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BYRON SHIRE COUNCIL

November 2002

TALLOW CREEK FLOOD STUDY

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FOREWORD

The State Government's Flood Policy is directed towards providing solutions to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. Policy and practice are defined in the Government's Floodplain Manual.

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

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

Stages of Floodplain Risk Management

Stage	Description
1. Flood Study	Determines the nature and extent of the flood problem.
2. Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed developments.
3. Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
4. Implementation of the Plan	Construction of flood mitigation works to protect existing development. Use of environmental plans to ensure new development is compatible with the flood hazard.

This study represents the first of the four stages. It has been prepared for Byron Shire Council to understand and define the existing flood behaviour and establish the basis for Stages 2 and 3 of the floodplain risk management process.

EXECUTIVE SUMMARY

The Tallow Creek catchment is located to the south of Byron Bay in New South Wales. The catchment consists of a steep to undulating upper catchment, which drains via three major creek systems through the residential suburbs of Baywood Chase and Byron Hills. These creek systems drain into an estuarine creek (Tallow Creek) formed in the sand dunes adjacent to the Pacific Ocean. Suffolk Park bounds the eastern edge of Tallow Creek. Figure 1.1 is a locality map showing the area of interest. The catchment area of Tallow Creek is 450 hectares.

In May 2001, Water Studies was invited by Byron Shire Council to undertake a flood study to determine the flooding behaviour of Tallow Creek. This flood study forms the basis for developing a Floodplain Risk Management Plan for the Tallow Creek catchment, under the New South Wales Government's Flood Prone Land Policy.

There are two distinct flooding mechanisms along Tallow Creek; local catchment rainfall flooding and Pacific Ocean storm tide flooding. Local catchment flooding occurs as a result of runoff generated from the natural catchment areas upstream of the Byron Hills and Baywood Chase subdivisions as well as from piped stormwater drainage system surcharge within the subdivisions. Storm tide flooding occurs as ocean levels rise and 'back up' into Tallow Creek. In addition to these two flooding mechanisms, the crest level of the sand bar at the Tallow Lake entrance can also affect flood levels.

A RAFTS hydrologic model and a TUFLOW hydraulic model were developed for the Tallow Creek catchment. The models were calibrated against peak flood level data and anecdotal rainfall data for the March 1999 flood event. A HEC-RAS one-dimensional steady state hydraulic model was used to assist with the calibration of the two models at locations where measured historical peak flood levels were available.

In general terms, the calibration of the models is considered to be reasonable. However, calibration of the models was hindered by:

- The lack of short duration rainfall,
- Uncertainties as to the entrance conditions at the time of the March 1999 flood event, and
- Limited recorded flood level data and no recorded discharge data.

The calibrated hydrologic and hydraulic models were used to estimate design flood discharges, flood levels, flood depths and velocities in the area of interest for the following event combinations:

- Local catchment flooding coinciding with a reduced severity design storm tide at the downstream boundary and the Tallow Lake entrance fully open.
- Local catchment flooding with the entrance fully closed and the ocean levels below the crest of the sand bar, and
- Storm tide flooding coinciding with a reduced severity local catchment design storm and the entrance fully open.

The maximum of the three event combinations was adopted for design purposes. Based on the model results, flood maps showing the extent of flooding, flood depths and velocities across the hydraulic model area were prepared for the 5 year, 20 year, 50 year, 100 year and 500 year ARI design storm events, as well as the PMP event. In addition, a provisional flood hazard map of Tallow Creek was developed showing high and low hazard zones. The high hazard zone was based on flood depth and velocity product exceeding one or the depth exceeding one metre for the 100 year ARI flood. The low hazard zone was based on the extent of flooding for the PMP design flood minus the adopted high hazard areas.

The following is of note with respect to the hydrological and hydraulic analyses:

- Local catchment flooding is the dominant flooding mechanism along Tallow Creek upstream of Suffolk Park Lake and along North Tallow Creek upstream of Broken Head Road. Flood levels for all design floods were independent of the Tallow Lake Entrance conditions in these areas.

- Storm tide levels were generally the dominant flooding mechanism along Suffolk Park Lake, Tallow Lake and North Tallow Creek downstream of Broken Head Road, except for the 5 year ARI event. The adopted crest level of the sand bar, entrance fully closed condition, was higher than the 5 year ARI storm tide level and thus dominated flood levels in these areas for this event

- The Tallow Lake entrance conditions impact on design flood levels for the 5 year ARI flood event. It is possible that the Tallow Lake entrance may also impact on flood levels for larger floods if the crest level of the sand bar is greater than the level adopted in this study. It is recommended that monitoring of the sand bar be undertaken and eventually a management strategy be developed to ensure that the sand bar does not significantly impact on flood levels.

- The Coogera Circuit detention basin spills or overflows during floods of 5 year ARI severity or greater. The overflowing floodwater drains at a shallow depth over much of the lower Byron Hills subdivision.

- Some of the overflowing floodwater from the Coogera Circuit detention basin is diverted northward along Drain A in an unconfined manner towards North Tallow Creek.

- South Tallow Creek overtops Broken Head Road for all design events investigated. That is, Broken Head Road is expected to be overtopped more frequently than every five years, on average.

- The small undeveloped catchment to the south of the Coogera Circuit Detention Basin draining in an easterly direction to the Beech Drive detention basin has been blocked (See Figure 2.2). Floodwater from this catchment is piped to the Coogera Circuit Basin, or it overflows through house lots eventually to the Beech Drive Detention Basin.

- The stormwater pipes adjacent to Teak Circuit in the Baywood Chase subdivision surcharge for all design events. The surcharge flows bypass the Baywood Chase Lake.

- Drain A is undefined for much of its length. The pipe in Drain A underneath Honeysuckle Drive is overtopped for floods in excess of the 20 year ARI event.

- South Tallow Creek floodwater is diverted over Broken Head Road onto Clifford Street and eventually into the natural flow path to the south of Clifford Street for floods in excess of the 5 year ARI event. This ponded water potentially affects houses adjacent to this natural flow path.

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1 INTRODUCTION

1.01 The Tallow Creek catchment is located to the south of Byron Bay in New South Wales. The catchment consists of a steep to undulating upper catchment, which drains via three major creek systems through the residential suburbs of Baywood Chase and Byron Hills. These creek systems drain into an estuarine creek (Tallow Creek) formed in the sand dunes adjacent to the Pacific Ocean. Suffolk Park bounds the eastern edge of Tallow Creek. Figure 1.1 is a locality map showing the area of interest. The catchment area of Tallow Creek is 450 hectares.

1.02 In May 2001, Water Studies was invited by Byron Shire Council to undertake a flood study to determine the flooding behaviour of Tallow Creek. This flood study forms the basis for developing a Floodplain Management Plan for the Tallow Creek catchment, under the New South Wales Government's Flood Prone Land Policy. As the study progressed, it became apparent that many of the drainage problems in the catchment were associated with deficiencies in the stormwater drainage system in the upper catchment. Thus, it became necessary to expand the study to include overland flows associated with the above stormwater drainage system. Note that only the stormwater drainage pipes associated with the major drainage system were included in the study. Minor drainage systems have little impact on flood behaviour and therefore, were ignored in the study.

1.03 This report describes the work undertaken to calibrate and test the hydrological and hydraulic models developed for Tallow Creek and its floodplain and how these models were used to define design flood levels, depths, velocities and provisional flood hazard. Three numerical models were developed to simulate the flooding behaviour in the Tallow Creek catchment.

- A runoff - routing model (RAFTS) was used to estimate flood discharges throughout the Tallow Creek catchment, and
- A two-dimensional unsteady flow hydraulic model (TUFLOW) was used to estimate flood levels throughout the study area.
- A one-dimensional steady flow hydraulic model (HEC-RAS) was used to assist with the calibration of the above two models at locations where measured historical peak flood levels were available.

1.04 This report contains a further 9 sections and is structured as follows:

- Section 2 describes the Tallow Creek catchment.
- Section 3 describes the available topographic, rainfall and flood data.
- Section 4 provides an overview of the study approach.
- Section 5 describes the adopted configuration of the Tallow Creek RAFTS hydrological model.
- Section 6 describes the adopted configuration of the Tallow Creek TUFLOW hydraulic model.
- Section 7 describes the calibration of the hydrological and hydraulic models. The calibration results are also presented in this section.
- Section 8 provides a check on the calibration of the hydrologic model by comparing design discharges and predicted design discharges against equivalent Rational Method estimates.

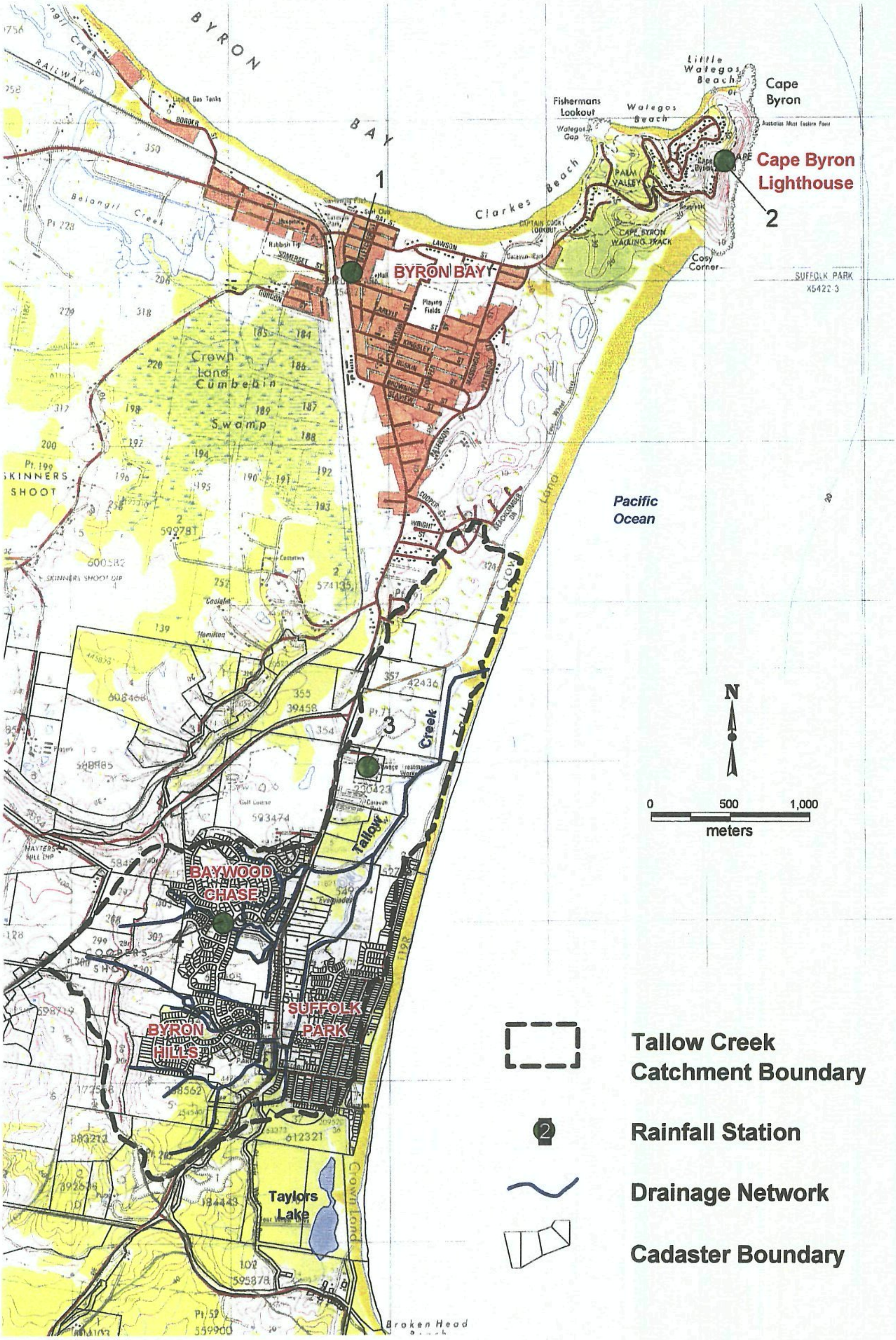

Figure 1.1 Locality Map, Tallow Creek Catchment and Environs

- Section 9 outlines the estimated design flood levels, flood velocities, flood depths and provisional hazard categories using the calibrated models for a range of design storm events.

- Section 10 outlines some conclusions on the study.

1.05 The report also contains seven appendices.

- Appendix A provides a list all previous Tallow Creek drainage study reports made available by Byron Shire Council.

- Appendix B provides details of the detention basins used in the hydrological model

- Appendix C describes the methodology and results of the HEC-RAS modelling undertaken at the locations of peak flood levels.

- Appendix D presents the Probabilistic Rational Method Calculations

- Appendix E presents the Deterministic Rational Method Calculations.

- Appendix F presents extent of flooding maps of Tallow Creek for the various design storms.

- Appendix G presents peak depth of flooding and maximum velocity maps of Tallow Creek for the various design storms.

2 CATCHMENT DESCRIPTION

2.01 Figures 2.1 and 2.2 show the Tallow Creek catchment and its drainage network. The catchment is characterised by steep to undulating topography to the west of Broken Head Road and very flat terrain to the east of Broken Head Road. The catchment area of Tallow Creek is 450 hectares. Approximately 30% of the Tallow Creek catchment has been developed for urban use.

2.02 The upper catchment of Tallow Creek consists of three major creek systems. These creeks have been named North, Mid and South Tallow Creek for convenience (See Figure 2.1). They drain into Tallow Creek or Tallow Lake downstream of Broken Head Road. The drainage characteristics of the creek systems are quite complex. Brief descriptions of the drainage characteristics of the creek systems are given below.

2.1 NORTH TALLOW CREEK

2.03 North Tallow Creek consists of a steep, heavily vegetated upper catchment and an urbanised lower catchment. North Tallow Creek drains the Baywood Chase subdivision. The catchment area of North Tallow Creek to Broken Head Road is about 95 hectares of which 53% of this area has been urbanised.

2.04 Runoff from the Baywood Chase subdivision draining through an extensive piped stormwater drainage system together with runoff from the natural upper catchment are directed into a large constructed lake (called Baywood Chase Lake). Runoff in excess of the capacity of the piped stormwater system in Baywood Chase surcharges and flows along Beech Drive around the Baywood Chase Lake, and eventually makes its way into the North Tallow Creek channel downstream of the lake (see Figure 2.2).

2.05 Baywood Chase Lake discharges into North Tallow Creek underneath Beech Drive via three 1,200 mm diameter pipes. No formal spillway has been incorporated into the lake. Downstream of Beech Drive, North Tallow Creek drains in a northerly direction before turning eastward to cross Broken Head Road at the Everglades property (See Figure 2.1). The North Tallow Creek channel between Baywood Chase Lake and Broken Head Road consists of a 450 mm diameter low flow pipe and a grass swale.

2.06 A small ill defined channel running parallel to Broken Head Road (which has been called Drain A) collects surface runoff from the area to the south of the Baywood Chase Lake and directs it northward underneath Beech Drive. A 900 mm pipe drains Drain A. This drain is piped underneath Honeysuckle Drive up to an area immediately to the east of the North Tallow Creek channel. Water ponds behind this pipe during runoff events, which effectively creates a detention basin. This has been called Drain A Detention Basin. Downstream of the pipe, water drains in an undefined manner eventually into North Tallow Creek immediately upstream of Broken Head Road.

2.07 Another small catchment drains into North Tallow Creek between Beech Drive and Broken Head Road, via a constructed grass swale. This constructed grass swale has been called Drain B in this report. Drain B crosses Redgum Place some 100 m upstream of its confluence with North Tallow Creek and drains into a small detention basin (Drain B detention basin) before spilling into North Tallow Creek.

Figure 2.1 Tallow Creek Drainage Network

Figure 2.2 Tallow Creek Developed Area

2.2 MID TALLOW CREEK

2.08 Similar to North Tallow Creek, Mid Tallow Creek consists of a steep, heavily vegetated upper catchment and an urbanised lower catchment. Mid Tallow Creek drains the Byron Hills subdivision. The catchment area of Mid Tallow Creek to Broken Head Road is about 62 hectares. Approximately 32% of this area has been urbanised.

2.09 Runoff from the steep, undeveloped upper catchment drains into a constructed detention basin (called Coogera Circuit Basin) located between Coogera Circuit and Bottlebrush Crescent. Water collected in this basin is piped, via a 750 mm diameter pipe, underneath Bottlebrush Crescent into another detention basin (called Beech Drive Basin) adjacent to Beech Drive. The locations of the basins are shown in Figure 2.1.

2.10 The Coogera Circuit Basin spills to the north onto Coogera Circuit (see Figure 2.2) where it either flows directly across Beech Drive or flows to the south along Beech Drive into Pepperbush Street or back into Mid Tallow Creek downstream of the Beech Drive basin. Floodwater from the Coogera Circuit Basin draining across Beech Drive and along Pepperbush Street either flows into Mid Tallow Creek or is directed to the north into Drain A, which is part of the North Tallow Creek catchment.

2.11 The small undeveloped catchment to the south of the Coogera Circuit Detention Basin draining in an easterly direction to the Beech Drive detention basin has been blocked (See Figure 2.2). Floodwater from this catchment is piped to the Coogera Circuit Basin, or it overflows through house lots eventually to the Beech Drive Detention Basin.

2.12 The Beech Drive basin collects runoff from a mostly urbanised catchment in addition to piped flow from the Coogera Circuit basin. This basin discharges via a 1,050 mm pipe underneath Beech Drive into Mid Tallow Creek. No formal spillway has been incorporated into the Beech Drive basin. Downstream of Beech Drive, Mid Tallow Creek drains in an easterly direction through urban development before turning southward back across Beech Drive and then eastwards towards Broken Head Road. The Mid Tallow Creek channel consists of a grass swale and a series of low flow pipes varying in size from 375 mm diameter piped at the upstream end to a 750 mm x 450 mm box culvert at the downstream end.

2.3 SOUTH TALLOW CREEK

2.13 The South Tallow Creek sub-catchment consists mostly of undisturbed natural bushland to the south of the Byron Hills development. The catchment area of South Tallow Creek to Broken Head Road is about 60 hectares. Approximately 11% of this catchment has been urbanised.

2.14 Runoff from South Tallow Creek drains from a steep escarpment into a low-lying wetland formed behind Broken Head Road (called Broken Head Road Wetland in this report). Mid Tallow Creek water also drains into this wetland. This wetland drains via 1,050 mm and 450 mm diameter pipes underneath Broken Head Road into what has been named Tallow Creek in this report. Floodwater in excess of the capacity of the pipes will overtop Broken Head Road and flow into Tallow Creek. A small levee was constructed in 1999 on the southern side of Tallow Creek parallel to Broken Head Road to direct floodwater that overtops the road back into Tallow Creek.

2.4 TALLOW CREEK/ TALLOW LAKE

2.15 Tallow Creek commences at Broken Head Road downstream of the Broken Head wetland. It drains in a northerly direction around the western side of Suffolk Park into what is commonly known as Tallow Lake. Downstream of Suffolk Park, the catchment is heavily vegetated. North Tallow Creek drains into the upstream end of Tallow Lake. Tallow Lake is separated from the Pacific Ocean by a mobile sand dune. Approximately half the Tallow Creek catchment is located downstream of Broken Head Road.

2.16 Suffolk Park area drains via stormwater pipes and overland along the roadways to Tallow Creek. Adjacent to Suffolk Park, the Tallow Creek channel has been excavated to form a long, thin lake, which is called Suffolk Park Lake in this report. A small rock weir has been constructed to retain water in this lake at all times. This weir becomes drowned out during flood conditions.

2.17 Tallow Creek gradients downstream of Broken Head Road are very low. Therefore, depending upon the build-up of sand at the entrance, water can pond behind the sand dune as far upstream as Broken Head Road at North Tallow Creek and almost to Broken Head Road at South Tallow Creek.

3 AVAILABLE DATA

3.1 OVERVIEW

3.01 Available data for the Tallow Creek Catchment consisted of:

- March 1999 Rainfall,
- March 1999 Flood Levels,
- Previous Reports, and
- Topographic information

3.02 Recorded rainfall, stream flow and flood level data are required to calibrate hydrological and hydraulic models. There was virtually no recorded rainfall, stream flow or flood level data to calibrate the models. Recorded rainfall data was generally limited to daily totals at stations outside the Tallow Creek catchment. Recorded flood level data is available downstream of the Broken Head Road wetland for historical floods prior to 1992, which is generally before the upper catchment was developed. There was no stream flow data available.

3.03 Due to the absence of suitable data for model calibration, a questionnaire was sent to all community members in the Tallow Creek catchment in an attempt to collect whatever anecdotal rainfall and water level data that may be available for the historical flood events. A total of 75 responses were received, which was an excellent response from the community. We thank the community for their support. Useful information was obtained for the March 1999 flood event. The data obtained included:

- Four hour rainfall data, and
- Several peak flood levels.

3.04 Peak flood level data was also obtained for several locations for the 1991 and 2001 storm events. However, due to the unavailability of short duration rainfall data, it was not possible to make use of the 1991 and 2001 data. As a result, the March 1999 storm provided the only data to calibrate the hydrological and hydraulic models.

3.05 Previous flood and drainage study reports were used to determine the drainage characteristics of the urban areas and to locate any other data that may be suitable for calibration of the hydrological and hydraulic models. Topographic data is used to define catchment boundaries and the extent and depth of flooding across the creeks and floodplain.

3.06 The following sections describe the available data for the Tallow Creek Catchment.

3.2 RAINFALL DATA

3.2a Daily Rainfalls

3.07 Table 3.1 shows the available daily rainfall data in the area of interest recorded in the 24 hours prior to 0900 hours in the days leading up to the March 1999 flood event. The locations of the daily rainfall stations are shown in Figure 1.1. The following is of note with respect to Table 3.1.

- The rainfall that produced the Tallow Creek flood on the 1st March 1999 appears to be very localised. Daily rainfalls varied widely over very short distances. The rainfalls recorded at Cape Byron Lighthouse and Byron Post Office rainfall stations, which are only about 3 km apart, varied by almost 180 mm on the day of the storm.

- The rainfalls recorded in the days preceding the March 1999 flood indicates that the Tallow Creek catchment would have been completely saturated before the flood producing storm event occurred.

Table 3.1 Available Daily Rainfall Data, March 1999 Flood

Station No.	Station Name	Figure 1.1 Locality Ref.	Source	Daily Rainfall to 0900 Hours (mm)		
				28 Feb	1 March	2 March
058007	Byron Bay Post Office	1	CBM	75.6	15.8	268.2
058009	Cape Byron Light House	2	CBM	55	31.4	91.1
-	Sewage Treatment Plant	3	BSC	80	21	122
-	99 Beech Drive, Baywood Chase	4	Resident	95	50	196

CBM: Commonwealth Bureau of Meteorology
BSC: Byron Shire Council

3.2b Pluviograph Data

3.08 A pluviograph rainfall station records rainfall as it occurs to enable short duration (less than 24 hours) rainfall intensities to be determined. The following short duration rainfall data is available for the March 1999 event.

- The nearest CBM pluviograph rainfall stations are located up to 18.5 km from the Tallow Creek catchment at Nashua (Station No. 7115), Goonengarry (Station No. 7093) and Repentance (Station No.7097). Rainfalls of less than 26 mm were recorded at all three stations to 0900 hours on 2 March.

- Cape Byron Lighthouse Rainfall Station records rainfall at 6 hourly intervals. A total of 26 mm was recorded between 1200 hours and 1800 hours on the 1st March at Cape Byron.

- The occupant of 99 Beech Drive (Mr Ted Kempnich) recorded 100 mm between 1300 and 1800 hours on the 1st March.

3.09 The three nearest CBM pluviograph stations and the Cape Byron Rainfall station appears to have been too far away to record this very localised storm. Thus, the data provided by the resident at Beech Drive is the only suitable rainfall data available to calibrate the hydrologic model. It is noted that the accuracy of this data is not known.

3.3 AVAILABLE FLOOD LEVEL DATA

3.10 Table 3.2 shows the available peak flood level data for the March 1999 flood event. Water Studies' staff interviewed the residents who provided the flood level information to locate the flood marks. These flood marks were later surveyed to obtain a height in AHD. The locations of the flood marks are shown in Figure 2.1.

3.11 In addition to the above flood level data, the residents reported that the Coogera Circuit detention basin overflowed onto Coogera Circuit during the storm. According to the residents, the Beech Drive basin and Baywood Chase Lake did not overflow other than from their low level outlets.

Table 3.2 Available Peak Flood Level Data, March 1999 Flood

Location	Figure 2.2 Locality Reference	Peak Flood Level (m AHD)
South Tallow Creek at Broken Head Road	A	5.25
Mid Tallow Creek at Beech Drive	B	5.25
Redgum Place on roadway (Sub-catchment 14/37)	C	4.3 to 4.4
Redgum Place on downstream Footpath	D	4.40 to 4.44
12 m Downstream of Redgum Place	E	4.10
North Tallow Creek at Broken Head Road	F	2.6
Korau Place	G	2.3
Firewheel Place	H	3.6

3.4 PREVIOUS REPORTS

3.12 Several flood study and drainage reports have been prepared in the past for developers to estimate peak discharges and peak flood levels along Tallow Creek. These reports were made available by Byron Shire Council to assist with model development and calibration. A list of all reports provided by Byron Shire Council is given in Appendix A. However, no calibration data was found in any of the drainage and flood study reports.

3.5 TOPOGRAPHIC DATA

3.13 Available topographic data for the Tallow Creek catchment consists of:

- 1:25,000 scale, 10 m contour map of Byron Bay (9640-4-S),
- 1:4,000 scale, 2m contour ortho-photographic maps of the catchment (X54222-9).
- Digital elevation data comprising ground levels over the entire catchment.
- Surveyed cross sections of Tallow Creek and its upper tributaries.

3.14 Airresearch Pty Ltd compiled the digital elevation data of the Tallow Creek catchment from aerial photography undertaken in December 2001. Digital ortho-photo images were supplied with a pixel size of 0.17 m. The accuracy of the available digital elevation data has been estimated at ±0.1m. The cross sections were surveyed by North Surveys Group in December 2001 and January 2002.

4 STUDY APPROACH

4.01 Three numerical models have been used to simulate the flooding behaviour in the Tallow Creek catchment.

- A runoff - routing model (RAFTS) was used to estimate flood discharges throughout the Tallow Creek catchment,

- A two-dimensional unsteady flow hydraulic model (TUFLOW) was used to estimate flood levels throughout the study area, and

- A one-dimensional steady flow hydraulic model (HEC-RAS) was used to assist with the calibration of the above two models at locations where measured historical peak flood levels were available.

4.02 The RAFTS model was used to estimate design flood discharge hydrographs at the boundaries of the hydraulic models as well as local catchment discharge hydrographs at each RAFTS model node. The hydraulic model was then used to estimate flood levels, the extent and depth of flooding and the maximum velocity of flood flows along the creek and its adjoining floodplain.

4.03 No recorded stream flow data or pluviograph (rainfall) data within the Tallow Creek catchment is available to calibrate the RAFTS hydrologic and TUFLOW hydraulic models of Tallow Creek. However, some peak flood level and short duration rainfall data for the March 1999 flood was provided by the community. The calibration of the hydrologic and hydraulic models was thus undertaken using the available March 1999 data.

4.04 The calibration of the RAFTS and TUFLOW models were undertaken jointly , via an iterative process. The TUFLOW model was used to estimate peak discharges from the March 1999 water levels. The RAFTS model was then calibrated against the March 1999 peak discharges estimated by the TUFLOW model. A few iterations of the two models were required to achieve consistent results between the hydrologic and hydraulic models. The HEC-RAS model was used to both check the results and to provide a preliminary estimate of peak flows where measured historical peak flood levels were available. A full description of the calibration methodology is provided in Section 7.1.

4.05 Once the models were calibrated, the design discharges predicted by the calibrated RAFTS model were compared against design discharges estimated using the Rational Method at numerous locations throughout the catchment.

4.06 The calibrated models were then used to estimate:

- Flood levels,
- Flood flows,
- Flood velocities,
- Flood depths, and
- Provisional flood hazard categories,

for the 5, 20, 50, 100, 500 Year ARI and PMP design storm events throughout the catchment.

5 HYDROLOGIC MODELLING

5.1 METHOD OF ANALYSIS

5.01 The RAFTS runoff-routing model was used to estimate design flood discharges for the Tallow Creek catchment. RAFTS uses a network of nodes to represent sub-catchments and links to represent the drainage system between sub-catchments. Sub-catchments are defined at each node using physical parameters such as total area, impervious area, average catchment slope, roughness factor and, if necessary, storage/basin information. Similarly, each link is represented by physical parameters such as channel length, average slope, cross section shape and roughness (Manning's 'n').

5.02 Not all rain that falls on a catchment will drain from the catchment as runoff. Some rainfall will infiltrate into the soil and some will be intercepted by natural storage areas. RAFTS uses initial and continuing losses to estimate the volume of runoff resulting from a particular rainfall event (rainfall excess). The initial loss accounts for initial catchment wetting where no catchment runoff is expected. The continuing loss accounts for infiltration once the catchment is saturated.

5.03 Prior to calculating rainfall excess, the model divides each sub-catchment area into 10 isochronal sub-catchment areas. Each isochronal sub area is treated as a concentrated conceptual storage. Excess rainfall and runoff is calculated on a sub area basis, routed through the sub area storage using the Muskingum method and sequentially combined. The outflow hydrograph from a node is then either lagged by a user-defined time (lag link) or routed using the Muskingum-Cunge method along the link that represents the drainage system (channel link) (WP Software, 1996).

5.2 RAFTS MODEL CONFIGURATION

5.04 Figure 5.1 shows the configuration of the RAFTS model for the Tallow Creek catchment. The model uses a total of 37 sub-catchments ranging in size from 3.2 to 27.6 ha.

5.05 A schematic diagram of the Tallow Creek RAFTS model configuration is shown in Figure 5.2. The circles represent sub-catchments (nodes) and the lines represent the channels (links) between each sub-catchment node. Details of the nodes and links are given in Tables 5.1 and 5.2 respectively. The following is of note with respect to the RAFTS model configuration:

- The sub-catchment boundaries were determined from the ground level contours. Modifications were made to sub-catchments 28 and 29, as well as sub-catchment 17, to incorporate the drainage characteristics of the piped stormwater drainage system.

- The major piped stormwater drainage systems have been included in the following locations:
  - North and Mid Tallow Creek channels, and
  - Sub-catchment 17 to the Baywood Chase Lake.

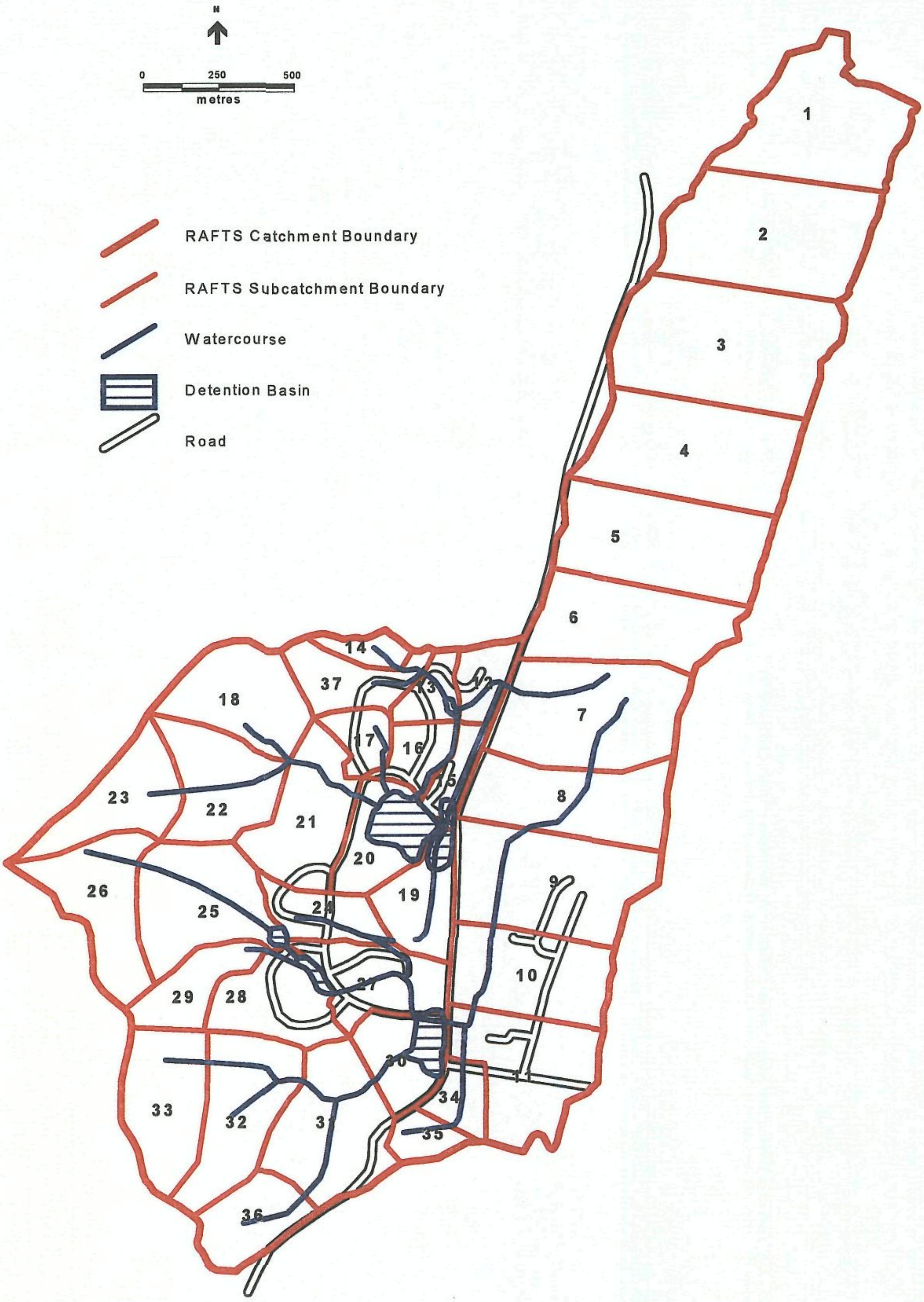

Figure 5.1 RAFTS Model Configuration, Tallow Creek

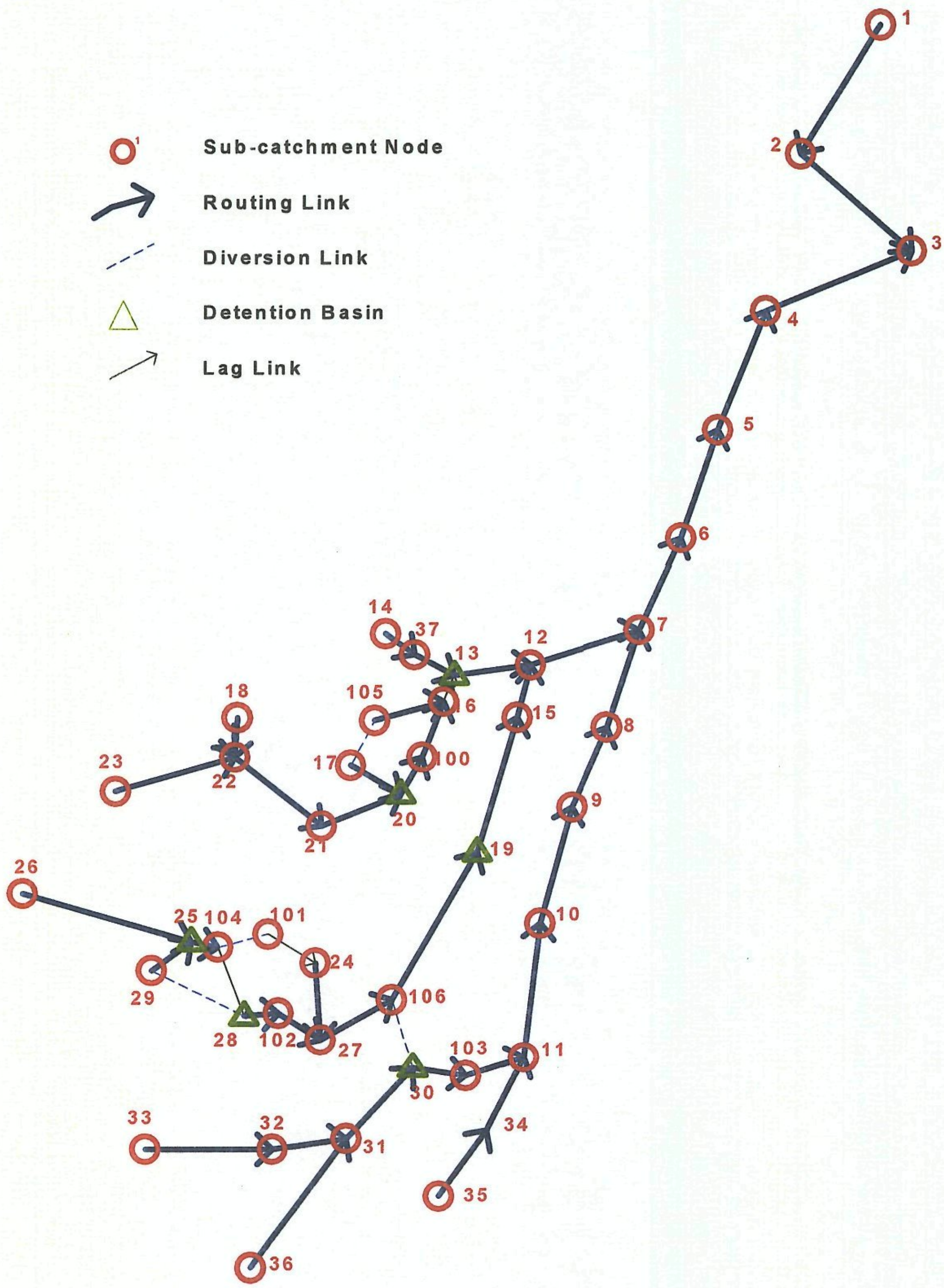

Figure 5.2 Schematic Diagram showing the Node and Link Network, Tallow Creek RAFTS Model

Table 5.1 Sub-Catchment Node Details, Tallow Creek RAFTS Model

No	Pervious Area (ha)	Pervious Manning's 'n'	Pervious Slope (%)	Impervious Area (ha)	Impervious Manning's 'n'	Impervious Slope (%)	Total Area (ha)
1	17.5	0.10	1.5	2.5	0.04	1.5	20.0
2	23.4	0.10	2.5	0.5	0.04	2.5	23.9
3	25.9	0.07	0.4	1.7	0.10	0.4	27.6
4	21.5	0.07	0.7	0.1	0.04	0.7	21.6
5	18.9	0.07	0.7	2.3	0.04	0.7	21.2
6	16.8	0.07	0.2	0.3	0.07	0.2	17.1
7	20.4	0.07	0.7	0.7	0.04	0.7	21.1
8	14.7	0.10	0.6	1.3	0.07	0.6	16.0
9	13.0	0.07	0.7	8.1	0.07	0.7	21.1
10	9.3	0.07	0.7	5.6	0.04	0.7	14.9
11	8.5	0.07	0.4	7.6	0.10	0.4	16.1
12	2.7	0.04	11.0	1.8	0.10	11.0	4.5
13	2.0	0.04	5.5	1.7	0.07	5.5	3.7
14	1.9	0.07	7.1	0.7	0.04	7.1	2.6
15	2.4	0.10	0.7	1.2	0.10	0.7	3.6
16	2.4	0.04	1.1	2.0	0.04	1.1	4.4
17	2.1	0.07	8.0	1.7	0.04	8.0	3.8
18	10.6	0.10	17.0	2.1	0.04	17.0	12.7
19	6.4	0.07	1.3	1.5	0.07	1.3	7.9
20	6.6	0.01	1.6	2.4	0.07	1.6	9.0
21	8.5	0.10	6.3	4.5	0.04	6.3	13.0
22	11.9	0.08	18.0	0.2	0.04	18.0	12.1
23	10.8	0.08	9.5	0.0	0.04	9.5	10.8
24	4.6	0.04	2.2	1.5	0.07	2.2	6.1
25	15.4	0.08	9.1	0.0	0.04	9.1	15.4
26	13.1	0.07	8.4	0.0	0.10	8.4	13.1
27	5.8	0.07	1.5	4.1	0.04	1.5	9.9
28	6.5	0.07	5.5	3.7	0.07	5.5	10.2
29	6.3	0.08	14.0	0.5	0.04	14.0	6.8
30	7.1	0.07	3.3	0.9	0.04	3.3	8.0
31	16.4	0.08	5.4	0.0	0.01	5.4	16.4
32	12.4	0.08	7.0	2.0	0.04	7.0	14.4
33	12.7	0.08	23.0	0.3	0.08	23.0	13.0
34	3.1	0.08	1.3	1.0	0.04	1.3	4.1
35	3.2	0.08	7.2	0.0	0.10	7.2	3.2
36	8.0	0.08	6.3	0.0	0.04	6.3	8.0
37	5.0	0.07	4.0	2.2	0.04	4.0	7.2
	377.8			66.7			444.5

Table 5.2 Sub-Catchment Link Details, Tallow Creek RAFTS Model

Name	From Node	To Node	Type	Channel Details			
				Length (m)	Slope (%)	Manning's n	Other
Link 1	1	2	Channel	403	0.10	0.1	-
Link 2	2	3	Channel	292	0.10	0.025	-
Link 3	4	3	Channel	447	0.01	0.025	-
Link 4	5	4	Channel	359	0.01	0.025	-
Link 5	6	5	Channel	360	0.01	0.025	-
Link 6	7	6	Channel	282	0.01	0.025	-
Link 7	8	7	Channel	414	0.01	0.025	-
Link 8	9	8	Channel	318	0.01	0.025	-
Link 9	10	9	Channel	357	0.04	0.05	-
Link 10	11	10	Channel	283	0.30	0.08	-
Link 11	12	7	Channel	459	0.70	0.08	-
Link 12	13	12	Channel	218	0.50	0.03	-
Link 13	14	37	Channel	115	0.40	0.04	-
Link 14	37	13	Channel	115	0.40	0.04	-
Link 15	15	12	Channel	201	0.01	0.1	-
Link 16	16	13	Lag 1	-	-	-	-
Link 17	100	16	Channel	293	0.50	0.03	450 mm low flow pipe
Link 18	20	100	Lag 1	-	-	-	-
Link 19	105	16	Channel	295	0.80	0.1	-
Link 20	17	105	Diversion 2	-	-	-	-
Link 21	17	20	Channel	85	2.40	0.025	600 and 750 mm pipes
Link 22	18	22	Lag 1	-	-	-	-
Link 23	19	15	Channel	130	0.01	0.1	-
Link 24	106	19	Channel	430	0.01	0.1	-
Link 25	21	20	Channel	71	4.00 0.00	0.04	-
Link 26	22	21	Channel	266	1.00	0.04	-
Link 27	23	22	Channel	447	4.00	0.1	-
Link 28	24	27	Channel	272	0.60	0.04	-
Link 29	25	104	Lag 1	-	-	-	-
Link 30	104	101	Diversion 3		0.00	0.04	-
Link 31	101	24	Lag 1	-	-	-	-
Link 32	104	28	Lag 1	-	-	-	-
Link 33	26	25	Channel	430	8.00	0.1	-
Link 34	28	102	Lag 1	-	-	-	-
Link 35	102	27	Channel	382	0.80	0.04	-
Link 36	27	106	Channel	10	1.00	0.08	-
Link 37	106	30	Diversion 4	-	-	-	-
Link 38	29	25	Channel	31	2.00	0.025	450 mm low flow pipe
Link 39	29	28	Diversion 5	-	-	-	-
Link 40	31	30	Channel	175	1.00	0.025	250 mm low flow pipe
Link 41	30	103	Lag 1	-	-	-	-
Link 42	103	11	Channel	159	5.00	0.06	-
Link 43	32	31	Channel	266	0.80	0.04	-
Link 44	33	32	Channel	336	5.00	0.1	-
Link 45	34	11	Channel	189	1.00	0.013	-
Link 46	35	34	Channel	224	2.00	0.1	-
Link 47	36	31	Channel	483	3.00	0.07	-

1 Lag time = 0 minutes
2 Divert all flows greater than pipe flow
3 Divert all flows greater than flow through low level outlet.
4 Divert 85% of all flows
5 Divert 50% of flows greater than pipe flow

- Link 39 is used to split flows from Sub-catchment 29 in excess of the 0.25 m pipe equally between the Coogera Circuit and Beech Drive Detention Basins. The 0.25 m pipe drains to the Coogera Circuit basin.
- Link 30 is used to bypass spills from the Coogera Circuit detention basin around the Beech Drive basin.
- Link 20 is used to divert pipe surcharge flows from Sub-catchment 17 around the Baywood Chase Lake. Two pipes of 0.6 m and 0.75 m diameter drain to the Baywood Chase Lake from Sub-catchment 17.
- Link 37 is used to split overland flows from sub-catchments 24 and 27 into sub-catchments 19 and 30. The flow split was defined using the TUFLOW hydraulic model.
- The RAFTS model channel routing parameters were obtained via joint calibration with the TUFLOW hydraulic model to provide consistent results between the two models (See Section 7.5b).
- Link cross section shapes were defined from the cross section surveys, where available.

5.2a Land Use Characteristics

5.06 The Tallow Creek catchment contains a mixture of developed (urban) and undeveloped areas. The runoff characteristics of the developed areas will be significantly different from the undeveloped areas because of the differences in the amount of impervious areas, such as roads, roof and driveways of houses. In the Tallow Creek RAFTS model, it was assumed that 50% of developed areas and none (0%) of the undeveloped areas were impervious. This assumption was based on the measurement of the impervious areas in Sub-catchment 27, which appeared to be typical of an urban area in the Tallow Creek catchment.

5.2b Detention Basins

5.07 Table 5.3 shows details of the six detention basins included in the RAFTS model. The Coogera Circuit and Beech Drive basins are located on Mid Tallow Creek and the Broken Head Road wetland is located at the junction of Mid and South Tallow Creeks. The Baywood Chase Lake is located on North Tallow Creek. Drain A detention basin and Drain B detention basin are located on Drain A and Drain B respectively. Note that Baywood Chase Lake has been excavated below the invert level of the outlet so that water can be stored at all times. Details of the Stage – Storage – Surface Area Curves and adopted spillway curves for the detention basins are provided in Appendix B.

Table 5.3 Adopted Detention Basin Configurations, Tallow Creek Catchment

	Beech Drive Hills Basin	Coogera Crescent Basin	Baywood Chase Lake	Broken Head Road Wetland	Drain A Basin	Drain B Basin
Surface Area at Spillway Level (m^2)	5,000	2,900	47,300	19,100	5,300	2,500
Storage Volume at Spillway Level (m^3)	4,000	3,800	50,000	9,000	2,200	2,070
Pipe Outlet: - Type	Concrete Pipe	Concrete Pipe	Concrete Pipe	Concrete Pipe	Concrete Pipe	-
- Pipe Size (m)	1.05	0.75	3 x 1.2	2x1.05 2x0.45	0.9	-
- Upstream Invert Level (m AHD)	7.31	9.47	4.04	2.91 & 3.97	3.25	-
Spillway Outlet - Type	Earth Embankment	Earth Embankment	Earth Embankment	Broken Head Road	Earth Embankment	Earth Embankment
- Invert Level (m)	8.91	12.01	5.64	5.0	5.0	3.39

6 HYDRAULIC MODELLING

6.1 METHOD OF ANALYSIS

6.01 The two-dimensional unsteady flow (TUFLOW) model, developed by WBM Oceanics Australia, was used to estimate design flood levels and flood velocities along Tallow Creek, its tributaries and floodplains. TUFLOW estimates flood levels and velocities on a fixed grid pattern by solving the full two-dimensional depth averaged momentum and continuity equations for free surface flow. It also incorporates a one-dimensional or quasi two-dimensional modelling system (ESTRY). The one-dimensional (ESTRY) and two-dimensional (TUFLOW) schemes are solved independently, but are dynamically linked at the boundary to ensure continuity (mass) is conserved.

6.2 HYDRAULIC MODEL CONFIGURATION

6.02 Figure 6.1 shows the extent of the TUFLOW model and the location of the one-dimensional (ESTRY) links. The two-dimensional model commences downstream of the detention basins and extends to the entrance of Tallow Creek at the Pacific Ocean. A 10 m grid has been adopted for the two-dimensional model. That is, flood levels and velocities are estimated every 10 m across the entire floodplain.

6.2a One-Dimensional ESTRY Links

6.03 One-dimensional ESTRY links have been used when the two-dimensional grid does not provide sufficient detail of the channel geometry. It is noted that much of the north and mid-Tallow Creek channels have a width of less than the adopted 10 m two-dimensional grid. One-dimensional links were also used to model the stormwater pipes, road bridges and culverts.

6.04 The following one-dimensional ESTRY links have been used to model the channels:

- Mid-Tallow Creek channel downstream of the Beech Drive detention basin up to Broken Head Road including the Beech Drive culverts.
- Drain A channel from the Byron Hills subdivision to North Tallow Creek. The Beech Drive culvert and the 900 mm pipe, which drains this channel underneath Honeysuckle Drive, have also been included in this link.
- North Tallow Creek downstream of Baywood Chase Lake up to Tallow Lake, including the Broken Head Road culverts.
- The Drain B channel from Redgum Place up to North Tallow Creek, including the Redgum Place culverts.

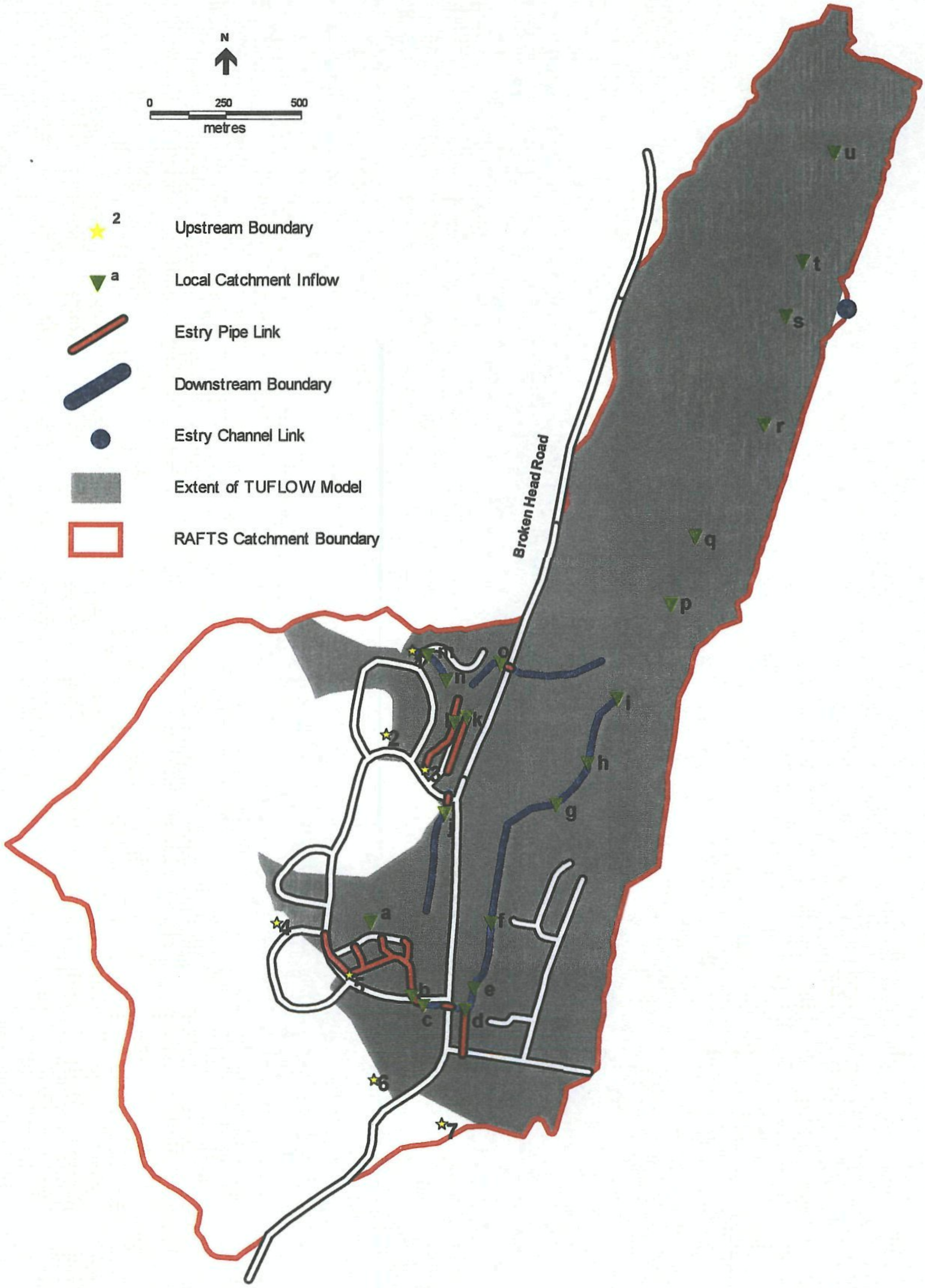

Figure 6.1 TUFLOW Model Boundary and ESTRY ID Links, Tallow Creek

- Tallow Creek from Broken Head Road up to Tallow Lake including the Broken Head Road culverts and Suffolk Park Lake. Note that flow over Broken Head Road has been included in the two-dimensional grid.

6.05 Table 6.1 shows the location and details of the piped stormwater drainage system included in the Tallow Creek hydraulic model.

Table 6.1 Stormwater Drainage Pipes and Culverts Included in the Tallow Creek Hydraulic Model

Location	Type and Size
North Tallow Creek, Baywood Chase Lake to Broken Head Road, Baywood Chase	1 x 450 *mm pipe culvert*
Mid Tallow Creek, Beech Drive Detention Basin to Beech Drive, Byron Hills	1 x 450 mm, 1 x 525 mm, 1 x 375 Pipe culverts, 1 x 750 x 450 mm box culvert
Drain A, Beech Drive to Honeysuckle Drive	1 x 900 mm pipe culvert
Clifford Street to Tallow Creek, Suffolk Park	1 x 1200 mm x 1200 mm box culvert
Pepperbush Street, Byron Hills	1 x 450 mm pipe culvert
Carissa Street, Byron Hills	1 x 450 mm pipe culvert
Silky Oak Ct, Byron Hills	1 x 450 mm pipe culvert
Beech Drive upstream of Mid Tallow Creek, Byron Hills	1 x 450 mm and 1 x 525 mm pipe culverts

6.2b Upstream Boundary Conditions (External Catchment Inflows)

6.06 Seven upstream boundaries were used to represent the external inflow hydrographs at the locations shown in Figure 6.1. A description of these locations are outlined below.

1. Sub-Catchment 14 upstream of Redgum Place (Baywood Chase).
2. Pipe surcharge from Sub-Catchment 17 (Baywood Chase).
3. Releases from the Baywood Chase Lake into North Tallow Creek (Baywood Chase).
4. Spillway flows from the Coogera Circuit detention basin into Mid Tallow Creek, (Byron Hills).
5. Pipe and overflow releases from the Beech Drive detention basin into Mid Tallow Creek (Byron Hills).
6. South Tallow Creek downstream of Sub-Catchment 31 (Byron Hills)
7. Upstream of Clifford Street at Sub-Catchment 35 (Suffolk Park).

6.2c Local Catchment Runoff

6.07 The hydraulic model incorporates some 60% of the total Tallow Creek catchment. Hence, local catchment runoff on the hydraulic model area will have a significant impact on predicted flood discharges and flood levels, particularly at the downstream end of the system. Local catchment runoff on the hydraulic model area has been estimated using the RAFTS model local catchment inflow hydrographs. Twenty one internal boundary conditions (labelled A to U in Figure 6.1) representing the 21 RAFTS node locations that overlap the hydraulic model have been included in the model.

6.08 It is noted that TUFLOW has its own 'in-built' rainfall - runoff model. However, TUFLOW appeared to significantly under-predict local catchment runoff when compared to local catchment flows estimated by the RAFTS model. An attempt was made to adjust the RAFTS model and TULOW model parameters to provide consistent estimates of local catchment flows between the two models. However, the RAFTS and TUFLOW model parameters were not consistent with other areas in the model and were outside the bounds of being acceptable when the local catchment flows were consistent.

6.09 Given that the RAFTS model local catchment flows were always higher and appeared to provide more realistic estimates of local catchment flows, the TUFLOW local catchment flows were ignored in favour of the RAFTS model local catchment flows.

6.2d Road Culverts/Bridges

6.10 Table 6.2 shows the locations and configurations of the road culverts included in the Tallow Creek hydraulic model. All culverts have been modelled as one-dimensional links, except for the walkway bridge over Tallow Lake at the Sewage Treatment Plant. The two-dimensional network was used to model this structure. Table 6.3 shows the head loss factors adopted for the bridge and culvert structures. The road surface above the culverts were modelled as broad-crested weirs using a weir coefficient of 1.44.

Table 6.2 Road Culverts and Bridges, Tallow Creek Hydraulic Model

Creek	Location	Type	Invert Level	
			Upstream	Downstream
South Tallow Creek	Broken Head Road	2 x 1,050 mm pipe	2.90	2.73
South Tallow Creek	Broken Head Road	2 x 450 mm pipe	3.97	3.20
Mid Tallow Creek	Beech Drive	2 x 1800 x 900 mm box culverts	3.26	3.10
Drain A	Beech Drive	1 x 1200 mm pipe	3.45	3.43
North Tallow Creek	Broken Head Road	2 x 2100 mm x 1500 mm box culverts	1.45	1.33
Tallow Lake	Sewage Treatment Plant	Walkway Bridge (3 Spans)		
South Tallow Creek	Clifford Street[a]	1 x 1200 mm pipe	3.05	2.20

[a] This pipe extends from Clifford Street underneath the Suffolk Park Hotel/Motel carpark to Tallow Creek

Table 6.3 Adopted Head Loss Factors for Bridges and Culverts, Tallow Creek Hydraulic Model

Loss Type	Value
Box Culvert Height Contraction Loss	0.6
Box Culvert Width Contraction Loss	0.9
Entrance Loss	0.5
Exit Loss	1.0
Manning's 'n'	0.013

6.2e Suffolk Park Lake

6.11 A rock weir with a crest height of 1.5 m AHD has been constructed at the northern end of Suffolk Park Lake (See Figure 2.2). This weir becomes drowned out during most flow situations. However, it has been modelled as a broad crested weir within the ESTRY network to regulate water levels when the Tallow Lake entrance has been breached.

6.3 DOWNSTREAM BOUNDARY CONDITIONS

6.12 Two downstream boundary conditions have been assessed in this study; representing the Tallow Lake entrance fully open and fully closed. The Pacific Ocean design storm tide levels are the downstream boundary when the entrance is fully open. The sand bar level blocking the Tallow Lake entrance is the downstream boundary when the entrance is fully closed. The Pacific Ocean levels are assumed to be below the level of the sand bar when the entrance fully closed.

6.3a Entrance Fully Open

6.13 Table 6.4 shows the adopted storm tide levels used for the various design storms. The 100 year and 20 year ARI storm tide levels were adopted from the Belongil Creek Flood Study Report (PWD, 1986). Belongil Creek is the next catchment to the north of Tallow Creek. These values were plotted on probability - log paper to determine the 5 year and 50 year ARI levels. Note that these levels are an average still water level and do not take into account short-term changes in water level resulting from wave sets or wave runup.

Table 6.4 Adopted Storm Tide Levels, Tallow Creek, Entrance Open Condition

ARI (Years)	Level (m AHD)
5	1.67
20	2.1
50	2.37
100	2.6

6.3b Entrance Fully Closed

6.14 For the entrance fully closed condition, there are two possible scenarios that could occur. First, water overtopping the entrance causes the sand to scour and the ocean levels become the control after some scouring period. In this instance, peak flood levels at the entrance will not reach significantly higher than the crest of the sand bar, assuming storm tide levels are lower than the crest.

6.15 Secondly, floodwater overtops the sand bar without causing scour. Water is drained from behind the sand bar on the first low tide after the peak ocean level has occurred by mechanical means. It is highly likely that the berm will scour if it is overtopped. However, in the unlikely event that this scenario does occur, peak flood levels will always be higher for this scenario than the first. Thus, only the second scenario (sand bar not being breached) has been analysed in this study. It has been assumed that storm tide levels are lower than the crest of the sand bar in this analysis.

6.16 In addition, the critical duration storm peaks at the outlet after about 2 hours and has almost completely receded back to the crest of the sand bar after about 5 hours. Thus, peak flood levels at the entrance at the time of mechanically breaching the sand bar will be at the crest height. As soon as the sand bar is breached, the lake will drain to the ocean levels.

6.17 Little information is known about the crest level of the sand bar at the Tallow Lake entrance. The crest was surveyed to be 1.82 m AHD during January 2002. It is not known if this level represents a reasonable estimate of the crest level or not. However, in the absence of better information, the level surveyed in January 2002 has been adopted in this study. Given that the sand bar level has such a significant impact on flood levels, it is recommended that the crest level be monitored to determine how much it varies. The adopted stage - discharge curve for the Tallow Lake entrance for the fully closed condition is shown in Table 6.5.

Table 6.5 Adopted Stage-Discharge Curve, Tallow Creek Entrance

Stage (m AHD)	Discharge (m^3/s)
1.82	0
1.87	0.5
1.89	1
1.92	2
1.96	4
2.01	8
2.09	16
2.36	64
2.6	128
2.89	256

7 HYDROLOGICAL AND HYDRAULIC MODEL CALIBRATION

7.1 CALIBRATION METHODOLOGY

7.01 Due to the absence of recorded flow data, calibration of the RAFTS hydrologic model and the TUFLOW hydraulic model was undertaken jointly using an iterative process. For the reasons given in Section 4, the models were calibrated only against the March 1999 flood event. Additional checks on the validity of model predictions were undertaken due to the unavailability of adequate calibration data as described in Section 8. Calibration of the models involved the following five stages:

1. HEC-RAS hydraulic models were developed at:
   - North Tallow Creek at Broken Head Road,
   - South Tallow Creek at Broken Head Road, and
   - Redgum Place

   to provide a preliminary estimate of peak discharges at the measured peak flood level locations, shown in Table 3.2. The locations shown in Table 3.2 are referred to as the 'calibration points'. Note that peak discharges along Tallow Creek at Korau Place and Firewheel Place were not estimated because the predicted peak flood levels at these two locations are dependent upon the entrance conditions of Tallow Lake. The entrance conditions of Tallow Lake at the time of the flood event are not known. Details of the HEC-RAS models are given in Appendix C.

2. The Tallow Creek RAFTS model parameters were adjusted to achieve a good fit between peak discharges estimated by the RAFTS model and peak discharges estimated at the calibration points using the HEC RAS models. This process produced preliminary inflow hydrographs at the TUFLOW model boundaries.

3. The TUFLOW hydraulic model was run with the RAFTS model preliminary inflow hydrographs to compare TUFLOW and RAFTS discharge hydrographs at the downstream RAFTS nodes. All local inflows were set to zero for this simulation. The RAFTS model channel routing parameters were adjusted until the hydraulic routing characteristics predicted by the TUFLOW model were reproduced at the downstream RAFTS nodes. These parameters were then fixed throughout the calibration process.

4. The TUFLOW hydraulic model was run again with the upstream and local catchment inflow hydrographs to compare TUFLOW model peak flood levels against measured flood levels at the calibration points.

5. The RAFTS model parameters were iteratively adjusted to determine new inflow hydrographs, which were then re-run through the TUFLOW model to achieve the best possible fit between measured and predicted peak March 1999 flood levels. Several iterations between the RAFTS hydrologic and TUFLOW hydraulic models were required to achieve a set of consistent results between the two models and a good fit with measured water levels.

7.02 The calibration of the hydraulic model is largely automatic as long as the hydraulic model configuration correctly represents the hydraulic characteristics of the catchment. It is noted that most of the major piped storm water drainage system was included to ensure the hydraulic characteristics were correctly modelled. Therefore, the joint calibration process mostly involved the adjustment of RAFTS model parameters. Calibration of the RAFTS model was achieved by:

- Adjusting the 'global' BX model parameter,
- Adjusting initial and continuing rainfall losses for the catchment, and
- Adjusting the PERN catchment roughness for various catchments.
- Adjusting catchment slopes for various catchments.
- Adjusting channel slopes in main channel.

7.2 ADOPTED HYDRAULIC MODEL ROUGHNESS VALUES

7.03 Table 7.1 shows the adopted roughness (Manning's 'n') values for the various areas in the Tallow Creek hydraulic model. Representative roughness values that are consistent with the hydraulic characteristics of the different areas were assigned. The distribution of the different types of areas is shown in Figure 7.1.

Table 7.1 Adopted Manning's 'n' Values, Tallow Creek Hydraulic Model

Area Type	Manning's 'n' Value
Short grass/Grass Swale	0.025 -0.04
Road	0.025
House (obstruction)	0.2
Dense Vegetation	0.1
Waterbody	0.025
Suburban Area	0.05
Vegetated Channel	0.06 - 0.08

7.3 ASSIGNMENT OF MARCH 1999 TOTAL RAINFALL AND TEMPORAL PATTERN

7.04 Figure 7.2 shows the total rainfall and temporal pattern adopted for the March 1999 storm event. Available information indicates the storm burst started after 1300 hours and ceased at or before 1645 hours on 1 March 1999. Thus, the 100 mm storm burst reported by Mr Kempnich effectively occurred over a 3 to 3.5 hour period. In the absence of better data, it was assumed that 100 mm of rainfall fell over the Tallow Creek catchment during the flood producing storm burst. No information was available on the temporal pattern of the storm. Therefore, the IEAUST (1998) Zone 3 temporal pattern for a 3 hour storm with a severity of less than 30 Years ARI was adopted.

7.4 HYDROLOGICAL MODEL CHANGES TO REPRESENT MARCH 1999 CONDITIONS

7.05 The March 1999 catchment was very similar to the current catchment conditions. However, a trench was dug between Sub-catchment 29 and the Coogera Circuit detention basin during the March 1999 storm. For model calibration, it was assumed that all runoff from this catchment drained into this detention basin for this storm rather than being split between the Coogera Circuit Detention basin and the Beech Drive Basin. It was assumed that the Tallow Lake entrance was fully closed for the analysis. Thus, the stage - discharge relationship shown in Table 6.5 was adopted as the downstream boundary condition.

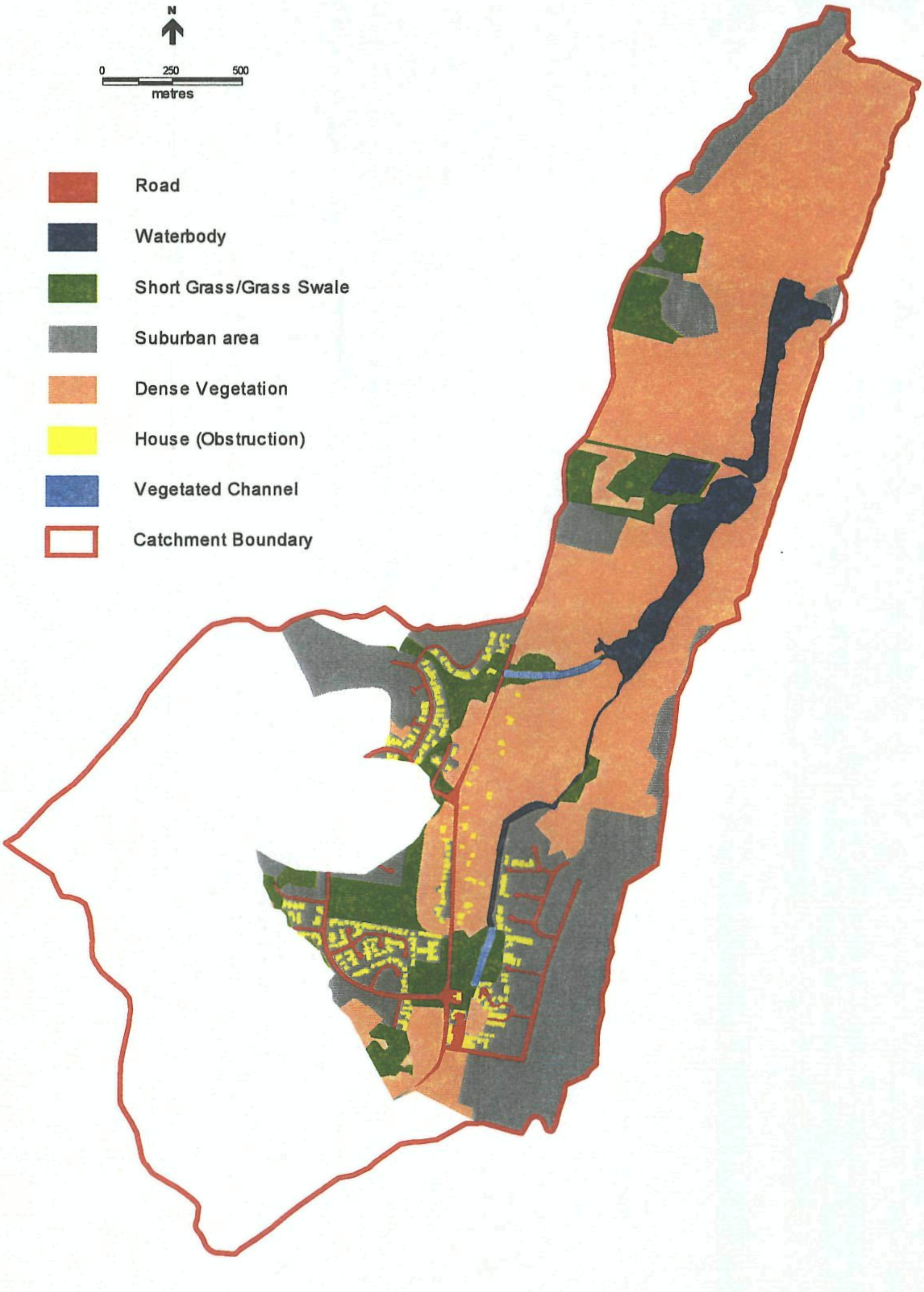

Figure 7.1 Distribution of Different Roughness Areas

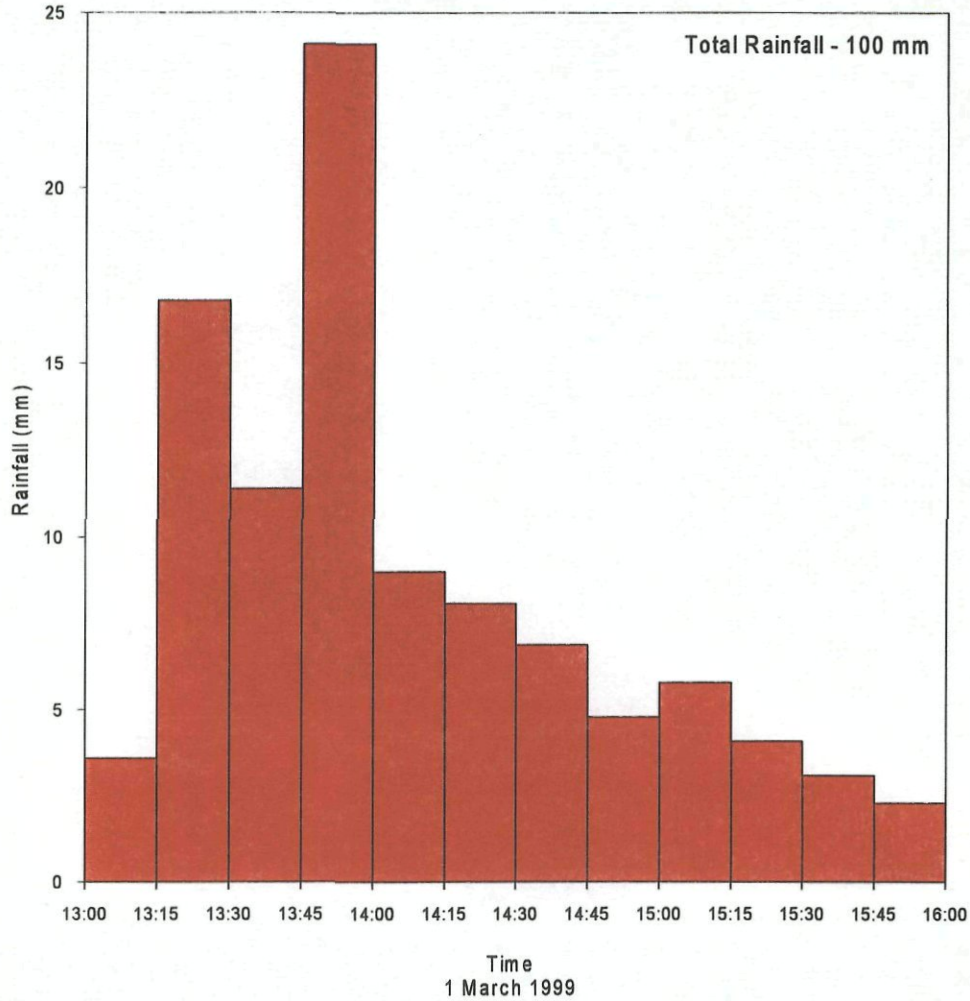

Figure 7.2 Adopted Total Rainfall and Temporal Pattern, March 1999 Flood

7.5 MARCH 1999 CALIBRATION RESULTS

7.5a Comparison of HEC-RAS and RAFTS Model Peak Discharges

7.06 Table 7.2 shows a comparison of peak discharges estimated by the RAFTS model and peak discharges estimated by the HEC-RAS model from the measured flood levels at the calibration points. A RAFTS model 'BX' factor of 1.0 was adopted for the analysis. Taking into account significant preceding rainfall, initial losses were set at zero. The continuing losses were set at 2.5 mm/hour. Details of the HEC-RAS analyses are provided in Appendix C. The following is of note with respect to the results shown in Table 7.2:

- Peak flood discharges compare reasonably well at South Tallow Creek at Broken Head Road and North Tallow Creek at Broken Head Road.
- The RAFTS model significantly under predicts peak discharges at Redgum Place. The reason for the under prediction at Redgum Place is unclear. It is possible that the Redgum Place culverts were completely blocked, which forced all water over the road. Alternatively, the resident was witnessing only the surface runoff from Redgum Place itself rather than water overflowing from the road. It is noted that the Redgum Place culvert has a capacity in excess of the estimated 100 Year ARI event. The available rainfall information indicates that the March 1999 storm had a severity of about 20 Years ARI. Thus, it is unlikely that the anomaly can be attributed to rainfall errors or the adopted temporal pattern. The most likely reason for the

differences in results between the models is that the HEC-RAS estimate is incorrect due to the inaccurate measured flood levels used in the analysis.

7.07 On this basis, the Redgum Place flood levels were excluded from the calibration process. Thus, calibration of the two models were based only on measured flood levels on South and North Tallow Creek at Broken Head Road.

Table 7.2 HEC-RAS and RAFTS Model Peak Discharge Comparison at the Calibration Points, March 1999 Flood

Location	HEC-RAS Peak Discharge (m^3/s)	RAFTS Model Peak Discharge (m^3/s)
South Tallow Creek at Broken Head Road	18	16.9
North Tallow Creek at Broken Head Road	7.5	9.4
Redgum Place	6	2.2

7.5b Comparison of TUFLOW and RAFTS Model Channel Routing

7.08 Figures 7.3, 7.4, and 7.5 show the TUFLOW and RAFTS model discharge hydrographs at:

- South Tallow Creek at Broken Head Road
- North Tallow Creek at Broken Head Road, and
- Tallow Creek Downstream of Sub-catchment 9.

using the preliminary March 1999 discharge hydrographs. Note that all local catchment inflows were set to zero in the analysis. The following is of note with respect to these figures.

- Figure 7.3 shows that the TUFLOW and RAFTS model channel routing parameters along South and Mid Tallow Creek are quite consistent. The RAFTS model slightly under-predicts discharges on the recession curve of the hydrograph. However, the timing of flows at the peak is consistent.

- Figure 7.4 shows that the TUFLOW and RAFTS model channel routing parameters of North Tallow Creek are excellent. Both the shape of the hydrograph and the flood peak are consistent.

- Figure 7.5 shows that the RAFTS model over-estimates peak discharges at Sub-Catchment 9 by about 10%. The channel storage effects of Suffolk Park Lake and Tallow Lake significantly affect peak discharges at this location. The RAFTS model parameters could not be adjusted sufficiently to overcome these storage effects. Therefore, the hydraulic model is likely to provide more accurate results under these conditions. As a result, peak discharges downstream of Broken Head Road were estimated using the TUFLOW model for all design runs.

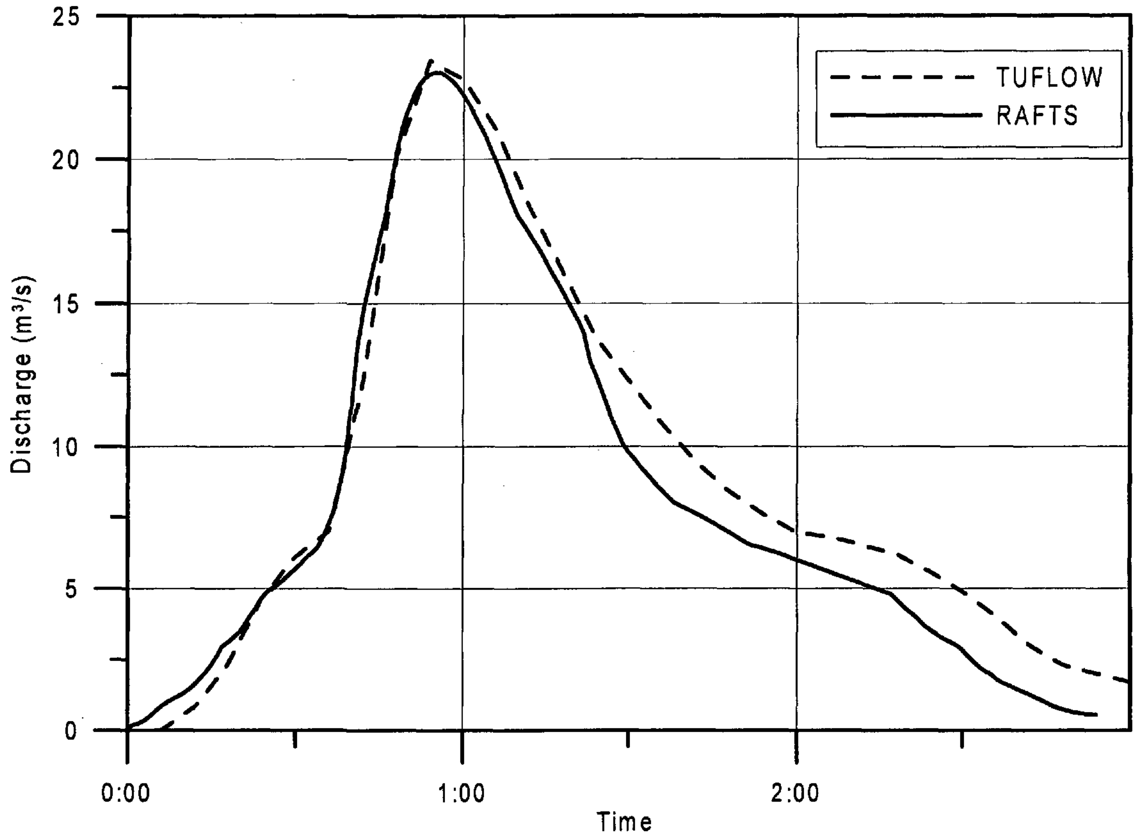

Figure 7.3 Comparison of RAFTS and TUFLOW River Routing Results, South Tallow Creek at Broken Head Road

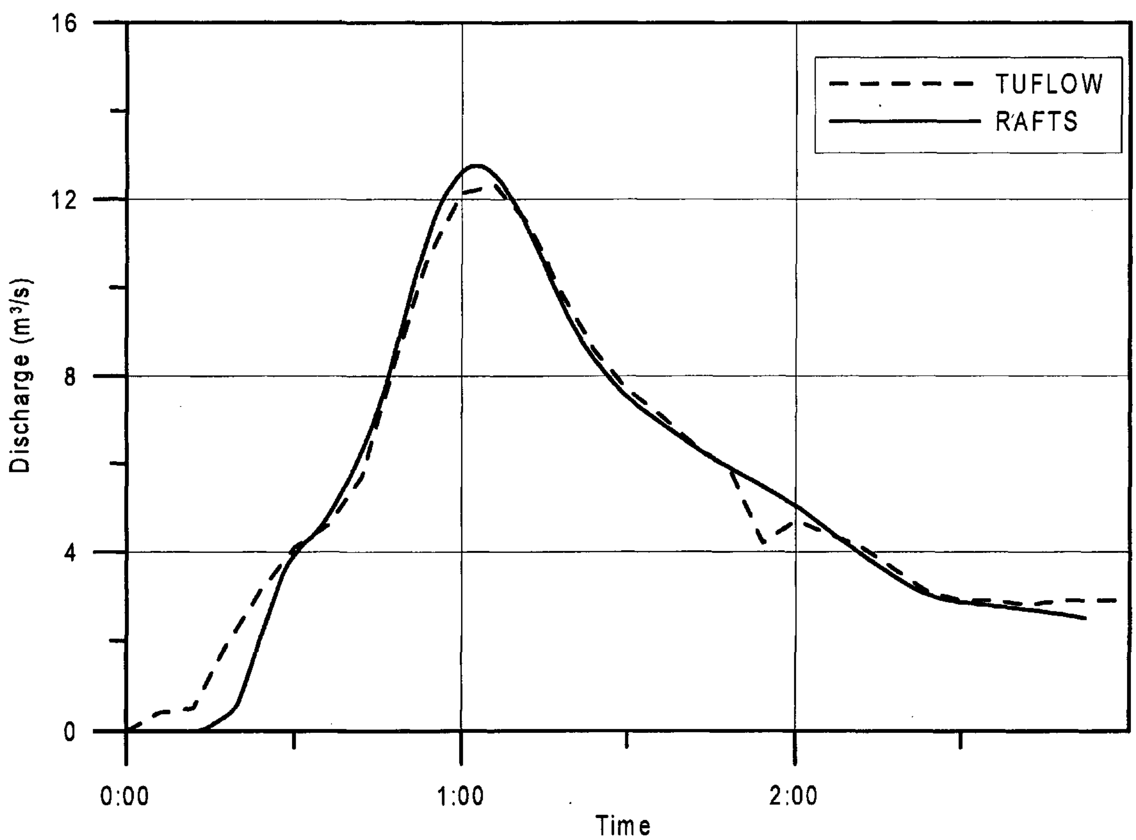

Figure 7.4 Comparison of RAFTS and TUFLOW River Routing Results, North Tallow Creek at Broken Head Road

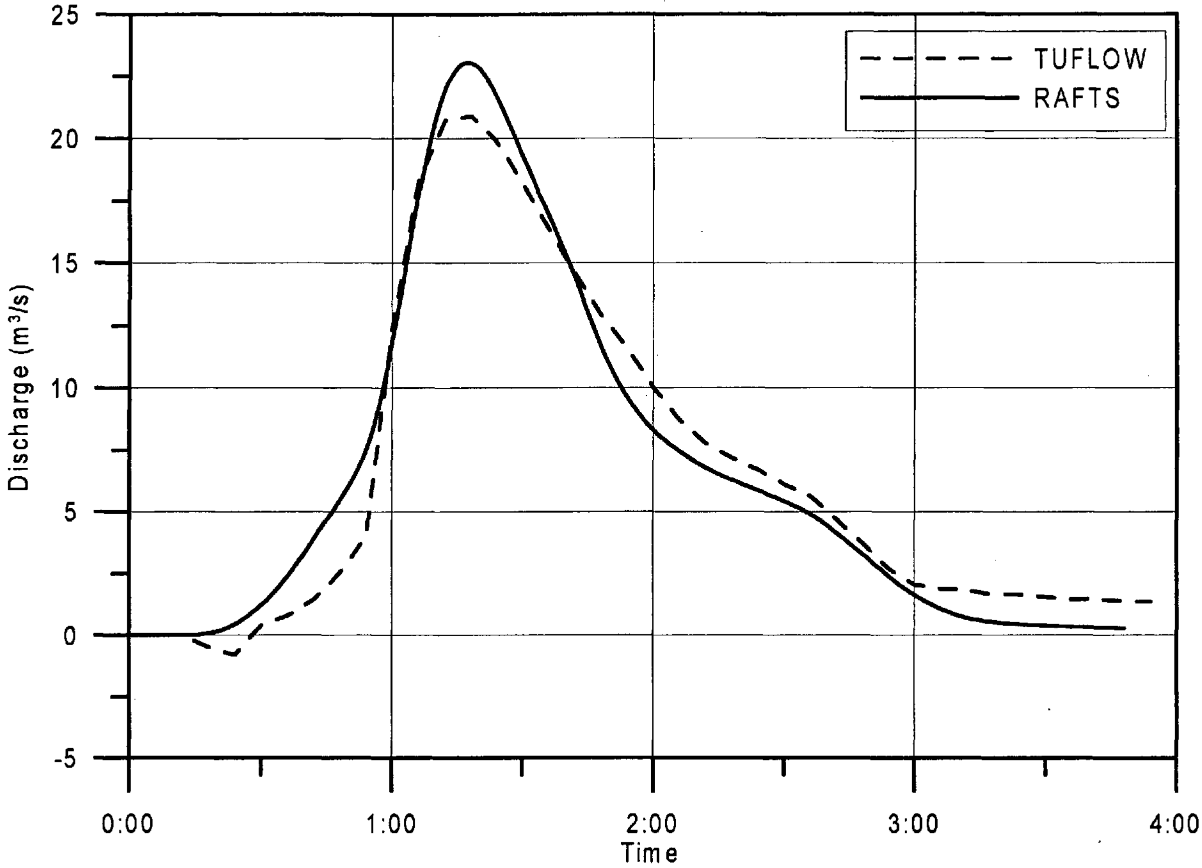

Figure 7.5 Comparison of RAFTS and TUFLOW River Routing at Tallow Creek Downstream of Sub-Catchment 9

7.5c Comparison of TUFLOW Peak Flood Levels against Measured Peak Flood Levels

7.09 Table 7.3 shows a comparison of peak flood levels estimated using the TUFLOW model against the measured flood levels at the calibration points. The following is of note with respect to Table 7.3.

- A good calibration was achieved at the locations on South Tallow Creek at Broken Head Road.
- The TUFLOW model marginally over-predicts peak flood levels at North Tallow Creek at Broken Head Road. Peak flood levels at this location are affected by Tallow Creek water levels, the vegetation characteristics of the North Tallow Creek channel downstream of Broken Head Road, as well as discharge estimates. Given these potential influences, the calibration at this location appears reasonable.

Table 7.3 Measured and Predicted Peak Flood Levels, March 1999 Flood, TUFLOW Model

Location	Figure 2.2 Locality Ref.	Measured Peak Flood Level (m AHD)	Predicted Peak Flood Level (m AHD)
South Tallow Creek at Broken Head Road	A	5.25 m	5.30
Mid Tallow Creek at Beech Drive	B	5.25 m	5.31
North Tallow Creek at Broken Head Road	F	2.56 m	2.67
Korau Place	G	2.30 m	2.36
Firewheel Place	H	3.60 m	3.52

- Peak flood levels compare reasonably well at Korau Place and Firewheel Place considering that these flood levels are influenced by the entrance conditions to Tallow Creek Lake.

7.6 SENSITIVITY ANALYSIS

7.10 A sensitivity analysis was undertaken by increasing channel and overland roughness by 50% to investigate the impact of adopted roughness values on predicted results. The increase in flood levels at various locations due to higher roughness values are shown in Table 7.4. The results indicate that peak flood levels are not overly sensitive to changes in channel roughness. This is most likely to be due to flood levels and velocities being controlled by the entrance levels to Tallow Lake.

Table 7.4 Impact of 50% higher Channel and Overbank Roughness Values on Peak Flood Levels, Tallow Creek.

Location	Predicted March 1999 Flood Level (m AHD)		Increase (m)
	Adopted Results	High Roughness Values	
South Tallow Creek at Broken Head Road	5.30	5.30	0.00
North Tallow Creek at Broken Head Road	2.67	2.73	0.06
Korau Place	2.36	2.42	0.06
Firewheel Place	3.52	3.56	0.04

8 COMPARISON OF RAFTS MODEL DISCHARGES WITH RATIONAL METHOD ESTIMATES

8.1 METHODOLOGY

8.02 Given that the limited available calibration data, design discharges predicted by the calibrated RAFTS model were compared against design discharges estimated using both the Probabilistic and Deterministic Rational Methods. The detention basins and their respective diversions were removed from the calibrated RAFTS model for the comparison because the Rational Method cannot take into account the impact of storages in flood discharges.

8.01 The calibrated RAFTS model (without detention basins) was used to estimate design flood discharges throughout the Tallow Creek Catchment based on design rainfall-intensity-frequency-duration data from Australian Rainfall and Runoff (IEAUST, 1998). Design flood discharges were estimated for a range of storm durations up to 6 hours for the 2, 5, 20, 50 and 100 Year Average Recurrence Interval (ARI) events and then compared against Rational method estimates.

8.2 DESIGN RAINFALLS

8.03 Design rainfall intensities and temporal patterns for storms of various durations up to 100 Year ARI were obtained from IEAUST (1998). An LPIII distribution was fit through the design rainfall intensities to extrapolate to the 500 Year ARI intensity. PMP rainfalls were determined using the Generalised Short Duration Method, as outlined in CBM (1994). The adopted design rainfall intensities for storms of various durations and severity are given in Table 8.1. An aerial reduction factor of 1 was applied to the entire catchment for all rainfalls because the Tallow Creek catchment area is only 450 ha. With respect to the estimation of PMP, the moisture adjustment factor was estimated at 0.77 and the catchment was assumed to be fully rough.

Table 8.1 Adopted Design Rainfall Intensities, Tallow Creek Catchment

Storm	Design Rainfall Intensity (mm/hr)						
Duration (mins)	2 Year ARI	5 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI	500 Year ARI	PMP
15	103	126	156	178	194	233	680
30	73	91	112	129	141	170	500
45	59	73	91	105	115	139	427
60	50	63	78	90	99	120	370
90	39	49	61	71	78	95	320
120	32	41	51	59	65	80	280
180	25	31	40	46	51	62	223
270	19	24	31	36	40	49	180
360	16	20	26	30	33	37	150

8.3 RAINFALL LOSSES

8.05 IEAUST (1998) provides regional estimates of initial and continuing losses for use in rainfall-runoff models, which were used to estimate peak discharges throughout the catchment. Adopted initial loss values for the Tallow Creek catchment are listed in Table 8.2. A continuing loss of 2.5 mm/hour was adopted for all ARI's. This is consistent with the March 1999 calibration and recommendations given in IEAUST (1998).

Table 8.2 Adopted Initial Losses for the Tallow Creek RAFTS Model

ARI (Years)	Initial Loss (mm)
2	20
5	20
20	20
50	15
100	10
500	10
PMP	10

8.4 ADOPTED TEMPORAL PATTERNS

8.06 Australia has been divided into eight zones on the basis of climatology and expected differences in temporal patterns (IEAust, 1998). Tallow Creek is located at the southern-most end of Zone 3 and is some 55 km to the north of Zone 1. This is generally outside the transition between the zone boundaries. That is, it is considered to be totally within Zone 3. However, both Zone 1 and Zone 3 temporal patterns were used to determine the maximum design discharge at each location. Generally speaking, the Zone 3 and Zone 1 temporal patterns produced similar peak discharges, with no temporal pattern always providing the highest peak. It is noted that the 1 hour temporal pattern is the same for both Zone 1 and Zone 3.

8.5 RAFTS MODEL DESIGN DISCHARGES (WITHOUT DETENTION BASINS)

8.07 Table 8.3 shows estimated 100 Year ARI design flood discharges at various locations throughout the Tallow Creek catchment from the calibrated RAFTS models (without the detention basins). Note that design discharges are shown for the comparison against rational method estimates. They do not relate to actual design discharges with detention basins.

Table 8.3 Tallow Creek Design Flood Discharges (Without Detention basins), 100 Year ARI Event

Node	RAFTS Discharge (m^3/s)
7	64.0
11	47.2
12	30.5
13	28.8
16	23.3
22	13.5
27	21.2
30	41.6
31	18.1

8.6 RATIONAL METHOD DESIGN DISCHARGES

8.08 The calibrated RAFTS model design discharges (without detention basins) were compared against design discharges estimated using the Rational Method, as described in IEAUST (1998) as a check on the calibration of the model. The most appropriate Rational Method procedure to use for Tallow Creek is unclear because of the mix of urban and rural areas.

- The Probabilistic Rational Method is a statistical method used to estimate design discharges. According to IEAUST (1998), the parameters for this method are based on recorded flood data from some 308 gauged catchments scattered throughout eastern New South Wales. In this method, rainfall intensity and runoff coefficients are determined based on the location of the catchment. This method has been widely used throughout New South Wales to estimate design discharges for ungauged catchments. However, it is generally only suitable for rural catchments.

- The Deterministic Rational Method is similar to the Probabilistic Method. However, it is based on physical parameters such as the response time or time of concentration of runoff to travel from the most remote point of the catchment to the outlet. The deterministic rational method is commonly used for small urban catchments where the physical parameters, such as pipe and inlet capacities are known.

8.6a Probabilistic Rational Method

8.09 Table 8.4 shows details of the Probabilistic Rational Method calculations for the 100 year ARI event for Tallow Creek at various RAFTS model nodes. Details of the calculations for the other design storms are given in Appendix D. Figure 8.1 shows a comparison between design discharges estimated using the Probabilistic Rational Method and design discharges estimated using the RAFTS model for all design discharges and all locations outlined in Table 8.4. Figure 8.1 shows that the Probabilistic Rational Method over-predicts peak discharges when compared to RAFTS model peak discharges by about 10%. At Node 7 (upstream end of Tallow Lake) the probabilistic Rational method over-estimates design discharges when compared to the RAFTS model by about 25%.

Table 8.4 Probabilistic Rational Method Calculations 100 Year ARI Event, Tallow Creek

Node	Area (ha)	Time of Concentration (min)	Rainfall Intensity (mm/h)	Rational Method Discharge (m^3/s)
7	313.1	70.4	90.65	97.8
11	144.7	52.5	106.47	53.1
12	95.4	44.8	115.56	38.0
13	79.4	41.8	119.89	32.8
16	65.8	38.9	124.33	28.2
22	35.7	30.8	139.64	17.2
27	61.5	37.9	126.01	26.7
30	121.3	49.1	110.25	46.1
31	51.8	35.5	130.10	23.2

8.6b Deterministic Rational Method

8.10 Table 8.5 shows details of the Deterministic Rational Method calculations for the 100 year ARI event for Tallow Creek at various RAFTS model nodes. Details of the calculations for the other design storms are provided in Appendix E. In the analysis, the Bransby Williams equation was used to estimate the time of concentration for the 'natural' catchment areas upstream of the urban development and Manning's equation was used to estimate travel time along the grass swales through the urban areas. Runoff coefficients were derived from Figure 1.13 in Book 8 of IEAUST (1998). Figure 8.2 shows a comparison between design discharges estimated using the Deterministic Rational Method and the design discharges estimated using the RAFTS model for all design discharges and all locations outlined in Table 8.5. Figure 8.2 shows RAFTS model and Deterministic Rational Method peak discharges compare reasonably well, except at the downstream end of the catchment (Node 7).

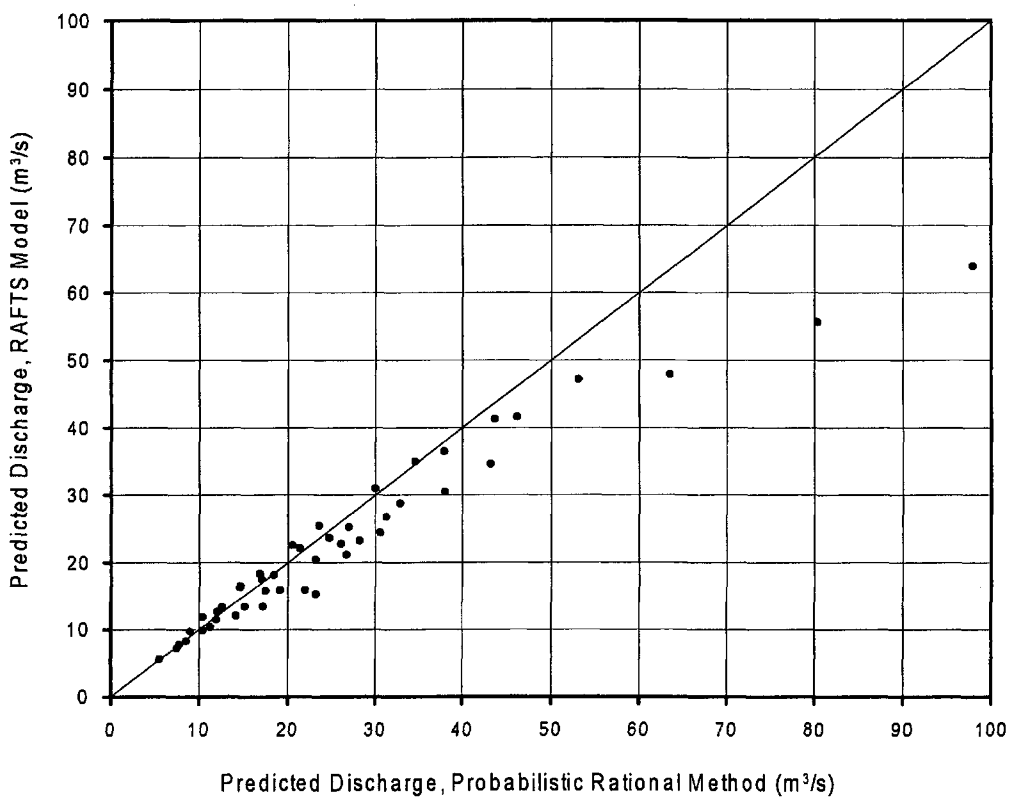

Figure 8.1 Comparison of Rafts Model and Probabilistic Rational Method Design Discharges at Nodes 7, 11, 12, 13, 16, 22, 27, 30, 31, 2 to 100 Year ARI Design Storms

Table 8.5 Deterministic Rational Method Calculations, 100 Year ARI Event, Tallow Creek

Node	Dev. Area - (Ad) (ha)	Undev. Area – (Au) (ha)	Ad x Cd	Au x Cu	ΣCA	Time of Conc. (mins)	Rainfall Intensity (mm/h)	Rational Method Discharge (m^3/s)
7	118.8	194.3	111.2	163.2	274.4	61	98.0	74.7
11	43.1	101.6	40.3	85.3	125.7	36	128.4	44.8
12	44.4	51.0	41.6	42.8	84.4	32	136.8	32.1
13	35.3	44.1	33.0	37.0	70.1	31	139.0	27.1
16	25.9	40.0	24.2	33.6	57.8	31	139.0	22.3
22	4.7	31.0	4.4	26.0	30.4	27	149.2	12.6
27	19.6	42.0	18.4	35.3	53.6	32	136.4	20.3
30	25.9	95.4	24.3	80.1	104.4	35	129.7	37.6
31	4.5	47.3	4.2	39.7	43.9	24	157.2	19.2

Ad – Area Developed
Au – Area Undeveloped
Cd – Runoff Coefficient Developed
Cu – Runoff Coefficient Undeveloped.

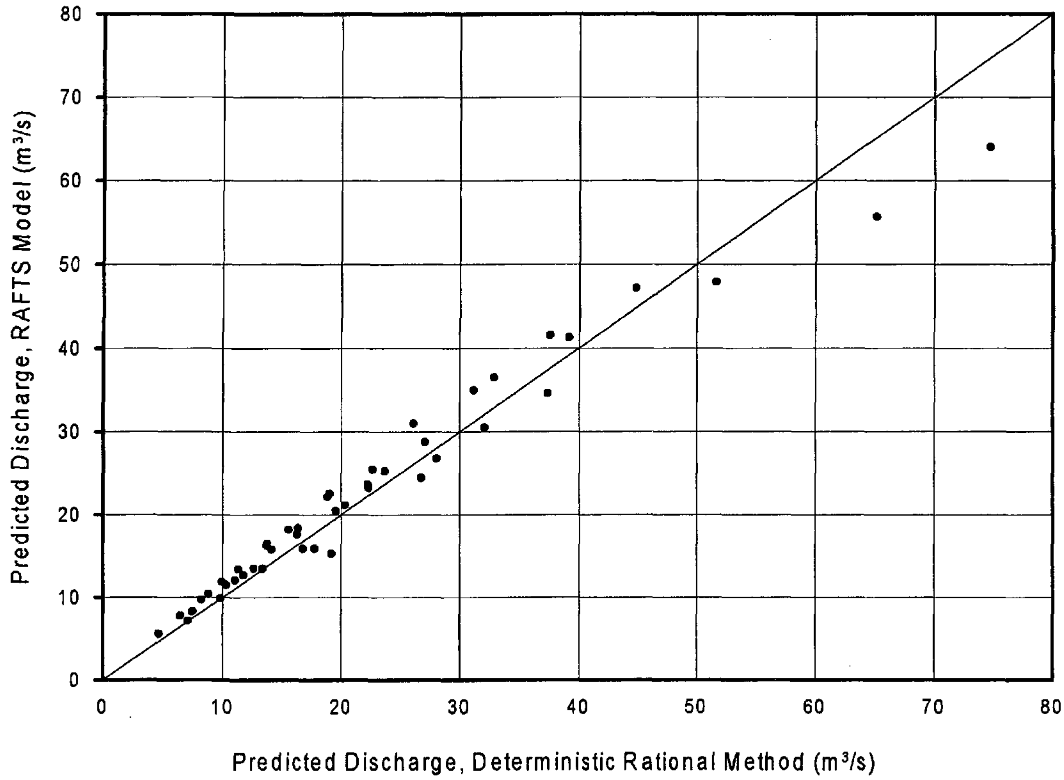

Figure 8.2 Comparison of Rafts Model and Deterministic Rational Method Design Discharges at Nodes 7, 11, 12, 13, 16, 22, 27, 30, 31, 2 to 100 Year ARI Design Storms

8.6c Discussion of Results

8.11 Figure 8.1 shows that the Probabilistic Rational Method over-predicts peak discharges by about 10% when compared to calibrated RAFTS model peak discharges. Given the level of urbanisation of the catchment, this finding is unusual but not unexpected. The parameters recommended for the Probabilistic Rational Method are based on an 'average' of a large number of recorded flood events from a large number of catchments. The Tallow Creek catchment has significantly more storage than an 'average' catchment. Therefore, less runoff is likely to be produced. Significant storage in the Tallow Creek catchment is evident from:

- The tea trees adjacent to the water courses. (This indicate that water is stored in the channels for extended periods).
- The undefined nature of flows in the urban areas. (This increases the available catchment storage).
- The low stream gradients downstream of Broken Head Road as well as Suffolk Park Lake and Tallow Lake. (This would significantly increase stream storage).

8.13 Figure 8.2 shows RAFTS model and Deterministic Rational Method peak discharges compare reasonably well. It is noted that the 'time of concentration' of the catchment is made up of travel time along the natural catchment areas and travel time along the urban areas. The estimated travel time through the natural areas is a significant contribution to the estimated peak discharge. It may be that the Bransby Williams equation marginally over predicts the travel time through the natural areas.

8.14 Based on the above Rational Method checks, it appears that the RAFTS model is adequately calibrated.

9 DESIGN FLOOD ESTIMATION

9.1 METHODOLOGY

9.01 The calibrated RAFTS and TUFLOW models were used to estimate design flood discharges throughout the Tallow Creek catchment. The RAFTS model was used to estimate design discharge hydrographs at the upstream boundaries of the hydraulic model (see Figure 6.1), as well as local inflow hydrographs at each RAFTS node within the hydraulic model area. The TUFLOW model was then used to route these hydrographs along the creek to estimate design flood discharges, flood levels and velocities along the modelled reach of the river.

9.02 Design flood discharges were estimated for a range of storm durations up to 6 hours for the 5, 20, 50, 100 and 500 year ARI events and for the Probable Maximum Precipitation (PMP) event. Design rainfalls, rainfall losses and the temporal patterns used to estimate design flood discharges are shown in Section 8.

9.2 DESIGN DISCHARGES

9.03 Table 9.1 shows estimated design flood discharges at various locations throughout the Tallow Creek catchment. As discussed in Section 7.5b, the RAFTS model was used to estimate design discharges upstream of Broken Head Road. The TUFLOW model was used to estimate design discharges downstream of Broken Head Road. The critical storm event producing the highest peak discharge varied from 1 hour upstream of Broken Head Road to 3 hours at the Tallow Lake entrance. The maximum design discharge at each location has been provided. Note that the Tallow Lake entrance conditions do no significantly affect design flood discharges.

Table 9.1 Estimated Design Flood Discharges, Tallow Creek, Various Locations, TUFLOW and RAFTS Models

Location	Peak Discharge (m^3/s)					
	5 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI	500 Year ARI	PMP
D/S Baywood Chase Lake	3.4	4.6	5.2	6.4	11.0	61.6
North Tallow Creek at Broken Head Road	9.0	10.8	12.0	15.2	20.9	96.5
Spillway Flows from Coogera Circuit Basin	3.2	6.2	8.3	11.2	13.9	41.5
South Tallow Creek at Broken Head Road	12.6	19.3	24.8	29.9	37.6	144.0
D/S End of Suffolk Park Lake	15.8	22.9	29.1	34.2	47.2	189.9
Junction North Tallow Ck & Tallow Lake	19.4	27.0	42.2	49.4	64.3	227.9
Tallow Lake Entrance	24.9	34.0	33.9	39.6	47.1	284.6

9.3 LOCAL CATCHMENT AND STORM TIDE EVENT COMBINATIONS

9.04 Design flood levels along Tallow Creek are affected by:

- Local flooding from rainfall over the local contributing catchment.
- Storm tide flooding backing up from the Pacific Ocean.
- A combination of local and storm tide flooding.

9.05 Due to the different mechanisms causing local catchment and storm tide flooding, the probability of simultaneous events of the same magnitude occurring in both systems is small. Hence, it is common practice to consider a reduced severity event in one system in conjunction with the design event in the other system. The appropriate event combinations for the area of interest are shown in Table 9.2. These were determined in consultation with DLWC. Note that these event combinations assume that the Tallow Lake entrance is fully open. It is assumed that Pacific Ocean levels are below the crest level of the sand bar for the entrance fully closed condition. This scenario determines the impact of the sand bar on local catchment design flood levels.

Table 9.2 Determination of Appropriate Event Combinations, Local Catchment Flooding and Storm Tide Events (Entrance Fully Open)

Local Flooding (Entrance Open)		Storm Tide Flooding	
Local Flood Event ARI	Adopted Storm Event ARI	Storm Tide Event ARI	Adopted Local Flood Event ARI
5	5	5	5
20	5	20	5
50	5	50	5
100	20	100	20
500	100	-	-
PMP	100	-	-

9.4 DESIGN FLOOD LEVELS

9.06 The TUFLOW model was used to estimate design flood levels throughout the Tallow Creek catchment for the 5, 20, 50, 100 and 500 year ARI events and the PMP event for the following event combinations:

- Local catchment flooding with the entrance fully open,
- Local catchment flooding with the entrance fully closed, and
- Storm tide flooding with the entrance fully open.

9.07 Table 9.3 shows the 100 year ARI design flood levels throughout the catchment for the three event combinations. The adopted design flood level, (the maximum flood level of the three event combinations) is also shown. The flood level locations are shown in Figure 9.1. Flood profiles of the three event combinations and the adopted design flood profile along Tallow Creek (and Mid Tallow Creek) is shown in Figure 9.2. Estimated design flood levels for the remaining events are provided in Appendix F.

9.08 The following is noted with respect to Table 9.3, Figure 9.2 and Appendix F:

- Local catchment flooding (entrance closed and open) is the dominant flooding mechanism upstream of Suffolk Park Lake and North Tallow Creek upstream of Broken Head Road. That is, the entrance conditions do not affect flood levels in the upstream areas.
- Storm tide flooding is the dominant flooding mechanism along Suffolk Park Lake, Tallow Lake and North Tallow Creek downstream of Broken Head Road.
- An exception to this occurs for the 5 year ARI event downstream of Suffolk Park Lake where the entrance fully closed condition is the dominant flooding mechanism. That is, the adopted crest of the sand bar is higher than the 5 year ARI storm tide level.

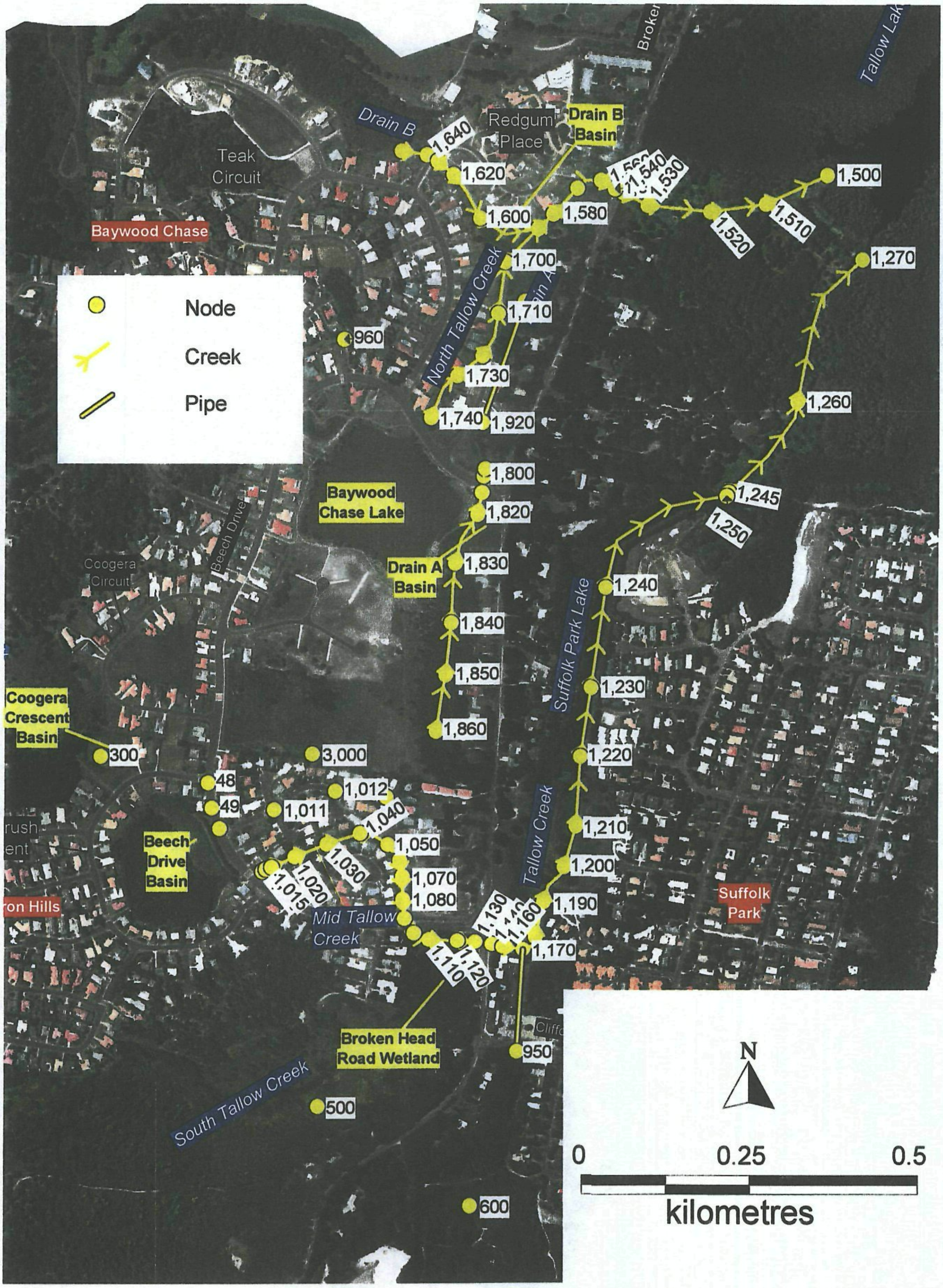

Figure 9.1 Locations of Design Flood Levels, Tallow Creek

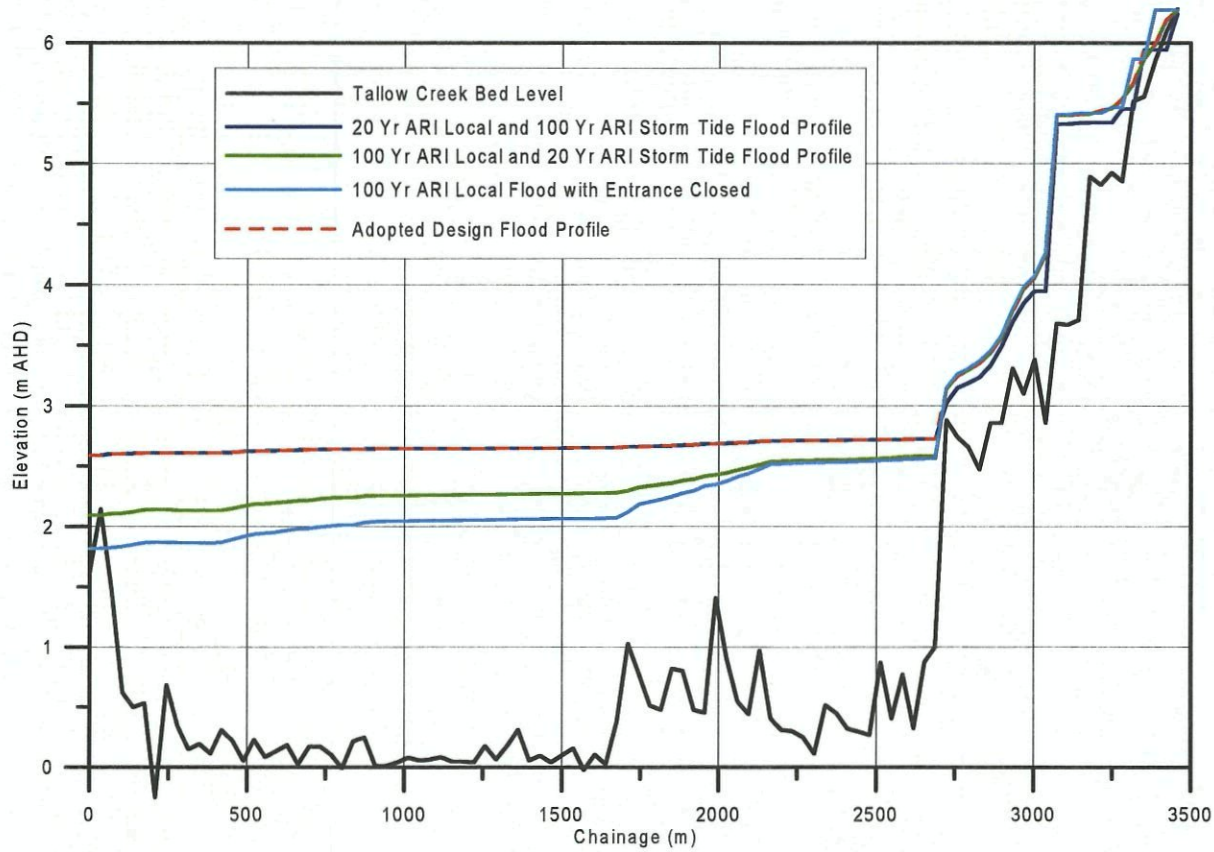

Figure 9.2 100 Year ARI Flood Profiles, Various Event Combinations, Tallow Creek

9.5 EXTENT OF FLOODING AND FLOOD LEVEL CONTOURS

9.09 Figure 9.4 shows the extent of flooding and flood level contours for the 100 year ARI event. This extent of flooding has been determined by overlaying the 100 year ARI local catchment extent of flooding (for each duration storm) over the 100 year ARI storm tide extent of flooding combination to determine the maximum extent of flooding. The extent of flooding and flood level contours for the remaining design flood events are provided in Appendix G.

9.6 MAXIMUM FLOOD VELOCITIES AND FLOOD DEPTHS

9.09 Table 9.4 shows the range of maximum flood velocities along the major drainage lines throughout the Tallow Creek catchment for the six design storms. Table 9.4 shows that flood velocities are moderate to low along most of the drainage lines, except for the PMP event, where flood velocities are high. Flood velocity vectors and flood depths for the 100 year ARI design flood are shown in Figure 9.3. Flood velocities and flood depths for the remaining design storms are provided in Appendix H. Figure 9.3 and Appendix H show that overland flow flood depths are generally small for most design storms, except the PMP event, and high velocities are concentrated along Mid-Tallow Creek and along the roads of Byron Hills.

9.7 PROVISIONAL FLOOD HAZARDS

9.10 The Tallow Creek floodplain has been divided into provisional hydraulic flood hazard categories based upon the depth of flooding and the velocity of floodwater at the site. A high hazard area is identified as those areas where a significant volume of floodwater flows. Any blockage of the high hazard area could cause an unacceptable increase in flood levels and/or a significant redistribution of flood flow. For the purpose of this report, the high hazard area has been identified where the depth velocity product exceeds one, or where the depth exceeds one metre, as defined in the New South *Wales Floodplain Management Manual (Figure G.2) (NSW Government, 2001) for the 100 year* ARI event. The low hazard area is the remaining area of land affected by flooding up to the PMP event. The locations of the low and high hazard areas for Tallow Creek are shown in Figure 9.5.

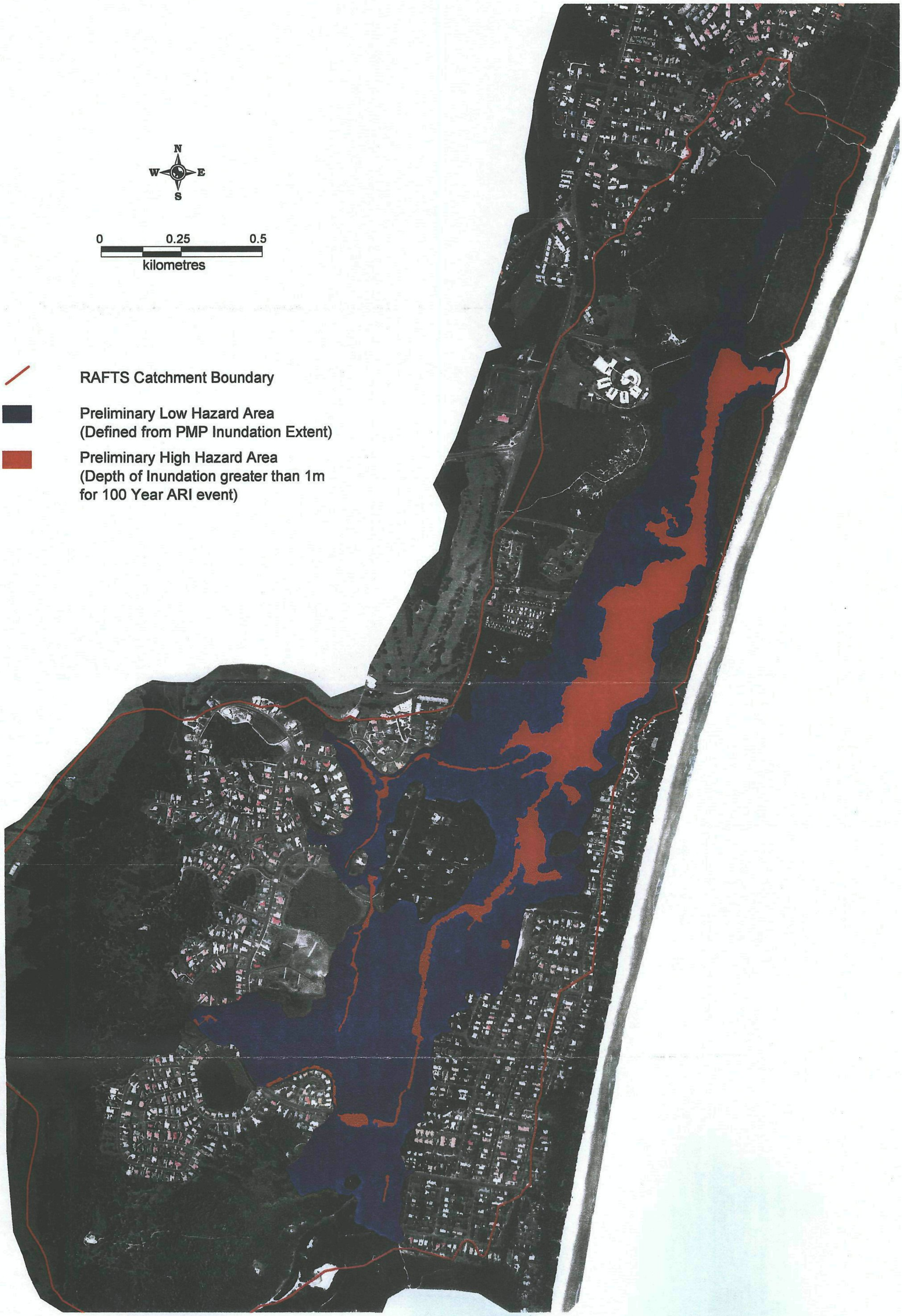

Figure 9.5 Locations of Low and High Hazard Areas, Tallow Creek

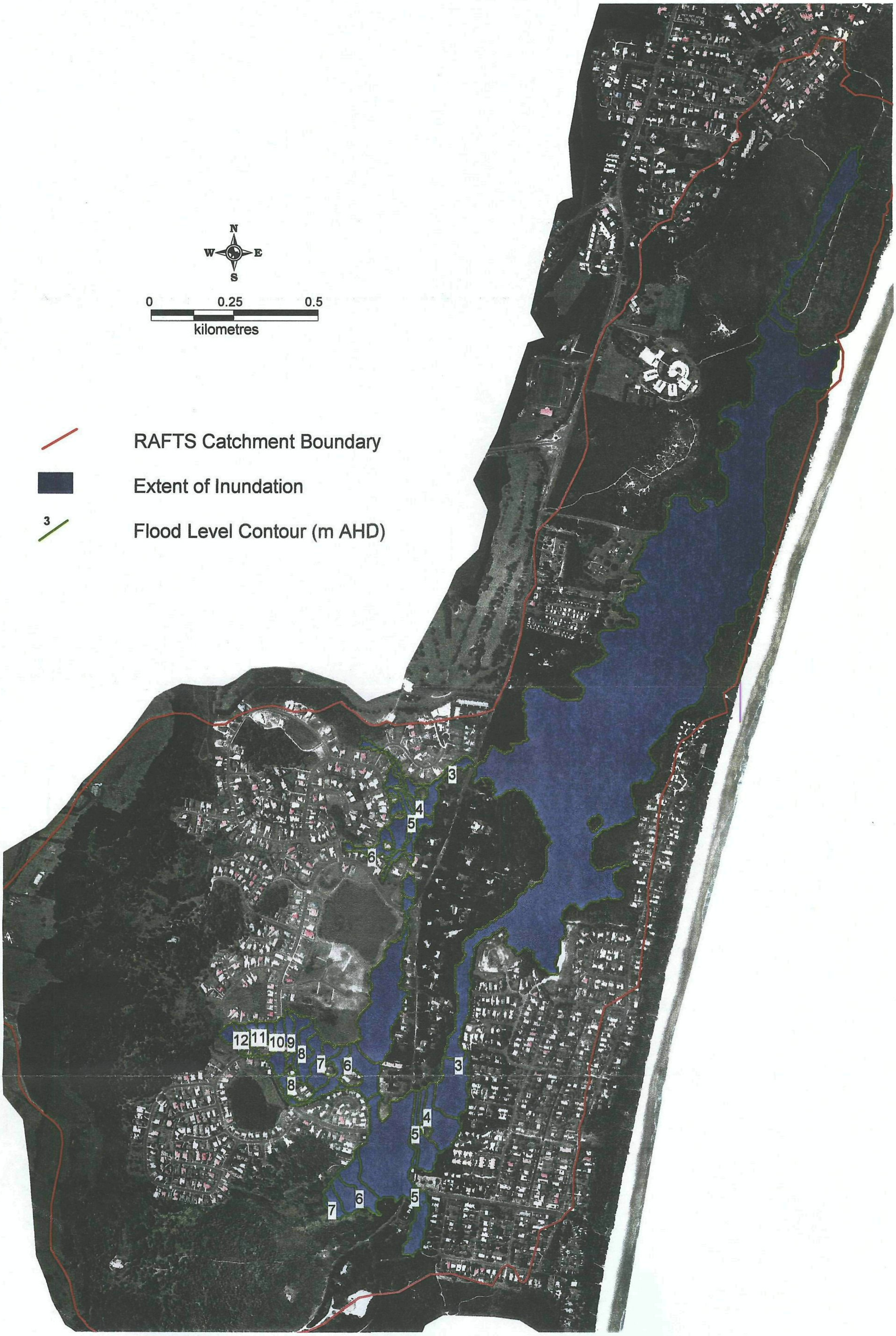

Figure 9.3 Extent of Flooding and Flood Contours, Tallow Creek, 100 Year ARI Event

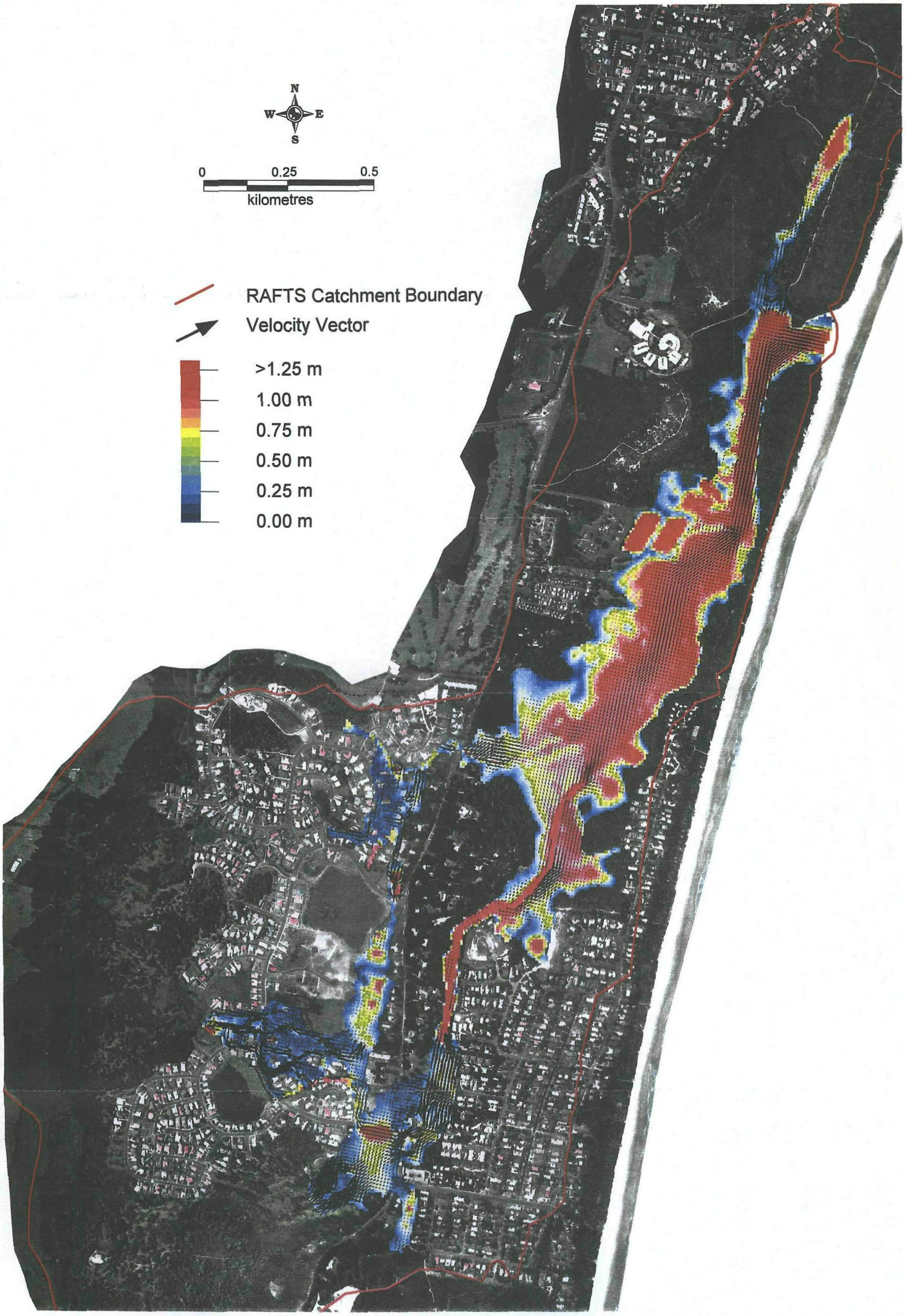

Figure 9.4 Flood Velocity Vectors and Flood Depths, Tallow Creek, 100 Year ARI Design Flood

Table 9.3 100 Year ARI Design Flood Levels, Various Event Combinations, Tallow Creek

Location	Node	100 Year ARI Peak Flood Level (m AHD)			
		Local Flooding Entrance Condition		Storm Tide[b] Flooding	Adopted Design Flood Level[c]
		Open[a]	Closed		
Byron Hills	3000	6.82	6.82	6.73	6.82
D/S Coogera Circuit Basin	300	12.39	12.40	12.26	12.40
Beech Drive	48	8.95	8.95	8.88	8.95
Beech Drive	49	8.77	8.77	8.71	8.77
Beech Drive	51	8.55	8.56	8.50	8.56
Pepperbush Carissa Ct	1012	6.17	6.16	6.14	6.17
Pepperbush Silky Ct	1011	7.18	7.19	7.14	7.19
Pepper Bush	10130	5.70	5.70	5.63	5.70
Mid Tallow Creek	1000	6.98	6.98	6.85	6.98
Mid Tallow Creek	1010	6.78	6.79	6.69	6.79
Mid Tallow Creek	1015	6.47	6.47	6.38	6.47
Mid Tallow Creek	1020	6.26	6.26	6.16	6.26
Mid Tallow Creek	1030	6.08	6.08	5.99	6.08
Mid Tallow Creek	1040	5.85	5.85	5.79	5.85
Mid Tallow Creek	1050	5.60	5.60	5.51	5.60
Mid Tallow Creek	1060	5.49	5.49	5.40	5.49
Mid Tallow Creek	1070	5.48	5.48	5.39	5.48
Mid Tallow Creek	1080	5.45	5.45	5.36	5.45
Mid Tallow Creek	1090	5.43	5.43	5.35	5.43
Mid Tallow Creek	1100	5.43	5.43	5.34	5.43
Mid Tallow Creek	1110	5.42	5.42	5.34	5.42
Mid Tallow Creek	1120	5.42	5.42	5.33	5.42
Mid Tallow Creek	1130	5.41	5.41	5.33	5.41
South Tallow Creek	500	7.08	7.07	6.97	7.08
Drain A	1246	3.62	3.62	3.47	3.62
Drain A	1790	5.46	5.46	4.85	5.46
Drain A	1800	5.35	6.13	4.96	6.13
Drain A	1810	5.29	5.29	4.96	5.29
Drain A	1820	5.30	5.29	4.97	5.30
Drain A	1830	5.32	5.33	5.02	5.33
Drain A	1840	5.32	5.32	5.02	5.32
Drain A	1850	5.33	5.33	5.02	5.33
Drain A	1860	5.33	5.32	5.03	5.33
Drain A	1920	5.24	5.19	4.84	5.24
North Tallow Creek	1500	2.28	2.09	2.67	2.67
North Tallow Creek	1510	2.31	2.15	2.65	2.65
North Tallow Creek	1520	2.33	2.22	2.68	2.68
North Tallow Creek	1530	2.61	2.56	2.72	2.72
North Tallow Creek	1540	2.63	2.59	2.72	2.72
North Tallow Creek	1550	2.88	2.86	2.81	2.88
North Tallow Creek	1560	2.91	2.89	2.83	2.91
North Tallow Creek	1570	3.01	2.99	2.87	3.01
North Tallow Creek	1580	3.06	3.04	2.90	3.06
North Tallow Creek	1590	3.09	3.08	2.92	3.09
North Tallow Creek	1700	3.29	3.29	3.10	3.29
North Tallow Creek	1710	4.08	4.08	3.82	4.08
North Tallow Creek	1720	4.28	4.28	3.98	4.28
North Tallow Creek	1730	4.56	4.56	4.21	4.56
North Tallow Creek	1740	4.95	4.95	4.55	4.95

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Table 9.3 100 Year ARI Design Flood Levels, Various Event Combinations, Tallow Creek - Cont'd

Location	Node	100 Year ARI Peak Flood Level (m AHD)			
		Local Flooding Entrance Condition		Storm Tide[b] Flooding	Adopted Design Flood Level[c]
		Open[a]	Closed		
Drain B	1600	3.40	3.39	3.25	3.40
Drain B	1620	3.96	3.96	3.86	3.96
Drain B	1630	4.01	4.01	3.91	4.01
Drain B	1640	4.09	4.09	3.95	4.09
Drain B	1950	4.09	4.09	3.96	4.09
Teak Circuit	960	6.71	6.71	6.67	6.71
Suffolk Park	600	4.13	4.13	4.08	4.13
Clifford St	950	4.38	4.31	4.43	4.43
Tallow Creek	1140	4.27	4.27	4.13	4.27
Tallow Creek	1160	4.21	4.20	4.10	4.21
Tallow Creek	1170	4.02	4.02	3.88	4.02
Tallow Creek	1180	3.98	3.98	3.85	3.98
Tallow Creek	1190	3.63	3.62	3.53	3.63
Tallow Creek	1200	3.39	3.39	3.26	3.39
Tallow Creek	1210	3.24	3.24	3.12	3.24
Tallow Creek	1220	2.61	2.58	2.73	2.73
Tallow Creek	1230	2.58	2.55	2.72	2.72
Tallow Creek	1240	2.57	2.54	2.72	2.72
Tallow Creek	1245	2.45	2.36	2.69	2.69
Tallow Creek	1250	2.55	2.52	2.71	2.71
Tallow Creek	1260	2.42	2.33	2.68	2.68
Tallow Creek	1270	2.32	2.18	2.66	2.66
Tallow Lake Entrance	700	2.10	1.82	2.60	2.60

[a] Entrance fully open condition assumes 100 Year ARI local catchment flood and 20 year ARI storm tide coincide
[b] Storm tide condition assumes 100 year ARI local catchment flood and 100 year ARI storm tide flood coincide
[c] Adopted design flood level is the maximum of all event combinations

Table 9.4 Design Flood Velocities Along the Major Drainage Lines - 5, 20, 50, 100 and 500 Year ARI and PMP Events

Location	Velocity Range (m/s)					
	5 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI	500 Year ARI	PMP
Drain A	0.3 - 1.3	0.3 - 0.9	0.2 - 0.9	0.2 - 0.9	0.2 - 0.9	0.2 - 0.8
Drain B	0.1 - 0.6	0.1 - 0.7	0.1 - 0.6	0.1 - 0.8	0.1 - 1.0	0.2 - 1.0
Mid Tallow Creek	0.6 - 1.7	0.6 - 1.7	0.6 - 1.7	0.6 - 1.7	0.6 - 1.7	0.6 - 1.8
North Tallow Creek	0.3 - 0.9	0.3 - 1.0	0.1 - 1.3	0.2 - 1.4	0.3 - 1.3	0.4 - 2.5
Suffolk Park Lake and Tallow Lake	0.3 - 0.5	0.4 - 0.7	0.4 - 0.7	0.5 - 0.8	0.6 - 0.9	1.4 - 2.0
Tallow Creek U/S Suffolk Park Lake	0.4 - 1.2	0.5 - 1.3	0.6 - 1.3	0.6 - 1.3	0.6 - 1.4	0.8 - 1.6

10 CONCLUSIONS

10.01 The Tallow Creek catchment consists of a steep to undulating upper catchment, which drains via three major creek systems through the residential subdivisions of Baywood Chase and Byron Hills. These creek systems drain into Tallow Creek downstream of Broken Head Road. Tallow Creek drains around the western edge of the Suffolk Park township eventually draining into Tallow Lake, which is an estuarine lake. Adjacent to Suffolk Park, Tallow Creek has been excavated into a permanent water body, which is called Suffolk Park Lake.

10.02 There are two distinct flooding mechanisms along Tallow Creek; local catchment rainfall flooding and Pacific Ocean storm tide flooding. Local catchment flooding occurs as a result of runoff generated from the natural catchment areas upstream of the Byron Hills and Baywood Chase subdivisions as well as from piped stormwater drainage system surcharge within the subdivisions. Storm tide flooding occurs as ocean levels rise and 'back up' into Tallow Creek. In addition to these two flooding mechanisms, the crest level of the sand bar at the Tallow Lake entrance can also affect flood levels.

10.03 A RAFTS hydrologic model and a TUFLOW hydraulic model were developed for the Tallow Creek catchment. The models were calibrated against peak flood level data and anecdotal rainfall data for the March 1999 flood event. A HEC-RAS one-dimensional steady state hydraulic model was used to assist with the calibration of the two models at locations where measured historical peak flood levels were available.

10.04 In general terms, the calibration of the models is considered to be reasonable. However, calibration of the models was hindered by:

- The lack of short duration rainfall,
- Uncertainties as to the entrance conditions at the time of the March 1999 event, and
- Limited recorded flood level data and no recorded discharge data.

10.05 The calibrated hydrologic and hydraulic models were used to estimate design flood discharges, flood levels, flood depths and velocities in the area of interest for the following event combinations:

- Local catchment flooding coinciding with a reduced severity design storm tide at the downstream boundary and the Tallow Lake entrance fully open.
- Local catchment flooding with the entrance fully closed and the ocean levels below the crest of the sand bar, and
- Storm tide flooding coinciding with a reduced severity local catchment design storm and the entrance fully open.

10.06 The maximum of the three event combinations was adopted for design purposes. Based on the model results, flood maps showing the extent of flooding, flood depths and velocities across the hydraulic model area were prepared for the 5 year, 20 year, 50 year, 100 year and 500 year ARI design storm events, as well as the PMP event. In addition, a provisional flood hazard map of Tallow Creek was developed showing high and low hazard zones. The high hazard zone was based on flood depth and velocity product exceeding one metre or the depth exceeding one for the 100 year ARI flood. The low hazard zone was based on the extent of flooding for the PMP design flood minus the adopted high hazard areas.

10.07 The following issues with respect to flooding in the Tallow Creek catchment are of note:

- Local catchment flooding is the dominant flooding mechanism along Tallow Creek upstream of Suffolk Park Lake and along North Tallow Creek upstream of Broken Head Road. Flood levels for all design floods were independent of the Tallow Lake Entrance conditions in these areas.

- Storm tide levels were generally the dominant flooding mechanism along Suffolk Park Lake, Tallow Lake and North Tallow Creek downstream of Broken Head Road, except for the 5 year ARI event. The adopted crest level of the sand bar, entrance fully closed condition, was higher than the 5 year ARI storm tide level and thus dominated flood levels in these areas for this event

- The Tallow Lake entrance conditions impact on design flood levels for the 5 year ARI flood event. It is possible that the Tallow Lake entrance may also impact on flood levels for larger floods if the crest level of the sand bar is greater than the level adopted in this study. It is recommended that monitoring of the sand bar be undertaken and eventually a management strategy be developed to ensure that the sand bar does not significantly impact on flood levels.

- The Coogera Circuit detention basin spills or overflows during floods of 5 year ARI severity or greater. The overflowing floodwater drains at a shallow depth over much of the lower Byron Hills subdivision.

- Some of the overflowing floodwater from the Coogera Circuit detention basin is diverted northward along Drain A in an unconfined manner towards North Tallow Creek.

- South Tallow Creek overtops Broken Head Road for all design events investigated. That is, Broken Head Road is expected to be overtopped more frequently than every five years, on average.

- The small undeveloped catchment to the south of the Coogera Circuit Detention Basin draining in an easterly direction to the Beech Drive detention basin has been blocked (See Figure 2.2). Floodwater from this catchment is piped to the Coogera Circuit Basin, or it overflows through house lots eventually to the Beech Drive Detention Basin.

- The stormwater pipes adjacent to Teak Circuit in the Baywood Chase subdivision surcharge for all design events. The surcharge flows bypass the Baywood Chase Lake.

- Drain A is undefined for much of its length. The pipe in Drain A underneath Honeysuckle Drive is overtopped for floods in excess of the 20 year ARI event.

- South Tallow Creek floodwater is diverted over Broken Head Road onto Clifford Street and eventually into the natural flow path to the south of Clifford Street for floods in excess of the 5 year ARI event. This ponded water potentially affects houses adjacent to this natural flow path.

10.08 It is recommended that any future Floodplain Management Plan should address these issues.

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12 GLOSSARY

Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
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.
Calibration	Method used to adjust modelled data to recorded data.
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.
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).
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 (refer Section 1.9) 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 Prone Land

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

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 flow, or a significant increase in flood levels.

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.

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 probably maximum precipitation. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with the PMF event should be addressed in a floodplain risk management study.

Probable Maximum Precipitation (PMP)

The greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to the estimation of the probable maximum flood.

Probability A statistical measure of the expected chance of flooding (see annual exceedance probability).

Runoff The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.

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.

Sub-Catchment The land area draining through a minor stream of a catchment to a particular site.

Water Surface Profile A graph showing the flood stage at any given location along a watercourse at a particular time.

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B RAFTS MODEL DETENTION BASIN DETAILS

B.1 BAYWOOD CHASE LAKE

Table B1 Adopted Stage - Storage Curve, Baywood Chase Lake

Stage (m AHD)	Storage Volume (m^3)
4.0	1,150
4.2	5,770
4.4	11,780
4.6	18,030
4.8	24,530
5.0	31,300
5.2	38,310
5.4	45,510
5.6	48,450
5.8	54,930
6.0	64,710
6.3	75,160

Table B2 Adopted Stage –Discharge Curve, Baywood Chase Lake Spillway

Stage (m)	Spillway Discharge (m^3/s)
5.64	0.0
5.66	0.1
5.75	2.1
6.00	38.3
6.25	125.5

B.2 COOGERA CIRCUIT DETENTION BASIN

Table B3 Adopted Stage Storage Curve, Coogera Circuit Detention Basin

Stage (m AHD)	Storage Volume (m^3)
9.47	0
9.73	0
10.0	7
10.2	60
10.4	200
10.6	450
10.8	800
11.0	1,220
11.2	1,670
11.4	2,140
11.6	2,650
11.8	3,190
12.0	3,750
12.01	3,780
12.25	4,530
12.5	5,420

Table B4 Adopted Stage –Discharge Curve, Coogera Circuit Detention Basin Spillway

Stage (m)	Spillway Discharge (m^3/s)
12.01	0
12.04	0
12.1	0
12.15	1
12.25	3
12.5	38
12.75	80

B.3 BEECH DRIVE DETENTION BASIN

Table B5 Adopted Stage Storage Curve, Beech Drive Detention Basin

Stage (m AHD)	Storage Volume (m^3)
7.31	0
7.60	20
7.80	170
8.00	510
8.20	1,030
8.40	1,700
8.60	2,480
8.80	3,420
8.82	3,530
9.00	4,470
9.25	5,990
9.50	7,900

Table B6 Adopted Stage –Discharge Curve, Beech Drive Detention Basin Spillway

Stage (m)	Spillway Discharge (m^3/s)
8.91	0
8.92	0
8.97	0
9.06	2
9.09	3
9.25	14
9.50	37

B.4 BROKEN HEAD ROAD WETLAND

Table B7 Adopted Stage Storage Curve, Broken Head Road Wetland

Stage (m AHD)	Storage Volume (m^3)
2.91	0
3.00	10
3.50	210
3.75	380
4.00	740
4.50	2,750
5.00	9,050
5.25	15,790
5.50	34,340
5.75	63,940

Table B8 Adopted Stage –Discharge Curve, Broken Head Road Wetland Spillway

Stage (m)	Spillway Discharge (m^3/s)
5.00	0
5.23	5
5.30	11
5.35	16
5.38	21
5.42	27
5.51	44
5.56	70
5.58	96

B.5 DRAIN A DETENTION BASIN

Table B9 Adopted Stage Storage Curve, Drain A Detention Basin

Stage (m AHD)	Storage Volume (m^3)
3.00	0
3.25	20
3.50	70
3.75	170
4.00	330
4.25	530
4.50	800
4.75	1,250
5.00	2,200
5.25	6,990

Table B10 Adopted Stage –Discharge Curve, Drain A Detention Basin

Stage (m)	Spillway Discharge (m^3/s)
5	0
5.25	9
5.5	35
5.75	75

B.6 DRAIN B DETENTION BASIN

Table B11 Adopted Stage Storage Curve, Drain B Detention Basin

Stage (m AHD)	Storage Volume (m^3)
1.24	0
1.40	1
1.60	10
1.80	50
2.00	110
2.20	220
2.40	360
2.60	550
2.80	800
3.00	1,120
3.20	1,540
3.39	2,070
3.75	3,360
4.25	6,580

Table B12 Adopted Stage –Discharge Curve, Drain B Detention Basin

Stage (m)	Spillway Discharge (m^3/s)
3.39	0.0
3.45	0.2
3.50	0.6
3.75	6.8
4.00	23.5
4.25	83.4

C Appendix
HEC-RAS MODEL DISCHARGE ESTIMATES AT THE CALIBRATION POINTS

C.1 CALIBRATION POINT DISCHARGE ESTIMATES

C.01 The HEC RAS one dimensional steady flow hydraulic model was used to provide a preliminary estimate of peak discharges at the locations of the measured water levels for the March 1999 flood event. HEC RAS models were developed at the following locations:

- South Tallow Creek at Broken Head Road
- North Tallow Creek at Broken Head Road, and
- Drain B at Redgum Place.

The following section describes the methodology used to estimate peak discharges from the measured water levels. The results of the analyses are also presented.

C.1a South Tallow Creek at Broken Head Road

(i) Location of Cross Sections.

C.02 Figure C.1 shows the locations of the cross-sections used in the HEC-RAS model of South Tallow Creek at Broken Head Road. Details of the culverts used are provided in Table 6.3 of the main report.

Figure C.1 Cross-Section Locations, South Tallow Creek at Broken Head Road, HEC-RAS Model

(ii) Model Configuration

C.03 A split flow hydraulic model was used to determine the culvert flow and roadway flow distribution. A series of cross-sections were used to represent the shape of the roadway rather than the HEC-RAS weir function because the weir function only allows an upstream and downstream cross-section. The section that controls the flow over Broken Head Road occurs at the centreline of the road. A Manning's 'n' of 0.015 was adopted for the roadway cross-sections.

(iii) Results

C.04 Table C.1 shows a comparison between the measured and predicted flood levels at the two locations using a peak discharge of 18 m^3/s. A sensitivity of the predicted peak discharge to culvert blockage was undertaken by blocking the lower half of the 1,050 mm diameter pipes. The results of the sensitivity check are also shown in Table C.1. The following is noted with respect to Table C.1:

- Calibration of the model to the Beech Drive flood level gave a flood level at Broken Head Road that was not consistent with several eyewitness and photographic accounts of the width and depth of flows over Broken Head Road. Thus, a higher weighting was placed on the accuracy of the Broken Head Road flood level, rather than the upstream level.
- The capacity of the Broken Head Road culverts is about 7.5 m^3/s. Any excess flows overtop Broken Head Road. This indicates that Broken Head Road is a significant constriction to South Tallow Creek flows.
- The sensitivity analysis indicates that a partial blockage of the pipes does not significantly change flood levels. Thus, the estimated peak discharge of 18 m^3/s appears to be robust.

Table C.1 Comparison between Measured and Predicted March 1999 Flood Levels, South Tallow Creek at Broken Head Road, HEC-RAS Model

Cross-Section No.	Location	Flood Level (m AHD)		Sensitivity Analysis
		Measured	Predicted	
3107.5	South Tallow Creek at Beech Drive	5.25	5.31	5.34
3043.4	Crest of Broken Head Road	5.25	5.24	5.26

C.1b Drain B at Redgum Place

(i) Location of Cross Sections.

C.05 Figure C.2 shows the locations of the cross-sections used in the HEC-RAS model of Drain B at Redgum Place. Drain B consists of a grass lined channel upstream and downstream of Redgum Place. Details of the culvert under Redgum Place are provided in Table 6.3.

(ii) Model Configuration

C.06 Again, a split flow hydraulic model was used to represent culvert flow and roadway flow at Redgum Place. Separate cross sections were used to represent the centre line of the road and the adjoining footpaths rather than the HEC-RAS weir equation because flood levels were provided over the centre line of the road and over the downstream footpath.

(iii) Results

C.07 Table C.2 shows a comparison between the measured and predicted flood levels using a peak discharge of 6 m^3/s. A sensitivity analysis was undertaken by blocking half the culvert. The results of the sensitivity analysis are also provided in Table B.2. The following is of note with respect to Table C.2:

Figure C.2 Cross-Section Locations, Drain B at Redgum Place, HEC-RAS Model

Table C.2 Comparison Between Measured and Predicted March 1999 Flood Levels, Drain B at Redgum Place, HEC-RAS Model

Cross-Section No.	Location	Flood Level (m AHD)		Sensitivity Analysis
		Anecdotal	Predicted	
	Roadway	4.3 - 4.45	4.46	4.48
2415	Downstream Footpath	4.40 - 4.44	4.41	4.43
2408	12 m downstream of Redgum Place	4.10	4.09 [a]	4.09

[a] Using an adopted channel Manning's 'n' of 0.040.

- The downstream flood level is heavily dependent on the adopted Manning's 'n' of the channel. Reducing Manning's 'n' of the channel to 0.030 lowers flood levels at the downstream cross-section by 0.08 m. The upstream flood level is not affected.

- The depth of floodwater over the centreline of Redgum Place and over the downstream footpath was predicted to be 0.45 m and 0.18 m. This corresponds quite well to the measured flood depths of 0.3 to 0.45 over the road and 0.2 m over the downstream footpath.

- Blocking half the culverts does not appear to have a significant impact on flood levels. Thus, the 6 m^3/s peak discharge estimate appears to be robust.

C.1c North Tallow Creek at Broken Head Road

C.08 Figure C.3 shows the locations of the cross-sections used in the North Tallow Creek at Broken Head Road HEC-RAS model. Details of the culvert under Broken Head Road are provided in Table 6.3.

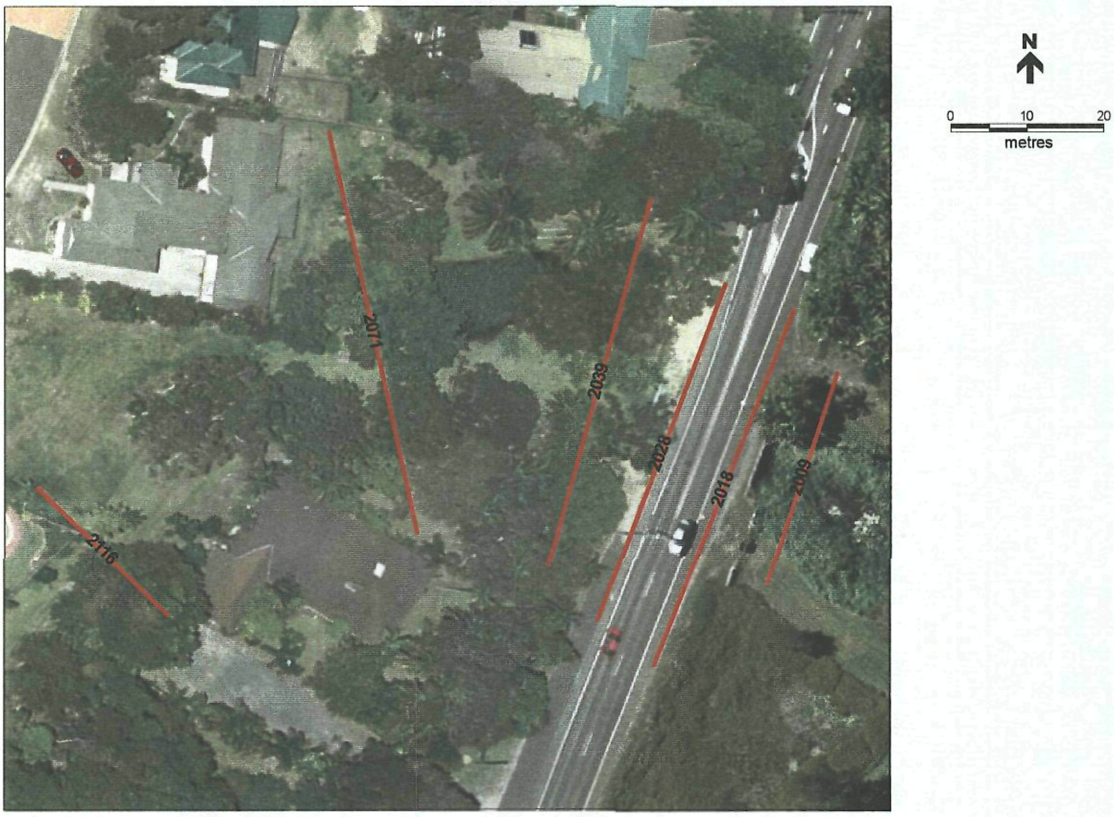

Figure C.3 Cross-Section Locations, North Tallow Creek at Broken Head Road, HEC-RAS Model

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(ii) Model Configuration

C.09 A resident estimated that water ponded in the culverts to about 0.5 m below the culvert obvert before the storm. However, the cross-sections indicated that water should freely drain from the culverts. It was assumed that Tallow Lake water levels caused water to pond in the culvert to this depth. Thus, a fixed downstream water level of 2.35 was adopted for the analysis.

(iii) Results

C.10 The HEC-RAS model indicated that March 1999 flood discharges at Broken Head Road peaked at about 7.5 m^3/s. It is noted that heavy vegetation in the channel downstream of Broken Head Road may have also caused water to pond to this depth. If this occurred, this vegetation would be expected to flatten during the storm, which would make the estimation of peak flood discharges from the recorded flood levels impossible. On this basis, this discharge estimate should be used with caution.

D Appendix
PROBABILISTIC RATIONAL METHOD DISCHARGES

Table D1 Probabilistic Rational Method Calculations, 2 Year ARI Event, Tallow Creek

Node	Area (ha)	Time of Concentration (min)	Rainfall Intensity (mm/h)	Rational Method Discharge (m^3/s)
7	313.1	70.4	45.64	30.6
11	144.7	52.5	54.15	16.8
12	95.4	44.8	59.06	12.1
13	79.4	41.8	61.42	10.4
16	65.8	38.9	63.84	9.0
22	35.7	30.8	72.23	5.5
27	61.5	37.9	64.76	8.5
30	121.3	49.1	56.19	14.6
31	51.8	35.5	67.00	7.4

Table D2 Probabilistic Rational Method Calculations, 5 Year ARI Event, Tallow Creek

Node	Area (ha)	Time of Concentration (min)	Rainfall Intensity (mm/h)	Rational Method Discharge (m^3/s)
7	313.1	1.173	57.09	43.2
11	144.7	0.875	67.49	23.6
12	95.4	0.747	73.49	17.0
13	79.4	0.696	76.36	14.7
16	65.8	0.648	79.30	12.6
22	35.7	0.514	89.48	7.7
27	61.5	0.632	80.42	12.0
30	121.3	0.818	69.98	20.5
31	51.8	0.592	83.14	10.4

Table D3 Probabilistic Rational Method Calculations, 20 Year ARI Event, Tallow Creek

Node	Area (ha)	Time of Concentration (min)	Rainfall Intensity (mm/h)	Rational Method Discharge (m^3/s)
7	313.1	70.4	71.48	63.5
11	144.7	52.5	84.22	34.6
12	95.4	44.8	91.53	24.8
13	79.4	41.8	95.03	21.4
16	65.8	38.9	98.62	18.4
22	35.7	30.8	111.00	11.2
27	61.5	37.9	99.98	17.4
30	121.3	49.1	87.26	30.0
31	51.8	35.5	103.28	15.2

Table D4 Probabilistic Rational Method Calculations, 50 Year ARI Event, Tallow Creek

Node	Area (ha)	Time of Concentration (min)	Rainfall Intensity (mm/h)	Rational Method Discharge (m^3/s)
7	313.1	70.4	82.43	80.4
11	144.7	52.5	96.94	43.7
12	95.4	44.8	105.27	31.3
13	79.4	41.8	109.24	27.0
16	65.8	38.9	113.32	23.2
22	35.7	30.8	127.39	14.2
27	61.5	37.9	114.86	22.0
30	121.3	49.1	100.40	37.9
31	51.8	35.5	118.62	19.1

Table D5 Probabilistic Rational Method Calculations, 100 Year ARI Event, Tallow Creek

Node	Area (ha)	Time of Concentration (min)	Rainfall Intensity (mm/h)	Rational Method Discharge (m^3/s)
7	313.1	70.4	90.65	97.8
11	144.7	52.5	106.47	53.1
12	95.4	44.8	115.56	38.0
13	79.4	41.8	119.89	32.8
16	65.8	38.9	124.33	28.2
22	35.7	30.8	139.64	17.2
27	61.5	37.9	126.01	26.7
30	121.3	49.1	110.25	46.1
31	51.8	35.5	130.10	23.2

E Appendix
DETERMINISTIC RATIONAL METHOD DISCHARGES

Table E1 Deterministic Rational Method Calculations, 2 Year ARI Event, Tallow Creek

Node	Dev. Area - (Ad) (ha)	Undev. Area – (Au) (ha)	Ad x Cd	Au x Cu	ΣCA	Time of Conc. (mins)	Rainfall Intensity (mm/h)	Rational Method Discharge (m^3/s)
7	118.8	194.3	78.76	115.61	194.37	61.38	49.57	26.8
11	43.1	101.6	28.56	60.45	89.01	36.49	66.09	16.3
12	44.4	51.0	29.44	30.35	59.78	32.22	70.65	11.7
13	35.3	44.1	23.40	26.24	49.64	31.12	71.90	9.9
16	25.9	40.0	17.17	23.80	40.97	31.12	71.90	8.2
22	4.7	31.0	3.12	18.45	21.56	27.39	77.50	4.6
27	19.6	42.0	12.99	24.99	37.98	32.37	70.48	7.4
30	25.9	95.4	17.17	56.76	73.93	35.78	66.75	13.7
31	4.5	47.3	2.98	28.14	31.13	24.71	81.93	7.1

Ad – Area Developed
Au – Area Undeveloped
Cd – Runoff Coefficient Developed
Cu – Runoff Coefficient Undeveloped.

Table E2 Deterministic Rational Method Calculations, 5 Year ARI Event, Tallow Creek

Node	Dev. Area - (Ad) (ha)	Undev. Area – (Au) (ha)	Ad x Cd	Au x Cu	ΣCA	Time of Conc. (mins)	Rainfall Intensity (mm/h)	Rational Method Discharge (m^3/s)
7	118.8	194.3	88.03	129.21	217.24	61.38	61.90	37.4
11	43.1	101.6	31.91	67.56	99.48	36.49	82.03	22.7
12	44.4	51.0	32.90	33.92	66.82	32.22	87.56	16.3
13	35.3	44.1	26.16	29.33	55.48	31.12	89.08	13.7
16	25.9	40.0	19.19	26.60	45.79	31.12	89.08	11.3
22	4.7	31.0	3.48	20.62	24.10	27.39	95.85	6.4
27	19.6	42.0	14.52	27.93	42.45	32.37	87.35	10.3
30	25.9	95.4	19.19	63.44	82.63	35.78	82.84	19.0
31	4.5	47.3	3.33	31.45	34.79	24.71	101.21	9.8

Ad – Area Developed
Au – Area Undeveloped
Cd – Runoff Coefficient Developed
Cu – Runoff Coefficient Undeveloped.

Table E3 Deterministic Rational Method Calculations, 20 Year ARI Event, Tallow Creek

Node	Dev. Area - (Ad) (ha)	Undev. Area – (Au) (ha)	Ad x Cd	Au x Cu	ΣCA	Time of Conc. (mins)	Rainfall Intensity (mm/h)	Rational Method Discharge (m^3/s)
7	118.8	194.3	97.30	142.81	240.11	61.38	77.37	51.6
11	43.1	101.6	35.27	74.68	109.95	36.49	101.94	31.1
12	44.4	51.0	36.36	37.49	73.85	32.22	108.67	22.3
13	35.3	44.1	28.91	32.41	61.32	31.12	110.51	18.8
16	25.9	40.0	21.21	29.40	50.61	31.12	110.51	15.5
22	4.7	31.0	3.85	22.79	26.63	27.39	118.72	8.8
27	19.6	42.0	16.05	30.87	46.92	32.37	108.41	14.1
30	25.9	95.4	21.21	70.12	91.33	35.78	102.92	26.1
31	4.5	47.3	3.69	34.77	38.45	24.71	125.21	13.4

Ad – Area Developed
Au – Area Undeveloped
Cd – Runoff Coefficient Developed
Cu – Runoff Coefficient Undeveloped.

Table E4 Deterministic Rational Method Calculations, 50 Year ARI Event, Tallow Creek

Node	Dev. Area - (Ad) (ha)	Undev. Area – (Au) (ha)	Ad x Cd	Au x Cu	ΣCA	Time of Conc. (mins)	Rainfall Intensity (mm/h)	Rational Method Discharge (m^3/s)
7	118.8	194.3	106.56	156.41	262.98	61.38	89.15	65.1
11	43.1	101.6	38.63	81.79	120.42	36.49	117.10	39.2
12	44.4	51.0	39.83	41.06	80.88	32.22	124.74	28.0
13	35.3	44.1	31.66	35.50	67.16	31.12	126.83	23.7
16	25.9	40.0	23.23	32.20	55.43	31.12	126.83	19.5
22	4.7	31.0	4.22	24.96	29.17	27.39	136.14	11.0
27	19.6	42.0	17.58	33.81	51.39	32.37	124.45	17.8
30	25.9	95.4	23.23	76.80	100.03	35.78	118.21	32.8
31	4.5	47.3	4.04	38.08	42.11	24.71	143.50	16.8

Ad – Area Developed
Au - Area Undeveloped
Cd – Runoff Coefficient Developed
Cu – Runoff Coefficient Undeveloped.

Table E5 Deterministic Rational Method Calculations, 100 Year ARI Event, Tallow Creek

Node	Dev. Area - (Ad) (ha)	Undev. Area – (Au) (ha)	Ad x Cd	Au x Cu	ΣCA	Time of Conc. (mins)	Rainfall Intensity (mm/h)	Rational Method Discharge (m^3/s)
7	118.8	194.3	111.20	163.21	274.41	61.38	97.97	74.7
11	43.1	101.6	40.31	85.34	125.66	36.49	128.44	44.8
12	44.4	51.0	41.56	42.84	84.40	32.22	136.75	32.1
13	35.3	44.1	33.04	37.04	70.08	31.12	139.03	27.1
16	25.9	40.0	24.24	33.60	57.84	31.12	139.03	22.3
22	4.7	31.0	4.40	26.04	30.44	27.39	149.16	12.6
27	19.6	42.0	18.35	35.28	53.63	32.37	136.44	20.3
30	25.9	95.4	24.24	80.14	104.38	35.78	129.65	37.6
31	4.5	47.3	4.21	39.73	43.94	24.71	157.16	19.2

Ad – Area Developed
Au – Area Undeveloped
Cd – Runoff Coefficient Developed
Cu – Runoff Coefficient Undeveloped.

F Appendix DESIGN FLOOD LEVELS

Table F1 5 Year ARI Design Flood Levels, Various Event Combinations, Tallow Creek

Location	Node	5 Year ARI Flood Level (m AHD)		
		Local Flooding Entrance Condition		Adopted Design Flood Level[b]
		Open[a]	Closed	
Byron Hills	3000	6.70	6.70	6.70
D/S Coogera Circuit Basin	300	12.10	12.10	12.10
Beech Drive	48	8.82	8.82	8.82
Beech Drive	49	8.64	8.64	8.64
Beech Drive	51	8.46	8.45	8.46
Pepperbush Carissa Ct	1012	6.17	6.20	6.20
Pepperbush Silky Ct	1011	7.13	7.13	7.13
Pepper Bush	10130	5.59	5.59	5.59
Mid Tallow Creek	1000	6.79	6.79	6.79
Mid Tallow Creek	1010	6.64	6.64	6.64
Mid Tallow Creek	1015	6.32	6.31	6.32
Mid Tallow Creek	1020	6.03	6.03	6.03
Mid Tallow Creek	1030	5.88	5.88	5.88
Mid Tallow Creek	1040	5.71	5.71	5.71
Mid Tallow Creek	1050	5.42	5.42	5.42
Mid Tallow Creek	1060	5.32	5.32	5.32
Mid Tallow Creek	1070	5.30	5.30	5.30
Mid Tallow Creek	1080	5.28	5.28	5.28
Mid Tallow Creek	1090	5.26	5.26	5.26
Mid Tallow Creek	1100	5.26	5.26	5.26
Mid Tallow Creek	1110	5.25	5.25	5.25
Mid Tallow Creek	1120	5.25	5.25	5.25
Mid Tallow Creek	1130	5.24	5.24	5.24
South Tallow Creek	500	6.96	6.96	6.96
Drain A	1246	3.49	3.46	3.49
Drain A	1790	4.91	4.59	4.91
Drain A	1800	5.06	5.06	5.06
Drain A	1810	4.68	4.68	4.68
Drain A	1820	4.70	4.70	4.70
Drain A	1830	4.84	4.84	4.84
Drain A	1840	4.84	4.84	4.84
Drain A	1850	4.85	4.85	4.85
Drain A	1860	4.99	4.95	4.99
Drain A	1920	4.60	4.59	4.60
North Tallow Creek	1500	1.80	1.92	1.92
North Tallow Creek	1510	1.93	2.00	2.00
North Tallow Creek	1520	2.07	2.10	2.10
North Tallow Creek	1530	2.22	2.25	2.25
North Tallow Creek	1540	2.24	2.26	2.26
North Tallow Creek	1550	2.36	2.39	2.39
North Tallow Creek	1560	2.40	2.42	2.42
North Tallow Creek	1570	2.49	2.51	2.51
North Tallow Creek	1580	2.55	2.56	2.56
North Tallow Creek	1590	2.58	2.59	2.59
North Tallow Creek	1700	3.04	3.04	3.04
North Tallow Creek	1710	3.72	3.72	3.72
North Tallow Creek	1720	3.87	3.87	3.87
North Tallow Creek	1730	4.11	4.11	4.11
North Tallow Creek	1740	4.44	4.44	4.44

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Table F1 5 Year ARI Design Flood Levels, Various Event Combinations, Tallow Creek - Cont'd

Location	Node	5 Year ARI Flood Level (m AHD)		
		Local Flooding Entrance Condition		Adopted Design Flood Level[b]
		Open[a]	Closed	
Drain B	1600	3.13	3.13	3.13
Drain B	1620	3.80	3.80	3.80
Drain B	1630	3.85	3.85	3.85
Drain B	1640	3.88	3.88	3.88
Drain B	1950	3.88	3.88	3.88
Teak Circuit	960	6.66	6.66	6.66
Suffolk Park	600	4.06	4.06	4.06
Clifford St	950	4.41	4.26	4.41
Tallow Creek	1140	4.00	4.00	4.00
Tallow Creek	1160	3.97	3.97	3.97
Tallow Creek	1170	3.77	3.77	3.77
Tallow Creek	1180	3.74	3.74	3.74
Tallow Creek	1190	3.46	3.46	3.46
Tallow Creek	1200	3.15	3.15	3.15
Tallow Creek	1210	3.00	3.01	3.01
Tallow Creek	1220	2.25	2.25	2.25
Tallow Creek	1230	2.23	2.24	2.24
Tallow Creek	1240	2.23	2.23	2.23
Tallow Creek	1245	2.07	2.11	2.11
Tallow Creek	1250	2.22	2.23	2.23
Tallow Creek	1260	2.05	2.09	2.09
Tallow Creek	1270	1.95	2.01	2.01
Tallow Lake Entrance	700	1.67	1.82	1.82

a Entrance fully open condition assumes 5 Year ARI local catchment flood and 5 year ARI storm tide flood coincide
b Adopted design flood level is the maximum of all event combinations

Table F2 20 Year ARI Design Flood Levels, Various Event Combinations, Tallow Creek

Location	Node	100 Year ARI Peak Flood Level (m AHD)			
		Local Flooding Entrance Condition		Storm Tide[b] Flooding	Adopted Design Flood Level[c]
		Open[a]	Closed		
Byron Hills	3000	6.73	6.73	6.70	6.73
D/S Coogera Circuit Basin	300	12.27	12.28	12.09	12.28
Beech Drive	48	8.89	8.90	8.82	8.90
Beech Drive	49	8.72	8.72	8.63	8.72
Beech Drive	51	8.51	8.51	8.45	8.51
Pepperbush Carissa Ct	1012	6.17	6.17	6.15	6.20
Pepperbush Silky Ct	1011	7.14	7.14	7.12	7.14
Pepper Bush	10130	5.63	5.63	5.59	5.63
Mid Tallow Creek	1000	6.91	6.86	6.80	6.91
Mid Tallow Creek	1010	6.73	6.69	6.64	6.73
Mid Tallow Creek	1015	6.40	6.40	6.32	6.40
Mid Tallow Creek	1020	6.18	6.17	6.03	6.18
Mid Tallow Creek	1030	6.01	6.00	5.88	6.01
Mid Tallow Creek	1040	5.80	5.80	5.71	5.80
Mid Tallow Creek	1050	5.51	5.51	5.42	5.51
Mid Tallow Creek	1060	5.41	5.41	5.32	5.41
Mid Tallow Creek	1070	5.39	5.40	5.30	5.40
Mid Tallow Creek	1080	5.37	5.37	5.28	5.37
Mid Tallow Creek	1090	5.36	5.36	5.26	5.36
Mid Tallow Creek	1100	5.34	5.34	5.26	5.34
Mid Tallow Creek	1110	5.34	5.34	5.25	5.34
Mid Tallow Creek	1120	5.34	5.34	5.25	5.34
Mid Tallow Creek	1130	5.34	5.34	5.24	5.34
South Tallow Creek	500	6.98	6.98	6.95	6.98
Drain A	1246	3.48	3.52	3.46	3.52
Drain A	1790	4.87	4.89	4.91	4.91
Drain A	1800	4.96	4.96	4.51	5.06
Drain A	1810	4.95	5.00	4.60	5.00
Drain A	1820	4.96	5.01	4.63	5.01
Drain A	1830	5.01	5.05	4.81	5.05
Drain A	1840	5.01	5.06	4.82	5.06
Drain A	1850	5.01	5.06	4.82	5.06
Drain A	1860	5.02	5.06	4.95	5.06
Drain A	1920	4.84	4.89	4.51	4.89
North Tallow Creek	1500	1.87	1.98	2.16	2.16
North Tallow Creek	1510	1.99	2.06	2.18	2.18
North Tallow Creek	1520	2.16	2.16	2.19	2.19
North Tallow Creek	1530	2.38	2.39	2.28	2.39
North Tallow Creek	1540	2.40	2.41	2.29	2.41
North Tallow Creek	1550	2.59	2.59	2.40	2.59
North Tallow Creek	1560	2.62	2.62	2.43	2.62
North Tallow Creek	1570	2.71	2.71	2.50	2.71
North Tallow Creek	1580	2.76	2.76	2.55	2.76
North Tallow Creek	1590	2.79	2.80	2.58	2.80
North Tallow Creek	1700	3.11	3.19	3.02	3.19
North Tallow Creek	1710	3.82	3.94	3.69	3.94
North Tallow Creek	1720	3.98	4.11	3.85	4.11
North Tallow Creek	1730	4.21	4.33	4.09	4.33
North Tallow Creek	1740	4.55	4.67	4.43	4.67

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Table F2 20 Year ARI Design Flood Levels, Various Event Combinations, Tallow Creek - Cont'd

Location	Node	100 Year ARI Peak Flood Level (m AHD)			
		Local Flooding Entrance Condition		Storm Tide[b] Flooding	Adopted Design Flood Level[c]
		Open[a]	Closed		
Drain B	1600	3.27	3.27	3.08	3.27
Drain B	1620	3.90	3.90	3.77	3.90
Drain B	1630	3.94	3.93	3.82	3.94
Drain B	1640	3.96	3.96	3.84	3.96
Drain B	1950	3.96	3.96	3.84	3.96
Teak Circuit	960	6.69	6.69	6.64	6.69
Suffolk Park	600	4.09	4.09	4.05	4.09
Clifford St	950	4.38	4.47	4.31	4.47
Tallow Creek	1140	4.14	4.13	4.00	4.14
Tallow Creek	1160	4.10	4.09	3.97	4.10
Tallow Creek	1170	3.88	3.88	3.77	3.88
Tallow Creek	1180	3.85	3.85	3.74	3.85
Tallow Creek	1190	3.53	3.53	3.46	3.53
Tallow Creek	1200	3.26	3.25	3.15	3.26
Tallow Creek	1210	3.11	3.11	3.01	3.11
Tallow Creek	1220	2.39	2.39	2.32	2.39
Tallow Creek	1230	2.37	2.37	2.31	2.37
Tallow Creek	1240	2.36	2.37	2.31	2.37
Tallow Creek	1245	2.19	2.22	2.25	2.25
Tallow Creek	1250	2.35	2.36	2.30	2.36
Tallow Creek	1260	2.16	2.19	2.24	2.24
Tallow Creek	1270	2.04	2.08	2.19	2.19
Tallow Lake Entrance	700	1.67	1.82	2.10	2.10

[a] Entrance fully open condition assumes 20 Year ARI local catchment flood and 5 year ARI storm tide flood coincide
[b] Storm tide condition assumes 5 year ARI local catchment flood and 20 year ARI storm tide flood coincide
c Adopted design flood level is the maximum of all event combinations

Table F3 50 Year ARI Design Flood Levels, Various Event Combinations, Tallow Creek

Location	Node	100 Year ARI Peak Flood Level (m AHD)			
		Local Flooding Entrance Condition		Storm Tide[b] Flooding	Adopted Design Flood Level[c]
		Open[a]	Closed		
Byron Hills	3000	6.77	6.77	6.70	6.77
D/S Coogera Circuit Basin	300	12.32	12.32	12.09	12.32
Beech Drive	48	8.93	8.93	8.82	8.93
Beech Drive	49	8.75	8.75	8.63	8.75
Beech Drive	51	8.54	8.54	8.45	8.54
Pepperbush Carissa Ct	1012	6.17	6.17	6.17	6.17
Pepperbush Silky Ct	1011	7.16	7.16	7.12	7.16
Pepper Bush	10130	5.67	5.67	5.59	5.67
Mid Tallow Creek	1000	6.91	6.89	6.80	6.91
Mid Tallow Creek	1010	6.72	6.72	6.64	6.72
Mid Tallow Creek	1015	6.43	6.43	6.32	6.43
Mid Tallow Creek	1020	6.22	6.21	6.03	6.22
Mid Tallow Creek	1030	6.04	6.03	5.88	6.04
Mid Tallow Creek	1040	5.82	5.82	5.70	5.82
Mid Tallow Creek	1050	5.56	5.55	5.42	5.56
Mid Tallow Creek	1060	5.45	5.45	5.32	5.45
Mid Tallow Creek	1070	5.44	5.44	5.30	5.44
Mid Tallow Creek	1080	5.41	5.41	5.28	5.41
Mid Tallow Creek	1090	5.40	5.40	5.26	5.40
Mid Tallow Creek	1100	5.39	5.39	5.26	5.39
Mid Tallow Creek	1110	5.39	5.39	5.25	5.39
Mid Tallow Creek	1120	5.38	5.38	5.25	5.38
Mid Tallow Creek	1130	5.38	5.38	5.24	5.38
South Tallow Creek	500	7.02	7.03	6.95	7.03
Drain A	1246	3.57	3.58	3.47	3.58
Drain A	1790	5.03	5.06	4.91	5.06
Drain A	1800	5.03	5.06	4.52	5.06
Drain A	1810	5.17	5.19	4.61	5.19
Drain A	1820	5.17	5.20	4.63	5.20
Drain A	1830	5.20	5.23	4.82	5.23
Drain A	1840	5.21	5.23	4.82	5.23
Drain A	1850	5.21	5.23	4.83	5.23
Drain A	1860	5.21	5.23	4.93	5.23
Drain A	1920	5.03	5.06	4.52	5.06
North Tallow Creek	1500	1.94	2.04	2.42	2.42
North Tallow Creek	1510	2.06	2.11	2.42	2.42
North Tallow Creek	1520	2.19	2.19	2.42	2.42
North Tallow Creek	1530	2.44	2.47	2.47	2.47
North Tallow Creek	1540	2.47	2.50	2.48	2.50
North Tallow Creek	1550	2.69	2.73	2.55	2.73
North Tallow Creek	1560	2.72	2.76	2.56	2.76
North Tallow Creek	1570	2.81	2.86	2.61	2.86
North Tallow Creek	1580	2.87	2.92	2.64	2.92
North Tallow Creek	1590	2.91	2.95	2.67	2.95
North Tallow Creek	1700	3.24	3.25	3.01	3.25
North Tallow Creek	1710	4.03	4.05	3.69	4.05
North Tallow Creek	1720	4.19	4.21	3.85	4.21
North Tallow Creek	1730	4.44	4.46	4.09	4.46
North Tallow Creek	1740	4.81	4.83	4.43	4.83

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Table F3 50 Year ARI Design Flood Levels, Various Event Combinations, Tallow Creek - Cont'd

Location	Node	100 Year ARI Peak Flood Level (m AHD)			
		Local Flooding Entrance Condition		Storm Tide[b] Flooding	Adopted Design Flood Level[c]
		Open[a]	Closed		
Drain B	1600	3.33	3.33	3.09	3.33
Drain B	1620	3.94	3.94	3.77	3.94
Drain B	1630	3.97	3.97	3.82	3.97
Drain B	1640	4.00	4.00	3.84	4.00
Drain B	1950	4.00	4.00	3.84	4.00
Teak Circuit	960	6.71	6.71	6.64	6.71
Suffolk Park	600	4.11	4.11	4.05	4.11
Clifford St	950	4.41	4.39	4.26	4.41
Tallow Creek	1140	4.21	4.21	4.00	4.21
Tallow Creek	1160	4.15	4.15	3.97	4.15
Tallow Creek	1170	3.96	3.97	3.77	3.97
Tallow Creek	1180	3.92	3.93	3.74	3.93
Tallow Creek	1190	3.58	3.58	3.46	3.58
Tallow Creek	1200	3.33	3.34	3.15	3.34
Tallow Creek	1210	3.18	3.18	3.01	3.18
Tallow Creek	1220	2.49	2.50	2.49	2.50
Tallow Creek	1230	2.47	2.47	2.48	2.48
Tallow Creek	1240	2.46	2.46	2.48	2.48
Tallow Creek	1245	2.28	2.30	2.46	2.46
Tallow Creek	1250	2.45	2.45	2.48	2.48
Tallow Creek	1260	2.24	2.27	2.45	2.45
Tallow Creek	1270	2.10	2.14	2.43	2.43
Tallow Lake Entrance	700	1.67	1.82	2.37	2.37

[a] Entrance fully open condition assumes 50 Year ARI local catchment flood and 5 year ARI storm tide flood coincide
[b] Storm tide condition assumes 5 year ARI local catchment flood and 50 year ARI storm tide flood coincide
c Adopted design flood level is the maximum of all event combinations

Table F4 500 Year ARI and PMP Design Flood Levels, Various Event Combinations, Tallow Creek

Location	Node	Peak Flood Level (m AHD)	
		500 Year ARI	PMP
Byron Hills	3000	6.91	7.11
D/S Coogera Circuit Basin	300	12.47	12.84
Beech Drive	48	8.98	9.24
Beech Drive	49	8.80	8.99
Beech Drive	51	8.58	8.71
Pepperbush Carissa Ct	1012	6.20	6.51
Pepperbush Silky Ct	1011	7.22	7.37
Pepper Bush	10130	5.74	6.03
Mid Tallow Creek	1000	7.13	7.43
Mid Tallow Creek	1010	6.90	7.22
Mid Tallow Creek	1015	6.59	7.01
Mid Tallow Creek	1020	6.41	6.88
Mid Tallow Creek	1030	6.21	6.64
Mid Tallow Creek	1040	5.94	6.29
Mid Tallow Creek	1050	5.67	5.99
Mid Tallow Creek	1060	5.56	5.85
Mid Tallow Creek	1070	5.54	5.84
Mid Tallow Creek	1080	5.51	5.81
Mid Tallow Creek	1090	5.49	5.80
Mid Tallow Creek	1100	5.49	5.80
Mid Tallow Creek	1110	5.48	5.78
Mid Tallow Creek	1120	5.47	5.76
Mid Tallow Creek	1130	5.47	5.77
South Tallow Creek	500	7.12	7.37
Drain A	1246	3.81	4.55
Drain A	1790	5.61	5.49
Drain A	1800	6.55	5.49
Drain A	1810	5.47	5.84
Drain A	1820	5.46	5.84
Drain A	1830	5.47	5.80
Drain A	1840	5.47	5.80
Drain A	1850	5.47	5.80
Drain A	1860	5.46	5.81
Drain A	1920	5.23	5.50
North Tallow Creek	1500	2.76	3.65
North Tallow Creek	1510	2.72	3.59
North Tallow Creek	1520	2.76	3.65
North Tallow Creek	1530	3.01	3.72
North Tallow Creek	1540	3.05	3.74
North Tallow Creek	1550	3.45	4.24
North Tallow Creek	1560	3.47	4.27
North Tallow Creek	1570	3.54	4.34
North Tallow Creek	1580	3.57	4.37
North Tallow Creek	1590	3.59	4.39
North Tallow Creek	1700	3.60	4.43
North Tallow Creek	1710	4.05	4.65
North Tallow Creek	1720	4.46	5.32
North Tallow Creek	1730	4.77	5.61
North Tallow Creek	1740	5.21	6.18

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Table F4 500 Year ARI and PMP Design Flood Levels, Various Event Combinations, Tallow Creek - Cont'd

Location	Node	Peak Flood Level (m AHD)	
		500 Year ARI	PMP
Drain B	1600	3.61	4.44
Drain B	1620	4.08	4.48
Drain B	1630	4.11	4.51
Drain B	1640	4.20	4.52
Drain B	1950	4.20	4.52
Teak Circuit	960	6.73	6.86
Suffolk Park	600	4.19	5.21
Clifford St	950	4.35	5.21
Tallow Creek	1140	4.36	4.82
Tallow Creek	1160	4.29	4.76
Tallow Creek	1170	4.10	4.60
Tallow Creek	1180	4.05	4.55
Tallow Creek	1190	3.71	4.26
Tallow Creek	1200	3.48	4.17
Tallow Creek	1210	3.33	4.08
Tallow Creek	1220	2.91	3.95
Tallow Creek	1230	2.89	3.90
Tallow Creek	1240	2.88	3.86
Tallow Creek	1245	2.81	3.73
Tallow Creek	1250	2.86	3.82
Tallow Creek	1260	2.80	3.71
Tallow Creek	1270	2.75	3.62
Tallow Lake Entrance	700	2.60	2.60

[a] Assumes design local catchment flood and 100 year ARI storm tide flood coincide

G Appendix
EXTENT OF FLOODING MAPS OF TALLOW CREEK FOR THE VARIOUS DESIGN STORMS

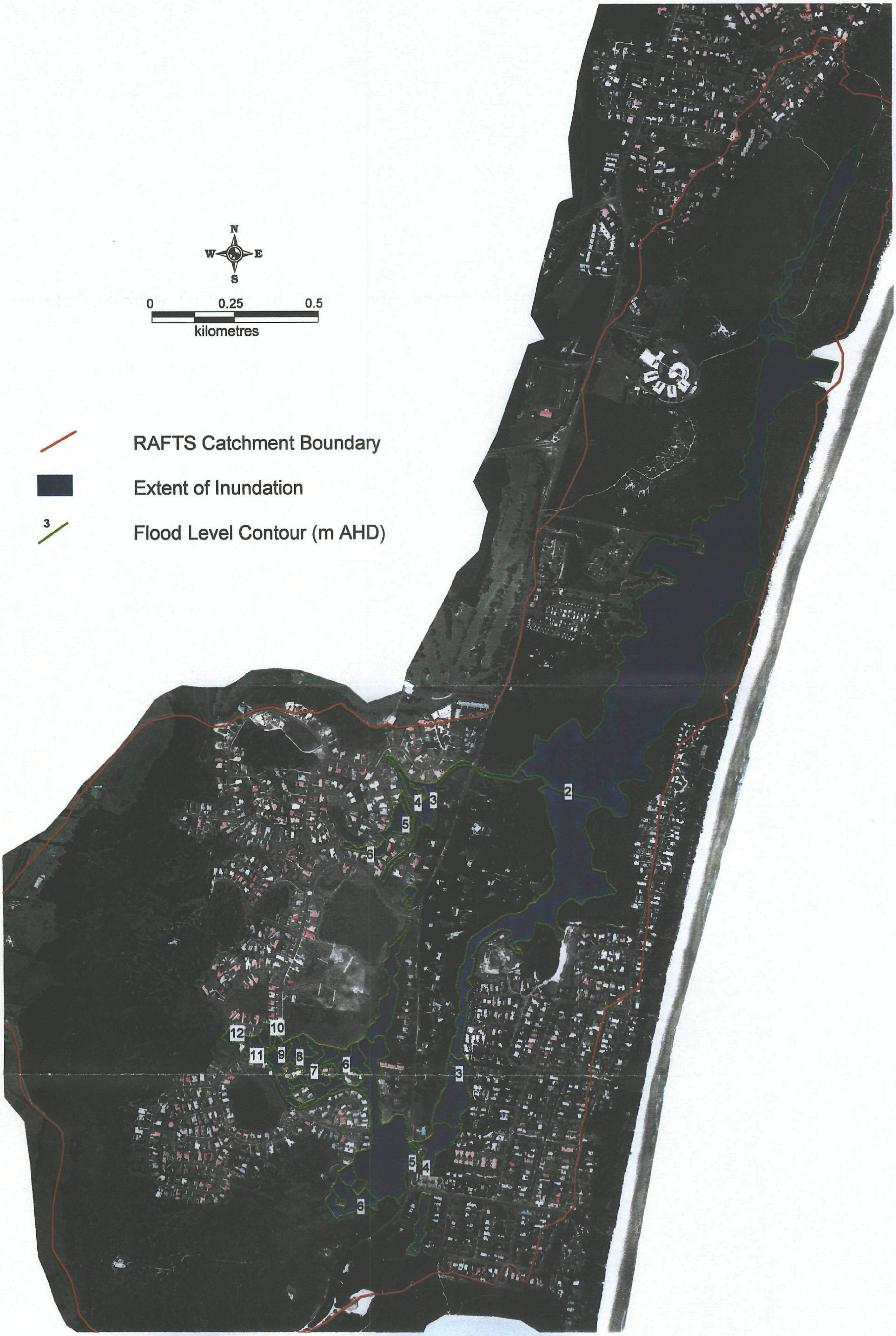

Figure G1 Extent of Flooding and Flood Contours, Tallow Creek, 5 Year ARI Event

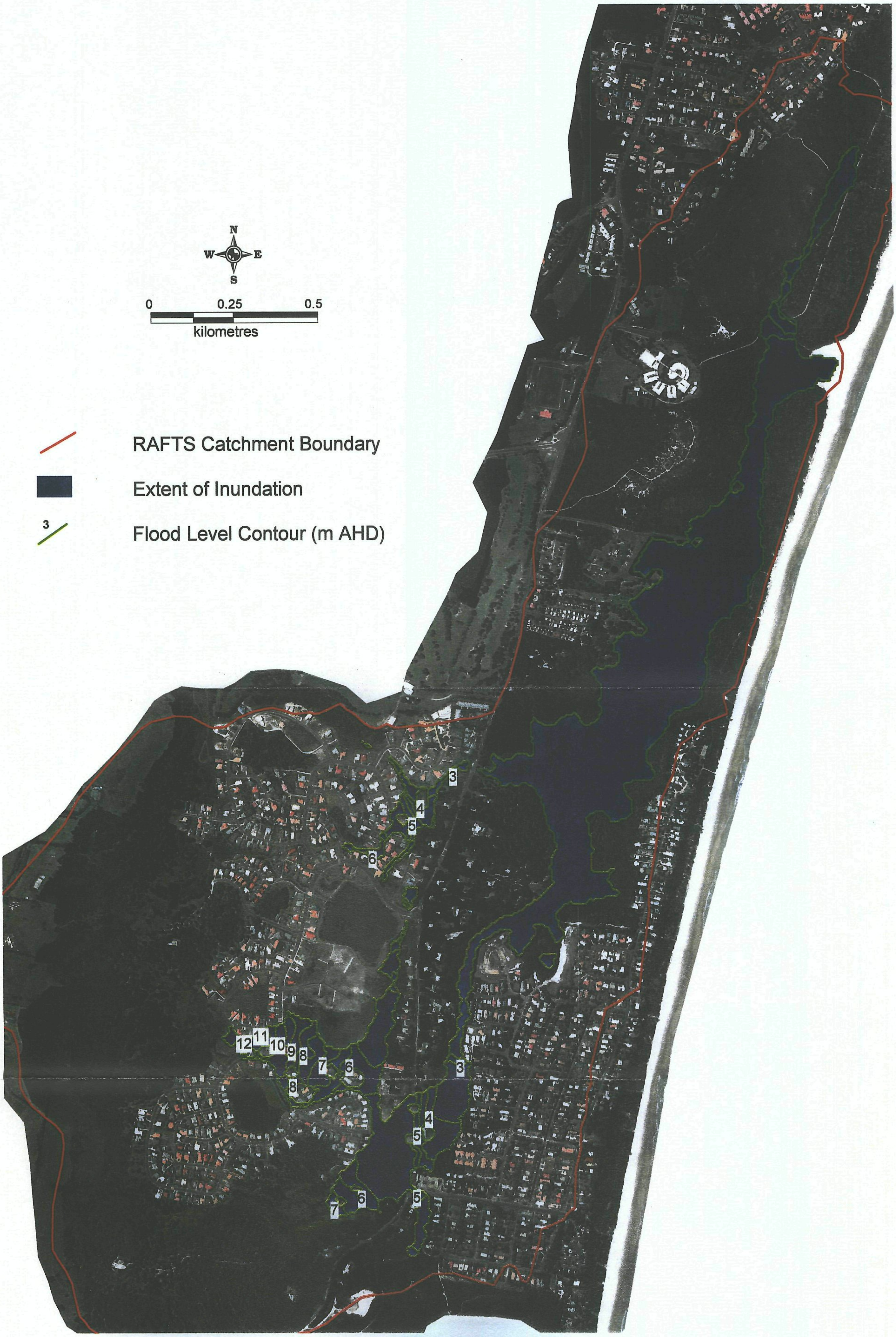

Figure G2 Extent of Flooding and Flood Contours, Tallow Creek, 20 Year ARI Event

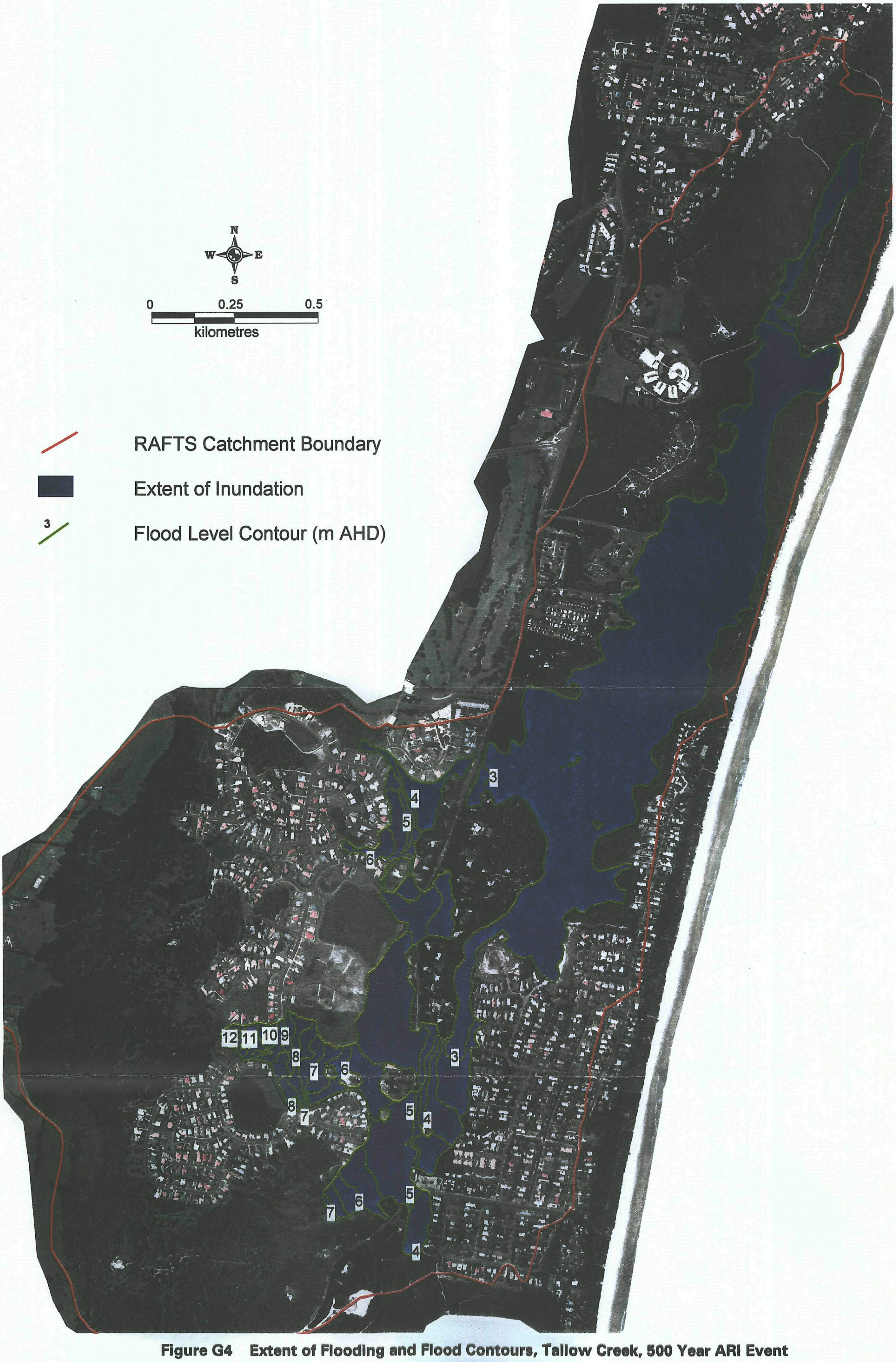

Figure G4 Extent of Flooding and Flood Contours, Tallow Creek, 500 Year ARI Event

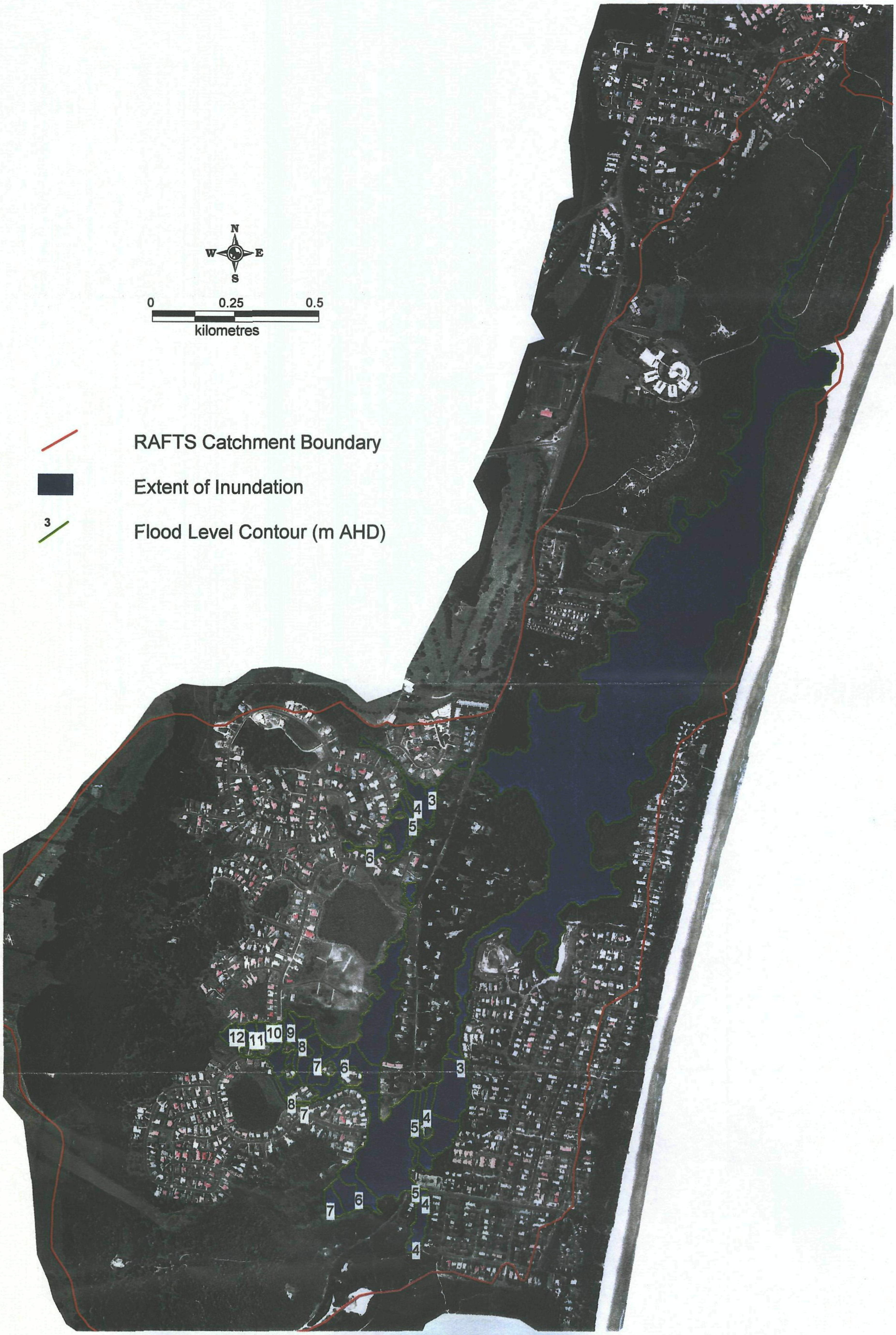

Figure G3 Extent of Flooding and Flood Contours, Tallow Creek, 50 Year ARI Event

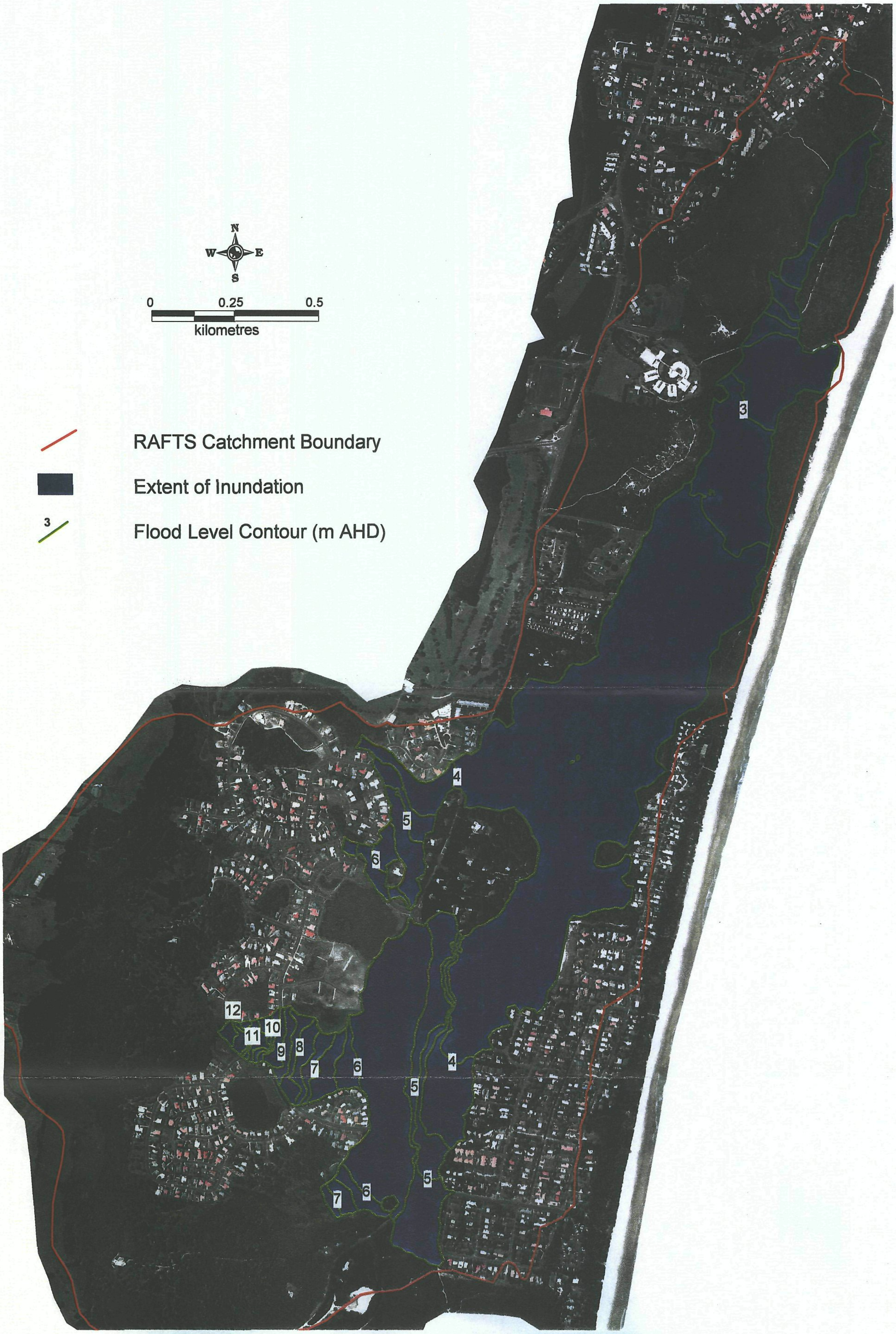

Figure G5 Extent of Flooding and Flood Contours, Tallow Creek, PMP Event

Appendix H
DEPTH OF FLOODING AND VELOCITY MAPS OF TALLOW CREEK FOR VARIOUS DESIGN STORMS

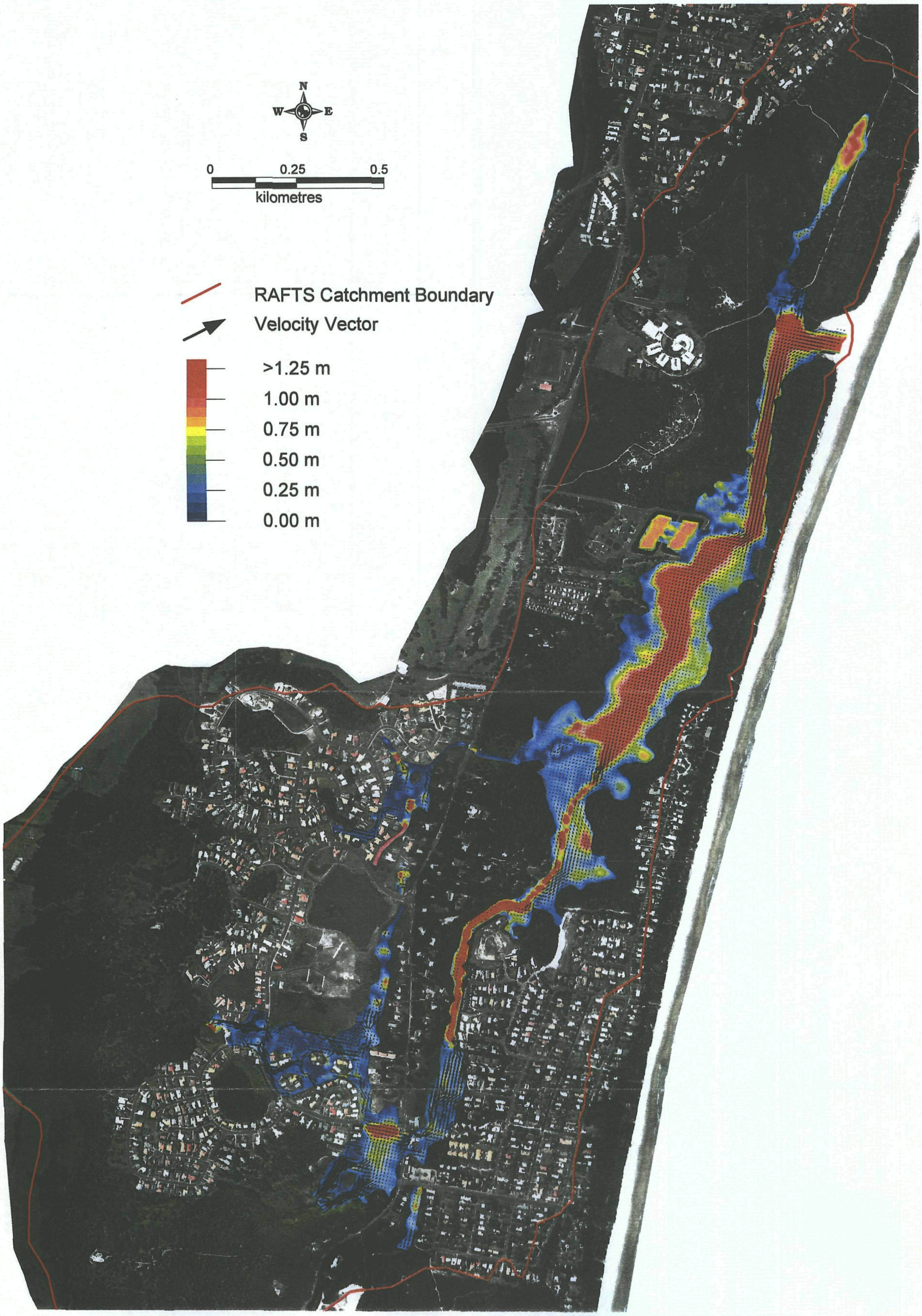

Figure H.1 Flood Velocity Vectors and Flood Depths, Tallow Creek, 5 Year ARI Event

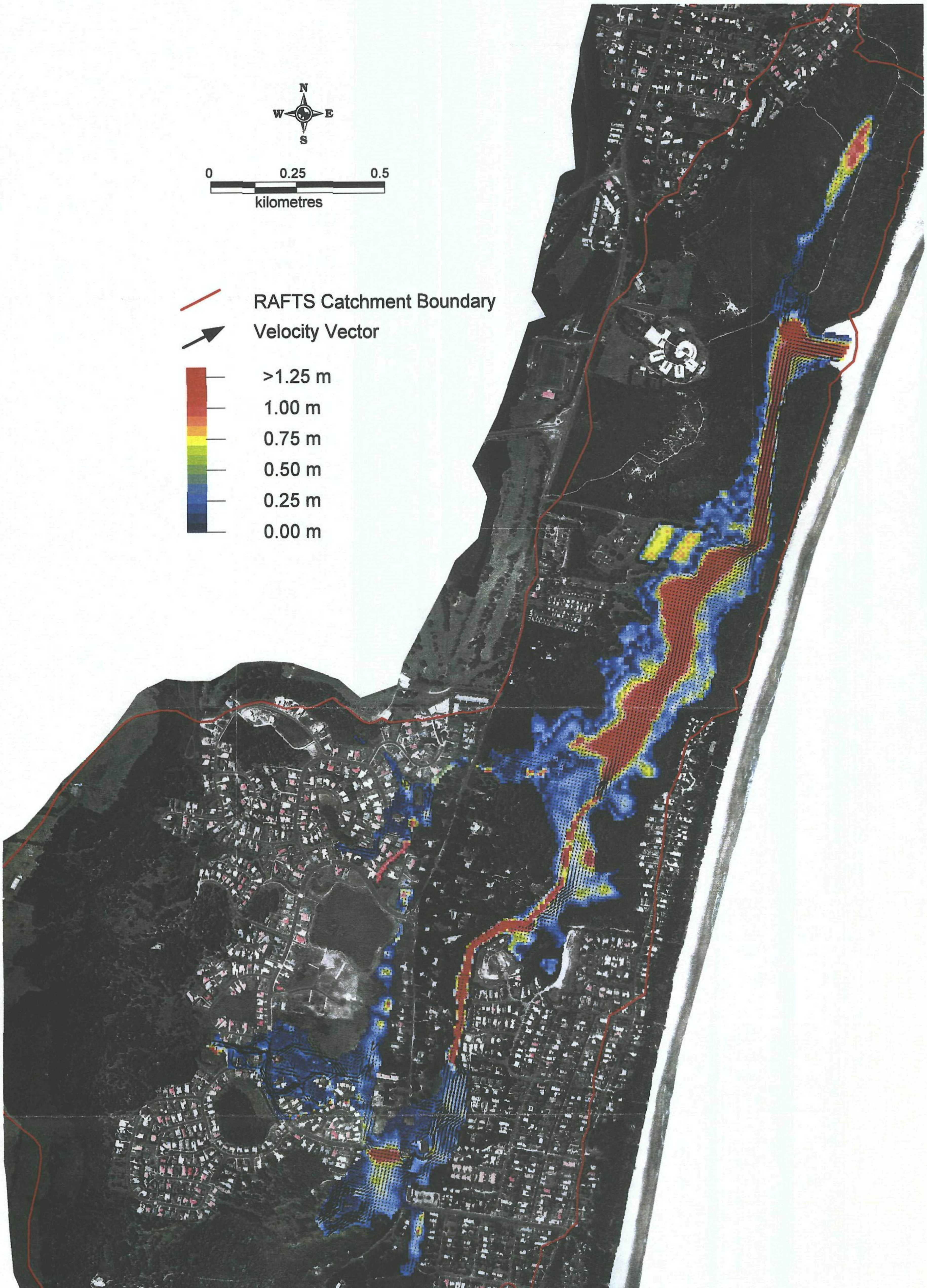

Figure H.2 Flood Velocity Vectors and Flood Depths, Tallow Creek, 20 Year ARI Event

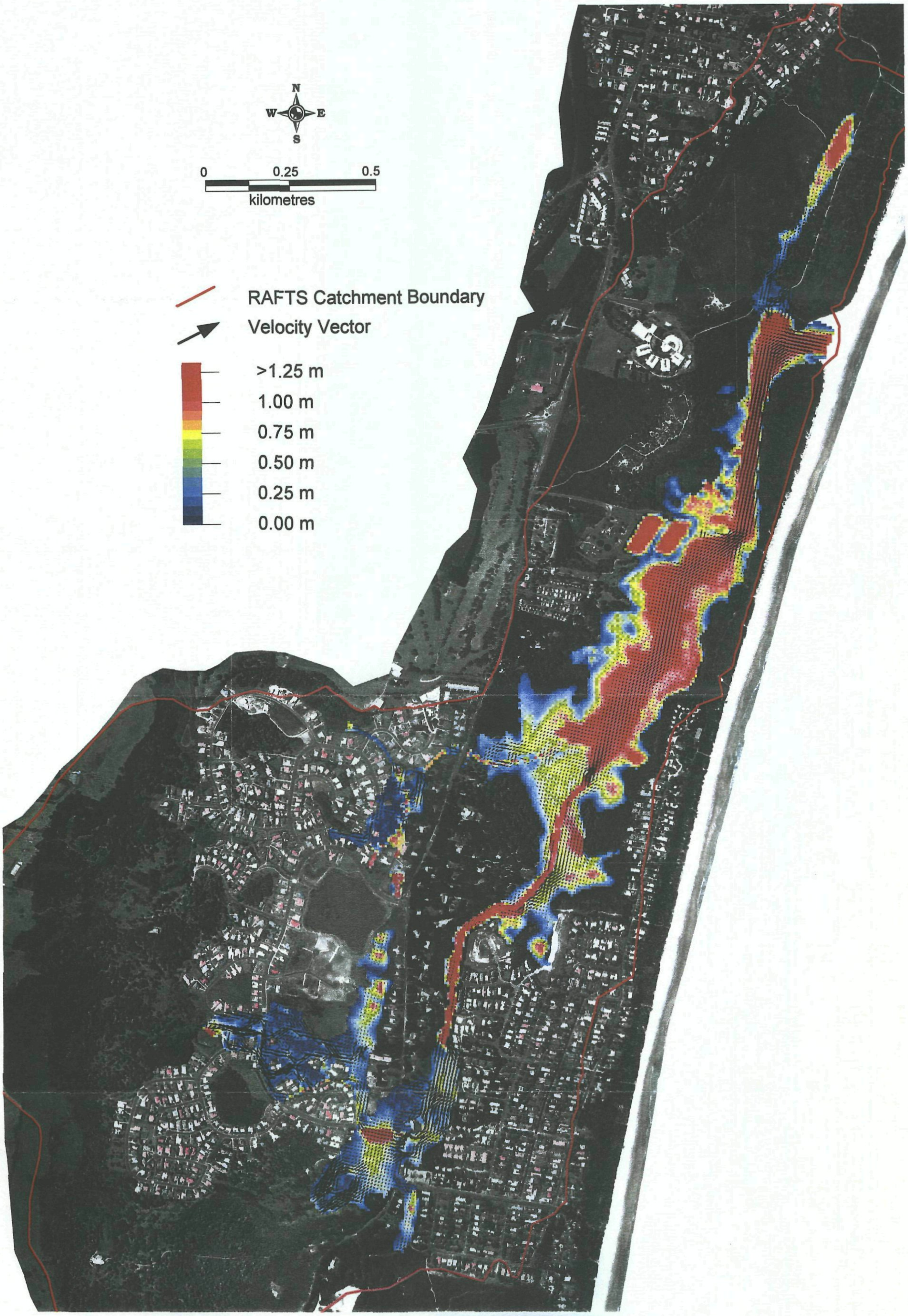

Figure H.3 Flood Velocity Vectors and Flood Depths, Tallow Creek, 50 Year ARI Event

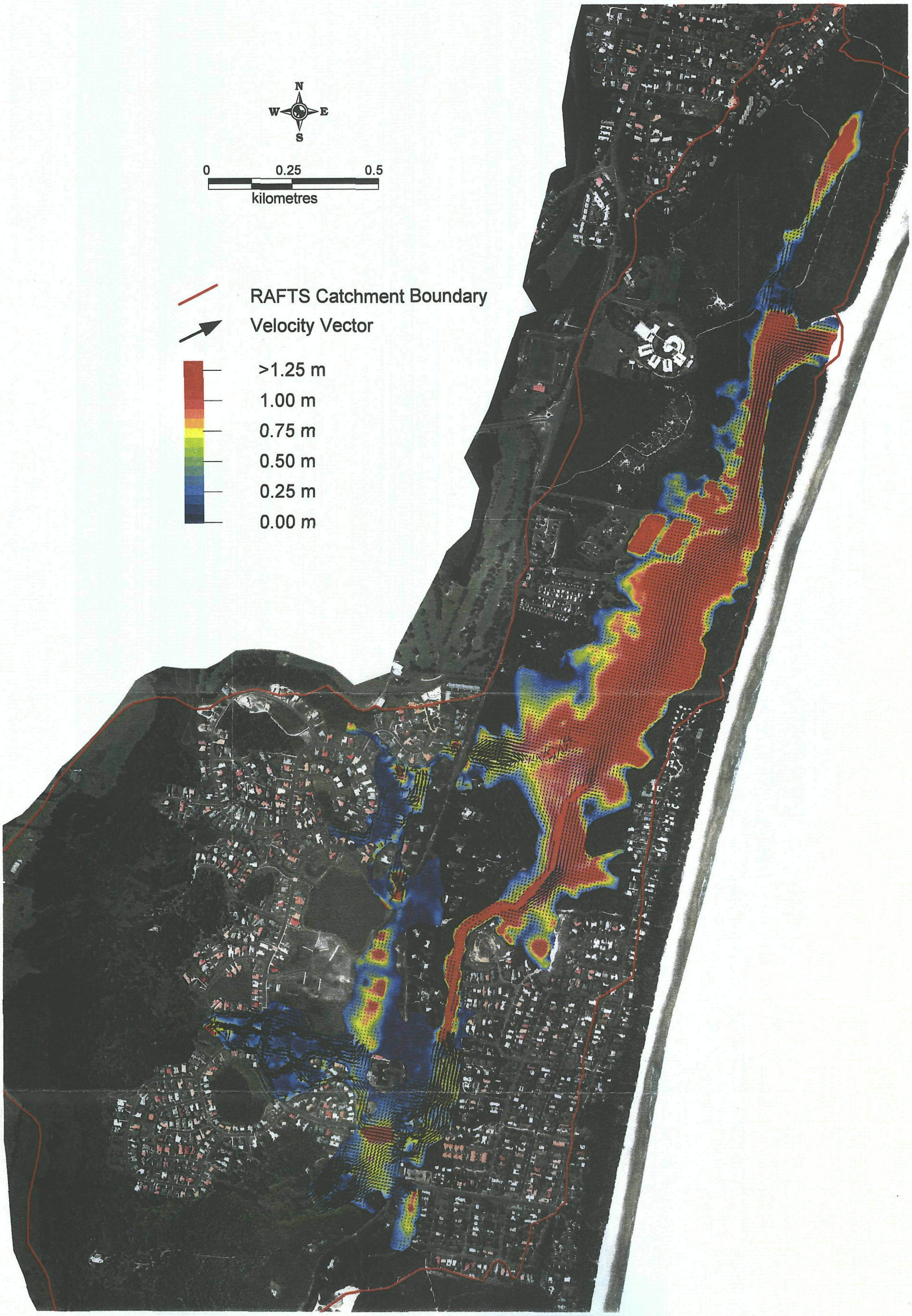

Figure H.4 Flood Velocity Vectors and Flood Depths, Tallow Creek, 500 Year ARI Event

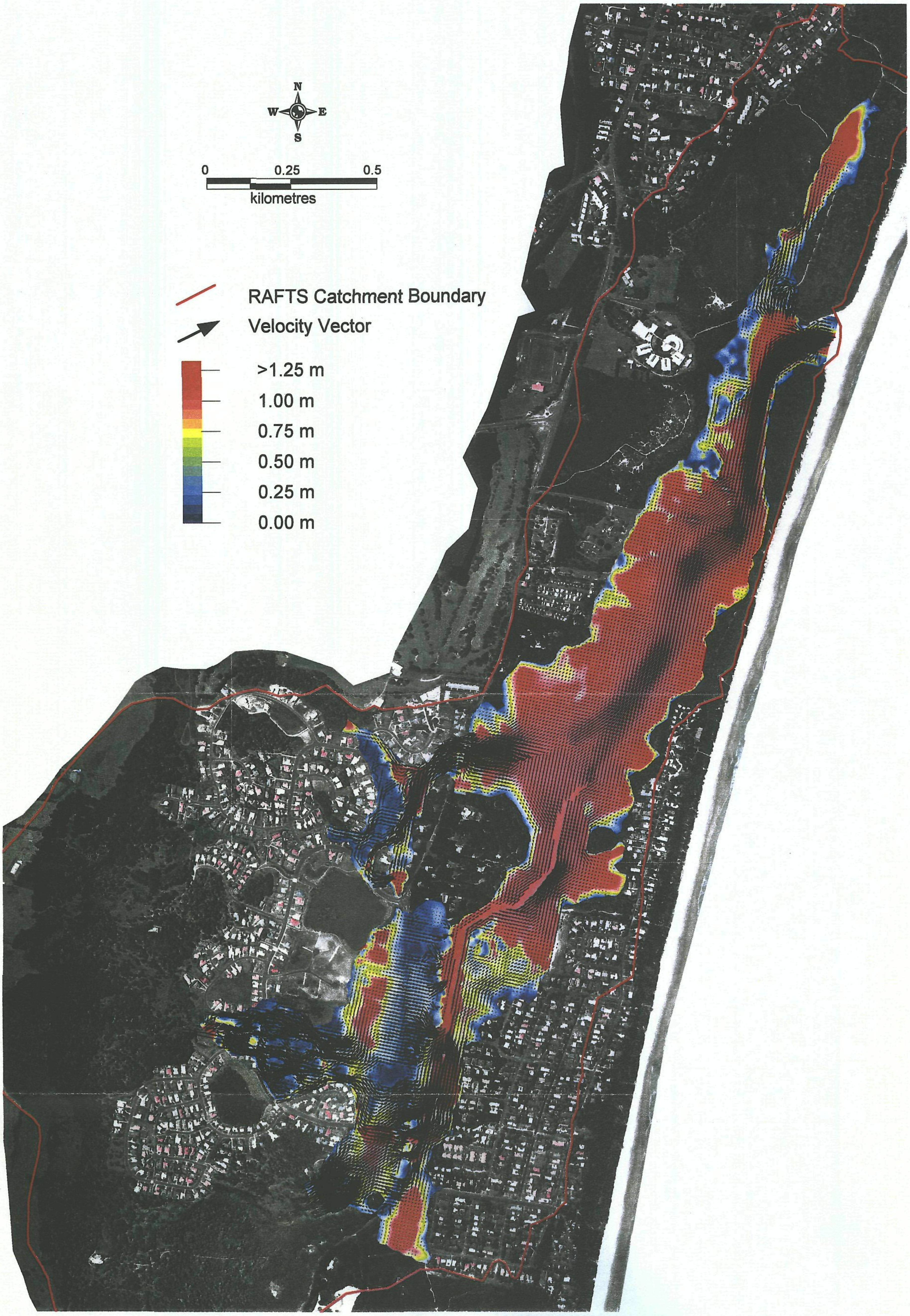

Figure H.5 Flood Velocity Vectors and Flood Depths, Tallow Creek, PMP Year ARI Event