BURRADOO BU2 CATCHMENT ASSESSMENT STUDY

STAGE 1 FLOOD STUDY REPORT

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FINAL & ADDENDUM
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FOREWORD

The NSW Government's Flood Prone Lands Policy is directed towards providing solutions to existing flood problems in developed areas utilising ecologically positive methods wherever possible and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the policy, the management of flood prone land is the responsibility of Local Government. To achieve its primary objective, the policy provides for State Government financial assistance to Councils for flood mitigation works to alleviate existing flooding problems. The policy also provides for State Government technical assistance to Councils to ensure that the management of flood prone land is consistent with the flood hazard and that future development does not create or increase flooding problems in flood prone areas.

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

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 development.
3. Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
4. Implementation of the Plan	Construction of flood mitigation works to protect existing development.
	Use of Environmental Planning Instruments to ensure new development is compatible with the flood hazard.

The Burradoo BU2 Catchment Flood Study is the first stage of the management process for the Burradoo BU2 Catchment. The study, which has been prepared for Wingecarribee Shire Council and Department of Environment, Climate Change and Water by Cardno Lawson Treloar Pty Ltd, defines flood behaviour for existing catchment conditions in the Burradoo BU2 catchment floodplain.

EXECUTIVE SUMMARY

A flood study of the Burradoo BU2 catchment has been undertaken to define the nature and extent of flooding in the area for a range of design flood events. The flood study has been carried out for the existing catchment conditions at the time of the analysis. Data for the study was collated from various sources, including Wingecarribee Shire Council, and specific information, such as field survey, was obtained during the preparation of this study.

The Burradoo BU2 catchment is situated in the suburb of Burradoo, south of Bowral, and drains westwards to Mittagong Creek which is a tributary of the Wingecarribee River. The catchment has an area of 244 hectares and land-use is predominantly rural-residential properties. Moss Vale Road and the Southern Railway are the main north-south transport corridors in the catchment.

The primary flowpath is ephemeral and varies from a defined channel near Stratford Way, to a generally unformed depression west of Moss Vale Road. Two detention basins, known as Pony Club basin and Informal basin, are located just east of Moss Vale Road. In the past, flooding in the catchment has impacted on residents.

The collated information for the study included ground survey and hydraulic structure data, previous flood study reports, historical rainfall data, and cadastral and topographic data. A resident survey was undertaken to identify flood awareness and past flooding events. The data was used to undertake the various components of the study as well as for the presentation of the study results.

Estimation of flooding behaviour was undertaken by developing two computer models to simulate the hydrologic and hydraulic aspects of flooding. The hydrologic modelling package XP-RAFTS was utilised for routing flow through the catchment and to determine runoff from various parts of the catchment. Predicted hydrographs from RAFTS were then input to the TUFLOW hydraulic model for the determination of peak flood level, velocity and discharge for various design rainfall events. The design events investigated for this study were the 100 year, 50 year, 20 year, and 5 year Average Recurrence Interval (ARI) events together with the Probable Maximum Flood (PMF).

Flood behaviour was assessed using two-dimensional high definition hydraulic modelling for the floodplain. This detailed modelling provides better understanding of flooding processes in the flood affected area. The model was validated to responses received from residents for the June 2007 storm event.

The modelling results reflect the observed flooding behaviour in the Burradoo BU2 catchment. A storm duration of 2 hours was generally found to be critical in the catchment.

Moss Vale Road, Holly Road and Burradoo Road were shown as inundated by runoff in the 5 year ARI event. The models indicate the railway line is overtopped in the PMF event. Modelling shows an extensive flooded area, with the Informal detention basin spilling flows south along Moss Vale Road and the Pony Club basin overtopping in the 100 year ARI event.

The limits of predicted flood extents for the 100 year, 50 year, 20 year, and 5 year ARI events together with the PMF are mapped using geographic information system (GIS). Similarly, the flood hazard and hydraulic categories have been determined for the modelled events and appropriate

figures have been provided in the report. All the above information has been prepared in a GIS format.

The impact of variability of significant model parameters has been assessed by conducting a sensitivity analysis. Model parameters such as catchment roughness, catchment runoff, culvert blockage and downstream boundary condition have been checked for sensitivity. Detailed results of the analysis are provided and compared with the design flood levels for the adopted catchment conditions.

Increased sea levels and increased rainfall intensities are expected to result from climate change effects. Sea level rise is not expected to impact on the Burradoo catchment but the impact of increased rainfall intensities up to 30% have been modelled. A preliminary flood damages assessment and initial identification of remedial options for the catchment were completed.

This study has produced flood behaviour information and provides a management tool in the form of a hydraulic model for future assessment of floodplain risk management options in the study area.

The draft report of this study was placed on public exhibition for six weeks from 26 August 2009 inviting submissions from interested residents and organisations. Submissions which were received during the exhibition period are summarised in this report.

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1. INTRODUCTION

The Burradoo BU2 catchment is within the Wingecarribee Shire Council (WSC) Local Government Area. It is located between Bowral and Moss Vale in the NSW Southern Highlands and is shown in Figure 1.1. The catchment is subjected to frequent flooding and WSC aims to undertake floodplain management measures in accordance with the Floodplain Risk Management Process as set out in the New South Wales *Floodplain Development Manual* (2005).

Cardno Lawson Treloar (CLT) was commissioned by WSC to undertake a flood study and a floodplain management study as part of the floodplain risk management process. In the first stage, a flood study has been completed to determine the flood behaviour in the Burradoo BU2 Catchment for the 100 year, 50 year, 20 year and 5 year Average Recurrence Interval (ARI) events and the Probable Maximum Flood (PMF).

This Report contains details of the flood study. The second stage would include assessment of potential flood mitigation measures and would be undertaken after finalisation of the flood study. The outcomes of the second stage would be reported separately.

In undertaking the flood study, firstly a hydrologic investigation was completed for the catchment utilising a hydrologic computer model. Secondly, a hydraulic computer model of the major channels and floodplain within the catchment was established and verified against historical flood event observations. The hydraulic model was then used with design rainfall conditions to simulate design flood behaviour in the catchment. Provisional hazard classification and hydraulic categorisation was established and preliminary flood damages were estimated for the catchment based on this modelling.

2. STUDY OBJECTIVES

2.1 Regulatory Context

The NSW Government Floodplain Development Manual (April 2005) sets out a process for floodplain risk management. A flowchart representation of this process is shown in Figure 2.1, which is adapted from the Floodplain Development Manual (April 2005).

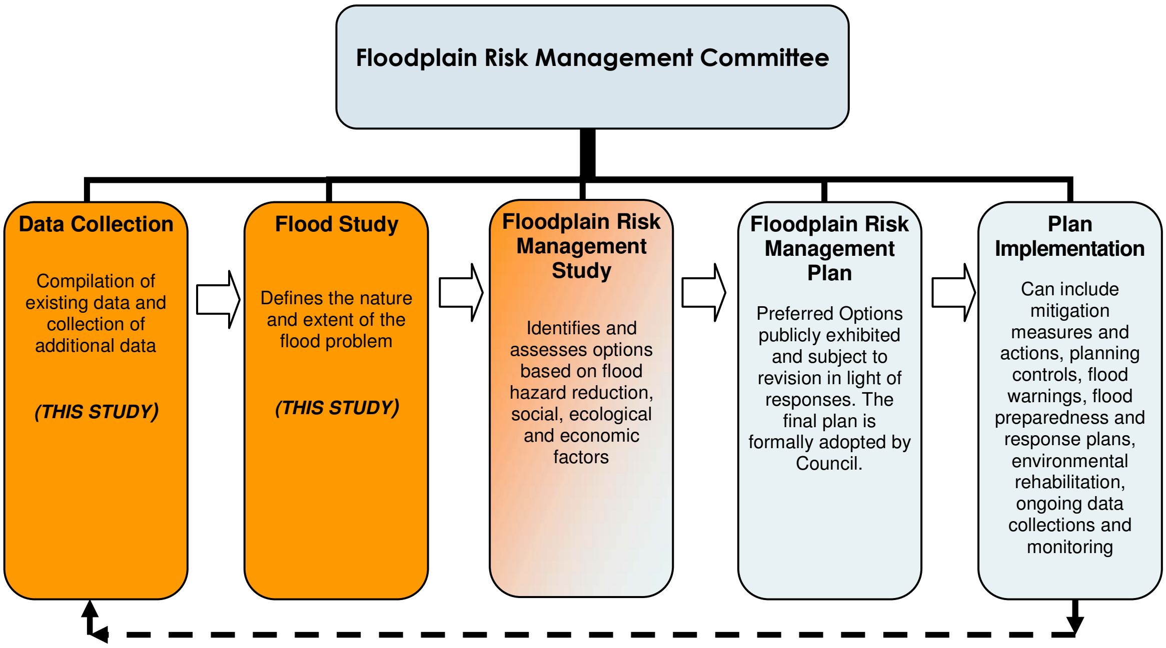

Figure 2.1 Floodplain Risk Management Process

The tasks being undertaken in this Stage 1 Flooding Assessment Report include the compilation of data, definition of the flood extent, and preliminary identification of remedial options. Assessment of the remedial options identified in this Study will be undertaken in the second stage “Remedial Measures Investigation” under the Floodplain Management Study.

2.2 Objectives

The objective of this Study is to define the nature of the existing flood behaviour in the Burradoo BU2 catchment.

To achieve the objective, the following tasks were undertaken:

- Collate available flood-related data,
- Define existing catchment condition flood behaviour for mainstream flooding in the catchment,
- Define design flood levels, velocities and flow distributions for the catchment,
- Define the extent of flooding the 5 year, 20 year, 50 year, and 100 year ARI and PMF events for the catchment,
- Define provisional flood hazard for the flood-affected areas,
- Define the hydraulic categories for the flood-affected areas,
- Assess impacts of climate change,
- Preliminary assessment of flood damages for the flood-affected areas,
- Identify preliminary remedial options.

2.3 Methodology

This Study was carried out using computer-based hydrologic and hydraulic modelling.

Two numerical modelling tools were developed:

- A hydrologic model was utilised to convert rainfall on the catchment to runoff. The hydrologic model RAFTS was used, which combines rainfall information with local catchment characteristics to estimate runoff hydrographs.
- A hydraulic model was utilised to convert runoff hydrographs into water levels and velocities in the study area. The model simulates the hydraulic behaviour of the water within the study area by accounting for flow in the major channels as well as potential overland flowpaths, which develop when the capacity of the channels is exceeded. It relies on boundary conditions, which were the runoff hydrographs produced by the hydrologic model and downstream boundary conditions from the creek into which it discharges. The TUFLOW modelling system was used for this purpose.

The Study details are grouped together under the following sections of the report:

- Section 3 provides a general description of the catchment
- Section 4 discusses the content and sources of relevant data, which were utilised for the study. Historical rainfall and flood data used in the calibration of the established hydrologic and hydraulic models and survey data used are detailed.
- Section 5 discusses the catchment characteristics and describes the hydrologic model setup for the study.
- Section 6 describes the hydraulic model utilised for the study, its verification and subsequent use for design rainfall events.
- Section 7 details results for the design flood events.
- Section 8 reviews the sensitivity of the model to the data used.
- Section 9 identifies the provisional flood hazard.
- Section 10 identifies the hydraulic categorisation.
- Section 11 reviews the impacts of climate change.

3. CATCHMENT DESCRIPTION

The Burradoo BU2 catchment is a sub-catchment of Mittagong Creek, which is a tributary of the Wingecarribee River. The BU2 catchment is located between the towns of Bowral and Moss Vale and extends from west of Eridge Park Road to west of the railway line. The main culvert under the railway line is located a short distance north of Burradoo railway station. Figure 3.1 shows the extents of the catchment which occupies an area of approximately 244 hectares.

Land use in the catchment is primarily residential housing, in a semi-rural setting. Land parcels are generally large, and include detached dwellings and larger open grassed or forested areas. Figure 3.2 shows an aerial photograph of the catchment area.

The catchment ridgeline to the east has a peak elevation of about 686m AHD, and rises to about 689m AHD in the south. An un-named, ephemeral watercourse with several branches conveys runoff in the catchment to the box culvert under the railway line at the catchment outlet. This culvert has an invert of 657.6m AHD and flows overland to Mittagong Creek to the west.

Near Stratford Way and Foldgarth Way, the channel is a formalised grass-lined channel with a concrete-lined invert for low-flows. Several driveway crossings with concrete culverts to convey flow are located in this section of channel discharging into a pond adjacent to Foldgarth Way.

The primary flowpath is generally an informal drainage depression downstream of Foldgarth Way. Flow is also conveyed along the drainage depression between houses from the intersection of Osborne Road and Toongoon Rd. Runoff is detained upstream of Moss Vale Road by the culvert under the road serving as the Informal basin and at the constructed detention basin at the Berrima District Pony Club (shown on Figure 5.2 in Section 5.3).

West of Moss Vale Road, flow is conveyed along drainage depressions within private property. Several driveways cross the flowpath and several ponds are also located within the drainage flowpath.

Photographs undertaken during a site visit of the Catchment in November 2006 are included in Appendix A.

4. AVAILABLE DATA

Data has been obtained from a number of sources and includes information required for input to the hydrologic and hydraulic models, together with information required for verification of model results and appropriate representation and presentation of those results.

4.1 Previous Studies

Two studies were reviewed as part of this report:

- Bowral Floodplain Risk Management Study and Plan (2005) Bewsher Consulting, and
- Burradoo BU2 Catchment Investigation Study (2006) Boyden and Partners

A brief summary of the two reports is provided below.

4.1.1 Bowral Floodplain Risk Management Study and Plan (2005) Bewsher Consulting

This study was undertaken to develop a Floodplain Risk Management Plan for the entire catchment of Mittagong Creek (ie upstream from its confluence with the Wingecarribee River). This catchment is approximately 30 km^2 and encompasses the town of Bowral as well as the Burradoo BU2 catchment.

The Flood Study phase included hydrologic modelling using RAFTS and 1D/2D Hydraulic modelling using TUFLOW (as per this current study). However, the study focussed on flood impacts to Bowral and regions directly adjacent to Mittagong Creek, and did not include detailed examination of flooding in the BU2 sub-catchment. For example, the hydrologic (RAFTS model) assessment of the Burradoo BU2 sub-catchment used a comparatively coarse catchment model, and only the total outflows from BU2 (at the confluence with Mittagong Creek) were used as inputs to the hydraulics (TUFLOW) model. Hence flood levels adjacent to Mittagong creek were examined, but flood levels within BU2 were not described. In addition, critical flood durations for the BU2 catchment may differ (ie be shorter duration) from those which are critical for the larger Mittagong Creek catchment.

The study provided information on regional historical flooding which is relevant to this Study. The relevant information is discussed in Sections 4.2.2 to 4.6 below.

4.1.2 Burradoo BU2 Catchment Investigation Study (2006) Boyden and Partners

This study was undertaken to investigate the effectiveness of a range of flood remediation measures in the BU2 catchment.

A hydrologic study of the BU2 catchment was undertaken using a RAFTS model, which was used to examine flood runoff for the design 1 yr, 5 yr, 20 yr and 100 yr ARI events for the cases of pre-development, current development and full development. The RAFTS model separated the BU2 catchment into 22 sub-catchments. A hydraulic analysis of the catchment was undertaken using the 1D HEC-RAS model in steady-state mode. The models were not calibrated against any past flood events.

Boyden and Partners advised that the hydraulic models were used only to assess the relative effectiveness of proposed remedial measures, and the models and source survey data was not of sufficient accuracy for designation of design flood levels within the catchment.

Five remedial options were investigated and the results compared to predevelopment, existing and fully developed conditions. These options were:

- An on-site detention policy within the upper catchment (upstream of Moss-Vale Road),
- Formalisation of the existing Informal detention basin just upstream of Moss Vale Rd (at 558 Moss Vale Road),
- Formalisation of an existing farm dam near Foldgarth Way,
- Development controls limiting the development of impervious areas, and
- Augmentation of the drainage system within the catchment.

These options were found to each have measurable effect in reducing peak flood flows.

4.2 Community Consultation

4.2.1 Questionnaire

A community questionnaire was distributed in Burradoo to obtain information on historical flooding from local residents. The questionnaire, prepared in consultation with WSC, was distributed to 440 residents within the Catchment. The questionnaire sought information regarding resident's experience of flooding, the nature and depth of flooding and timing of such floods. The residents were also asked whether they could identify any historic flood levels. A copy of the questionnaire and comprehensive summary is provided in Appendix B.

A total of 154 responses were received. The BU2 catchment was described by residents to respond to short higher intensity rainfall bursts, with runoff observed "after 20mm of rainfall". The impacts of flooding that occurred in these events were described by residents to result in flooding of public and private landowners. This is generally shallow flooding of properties although in a few cases (5 cases reported) flood waters have come above floor levels of residential dwellings. There are no reports of loss of life, evacuation risks or serious hazards from past flood events.

Residents were prompted to provide information on the floods listed in Table 4.1. The number of residents that reported flood impacts for each of these floods is also shown. It can be seen that the significant majority of information related to the most recent event of June 2007 followed by the October 1999 event. Additionally, three residents reported flood impacts from the February 2005 event which was an event not listed on the questionnaire. Photos of flooding events forwarded by residents are included in Appendix A.

Table 4.1 Summary of Resident Records of Selected Historical Flood Events

Flood Event	No. of Resident Records
Mar-1975	2
Mar-1978	1
Nov-1985	4
Aug-1986	6
Apr-1988	5
Oct-1999	17
Jun-2007	38

4.2.2 Public Exhibition

Council resolved on 26 August 2009 to place the Draft Report on exhibition for six weeks to allow comments from interested residents and organisations. One response was received which has been included as Appendix I. The submission requested flood extent information for an area outside the modelled extent for this Study.

The objective of the study is to investigate the mainstream flooding within the catchment. The extent of the modelling therefore does not include all overland flow paths within the catchment. Flood behaviour in areas outside the modelled extent have thus not been reviewed.

4.3 Flood History

In the Bowral Floodplain Risk Management Study and Plan (Bewsher, 2005), the following historical flood events were identified for the Bowral region:

- March 1975
- March 1978
- November 1985
- August 1986
- April 1988
- October 1999

The severity of these events was unknown and little or no rainfall and flood level records were available. The Bewsher (2005) study used limited rainfall and flood level data for the April 1988 and October 1999 to validate their models, and from this process concluded that the April 1988 and October 1999 events were less severe than the design 5yr ARI event.

Additional searches were made of available rainfall records to identify any additional historical flood events relevant to the Burradoo BU2 catchment. The following additional events were noted:

- August 2001
- February 2005
- June 2007

An analysis of two of the recent flood events (February 2005 and June 2007) is presented in Section 5.6. For durations that would be critical for the BU2 catchment, these events appear to be less severe than the design 1 yr ARI event. This would appear to endorse the statement made in the Bowral Flood Study (Bewsher, 2005) that “residents … have not experienced genuinely serious flooding for many years”.

4.4 Historical Rainfall Data

Several daily rainfall gauging stations operated by the Bureau of Meteorology (BoM) are located within 12 km of the catchment. The BoM operates a pluviograph recording rainfall in six-minute timesteps is located at Parry Drive and an automatic weather station recording hourly rainfall depths since January 2001 is located at Moss Vale, 3 km to the south of the catchment. A pluviograph recording rainfall depths at a 5 minute timestep is operated by Manly Hydraulics Laboratory at Clover Hill Road in Macquarie Pass, 23 km to the east of the Burradoo BU2 catchment.

Locations of the rainfall stations are shown in Figure 4.1.

A summary of available rainfall data from these gauges for recent events that were reported by residents is shown in Table 4.2. Calibration of the model to historical storm events is discussed in Section 5.6.

4.5 Stream Gauging Data

There is no stream gauging data available from within the Burradoo BU2 catchment.

4.6 Historical Flood Levels

No surveyed or documented records of historical flood levels are available in the Burradoo BU2 catchment. Specific flood levels resulting from the June 2007 storm event were not identified in the responses of the questionnaire. However, anecdotal information about flood extents and inundation was provided which will be used to assess the model.

Table 4.2 Rainfall Data Summary - October 1999, February 2005 and June 2007 Events

				Precipitation in 24hrs before 9 am								
Station ID	**Station Name**	**Source**	**Data Type**	October 1999			February 2005			June 2007		
				23rd	*24th*	*25th*	*20th*	*21st*	*22nd*	*15th*	*16th*	*17th*
068186	Berrima West	BoM	Daily	2.8	73.2	30.8	45.6	55.2	5.6	65.8	51.6	13.2
068033	Mittagong (Kia Ora)	BoM	Daily	0	113.6	25.4	4	40	6	85	36	48
068044	Mittagong (Beatrice St)	BoM	Daily	2	97	33	8	38.6	7	72	60	25.6
068101	Bowral (Riverside)	BoM	Daily	0	0	0	No Data	No Data	No Data	No Data	No Data	No Data
068102	Bowral (Parry Drive)	BoM	Daily	No Data	No Data	No Data	No Data	No Data	No Data	69	50.8	28.2
068102	Bowral (Parry Drive)	BoM	Pluvio (6 minute)	No Data	No Data	No Data	11.0	46.4	9.2	67.6	47.5	25.8
068239	Moss Vale	BoM	Pluvio (1 hour)	No Data	No Data	No Data	18.8	42.6	5.6	59	48.9	20.4
568113	Wingecarribee Dam	BoM	Pluvio (6 minute)	No Data	No Data	No Data	No Data	No Data	No Data	60.5	54.5	14.5
568310	Clover Hill Road	MHL	Pluvio (5 minute)	No Data	No Data	No Data	8.5	26.5	7.5	104.5	81.5	48.5

4.7 Cadastral and Survey Data

Wingecarribee Shire Council supplied Geographic Information System (GIS) data for the Study, including cadastre, aerial photography, sewer plans (which included 1m contours), and available details of major developments within the catchment.

Available field survey data was collated and additional survey was undertaken to provide adequate information for the hydraulic modelling. The survey information supplied by Council included detailed field survey of parts of the catchment prepared for the 2006 Boyden and Partners catchment investigation study and contours and levels for several development sites within the catchment. Additional field survey of channel cross-sections, hydraulic structures, floor levels, and general levels in parts of the catchment was completed by Lawrence Group. Figures from the Lawrence Group survey are included in Appendix C. Further survey of house floor levels and ground levels was completed by Richard Cox.

5. HYDROLOGY

5.1 Introduction

Hydrologic modelling was undertaken to establish runoff hydrographs in the catchment for the historic and design rainfall events. The hydrologic model generated in the XP-RAFTS modelling system, was set up to obtain discharge hydrographs at selected locations in the catchment which were than used as inputs to the TUFLOW 2D hydraulic model. The model was used to generate runoff hydrographs for the 100 year, 50 year, 20 year, and 5 year ARI events, together with the PMF.

The RAFTS model utilises a series of input data to define the catchment, including contributing areas, impervious percentages, and rainfall loss rates. The existing detention basins at Moss Vale Road, namely the Pony Club basin and the Informal basin (shown in Figure 5.2) have been included in the model. Design rainfall intensity-frequency-duration (IFD) data was input to the model to develop rainfall hyetographs. Historic storm events are input to the model to develop flows for calibrating the hydraulic model.

5.2 Sub-catchments

The catchment was divided into seventy-seven sub-catchments based on the topography. These sub-catchments are connected to a series of nodes to combine flows where multiple areas contribute to a single location or channel. Figure 5.1 shows the RAFTS sub-catchment layout and the main watercourse locations.

Each sub-catchment is separated into two sub-areas based on the predominant land-uses present. The land-use types have different characteristics applied for modelling of runoff in RAFTS. Table 5.1 shows the representative land-use types and their respective runoff parameters. Details of the RAFTS sub-catchments are included in Appendix D.

Table 5.1 RAFTS Model Parameters

Land-Use Type	Percent Impervious	Roughness Parameter	Initial Loss (mm)	Continuing Loss (mm)
Established Residential	25	0.05	5	2.5
Modern Residential	25	0.03	5	2.5
High Density Development	50	0.025	3.5	2
Open Spaces / Vegetation	5	0.04	15	3

5.3 Detention Basins

Two existing detention basins (shown on Figure 5.2) are incorporated into the RAFTS model. The Pony Club detention basin has been specifically constructed as a detention basin, while at the other culvert under Moss Vale Road, flow restriction results in extensive upstream ponding giving rise to an informal detention basin. The stage-storage and stage-discharge characteristics for the basins were adopted from the 2006 Boyden and Partners Report and are presented in Tables 5.2 and 5.3 for the respective basins.

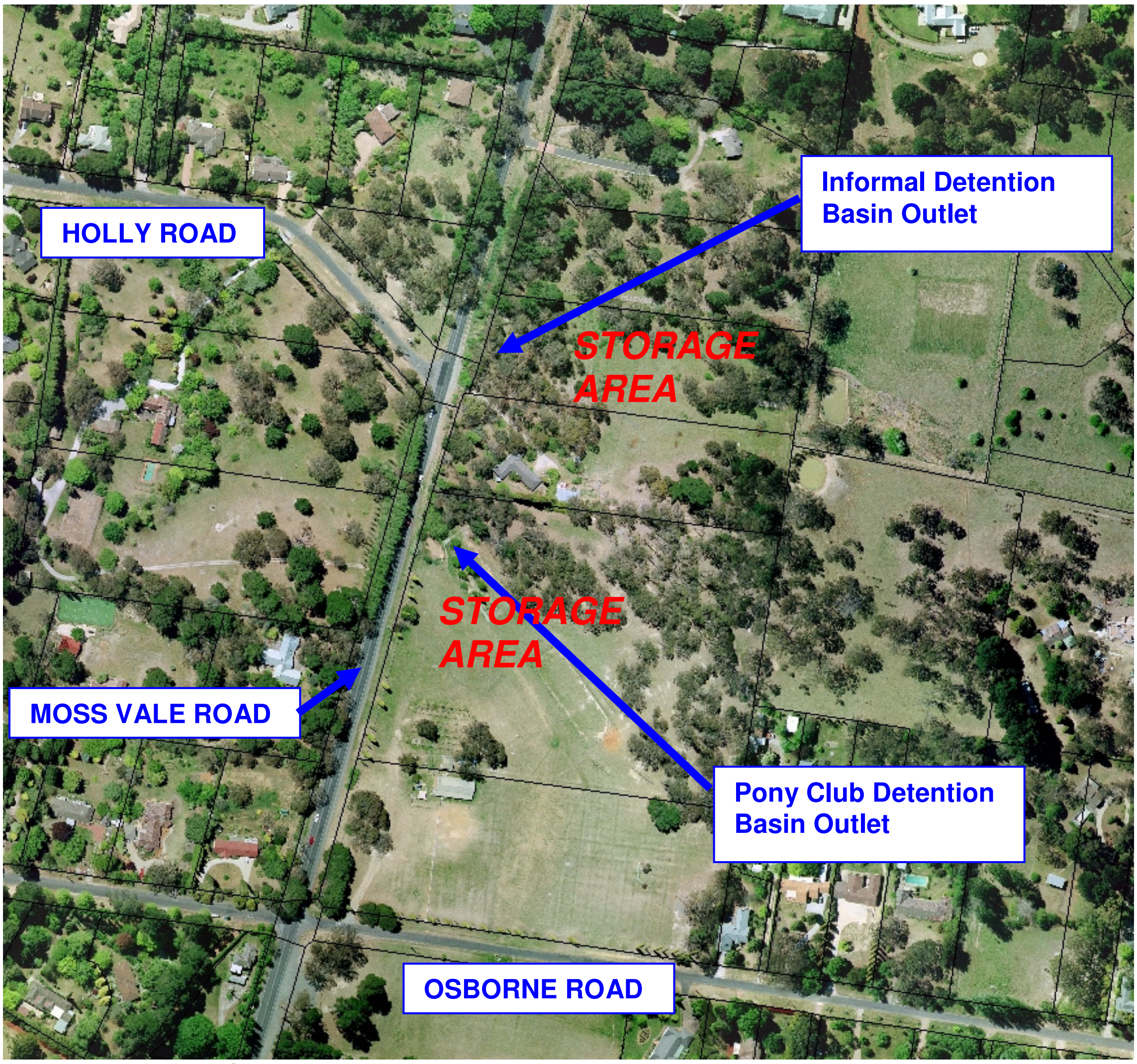

Figure 5.2 RAFTS Detention Basins

Table 5.2 Pony Club Detention Basin Details

Stage (m)	Storage (m^3)	Discharge (m^3/s)
0.0	0	0.0
0.5	205	0.7
1.0	2,278	1.0
1.5	6,972	1.2
2.0	14,425	1.4
2.5	25,495	1.6
Top of wall 670.5m AHD, Invert of basin 667.9m AHD		

Table 5.3 Informal Detention Basin Details

Stage (m)	Storage (m^3)	Discharge (m^3/s)
0.0	0	0.0
0.5	280	0.6
1.0	1,917	1.5
1.5	5,477	3.0
2.0	12,235	5.7
Top of wall 669.6m AHD, Invert of basin 667.5m AHD		

5.4 Rainfall IFD

Uniform areal distribution of design storms within the catchment was assumed in the hydrologic analysis. Design rainfall depths and temporal patterns for various ARI events were developed using standard techniques provided in Australian Rainfall and Runoff (AR&R) (2001). The IFD parameters input to RAFTS from which the design rainfall patterns were derived are listed in Table 5.4.

Table 5.4 Design IFD Parameters for Burradoo

Parameter	Value
2 Year ARI 1 hour Intensity	31.3 mm/hr
2 Year ARI 12 hour Intensity	6.9 mm/hr
2 Year ARI 72 hour Intensity	2.3 mm/hr
50 Year ARI 1 hour Intensity	63.3 mm/hr
50 Year ARI 12 hour Intensity	14.6 mm/hr
50 Year ARI 72 hour Intensity	4.4 mm/hr
Skew	0.03
F2	4.28
F50	15.74

The Probable Maximum Precipitation (PMP) was estimated using the publication *Estimation of Probable Maximum Precipitation in Australia: Generalised Short- Duration Method* (Hydrometeorological Advisory Services, June 2003) recommended by the Bureau of Meteorology. Table 5.5 lists the recommended values used in the calculation of the PMP.

Table 5.5 PMP Calculation Values

Parameter	Value
Moisture Adjustment Factor	0.6825
Elevation Adjustment Factor	1.0
Elevation	< 1500 m
Area Enclosed (km2)	2.6 (ie entire catchment)

Estimated design storm rainfall intensities for the full range of storm events and durations are presented in Table 5.6.

Table 5.6 Summary of Design Rainfall – Burradoo

Rainfall Intensity (mm / hr)					
Duration	**5yr ARI**	**20yr ARI**	**50yr ARI**	**100yr ARI**	**PMP**
15 min	84	111	131	146	640
30 min	60	79	93	104	460
45 min	48	63	75	84	387
1 hour	40.8	54	64	71	340
1.5 hour	32.1	42.6	50	57	293
2 hour	27.1	36	42.7	47.8	255
3 hour	21.2	28.2	33.5	37.6	207
6 hour	13.9	18.6	22.2	25	137
9 hour	10.9	14.6	17.5	19.6	-
12 hour	9.16	12.3	14.7	16.6	-

5.5 Model Comparison

Flow results from the 100 year ARI and 5 year ARI events for storm durations from 15 minutes to 9 hours were compared to the results of Boyden and Partners 2006 Report for similar locations. The 2006 Report modelled several scenarios of "existing conditions" and "full development". However, this current RAFTS model includes recent developments in the catchment, such as Stratford Way and Foldgarth Estate, meaning this model represents conditions between the two scenarios of the 2006 Report.

A summary of peak flows from selected nodes within the catchment for the design 5 yr ARI and 100 yr ARI events are shown in Tables 5.7 and 5.8 respectively. The 2 hour duration event is shown to be the critical duration for both ARI events. The results from the current RAFTS model also show reasonable agreement to the range of flows at similar nodes from the Boyden Partners modelling (2006).

Detailed flow results from the RAFTS model for the recurrence intervals modelled are included as Appendix E. Additional nodes have been included, compared to the Table in Appendix D for determining flows in the primary flowpath for input into the TUFLOW model. These additional nodes do not have catchment areas and thus do not contribute additional flow.

Table 5.7 Summary of Flows, Design 5 yr ARI Event

		Peak Flows for Design 5 yr ARI Event (m^3/s)		
Model	Duration	Pony Club Detention Basin Inflow	Informal Detention Basin Inflow	Flow to Main Southern Railway
	30 m	2.65	13.31	11.92
	1 hr	3.00	15.23	15.22
	1.5 hr	3.48	15.42	15.84
	2 hr	**3.59**	**16.21**	**16.34**
	3 hr	2.60	12.63	14.68
	4.5 hr	3.05	11.08	15.64
	6 hr	2.83	9.98	14.85
Boyden Existing Conditions	"Peak Duration"	3.2	9.7	11.9
Boyden Full Development	"Peak Duration"	**5.4**	**15.2**	**18.2**

Table 5.8 Summary of Flows, Design 100 yr ARI Event

		Peak Flows for Design 100 yr ARI Event (m^3/s)		
Model	Duration	Pony Club Detention Basin Inflow	Informal Detention Basin Inflow	Flow to Main Southern Railway
	30 m	5.90	26.01	24.23
	1 hr	7.15	28.43	31.96
	1.5 hr	7.96	28.25	33.57
	2 hr	**8.12**	**29.41**	**35.03**
	3 hr	6.18	23.12	30.76
	4.5 hr	6.18	21.18	31.80
	6 hr	5.37	17.49	29.37
	9 hr	4.73	15.48	27.48
Boyden Existing Conditions	"Peak Duration"	7	21.5	28.3
Boyden Full Development	"Peak Duration"	**11.3**	**29.6**	**34.1**

5.6 Historical Storm Events

The critical duration of 2 hours for the catchment means that historical rainfall data is required at frequent intervals. The nearest available data is from the Parry Road pluviograph which records rainfall in six-minute timesteps. This site is located just downstream of the catchment and is the most suitable for the flooding assessment. Burradoo BU2 catchment is relatively small and differences to the rainfall pattern across the catchment are not expected. However, the hourly rainfall records at Moss Vale are used to compare the rainfall at the upstream reaches of the catchment.

Figure 5.3 shows the rainfall pattern recorded at the Parry Drive Pluviograph for the June 2007 storm event and **Figure 5.4** shows the pattern for the February 2005 event.

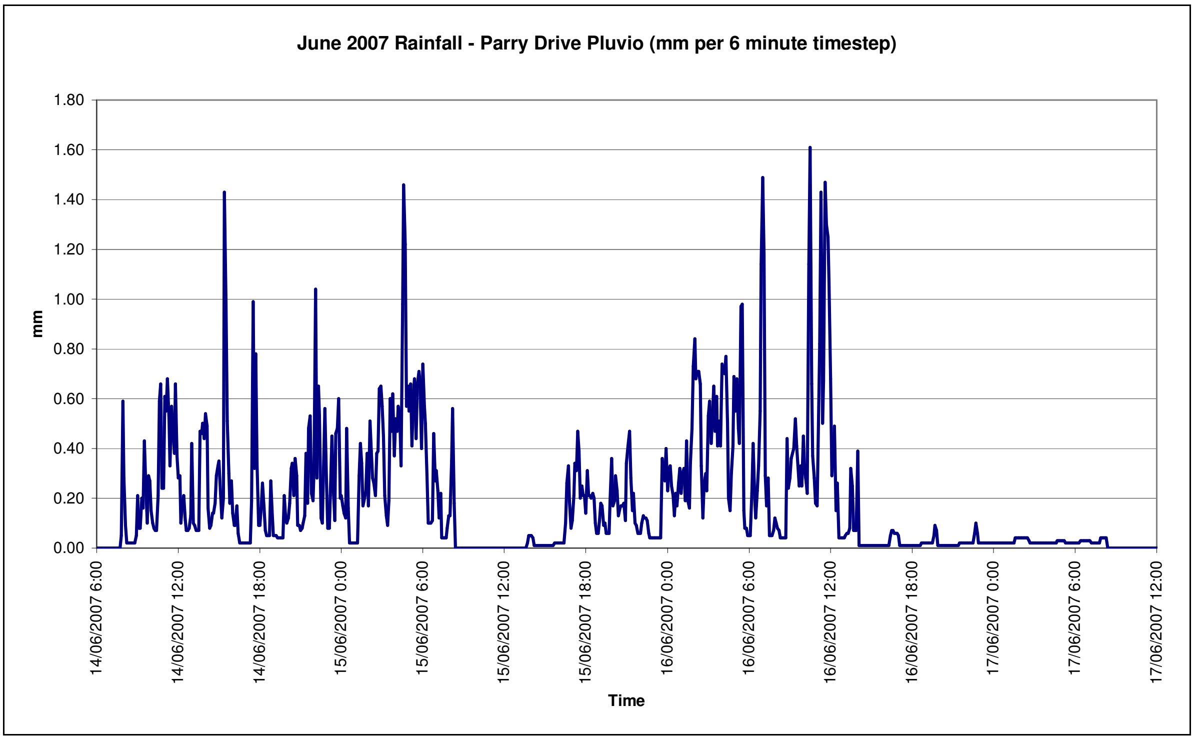

Figure 5.3 June 2007 Storm Event Rainfall

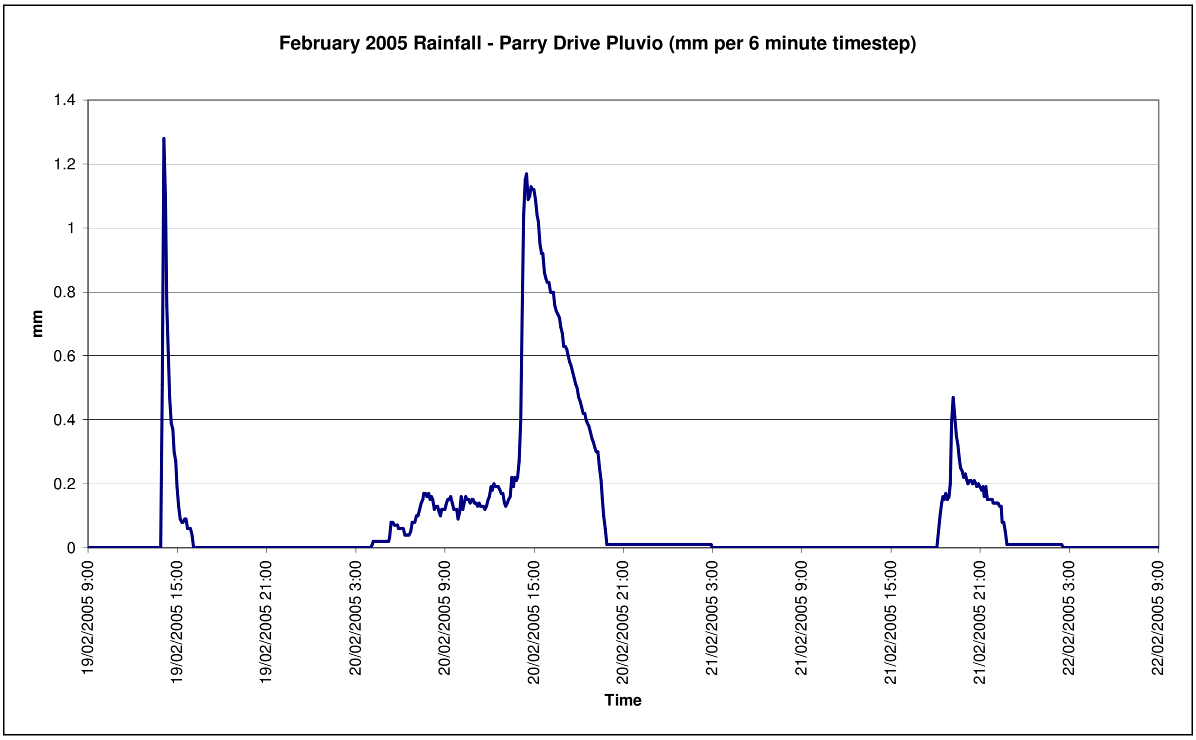

Figure 5.4 February 2005 Storm Event Rainfall

Figure 5.5 shows that there is little variation in the rainfall pattern near the upstream edge of the catchment (Moss Vale gauge) and the gauge near the downstream edge (Parry Road). The total depth of rainfall for time shown at the two gauges is 128 mm at Moss Vale and 141mm at Parry Drive. Similarly, the total rainfall for this period at the Wingecarribee Dam Pluvio was 130 mm.

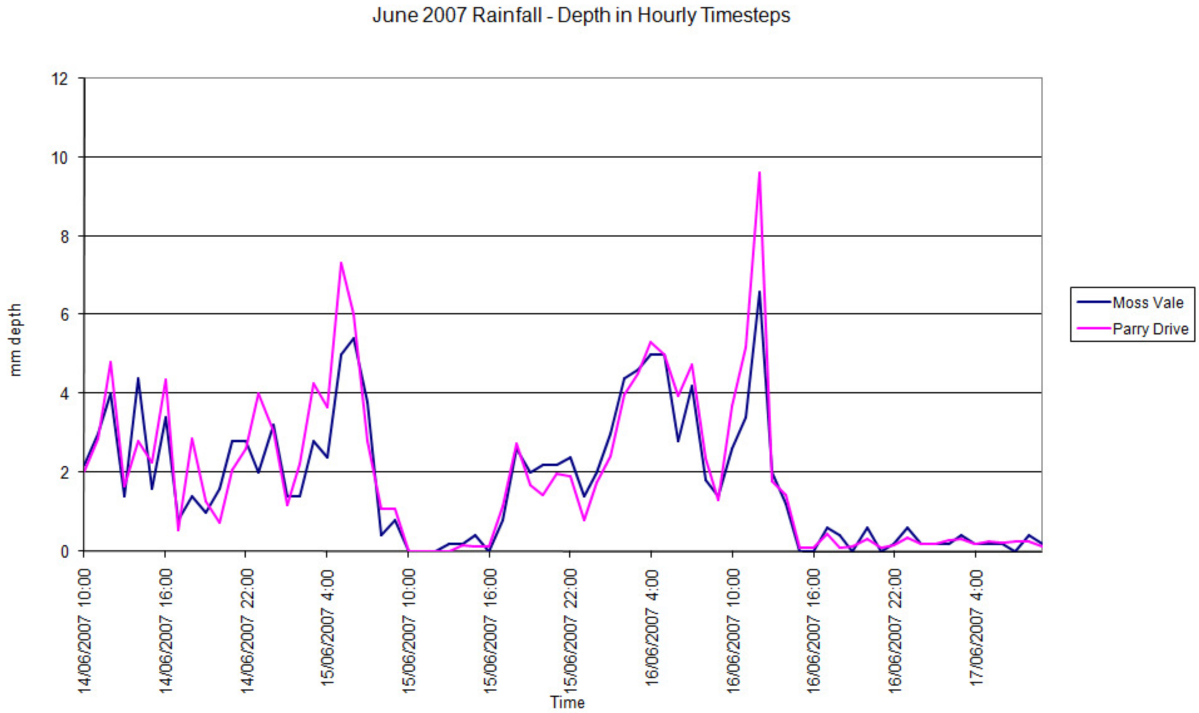

Figure 5.5 June 2007 Storm Event Rainfall Comparison

Figure 5.6 shows a large peak around 4pm on 20 February for Moss Vale but the rainfall for Parry Road has a similar total rainfall over the period between 2pm and 6pm to the Moss Vale recorded depths. Over the time shown on the figure, both sites recorded a total rainfall of 67mm.

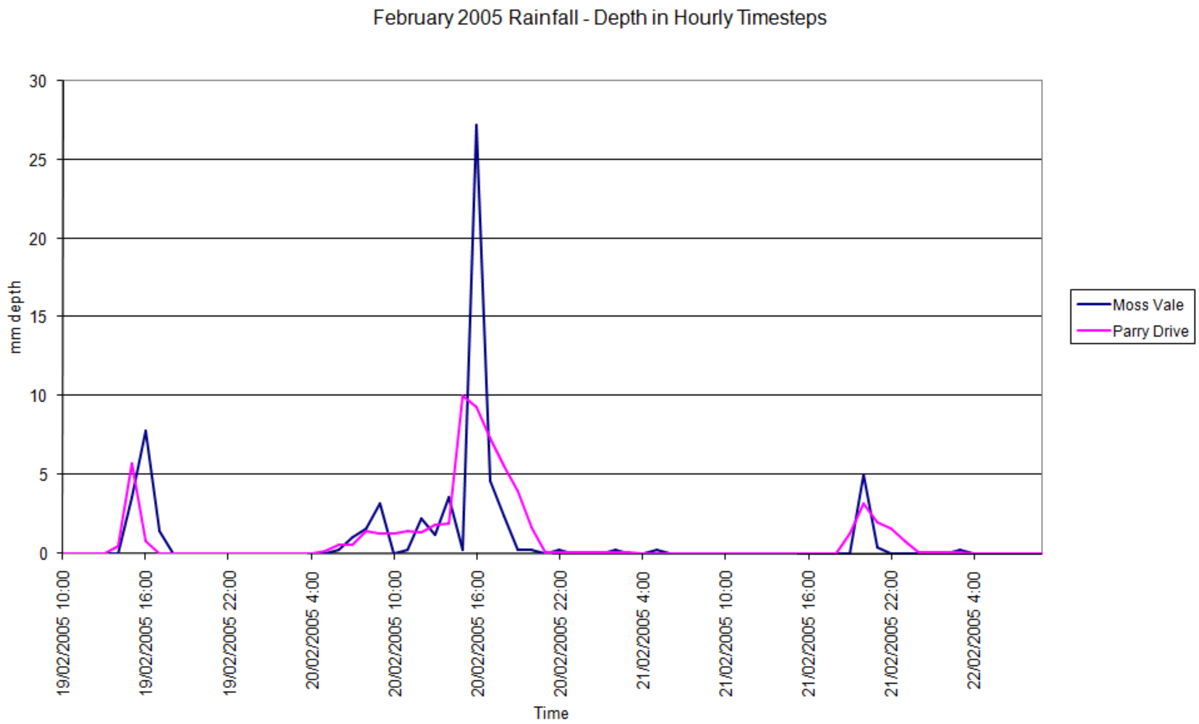

Figure 5.6 February 2005 Storm Event Rainfall Comparison

The storm event rainfall for June 2007 and February 2005 was compared to the IFD design rainfalls as shown on Figure 5.7. Both storm events are estimated as being of recurrence interval less than 1 year ARI.

For the model verification, the June 2007 storm event was modelled and assessed. The February 2005 event was not modelled as insufficient details about the event were received from the questionnaire. The 2005 event is also similar to the June 2007 event which has an ARI of less than one year. Assessment of the October 1999 storm event is described in **Appendix J.** Ideally, the model would be calibrated to larger, less frequent storm events but sufficient data for this is not available.

6. HYDRAULICS

6.1 General

The modelling system TUFLOW was used for the hydraulic modelling. TUFLOW is a fully dynamic hydraulic-routing model which is widely used and has an accepted performance of providing reliable and robust simulation of flood behaviour in a wide range of applications. The model allows dynamic coupling of two dimensional flow with one dimensional elements.

In the modelling of the Burradoo BU2 catchment, the topography is represented as a 2D grid of the floodplain over which flow is conveyed. Culverts are incorporated in the model as 1D elements which are dynamically coupled to the 2D domain allowing flows to be conveyed.

6.2 Model Establishment

6.2.1 2D Model Setup

The major component of the 2D model is the topographic grid, or Digital Terrain Model (DTM). The model topography was developed from survey data captured for this study as well as previous studies. The civil and surveying package 12D was used to generate a three dimensional surface of the floodplain adjacent to the main channel. The extent of the DTM is limited to the range of the available survey data and is shown in Figure 6.2. A grid cell spacing of 2m x 2m was used to represent the modelled area.

Inflow hydrographs for the TUFLOW model were extracted from the RAFTS model and input at nodes on the 2D grid in the primary flowpath.

6.2.2 1D Model Setup

The 1D network comprises key hydraulic structures such as culverts at main road and driveway crossings, and detention basins. These were defined in the model based on the survey data available (Appendix C). Figure 6.1 shows the location of the culvert 1D elements.

6.2.3 Hydraulic Roughness

The hydraulic roughness parameters adopted to represent the catchment for the 1D components and the 2D grid are summarised in Table 6.1.

Figure 6.3 shows the layout of the roughness values used on the grid.

Houses in the floodplain were modelled with a high roughness and assumed not to block the flow of floodwaters, thereby accounting for some potential storage of floodwaters at these locations (eg under-floor voids, verandah areas, and above-floor inundation).

6.2.4 Model Boundaries

The Burradoo BU2 catchment discharges to Mittagong Creek downstream of the railway line. A stage-discharge rating relationship listed in Table 6.2 was adopted as the downstream boundary condition for the model. The relationship was developed utilising design storm results for Mittagong Creek presented in the Bowral Floodplain Risk Management Study and Plan (Bewsher Consulting, 2005). Table 6.2 lists the adopted rating curve. Sensitivity of the model to the adopted tailwater level is discussed in Section 8.

The model upstream boundaries are defined by the extents of the DTM.

Table 6.1 Summary of Hydraulic Roughness Values Used

Component	Roughness
1D Elements	
Box culvert	0.014
2D Elements	
Road	0.02
Concrete lined channel	0.02
Ponds / Open water surfaces	0.02
Open Space	0.035
Residential area	0.045
Houses	0.1

Table 6.2 Downstream Boundary Stage-Discharge Relation

Level (m AHD)	Discharge (m^3/s)
655.90	0.00
656.00	2.85
656.20	8.58
656.40	14.38
656.60	20.22
656.80	26.13
657.00	32.08
657.20	38.10
657.40	44.17
657.60	50.29
657.80	56.47
658.00	62.70
659.00	94.70
660.00	128.08
661.00	162.84
662.00	198.98
663.00	236.50

6.3 Model Comparison

6.3.1 June 2007 Event

The assessment of the rainfall data for the June 2007 event (Figure 5.7) indicates that this event has a recurrence interval of less than 1 year. However, more historical data and more responses in the community questionnaire were received for this event than other events. Therefore this event was modelled to assess the results of the hydraulic model.

The resultant flow hydrographs from the RAFTS hydrologic model for the 15 to 17 June 2007 event from Parry Drive rainfall were input to the TUFLOW hydraulic model. The peak water depths for the June 2007 storm modelling are shown in Figure 6.4.

The responses from the community questionnaire (discussed in Section 4.2) were used for a qualitative evaluation of the model, noting that the extent of the hydraulic model does not cover the questionnaire extents. Figure 6.5 shows the June 2007 flood extent along with responses from the residents. The responses were classified into four categories:

- No flooding,
- Inundation of yard,
- Above floor flooding, and
- Noted areas of flooding.

Twenty-five of the responses received indicated flood impacts on properties during the June 2007 storm event. These responses were assessed to determine their correlation to the modelled flood behaviour for this event. It is noted that some responses for flood impact would be the result of local surface flows not mainstream flows modelled in the primary flowpath. The responses evaluated included responses of areas not flooded, locations and descriptions of inundation within yards, and flood impacts on neighbouring properties and roads. These included:

- Flows over roads – Holly Road, Moss Vale Rd (near Pony Club), Osborne Road (near Pony Club), Toongoon Road;
- Pony Club looked like lake – (note the detention basin in operation);
- Flows over ponds near Burradoo Road and Yean Street;
- No flooding to some properties in Stratford Way and southern side of Holly Road;
- Inundation of yard but not of house for some properties in Burradoo Road, Moynoe Close, Holly Road, Stratford Way, and Toongoon Road;
- Some responses noting direction of flow and location of property inundated.

Appendix A includes photos taken by Council on the 16 June 2007.

As the June 2007 event was a small, relatively frequent event, specific levels were not identified by residents for direct comparison, but the modelling showed general consensus with the responses received.

Within the modelled area, no responses were received advising of flooding above the floor level. The modelled flood behaviour also showed no above-floor flooding.

Given the assumptions made in generating the rainfall time series of the June 2007 event for the catchment, the hydraulic model results indicate suitable modelling of the catchment.

6.3.2 Boyden and Partners Analysis

In addition to the June 2007 historic event, the model results were also compared with a previous study carried out by Boyden and Partners (2006).

The Boyden and Partners Study (2006) utilised HEC-RAS, a one-dimensional steady state model to determine water levels to allow assessment of the flood remedial measures. This Study states that the HEC-RAS level estimates are not to be utilised for the designation of flood levels. This modelling is limited in comparison to the two-dimensional unsteady-state TUFLOW modelling. The fundamental differences between the TUFLOW and HEC-RAS modelling methodologies suggest that the peak water levels for the design flood events are likely to be significantly different. Table 6.3 provides a comparison of the results. Figure 6.6 shows the location of the TUFLOW peak water level reference locations.

Peak waters levels between the two models are similar at a few locations, but vary at others. The Tuflow modelling system allows for more definition of the terrain and thus different results may be due to additional storages and routing of flow through the 2D domain. Location 18 shows a higher level as the 2D grid may provide additional flow restrictions within the storage pond. Similarly, additional storage may be modelled in Tuflow at Locations 6 and 7 resulting in higher comparative levels. The lower comparative level at the Railway (Location 2) is potentially due to the additional storage capacity being modelled in the upstream areas. TUFLOW Reference point 13 (Figure 6.6) is about 0.5m lower than the Boyden levels, partly due to the Boyden analysis incorporating a blockage depth of 0.4m to the culvert.

Table 6.3 Comparison to Boyden & Partners 100y ARI Peak Water Levels (m AHD)

TUFLOW Reference	Location	TUFLOW	Boyden & Partners HEC-RAS		
		Peak Level	Location	'Existing'	'Fully Developed'
2	u/s Railway	659.47	XS 1	660.51	660.81
4	u/s Burradoo Road	661.09	XS 4	661.06	661.12
6	d/s Ranelagh Road	662.80	Near XS 7	662.56	662.62
7	u/s Ranelagh Road	663.35	Near XS 7	662.56	662.62
8	d/s Holly Road	664.29	XS 10	664.46	664.53
10	d/s Holly Road	665.31	XS 13	665.46	665.51
11	u/s Holly Road	665.78	XS 14	665.93	665.98
12	d/s Moss Vale Road	667.61	XS 16	667.51	667.53
13	u/s Moss Vale Road	670.24	XS 17	670.42	670.54
18	Foldgarth Way	672.65	XS 20	672.18	672.20
21	u/s Stratford Avenue	675.18	XS 23	674.57	674.71

7. DESIGN FLOOD ESTIMATION

Design flow hydrographs were obtained from the RAFTS hydrologic model and applied to the 1D/2D TUFLOW hydraulic model.

7.1 Critical Duration

To determine the critical duration of the Burradoo BU2 catchment, 100 year ARI storm events for durations 1, 1.5, 2, 3, 4.5, 6, 9, and 12 hours were modelled. The results are summarised in Table 7.1 for the peak water levels at the reference locations (shown on Figure 6.6).

The critical duration within the catchment is 2 hours except for 6 hours at the downstream extents of the catchment but there is only 0.01m difference to the 2 hour level. Reference point 15 is located in the Pony Club Detention Basin and has a critical duration of 9 hours due to the increased volume of flow into the basin for this event. Reference point 14 is just downstream of this basin and the peak water level occurs for the 2 hour event. Critical duration for the 5 year ARI event is generally 2 hours and for the PMF event is between 30 minutes in the upstream areas and 1 hour in the downstream areas.

Table 7.1 Peak flood levels for 100y ARI storm events (m AHD)

Point	1hr	1.5hr	2hr	3hr	4.5hr	6hr	9hr	12hr	Max.	Critical Duration
1	658.13	658.14	658.14	658.13	658.13	658.15	658.14	658.13	**658.15**	6hr
2	659.35	659.41	659.47	659.42	659.44	659.48	659.47	659.35	**659.48**	6hr
3	660.14	660.14	660.15	660.12	660.14	660.13	660.13	660.10	**660.15**	2hr
4	661.08	661.08	661.09	661.07	661.08	661.08	661.07	661.06	**661.09**	2hr
5	661.08	661.09	661.09	661.07	661.08	661.09	661.08	661.07	**661.09**	2hr
6	662.79	662.79	662.80	662.79	662.79	662.79	662.79	662.78	**662.80**	2hr
7	663.32	663.33	663.35	663.33	663.33	663.34	663.34	663.32	**663.35**	2hr
8	664.28	664.29	664.29	664.25	664.23	664.21	664.20	664.21	**664.29**	2hr
9	665.57	665.57	665.57	665.56	665.55	665.54	665.54	665.55	**665.57**	2hr
10	665.27	665.29	665.31	665.29	665.29	665.30	665.30	665.26	**665.31**	2hr
11	665.75	665.77	665.78	665.76	665.76	665.77	665.77	665.73	**665.78**	2hr
12	667.61	667.61	667.61	667.60	667.60	667.61	667.60	667.60	**667.61**	2hr
13	670.18	670.21	670.24	670.17	670.21	670.20	670.19	670.13	**670.24**	2hr
14	667.41	667.43	667.44	667.42	667.43	667.44	667.43	667.39	**667.44**	2hr
15	669.68	669.81	669.89	669.96	670.00	670.04	670.10	670.08	**670.10**	9hr
16	670.70	670.70	670.71	670.67	670.67	670.64	670.62	670.63	**670.71**	2hr
17	671.24	671.24	671.25	671.22	671.21	671.19	671.19	671.19	**671.25**	2hr
18	672.63	672.63	672.65	672.60	672.59	672.57	672.54	672.54	**672.65**	2hr
19	673.36	673.37	673.38	673.32	673.30	673.28	673.24	673.24	**673.38**	2hr
20	674.95	674.97	674.98	674.91	674.89	674.86	674.84	674.84	**674.98**	2hr
21	675.14	675.16	675.18	675.10	675.05	675.00	674.98	674.99	**675.18**	2hr
22	676.36	676.37	676.38	676.33	676.32	676.27	676.25	676.25	**676.38**	2hr

7.2 Results

The model was run for the following average recurrence intervals and durations:

- PMF – 30 min, 45 min, 1 hour, 1.5, and 2 hours;
- 100 year ARI – 1 hour, 1.5, 2, 3, 4.5, 6, 9, and 12 hours;
- 50 year ARI – 1 hour, 1.5, 2, 3 and 6 hours;
- 20 year ARI – 1 hour, 1.5, 2, 3 and 6 hours;
- 5 year ARI – 1 hour, 1.5, 2, and 3 hours.

Table 7.2 lists the peak water levels at the reference locations for the durations modelled for each recurrence intervals.

Table 7.2 Peak flood levels for storm recurrences modelled (m AHD)

Point	Location	Ground Elevation	PMF	100y	50y	20y	5y
1	d/s Railway	657.26	658.82	658.15	658.12	658.08	658.02
2	u/s Railway	658.23	662.29	659.48	659.29	659.12	658.83
3	d/s Burradoo Road	658.66	662.29	660.15	660.09	660.01	659.90
4	u/s Burradoo Road	659.45	662.33	661.09	661.05	661.00	660.91
5	u/s Burradoo Road	660.50	662.38	661.09	661.05	661.00	660.91
6	d/s Ranelagh Road	662.51	663.55	662.80	662.77	662.74	662.69
7	u/s Ranelagh Road	662.91	664.44	663.35	663.30	663.26	663.18
8	d/s Holly Road	664.09	664.77	664.29	664.27	664.25	664.21
9	u/s Holly Road	665.51	665.69	665.57	665.57	665.56	665.55
10	d/s Holly Road	664.11	666.28	665.31	665.26	665.21	665.10
11	u/s Holly Road	665.36	666.74	665.78	665.72	665.70	665.64
12	d/s Moss Vale Road	666.97	667.79	667.61	667.60	667.60	667.53
13	u/s Moss Vale Road	667.64	671.59	670.24	670.11	669.95	669.59
14	d/s Moss Vale Road	667.20	668.38	667.44	667.39	667.34	667.29
15	u/s Moss Vale Road	668.10	670.62	670.10	669.87	669.67	669.29
16	u/s Moss Vale Road	670.31	671.58	670.71	670.69	670.65	670.59
17	d/s Osborne Rd	671.07	671.63	671.25	671.23	671.22	671.19
18	Foldgarth Way	672.00	673.10	672.65	672.62	672.58	672.49
19	d/s Stratford Way	672.79	673.86	673.38	673.36	673.31	673.24
20	u/s Stratford Way	673.56	675.38	674.98	674.95	674.91	674.85
21	u/s Stratford Way	674.17	675.79	675.18	675.15	675.09	674.98
22	u/s Stratford Way	675.60	676.75	676.38	676.35	676.33	676.26

Peak flood levels and extents are shown for the PMF, 100 year ARI, 50 yr ARI, 20 yr ARI and 5 yr ARI design events in Figures 7.1 through 7.5 respectively.

Peak flow velocities are shown for the PMF, 100 year ARI, 50 yr ARI, 20 yr ARI and 5 yr ARI design events in Figures 7.6 through 7.10 respectively. For clarity in the figures, arrows showing velocity direction are not shown.

Figure 7.11 shows the locations of longitudinal profiles for the ARI events presented in the following figures:

- Figure 7.12 – Line 1 along primary flowpath from upstream of Stratford Way to the outlet west of the railway,
- Figure 7.13 – Line 2 from Pony Club detention basin across Holly Rd to confluence with Line 1,
- Figure 7.14 – Line 3 from near intersection of Osborne Road and Toongoon Road north-west to confluence with Line 1.

A preliminary flood damages assessment is included in Appendix G and a review of potential flood mitigation measures is included in Appendix H.

8. SENSITIVITY

The sensitivity of the hydraulic model was tested to demonstrate the range of uncertainty in the model results for changes in key parameters. The following variables were tested for sensitivity:

- Catchment runoff – increased and decreased by 20%,
- Catchment roughness – increased and decreased by 20%,
- Downstream boundary condition – with high tailwater level,
- Culvert blockage – 50% and 100% blockage.

The sensitivity results for the varied parameters were assessed for the 100 year ARI 2 hour duration critical event. Comparative results are shown in Appendix F. The locations of the comparison points are shown on Figure 6.6.

8.1 Catchment Runoff

The flowrates of the hydrographs applied at each input node within the TUFLOW model were increased by 20% and decreased by 20%. Results are listed in Table F.1 in Appendix F.

The water level changes for the scenarios are generally within the range of ±0.10m, except at the three main ponding locations, namely just upstream of the railway line (Location 2 on Figure 6.6), at the Informal detention basin (Location 13), and at the Pony Club detention basin (Location 15). At other locations, the additional water is conveyed at a higher depth and consequently a wider area. In the case of these ponds, the outlet conveyance is already restricted so the additional flow generates a higher relative depth compared to flow in channel areas.

8.2 Catchment Roughness

The 20% increase and decrease to model roughness does not affect peak flow levels as markedly as do variations in the catchment runoff. Results shown in Table F.2 show differences are only a maximum of ±0.03m in the 100 year ARI 2 hour event.

The results confirm the general expectation that a decrease in the roughness would result in a decrease in the peak water levels as the runoff is able to be conveyed at a higher velocity and hence lower level. Similarly, the results show that increasing the roughness raises the flood level due to the retarding effect on runoff conveyance. However, the opposite occurs to water levels at the upstream side of the railway (Point 2) as the increased roughness reduces the velocity of runoff resulting in a reduced peak arriving at this location.

8.3 Downstream Boundary

A stage-discharge relation (detailed in Section 6.2.4) is applied as the downstream boundary condition for the model. The sensitivity to the tailwater level is assessed by applying the PMF level of RL 663.0m estimated at the model's outlet to Mittagong Creek from the Bowral Floodplain Risk Management Study and Plan (Bewsher, 2005). Comparative results for the 100 year ARI 2 hour event are presented in Table F.3 in Appendix F.

Changes to the tailwater level affect only the downstream area below Ranelagh Road. The PMF tailwater level applied is the resulting peak water level for locations downstream of Ranelagh Road but upstream of this location (Point 7 and above) show water levels that are independent of the boundary level.

8.4 Culvert Blockage

The 50% and 100% blockage scenarios applied to all the culverts means that all the culverts act as de-facto detention / retention basins. Depending on the culvert characteristics and topography, the blockages can significantly raise levels at the culvert and reduce levels just downstream or further downstream.

Changing the blockage to the railway culvert results in significant additional depth of water stored to the east (Point 2), and consequently the flow downstream is reduced. For the 100% blockage case, the backwater from the ponding increases levels up to Location 5.

Flow levels in the Informal detention basin (Location13) and the Pony Club detention basin (Location 15) increase due to the blockage of their outlet structures. As a result, the peak water level downstream of the Informal basin decreases, but levels downstream of the Pony Club basin (Location 14) increase as flow spills from the informal basin to this watercourse.

Blockages applied to the culverts within the channel near Foldgarth Way and Stratford Way result in some increases in peak water level. The culverts at Location 21 are the first culverts modelled in the primary flowpath and thus have a significant influence to the downstream locations.

9. PROVISIONAL FLOOD HAZARD

9.1 General

Flood hazard can be defined as the risk to life and limb and damage caused by a flood. The hazard caused by a flood varies both in time and place across the floodplain. The Floodplain Management Manual (NSW Government, 2001) describes various factors to be considered in determining the degree of hazard. These factors are:

- Size of the flood,
- Depth and velocity of floodwaters,
- Effective warning time,
- Flood awareness,
- Rate of rise of floodwaters,
- Duration of flooding,
- Evacuation problems,
- Access.

Hazard categorisation based on all the above factors is part of establishing a Floodplain Risk Management Plan. The scope of the present study calls for determination of provisional flood hazards only, which when considered in conjunction with the above listed factors provides comprehensive analysis of the flood hazard.

9.2 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters as detailed in the Floodplain Development Manual (NSW Government, 2005). The two categories for provisional hazard are defined as High and Low shown in Figure 9.1.

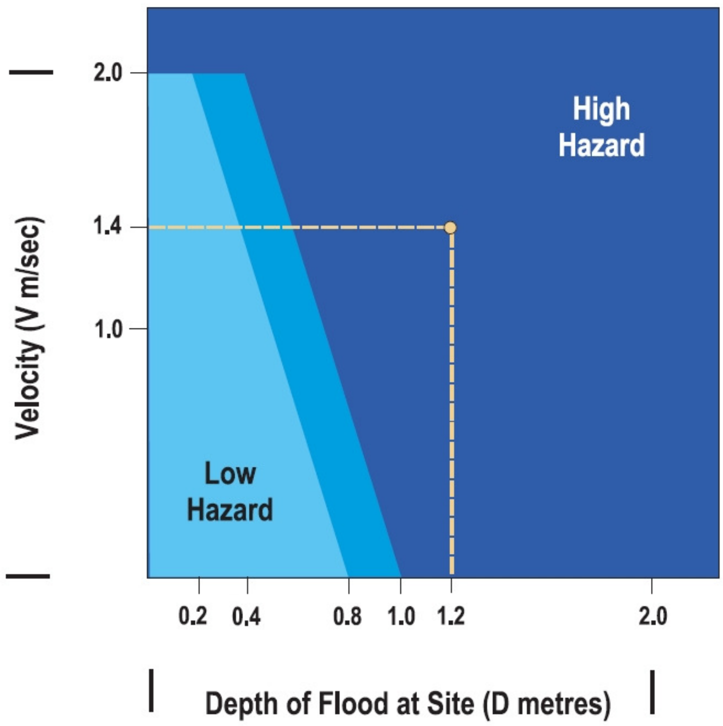

Figure 9.1 Provisional Hazard Classification (NSW Government)

The model results were processed based on the peak flood depth and velocity for each recurrence interval to determine the provisional hazard. Provisional flood hazard for the PMF, 100, 50, 20, 10 and 5 year ARI floods is presented in Figures 9.2 to 9.6 respectively.

High provisional hazard for the 5 year ARI is shown in parts within the open channel near Stratford Way, in sections of the drainage depressions downstream of Moss Vale Road to Burradoo Road, and adjacent to the culvert opening under the railway. The Informal detention basin, Pony Club basin, and ponds just upstream of Burradoo Road are also identified as high provisional hazard areas.

The areas determined as high provisional hazard extend with the less frequent storm events but does not result in a continuous line along the primary flowpaths in the 100 year ARI event. Extensive areas along the primary flowpath are high provisional hazard in the PMF event. In this event, high provisional hazard is shown within the banks of the open channel adjacent to Stratford Way.

10. HYDRAULIC CATEGORISATION

10.1 General

Hydraulic categorisation of the floodplain is used in the development of the Floodplain Risk Management Plan. The Floodplain Management Manual (2005) defines flood prone land to fall into one of the following three hydraulic categories:

- **Floodway** - Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.

- **Flood Storage** - Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%.

- **Flood Fringe** - Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant affect on the flood pattern or flood levels.

10.2 Hydraulic Category Identification

Floodways were determined for the PMF, 100, 50, 20, and 5 years ARI by considering those model branches that conveyed a significant portion of the total flow. These branches, if blocked or removed, would cause a significant redistribution of the flow. The criteria used to define the floodways are described below.

As a minimum, the floodway was assumed to follow the creekline from bank to bank where it was sufficiently defined. In addition, the following depth and velocity criteria were used to define a floodway:

- Velocity * Depth product must be greater than 0.25 m^2/s and velocity must be greater than 0.25 m/s, OR
- Velocity is greater than 1 m/s.

Flood storage was defined as those areas outside the floodway, which if completely filled would cause peak flood levels to increase by 0.1 m and/or would cause peak discharge anywhere to increase by more than 10%. Previous analysis of flood storage in 1D cross-sections assumed that if the cross-sectional area is reduced such that 10% of the conveyance is lost, the criteria for flood storage would be satisfied. To determine the limits of 10% conveyance in a cross-section, the depth was determined at which 10% of the flow was conveyed. This depth, averaged over several cross-sections, was found to be 0.2 m (Howells et al, 2003). Thus the criteria used to determine the flood storage is:

- Depth greater than 0.2m
- Not classified as floodway.

All areas that were not categorised as Flood Way or Flood Storage, but still within the flood extent are represented as Flood Fringe.

The hydraulic categories for the PMF, 100, 50, 20, and 5 year ARI based on the peak flood depth and velocity criteria described are shown in Figures 10.1 through 10.5 respectively.

For the 5 year ARI event, sections of floodway are shown along the primary flowpaths of the Stratford Way channel and main depressions conveying runoff to the railway. Flood storage areas are shown at the Foldgarth Way pond, Informal detention basin, Pony Club detention basin, just upstream of Burradoo Road and just upstream of the railway.

Flood storage areas are increased as the storm event frequency is reduced and the floodway is almost continuous along the primary flowpath at the 100 year ARI event. In a PMF event, floodway extent is generally continuous along the flowpath reaches and includes sections within the main storage areas and across roads.

11. CLIMATE CHANGE

Increased sea levels and increased rainfall intensities are expected to result from climate change effects. Potential impacts to flood behaviour in the Burradoo BU2 catchment due to climate change have been analysed.

The Department of Environment and Climate Change in the guideline 'Practical Consideration of Climate Change' (2007) recommended that climate change assessments review three scenarios of increases to rainfall intensities: 10%, 20%, and 30%. Potential increases to the sea level do not influence flow behaviour in this catchment due to its elevation at more than 650m above sea level.

The critical storm event of 1% AEP 2 hour duration was used for the climate change assessment. Rainfall intensities were increased by the relative percentage in the XP-RAFTS model and the flows input to the Tuflow model.

Peak water levels for the climate change scenarios at the reference locations (shown in Figure 6.6) are listed in Table 11.1. Figure 11.1 shows the peak water for the 100y ARI 2 hour event with a 30% increase in rainfall intensity.

Table 11.1 Climate Change Scenarios Peak Levels Modelled (m AHD)

Point	Location	Ground Elevation	100y 2h (Base)	100y 2h + 10%	100y 2h + 20%	100y 2h + 30%	Difference +30% to Base (m)
1	d/s Railway	657.26	658.14	658.17	658.20	658.22	0.08
2	u/s Railway	658.23	659.47	659.66	659.83	660.01	0.54
3	d/s Burradoo Road	658.66	660.15	660.21	660.24	660.28	0.13
4	u/s Burradoo Road	659.45	661.09	661.13	661.17	661.20	0.11
5	u/s Burradoo Road	660.50	661.09	661.14	661.17	661.20	0.11
6	d/s Ranelagh Road	662.51	662.80	662.83	662.85	662.88	0.08
7	u/s Ranelagh Road	662.91	663.35	663.39	663.43	663.47	0.12
8	d/s Holly Road	664.09	664.29	664.30	664.31	664.33	0.04
9	u/s Holly Road	665.51	665.57	665.58	665.58	665.58	0.01
10	d/s Holly Road	664.11	665.31	665.35	665.39	665.43	0.12
11	u/s Holly Road	665.36	665.78	665.82	665.86	665.90	0.12
12	d/s Moss Vale Road	666.97	667.61	667.61	667.62	667.63	0.02
13	u/s Moss Vale Road	667.64	670.24	670.34	670.43	670.52	0.28
14	d/s Moss Vale Road	667.20	667.44	667.50	667.55	667.59	0.15
15	u/s Moss Vale Road	668.10	669.89	670.00	670.11	670.20	0.31
16	u/s Moss Vale Road	670.31	670.71	670.73	670.75	670.77	0.06
17	d/s Osborne Rd	671.07	671.25	671.26	671.27	671.28	0.03
18	Foldgarth Way	672.00	672.65	672.67	672.69	672.71	0.06
19	d/s Stratford Way	672.79	673.38	673.40	673.43	673.46	0.08
20	u/s Stratford Way	673.56	674.98	674.99	675.01	675.04	0.06
21	u/s Stratford Way	674.17	675.18	675.28	675.34	675.38	0.20
22	u/s Stratford Way	675.60	676.38	676.41	676.43	676.45	0.07

Water levels for the scenarios increase steadily with the increase to the rainfall intensity. The largest increases occur at reference locations 2, 13 and 15 where water ponds and is detained at the railway embankment or detention basins. A minor depth increase occurs at location 9 upstream of Holly Road as it has the lowest flow rate of the reference locations thus the percentage increase for climate change only results in a small depth increase.

12. CONCLUSION

This report has been prepared for Wingecarribee Shire Council to define the nature and extent of flooding for the study area in Burradoo BU2 catchment. Hydrologic and hydraulic modelling was completed to assess flood behaviour within the catchment. Flow characteristics including depth, velocity and provisional hazard were evaluated based on the computer modelling.

A preliminary flood damages assessment is included in Appendix G and review of potential flood mitigation measures is included in Appendix H.

The investigation and modelling procedures adopted for this study follow current best practice and considerable care has been applied to the preparation of the results. However, model set-up and calibration depends on the quality of data available and there will always be some uncertainties. The flow regime and the flow control structures are very complicated and can only be represented by schematised model layouts. Hence there will be an unknown level of uncertainty in the results and this should be borne in mind in their application.

The next stage of the floodplain risk management process following the adoption of the Flood Study is the Floodplain Risk Management Study and Plan. This stage will investigate various floodplain risk management measures and prioritise these measures for implementation.

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FIGURES

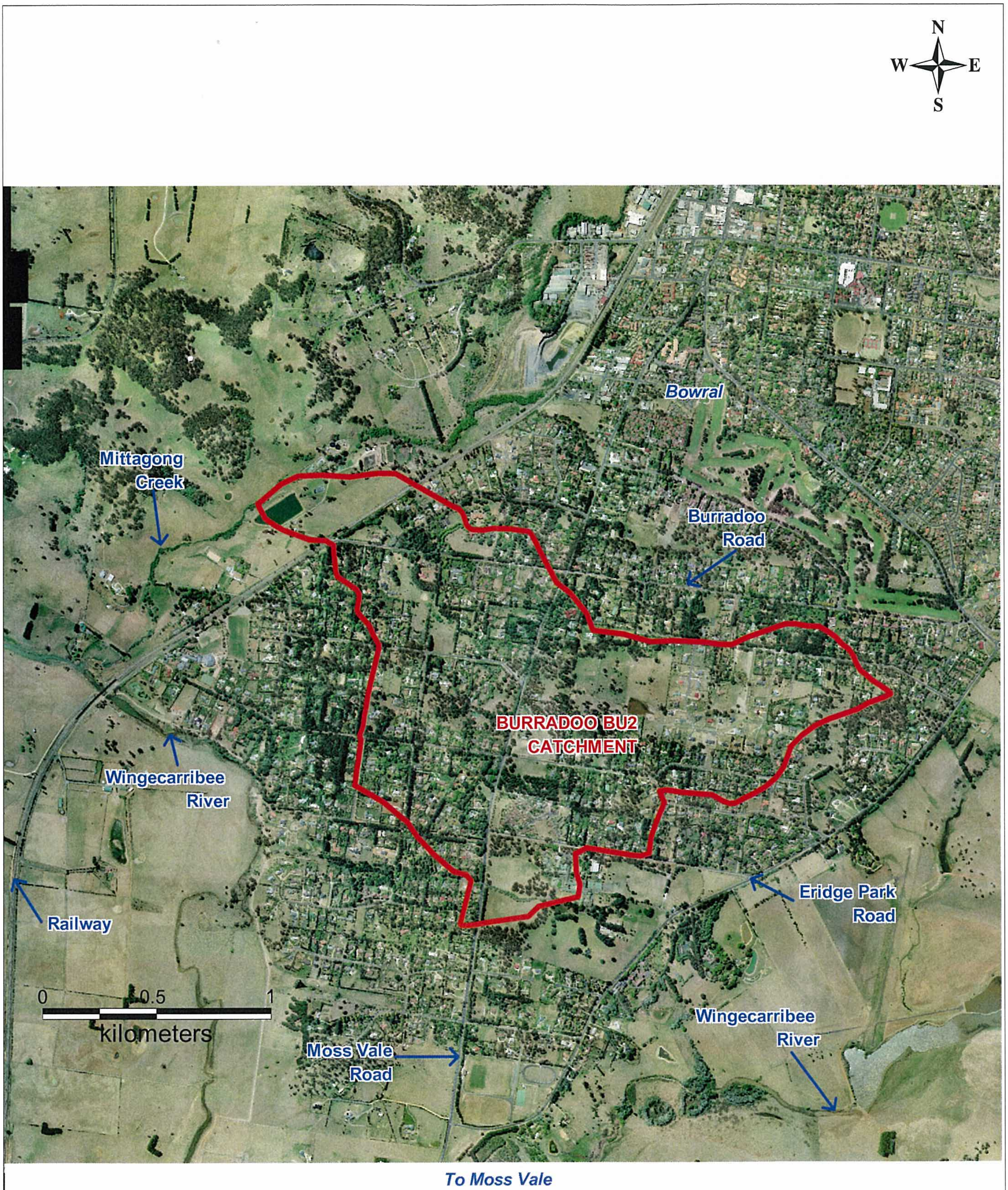

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FIGURE 1.1
LOCALITY PLAN

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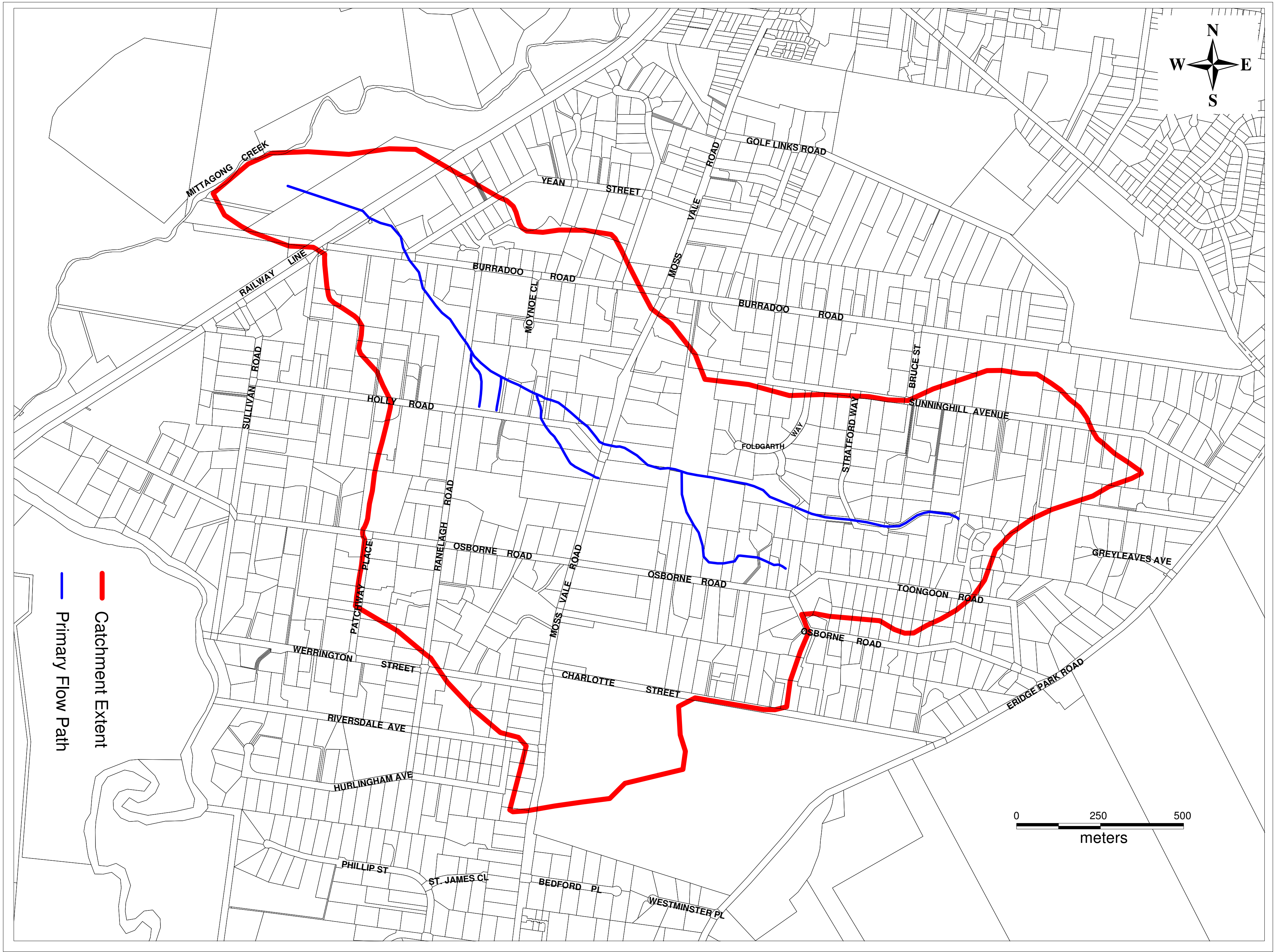

FIGURE 3.1
CATCHMENT EXTENTS

J2575\MapInfo\Figure3.1 Catchment.Wor


N
W
E
S
MITTAGONG CREEK
RAILWAY LINE
GOLF LINKS ROAD
BURRADOO ROAD
SUNNINGHILL AVENUE
FOLDGARTH
STRATFORD WAY
OSBORNE ROAD
TOONGOON ROAD
GREYLEAVES AVE
CHARLOTTE STREET
WERRINGTON
HURLINGHAM AVE
PHILLIP ST
ST JAMES CL
Catchment Boundary
Primary Flow Path
0
250
500
meters

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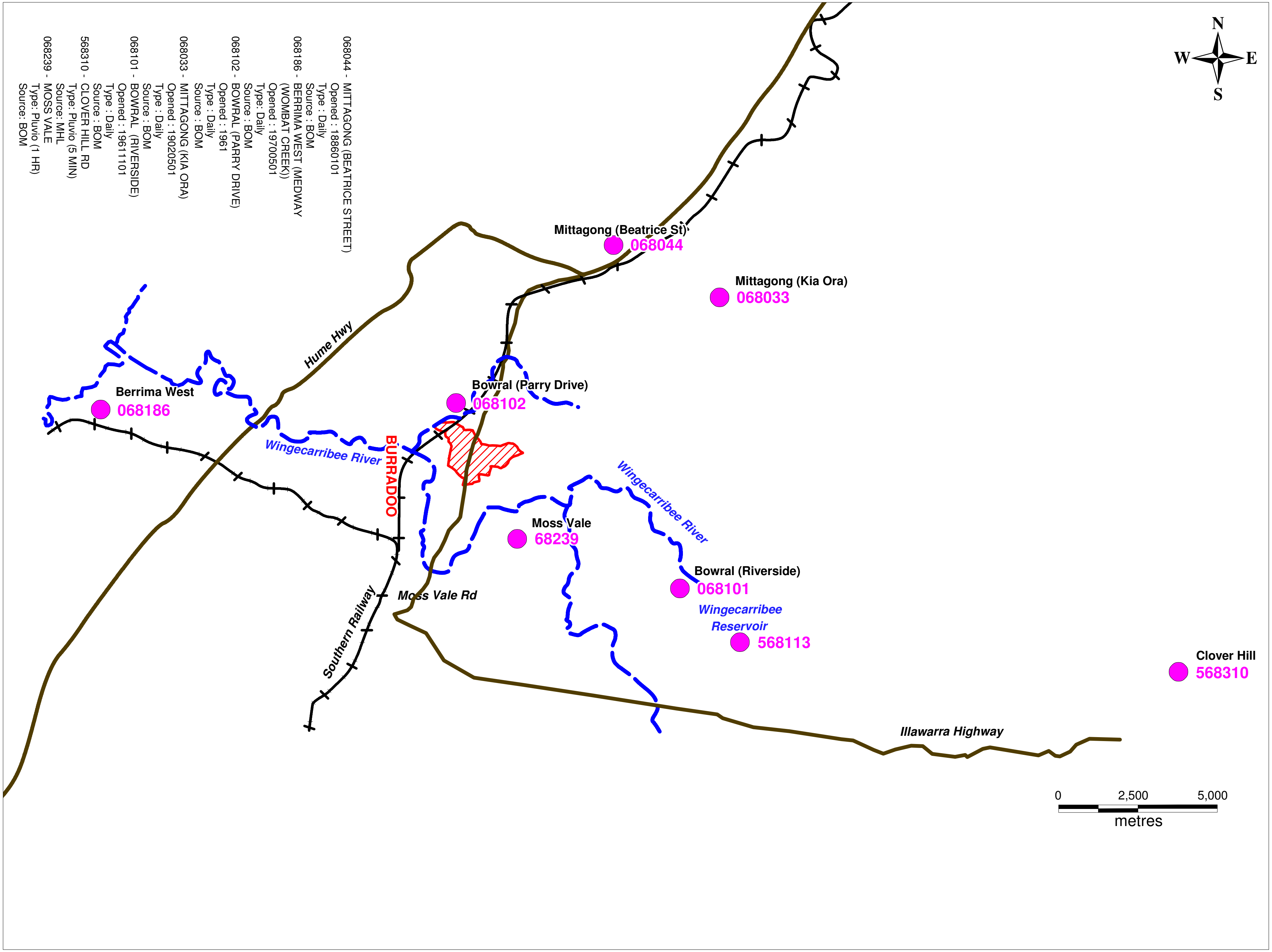
FIGURE 4.1
RAIN GAUGES



068044 - MITTAGONG (BEATRICE STREET)
Opened : 18860101
Type : Daily
Source : BOM

068186 - BERRIMA WEST (MEDWAY
(WOMBAT CREEK))
Opened : 19700501
Type: Daily
Source : BOM

068102 - BOWRAL (PARRY DRIVE)
Opened : 1961
Type : Daily
Source : BOM

068033 - MITTAGONG (KIA ORA)
Opened : 19020501
Type : Daily
Source : BOM

068101 - BOWRAL (RIVERSIDE)
Opened : 19611101
Type : Daily
Source : BOM

568310 - CLOVER HILL RD
Type: Pluvio (5 MIN)
Source: MHL

068239 - MOSS VALE
Type: Pluvio (1 HR)
Source: BOM

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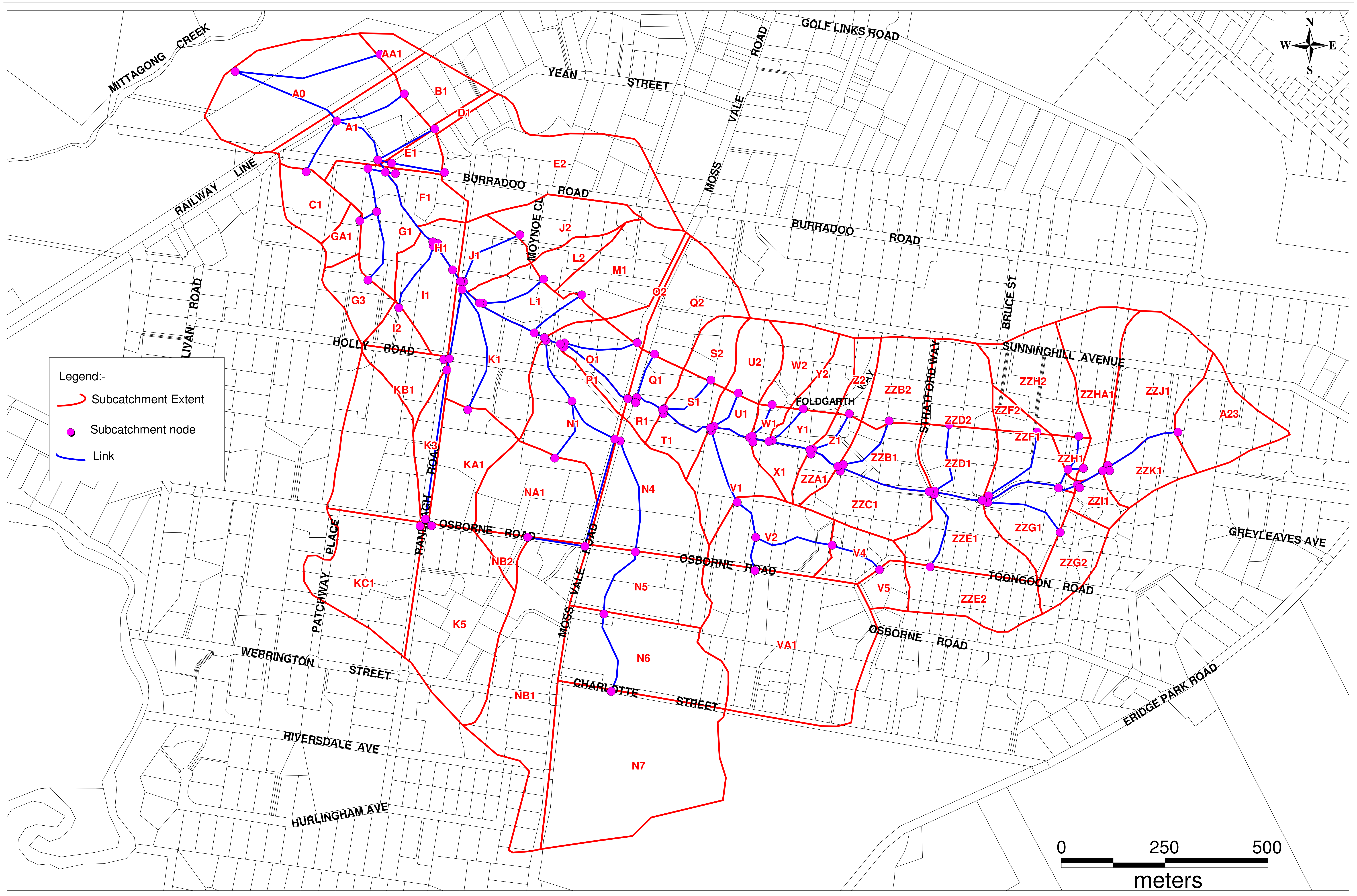
J2575\MapInfo\Figure 4.1 Gauges.Wor


N
W
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MITTAGONG CREEK
RAILWAY LINE
YEAN STREET
GOLF LINKS ROAD
MOSS VALE ROAD
BURRADOO ROAD
MOYNOE CL
HOLLY ROAD
RANELAGH ROAD
OSBORNE ROAD
TOONGOON ROAD
SUNNINGHILL AVENUE
BRUCE ST
STRATFORD WAY
FOLDGARTH WAY
GREYLEAVES AVE
ERIDGE PARK ROAD
PATCHWAY PLACE
WERRINGTON STREET
CHARLOTTE STREET
RIVERSDALE AVE
HURLINGHAM AVE
Legend:-
Subcatchment Extent
Subcatchment node
Link
0
250
500
meters

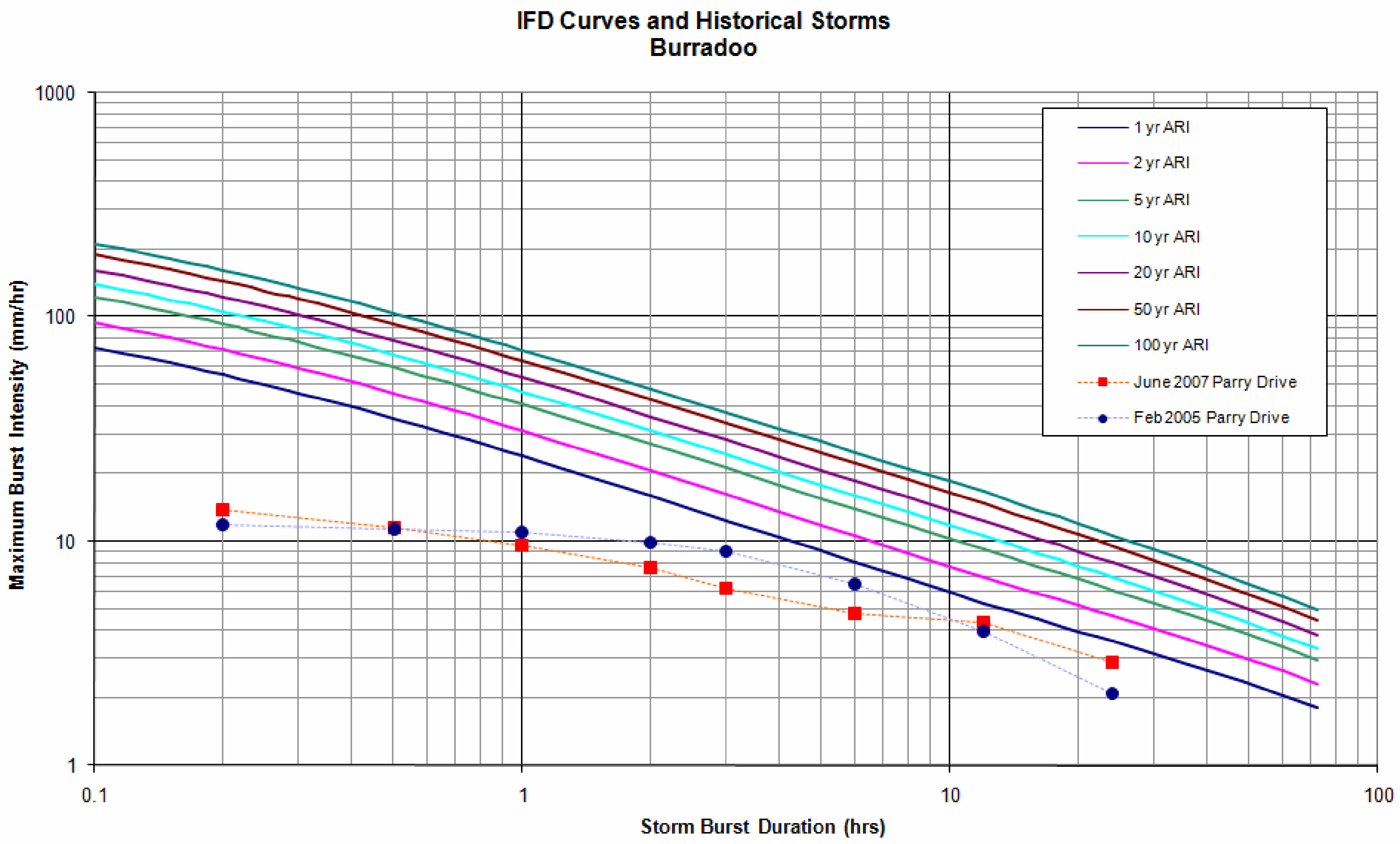

FIGURE 5.7
February 2005 And June 2007 - Rainfall IFD Data

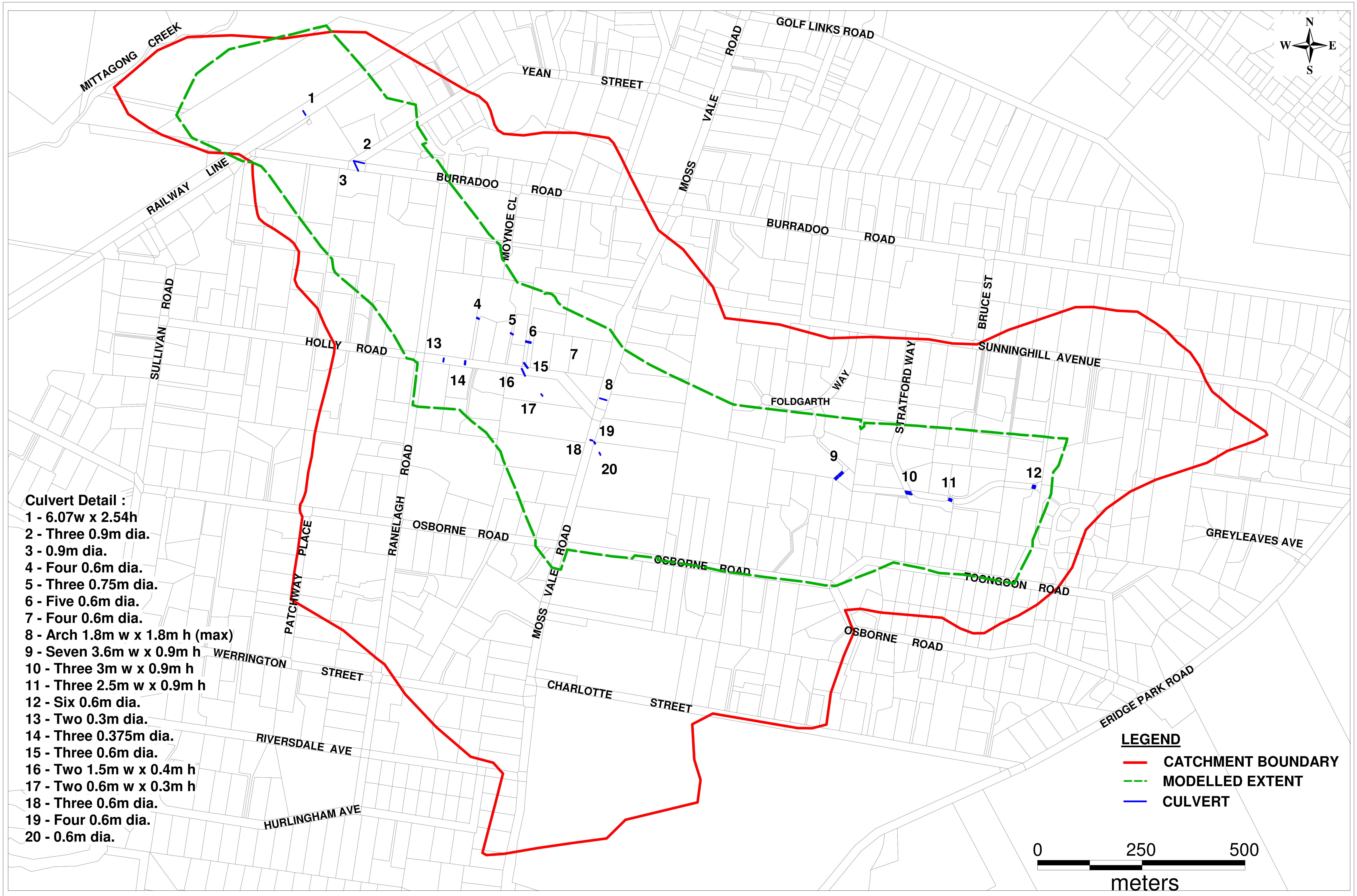

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FIGURE 6.1
HYDRAULIC MODEL 1D ELEMENTS

J2575\Mapinfo\Figure 6.1 1D Elements.Wor

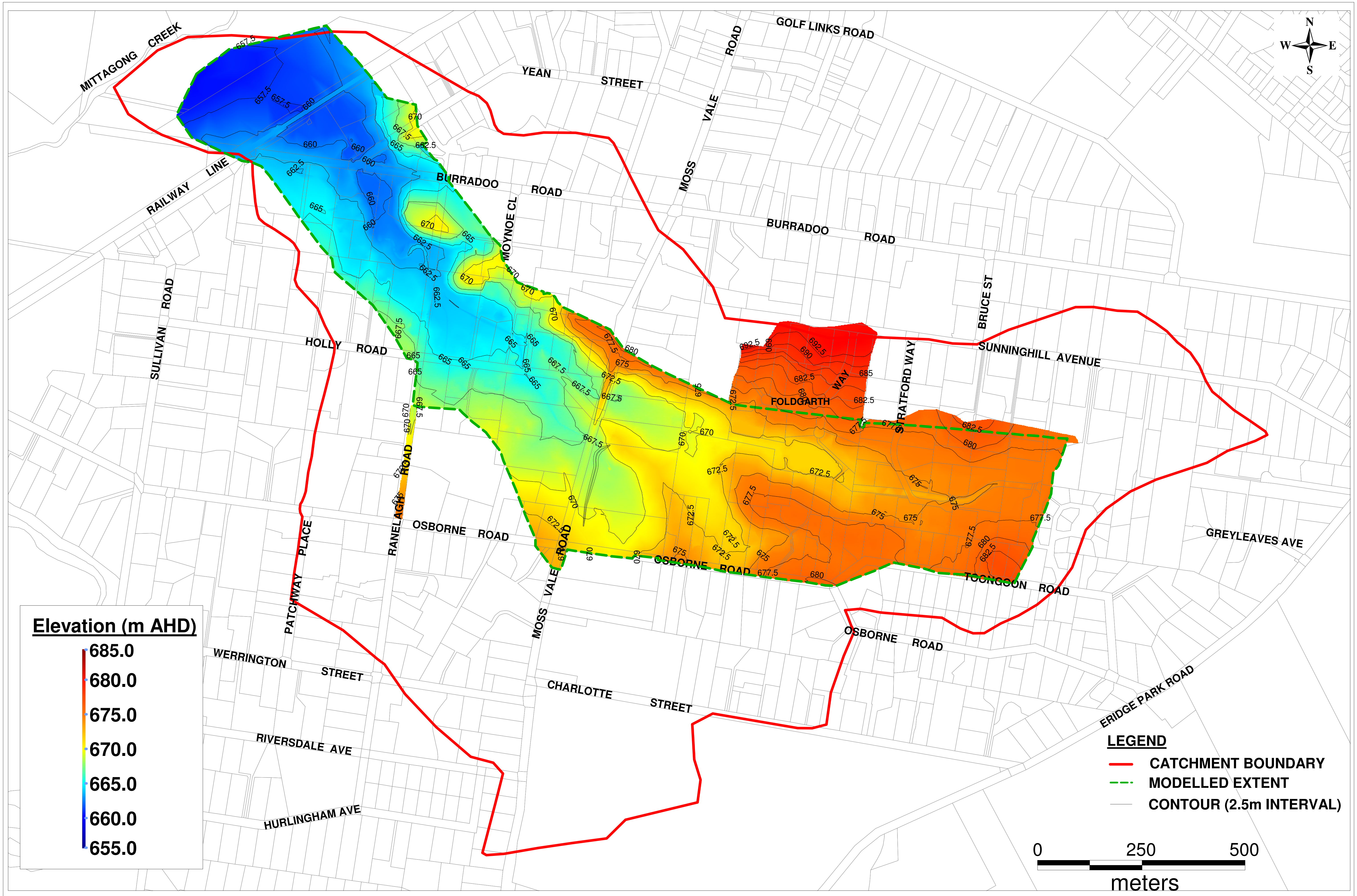

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FIGURE 6.2
MODEL ELEVATIONS

J2575\Mapinfo\Figure 6.2 Elevations.Wor

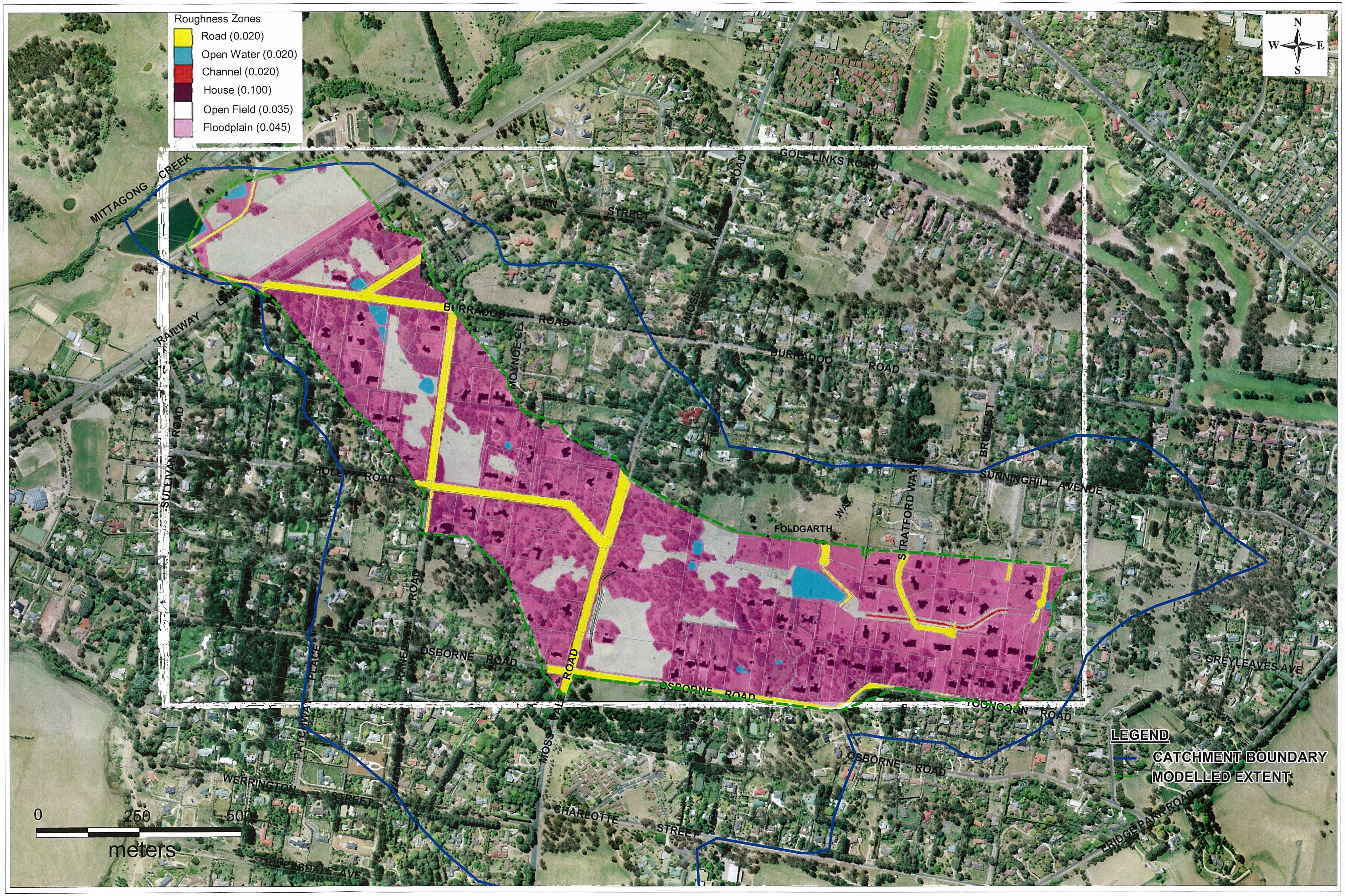

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FIGURE 6.3
MODEL HYDRAULIC ROUGHNESS

J2575\Mapinfo\Figure 6.3 Model Roughness.Wor

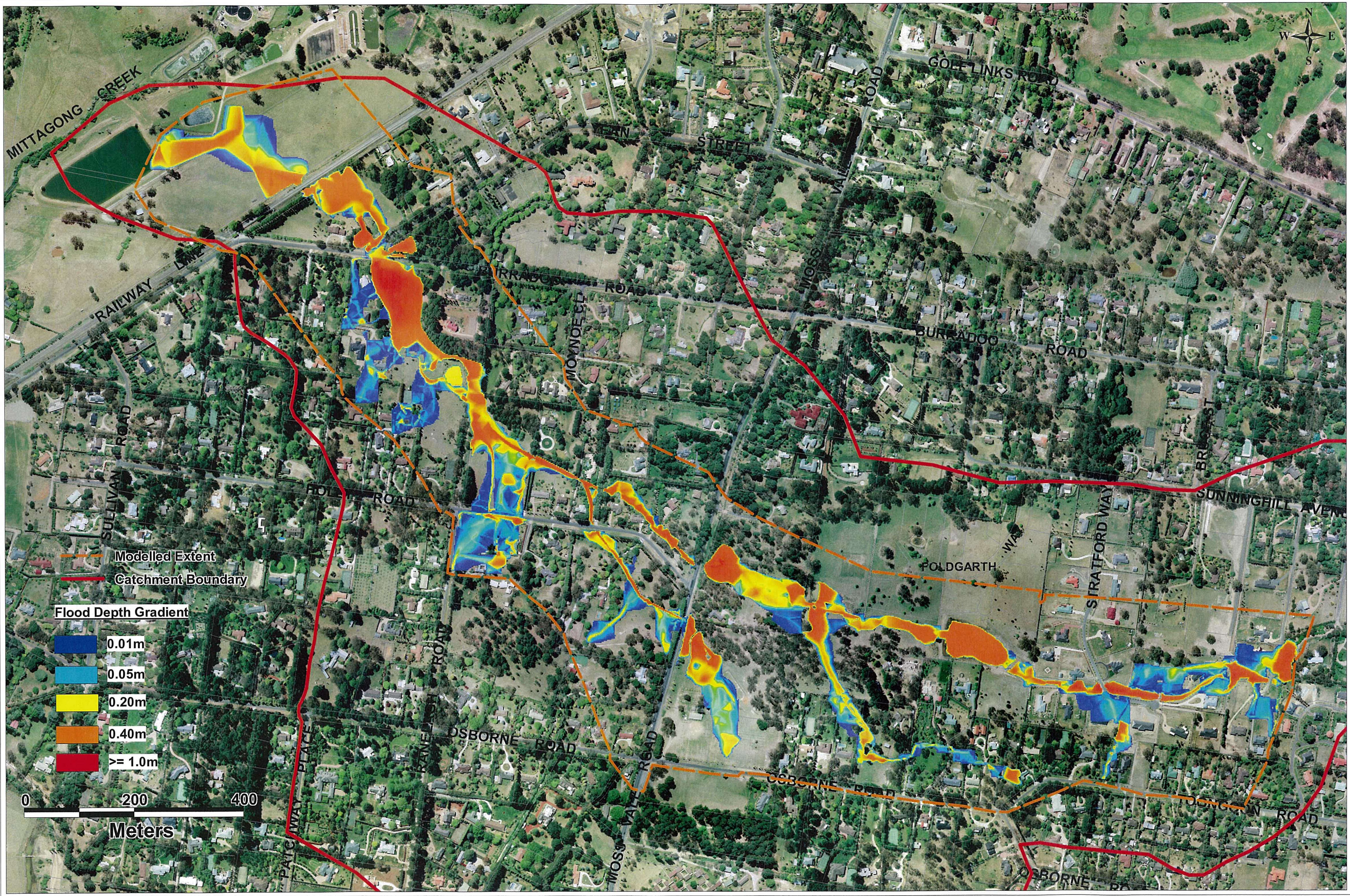

FIGURE 6.4
JUNE 2007 FLOOD EVENT

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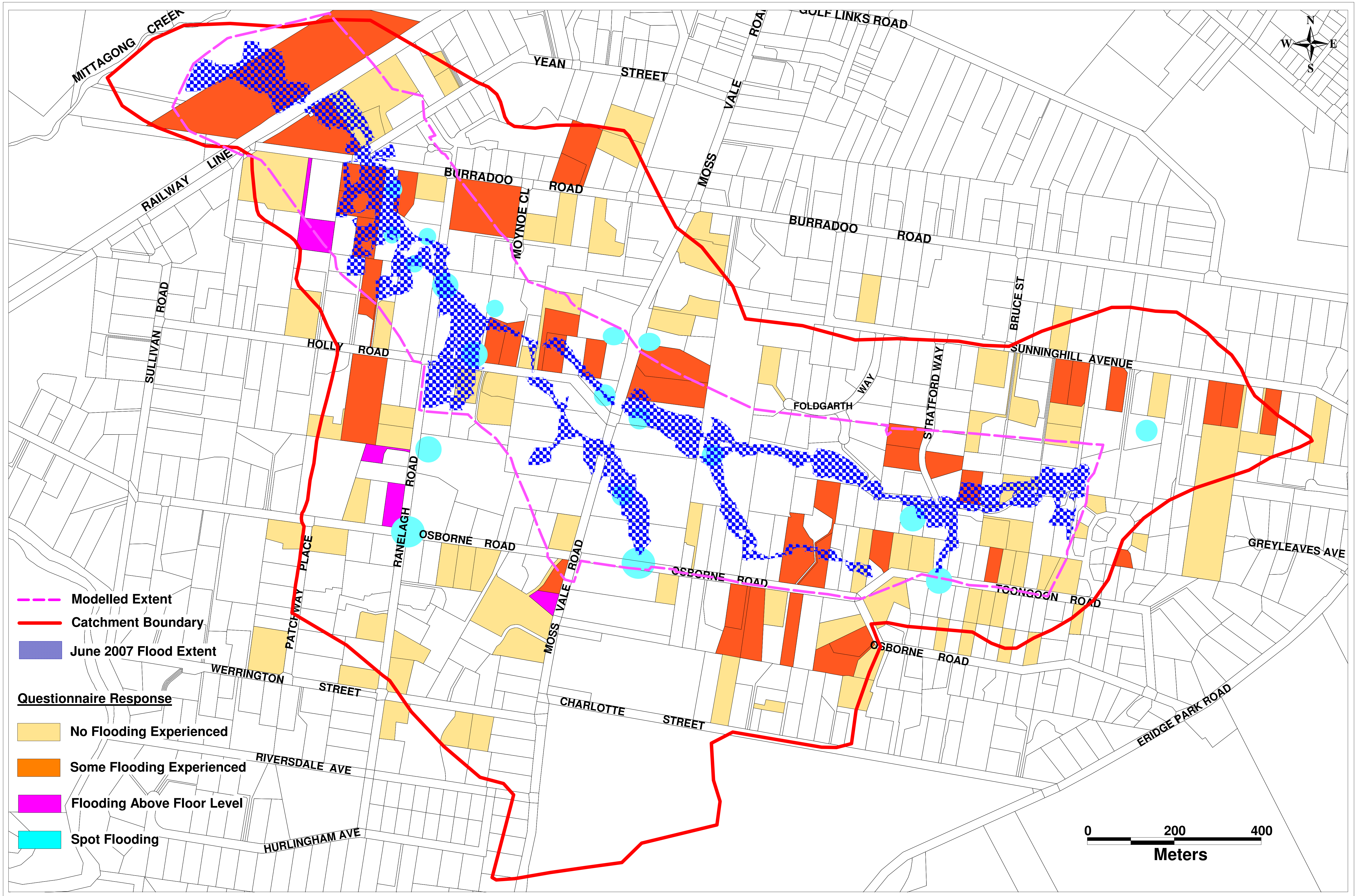

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FIGURE 6.5
Comparison of Community Responses with Modelled Results for the June 2007 Event.
Mapinfo\Report figures May 2009\Figure6_5 June07 Questionnaire.wor

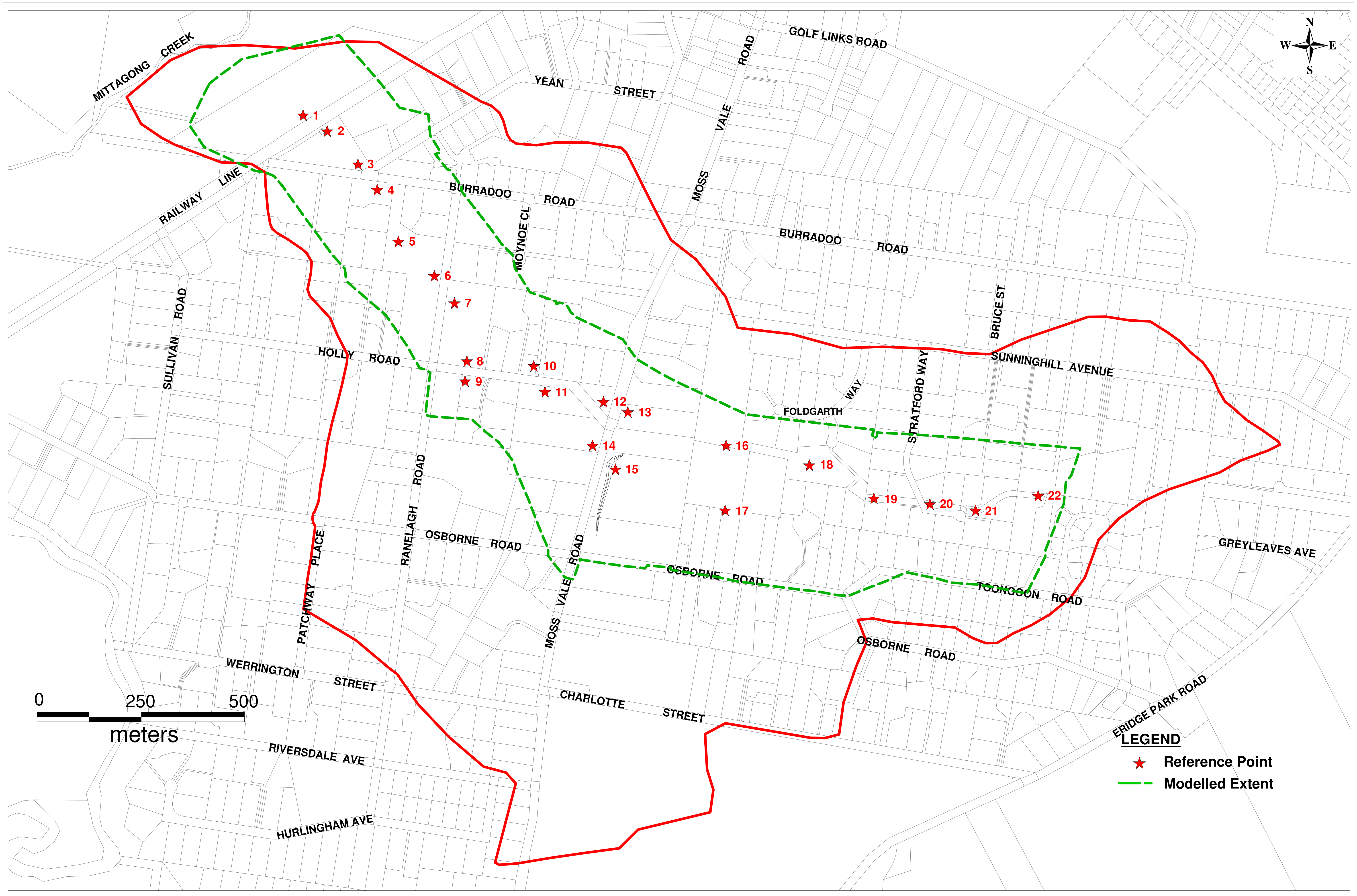

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FIGURE 6.6
HYDRAULIC MODEL REFERENCE POINTS

J2575\Mapinfo\Figure 6.6.Wor

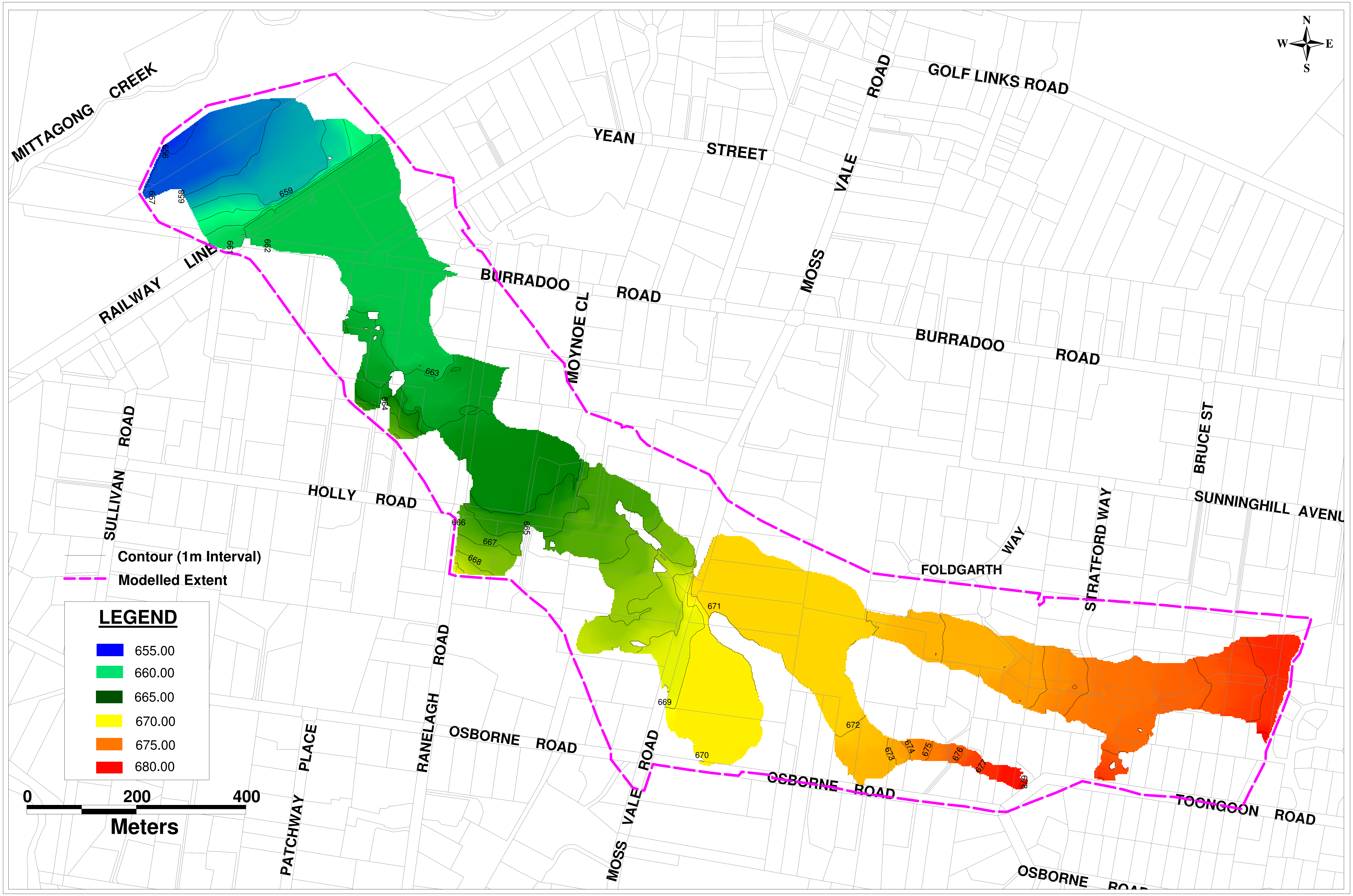

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FIGURE 7.1
PMF_PeakWaterLevel

J2575\Mapinfo\Report figures May 2009\Figure7_1 PMF WL.WOR

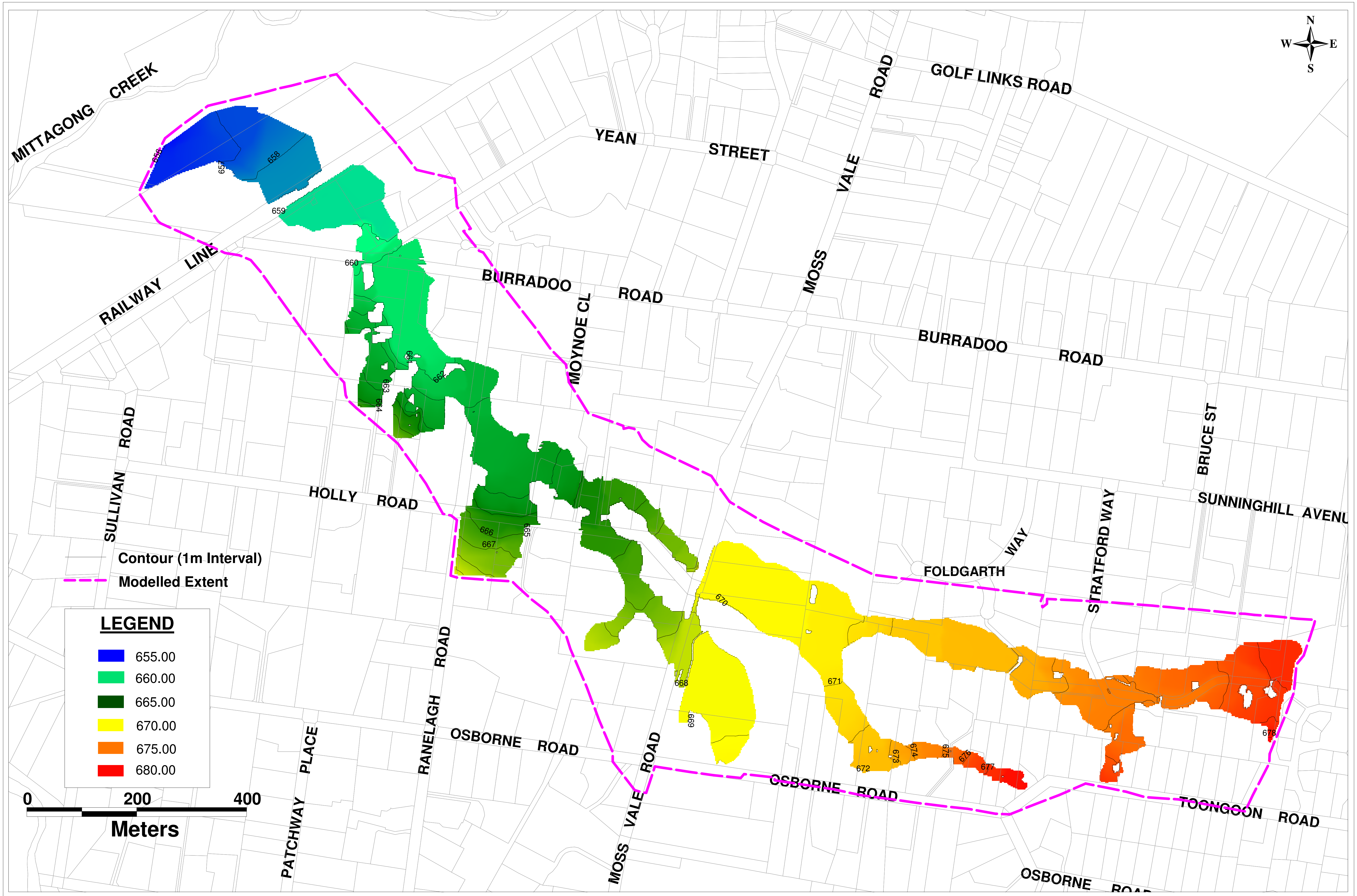

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FIGURE 7.2
100YearARI_PeakWaterLevel

J2575\Mapinfo\Report figures May 2009\Figure7_2 100yrARI WL.WOR

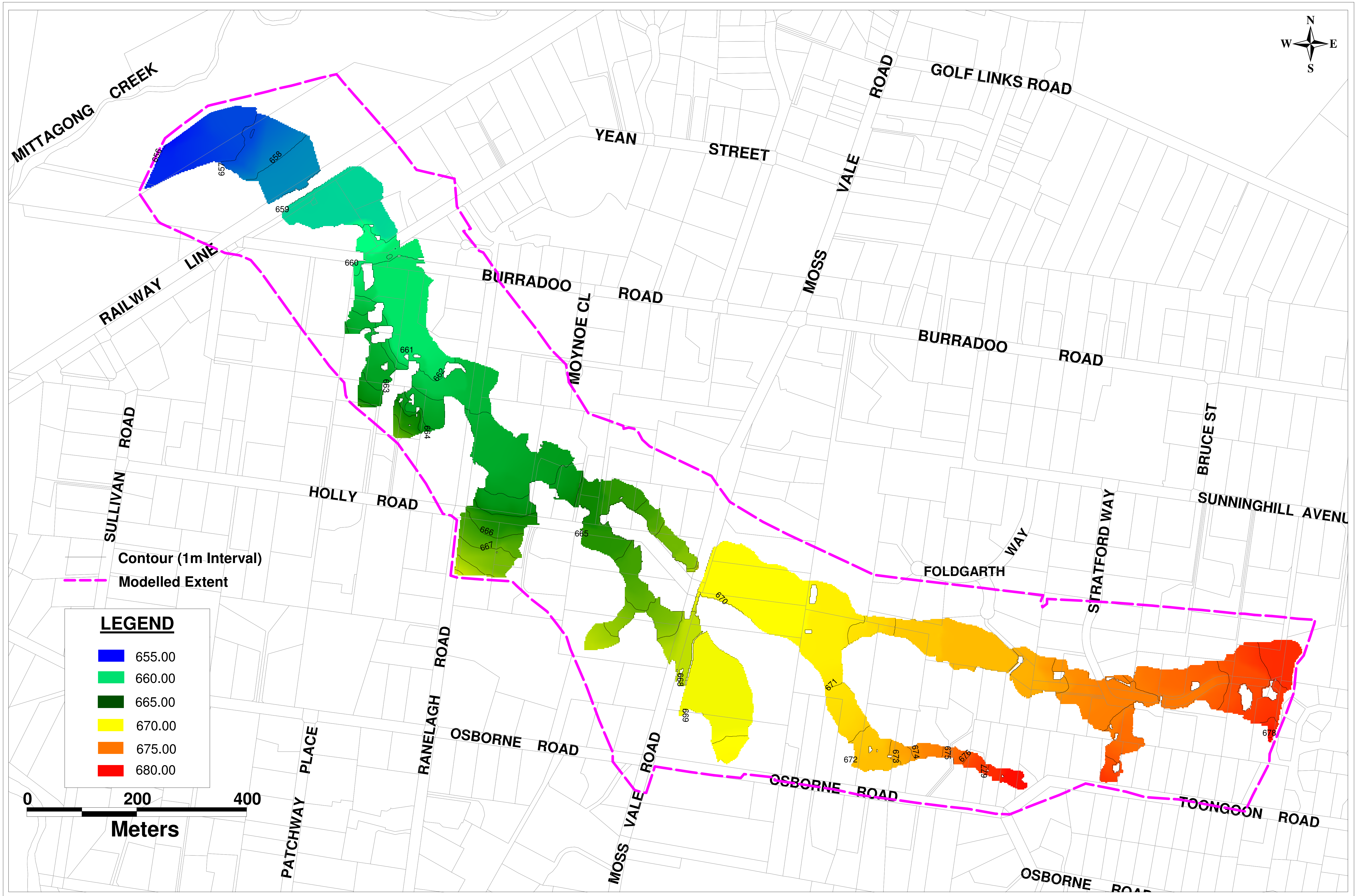

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FIGURE 7.3
50YearARI_PeakWaterLevel

J2575\Mapinfo\Report figures May 2009\Figure7_3 50yrARI WL.WOR

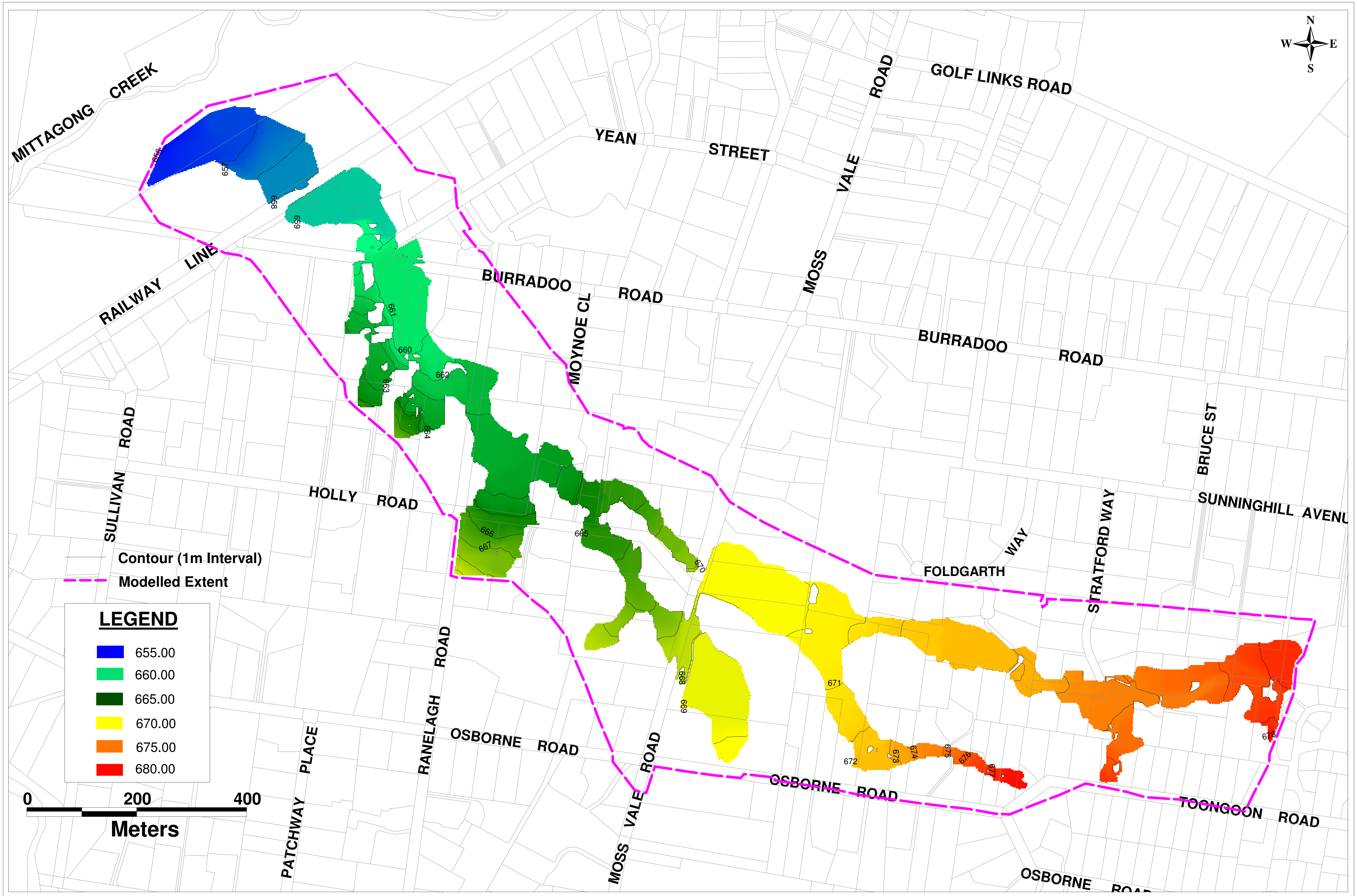

FIGURE 7.4
20YearARI_PeakWaterLevel

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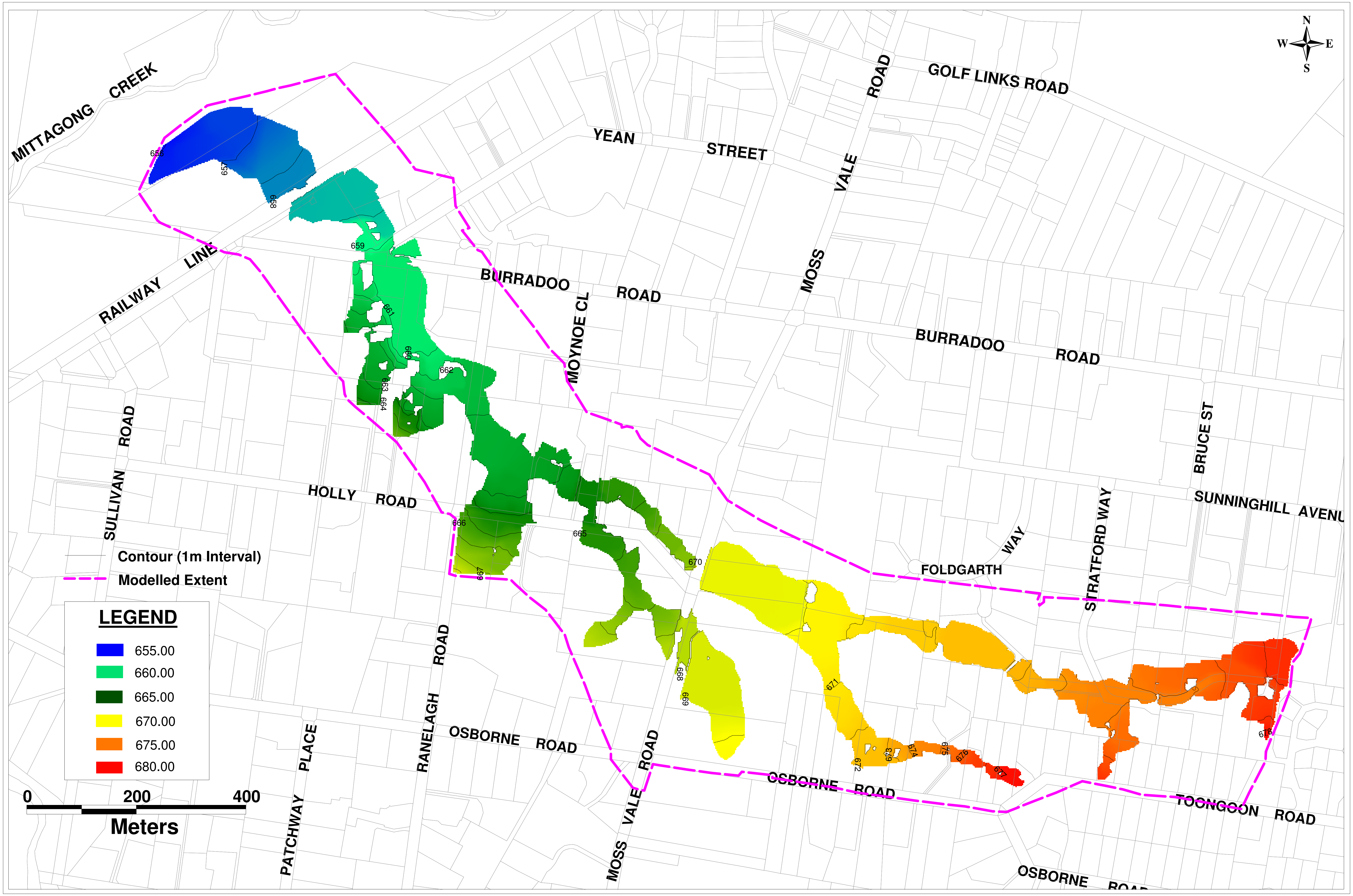

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FIGURE 7.5
5YearARI_PeakWaterLevel
J2575\Mapinfo\Report figures May 2009\Figure7_5 5yrARI WL.WOR

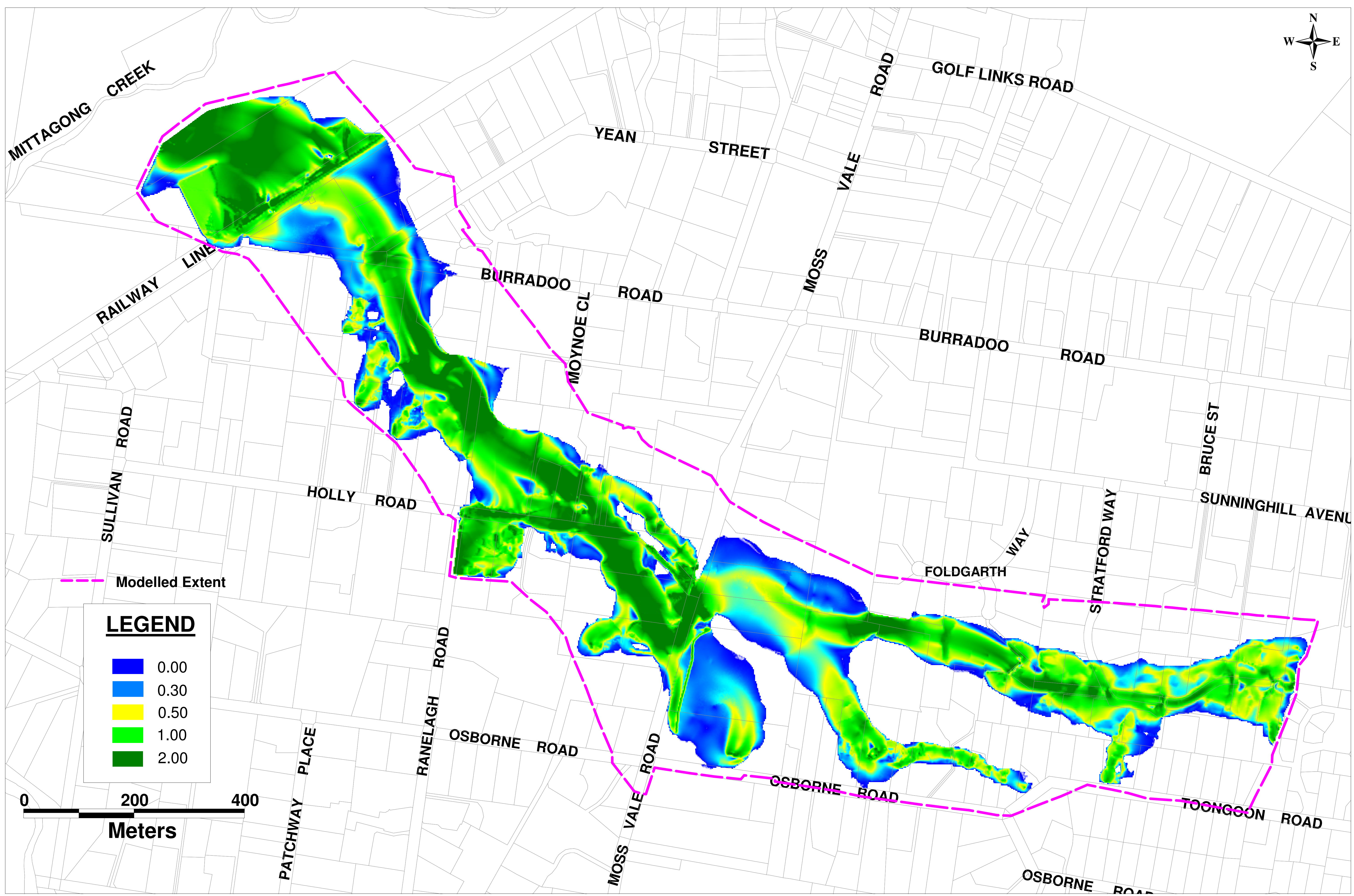

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FIGURE 7.6
PMF_PeakVelocity

J2575\Mapinfo\Report figures May 2009\Figure7_6 PMF Velocity.WOR

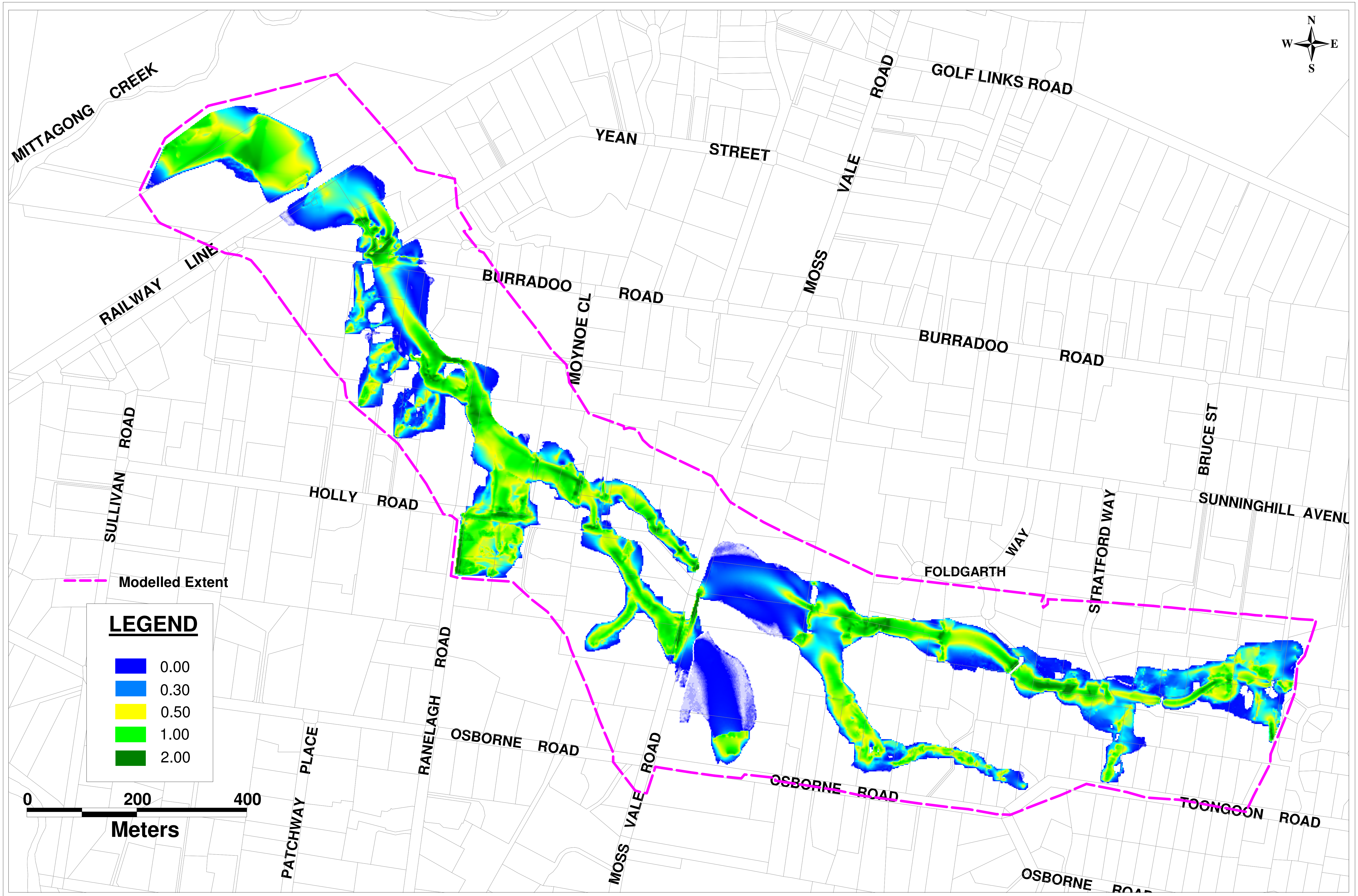

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FIGURE 7.7
100YearARI_PeakVelocity

J2575\Mapinfo\Report figures May 2009\Figure7_7 100yrARI Velocity.WOR

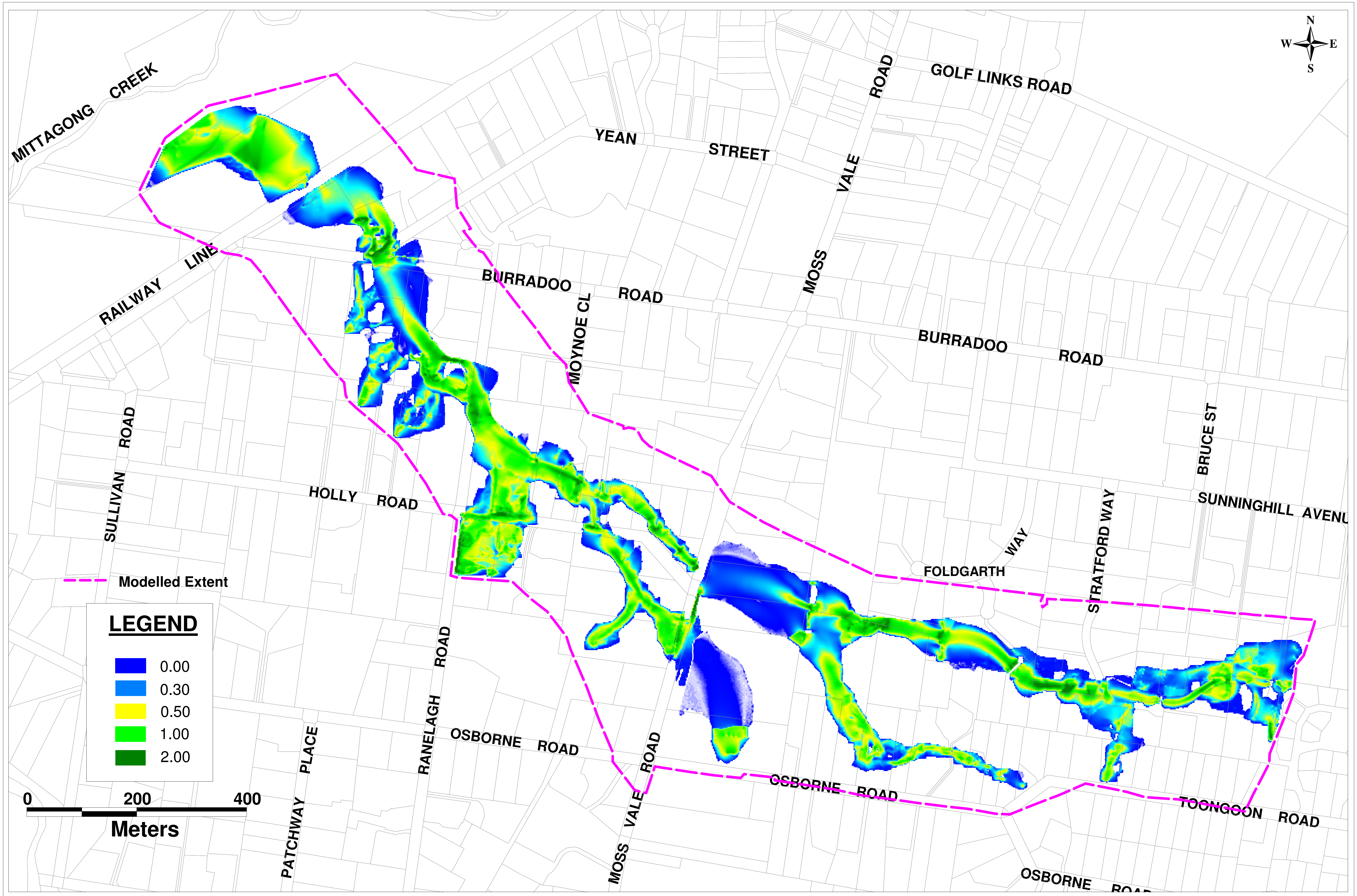

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FIGURE 7.8
50YearARI_PeakVelocity

J2575\Mapinfo\Report figures May 2009\Figure7_8 50yrARI Velocity.WOR

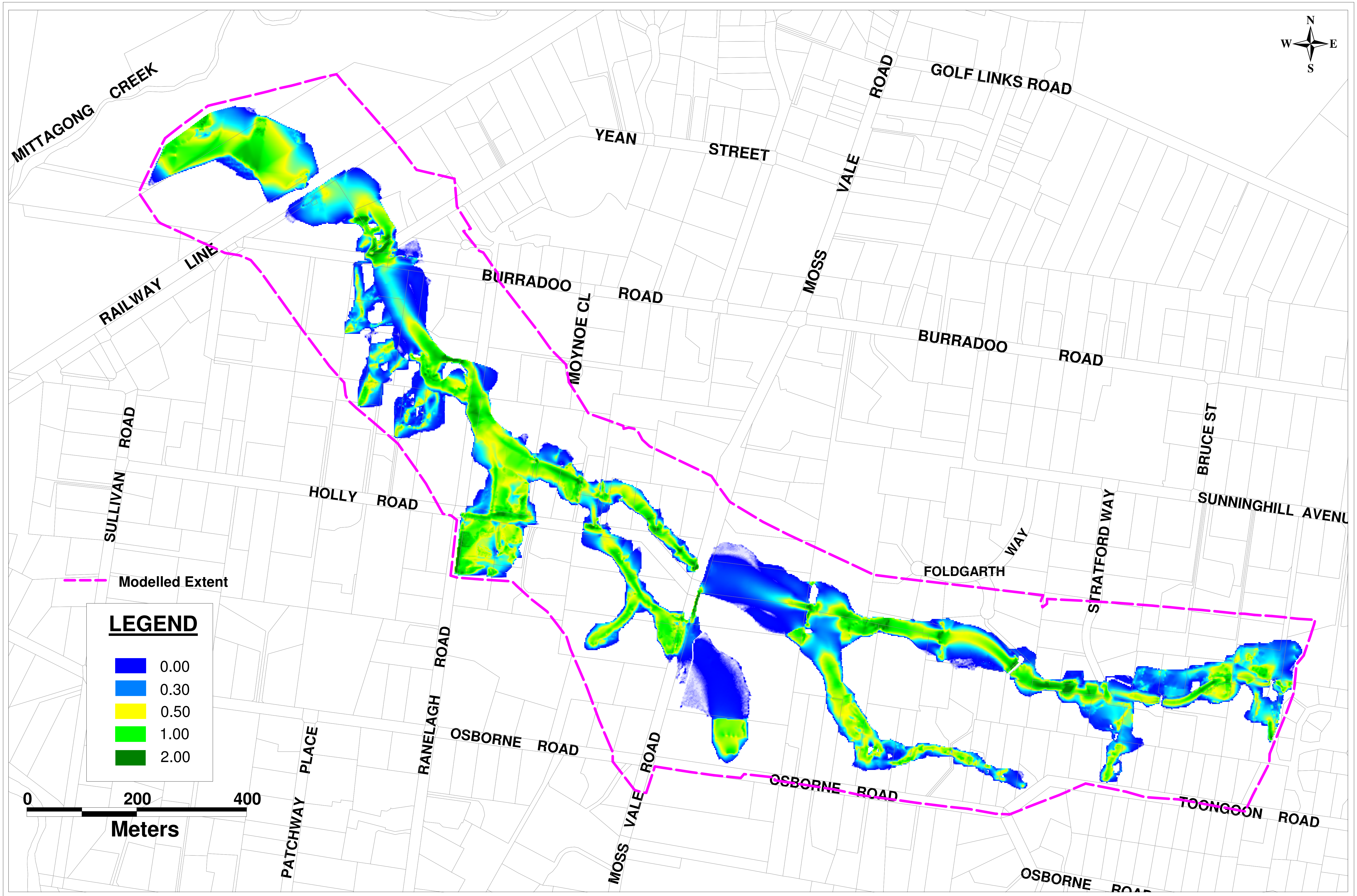

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FIGURE 7.9
20YearARI_PeakVelocity
J2575\Mapinfo\Report figures May 2009\Figure7_9 20yrARI Velocity.WOR

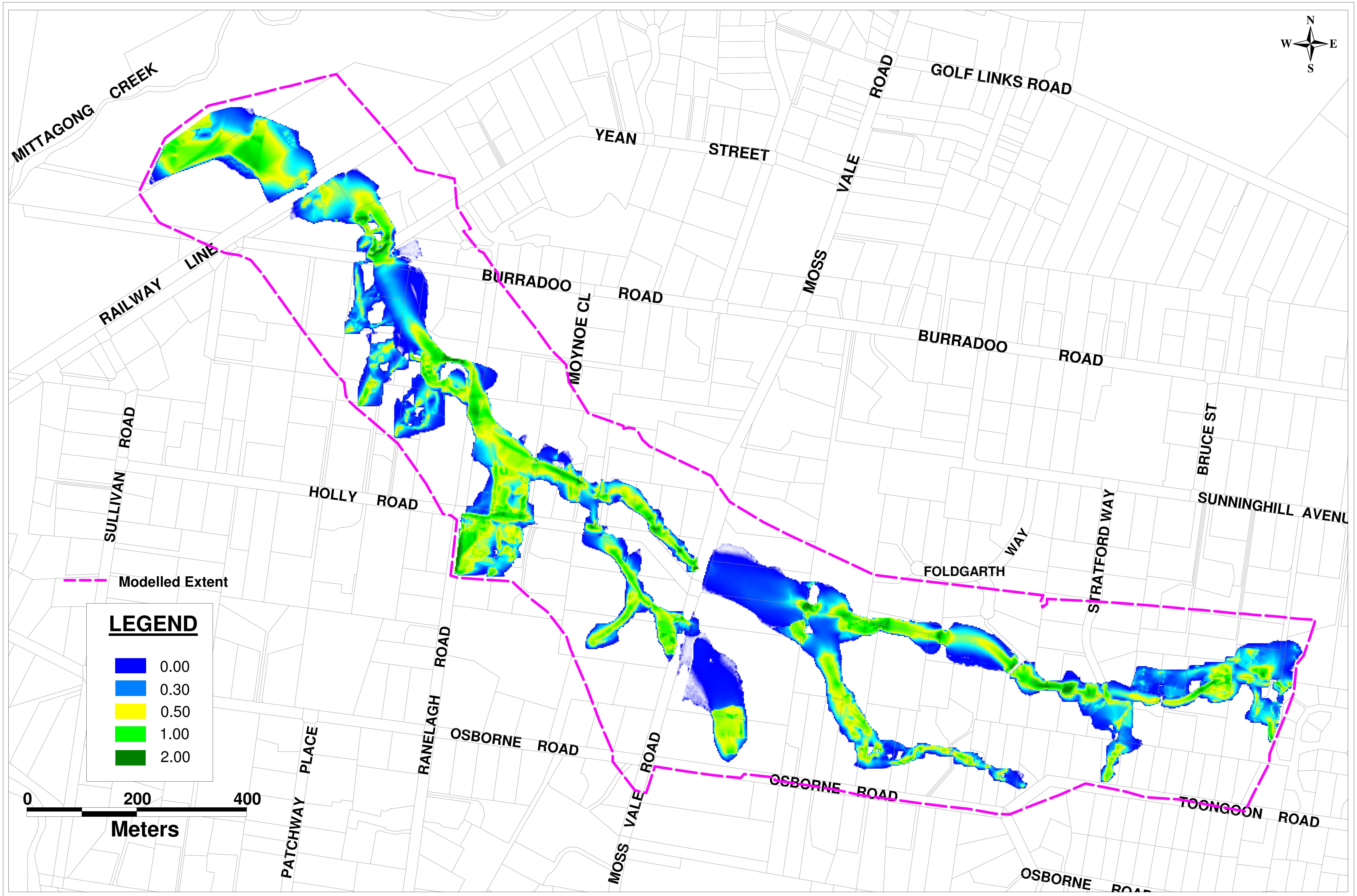

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FIGURE 7.10
5YearARI_PeakVelocity

J2575\Mapinfo\Report figures May 2009\Figure7_10 5yrARI Velocity.WOR

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FIGURE 7.11
Longitudinal Profile Lines (100y ARI Extent)
J2575\Mapinfo\Report figures May 2009\Figure7_11 Longitudinal Profiles.WOR

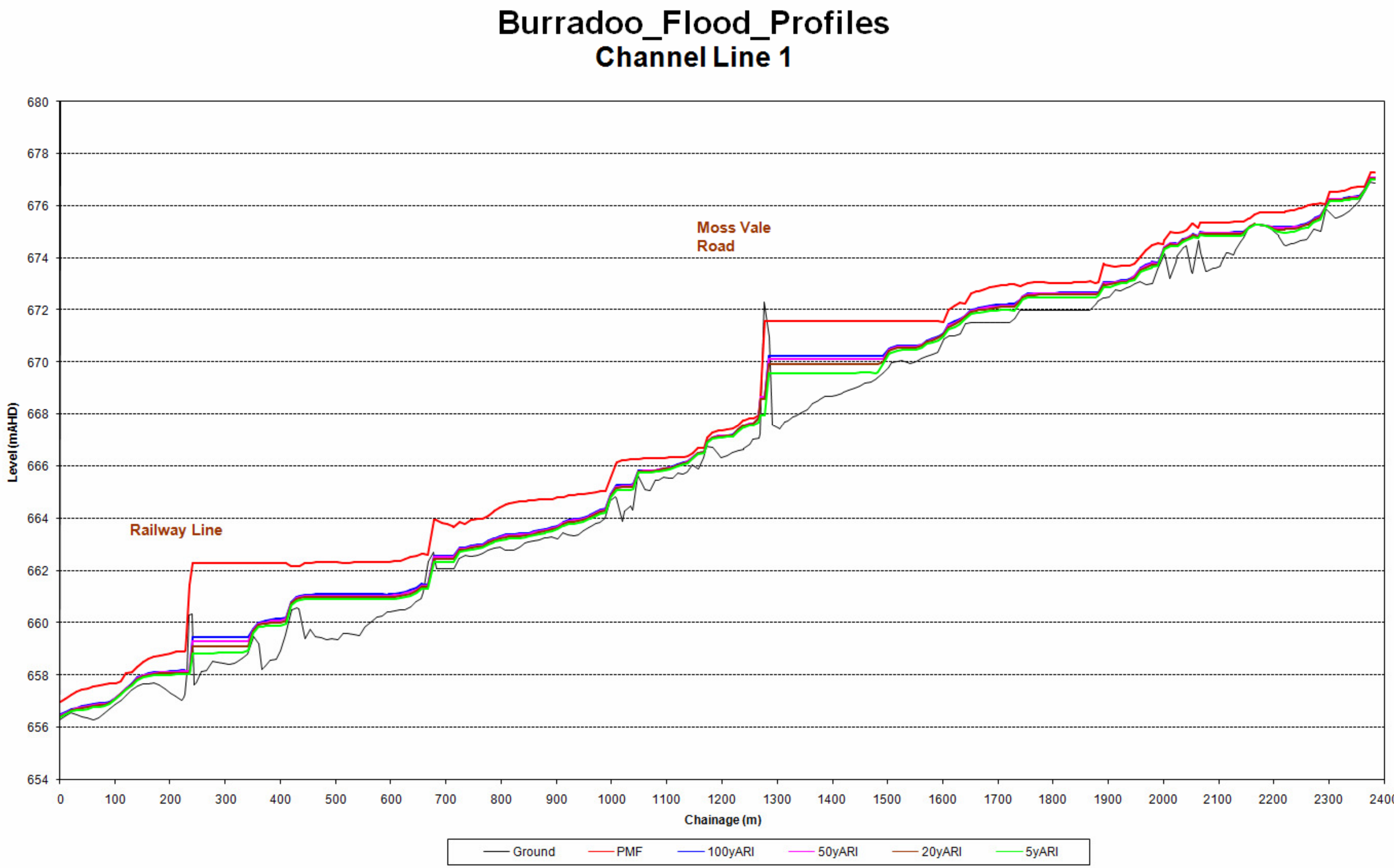

FIGURE 7.12
Longitudinal Profile – Line 1

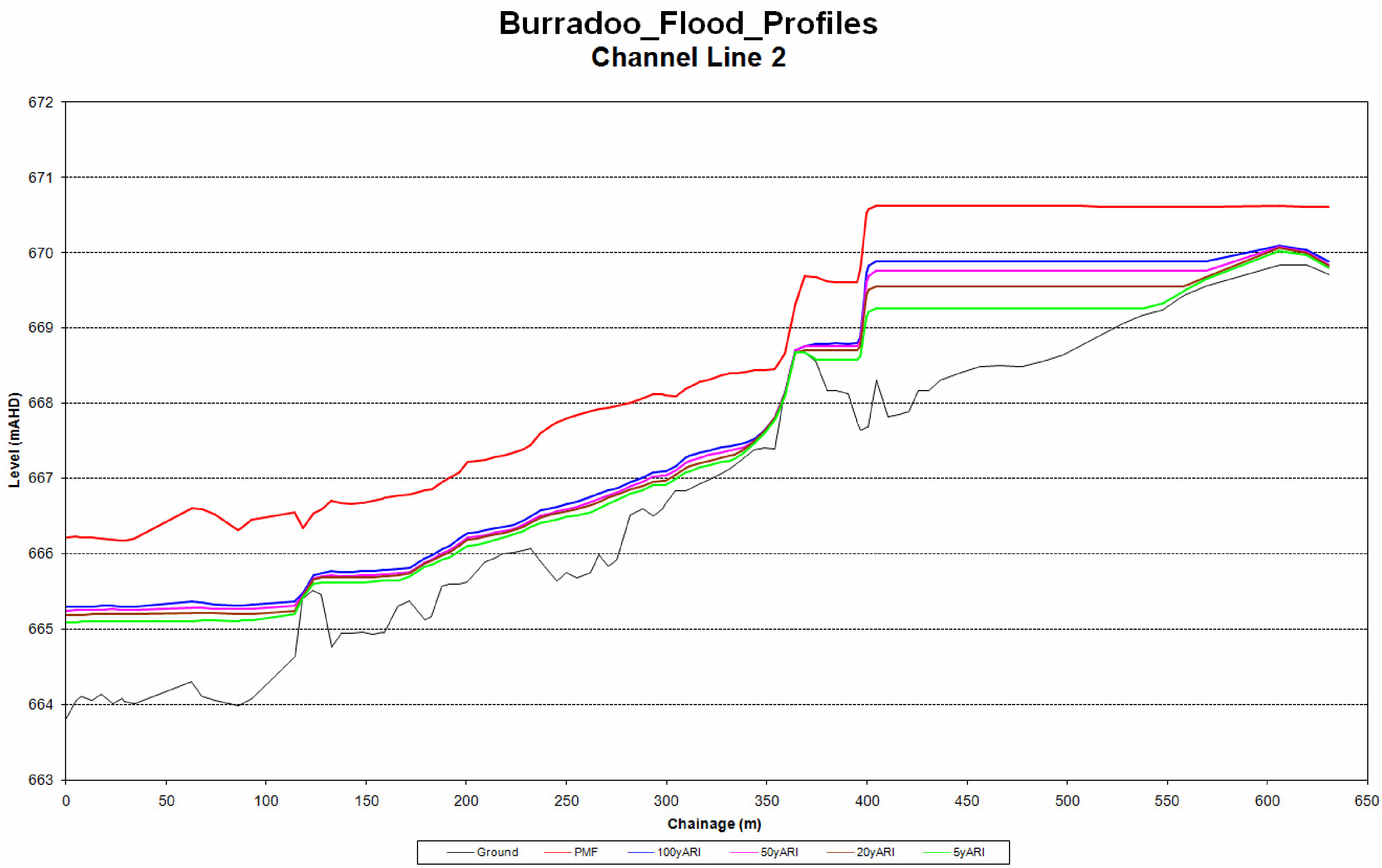

FIGURE 7.13
Longitudinal Profile – Line 2

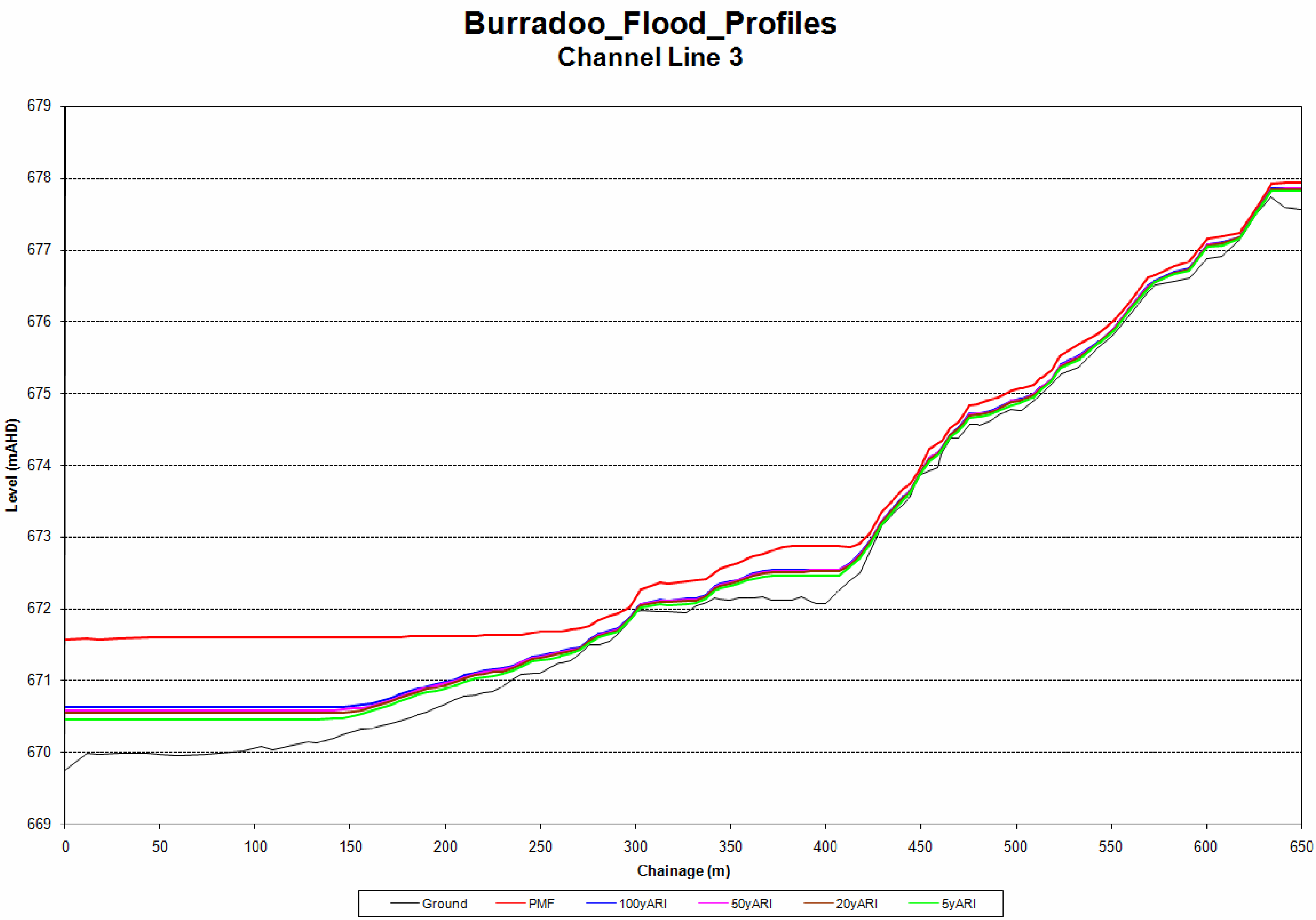

FIGURE 7.14
Longitudinal Profile – Line 3

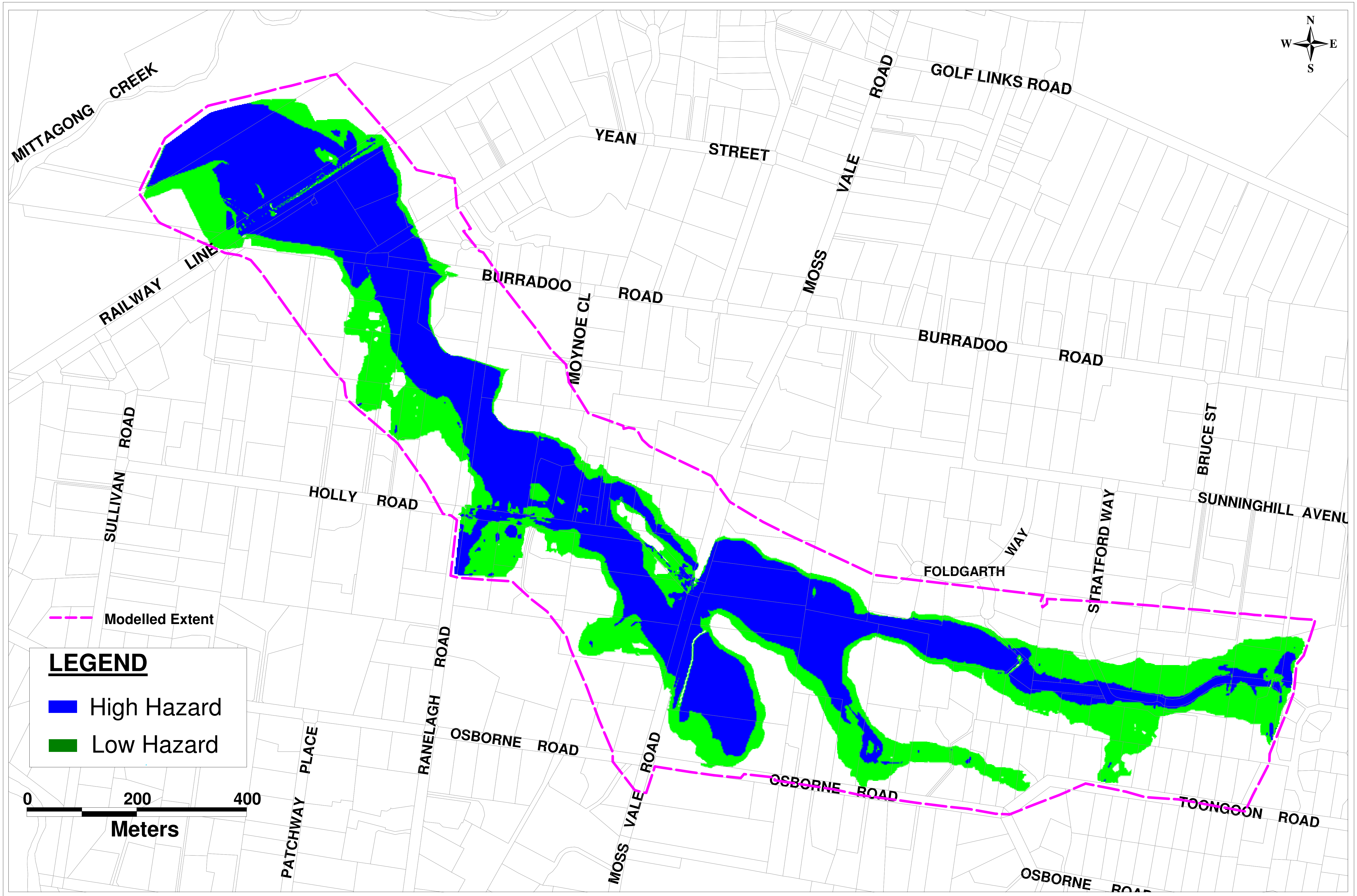

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FIGURE 9.2

PMF_ProvisionalHazard

J2575\Mapinfo\Report figures May 2009\Figure9_2 PMF ProvisionalHazard.WOR

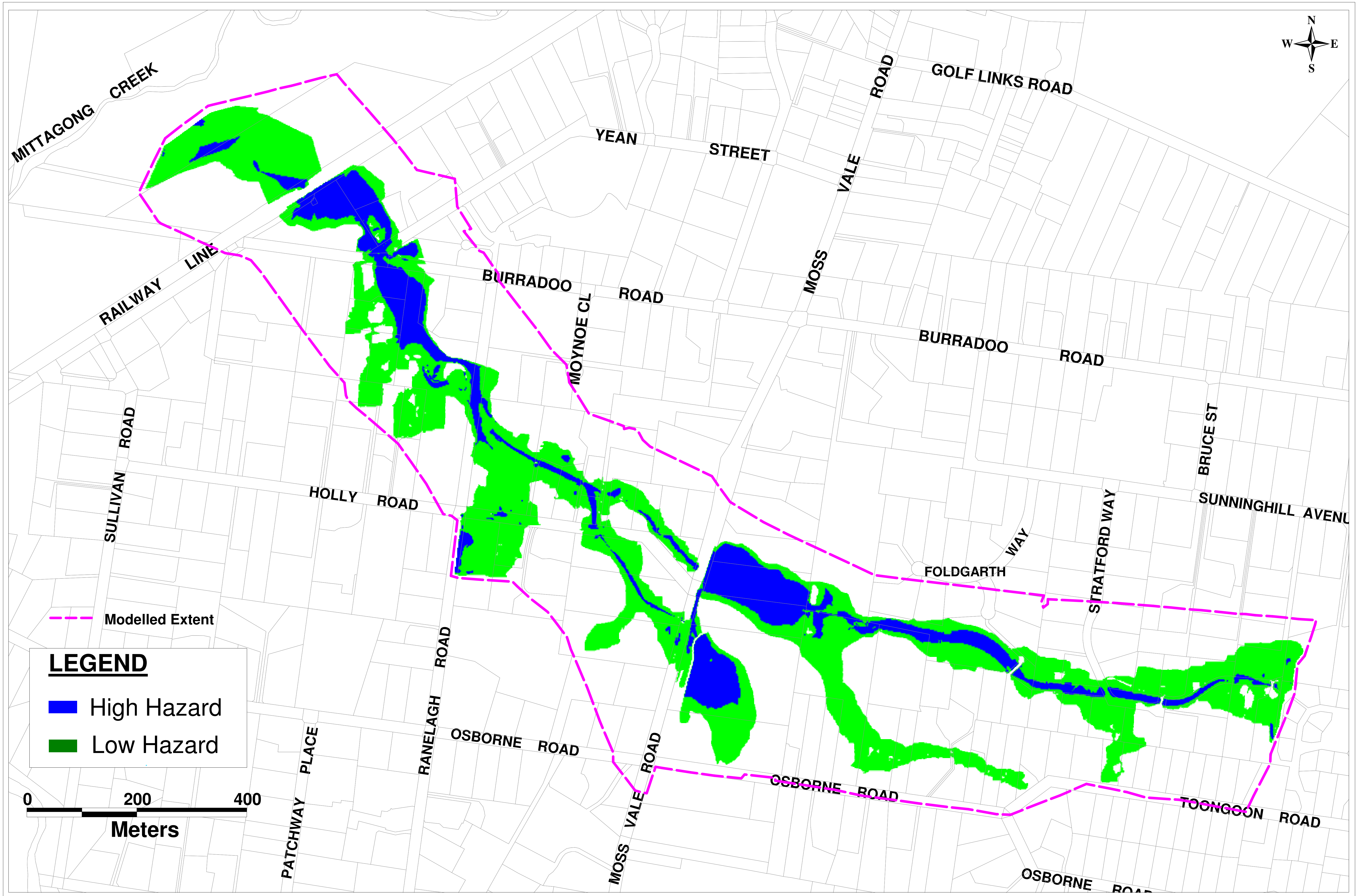

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FIGURE 9.3
100Year ARI_ProvisionalHazard

J2575\Mapinfo\Report figures May 2009\Figure9_3 100YearARI_ProvisionalHazard.WOR

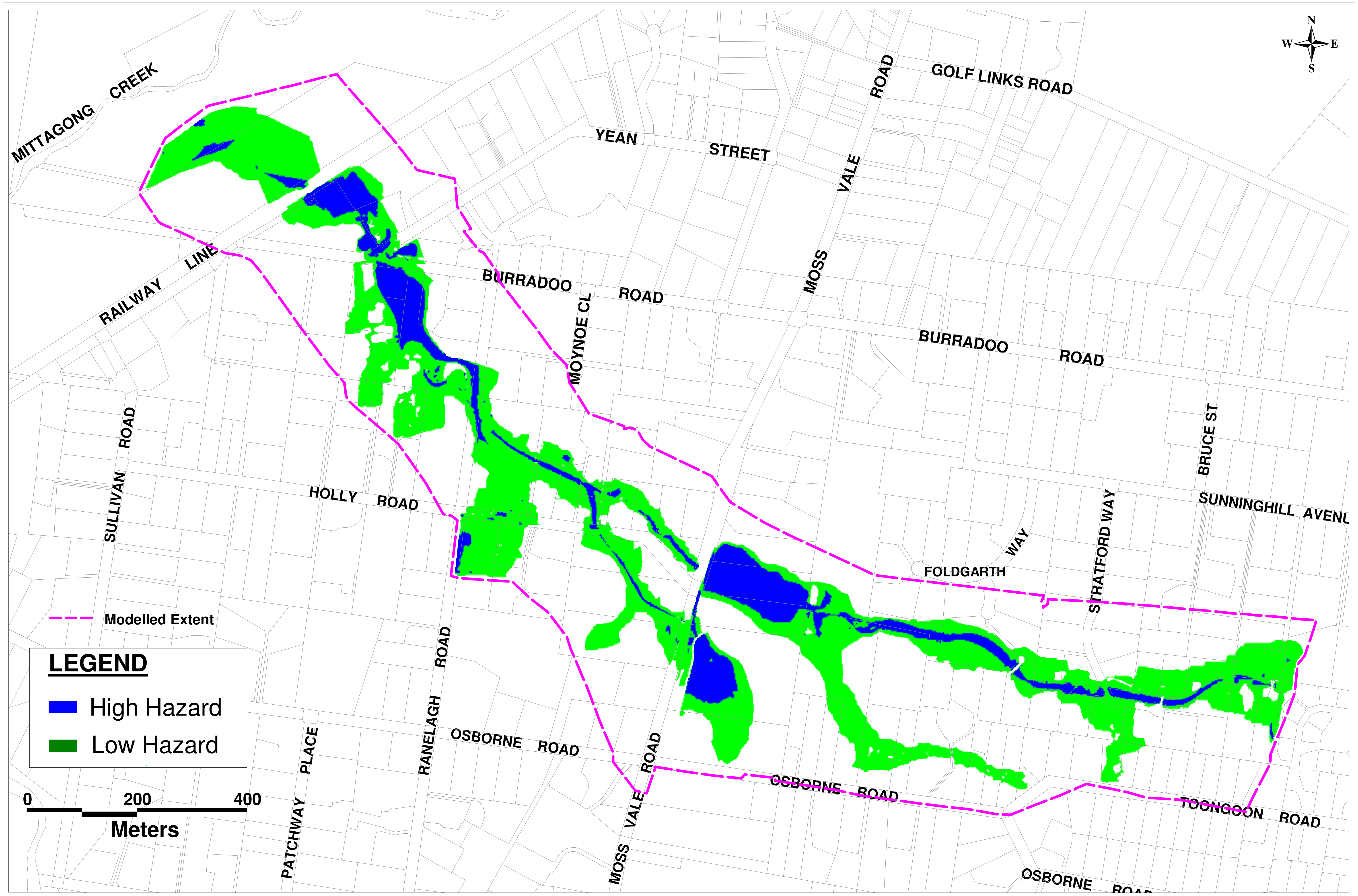

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FIGURE 9.4
50Year ARI_ProvisionalHazard

J2575\Mapinfo\Report figures May 2009\Figure9_4 50YearARI_ProvisionalHazard.WOR

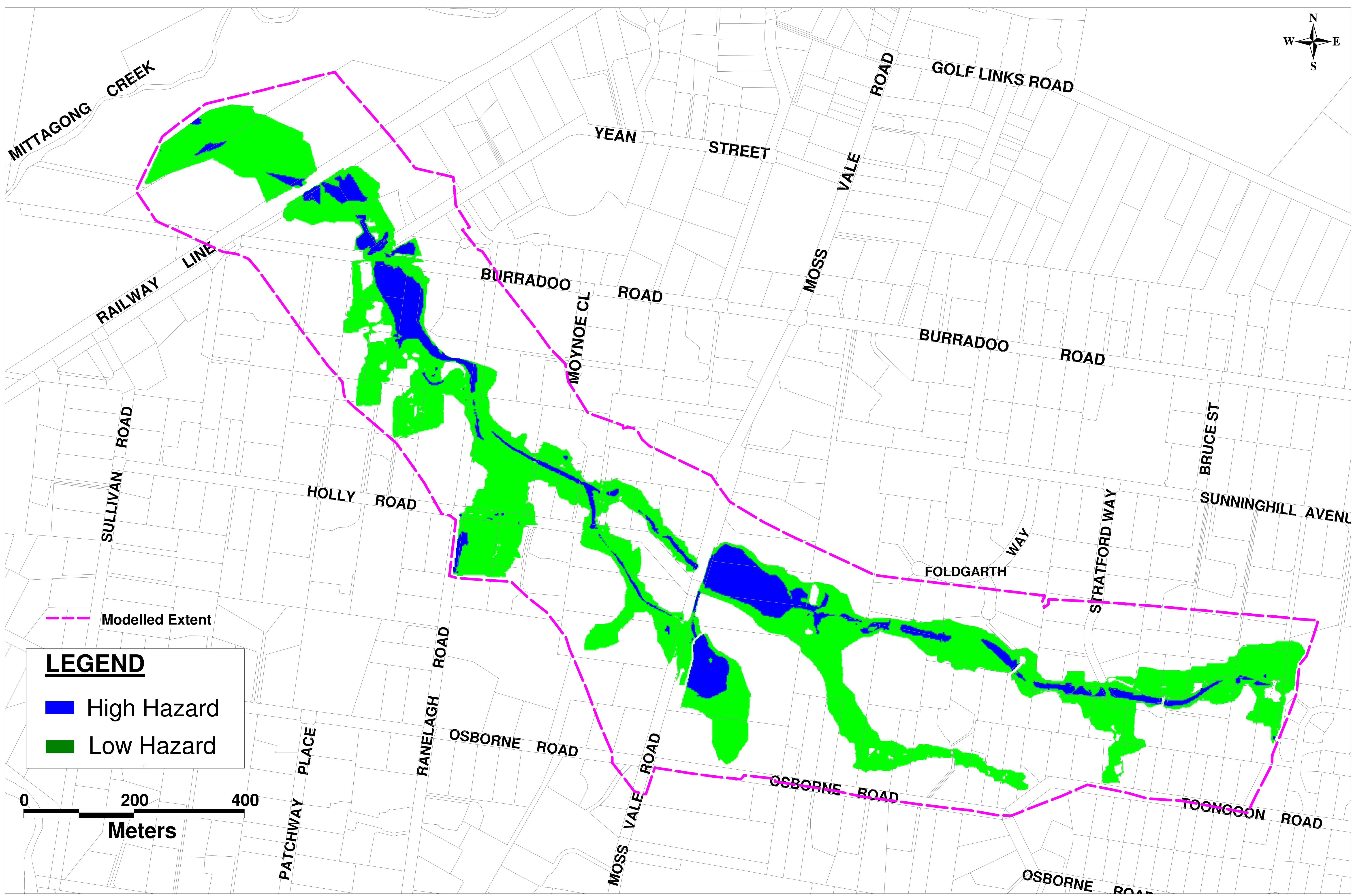

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FIGURE 9.5
20Year ARI_ProvisionalHazard

J2575\Mapinfo\Report figures May 2009\Figure9_5 20YearARI_ProvisionalHazard.WOR

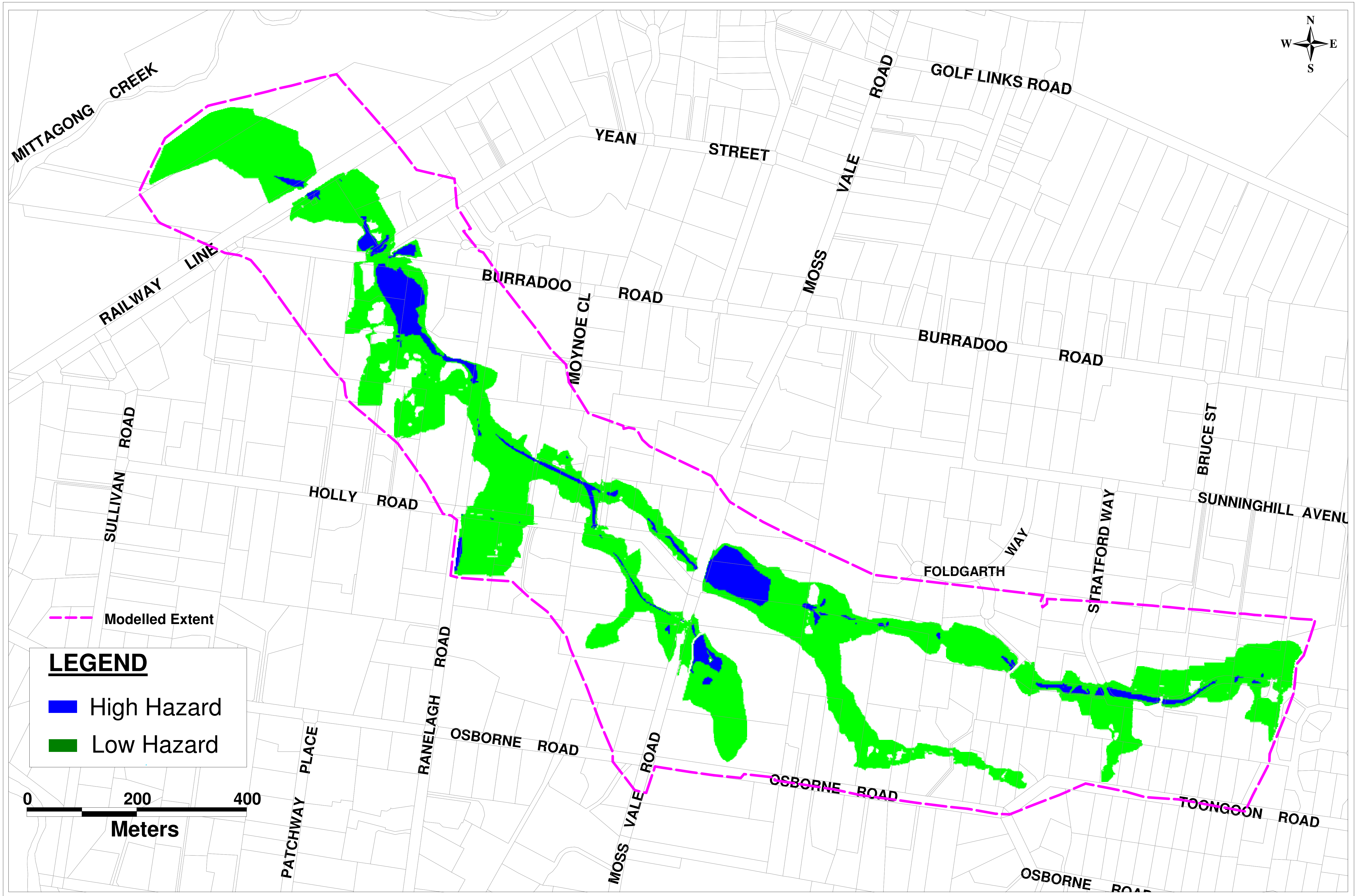

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FIGURE 9.6
5Year ARI_ProvisionalHazard

J2575\Mapinfo\Report figures May 2009\Figure9_6 5YearARI_ProvisionalHazard.WOR

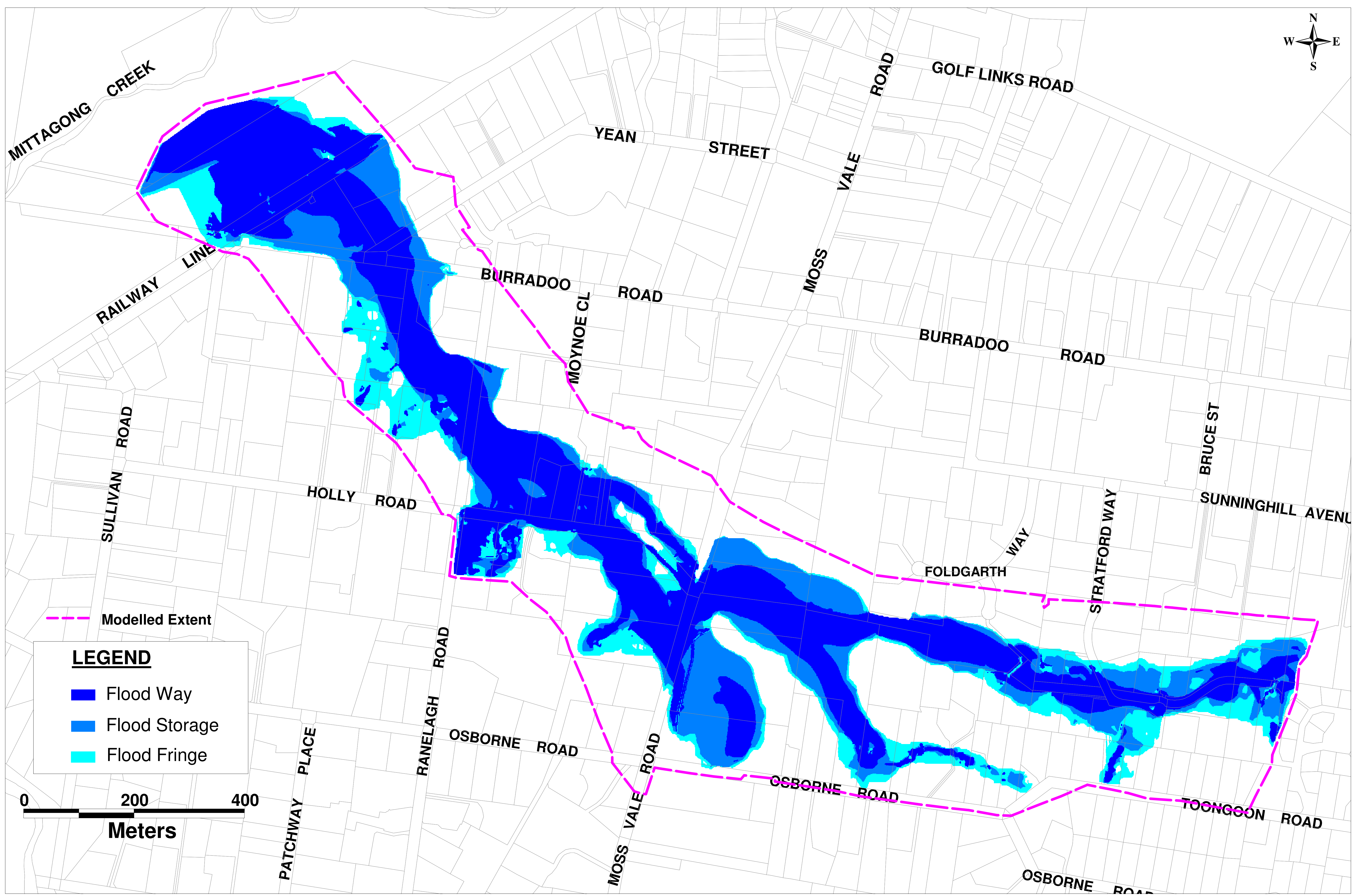

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FIGURE 10.1
PMF_Hydraulic Categories

J2575\Mapinfo\Report figures May 2009\Figure10_1 PMF_HydraulicCategories.WOR

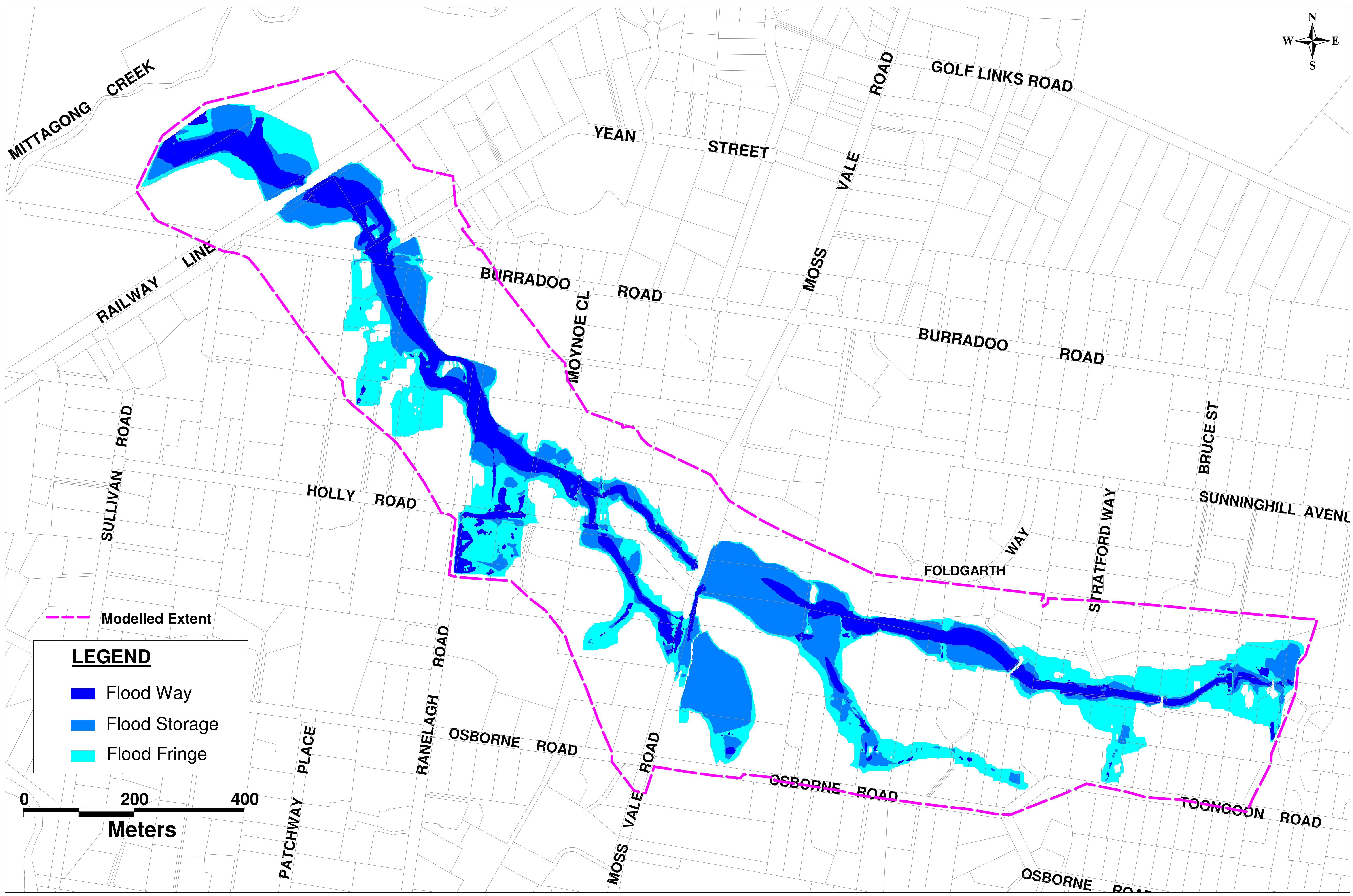

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FIGURE 10.2
100YearARI_Hydraulic Categories

J2575\Mapinfo\Report figures May 2009\Figure10_2 100YearARI_HydraulicCategories.WOR

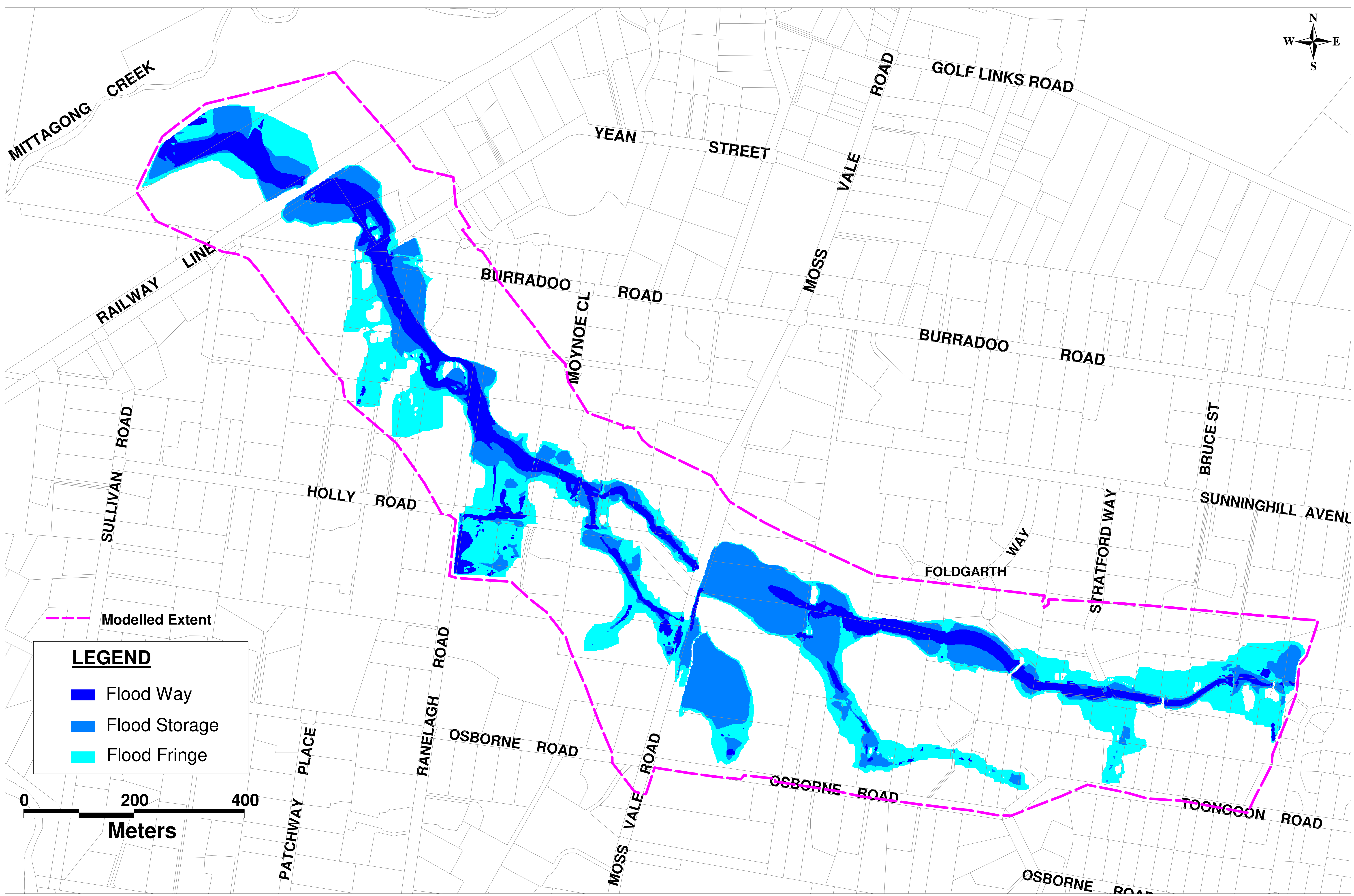

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FIGURE 10.3
50YearARI_Hydraulic Categories

J2575\Mapinfo\Report figures May 2009\Figure10_3 50YearARI_HydraulicCategories.WOR

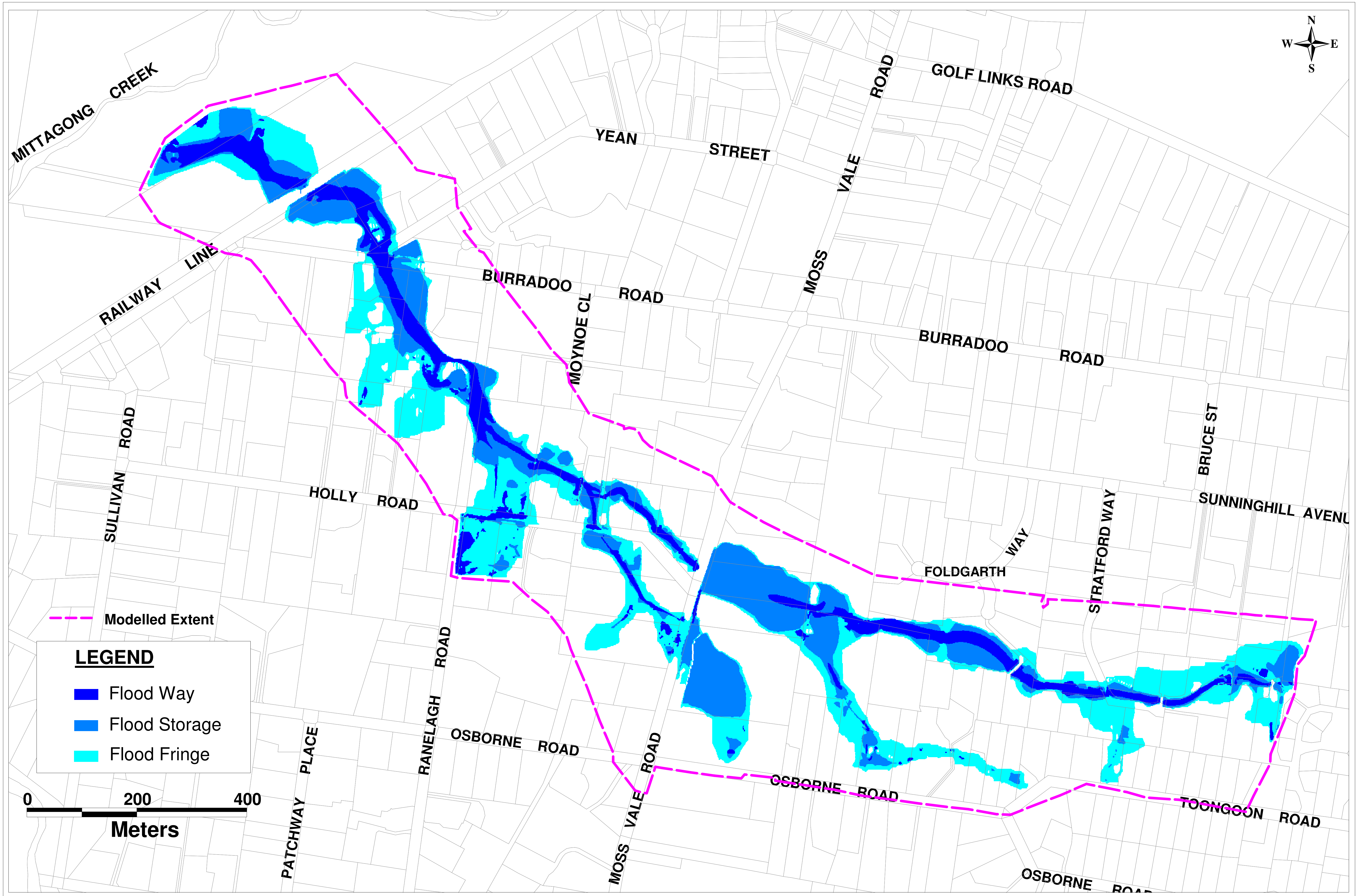

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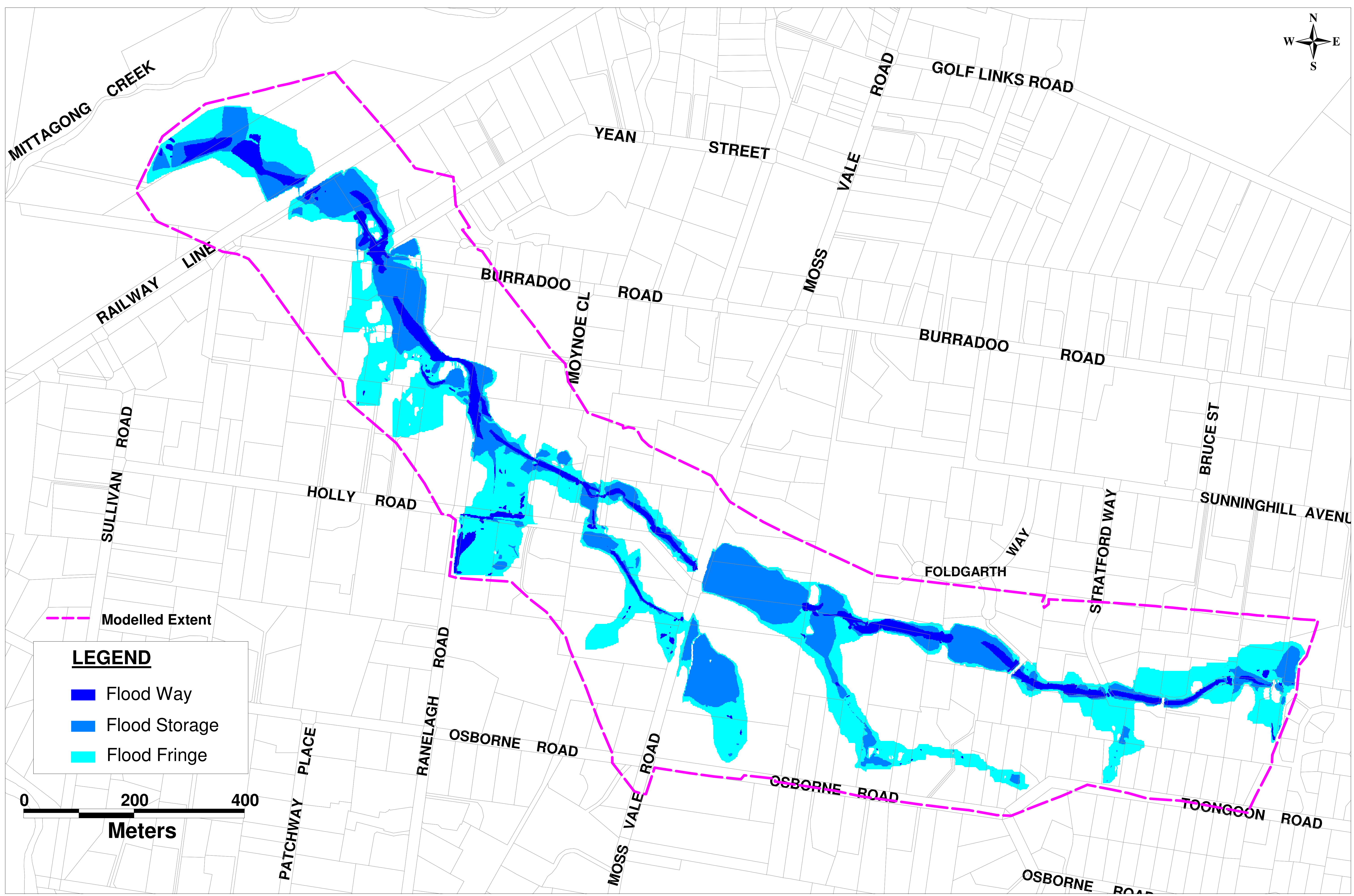
FIGURE 10.4
20YearARI_Hydraulic Categories

J2575\Mapinfo\Report figures May 2009\Figure10_4 20YearARI_HydraulicCategories.WOR



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J2575/V4
December 2009

FINAL

Burradoo BU2 Catchment Flood Study

FIGURE 10.5
5YearARI_Hydraulic Categories

J2575\Mapinfo\Report figures May 2009\Figure10_5 5YearARI_HydraulicCategories.WOR

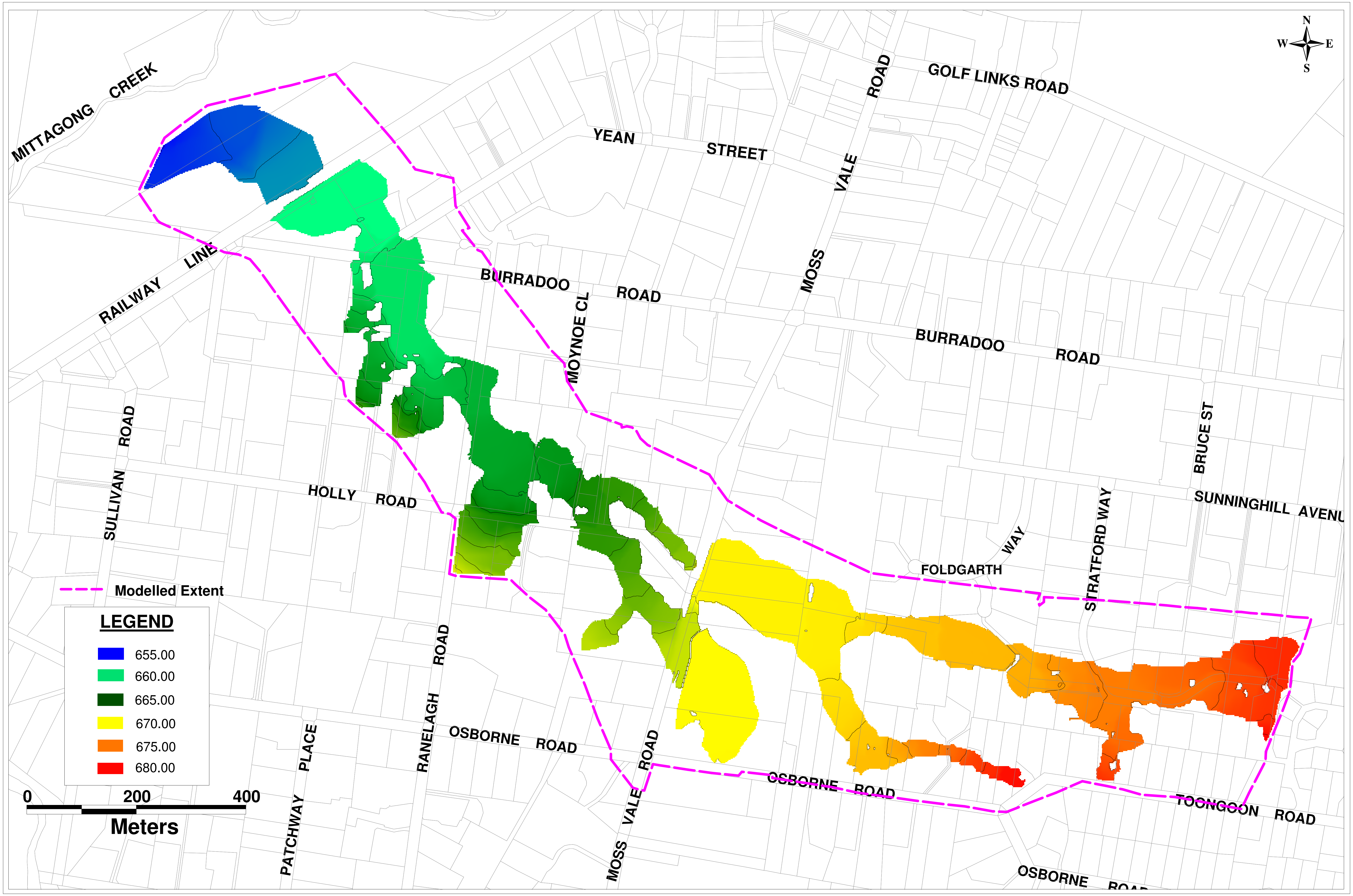

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FIGURE 11.1
100YearARI + 30%Rain_PeakWaterLevel

J2575\Mapinfo\Report figures May 2009\Figure7_2 100yrARI WL.WOR

APPENDIX A

Photos

Upstream of Moss Vale Road

Culverts – near 41D Sunninghill Avenue

Lined invert to channel – near Stratford Way


Lined invert to channel – near Stratford Way


End of lined invert to channel – near Stratford Way


Waterbody – near Stratford Way (Foldgarth Estate)


Waterbody – near Stratford Way (Foldgarth Estate)

Downstream of waterbody – Foldgarth Estate

Near Moss Vale Road

Intersection of Moss Vale Road and Osborne Road


Pony Club Detention Basin east of Moss Vale Road


Spillway from Pony Club Detention Basin to Moss Vale Road

Downstream of Moss Vale Road


Open Channel


Open Channel


Open Channel – 573 Moss Vale Road


Open Channel – at Holly Park


Open Channel –at Holly Park


Waterbody – Corner Burradoo Road and Yean Street

Downstream of Railway Line

Culvert under railway line facing downstream

Facing west from railway culvert

Photographs by Council on 16 June 2007

Stratford Way

Stratford Way

Stratford Way

Foldgarth Way


Foldgarth Way


Foldgarth Way

Foldgarth Way

Foldgarth Way

Foldgarth Way

Moss Vale Road – adjacent to #573

Pony Club

Moss Vale Road – adjacent to Pony Club

Pony Club

Pony Club

Moss Vale Road – at #573

Moss Vale Road – Upstream


Moss Vale Road – Upstream


Holly Park

Holly Park

Holly Road – adjacent to #12

Holly Road – adjacent to #22

10 Holly Road


12 Holly Road – facing west


14 Holly Road – facing west

Driveway crossing of 20 Holly Road

Driveway crossing of 20 Holly Road

Holly Road

20 Holly Road


20 Holly Road – facing east


20 Holly Road – facing west

Ranelagh Road

Ranelagh Road

Ranelagh Road

Burradoo Road

Burradoo Road

Burradoo Road


Burradoo Road


Burradoo BU2 Outlet

Burradoo BU2 Outlet

Burradoo BU2 Outlet

Burradoo BU2 Outlet

Photographs forwarded by residents

Driveway culvert at property on Holly Road – noting deposited debris at inlet

February 2005 – note water to driveway crossing of previous photo

June 2007 - Property west of Ranelagh Road upstream of Burradoo Road

June 2007 - Property west of Ranelagh Road upstream of Burradoo Road


June 2007 – Ranelagh Track


June 2007 – Ranelagh Track


June 2007 – Ranelagh Track


June 2007 – Ranelagh Track


June 2007 – Ranelagh Track noting post-storm disturbance to vegetation


Surface water on property Stratford Way

Property near Railway Line

APPENDIX B

Resident Questionnaire

Resident Questionnaire

A total of 154 replies were received from the 440 questionnaires, which were distributed to residences within the study area in August 2007. The purpose of the questionnaire was to compile the experiences of residents during past flood events and enable a comparison to results generated by the computer flood model. The questionnaire and cover letter distributed to residents is included in this Appendix. A summary of responses to questions is also included in this Appendix.

Events Experienced

Residents were prompted to provide information on the floods listed in Table B.1. The number of residents that reported flood impacts for each of these floods is also shown. It can be seen that the significant majority of information related to the most recent events – the October 1999 and June 2007. Three residents independently reported flood impacts from a storm event around February 2005.

Table B.1 Flood Event Responses

Flood Event	No. of Resident Responses
Mar-1975	2
Mar-1978	1
Nov-1985	4
Aug-1986	6
Apr-1988	5
Oct-1999	17
Jun-2007	38

Time of Residence

The time of residence for the respondents was relatively well distributed, with 70% of the respondents reported to have been living in the catchment for between 2 and 20 years. Approximately 15% of respondents have been living in the catchment for less than 2 years, and 15% for more than 20 years. This distribution is depicted in Figure B.1.

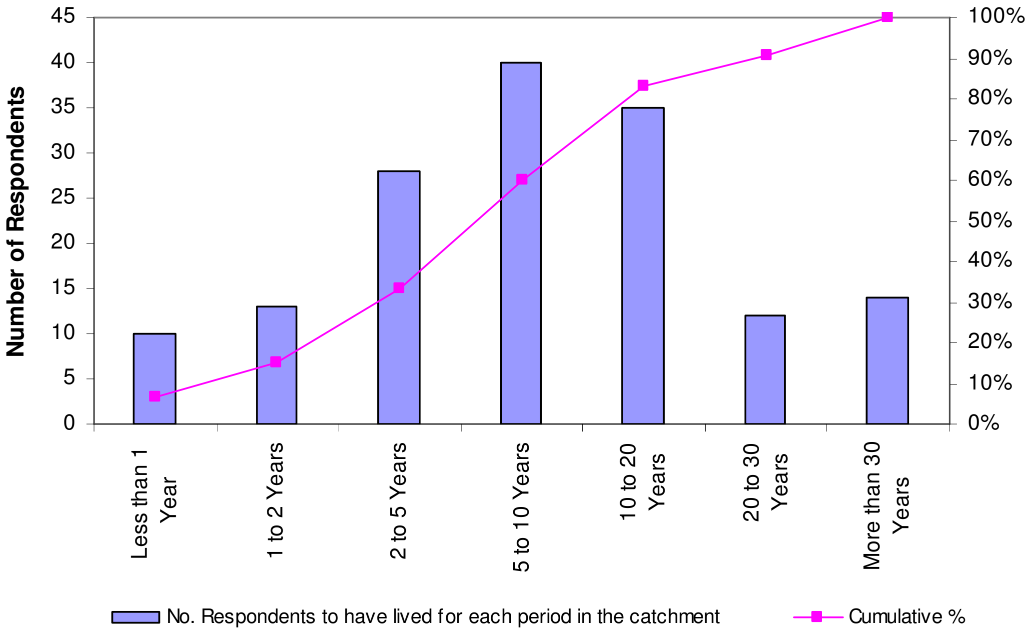

Figure B.1 Respondents Time of Residence

Flood Awareness

There was generally high awareness of flooding amongst the respondents, which may be a motivation for their submission of a response. A total of 101 of the 154 (66%) respondents indicated awareness or some knowledge of flooding in the catchment. There was not a significant correlation observed between time lived in the catchment and awareness of flooding, and generally 60% to 70% of all respondents were aware or had some knowledge of flooding in the catchment. Figure B.2 is a graph of the flood awareness. More than 50% of respondents who had been living in the catchment for less than a year reported awareness or had some knowledge of flooding in the catchment. This relatively high and well distributed recognition of flooding may reflect the recent 2007 flood event.

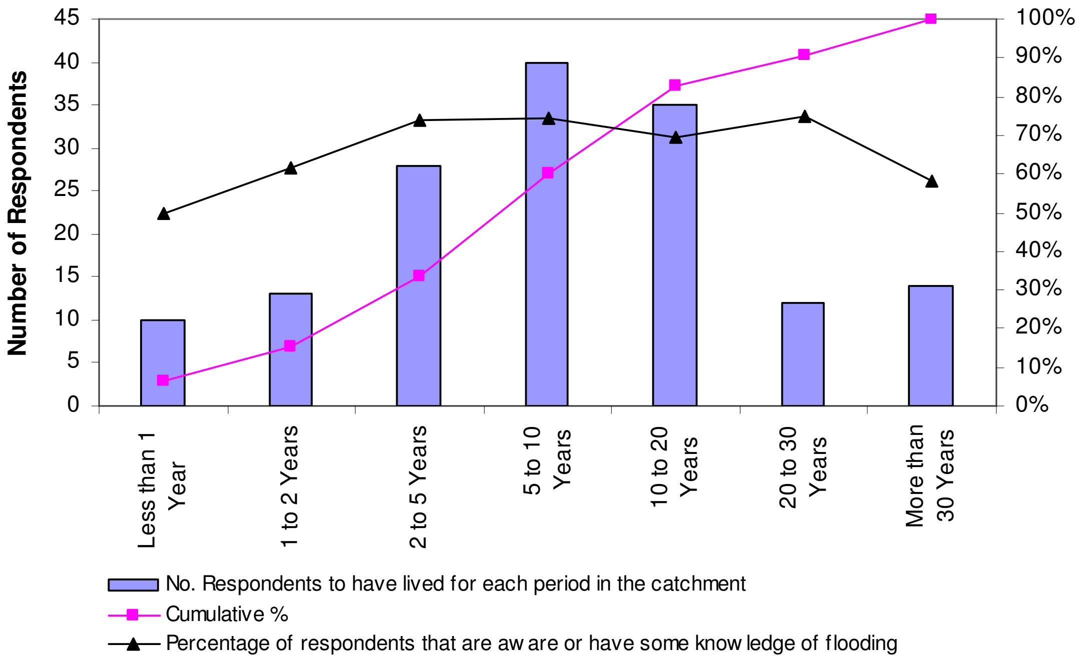

Figure B.2 Flood Awareness

Some residents who have lived in the catchment for over 30 years indicated that they had no experience of flooding. This response may be due to the respondent's location in the catchment, potentially away from the main drainage lines.

Flood Impacts

Forty-nine of the respondents (approximately 30%) reported being directly impacted or inconvenienced by past flooding.

Thirty-seven of these respondents reported having their property flooded in the past, of which five reported having their residences flooded above floor level in past events.

These reported impacts relate primarily to more recent events, as shown in Table B.2. The prevalence of impacts from more recent events may reflect the time of the respondent's residence and does not necessarily indicate that the more recent events were more severe.

Table B.2 Flood Event Responses

Response for Event	Mar-75	Mar-78	Nov-85	Aug-86	Apr-88	Oct-99	Jun-07
Inconvenienced	1	1	2	3	2	5	11
Property Flooded	1	0	2	5	4	16	29
Dwelling Flooded	-	-	-	-	-	1	4
Time of residence required to experience event (years)	33	30	22	21	20	8	< 1
No. of respondents that may have experienced event	12	14	22	24	33	75	145

Descriptions given by respondents were revealing of the character of flooding in the catchment. Respondents gave general observations of water courses, channels and hydraulic structures just reaching capacity with consequent shallow flooding of gardens and parklands to depths which are generally better measured in "inches" rather than "feet". Saturation of land to create 'sodden' and 'boggy' regions was regularly noted, and described as an occasional inconvenience. Observations generally indicated a rapid onset of these effects, generally 'within an hour' of heavy rainfall. Some observers noted the initiation of flooding effects after "20 mm of rain", with increasing effects for "50" and "100 mm" events. Land was generally observed to stay flooded for up to 4 to 5 days, but might stay saturated for a month or, in some cases, a number of months.

Observations of flood prone areas focussed on flooding of open areas such as private and public gardens as well as roadways. There were relatively few observations made of buildings that were flood affected, and no concerns relating to flood hazard or flood safety were given.

Flood Solutions

Residents were prompted to comment on the perceived causes and preferred solutions to flood issues that were observed. Sixty of the respondents provided comments on preferred solutions, and usually provided comments supporting application of more than one option. Of the proposed options, comments favoured the culvert / pipe enlargement and stormwater harvesting options. Responses for the various options presented are summarised in Table B.3.

Table B.3 Mitigation Option Responses

Option	Proportion of Supporting Comments Received
Retarding of detention basins	9%
Improved overland flow paths	12%
Culvert / Pipe Enlarging	26%
Channel widening or deepening	11%
Flood walls / Levee Banks	4%
Infiltration Basins and Trenches	5%
Stormwater Harvesting	24%
Planning Controls	10%

Some further comments were made, which suggested that restrictions should be placed on developments on flood prone areas. Concerns were expressed at the location of existing and current developments.

Comments emphasised that the community would like to stay informed regarding development of any of these solutions, and some comments expressed the wish that solutions which did not affect existing street landscapes and had no impacts to residents should be adopted.

Our Ref LJ2575/L1304

Contact Andrew Reid

20 August 2007

To the Resident

Cardno Lawson Treloar Pty Ltd
ABN 55 001 882 873

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Mackay
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Sunshine Coast
Toowoomba
Gold Coast
Gosford
Baulkham Hills
Wollongong
Busselton

Papua New Guinea
Indonesia
Vietnam
China
Kenya
United Arab Emirates
United Kingdom
United States

Dear Sir/Madam,

BURRADOO BU2 CATCHMENT ASSESSMENT STUDY

Cardno Lawson Treloar have been commissioned by Wingecarribee Shire Council to undertake a Catchment Assessment Study for the Burradoo BU2 catchment. A catchment layout and the study area are shown on the attached figure.

This Study will form part of the overall Floodplain Risk Management process for the catchment. This process follows the methodology presented in the NSW State Government Floodplain Development Manual (2005). The proposed stages of the Study are:

1. Flood Study
2. Floodplain Risk Management Study

Stage 1 incorporates a Flood Study comprising a comprehensive technical investigation of flood behaviour in the catchment. The study defines the nature and extent of the flood risk by providing information on the level and velocity of floodwaters and on the distribution of flood flows at various locations in the floodplain. The flood study establishes flood behaviour for various design flood events ranging from more frequent events such as 1 in 5 year Average Recurrence Interval (ARI) to rarer events such as 1 in 100 year event including the Probable Maximum Flood (PMF).

Stage 2 incorporates a Floodplain Risk Management Study to identify and evaluate various risk management options available in the catchment. Various options that are identified in the study are then assessed for their social, economic, ecological and cultural impacts, together with opportunities to maintain and enhance creek and floodplain environment. A range of management options is investigated and may include flood modification measures, modification measures for property and enhancing community response to floods. The study draws together the results of the Flood Study and builds upon the data collected during Stage 1.

Community involvement is important at all stages of the Floodplain Management Process. Resident's local knowledge of the catchment and personal experiences of flooding provide an invaluable source of data to define the nature and extent of flooding at the Flood Study stage of the process. In this regard, Council seeks your assistance in undertaking this Flood Study.

Enclosed please find a questionnaire, which focuses on whether your property or any nearby property has been flooded in the past.

Please take the time to read the questions and answer them as best as you can. Any information you provide may prove vital to the success and accuracy of the study results.

Also included in the questionnaire (as Question 10) is a list of common management and structural options to mitigate flooding impacts to residents for your comment. The listed options are:

- **Retarding or detention basins** that serve a large catchment area and retard water flow so that flood levels are reduced downstream of the basin. This is achieved by releasing flood water slowly from the basin after the main peak flows have passed through the system.
- **Improved overland flow paths** involve the creation of formal land depressions (or channels) to convey the water.
- **Culvert/ pipe enlarging** to increase the amount of water conveyed by structures in the flowpath and therefore reduce the frequency of stormwater overflow.
- **Channel widening and deepening** where possible to increase the volume of water conveyed in the channel and thus reduce overall flood levels.
- **Levee Banks** which help keep flood waters away from the areas they protect.
- **Infiltration basins and trenches** are small depressions or water storage areas with a permeable base that can collect flow and allow it to pond and percolate slowly away through the ground down to the water table.
- **Stormwater harvesting** is the retention of water in tanks or storages for later reuse for irrigation etc.
- **Planning controls** at the property development or redevelopment stage to ensure properties and buildings will be less likely to flood, and also so that particular types of development do not worsen flooding to other properties in any way.

Would you **please return** the questionnaire in the enclosed reply paid envelope **within three weeks of receipt of this letter.**

Following receipt of the questionnaires, Cardno Lawson Treloar will prepare a report for Council detailing the responses, the nature of flooding in the catchment, and an evaluation of potential management options.

Please contact Andrew Reid from Cardno Lawson Treloar or Bob Lewis from Wingecarribee Shire Council if you want to discuss or clarify items regarding the catchment study.

- Andrew Reid
  - Cardno Lawson Treloar
  - Telephone: 02 9499 3000
  - Facsimile: 02 9499 3033
  - Email: andrew.reid@cardno.com.au

- Bob Lewis
  - Wingecarribee Shire Council
  - Telephone: 02 4868 0888
  - Facsimile: 02 4869 1203
  - Email: wscmail@wsc.nsw.gov.au

Yours faithfully

Andrew Reid
Project Engineer
for **Cardno Lawson Treloar**

Encl. Burradoo Questionnaire

Burradoo BU2 Catchment
Flood Assessment Study

QUESTIONNAIRE

Please answer the following questions as best as you can. When you have finished answering the questions, please return these pages in the enclosed "reply paid" envelope.

If you have any queries, please contact:

Andrew Reid – CARDNO LAWSON TRELOAR — Ph: 02 9499 3000, Fax: 02 9499 3033, andrew.reid@cardno.com.au

Bob Lewis – WINGECARRIBEE SHIRE COUNCIL — Ph: 02 4868 0796, Fax: 02 4869 1203

Question 1

Could you please provide us with the following details? We may need to contact you to check some of the information with you.

(The information will remain completely CONFIDENTIAL)

Name: ______________________________

Day time phone Number: ______________________________

Email Address: ______________________________

Address: ______________________________

____

____

Question 2

How long have you lived in this locality?

______ Years ______ Months

Have you previously lived at another address within the catchment (shown on the attached map)?

Details: ______________________________

____

____

Question 3

Are you aware of flooding in the catchment?

Please Tick One:

Aware _____

Some knowledge _____

Not Aware _____

Question 4

Have you ever been inconvenienced, or has your property been flooded because of uncontrolled floodwater in this locality?

(Your property may have been flooded inside the house or in your backyard, or you might have been stopped from getting to work)

Please Tick:

INSIDE HOUSE FLOODED -	YES	______	NO	______
PROPERTY/YARD FLOODED -	YES	______	NO	______
INCONVENIENCED -	YES	______	NO	______

Question 5

Can you remember when that was?

Please Tick:

YES ______

NO ______

If you answered YES, please give us as much detail as possible.
To assist, flooding may have occurred on the following dates:

1. March 1975 ☐
2. March 1978 ☐
3. November 1985 ☐
4. August 1986 ☐

5. April 1988 ☐
6. October 1999 ☐
7. June 2007 ☐
8. ___________
9. ___________

Details of flooding and when it occurred:
(How long after the rain started? How high was the water level? How long did it stay at this level? When did the water level reach its peak?)

____
____
____
____
____
____
____
____
____

____

Question 6

If you have experienced flooding in this locality, do you have any evidence of the extents of the floods (such as flood levels or depths at certain locations)?

Please Tick:

YES ______

NO ______

If you answered YES, please give as much detail as possible.

You may have an old photograph, or may have taken a video. Some people remember marks on walls and posts, and this information could prove quite important.

Alternatively, you may know someone who has lived in the locality for a long time who might have that type of information.

Details of information:

____

____

____

____

____

____

____

____

____

____

____

Question 7

If you answered Yes to Question 6, what type of property did you see flooded?

You may tick more than one:

RESIDENTIAL ______ COMMERCIAL ______

PARKS ______ ROADS & PATHS ______

OTHER ______

Please Specify: ____

Can you describe the area of the property that was flooded?

You may tick more than one.

BACKYARD ______

GARAGE ______

BUILDING (ABOVE FLOOR LEVEL) ______

BUILDING (BELOW FLOOR LEVEL) ______

FRONTYARD ______

OTHER ______

Please Specify: ____

Question 8

If possible, can you show the location of the flooding on the enclosed map?

Please Tick:

YES ______

NO ______

If you have indicated yes, please remember to enclose the map in the envelope, clearly marked.

Question 9

Is there anything else you can tell us about the flooding in this locality?

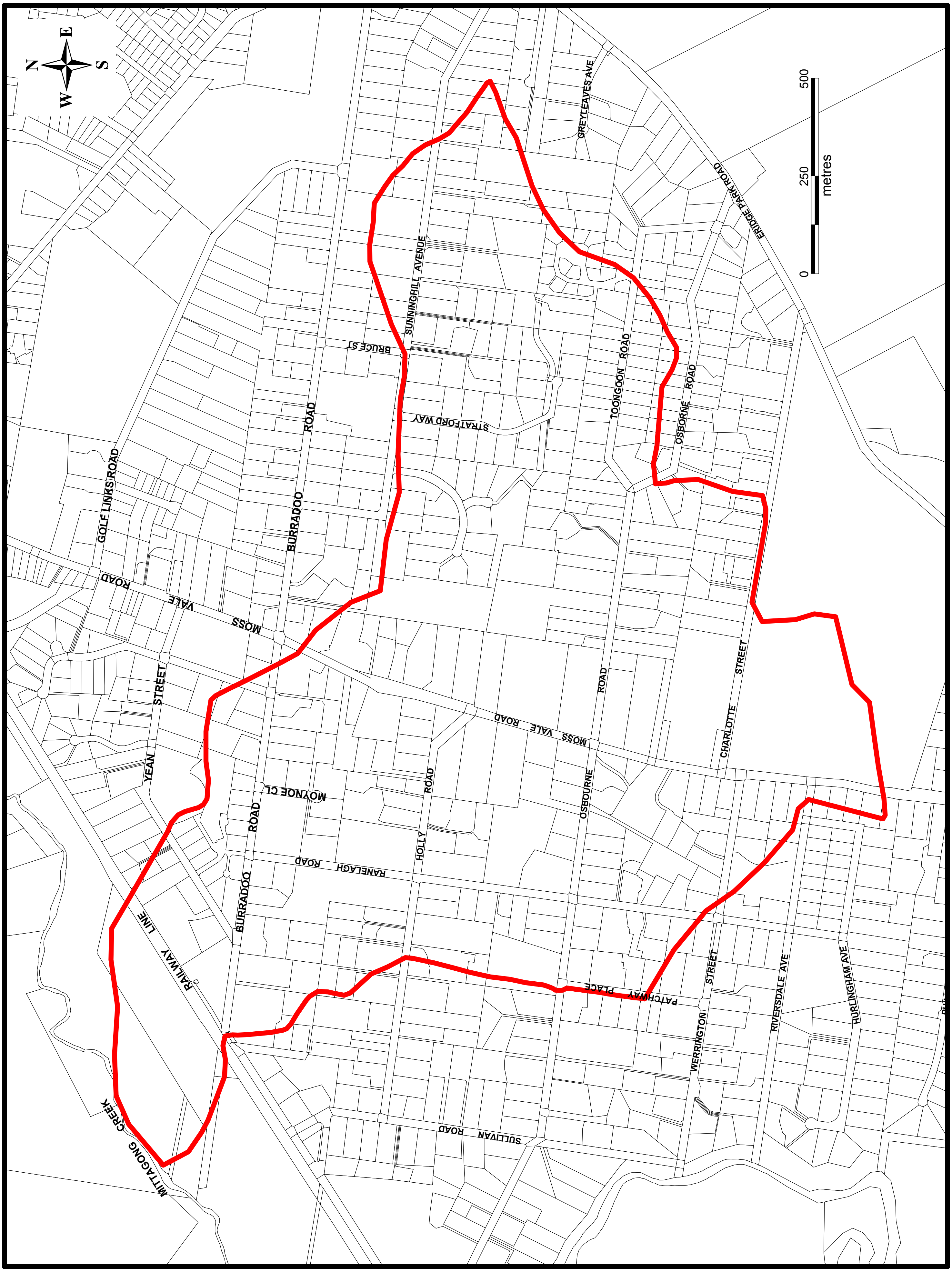
If so, please provide the information below.

Question 10

Being a local resident and (probably) having witnessed a number of flooding/drainage problems you may have your own ideas on how to solve the problems. Which of the following flood management options do you prefer? Please tick all preferred options and suggest where you think they may be suitable. The options mentioned in the following table have been briefly explained in the accompanying letter.

Proposed Options	Suggested Location and Comments
Retarding or detention basins	
Improved overland flow paths	
Culvert/ Pipe enlarging	
Channel widening or deepening	
Flood Walls/ Levee Banks	
Infiltration basins and trenches	
Stormwater Harvesting	
Planning controls	
Other	

Thank you for providing the above information. Please remember to put it back in the reply paid envelope. A representative from Cardno Lawson Treloar may contact you in the near future to discuss your response.



Cardno Lawson Treloar

FIGURE 1
STUDY AREA

LJ2575			Q2		Q3			Q4			Q5										Q6		
Survey Ref. No	How long - years	How long - months	Any other address- Yes	Any other address - No	Aware	Some knowledge	Not Aware	Inside	Yard	Inconv.	Yes	No	Mar-75	Mar-78	Nov-85	Aug-86	Apr-88	Oct-99	Jun-07	Comments	Yes	No	Comments
1	2			N	1			N	N	N		N								Limited knowledge due to short time there. This July-Aug rain flooding affected Osborne Rd between Moss vale Rd & Toongoon ran across Moss Vale Rd, Holly Rd towards Burradoo Railway Station - highly elevated flows and levels.		No	
2	3	6		N			1	N	N	N		N										No	
3	3			N		1		N	N	Y	Yes								1	Osborne Rd covered in water at intersection of Ranelagh Rd due to blockage of drains on all sides of Ranelagh towards Holly Rd. Subdivison at x Osborne and x Patchway Pl. has increased outflow.	Yes		Road cover slight.
4	12						1	N	N	N													
5	7	3		N	1			N	Y	N	Yes								1	Following minor storms watercourse flow speads out over banks of backyard pond. Have not experienced flood that has built up at inlet to twin pipe culvert beneath Burradoo Rd. At peak rainfalls culvert only 1/4 full at inlet. Told that in 1980's water crossed Burradoo Rd at Yearn St.		No	
6	44			N				N	N	N												No	
7	3			N		1		N	N	N												No	
8	4	7		N			1	N	Y	Y	Yes									2005 Run off from blocked gutter culvert entrance pipe & easement at rear of property. Estimate 1-2 hrs. ankle depth .		No	
9	15			N			1	N	N	N												No	
10	7	3		N																			
11	11	11		N		1		N	N	N													
12	4	3		N			1	N	N	N												No	
13	12			N			1	N	N	N													
14	14			N				N	N	N		N										No	
15	4			N		1		N	N	N												No	
16	5			N		1		N	N	N													
17	4	9		n		1			y		y								1	Floods front third of yard. Floods up to about halfway up rubbish bin.	y		no evidence
18	2			N			1	N	N	N													
19	10		Y			1		Y	Y	Y	Y									Each time we get a storm it stays flooded until street has drained.	Y		Council have inspected.
20	2			N	1			N	N	N													
21	2			N		1				Y									1	About 1 week after rain started, could not get to horse agisted on property off Railway Pde. Rd blocked at bridge for 2 days.		N	
22		4				1		N	N	N													
23	2			N		1		N	N	N													
24	6	9		N			1	N	Y	N	Y								1	Very minor. After heavy rain for 12 hours - stormwater drainage could not cope. Depth 5 to 10 cms. - remained for approx 24 hrs. No inconvenience.		N	
25	2	9		N				N	N	N											Y		During heavy rain N end of Ranelagh Rd floods - still passable.Stormwater drains not coping - some blocked.
26	20			N	1				Y		Y						1	1	1	Prolonged heavy rain causes floods at the bottom of paddock. Flooding should be on Council records as they had to clean up sewage mess & spread earth. Water came further up paddock because Councl ignored requests to deepen Easement & keep drainage pipes cleared of debris. See enclosed 3 letters. Dam fills & overflows fairly soon after heavy downpours as it is the natural catchment of water from 3 directions. North, East & South.	Y		Have 2 photos 24th Oct, 99(not enclosed) also 15th June.
27	3	9		N			1	N	N	N													

LJ2575		Q2			Q3			Q4			Q5									Q6		
Survey Ref. No	How long - years	How long - months	Any other address- Yes	Any other address - No	Aware	Some knowledge	Not Aware	Inside	Yard	Inconv.	Yes	No	Mar-75	Mar-78	Nov-85	Aug-86	Apr-88	Oct-99	Jun-07	Comments	Yes	No	Comments
28	12			N	1			N	N	N											Y		Drainage from x,x & x Holly Rd flow into culvert is restricted by footpath design. Also flow of water in culvert in front of x is restricted by silt build up N side of Holly Rd - unable to flow across vacant paddock
29	60			N	1					Y	Y		1	1	1	1				Started with rainwater from property behind - about 1/2 metre - perhaps 3 to 6 days - peak after rain		N	May have old photo's somewhere. SEE DIAGRAM.
30	3			N	1				Y	Y	Y									One day water shin high - 2 days after rain stopped.		N	
31	21			N	1			N	N	Y	Y						1			Culvert under Moss Vale Rd into Holly Rd would be full - backed up behind pipe. Significant water flow and retention also occurred in Holly Rd as shown on map.	Y	N	Refer previous comment.
32	17	7	Y			1		N	N	N									1	Back garden water level 2-3 cm after 3-4 days rain. Not inconvenienced.		N	
33	1			N	1			N	N	N													
34	19	7		N	1			N	N	N											Y		In 1988 water almost reached back fence. Almost all of paddock behind flooded several days. Creek regularly broke its banks until the most recent drought.
35	5	2		N		1		N	N	N		N								No real flooding but block directly behind goes completely under during consistent heavy rain. Our backyard gets very soggy - need "duckboards" to et to clothesline.		N	
36	5			N	1			N	N	N									1	Observation only		N	
37	8			N	1			Y	Y	N								1					
38	3	9		N	1			N	Y	Y	Y									Floods almost immediately after rain. Approx. 1-5 metres (See Photo's) Stays at this level during heavy rain. Reached its peak after about 6 hrs.	Y		Photo's sent to Mr. Lewis at Council. Despite repeated efforts for almost 3 years problem not rectified by Council.
39	6	9		N		1		N	Y	N		N						1		Flooding only at lower part of property (W end) Water recedes quickly but block often boggy.		N	
40	35			N		1		N	N	N											Y		
41	8	6		N	1			N	N	N												N	
42	18	8		N	1			N	N	N											Y		Lived in x Burradoo Rd, (marked on map). In 1987 or 1988 the back of our property was submerged as well as land on Links Rd. Flood shown on map.
43	10			N	1			N	N	N													
44		3																					
45	5			N		1		N	N	N		N											
46	15			N		1		N	N	N												N	
47	28			N	1			N	N	N		N										N	
48		9		N		1		N	N	N									1	Witnessed flooding or large pools of water in adjoining 2 blocks of land. Were not inconvenienced by this.	Y		
49	1	2		N		1		N	N	N		N											
50	8			N			1		Y			N								After days of heavy rain, water flows thru yard into neighbour at front - never more than 12" deep - stayed for approx 4-5 days.		N	
51	20			N	1			N	Y	N					1	1	1	1	1	Floodiing quite quickly after rain started. 20cm approx. Water is slow to get away. Paddock is still swamp from June rain with more rain in August which has raised water levels again.	Y		

LJ2575		Q2			Q3			Q4			Q5										Q6		
Survey Ref. No	How long - years	How long - months	Any other address- Yes	Any other address - No	Aware	Some knowledge	Not Aware	Inside	Yard	Inconv.	Yes	No	Mar-75	Mar-78	Nov-85	Aug-86	Apr-88	Oct-99	Jun-07	Comments	Yes	No	Comments
52	48			N	1			N	N	N												N	
53	10			N		1		N	Y	Y								1	1	Flooding of front garden caused by poor road maintenance. Estimate depth of water 200mm & drains in approx 2 days.	Y		See enclosed photographs.
54	20			N	1			N	Y	N	Y					1		1	1	August 2007. In total 5 acres small dam at lowest point of property has burst its banks a few times quickly subsiding.		N	
55	6			N	1				Y	Y	Y								1	Flooding starts 1 hour after heavy rain. 300mm in gully across property and 50mm across driveway. Stayed like this for several hours. Peak was 1-2 hours after commencment.	Y		Photos available
56	3	8		N		1		N	N	N												N	
57	2	1		N	1			N	N	N												N	
58	20			N		1			Y		Y		1						1			N	
59	13			N		1		N	N	N		N										N	
60	7	2		N		1		N	N	N		N										N	
61	2					1		N	N	N												N	
62	7	11		N	1			N	N	N		N										N	
63		6		N			1	N	N	N												N	
64	10			N	1			N	Y	Y		N							1			N	
65	9	3		N			1	N	N	N													
66	1	4					1																
67	27			N			1	N	N	N												N	
68	32			N			1	N	N	N													
69	1	6		N			1	N	N	N													
70	5			N		1		N	Y	N	Y								1	12 hrs. after rain started, surface water in backyard & part frontyard stayed at 3-4cms and lasted approx 48 hrs. during constant rain approx 160mm over 2-1/2 days. Water then peaked.	Yes		Watercourse passing thru x at x Toongoon Rd overflows onto adjacent properties before draining past Statford Way then Foldgarth Est. area.
71	25				1				Y		Y								1	July, 2007 also. Have an illegal drain which blocks & floods house. Council informed - done nothing.	Yes		
72	7	1		N		1		N	Y	N	Y								1	Water formed pond in backyard after heavy deluge & took a while to subside.	Yes		Parts of bike track from Osborn Rd to Moss Vale were too deep to ride thru. Burradoo Rd & Sunninghill were flooded in places. Pony Club looked like a lake & drainage from new easement was rushing into Holly Rd. Property next to Pony Club were underwater.
73	2			N	1			N	Y	Y	Y								1	10% of yard covered with water (several cm's) for days after rain stopped. Water continued to flow into our yard via easement, neighbour east & north's land.		N	
74	36			N			1	N	N	N												N	
75	8			N	1			N	N	N												N	
76	22	6		N	1			N	N	N												N	
77	10	3				1		N	N	N												N	
78	6			N	1			N	N	N		N										N	
79	13	1		N	1			N	N	N		N										N	
80	20	1		N	1			N	N	N		N									Yes		Pony Club, Park in Holly Rd & around Sproules Lane.
81	8			N			1	N	N	N													
82	7	6		N		1		N	Y	N	Y							1	1	Lower edge of our 1.5 acres is in natural watercourse area - heavy rain on our catchment zone channels water into dam and close paddock areas.	Yes		Our dam regularly overflows and water on one occasion reached bottom rung of our fence - rapidly subsides.
83	12		Y				1	N	Y		Y								1	During heavy rainstorm water level rose to about .5 m in front of house. Subsided 1 hr after rain stopped.		N	
84	8	5		N		1		N	N	N											Yes		Large areas of water at Pony Club
85	40			N			1	N	N	N		N										N	
86				N		1		Y			Y								1	Commenced same week as rain, ankle deep, lasted approx 1 week.	Yes		Mini waterfall from flooded area over rocks lining culvert. Extensive flooding at entry to driveway Sunnyhill Ave. Like a lake.

LJ2575			Q2		Q3			Q4			Q5										Q6		
Survey Ref. No	How long - years	How long - months	Any other address- Yes	Any other address - No	Aware	Some knowledge	Not Aware	Inside	Yard	Inconv.	Yes	No	Mar-75	Mar-78	Nov-85	Aug-86	Apr-88	Oct-99	Jun-07	Comments	Yes	No	Comments
87	9	3		N		1		Y	Y		Y							1	1	In 1999 water came to back door, ground very boggy for a long time. Have put drainage across back to keep it away from door. Drainage terrible.		N	
88	13	7		N	1			N	N	N												N	
89	19	5	Y			1		N	N	N		N									Yes		In 1979(?) new dam at Robertson was tested at night and the water level of the Wingecarabee River rose just short of the Railway bridge rails. Water level came up to the lower fence of "York Cottage" paddock.
90	1			N			1	N	N	N		N										N	
91	8	7		N		1		N	N	N	Y							1		Canal in our estate reached capacity and at least one neighbour's yard and garage became flooded.		N	
92	4	3		N			1	N	N	N												N	
93	3	10		N	1			N	N	N													
94	4	7		N		1			Y		Y								1	Flooded lower parts of backyard, underhouse below floorboards. About 2-3 weeks to clear. Reached 10 - 15 cm.	Yes		
95		9		N			1	N	N	N													
96	12			N	1			N	Y	N	Y								1	Quite shallow along the natural water course.		N	
97	14			N	1			N	N	N												N	
98	5	7		N			1	N	Y	N										October 2004 lowest section of land has remained water logged for several months after heavy rains. Feb 2005 Garage flooded approx 5cm. Flooding occurred within approx 1 hr of start of rain, cleared approx 1 hr after. Flooded again 20/02/05 but since installed swail to divert water around house.		N	
99	6			N	1				Y		Y								1	Also 2002. Water flowed from x Osborne Rd to lower half of rear of property. Approx.4" deep - unable to flow thru to next door property due to side access road and inadequate culvert/piping. Water remained for 4-5 days. Ground soggy for up to 2 weeks.	Yes		
100	3					1		N	N	N													
101	1	2		N	1			N	N	N													
102	9			N		1		N	Y	Y	Y							1		Knee high down Sunninghill Av. Duration approx 2 hrs.		N	
103	7			N			1	N	N	N		N											
104	2			N			1	N	N	N													
105	18						1	N	N	N												N	
106	41			N	1			N	N	N										Concern that water passes front of property in good storm 2m wide (not deep).			
107	20			N	1			N	N	N											Y		
108	5	9		N	1			N	N	N											Y		Area shaded in yellow is low lying land - always sodden. In wet periods water flows into creek & dam on property adj. to BurradooRd then under Railway Bridge. Please note Ranelagh Rd stops at Holly Rd & does not continue thru to Burradoo Rd for reason stated above. (See Map)
109	11	8		N			1	N	N	N													
110	33			N			1	N	N	N												N	
111	8	9		N	1			N	Y	N									1	Front yard flooded for several days.	Y		Photos enclosed.

LJ2575			Q2		Q3			Q4			Q5										Q6		
Survey Ref. No	How long - years	How long - months	Any other address- Yes	Any other address - No	Aware	Some knowledge	Not Aware	Inside	Yard	Inconv.	Yes	No	Mar-75	Mar-78	Nov-85	Aug-86	Apr-88	Oct-99	Jun-07	Comments	Yes	No	Comments
112	4			N	1			N	Y	Y	Y				1	1			1	Nov 05 & Feb 07. During substantial rain property to S floods and overflow spills onto lower section of our property - also unformed section of Ranelagh Rd which becomes fast flowing flood section. Depth up to .5 metre. Depending on intensity several hrs to several days. In Feb 07 & June water from these 2 areas was evident in depth for several days (See Photos)	Y		See Photos - Previous owners have extensive photo record.
113	12			N	1			N	Y	N	Y							1	1	Recent 2007 heavy rains. Earlier 1999 heavy rains	Y		Absolute flooding across the course of Bowral Golf Course Kangaloon Rd. Bowral
114	21	7		N	1				Y	Y	Y					1	1	1	1	Aug.2007 - Still Swamp. See questionnaire for further info.			
115	6	10		N	1				Y	Y		N						1	1	After 20mm of rain yard is flooded, street and nature strip under water.	Y		See Photos
116	4	2		N			1																
117	3			N			1																
118	40			N			1	N	N	N		N										N	
119		6		N			1	N	N	N												N	Property week-end home.
120	10			N			1															N	
121	1					1		N	N	N													
122	10			N			1	N	N	N												N	
123	3					1		N	N	N		N										N	
124	10	8		N				N	N	N													
125	23	10	Y		1			N	Y	N	Y					1	1			Had watercourse thru rear - when rain stopped levels dropped.	Y		In watercourse between Osborne Rd & Sunninghll Ave - this area was a swamp - "wildlife reserve"
126	9						1	N	N	N													
127	6	10		N		1		N											1	A lot of water running down hill thru backyard. Yard water logged at back even though improved drainage. Insufficient stormwater drainage to front yard, poor culverts in driveways. Water rushes down hill.		N	
128	13			N	1			N	Y	N	Y							1	1	Only part of property affected - water 50mm high? Takes weeks to drain due to clay.	Y		
129	25			N			1	N	N	N		N										N	
130	20			N			1	N	N	N													
131	2			N			1	N	N	N												N	
132	6	3		N			1	N	N	N												N	
133	12	3		N			1	N	N	N		N										N	
134	17	2		N			1	N	N	N												N	Flooding occurs in area north of area outlined on Fig.1 Study Area.
135	6	9		N		1		N	Y	N	Y									Dec 2000. One day after heavy rain steady river from neighbour x thru my place into x. Ditch on footpath was flooded across road. Backyard not flooded since 2000 but footpath has.		N	
136	34			N	1			N	N	N										Near Holly Rd near Moss Vale Rd (red on map)		N	
137	18		Y		1			N	N	N		N										N	
138	0				1			N	N	N		N										N	
139	7	11		N		1		N	Y	N	Y							1		24hrs after rain started, height - 30cm - stayed 48hrs - reached peak Sunday afternoon.	Y		
140	7			N	1			N	Y	N	Y								1	Creek runs thru property into dam. Creek flows with very heavy continuous rain. See attached letter for further comments.		N	
141	24	4					1	N	N	N												N	
142	4			N		1				Y	Y								1	Flooding in N section of garden.		N	
143	30				1				Y	Y	Y							1	1	How long? - 12 hrs, How High? Varied. How long stay? Several days. Peak? Unknown.	Y		SEE PHOTOS
144	19	6		N		1		N	N	N											Y		
145	50		Y		1					Y		N											
146	20			N			1	N	N	N													

LJ2575			Q2			Q3			Q4									Q5				Q6	
Survey Ref. No	How long - years	How long - months	Any other address- Yes	Any other address - No	Aware	Some knowledge	Not Aware	Inside	Yard	Inconv.	Yes	No	Mar-75	Mar-78	Nov-85	Aug-86	Apr-88	Oct-99	Jun-07	Comments	Yes	No	Comments
147	40			N				N	N	N					1					Lower portion of backpaddock when 39 Sunnyhill was built up 3-4 feet.		N	
148	7				1			N	N	N													
149	4	7		N	1			N	N	N									1	Water flowed across Tennis Court for several days. Water across road.		N	
150	22			N	1			Y	Y	Y	Y									Feb 2005 See photos	Y		
151	11	11		N	1				Y		Y							1	1			N	
152	response by phone																						
153	2	9		N	1			N	N	N													
154	57	9		N		1				Y		N									Y		Bottom paddock under water on occassions - water from culvert from Osborne Rd onto my property overflows into surrounding land.

LJ2575	Q7											Q8		Q9	Q10								
Survey Ref. No	Res	Parks	Other	Comm.	Rds & Paths	Backyard	Garage	Bldg-Above	Bldg-Below	Front yard	Other	Yes	No	Comment	Retard	Improv	Culvert	Channel	Flood walls	Infiltration	Strmwtr	PlanCntrl	Other/Comments
1																	Along flow path described previously Q5	As previous			Anywhere possible.		
2													N		1	1	1	1					
3					1						Roadway & drains Osborne Rd & Ranelagh Rd Stormwater to Osborne Rd from recent subdivision at Patchway Place.	Y		Council cleared some drain blockage at Ranelagh and Osborne but permanent rebuilding required. Believe Roads Dept. would be concerned at stormwater outlet from subdiv. Including Osborne Rd and Patchway Pl.			1						Restore max. drainage channels including growth & weeds
4																						1	No developments in flood prone areas
5													N		1								There are flood prone areas between Holly Rd & Burradoo Rd that may be suitable for detention basins.
6												Y		My concern is intersection of Osborne Rd and Ranelagh Rd. Floods with limited rainfall due to inadequate drainage system. No serious flooding in this area during my time here. Most heavy rain runs off well.			1	1					
7																							
8						1				1		Y				1							Burradoo Rd.
9																							
10																							
11																							
12																							
13																							
14				Pony Club							Pony Club Grounds	Y		Since levee bank in Pony Club grounds adjacent to Mossvale Rd, water has been controlled well. Culvert either side of Osborne Rd badly needs cleaning out & kept clean otherwise floods over & across Osborne Rd.			Cleaning						
15																					1		
16																							
17		1		Pony club, osborne rd	1					1		Y											Problem should be resolved with no real change to street landscape and with as little disruption to residents as possible.
18																							
19	1				1					1	Gateway	Y		Reported to Council 2 yrs ago - nothing done. Floods right across front exit.				1					Channel needs digging out from 2 houses up.
20																							
21																							
22																							
23																							Would like to be kept informed of plans which may impact on flood conditions.
24													N	If existing drainage is well maintained, system can usually cope.				1					
25					1							Y						Cleaning					
26	1		1	Road & bridge over Wingecarribee River south from Burradoo Rail Station. Road (bridge) closed - took photos 17th June 2007.							Paddock near sewer pumping station - about the lowest point on your flood map - see area shaded red.	Y		Pls.see 3 enclosed letters.			At W end of easement near sewer pumping station.	Deepening					
27																							

LJ2575			Q7									Q8		Q9	Q10								
Survey Ref. No	Res	Parks	Other	Comm.	Rds & Paths	Backyard	Garage	Bldg-Above	Bldg-Below	Front yard	Other	Yes	No	Comment	Retard	Improv	Culvert	Channel	Flood walls	Infiltration	Strmwtr	PlanCntrl	Other/Comments
28			Paddock		1							Y		Flooding N of Holly Rd is due to non existance of clear path across vacant land opposite x & x Holly Rd. Old Council pipes obstucted and flow also blocked by another property - stormwater has no where to flow hence flooding.		1	Clearing						
29					1						Part of orchard and large grazing ground 200m on left towards Moss Vale Rd.	Y		Too dry for the past 10 years. Only last month water again running thru drains and gutter to Holly Rd for about 1-2 weeks.			1						Perhaps pipe underground in Holly Rd to take very occasional overflow from my waterhole.
30						1				1		Y											
31	1		Open land									Y											Don't build on flood plains. Culvert moves the problem elsewhere. Council to employ competent engineers & take responsibility for design.
32																							
33																							
34	1	1			1						Along creek behind x Toongoon Rd.	Y		The area behind us regularly flooded before subdivided. Also there were several "soaks" in the area. One major "soak" excavated and re-filled as part of development of subdivision.									Too late for any of these. Sub-division should never have been approved. At least one of the houses should be demolished due to impending damage.
35																	1				1		
36												Y		When purchased property in 1999 Council could not give any info on flooding details - maps, dates, areas!!	1		1			1	1		
37																							
38	1				1	1					Driveway over stormwater easement at rear also circular drive at x.	Y		See letter dated 19th Oct. 06. Real problem is water build up behind our property & x Holly Rd.	1	1	At x Holly Rd.		Clear easeme	1	1	Clear easement	Culvert pipes to x driveway incease pipes to larger sizes to allow better flow from channel.
39						1				1				Basically just per Q5 but happy to discuss further if that helps.			1	1			1	1	The key is to allow water to escape to river by eliminating whatever is preventing that from happening.
40					1									Yean St dangerous as gutters never cleaned out. Large trees causing clogging extending over half the road - busy, narrow road with Oxley School traffic.									Road gutters cleaned regularly
41														Rain water southern side of Sunninghill Ave. diverted under roadway - about 40 metres E of my driveway then runs down side of x Sunninghill Ave across rear of x then into adjacent properties. Why?									See notes Q9
42	1		1			1					The property at the time would have been rural.	Y		Hope BU2 is not the only study area as most of ths area is slightly raised above surrounding area. Would like to see areas N,S,W & E also have a questionaire.		1					1	1	Planning may be too late for some properties.
43														Several neighbours - low lying land - flooding of garden & garages.							1	1	
44																							
45																							
46														Only possible flooding would come from back half of x. We slope back from Charlotte St. towards Osborne Rd. so any excess water from x would flow that way. (See sketch)									
47																							
48			Land								Land	Y											
49																							
50												Y		Front neighbours have installed drainage system which has eliminated problem.	1						1		
51	1	1			1	1					Vietnam Memorial Reserve - Bong Bong	Y		See attached letter.									See attached letter.

LJ2575					Q7							Q8		Q9				Q10					
Survey Ref. No	**Res**	**Parks**	**Other**	**Comm.**	**Rds & Paths**	**Backyard**	**Garage**	**Bldg-Above**	**Bldg-Below**	**Front yard**	**Other**	**Yes**	**No**	**Comment**	**Retard**	**Improv**	**Culvert**	**Channel**	**Flood walls**	**Infiltration**	**Strmwtr**	**PlanCntrl**	**Other/Comments**
52														Just noted general lack of drainage in locailty - in particular as the number of residences has increased. Main concern is flooding around sewerage treatment works near Burradoo Railway Station.			1	1	1		1		Combination of several of the above would be necessary.
53	1				1	1				1		Y				1	1						
54												Y					1				1		
55	1				1					1		Y		Regular flooding on our land - have easement across property for flood. 20mm of rain in one day get our easement running with water. 50mm of rain in one day means gully will flood over driveway. 100mm of rain in one day means Osborne Rd may have flooding across it opposite x.			1				1		
56																1							
57																							
58										1													
59	1	1			1							Y											
60		1										Y					1						
61																							
62																							
63																							
64																							
65																							
66																							
67																							
68												Y		In 32 years we have lived here, not aware of any flooding within the catchment area outlines on the map.									
69														In 40 years as a Bowral & Burradoo Res. We have never seen any evidence of flooding as described in Q4.			1				1		
70	1				1	1				1	Adj to watercourse in x.	Y					1				1	1	Avoid indiscriminate development in known flood areas.
71		1			1	1						Y											
72	1	1			1	1				1		Y						Enlarging of easement of Foldgarth Est not deep enough - ruined natural spring.			Stormwater channelled to pony club too much for Holly Rd to cope with.		Modified dam at Foldgarth Estate is a mess - stagnant water hole. Wild birds haven't returned - there is scum & algae all the time.
73																					Neighbours should harvest roof runoff.	Water tanks to future developments	Neighbours property saturated with bore water - when it rains all rain water runs onto my property.
74																							
75															1	1	1	1	1	1	1	1	
76																							
77																							
78																1	1	1	1		1	1	
79																							
80	1	1				1				1		Y											
81																							
82			1	Yard not house		1						Y		Rapidly subsides.		1							At east end of our land is natural water course (non building area), flood water spreads across this and into neighbours dam before moving onto Wingec'ee river.
83		1	Pony Club		Osborn Rd										East side of Osborne Rd.		East side Osborne Rd				Pony Club Osborne Rd.		
84		1										Y											
85																					1		
86	1				1						Ankle deep at gate entrance & bottom 5 metres of block.	Y		You have to do something about lingering puddles on edge of roads & footpaths.									

LJ2575	Q7											Q8		Q9	Q10								
Survey Ref. No	Res	Parks	Other	Comm.	Rds & Paths	Backyard	Garage	Bldg-Above	Bldg-Below	Front yard	Other	Yes	No	Comment	Retard	Improv	Culvert	Channel	Flood walls	Infiltration	Strmwtr	PlanCntrl	Other/Comments
87	1			Neighbour could not get out into yard for weeks.		1				1							Pipes not large enough in some places.				1		
88																							
89																							
90																	1				1		
91	1					1	1			1		Y		Since 1999 flooding or neighbours yard & garage, extra drains established and no further flooding has occurred to my knowledge.									
92												Y											
93																							
94	1					1			1			Y		Water in heavy rainfalls follows slope, enters properties via driveways as no external drainage is provided.									
95																					1		
96												Y		Minor flooding we experience from time to time along the natural water course causes no inconvenience.									
97														There is no flooding at our address or locality.									
98														Flooding appears to be caused by run off from adjoining properties. x Osborne Rd appears to have continually blocked drains which increase problem.									
99	1					1						Y					1			1	1		Culvert on side road so water can flow downhill through rear yards.
100														No flooding as such - water lies in bottom of block for a while after very heavy continued rain.		1	1				1		
101	1				1	1			1			Y		No flooding as property on hill, x Toongoon Rd had water under house & in yard. Suggest kerb & guttering.									
102	1				1	1				1		Y		Flooding made worse by lack of drainage in Sunninghill Av. Especially high part.		1							
103																							
104														In 40 yrs as Bowral/Burradoo res. Not seen evidence of flooding as described in Q4.			1				1		
105													N										
106					1						Verge Moss Vale Rd.	Y			Already there.		From Moss Vale Rd (W) to Rd between Park.						
107	1	1				1					Pony Club	Y		Properties in Stratford Way near drain - backyards subject to flood. Should not have been developed for res. A series of ponds linked by creek would have been better than drain.		1					1	1	
108	1		1								See area on map.	Y											As Ranelagh Rd not thru rd - recommend boardwalk over saturated land for foot traffic.
109														Catchment area outline chosen seems arbitrary - possibility of flooding at E and W extremities likely to be higher than centrally and subject to run-off from adjacent catchments.									
110														Roadway collected puddles - road repairs would overcome this.									
111	1				1							Y									1	1	

LJ2575	Q7											Q8		Q9	Q10								
Survey Ref. No	**Res**	**Parks**	**Other**	**Comm.**	**Rds & Paths**	**Backyard**	**Garage**	**Bldg-Above**	**Bldg-Below**	**Front yard**	**Other**	**Yes**	**No**	**Comment**	**Retard**	**Improv**	**Culvert**	**Channel**	**Flood walls**	**Infiltration**	**Strmwtr**	**PlanCntrl**	**Other/Comments**
112			1	Vacant land S side (Holly Rd & Ranelagh Rd)	1						Undeveloped block on our S side.	Y		Flooding occurs on undevelopoed land adjoining our property therefore minimal inconvenience at the mement. However lower section of property remains water-logged from June07 flooding .									
113	1			Golf Course major flooding.								Y			1			1			1		
114												Y			Lake built x					1			
115	1				1	1				1	Street & Nature strip	Y		Constructed small dam N side. After about 20 mm dam full & overflows thru pipe to back corner and into nextdoor backyard. Neighbour S side built levee to prevent flood runoff into house. Street floods regularly. Have 4500L water tank on house and 3600L on garage. Stormwater outlet to street regularly under water causing backup.			1			1			Pipes at least 40mm to carry water from nature strip. Basin in nature strip connected by pipes to basin further down street.
116																							
117																							
118																							
119																							
120													N										
121																							
122																							
123													N								1		
124																							
125		1	1	As previous.								Y											
126																							
127																	Along Stratford Way driveways.						
128				Sunninghill Ave regularly flooded	1	1				1	Many properties in this street affected.	Y											
129																							
130													N		1	1	1	1	1	1	1	1	
131																							
132																1	1						Improve flow paths - Ranelagh Rd unsealed portion to convey water. Culvert/pipe - channels along Osborne Rd.
133													N										
134																	1	1					
135																							
136														Minor floodig Osborne Rd & Pony Club paddock & x Toongoon Rd.			1						Culvert plus raising road level for larger pipe culvert.
137												Y		My experience is that area outlined has not been troubled much apart from close to stormwater easements.									
138																							
139	1					1						Y				1						1	
140																							
141														Only flooding caused by roadbase washing into culvert at the Ranelagh Rd junction with Osborne Rd. Council caused this.									
142						1						Y											
143											Rural grazing land. See map.	Y		SEE QUESTIONAIRE									
144											Paddocks & Grasslands	Y		Land was a sink - flooded in heavy rain. Now covered in houses and drained. No heavy rain has occurred.								1	
145																							
146													N										

LJ2575					Q7							Q8		Q9				Q10					
Survey Ref. No	Res	Parks	Other	Comm.	Rds & Paths	Backyard	Garage	Bldg-Above	Bldg-Below	Front yard	Other	Yes	No	Comment	Retard	Improv	Culvert	Channel	Flood walls	Infiltration	Strmwtr	PlanCntrl	Other/Comments
147																							
148																							
149												Y									1		Street drainage
150	1						1	1		1		Y											
151														Water thru our property better regulated since dam built in Pony Paddock on Moss Vale Rd.	1		1						
152																							
153																							
154												Y											

APPENDIX C

Survey Data

Source: Lawrence Group

SHEET INDEX

NOTE :-
SHEET 5 of 5 IS THE CULVERT DETAILS

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Issue	Amendment	Date

LEGEND

CLIENT
CARDNO LAWSON TRELOAR

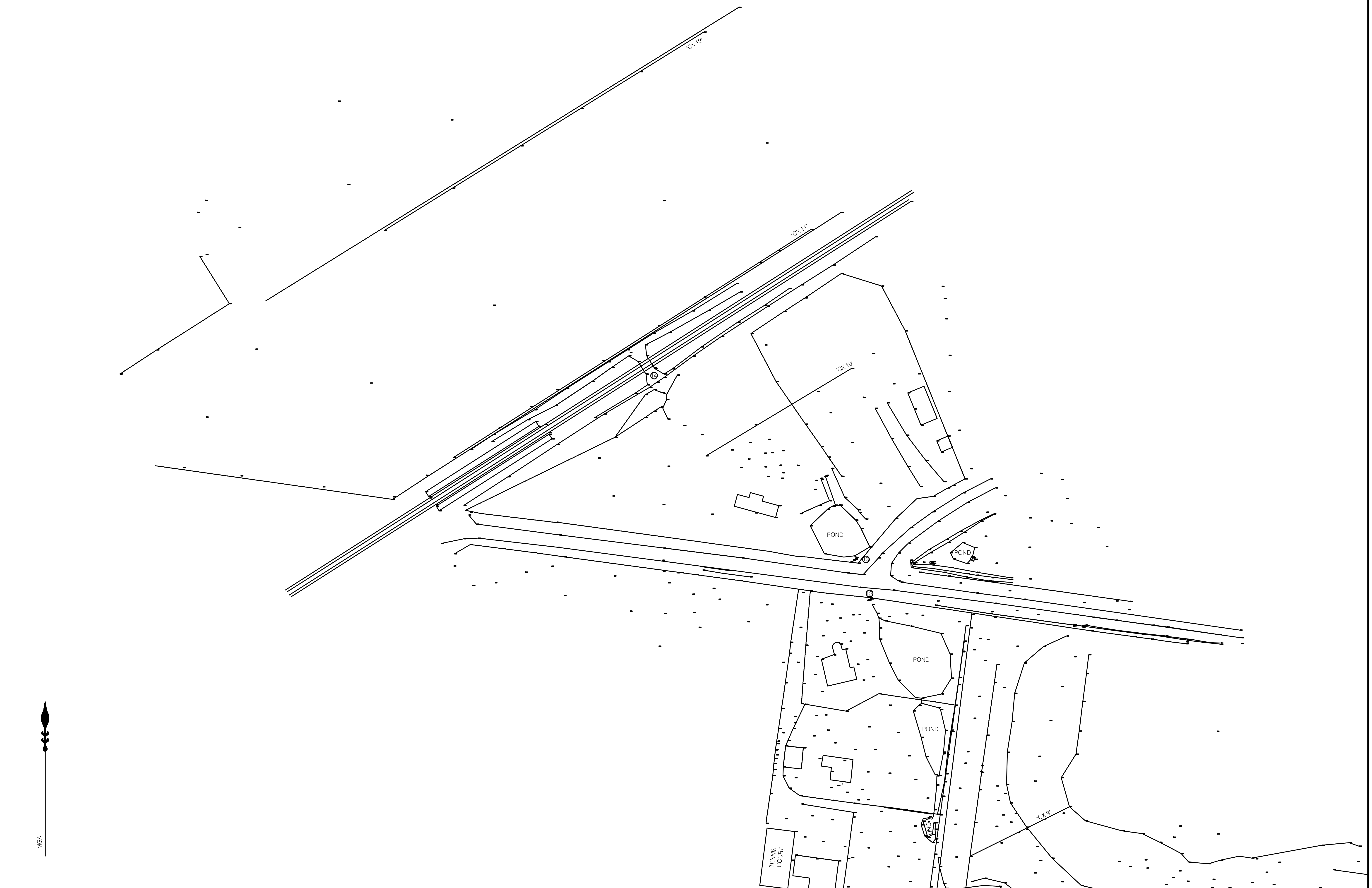
PROJECT
BURRADOO
FLOOD SURVEY

DRAWING TITLE
LEVEL SURVEY

TITLE INFORMATION
Lot:
Plan No.:
Title / Folio:
L.G.A.:
Parish:
County:

QUALITY ASSURANCE
Surveyor: BJ
Drawn: JK
Checked by: CH Date: 07/05/07
Approved by: CH Date: 07/05/07

Date of Survey: 02/04/07	Date of Plan: 07/05/07
Datum: AHD	Co-ords:
Scale: Not to Scale	(Original size A1)
Cad ref.:	Sheet 0 of 5
JOB NUMBER 071364	DRAWING NUMBER / ISSUE DET-001 / A



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COMPLETION OF QUALITY ASSURANCE IS EVIDENCE THAT THE SURVEY/WORKS UNDERTAKEN AND THE DRAWING HAVE BEEN VERIFIED AS CONFORMING WITH THE REQUIREMENTS OF THE QUALITY PLAN. WHERE THE QUALITY ASSURANCE IS INCOMPLETE ALL INFORMATION ON THIS DRAWING IS INTENDED FOR PRELIMINARY PURPOSES ONLY AS IT IS UNCHECKED.

Date of Survey: 02/04/07
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(Original size A1)
Cad ref.:
Sheet 1 of 5
JOB NUMBER
071364
DRAWING NUMBER / ISSUE
DET-001 / A

① to ⑨ & ⑪ - CULVERT CROSSINGS
⑩ - TUNNEL UNDER MOSS VALE RD
(ALSO SEE SHEET 5 of 5)

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Cad ref :
Sheet 2 of 5
JOB NUMBER
071364
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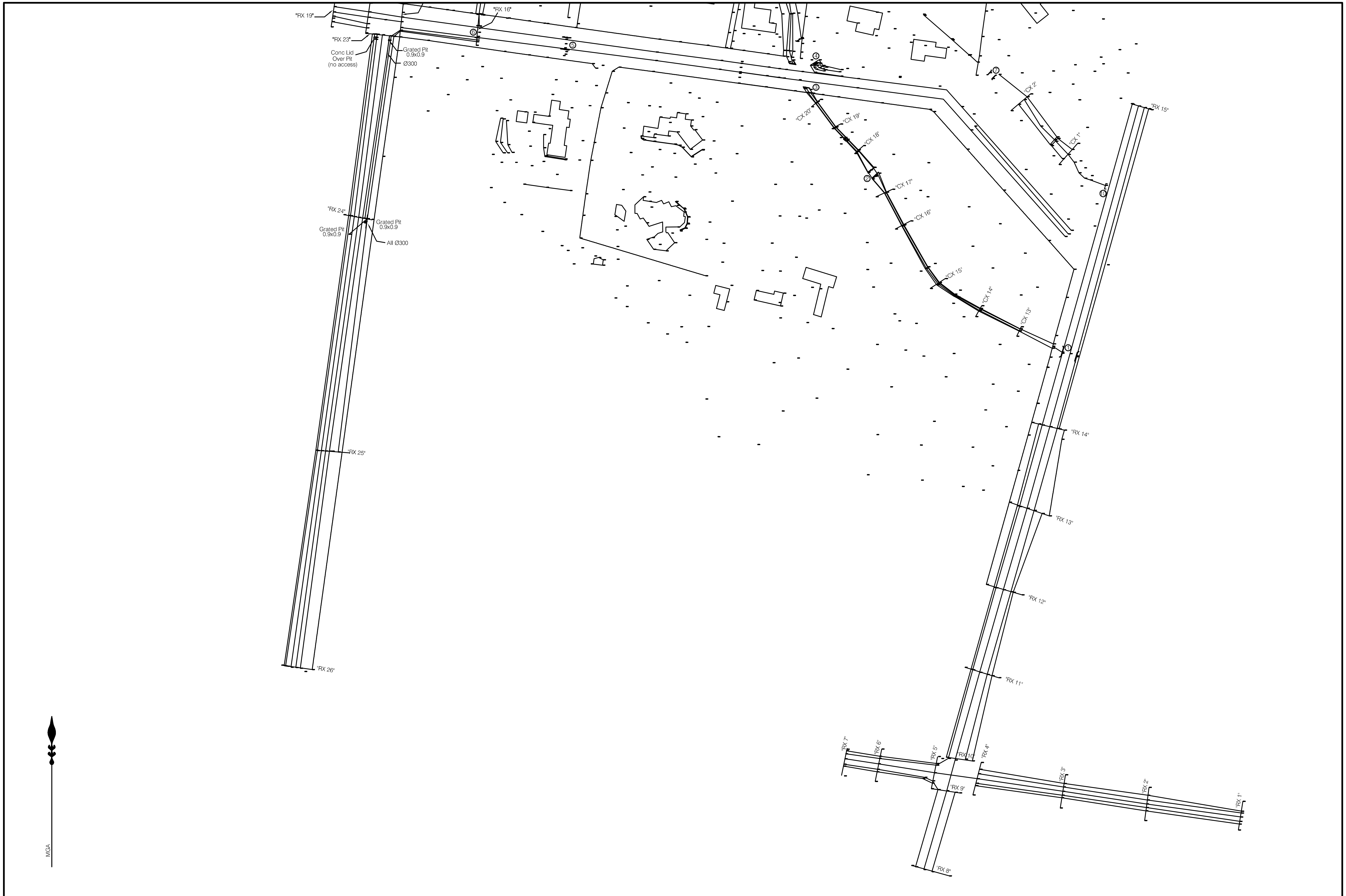
DET-001 / A



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Surveyor: BJ
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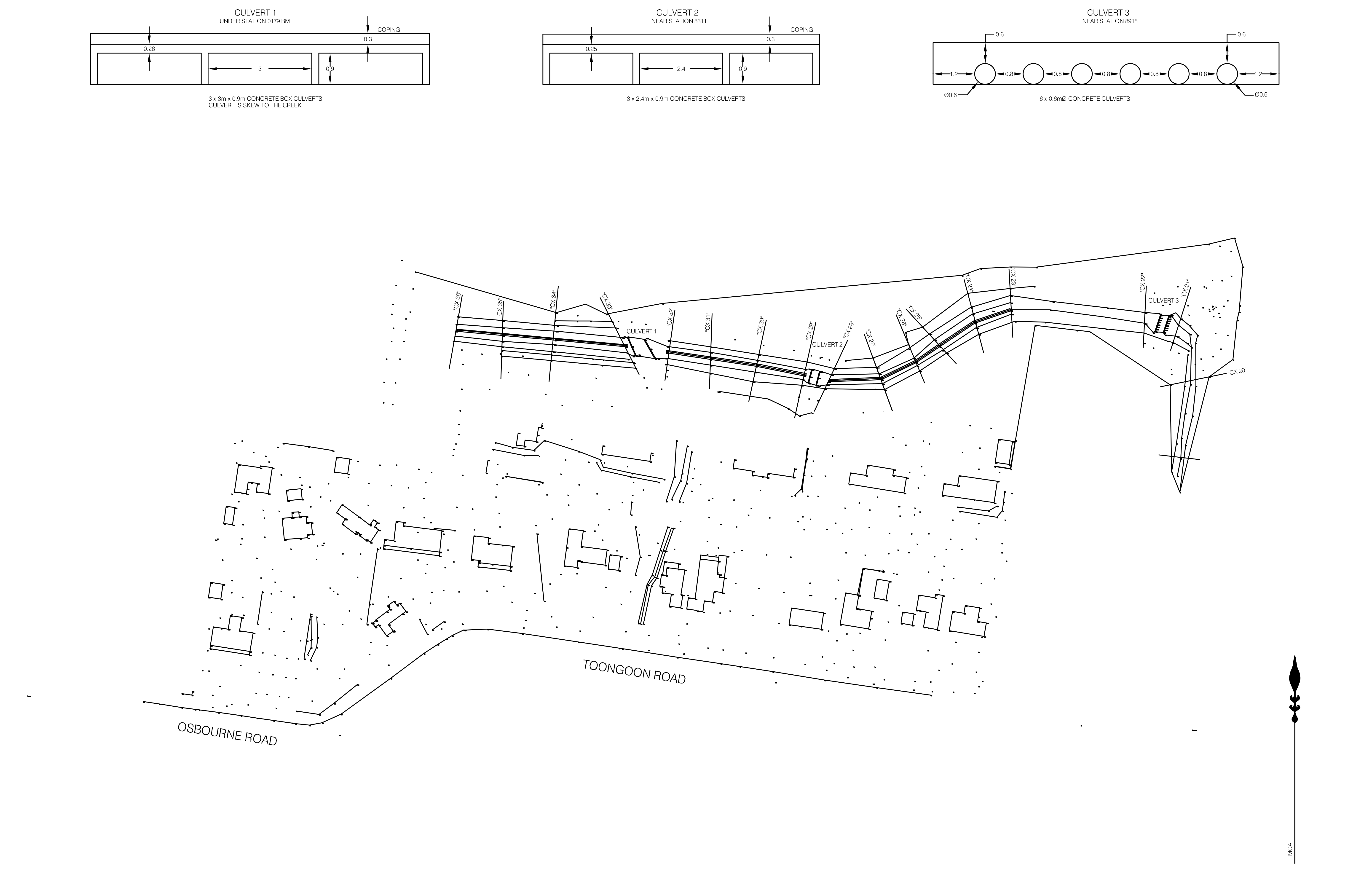
Datum: AHD	Co-ords:
Scale: 1:1000	(Original size A1)
Cad ref.:	Sheet 3 of 5

JOB NUMBER
071364

DRAWING NUMBER / ISSUE
DET-001 / A



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Date of Survey: 02/04/07	Date of Plan: 07/05/07
Datum: AHD	Co-ords:
Scale: 1:1000	(Original size A1)
Cad ref.:	Sheet 4 of 5

JOB NUMBER
071364

DRAWING NUMBER / ISSUE
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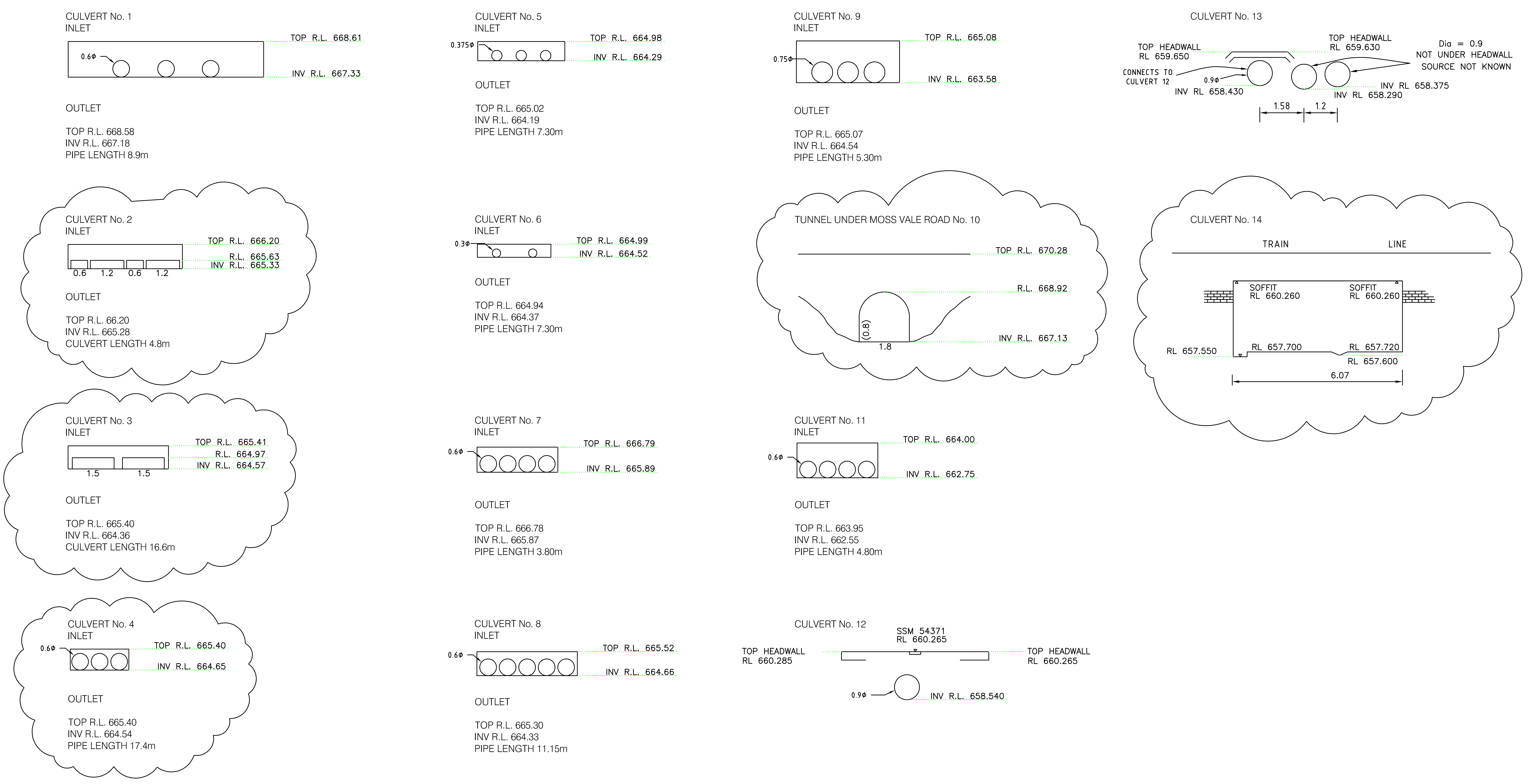

NOTE:

AMENDMENTS MADE TO CULVERTS
2,3,4,10 AND 14.

NOTE :-
THESE DETAILS REFER TO CULVERTS & TUNNEL
LOCATED ON SHEET Nos 2 AND 3

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LEGEND	
CLIENT	CARDNO LAWSON TRELOAR
PROJECT	BURRADOO FLOOD SURVEY
DRAWING TITLE	LEVEL SURVEY
TITLE INFORMATION	Lot: / Plan No.: / Title / Folio: / L.G.A.: / Parish: / County:
QUALITY ASSURANCE	Surveyor: BJ; Drawn: JK; Checked by: CH, Date: 07/05/07; Approved by: CH, Date: 07/05/07
Date of Survey:	02/04/07
Date of Plan:	07/05/07
Datum:	AHD
Co-ords:	
Scale:	1 :100
(Original size A2)	
Cad ref :	
Sheet	5 of 5
JOB NUMBER	071364
DRAWING NUMBER / ISSUE	DET-001 / B

APPENDIX D

Sub-catchment Details

Table D.1 RAFTS Sub-catchment Data

Catchment	Total Area	Catchment Slope	Catchment Division 1				Catchment Division 2			
			Area	Catchment Mannings	Percentage Impervious	Init/Cont Rainfall Loss	Area	Catchment Mannings	Percentage Impervious	Init/Cont Rainfall Loss
	Ha	%	Ha	n	%		Ha	n	%	
A0	7.819	1.6	7.815	0.04	5	Open Spaces Vegetation	0.004	0.05	25	Established Residential
A1	4.607	4.1	2.827	0.041	5	Open Spaces Vegetation	1.780	0.05	25	Established Residential
A23	3.878	2.5	2.002	0.04	5	Open Spaces Vegetation	1.876	0.05	25	Established Residential
AA1	0.766	1.9	0.761	0.04	5	Open Spaces Vegetation	0.006	0.05	25	Established Residential
B1	2.164	4.8	2.164	0.05	25	Established Residential				
C1	2.014	2	2.014	0.05	25	Established Residential				
D1	0.345	3.5	0.085	0.05	5	Dense	0.260	0.05	25	Established
E1	0.882	12.5	0.858	0.05	5	Dense	0.024	0.05	25	Established
E2	10.041	4.9	4.168	0.045	5	Open Spaces Vegetation	5.873	0.05	25	Established Residential
F1	1.734	5.4	0.950	0.047	5	Open Spaces Vegetation	0.784	0.05	25	Established Residential
G1	3.589	2	0.336	0.04	5	Open Spaces Vegetation	3.253	0.05	25	Established Residential
G3	1.820	2.8	1.820	0.05	25	Established Residential				
GA1	0.858	2.8	0.858	0.05	25	Established Residential				
H1	0.797	12.8	0.668	0.046	5	Dense	0.128	0.05	25	Established
I1	2.962	3.4	1.546	0.04	5	Open Spaces Vegetation	1.415	0.05	25	Established Residential
I2	0.994	1.9	0.013	0.04	5	Open Spaces Vegetation	0.982	0.05	25	Established Residential
J1	2.052	5.4	0.552	0.048	5	Dense	1.500	0.05	25	Established
J2	2.985	7.5	2.985	0.05	25	Established Residential				
K1	5.263	2.8	3.679	0.05	25	Established Residential	1.584	0.04	5	Open Spaces Vegetation
K3	1.555	2.8	1.430	0.05	25	Established Residential	0.125	0.04	5	Open Spaces Vegetation
K5	8.613	1.2	8.613	0.05	25	Established Residential				
KA1	3.861	3.4	1.996	0.05	25	Established Residential	1.865	0.04	5	Open Spaces Vegetation
KB1	1.879	5.7	1.135	0.05	25	Established Residential	0.744	0.04	5	Open Spaces Vegetation
KC1	6.252	1.2	6.252	0.05	25	Established Residential				
L1	2.764	4.7	0.538	0.047	5	Dense	2.226	0.05	25	Established
L2	1.279	5.9	1.279	0.05	25	Established Residential				
M1	4.059	7.7	4.059	0.05	25	Established Residential				
N1	4.945	1.3	2.825	0.05	25	Established Residential	2.120	0.04	5	Open Spaces Vegetation
N4	5.979	2.2	5.506	0.04	5	Open Spaces Vegetation	0.473	0.05	25	Established Residential
N5	4.891	4.3	4.088	0.046	5	Dense	0.803	0.05	25	Established
N6	6.931	3	2.619	0.04	5	Open Spaces Vegetation	4.312	0.029	46.4	High Density Development
N7	13.327	2.1	10.984	0.04	5	Open Spaces Vegetation	2.343	0.026	49.5	High Density Development
NA1	5.484	4.1	1.312	0.04	5	Open Spaces Vegetation	4.172	0.05	25	Established Residential
NB1	9.827	2.3	0.071	0.04	5	Open Spaces Vegetation	9.756	0.05	25	Established Residential
NB2	0.825	2.6	0.825	0.05	25	Established Residential				
O1	2.069	6.9	1.453	0.05	25	Established Residential	0.615	0.04	5	Open Spaces Vegetation
O2	0.825	4.6	0.003	0.04	5	Open Spaces Vegetation	0.821	0.05	25	Established Residential

Catchment	Total Area	Catchment Slope	Catchment Division 1				Catchment Division 2			
			Area	Catchment Mannings	Percentage Impervious	Init/Cont Rainfall Loss	Area	Catchment Mannings	Percentage Impervious	Init/Cont Rainfall Loss
	Ha	*%*	*Ha*	*n*	*%*		*Ha*	*n*	*%*	
P1	0.593	5	0.234	0.05	25	Established Residential	0.359	0.04	5	Open Spaces Vegetation
Q1	1.146	8.2	1.146	0.04	5	Open Spaces Vegetation				
Q2	4.028	5.6	0.877	0.04	5	Open Spaces Vegetation	3.151	0.05	25	Established Residential
R1	0.592	4.2	0.592	0.04	5	Open Spaces Vegetation				
S1	1.339	5	1.339	0.04	5	Open Spaces Vegetation				
S2	1.589	18.3	1.135	0.04	5	Open Spaces Vegetation	0.454	0.05	25	Established Residential
T1	1.167	2.3	1.167	0.04	5	Open Spaces Vegetation				
U1	0.880	5.2	0.880	0.04	5	Open Spaces Vegetation				
U2	1.899	13.2	0.521	0.04	5	Open Spaces Vegetation	1.378	0.05	25	Established Residential
V1	3.171	1.6	0.909	0.05	25	Established Residential	2.262	0.04	5	Open Spaces Vegetation
V2	4.422	2.9	4.360	0.05	25	Established Residential	0.062	0.04	5	Open Spaces Vegetation
V4	1.841	2.9	1.841	0.05	25	Established Residential				
V5	1.093	2.5	1.093	0.05	25	Established Residential				
VA1	12.900	2	11.382	0.05	25	Established Residential	1.518	0.04	5	Open Spaces Vegetation
W1	0.491	5.5	0.491	0.04	5	Open Spaces Vegetation				
W2	2.174	11.2	1.709	0.04	5	Open Spaces Vegetation	0.466	0.049	25	Established Residential
X1	1.114	4.5	0.407	0.05	25	Established Residential	0.707	0.04	5	Open Spaces Vegetation
Y1	1.031	5.1	0.308	0.03	25	Modern	0.723	0.04	5	Open Spaces
Y2	1.441	9.3	0.263	0.04	5	Open Spaces Vegetation	1.178	0.036	25	Modern Residential
Z1	0.802	5.1	0.342	0.04	5	Open Spaces Vegetation	0.460	0.03	25	Modern Residential
Z2	1.108	9.3	0.748	0.03	25	Modern	0.361	0.05	25	Established
ZZA1	0.777	6.7	0.513	0.05	25	Established Residential	0.264	0.04	5	Open Spaces Vegetation
ZZB1	2.557	2.6	0.017	0.04	5	Open Spaces Vegetation	2.540	0.03	25	Modern Residential
ZZB2	2.912	8.3	0.210	0.05	25	Established Residential	2.702	0.03	25	Modern Residential
ZZC1	3.256	2.9	3.233	0.038	25	Modern	0.023	0.04	5	Open Spaces
ZZD1	2.840	3.3	2.840	0.03	25	Modern				
ZZD2	3.046	6.7	1.261	0.05	25	Established Residential	1.785	0.03	25	Modern Residential
ZZE1	3.959	3.9	1.185	0.03	25	Modern	2.775	0.05	25	Established
ZZE2	3.640	4	3.640	0.05	25	Established Residential				
ZZF1	2.227	4.2	2.135	0.03	25	Modern	0.091	0.05	25	Established
ZZF2	0.744	4.8	0.328	0.05	25	Established Residential	0.416	0.03	25	Modern Residential
ZZG1	2.830	3.5	2.227	0.03	25	Modern	0.603	0.03	25	Established
ZZG2	2.312	3.3	2.303	0.05	25	Established Residential	0.009	0.03	25	Modern Residential
ZZH1	0.580	1.9	0.360	0.03	25	Modern	0.219	0.05	25	Established
ZZH2	4.123	2.7	1.938	0.03	25	Modern	2.185	0.05	25	Established
ZZHA1	3.956	1.8	1.176	0.05	5	Dense	2.780	0.046	25	Established
ZZI1	1.072	7.8	1.072	0.05	25	Established Residential				
ZZJ1	5.624	2.1	2.111	0.047	5	Dense	3.513	0.05	25	Established
ZZK1	2.275	8.4	1.172	0.05	25	Established Residential	1.103	0.04	5	Open Spaces Vegetation

APPENDIX E

RAFTS Flow Summary

XP-RAFTS Flow Summary - Burradoo BU2 Catchment
PMF Event - (results in m^3/s)

Node	15 min	30 min	45 min	60 min	90 min	120 min	180 min	360 min	Peak
AA1	1.324	1.20	1.10	1.01	0.87	0.77	0.65	0.46	**1.32**
A0	7.906	9.86	9.65	9.17	8.49	7.68	6.28	4.37	**9.86**
InQ24	9.211	11.01	10.68	10.13	9.35	8.43	6.90	4.83	**11.01**
O1	4.774	3.69	3.16	2.86	2.59	2.31	1.89	1.25	**4.77**
P1	1.312	1.05	0.89	0.81	0.73	0.65	0.54	0.36	**1.31**
InQ15	6.062	4.74	4.04	3.67	3.33	2.96	2.43	1.60	**6.06**
Q2	9.048	7.13	6.08	5.45	4.93	4.41	3.66	2.42	**9.05**
Q1	11.409	9.10	7.81	6.99	6.29	5.63	4.67	3.11	**11.41**
R1	1.233	1.02	0.89	0.79	0.70	0.63	0.53	0.36	**1.23**
InQ11	12.63	10.11	8.69	7.78	6.99	6.26	5.21	3.47	**12.63**
S2	3.734	2.87	2.48	2.29	2.02	1.79	1.45	0.96	**3.73**
S1	6.39	5.09	4.38	3.89	3.58	3.20	2.65	1.76	**6.39**
T1	2.032	1.83	1.67	1.53	1.33	1.18	1.00	0.70	**2.03**
InQ10	8.149	6.77	6.02	5.38	4.70	4.31	3.65	2.46	**8.15**
U2	4.611	3.46	3.03	2.75	2.43	2.14	1.73	1.14	**4.61**
U1	6.218	4.90	4.16	3.79	3.47	3.09	2.53	1.67	**6.22**
V1	4.544	4.50	4.29	3.97	3.58	3.13	2.60	1.86	**4.54**
InQ9	10.128	8.81	8.21	7.55	6.73	5.87	5.03	3.53	**10.13**
Y2	3.582	2.61	2.30	2.10	1.85	1.62	1.32	0.87	**3.58**
Y1	5.626	4.36	3.75	3.44	3.09	2.74	2.25	1.49	**5.63**
InQ6	5.626	4.36	3.75	3.44	3.09	2.74	2.25	1.49	**5.63**
ZZB2	7.463	5.53	4.70	4.25	3.75	3.28	2.67	1.75	**7.46**
ZZB1	13.471	10.06	8.63	7.76	6.91	6.10	4.99	3.29	**13.47**
ZZC1	7.369	5.79	4.95	4.42	3.96	3.54	2.95	1.96	**7.37**
InQ4	20.651	15.66	13.52	12.18	10.87	9.64	7.94	5.25	**20.65**
ZZE2	8.08	6.43	5.51	4.92	4.38	3.93	3.29	2.19	**8.08**
ZZE1	15.681	13.08	11.44	10.15	9.00	8.04	6.76	4.57	**15.68**
ZZD2	7.419	5.62	4.88	4.41	3.89	3.43	2.78	1.83	**7.42**
ZZD1	13.899	10.71	9.21	8.25	7.32	6.50	5.37	3.54	**13.90**
InQ3	28.527	23.27	20.26	18.09	16.25	14.47	12.10	8.11	**28.53**
ZZJ1	9.534	8.44	7.84	7.16	6.36	5.56	4.73	3.35	**9.53**
ZZK1	5.084	4.05	3.43	3.09	2.83	2.53	2.08	1.37	**5.08**
In1	13.9	12.21	11.05	10.15	8.94	7.81	6.74	4.71	**13.90**
A23	6.875	6.10	5.52	5.06	4.40	3.90	3.36	2.32	**6.88**
A22	20.364	17.97	16.52	15.14	13.34	11.70	10.03	7.03	**20.36**
ZZI1	2.647	1.99	1.72	1.55	1.37	1.21	0.98	0.65	**2.65**
node4	2.647	1.99	1.72	1.55	1.37	1.21	0.98	0.65	**2.65**
A21	21.848	19.55	17.91	16.45	14.55	12.76	10.90	7.64	**21.85**
node106	21.848	19.55	17.91	16.45	14.55	12.76	10.90	7.64	**21.85**
ZZHA1	6.974	6.12	5.57	5.08	4.48	3.92	3.37	2.36	**6.97**
ZZH2	9.106	7.24	6.20	5.53	5.01	4.49	3.74	2.48	**9.11**
ZZH1	1.392	1.05	0.90	0.82	0.73	0.65	0.53	0.35	**1.39**
node110	17.101	14.09	12.53	11.27	9.80	8.89	7.64	5.19	**17.10**
InQ1	36.904	32.78	30.01	27.50	24.34	21.31	18.25	12.80	**36.90**
ZZG2	5.131	4.08	3.49	3.12	2.79	2.51	2.09	1.39	**5.13**
ZZG1	10.456	8.80	7.73	6.84	6.06	5.45	4.60	3.09	**10.46**
ZZF2	1.867	1.39	1.20	1.09	0.96	0.84	0.68	0.45	**1.87**
ZZF1	6.992	5.38	4.63	4.14	3.70	3.31	2.71	1.79	**6.99**
InQ2	16.56	13.84	12.18	10.75	9.68	8.73	7.31	4.88	**16.56**
A19	47.979	44.67	41.04	37.44	33.47	29.30	24.91	17.53	**47.98**

A18	68.027	64.02	59.23	54.13	48.66	42.58	35.99	25.50	**68.03**
A17	76.037	75.49	70.17	64.75	58.32	51.17	42.96	30.47	**76.04**
Z2	2.867	2.12	1.82	1.66	1.44	1.25	1.01	0.67	**2.87**
Z1	4.585	3.49	3.00	2.75	2.43	2.14	1.74	1.15	**4.59**
ZZA1	1.83	1.39	1.20	1.10	0.98	0.87	0.71	0.47	**1.83**
InQ5	6.415	4.88	4.20	3.83	3.41	3.01	2.45	1.62	**6.42**
A16	78.165	78.97	73.42	68.09	61.28	53.81	45.11	31.99	**78.97**
A15	79.35	82.00	76.37	70.96	63.97	56.25	47.08	33.35	**82.00**
X1	2.319	1.93	1.67	1.48	1.34	1.21	1.01	0.67	**2.32**
W2	4.825	3.86	3.28	2.94	2.69	2.40	1.98	1.31	**4.83**
W1	5.885	4.73	4.02	3.60	3.29	2.94	2.42	1.60	**5.89**
InQ7	8.201	6.66	5.69	5.07	4.62	4.15	3.43	2.27	**8.20**
A14	80.725	86.24	80.86	75.02	67.91	59.97	50.10	35.43	**86.24**
V5	2.444	1.95	1.66	1.48	1.33	1.19	0.99	0.66	**2.44**
V4	6.355	5.16	4.43	3.95	3.53	3.15	2.64	1.77	**6.36**
VA1	22.346	20.20	18.49	16.84	14.70	12.98	10.94	7.68	**22.35**
V3	28.632	25.26	22.75	20.70	18.05	16.02	13.58	9.44	**28.63**
V2	34.949	31.89	28.98	26.22	23.06	20.42	17.30	12.01	**34.95**
InQ8	34.949	31.89	28.98	26.22	23.06	20.42	17.30	12.01	**34.95**
A13	117.64	123.64	116.39	107.84	97.25	85.81	71.66	50.73	**123.64**
A12	119.35	128.07	121.17	112.55	101.59	89.84	74.93	52.96	**128.07**
Det-inf	121.12	133.91	127.69	118.87	107.56	95.51	79.53	56.03	**133.91**
A11	78.972	98.69	102.97	100.47	96.39	88.58	75.58	52.02	**102.97**
N7	14.277	17.19	16.64	16.10	14.68	13.12	10.72	7.58	**17.19**
N6	23.385	25.42	24.81	23.80	22.08	19.91	16.26	11.54	**25.42**
N5	30.618	31.34	30.74	29.32	27.32	24.64	20.17	14.35	**31.34**
InQ12	30.618	31.34	30.74	29.32	27.32	24.64	20.17	14.35	**31.34**
N4	7.761	8.38	7.90	7.47	6.74	5.90	4.88	3.46	**8.38**
InQ13	7.761	8.38	7.90	7.47	6.74	5.90	4.88	3.46	**8.38**
Det-PC	36.973	38.37	37.86	36.12	33.77	30.28	24.94	17.72	**38.37**
NB2	1.879	1.47	1.26	1.13	1.01	0.90	0.75	0.50	**1.88**
NB1	19.978	17.45	15.53	14.01	12.22	10.88	9.20	6.38	**19.98**
node58	19.978	17.45	15.53	14.01	12.22	10.88	9.20	6.38	**19.98**
NA1	11.512	9.44	8.22	7.27	6.49	5.86	4.92	3.30	**11.51**
InQ14	29.358	26.03	23.33	21.18	18.45	16.43	13.95	9.64	**29.36**
N3	30.628	34.11	43.27	45.09	44.73	42.33	36.32	24.85	**45.09**
N2	30.628	34.11	43.27	45.09	44.73	42.33	36.32	24.85	**45.09**
N1	7.612	7.12	6.73	6.18	5.57	4.87	4.06	2.91	**7.61**
O2	1.986	1.50	1.29	1.17	1.04	0.92	0.75	0.50	**1.99**
InQ16	9.361	8.49	7.89	7.21	6.51	5.68	4.78	3.41	**9.36**
A10	92.996	134.48	150.73	151.43	148.21	137.62	117.85	80.29	**151.43**
A9	92.996	134.48	150.73	151.43	148.21	137.62	117.85	80.29	**151.43**
A8	92.996	134.48	150.73	151.43	148.21	137.62	117.85	80.29	**151.43**
A7	92.996	134.48	150.73	151.43	148.21	137.62	117.85	80.29	**151.43**
L1	6.139	4.86	4.15	3.71	3.37	3.03	2.51	1.66	**6.14**
K1	10.193	8.73	7.76	6.92	6.06	5.43	4.63	3.16	**10.19**
J2	7.086	5.41	4.64	4.17	3.73	3.33	2.72	1.80	**7.09**
J1	11.392	9.01	7.71	6.91	6.15	5.46	4.55	3.03	**11.39**
M1	9.601	7.31	6.26	5.64	5.07	4.51	3.70	2.44	**9.60**
L2	3.063	2.33	2.00	1.81	1.62	1.43	1.17	0.77	**3.06**
InQ18	39.991	31.85	27.44	24.49	22.04	19.77	16.53	11.07	**39.99**
KA1	7.336	6.36	5.67	5.08	4.43	4.00	3.41	2.32	**7.34**
InQ17	7.336	6.36	5.67	5.08	4.43	4.00	3.41	2.32	**7.34**
A6	93.537	136.24	159.43	165.25	166.36	155.55	134.99	92.00	**166.36**

KB1	4.159	3.31	2.83	2.54	2.32	2.07	1.71	1.13	**4.16**
KC1	10.042	9.57	8.85	8.06	7.10	6.25	5.22	3.68	**10.04**
K5	13.153	12.86	12.04	10.93	9.77	8.56	7.13	5.06	**13.15**
K4	23.195	22.38	20.89	18.99	16.87	14.80	12.35	8.74	**23.20**
K3	23.811	24.22	22.73	20.89	18.56	16.33	13.59	9.58	**24.22**
InQ20	24.495	26.41	24.99	23.19	20.67	18.18	15.09	10.59	**26.41**
A5	98.932	147.12	175.76	182.66	183.14	171.21	148.52	101.62	**183.14**
H1	1.847	1.43	1.22	1.11	1.00	0.89	0.73	0.48	**1.85**
I2	2.145	1.75	1.50	1.33	1.19	1.07	0.90	0.60	**2.15**
I1	7.744	6.65	5.87	5.21	4.60	4.13	3.49	2.38	**7.74**
InQ19	9.274	7.97	7.05	6.26	5.51	4.95	4.21	2.86	**9.27**
A4	99.049	147.56	177.65	185.85	187.02	174.97	152.25	104.11	**187.02**
GA1	1.967	1.54	1.31	1.18	1.06	0.94	0.78	0.52	**1.97**
G3	3.989	3.21	2.75	2.45	2.19	1.97	1.65	1.10	**3.99**
G2	5.738	4.66	4.03	3.59	3.22	2.88	2.40	1.61	**5.74**
G1	12.317	10.63	9.36	8.33	7.38	6.58	5.50	3.77	**12.32**
F1	3.538	2.94	2.59	2.29	2.06	1.87	1.56	1.04	**3.54**
InQ21	15.254	13.40	11.89	10.62	9.36	8.32	6.96	4.81	**15.25**
A3	99.225	148.20	180.68	191.07	193.53	181.20	158.24	108.32	**193.53**
E2	18.742	16.35	14.58	13.18	11.44	10.23	8.81	6.03	**18.74**
E1	20.26	17.69	15.82	14.29	12.44	11.11	9.56	6.54	**20.26**
D1	0.795	0.61	0.53	0.48	0.43	0.39	0.31	0.21	**0.80**
InQ22	20.985	18.26	16.34	14.74	12.83	11.47	9.88	6.75	**20.99**
A2	104.13	149.16	185.49	198.62	202.78	190.09	167.00	114.24	**202.78**
A1	8.494	7.51	6.70	6.05	5.25	4.68	4.05	2.77	**8.49**
C1	4.145	3.43	3.02	2.67	2.37	2.12	1.79	1.21	**4.15**
B1	5.044	3.88	3.31	2.97	2.67	2.38	1.97	1.30	**5.04**
InQ23	17.58	14.77	12.96	11.55	10.21	9.19	7.77	5.28	**17.58**
node95	115.56	149.61	188.05	203.81	209.93	196.72	173.41	118.86	**209.93**
Out	123.67	151.44	191.66	209.37	217.07	203.26	179.40	123.38	**217.07**

XP-RAFTS Flow Summary - Burradoo BU2 Catchment
100 Year ARI - (results in m^3/s)

Node	30 min	60 min	90 min	120 min	180 min	270 min	360 min	540 min	720 min	Peak
AA1	0.18	0.22	0.24	0.26	0.20	0.17	0.14	0.13	0.13	**0.26**
A0	1.13	1.48	1.50	1.57	1.27	1.51	1.29	1.13	1.19	**1.57**
InQ24	1.30	1.67	1.70	1.81	1.44	1.66	1.44	1.26	1.32	**1.81**
O1	0.94	0.94	1.00	0.95	0.59	0.53	0.39	0.34	0.35	**1.00**
P1	0.25	0.27	0.29	0.27	0.17	0.15	0.11	0.10	0.10	**0.29**
InQ15	1.20	1.21	1.29	1.22	0.76	0.68	0.50	0.44	0.45	**1.29**
Q2	1.75	1.71	1.80	1.72	1.15	1.03	0.75	0.67	0.68	**1.80**
Q1	2.16	2.14	2.24	2.19	1.48	1.31	0.97	0.86	0.87	**2.24**
R1	0.19	0.22	0.24	0.24	0.17	0.15	0.11	0.10	0.10	**0.24**
InQ11	2.34	2.36	2.47	2.43	1.65	1.46	1.08	0.96	0.97	**2.47**
S2	0.78	0.77	0.82	0.77	0.46	0.41	0.30	0.26	0.27	**0.82**
S1	1.16	1.25	1.33	1.28	0.83	0.74	0.55	0.49	0.49	**1.33**
T1	0.27	0.33	0.36	0.39	0.30	0.26	0.22	0.19	0.19	**0.39**
InQ10	1.36	1.54	1.69	1.62	1.13	1.00	0.76	0.68	0.69	**1.69**
U2	0.95	0.94	1.00	0.95	0.54	0.49	0.35	0.32	0.32	**1.00**
U1	1.22	1.27	1.36	1.28	0.79	0.71	0.52	0.46	0.47	**1.36**
V1	0.61	0.78	0.88	0.92	0.72	0.67	0.57	0.50	0.52	**0.92**
InQ9	1.81	1.97	2.24	2.04	1.50	1.37	1.09	0.96	0.98	**2.24**
Y2	0.74	0.72	0.77	0.74	0.41	0.37	0.27	0.24	0.24	**0.77**
Y1	1.08	1.12	1.19	1.16	0.71	0.63	0.46	0.41	0.41	**1.19**
InQ6	1.08	1.12	1.19	1.16	0.71	0.63	0.46	0.41	0.41	**1.19**
ZZB2	1.49	1.46	1.57	1.49	0.83	0.75	0.54	0.48	0.49	**1.57**
ZZB1	2.65	2.53	2.67	2.63	1.57	1.40	1.02	0.91	0.92	**2.67**
ZZC1	1.49	1.38	1.43	1.37	0.93	0.83	0.61	0.54	0.55	**1.49**
InQ4	4.14	3.91	4.10	3.99	2.50	2.23	1.63	1.45	1.46	**4.14**
ZZE2	1.61	1.51	1.55	1.50	1.04	0.93	0.68	0.60	0.61	**1.61**
ZZE1	3.12	3.02	3.07	3.08	2.16	1.91	1.42	1.26	1.27	**3.12**
ZZD2	1.54	1.49	1.60	1.50	0.87	0.78	0.57	0.51	0.51	**1.60**
ZZD1	2.78	2.57	2.69	2.75	1.69	1.51	1.10	0.98	0.99	**2.78**
InQ3	5.89	5.58	5.76	5.76	3.85	3.42	2.52	2.24	2.26	**5.89**
ZZJ1	1.50	1.67	1.85	1.88	1.42	1.27	1.03	0.91	0.93	**1.88**
ZZK1	0.97	1.03	1.11	1.04	0.65	0.58	0.43	0.38	0.38	**1.11**
In1	2.45	2.67	2.90	2.79	2.07	1.84	1.46	1.29	1.31	**2.90**
A23	1.08	1.22	1.38	1.39	1.04	0.91	0.72	0.64	0.65	**1.39**
A22	3.37	3.71	4.12	4.10	3.06	2.73	2.18	1.92	1.96	**4.12**
ZZI1	0.54	0.52	0.56	0.53	0.31	0.27	0.20	0.18	0.18	**0.56**
node4	0.54	0.52	0.56	0.53	0.31	0.27	0.20	0.18	0.18	**0.56**
A21	3.70	4.08	4.45	4.43	3.31	2.96	2.37	2.09	2.13	**4.45**
node106	3.70	4.08	4.45	4.43	3.31	2.96	2.37	2.09	2.13	**4.45**
ZZHA1	1.19	1.26	1.35	1.37	1.01	0.91	0.73	0.65	0.66	**1.37**
ZZH2	1.88	1.76	1.85	1.74	1.18	1.05	0.77	0.68	0.69	**1.88**
ZZH1	0.29	0.27	0.29	0.27	0.17	0.15	0.11	0.10	0.10	**0.29**
node110	3.36	3.30	3.48	3.31	2.36	2.11	1.61	1.43	1.45	**3.48**
InQ1	6.57	7.07	7.49	7.58	5.57	4.98	3.97	3.51	3.57	**7.58**
ZZG2	1.03	0.97	1.00	0.96	0.66	0.59	0.43	0.38	0.39	**1.03**
ZZG1	2.17	2.13	2.18	2.10	1.46	1.30	0.96	0.85	0.86	**2.18**
ZZF2	0.38	0.37	0.40	0.38	0.21	0.19	0.14	0.12	0.12	**0.40**
ZZF1	1.46	1.35	1.44	1.39	0.85	0.76	0.56	0.49	0.50	**1.46**
InQ2	3.60	3.48	3.60	3.47	2.32	2.06	1.52	1.35	1.36	**3.60**
A19	8.94	9.60	9.93	10.14	7.51	6.77	5.46	4.82	4.91	**10.14**

A18	13.21	14.00	14.50	14.90	11.10	9.91	7.94	7.03	7.14	**14.90**
A17	15.35	16.39	16.56	17.19	13.14	11.72	9.51	8.41	8.56	**17.19**
Z2	0.57	0.56	0.60	0.59	0.32	0.28	0.21	0.18	0.19	**0.60**
Z1	0.92	0.92	0.97	0.94	0.55	0.49	0.36	0.32	0.32	**0.97**
ZZA1	0.38	0.37	0.40	0.37	0.22	0.20	0.15	0.13	0.13	**0.40**
InQ5	1.30	1.28	1.36	1.32	0.77	0.69	0.50	0.45	0.45	**1.36**
A16	15.87	17.02	17.04	17.80	13.73	12.25	9.99	8.84	8.99	**17.80**
A15	16.36	17.60	17.55	18.33	14.26	12.74	10.43	9.23	9.37	**18.33**
X1	0.41	0.45	0.49	0.46	0.32	0.28	0.21	0.18	0.19	**0.49**
W2	0.90	0.96	1.03	0.96	0.62	0.56	0.41	0.36	0.36	**1.03**
W1	1.08	1.17	1.25	1.16	0.76	0.68	0.50	0.44	0.45	**1.25**
InQ7	1.48	1.62	1.73	1.63	1.08	0.96	0.71	0.63	0.63	**1.73**
A14	17.16	18.48	18.38	19.17	15.00	13.49	11.07	9.80	9.97	**19.17**
V5	0.50	0.46	0.48	0.45	0.31	0.28	0.20	0.18	0.18	**0.50**
V4	1.27	1.20	1.22	1.21	0.84	0.74	0.55	0.49	0.49	**1.27**
VA1	3.47	3.99	4.28	4.35	3.38	2.86	2.39	2.11	2.14	**4.35**
V3	4.62	5.17	5.38	5.56	4.21	3.60	2.94	2.60	2.64	**5.56**
V2	5.91	6.57	6.84	6.99	5.27	4.61	3.74	3.31	3.36	**6.99**
InQ8	5.91	6.57	6.84	6.99	5.27	4.61	3.74	3.31	3.36	**6.99**
A13	24.11	26.28	26.42	27.57	21.38	19.27	15.85	14.02	14.26	**27.57**
A12	24.95	27.22	27.26	28.45	22.16	20.08	16.55	14.64	14.88	**28.45**
Det-inf	26.01	28.44	28.25	29.41	23.12	21.18	17.49	15.48	15.70	**29.41**
A11	14.88	19.04	19.48	20.29	16.13	17.53	15.19	13.69	13.93	**20.29**
N7	2.02	2.58	2.93	2.93	2.36	2.59	2.31	2.00	2.10	**2.93**
N6	3.95	4.46	5.15	5.12	3.93	3.92	3.53	3.08	3.21	**5.15**
N5	4.96	5.80	6.60	6.65	5.04	4.97	4.38	3.84	3.97	**6.65**
InQ12	4.96	5.80	6.60	6.65	5.04	4.97	4.38	3.84	3.97	**6.65**
N4	1.08	1.36	1.37	1.51	1.22	1.22	1.07	0.93	0.96	**1.51**
InQ13	1.08	1.36	1.37	1.51	1.22	1.22	1.07	0.93	0.96	**1.51**
Det-PC	5.90	7.15	7.96	8.12	6.18	6.19	5.37	4.73	4.84	**8.12**
NB2	0.38	0.35	0.36	0.35	0.24	0.21	0.15	0.14	0.14	**0.38**
NB1	3.34	3.67	3.84	3.85	2.91	2.48	1.98	1.76	1.78	**3.85**
node58	3.34	3.67	3.84	3.85	2.91	2.48	1.98	1.76	1.78	**3.85**
NA1	2.13	2.16	2.28	2.22	1.56	1.38	1.03	0.91	0.92	**2.28**
InQ14	5.10	5.63	5.84	5.87	4.40	3.78	3.00	2.66	2.70	**5.87**
N3	6.00	6.61	6.87	6.92	5.44	4.89	4.21	3.94	4.00	**6.92**
N2	6.00	6.61	6.87	6.92	5.44	4.89	4.21	3.94	4.00	**6.92**
N1	1.09	1.31	1.43	1.50	1.14	1.05	0.90	0.79	0.81	**1.50**
O2	0.41	0.38	0.40	0.38	0.24	0.21	0.15	0.14	0.14	**0.41**
InQ16	1.47	1.67	1.79	1.86	1.38	1.26	1.05	0.92	0.95	**1.86**
A10	18.44	23.89	24.39	25.20	20.66	22.54	19.90	18.25	18.28	**25.20**
A9	18.44	23.89	24.39	25.20	20.66	22.54	19.90	18.25	18.28	**25.20**
A8	18.44	23.89	24.39	25.20	20.66	22.54	19.90	18.25	18.28	**25.20**
A7	18.44	23.89	24.39	25.20	20.66	22.54	19.90	18.25	18.28	**25.20**
L1	1.21	1.17	1.24	1.17	0.79	0.70	0.52	0.46	0.46	**1.24**
K1	1.73	1.85	2.01	2.01	1.46	1.27	0.98	0.87	0.88	**2.01**
J2	1.46	1.35	1.44	1.36	0.86	0.77	0.56	0.50	0.50	**1.46**
J1	2.21	2.10	2.15	2.22	1.44	1.29	0.94	0.84	0.84	**2.22**
M1	1.99	1.82	1.94	1.83	1.16	1.04	0.76	0.67	0.68	**1.99**
L2	0.63	0.59	0.63	0.60	0.37	0.33	0.24	0.21	0.21	**0.63**
InQ18	7.66	7.42	7.75	7.74	5.22	4.63	3.44	3.05	3.08	**7.75**
KA1	1.25	1.37	1.51	1.48	1.08	0.94	0.72	0.64	0.65	**1.51**
InQ17	1.25	1.37	1.51	1.48	1.08	0.94	0.72	0.64	0.65	**1.51**
A6	19.01	25.90	26.89	27.99	23.63	24.47	22.63	20.98	19.77	**27.99**

KB1	0.78	0.81	0.87	0.83	0.54	0.48	0.35	0.31	0.32	**0.87**
KC1	1.63	1.88	2.03	2.05	1.61	1.35	1.15	1.01	1.03	**2.05**
K5	2.14	2.47	2.60	2.66	2.16	1.82	1.57	1.37	1.41	**2.66**
K4	3.77	4.35	4.63	4.71	3.76	3.17	2.71	2.39	2.44	**4.71**
K3	4.03	4.68	5.01	5.05	4.05	3.47	2.95	2.61	2.62	**5.05**
InQ20	4.33	5.09	5.41	5.44	4.34	3.83	3.25	2.86	2.93	**5.44**
A5	21.51	29.11	29.99	31.14	26.33	27.79	25.35	23.47	22.70	**31.14**
H1	0.35	0.36	0.39	0.36	0.23	0.20	0.15	0.13	0.13	**0.39**
I2	0.42	0.40	0.41	0.40	0.28	0.25	0.19	0.16	0.17	**0.42**
I1	1.27	1.41	1.53	1.53	1.10	0.96	0.74	0.66	0.66	**1.53**
InQ19	1.61	1.76	1.89	1.85	1.33	1.17	0.89	0.79	0.80	**1.89**
A4	21.66	29.54	30.52	31.74	26.97	28.40	25.93	24.05	23.26	**31.74**
GA1	0.40	0.36	0.38	0.37	0.25	0.22	0.16	0.14	0.14	**0.40**
G3	0.80	0.76	0.77	0.75	0.52	0.46	0.34	0.30	0.31	**0.80**
G2	1.14	1.10	1.12	1.10	0.76	0.67	0.50	0.44	0.45	**1.14**
G1	2.31	2.33	2.30	2.43	1.76	1.52	1.17	1.04	1.05	**2.43**
F1	0.61	0.69	0.75	0.70	0.49	0.43	0.32	0.29	0.29	**0.75**
InQ21	2.78	2.90	2.88	3.06	2.23	1.94	1.49	1.33	1.34	**3.06**
A3	21.91	30.26	31.40	32.67	28.05	29.39	26.91	25.03	24.17	**32.67**
E2	3.29	3.47	3.82	3.80	2.76	2.44	1.87	1.66	1.68	**3.82**
E1	3.60	3.80	4.13	4.10	2.98	2.65	2.03	1.80	1.83	**4.13**
D1	0.16	0.16	0.17	0.16	0.10	0.09	0.06	0.06	0.06	**0.17**
InQ22	3.74	3.95	4.29	4.23	3.08	2.74	2.10	1.86	1.88	**4.29**
A2	23.08	31.25	32.65	34.05	29.58	30.81	28.30	26.41	25.61	**34.05**
A1	1.37	1.53	1.76	1.73	1.26	1.11	0.86	0.76	0.77	**1.76**
C1	0.79	0.80	0.81	0.80	0.57	0.50	0.38	0.33	0.34	**0.81**
B1	1.04	0.95	1.00	0.95	0.62	0.55	0.40	0.36	0.36	**1.04**
InQ23	3.09	3.25	3.38	3.45	2.45	2.15	1.64	1.46	1.47	**3.45**
node95	24.23	31.96	33.57	35.03	30.76	31.80	29.37	27.48	26.66	**35.03**
Out	25.31	32.95	34.64	36.15	31.90	32.99	30.52	28.58	27.71	**36.15**

XP-RAFTS Flow Summary - Burradoo BU2 Catchment
50 Year ARI - (results in m^3/s)

Node	60min	90 min	120 min	360 min	Peak
A0	1.24	1.26	1.30	1.13	**1.30**
AA1	0.19	0.20	0.22	0.13	**0.22**
InQ24	1.39	1.42	1.49	1.25	**1.49**
O1	0.82	0.88	0.84	0.34	**0.88**
P1	0.23	0.26	0.24	0.10	**0.26**
InQ15	1.06	1.14	1.08	0.44	**1.14**
Q2	1.51	1.58	1.52	0.67	**1.58**
Q1	1.88	1.98	1.94	0.86	**1.98**
R1	0.19	0.21	0.21	0.10	**0.21**
InQ11	2.07	2.18	2.15	0.95	**2.18**
S2	0.68	0.73	0.68	0.26	**0.73**
S1	1.08	1.17	1.13	0.48	**1.17**
T1	0.28	0.30	0.33	0.19	**0.33**
InQ10	1.32	1.46	1.41	0.68	**1.46**
U2	0.83	0.89	0.84	0.31	**0.89**
U1	1.11	1.20	1.13	0.46	**1.20**
V1	0.65	0.70	0.76	0.50	**0.76**
InQ9	1.69	1.90	1.74	0.96	**1.90**
Y2	0.65	0.69	0.66	0.24	**0.69**
Y1	0.98	1.05	1.02	0.41	**1.05**
InQ6	0.98	1.05	1.02	0.41	**1.05**
ZZB2	1.30	1.39	1.32	0.48	**1.39**
ZZB1	2.24	2.37	2.32	0.91	**2.37**
ZZC1	1.22	1.26	1.21	0.54	**1.26**
InQ4	3.46	3.63	3.52	1.44	**3.63**
ZZE2	1.34	1.37	1.33	0.60	**1.37**
ZZE1	2.68	2.71	2.73	1.26	**2.73**
ZZD2	1.32	1.41	1.33	0.50	**1.41**
ZZD1	2.28	2.38	2.44	0.97	**2.44**
InQ3	4.94	5.09	5.11	2.23	**5.11**
ZZJ1	1.43	1.57	1.61	0.91	**1.61**
ZZK1	0.89	0.97	0.91	0.38	**0.97**
In1	2.30	2.49	2.41	1.29	**2.49**
A23	1.02	1.18	1.20	0.64	**1.20**
A22	3.18	3.51	3.52	1.92	**3.52**
ZZI1	0.46	0.50	0.46	0.18	**0.50**
node4	0.46	0.50	0.46	0.18	**0.50**
A21	3.51	3.81	3.81	2.09	**3.81**
node106	3.51	3.81	3.81	2.09	**3.81**
ZZHA1	1.10	1.17	1.18	0.65	**1.18**
ZZH2	1.56	1.62	1.53	0.68	**1.62**
ZZH1	0.24	0.26	0.24	0.10	**0.26**
node110	2.90	3.05	2.91	1.42	**3.05**
InQ1	6.17	6.50	6.56	3.51	**6.56**
ZZG2	0.86	0.88	0.85	0.38	**0.88**
ZZG1	1.89	1.93	1.86	0.85	**1.93**
ZZF2	0.33	0.35	0.33	0.12	**0.35**
ZZF1	1.20	1.28	1.23	0.49	**1.28**
InQ2	3.09	3.19	3.07	1.34	**3.19**
A19	8.39	8.69	8.88	4.82	**8.88**

A18	12.27	12.74	13.08	7.02	**13.08**
A17	14.37	14.62	15.13	8.40	**15.13**
Z2	0.50	0.54	0.52	0.18	**0.54**
Z1	0.81	0.86	0.84	0.32	**0.86**
ZZA1	0.33	0.35	0.33	0.13	**0.35**
InQ5	1.13	1.20	1.17	0.44	**1.20**
A16	14.93	15.06	15.69	8.84	**15.69**
A15	15.45	15.47	16.16	9.22	**16.16**
X1	0.39	0.43	0.40	0.18	**0.43**
W2	0.84	0.91	0.84	0.36	**0.91**
W1	1.02	1.10	1.03	0.44	**1.10**
InQ7	1.41	1.52	1.43	0.63	**1.52**
A14	16.25	16.13	16.90	9.79	**16.90**
V5	0.40	0.41	0.40	0.18	**0.41**
V4	1.05	1.07	1.07	0.49	**1.07**
VA1	3.47	3.68	3.78	2.11	**3.78**
V3	4.49	4.67	4.84	2.60	**4.84**
V2	5.74	5.96	6.11	3.31	**6.11**
InQ8	5.74	5.96	6.11	3.31	**6.11**
A13	23.08	23.16	24.22	14.01	**24.22**
A12	23.92	23.92	25.01	14.62	**25.01**
Det-inf	24.95	24.82	25.87	15.44	**25.87**
A11	15.96	16.27	16.96	13.09	**16.96**
N7	2.12	2.42	2.39	2.00	**2.42**
N6	3.78	4.37	4.35	3.08	**4.37**
N5	4.91	5.60	5.69	3.83	**5.69**
InQ12	4.91	5.60	5.69	3.83	**5.69**
N4	1.13	1.15	1.24	0.94	**1.24**
InQ13	1.13	1.15	1.24	0.94	**1.24**
Det-PC	6.04	6.75	6.92	4.70	**6.92**
NB2	0.31	0.32	0.31	0.14	**0.32**
NB1	3.22	3.37	3.39	1.76	**3.39**
node58	3.22	3.37	3.39	1.76	**3.39**
NA1	1.87	1.98	1.96	0.91	**1.98**
InQ14	4.92	5.13	5.18	2.66	**5.18**
N3	5.86	6.11	6.18	3.80	**6.18**
N2	5.86	6.11	6.18	3.80	**6.18**
N1	1.12	1.21	1.27	0.79	**1.27**
O2	0.33	0.35	0.34	0.14	**0.35**
InQ16	1.44	1.53	1.59	0.92	**1.59**
A10	20.26	20.67	21.36	17.30	**21.36**
A9	20.26	20.67	21.36	17.30	**21.36**
A8	20.26	20.67	21.36	17.30	**21.36**
A7	20.26	20.67	21.36	17.30	**21.36**
L1	1.03	1.09	1.04	0.46	**1.09**
K1	1.60	1.73	1.76	0.87	**1.76**
J2	1.20	1.27	1.20	0.49	**1.27**
J1	1.85	1.90	1.96	0.83	**1.96**
M1	1.60	1.70	1.60	0.67	**1.70**
L2	0.53	0.56	0.53	0.21	**0.56**
InQ18	6.52	6.81	6.81	3.04	**6.81**
KA1	1.15	1.31	1.30	0.64	**1.31**
InQ17	1.15	1.31	1.30	0.64	**1.31**
A6	21.98	22.86	23.79	19.69	**23.79**

KB1	0.71	0.78	0.73	0.31	**0.78**
KC1	1.63	1.73	1.77	1.01	**1.77**
K5	2.15	2.25	2.32	1.38	**2.32**
K4	3.78	3.97	4.10	2.39	**4.10**
K3	4.07	4.32	4.41	2.60	**4.41**
InQ20	4.42	4.68	4.74	2.86	**4.74**
A5	24.79	25.57	26.53	22.03	**26.53**
H1	0.32	0.34	0.32	0.13	**0.34**
I2	0.35	0.36	0.36	0.16	**0.36**
I1	1.19	1.32	1.34	0.65	**1.34**
InQ19	1.50	1.64	1.63	0.79	**1.64**
A4	25.16	26.04	27.05	22.54	**27.05**
GA1	0.32	0.33	0.32	0.14	**0.33**
G3	0.67	0.68	0.66	0.30	**0.68**
G2	0.97	0.99	0.97	0.44	**0.99**
G1	2.05	2.03	2.15	1.04	**2.15**
F1	0.59	0.65	0.62	0.29	**0.65**
InQ21	2.55	2.55	2.71	1.32	**2.71**
A3	25.80	26.81	27.86	23.40	**27.86**
E2	2.98	3.32	3.30	1.66	**3.32**
E1	3.28	3.60	3.57	1.80	**3.60**
D1	0.14	0.15	0.14	0.06	**0.15**
InQ22	3.41	3.74	3.69	1.86	**3.74**
A2	26.70	27.90	29.03	24.62	**29.03**
A1	1.30	1.50	1.49	0.76	**1.50**
C1	0.70	0.72	0.70	0.33	**0.72**
B1	0.84	0.88	0.83	0.36	**0.88**
InQ23	2.82	2.95	3.01	1.45	**3.01**
node95	27.31	28.70	29.89	25.56	**29.89**
Out	28.18	29.64	30.87	26.56	**30.87**

XP-RAFTS Flow Summary - Burradoo BU2 Catchment
20 Year ARI - (results in m^3/s)

Node	60min	90 min	120 min	360 min	Peak
A0	0.96	1.00	1.03	0.97	**1.03**
AA1	0.15	0.16	0.18	0.11	**0.18**
InQ24	1.08	1.14	1.19	1.08	**1.19**
O1	0.72	0.79	0.74	0.31	**0.79**
P1	0.20	0.23	0.21	0.09	**0.23**
InQ15	0.93	1.02	0.95	0.40	**1.02**
Q2	1.31	1.41	1.34	0.60	**1.41**
Q1	1.64	1.76	1.71	0.77	**1.76**
R1	0.16	0.19	0.18	0.09	**0.19**
InQ11	1.79	1.94	1.89	0.86	**1.94**
S2	0.60	0.66	0.61	0.24	**0.66**
S1	0.91	1.03	0.98	0.43	**1.03**
T1	0.23	0.24	0.26	0.17	**0.26**
InQ10	1.09	1.26	1.19	0.61	**1.26**
U2	0.75	0.80	0.75	0.28	**0.80**
U1	0.97	1.08	1.00	0.41	**1.08**
V1	0.51	0.56	0.61	0.45	**0.61**
InQ9	1.44	1.64	1.50	0.86	**1.64**
Y2	0.58	0.62	0.60	0.21	**0.62**
Y1	0.85	0.95	0.91	0.37	**0.95**
InQ6	0.85	0.95	0.91	0.37	**0.95**
ZZB2	1.17	1.26	1.19	0.43	**1.26**
ZZB1	1.99	2.12	2.08	0.81	**2.12**
ZZC1	1.09	1.13	1.08	0.48	**1.13**
InQ4	3.08	3.24	3.14	1.30	**3.24**
ZZE2	1.19	1.22	1.18	0.54	**1.22**
ZZE1	2.36	2.41	2.42	1.13	**2.42**
ZZD2	1.18	1.28	1.20	0.45	**1.28**
ZZD1	2.02	2.11	2.17	0.87	**2.17**
InQ3	4.36	4.52	4.56	2.00	**4.56**
ZZJ1	1.21	1.33	1.36	0.81	**1.36**
ZZK1	0.76	0.86	0.80	0.34	**0.86**
In1	1.96	2.15	2.07	1.15	**2.15**
A23	0.83	0.96	0.99	0.57	**0.99**
A22	2.70	2.98	2.99	1.72	**2.99**
ZZI1	0.41	0.44	0.42	0.16	**0.44**
node4	0.41	0.44	0.42	0.16	**0.44**
A21	2.98	3.26	3.25	1.87	**3.26**
node106	2.98	3.26	3.25	1.87	**3.26**
ZZHA1	0.93	1.01	1.01	0.58	**1.01**
ZZH2	1.38	1.44	1.36	0.61	**1.44**
ZZH1	0.21	0.23	0.21	0.09	**0.23**
node110	2.52	2.68	2.54	1.28	**2.68**
InQ1	5.29	5.66	5.68	3.13	**5.68**
ZZG2	0.76	0.78	0.75	0.34	**0.78**
ZZG1	1.67	1.73	1.66	0.76	**1.73**
ZZF2	0.30	0.32	0.30	0.11	**0.32**
ZZF1	1.08	1.14	1.10	0.44	**1.14**
InQ2	2.75	2.86	2.74	1.20	**2.86**
A19	7.17	7.52	7.72	4.30	**7.72**

A18	10.58	11.18	11.46	6.27	**11.46**
A17	12.45	12.78	13.26	7.51	**13.26**
Z2	0.45	0.49	0.47	0.16	**0.49**
Z1	0.72	0.78	0.75	0.28	**0.78**
ZZA1	0.29	0.32	0.30	0.12	**0.32**
InQ5	1.00	1.09	1.05	0.40	**1.09**
A16	12.94	13.15	13.75	7.89	**13.75**
A15	13.38	13.46	14.17	8.23	**14.17**
X1	0.33	0.38	0.35	0.17	**0.38**
W2	0.72	0.81	0.74	0.32	**0.81**
W1	0.87	0.98	0.90	0.40	**0.98**
InQ7	1.20	1.36	1.25	0.56	**1.36**
A14	14.07	14.08	14.84	8.73	**14.84**
V5	0.35	0.36	0.35	0.16	**0.36**
V4	0.92	0.95	0.94	0.44	**0.95**
VA1	2.91	3.14	3.23	1.89	**3.23**
V3	3.79	4.03	4.17	2.32	**4.17**
V2	4.86	5.15	5.29	2.95	**5.29**
InQ8	4.86	5.15	5.29	2.95	**5.29**
A13	19.83	20.13	21.09	12.50	**21.09**
A12	20.52	20.78	21.76	13.05	**21.76**
Det-inf	21.34	21.53	22.51	13.78	**22.51**
A11	12.51	13.06	13.75	10.95	**13.75**
N7	1.63	1.97	1.88	1.73	**1.97**
N6	3.13	3.68	3.61	2.68	**3.68**
N5	4.01	4.68	4.71	3.35	**4.71**
InQ12	4.01	4.68	4.71	3.35	**4.71**
N4	0.89	0.92	1.00	0.83	**1.00**
InQ13	0.89	0.92	1.00	0.83	**1.00**
Det-PC	4.87	5.58	5.71	4.12	**5.71**
NB2	0.27	0.28	0.27	0.12	**0.28**
NB1	2.75	2.94	2.96	1.57	**2.96**
node58	2.75	2.94	2.96	1.57	**2.96**
NA1	1.60	1.73	1.71	0.81	**1.73**
InQ14	4.19	4.48	4.53	2.38	**4.53**
N3	5.10	5.43	5.48	3.46	**5.48**
N2	5.10	5.43	5.48	3.46	**5.48**
N1	0.92	1.01	1.05	0.70	**1.05**
O2	0.29	0.31	0.30	0.12	**0.31**
InQ16	1.21	1.30	1.33	0.82	**1.33**
A10	16.09	16.81	17.59	14.66	**17.59**
A9	16.09	16.81	17.59	14.66	**17.59**
A8	16.09	16.81	17.59	14.66	**17.59**
A7	16.09	16.81	17.59	14.66	**17.59**
L1	0.89	0.96	0.91	0.41	**0.96**
K1	1.35	1.48	1.49	0.78	**1.49**
J2	1.07	1.14	1.07	0.44	**1.14**
J1	1.64	1.69	1.74	0.75	**1.74**
M1	1.42	1.51	1.42	0.60	**1.51**
L2	0.47	0.51	0.47	0.19	**0.51**
InQ18	5.70	6.02	5.97	2.73	**6.02**
KA1	0.95	1.10	1.11	0.57	**1.11**
InQ17	0.95	1.10	1.11	0.57	**1.11**
A6	17.30	18.51	19.54	16.74	**19.54**

KB1	0.61	0.68	0.63	0.28	**0.68**
KC1	1.37	1.45	1.51	0.90	**1.51**
K5	1.81	1.90	1.99	1.23	**1.99**
K4	3.17	3.35	3.50	2.13	**3.50**
K3	3.40	3.66	3.78	2.32	**3.78**
InQ20	3.67	3.98	4.06	2.53	**4.06**
A5	19.50	20.73	21.87	18.74	**21.87**
H1	0.28	0.31	0.28	0.12	**0.31**
I2	0.31	0.32	0.32	0.15	**0.32**
I1	0.99	1.11	1.15	0.59	**1.15**
InQ19	1.26	1.40	1.40	0.70	**1.40**
A4	19.75	21.09	22.26	19.18	**22.26**
GA1	0.29	0.30	0.29	0.13	**0.30**
G3	0.59	0.61	0.58	0.27	**0.61**
G2	0.86	0.88	0.86	0.40	**0.88**
G1	1.79	1.78	1.89	0.93	**1.89**
F1	0.49	0.57	0.53	0.26	**0.57**
InQ21	2.20	2.22	2.38	1.19	**2.38**
A3	20.21	21.69	22.91	19.93	**22.91**
E2	2.52	2.83	2.82	1.49	**2.83**
E1	2.77	3.09	3.06	1.61	**3.09**
D1	0.12	0.13	0.12	0.05	**0.13**
InQ22	2.89	3.21	3.17	1.66	**3.21**
A2	20.87	22.55	23.83	20.99	**23.83**
A1	1.06	1.27	1.26	0.68	**1.27**
C1	0.61	0.63	0.62	0.30	**0.63**
B1	0.74	0.78	0.74	0.32	**0.78**
InQ23	2.39	2.56	2.60	1.30	**2.60**
node95	21.28	23.14	24.47	21.80	**24.47**
Out	22.29	23.95	25.28	22.65	**25.28**

XP-RAFTS Flow Summary - Burradoo BU2 Catchment
5 Year ARI - (results in m^3/s)

Node	30 min	60 min	90 min	120 min	180 min	270 min	360 min	Peak
A0	0.29	0.56	0.60	0.64	0.59	0.69	0.65	**0.69**
AA1	0.06	0.09	0.09	0.11	0.07	0.09	0.08	**0.11**
InQ24	0.35	0.64	0.66	0.71	0.65	0.78	0.72	**0.78**
O1	0.48	0.50	0.56	0.52	0.35	0.31	0.23	**0.56**
P1	0.10	0.11	0.15	0.14	0.10	0.09	0.07	**0.15**
InQ15	0.57	0.61	0.71	0.65	0.45	0.40	0.29	**0.71**
Q2	0.90	0.92	1.01	0.96	0.68	0.61	0.44	**1.01**
Q1	1.03	1.12	1.25	1.22	0.86	0.77	0.57	**1.25**
R1	0.06	0.09	0.12	0.12	0.09	0.09	0.06	**0.12**
InQ11	1.07	1.20	1.37	1.34	0.94	0.86	0.63	**1.37**
S2	0.30	0.39	0.48	0.43	0.27	0.24	0.17	**0.48**
S1	0.41	0.57	0.70	0.64	0.46	0.43	0.32	**0.70**
T1	0.09	0.14	0.15	0.16	0.13	0.14	0.13	**0.16**
InQ10	0.45	0.66	0.83	0.79	0.59	0.56	0.45	**0.83**
U2	0.49	0.53	0.60	0.55	0.33	0.29	0.21	**0.60**
U1	0.55	0.65	0.77	0.69	0.46	0.42	0.30	**0.77**
V1	0.24	0.32	0.36	0.38	0.29	0.34	0.31	**0.38**
InQ9	0.77	0.95	1.13	1.01	0.75	0.72	0.62	**1.13**
Y2	0.41	0.41	0.46	0.42	0.25	0.22	0.16	**0.46**
Y1	0.51	0.58	0.67	0.63	0.41	0.37	0.27	**0.67**
InQ6	0.51	0.58	0.67	0.63	0.41	0.37	0.27	**0.67**
ZZB2	0.93	0.87	0.93	0.87	0.50	0.44	0.32	**0.93**
ZZB1	1.60	1.49	1.56	1.52	0.94	0.83	0.60	**1.60**
ZZC1	0.81	0.80	0.82	0.79	0.56	0.49	0.36	**0.82**
InQ4	2.40	2.27	2.38	2.30	1.49	1.32	0.96	**2.40**
ZZE2	0.85	0.87	0.90	0.87	0.62	0.54	0.40	**0.90**
ZZE1	1.65	1.72	1.77	1.78	1.28	1.11	0.83	**1.78**
ZZD2	0.95	0.87	0.94	0.88	0.52	0.46	0.33	**0.95**
ZZD1	1.64	1.51	1.56	1.60	1.01	0.89	0.65	**1.64**
InQ3	3.23	3.23	3.32	3.37	2.29	2.00	1.48	**3.37**
ZZJ1	0.65	0.81	0.91	0.92	0.71	0.65	0.58	**0.92**
ZZK1	0.45	0.50	0.59	0.54	0.38	0.34	0.25	**0.59**
In1	1.07	1.28	1.50	1.45	1.09	0.99	0.83	**1.50**
A23	0.45	0.54	0.63	0.65	0.48	0.47	0.42	**0.65**
A22	1.47	1.80	2.04	2.04	1.54	1.43	1.25	**2.04**
ZZI1	0.33	0.30	0.32	0.30	0.18	0.16	0.12	**0.33**
node4	0.33	0.30	0.32	0.30	0.18	0.16	0.12	**0.33**
A21	1.63	1.99	2.27	2.24	1.69	1.57	1.35	**2.27**
node106	1.63	1.99	2.27	2.24	1.69	1.57	1.35	**2.27**
ZZHA1	0.53	0.61	0.69	0.71	0.52	0.48	0.42	**0.71**
ZZH2	1.02	1.01	1.06	0.99	0.70	0.61	0.45	**1.06**
ZZH1	0.17	0.16	0.16	0.15	0.10	0.09	0.06	**0.17**
node110	1.71	1.77	1.91	1.83	1.32	1.18	0.94	**1.91**
InQ1	3.10	3.55	3.93	3.99	2.95	2.71	2.28	**3.99**
ZZG2	0.55	0.56	0.57	0.55	0.39	0.34	0.25	**0.57**
ZZG1	1.16	1.22	1.28	1.22	0.87	0.75	0.56	**1.28**
ZZF2	0.24	0.22	0.24	0.22	0.13	0.11	0.08	**0.24**
ZZF1	0.88	0.80	0.84	0.81	0.51	0.45	0.33	**0.88**
InQ2	2.03	2.02	2.12	2.02	1.38	1.20	0.89	**2.12**
A19	4.44	4.98	5.31	5.44	4.04	3.75	3.13	**5.44**

A18	6.90	7.48	7.97	8.22	6.12	5.52	4.57	**8.22**
A17	8.12	8.88	9.24	9.56	7.26	6.60	5.47	**9.56**
Z2	0.36	0.34	0.37	0.35	0.19	0.17	0.12	**0.37**
Z1	0.51	0.51	0.57	0.53	0.32	0.29	0.21	**0.57**
ZZA1	0.18	0.19	0.22	0.20	0.13	0.12	0.09	**0.22**
InQ5	0.70	0.70	0.78	0.74	0.46	0.41	0.29	**0.78**
A16	8.41	9.24	9.54	9.91	7.60	6.90	5.75	**9.91**
A15	8.67	9.57	9.78	10.23	7.89	7.18	5.99	**10.23**
X1	0.16	0.19	0.26	0.24	0.18	0.17	0.12	**0.26**
W2	0.30	0.41	0.55	0.51	0.36	0.33	0.24	**0.55**
W1	0.35	0.49	0.66	0.62	0.44	0.40	0.29	**0.66**
InQ7	0.48	0.67	0.92	0.86	0.62	0.56	0.41	**0.92**
A14	9.09	10.10	10.19	10.73	8.32	7.61	6.35	**10.73**
V5	0.25	0.26	0.27	0.26	0.19	0.16	0.12	**0.27**
V4	0.65	0.66	0.68	0.69	0.49	0.43	0.32	**0.69**
VA1	1.66	2.01	2.15	2.26	1.80	1.59	1.38	**2.26**
V3	2.15	2.62	2.81	2.94	2.29	2.01	1.70	**2.94**
V2	2.82	3.38	3.62	3.77	2.91	2.58	2.16	**3.77**
InQ8	2.82	3.38	3.62	3.77	2.91	2.58	2.16	**3.77**
A13	12.42	14.13	14.37	15.15	11.72	10.80	9.06	**15.15**
A12	12.80	14.62	14.84	15.62	12.10	11.25	9.45	**15.62**
Det-inf	13.31	15.23	15.42	16.21	12.63	11.88	9.98	**16.21**
A11	5.03	7.52	7.84	8.28	6.76	7.87	7.02	**8.28**
N7	0.89	0.98	1.22	1.15	1.04	1.29	1.14	**1.29**
N6	2.05	2.07	2.39	2.35	1.72	1.99	1.81	**2.39**
N5	2.39	2.53	2.98	3.01	2.18	2.47	2.29	**3.01**
InQ12	2.39	2.53	2.98	3.01	2.18	2.47	2.29	**3.01**
N4	0.32	0.53	0.55	0.58	0.47	0.64	0.57	**0.64**
InQ13	0.32	0.53	0.55	0.58	0.47	0.64	0.57	**0.64**
Det-PC	2.65	2.97	3.48	3.59	2.60	3.05	2.84	**3.59**
NB2	0.21	0.20	0.21	0.20	0.14	0.12	0.09	**0.21**
NB1	1.59	1.91	2.08	2.14	1.65	1.39	1.16	**2.14**
node58	1.59	1.91	2.08	2.14	1.65	1.39	1.16	**2.14**
NA1	1.02	1.12	1.22	1.21	0.88	0.79	0.60	**1.22**
InQ14	2.42	2.88	3.18	3.24	2.47	2.14	1.75	**3.24**
N3	3.23	3.73	4.03	4.11	3.32	3.02	2.70	**4.11**
N2	3.23	3.73	4.03	4.11	3.32	3.02	2.70	**4.11**
N1	0.49	0.61	0.67	0.70	0.55	0.55	0.49	**0.70**
O2	0.24	0.22	0.23	0.22	0.14	0.13	0.09	**0.24**
InQ16	0.66	0.81	0.89	0.91	0.69	0.64	0.58	**0.91**
A10	6.96	10.05	10.57	11.15	9.48	10.47	9.84	**11.15**
A9	6.96	10.05	10.57	11.15	9.48	10.47	9.84	**11.15**
A8	6.96	10.05	10.57	11.15	9.48	10.47	9.84	**11.15**
A7	6.96	10.05	10.57	11.15	9.48	10.47	9.84	**11.15**
L1	0.63	0.62	0.69	0.65	0.46	0.41	0.30	**0.69**
K1	0.78	0.91	1.01	1.02	0.77	0.71	0.57	**1.02**
J2	0.86	0.79	0.83	0.78	0.51	0.45	0.33	**0.86**
J1	1.23	1.20	1.25	1.27	0.85	0.76	0.55	**1.27**
M1	1.15	1.06	1.11	1.05	0.70	0.62	0.45	**1.15**
L2	0.38	0.34	0.36	0.34	0.22	0.19	0.14	**0.38**
InQ18	4.07	4.05	4.31	4.31	2.99	2.67	2.02	**4.31**
KA1	0.56	0.63	0.71	0.72	0.53	0.51	0.42	**0.72**
InQ17	0.56	0.63	0.71	0.72	0.53	0.51	0.42	**0.72**
A6	7.89	10.77	11.69	12.43	10.94	11.25	11.31	**12.43**

KB1	0.37	0.41	0.47	0.45	0.32	0.28	0.21	**0.47**
KC1	0.77	0.96	0.99	1.04	0.84	0.76	0.65	**1.04**
K5	1.02	1.24	1.26	1.35	1.10	1.02	0.89	**1.35**
K4	1.79	2.20	2.24	2.39	1.95	1.78	1.54	**2.39**
K3	1.89	2.35	2.43	2.57	2.10	1.95	1.68	**2.57**
InQ20	2.02	2.51	2.65	2.77	2.26	2.15	1.83	**2.77**
A5	9.91	12.41	13.24	14.09	12.42	12.83	12.70	**14.09**
H1	0.11	0.18	0.22	0.20	0.14	0.12	0.09	**0.22**
I2	0.21	0.22	0.23	0.23	0.17	0.15	0.11	**0.23**
I1	0.58	0.68	0.74	0.78	0.58	0.54	0.43	**0.78**
InQ19	0.69	0.84	0.96	0.97	0.71	0.66	0.52	**0.97**
A4	10.14	12.78	13.49	14.36	12.75	13.05	13.01	**14.36**
GA1	0.22	0.21	0.22	0.21	0.15	0.13	0.09	**0.22**
G3	0.41	0.42	0.44	0.43	0.31	0.27	0.20	**0.44**
G2	0.61	0.62	0.64	0.63	0.45	0.39	0.29	**0.64**
G1	1.16	1.28	1.29	1.34	1.00	0.86	0.69	**1.34**
F1	0.27	0.32	0.38	0.36	0.27	0.25	0.19	**0.38**
InQ21	1.33	1.54	1.58	1.67	1.26	1.10	0.87	**1.67**
A3	10.64	13.47	13.90	14.82	13.31	13.66	13.53	**14.82**
E2	1.52	1.65	1.87	1.91	1.38	1.33	1.09	**1.91**
E1	1.63	1.81	2.06	2.10	1.51	1.45	1.18	**2.10**
D1	0.08	0.08	0.09	0.08	0.06	0.05	0.04	**0.09**
InQ22	1.71	1.90	2.15	2.18	1.57	1.50	1.22	**2.18**
A2	11.38	14.47	14.82	15.47	14.09	14.80	14.29	**15.47**
A1	0.59	0.64	0.77	0.79	0.59	0.59	0.50	**0.79**
C1	0.36	0.42	0.45	0.45	0.33	0.28	0.22	**0.45**
B1	0.58	0.55	0.57	0.54	0.37	0.33	0.24	**0.58**
InQ23	1.46	1.59	1.74	1.77	1.28	1.20	0.96	**1.77**
node95	11.92	15.22	15.84	16.34	14.68	15.64	14.85	**16.34**
Out	12.26	15.85	16.46	17.00	15.27	16.37	15.43	**17.00**

APPENDIX F

Hydraulic Model Sensitivity Analyses

Catchment Runoff

Table F.1 Catchment Runoff Sensitivity - 100 year ARI 2 hour

Point	Location	100y 2h (Base Case)	20% Decrease		20% Increase	
		Peak Water Level	Peak Water Level	Difference to Base	Peak Water Level	Difference to Base
1	d/s Railway	658.14	658.09	-0.05	658.19	0.04
2	u/s Railway	659.47	659.20	-0.28	659.79	0.31
3	d/s Burradoo Road	660.15	660.05	-0.10	660.23	0.08
4	u/s Burradoo Road	661.09	661.02	-0.07	661.15	0.06
5	u/s Burradoo Road	661.09	661.02	-0.07	661.16	0.07
6	d/s Ranelagh Road	662.80	662.75	-0.05	662.84	0.04
7	u/s Ranelagh Road	663.35	663.27	-0.07	663.42	0.07
8	d/s Holly Road	664.29	664.26	-0.03	664.31	0.02
9	u/s Holly Road	665.57	665.56	-0.01	665.57	0.00
10	d/s Holly Road	665.31	665.24	-0.07	665.38	0.07
11	u/s Holly Road	665.78	665.71	-0.07	665.85	0.07
12	d/s Moss Vale Road	667.61	667.59	-0.01	667.62	0.01
13	u/s Moss Vale Road	670.24	670.03	-0.21	670.41	0.17
14	d/s Moss Vale Road	667.44	667.36	-0.08	667.54	0.09
15	u/s Moss Vale Road	669.89	669.67	-0.22	670.08	0.19
16	u/s Moss Vale Road	670.71	670.67	-0.04	670.75	0.04
17	d/s Osborne Rd	671.25	671.22	-0.02	671.27	0.02
18	Foldgarth Way	672.65	672.60	-0.05	672.69	0.04
19	d/s Stratford Way	673.38	673.34	-0.04	673.42	0.04
20	u/s Stratford Way	674.98	674.92	-0.05	675.01	0.03
21	u/s Stratford Way	675.18	675.11	-0.07	675.32	0.14
22	u/s Stratford Way	676.38	676.34	-0.04	676.42	0.04

* Location of reference points shown on Figure 6.6

Catchment Roughness

Table F.2 Catchment Roughness Sensitivity - 100 year ARI 2 hour

Point	Location	100y 2h (Base Case)	20% Decrease		20% Increase	
		Peak Water Level	Peak Water Level	Difference to Base	Peak Water Level	Difference to Base
1	d/s Railway	658.14	658.12	-0.02	658.17	0.02
2	u/s Railway	659.47	659.51	0.03	659.44	-0.03
3	d/s Burradoo Road	660.15	660.14	-0.01	660.16	0.01
4	u/s Burradoo Road	661.09	661.09	0.00	661.09	0.00
5	u/s Burradoo Road	661.09	661.09	0.00	661.10	0.01
6	d/s Ranelagh Road	662.80	662.78	-0.02	662.81	0.01
7	u/s Ranelagh Road	663.35	663.31	-0.03	663.36	0.02
8	d/s Holly Road	664.29	664.28	-0.01	664.29	0.00
9	u/s Holly Road	665.57	665.56	-0.01	665.58	0.01
10	d/s Holly Road	665.31	665.29	-0.01	665.33	0.02
11	u/s Holly Road	665.78	665.77	-0.01	665.79	0.01
12	d/s Moss Vale Road	667.61	667.58	-0.02	667.63	0.03
13	u/s Moss Vale Road	670.24	670.24	0.00	670.24	0.00
14	d/s Moss Vale Road	667.44	667.42	-0.03	667.47	0.03
15	u/s Moss Vale Road	669.89	669.89	0.00	669.89	0.00
16	u/s Moss Vale Road	670.71	670.69	-0.02	670.74	0.03
17	d/s Osborne Rd	671.25	671.22	-0.02	671.27	0.02
18	Foldgarth Way	672.65	672.64	-0.01	672.66	0.01
19	d/s Stratford Way	673.38	673.36	-0.02	673.41	0.03
20	u/s Stratford Way	674.98	674.96	-0.01	674.98	0.01
21	u/s Stratford Way	675.18	675.16	-0.02	675.21	0.03
22	u/s Stratford Way	676.38	676.36	-0.02	676.40	0.02

* Location of reference points shown on Figure 6.6

Downstream Boundary Conditions

Table F.3 Boundary Condition Sensitivity - 100 year ARI 2 hour

Point	Location	100y 2h (Base Case)	Tailwater RL 663.0m	
		Peak Water Level	Peak Water Level	Difference to Base
1	d/s Railway	658.14	663.00	4.86
2	u/s Railway	659.47	663.00	3.53
3	d/s Burradoo Road	660.15	663.00	2.85
4	u/s Burradoo Road	661.09	663.01	1.91
5	u/s Burradoo Road	661.09	663.01	1.92
6	d/s Ranelagh Road	662.80	663.02	0.22
7	u/s Ranelagh Road	663.35	663.34	0.00
8	d/s Holly Road	664.29	664.29	0.00
9	u/s Holly Road	665.57	665.57	0.00
10	d/s Holly Road	665.31	665.31	0.00
11	u/s Holly Road	665.78	665.78	0.00
12	d/s Moss Vale Road	667.61	667.61	0.00
13	u/s Moss Vale Road	670.24	670.24	0.00
14	d/s Moss Vale Road	667.44	667.44	0.00
15	u/s Moss Vale Road	669.89	669.89	0.00
16	u/s Moss Vale Road	670.71	670.71	0.00
17	d/s Osborne Rd	671.25	671.24	0.00
18	Foldgarth Way	672.65	672.65	0.00
19	d/s Stratford Way	673.38	673.38	0.00
20	u/s Stratford Way	674.98	674.97	0.00
21	u/s Stratford Way	675.18	675.19	0.00
22	u/s Stratford Way	676.38	676.38	0.00

* Location of reference points shown on Figure 6.6

Culvert Blockage

Table F.4 Culvert Blockage Sensitivity - 100 year ARI 2 hour

Point	Location	100y 2h (Base Case)	50% Blockage		100% Blockage	
		Peak Water Level	Peak Water Level	Difference to Base	Peak Water Level	Difference to Base
1	d/s Railway	658.14	658.11	-0.04	657.93	-0.21
2	u/s Railway	659.47	660.18	0.71	661.73	2.26
3	d/s Burradoo Road	660.15	660.23	0.07	661.73	1.58
4	u/s Burradoo Road	661.09	661.09	0.00	661.73	0.64
5	u/s Burradoo Road	661.09	661.09	0.00	661.73	0.64
6	d/s Ranelagh Road	662.80	662.79	-0.01	662.79	-0.01
7	u/s Ranelagh Road	663.35	663.32	-0.03	663.31	-0.04
8	d/s Holly Road	664.29	664.29	0.00	664.29	0.00
9	u/s Holly Road	665.57	665.57	0.00	665.57	0.00
10	d/s Holly Road	665.31	665.30	0.00	665.30	-0.01
11	u/s Holly Road	665.78	665.82	0.04	665.87	0.09
12	d/s Moss Vale Road	667.61	667.48	-0.13	666.92	-0.69
13	u/s Moss Vale Road	670.24	670.36	0.12	670.47	0.23
14	d/s Moss Vale Road	667.44	667.48	0.04	667.53	0.08
15	u/s Moss Vale Road	669.89	670.03	0.14	670.16	0.27
16	u/s Moss Vale Road	670.71	670.70	-0.01	670.69	-0.02
17	d/s Osborne Rd	671.25	671.25	0.00	671.24	0.00
18	Foldgarth Way	672.65	672.63	-0.02	672.63	-0.02
19	d/s Stratford Way	673.38	673.37	-0.01	673.64	0.26
20	u/s Stratford Way	674.98	674.96	-0.02	675.03	0.05
21	u/s Stratford Way	675.18	675.40	0.21	675.58	0.39
22	u/s Stratford Way	676.38	676.38	0.00	676.37	-0.01

* Location of reference points shown on Figure 6.6

APPENDIX G

Preliminary Flood Damages Assessment

FLOOD DAMAGES

Background

The economic impact of flooding can be defined by what is commonly referred to as 'flood damages'. Table G.1 lists classifications of various types of flood damages incurred in a catchment. Direct damage costs are just one component of the entire cost of a flood event. There are also indirect costs. Both direct and indirect costs are referred to as 'tangible' costs. In addition to this there are also 'intangible' costs. The values discussed in this report are the 'total' damages and include an assumed intangible cost of 25% of the tangible cost.

Table G.1 Types of Flood Damages

Type	Description
Direct	Building contents (internal) Structural (building repair and clean) External items (vehicles, contents of sheds etc)
Indirect	Clean-up (immediate removal of debris) Financial (loss of revenue, extra expenditure) Opportunity (non-provision of public services)
Intangible	Social – increased levels of insecurity, depression, stress General inconvenience in post-flood stage

Flood damages can be assessed by a number of means including the use of programs such as FLDAMAGE or ANUFLOOD or via more generic methods using spreadsheets. For the purposes of this project, generic spreadsheets have been developed based on damage curves adapted from DIPNR.

Floor Level and Property Survey

The Burradoo BU2 catchment includes only residential properties, and does not include commercial or industrial land-uses. Some floor levels were obtained for properties within the modelled extent by field survey and supplemented by assumed levels based on the ground levels where surveyed levels were not available.

Stage – Damage Curves

The draft DIPNR Floodplain Management Guideline No.4 *Residential Flood Damage Calculation* (2004) was used for this study. This guideline includes a template spreadsheet program that determines damage curves for three types of residential buildings:

- Single Storey, slab on ground
- Two Storey, slab on ground
- Single Storey, 'high-set' eg piered structures (floor level assumed to be 1.5m above the ground).

All buildings were assumed to be single storey slab on ground. Properties without a surveyed floor level were assumed to have a floor level 0.15m above the ground level.

The DIPNR curves are derived for late 2001 (base curves). General recommendations by DIPNR are to adjust values in the base residential damage curves by Average Weekly

Earnings (AWE), rather than by the inflation rate as measured by the Consumer Price Index (CPI). While not specified, we have assumed that the base curves were derived in November 2001, which allows the use of November 2001 AWE statistics (issued quarterly). November 2001 average weekly earnings are shown in Table G.2. The most recent data for AWE from the Australian Bureau of Statistics at the time of assessment was for November 2008. AWE values were sourced from the Australian Bureau of Statistics (ABS, 2009).

Table G.2 AWE Statistics from 2001 and 2008

Month	Year	AWE
November	2001	$676.40
November	2008	$912.40
Change	34.9%	

All ordinates in the base residential flood damage curves were therefore converted into November 2008 dollars. In addition, DIPNR recommends that all damage curves include GST and as such GST was included. Consequently, all ordinates on the damage curves are increased by 35% and GST has been added.

Damages are generally incurred on a property prior to any over floor flooding. The scenarios adopted are:

- The flooding overtops the garden but does not necessarily reach the main structure. For this type of flooding, a minimum ground level on the property was obtained from the collated survey data to be the representative ground level for the property. When this representative ground level is exceeded, a nominal value of $1,100 was assigned to represent garden damage.
- The flooding overtops the garden and also reaches the structure. The DIPNR curves allow for a damage of $9,950 (November 2008 dollars) to be incurred when the water level reaches the base of the house (the base of the house is determined by 0.1m below the floor level for slab on ground). The size of properties within the catchment means there may be a significant difference between the adopted ground level and the floor level. Therefore a damage of $3,300 is adopted for a flood level 0.5m below the floor level, linearly interpolated up to 0.1m below the floor level. This accounts for some garden and structural damage, such as to sheds or other external buildings near to the house floor level.
- The DIPNR curves are then used for determining damages for flooding higher than 0.1m below the floor level.

The adopted damage curve is shown in Figure G.1.

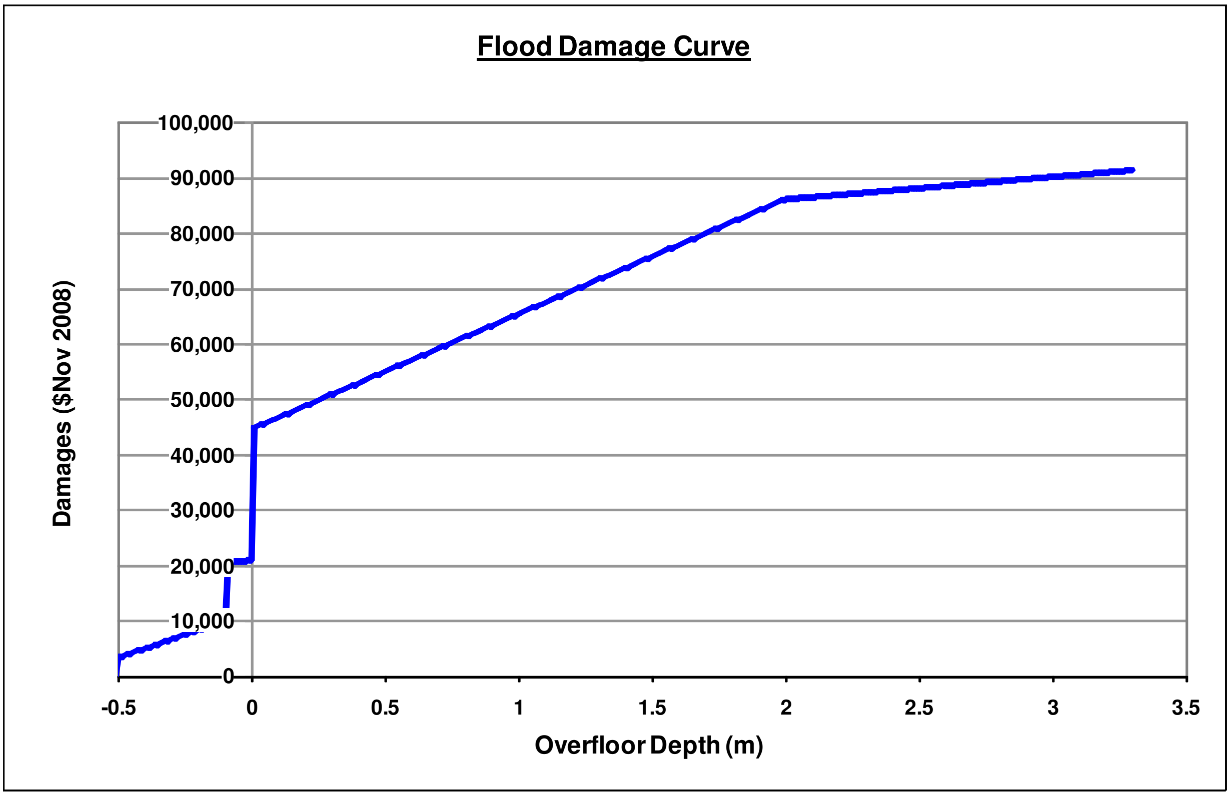

Figure G.1 Flood Damage Curve

Results

A total of 90 houses were examined for flood impact within the modelled area and Table G.3 shows the results of the flood damages assessment. Based on the analysis, the average annual damage for the modelled floodplain is approximately $170,000.

Table G.3 Flood Damage Assessment Summary

Event	Properties with Overfloor Flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Properties with Flooding Adjacent to House	Total Damage ($Nov 2008)
PMF	21	0.38	1.91	38	$ 1,277,311
100y ARI	3	0.14	0.33	27	$ 388,590
50y ARI	2	0.19	0.32	27	$ 357,949
20y ARI	2	0.18	0.31	25	$ 308,546
5y ARI	2	0.16	0.27	20	$ 250,673

APPENDIX H

Preliminary Remedial Options Assessment

PRELIMINARY REMEDIAL OPTIONS ASSESSMENT

A variety of flood mitigation measures may be applicable to the Burradoo BU2 catchment. These include:

- Detention basin modifications,
- Channel augmentation, and
- Culvert upgrades.

The major existing detention basins within the catchment are the Pony Club basin and the Informal basin. Boyden and Partners (2006) noted from their analysis that formalisation of the Informal basin resulted in flood level decreases downstream of Moss Vale Road. Reconfiguring of the Informal basin is thus recommended for further investigation.

Sites suitable for other detention basins within the catchment are limited, but a small basin combined with the open space upstream of Charlotte Street may improve downstream conditions.

The watercourse downstream of Moss Vale Road is generally an unformed depression within properties. Flows are not contained to a narrow width but spread over a wider area. Therefore, confinement of flows within a defined channel may not be possible for large storm events, but more frequent storm events may be able to be contained within a channel. Currently, most properties allow for the drainage depression, some with driveway crossings, but constructing a defined channel may reduce the amenity of properties.

Clearing debris and overgrowth from the main watercourse area may also improve the flow conveyance such that flood levels are reduced. Responses from the resident questionnaire reported that some driveway crossings required maintenance to remove collected debris.

Culverts upstream of Moss Vale Road, such as near Stratford Way, are comparatively larger than the culverts on driveway crossings downstream. The influence of these culverts on flood levels is recommended to be assessed to determine if upgrading of these systems is warranted. The culvert under the railway line may also be retaining flow and impacting upstream levels. Similarly, the culverts under Burradoo Road may warrant assessment for upgrading to mitigate the flood extent.

The catchment is now significantly developed, albeit with predominantly large rural-residential lots, and thus the influence of development controls to have a large impact on flood levels is lessened. The Boyden and Partners report (2006) advised of reductions in flood levels due to Council's on-site detention policy and reviewed the potential for the control of impervious areas of developments.

In summary, potential flood mitigation options for the catchment would focus on structural measures. The measures for investigation would be across the whole catchment and not necessarily confined to the modelled extent. Recommended measures for assessment are:

- Reconfiguring of the Informal detention basin,
- Review of other potential detention basins,
- Clearing debris and overgrowth from the channel,
- Formalising the watercourse channel downstream of Moss Vale Road,
- Upgrade culverts at various locations within the catchment.

Stage 2 of the floodplain risk management process is the Floodplain Risk Management Study and Plan to assess the benefits and prioritise flood mitigation measures.

APPENDIX I

Public Exhibition Response

Burradoo NSW 2576
21 September 2009

The Acting General Manager
Wingecarribee Shire Council
Elizabeth Street
MOSS VALE NSW 2577

Dear Mr Lee

Reference: Burradoo BU2 Catchment Assessment Study

Thank you for providing the opportunity to comment on the above draft final study. The study should be useful in determining development requirements for properties within the catchment and appropriate flood mitigation measures.

We note that the catchment that it covers includes land east of Moss Vale Road and south of Osborne Road, but this subcatchment was not investigated nor modelled in the study. Within this area is a tributary that drains land in Osborne Road and Charlotte Street, including part of Chevalier College grounds.

During the 1980s and 1990s there were several flood events which affected properties in this subcatchment. Also, a number of flood studies were carried out in conjunction with subdivision applications. The flood studies identified land that would be affected in the 100 year average recurrent interval. As a result covenants were placed on the land by Wingecarribee Council.

Could you please tell us why land in this subcatchment was excluded from the investigation area, and, if it is no longer considered that there is a flood risk, will Council be removing the covenants that it placed on land within it?

Yours sincerely

Richard and Laurel Cheetham

WINGECARRIBEE SHIRE COUNCIL
Classification: MAILIN
Doc. No.
File No. 8100/5
25 SEP 2009
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APPENDIX J

Addendum – October 1999 Storm Event Assessment

Burradoo BU2 Catchment Assessment Study - Addendum
October 1999 Event Modelling

Cardno Project LJ2575
23 September 2010

1 Introduction

Additional information of flooding in October 1999 was received subsequent to the preparation of final report for the Burradoo BU2 Catchment Assessment Study – Stage 1 Flood Study Report (December 2009). This assessment reviews the flooding for the October 1999 event using the model of the Report.

2 Rainfall

A storm occurred in the Southern Highlands area around Sunday 24th October 1999. Rainfall depths, from the Bureau of Meteorology (BoM) for the 24 hours prior to 9am, are shown in Table 1 for several locations (shown in Figure 1).

Table 1: Rainfall Depths for 24 hours (mm)

Date	Bowral (Parry Drive) (#68102)	EAST - Robertson (St Anthonys) (#68117)	NORTH - Mittagong (Beatrice St) (#68044)	WEST - Berrima West (#68186)	SOUTH - Moss Vale (Hoskins St) (#68045)
22/10/1999	0	0	0	0	0
23/10/1999	1.4	3	2	2.8	0.8
24/10/1999	79.4	149	97	73.2	62
25/10/1999	56.2	76	33	30.8	41.6
26/10/1999	0	0	0	0	0

The nearest rainfall pluviograph with frequent rainfall intensity data (6 minute) for the October 1999 event is at Robertson (St Anthonys, BoM Station 68117). Only four measurements were recorded in October 1999 at the Bowral Parry Drive site (BoM Station 68102) and the Moss Vale automatic weather station did not open until 2001. However, rainfall records for the Bowral Weather Station (BoM Station not referenced) for the October 1999 event was obtained by a resident. These measurements are listed in Table 2 and also the equivalent rainfall measured at Robertson.

Rainfall at Robertson is generally higher than at the Bowral station which is closer to the catchment. This pattern is also shown in Table 3 which lists the daily rainfall for storm events in 1998 and 2000.

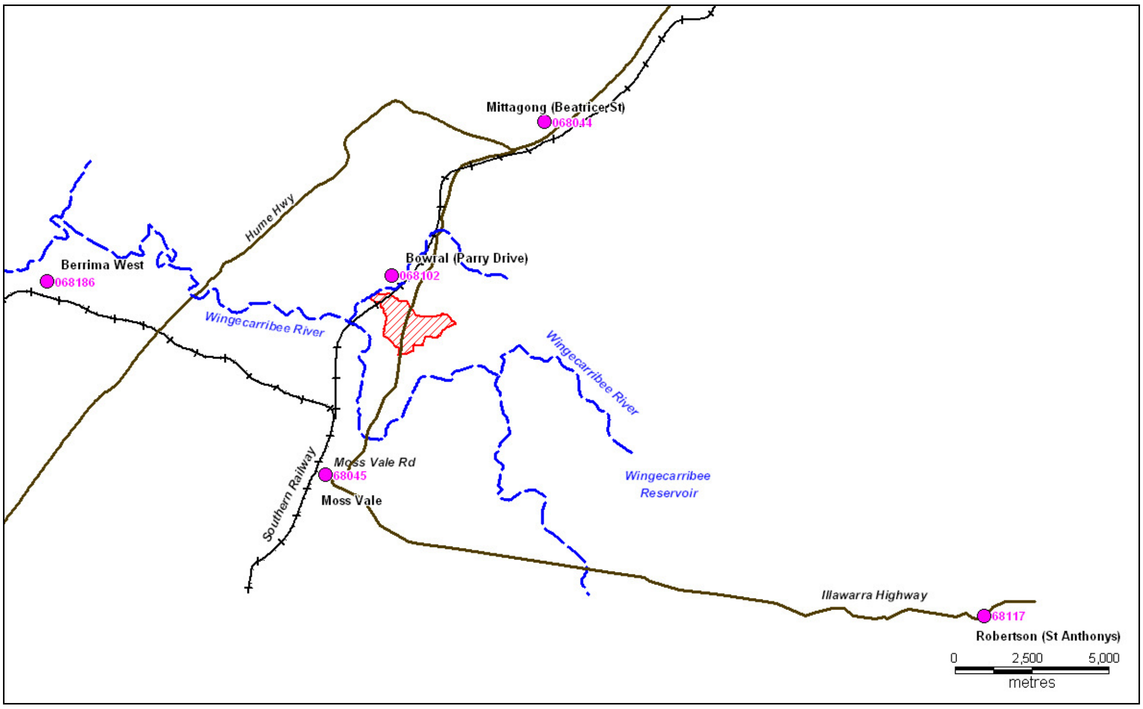


Figure 1: Daily Rainfall Stations

Table 2: Pluviograph Rainfall Data

Date	Time	Bowral Measured Rainfall (mm)	Duration to Previous Reading	Robertson Pluvio Measured Rainfall (mm)
23/10/1999	09:00	0.4	3 hours	0.9
	12:00	1.2	3 hours	0.4
	15:00	2.2	3 hours	3.1
	18:00	6.4	3 hours	6.5
	21:00	6.2	3 hours	12.5
24/10/1999	06:00	42.8	9 hours	69.5
	09:00	29.6	3 hours	49.6
	12:00	33.8	3 hours	50.4
	15:00	Trace	3 hours	0.3
	18:00	-	3 hours	0
	21:00	0.8	3 hours	0
25/10/1999	06:00	11.6	9 hours	18.7
	09:00	trace	3 hours	0.2

Comparison of the rainfall intensity for several durations (12 minutes to 12 hours) showed the Robertson pluviograph data for the October 1999 event to be about a 2 year ARI event. Based the above rainfall data and assessment, the Robertson pluviograph data was multiplied by 0.75 to estimate the rainfall in the Burradoo BU2 catchment. The resultant rainfall intensity for the converted rainfall is about a 2 year ARI for the Burradoo catchment.

Table 3: Daily Rainfall Data

Date	Bowral (Parry Drive) (#68102)	EAST - Robertson (St Anthonys) (#68117)
5/08/1998	10.2	8
6/08/1998	6.6	5.4
7/08/1998	25.6	56
8/08/1998	114.8	191
9/08/1998	9.4	16.8
7/03/2000	3.6	6.8
8/03/2000	28.6	34
9/03/2000	50	50.2
10/03/2000	10.8	13.8
11/03/2000	2.4	2.2

3 Hydrology Model

The XP-RAFTS hydrology model was adjusted to reflect changes in the catchment for the October 1999 period compared to the current conditions. In October 1999 the Foldgarth Way development was not constructed thus the sub-catchment land-use parameters were adjusted to represent this change. Similarly, the Pony Club detention basin (located on the north-east corner of the Moss Vale Road and Osborne Road intersection) was not constructed in October 1999 and was excluded from the model. Flow rates calculated by the XP-RAFTS model were input to the TUFLOW hydraulic model.

4 Hydraulic Model

The TUFLOW model used for the Flood Study Report was amended to exclude the Pony Club detention basin. The Foldgarth Way development is not generally within the TUFLOW model extent thus the model grid was not revised.

5 Results

Peak water levels for the October 1999 event are listed in Table 4 for the reference locations shown in Figure 2 (also shown in the Report Figure 6.6). Results for the 5 year ARI, 20 year, and 50 year ARI peak water levels from the Report are also included in the table.

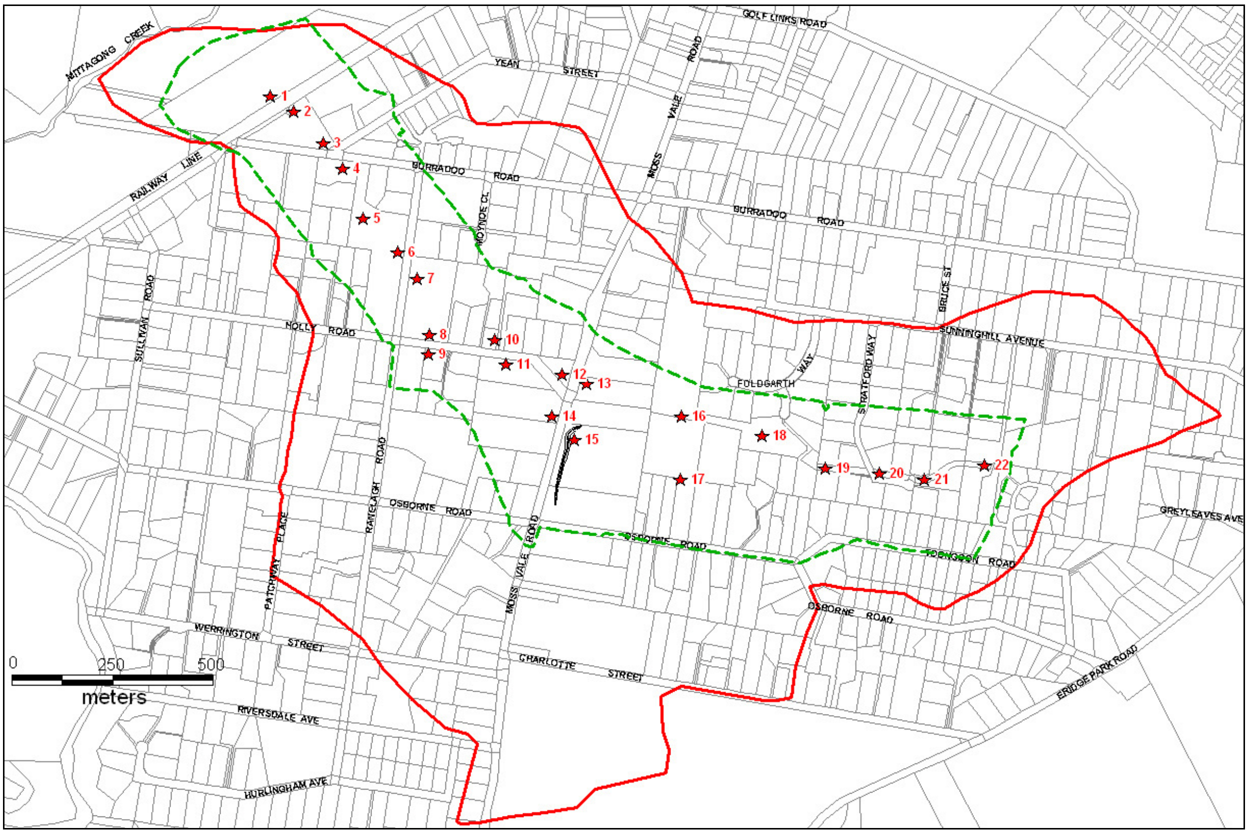


Figure 2: Peak Water Level Reference Locations

Table 4: Peak Water Levels (m AHD) at Reference Points

Reference Point	October 1999 Event	5 year ARI	20 year ARI	50 year ARI
1	658.07	658.02	658.08	658.11
2	659.04	658.83	659.09	659.28
3	660.01	659.90	660.01	660.09
4	660.98	660.91	661.00	661.05
5	660.99	660.91	661.00	661.05
6	662.74	662.69	662.74	662.77
7	663.26	663.18	663.25	663.30
8	664.19	664.21	664.25	664.27
9	665.55	665.54	665.56	665.57
10	665.20	665.10	665.20	665.26
11	665.71	665.64	665.70	665.72
12	667.54	667.53	667.59	667.60
13	669.64	669.59	669.94	670.11
14	667.36	667.29	667.33	667.39
15	668.73	669.26	669.56	669.76
16	670.59	670.59	670.65	670.69
17	671.17	671.19	671.22	671.23
18	672.48	672.49	672.58	672.62
19	673.21	673.24	673.31	673.36
20	674.82	674.85	674.91	674.95
21	674.94	674.98	675.08	675.15
22	676.24	676.26	676.32	676.35

The results show that upstream of Moss Vale Road the October 1999 flooding is equivalent to a 5 year ARI event, but downstream it is closer to 20 year ARI event due to the Pony Club detention basin not being constructed.

6 Responses

Responses from residents for flooding from the October 1999 event received in the questionnaire of the Report and subsequent to the Report are listed in Table 5.

Table 5: Responses

Address	Response	Review	Comment
Upstream of Moss Vale Road			
12 Stratford Way	Water came to back door	Surveyed floor level = 675.38m AHD. Modelled flood level = 675.27.	Satisfactory result
21 Stratford Way	Not affected by flooding in the event	No significant flood affectation shown in model.	Satisfactory result
20 Stratford Way	Canal in estate reached capacity and at least one neighbour's yard and garage became flooded	Model results show that the capacity of the channel is exceeded in the event. Affected neighbour not specified but some nearby properties have surface flows.	Satisfactory result
Downstream of Moss Vale Road			
124 Burradoo Road	Flooding occurred 24th October – no specific details	October 24th coincides with peak of rainfall	Satisfactory result
14B Holly Road	Driveway level of 665.08 overtopped. Flood extent to about rear deck of 16 Holly Road and northern edge on circular driveway of 20 Holly Road	Modelled flood level of 14B driveway = 665.10. Modelled extents on 16 and 20 similar to as reported.	Refer to comment below
10 Holly Road	Flooding only occurred at lower part of property (western end)	Flood inundation not explicitly modeled in this location.	Satisfactory result
8 Holly Road	24 hours after rain started height ~30cm. Stayed 48 h. Peak Sunday afternoon	Modelled water depth between the house and channel about 0.25-0.3m. The peak water level in the model occurs on Sunday 11am. The small difference in timing is due to the pluviograph data at Robertson being earlier than the catchment locality.	Satisfactory result

The response for 14B Holly Road enabled the TUFLOW model to be reviewed at the property driveway. The elevation grid of the model was revised at this location, as well as at the driveway downstream at 20 Holly Road, to more effectively represent the actual conditions. Peak water level differences for the October 1999 event of the revised model compared to the Flood Study Report model are shown in Figure 3. The revised model indicates a peak water level of 665.23m AHD at the driveway of 14B Holly Road which is considered more consistent with the reported flood observation.

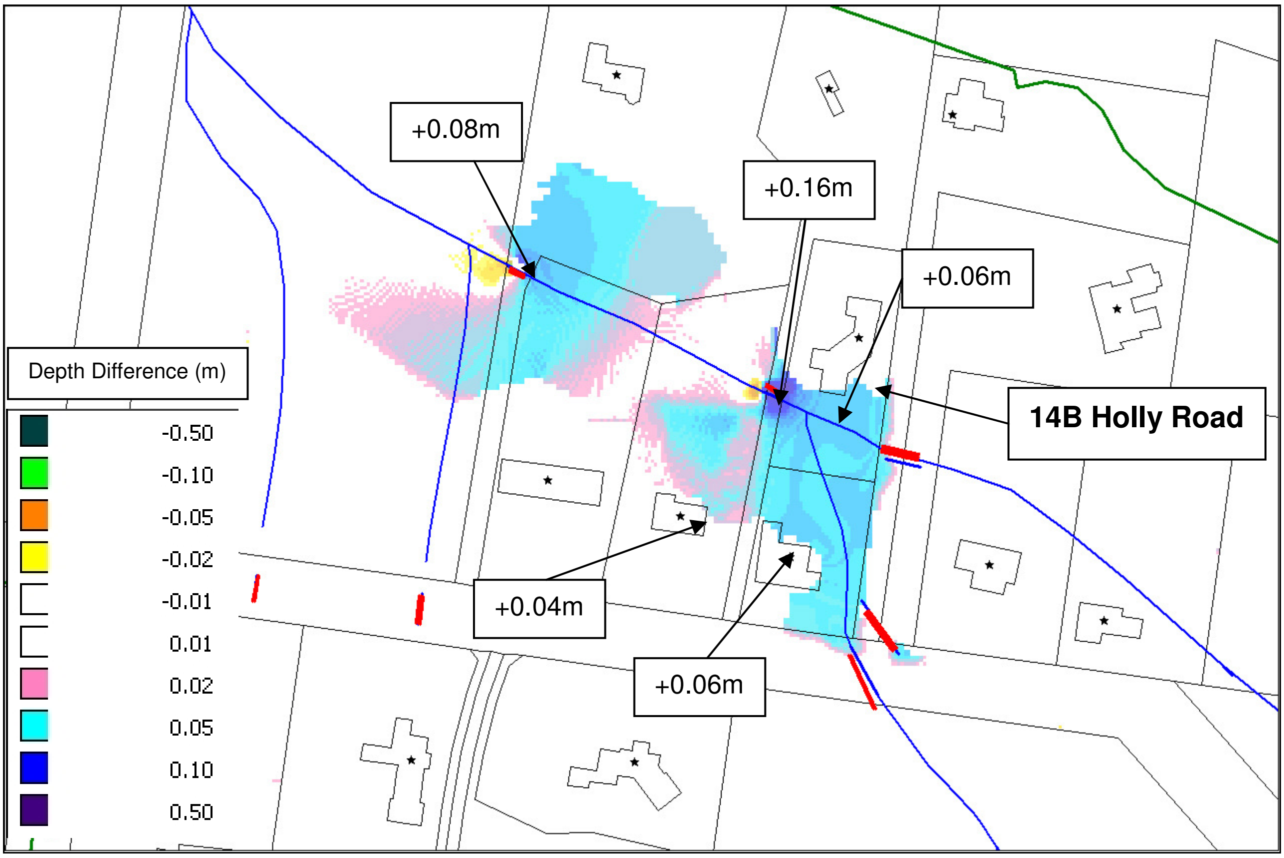


Figure 3: Peak Water Level Difference – Revised model compared to Flood Study Report model.

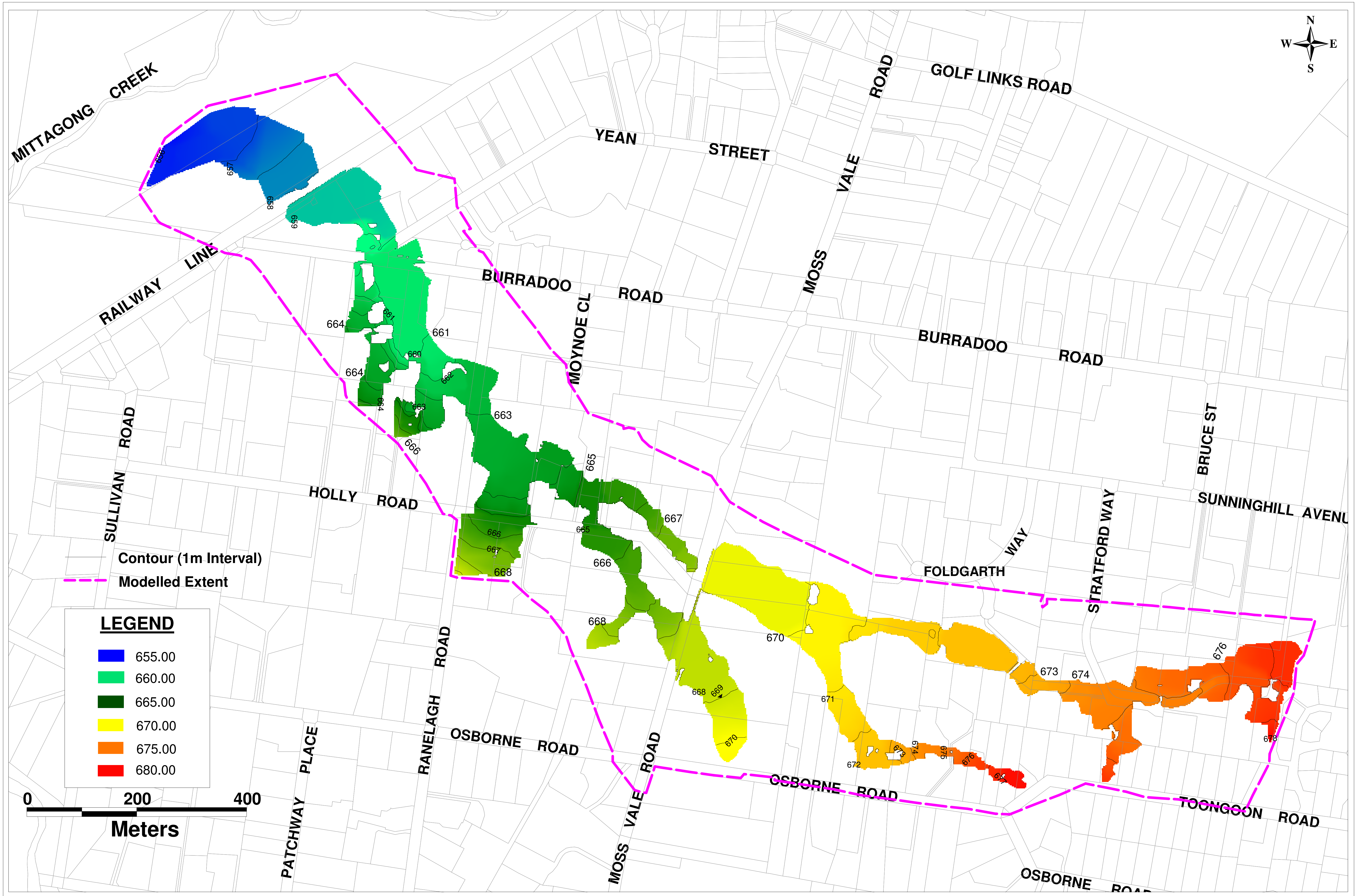
Peak water levels modelled for the October 1999 event in the revised model are shown in Figure 4.

7 Conclusion

Rainfall on the weekend of 24th October 1999 resulted in peak flood levels equivalent to an event of about 5 year ARI upstream of Moss Vale Road and about 20 year ARI downstream of Moss Vale Road for the present catchment condition.

It is recommended for the Burradoo BU2 Catchment flood management process:

- Incorporate the October 1999 Event assessment as an addendum to the Stage 1 Flood Study Report; and
- The Floodplain Risk Management Study Report to incorporate this assessment for the review of the management options and flood damages assessment.



Cardno Lawson Treloar

J2575/V5
September 2010

Burradoo BU2 Catchment Flood Study - Addendum
October 1999 Event

FIGURE 4
October 1999 Event PeakWaterLevel