48	17.3	0.9	1.48	20.4	1.0	1.48	25.8	1.1	1.70	31.6	0.9	1.95	32.0	0.5	2.00	36.0	0.6	2.00	139.1	1.8
	MUDFLAT CREEK	292	98	1.48	17.3	1.0	1.48	20.3	1.0	1.48	25.6	1.1	1.70	31.2	0.8	1.95	32.0	0.5	2.00	36.0	0.6	2.00	139.1	2.0
	MUDFLAT CREEK	302	89	1.48	17.3	0.9	1.48	20.3	1.0	1.48	25.4	1.0	1.70	31.9	0.7	1.95	32.0	0.4	2.00	36.0	0.5	2.00	139.1	1.8
	MUDFLAT CREEK	311	79	1.48	17.2	1.0	1.48	20.2	1.0	1.48	25.3	0.9	1.70	30.6	0.6	1.95	32.0	0.4	2.00	36.0	0.4	2.00	139.9	1.6
	MUDFLAT CREEK	323	67	1.48	17.2	0.9	1.48	20.1	1.0	1.48	24.9	0.7	1.70	30.9	0.5	1.95	32.0	0.3	2.00	36.0	0.4	2.00	140.1	1.4
	MUDFLAT CREEK	335	55	1.48	17.2	0.8	1.48	20.1	0.9	1.48	25.3	0.6	1.70	33.5	0.5	1.95	32.0	0.3	2.00	36.0	0.3	2.00	141.1	1.2
	MUDFLAT CREEK	343	48	1.48	17.2	0.4	1.48	20.1	0.4	1.48	25.4	0.1	1.70	33.8	0.0	1.95	32.0	0.0	2.00	36.0	0.0	2.00	141.2	0.1
	MUDFLAT CREEK	350	40	1.48	17.2	0.0	1.48	20.1	0.0	1.48	25.4	0.0	1.70	34.0	0.0	1.95	32.0	0.0	2.00	36.0	0.0	2.00	141.3	0.0
	MUDFLAT CREEK	360	30	1.48	17.2	0.0	1.48	20.0	0.0	1.48	25.3	0.0	1.70	34.3	0.0	1.95	32.0	0.0	2.00	36.0	0.0	2.00	141.4	0.0
	MUDFLAT CREEK	370	20	1.48	17.2	0.0	1.48	20.0	0.0	1.48	25.2	0.0	1.70	34.5	0.0	1.95	32.0	0.0	2.00	36.0	0.0	2.00	141.5	0.0
	MUDFLAT CREEK	370	20	1.48	18.8	0.0	1.48	21.9	0.0	1.48	27.2	0.0	1.70	37.4	0.0	1.95	35.2	0.0	2.00	39.7	0.0	2.00	152.1	0.0
	MUDFLAT CREEK	380	10	1.48	18.8	0.0	1.48	21.9	0.0	1.48	27.4	0.0	1.70	37.7	0.0	1.95	35.2	0.0	2.00	39.7	0.0	2.00	152.2	0.0
	MUDFLAT CREEK	390	0	1.48	18.8	0.0	1.48	21.9	0.0	1.48	27.4	0.0	1.70	37.8	0.0	1.95	35.2	0.0	2.00	39.7	0.0	2.00	152.3	0.0
	STANLEY STREET	0	210	4.95	1.5	0.2	4.97	1.7	0.3	4.99	2.0	0.3	5.01	2.3	0.3	5.03	2.6	0.3	5.05	2.9	0.4	5.32	8.6	0.8
	STANLEY STREET	10	200	4.48	1.5	0.0	4.49	1.7	0.0	4.50	2.0	0.0	4.51	2.3	0.0	4.52	2.6	0.0	4.53	2.9	0.0	4.63	8.6	0.1
	STANLEY STREET	20	190	4.17	1.5	0.0	4.18	1.7	0.0	4.19	2.1	0.0	4.20	2.3	0.0	4.19	2.6	0.0	4.19	2.9	0.0	4.29	8.6	0.1
	STANLEY STREET	40	170	3.55	1.5	0.0	3.57	1.7	0.0	3.58	2.1	0.0	3.60	2.3	0.0	3.61	2.6	0.0	3.61	2.9	0.0	3.71	8.6	0.1
	STANLEY STREET	59	151	2.84	1.4	0.0	2.84	1.7	0.0	2.87	2.0	0.1	2.93	2.3	0.1	2.94	2.6	0.1	2.95	2.9	0.1	3.04	8.6	0.1
	STANLEY STREET	79	131	2.40	1.7	0.0	2.43	2.1	0.0	2.46	2.4	0.0	2.47	2.8	0.0	2.49	3.1	0.0	2.51	3.5	0.0	2.73	10.3	0.0
	STANLEY STREET	92	119	2.31	1.9	0.1	2.35	2.3	0.1	2.39	2.7	0.1	2.41	3.0	0.1	2.43	3.5	0.1	2.45	3.9	0.1	2.68	11.4	0.1
	STANLEY STREET	104	106	2.10	1.9	0.1	2.15	2.3	0.1	2.20	2.7	0.1	2.22	3.0	0.1	2.26	3.5	0.1	2.29	3.9	0.1	2.58	11.4	0.1
	STANLEY STREET	115	95	1.71	1.9	1.0	1.75	2.3	1.0	1.79	2.7	1.1	1.82	3.0	1.1	1.95	3.5	1.1	2.00	3.9	1.1	2.30	11.4	1.7
	STANLEY STREET	126	84	1.48	1.9	0.1	1.49	2.3	0.1	1.54	2.7	0.1	1.70	3.0	0.1	1.95	3.5	0.1	2.00	3.9	0.1	2.05	11.4	0.1
	STANLEY STREET	143	67	1.48	1.9	0.1	1.48	2.3	0.1	1.48	2.7	0.1	1.70	3.0	0.1	1.95	3.5	0.0	2.00	3.9	0.0	2.00	11.4	0.1
	STANLEY STREET	160	50	1.48	1.9	0.1	1.48	2.3	0.1	1.48	2.7	0.1	1.70	3.1	0.0	1.95	3.5	0.0	2.00	3.9	0.0	2.00	11.4	0.0
	STANLEY STREET	176	34	1.48	1.9	0.1	1.48	2.3	0.1	1.48	2.7	0.0	1.70	3.2	0.0	1.95	3.5	0.0	2.00	3.9	0.0	2.00	11.4	0.0
	STANLEY STREET	193	17	1.48	1.9	0.0	1.48	2.3	0.0	1.48	2.7	0.0	1.70	3.6	0.0	1.95	3.5	0.0	2.00	3.9	0.0	2.00	11.4	0.0
	STANLEY STREET	210	0	1.48	1.9	0.0	1.48	2.3	0.0	1.48	2.9	0.0	1.70	4.1	0.0	1.95	3.5	0.0	2.00	3.9	0.0	2.00	11.3	0.0