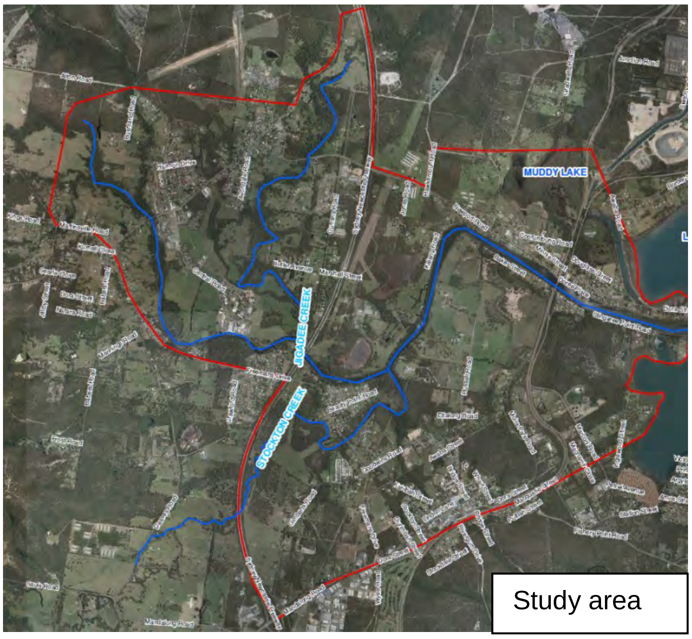
LAKE MACQUARIE CITY COUNCIL

DORA CREEK FLOOD STUDY

Final Report



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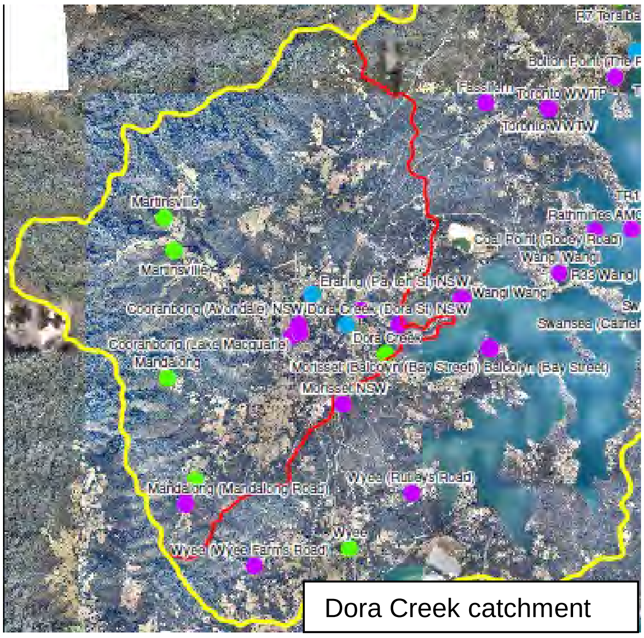

Dora Creek catchment

1990 – From western railway platform stairs looking south across Newport Road towards Baker Street


1977 - Northern bank looking south across Dora Creek to Baker Street

May 2015

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DORA CREEK FLOOD STUDY

FINAL REPORT
MAY, 2015

Project Dora Creek Flood Study	**Project Number** **113016**
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Revision	Description	Date
1	1st Calibration Draft	December 2013
2	Draft Report	February 2014
3	Public Exhibition Draft	July 2014
4	Final Report	5 May 2015

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LIST OF ACRONYMS

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AR&R	Australian Rainfall and Runoff
ALS	Airborne Laser Scanning sometimes known as LiDAR
BoM	Bureau of Meteorology
CELLS	1D hydraulic computer model sometimes known as SAMOD
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CFERP	Community Flood Emergency Response Plan
DRAINS	Hydrologic computer model
DWR	Department of Water Resources
EC	Electricity Commission
ERP	Emergency Response Classification
EY	Exceedances per Year
GEV	Generalised Extreme Value probability distribution
GSAM	General Southeast Australia Method
GSDM	Generalised Short Duration Method
HEC-RAS	1D hydraulic computer model
HW	Hunter Water Corporation
IFD	Intensity, Frequency and Duration of Rainfall
IPCC	Intergovernmental Panel on Climate Change
LEP	Local Environmental Plan
LP3	Log Pearson III probability distribution
m	metre
MHL	Manly Hydraulics Laboratory
MIKE-11	1D hydraulic computer model
m^3/s	cubic metres per second (flow measurement)
m/s	metres per second (velocity measurement)
NOW	NSW Office of Water
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PINNEENA	Database of water resources information
PRM	Probabilistic Rational Method
PWD	Public Works Department
RAFTS	Hydrologic computer model
RMA-2	2D hydraulic computer model
SOBEK	2D hydraulic computer model
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software program (hydraulic computer model)
WBNM	Watershed Bounded Network Model (hydrologic computer model)
WRC	Water Resources Commission
WWTP	Waste water treatment plant
1D	One dimensional hydraulic computer model
2D	Two dimensional hydraulic computer model

FOREWORD

The NSW State Government's Flood Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

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

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

1. Flood Study
- Determine the nature and extent of the flood problem.

2. Floodplain Risk Management Study
- Evaluates management options for the floodplain in respect of both existing and proposed development.

3. Floodplain Risk Management Plan
- Involves formal adoption by Council of a plan of management for the floodplain.

4. Implementation of the Plan
- Construction of flood mitigation works to protect existing development, use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

The Dora Creek Flood Study constitutes a review of the first stage of the management process, namely to update the 1986 Dora Creek Flood Study. This study has been prepared by WMAwater for Lake Macquarie City Council and was undertaken to update and extend the study area to include the townships of Dora Creek, Cooranbong and Avondale and to incorporate the implications of predicted climate change. The results provide the basis for future management of flood liable lands within the study area.

EXECUTIVE SUMMARY

Dora Creek has a catchment area of approximately 238 square kilometres and is located on the western side of Lake Macquarie waterway on the Central Coast. Dora Creek has two main tributaries, Jigadee Creek which enters from the north and Stockton Creek which enters from the south.

Dora Creek drains into Lake Macquarie waterway which ultimately drains to the Pacific Ocean by the narrow and shallow 4 kilometre long Swansea Channel. The lake level is normally at 0.1 mAHD and tidal fluctuations are generally only ± 0.05m. Elevated ocean levels due to high tides and storm surge as well as intense rainfall over the catchment cause the lake level to rise and thus elevate the lower parts of Dora Creek. In both February 1990 and June 2007 the peak lake level reached approximately 1 m AHD.

Flooding along Dora Creek and to a lesser extent along Jigadee and Stockton Creeks has been recorded since the 1930's. The February 1981 event was the largest accurately recorded on Dora Creek though historical photographs indicate that major flooding occurred previously. In recent times two significant events occurred on Dora Creek, in February 1990 and June 2007. In both these events there was extensive flooding in the Newcastle, Lake Macquarie and Wyong/Gosford regions. Flooding causes significant hardship, including both tangible and intangible damages, to the community and for this reason Lake Macquarie City Council has undertaken a program of studies to address the management of the flood problem.

The present study was initiated by Lake Macquarie City Council to reassess design flood levels in light of updated data and technology, and in addition incorporate sea level rise benchmarks based on predictions by the Intergovernmental Panel on Climate Change (IPCC) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) technical review for Australia, and also the potential increase in rainfall intensities due to climate change.

Reasons for Updating the Hydraulic Modelling Approach

The main reasons for updating the previous 1986 Flood Study are as follows:

- use of a two-dimensional (2D) hydraulic model rather than the one dimensional (1D) model used previously;
- availability of detailed bathymetric data of lower Dora Creek to better describe the bed of the channel rather than the use of cross sections used in previous studies;
- availability of Airborne Laser Scanning (ALS) or LiDAR survey that provides a very accurate definition of the topography of the floodplain;
- detailed field survey of the major river crossings;
- field survey of the channels that could not be picked up by ALS;
- incorporation of data for the February 1990, and June 2007 events in the calibration process;
- to assess the potential impacts of climate change.

Past Studies

Initially a comprehensive review of the available reports and data was undertaken. The lower parts of the Dora Creek floodplain have been the subject of a Flood Study (1986) and a subsequent Floodplain Management Study (1992) and Management Plan (1998) under the auspices of the NSW Government's Floodplain Management Program.

Dora Creek has also been the subject of several studies undertaken by developers as well as detailed modelling studies of possible mitigation measures.

Rainfall and Flood Height Data

There is only a limited amount of rainfall data covering the catchment and particularly pluviometer data which is needed to describe the temporal pattern of historical events. The best recorded event is the June 2007 event which benefited from installation of pluviometers by Hunter Water (HW) and Manly Hydraulics Laboratory (MHL).

There are four water level gauges in the Dora Creek catchment with the Jigadee Creek gauge including velocity measurements and thus estimates of flow are available. This means that the flow data from the Jigadee Creek gauge can be used to calibrate the hydrologic model.

Lake Macquarie City Council has maintained a comprehensive database of peak levels for floods since the 1930's. The largest events in recent times are March 1977, February 1981 and June 2007.

A limited amount of peak height data is also available from maximum height recorders monitored by MHL.

Adopted Hydrologic/Hydraulic Modelling Approach

The adopted approach was to establish a Watershed Bounded Network Model (WBNM) hydrologic model of the catchment that was used to generate design inflows for the hydraulic model (TUFLOW). TUFLOW is a 1D/2D hydraulic model that is widely used throughout NSW for flood studies. The model used a 10 m by 10 m grid for the 2D modelled overbank areas with the main channels in 1D.

Model Calibration

The WBNM/TUFLOW modelling system was calibrated to the March 1977, February 1981, June 1989, February 1990, June 2007 and February 2013 events by matching the model results to the water level and flow data as well as to the recorded peak levels. Due to the variability of the historical data it was not possible to match to every recorded level.

Design Flood Estimation

The calibrated WBNM/TUFLOW modelling system was then used to determine design flood levels, flows and velocities based on the available design rainfall data. The 36 hour storm was determined as the critical storm durations by producing the highest flood level along Dora Creek. For the Probable Maximum Flood (PMF) a 5 hour duration event was adopted for Dora Creek.

Maps were produced indicating the peak water depths, contours, velocities, hazard and hydraulic classification for the range of design events from the 0.2 EY (1 in 5 year) to the PMF.

Sensitivity Analysis, Blockage and Climate Change

Sensitivity analysis and blockage assessments were undertaken to assess the effects of varying key model parameters. In addition the effects of a sea level rise elevating the adopted design water levels in Lake Macquarie waterway and an increase in design rainfall intensities were undertaken.

Review of Calibration Data and Previous Studies

This study area is different to many similar such study areas as there is a significant amount of recorded data and past studies, although the studies are now over 20 years old, as well as level data and flow estimates at one gauge going back for approximately 30 years. For this reason a review of the calibration data and previous studies was undertaken which indicates that:

- greater emphasis should be placed on improving data collection and storage during large wet weather events (supported by community feedback through the consultation process);
- following each subsequent flood a report should be written documenting the available rainfall and flood height data together with photographs. This should also compare the peak levels to past events to put the event into some perspective.

1. INTRODUCTION

1.1. Background

The Dora Creek catchment is located on the western side of Lake Macquarie waterway, 30 km south west of Newcastle and 120 km north of Sydney. Dora Creek has a catchment area of approximately 238 km^2 and is the largest catchment flowing into the Lake Macquarie waterway which has a total catchment of 684 km^2 (Figure 1).

The present study has been commissioned by Lake Macquarie City Council (Council), with assistance from the NSW Office of Environment and Heritage (OEH) to define flood behaviour in the Dora Creek catchment.

1.2. Objectives

The primary objective of the Flood Study was to develop a suitably robust hydrologic and hydraulic modelling system to be used to assist Council in defining flood behaviour, peak flood levels and inundation extents within the study area. This system may subsequently be used within a Floodplain Risk Management Study and Plan to assess the effectiveness and suitability of flood mitigation works.

The key stages in the flood study process are:

- undertake a comprehensive review of the available flood related data including previous studies, available survey data, historical rainfall and flood level data;
- establish a hydrologic model for the entire Dora Creek catchment;
- develop a suitable hydraulic model of Dora Creek and major tributaries within the study area;
- calibration of the hydrologic and hydraulic models to historic flood data;
- define the flood behaviour and produce information on flood levels, velocities and flows for a full range of design flood events under existing conditions;
- assess the sensitivity of blockage and other assumptions on peak flood flows and levels;
- assess the impacts of sea level rise and increase in rainfall and runoff intensities due to climate change;
- prepare hazard and hydraulic category mapping;
- prepare a Community Flood Emergency Response Plan (CFERP).

This report details the results and findings of the above investigations.

1.3. Floodplain Risk Management Process

As described in the 2005 NSW Government's Floodplain Development Manual (Reference 1), the Floodplain Risk Management Process entails four sequential stages:

Stage 1: Flood Study
Stage 2: Floodplain Risk Management Study
Stage 3: Floodplain Risk Management Plan
Stage 4: Implementation of the Plan

The above first three stages were completed with publication of the 1986 Dora Creek Flood Study (Reference 2), the 1992 Dora Creek Floodplain Risk Management Study (Reference 3) and 1998 Floodplain Risk Management Plan (Reference 4). Several other flood studies have also been undertaken for private developers and these are reviewed in Section 2.

This present document provides a review of the past flood studies and updates the design flood analysis to current best practice. A Flood Study is a technical document and is not always easily understood by the general public. A glossary of flood related terms is provided in Appendix A to assist. If more explanation of terms or a better understanding of the approach is required, type "*NSW Government Floodplain Development Manual*" into an internet search engine and you will be directed to the NSW Government web site which provides a copy of this manual (Reference 1) and further explanation.

Engineers Australia as part of the team developing the updated Australian Rainfall and Runoff (AR&R) have produced a set of draft guidelines for appropriate terminology when referring to the probability of floods. In the past, Annual Exceedance Probability (AEP) has generally been used for those events with greater than 10% probability of occurring in any one year, and Annual Recurrence Interval (ARI) used for events more frequent than this. However, the ARI terminology is to be replaced with a new term, Exceedances per year (EY).

AEP is expressed using percentage probability. It expresses the probability that an event of a certain size or larger will occur in any one year, thus a 1% AEP event has a 1% chance of being equalled or exceeded in any one year. For events smaller than the 10% AEP event however, an annualised exceedance probability can be misleading, especially where strong seasonality is experienced. Consequently, events more frequent than the 10% AEP event are expressed as X Exceedances per Year (EY). Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a 0.2 EY event. For example an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6 month average recurrence interval where there is no seasonality, or an event that is likely to occur twice in one year.

While AEP has long been used for larger events, the use of EY is to replace the use of ARI, which has previously been used in smaller magnitude events. The use of ARI, the Average Recurrence Interval, which indicates the long term average number of years between events, is now discouraged. It can incorrectly lead people to believe that because a 100-year ARI (1% AEP) event occurred last year it will not happen for another 99 years. For example there are several instances of 1% AEP events occurring within a short period, for example the 1949 and 1950 events at Kempsey.

The Probable Maximum Flood (PMF) is a term also used in describing floods. This is the Probable Maximum Flood that is likely to occur. It is related to the PMP, the Probable Maximum

Precipitation.

This report has adopted the approach of the Engineers Australia AR&R draft terminology guidelines and uses % AEP for all events greater than the 10% AEP and EY for all events smaller and more frequent than this.

All levels in this report are in metres to Australian Height Datum (AHD). 0 mAHD approximates mean sea level.

1.4. Accuracy of Model Results

The accuracy of all model results provided in this report is dependent on the accuracy of the input data sets and the ability of the modelling approach to accurately replicate recorded historical flood data. As modelling approaches improve over time and additional flood data becomes available from future flood events the accuracy of the results will improve.

A key input data set is the topographic information provided by Lake Macquarie City Council for use in this study. The topographic information was derived from ALS with an estimated accuracy of ± 0.15m in cleared areas, such as car parks or on roads. In locations with more complex terrain, such as vegetated areas, the accuracy is likely to be much lower and could significantly vary, by up to ± 1m. It is cost prohibitive to obtain detailed field survey throughout the entire study area and the ALS is assumed to be correct. However due to these potential accuracy limitations, some of the floodway extents, depth estimates and design flood levels may change if more accurate field survey is obtained. It is estimated that an order of accuracy of the design flood levels is ± 0.3 m where quality historical calibration data are available nearby and up to ± 0.5 m where no such data are available.

The results from the present study incorporate best practice in design flood estimation at this time but it is acknowledged that changes in approach in the future will cause changes to design flood levels. A good example of this is the collection of rainfall data which forms the basis of design flood estimation. As more and more rainfall data are collected and analysed (and particularly from continuously read gauges termed pluviometers) the Bureau of Meteorology (BoM) will be providing new estimates of design rainfalls and design temporal patterns over NSW. An updated version of the 1987 edition of Australian Rainfall and Runoff (AR&R - Reference 5) will also introduce new approaches and guidelines which may change design flood levels.

2. BACKGROUND

2.1. Study Area

The study area focuses on the existing township of Dora Creek and includes the townships of Cooranbong and Avondale, where new and planned rural and urban developments are proposed within the floodplain. The upper limit of the study area extends above Freemans Drive to Cooranbong and downstream to the confluence of Dora Creek with the Lake Macquarie waterway (Figure 1 and Figure 2).

There are three main tributaries within the catchment with Dora Creek being joined by Jigadee Creek at Cooranbong and then Stockton Creek before draining into Lake Macquarie waterway at Bonnells Bay and Lake Eraring. Significant tributaries within the Dora Creek catchment are shown in Table 1.

Table 1: Significant Tributaries within the Dora Creek Catchment

MAJOR TRIBUTARIES	Area (km^2)
Jigadee Creek	61
Stockton Creek	55
MINOR TRIBUTARIES	
Gap Creek	19
Felled Timber Creek	15
Blarney Creek	10

Watercourses within the catchment area and above the tidal limit are narrow; Dora Creek is typically less than 15 m wide upstream of Freemans Drive. Below the tidal limit the creeks become broader with Dora Creek varying from a width of 50 m at the Sydney to Newcastle Freeway to 100 m where it forms a delta into Lake Macquarie waterway. Upstream of the delta the Eraring Power station draws cooling water for steam condensation from Bonnells Bay, which passes under Dora Creek through a concrete tunnel and open canal. Photographs of Dora Creek in flood are provided in Photo 1 and Photo 2.

Photo 1: Dora Creek at Cooranbong (July 1988 event)

Photo 2: Lower Dora Creek (March 1977 event)

2.2. Flooding History

Flooding within the Dora Creek and Cooranbong townships occurs following heavy rainfall where flood flows in excess of channel capacities results in overbank flooding. Within the lower reaches of Dora Creek, flooding may also be influenced by high water levels in Lake Macquarie waterway.

The dates of all known significant floods in the Dora Creek catchment include those shown in Table 2, however there is no long term flood height record at a single location which would allow the height of these floods to be compared.

Table 2: Significant Floods in the Dora Creek Catchment

April 1927	June 1975	June 1989
June 1949	March 1977	February 1990
1953	March 1978	August 1990
1962	February 1981	April 1992
1963	April 1983	June 2007
June 1974	1985	
February 1975	1988	

The dates and approximate peak lake levels of all known significant floods in Lake Macquarie waterway are shown in Table 3. According to the 2012 Lake Macquarie Waterway Flood Study (Reference 6) the February 1990 and June 2007 long weekend events were both smaller than a 5% (1 in 20 year level of 1.23m AHD) AEP event and in the Lake Macquarie waterway. It should be noted that the design magnitude of a historical flood will vary across a region. For example near Newcastle the June 2007 long weekend event exceeded a 1% (1 in 100 year) AEP event.

Table 3: Significant Flood Events on Lake Macquarie Waterway

Date (in order of severity)	Approximate Peak Lake Level (mAHD)
18 June 1949	1.25
April 1946	1.20
11 June 1930	1.10
9 June 2007	1.05
2 May 1964	1.00
4 February 1990	1.00
1953	0.90
1926/27	0.80
25 February 1981	0.80
May 1974	0.80
4 March 1977	0.70

Notes: Data obtained from the 2012 Lake Macquarie Flood Study - Reference 6.
Levels are an average of several recorded heights.
It is likely that several floods prior to 1970 may not have been recorded.

2.3. Previous Studies

2.3.1. Dora Creek Flood Study, May 1986 – (Reference 2)

This study was undertaken by the Public Works Department (PWD) for Council to define the nature and extent of the existing flood hazard. The study encompassed Dora Creek and its two main tributaries up to their tidal limits. Flood levels were determined downstream of the weir below the Freemans Drive bridge (Cooranbong) on Dora Creek, downstream of the Newport Road bridge (Avondale) on Jigadee Creek, and downstream of the Cooranbong Road bridge on Stockton Creek.

Design rainfall intensities were obtained from rainfall intensity-frequency-duration (IFD) curves prepared by the BoM for Newcastle and compared with rainfall from Australian Rainfall and Runoff (AR&R 77 – Reference 5). These rainfall intensities were then used to create flow hydrographs using the Cordery-Webb method which was calibrated to gauged flows on Jigadee Creek for the February 1981 flood event. The resultant design flows are reproduced in Table 4.

Table 4: Peak Flow estimates using Cordery-Webb method (Table 4 in the 1986 Dora Creek Flood Study (Reference 2))

Location	5% (1 in 20 year) AEP (m^3/s)	2% (1 in 50 year) AEP (m^3/s)	1% (1 in 100 year) AEP (m^3/s)
Jigadee Creek	244	297	340
Upper Dora Creek	255	310	355
Stockton Creek	237	288	330
Dora Creek (Railway)(1)	746	909	1044

Note (1): The peak flow of Dora Creek at the railway was considered to be unrealistic as the hydrologic model did not take into account floodplain storage in the lower part of the catchment.

Hydraulic modelling was undertaken using the SAMOD or CELLS quasi 2D hydraulic model. A limited calibration of the model was undertaken to the February 1981 event, involving adjustment of Manning's roughness coefficients in order for modelled results to reproduce recorded flood levels.

Reported flood data from maximum height recorders for the May 1979, February 1981 and May 1981 flood events are reproduced in Section 3.5.2. Stream gauging undertaken by the PWD and the Electricity Commission (EC) during the March 1977 and February 1981 events is reproduced in Table 5.

Table 5: Stream Gauge Records (Appendix A in the 1986 Dora Creek Flood Study Reference 2)

Date	Location	Peak Flood Level (m AHD)	Level (m AHD) when Velocity measured	Average Velocity (m/s)	Gauging By
4 Mar 1977	Dora Creek – 50 m upstream Railway Bridge	2.05	0.60	0.72	EC
7 Feb 1981	Dora Creek Railway Bridge	1.46	1.43	1.20	PWD
7 Feb 1981	Stockton Creek Bridge	1.98	1.89	1.00	PWD
7 Feb 1981	Dora Creek Bridge – Cooranbong	4.79	4.14	2.10	PWD
7 Feb 1981	Jigadee Creek Bridge	5.81	4.76	1.60	PWD

2.3.2. Dora Creek Floodplain Management Study (Reference 3)

In this study the design discharges and hydraulic modelling undertaken as part of the 1991 Dora Creek Floodplain Risk Management Study - Hydraulic Analysis of Subdivision Options (Reference 7) were adopted in order to investigate several flood mitigation options proposed by Council.

2.3.3. Dora Creek Floodplain Management Study – Hydraulic Analysis of Subdivision Options, February 1991 (Reference 7)

The study was carried out to assist Lake Macquarie City Council with the formulation of a floodplain management strategy. This was undertaken by identifying the nature and extent of the flood hazard and the hydraulic impacts and flood damage costs which may have resulted from various subdivision development options within the floodplain of lower Dora Creek. The area under investigation included Dora Creek from the junction of Stockton Creek downstream to Bonnells Bay.

Design rainfall data from AR&R 1987 (Reference 5) was applied to the Cordery-Webb hydrologic model, with parameters from the 1986 Dora Creek Flood Study (Reference 2) to obtain discharge hydrographs. Flood levels were evaluated using the 1D MIKE-11 hydraulic model which was calibrated to the February 1981 event using data from the 1986 Dora Creek Flood Study (Reference 2).

Design flood levels for the 5% (1 in 20 year) and 1% (1 in 100 year) AEP events were compared to the 1986 Dora Creek Flood Study (Reference 2) and the available historical flood heights and it was concluded in the report that the revised 5% (1 in 20 year) AEP event flood profile may have been a little high. However, given the lack of long term homogenous flood data for the study area the revised flood flows and levels were considered appropriate for the study.

The study identified significant overbank flows being conveyed to Muddy Lake through low lying areas including along Watt Street, Minnie Street and Newport Road.

2.3.4. Dora Creek, Kalang Road: Two Dimensional Study and Preliminary Design of Flood Deflector Levee, February 1994 (Reference 8)

This study was an extension of a flood study undertaken in November 1992 by Patterson Britton & Partners and focused on flooding in the vicinity of Kalang Road. The previous study used a two dimensional finite element model 123DFE (a version of the RMA model), which was calibrated against the February 1981 flood event and compared with flood levels and velocities produced in the 1991 Dora Creek Floodplain Risk Management Study - Hydraulic Analysis of Subdivision Options (Reference 7). No mention was made of the hydrologic model or flows adopted for the study.

Design 1% (1 in 100 year) AEP flood levels of approximately 3.15 mAHD were predicted to occur along Kalang Road with depth averaged velocities ranging from 0.4 m/s up to 1.2 m/s between houses.

The study investigated the hydraulic implications of constructing an earth fill deflector levee immediately upstream of Kalang Road, Dora Creek in order to reduce flood velocities in the vicinity of houses along Kalang Road. Dora Creek undertakes a 90 degree bend at this location.

2.3.5. Lake Macquarie Flood Study, January 1998 (Reference 9)

The Flood Study completed in January 1998 by MHL was undertaken to determine design flood behaviour for the 1% (1 in 100 year), 2% (1 in 50 year) and 5% (1 in 20 year) AEP design floods and an extreme flood event for the Lake Macquarie waterway. The flood level at a particular location around the lake depends upon a combination of the still water design lake levels and the effect of local wind/wave action, termed wave run-up.

This study is of relevance to the present Dora Creek Flood Study as the hydrologic model was calibrated to the Jigadee gauge in the Dora Creek catchment.

Rainfall runoff hydrographs were estimated using design flood estimation procedures outlined in AR&R 1987 (Reference 5). However, local rainfall data supplied by BoM was used in this study for the longer duration storm events.

Temporal patterns for storms of 72 hour duration or less were derived from AR&R 1987 (Reference 5) while the 96 hour and 120 hour durations were derived by the BoM using the Generalised Southeast Australia Method (GSAM). For durations longer than 120 hours, the 120 hour pattern was proportioned to fit the 144 hour and the 168 hour durations.

A hydrologic model (WBNM) was used to convert rainfall to runoff hydrographs and was calibrated to data at the Jigadee Creek gauge (Section 3.5). The catchment upstream of the gauge was represented by a single sub-catchment with a catchment lag parameter “C” = 2.3 and a non-linearly exponent “n” of 0.23.

Still water design lake levels were obtained using inflows from the hydrologic model into a 2D hydraulic (RMA-2) computer model. The hydraulic model was based on hydro-survey undertaken in 1977. Both models were calibrated to historical data (November 1983, May 1974, February 1990 and March 1990 floods) and the critical duration was found to be 6 days (144 hours). A separate flood frequency analysis of design lake water levels was undertaken based on available lake water level records for the period 1926 to 1994.

2.3.6. Jigadee Creek Flood Study for Proposed Development at Lot 2 DP778019 & Lot 15 DP129150, July 2004 (Reference 10)

In March 2004 Lake Macquarie Council released a new Local Environment Plan (LEP) which changed the zoning of some of the land within the Jigadee Creek catchment from rural to rural/residential investigation. As a result of this rezoning, this study was commissioned to investigate flooding of Jigadee Creek and the potential flood impacts associated with developing land within the Jigadee Creek floodplain. The study area consisted of Lot 2 DP778019 and Lot 15 DP129150, Newport Road, Cooranbong.

A WBNM hydrologic model was set up to cover the entire Jigadee Creek catchment draining to Dora Creek. A MIKE-11 hydraulic model was constructed to model the main creek within the designated study area. Calibration of the models was undertaken to the February 1990 event, and verified against the February 1981 and June 1989 events.

Using the rating curve from Pinneena (Reference 11 - a DVD containing water resource information for NSW), it was found that peak flows and levels could not be matched using reasonable hydrologic loss rates and hydraulic roughness parameters. A different rating curve, and thus peak flows were assumed and the calibration involved matching gauged heights and the timing of the flood peak for all three events.

Topographic survey data used in the study included cross-section details of Jigadee Creek at approximately 80 metre intervals through the subject properties, one section upstream of Newport Road and three sections downstream of the property towards the confluence with Dora Creek.

2.3.7. Flood Study: Mandalong Coal Mine, December 2004 (Reference 12)

The flood study was undertaken on behalf of the Department of Infrastructure Planning and Natural Resources to fulfil requirements for an extension to underground coal mining activities for Cooranbong Colliery (now known as the Mandalong coal mine).

The study adopted a rainfall-runoff method using the RAFTS hydrological model and the RMA-2 hydraulic model to produce a description of design flood behaviour. Given uncertainty about flow gauging at Stockton Creek during the February 1981 event and the lack of gauged flows during the June 1989 event, the hydrologic and hydraulic models were independently verified against historic data and regional flood frequency analysis.

Design rainfall depths for various durations for the 1% (1 in 100 year) AEP design storm were derived using rainfall from AR&R 1987 (Reference 5). A uniform rainfall depth was applied across the catchment with IFD relationships derived for the centre of the catchment. Given the small catchment size of 50 km^2 no aerial reduction factor was applied.

Verification of the design flows from the RAFTS model within Stockton Creek were made using a regional flood frequency method based on the Probabilistic Rational Method (PRM) and the Index Flood Method as outlined in AR&R 1987 (Reference 5). The Index Flood Method was based on flow gauging stations for small catchments located within the Central Coast and Lower Hunter regions.

No cross-sectional survey was undertaken of the channel creeks; however ALS data (surveyed in 2003 to 2004) was processed with breaklines to define the creek bathymetry. Stage-discharge relationships for flows under the M1 Motorway (formerly F3 Freeway), Mandalong Road and Deaves Road were developed using HEC-RAS and incorporated into RMA-2.

The study found that significant backwater effects occurred behind the M1 Motorway during a 1% (1 in 100 year) AEP event due to the restricted hydraulic capacity of the bridges under the M1 Motorway.

2.3.8. Flood Investigation for Rezoning & Master Plan – Land off Freemans Drive, Cooranbong, December 2005 (Reference 13)

The purpose of the study was to assess existing flooding conditions and flooding impacts of a hypothetical development between Freemans Drive and Newport Road. Survey of the study area was obtained from 1:25,000 and 1:4,000 topographical maps and no hydro-survey or detail structure survey was undertaken.

Peak 1% (1 in 100 year) AEP flows were estimated upstream of Newport Road using the PRM method. The peak flow was compared against RAFTS modelling and the results in the 2004 Jigadee Creek Flood Study for a Proposed Development (Reference 10). Comparisons are shown in Table 6. PMF flow estimates were taken from the 2004 Jigadee Creek Flood Study for a Proposed Development (Reference 10). It was assumed that the flows estimated at Newport Road would be relatively constant across the study area and were applied at the upstream end near Freemans Drive.

Table 6: Peak 1% (1 in 100 year) AEP flow estimates at Newport Road in Reference 13

Method	Peak Flow (m^3/s)
PRM	310
RAFTS	351
2004 Jigadee Creek Flood Study for a Proposed Development	312

Peak flows were translated into flood levels using a steady state HEC-RAS model based on topographic maps and estimated details of Newport Road bridge. Blockage of the bridge was not considered.

2.3.9. Flood Study Investigation at Various Lots off Newport and Avondale Roads, Cooranbong, November 2008 (Reference 14)

The study investigated flood impacts due to a proposed development downstream of Newport Road. Peak flows from the 2004 Jigadee Creek Flood Study for a Proposed Development (Reference 10) were input into a DRAINS hydraulic model to determine flood levels for both the existing scenario and proposed development. Creek and ALS survey were used to inform the DRAINS model. Resident interviews were undertaken as part of the study and are summarised in Table 7.

Table 7: Summary of Resident interviews undertaken as part of Reference 14

Resident	Address	Length of Residence	Comments
Mr and Mrs Borgas	20/40 Newport Road	80+ years	Flood water up to 600 mm over the floodplain area up to the Newport Road fill embankment (approximately 4.9 – 5.0 mAHD)
Mr Peter Butcher	47 Avondale Road	30+ years	Floodwaters up to 4.9 mAHD in and adjacent to lot

2.3.10. Lake Macquarie Waterway Flood Study, June 2012 (Reference 6)

The Lake Macquarie Waterway Flood Study was initiated by Council to research and update the 1998 Lake Macquarie Flood Study (Reference 9), to incorporate predicted impacts of climate change. The study included modelling of the June 2007 long weekend event and incorporated recent detailed bathymetric survey within the Swansea Channel.

The study established a hydrologic model (WBNM) and hydraulic model (TUFLOW), which were calibrated and validated to the February 1990 and June 2007 long weekend events. The following conditions were adopted for the design flood analysis:

- 0.1 mAHD initial water level in the Lake Macquarie waterway (average lake level);
- 48 hour critical rainfall storm duration inflows (for all design events except the PMF) in conjunction with the respective ocean tides;
- design ocean levels based on the design levels in Fort Denison/Sydney Harbour plus a wave setup component (0.2 m assumed for the 1% (1 in 100 year) AEP event);
- all design tides assume the “shape” of the tidal hydrograph of the May 1974 east coast low event as recorded at Fort Denison in Sydney Harbour. This tidal hydrograph approximates the 1% (1 in 100 year) AEP design ocean event;
- the wave setup component was assumed to increase linearly to peak at the same time as the ocean peak;
- the peak ocean level was coincided with the peak rainfall burst in the 48 hour duration event.

Design flood levels in Lake Macquarie waterway from the 2012 Lake Macquarie Waterway Flood Study (Reference 6) are reproduced in Table 8. Climate change scenarios were analysed for the 20% (1 in 5 year), 5% (1 in 20 year) and 1% (1 in 100 year) AEP events and summarised also in Table 8. The flood levels shown in Table 8 exclude wave runup in the lake.

Table 8: Summary of Design Flood Levels in the 2012 Lake Macquarie Waterway Flood Study (Reference 6)

	Peak Lake Level (mAHD)					
		Sea Level Rise		Rainfall Increase		
Event (AEP)	**Existing**	**+ 0.4m**	**+ 0.9m**	**10%**	**20%**	**30%**
0.5EY (1 in 2 year)	0.65	1.04	1.54	0.71	0.77	0.83
0.2 EY (1 in 5 year)	0.82	1.21	1.71	0.88	0.94	1.00
10% (1 in 10 year)	0.94	1.32	1.81	1.03	1.11	1.19
5% (1 in 20 year)	1.23	1.61	2.10	1.32	1.40	1.49
2% (1 in 50 year)	1.38	1.74	2.20	1.50	1.61	1.72
1% (1 in 100 year)	1.50	1.86	2.32	1.62	1.73	1.84
0.5% (1 in 200 year)	1.69	2.05	2.51	1.81	1.92	2.03
0.2% (1 in 500 year)	1.87	2.23	2.69	1.99	2.10	2.21
PMF	2.45	2.81	3.27	2.57	2.68	2.79

Note: Underlined levels have been derived from interpolation from model results rather than actual modelling

3. AVAILABLE DATA

3.1. Topographic and Bathymetric Survey

ALS survey of the study area and its immediate surroundings were provided for the study by Council. The data were collected in January 2007. It should be noted that the accuracy of the ground information obtained from ALS survey can be adversely affected by the nature and density of vegetation, the presence of steeply varying terrain, the vicinity of buildings and/or the presence of water.

As ALS survey is unable to penetrate below water surfaces detailed bathymetric survey data of Dora Creek was obtained from the OEH web site. The bathymetric survey was collected between July 2010 and March 2012 and was used to define in-bank capacity in the tidal reaches of Dora Creek and major tributaries of Jigadee and Stockton Creeks.

Survey of Jigadee Creek was undertaken as part of the 2004 Jigadee Creek Flood Study for a Proposed Development (Reference 10), and was used to extend the OEH surveyed cross-sections to upstream of Newport Road. A summary of available survey data is provided in Table 9 and on Figure 3.

Table 9: Summary of Available Topographic and Bathymetric Survey Data

Type	Coverage	Source	Date of Survey
ALS	Topographic Survey	Council	2007
Bathymetry	Dora Creek, Jigadee and Stockton Creek	OEH	2010 to 2012
Bathymetry	Jigadee Creek from Dora Creek to Newport Road	Reference 10	2004

Previous bathymetric survey of Dora Creek was undertaken by Council in 1997 prior to completion of the Dora Creek Floodplain Management Plan (Reference 4). Cross-sections were surveyed at the same location as historical survey undertaken in 1989. A comparison of the 1997 and 1989 sections in the Dora Creek Floodplain Management Plan (Reference 4) indicated an apparent shallowing of the creek bed, particularly in the lower reaches.

3.2. Structure Survey

Bridges within the study area shown on Table 10 were surveyed in August 2013. Photographs on Figure 4 provide a descriptive overview of the key characteristics of the waterways.

Table 10: Key Bridge Crossings (shown on Figure 4)

Location	Creek System	Width (m)	Height to Soffit (m)	Approx. Waterway Area to Soffit (m^2)	Photograph
Freemans Drive	Stockton Creek	39	3.7	170	A
M1 Motorway	Stockton Creek	58	6.5	222	B
Macquarie Street	Dora Creek	150	8.3	836	C
Railway	Dora Creek	148	8.2	849	D
M1 Motorway	Dora Creek	189	6.5	1000	E
Wilson Lane	Dora Creek	43	4.8	267	F
Freemans Drive	Dora Creek	32	7.0	157	G
Bushland Road	Felled Timber Creek	1.8 diameter culvert		2.5	H
Newport Road	Jigadee Creek	42	6.9	145	I
Freemans Drive	Jigadee Creek tributary	7.7	3.8	22	J
Freemans Drive	Jigadee Creek tributary	0.6 diameter culvert		0.3	K

3.3. Design Rainfall

Design rainfall intensities were based on procedures in AR&R 1987 (Reference 5). Given the size of the catchment, design rainfall intensities were determined for every 0.025 degree change in longitude and latitude and made into a grid. For each design event the mean rainfall depth based on the grids within each sub-catchment was calculated. Aerial-reduction factors were based on AR&R 1987 (Reference 5). Design rainfall intensities at the centre of the catchment are provided as an example in Table 11.

Table 11: Design Rainfall Intensities (AEP) at the catchment centre (mm/h)

Storm Duration	1EY (1 in 1 year)	0.5EY (1 in 2 year)	0.2EY (1 in 5 year)	10% (1 in 10 year)	5% (1 in 20 year)	2% (1 in 50 year)	1% (1 in 100 year)	0.5% (1 in 200 year)	0.2% (1 in 500 year)
1 hour	25.2	32.5	41.7	47.1	54.2	63.5	70.6	77.9	87.7
1.5 hour	20.2	26.1	33.6	38.0	43.8	51.4	57.3	63.3	71.3
2 hour	17.2	22.2	28.7	32.5	37.5	44.2	49.2	54.4	61.4
3 hour	13.7	17.7	22.9	26.0	30.1	35.5	39.6	43.9	49.6
4.5. hour	10.9	14.1	18.3	20.8	24.2	28.5	31.9	35.3	10.0
6 hour	9.2	12.0	15.6	17.8	20.7	24.4	27.3	30.3	34.4
9 hour	7.3	9.5	12.5	14.3	16.6	19.7	22.0	24.4	27.7
12 hour	6.2	8.1	10.7	12.2	14.2	16.8	18.9	21.0	23.9
18 hour	4.9	6.4	8.4	9.7	11.3	13.4	15.0	16.7	19.0
24 hour	4.1	5.4	7.1	8.2	9.5	11.6	12.8	14.2	16.2
30 hour	3.6	4.7	6.2	7.2	8.4	10.0	11.2	12.5	14.2
36 hour	3.2	4.2	5.8	6.4	7.5	8.9	10.0	11.2	12.8
48 hour	2.7	3.5	4.7	5.4	6.3	7.5	8.4	9.4	10.7
72 hour	2.0	2.6	3.5	4.1	4.8	5.7	6.5	7.2	8.2

Probable Maximum Precipitation (PMP) design rainfall depths were calculated using the 2003 BoM Generalised Short Duration Method (Reference 15) for durations up to 6 hours and the 2005 BoM Generalised Tropical Storm Method (Reference 16) for longer durations.

3.4. Rainfall Stations

3.4.1. Background

Rainfall data from past flood events are required for the calibration of hydrologic models. For this reason rainfall data has been collected from the relevant rainfall stations and flood events (refer Figure 1 and Figure 12) within or near to the Dora Creek catchment. Whilst daily rainfall is important this information provides no indication of the peak intensities within the 24 hour period. For flood modelling the temporal pattern is essential and this is available from pluviometers which are gauges that continuously record the rainfall. The availability of pluviometer data are therefore a critical factor in determining which historical events can be used for model calibration as while daily rainfall data has been available for up to 100 years in this area pluviometer data is much less well recorded and generally only available since the 1960s.

The sourcing of daily rainfall data is relatively straight forward and is obtained from the BoM. However a number of different authorities operate pluviometers and it is much harder to source this data as these authorities are not necessarily public bodies whose role is to readily provide such information. Without pluviometer data a record of peak heights from a past event is of only limited value in calibration.

It is preferable to obtain pluviometer data from a gauge within or close to the study area but this is not always possible and for this reason pluviometer data has had to be obtained from Milfield Composite and Maryville for the older historical events (Table 12). However for the more recent events in the June 2007 long weekend and February 2013 there are pluviometers within the catchment and thus data from the pluviometers further away from the catchment has not been collected.

The longest pluviometer records are from the Milfield Composite and Maryville (both since 1958). Hunter Water has installed a number of pluviometers since the 1990s in the region but for various reasons data is not always available for every event and from every gauge. Hunter Water has over 15 pluviometers on the east side of Lake Macquarie waterway near Charlestown but data from these gauges has not been collected as pluviometer data is available from much nearer gauges.

A summary of relevant available data during significant recent rainfall events are presented in Table 12 (pluviometer) and Table 13 (daily read).

Table 12: Availability of Pluviometer Rainfall Data

Number	Station	Owner	Opened	Closed	Mar 1977	Feb 1981	June 1989	Feb 1990	Jun 2007	Feb 2013
61133	Bolton Point (The Ridge Way)	BoM	1970	1978	-	-	-	-	-	-
61152	Congewai (Greenrock)	BoM	1959	1971	-	-	-	-	-	-
61174	Milfield Composite	BoM	1958	1981	✓	✓	-	-	-	-
61223	Maryville	BoM	1964	1991	✓	✓	✓	✓	-	-
61224	Congewai	BoM	1967	1974	-	-	-	-	-	-
61273	Norah Heads Lighthouse	BoM	1969	2004	-	-	-	-	-	-
61366	Norah Heads AWS	BoM	1995	current	-	-	-	-	-	(1)
61390	Newcastle University	BoM	1998	2012	-	-	-	-	✓	(1)
61412	Cooranbong (Lake Macquarie)	BoM	2008	current	-	-	-	-	-	(1)
561083	Martinsville	MHL	1988	current	-	-	✓	-	✓	✓
561081	Mandalong	MHL	1988	current	-	-	✓	-	✓	✓
561097	Wyee	MHL	1992	current	-	-	-	-	✓	✓
	Barnsley	MHL	1988	current	-	-	-	✓	✓	(1)
	Wyong	MHL	1979	1992	-	✓-	-	✓	-	-
	Wyong Weir	MHL	1993	current	-	-	-	-	-	(1)
	Yarramalong	MHL	1995	current	-	-	-	-	✓	(1)
	Whitemans Ridge	MHL	(1)	(1)	(1)	(1)	(1)	✓	(1)	(1)
R32	Dora Creek	HW	2010	current	-	-	-	-	-	✓
R33	Wangi Wangi	HW	1998	current	-	-	-	-	✓	✓
	Lake Eraring	(1)	(1)	(1)	-	✓	-	-	-	-
	Lake Munmorah	(1)	(1)	(1)	-	✓	-	-	-	-

Notes **(1)**: Data may be available but was not collected/used for in this study as more suitable data available
(2) Locations only shown on Figure 12 where pluviometer data has been obtained

Table 13: Availability of Daily Read Rainfall Data

Number	Station	Owner	Opened	Closed	Mar 1977	Feb 1981	June 1989	Feb 1990	Jun 2007	Feb 2013
61011	Cockle Creek (Pasminco Metals)	BoM	1900	2003	✓	✓	✓	✓	-	-
61012	Cooranbong (Avondale)	BoM	1903	current	✓	✓	✓	✓	✓	✓
61019	Fassifern	BoM	1924	1961	-	-	-	-	-	-
61041	Morriset (Balcolyn (Bay Street))	BoM	2001	current	-	-	-	-	✓	✓
61063	Rathmines AMO	BoM	1940	1950	-	-	-	-	-	-
61082	Wyee (Wyee Farms Road)	BoM	1899	current	✓	✓	✓	✓	✓	✓
61133	Bolton Point (The Ridge Way)	BoM	1962	2012	✓	✓	✓	✓	-	-
61141	Quorrobolong (Emmavale)	BoM	1959	1971	-	-	-	-	-	-
61152	Congewai (Greenrock)	BoM	1959	current	✓	✓	✓	✓	✓	✓
61174	Milfield Composite	BoM	1959	1983	✓	✓	-	-	-	-
61219	Dooralong	BoM	1963	1976	-	-	-	-	-	-
61223	Maryville	BoM	1964	1993	✓	✓	✓	✓	-	-
61224	Congewei	BoM	1898	1924	-	-	-	-	-	-
61256	Coal Point (Robey Road)	BoM	1968	1977	✓	-	-	-	-	-
61262	Munmorah Power Station	BoM	1963	1969	-	-	-	-	-	-
61276	Morisset	BoM	1911	1915	-	-	-	-	-	-
61282	Dora Creek (Dora St)	BoM	1907	current	-	-	-	-	✓	✓
61299	Belmont WWTP	BoM	1900	current	-	-	-	✓	✓	✓
61322	Toronto WWTP	BoM	1972	current	✓	✓	✓	✓	✓	✓
61323	Dora Creek (Cooranbong Road)	BoM	1972	1993	✓	✓	✓	✓	-	-
61333	Wangi Wangi	BoM	1919	1925	-	-	-	-	-	-
61357	Mandalong (Mandalong Road)	BoM	1986	current	-	-	✓	✓	✓	✓
61359	Mt Hutton (Auklet Rd)	BoM	1987	2005	-	-	✓	✓	-	-
61362	Warmervale (Hakone Road)	BoM	1988	1993	-	-	✓	✓	-	-
61367	Belmont North (Wommara Ave)	BoM	1990	1997	-	-	-	-	-	-
61370	Barnsley (Bendigo Street)	BoM	1991	1997	-	-	-	-	-	-
61376	Eraring (Payten St)	BoM	1993	current	-	-	-	-	✓	✓
61377	Swansea (Catherine St)	BoM	1987	2013	-	-	✓	✓	✓	✓
61385	Wyong (Olney Forest)	BoM	2000	current	-	-	-	-	✓	✓
61387	Gorokan (Goobarabah St)	BoM	1996	current	-	-	-	-	✓	✓
61389	Wyee (Rutleys Road)	BoM	1997	2011	-	-	-	-	✓	-
61406	Newcastle (Blacksmiths)	BoM	2004	current	-	-	-	-	✓	✓
61412	Cooranbong (Lake Macquarie AWS)	BoM	2008	current	-	-	-	-	-	✓
61424	Brunkerville (Sunrise B&B)	BoM	2009	current	-	-	-	-	-	✓

Note (1) For clarity only gauges within the catchment and where data has been used shown on Figure 1

3.4.2. Analysis of Daily Read Data

An analysis of daily read data was undertaken to identify and place past rainfall events in some context. All daily rainfall depths greater than 150 mm recorded at Cooranbong (Avondale) (110 years of record), Wyee (Wyee Farms Road) (114 years of record), Dora Creek (Dora Street) (104 years of record) and Congewai (Greenrock) (53 years of record) have been ranked and are shown in Table 14 and Table 15.

Table 14: Daily Rainfall Greater than 150 mm

Cooranbong (Avondale) (61012)		
Records Since 1903		
Rank	Date	Rainfall
1	16-Apr-1927	221
2	9-Jun-2007	201
3	14-Aug-1952	187
4	17-Jun-1930	184
5	18-Jun-1930	179
6	12-Sep-1950	178
7	23-Apr-1931	177
8	18-Jun-1949	175
9	21-Jun-1989	166
10	29-Dec-1926	159
11	24-Feb-1908	158
12	11-Jun-1964	158
13	16-Apr-1946	157
14	5-Feb-1990	157
15	10-Dec-1920	156
16	22-Jan-1924	154
17	17-Jun-1949	153
18	3-Apr-1905	152

Wyee (Wyee Farms Road) (61082)		
Records Since 1899		
Rank	Date	Rainfall
1	3-Apr-1905	273
2	3-Feb-1990	246
3	2-Apr-1905	233
4	16-Apr-1927	227
5	4-Mar-1977	200
6	18-Jun-1930	179
7	15-Mar-1907	178
8	11-Jun-1964	177
9	7-Feb-1981	176
10	10-Dec-1920	175
11	3-May-1953	174
12	29-Jan-2013	172
13	16-Feb-1967	171
14	14-Aug-1952	162
15	4-Feb-1990	160
16	18-Jun-1949	158
17	31-Aug-1996	156
18	22-Mar-1942	152

In June 2007 at Wyee the rainfall was accumulated to a 2 day total of 225mm

Dora Creek (Dora St) (61282)		
Records Since 1907		
Rank	Date	Rainfall
1	1-Dec-2007	188
2	24-Feb-1908	155

Congewai (Greenrock) (61152)		
Records Since 1959		
Rank	Date	Rainfall
1	20-Mar-1978	250
2	23-Jun-1989	220
3	9-Jun-2007	200
4	4-Mar-1977	166

Table 15: Significant Accumulated Daily Rainfalls

Cooranbong (Avondale) (61012)		
Records Since 1903		
Date	Rainfall	Days
4-Feb-1990	260	2
4-May-1953	237	2
28-Oct-1985	226	3
9-Feb-1981	200	3

Congewai (Greenrock) (61152)		
Records Since 1959		
Date	Rainfall	Days
5-Feb-1990	180	2
4-Aug-1990	170	4

The main points regarding these data are:

- The Dora Street gauge, although in operation for 104 years, has recorded very little significant rainfall;
- Significant events include April 1905, March 1907, April 1927, June 1930, September 1950, August 1952, March 1977, February 1981, June 1989, February 1990 and June 2007 long weekend ;
- The largest recorded rainfall at the Wyee (Wyee Farms Road) gauge was in April 1905, with 503 mm over two days. A significant variation in rainfall was found across the catchment with only 200 mm of rain falling at the Cooranbong (Avondale) gauge over those days.

3.5. Historical Flood Data

3.5.1. Streamflow Gauges

The only stream gauge with an associated flow rating curve located within the Lake Macquarie waterway catchment is the Jigadee Creek gauge at Avondale in the Dora Creek catchment. The gauge was installed in 1969 and has approximately 36 complete years of record. The gauge control section is a V notch concrete weir (Photo 3) approximately 9 m wide. This structure provides an excellent measurement of flow using the weir formula at depths up to approximately 1m to 2m. Above this depth the weir is drowned out and estimates of flow using a weir formula cannot be accurately determined.

Photo 3: Jigadee Creek gauge at Avondale

The Jigadee Creek gauge has several rating curves developed by the NSW Office of Water (NOW) and its predecessors (WRC, DWR) as given in Pinneena. The original rating curve developed in 1969 was updated in 1973 and 1974 with additional velocity gauging data which allowed for a better curve fit. The gauge zero is 2.047 mAHD.

The maximum gauged level (when velocity measurements were taken) was 3.1 m (5.1 mAHD) during the June 1975 event which accounts for 84% of all peak annual water levels. The highest water level on record occurred during the February 1981 event and reached a level of 3.8 m (5.8 mAHD). All rating curves are shown on Figure 5 along with historical flow gauging data. It is presumed that velocity measurements were taken by dropping a current meter from the upstream Newports Road bridge.

Graphs of the annual peak water levels and flows are provided on Figure 6.

Issues with the rating curve were found in the 2004 Jigadee Creek Flood Study for a Proposed Development (Reference 10) which was unable to match both the Pinneena flows and flood levels with modelled results using reasonable parameters. Site inspection identified low overbank areas, which would make it difficult to define an accurate rating curve once the channel capacity is exceeded, as overbank flow behaviour would be significantly different to flow behaviour defined at the weir. A review of the records at the Jigadee Creek gauge was undertaken in the 2012 Lake Macquarie Waterway Flood Study (Reference 6) and is repeated below.

Figure 3 of the 1986 Dora Creek Flood Study (Reference 2 in this present Dora Creek Flood Study*) includes peak water levels for the 1977 and 1981 floods (it should be noted that the level of 6.5 mAHD quoted thereon for the 1981 event at the Jigadee Creek gauge appears to be a typographic error because Table 6 of Reference* 2 *lists the peak water level as 5.81 mAHD). The available gauge records (refer to Figure 5) indicate the highest water level occurred in 1981 with five other annual peaks within 0.4 m of the February 1981 peak. The June 2007 long weekend storm/flood event was the 2nd highest on record.*

For calibration of a hydrologic model and to a lesser extent a hydraulic model, a recorded flow (in m^3/s) in a creek in the catchment is required. The estimated flow at a given water level is obtained from a rating curve which provides a relationship between the known water level and estimated flow. This relationship is derived from velocity readings (obtained from a current meter) at a known water level and cross sectional water area (obtained by survey). Many of these velocity readings are taken over a period of years at different water levels (termed gaugings) and in this way, a rating curve is developed as a "line of best fit" between the gaugings.

It is relatively easy to obtain "low flow" gaugings as small rises in water level occur frequently and the gauging party has therefore ample opportunity to undertake them. They can also be estimated using the weir formula. It is much harder to obtain "high flow" gaugings as they can only be obtained during large floods (which occur infrequently) and it may be that the gauging party cannot get access to the site or are otherwise engaged. Thus all rating curves have few "high flow" gaugings and there is therefore considerable uncertainty about the flow estimates at high water levels. A graph of the gaugings indicates how many "high flow" gaugings were undertaken and the height at which they were taken, from this an estimate of the accuracy of the high flows can be made. Generally there are no gaugings taken at the peak of a flood and thus the highest gaugings are below the peak and the rating curve must be extrapolated.

*Gaugings are usually taken from a bridge over the river with several velocity measurements at various depths and distances across the river. These velocity measurements are averaged and the flow calculated (flow {m^3/s} = mean velocity {m/s}*waterway area {m^2}).*

The Pinneena rating curves (flow versus height relationship) including the actual gaugings for two periods are provided as Figure 5. The differences between the curves should not be interpreted as there being a difference in the channel morphology at the changeover date.

Rather, rating curves are derived based on the gaugings available at the time, thus the later rating curve is based on a different dataset to the former or a different interpretation of the dataset.

Once the flow overtops the banks (Photo 3) the floodplain widens significantly. This means that a small increase in level equates to a very large increase in peak flow which means it is difficult to obtain consistent high flow gaugings.

3.5.2. Water Level Recorders

The most reliable sources of flood level data for this study are the water level recorders shown on Figure 1 on Jigadee Creek at Avondale, Stockton Creek at Morisset, and Dora Creek at Cooranbong and Kalang Road, as indicated in Table 16. In addition there are three water level recorders on Lake Macquarie waterway at Marmong Point, Belmont and Swansea. The complete historical records for the four gauges on Dora Creek are shown on Figure 7 with annual maximums for the Jigadee Creek and Cooranbong gauge provided on Figure 6. Interestingly the Jigadee Creek record on Figure 7 shows many more floods in the period from 1969 to 1992 than from 1992 to present.

Table 16: Water Level Recorders in the Study Area

		Data Available					
Name	**Opened**	**March 1977**	**Feb 1981**	**June 1989**	**Feb 1990**	**June 2007**	**Feb 2013**
Jigadee Creek at Avondale	1969	✓	✓	✓	✓	✓	✓
Stockton Creek at Morisset	1984	-	-	✓	-	✓	✓
Dora Creek at Cooranbong	1990	-	-	-	-	✓	✓
Dora Creek at Kalang Road	1993	-	-	-	-	✓	✓

Three automatic water level recorders were previously operated by the WRC and EC at the locations of the current Avondale, Morisset and Cooranbong gauges. The only available data from these historical gauges is from the 1986 Dora Creek Flood Study (Reference 2) which indicated a recorded hydrograph on Stockton Creek from the February 1981 event, shown on Photo 4.

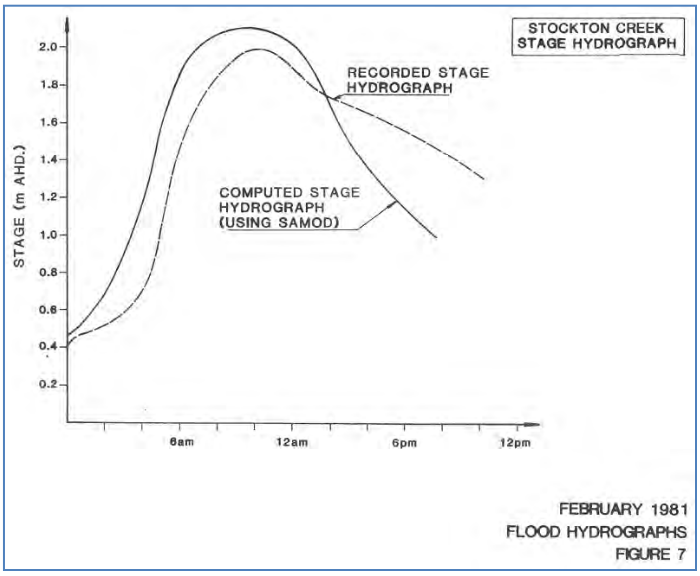


Photo 4: Scan from the 1986 Dora Creek Flood Study (Reference 2)

In addition water level data from maximum height recorders are available from the 1986 Dora Creek Flood Study (Reference 2) and these are summarised in Table 17 with locations shown on Figure 2.

Table 17: Maximum Height Recorder Data from the 1986 Dora Creek Flood Study (Reference 2)

Location	Level (m AHD) in		Comments
	May 1979	February 1981	
(1)	-	-	Not operative
(2)	-	1.45	d/s road bridge
(3)	-	1.46	u/s railway bridge
(4)	-	-	removed by Council
(5)	-	1.56	Baker Street
(6)	-	1.65	"Evungala"
(7)	-	-	missing
(8)	-	2.46	Sanitarium footbridge
(9)	1.40	4.79	1979 – No. 1 Cooranbong bridge 1981 – No. 3 Cooranbong bridge
(10)	-	1.98	No. 1 Stockton Creek Bridge
(11)	3.82	5.81	1979 – No. 1 Jigadee Creek bridge 1981 – No. 2 Jigadee Creek bridge

3.5.3. Flood Levels from Debris or Other Marks

Apart from the water level recorders the other source of flood levels are the surveyed flood marks recorded during or after a flood. The accuracy of these levels will vary depending upon the nature of the mark. A "tide mark" on a building wall or fence is probably accurate to within a few centimetres but surveying of a "vegetative debris" mark is probably only accurate to ± 0.3 m depending on the exact nature of the mark. A level from a photograph provides an accurate estimate of the water level at the time of the photograph but this may not be the peak level.

A significant amount of flood level data is available for the 1977, 1978, 1981, 1990 and 2007 flood events, from Council's records and from the 1986 Dora Creek Flood Study (Reference 2).

A summary of available flood level data from debris or other marks is shown on Figure 8.

3.6. Flood Photographs

A large number of flood photographs taken during floods are available and selected photographs are provided on Figure 9. In the absence of other automatic water level recorded data or flood mark survey, these photographs provide a valuable source for estimating peak flood levels.

3.7. Community Consultation

As part of the initial phase of this study a newsletter and questionnaire was sent out. A copy of these documents and results from the questionnaire are provided in Appendix B. Many of the flood photographs were collected this way as well as 11 peak flood levels which were surveyed and listed in Appendix B.

4. APPROACH

The approach adopted in flood studies to determine design flood levels largely depends upon the objectives of the study and the quantity and quality of the data (survey, flood, rainfall, flow etc.). Whilst there is a limited flood record from the Jigadee gauge there is no extensive historical flood record on Dora Creek or Stockton Creek, a flood frequency approach can be undertaken at the Jigadee gauge but reliance must also be made on the use of design rainfalls and establishment of a hydrologic/hydraulic modelling system. A diagrammatic representation of the flood study process undertaken in this manner is shown below.

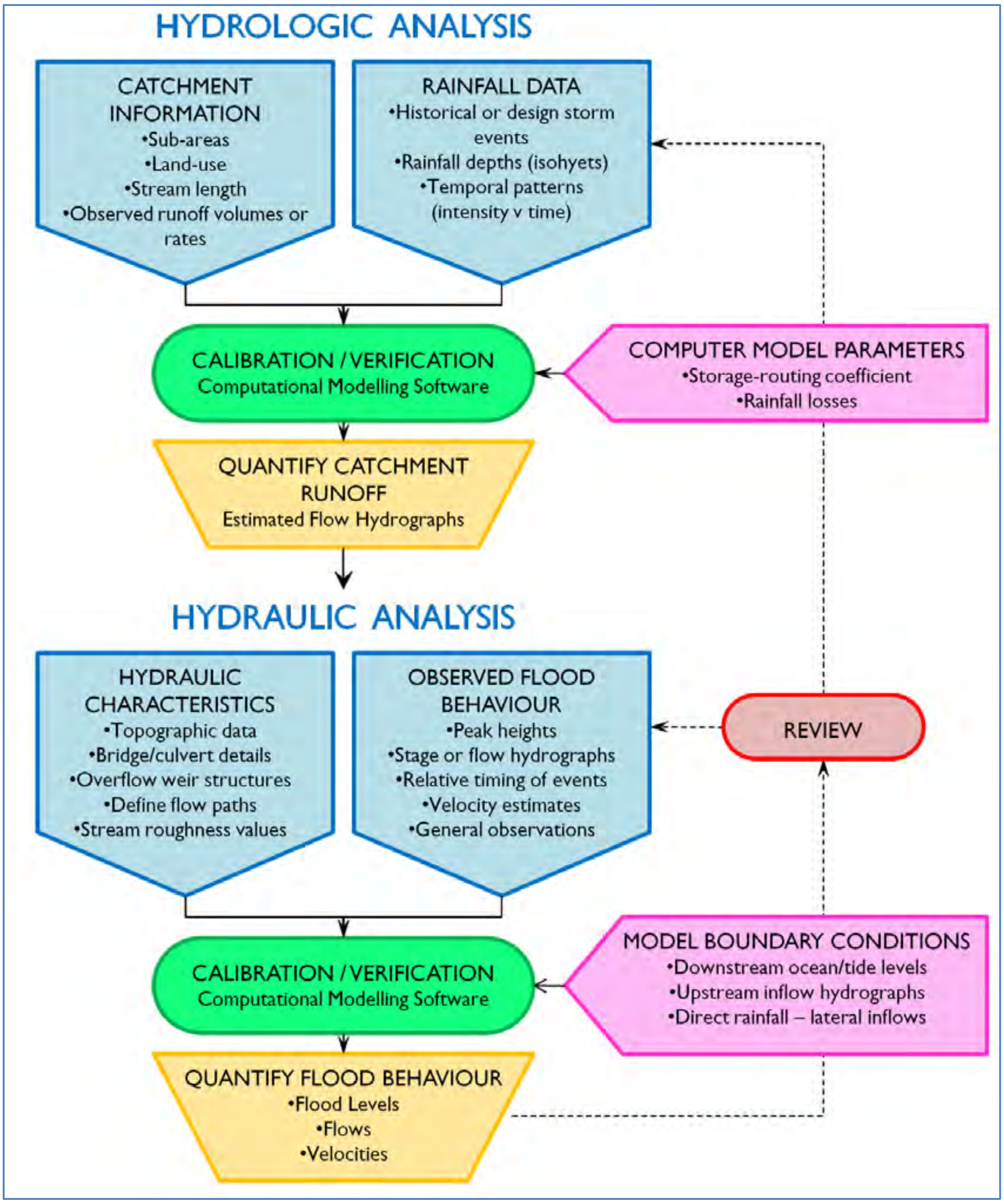


Diagram 1: Flood Study Process

4.1. Hydrologic Model

Inflow hydrographs are required as inputs at the boundaries of the hydraulic model. Typically in flood studies a rainfall-runoff hydrologic model (converts rainfall to runoff) is used to provide these inflows. A range of runoff routing hydrologic models is available as described in AR&R 1987 (Reference 5). These models allow the rainfall depth to vary both spatially and temporarily over the catchment and readily lend themselves to calibration against recorded data. The WBNM model was adopted for the reason that it was used in the 2012 Lake Macquarie Flood Study (Reference 6) and the 2004 Jigadee Creek Flood Study (Reference 10) and this allowed a comparison between the results from these studies.

The WBNM model has a default value for the storage routing parameter – C which is adopted if no data are available for model calibration. However, if flow data obtained by estimation of the average velocity and waterway area at a given water level are available at a water level gauge, then the WBNM model can be calibrated to this data through adjustment of the C parameter and/or rainfall losses. Flow data at a water level gauge can also be determined through the use of a hydraulic model.

For the historical events used to calibrate the hydraulic model historical rainfall data was input to the WBNM model to obtain the inflows and the WBNM model calibrated to the water level data at the Jigadee Creek gauge and water level data at the other gauges. The use of the flow data provided in Pinneena for the Jigadee gauge was not used in calibration as it was found that to match these flows unrealistic model parameters had to be adopted (refer Section 3.5.1).

The WBNM model layout is shown on Figure 10.

4.2. Hydraulic Model

The availability of high quality ALS and bathymetric data as well as detailed aerial photographic data means that the study area is suitable for 2D hydraulic modelling. Various 2D software packages are available (SOBEK, TUFLOW, RMA-2) and the TUFLOW package was adopted as it is the most widely used model of this type in Australia.

In TUFLOW the ground topography is represented as a uniform grid with a ground elevation and Manning's *n* roughness value assigned to each grid cell. The size of grid is determined as a balance between the model result definition required, the dimensions of the river channel (as a rough guide the channel should have over 4 cells widths in order to accurately define it) and the computer run time (depends on the number of grid cells).

The adopted approach was to establish a 10m by 10m grid TUFLOW model with cross sections defining the channel where the grid structure was not appropriate. The model extends 1.8 km upstream of Freemans Drive on Dora Creek, near Mandalong Road on Moran Creek and Stockton Creek and approximately 1.6 km upstream of Newports Road on Jigadee Creek (Figure 11).

By modelling historical flood events and matching the model versus the recorded data the

TUFLOW model can be "calibrated" or tuned to replicate historical flood events. This process is critical to the success of the approach and comprises the majority of the effort in the study.

4.3. Calibration

4.3.1. Approach

The approach to model calibration was initially to adjust the storage routing C parameter for the WBNM hydrologic model based on calibration at the Jigadee gauge using the Pinneena rating curve. This approach was modified as it was found from this and previous studies (refer Section 3.5.1) that the high flow estimates from Pinneena were not realistic. As a result the calibration became a joint hydrologic/hydraulic model calibration to the recorded water level data.

Flows from the WBNM hydrologic model for the historical events were input to the TUFLOW hydraulic model. Through adjustment within accepted bounds of the model parameters in TUFLOW as well as the C parameter in the WBNM hydrologic model, the water level results from TUFLOW were matched to the recorded peak levels and hydrographs for the historical events.

This approach makes the reasonable assumption that the storage routing C parameter for the WBNM hydrologic model is the same throughout the Dora Creek catchment.

4.3.2. Calibration Events

The choice of calibration events for flood modelling depends on a combination of the flood event and the quality and quantity of available flood data. It is preferable to use the larger events for calibration but the recent events, whilst smaller in magnitude generally have a higher quality and quantity of data. Calibration to events earlier than 1970 is not possible due to the lack of pluviometer and water level data. A summary of collected data for significant flood events is shown in Table 17.

Table 18: Summary of Historic Flood Data

Rainfall Event	Rainfall Stations		Peak gauge levels (m AHD)				Velocity Gauging	Council flood levels
	Pluviometer	Daily	Jigadee Creek	Stockton Creek	Cooranbong Dora Creek	Kalang Road		
1962	not used		-	-	-	-	-	1
1963	not used		-	-	-	-	-	1
June 1974	not used		5.4	-	-	-	-	1
February 1975	not used		5.1	-	-	-	-	1
June 1975	not used		5.3	-	-	-	-	0
February 1976	not used		5.1	-	-	-	-	0
March 1977	2	10	5.5	-	-	-	1	73
March 1978	not used		5.5	-	-	-	-	10
February 1981	4	9	5.8	-	-	-	4	10
April 1983	not used		4.4	-	-	-	-	1
1985	not used		4.8	0.9	-	-	-	1
1988	not used		4.3	2.5	-	-	-	2
June 1989	3	12	5.0	2.2	-	-	-	76
February 1990	4	13	5.1	-	-	-	-	56
April 1992	not used		-	1.7	4.5	-	-	4
June 2007	6	14	5.6	2.5	5.4	2.1	-	13
February 2013	2[(1)]	15	5.1	0.9	4.4	0.7	-	0

Note (1): limited pluviometer data was collected for the February 2013 event

The magnitude of flooding for each rainfall event varies within the catchment. The largest flood event recorded, based on peak levels, on Dora Creek occurred on March 1977 followed by the June 2007 long weekend . On Jigadee Creek the largest recorded event occurred on February 1981, followed by the June 2007 long weekend, March 1977, February 1990/February 2013 and June 1989.

Given the availability of data the hydrologic and hydraulic models were calibrated against the March 1977, February 1981, June 1989, February 1990 and June 2007 long weekend events. The February 2013 event was included as it reached a reasonable height at the Jigadee gauge and had pluviometer data from within the catchment, rather than relying on data from outside the catchment. However the February 2013 event did not produce significant flooding downstream on Dora Creek. This event is therefore a good example of how flooding can occur on a tributary but not across the entire catchment.

The locations of available water level and rainfall stations are shown on Figure 1, Figure 2 and Figure 12. Rainfall isohyets were estimated for each event using the total rainfall depth at each gauge and interpolating across the catchment using the natural neighbour method. Isohyets for the 1977, 1981, 1989, 1990, 2007 and 2013 events are shown on Figure 13. Water level hydrographs and rainfall mass curves for each of the calibration events are shown on Figure 14 to Figure 19.

A comparison of significant storm burst intensities was made against design rainfall intensities from AR&R 1987 at the Maryville and Martinsville gauges on Figure 20. These gauges were chosen as Maryville had records for the early events and Martinsville had records for the more recent events. Rainfall intensities can vary significantly over short distances and this was particularly noticeable in the June 2007 long weekend event where the intensities could be compared at several Hunter Water pluviometers (refer the 2012 Lake Macquarie Waterway Flood Study - Reference 6).

March 1977 Event: Flooding during March 1977 was the most extensive recent event, with two flood peaks occurring over a three day period. Flooding in Jigadee Creek was less severe than in the remainder of the catchment.

This event had a significant number of peak levels and gauging data however the closest pluviometers active during the event were Milfield Composite (16 km) and Maryville (24 km), both significant distances from the catchment and therefore very unlikely to be representative of rainfall temporal patterns within the catchment.

The event was the largest to occur recently and for this reason a large number of peak height data is held by Council. However the lack of nearby pluviometers meant that only a limited emphasis was placed on the March 1977 event for model calibration purposes.

February 1981 Event: The event was the largest recorded within the Jigadee Creek catchment and included a reasonable number of peak levels downstream as well as a velocity gauging. Four nearby pluviometers at Maryville, Eraring, Munmorah and Wyong were active during the event. The Milfield Composite pluviometer was active but recorded little rain at the time of the recorded flooding and was therefore not considered further. Pluviometer records shown on Figure 15 indicate that the storm timing varies amongst the gauges; this suggests that storm cells moved around the area. This makes it difficult to be confident about choosing a representative pluviometer for the temporal pattern over the entire Dora Creek catchment. Eraring is the only pluviometer within the catchment and produces a reasonable calibration.

February 1990 Event: This event produced widespread rainfall in the period of 2nd to 7th February 1990 over the Central Coast region. The rainfall occurred in several intense bursts which produced flooding on small creeks from Gosford to Newcastle but was also relatively continuous and produced up to 5% (1 in 20 year) AEP events in both Tuggerah Lakes and Lake Macquarie waterway.

The Martinsville and Mandalong rainfall gauges operated by MHL did not record any rainfall during the February 1990 event however the Barnsley and Whitemans Ridge pluviometers did function. Whilst these gauges are a significant distance from the catchment they show similar patterns (Figure 17) and were used for calibration.

June 1989, June 2007 long weekend and February 2013 events: The Martinsville and Mandalong pluviometers were operational and were considered to provide a reasonable representation of rainfall patterns within the Dora Creek catchment for these events. Thus pluviometer data from gauges outside the catchment were not collected.

For the June 1989 event the peak rainfall bursts occurred some four hours apart, suggesting that the storm cell was moving from south to north. The Martinsville peak burst was also more intense.

Figure 18 indicates pluviometer data for the June 2007 long weekend event at Wyee, Wangi Wangi and Barnsley as well as Martinsville and Mandalong. This indicates that the storm must have tracked generally to the west of the lake itself as both the Wangi Wangi and Wyee gauges recorded less rainfall than Barnsley, Martinsville and Mandalong. Wangi Wangi had just less than 50% of the total rainfall at Martinsville and Mandalong.

Limited data was collected for the February 2013 event as there was only minor flooding along Dora Creek. The event was of interest as it recorded a peak level on Jigadee Creek similar to June 1989 and February 1990. The Martinsville and Mandalong pluviometers recorded similar patterns but a maximum of only 130mm in the two day period, a similar amount to the March 1977 event. However the March 1977 event recorded approximately 120mm in a 12 hour period whilst in February 2013 it was only 90mm in a 12 hour period.

4.4. Design Flood Modelling

Following model establishment and calibration the following steps were undertaken:

- design tributary inflows were obtained from the WBNM hydrologic model and included in the TUFLOW model;
- flood frequency of the gauge records on Jigadee Creek. Flood frequency at the other gauge locations was not undertaken due to their short period of record;
- assessment of the design event causing the maximum water levels which is termed the critical storm duration;
- sensitivity analyses were undertaken to assess the effect of changing model parameters and the assumed water level in Lake Macquarie waterway,
- assessment of possible effects of climate change on design flood levels.

5. FLOOD FREQUENCY ANALYSIS

5.1. Overview

Flood frequency analysis enables the magnitudes of floods (5% (1 in 20 year), 1% (1 in 100 year) AEP etc.) to be estimated based on statistical analysis of recorded floods. It can be undertaken graphically or using a mathematical distribution.

The reliability of the flood frequency approach depends largely upon the length and quality of the observed record and accuracy of the rating curve. In addition, flood frequency inherently accounts for many assumptions which are required in rainfall-runoff routing for determining the magnitude of floods for annual exceedance probabilities.

This approach has the following advantages in design flood estimation:

- no assumptions are required regarding the relationship between probabilities of rainfall and runoff;
- all factors affecting flood magnitude are already integrated into the data;
- estimation of rainfall losses is not required;
- confidence limits can be estimated;
- historic rainfall data is not required.

The flood frequency approach does however have some limitations. These are:

- there is no "perfect" distribution", thus different distributions will provide different answers;
- as most flood records are relatively short (compared to the design event for which a magnitude is required) there is considerable uncertainty. Whilst rainfall records at a particular location are also short, data can be used by the BoM from other gauges to accurately estimate design intensities much greater than the period of record at a single gauge;
- changes to the local topography such as levee banks, hydraulic controls and the construction of dams or bridges can affect the homogeneity of the data set;
- short to medium term climatic changes may influence the flood record; and
- there are many issues with the accuracy of rating curves, especially at high flows. However this is less of an issue with the use of hydraulic models based on high quality survey (ALS) to obtain site rating curves.

While some of these factors can affect the quality of the flood frequency analysis, for the purpose of providing confirmation for the runoff routing results they are considered reasonable.

Four water level gauges are operational within the catchment and their usefulness for flood frequency analysis is summarised in Table 19.

Table 19: Water Level Gauges for Flood Frequency Analysis

Gauge Name	Catchment Area (km^2)	Years of Record	Comments
Jigadee Creek at Avondale	56	45	Reasonable period of record, good gauging data, official rating curve and sufficient cross-sectional data
Stockton Creek at Morisset	53	29	Insufficient record, limited gauging data, no rating curve, sufficient cross-sectional data and significant hysteresis during flood events
Dora Creek at Cooranbong	87	24	Insufficient record, no gauging data, no rating curve, insufficient cross-sectional data
Dora Creek at Kalang Road	214	21	Insufficient record, no gauging data, no rating curve, sufficient cross-sectional data and significant hysteresis during flood events

The Stockton Creek gauge at Morisset and Dora Creek gauge at Kalang Road were considered unsuitable for flood frequency analysis due to the effects of hysteresis. Hysteresis occurs when storage within the floodplain is filled as a flood event progresses and the relationship between flow and water level at the same location varies in time. Flood frequency was initially undertaken at the Jigadee Creek and Cooranbong gauges. It was found that the period of record at the Cooranbong gauge was too short to be reliable (Figure 21). A large proportion of known flood events have occurred outside the period of record and as a result frequency analysis appeared to underestimate design flows at the gauge. An older gauge at the same location was operated by PWD however the records from the previous gauge were unable to be found.

The Jigadee Creek gauge has been in operation since December 1969 and contains a number of significant flood events. Given the limited period of record, flow estimates from Pinneena for the rarer events contain considerable uncertainty. Therefore it was only appropriate to estimate design flows for up to a 5% (1 in 20 year) AEP event with the 2% (1 in 50 year) AEP just beyond the credible range for extrapolation.

In addition to the limited data, flow records at the gauge are unlikely to be representative of the greater Dora Creek catchment. The catchment to the Jigadee Creek gauge is approximately a quarter of the greater catchment and there are a number of historic events which have produced greater flooding within Dora Creek than recorded at the Jigadee Creek gauge.

At some locations in Australia there is the potential to extend the flood record through the use of paleo-flood records (determining peak levels from past evidence of flooding, e.g. debris in caves or sediment analysis). This is not possible (as far as we are aware) within the Dora Creek catchment as no data is available.

5.2. Rating Curve

Rating and gauging data were obtained from Pinneena 9.3 and the New South Wales Office of Water (NOW) website. The NOW rating curve was estimated based on statistical curve fitting to the gauging data (typically a simple power relationship) and does not take into account changes in the cross-section outside of the range of available data.

As part of this study a new rating curve estimate was calculated at the Jigadee Creek gauge using the hydraulic model. This was obtained by modelling floods of varying magnitude and obtaining the flow at peak level at the gauge location. A plot of the resulting rating curve is shown on Figure 5 and shows a good fit within the lower range to gauging data.

At higher flows the slope of the rating curve changes and reflects the increase in available conveyance within the overbank. This change in relationship does not appear to be reflected in the NOW rating curve, which is limited by the number of gauging during significant floods. The adopted curve was derived from the hydraulic model and was used to convert peak flood heights for use in flood frequency analysis and to calibrate the hydrologic model to historical events.

5.3. Annual Series

Water level data at the Jigadee Creek gauge (211008) was obtained from the NOW for the period from December 1969 to February 2014 and assessed for completeness. The peak annual heights were extracted from the data and the date on which the maximum flow occurred was assessed by comparison to daily rainfall records, Pinneena (version 9.3) and data at the Cooranbong (211470), Kalang Road (211475) and Morisset (211480) gauges.

It was found that data was missing from the Jigadee Creek gauge at the time that the highest annual flood was recorded at the Cooranbong gauge during 1993 and 1997. The largest flood events recorded at either gauge during these years were minor and it was assumed that the events recorded at the Jigadee gauge were in fact the largest at the gauge for that year. The adopted annual series of flood heights and flows are shown in Table 20 and on Figure 21.

Table 20: Adopted Annual Series of Flood Heights at the Jigadee Creek gauge

Date	Level (mAHD)	Flow (m^3/s)
1970	4.2	40
1971	4.1	35
1972	4.9	81
1973	4.0	31
1974	5.4	182
1975	5.4	175
1976	5.2	118
1977	5.5	212
1978	5.6	235
1979	4.2	38
1980	2.9	4
1981	5.8	332
1982	4.8	70
1983	4.4	48
1984	5.0	96
1985	4.8	73
1986	4.3	41
1987	4.5	55
1988	5.0	89
1989	5.0	100
1990	5.1	113
1991	3.8	24

Date	Level (mAHD)	Flow (m^3/s)
1992	4.6	61
1993	3.3	12
1994	3.1	9
1995	3.2	11
1996	3.1	8
1997	3.6	20
1998	4.0	33
1999	3.9	27
2000	4.0	33
2001	4.4	49
2002	4.9	80
2003	3.2	10
2004	3.9	29
2005	3.9	29
2006	5.1	102
2007	5.6	245
2008	4.7	63
2009	2.7	2
2010	3.8	26
2011	4.8	77
2012	4.2	38
2013	5.1	110

5.4. Design Flow Estimates

AR&R (Reference 5 and 18) recommends that flood frequency analysis should be applied to peak flows rather than heights. In frequency analysis of flows, the fitting of a particular distribution may be carried out analytically or by fitting a probability distribution. The data may consist of an annual series, where the largest peak in each year is used, or a partial series, where all flows above a selected base value are used. The relative merits of each method are discussed in detail in AR&R. In general, an annual series is preferable as there are more methods and experience available. An annual data set was used for this study.

Many probability distributions have been applied to flood frequency analyses and this is a very active field of research. However it is not possible to determine the "correct" form of the distribution as there is no rigorous "proof" that any particular distribution is more appropriate than another. AR&R provides further discussion on this issue.

Since publication of AR&R in 1987 there have been significant developments in the field of flood frequency analysis both in Australia and overseas. The approach adopted in this study reflects these developments. Recent research has suggested that the fitting method is as important as the adopted distribution. The traditional fitting method has generally been based on moments and this makes the fit very sensitive to the highest and lowest values. Recent research has shown that L-moment and Bayesian likelihood approaches are much more robust than traditional moment fitting and are now the recommended methods.

For this analysis a Bayesian maximum likelihood approach has been adopted in preference to L-moments because the method readily lends itself to include limited information about events outside the continuous period of record. The Flike flood frequency analysis software developed by Kuczera (Reference 19) uses the Bayesian approach and was utilised in this study.

The rating curve (height-discharge relationship) adopted for the estimation of streamflows from the recorded gauge heights is critical to the success of flood frequency analysis. The flood frequency analysis was conducted using the rating curve derived from the calibrated hydraulic model (refer subsequent sections). Low flow thresholds were investigated and the Grubbs Beck criterion for low flow exclusion was adopted (Reference 20).

Two probability distributions were tested, Log Pearson III (LP3) and Generalised Extreme Value (GEV) distributions and it was found that the LP3 distribution produced a better curve fit to the data. The curves produced by the GEV and LP3 distributions were very similar with the 5% (1 in 20 year) AEP flow estimate as 251 m^3/s and 243 m^3/s for the GEV and LP3 respectively. The LP3 distribution was adopted as it generally provides better results for flood frequency in NSW and produces slightly improved confidence limits over the GEV distribution for the 5% (1 in 20 year) AEP flow.

The results of the flood frequency analysis are provided in Table 21 and shown on Figure 22 for the LP3 distribution. The choice of distribution was found to have little influence on design flow estimates.

Table 21: At Site Flood Frequency Analysis – Jigadee Creek gauge

Design Flood Event	Peak Flow (m^3/s)	
	LP3 Distribution	GEV Distribution
0.5 (1 in 2 year) EY	51	51
0.2 (1 in 5 year) EY	119	113
10% (1 in 10 year) AEP	178	173
5% (1 in 20 year) AEP	243	251
2% (1 in 50 year) AEP(1)	337	394
1% (1 in 100 year) AEP(1)	414	544

Note (1): The 2% (1 in 50 year) and 1% (1 in 100 year) AEP estimates are outside of the extrapolation limit

5.5. Combined at Site and Regional Flood Frequency Analysis

The Bayesian approach allows for the use of prior information about the expected shape of the frequency distribution. A regional flood frequency analysis was undertaken using the draft regional flood frequency method developed as part of the update of AR&R (November 2012) in Reference 17. The resultant regional distribution was then incorporated into the at site frequency analysis.

It was found that the additional regional data had little effect on the design flow estimates at the Jigadee Creek gauge (as seen on Figure 23). The regional FFA method is still in draft form and it is not currently recommended for use in design flow estimates.

6. HYDROLOGIC MODELLING

6.1. Watershed Bounded Network Model (WBNM)

Techniques suitable for design flood estimation are described in AR&R 1987 (Reference 5). These techniques range from simple procedures to estimate peak flows (e.g. PRM), to more complex rainfall-runoff routing models that estimate complete flow hydrographs and can be calibrated to recorded flow data.

The WBNM hydrologic runoff-routing model was used to determine inflows from the tributary creeks for inclusion into the TUFLOW hydraulic model. The WBNM model is widely used throughout NSW and includes a storage lag factor termed C and rainfall initial and continuing loss as model parameters. The entire catchment of Dora Creek to Lake Macquarie waterway was divided into 187 sub areas. These are shown on Figure 10 and were derived from topographical data with the objectives of having as far as possible a minimum of 3 sub areas upstream of an inflow model boundary and similar sized catchment areas.

The model was used to generate flow hydrographs for the six historical events using available rainfall data and then used to generate flow hydrographs for the design flood events.

6.2. Calibration

6.2.1. General

The only flow gauging records available are for Jigadee Creek (Figure 5). The accuracy of the flow gaugings has been investigated in the 2004 Jigadee Creek Flood Study (Reference 10) which concluded that it was likely that the rating curve (Figure 5) was underestimating the flows at high flood levels. The 2004 Jigadee Creek Flood Study (Reference 10) established a WBNM and a 1D MIKE-11 hydraulic model and undertook a joint hydrologic/hydraulic model calibration to the recorded stage hydrographs for the February 1981, June 1989 and February 1990 events. This approach is the most accurate that is possible as it relies on a hydraulic model, using surveyed cross sections, to match to the recorded heights through adjustment of the model parameters in WBNM to determine the necessary inflows. The adopted design model parameters in the 2004 Jigadee Creek Flood Study (Reference 10) were:

C value = 2.3;
Initial Loss = 20 mm;
Continuing Loss = 2.5 mm/h.

These parameters were identical to those adopted in the prior 1998 Lake Macquarie Flood Study (Reference 9) with the exception of an urban initial loss of 10 mm and a rural initial loss of 25 mm. For the 2012 Lake Macquarie Waterway Flood Study (Reference 6) the following parameters were adopted for the calibration (February 1990 and the June 2007 long weekend events) and design events:

C value = 2.4;
Initial Loss = 10 mm;
Continuing Loss = 2.5 mm/h;
On the Lake Macquarie waterway no losses assumed.

6.2.2. Approach

The Jigadee Creek gauge is the only automatic water level recorder site in the Lake Macquarie waterway catchment that has a reasonably long period of record (thus can compare the hydrograph from more than one flood) and has a rating curve derived using velocity measurements. The gauge is therefore ideally suited for calibration of a hydrologic model and in the absence of any other suitable data the calibration parameters can reasonably be applied to surrounding catchments.

The three prior studies noted above have derived similar calibration parameters, though WMAwater was the consultant for both the 2004 Jigadee Creek Flood Study (Reference 10) and the 2012 Lake Macquarie Waterway Flood Study (Reference 6) and thus these two studies are not independent of each other.

As described in Section 4.3.1 an independent calibration of the hydrologic model is not possible and only a joint hydrologic/hydraulic model calibration can be undertaken. There is no unique combination of Mannings *n* values in TUFLOW and a C value in WBNM which will provide a perfect match to the data and thus a range of combinations are possible.

To ensure consistency with the prior studies the approach taken was to assess if a C value of 2.4 could be adopted with reasonable Mannings *n* values in TUFLOW to achieve a sound match to the historical data for the six historical events at the water level gauges and for the available peak height data. If this could be achieved then this C value would be adopted for design, if this approach did not achieve a suitable calibration then a different C value would be adopted and tested. The results indicate that a C value of 2.4 can be adopted for design.

6.2.3. Calibration Results

For a C value of 2.4 the WBNM hydrologic model rainfall loss parameters and pluviometers used for calibration events are shown in Table 22. Based on calibration results, adopted parameters for design are given in Table 23.

Table 22: WBNM Hydrologic Model Rainfall Losses used for Historical Events

Flood Event	Pluviometersl	Initial Loss (mm)	Continuing Loss (mm/h)
March 1977 Event	Maryville	10	2.5
	Milfield	10	2.5
February 1981 Event	Eraring	10	2.5
	Maryville	10	2.5
	Munmorah	10	2.5
	Wyong	50	2.5
February 1989 Event	Martinsville & Mandalong	30	2.5
February 1990 Event	Barnsley	40	2.5
	Whitemans Ridge	10	2.5
February 2007 Event	Martinsville, Wyee & Mandalong	10	2.5
February 2013 Event	Martinsville, Cooranbong & Mandalong	40	2.5

Note: The adopted pluviometers for the adopted calibration are shown on Table 24

Table 23: Adopted WBNM Hydrologic Model Parameters for Design

Parameter	Value
Lag Parameter, C	2.4
Initial Loss (mm)	10
Continuing Loss (mm/h)	2.5

Comparisons between the flows from WBNM and water levels from TUFLOW derived using the available pluviometer data and the recorded data are shown on Figure 24 to Figure 29. As noted above the WBNM flows at the Jigadee gauge are much higher than those using the Pinneena rating curve. The results provide a reasonable match to the water level data using the rating curve obtained from the TUFLOW model.

Sensitivity analysis was not undertaken to assess the impacts of varying the above hydrologic model parameters as the hydrologic/hydraulic modelling approach was calibrated in tandem to recorded levels, thus any significant change to any of the parameters would require an adjustment of other parameters (say Manning's *n*) to achieve the same calibration.

6.2.4. Reconciling Flood Frequency and Rainfall Runoff Results

When compared to flood frequency design flow estimates those from WBNM appear to overestimate flows for more frequent events and underestimate flow in the 2% (1 in 50 year) AEP event or greater (Figure 23).

There are many explanations as to why the flood frequency and rainfall runoff modelling do not reconcile. These are primarily due to data limitations as well as the adequacy of the hydrologic model in representing the runoff routing behaviour of the catchment. Some of the main limitations of the flood frequency analysis are the limited period of record as well as rating curve errors. Due to the nature of the rating curve, high flow estimates at the Jigadee Creek gauge are very sensitive to small changes in the water level.

In addition to potential uncertainty of the analysis it is important to realise that the flood frequency relationship may not be representative of the greater Dora Creek catchment given that Jigadee Creek only covers a proportion of the whole catchment.

The largest difference in flow occurs for more frequent events, which are less important for floodplain management and planning for future development. As flood frequency estimates become more uncertain for less frequent flooding such as the 1% (1 in 100 year) AEP which is generally adopted for development control purposes, flow estimates from WBNM were adopted for the current study.

6.2.5. Comparison of Results from Previous Studies

A comparison between results (calibration and design) from the following hydrologic modelling approaches is given in Table 24:

- Current WBNM hydrologic model;
- WBNM model used in the 2012 Lake Macquarie Waterway Flood Study (Reference 6), the 1998 Lake Macquarie Waterway Flood Study (Reference 9) and the 2004 Jigadee Creek Flood Study (Reference 10);
- Cordery-Webb method used in the 1986 Dora Creek Flood Study (Reference 2);
- Pilgrim McDermott method used in the 1986 Dora Creek Flood Study (Reference 2);
- Probabilistic Rational Method (PRM) as outlined in AR&R 1987 (Reference 5).

Table 24: Hydrologic Model Flow Comparisons (m^3/s) at Jigadee Gauge

Method	Floods Mar 1977	Feb 1981	Jun 1989	Feb 1990	Jun 2007	Feb 2013	0.2 (1 in 5 year) EY	5% (1 in 20 year) AEP	1% (1 in 100 year) AEP
WBNM -present study Pluviometer	289 Milfield	329 Eraring	189 Mandalong Martinsville	160 Whitemans Ridge	272 Mandalong Martinsville Wyee	80 Mandalong Martinsville Cooranbong	172	250	333
WBNM - 2012 Lake Macquarie Waterway Flood Study (Reference 6)	-	-	-	148	240	-	-	-	-
WBNM - 1998 Lake Macquarie Waterway Flood Study (Reference 9)	-	164	-	98	-	-	-	-	-
WBNM - 2004 Jigadee Creek Flood Study (Reference 10)	-	-	-	153	269	-	-	232	312
Cordery-Webb method - 1986 Dora Creek Flood Study (Reference 2)	-	170	-	-	-	-	-	244	340
Pilgrim McDermott method - 1986 Dora Creek Flood Study (Reference 2)	-	-	-	-	-	-	-	214	357
PRM (AR&R 1987)	-	-	-	-	-	-	72	186	308
Jigadee Ck gauge peak level (m AHD)	5.5	5.8	5.0	5.1	5.6	5.1	5.4	5.6	5.8
Stockton Ck gauge peak level (m AHD)	-	-	2.2	-	2.5	0.9	2.6	3.2	3.8
Cooranbong gauge peak level (m AHD)	-	-	-	-	5.4	4.4	5.1	5.4	5.7
Kalang Road gauge peak level (m AHD)	-	-	-	-	2.1	0.7	2.1	2.5	3.0

Sensitivity testing was undertaken to assess the effects of changing model parameters and this is provided in Section 8.

6.3. Design Rainfall Data

Rainfall intensities were derived from the BoM website using AR&R 1987 data. Calculation of the Probable Maximum Precipitation (PMP) was undertaken using guidelines in the The Estimate of Probable Maximum Precipitation in Australia: Generalised Short Duration Method (Reference 15). These design rainfall estimates were gridded and the mean rainfall intensity calculated for each sub-catchment.

For the PMP estimate the following criteria applied:

- as the catchment area is less than 1000 km^2 and located in the coastal transitional area the Generalised Short Duration Method (GSDM) was adopted;
- zero adjustment for elevation was assumed as the catchment topography is less than 1500 mAHD;
- a moisture adjustment factor of 0.72 was adopted;
- the catchment is considered to be 80% 'rough'.

The adopted rainfall losses for PMF events are:

Initial Loss = 0 mm;

Continuing Loss = 1 mm/h.

7. HYDRAULIC MODELLING

7.1. TUFLOW

The TUFLOW modelling package includes a finite difference numerical model for the solution of the depth averaged shallow water equations in two dimensions. The TUFLOW software has been widely used for a range of similar floodplain projects both internationally and within Australia and is capable of dynamically simulating complex overland flow regimes. The TUFLOW model build used in this study is 2012-05-AE-w64 and further details regarding TUFLOW software can be found in the User Manual (Reference 21). The model extent for the catchment was determined in conjunction with Council and is shown on Figure 11.

7.2. Model Configuration

The model consists of a 2D 10m grid defining the overbank and 1D areas defining in-bank areas within the upper reaches of the model. Where the channel is sufficiently wide or where there is a significant flow junction the entire channel was defined in 2D.

Bridges and other hydraulic constraints were included in TUFLOW as well as reducing the overbank conveyance to include building outlines. The building outlines were included wherever it was considered that they would have a significant impact on flow conveyance and were digitised using aerial photography provided by Council (circa 2010).

Since the time of the oldest calibration event in March 1977 it is likely there have been some changes to the building outlines and other developments on the floodplain. Probably the most significant change was construction of the M1 Motorway (previously the F3 Freeway). No details of other significant changes are available. These changes are likely to have a maximum impact of ± 200mm for any of the historical events, whilst this is a significant change in flood level the impact downstream where the majority of peak height data are available will be much less. If detailed plans of the changes were available the impacts of the changes could be assessed and incorporated in the calibration, however in the absence of such data the hydrologic and hydraulic models have not been adjusted to reflect changes in the topography over the period of the historical events (1977 to date).

7.3. Calibration and Verification

7.3.1. Discussion

The calibration process was based on matching the TUFLOW results to produce the best fit to the recorded water level data for the most recent flood events in March 1977, February 1981, June 1989, February 1990, June 2007 long weekend and February 2013 events using inflows from the WBNM hydrologic model with a C value of 2.4.

The inflows from the calibrated WBNM hydrologic model were included into TUFLOW and the model run for all historical events and for the available pluviometers for each event. The Manning's *n* values within the study area were adjusted so that the modelled stage hydrographs at the water level gauges matched the recorded hydrographs and the peak results matched the recorded peak levels.

This was an iterative procedure and the adopted Manning's *n* values are discussed in Section 7.3.2. However it should be noted that other combinations of hydrologic and hydraulic parameters could produce similar results. The aim was to produce the best overall match across the range of historical events. Greater emphasis was placed on matching to the more accurate water level gauge data but also taking into account the closeness of the available pluviometer data and results for the range of pluviometers available for each event.

The calibration results are provided in Figure 24 to Figure 35. Figure 31 to Figure 35 show results using the following pluviometers:

- March 1977 - Milfield Composite;
- February 1981 - Eraring;
- June 1989 – Mandalong and Martinsville;
- February 1990 – Whitemans Ridge;
- June 2007 long weekend – Mandalong, Martinsville and Wyee;
- February 2013 – Mandalong, Martinsville and Cooranbong.

7.3.2. Adopted Manning's Roughness

The roughness coefficient, *n*, is an empirically derived parameter which represents the retarding force applied to flowing water by the channel bed or ground surface. In practice, in computational modelling of real systems, this parameter can also incorporate other sources of energy loss such as turbulence and flow expansion/contraction from non-uniform cross sections.

There is significant difficultly in the determination of an appropriate roughness parameter *n*. The value of *n* represents the resistance to flow in a given channel which depends on a number of factors such as:

- surface roughness;
- vegetation;
- channel irregularity and alignment;
- obstructions;
- silting and scouring;
- the size and shape of the channel; and
- the stage and discharge.

The main channels within upper tributaries of Dora Creek, Jigadee Creek and Stockton Creek are generally less than 10 m wide and surrounded by dense vegetation. These sections are typically modelled as 1D/2D elements where the 1D section includes the main channel and some amount of the overbank. In order to reduce the complexity of calibrating to several historical events, a single roughness value was applied to approximate the resistance over a whole cross-section.

The upper tributaries are meandering, natural channels with a high degree of irregularity and dense vegetation (Photo 5). As the channels are in 1D, the roughness values must also account for energy losses from effects such as from changes in the direction of flow which would inherently be accounted for in the 2D model.

Therefore a relatively high Manning's *n* roughness value was applied within the upper tributaries. As the channel widens, the relatively steep slope decreases and the level of overbank vegetation thins a lower Manning's *n* roughness is applied. Within the lower Dora Creek area, downstream of the M1 Motorway, a much lower in-bank Manning's *n* was applied as the channel is relatively straight, consistent and has a bed of sand (Photo 6). Buildings in the overbank were blocked out and thus not included in the Manning's *n* roughness value.

As the downstream channel is represented within the 2D domain, energy losses due to Dora Creek intersecting with Jigadee Creek or Stockton Creek or due to the change in direction near Kalang Road are inherently accounted for within the numerical scheme and are not required to be accounted for by increasing roughness values.

Photo 5: Dora Creek at Freemans Drive, Cooranbong looking downstream

Photo 6: Aerial view of Dora Creek township

The Manning's *n* values adopted for flowpaths are shown in Table 25. These values have been adopted based on site inspection, literature such as Chow, 1959 (Reference 22), Henderson, 1966 (Reference 23), Subramanya, 1997 (Reference 24), calibration and past experience in similar floodplain environments.

Table 25: Adopted Manning's *n* Values – TUFLOW model

Model Domain	Surface	Manning's *n*
2D	Roads and Pavement	0.015
2D	Rural	0.045
2D	Urban Residential	0.040
2D	Commercial/Industrial	0.040
2D	Light Vegetation	0.030
2D	Heavy Vegetation	0.090
	Waterways (*n* = 0.02 to 0.08)	
1D	Upper Dora Creek	0.080
1D	Upper Jigadee Creek	0.080
1D	Upper Stockton Creek	0.070
2D	Lower Dora Creek and Lake	0.020

7.3.3. March 1977 Event

This event had limited available pluviometer data with the closest operational gauges at Milfield Composite (16 km) and Maryville (24 km). A large number of peak water levels were available including the Jigadee Creek water level gauge (Figure 8 and Figure 14).

The recorded hydrograph at Jigadee Creek indicated two peaks within a three day period. Only the larger second peak which occurred on 3 March 1977 was modelled. The Milfield Composite pluviometer had missing data during the first peak and the Maryville gauge showed three intense rainfall bursts instead of two. Sensitivity testing found that antecedent flow conditions prior to the second peak had limited affect on the modelled flood hydrograph.

The temporal pattern from the Milfield Composite pluviometer was found to produce the best match to peak flood levels within the catchment. Modelled results are shown on Figure 24, Figure 30 and Figure 31. Modelled results significantly underestimate the single peak flood level upstream of Freemans Drive but overestimate levels at three locations in Stockton Creek. These three levels at the mouth of Stockton Creek indicate a peak of 2 mAHD or less, however these levels appear incorrect as the levels downstream at Kalang Road are at 2.4 m AHD or above.. Flood levels downstream of the intersection of Stockton and Dora Creeks match recorded data well and a reasonable match to the Jigadee gauge is obtained (Figure 24).

Stream gauging was undertaken during the event by PWD and the EC upstream of the railway bridge on Dora Creek. At the time when the velocity measurements were undertaken the water level was well below the peak (water levels were 0.6 mAHD with the peak at 2.1 mAHD). As the downstream water level was assumed to be a constant 0.7 mAHD an approximate comparison of modelled versus gauged data is made in Table 26.

Table 26: Comparison of Modelled and Gauge data 50 m upstream of the Railway Bridge – 4th March 1977

	Peak Flood Level (mAHD)	Average Velocity at the Peak (m/s)	Level (m AHD) when Velocity measurement undertaken	Average Gauged Velocity (m/s)
Recorded	2.1	-	0.6	0.7
TUFLOW	2.0	1.2	0.7(1)	0.5(1)

Note (1): The tailwater level applied during the March 1977 event was a constant 0.7 mAHD and as such any velocity comparison below this level is an approximation only and is likely to underestimate velocities.

Given the Milfield Composite pluviometer is located approximately 16 kilometres from the catchment and therefore unlikely to accurately represent the temporal pattern over Dora Creek, the calibration was considered reasonable.

7.3.4. February 1981 Event

Data from four pluviometers were available from BoM with patterns for the Lake Eraring and Lake Munmorah pluviometers obtained from the 1986 Dora Creek Flood Study (Reference 2). The temporal patterns derived from the gauges are given on Figure 15 and appear to indicate a moving storm. Modelled results for the event are shown on Figure 25, Figure 30 and Figure 32.

Recorded flood level hydrographs were available at the Jigadee Creek gauge and at the historical Stockton Creek gauge at Morisset (from the 1986 Dora Creek Flood Study - Reference 2). Modelled results match the peak level at the Jigadee Creek gauge but overestimate levels within Stockton Creek by up to 1.5 m depending upon the pluviometer used.

This storm event was the largest recorded within the Jigadee Creek catchment however flooding within the rest of the catchment was less severe and few peak levels are recorded in the Council database. The closest pluviometer to both the entire Dora Creek as well as the Jigadee Creek catchments was Lake Eraring. Four pluviometer temporal patterns were modelled and the Maryville gauge was found to produce flood levels closest to those recorded on Dora Creek. However, the 19 km distance of the gauge to the catchment means it is unlikely it is representative of the rainfall pattern within Dora Creek and the results on Figure 25 suggests that the timing of the rainfall was very different to that over Dora Creek.

Stream gauging was undertaken during the event by PWD at several locations and a comparison of modelled versus gauged data is made in Table 27.

Table 27: Comparison of Modelled and Gauge Data – 7th February 1981

Location	Source	Peak Flood Level (mAHD)	Average Velocity at the Peak (m/s)	Gauged Level (m AHD)	Average Gauged Velocity (m/s)
Dora Creek Railway Bridge	Recorded	1.5	-	1.4	1.2
	TUFLOW (Eraring)	2.0	1.5	1.4	1.0
	TUFLOW (Maryville)	1.8	1.3	1.4	1.1
Stockton Creek Bridge	Recorded	2.0	-	1.9	1.0
	TUFLOW (Eraring)	3.1	1.0	1.9	0.8
	TUFLOW (Maryville)	2.7	0.8	1.9	0.8
Dora Creek Bridge Cooranbong	Recorded	4.8	-	4.1	2.1
	TUFLOW (Eraring)	5.4	1.9	4.1	1.1
	TUFLOW (Maryville)	5.1	1.7	4.1	1.2
Jigadee Creek Bridge	Recorded	5.8	-	4.8	1.6
	TUFLOW (Eraring)	5.8	2.5	4.8	1.3
	TUFLOW (Maryville)	5.4	2.1	4.8	1.2

Note: The Gauged level is the level at which the velocity measurement was taken

The Cooranbong (Avondale) daily read rainfall gauge was reported as being overtopped during the event in the 1986 Dora Creek Flood Study (Reference 2), potentially underestimating rainfall depths applied across the entire catchment.

Generally, flood level differences were largest within Stockton Creek with the model overestimating results and this could be attributed to the temporal pattern or the total rainfall depth which fell within the Stockton Creek catchment. However there is no rainfall gauge data to confirm this. The model overestimation in Stockton Creek is similar to that occurring with the March 1977 event. The lack of local rainfall data means that it is not possible to reflect a reduced rainfall over the Stockton Creek catchment.

7.3.5. June 1989 Event

This event had a high quality pluviometer record with data at Martinsville and Mandalong pluviometers both available (Figure 12 and Figure 16). Water level hydrographs were available at both the Jigadee Creek gauge at Avondale and the Stockton Creek gauge at Morisset as well as recorded peak levels throughout the catchment. Modelled results are shown on Figure 26, Figure 30 and Figure 33.

Modelled levels are 0.4m too high at the Jigadee Creek but match at the Stockton Creek gauge (Figure 26). Within Dora Creek the modelled level underestimates one of the recorded peak levels at Freemans Drive near Kalang Road and upstream of the railway bridge by 0.2 m to 0.3 m but provide a reasonable match downstream of the railway bridge.

7.3.6. February 1990 Event

Recorded flood levels within Dora Creek indicate that the February 1990 event was of a similar magnitude to June 1989. The two pluviometers within the catchment, Mandalong and Martinsville, were not operating during the event and the closest active pluviometers were located at Whitemans Ridge and Barnsley which are both over seven kilometres from the catchment. The storm event prevailed for several days and the rainfall intensity was reasonably consistent and consequently major flooding occurred within the Lake Macquarie waterway.

Available rainfall and water level data for the event is shown on Figure 13 and Figure 17. Modelled results are shown on Figure 27, Figure 30 and Figure 34. Both pluviometer temporal patterns produce a different runoff shape than the recorded Jigadee Creek gauge data (Figure 27); however match the peak flood levels reasonably well.

Flood level comparisons are shown on Figure 34 which indicates that modelled results generally underestimate flood levels within Dora Creek by 0.2 to 0.4 m and to the sole level in Stockton Creek.

Undue reliance cannot be placed on this event in the calibration process due to the lack of pluviometer data within the catchment.

7.3.7. June 2007 Long Weekend Event

This event had a high quality pluviometer record with data at both Martinsville and Mandalong pluviometers (Figure 12 and Figure 18). Continuous water level hydrographs were available on Jigadee Creek, Stockton Creek at Morisset and Dora Creek at Cooranbong and Kalang Road and peak flood heights were recorded near Kalang Road and other downstream areas. Modelled results are shown on Figure 28, Figure 30 and Figure 35.

The peak rainfall burst recorded at the Martinsville and Mandalong appeared to occur earlier than the recorded peaks at all of the gauges. Peak flood levels closely match the peak at the Jigadee Creek and Cooranbong gauges however flood levels within Stockton Creek and at

Kalang Road were overestimated by up to 0.4 m with modelled and recorded hydrographs shown on Figure 28. Within lower Dora Creek modelled flood levels are typically higher than recorded by 0.1 m. Interestingly much fewer flood levels are recorded in Council's database for this event than for the February 1990 event which was 0.6m lower at the Jigadee Creek gauge. Both February 1990 and June 2007 long weekend events appeared to have reached similar levels at Freemans Drive.

7.3.8. February 2013 Event

The February 2013 event was a relatively localised storm as it caused flooding at the Jigadee Creek gauge to similar levels in the June 1989 and February 1990 events but very minor flooding at Kalang Road and on Stockton Creek. The Council database records no floods levels.

High quality pluviometer data is available from the Martinsville and Mandalong pluviometers along with data from all four automatic water level recorders. Modelled results are shown Figure 29 and Figure 30.

Results on Figure 29 underestimate flood levels at both the Jigadee Creek gauge and the Cooranbong gauge by approximately 0.2 m. At both the Stockton Creek and Kalang Road gauges flood levels are overestimated by approximately 0.4 m.

A comparison of the pluviometer data indicates that the February 2013 event had only approximately 50% of the rainfall of June 1989 and this explains the low matches at the Jigadee Creek gauge. Comparison of historic rainfall intensities with the design IFD data indicates that this event was a maximum of a 0.5 EY (Figure 20) compared to the June 1989 event which indicated design intensities up to 5% (1 in 20 year) AEP. However the peak levels for these two events at the Jigadee gauge were nearly identical (approximately 5 m AHD – see Figure 6).

7.3.9. Summary

It should be noted that the emphasis in calibration / verification of the computer models was to find the optimal balance of model parameters (such as roughness) that gave the overall best match to observed historic flood behaviour. This set of parameters could then be used to estimate design flood behaviour.

The overall conclusion is that the calibrated hydrologic and hydraulic modelling process is suitable for design flood estimation and for use in a subsequent floodplain risk management study. The accuracy of this process is of the order of ± 0.3m where calibration data is available but in areas where there is no calibration data the accuracy is probably only of the order of ± 0.5m. This level of accuracy can only be improved upon with the collection of high quality rainfall and flood level data.

7.4. Design Flood Modelling

7.4.1. Critical Duration

The design inflows to the TUFLOW model were determined using the calibrated WBNM model. Rainfall intensities from AR&R 1987 were derived from the BoM website at 0.025 degree intervals. The design rainfall estimates were gridded and the mean rainfall intensity calculated for each sub-catchment. Aerial reduction factors were calculated in the WBNM model based on the catchment size (approximately 0.95).

Analysis to determine the storm duration which produces the highest flood level, termed the critical duration was undertaken for the 1% (1 in 100 year) AEP and the PMF events. The critical duration for the 1% (1 in 100 year) AEP was then adopted as the design duration for the 0.5% (1 in 200 year) AEP event and more frequent events.

The Dora Creek 1% (1 in 100 year) AEP results indicate that several design storm durations produced similar peak flows throughout the catchment. The highest flows were produced by the 36 hour duration storm and this was found to produce the highest water levels throughout the study area. For the PMF event, all standard durations up to and including the 6 hour event were modelled and the 5 hour duration was found to be critical.

Peak flows from WBNM at various locations are reproduced in Table 28.

Table 28 Critical Duration Analysis – WBNM 1% (1 in 100 year) AEP Peak Flows (m^3/s)

Storm Duration (hours)	Jigadee Creek Gauge	Cooranbong Gauge	Dora Creek near Lake Macquarie waterway
2	157	253	566
3	203	333	749
4.5	247	410	942
6	273	458	1078
9	317	536	1275
12	310	519	1290
18	304	508	1308
24	301	512	1267
30	308	512	1290
36	**333**	**556**	**1435**
48	321	536	1332
72	234	397	965

7.4.2. Approach for Coincidence of Rainfall and Water Levels in Lake Macquarie

Peak water levels in the Lake Macquarie waterway result from a combination of rainfall over the catchment and elevated ocean levels. Thus the assumed design ocean level in conjunction with the design rainfall event will affect the resulting design flood level in the Lake Macquarie waterway. Design flood levels in the 2012 Lake Macquarie Waterway Flood Study (Reference

6) were determined using an envelope approach of:

- the 48 hour duration design inflow in combination with an elevated tide, taken as a synthetic tide oscillating between 0 mAHD and 1 mAHD in 12.5 hour cycles representing a normal tide with a 0.4 m anomaly added uniformly and,
- the design ocean tide in combination with a low inflow (0.2 EY inflow).

These are termed the **Rainfall Induced** (design inflow event) and **Ocean Induced** (design ocean level) dominated flooding mechanisms. Further details are provided in the 2012 Lake Macquarie Waterway Flood Study (Reference 6).

Comparison of the above two flooding scenarios indicates that the **Rainfall Induced** flood scenario produces the greater flood level in the lake and was adopted as the 1% (1 in 100 year) AEP design flood scenario for the lake. The resulting design flood levels in the Lake Macquarie waterway are shown in Table 29.

Table 29: Adopted Design Peak Flood Levels in Lake Macquarie Waterway

Event (AEP)	Peak Level in Lake Macquarie Waterway (m AHD)	Adopted Constant Water Level in Lake Macquarie Waterway Coincident with the Design Event in Dora Creek (m AHD)
PMF/extreme	2.45	2.45
0.2% (1 in 500 year)	1.87	1.23
0.5% (1 in 200 year)	1.69	1.23
1% (1 in 100 year)	1.50	1.23
2% (1 in 50 year)	1.38	1.23
5% (1 in 20 year)	1.23	1.23
10% (1 in 10 year)	0.94	0.94
0.2EY (1 in 5 year)	0.82	0.82

There is little data or guidance available on the likely joint probabilities of flooding in the Dora Creek catchment and the coincident peak water level in Lake Macquarie waterway. The adopted approach assumes all design events have been run in conjunction with a constant level in Lake Macquarie waterway as indicated in Table 29. For the 5% AEP (1 in 20 year) to the 0.2% AEP (1 in 500 year) events in Dora Creek this was taken as the 5% AEP (1 in 20 year) level of 1.23 m AHD in Lake Macquarie waterway. For the 0.2 EY (1 in 5 year) and 10% AEP (1 in 10 year) the constant level was assumed as the peak of the same design event in Lake Macquarie waterway, namely 0.82 and 0.94 m AHD respectively. The February 1990 and June 2007 long weekend events both reached approximately 1.0 m AHD in Lake Macquarie waterway.

For the PMF a peak level in Lake Macquarie waterway of 2.45 mAHD was adopted. This is a conservative assumption as it is unlikely that the lake and local catchment PMF events would coincide.

7.4.3. Blockage Assumptions

Blockage of hydraulic structures can occur with the transportation of a number of materials by flood waters. This includes vegetation, garbage bins, building materials and cars, the latter of which has been seen in the June 2007 long weekend Newcastle and August 1998 Wollongong floods (Photo 7 and Photo 8). However, the disparity in materials that may be mobilised within a catchment can vary greatly between catchments and between floods in the same catchment.

Photo 7: Cars in a culvert inlet – Newcastle (Reference 25)

Photo 8: Urban debris in Wollongong (Reference 25)

Debris availability and mobility can be influenced by factors such as channel shear stress, height of floodwaters, severity of winds, storm duration and seasonal factors relating to vegetation. The channel shear stress and height of floodwaters that influence the initial dislodgment of blockage materials are also related to the magnitude of the event. Storm duration is another influencing factor, with the mobilisation of blockage materials generally increasing with a longer storm duration.

The potential effects of blockage include:

- decreased conveyance of flood waters through the blocked hydraulic structure or drainage system;
- variation in peak flood levels;
- variation in flood extent due to flows diverting into adjoining flow paths; and
- overtopping of hydraulic structures.

Existing practices and guidance on the application of blockage can be found in:

- AR&R Revision Project 11 Blockage of Hydraulic Structures, 2013 (Reference 25); and
- the policies of various local authorities and infrastructure agencies.

The guidelines proposed by the AR&R Revision Project 11 utilise generic blockage factors presented in Table 30.

Table 30: Suggested 'Design' and 'Severe' Blockage Conditions for Various Structures (Reference 25)

TYPE OF STRUCTURE		BLOCKAGE CONDITIONS	
		Design blockage	**Severe blockage**
Sag Kerb Inlet	Kerb slot inlet only Grated inlet only Combined inlets	0/20% 0/50% [1]	100% (all cases)
On-grade kerb inlets	Kerb slot inlet only Grated inlet only (longitudinal bars) Grated inlet only (transverse bars) Combined inlets	0/20% 0/40% 0/50% [2]	100% (all cases)
Field (drop) inlets	Flush mounted Elevated (pill box) horizontal grate Dome screen	0/80% 0/50% 0/50%	100% (all cases)
Pipe inlets and waterway culverts	*Inlet height < 3m and width < 5m* Inlet Chamber	0/20% [3]	100% [4]
	Inlet height > 3m and width > 5m Inlet Chamber	0/10% [3]	25% [3]
	Culverts and pipe inlets with effective debris control features	As above	As above
	Screened pipe and culvert inlets	0/50%	100%
Bridges	Clear opening height < 3 m Clear opening height > 3 m Central piers	[5] 0% [7]	100% [6] [7]
Solid handrails and traffic barriers associated with bridges and culverts		100%	100%
Fencing across overland flow paths		[8]	100%
Screened stormwater outlets		100%	100%

[1] At a sag, the capacity of a combination inlet (kerb inlet with grate) should be taken to be the theoretical capacity of the kerb opening with 100% blockage of the grate.
[2] On a continuous grade the capacity of a combination inlet should be taken to be 90% of the combined theoretical zero blockage capacity of the grate plus kerb opening.
[3] Adopt 25% bottom-up sediment blockage unless such blockage is unlikely to occur.
[4] Degree of blockage depends on availability of suitable "bridging" matter. If a wide rang of bridging matter is available within the catchment, such as large branches and fallen trees, then 100% blockage is possible for such culverts.
[5] Typical event blockage depends on risk of debris rafts and large floating debris.
[6] Blockage considerations are normally managed by assuming 100% blockage of handrails and traffic barriers, plus expected debris matter wrapped around piers.
[7] Typical event blockage depends on risk of debris wrapped around central piers. The larger the piers, the lower the risk normally associated with debris wrapped around piers.
[8] Whether a control feature is "effective" is hard to define, though monitoring trial measures may give some guidance.

Blockage within the Dora Creek catchment may occur at bridges, culverts and within the channel itself. Blockage of major structures has the potential to significantly impact the functioning capacity of the creek and as such it was reviewed in detail.

Design blockage criteria were based on site inspection, sensitivity analyses and guidance from Reference 25. Most waterway crossings over Dora Creek and its tributaries were large enough that blockage was considered very unlikely. An assessment was made for each structure and the potential for blockage and design blockage assumptions are detailed in Table 31.

Table 31: Likelihood of Blockage at Key Waterway Crossings (shown on Figure 4)

Description	Photograph	Likelihood of Blockage	Adopted Blockage
Stockton Creek at Freemans Drive	A	Unlikely	0%
Stockton Creek at M1 Motorway	B	Unlikely	0%
Dora Creek at Macquarie Street	C	Unlikely	0%
Dora Creek at Railway Bridge	D	Unlikely	0%
Dora Creek at M1 Motorway	E	Unlikely	0%
Dora Creek near Wilson Lane	F	Unlikely	0%
Dora Creek at Freemans Drive	G	Low	0%
Felled Timber Creek at Bushland Road	H	Medium	0%(1)
Jigadee Creek at Newport Road	I	Unlikely	0%
Jigadee Creek at Freemans Drive	J	Low	0%
Jigadee Creek at Freemans Drive	K	High	100%

Note (1): Sensitivity analysis on blockage at Bushland Road found it had little impact on flood levels within the study area

7.4.4. Design Results

Peak flood depths, extents and water level contours for the 0.2 (1 in 5 year) EY through to the 0.2% (1 in 500 year) AEP and the PMF event are shown on Figure 38 through to Figure 45. For the same range of events peak velocities are shown on Figure 46 through to Figure 53. Design hydrographs at selected locations are shown in Figure 36.

Tabular results of peak flood levels and flows are shown on Table 32 and Table 33 for all locations marked on Figure 11.

Table 32: Peak Design Water Levels (mAHD) (for locations refer to Figure 11)

Code	Creek	Name	0.2 (1 in 5 year) EY	10% (1 in 10 year)	5% (1 in 20 year)	2% (1 in 50 year)	1% (1 in 100 year)	0.5% (1 in 200 year)	0.2% (1 in 500 year)	PMF
H01	Jigadee	U/S Newports Rd	5.7	5.8	6.0	6.1	6.2	6.3	6.4	8.6
H02	Jigadee	D/S Newports Rd	5.6	5.7	5.8	5.9	3.0	6.1	6.2	8.6
H03	Jigadee	Jigadee gauge	5.4	5.5	5.6	5.7	5.8	5.9	6.1	8.6
H04	Stockton	U/S Freemans Dr	2.7	3.0	3.3	3.6	3.9	4.1	4.5	7.0
H05	Stockton	Morisset gauge	2.6	2.9	3.2	3.5	3.8	4.1	4.4	6.8
H06	Dora	U/S Cooranbong Rd	5.4	5.5	5.7	5.8	5.9	6.1	6.2	8.7
H07	Dora	Cooranbong gauge	5.1	5.3	5.4	5.5	5.7	5.8	6.0	8.6
H08	Dora	Junction Jigadee Ck	3.0	3.4	3.8	4.1	4.3	4.6	4.9	8.3
H09	Dora	D/S M1 Motorway	2.8	3.2	3.5	3.8	4.0	4.3	4.6	7.0
H10	Dora	Junction Stockton Ck	2.5	2.8	3.1	3.4	3.7	3.9	4.3	6.7
H11	Dora	Kalang Rd gauge	2.1	2.3	2.5	2.8	3.0	3.2	3.5	5.6
H12	Dora	U/S Railway	1.7	1.9	2.1	2.2	2.4	2.5	2.7	4.1
H13	Dora	D/S Railway	1.7	1.9	2.1	2.2	2.3	2.5	2.6	3.6

Table 33: Peak Design Flows (m^3/s) (for locations refer to Figure 11)

Code	Creek	Name	0.2 (1 in 5 year) EY	10% (1 in 10 year)	5% (1 in 20 year)	2% (1 in 50 year)	1% (1 in 100 year)	0.5% (1 in 200 year)	0.2% (1 in 500 year)	PMF
Q01	Jigadee	Newports Road	169	203	249	289	332	377	439	1263
Q02	Stockton	Freemans Drive	170	202	261	334	393	430	483	1168
Q03	Dora	Cooranbong Road	283	339	414	479	552	628	732	2195
Q04	Dora	M1 Motorway	427	506	628	741	856	974	1140	2944
Q05	Dora	Railway Bridge	555	685	854	1015	1187	1368	1632	4002

7.4.5. Comparison with Past Studies

The following tables provide a comparison between the results of previous studies and the present study.

Table 34 Comparison with Results from the 1986 Dora Creek Flood Study (Reference 2)

Location	Peak Flows (m^3/s) Reference 2			Peak Flows (m^3/s) this Study		
AEP	**5%** (1 in 20 year)	**2%** (1 in 50 year)	**1%** (1 in 100 year)	**5%** (1 in 20 year)	**2%** (1 in 50 year)	**1%** (1 in 100 year)
Jigadee Creek gauge	244	297	340	249	289	332
Cooranbong gauge	255	310	355	414	479	552
Stockton Creek gauge	237	288	330	261	334	393
Dora Creek at the railway	611	758	889	854	1015	1187
	Peak Levels (mAHD) Reference 2			**Peak Levels (mAHD) this Study**		
Jigadee Creek gauge	6.1	6.3	6.4	5.6	5.7	5.8
Cooranbong gauge	4.4	4.8	5.0	5.4	5.5	5.7
Stockton Creek gauge	2.8	3.1	3.3	3.2	3.5	3.8
Dora Creek at the railway	1.8	2.1	2.3	2.1	2.2	2.4

Table 35 Comparison with Results from the 1992 Dora Creek FMS (Reference 3)

Location	Peak Flows (m^3/s) Reference 3		Peak Flows (m^3/s) this Study	
AEP	**5%** (1 in 20 year)	**1%** (1 in 100 year)	**5%** (1 in 20 year)	**1%** (1 in 100 year)
Jigadee Creek gauge	287	385	249	332
Cooranbong gauge	307	412	414	552
Stockton Creek gauge	277	370	261	393
Dora Creek at the railway	839	1138	854	1187
	Peak Levels (mAHD) Reference 3		**Peak Levels (mAHD) this Study**	
Jigadee Creek gauge	5.5	5.7	5.6	5.8
Cooranbong gauge	4.6	5.1	5.4	5.7
Stockton Creek gauge	3.1	3.6	3.2	3.8
Dora Creek at the railway	2.1	2.6	2.1	2.4

Table 36: Comparison with Results from Reference 10

Location (Ch from Figure 37C)	Peak Levels (mAHD) Reference 10		Peak Levels (mAHD) this Study	
AEP	**5%** (1 in 20 year)	**1%** (1 in 100 year)	**5%** (1 in 20 year)	**1%** (1 in 100 year)
Flow at Jigadee Creek gauge	232	312 m^3/s	249	332 m^3/s
Section 1 (Ch 1.44 km)	5.7	6.2	6.6	6.8
Section 3 (Ch 1.89 km)	5.3	5.6	5.8	6.0
Section 4 (Ch 1.98 km)	5.2	5.4	5.6	5.8
Section 5 (Ch 2.05 km)	5.2	5.4	5.4	5.6
Section 6 (Ch 2.14 km)	5.0	5.2	5.0	5.4
Section 7 (Ch 2.26 km)	4.8	5.0	4.9	5.1
Section 8 (Ch 2.36 km)	4.6	4.8	4.7	4.9
Section 9 (Ch 2.50 km)	4.5	4.7	4.6	4.9
Section 10 (Ch 2.57 km)	4.4	4.6	4.5	4.8
Section 11 (Ch 2.64 km)	4.2	4.4	4.4	4.8
Section 12 (Ch 2.81 km)	3.7	4.0	4.3	4.7
Section 13 (Ch 2.91 km)	3.5	3.9	4.1	4.6
Section 14 (Ch 3.17 km)	3.4	3.9	4.0	4.5
Section 15 (Ch 3.71 km)	3.4	3.9	3.8	4.4
Section 16 (Ch 4.66 km)	3.4	3.9	3.8	4.4

7.5. Provisional Hazard and Preliminary Hydraulic Categorisation

The risk to life and potential damages to buildings during floods varies both in time and place across the floodplain. In order to provide an understanding of the effects of a proposed development on flood behavior and the effects of flooding on development and people the floodplain can be sub-divided into hydraulic and hazard categories. This categorization should not be used for the assessment of development proposals on an isolated basis, rather they should be used for assessing the suitability of future types of land use and development in the formulation of a floodplain risk management plan.

Hazard is a measure of the overall harm caused by flooding and should consider a number of factors including the depth of flooding, velocity of flood waters, access to escape routes, duration etc. In the first instance Provisional hazard categories can be defined based on the depth and velocity of floodwaters. Provisional flood hazard categories were defined in this study in accordance with the *Floodplain Development Manual - Figure L2* (Reference 1) as indicated below.

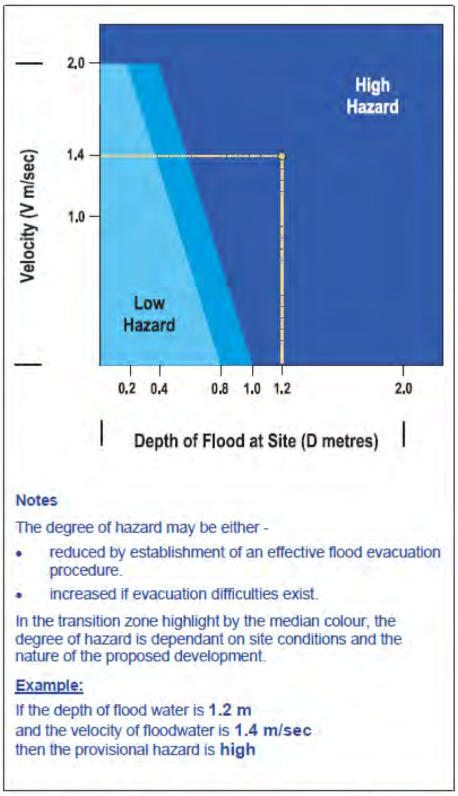


FIGURE L2 - Provisional Hydraulic Hazard Categories

The hazards are provisional because they only consider the hydraulic aspects of flood hazard. High and low provisional hazard areas were defined for the 5% (1 in 20 year), 2% (1 in 50 year), 1% (1 in 100 year) AEP and PMF event and are provided in Figure 54 through to Figure 57. The *Floodplain Development Manual* (Reference 1) requires that other factors be considered in determining the "true" hazard such as size of flood, effective warning time, flood readiness, rate of rise of floodwaters, depth and velocity of flood waters, duration of flooding, evacuation problems, effective flood access, type of development within the floodplain, complexity of the stream network and the inter-relationship between flows.

Hydraulic categorization of the floodplain is used in the development of the Floodplain Risk Management Plan. The *Floodplain Development Manual* (Reference 1) defines flood prone land to fall into one of the following three hydraulic categories (refer definition in Appendix A taken from the *Floodplain Development Manual* Reference 1):

- Floodway;
- Flood Storage;
- Flood Fringe.

Floodways are areas of the floodplain where a significant discharge of water occurs during floods and by definition if blocked would have a significant affect on flood flows, velocities or depths. Flood storage are areas of importance for the temporary storage of floodwaters and if filled would significantly increase flood levels due to the loss of flood attenuation. The remainder of the floodplain is defined as flood fringe. There is no technical definition of hydraulic categorisation and different approaches are used by different consultants and authorities.

For this study hydraulic categorisation was defined according to the following approach that has been adopted in many flood studies, namely:

*Floodway = Velocity * Depth > 0.25m^2/s AND Velocity > 0.25m/s OR Velocity > 1m/s*

The remainder of the floodplain outside the Floodway becomes either Flood Storage or Flood Fringe. In this study Flood Storage was defined as the land outside the Floodway if the depth is greater than 1m and Flood Fringe if the depth is less than 1m. As noted in the *Floodplain Development Manual* (Reference 1) *"it is impossible to provide explicitly quantitative criteria for defining floodways and flood storage areas, as the significance of such areas is site specific"*.

Hydraulic categorization is provided in Figure 58 and Figure 59 for the 1% (1 in 100 year) AEP and PMF events.

8. SENSITIVITY AND CLIMATE CHANGE ANALYSIS

8.1. Sensitivity Analysis

In order to gain confidence in the modelled results, sensitivity analysis was undertaken for a range of model parameters for the 1% (1 in 100 year) AEP 36 hour duration event. The parameters in Table 37 were assessed and the modelled sensitivity reported.

Table 37: Overview of Sensitivity Analyses

Sensitivity	Specific Details	Description
Routing	Manning's *n*	Hydraulic roughness values increased and decreased by 10%
Blockage	Bushland Road culverts	Sensitivity to blockage of culverts was assessed for 25% and 50% blockage
Rainfall	Climate Change	Sensitivity to rainfall and runoff estimates were assessed by increasing the rainfall intensities by 10%, 20% and 30% as recommended under the current guidelines.
Tailwater	Climate Change	Sensitivity to tailwater levels within Lake Macquarie waterway were assessed

8.2. Climate Change Background

The 2005 Floodplain Development Manual (Reference 1) requires that Flood Studies and Floodplain Risk Management Studies consider the impacts of climate change on flood behaviour.

Since completion of the 1986 Dora Creek Flood Study (Reference 2), current best practice for considering the impacts of climate change (ocean level rise and rainfall increase) has been evolving rapidly. In October 2009 the NSW Government issued its Policy Statement on Sea Level Rise (Reference 25) which states: "*Over the period 1870-2001, global sea levels rose by 20 cm, with a current global average rate of increase approximately twice the historical average. Sea levels are expected to continue rising throughout the twenty-first century and there is no scientific evidence to suggest that sea levels will stop rising beyond 2100 or that the current trends will be reversed.*

Sea level rise is an incremental process and will have medium to long-term impacts. The best national and international projections of sea level rise along the NSW coast are for a rise relative to 1990 mean sea levels of 40 cm by 2050 and 90 cm by 2100. However, the 4th Intergovernmental Panel on Climate Change in 2007 also acknowledged that higher rates of sea level rise are possible" (subsequently a 5th report has been issued by the Intergovernmental Panel on Climate Change in 2014).

In addition, an accompanying document *Derivation of the NSW Government's sea level rise planning benchmarks* (Reference 27) provided technical details on how the sea level rise assessment was undertaken

In August 2010 the draft guidelines were adopted by the NSW State Government and issued as follows:

- Flood Risk Management Guide (Reference 26): Incorporating sea level rise benchmarks in flood risk assessments. (DECCW);

- Coastal Risk Management Guide: Incorporating sea level rise benchmarks in coastal risk assessments (DECCW);
- NSW Coastal Planning Guideline: Adapting to sea level rise (NSW Planning).

As a result of the information provided in the above and other documents, and to keep up-to-date with current best practice, this study incorporates an assessment of climate change. In October 2012 the NSW Government advised that the Sea Level Rise Policy is no longer NSW Government policy and advised Councils to adopt their own sea level rise projections based on competent and credible scientific advice. Council, along with most NSW Coastal Councils, adopted the benchmarks from the old NSW Sea Level Rise Policy Statement. This is based on current scientific advice, supported by a review by the NSW Chief Scientist and Engineer in April 2012.

These levels are a projected rise in average sea level from 1990 of 0.4metres by 2050, and by 0.9metres by 2100. However, it should be noted that climate change and sea level rise due to man-made or natural processes will continue beyond 2100.

There is no NSW Government Policy on increases in rainfall intensity due to climate change, but the DECC Floodplain Risk Management Guideline – Practical consideration of climate change 2007 (Reference 28) advised that Flood Studies should include a test for the sensitivity of flood levels to rainfall increases due to climate change across the following range:

increase in peak rainfall and storm volume:
low level rainfall increase = 10%;
medium level rainfall increase = 20%;
high level rainfall increase = 30%.

The high levels of uncertainty about future changes to rainfall patterns at a catchment level means these scenarios are indicative rather than predictive. It is generally acknowledged that a 30% rainfall increase is probably overly conservative. The timeframe for the provision of more accurate predictions of the likely increase is unknown.

8.3. Results

The sensitivity scenario results were compared to the 1% (1 in 100 year) AEP rainfall event. A summary of peak flood level and peak flow differences at various locations are provided in:

- Table 38 and Table 39 for variations in routing and roughness;
- Table 40 and Table 41 for variations in blockage at Bushlands Road; and
- Table 42 and Table 43 for variations in climate change and tailwater assumptions.

Table 38: Results of Routing Sensitivity – 1% (1 in 100 year) AEP Levels (m)

Code	Creek	Name	Peak Flood Level 1% (1 in 100 year) AEP (mAHD)	Difference (m)	
				Routing Decreased by 10%	Routing Increased by 10%
H01	Jigadee	U/S Newports Rd	6.2	-0.07	0.07
H02	Jigadee	D/S Newports Rd	3.0	-0.07	0.07
H03	Jigadee	Jigadee gauge	5.8	-0.07	0.07
H04	Stockton	U/S Freemans Dr	3.9	-0.08	0.09
H05	Stockton	Morisset gauge	3.8	-0.09	0.07
H06	Dora	U/S Cooranbong Rd	5.9	-0.07	0.06
H07	Dora	Cooranbong gauge	5.7	-0.08	0.07
H08	Dora	Junction Jigadee Ck	4.3	-0.08	0.08
H09	Dora	D/S M1 Motorway	4.0	-0.07	0.08
H10	Dora	Junction Stockton Ck	3.7	-0.08	0.08
H11	Dora	Kalang Rd gauge	3.0	-0.08	0.07
H12	Dora	U/S Railway	2.4	-0.06	0.05
H13	Dora	D/S Railway	2.3	-0.05	0.04

Note: A change in flood level of less than 0.01 m is considered negligible and marked as "-"

Table 39: Results of Routing Sensitivity – 1% (1 in 100 year) AEP Flows (m^3/s)

Code	Creek	Name	Peak Flood Flow 1% (1 in 100 year) AEP (m^3/s)	Difference (m)	
				Routing Decreased by 10%	Routing Increased by 10%
Q01	Jigadee	Newports Road	332	0%	0
Q02	Stockton	Freemans Drive	393	2%	-2%
Q03	Dora	Cooranbong Road	552	0%	0%
Q04	Dora	M1 Motorway	856	1%	-1%
Q05	Dora	Railway Bridge	1187	1%	-1%

Table 40: Results of Blockage Sensitivity – 1% (1 in 100 year) AEP Levels (m)

Code	Creek	Name	Peak Flood Level 1% (1 in 100 year) AEP (mAHD)	Difference (m)	
				Culverts Blocked by 25%	Culverts Blocked by 50%
H01	Jigadee	U/S Newports Rd	6.2	-	-
H02	Jigadee	D/S Newports Rd	3.0	-	-
H03	Jigadee	Jigadee gauge	5.8	-	-
H04	Stockton	U/S Freemans Dr	3.9	-	-
H05	Stockton	Morisset gauge	3.8	-	-
H06	Dora	U/S Cooranbong Rd	5.9	-	-
H07	Dora	Cooranbong gauge	5.7	-	-
H08	Dora	Junction Jigadee Ck	4.3	-	-
H09	Dora	D/S M1 Motorway	4.0	-	-
H10	Dora	Junction Stockton Ck	3.7	-	-
H11	Dora	Kalang Rd gauge	3.0	-	-
H12	Dora	U/S Railway	2.4	-	-
H13	Dora	D/S Railway	2.3	-	-

Note: A change in flood level of less than 0.01 m is considered negligible and marked as "-"

Table 41: Results of Blockage Sensitivity – 1% (1 in 100 year) AEP Flows (m^3/s)

Code	Creek	Name	Peak Flood Flow 1% (1 in 100 year) AEP (m^3/s)	Difference (m)	
				Culverts Blocked by 25%	Culverts Blocked by 50%
Q01	Jigadee	Newports Road	332	0%	0%
Q02	Stockton	Freemans Drive	393	0%	0%
Q03	Dora	Cooranbong Road	552	0%	0%
Q04	Dora	M1 Motorway	856	0%	0%
Q05	Dora	Railway Bridge	1187	0%	0%

Table 42: Results of Climate Change Analysis – 1% (1 in 100 year) AEP Levels (m)

Code	Creek	Name	Peak Flood Level 1% (1 in 100 year) AEP (mAHD)	Difference (m)				
				Rain +10%	Rain +20%	Rain +30%	SLR 2050	SLR 2100
H01	Jigadee	U/S Newports Rd	6.2	0.09	0.17	0.25	-	-
H02	Jigadee	D/S Newports Rd	3.0	0.09	0.17	0.25	-	-
H03	Jigadee	Jigadee gauge	5.8	0.09	0.18	0.27	-	-
H04	Stockton	U/S Freemans Dr	3.9	0.23	0.45	0.66	0.03	0.09
H05	Stockton	Morisset gauge	3.8	0.22	0.43	0.64	0.02	0.08
H06	Dora	U/S Cooranbong Rd	5.9	0.11	0.22	0.33	-	-
H07	Dora	Cooranbong gauge	5.7	0.12	0.24	0.36	-	-
H08	Dora	Junction Jigadee Ck	4.3	0.24	0.47	0.67	0.02	0.07
H09	Dora	D/S M1 Motorway	4.0	0.22	0.43	0.62	0.03	0.08
H10	Dora	Junction Stockton Ck	3.7	0.24	0.46	0.66	0.03	0.10
H11	Dora	Kalang Rd gauge	3.0	0.22	0.41	0.58	0.04	0.14
H12	Dora	U/S Railway	2.4	0.12	0.23	0.33	0.04	0.17
H13	Dora	D/S Railway	2.3	0.10	0.19	0.27	0.03	0.16

Note: A change in flood level of less than 0.01 m is considered negligible and marked as "-"

Table 43: Results of Climate Change Analysis – 1% (1 in 100 year) AEP Flows (m^3/s)

Code	Creek	Name	Peak Flood Flow 1% (1 in 100 year) AEP (m^3/s)	Difference (m)				
				Rain +10%	Rain +20%	Rain +30%	SLR 2050	SLR 2100
Q01	Jigadee	Newports Road	332	12%	24%	37%	0%	0%
Q02	Stockton	Freemans Drive	393	8%	16%	26%	0%	0%
Q03	Dora	Cooranbong Road	552	12%	24%	36%	0%	0%
Q04	Dora	M1 Motorway	856	12%	25%	38%	0%	1%
Q05	Dora	Railway Bridge	1187	14%	28%	42%	2%	5%

The above results can be summarised as follows:

- the changes to the routing and blockage of culverts make little difference to the resulitng peak levels;
- rainfall increase makes a significant difference to peak levels with up to a 0.2m, 0.5m and 0.7m for the 10%, 20% and 30% increase scenarios respectively;
- sea level rise of 0.4m makes less than a 0.1m increase in levels at the locations given but up to 0.2m with a 0.9m increase. However at locations immediately upstream of the Lake Macquarie waterway the full increase will be realised. These results indicate that the effect of sea level rise relatively quickly diminishes upstream of the Lake Macquarie Waterway.

9. ACKNOWLEDGEMENTS

Lake Macquarie City Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage. The assistance of the following in providing data and guidance to the study is gratefully acknowledged:

- Lake Macquarie City Council;
- NSW Office of Environment and Heritage;
- Bureau of Meteorology;
- Hunter Water;
- Manly Hydraulics Laboratory;
- Residents of the Dora Creek study area.

10. REFERENCES

1. **Floodplain Development Manual**
NSW Government, April 2005

2. Public Works Department NSW
Dora Creek Flood Study
NSW Public Works, PWD 85019, May 1986

3. Public Works Department NSW
Dora Creek Floodplain Management Study – Hydraulic Analysis of Flood Mitigation Options
NSW Public Works, PWD 91016, February 1992

4. Lake Macquarie City Council
Dora Creek Floodplain Management Plan
NSW Department of Land and Water Conservation, June 1998

5. Pilgrim H (Editor in Chief)
Australian Rainfall and Runoff – A Guide to Flood Estimation
Institution of Engineers, Australia, 1987

6. Lake Macquarie City Council
Lake Macquarie Waterway Flood Study
WMAwater, June 2012

7. Public Works Department NSW
Dora Creek Floodplain Risk Management Study – Hydraulic Analysis of Subdivision Options
NSW Public Works, PWD 90015, February 1991

8. Public Works Department NSW
Dora Creek, Kalang Road: Two Dimensional Study and Preliminary Design of a Flood Deflector Levee
Patterson Britton & Partners, February 1994

9. Public Works Department, NSW
Lake Macquarie Flood Study
Manly Hydraulics Laboratory, MHL 682, January 1998

10. Chase Burke and Harvey
Jigadee Creek Flood Study for Proposed Development at Lot 2 DP778019 & LOT 15 DP129150
Webb, McKeown & Associates Pty Ltd, July 2004

11. NSW Government
Pinneena CM DVD Version (latest version May 2014)

12. NSW Department of Infrastructure, Planning and Natural Resources
Flood Study: Mandalong Coal Mine
Hughes Truman, December 2004

13. D Alsop and D Weber, c/o de Witt Consulting
Flood Study Investigation Assessment for Rezoning & Master Plan – Land off Freemans Drive, Cooranbong
Northrop Engineers, December 2005

14. RPS HSO
Flood Study Investigation at Various Lots off Newport and Avondale Roads, Cooranbong
Barker Harle, November 2008

15. Bureau of Meteorology
The Estimate of Probable Maximum Precipitation in Australia: Generalised Short Duration Method
June 2003

16. Bureau of Meteorology
Guidebook to the Estimation of Probable Maximum Precipitation: Generalised Tropical Storm Method
September 2005

17. Rahman, A. et al
Australian Rainfall and Runoff – Revision Project 5: Regional Flood Methods
Engineers Australia, June 2012

18. Kuczera, G. and Franks. S.
Australian Rainfall and Runoff – Book IV – Estimation of Peak Discharge - Draft
Engineers Australia, January 2006

19. Kuczera, G
Bayesian Flood Frequency Analysis Software (Version 4.50)
Department of Civil Surveying Environmental Engineering, University of Newcastle, NSW, 2001

20. Jonathan, R. Et al
Robust National Flood Frequency Guidelines: What is an Outlier?
World Environmental and Water Resources Congress 2013

21. TUFLOW User Manual
Version 2012-05-AE

BMT WBM, 2011

22. Chow, V. T.
Open Channel Hydraulics
McGraw Hill, 1959

23. Henderson, F. M.
Open Channel Flow
MacMillian, 1966

24. Subramanya, K.
Flow in Open Channels
Tata McGraw Hill, 1997

25. Engineers Australia
Australian Rainfall and Runoff: Revision Projects
Project 11: Blockage of Hydraulic Structures (Stage 2)
Engineers Australia, February 2013

26. **NSW Sea Level Rise Policy Statement**
New South Wales Government, October 2009

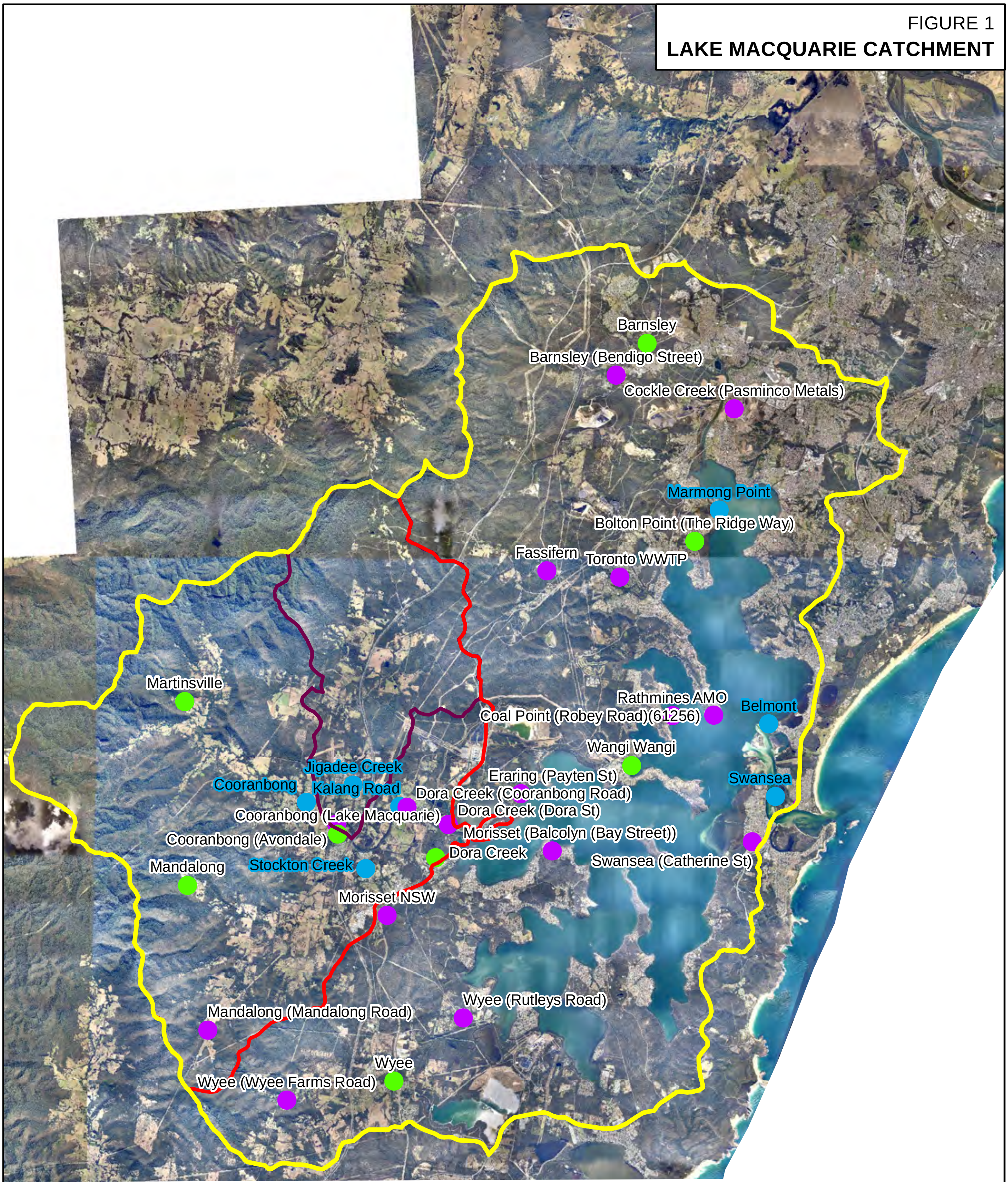
27. Department of Environment, Climate Change and Water
Flood Risk Management Guide
August 2010

28. Department of Environment, Climate Change and Water
Derivation of the NSW Government's Sea Level Rise Planning Benchmarks
October 2009

29. NSW Department of Environment and Climate Change
Floodplain Risk Management Guidelines – Practical Consideration of Climate Change
October 2007

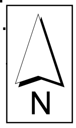
Figures

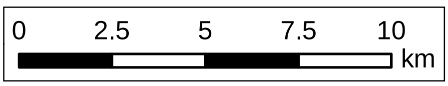
FIGURE 1
LAKE MACQUARIE CATCHMENT



NOTE:

1. Hunter Water operates approximately 15 pluviometers on the north east side of Lake Macquarie between Belmont and Wallsend. For clarity these gauges are not shown on this figure (refer to Lake Macquarie Waterway Flood Study, (See reference 6 for further details).
2. Refer to Figure 12 for more detailed information on the pluviometer records.
3. Only gauges wihtin the Lake Macquarie catchment are shown on this figure.





Lake Macquarie Catchment
Dora Creek Catchment
Jigadee Creek Catchment
Pluviometer
Daily
Water Level

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FIGURE 2
DORA CREEK STUDY AREA

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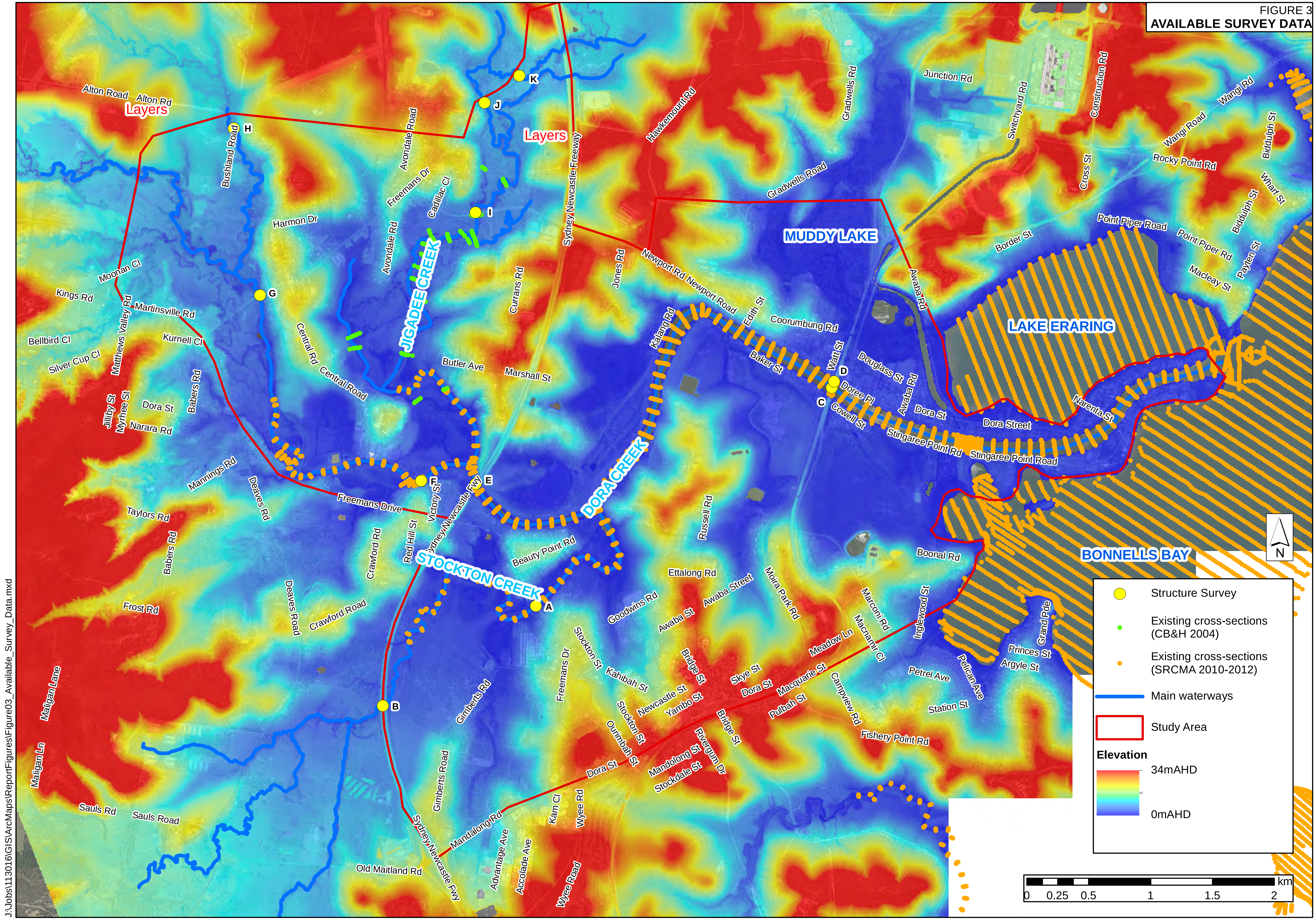


FIGURE 3
AVAILABLE SURVEY DATA
MUDDY LAKE
LAKE ERARING
BONNELLS BAY
JIGADEE CREEK
DORA CREEK
STOCKTON CREEK
Layers
Layers
A
B
C
D
E
F
G
H
I
J
K
Structure Survey
Existing cross-sections (CB&H 2004)
Existing cross-sections (SRCMA 2010-2012)
Main waterways
Study Area
Elevation
34mAHD
0mAHD
N
0 0.25 0.5 1 1.5 2 km
J:\Jobs\113016\GIS\ArcMaps\ReportFigures\Figure03_Available_Survey_Data.mxd

PHOTOGRAPHS OF STRUCTURES

A - Stockton Creek at Freemans Drive

B – Stockton Creek at M1 Motorway

C – Dora Creek at Macquarie Street

D – Dora Creek at Railway Bridge

E – Dora Creek at M1 Motorway south bound

F – Dora Creek at Swinging Bridge

G – Dora Creek at Freemans Drive

H – Felled Timber Creek at Bushland Road

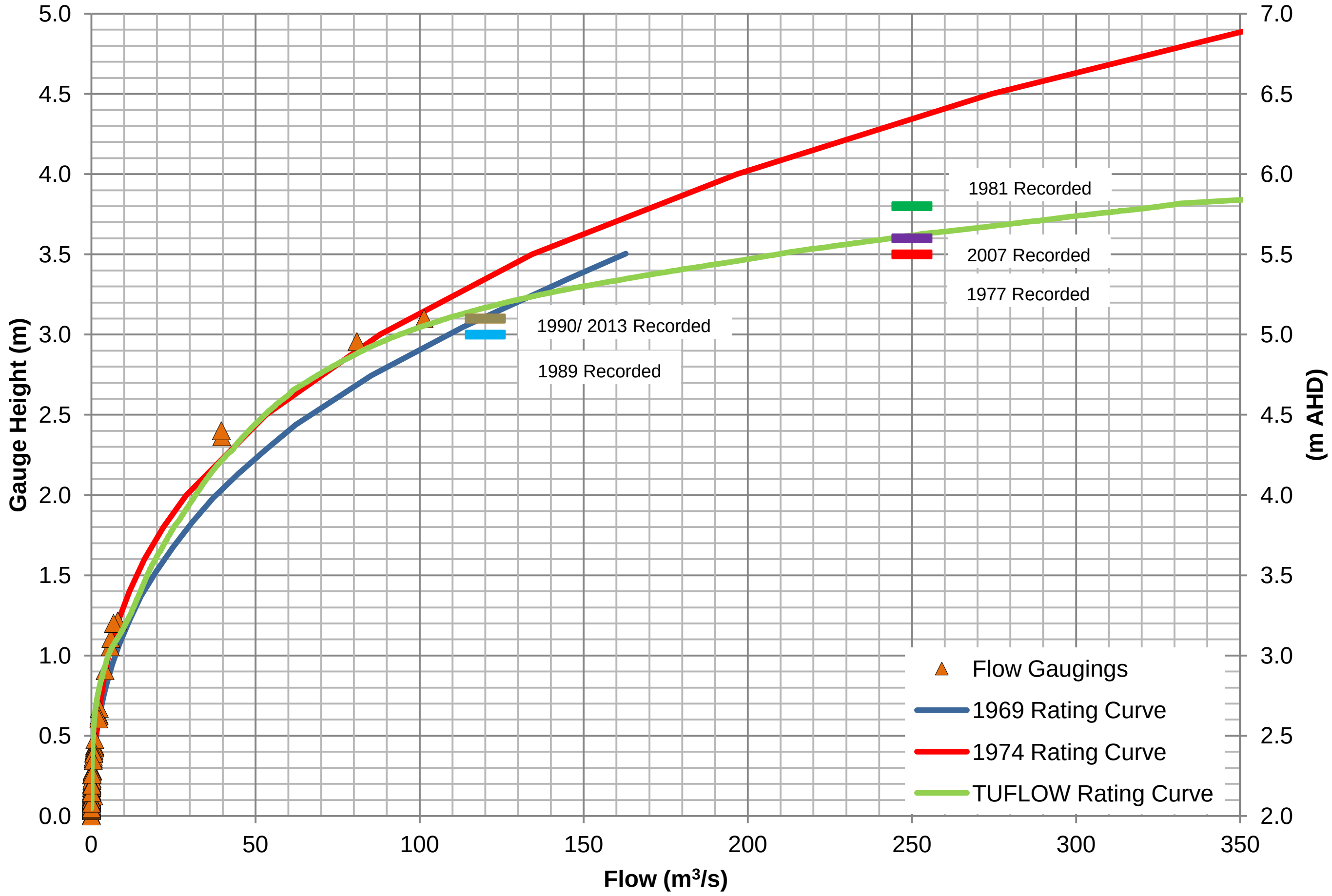
I – Jigadee Creek at Newport Road

J – Jigadee Creek at Freemans Drive

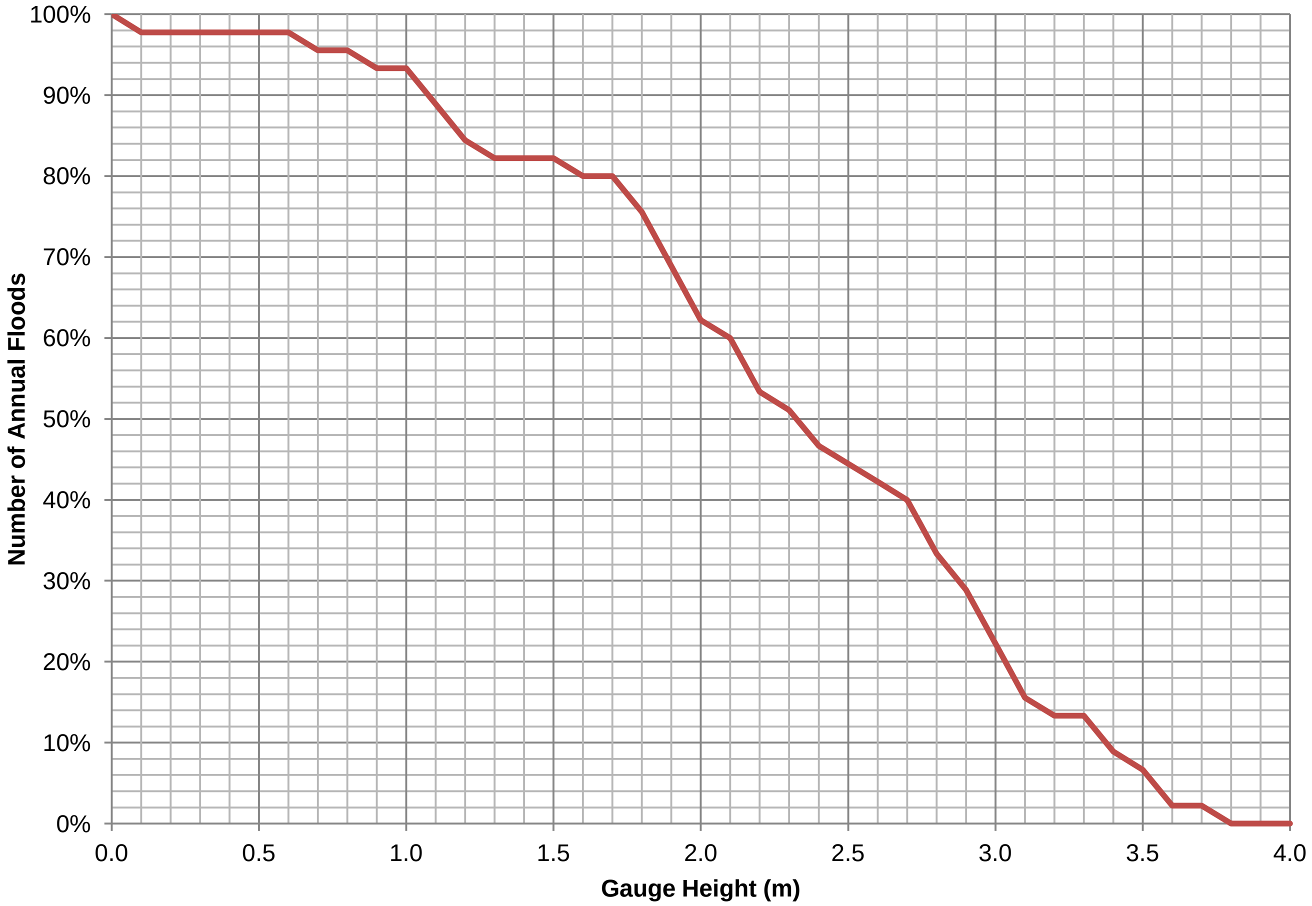
K – Jigadee Creek at Freemans Drive

FIGURE 5

JIGADEE CREEK RATING CURVE AND GAUGING DATA



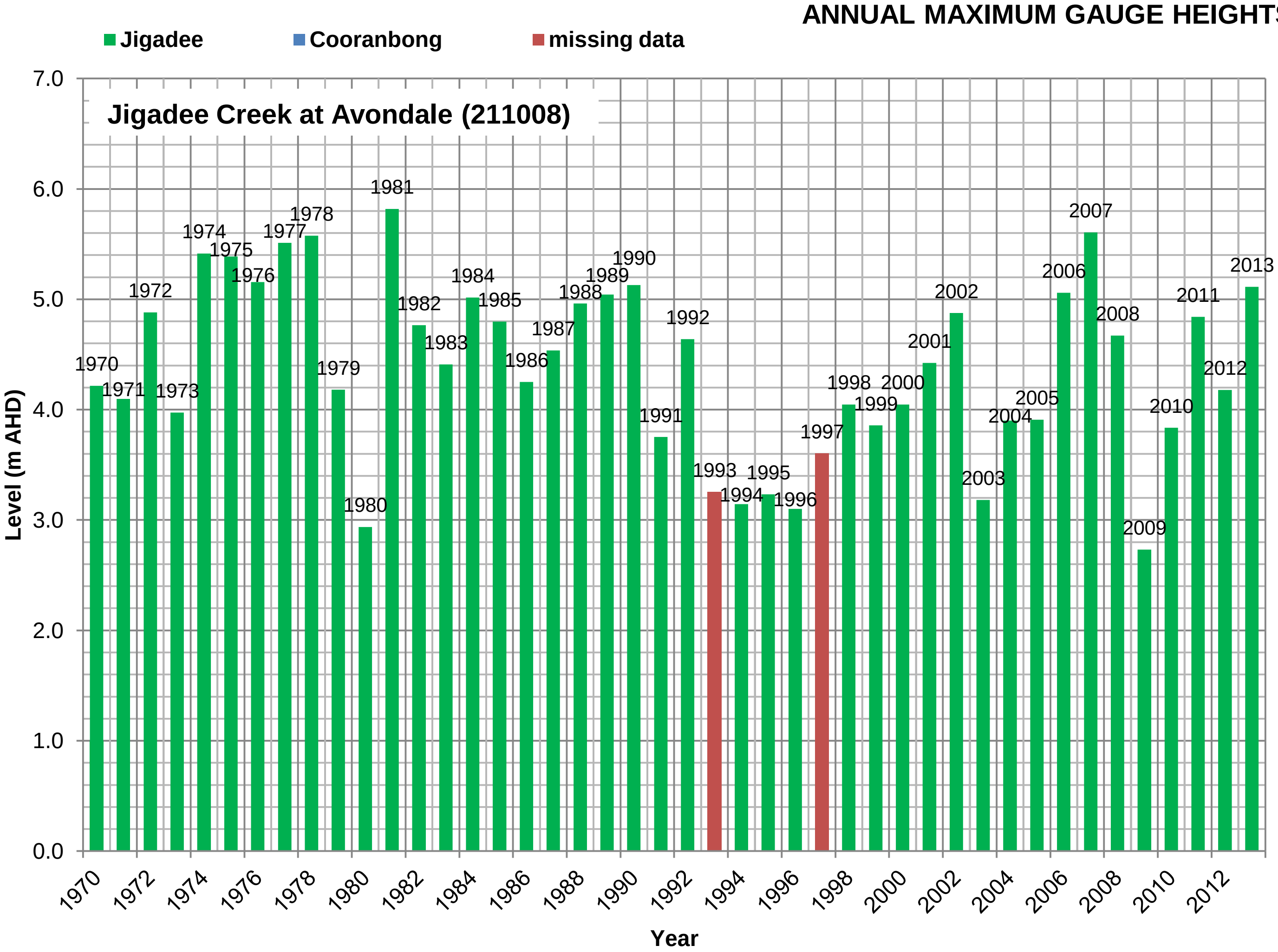
PERCENTAGE OF PEAK ANNUAL FLOODS EXCEEDING GAUGE HEIGHT

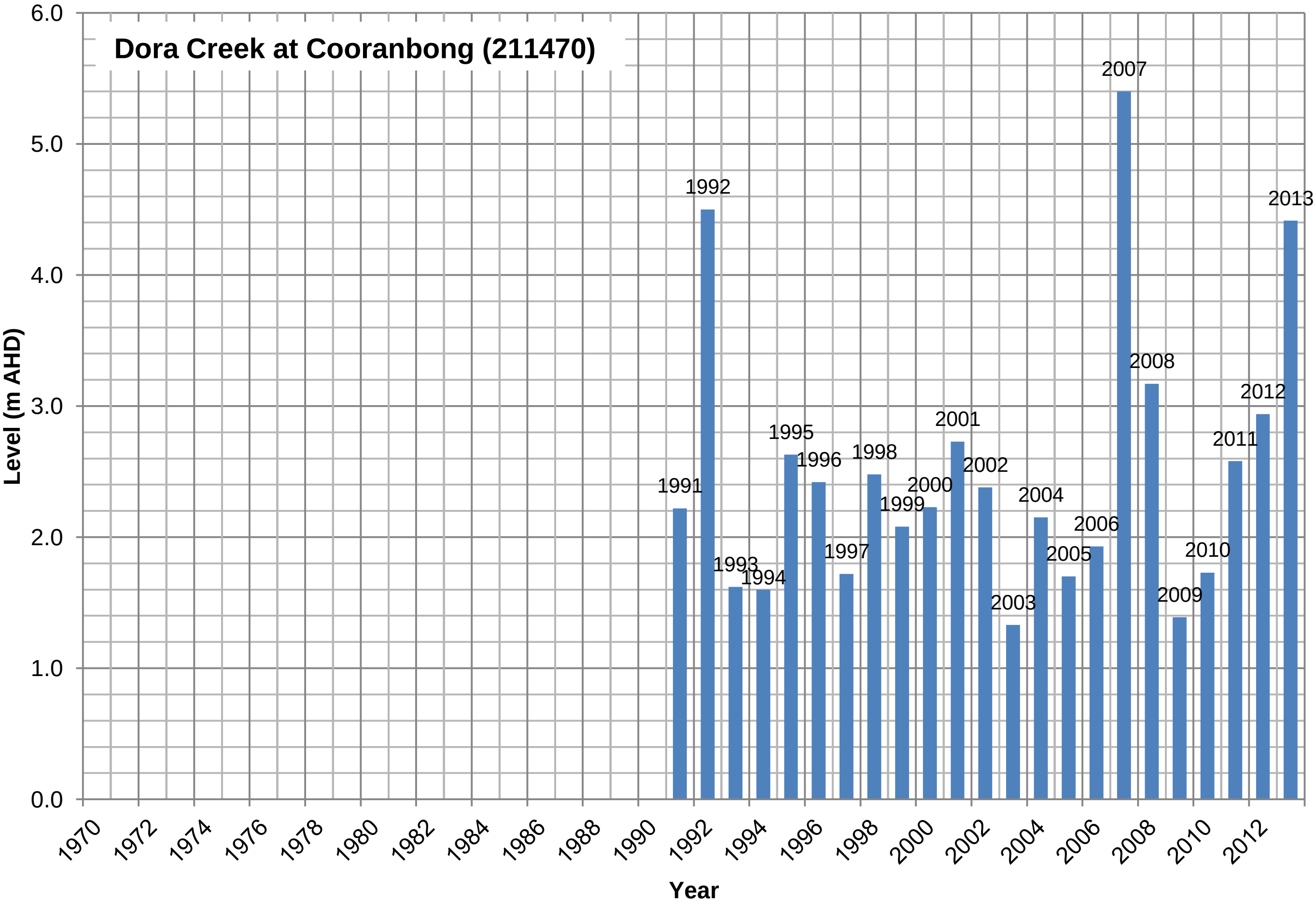


J:\113016\Hydrology\FlowGauge.xlsx

FIGURE 6

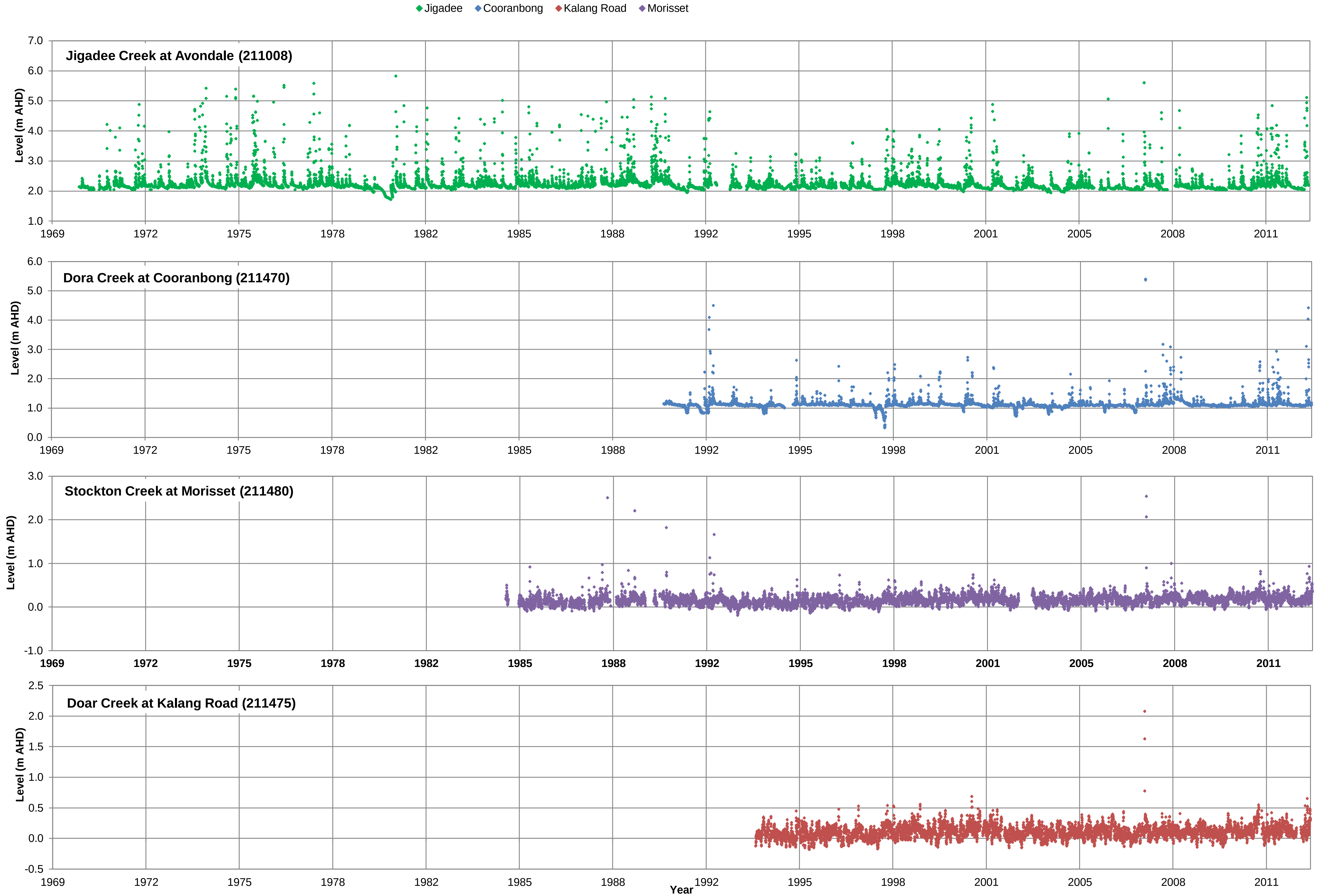
ANNUAL MAXIMUM GAUGE HEIGHTS





J:\113016\Hydrology\FlowGauge.xlsx

FIGURE 7
WATER LEVEL GAUGE RECORDS



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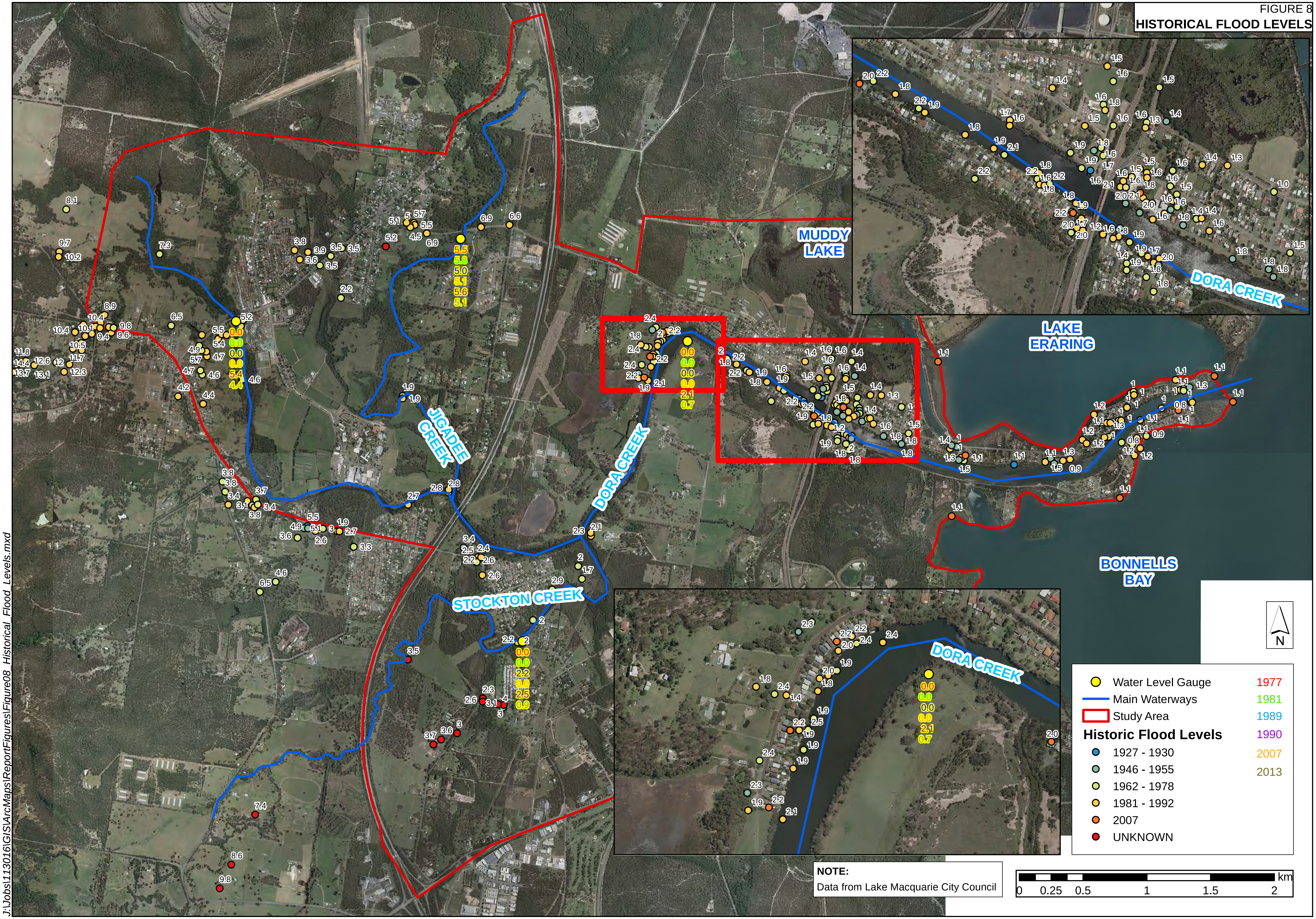


FIGURE 8
HISTORICAL FLOOD LEVELS
MUDDY LAKE
LAKE ERARING
BONNELLS BAY
DORA CREEK
JIGADEE CREEK
STOCKTON CREEK
Water Level Gauge
Main Waterways
Study Area
Historic Flood Levels
1927 - 1930
1946 - 1955
1962 - 1978
1981 - 1992
2007
UNKNOWN
1977
1981
1989
1990
2007
2013
N
NOTE:
Data from Lake Macquarie City Council
0 0.25 0.5 1 1.5 2 km
J:\Jobs\113016\GIS\ArcMaps\Report Figures\Figure08_Historical_Flood_Levels.mxd

HISTORICAL FLOOD PHOTOGRAPHS

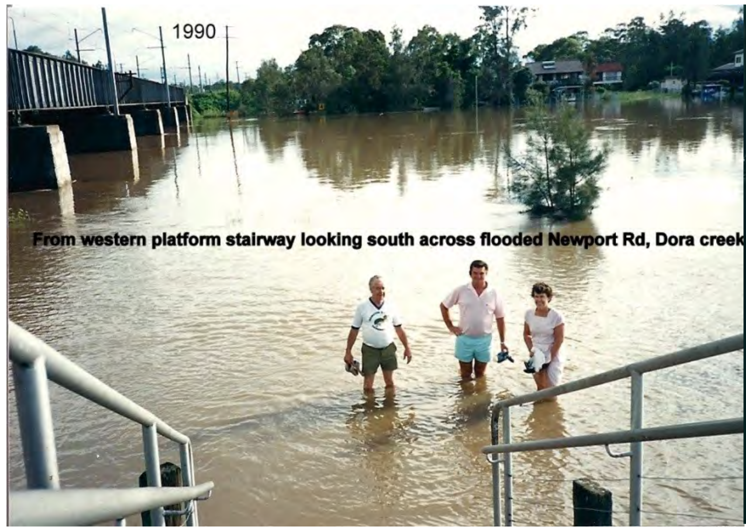
1927 - Taaffe Store - Exact location unknown


1977 - Dora Creek Reserve in front of Post Office

1977 – Watt Street, Dora Creek opposite old Seafood Shop looking north towards Dora Creek Workers Club


1977 – Flooding at 401 Freemans Drive, Cooranbong

1990 – Wamsley Street, Dora Creek looking north



1990 – From western railway platform stairs looking south across Newport Road towards Baker Street

1990 – Newport Road, Dora Creek under railway bridge looking west


1990 – Dora Creek at Cooranbong back of paddocks


2007 - Looking from backyard of Pamela Avenue, Dora Creek


2007 - Looking west along Baker Street, Dora Creek


2007 – Looking from backyard across Dora Creek

2007 – Front of house flooded on Dora Street, Dora Creek

FIGURE 10
HYDROLOGIC MODEL LAYOUT

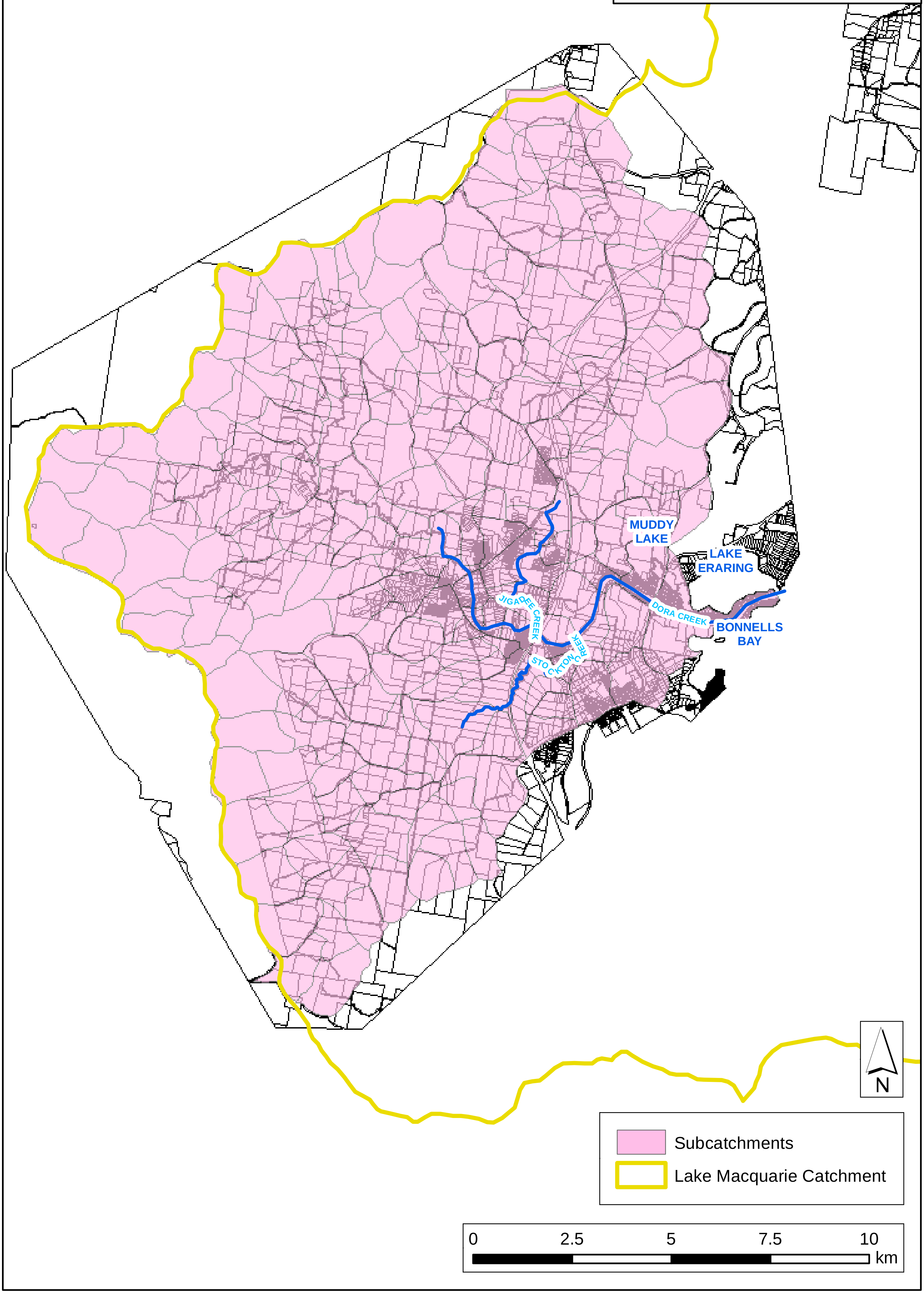


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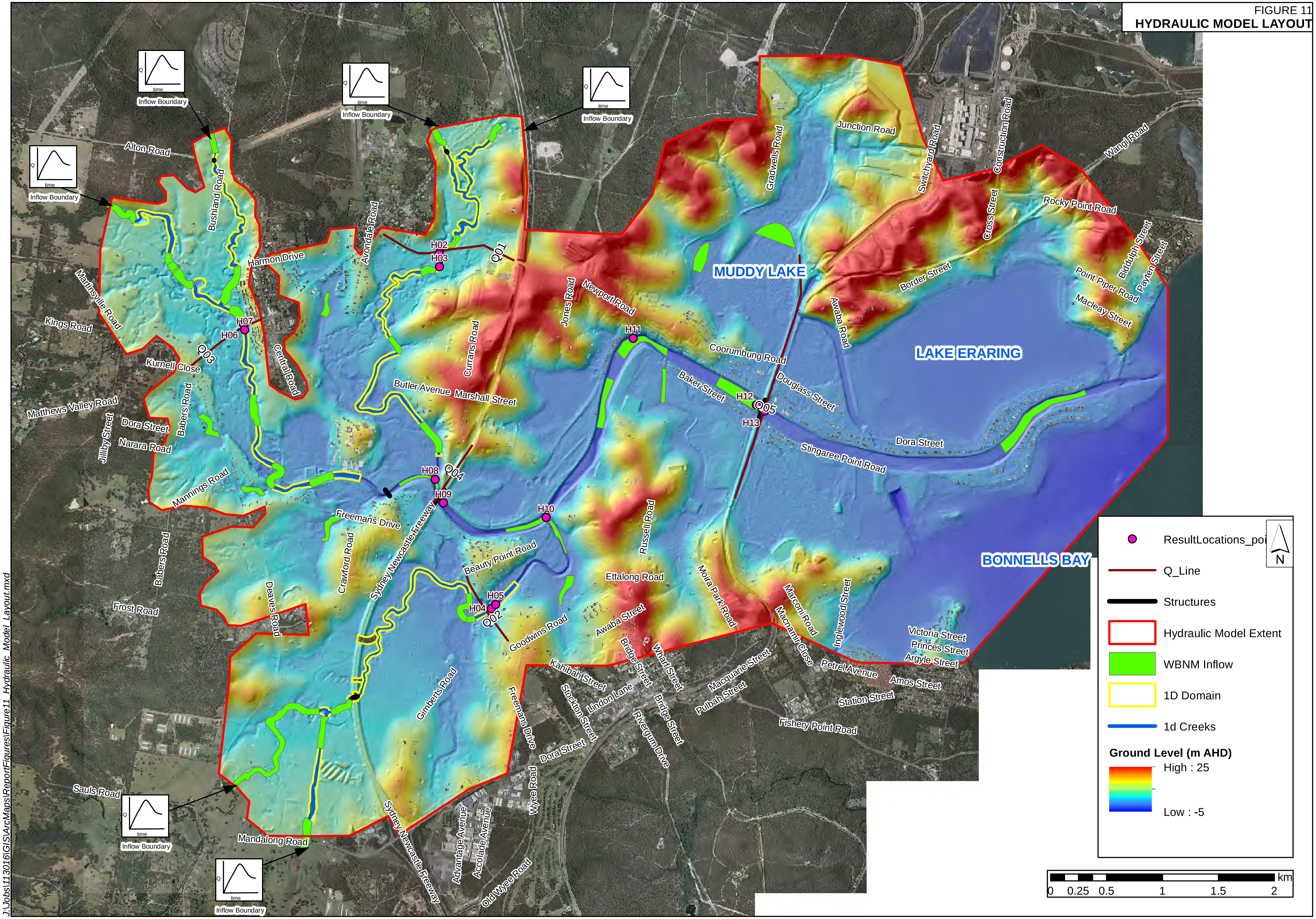
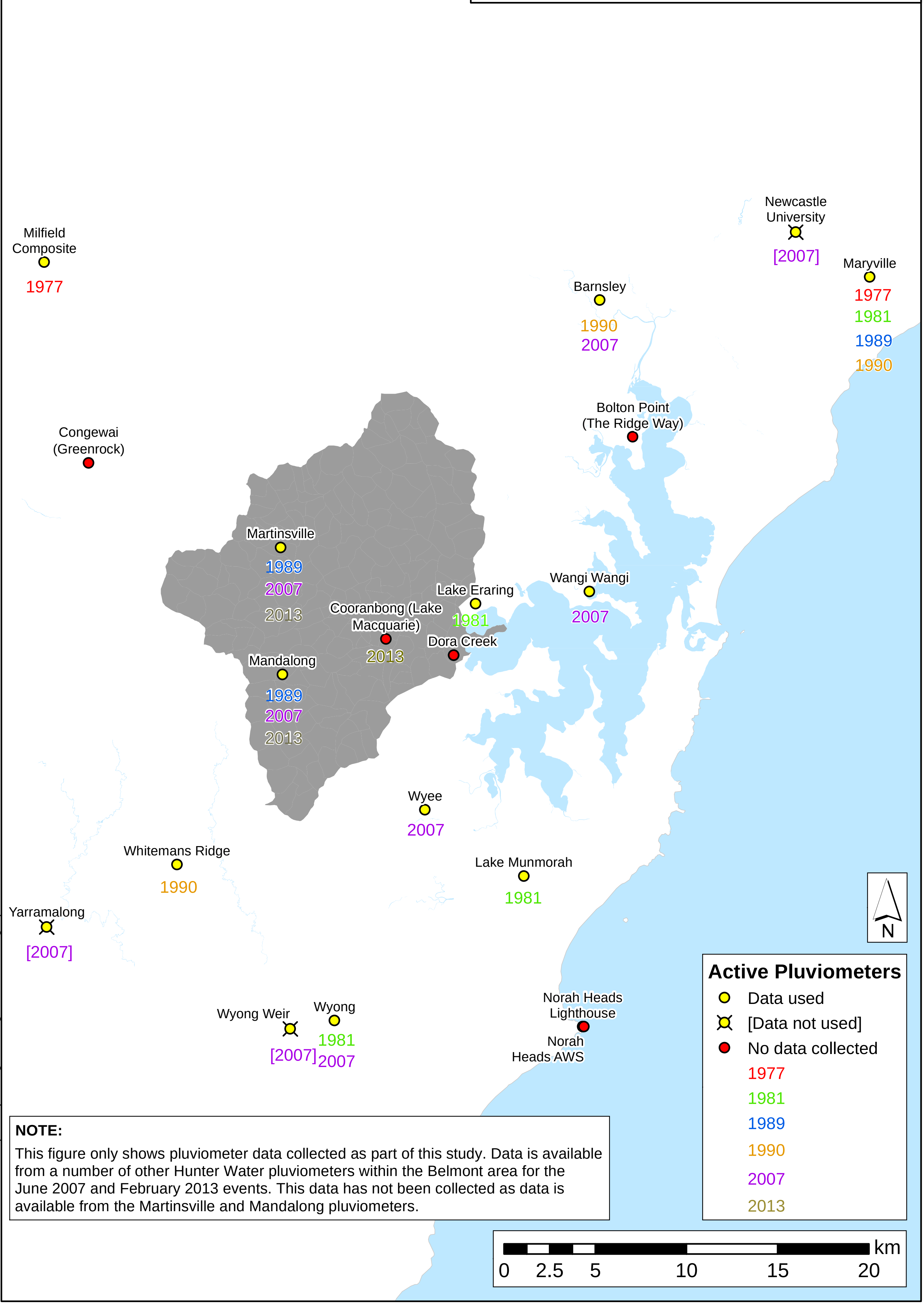
FIGURE 11
HYDRAULIC MODEL LAYOUT



J:\Jobs\113016\GIS\ArcMaps\ReportFigures\Figure11_Hydraulic_Model_Layout.mxd

FIGURE 12
LOCATION OF COLLECTED PLUVIOMETER DATA



NOTE:
This figure only shows pluviometer data collected as part of this study. Data is available from a number of other Hunter Water pluviometers within the Belmont area for the June 2007 and February 2013 events. This data has not been collected as data is available from the Martinsville and Mandalong pluviometers.

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FIGURE 13
HISTORICAL RAINFALL ISOHYETS

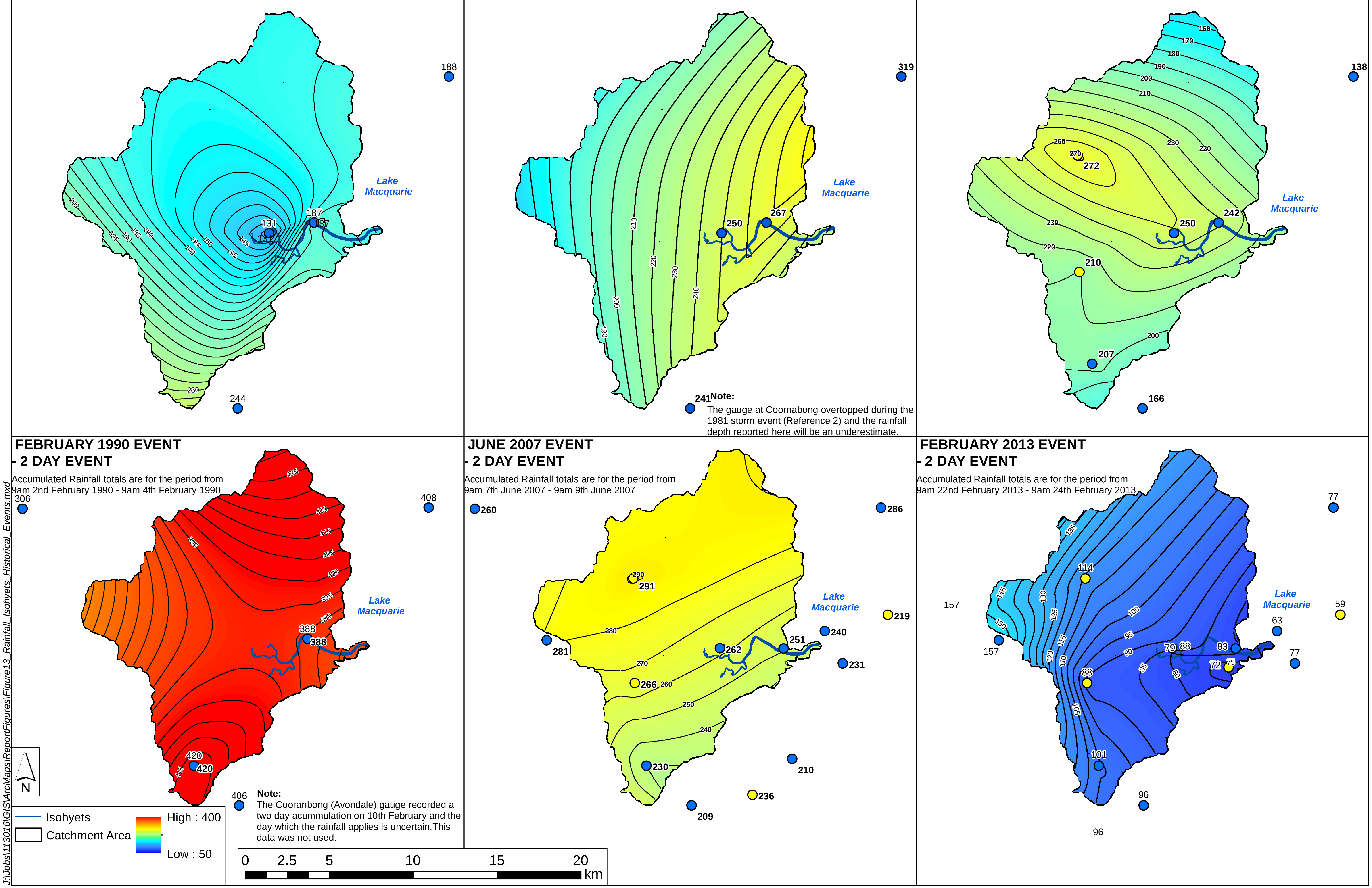

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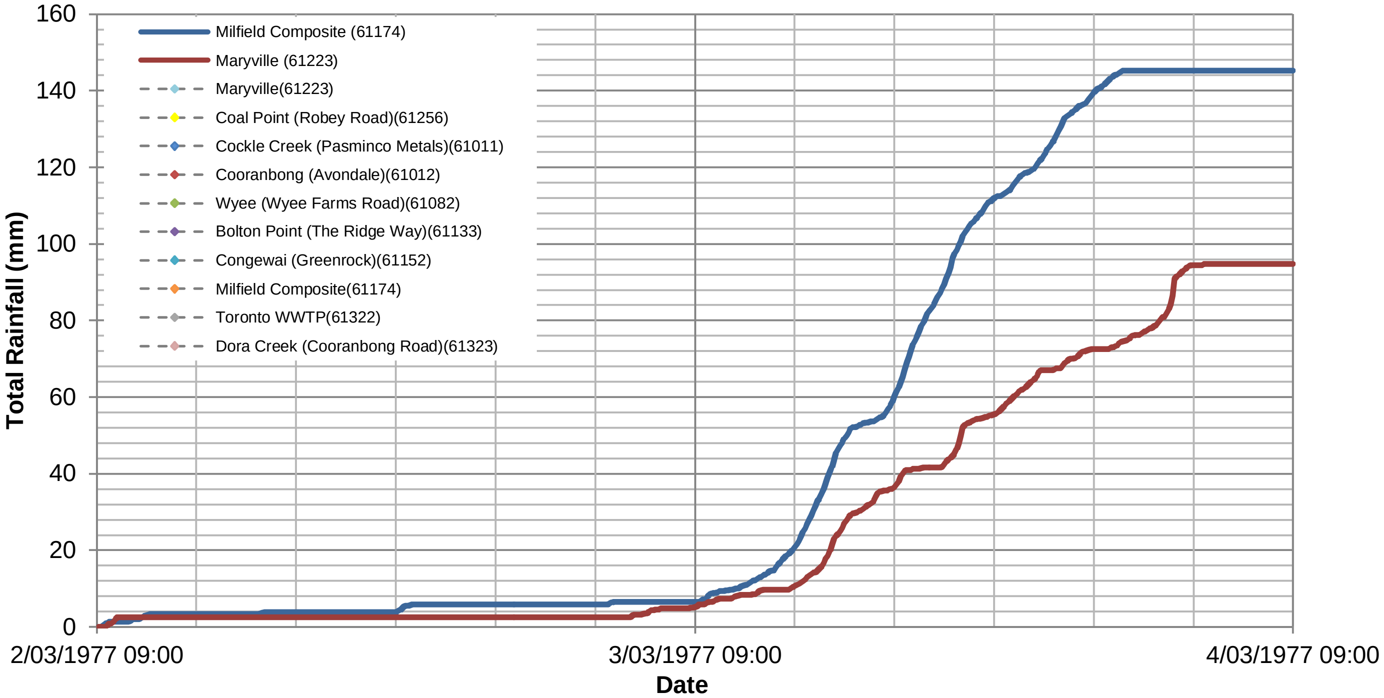
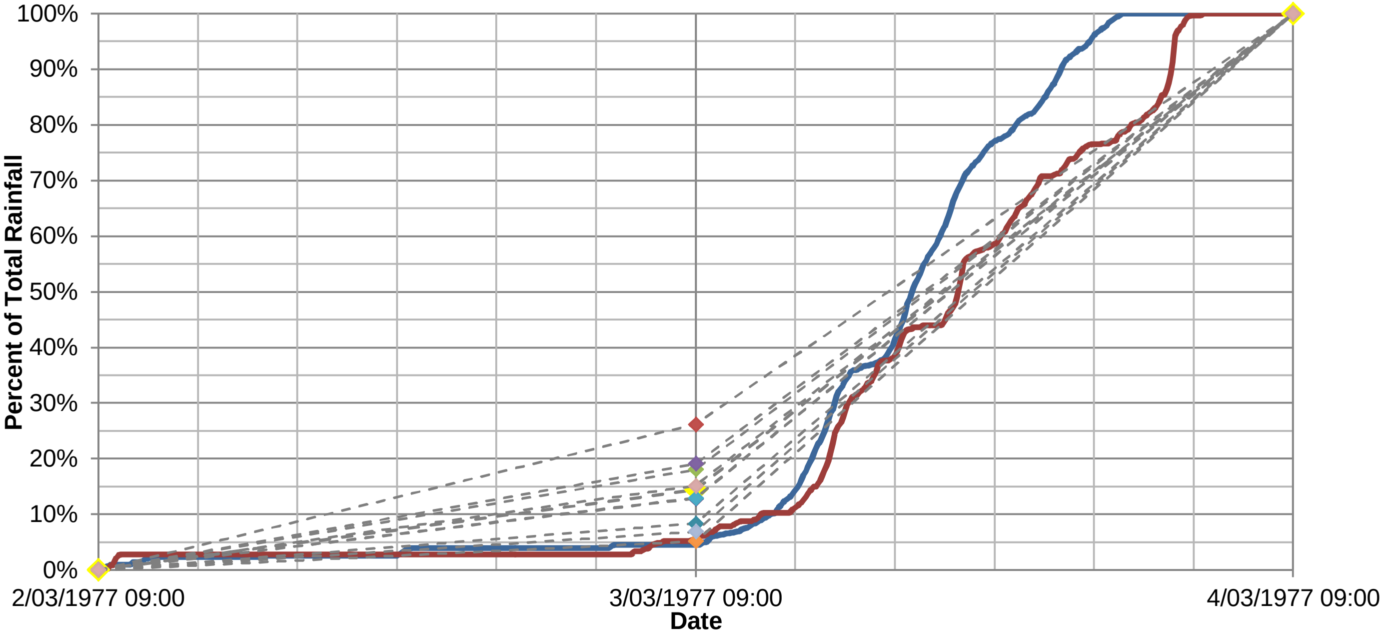
FIGURE14

RAINFALL AND WATER LEVEL DATA
MARCH 1977 EVENT





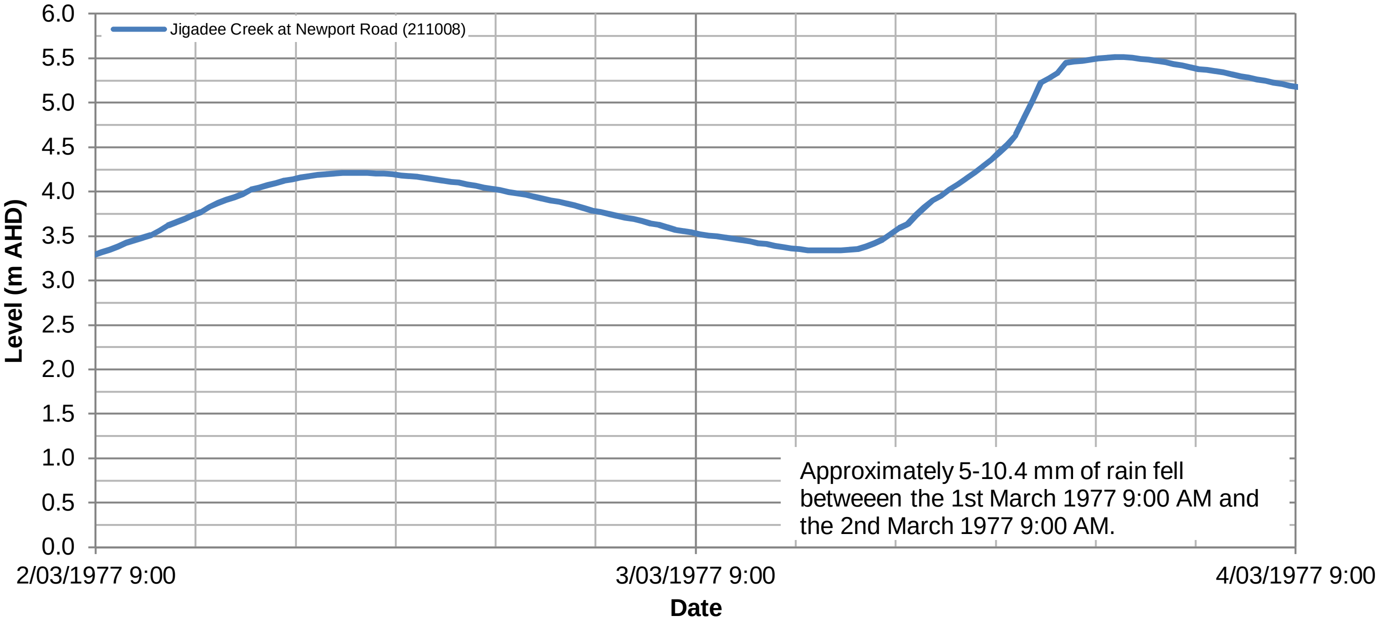


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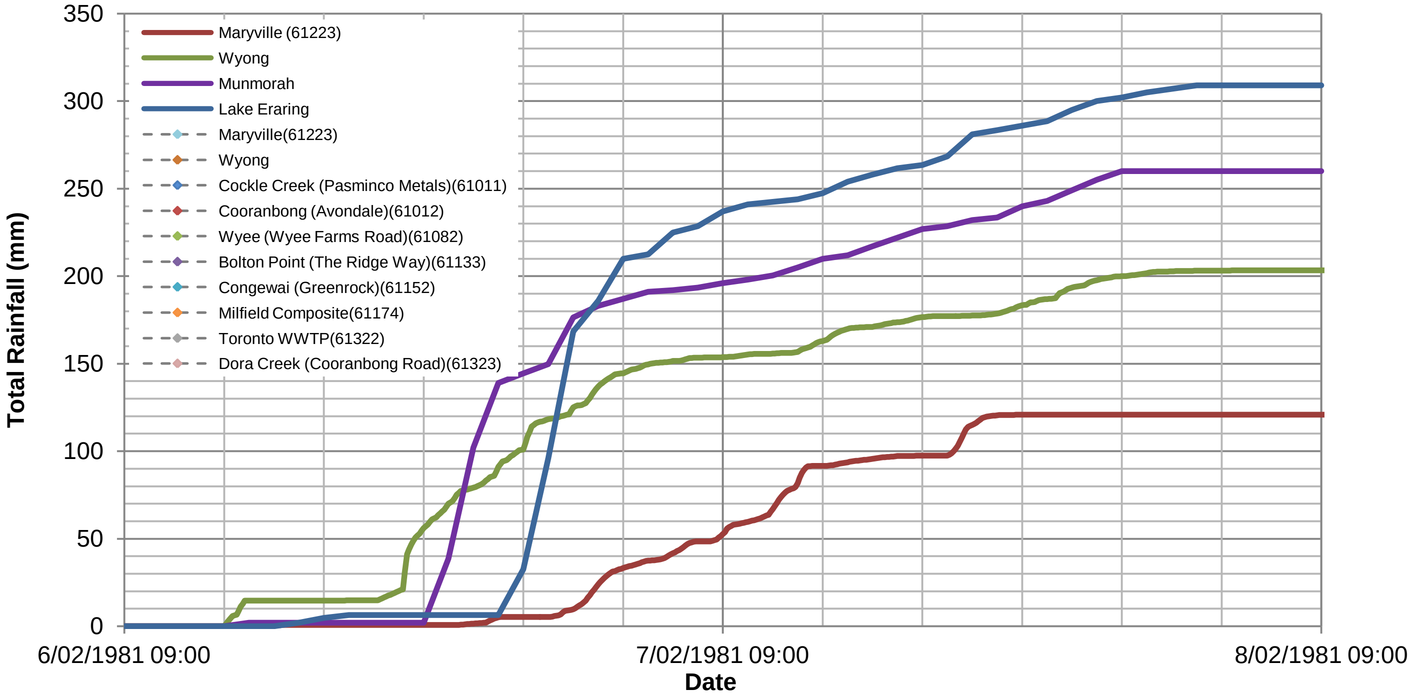
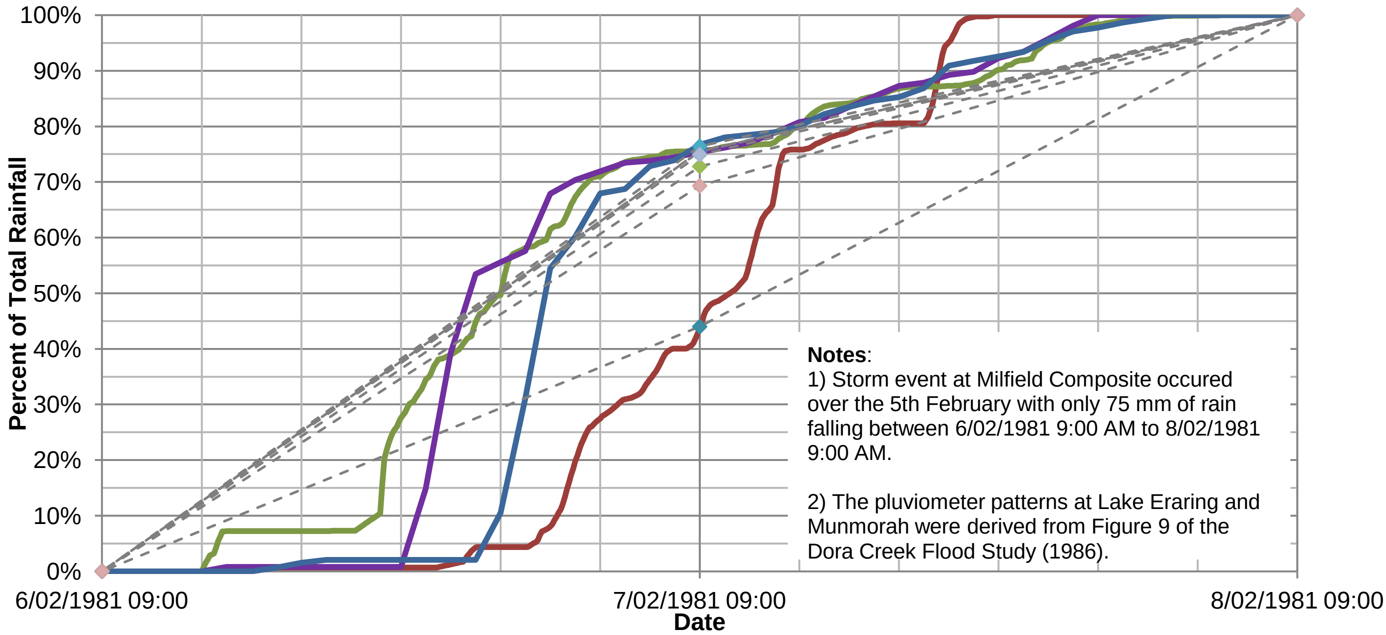
FIGURE15

RAINFALL AND WATER LEVEL DATA
FEBRUARY 1981 EVENT





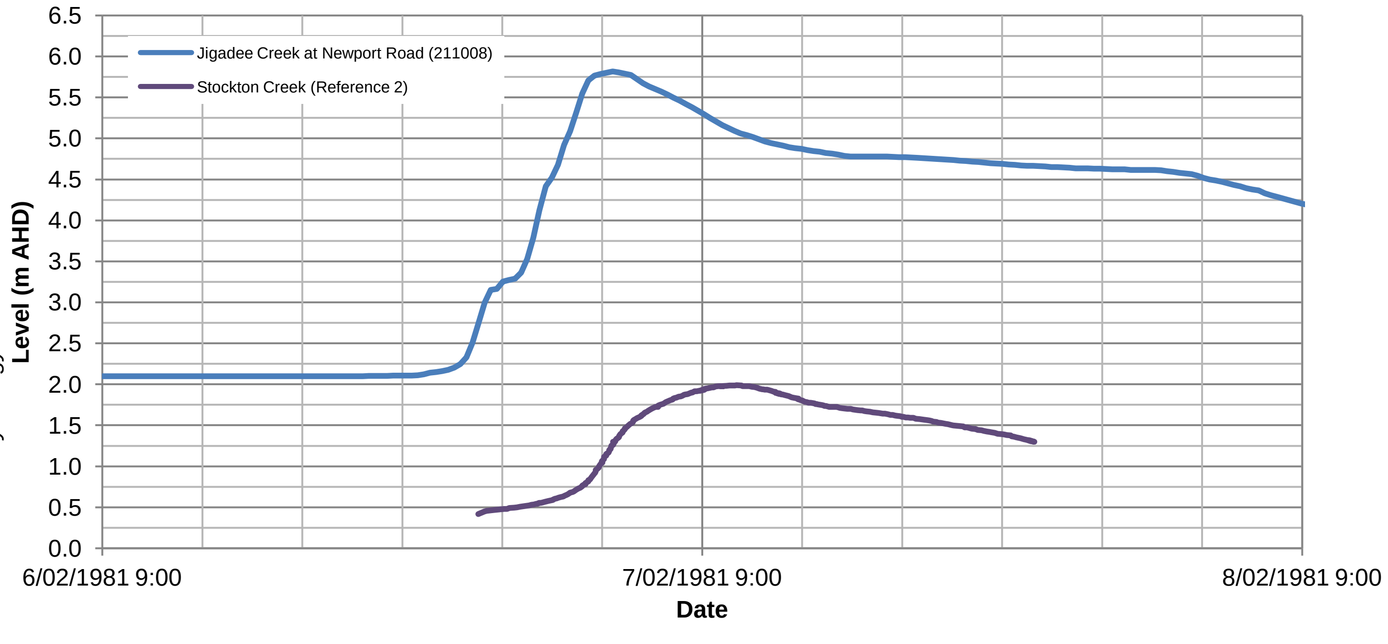


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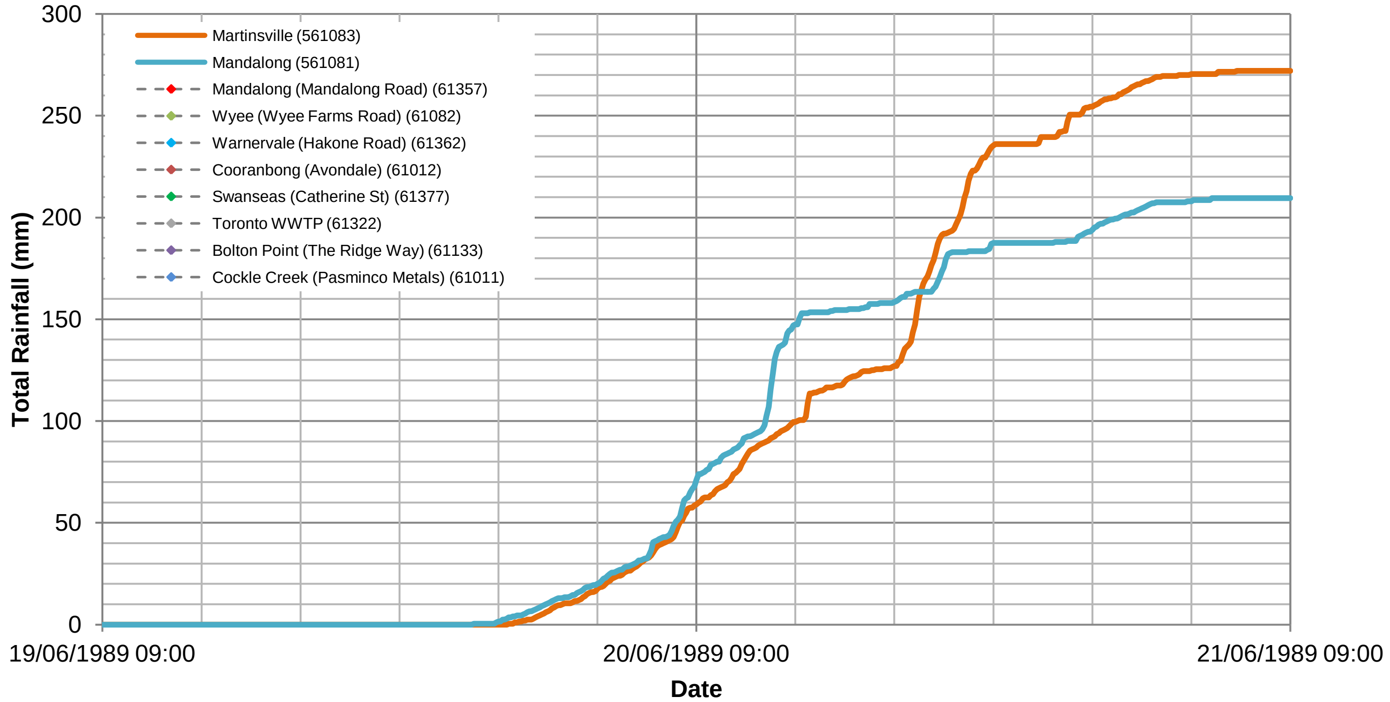
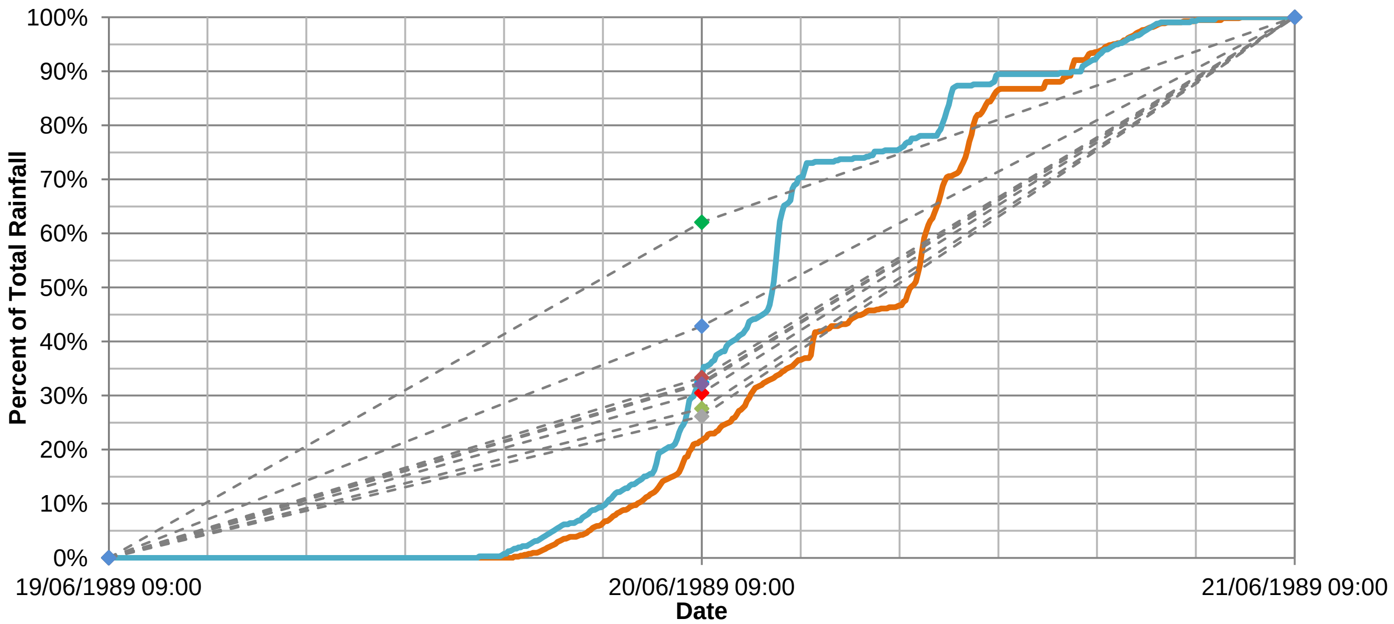
FIGURE 16
RAINFALL AND WATER LEVEL DATA
JUNE 1989 EVENT





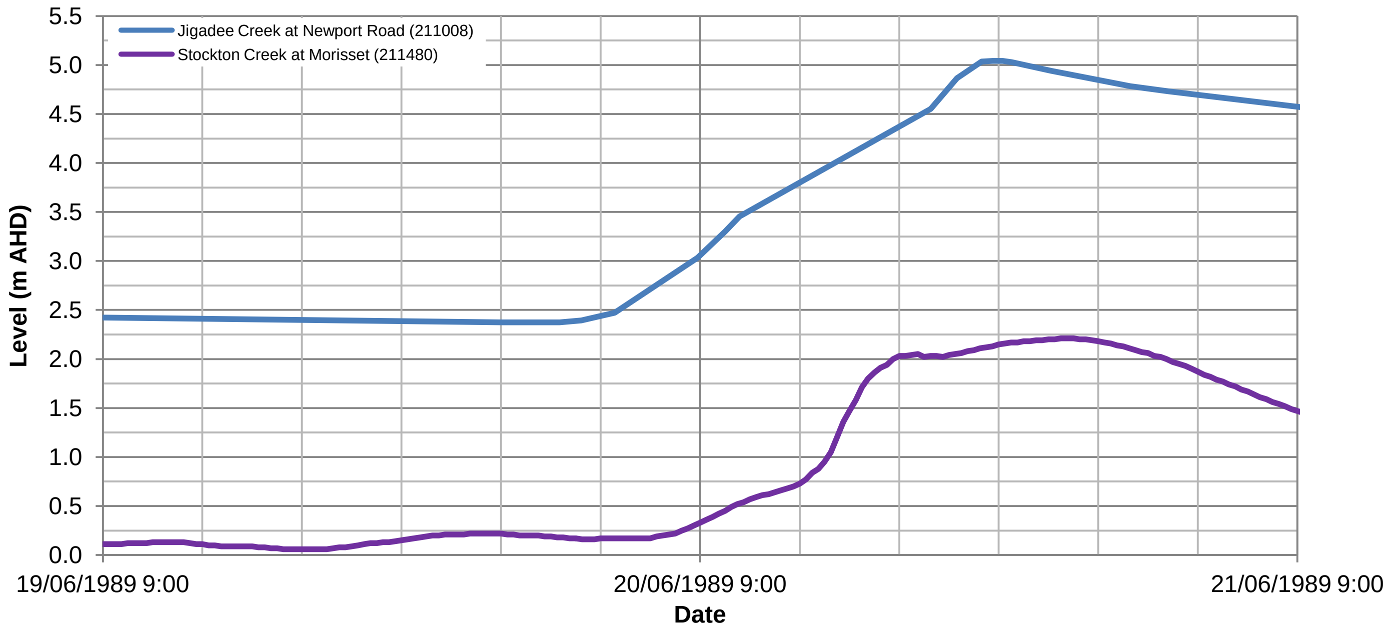


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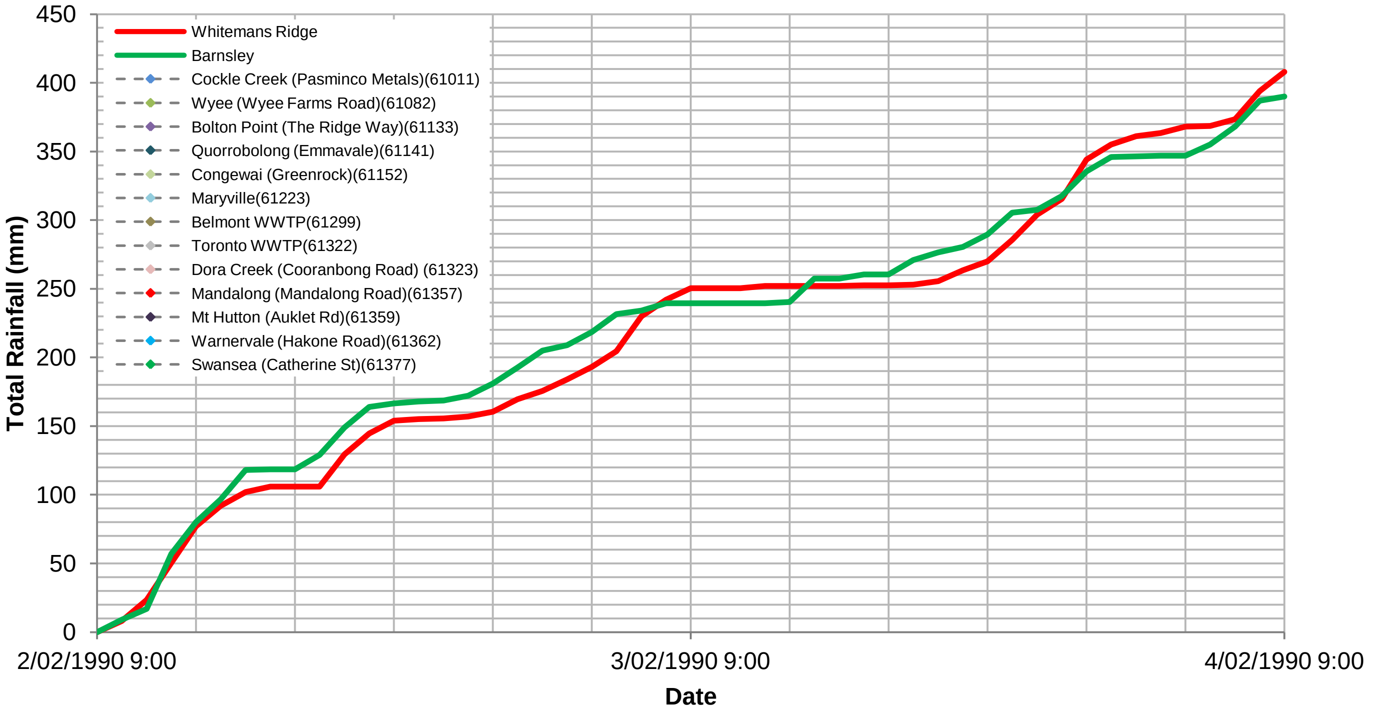
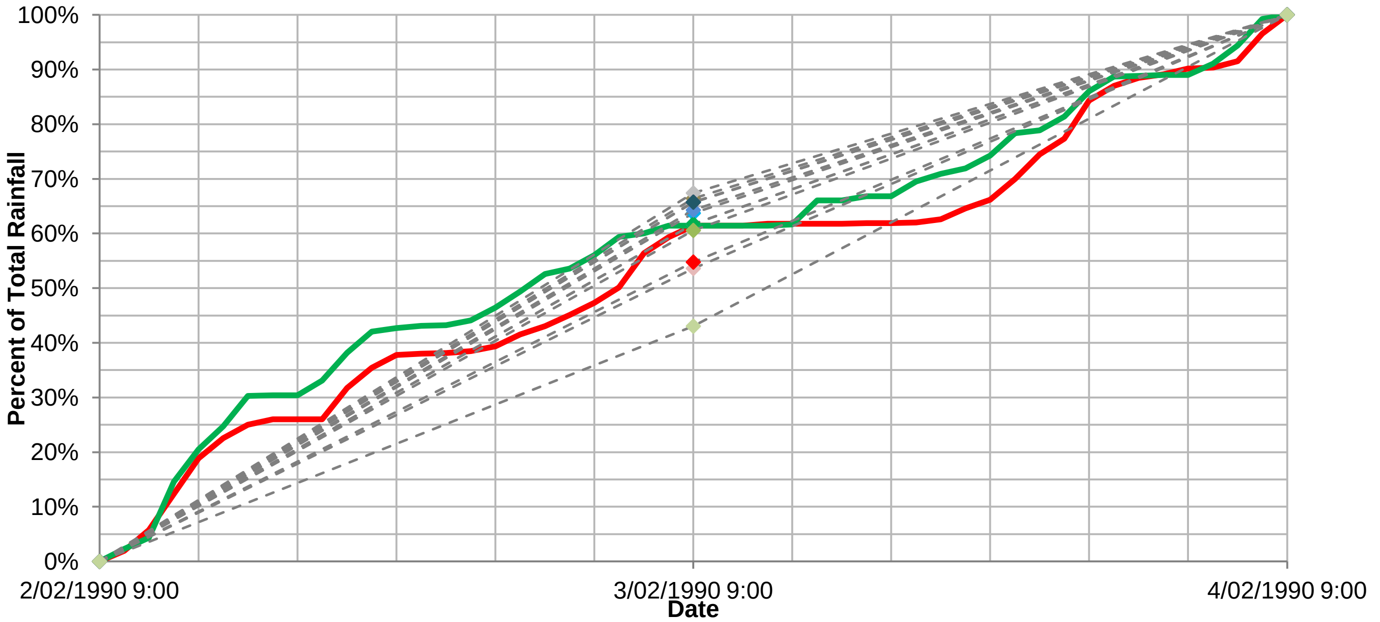
FIGURE 17
RAINFALL AND WATER LEVEL DATA
FEBRUARY 1990 EVENT





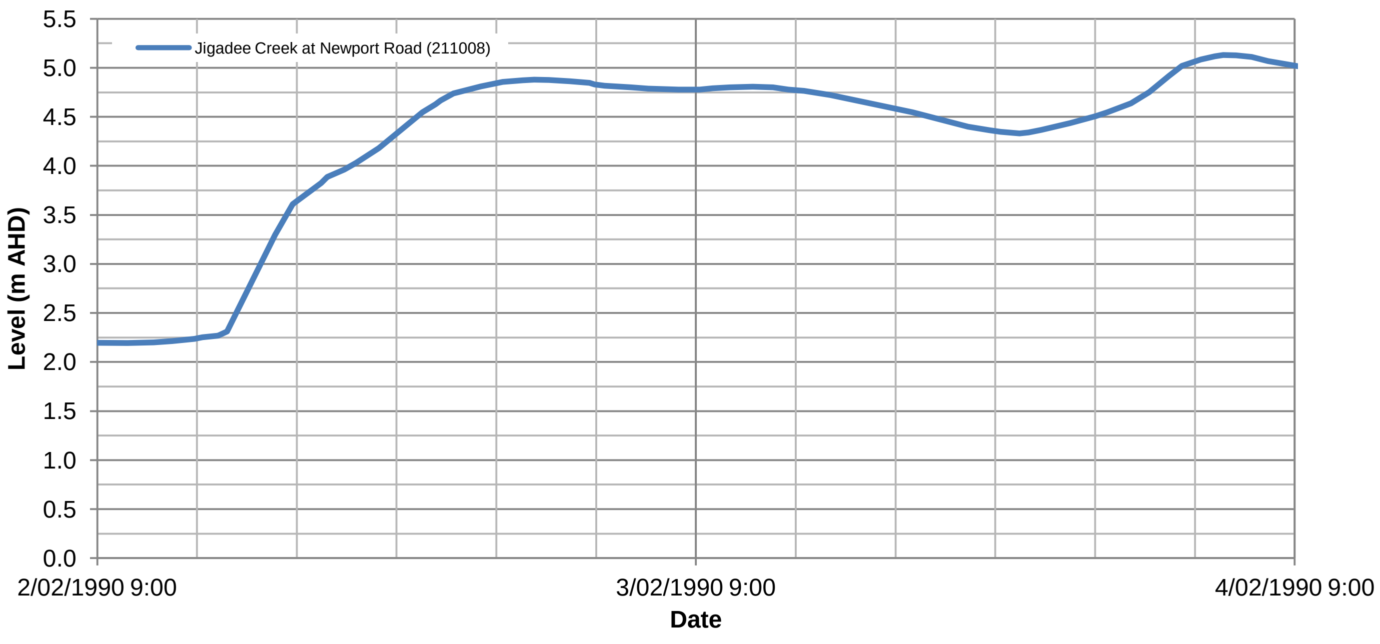


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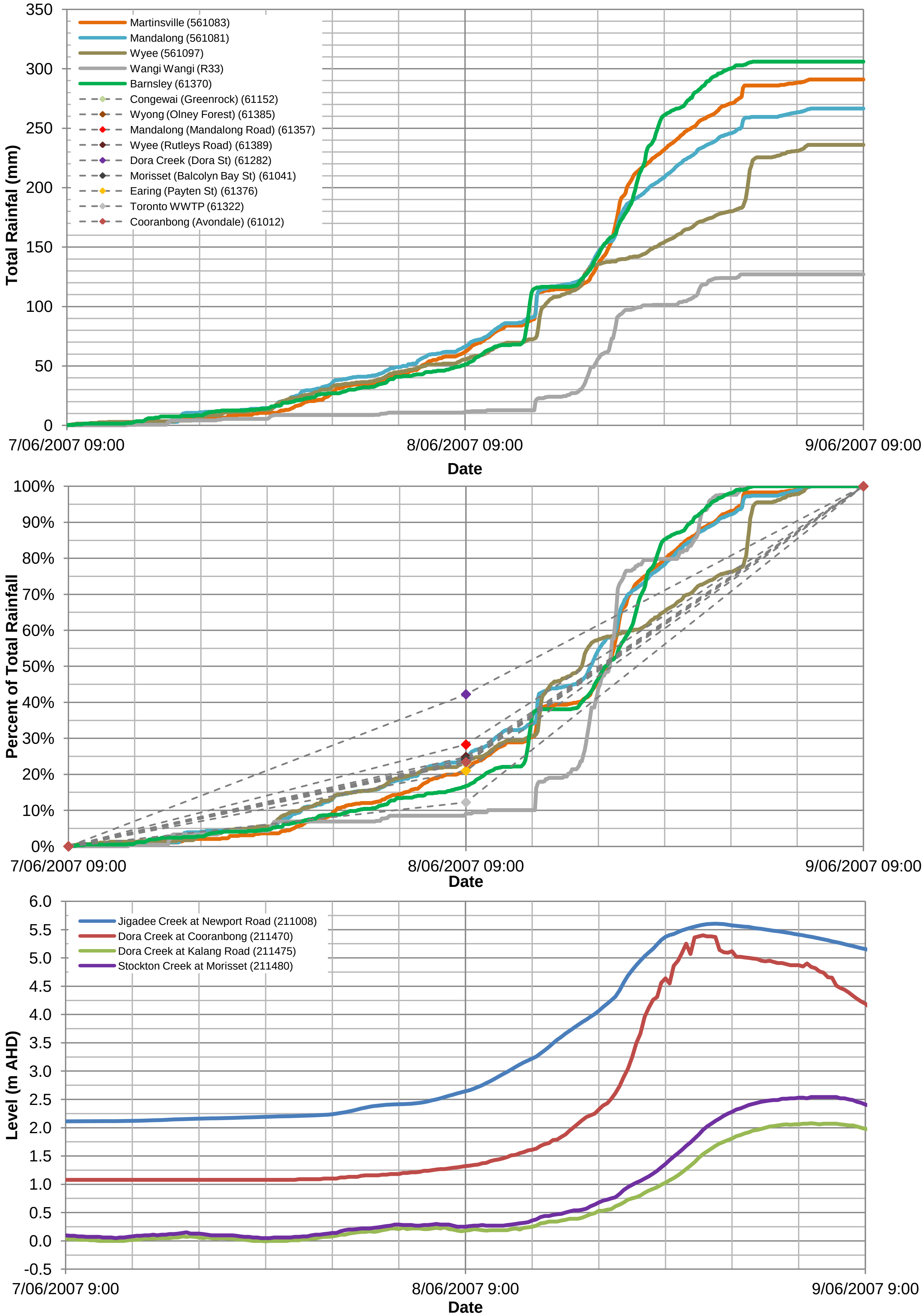
FIGURE 18
RAINFALL AND WATER LEVEL DATA
JUNE 2007 EVENT



J:\Jobs\113016\Hydrology\Rainfall\Historic\HistoricRainfall.xlsx

FIGURE 19
RAINFALL AND WATER LEVEL DATA
FEBRUARY 2013 EVENT

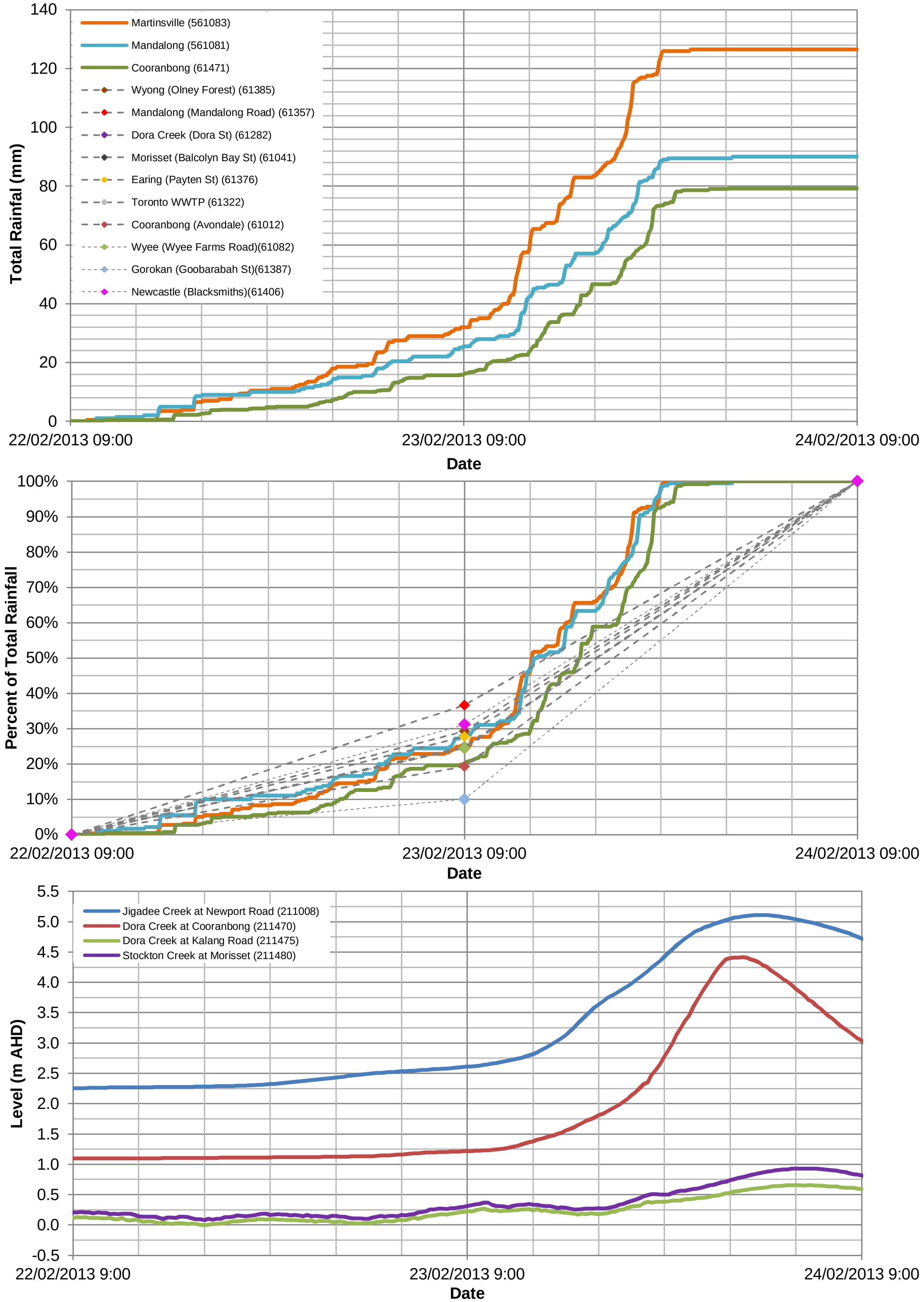


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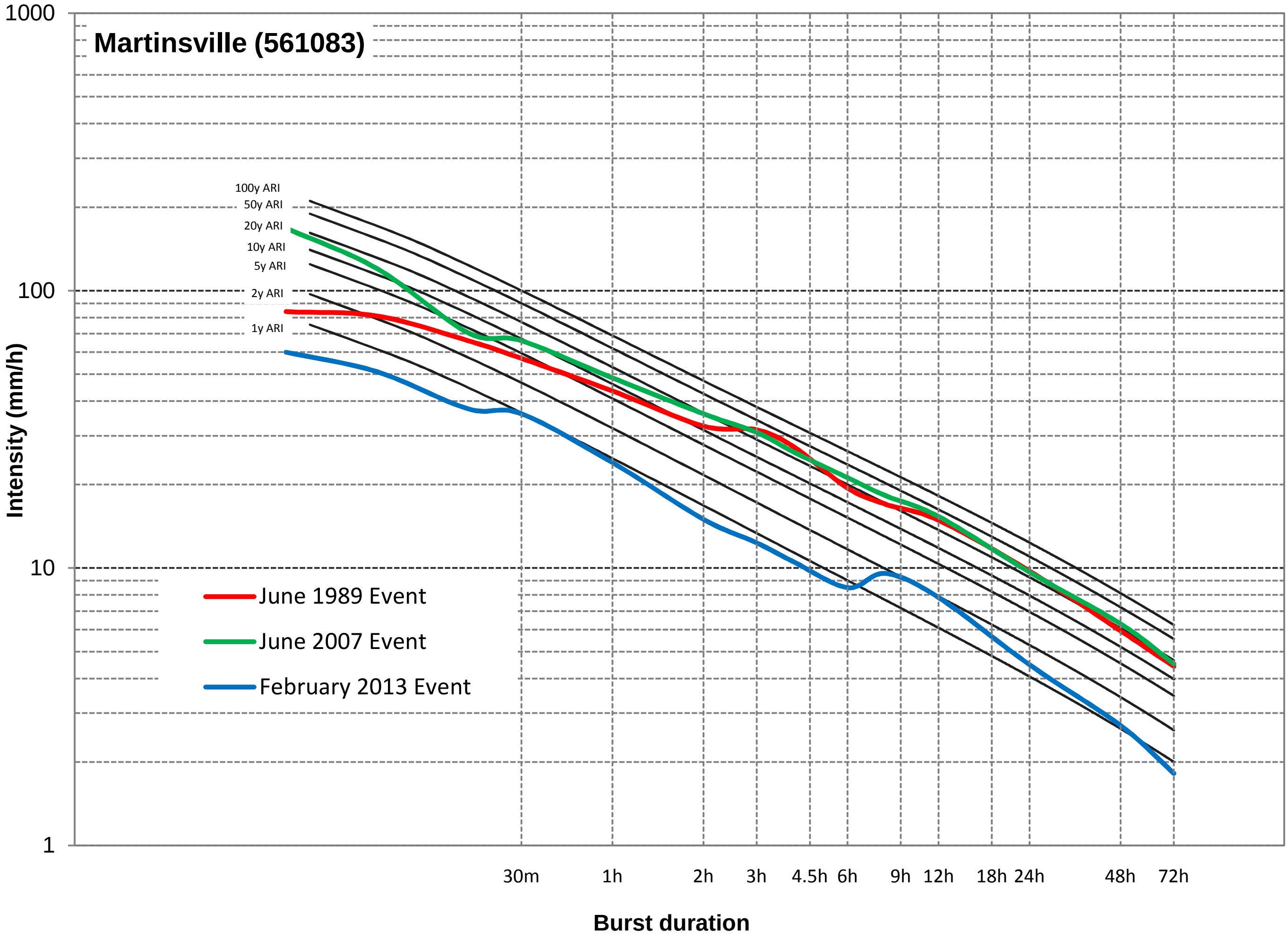
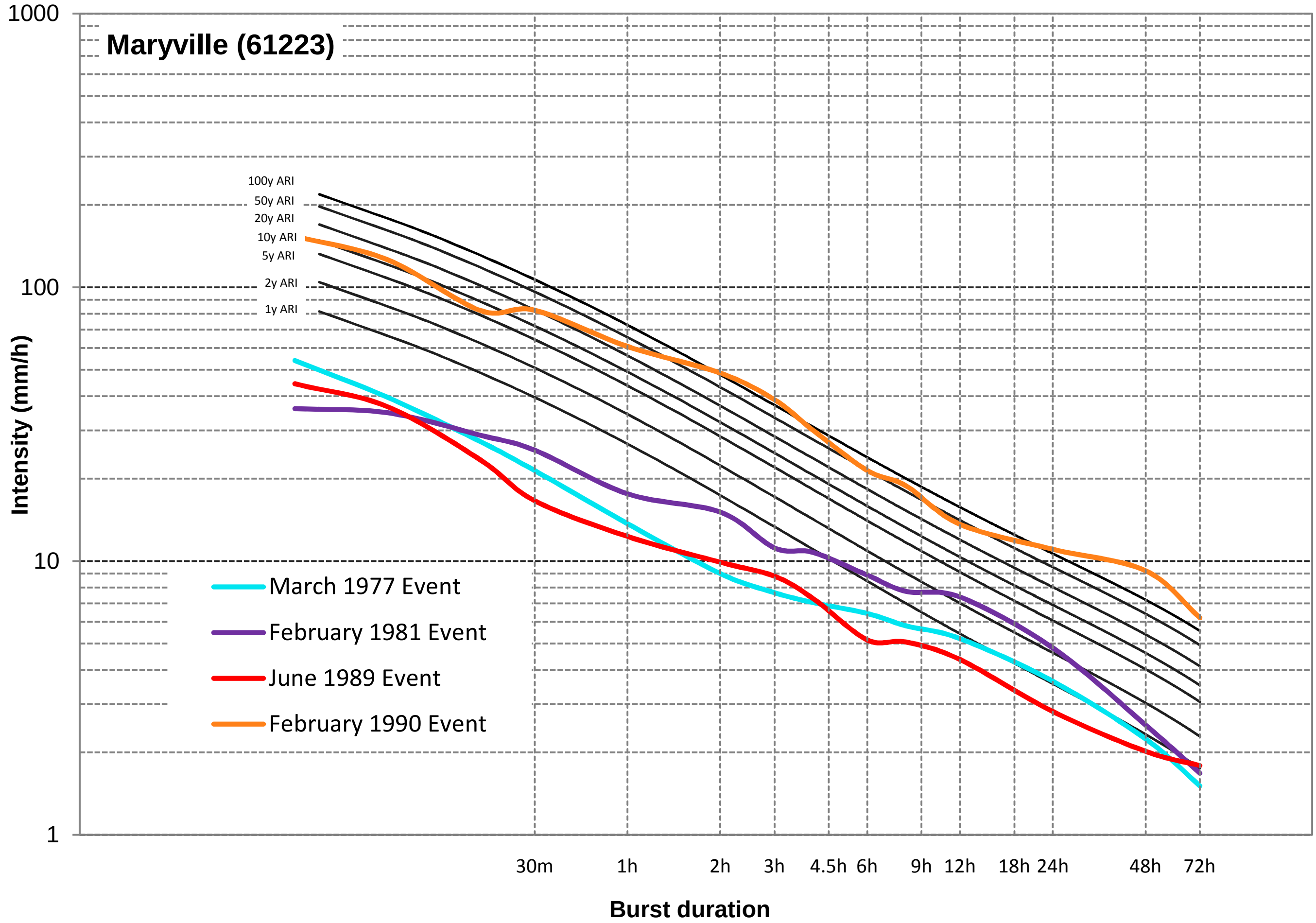
FIGURE 20

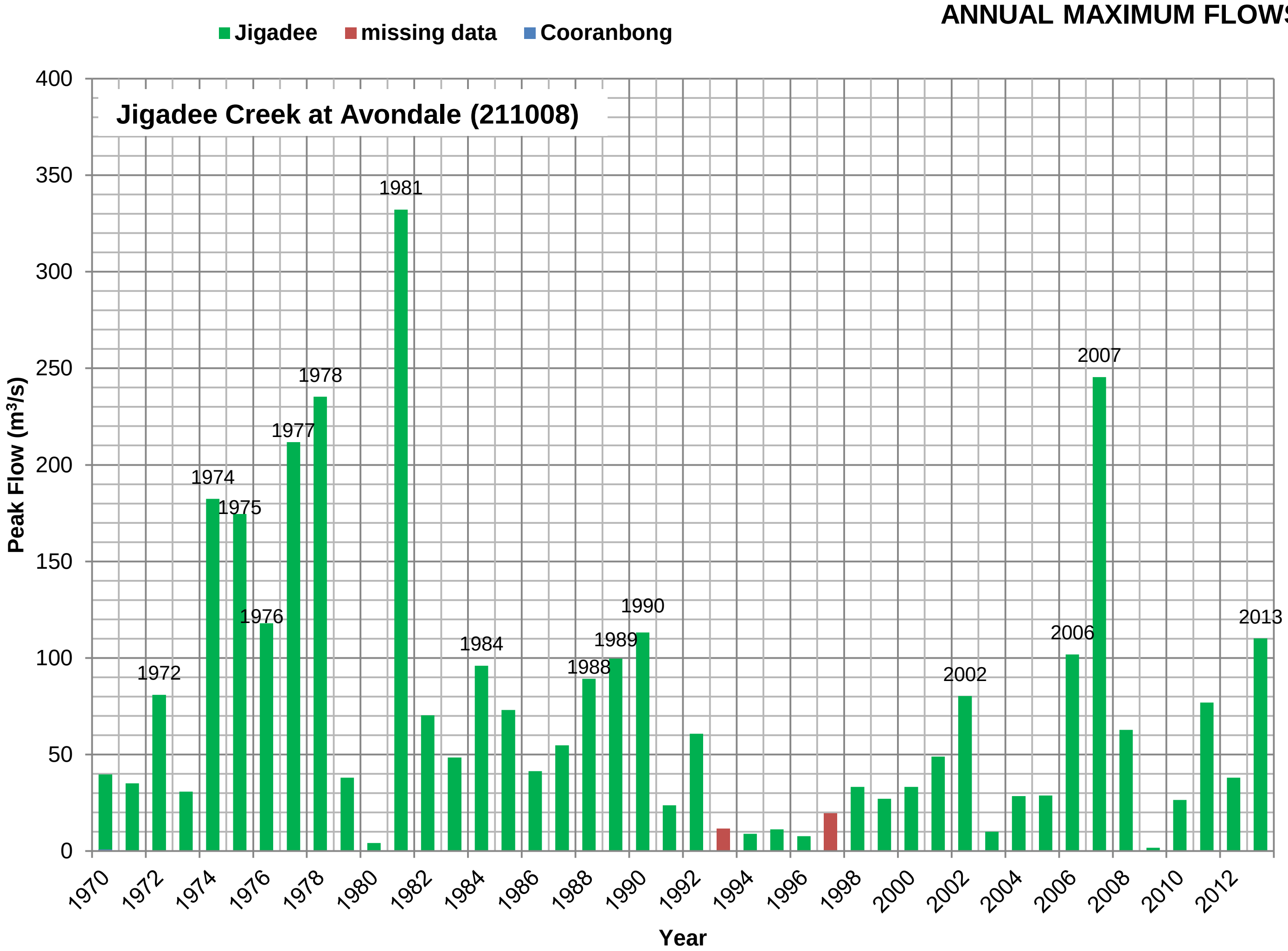
HISTORIC RAINFALL VERSUS AR&R 1987 IFD DATA

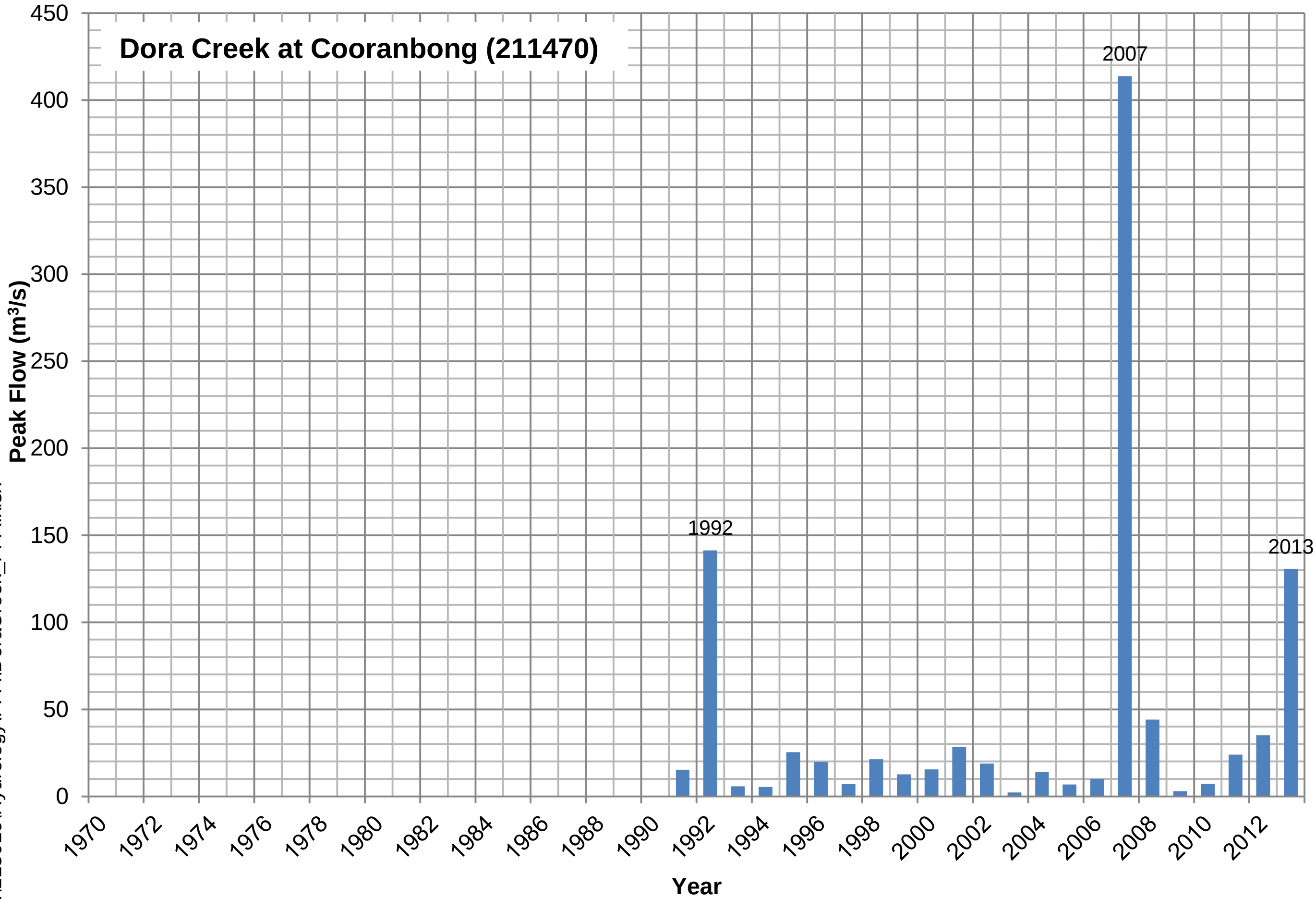




J:\Jobs\113016\Hydrology\Rainfall\Historic\RainfallAnalysis.xlsx

FIGURE 21
ANNUAL MAXIMUM FLOWS





J:\113016\Hydrology\FFA\DoraCreek_FFA.xlsx

J:\Jobs\113016\Hydrology\FFA\DoraCreek_FFA

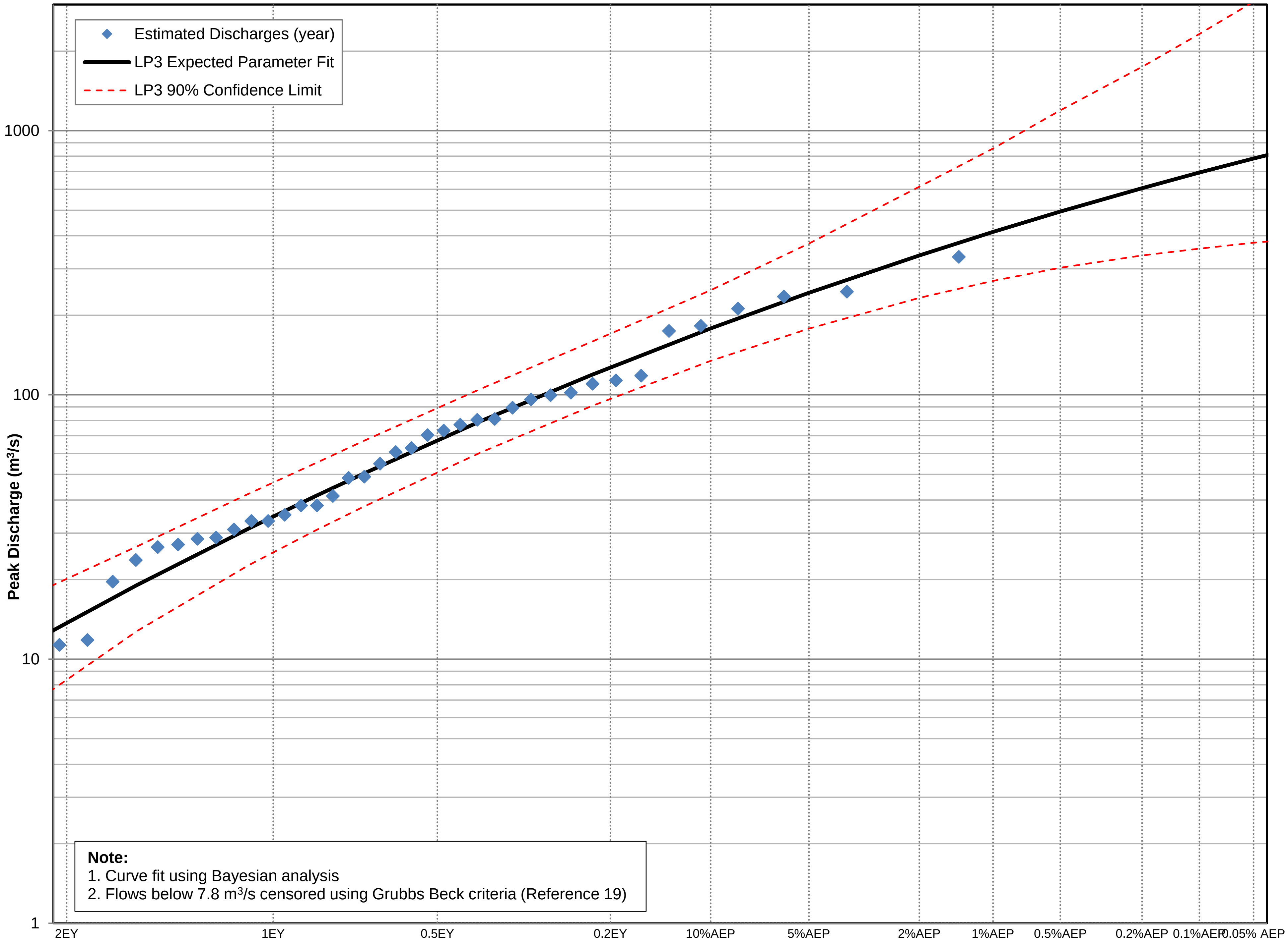


FIGURE 22
FLOOD FREQUENCY ANALYSIS
LP3 JIGADEE GAUGE (211008)
1970 - 2013

J:\Jobs\113016\Hydrology\FFA\DoraCreek_FFA

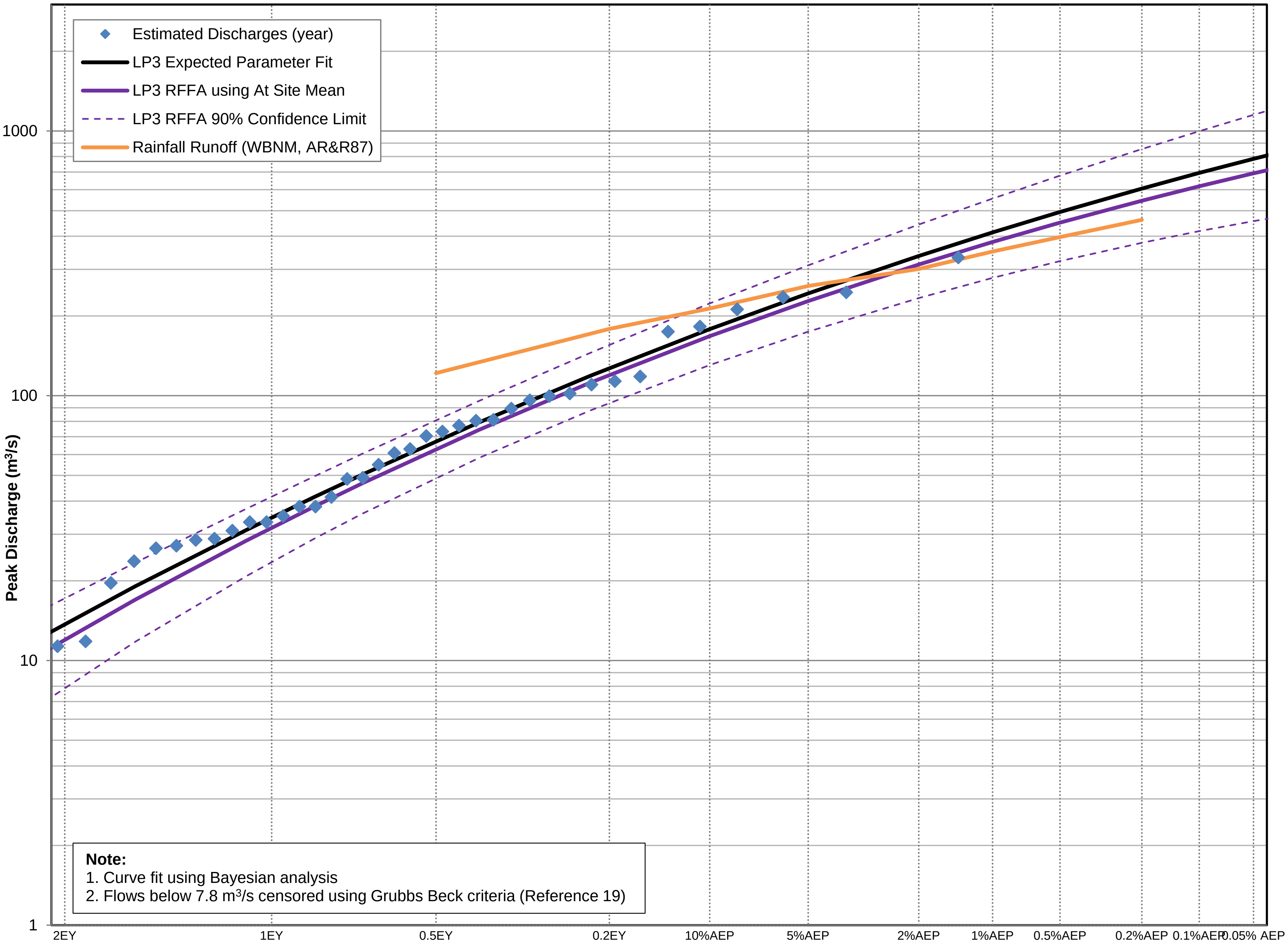
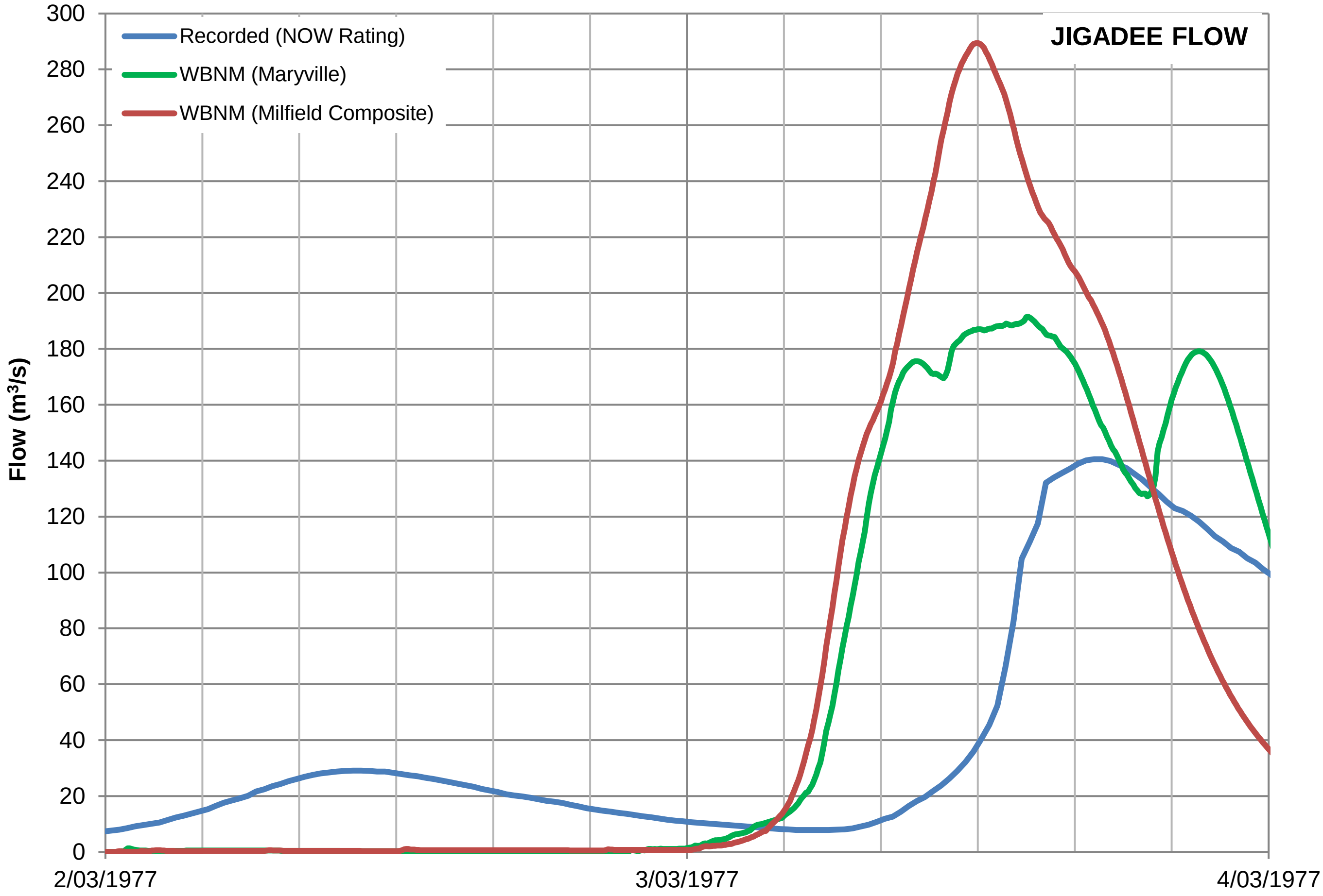


FIGURE 23
COMPARISON OF FLOOD FREQUENCY AND RAINFALL RUNOFF APPROACHES

FIGURE 24
HYDRAULIC CALIBRATION
MARCH 1977 EVENT



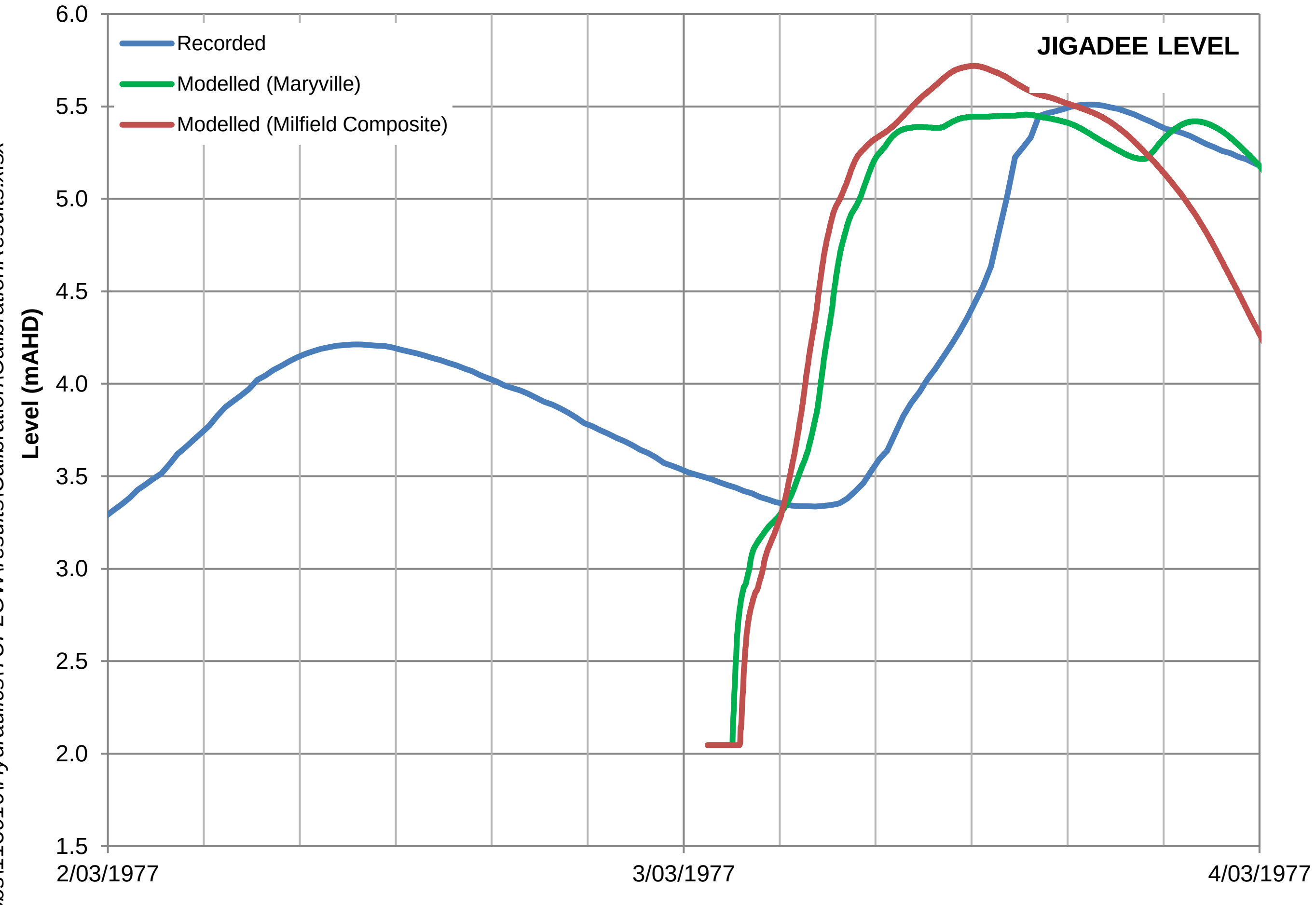


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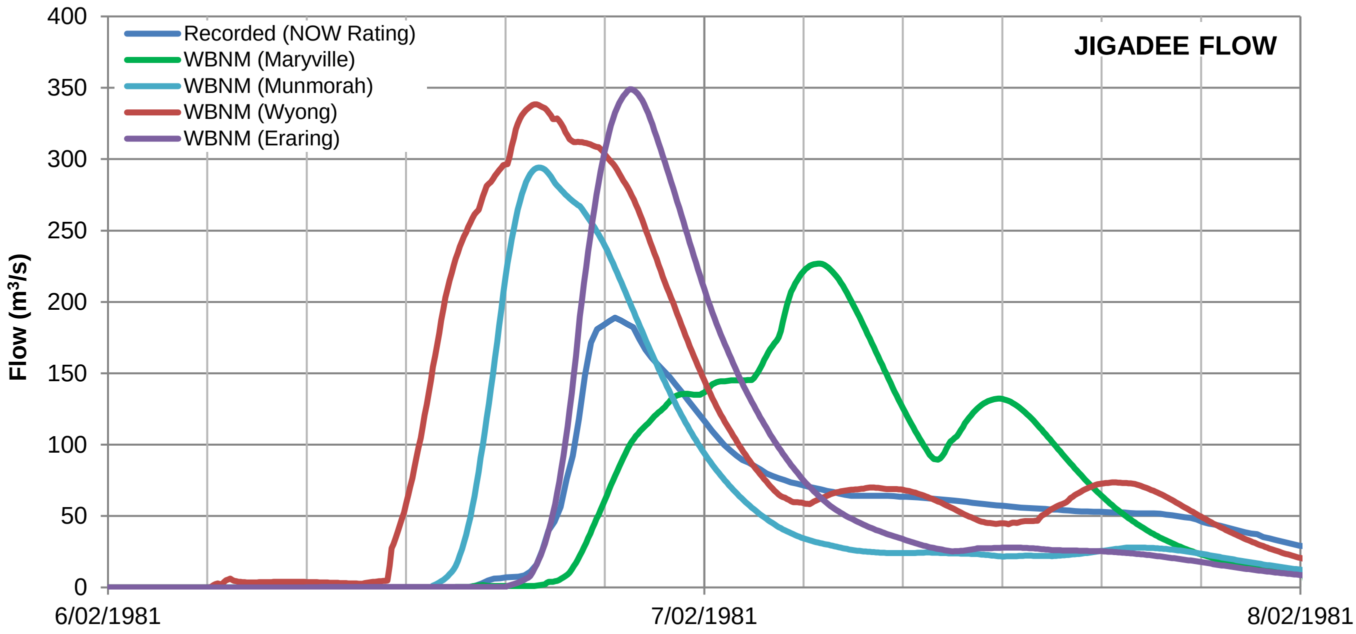
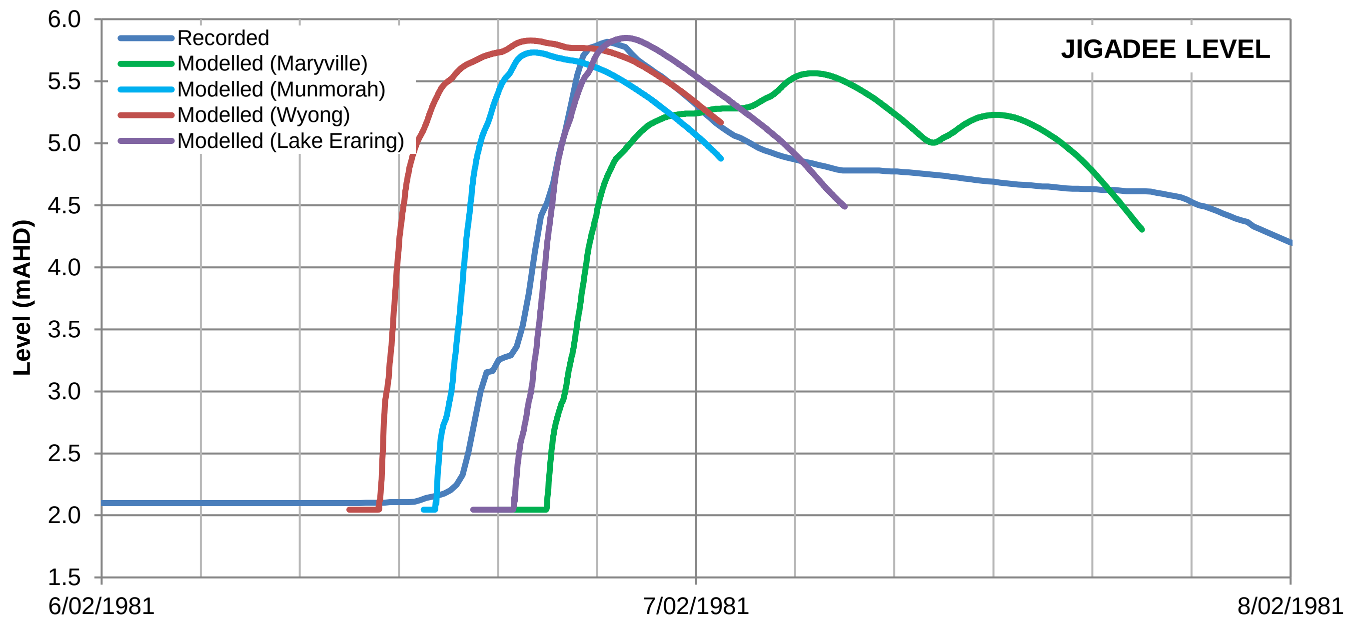
FIGURE 25
HYDRAULIC CALIBRATION
FEBRUARY 1981 EVENT





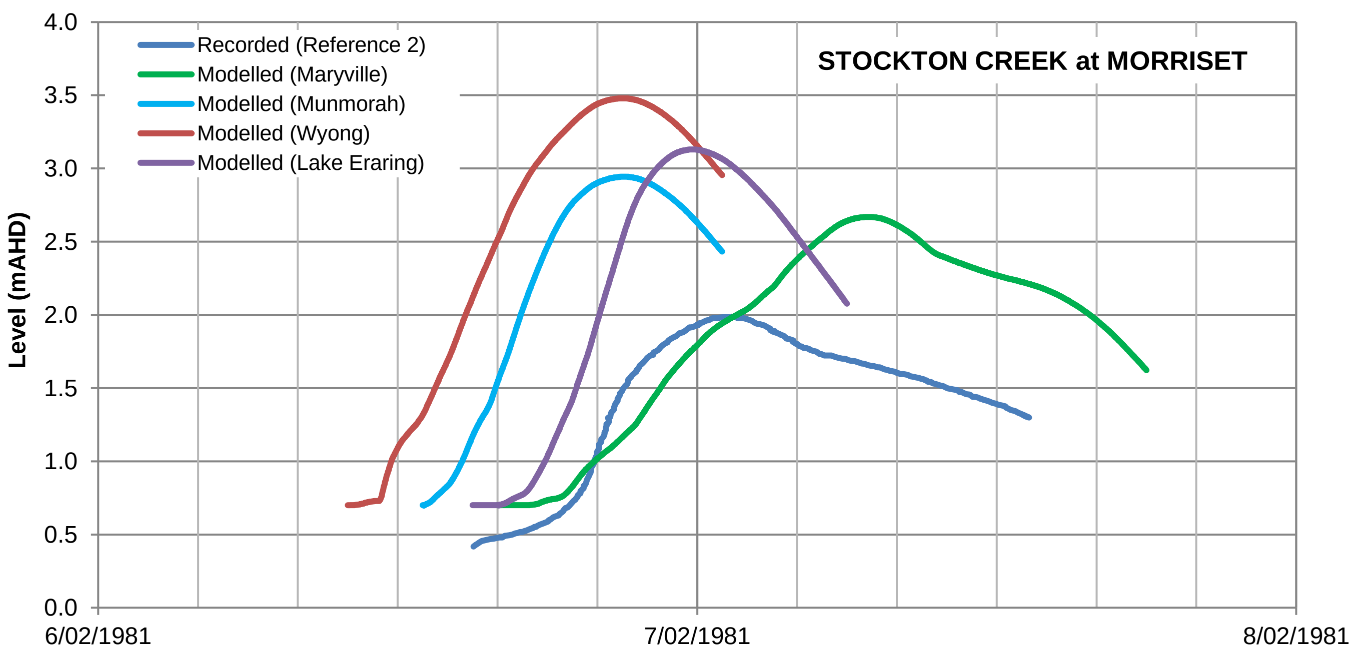


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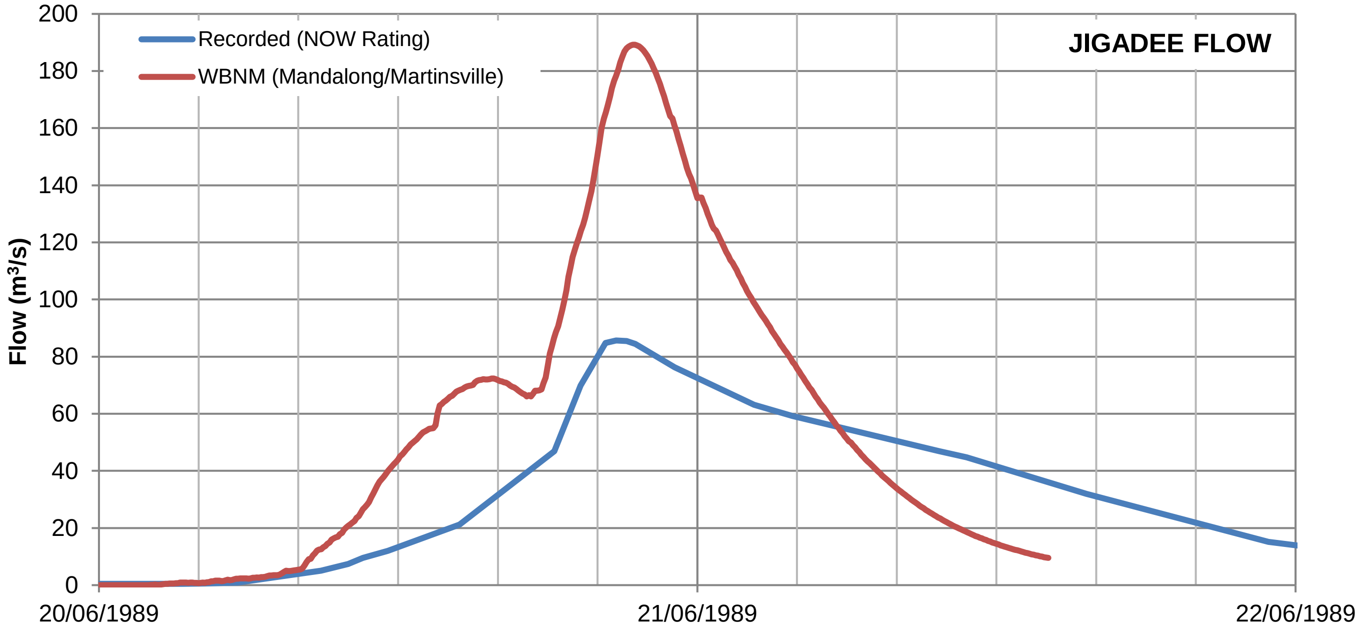
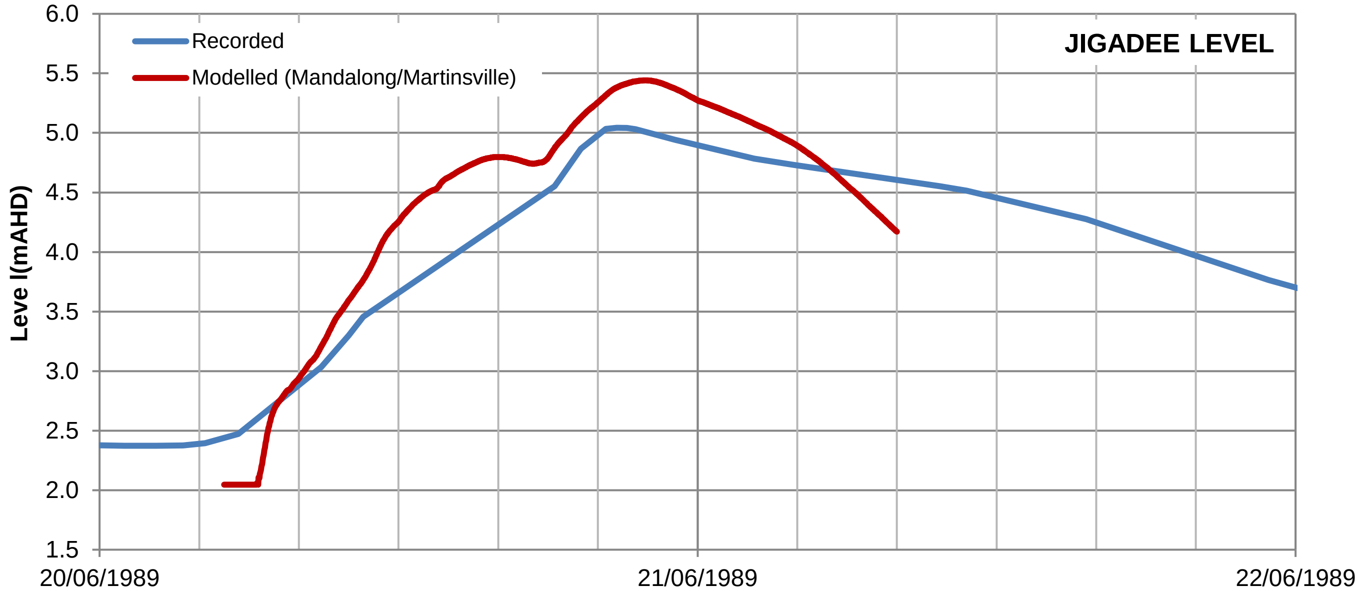
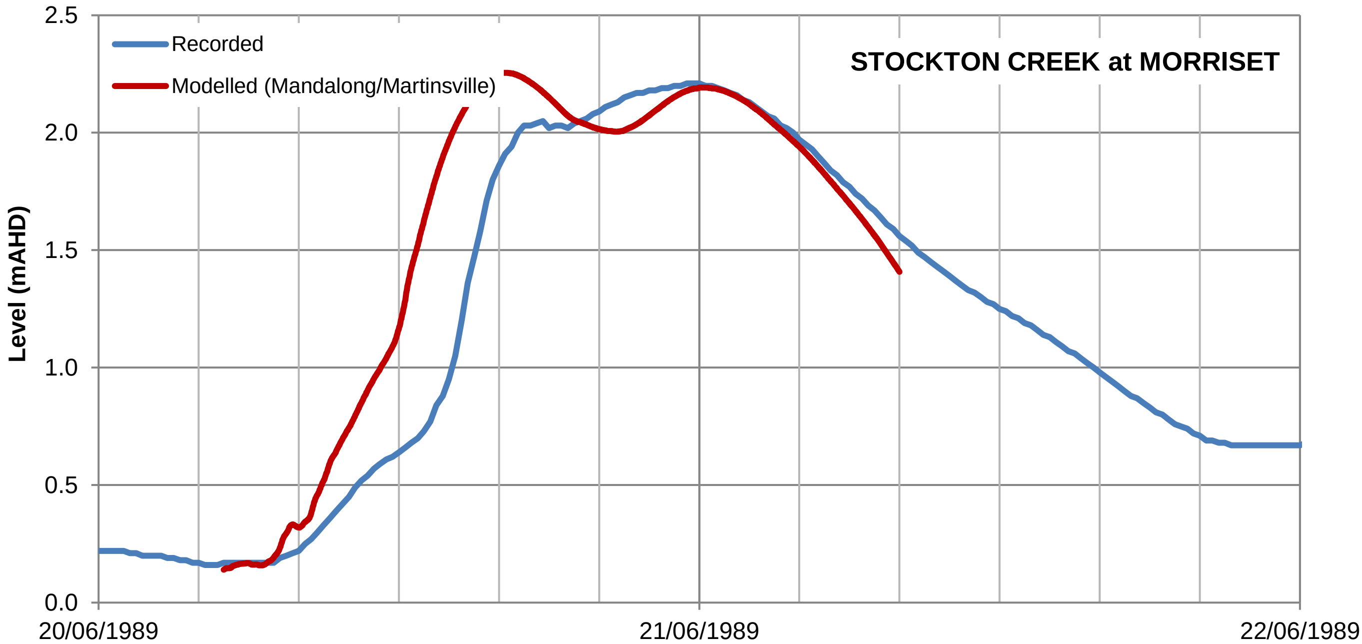
FIGURE 26
HYDRAULIC CALIBRATION
JUNE 1989 EVENT

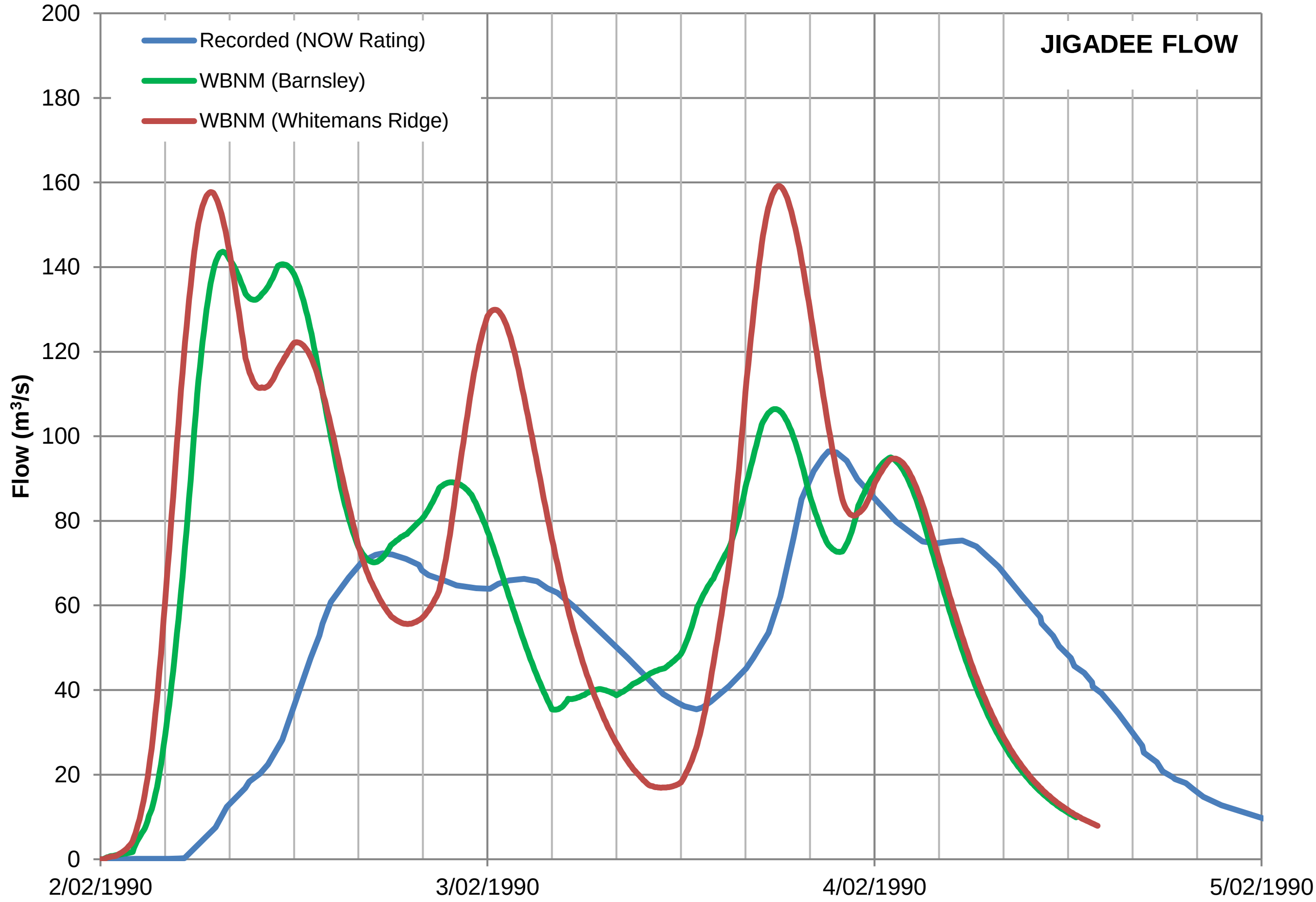






J:\Jobs\113016\Hydraulics\TUFLOW\results\Calibration\CalibrationResults.xlsx

FIGURE 27
HYDRAULIC CALIBRATION
FEBRUARY 1990 EVENT



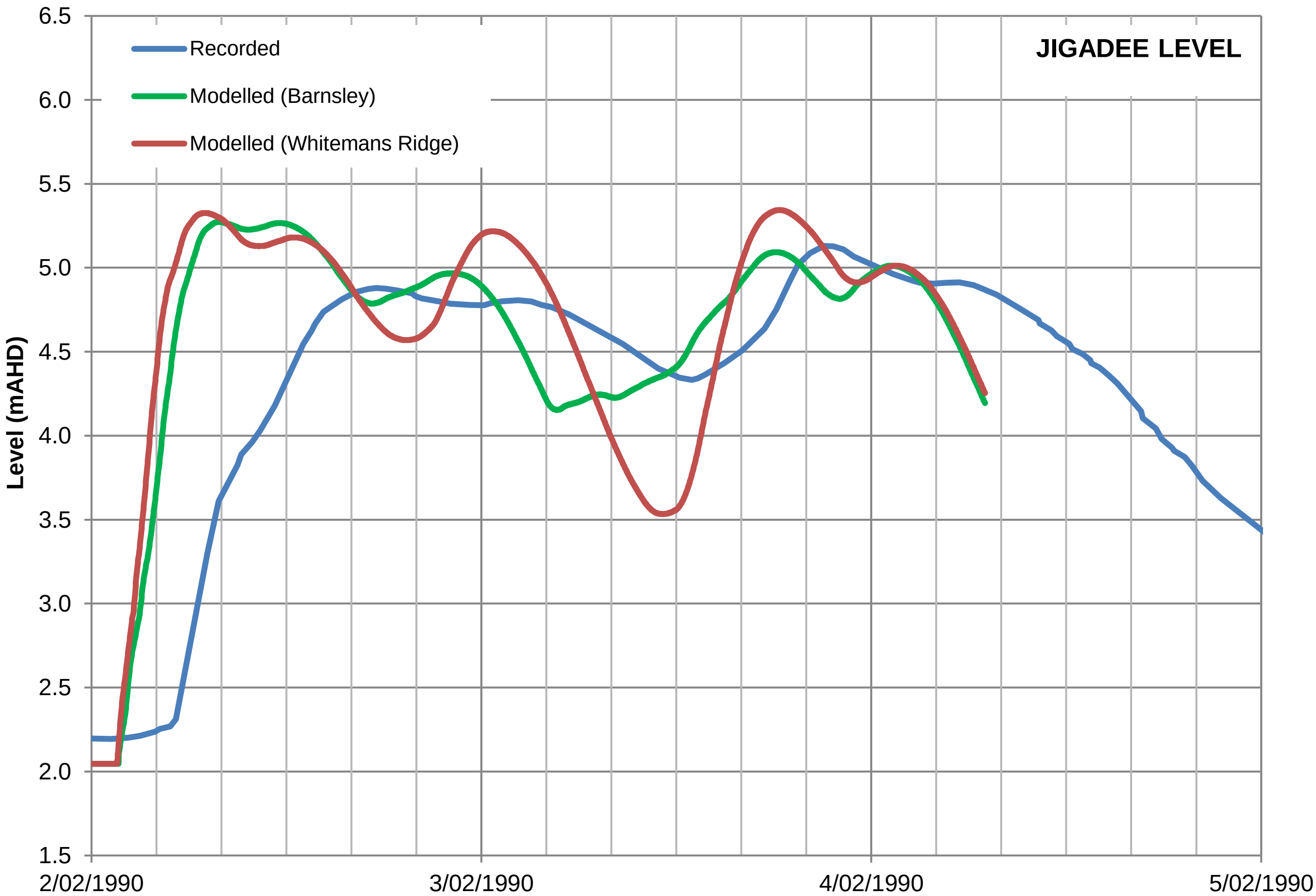


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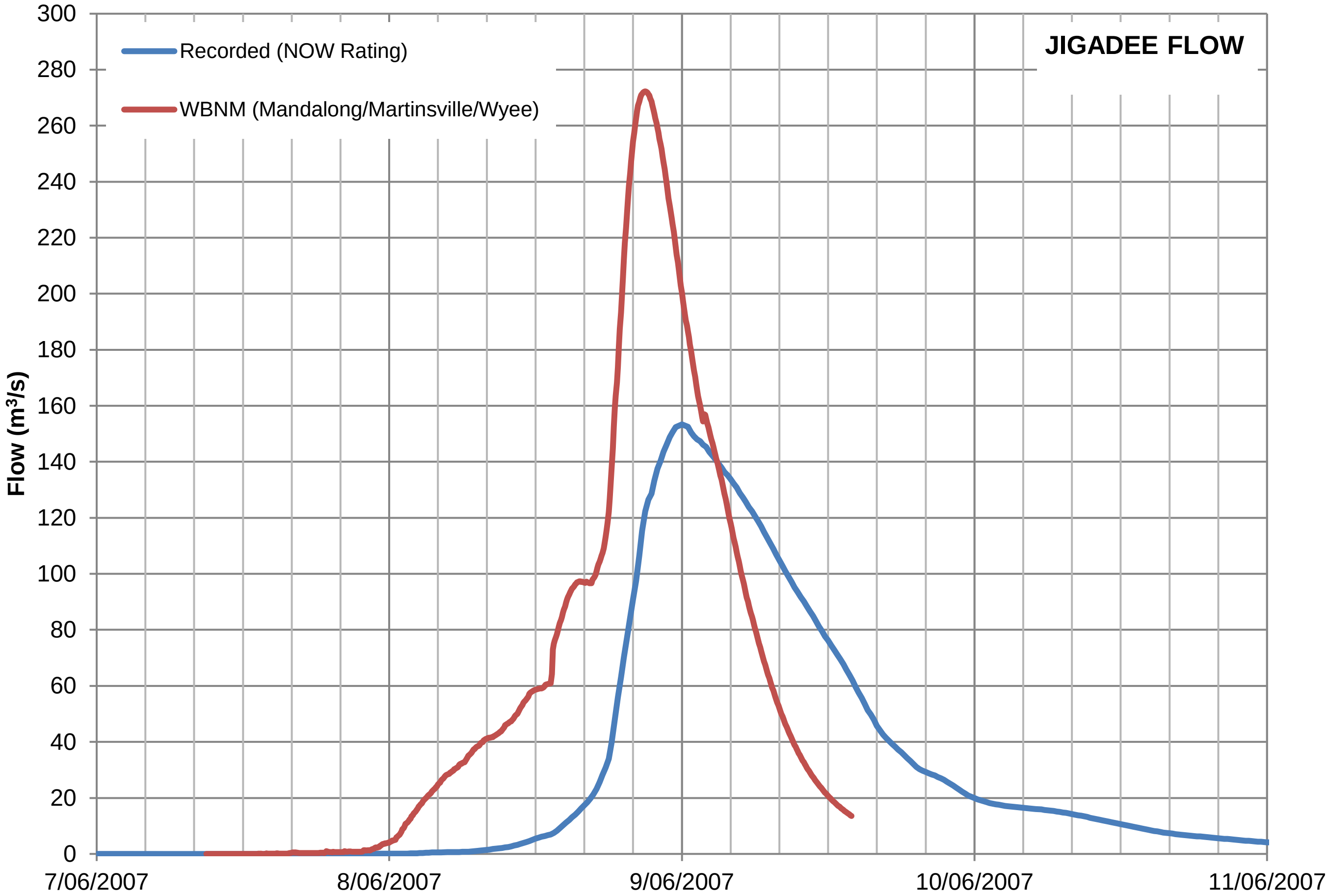
FIGURE 28A
HYDRAULIC CALIBRATION
JUNE 2007 EVENT



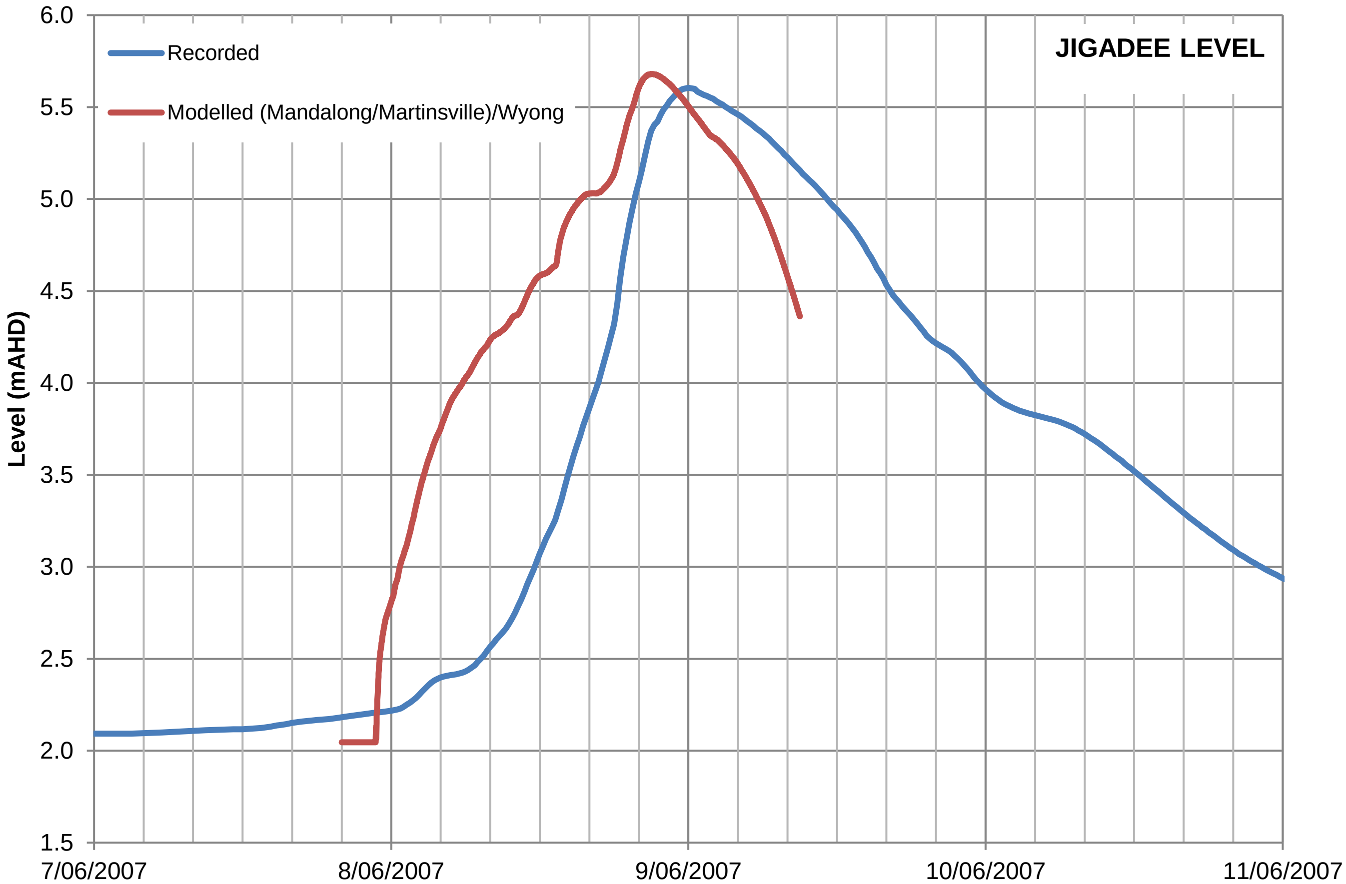


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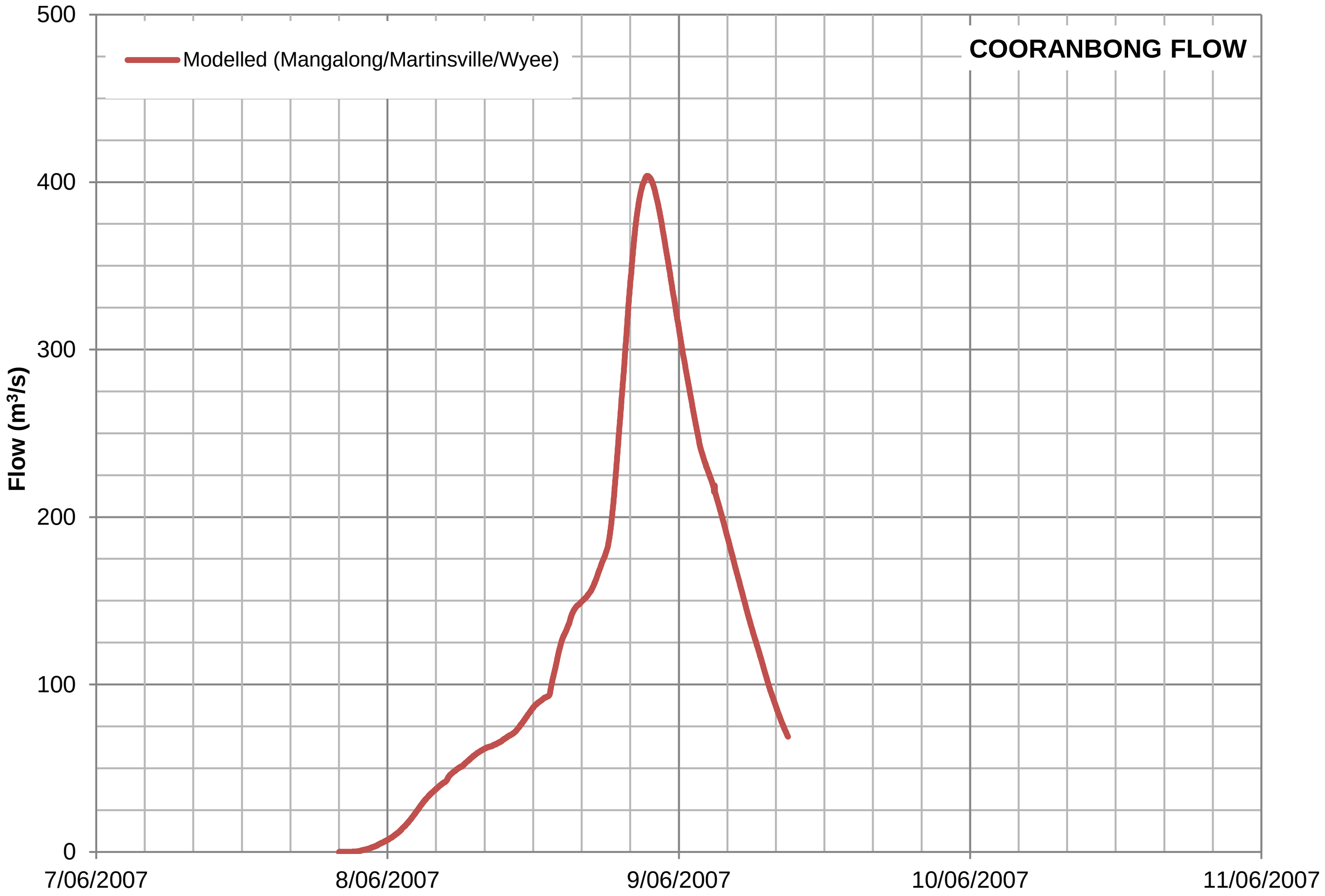
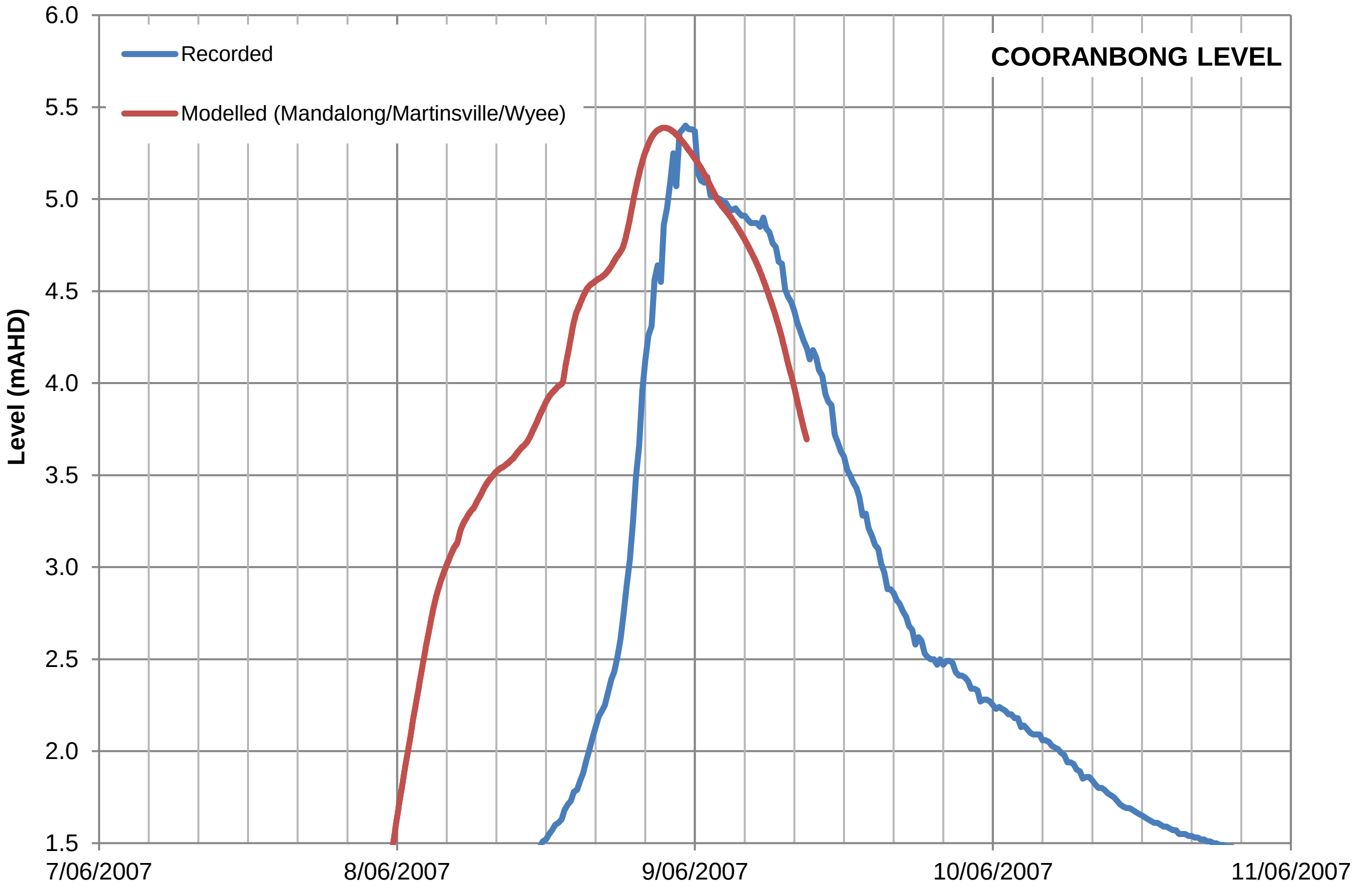
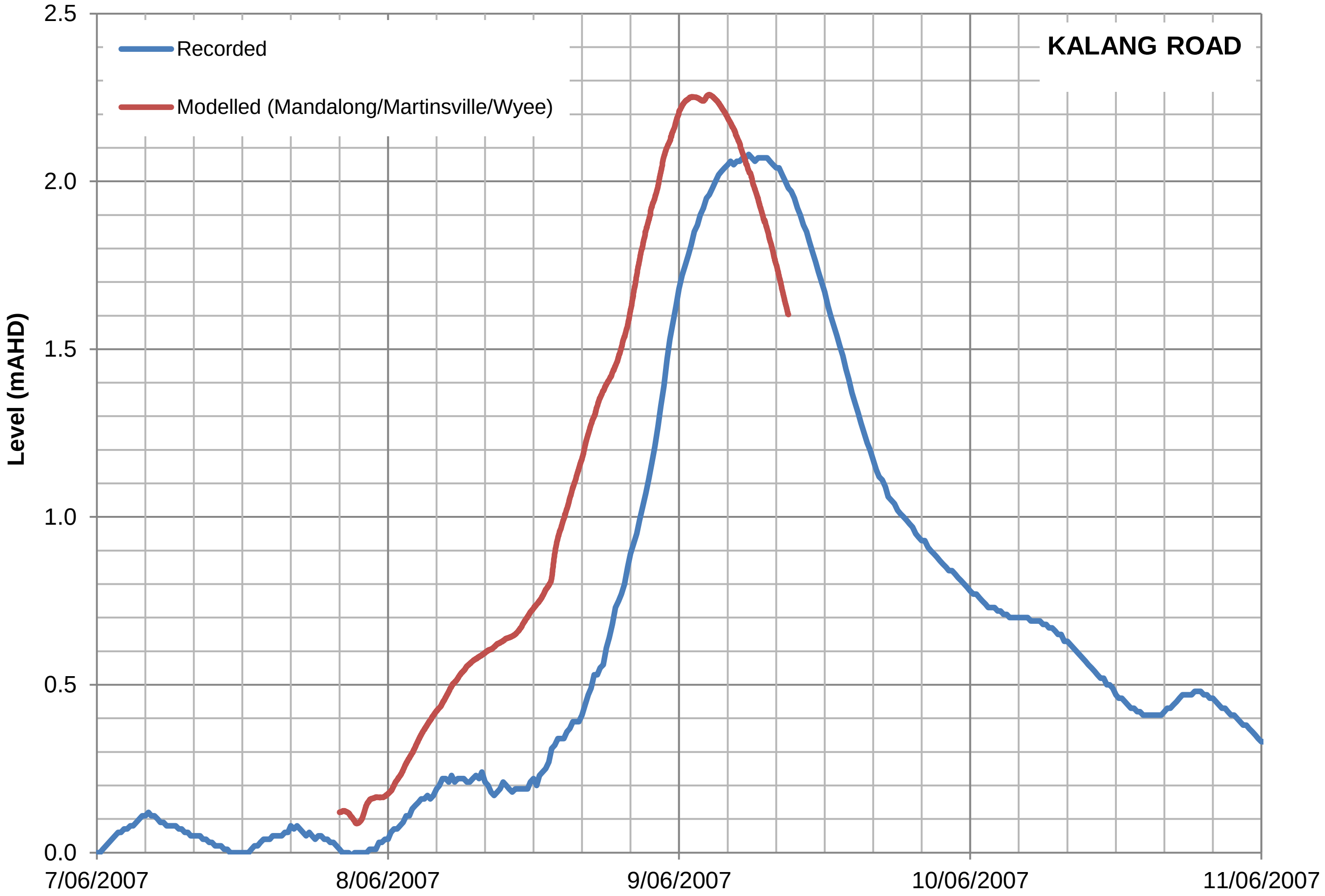
FIGURE 28B
HYDRAULIC CALIBRATION
JUNE 2007 EVENT

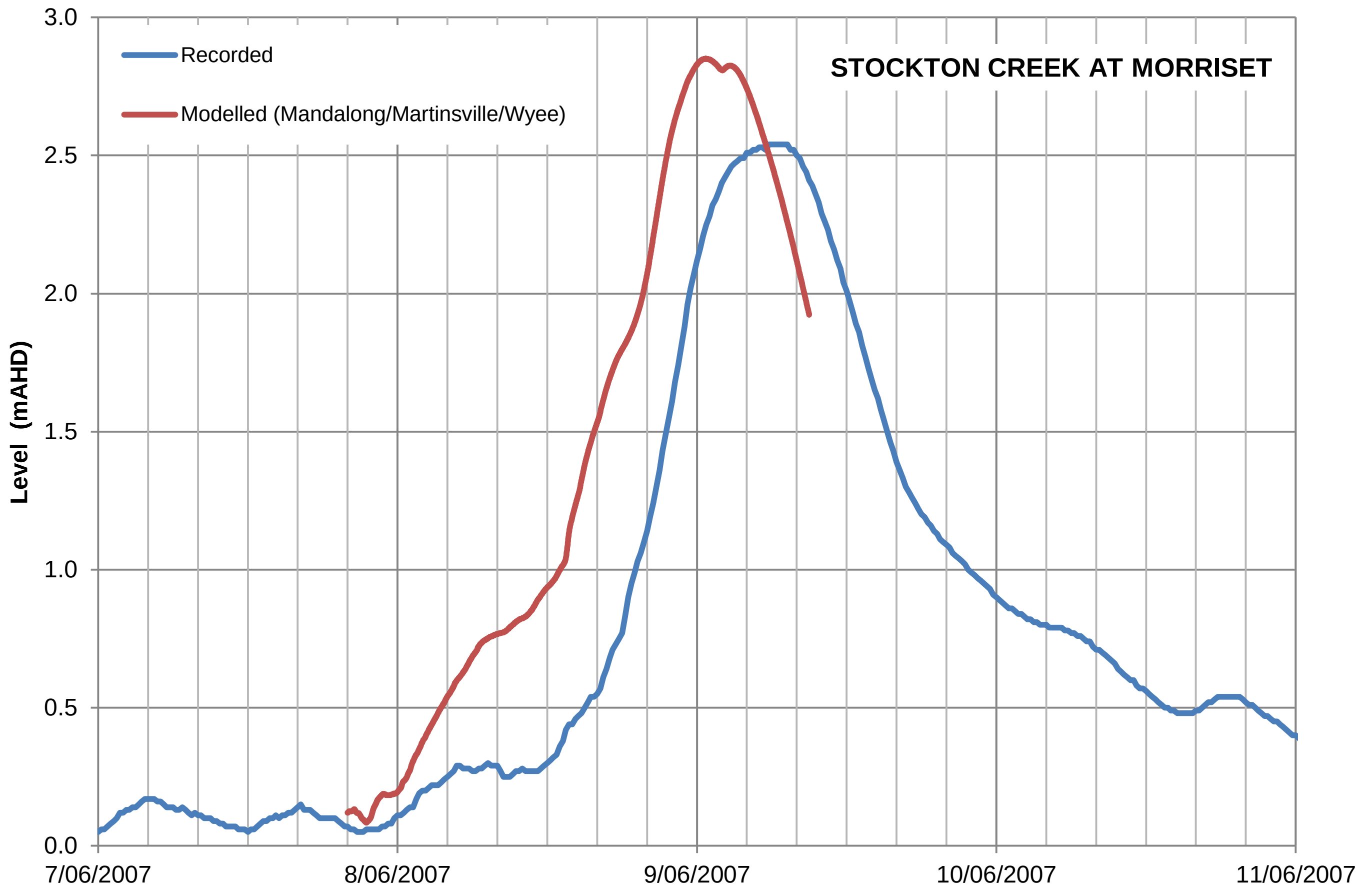




J:\Jobs\113016\Hydraulics\TUFLOW\results\Calibration\CalibrationResults.xlsx

FIGURE 28C
HYDRAULIC CALIBRATION
JUNE 2007 EVENT





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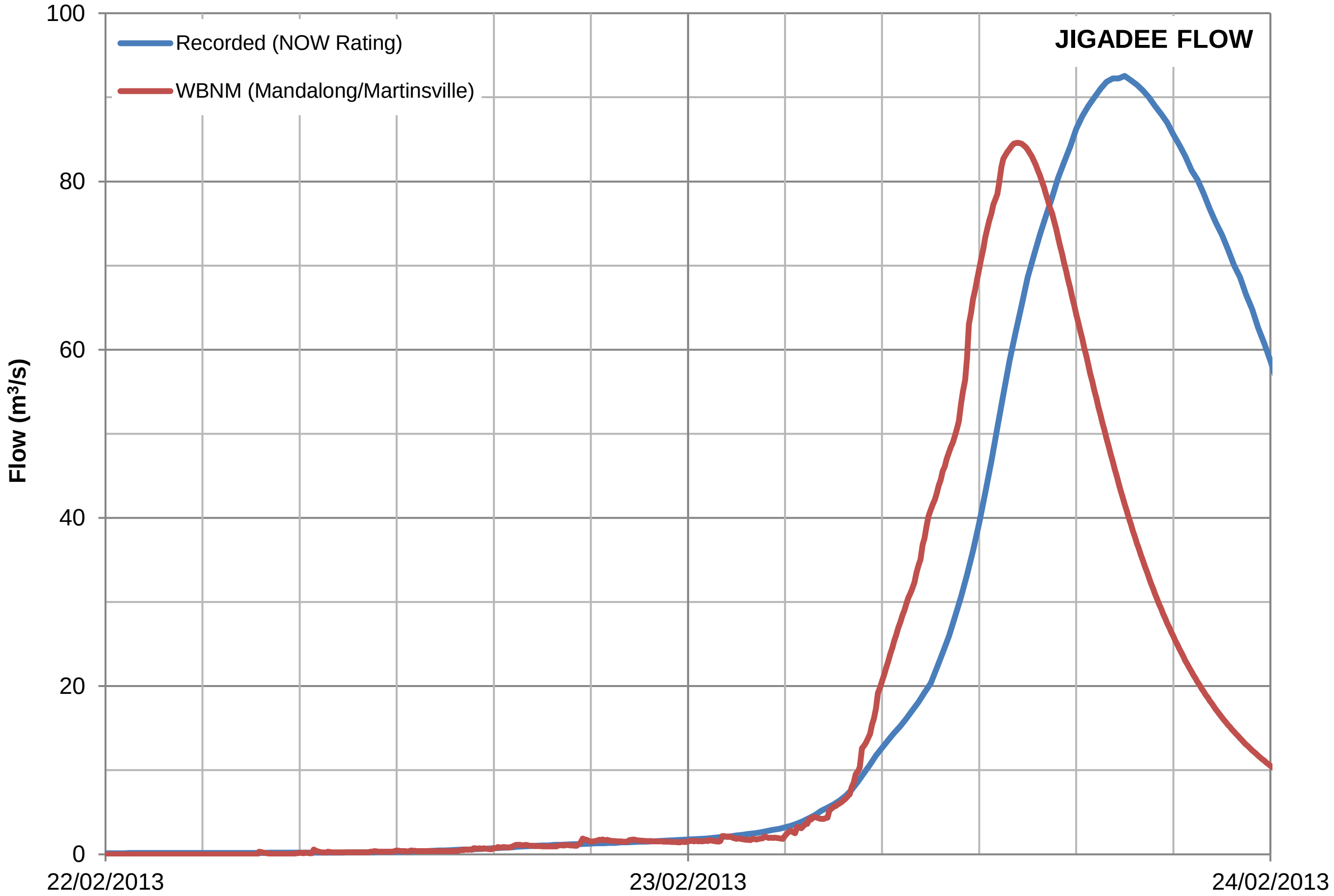
**HYDRAULIC CALIBRATION
FEBRUARY 2013 EVENT**



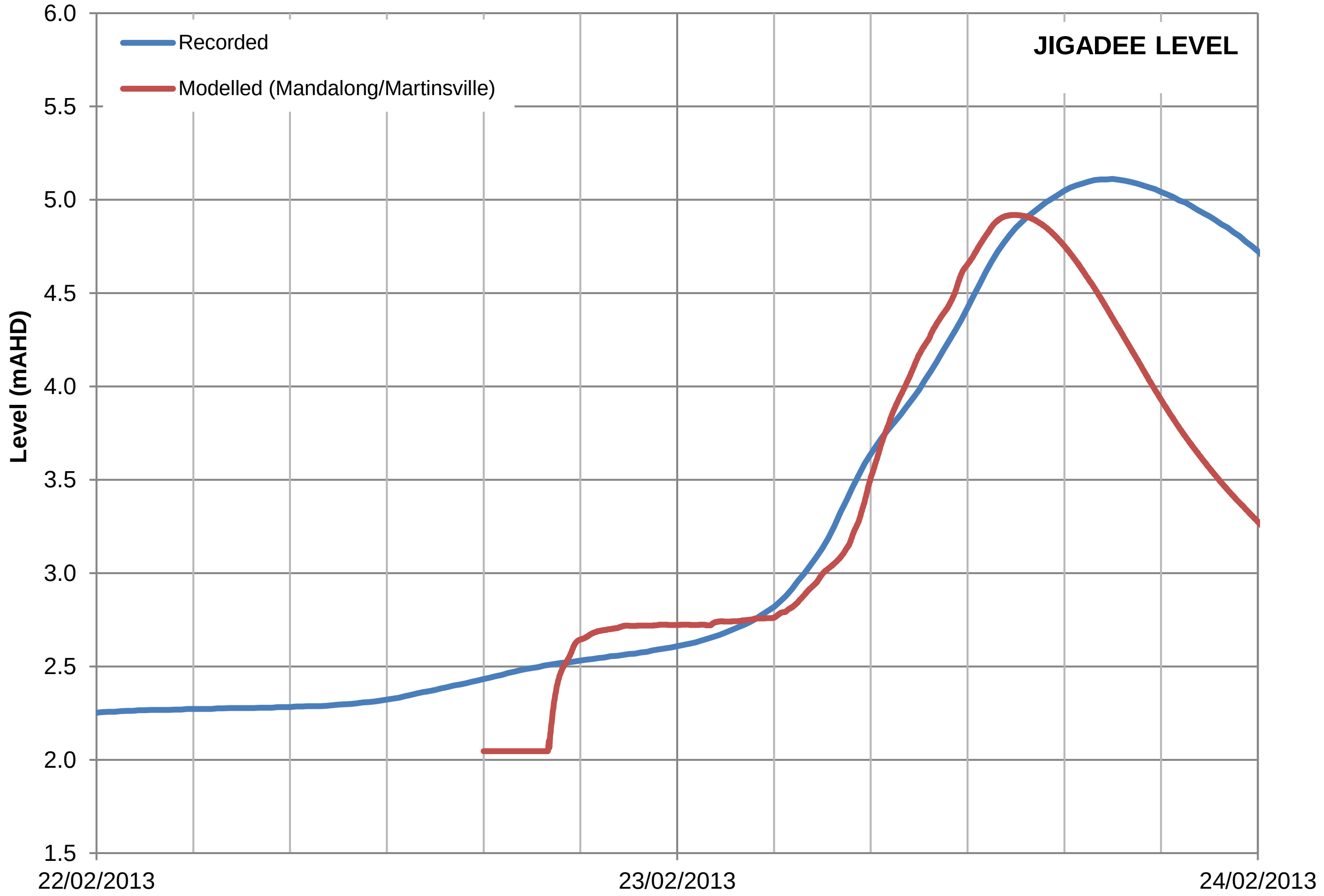
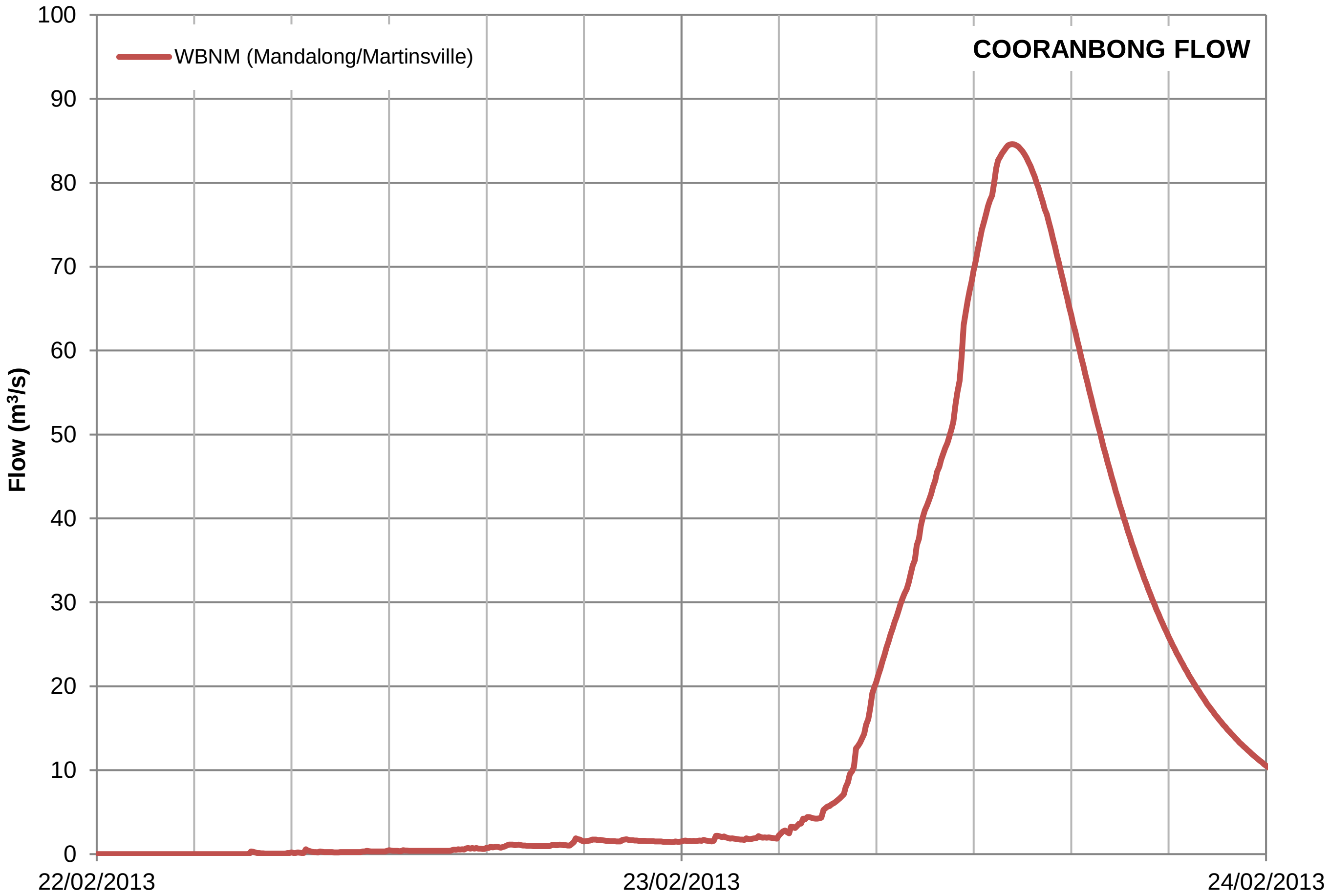
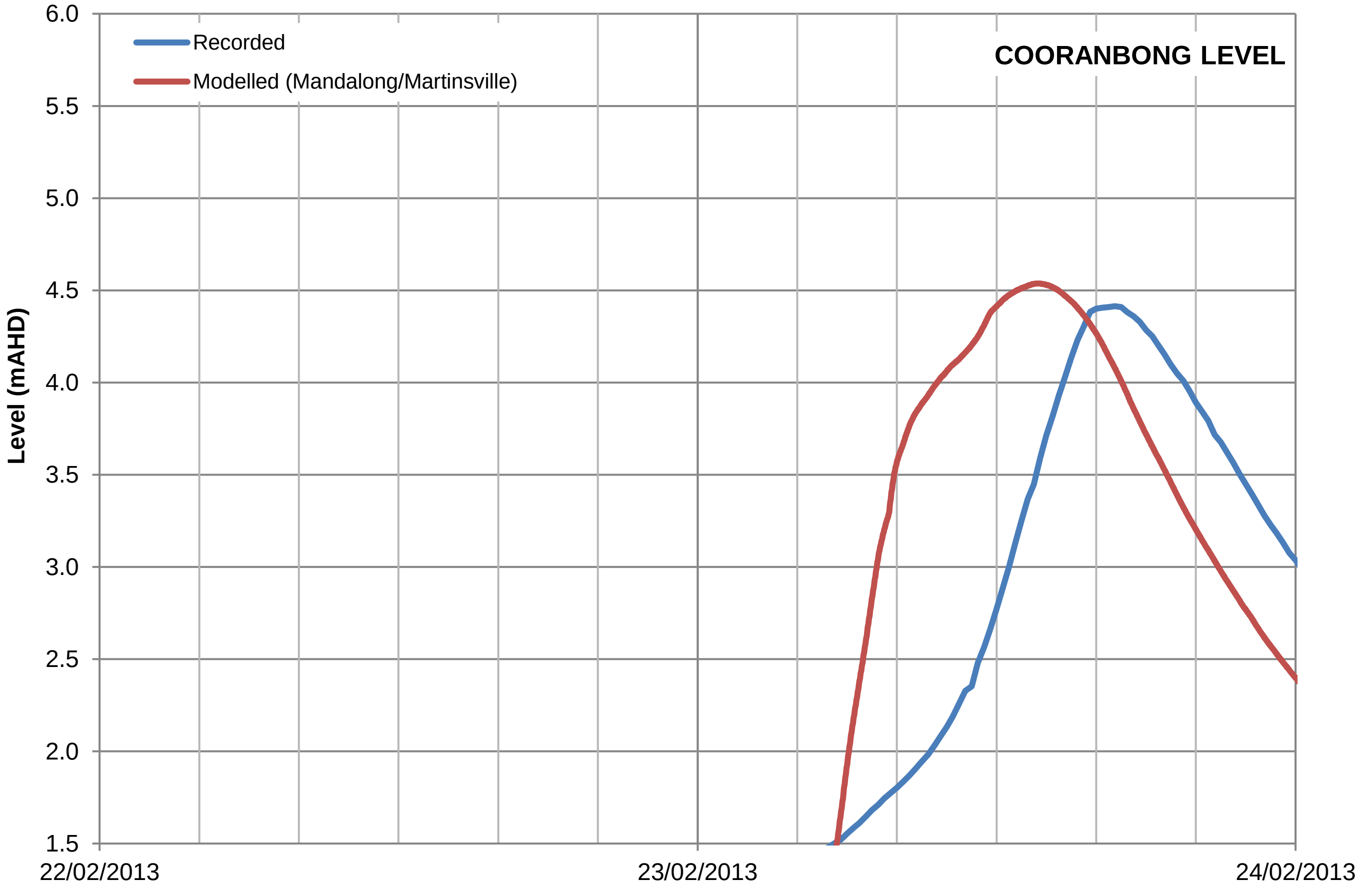


FIGURE 29B
HYDRAULIC CALIBRATION
FEBRAURY 2013 EVENT





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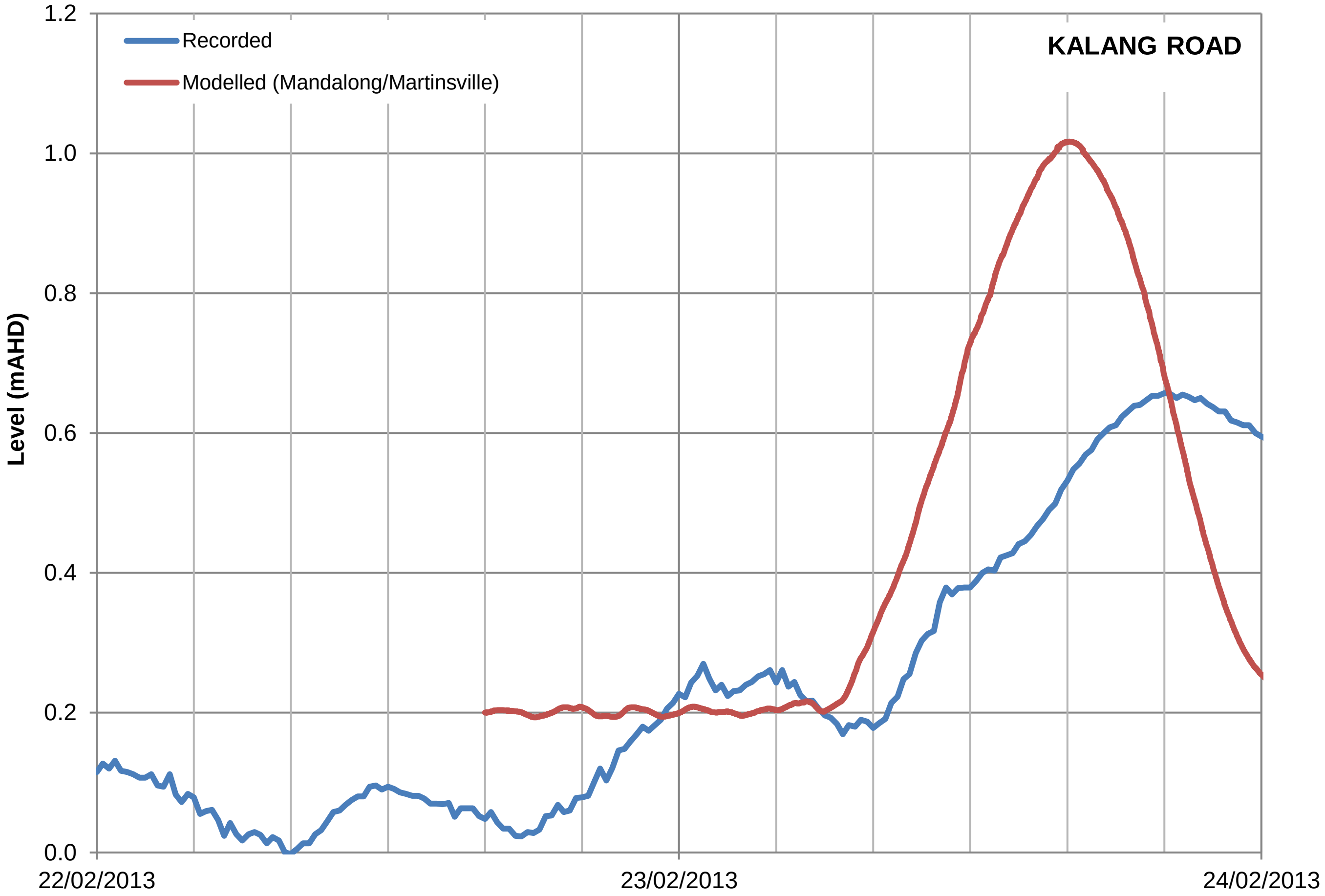
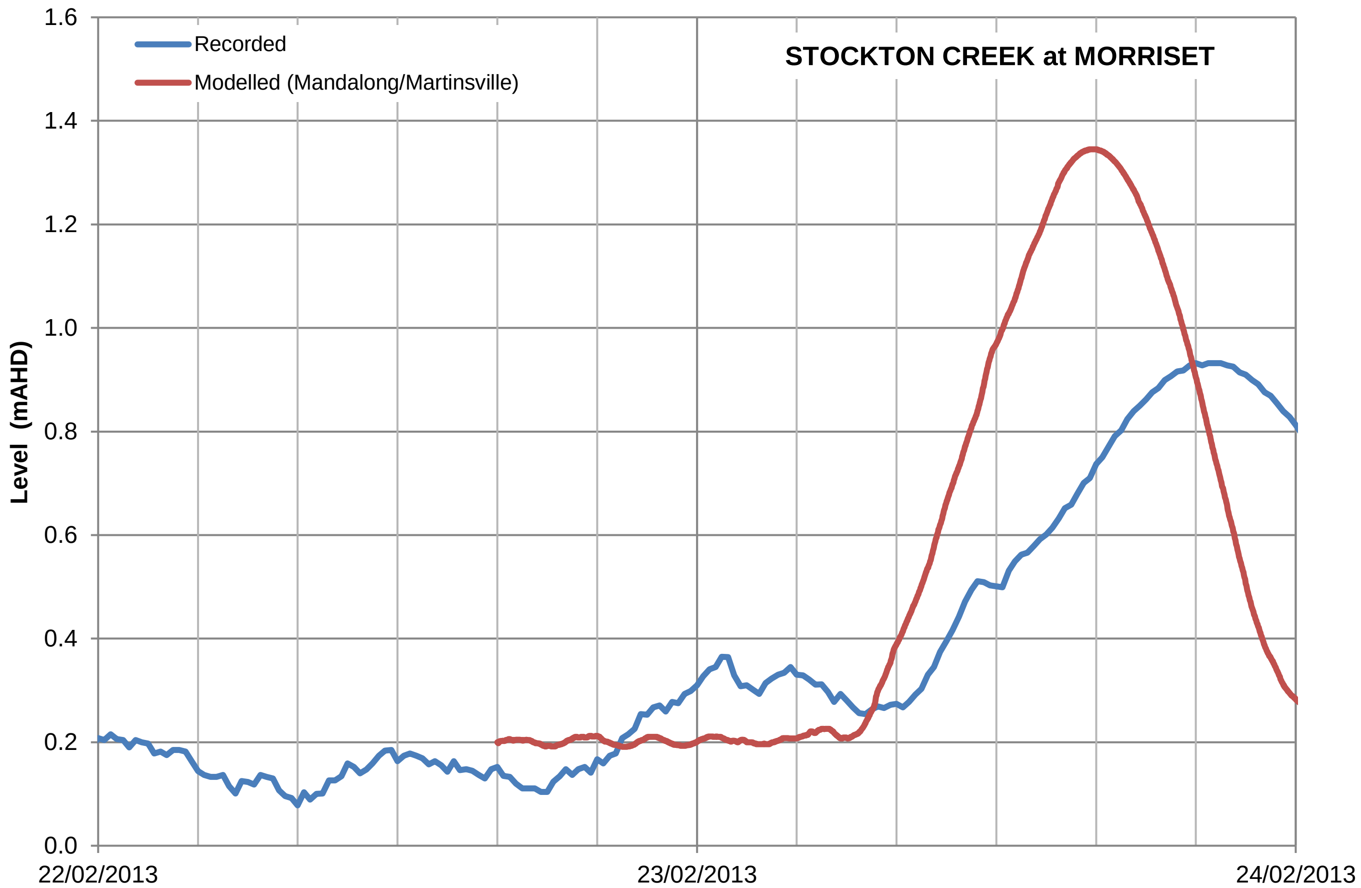
HYDRAULIC CALIBRATION
FEBRAURY 2013 EVENT





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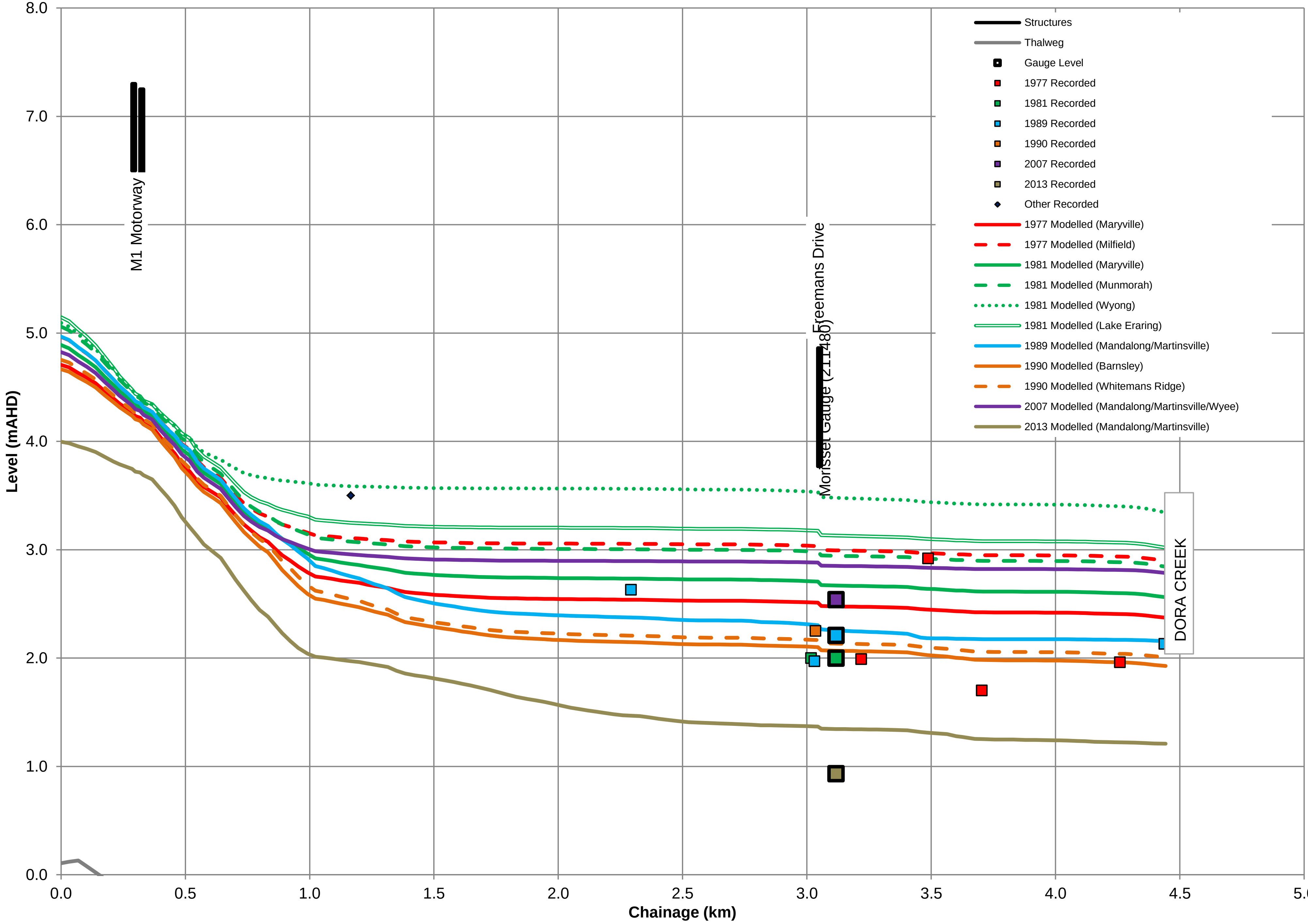

FIGURE 30A
PEAK HEIGHT PROFILES
CALIBRATION EVENTS
STOCKTON CREEK

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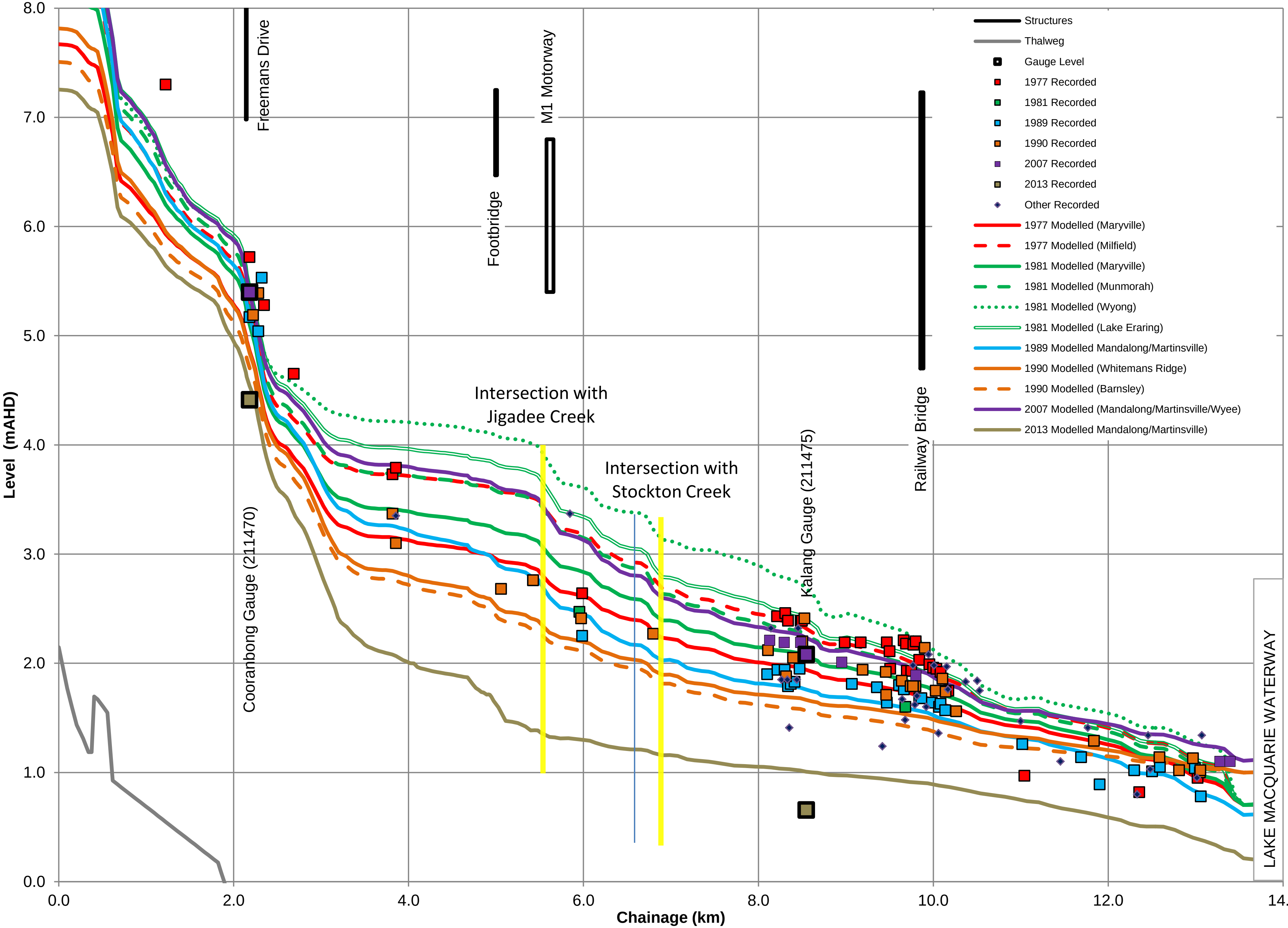

FIGURE 30B
PEAK HEIGHT PROFILES CALIBRATION EVENTS DORA CREEK

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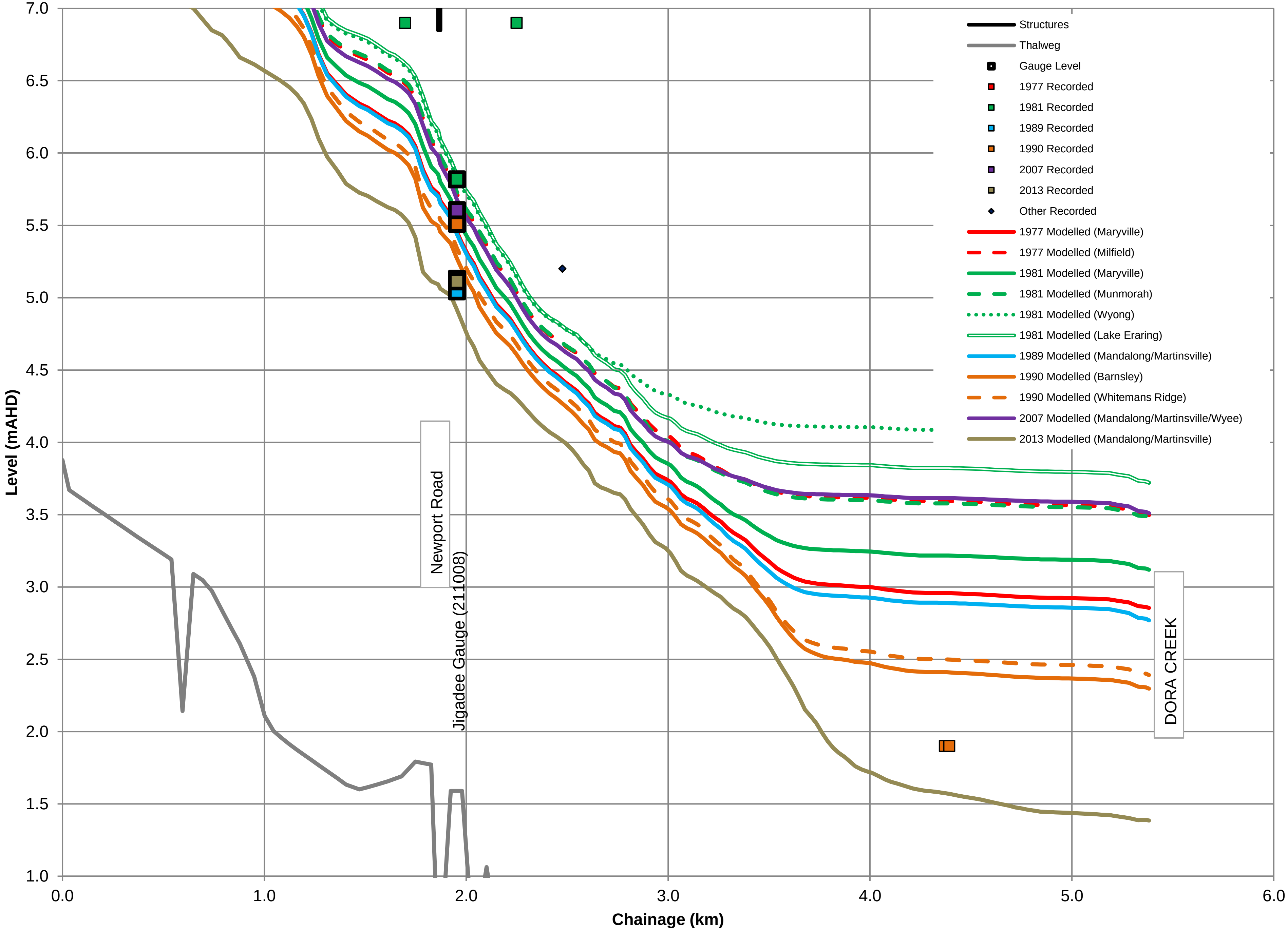


FIGURE 30C
PEAK HEIGHT PROFILES
CALIBRATION EVENTS
JIGADEE CREEK

FIGURE 31
FLOOD LEVEL COMPARISON MARCH 1977 EVENT

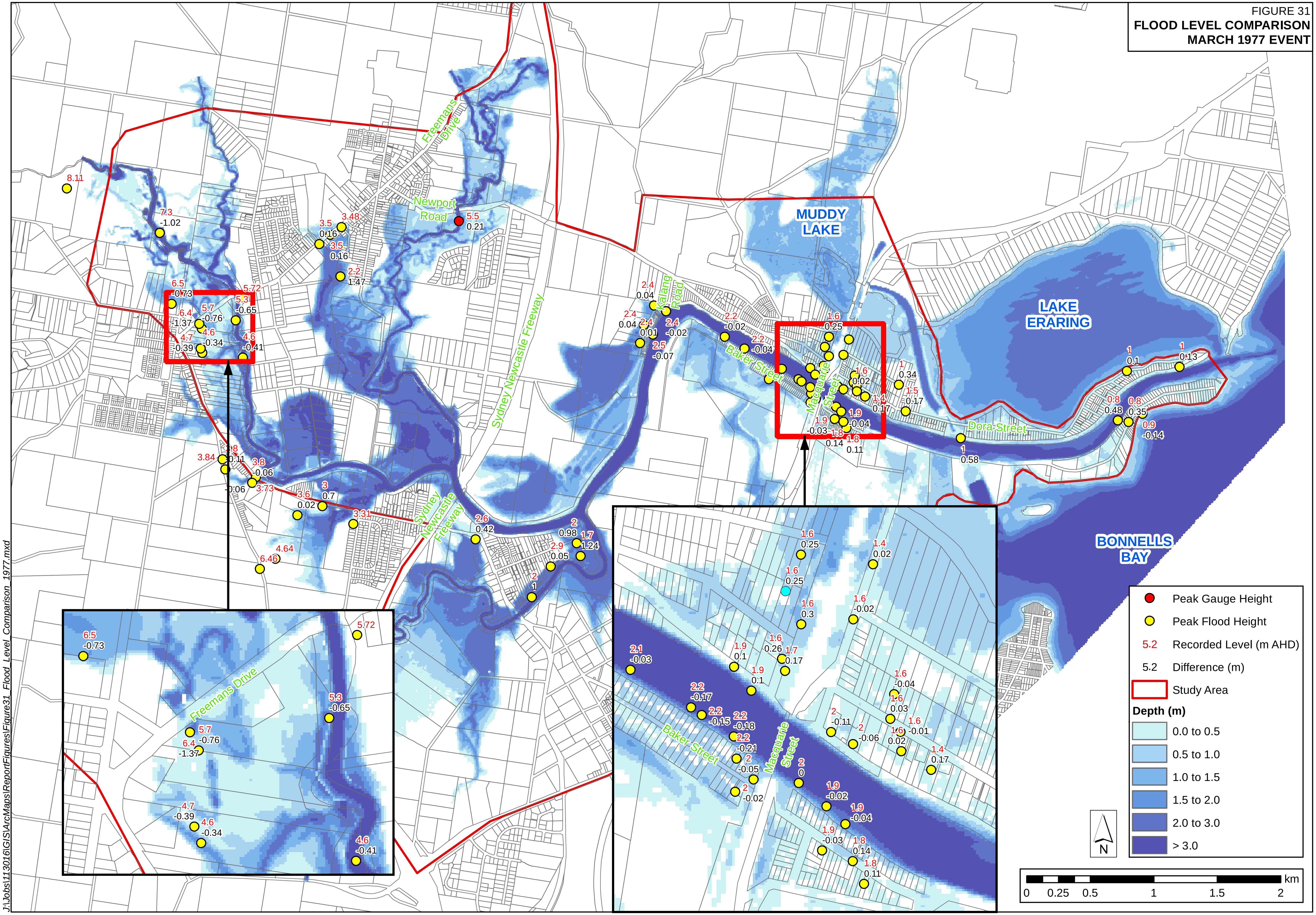
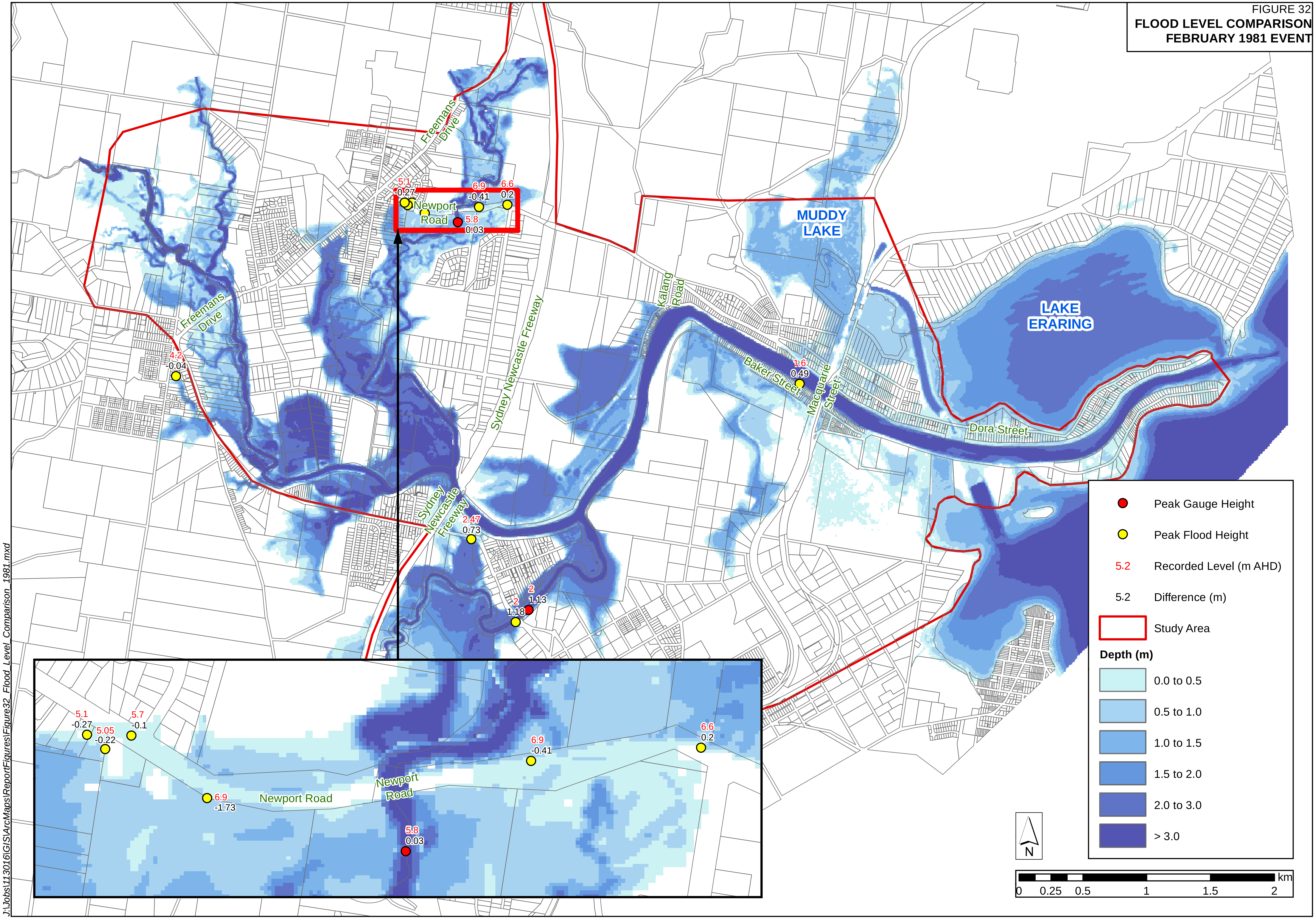


FIGURE 32
FLOOD LEVEL COMPARISON
FEBRUARY 1981 EVENT



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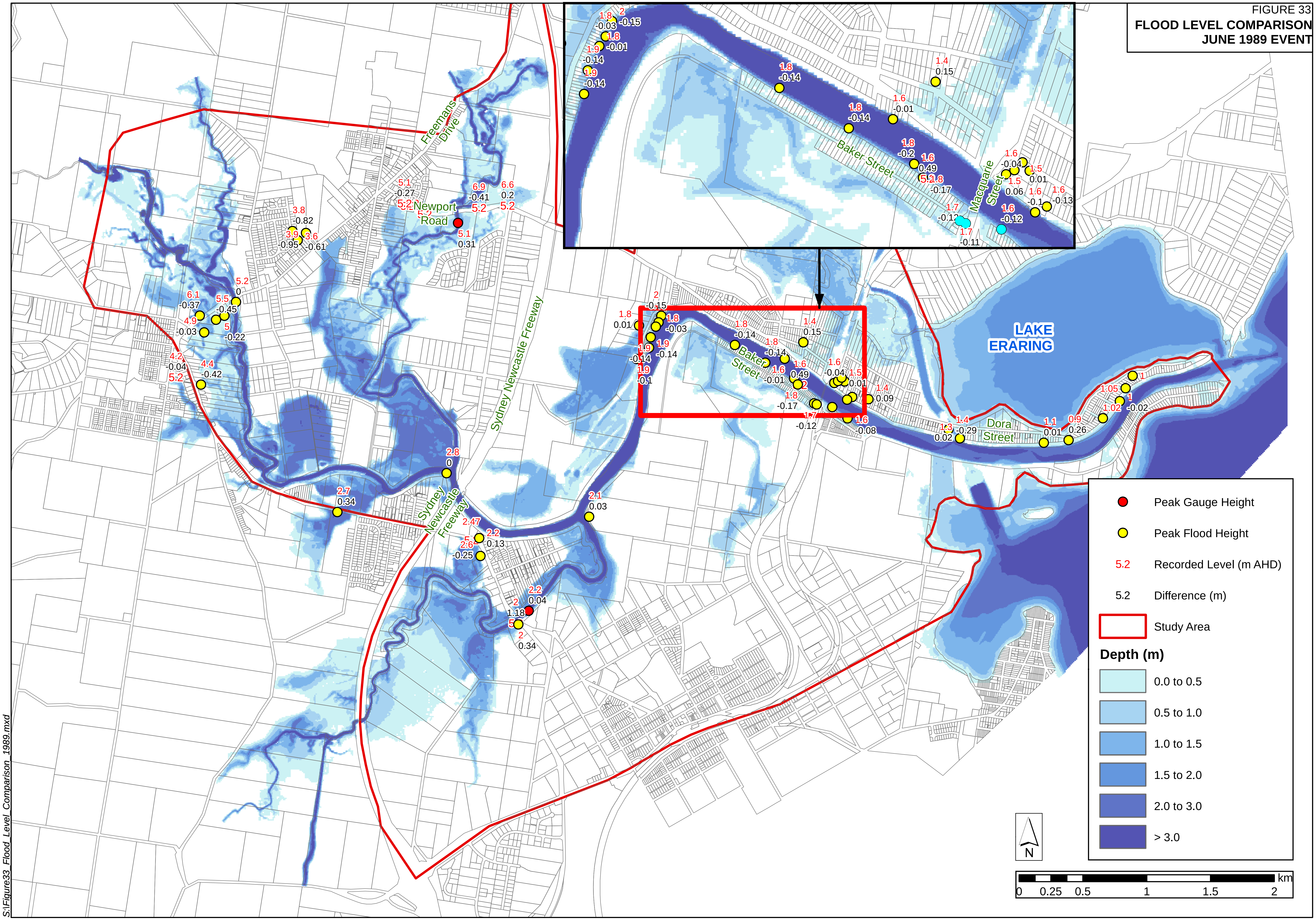

FIGURE 33
FLOOD LEVEL COMPARISON
JUNE 1989 EVENT
LAKE ERARING
Baker Street
Macquarie Street
Dora Street
Newport Road
Freemans Drive
Sydney Newcastle Freeway
Peak Gauge Height
Peak Flood Height
5.2 Recorded Level (m AHD)
5.2 Difference (m)
Study Area
Depth (m)
0.0 to 0.5
0.5 to 1.0
1.0 to 1.5
1.5 to 2.0
2.0 to 3.0
> 3.0
N
0 0.25 0.5 1 1.5 2 km
S:\Figure33_Flood_Level_Comparison_1989.mxd

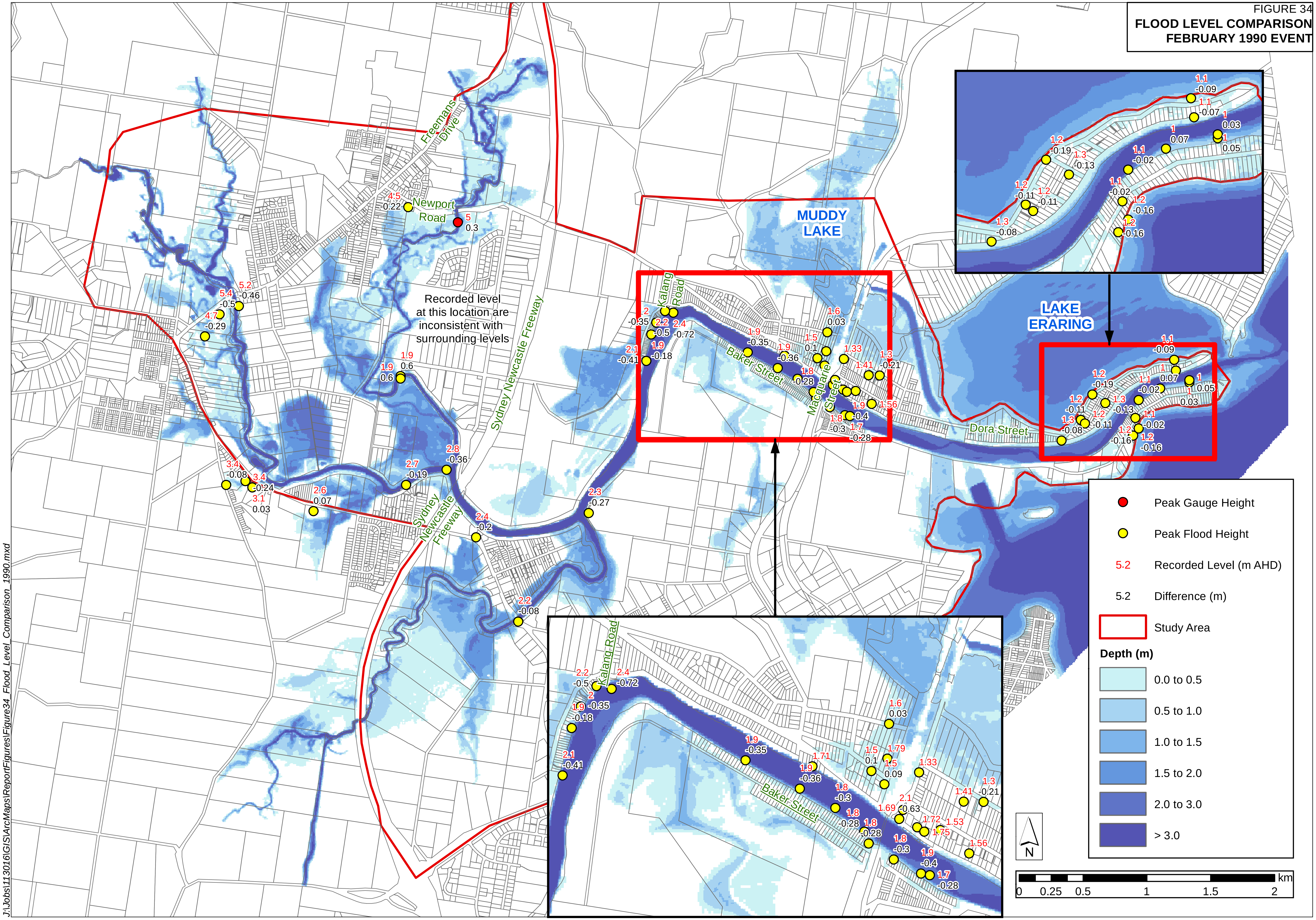

FIGURE 34
FLOOD LEVEL COMPARISON
FEBRUARY 1990 EVENT
MUDDY LAKE
LAKE ERARING
Freemans Drive
Newport Road
Sydney Newcastle Freeway
Kalang Road
Baker Street
Macquarie Street
Dora Street
Recorded level at this location are inconsistent with surrounding levels
Peak Gauge Height
Peak Flood Height
5.2 Recorded Level (m AHD)
5.2 Difference (m)
Study Area
Depth (m)
0.0 to 0.5
0.5 to 1.0
1.0 to 1.5
1.5 to 2.0
2.0 to 3.0
> 3.0
N
km
0 0.25 0.5 1 1.5 2
J:\Jobs\113016\GIS\ArcMaps\ReportFigures\Figure34_Flood_Level_Comparison_1990.mxd

FIGURE 35
FLOOD LEVEL COMPARISON
JUNE 2007 EVENT

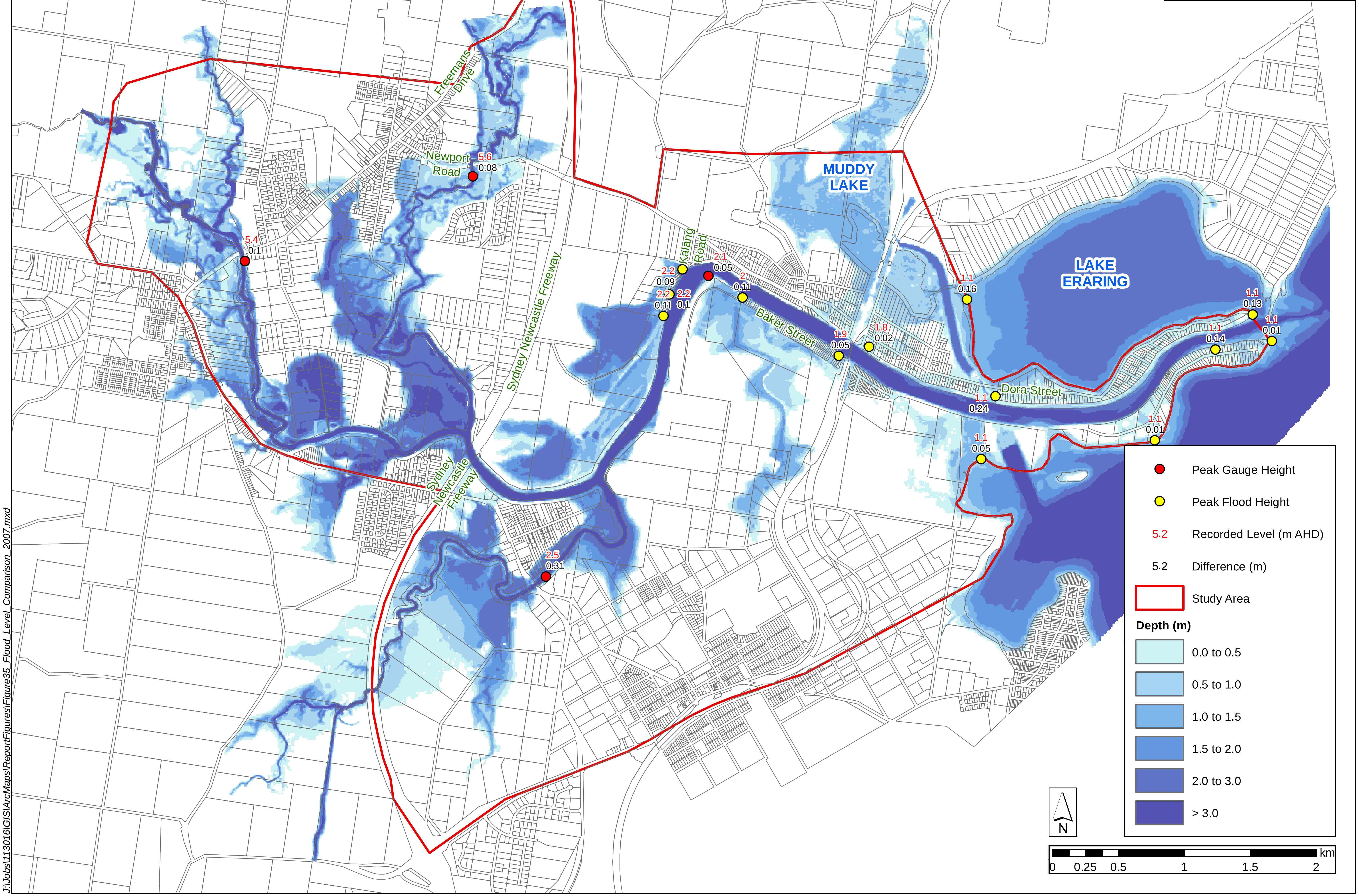

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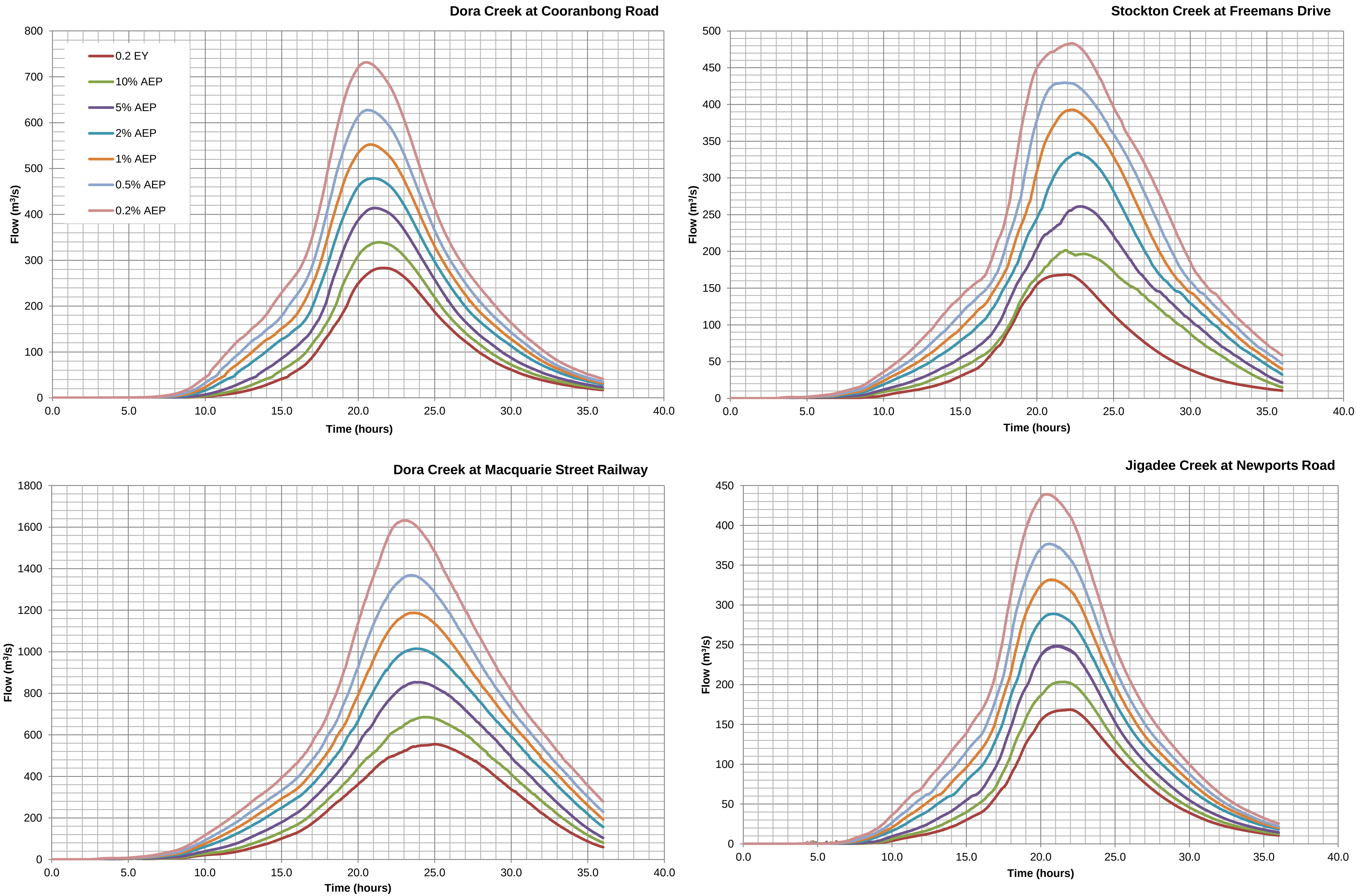
FIGURE 36
DESIGN FLOW HYDROGRAPHS



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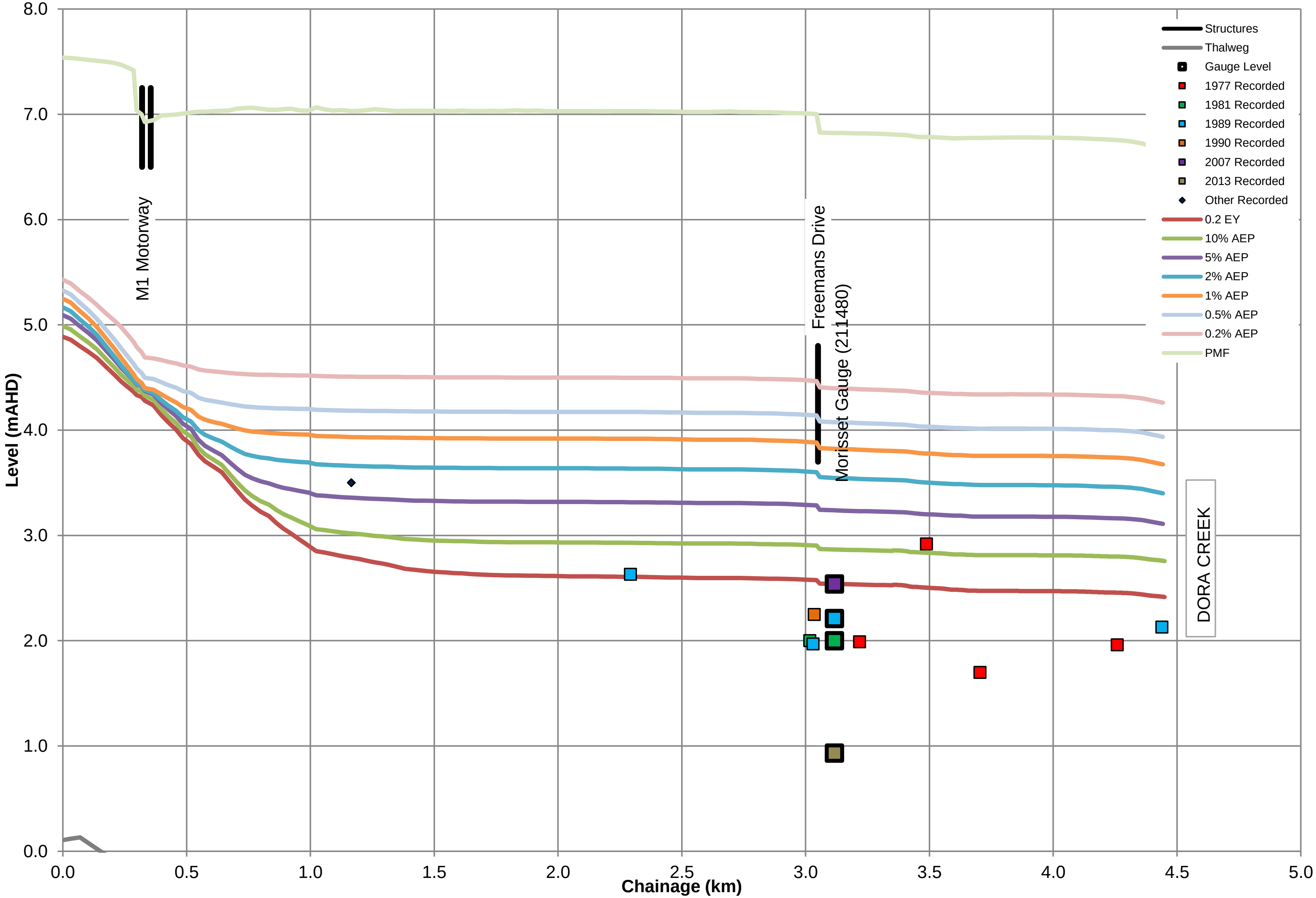


FIGURE 37A
PEAK HEIGHT PROFILES
DESIGN EVENTS
STOCKTON CREEK

J:\Jobs\113016\Hydraulics\TUFLOW\results\Design\DesignResults.xlsx

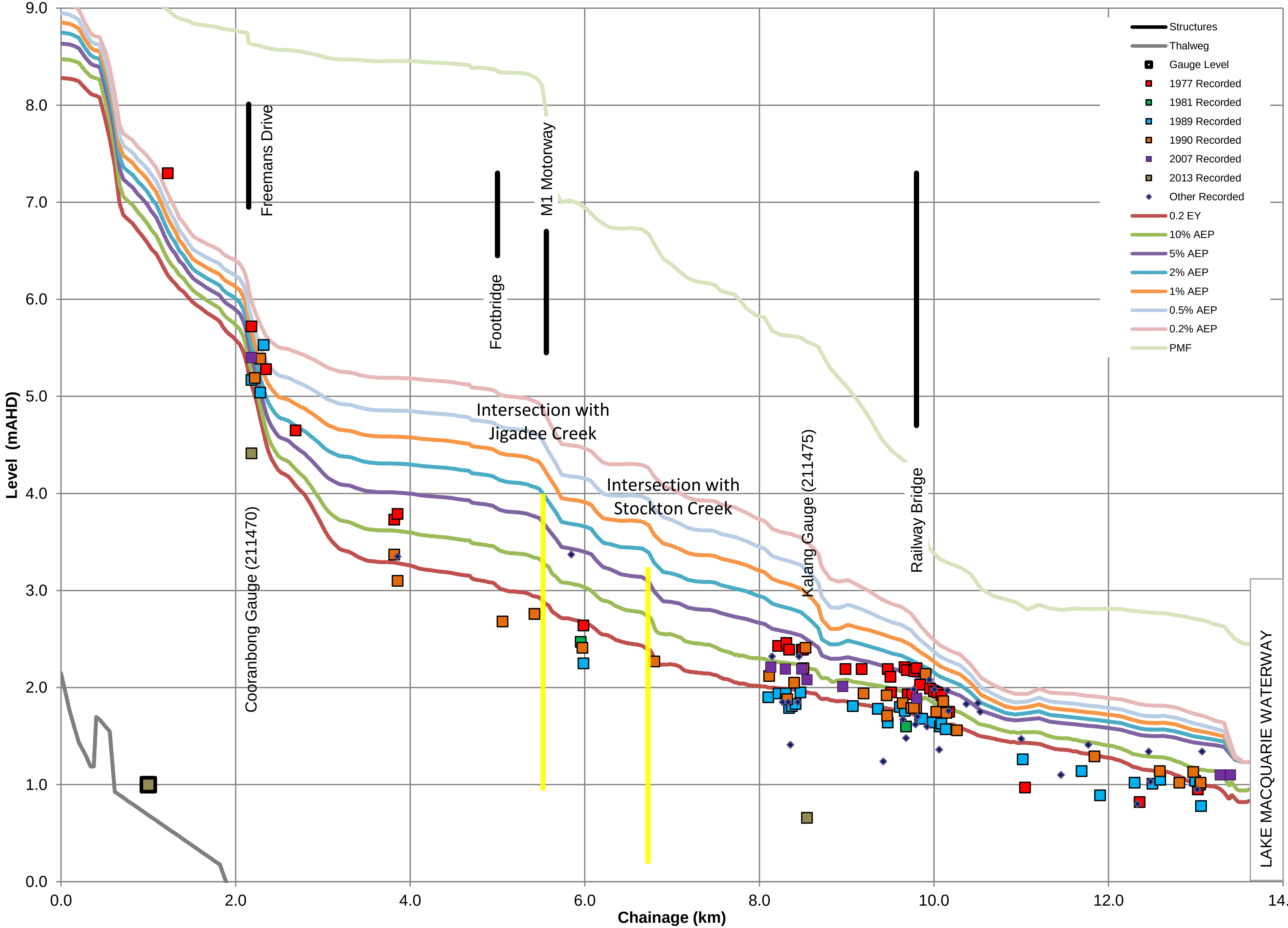


FIGURE 37B
PEAK HEIGHT PROFILES
DESIGN EVENTS
DORA CREEK

J:\Jobs\113016\Hydraulics\TUFLOW\results\Design\DesignResults.xlsx

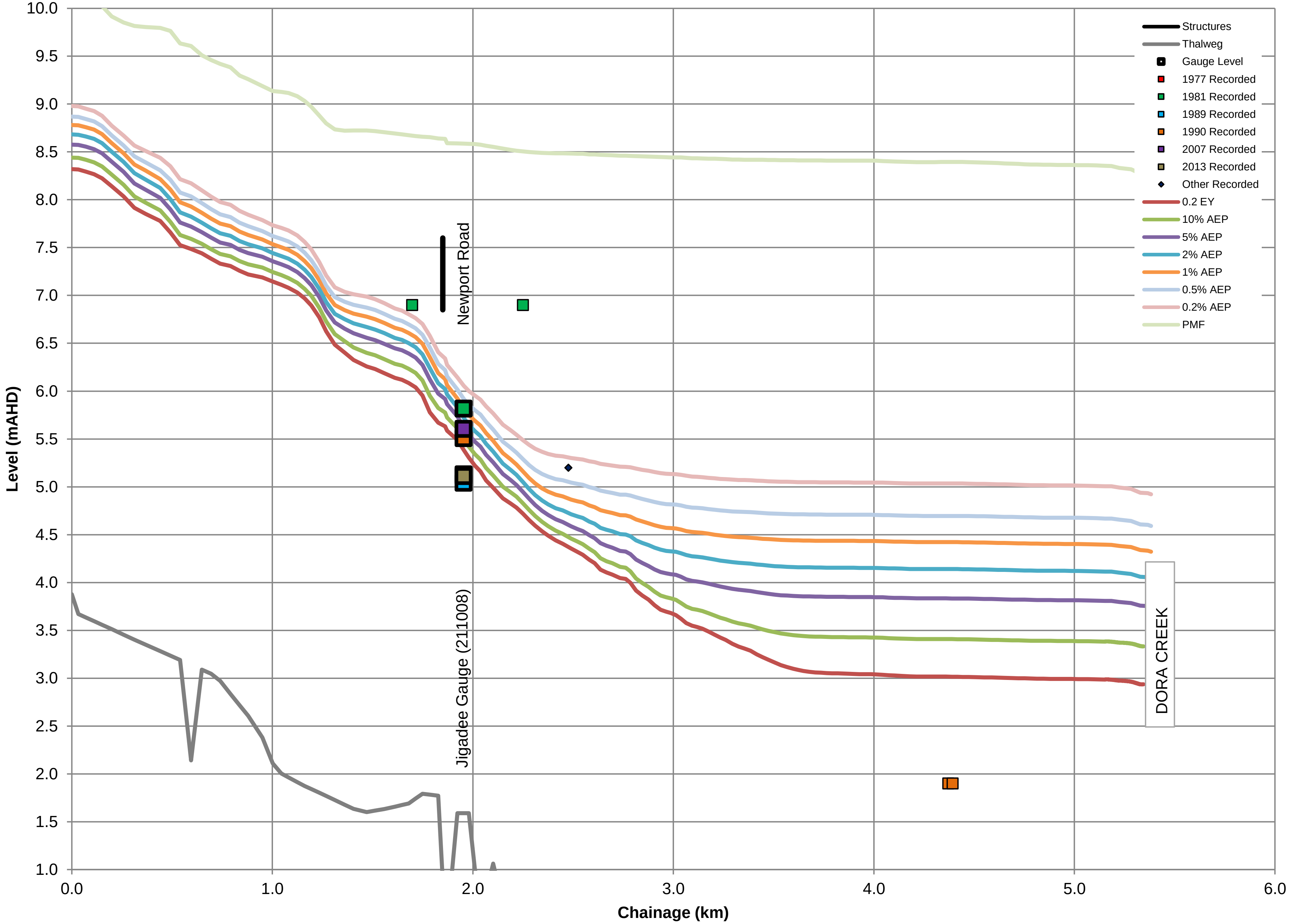
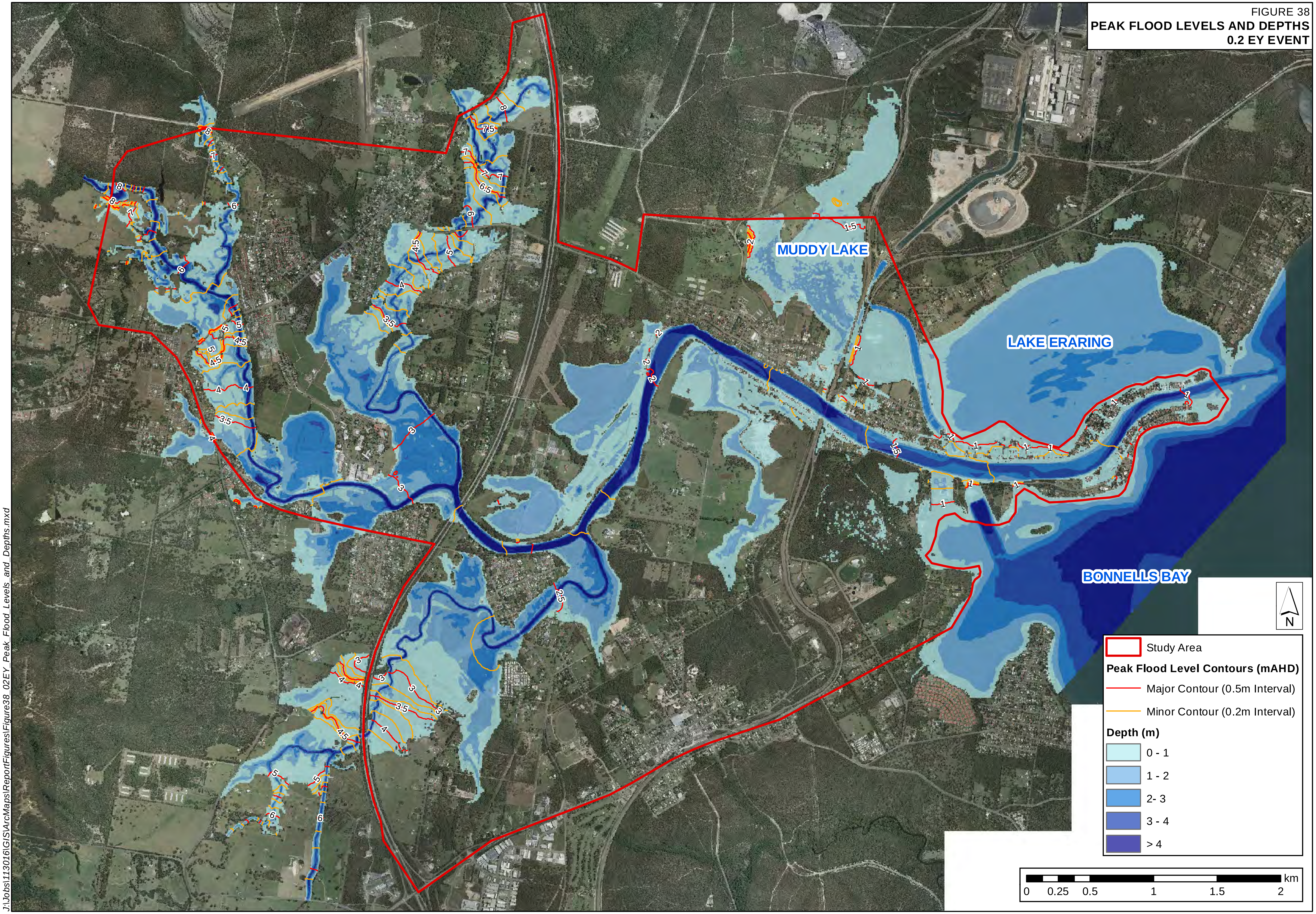


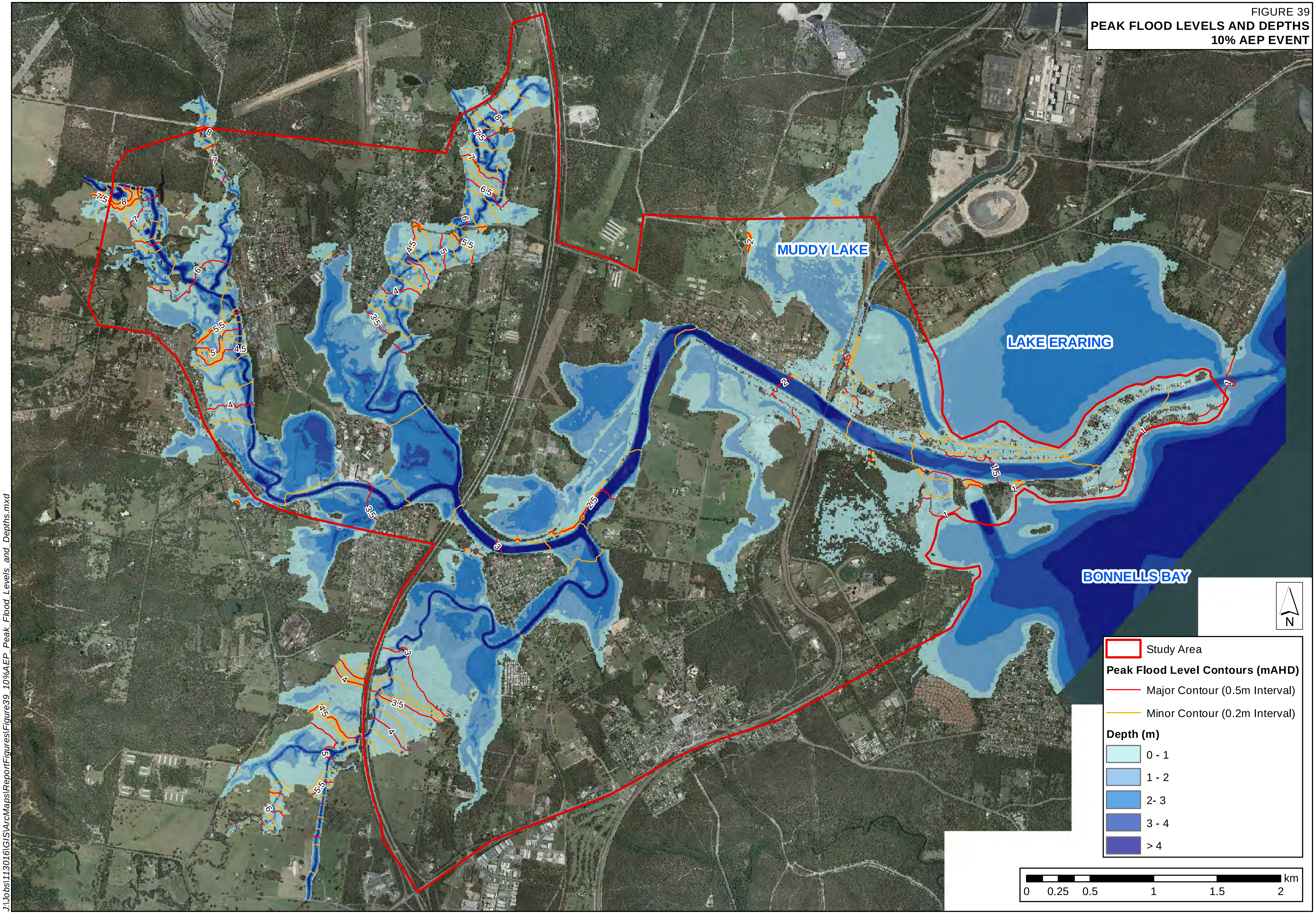
FIGURE 37C
PEAK HEIGHT PROFILES
DESIGN EVENTS
JIGADEE CREEK

FIGURE 38
PEAK FLOOD LEVELS AND DEPTHS
0.2 EY EVENT



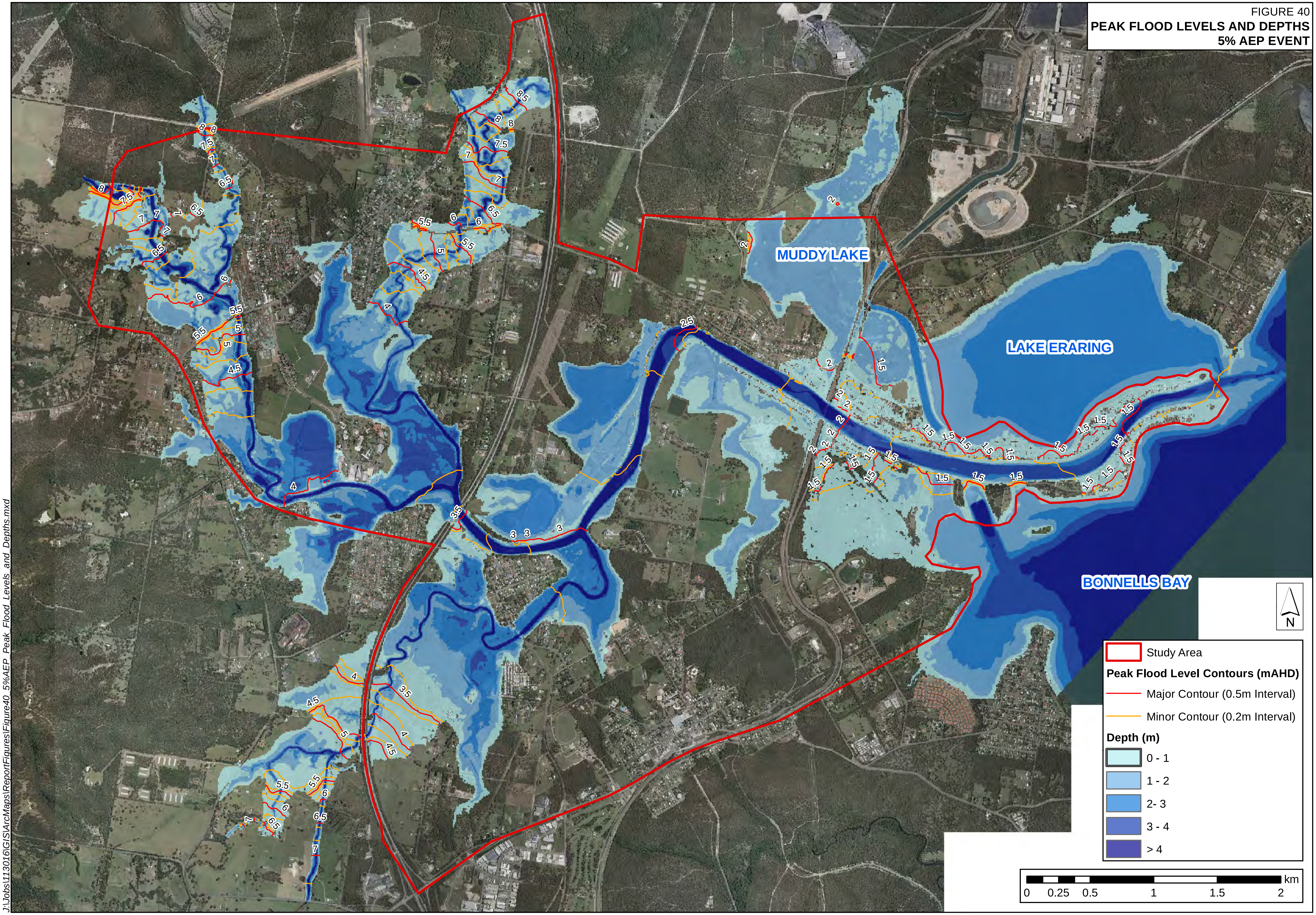
J:\Jobs\113016\GIS\ArcMaps\ReportFigures\Figure38_02EY_Peak_Flood_Levels_and_Depths.mxd

FIGURE 39
PEAK FLOOD LEVELS AND DEPTHS
10% AEP EVENT



J:\Jobs\113016\GIS\ArcMaps\Report Figures\Figure39_10%AEP_Peak_Flood_Levels_and_Depths.mxd

FIGURE 40
PEAK FLOOD LEVELS AND DEPTHS
5% AEP EVENT



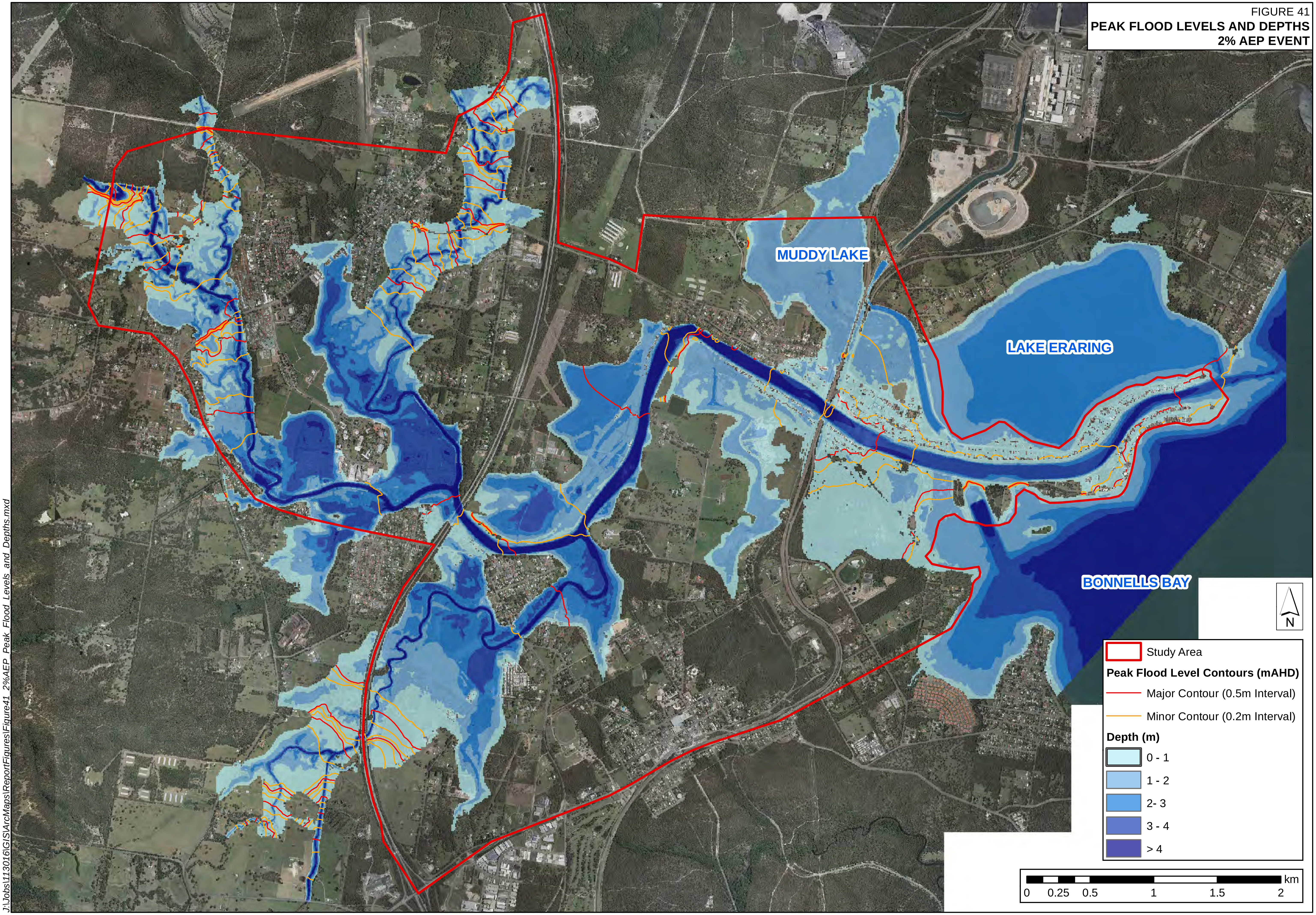
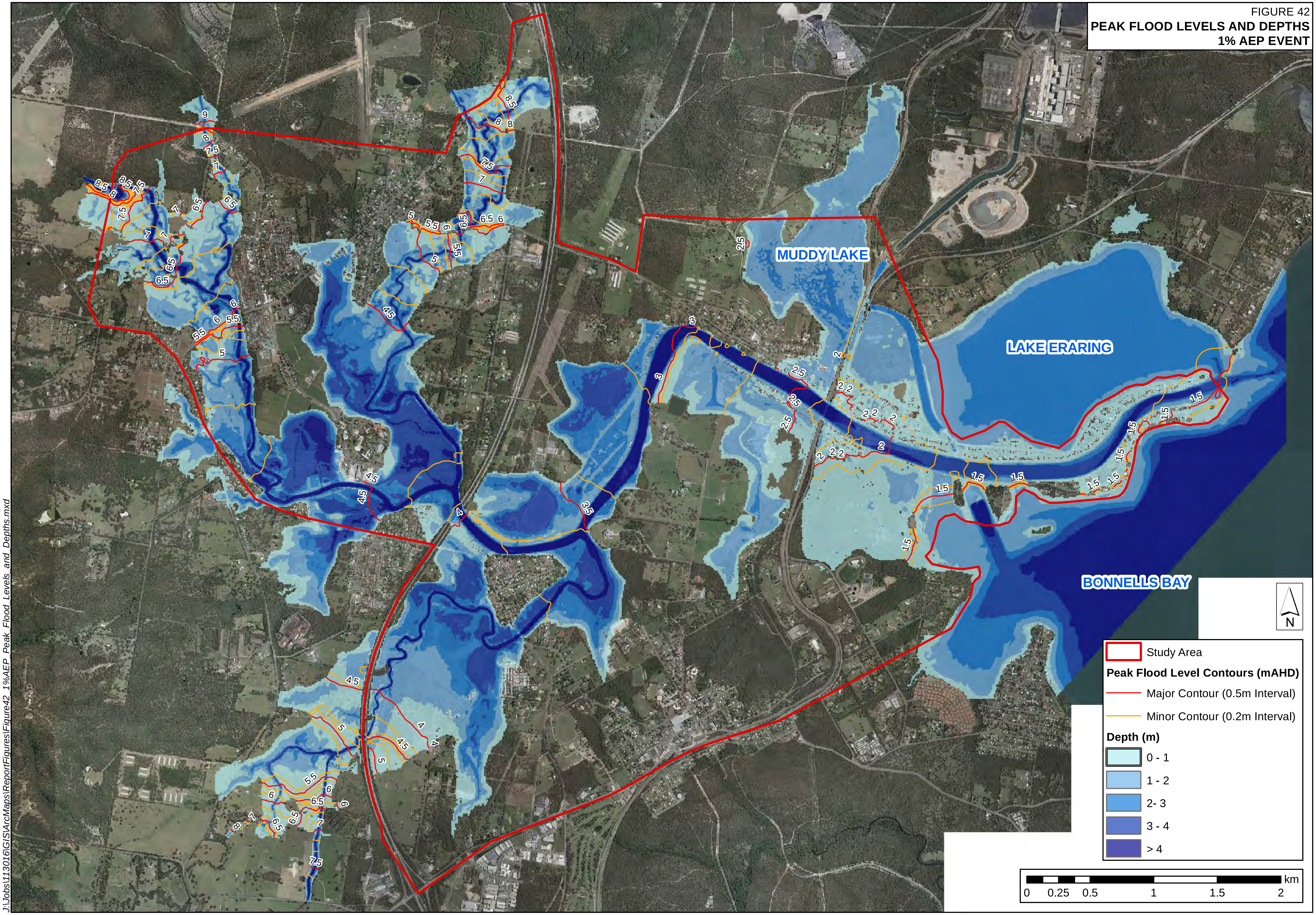


FIGURE 41
PEAK FLOOD LEVELS AND DEPTHS
2% AEP EVENT

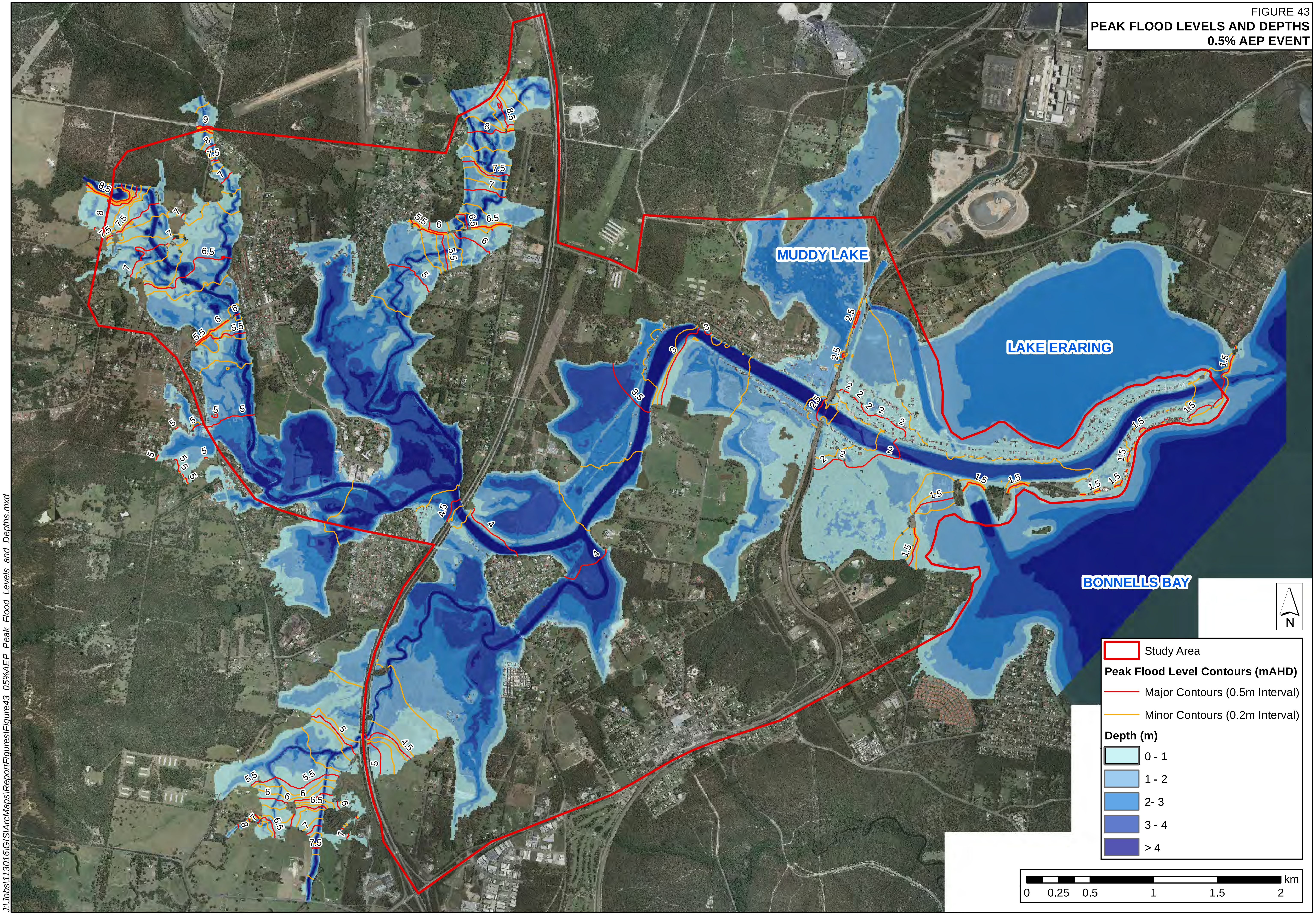
J:\Jobs\113016\GIS\ArcMaps\ReportFigures\Figure41_2%AEP_Peak_Flood_Levels_and_Depths.mxd

FIGURE 42

PEAK FLOOD LEVELS AND DEPTHS 1% AEP EVENT

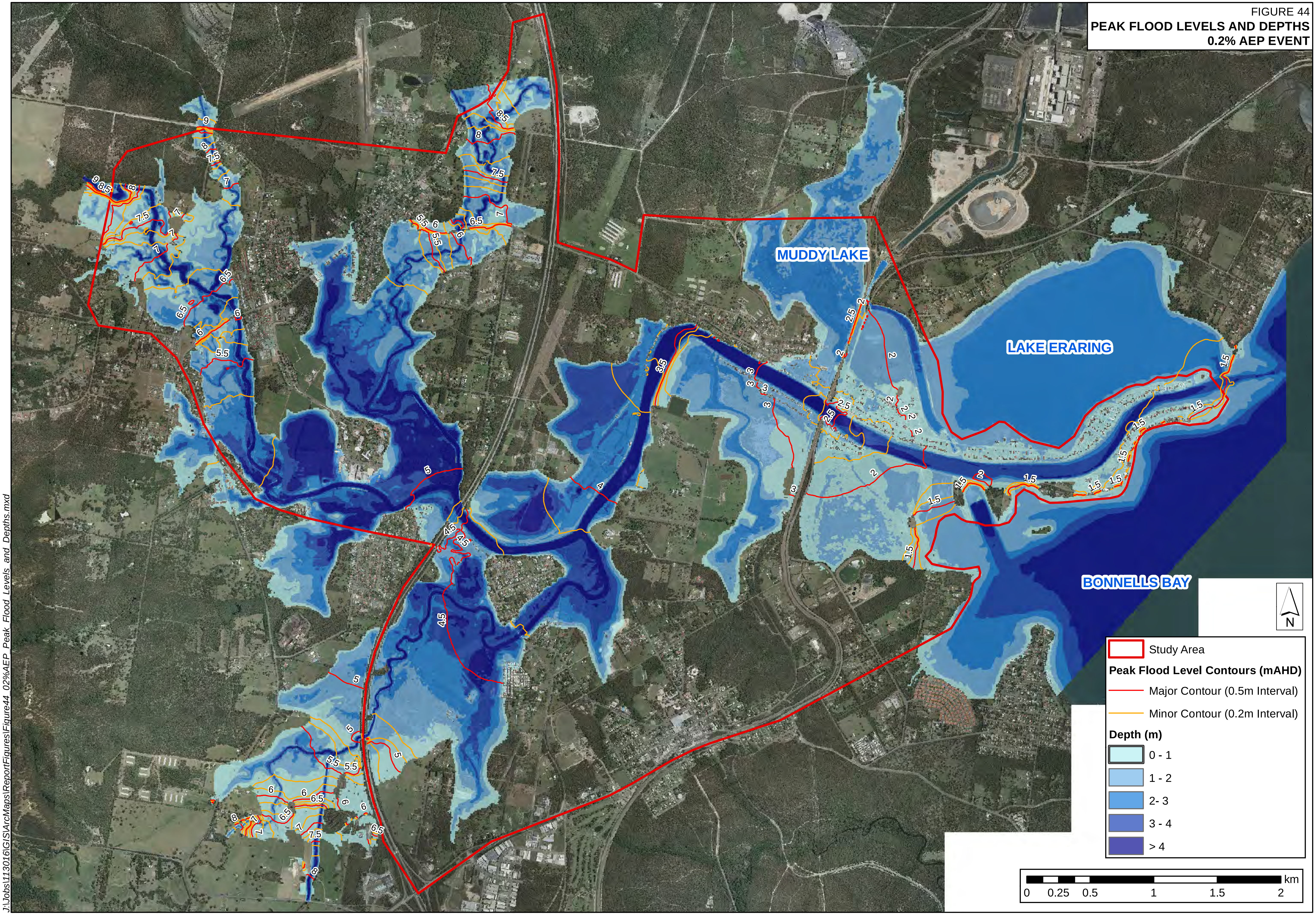


J:\Jobs\113016\GIS\ArcMaps\Report Figures\Figure42_1%AEP_Peak_Flood_Levels_and_Depths.mxd



J:\Jobs\113016\GIS\ArcMaps\ReportFigures\Figure43_05%AEP_Peak_Flood_Levels_and_Depths.mxd

FIGURE 44
PEAK FLOOD LEVELS AND DEPTHS
0.2% AEP EVENT



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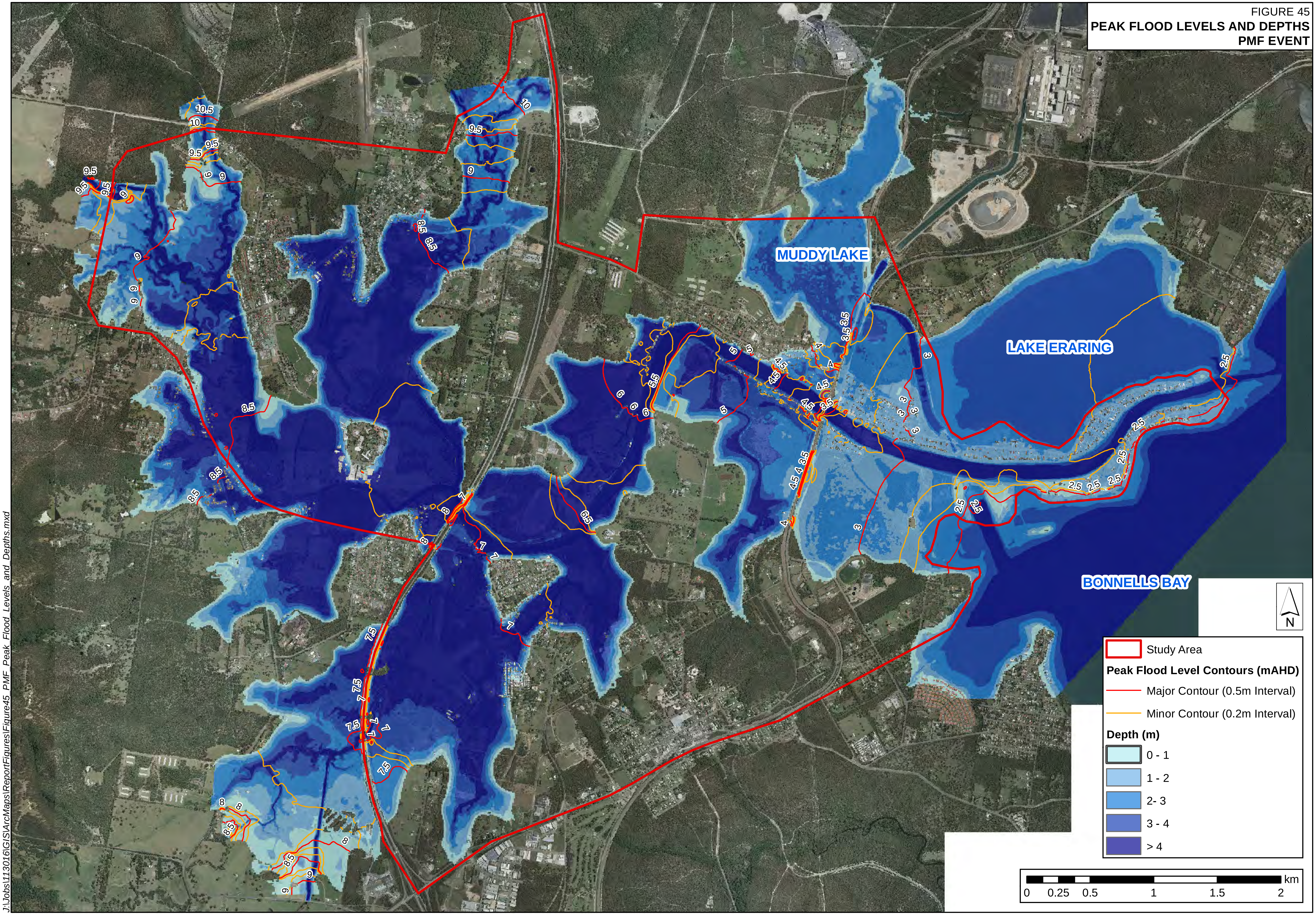

J:\Jobs\113016\GIS\ArcMaps\ReportFigures\Figure45_PMF_Peak_Flood_Levels_and_Depths.mxd

FIGURE 46
PEAK VELOCITIES
0.2 EY EVENT

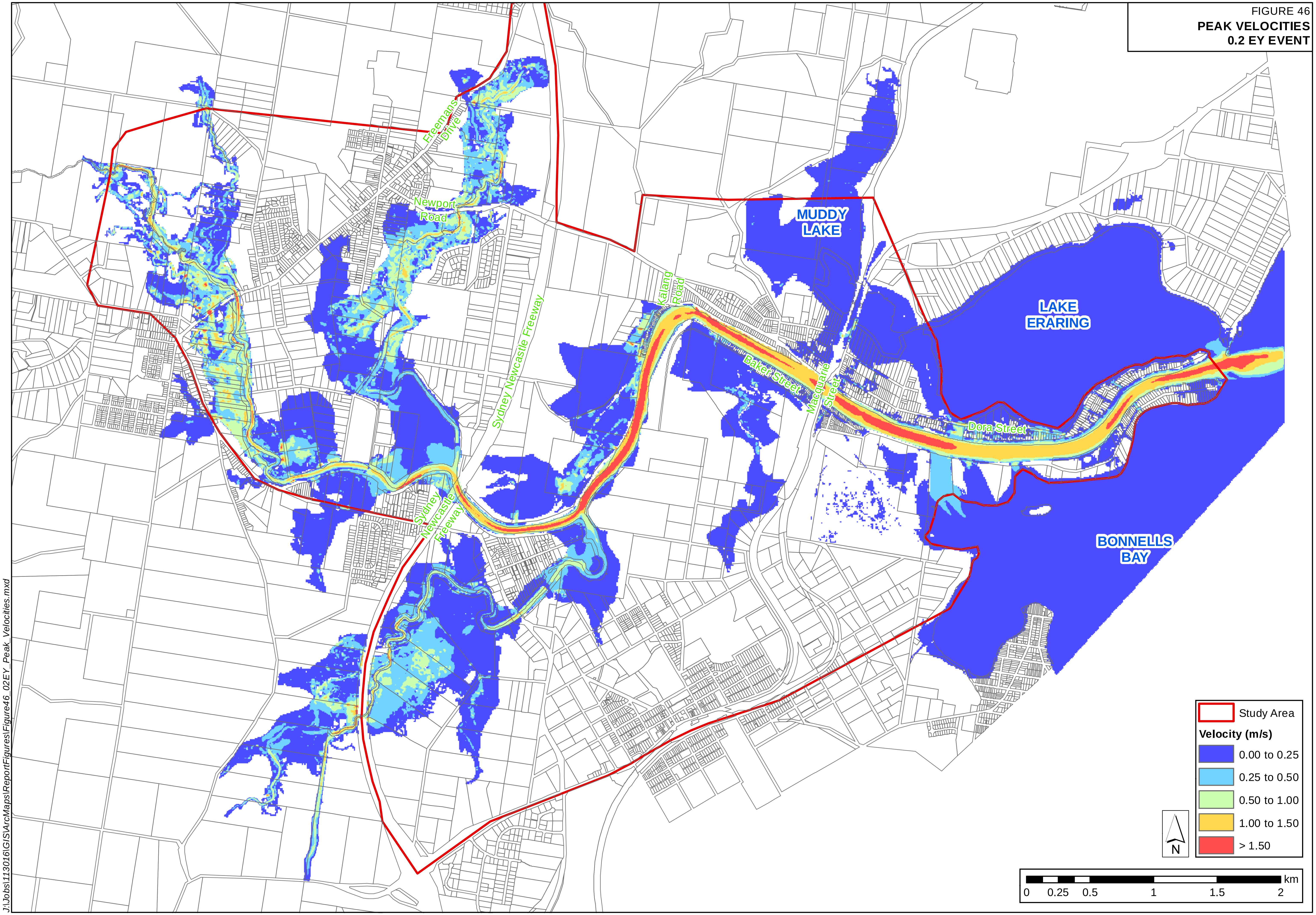

FIGURE 47
PEAK VELOCITIES
10% AEP EVENT

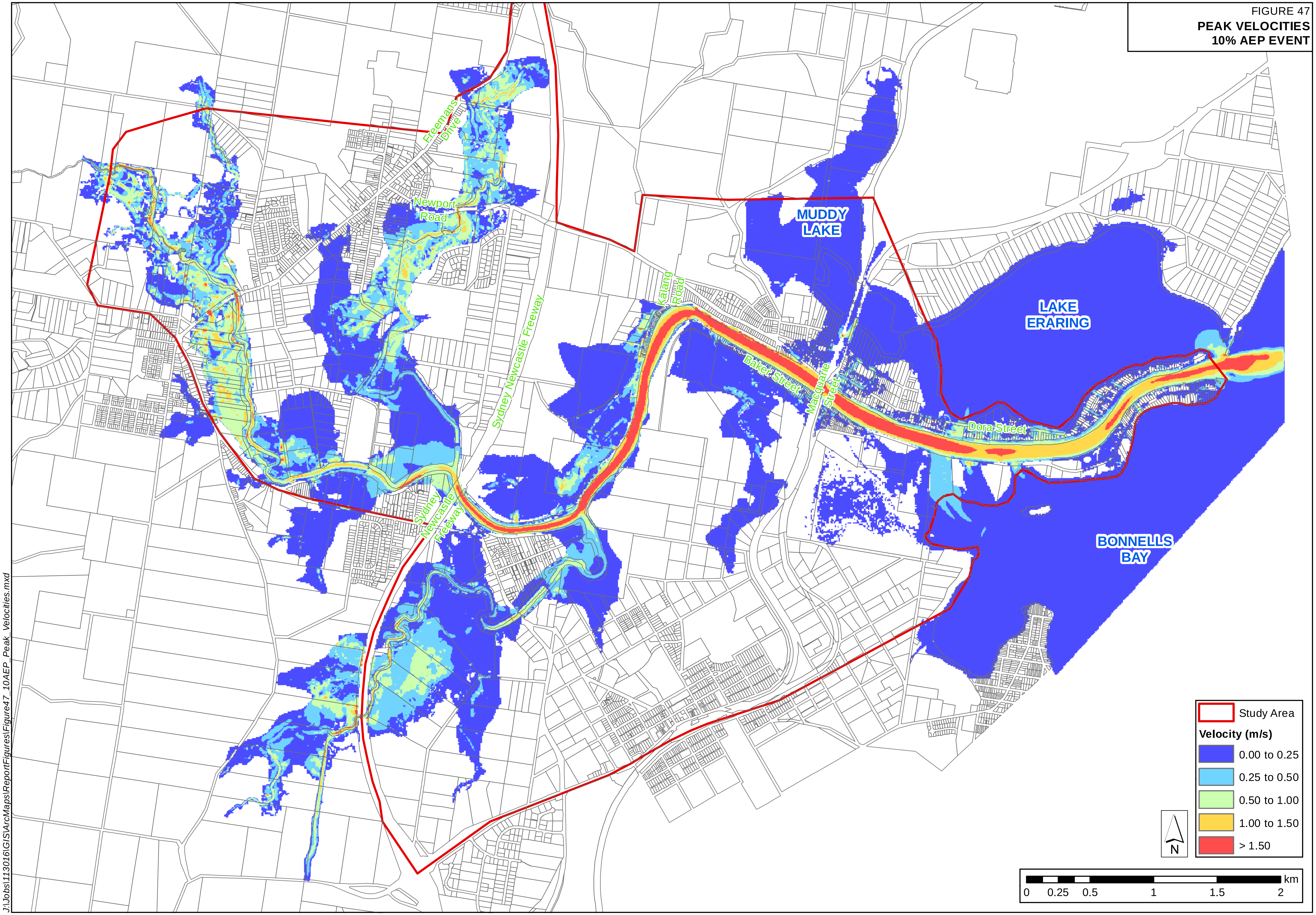

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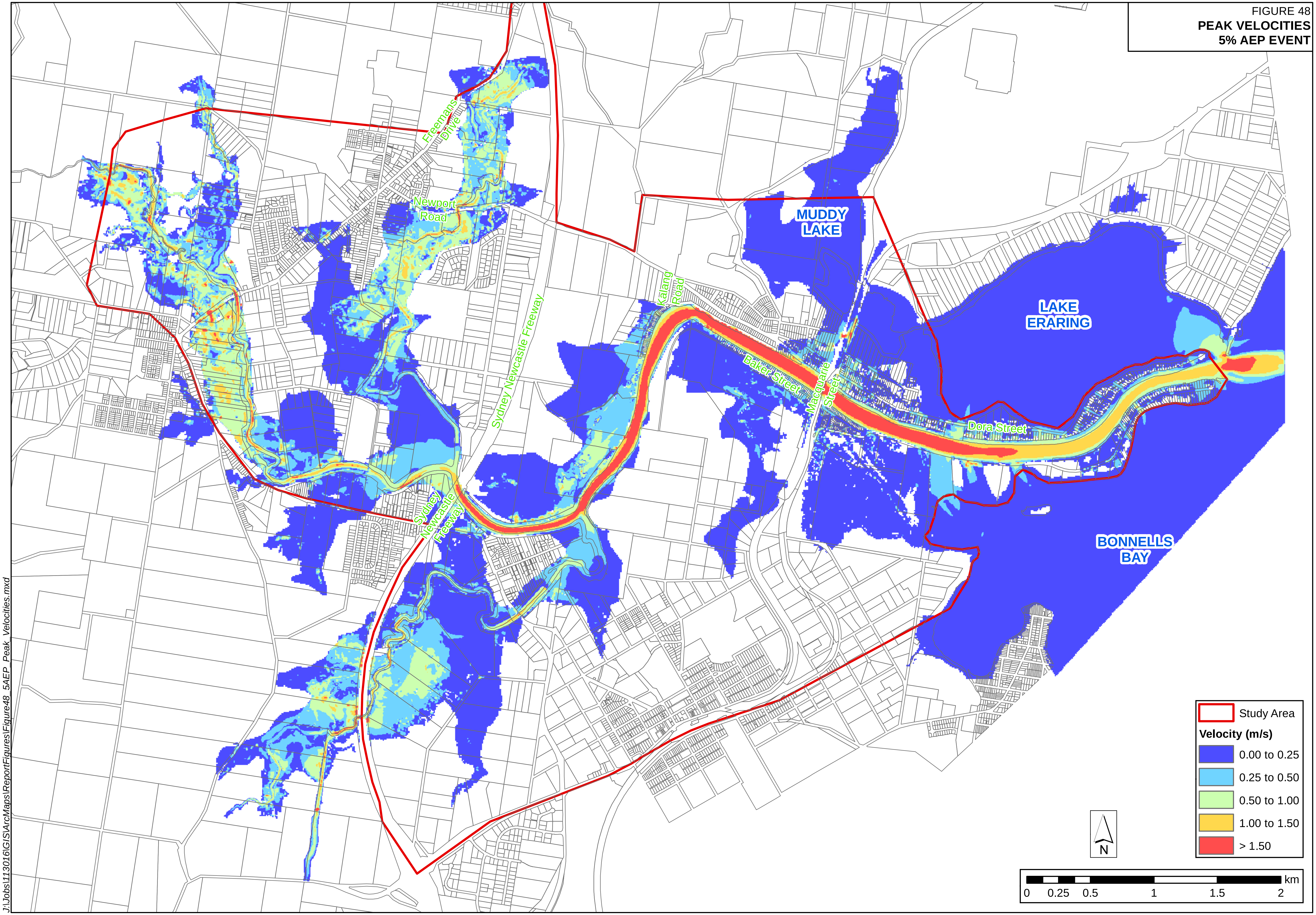
FIGURE 48
PEAK VELOCITIES
5% AEP EVENT



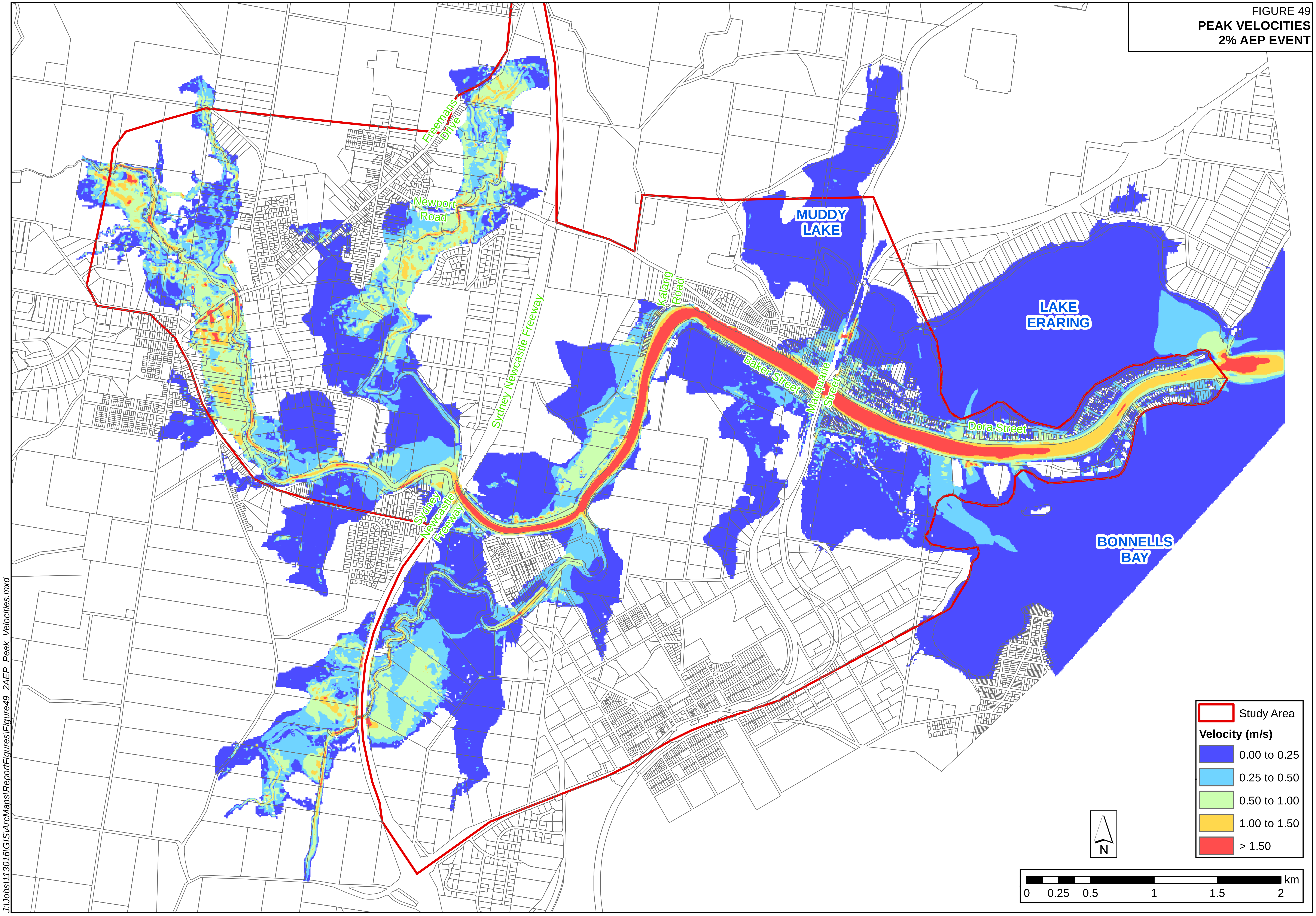


FIGURE 49
PEAK VELOCITIES
2% AEP EVENT
Freemans Drive
Newport Road
Sydney Newcastle Freeway
Kalang Road
Baker Street
Macquarie Street
Dora Street
MUDDY LAKE
LAKE ERARING
BONNELLS BAY
Sydney Newcastle Freeway
Study Area
Velocity (m/s)
0.00 to 0.25
0.25 to 0.50
0.50 to 1.00
1.00 to 1.50
> 1.50
N
0
0.25
0.5
1
1.5
2
km
J:\Jobs\113016\GIS\ArcMaps\ReportFigures\Figure49_2AEP_Peak_Velocities.mxd

FIGURE 50
PEAK VELOCITIES
1% AEP EVENT

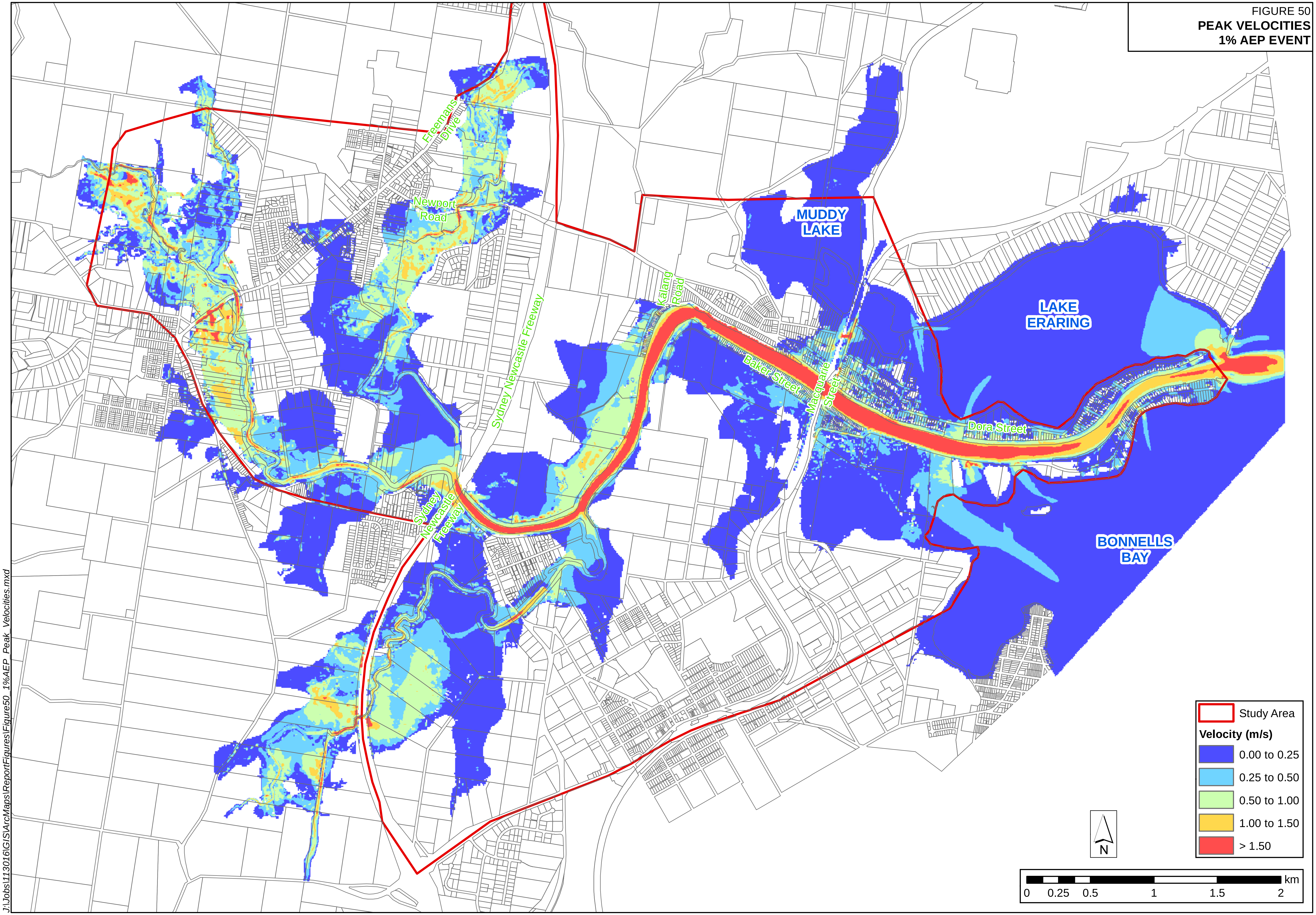


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FIGURE 51
PEAK VELOCITIES
0.5% AEP EVENT

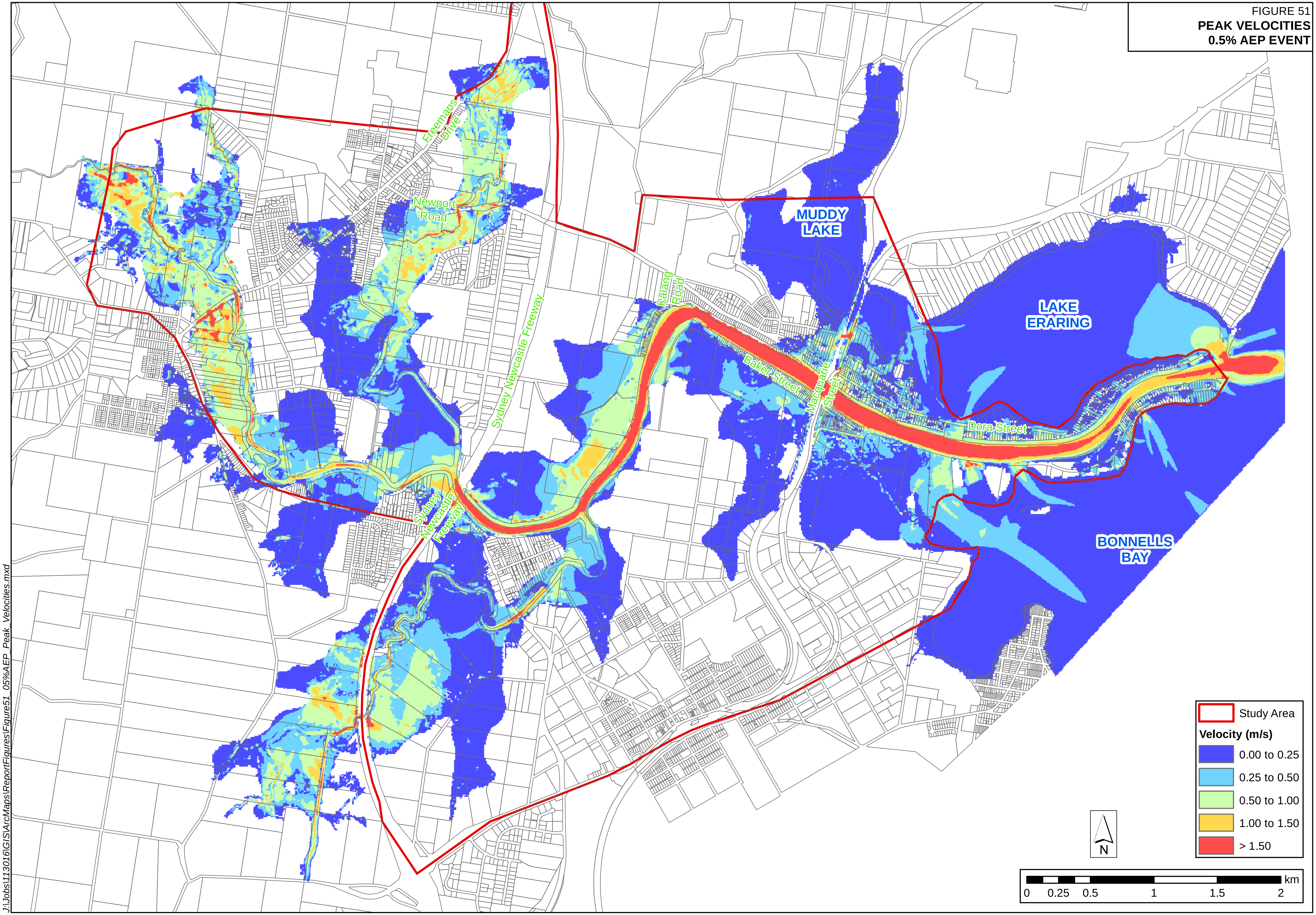
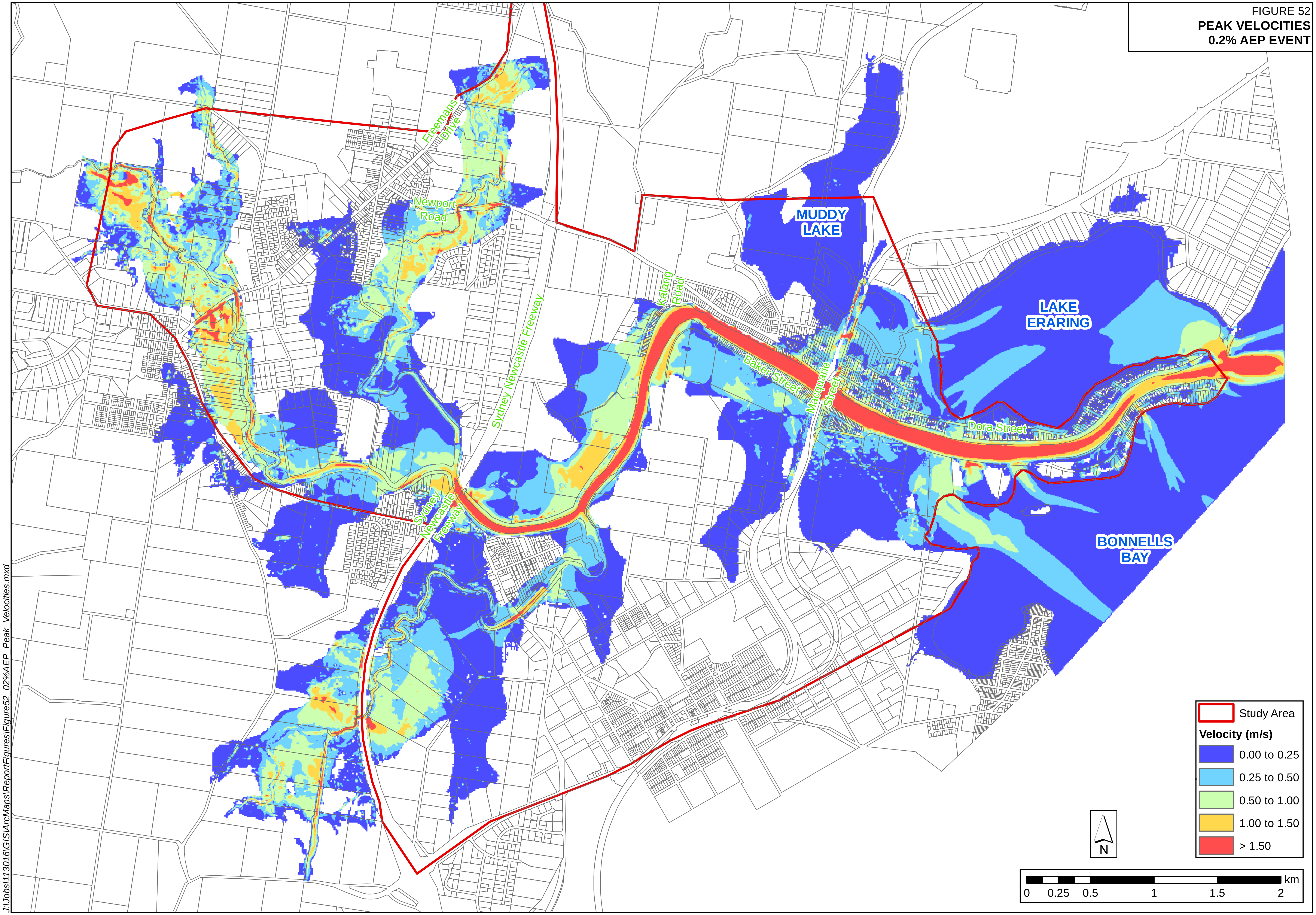
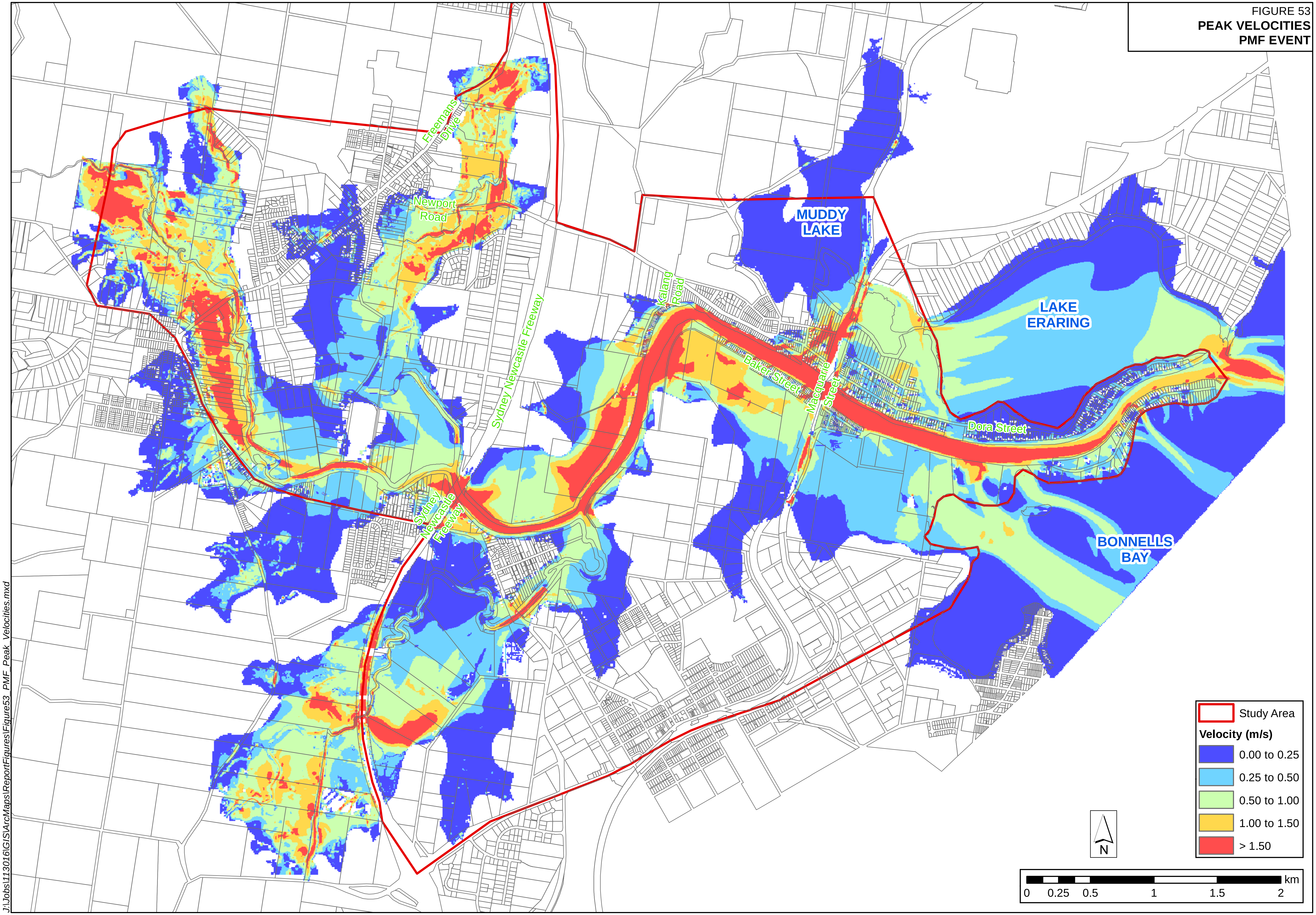


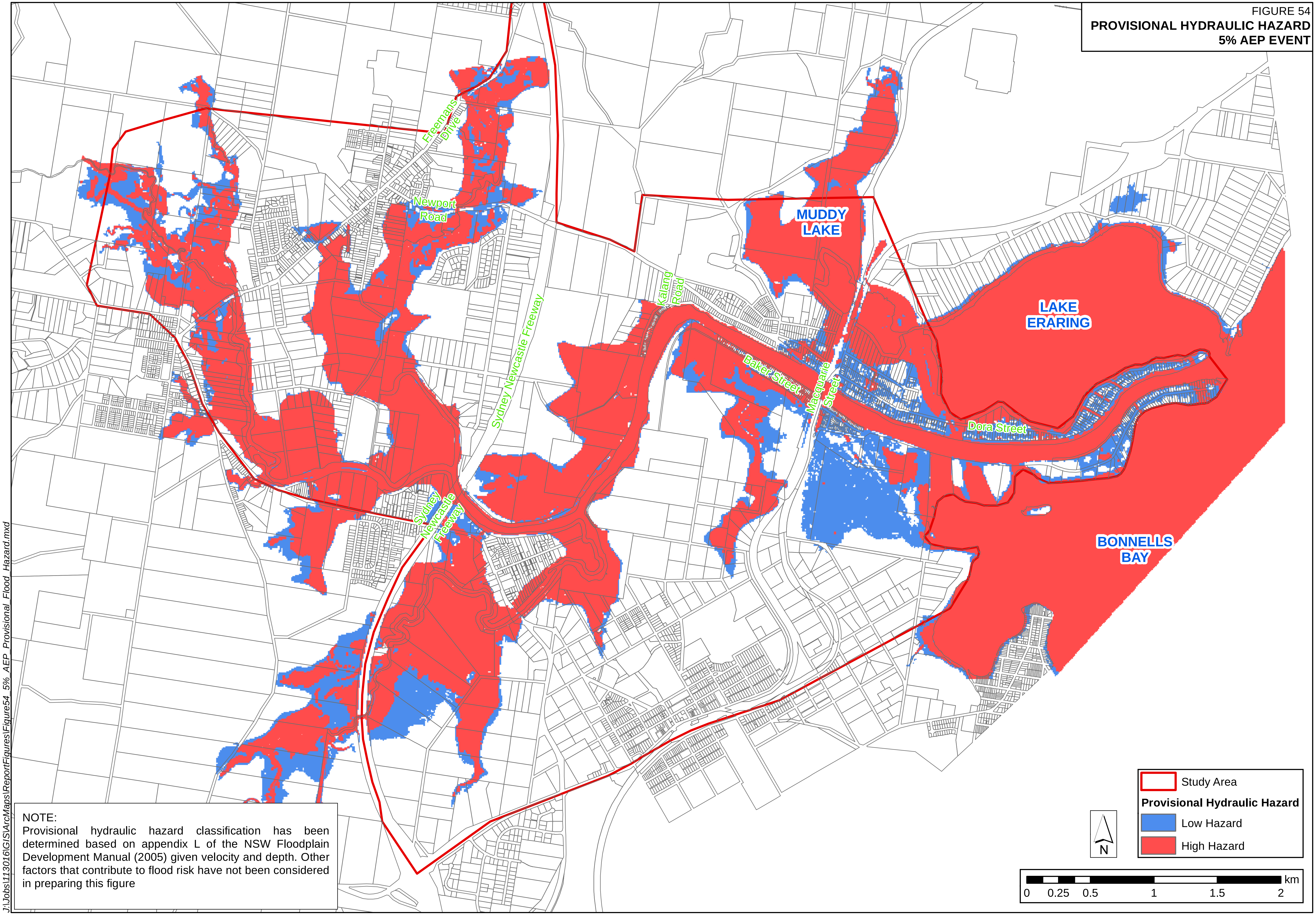
FIGURE 52
PEAK VELOCITIES
0.2% AEP EVENT



J:\Jobs\113016\GIS\ArcMaps\ReportFigures\Figure52_02%AEP_Peak_Velocities.mxd

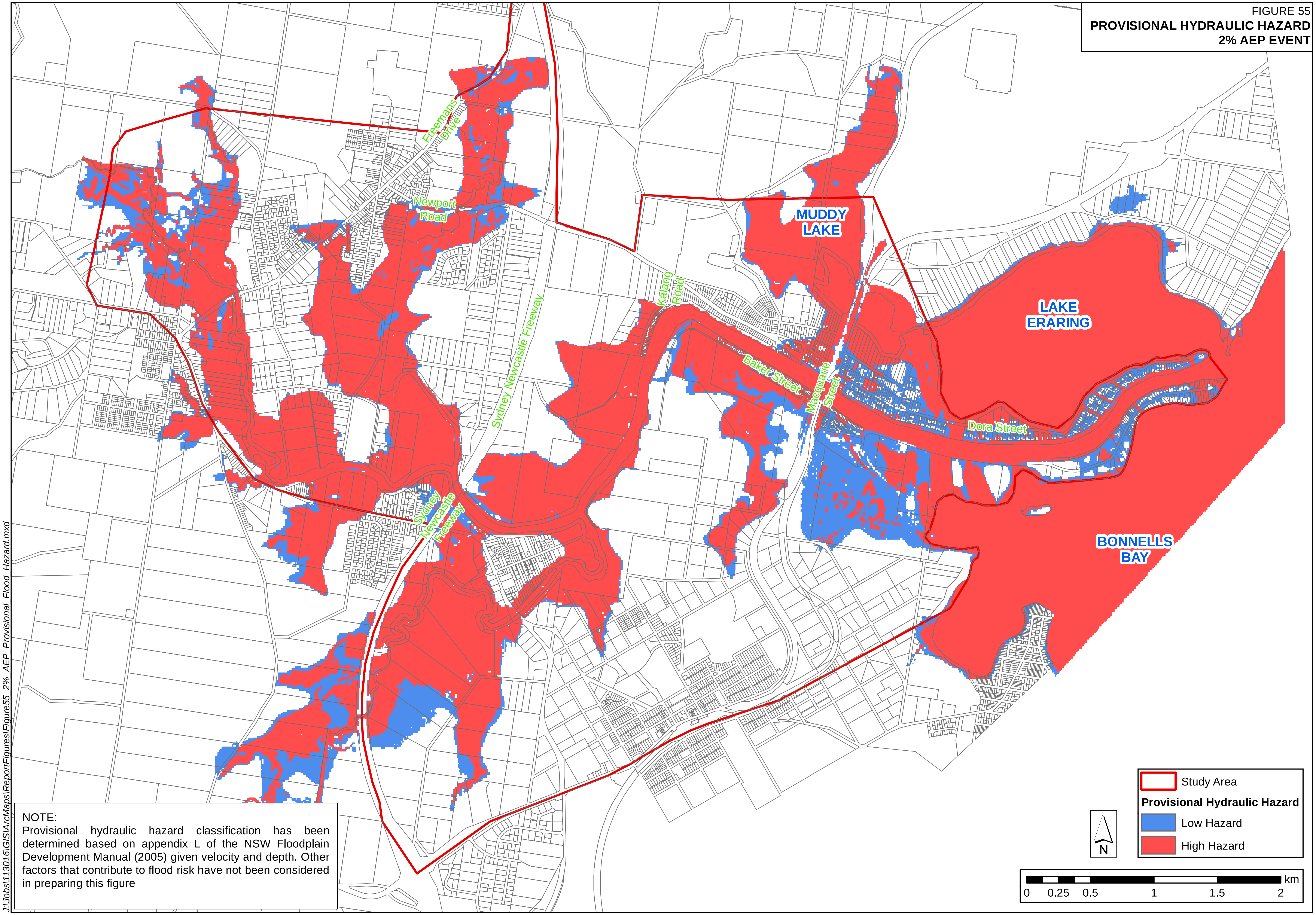
FIGURE 53
PEAK VELOCITIES
PMF EVENT





NOTE:
Provisional hydraulic hazard classification has been determined based on appendix L of the NSW Floodplain Development Manual (2005) given velocity and depth. Other factors that contribute to flood risk have not been considered in preparing this figure

FIGURE 55
PROVISIONAL HYDRAULIC HAZARD
2% AEP EVENT



NOTE:
Provisional hydraulic hazard classification has been determined based on appendix L of the NSW Floodplain Development Manual (2005) given velocity and depth. Other factors that contribute to flood risk have not been considered in preparing this figure

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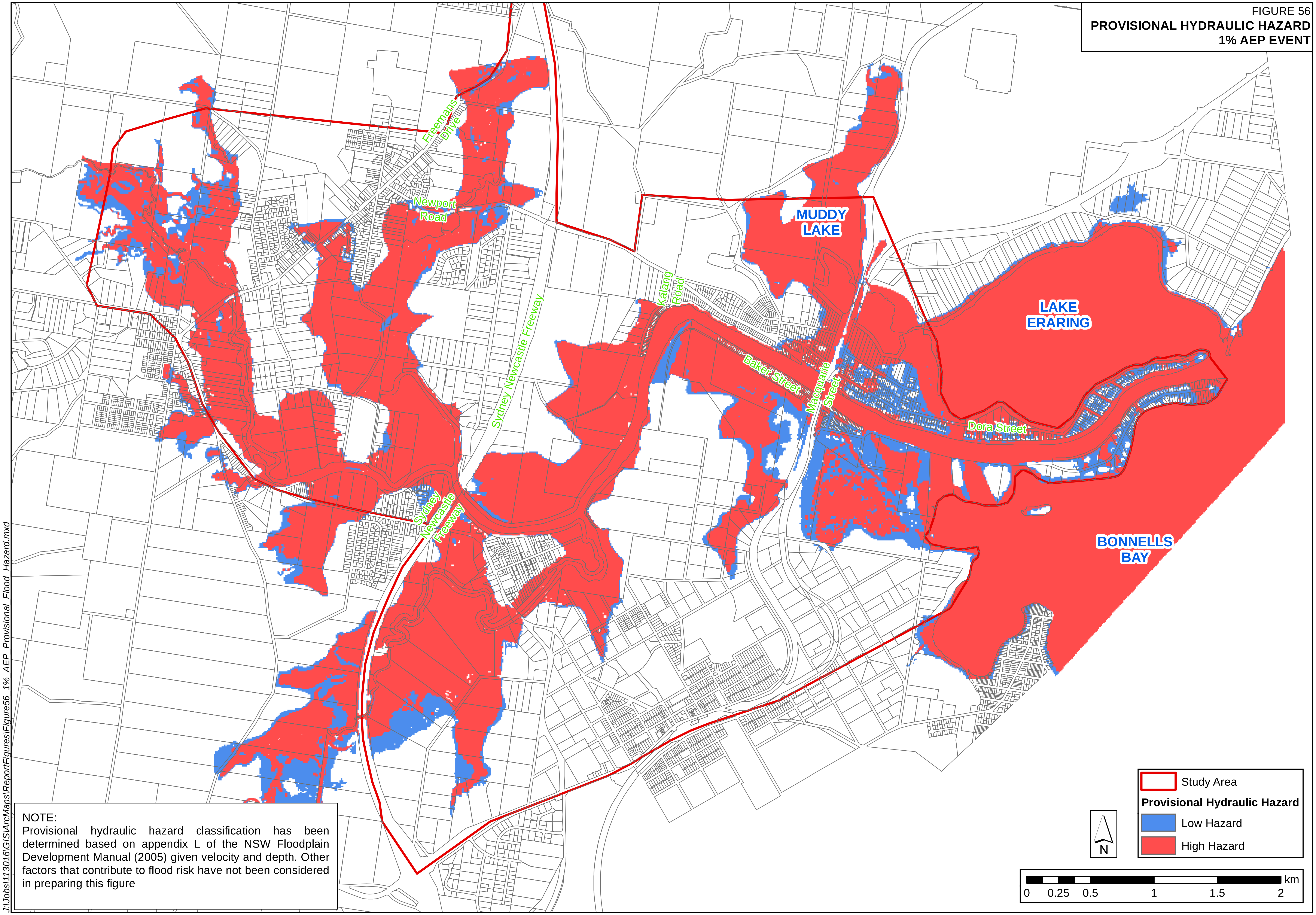
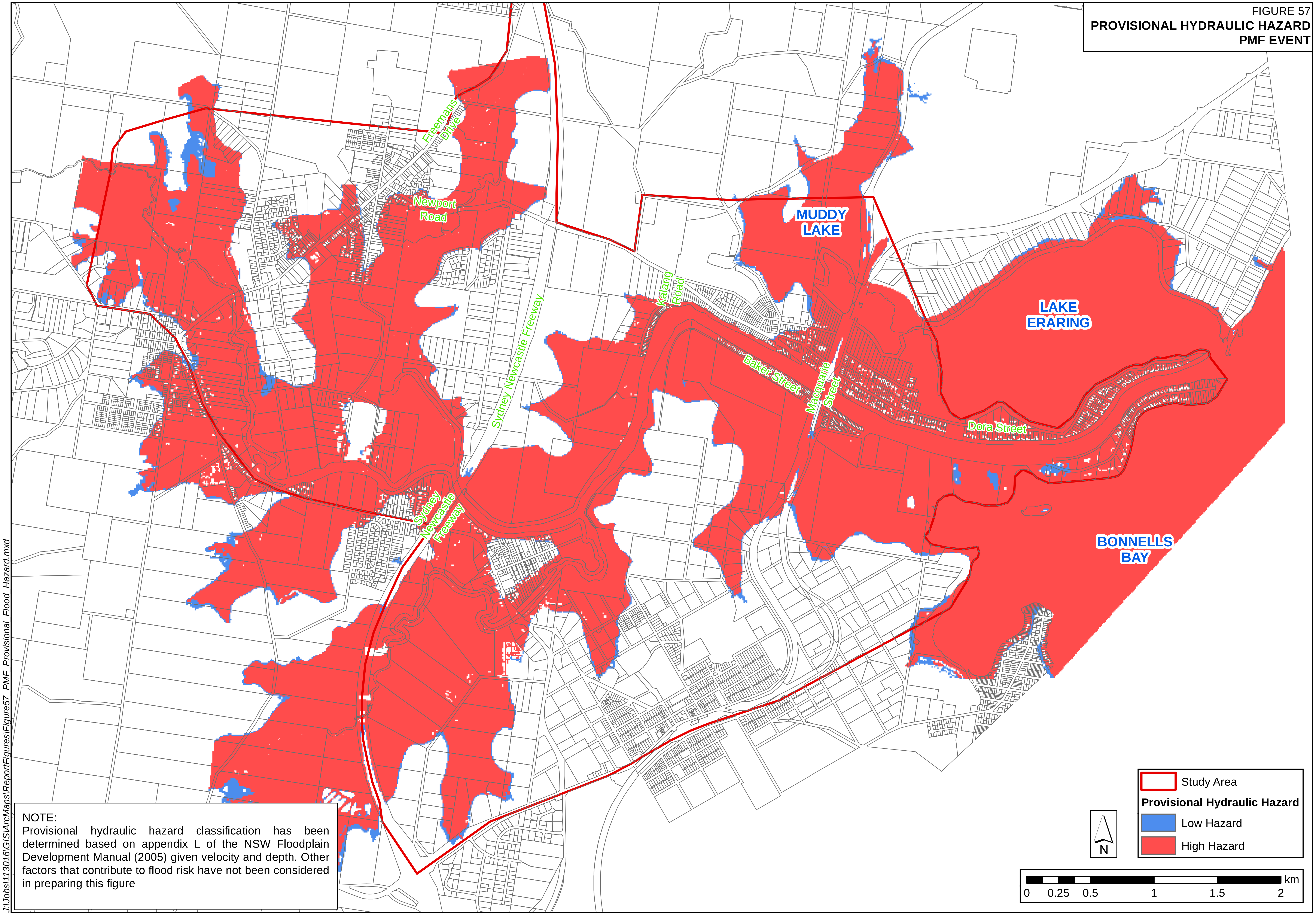
FIGURE 56
PROVISIONAL HYDRAULIC HAZARD 1% AEP EVENT



NOTE:
Provisional hydraulic hazard classification has been determined based on appendix L of the NSW Floodplain Development Manual (2005) given velocity and depth. Other factors that contribute to flood risk have not been considered in preparing this figure

FIGURE 57
PROVISIONAL HYDRAULIC HAZARD
PMF EVENT



NOTE:
Provisional hydraulic hazard classification has been determined based on appendix L of the NSW Floodplain Development Manual (2005) given velocity and depth. Other factors that contribute to flood risk have not been considered in preparing this figure

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FIGURE 58
HYDRAULIC CATEGORISATION 1% AEP EVENT

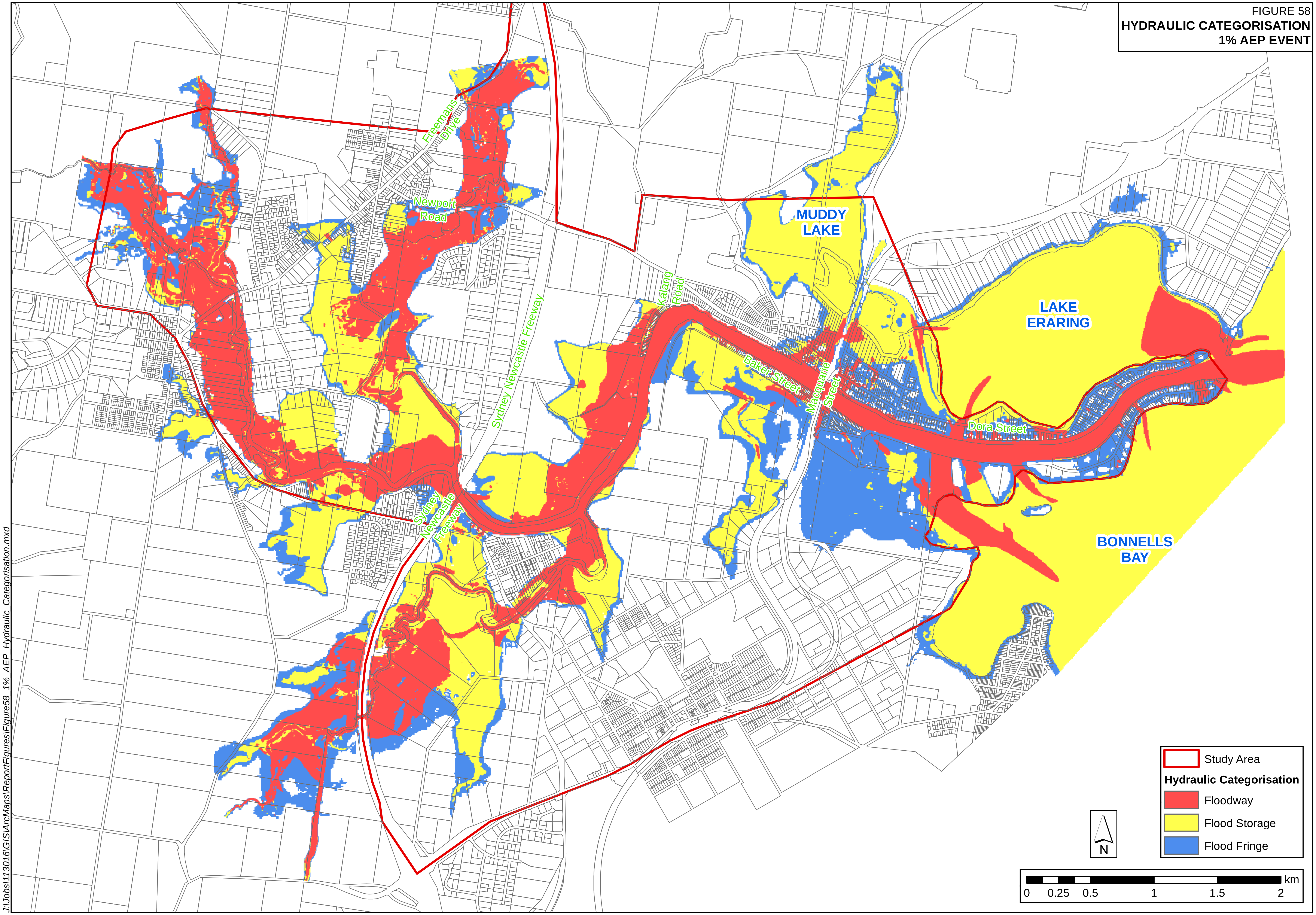

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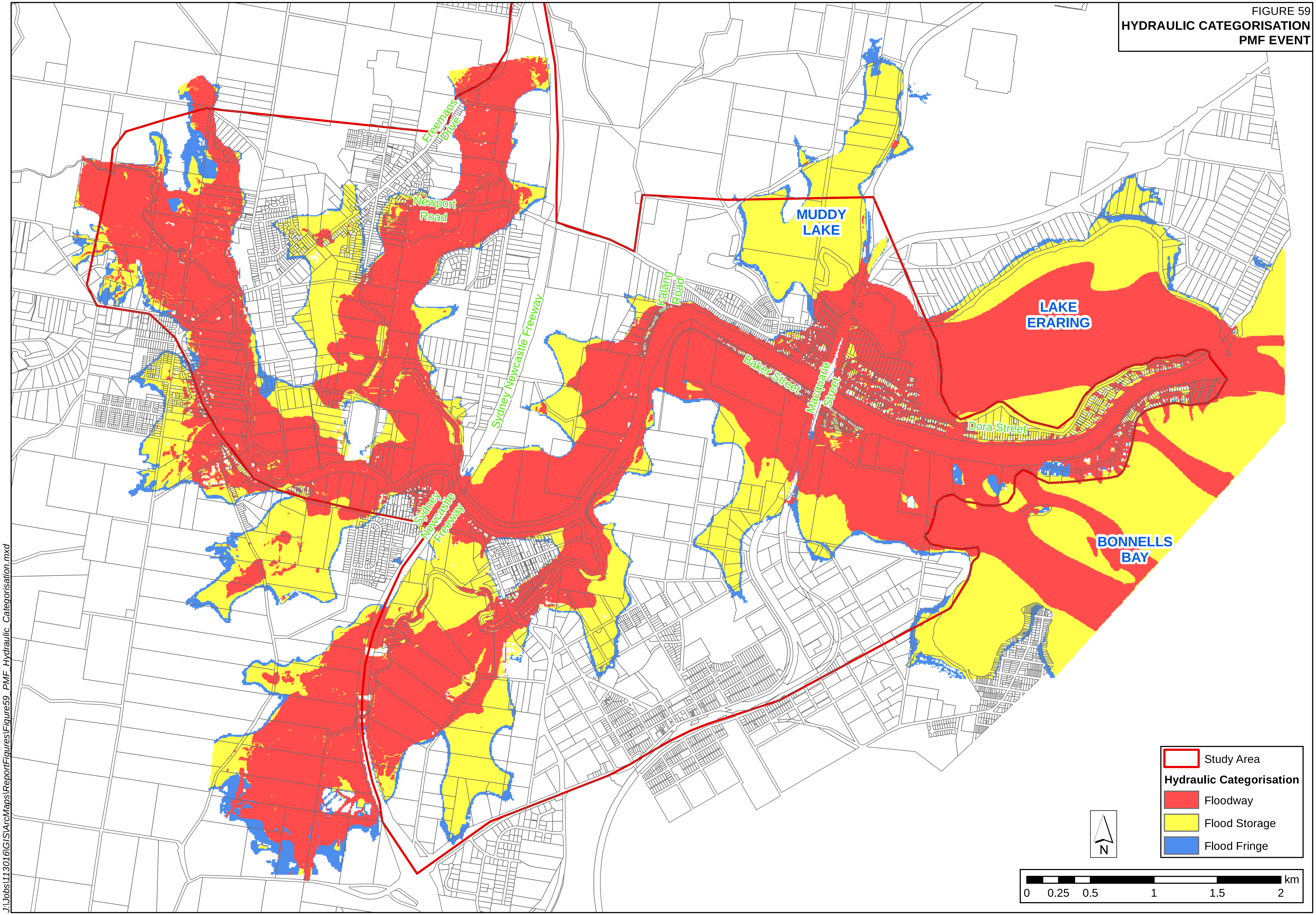
FIGURE 59
HYDRAULIC CATEGORISATION
PMF EVENT



Appendix A

APPENDIX A: GLOSSARY of TERMS

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, Government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of

	connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.

flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the "flood liable land" concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPL's are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "standard flood event" in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the

	Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: • the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or • water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or • major overland flow paths through developed areas outside of defined drainage reserves; and/or • the potential to affect a number of buildings along the major flow path.
mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: **minor flooding:** causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock

	and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.
peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to "water level". Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

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PREPARING FOR OUR CHANGING ENVIRONMENT

Lake Macquarie City Council

Dora Creek Flood Study

Newsletter No. 1 September 2013

Overview

Lake Macquarie City Council has appointed WMAwater, a Sydney based consultancy specialising in flood models and floodplain management, to carry out a Flood Study for the Dora Creek catchment at Morisset, Dora Creek and Cooranbong. The study will help Council to plan and manage existing and future flood risks.

Under the NSW Government's Flood Prone Land Policy, management of flood prone land is primarily, the responsibility of councils. The Policy specifies a staged planning process (see flowchart) that will be followed by Lake Macquarie City Council in your area.

The objectives of the Dora Creek Flood Study are to:

- collect available historical rainfall and flood height information,
- establish hydrologic and hydraulic computer models of the catchment based on detailed survey information, that will convert rainfall into runoff, flood levels and velocities, and
- use the above models to establish design flood levels, extents and velocities within the study area.

Council will then consider adoption of the study results for flood related development control purposes.

Our Involvement

We are preparing the Dora Creek Flood Study and we would like your help. A Floodplain Management Committee has been formed that includes representatives of the community from this catchment. The committee will oversee the flood study process and assist with reviews.

Public Exhibition

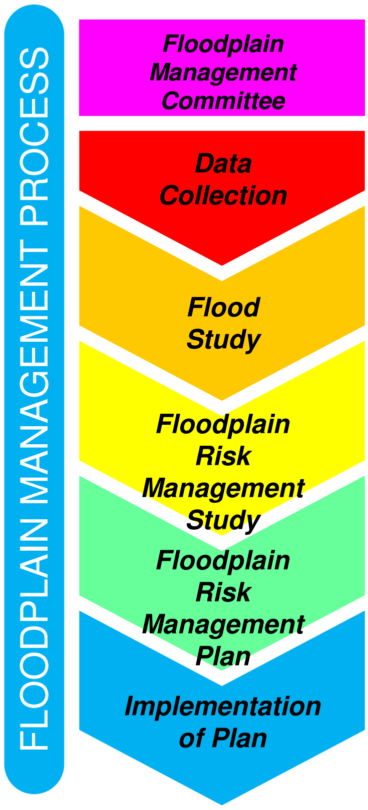
The Draft Flood Study Report is scheduled for completion in early 2014. The community will be invited to view and comment on the Draft Report.

Previous Studies

In this catchment area, previous studies have been completed including the Dora Creek Flood Study undertaken by the NSW Public Works Department in 1986. The new study will update the previous studies using current flood modelling technology and more comprehensive survey data that has only recently become available.

History of Flooding

There is a reasonably well documented history of flooding in the Dora Creek catchment. In particular, the April 1927, March 1977, February 1981, February 1990 and June 2007 events caused significant damage and inundation of overbank areas.



Past Floods


March 1977


June 2007

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PREPARING FOR OUR CHANGING ENVIRONMENT

Lake Macquarie City Council

Dora Creek Flood Study

Newsletter No. 1 September 2013

Dora Creek Catchment

Note: The study area is defined by the limits of the red line indicated on this map.

Have your say

Our community consultation includes this newsletter and a questionnaire to collect information about previous floods. The local knowledge of residents' personal experiences of flooding are an important source of information. We are specifically interested in historical records of flooding such as photographs, flood marks or recorded observations that residents may have. This information will help Council better understand how floods happen in the catchment and lead to better management of existing and potential future flood hazards and risks.

Please complete the questionnaire where possible and return it in the reply paid envelope.

For further inquiries please contact:

WMAwater
Richard Dewar
Director
Ph: 9299 2855

Lake Macquarie City Council
Greg D Jones
Senior Sustainability Officer
(Natural Disaster Management)
Ph: 4921 0333

wma water

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PREPARING FOR OUR CHANGING ENVIRONMENT

Dora Creek Catchment Flood Study

Lake Macquarie City Council

Community Questionnaire

September 2013

INTRODUCTION

Lake Macquarie City Council is carrying out a Flood Study for the Dora Creek catchment at Morisset, Dora Creek and Cooranbong.

Your local knowledge of the catchment and personal experiences of flooding will help us to undertake this flood study.

The extent of the Dora Creek catchment is shown on the enclosed map.

1

The purpose of the Flood Study is to identify the nature of flooding in the catchment area to enable Council to better understand, plan and manage the potential flood risk. We may contact you to discuss some of the information that you provide.

Name: ____________________

Address: ____________________

Email: ____________________

Phone (H/M): ____________________

2

How long have you lived or worked in the area?

____________ years

3

Are you aware of stormwater flooding from streets or channels in your catchment? (Please tick one)

☐ Aware ☐ Some Knowledge ☐ Not Aware

4

Have you ever been inconvenienced by uncontrolled floodwater/stormwater from streets or channels in this area?

☐ Yes ☐ No

If no, please proceed to question 6

4 CONTINUED

Please show how uncontrolled floodwater/stormwater has inconvenienced you?

✓	Answer	Dates/Times/Description
	Daily routine was affected	
	Safety was threatened	
	Access to property was affected	
	Property and/or its contents were damaged	
	Business was unable to operate during the flooded period	
	Other (please specify)	

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PREPARING FOR OUR CHANGING ENVIRONMENT

Lake Macquarie City Council

Dora Creek Catchment Flood Study

Community Questionnaire

September 2013

5

Can you remember *when* you were inconvenienced by uncontrolled floodwater/stormwater from streets or channels in this area?

☐ Yes ☐No

☐ April 1927 ☐ Mar 1977 ☐ Feb 1981

☐ Feb 1990 ☐ Jun 2007

6

Has your home or other property been flooded because of uncontrolled floodwater/stormwater from streets or channels in this area?

☐ Yes ☐ No

If Yes, where was your property flooded, and when did it happen? (You may tick more than one)

✓	Location	Dates/Times/Description
	Frontyard or backyard	
	Garage or shed	
	Residential (below floor level)	
	Residential (above floor level)	
	Commercial (e.g. shops) (below floor level)	
	Commercial (above floor level)	
	Industrial (e.g. factories)	
	Other (please give details)	

7

Did you notice any bridges and/or drains to be blocked during the flooding?

☐ Yes ☐ No

If you answered Yes, please provide details and how blocked would you say it was? (i.e. 50% blocked, 80% blocked). What was causing the blockage?

___

___

8

Do you have any evidence of past floods (e.g. photos, video footage, records, watermarks on walls or posts) ?

☐ Yes ☐ No

If yes, please give as much detail as possible:

___

___

___

9

Do you have any more information you think might help in relation to the Dora Creek Catchment Flood Study:

___

___

___

PRIVACY NOTICE: The information obtained from the Dora Creek Catchment Flood Study questionnaire will be used by staff at Lake Macquarie City Council and consultant WMAwater only. Supply of this information is voluntary. The information will be stored on Council's file and used for the duration of the project only.

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PREPARING FOR OUR CHANGING ENVIRONMENT

Lake Macquarie City Council

Dora Creek Catchment Flood Study

Community Questionnaire

September 2013

Map of the Dora Creek Catchment

Note: The study area is defined by the limits of the red line indicated on this map.

Thank you for providing this information. Please remember to place all pages in the reply paid envelope and send to WMAwater. A representative from WMAwater may contact you in the near future to discuss your response.

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Lake Macquarie City Council

Dora Creek Catchment Flood Study

Community Questionnaire

September 2013

Examples of Historic Flooding Photos

MAIN ROAD 392 COORANBONG `EASTER' 1927 FLOOD.
PHOTO TAKEN LOOKING SOUTH FROM OLD BRIDGE OVER DORA CREEK. WATER FLOWING RIGHT TO LEFT.

WAMSLEY STREET, DORA CREEK. 4 TH MARCH, 1977 FLOOD.
OLD SHOP AT RIGHT OF PICTURE IS AT INTERSECTION WITH DOREE PLACE.
FLOOD LEVEL = RL 1·99 AHD

WAMSLEY STREET, DORA CREEK. H MARCH, 1977 FLOOD.
LOOKING EAST FROM RAILW. TOWARDS SHOPS, No. 17.
FLOOD LEVEL = RL 1·99 AHD

DORA CREEK FLOOD
04-02-90

No. 1 Cowell St. Dora Creek

21/6/89

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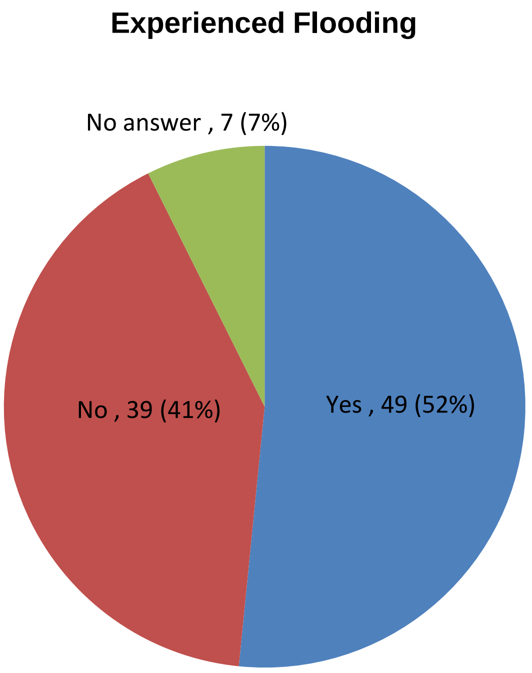

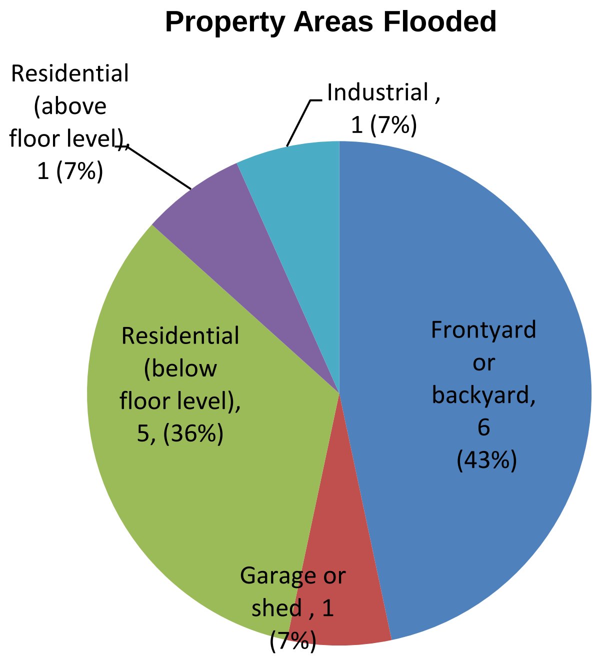

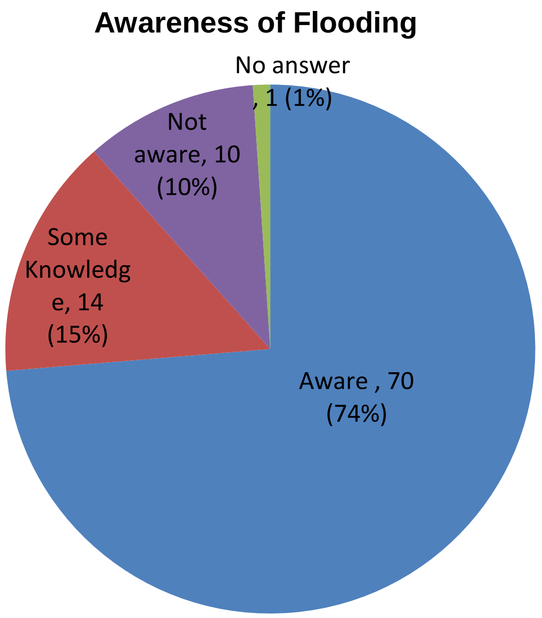

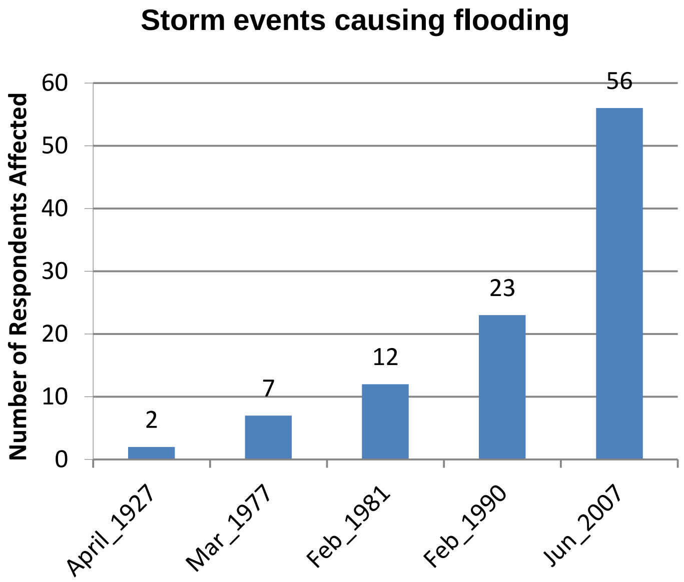

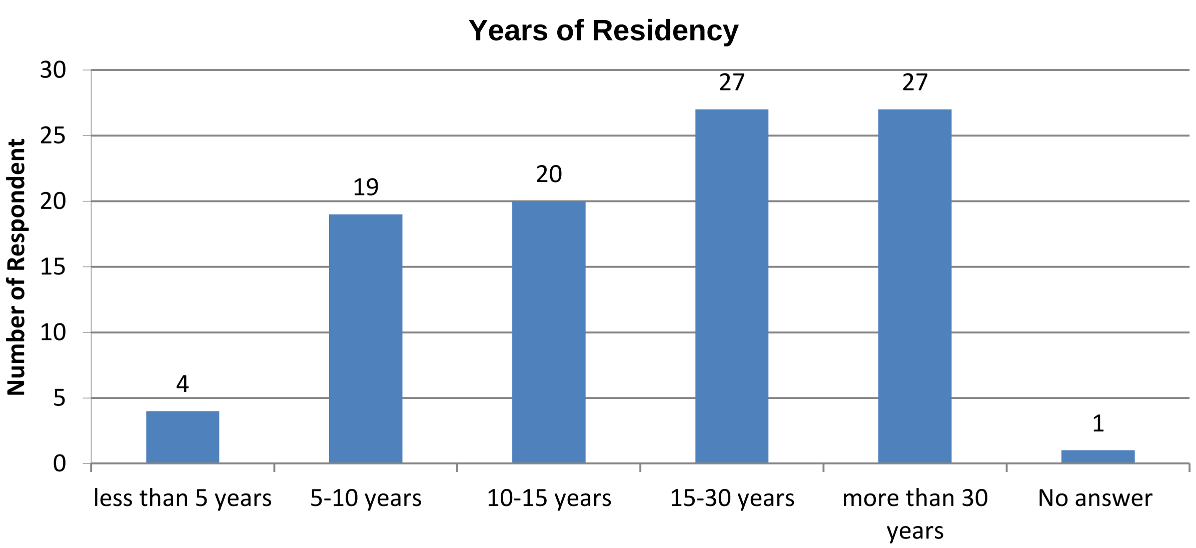

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