A part of BMT in Energy and Environment

Jewells Wetland Flood Study

Final Report

R.N2242.001.03

August 2013

Lake Macquarie

DOCUMENT CONTROL SHEET

BMT WBM Pty Ltd BMT WBM Pty Ltd 126 Belford Street BROADMEADOW NSW 2292 Australia PO Box 266 Broadmeadow NSW 2292 Tel: +61 2 4940 8882 Fax: +61 2 4940 8887 ABN 54 010 830 421 003 www.wbmpl.com.au	***Document :*** ***Project Manager :*** ***Client :*** ***Client Contact:*** ***Client Reference***	R.N2242.001.03.docx Darren Lyons Lake Macquarie City Council Greg D Jones

Title :	Jewells Wetland Flood Study –Final Report
Author :	Darren Lyons
Synopsis :	Report for the Jewells Wetland Flood Study covering the development and calibration of computer models, establishment of design flood behaviour and flood mapping.

REVISION/CHECKING HISTORY

REVISION NUMBER	DATE OF ISSUE	CHECKED BY		ISSUED BY	
0	19/01/13	DJL		DJL	
1	02/04/13	DJL		DJL	
2	22/05/13	DJL		DJL	
3	07/08/13	DJL		DJL	

DISTRIBUTION

DESTINATION	REVISION			
	0	1	2	3
Lake Macquarie City Council	1e	1e	1e	10p,5e
BMT WBM File	1e	1e	1e	1e
BMT WBM Library				

EXECUTIVE SUMMARY

Introduction

The Jewells Wetland Flood Study has been prepared for Lake Macquarie City Council (Council) to define the existing flood behaviour in the Jewells Wetland catchment and establish the basis for subsequent floodplain management activities.

The primary objective of the Flood Study is to define the flood behaviour of the Jewells Wetland catchment through the establishment of appropriate numerical models. The study has produced information on flood flows, velocities, levels and extents for a range of flood event magnitudes under existing catchment and floodplain conditions. Specifically, the study incorporates:

- Compilation and review of existing information pertinent to the study and acquisition of additional data including survey as required;
- Development and calibration of appropriate hydrologic and hydraulic models;
- Determination of design flood conditions for a range of design event including the 50% AEP, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and PMF event; and
- Presentation of study methodology, results and findings in a comprehensive report incorporating appropriate flood mapping.

Catchment Description

The Jewells Wetland catchment is a significant catchment located in the north-east region of the city of Lake Macquarie. The catchment occupies a total catchment area of around 21km^2, extending from the ring of townships along the catchment ridgeline, including Dudley, Whitebridge, Charlestown, Mount Hutton, Tingira Heights, and Floraville, draining through a number of creek systems to the coastal outlet at Nine-Mile Beach, Redhead. In addition to the Jewells Wetland catchment, the study also incorporates the neighbouring Freshwater Creek catchment which encompasses an additional area of some 3km^2.

Evident in the catchment topography are the numerous sub-catchments typically defined by relative steep upper catchments emanating from the ridgeline running around the hill top suburbs of Tingira Heights, Mt Hutton, Charlestown and Whitebridge. The main flowpaths through the catchments are generally well-defined draining through to the low-lying Jewells Wetland and on to the coastal outlet.

The lower Jewells Wetland (Crokers Creek) is an Intermittently Closed and Open Lake or Lagoon (ICOLL), which are a characteristic feature of the NSW coastline. An ICOLL has an intermittent connection to the ocean, being terminated periodically by an accumulation of marine sediment in the form of an entrance berm. The entrance berm typically undergoes a period of building during heavy seas, in which the berm level is raised, reducing the connectivity between lake and ocean. Catchment runoff following rainfall events is the natural process through which the entrance berm overtops and scours (entrance breakout), increasing connectivity between lake and ocean.

It is noted that the entrance system consists of a number of potential channels that can scour through the main barrier at the front on Nine-Mile Beach. Under flood conditions, the ability of these channels to scour and convey floodwater from the system has a potentially significant effect on peak flood levels, particularly in the lower catchment below Kalaroo Road.

A significant proportion of the catchment is urbanised consisting of a mix of predominantly residential and some commercial land use. The Bennetts Green and Gateshead estates represent the main commercial/industrial centres within the catchment. The predominant land uses within the catchment can be summarised as approximately 50% natural catchment, 35% urban residential and 7% commercial/industrial.

Given the nature of the catchment topography, the majority of urban area is located on typically higher ground. However, some development has encroached on the floodplain areas of the key tributary particularly around Windale and Gateshead. The lower lying areas around Jewells Wetland are largely undeveloped. However some tourist park and retirement communities along Kalaroo Road are located on relatively low-lying land immediately adjacent to the entrance channels at the downstream end of the catchment.

Historical Flooding

Many areas of the catchment have been subjected to major recorded flooding events dating back to 1969. Significant flooding has occurred at Scrubby Creek, Windale during 1988, 1989 and 2007, with a drowning recorded in Windale during a flash flood event in the late 1990s.

Flooding has also been recorded in the urban areas of Gateshead West to the immediate east of the Charlestown bypass roadway. Downstream at Pacific Highway, Bennetts Green the roadway has been cut on a number of occasions (causing short duration disruption) with major flooding recorded at the industrial areas of Oakdale Road, Gateshead in 1988/89 and 2007. The Jewells Wetland crossing at Kalaroo Road has been cut by floodwaters by over a metre in depth on many occasions during significant flood events, including most recently in 2007, rendering the road impassable for up to forty eight hours. This road is the main thoroughfare between Belmont, Jewells Town and Redhead/Dudley townships.

The June 2007 storm represents a significant event in the catchment being estimated in excess of the 1% AEP design magnitude. Inundation to numerous properties were recorded, a number identified through the community consultation process.

Community Consultation

Community consultation has been an important component of the current study. The consultation has aimed to inform the community about the development of the flood study and its likely outcome as a precursor to subsequent floodplain management activities. It has provided an opportunity to collect information on their flood experience, their concern on flooding issues and to collect feedback and ideas on potential floodplain management measures and other related issues.

The key elements of the consultation process include:

- Distribution of a questionnaire to landowners, residents and businesses within the study area;
- Consultation through the Floodplain Risk Management Committee; and

- Public exhibition of the draft Flood Study.

Model Development (and additional survey)

Development of hydrologic and hydraulic models has been undertaken to simulate flood conditions in the catchment. The hydrological model developed using XP-RAFTS software provides for simulation of the rainfall-runoff process using the catchment characteristics of Jewells Wetland and historical and design rainfall data. The hydraulic model, simulating flood depths, extents and velocities utilises the TUFLOW two-dimensional (2D) software developed by BMT WBM. The 2D modelling approach is suited to model the complex interaction between channels and floodplains and converging and diverging of flows through structures and urban environments.

The floodplain topography is defined using a digital elevation model (DEM) derived from topographic, hydrographic and topographic survey data provided by Council. To supplement the available data, additional cross section survey of the Scrubby Creek and Crokers Creek channels and significant hydraulic structures was acquired during the course of the study.

With consideration to the available survey information and local topographical and hydraulic controls, a hydraulic model was developed extending from the coastal lagoon entrance at the downstream limit, upstream along the major creek alignments. The area modeled within the 2D domain incorporates the majority of the floodplain area of the Jewells Wetland catchment.

Model Calibration and Validation

The selection of suitable historical events for calibration of computer models is largely dependent on available historical flood information. Ideally the calibration and validation process should cover a range of flood magnitudes to demonstrate the suitability of a model for the range of design event magnitudes to be considered.

A number of responses from the community questionnaire provide for valuable anecdotal reports of flooding conditions experienced in the June 2007 event, as well as flood marks (many supported by photographic evidence) which have been subsequently surveyed to establish actual flood level.

The records for the June 2007 event provide the most comprehensive coverage of the catchment of all the historical events identified. The model calibration process therefore is based principally on the historical data available for the June 2007 event. Whilst not as extensive as the June 2007 event in terms of availability of data, the data available for the April 1988 and February 1990 events provided the opportunity for validating the developed model to other actual events experienced in the catchment

Design Event Modelling and Output

The developed models have been applied to derive design flood conditions within the Jewells Wetland catchment. Design rainfall depth is based on the generation of intensity-frequency-duration (IFD) design rainfall curves utilising the procedures outlined in AR&R (2001). A range of storm durations using standard AR&R (2001) temporal patterns, were modelled in order to identify the critical storm duration for design event flooding in the catchment.

A suite of design event scenarios was defined that is most suitable for future floodplain management planning in the Jewells Wetland catchment. Consideration was given to flood events driven by both catchment and ocean processes. The potential impact of climate change on flood behaviour within the catchment has also been considered. The catchment derived events were found to be the critical events in terms of determining maximum flood levels.

The design events considered in this study include the 50% AEP, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and PMF events. The model results for the design events considered have been presented in a detailed flood mapping series for the catchment (see Appendix A). The flood data presented includes design flood inundation, peak flood water levels and depths and peak flood velocities.

Provisional flood hazard categorisation in accordance with Figure L2 of the NSW Floodplain Development Manual (2005) has been mapped in addition to the hydraulic categories (floodway, flood fringe and flood storage) for flood affected areas.

Sensitivity Testing

A number of sensitivity tests have been undertaken to identify the impacts of the adopted model conditions on the design flood levels. Sensitivity tests included:

- The modelled lake entrance berm conditions;
- The coincident catchment and ocean flooding conditions;
- Increased catchment rainfall intensities;
- Initial Wetland water levels; and
- Changes in the adopted roughness parameters.

The modelled entrance berm conditions were found to have a relatively limited impact only in the lower end of the study area.

Conclusions

In completing the flood study, the following activities were undertaken:

- Collation of historical and recent flood information for the study area;
- Development of computer models to simulate hydrology and flood behaviour in the catchment;
- Calibration of the developed models using the available flood data, primarily relating to the June 2007 event with further validation to the April 1988 and February 1990 events;
- Prediction of design flood conditions in the catchment and production of design flood mapping series.

The flood study will form the basis for the subsequent floodplain risk management activities, being the next stage of the floodplain risk management process. The key locations to consider during this process have been identified as:

- Properties in Windale adjacent to Scrubby Creek

- Properties within the Gateshead industrial area;
- Properties in the lower catchment downstream of Kalaroo Road; and
- Kalaroo Road flood immunity.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

The Jewells Wetland Flood Study has been prepared for Lake Macquarie City Council (Council) to define the existing flood behaviour in the Jewells Wetland catchment and establish the basis for subsequent floodplain management activities.

This project has received technical and financial support from the NSW Government‟s Floodplain Management Program.

1.1 Study Location

The Jewells Wetland catchment encompasses an area of approximately 21km^2 located on the New South Wales coast as shown in Figure 1-1. The Jewells Wetland water body is located behind the coastal dune system and is connected to the Tasman Sea via a number of entrance channels. In addition to the Jewells Wetland catchment, the study also incorporates the neighbouring Freshwater Creek catchment which encompasses an additional area of some 3km^2.

The study area includes parts of the suburbs of Mt Hutton, Tingira Heights, Windale, Gateshead, Bennetts Green, Redhead and Jewells. As noted in Council‟s brief, this significant catchment area incorporates:

- Residential area of 700ha;
- Industrial area of 150ha;
- A population of some 18,000; and
- Number of dwellings 7,000

The flooding risk in the catchment emanates from a number of major tributaries that generally drain to the Jewells Wetland including Scrubby Creek, Johnsons Creek, Crokers Creek, and other smaller local watercourses. The rapid catchment response to heavy rainfall and subsequent flooding in highly urbanised areas, including relatively low-lying areas of the wetland and lower catchment, presents a major risk to people and property. The lower parts of the catchment around Redhead and Kalaroo Road are also at risk of ocean derived flooding from tides and storm surge.

1.2 Study Background

The study area is defined as principally the Crokers Creek/ Jewells Wetland catchment area, which itself contains a number of significant tributary sub-catchments. There has been no previous detailed investigation of the flood behaviour across the Jewells Wetland catchment. To date, only piecemeal analysis has been undertaken on some individual sub-catchments in attempting to define local catchment flood behaviour and derive flood levels.

Significant flooding has occurred most recently in the catchment on the long weekend in June 2007. This was associated with the same rainfall event that resulted in flooding across the broader Lower Hunter and Central Coast regions, including widespread flooding in Newcastle and Lake Macquarie, The event is now commonly referred to as the “Pasha Bulka” storm in reference to the coal ship that ran aground on Nobbys Beach in Newcastle. There are other records of historical flooding, most notably the February 1990 and April 1988.

Title:
Study Locality

Figure: 1-1

Rev: A

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Locality_Plan.WOR

1.3 The Need for Floodplain Risk Management in the Jewells Wetland Catchment

The historic flooding of residential and commercial premises in the Jewells Wetland catchment, including most recently in 2007, has highlighted the risk of developed areas situated within the floodplain of Jewells Wetland and its contributing creeks. Future sea level rise predictions put further pressure on both the current and planned development situated within low-lying coastal areas.

Current practice in floodplain management generally requires consideration of the impact of potential climate change scenarios on design flood conditions. For the Jewells Wetland catchment this includes both increases in design rainfall intensities and sea level rise scenarios impacting on ocean boundary conditions. Accordingly, these potential changes will translate into increased design flood inundation, such that future planning and floodplain management in the catchment will need to take due consideration of this increased flood risk.

Floodplain risk management considers the consequences of flooding on the community and aims to develop appropriate floodplain management measures to minimise and mitigate the impact of flooding. This incorporates the existing flood risk associated with current development, and future flood risk associated with future development and changes in land use.

Accordingly, Council desires to approach local floodplain management in a considered and systematic manner. This study comprises the initial stages of that systematic approach, as outlined in the Floodplain Development Manual (NSW Government, 2005). The approach will allow for more informed planning decisions within the floodplain of Jewells Wetland and the contributing creeks.

1.4 The Floodplain Risk Management Process

The State Government‟s Flood Prone Land Policy is directed towards providing solutions to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. Policy and practice are defined in the Government‟s Floodplain Development Manual (2005).

Under the Policy the management of flood liable land remains the responsibility of Local Government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. The Policy provides for technical and financial support by the State Government through the following four sequential stages:

Stages of Floodplain Management

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

This study represents Stage 1 of the above process and aims to provide an understanding of flood behaviour within the Jewells Wetland catchment.

1.5 Study Objectives

The primary objective of the Flood Study is to define the flood behaviour of the Jewells Wetland catchment through the establishment of appropriate numerical models. The study has produced information on flood flows, velocities, levels and extents for a range of flood event magnitudes under existing catchment and floodplain conditions. Specifically, the study incorporates:

- Compilation and review of existing information pertinent to the study and acquisition of additional data including survey as required;
- Development and calibration of appropriate hydrologic and hydraulic models;
- Determination of design flood conditions for a range of design event including the 50% AEP, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and PMF event; and
- Presentation of study methodology, results and findings in a comprehensive report incorporating appropriate flood mapping.

The principal outcome of the flood study is the understanding of flood behaviour in the catchment and in particular design flood level information that will be used to set appropriate flood planning levels for the study area.

1.6 About this Report

This report documents the Study"s objectives, results and recommendations.

Section 1 introduces the study.

Section 2 provides an overview of the approach adopted to complete the study.

Section 3 outlines the community consultation program undertaken.

Section 4 provides information on the additional survey collected for this study.

Section 5 details the development of the computer models.

Section 6 details the model calibration and validation process including sensitivity tests.

Section 7 presents the adopted design flood inputs and boundary conditions.

Section 8 presents design flood simulation results and associated flood mapping.

2 STUDY APPROACH

2.1 The Study Area

2.1.1 Catchment Description

The Jewells Wetland catchment is a significant catchment located in the north-east region of the city of Lake Macquarie. The catchment occupies a total catchment area of around 21km^2, extending from the ring of townships along the catchment ridgeline, including Dudley, Whitebridge, Charlestown, Mount Hutton, Tingira Heights, and Floraville, draining through a number of creek systems to the coastal outlet at Nine-Mile Beach, Redhead.

The topography of the catchment is shown in Figure 2-1. Evident in the catchment topography are the numerous sub-catchments typically defined by relatively steep upper catchments emanating from the ridgeline running around the hill top suburbs of Tingira Heights, Mt Hutton, Charlestown and Whitebridge. The main flowpaths through the catchments are generally well-defined draining through to the low-lying Jewells Wetland area and on to the coastal outlet.

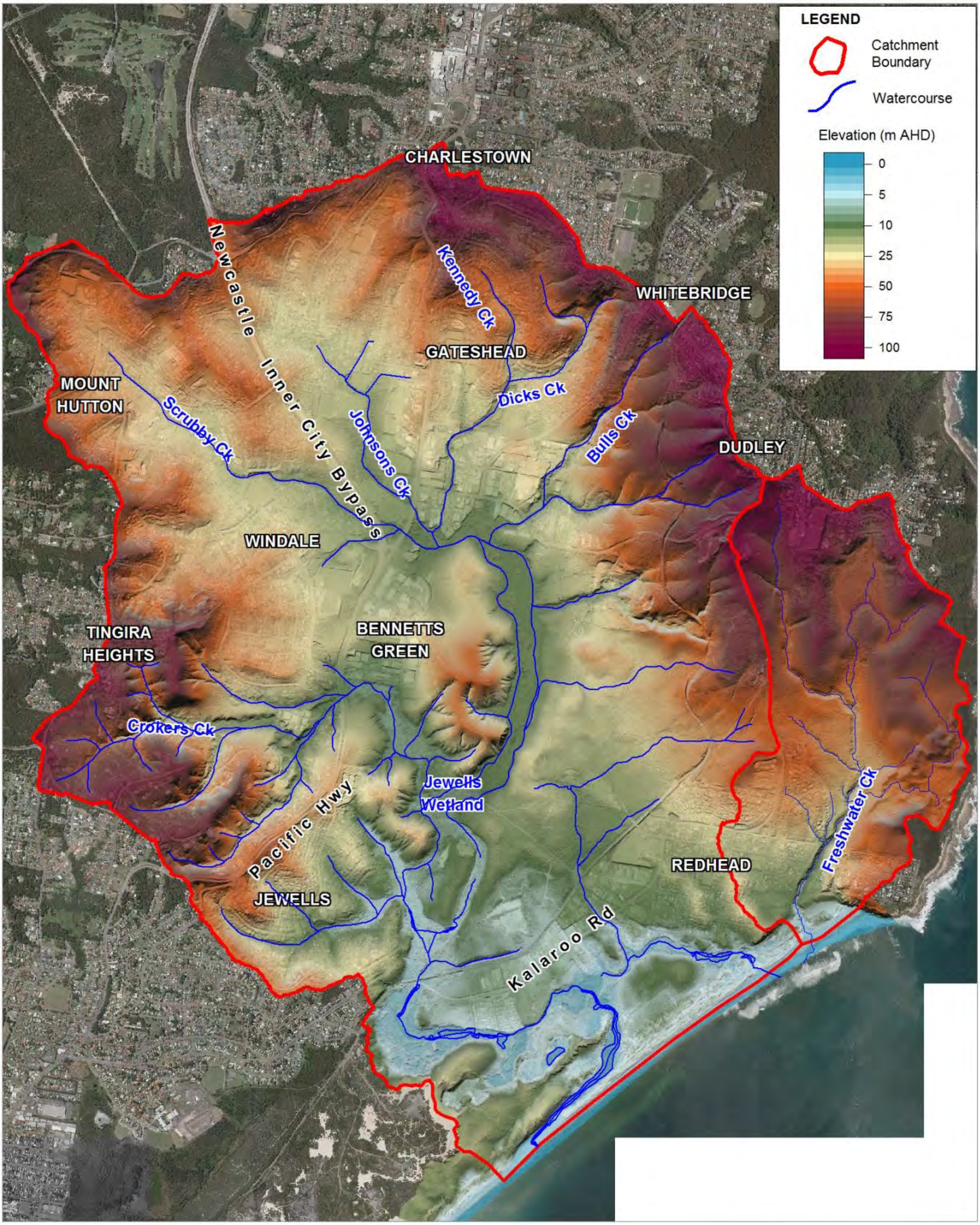
The lower Jewells Wetland (Crokers Creek) is an Intermittently Closed and Open Lake or Lagoon (ICOLL), which are a characteristic feature of the NSW coastline. An ICOLL has an intermittent connection to the ocean, being terminated periodically by an accumulation of marine sediment in the form of an entrance berm. The entrance berm typically undergoes a period of building during heavy seas, in which the berm level is raised, reducing the connectivity between lake and ocean. Catchment runoff following rainfall events is the natural process through which the entrance berm overtops and scours (entrance breakout), increasing connectivity between lake and ocean.

It is noted that the entrance system consists of a number of potential channels that can scour through the main barrier at the front on Nine-Mile Beach. Under flood conditions, the ability of these channels to scour and convey floodwater from the system has a potentially significant effect on peak flood levels, particularly in the lower catchment below Kalaroo Road.

A significant proportion of the catchment is urbanised consisting of a mix of predominantly residential and some commercial land use. The Bennetts Green and Gateshead estates represent the main commercial/industrial centres within the catchment. The predominant land uses within the catchment can be summarised as approximately 50% natural catchment, 35% urban residential and 7% commercial/industrial.

Given the nature of the catchment topography, the majority of urban area is located on typically higher ground. However, some development has encroached on the floodplain areas of the key tributary particularly around Windale and Gateshead. The lower lying areas around Jewells Wetland are largely undeveloped. However some tourist park and retirement communities along Kalaroo Road are located on relatively low-lying land immediately adjacent to the entrance channels at the downstream end of the catchment.

The catchment is traversed by the major transport routes of the Pacific Highway and the Newcastle Inner City Bypass. There is the potential for sections of the highway to become overtopped by flood waters during large magnitude flood events.



Title:

Study Area Topography

Figure: **2-1**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\DEM.WOR

2.1.2 History of Flooding

Council"s study brief noted all areas of the catchment have been subjected to major recorded flooding events dating back to 1969. Significant flooding has occurred at Scrubby Creek, Windale during 1988, 1990 and 2007, with a drowning recorded in Windale during a flash flood event in the late 1990s.

Flooding has also been recorded in the urban areas of Gateshead West to the immediate east of the Charlestown bypass roadway. Downstream at Pacific Highway, Bennetts Green the roadway has been cut on a number of occasions (causing short duration disruption) with major flooding recorded at the industrial areas of Oakdale Road, Gateshead in 1988, 1990 and 2007. The Jewells Wetland crossing at Kalaroo Road has been cut by floodwaters by over a metre in depth on many occasions during significant flood events, including most recently in 2007, rendering the road impassable for up to forty eight hours. This road is the main thoroughfare between Belmont, Jewells Town and Redhead/Dudley townships.

In addition to the anecdotal evidence of previous flooding, Council records provide for a number of recorded flood levels throughout the catchment. Further data has also been sought through questionnaires as part of the community consultation for the study.

The major events for which most of the collected data relates to includes:

- April 1988;
- February 1990; and
- June 2007

2.1.3 Previous Investigations

There has been no previous comprehensive study of flood behaviour within the study catchment. However, a number of flood investigations have been undertaken for the selected reaches including Scrubby Creek through Windale and the lower reaches of Jewells Wetland downstream of Kalaroo Road to the coastal entrance. The most relevant of these studies were provided by Council and are discussed in Section 2.2.1.

2.2 Compilation and Review of Available Data

2.2.1 Previous Studies

2.2.1.1 Lower Jewells Swamp Flood Study (Patterson Britton & Partners, 1995

The flood study focussed on the lower end of the Jewells Wetland catchment, specifically the reach below Kalaroo Road. The study used a 1-dimensional (MIKE-11 software) to derive 1% AEP flood level conditions in the lower reach. The model utilised a simplified representation to simulate the impact of entrance scour on flood levels. The study also included a brief assessment of entrance management options including maintenance of berm height levels and provision for a permanently open entrance.

Whilst providing some useful background information, the current study will largely supersede the modelling from the previous investigation.

2.2.1.2 Gateshead West Hydrology Study (Hunter Water Board, 1991)

The Gateshead West study investigated a catchment area of 205 ha located in the upper reaches of Johnsons Creek. The study largely deals with the local overland flow and stormwater drainage system capacity. The study was initiated after the area experienced repeated instances of flooding, including April 1988 which is identified as a significant event in the catchment.

The study largely identified a drainage improvement strategy to address the existing flood problems. It is understood that subsequent to the study major stormwater upgrades were completed in the area.

2.2.2 Historical Flood Levels

As discussed in Section 2.1.2, Council"s existing flood databases have some historical flood records available in the Jewells catchment. The recent flood events of June 2007 provided a substantial amount of additional flood information. The majority of this information was sourced through the community consultation process undertaken for the study.

The collected data has been used during the model calibration process, detailed in Section 6.

2.2.3 Rainfall Data

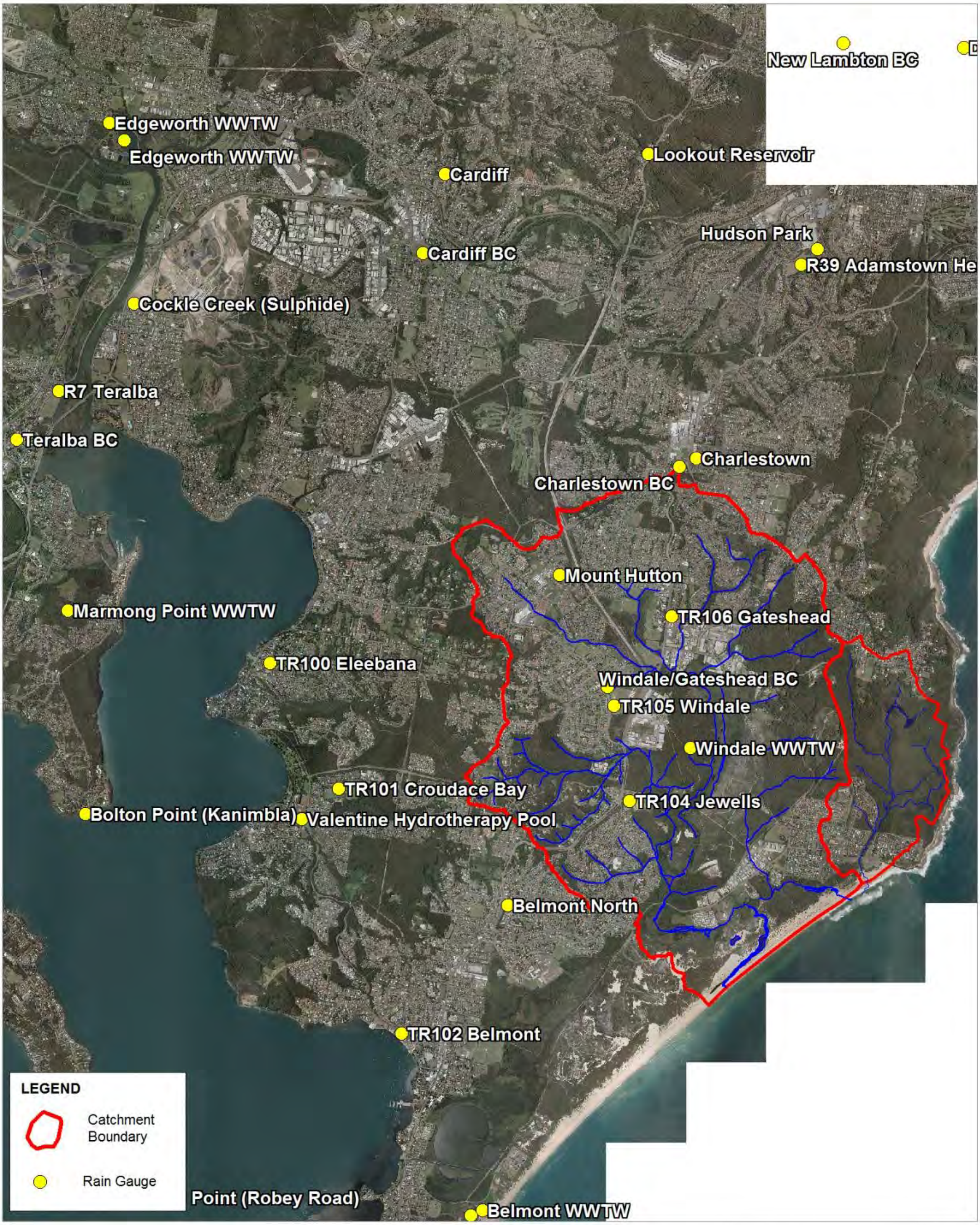
There is an extensive network of rainfall gauges across the wider Lake Macquarie area operated by the Bureau of Meteorology (BoM) and Hunter Water Corporation (HWC). The full list of rainfall stations, including closed stations, within approximately a 5km radius of the Jewells Wetland catchment is shown in Table 2-1 with their respective period of record. The distribution of these gauges is shown in Figure 2-2.

Significantly, there are a number of operational rain gauges situated within the study catchment. These include the Hunter Water pluvio stations:

- TR104 Greenleaf Retirement Village at Ntaba Road, Jewells;
- TR105 Tooltaba Reserve at South Street, Windale; and
- TR106 No. 5 Macquarie Avenue Gateshead.

The above gauges remained operational during the June 2007 event and recorded valuable rainfall data utilised in the current study for model calibration as discussed in Section 6.

As indicated in Table 2-1 the majority of rainfall stations nearby the Jewells catchment have a relatively short term rainfall record. The closest gauge with a substantial period of record of some 104 years is the daily gauge at the former Pasminco site on Cockle Creek. The five largest daily rainfall totals recorded at the gauge site are presented in Table 2-2. Of the known major recent flood events in the catchment only January 1990 is listed, with only minor rainfall recorded for the April 1988 event and the station closed prior to June 2007.



Title:

Rain Gauges in Vicinity of Jewells Wetland

Figure: 2-2

Rev: A

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Rain_Gauges_Broad.WOR

Table 2-1 Summary of Rainfall Gauges in the Jewells Wetland Locality

Station No.	Name	Operator	Type	Start Year	End Year
061011	Cockle Creek (Pasminco)	BoM	Daily	1900	2003
061133	Bolton Point (The Ridgeway)	BoM	Daily	1962 2006	1990 current
061254	Charlestown	BoM	Daily	1968	1972
061299	Belmont WWTP	BoM	Daily	1990	current
061359	Mount Hutton (Auklet Road)	BoM	Daily	1987	2005
061367	Belmont North (Wommara Ave)	BoM	Daily	1990 1996	1991 1997
061391	Merewether (Burwood Rd WWTP)	BoM	Daily	1990	current
R2	Belmont WWTW	Hunter Water	Pluvio	1991	current
R5	Charlestown BC	Hunter Water	Pluvio	1986	current
R13	Valentine Hydrotherapy Pool	Hunter Water	Pluvio	1991	current
R17	Windale/Gateshead BC	Hunter Water	Pluvio	1990	current
R58	Belmont WWTW	Hunter Water	Daily	1990	current
R62	Burwood Beach WWTW	Hunter Water	Daily	1990	current
R75	Windale WWTW	Hunter Water	Daily	1990	current
TR99	Warners Bay Soccer Club	Hunter Water	Pluvio	1991	current
TR100	Eleebana Oval	Hunter Water	Pluvio	1991	current
TR101	Croudace Bay Playing Fields	Hunter Water	Pluvio	1991	current
TR102	Belmont No.6 WWPS	Hunter Water	Pluvio	1991	current
TR103	Belmont No.2 WWPS	Hunter Water	Pluvio	1991	current
TR104	Greenleaf Retirement Village	Hunter Water	Pluvio	1991	current
TR105	Tooltaba Reserve Windale	Hunter Water	Pluvio	1991	current
TR106	No. 5 Macquarie Avenue	Hunter Water	Pluvio	1991	current

Table 2-2 Cockle Creek Highest Daily Rainfall Records

Date	1-day Rainfall (mm)	Date	2-day Rainfall (mm)
February 1990	270	February 1990	420
February 1908	265	June 1930	388
February 1908	250	April 1927	326
April 1927	248	June 1949	322
June 1930	241	February 1908	287
March 1913	225	February 1981	278

The list of daily totals shown in Table 2-2 does not necessarily indicate the largest flood events, as short duration high intensity storm events with lower daily rainfall totals may have resulted in more substantial flooding than some of the events indicated by the daily rainfall record.

The April 1988 and February 1990 events are the other two major events occurring in the Jewells Wetland catchment for which flood level records are available. Whilst daily read rainfall records within the catchment and near vicinity are available, the closest operable continuous rainfall gauges for these events are located at Maryville and Barnsley, each approximately 12km from the Jewells Wetland.

Further discussion on recorded rainfall data for historical events is presented with the calibration and validation of the models developed for the study in Section 6.

2.2.4 Council Data

Digitally available information such as aerial photography, cadastral boundaries, topography, watercourses, drainage networks, land zoning, vegetation communities and soil landscapes were provided by Council in the form of GIS datasets.

LiDAR land survey data covering the entire study area was acquired in 2007. Flood behaviour is inherently dependent on the ground topography and for this study an accurate representation of the floodplain is essential. Advanced GIS analysis also allows the LiDAR imagery to be assessed in concert with spatial 2-D flood model data, facilitating mapping, categorisation, and overall flood management.

2.3 Site Inspections

A number of site inspections were undertaken during the course of the study to gain an appreciation of local features influencing flooding behaviour. Some of the key observations to be accounted for during the site inspections included:

- Presence of local structural hydraulic controls including the road bridges/culverts and associated embankments, the stormwater drainage network and the Fernleigh Track embankment;
- General nature of the main creeks and tributary channels and associated floodplain noting river plan form, vegetation type and coverage and the presence of significant flow paths;
- Entrance conditions and connectivity between Jewells Wetland and the ocean, and configuration of beachfront topography; and
- Location of existing development and infrastructure on the floodplain.

This visual assessment was useful for defining hydraulic properties within the hydraulic model and ground-truthing of topographic features identified from the survey datasets.

2.4 Additional Survey

The review of available topographic data identified the requirement for additional survey to be undertaken to provide the necessary coverage and detail required to build the hydraulic model. The additional survey incorporated:

- Cross sections of the major drainage channels to supplement the existing LiDAR topographical data. Due to limitations in the aerial survey method, the detail of watercourses is often obscured (e.g. by standing water, vegetation etc.). Ground survey is required to provide the required detail of the watercourses to integrate with the LiDAR data; and

- A number of flood drainage structures (including bridges and culverts) for which no existing details were available.

The NSW Office of Environment and Heritage (OEH) undertook survey of the coastal entrances of the Jewells Wetland catchment in December 2011. This survey data incorporated survey of the entrance berms, channels and broader dune system, and also included survey of debris lines potentially from previous flood events.

The acquisition of the additional survey is discussed in further detail in Section 4.

2.5 Community Consultation

The success of a floodplain management plan hinges on its acceptance by the community, residents within the study area, and other stake holders. This can be achieved by involving the local community at all stages of the decision-making process. This includes the collection of their ideas and knowledge on flood behaviour in the study area, together with discussing the issues and outcomes of the study with them.

A community consultation program is typically undertaken as part of the flood study. This is to both inform the community of the progress of the study and to acquire supplementary flood information to assist with the model calibration.

The key elements of the consultation process in undertaking the flood study have been:

- Issue of a questionnaire to obtain historical flood data and community perspective on flooding issues, including follow up consultation with relevant respondents of the questionnaire; and

- Public exhibition of Draft Report and community information session.

These elements are discussed in further detail in Section 3.

2.6 Development of Computer Models

2.6.1 Hydrological Model

For the purpose of the Flood Study, a hydrologic model (discussed in Section 5.1) was developed to simulate the rate of storm runoff from the catchment. The model predicts the amount of runoff from rainfall and the attenuation of the flood wave as it travels down the catchment. This process is dependent on:

- Catchment area, slope and vegetation;
- Variation in distribution, intensity and amount of rainfall; and
- Antecedent conditions of the catchment.

The output from the hydrologic model is a series of flow hydrographs at selected locations such as at the boundaries of the hydrodynamic model. These hydrographs are used by a hydrodynamic model to simulate the passage of a flood through the Jewells Wetland catchment to the downstream study limits at the entrance into the Tasman Sea.

2.6.2 Hydraulic Model

The hydraulic model (discussed in Section 5.2) developed for this study includes:

- two-dimensional (2D) representation of the floodplain of Jewells Wetland and its contributing Creeks, which includes all of the floodplain in the developed areas; and
- morphological representation of the channel entrance and surrounds, utilising the van Rijn erosion method.

The hydraulic model is applied to determine flood levels, velocities and depths across the study area for historical and design events.

2.7 Calibration and Sensitivity Testing of Models

The hydrologic and hydrodynamic models were calibrated and verified to available historical flood event data to establish the values of key model parameters and confirm that the models were capable of adequately simulating real flood events.

The following criteria are generally used to determine the suitability of historical events to use for calibration or validation:

- The availability, completeness and quality of rainfall and flood level event data;
- The amount of reliable data collected during the historical flood information survey; and
- The variability of events – preferably events would cover a range of flood sizes.

The major historical flood events of June 2007, January 1990 and April 1988 were identified as potentially suitable events for calibration/validation of the developed models. Assessment of the model performance also incorporated a range of sensitivity tests of key variables/model assumptions. Sensitivity testing was undertaken for the design flood events and has been reported in Section 8.5.

2.8 Establishing Design Flood Conditions

Design floods are statistical-based events which have a particular probability of occurrence. For example, the 1% Annual Exceedance Probability (AEP) event is the best estimate of a flood with a peak discharge that has a 1% (i.e. 1 in 100) chance of occurring in any one year. For the Jewells Wetland catchment, design floods were based on design rainfall estimates in accordance with the procedures Australian Rainfall and Runoff (IEAust, 2001).

The design flood conditions form the basis for floodplain management in the catchment and in particular design planning levels for future development controls. The adopted design flood conditions are presented in Section 7.

2.9 Mapping of Flood Behaviour

Design flood mapping is undertaken using output from the hydrodynamic model. Maps are produced showing water level, water depth and velocity for each of the design events. The maps present the peak value of each parameter. Provisional flood hazard categories and hydraulic categories are derived from the hydrodynamic model results and are also mapped. The mapping outputs are described in Section 8 and presented in Appendix A.

3 COMMUNITY CONSULTATION

3.1 The Community Consultation Process

Community consultation has been an important component of the current study. The consultation has aimed to inform the community about the development of the flood study and its likely outcome as a precursor to subsequent floodplain management activities. It has provided an opportunity to collect information on their flood experience, their concern on flooding issues and to collect feedback and ideas on potential floodplain management measures and other related issues.

The key elements of the consultation process include:

- Distribution of a questionnaire to landowners, residents and businesses within the study area;
- Follow up consultation with questionnaire respondents;
- Consultation through the Floodplain Risk Management Committee; and
- Public exhibition of the draft Flood Study (to be undertaken).

These elements are discussed further below.

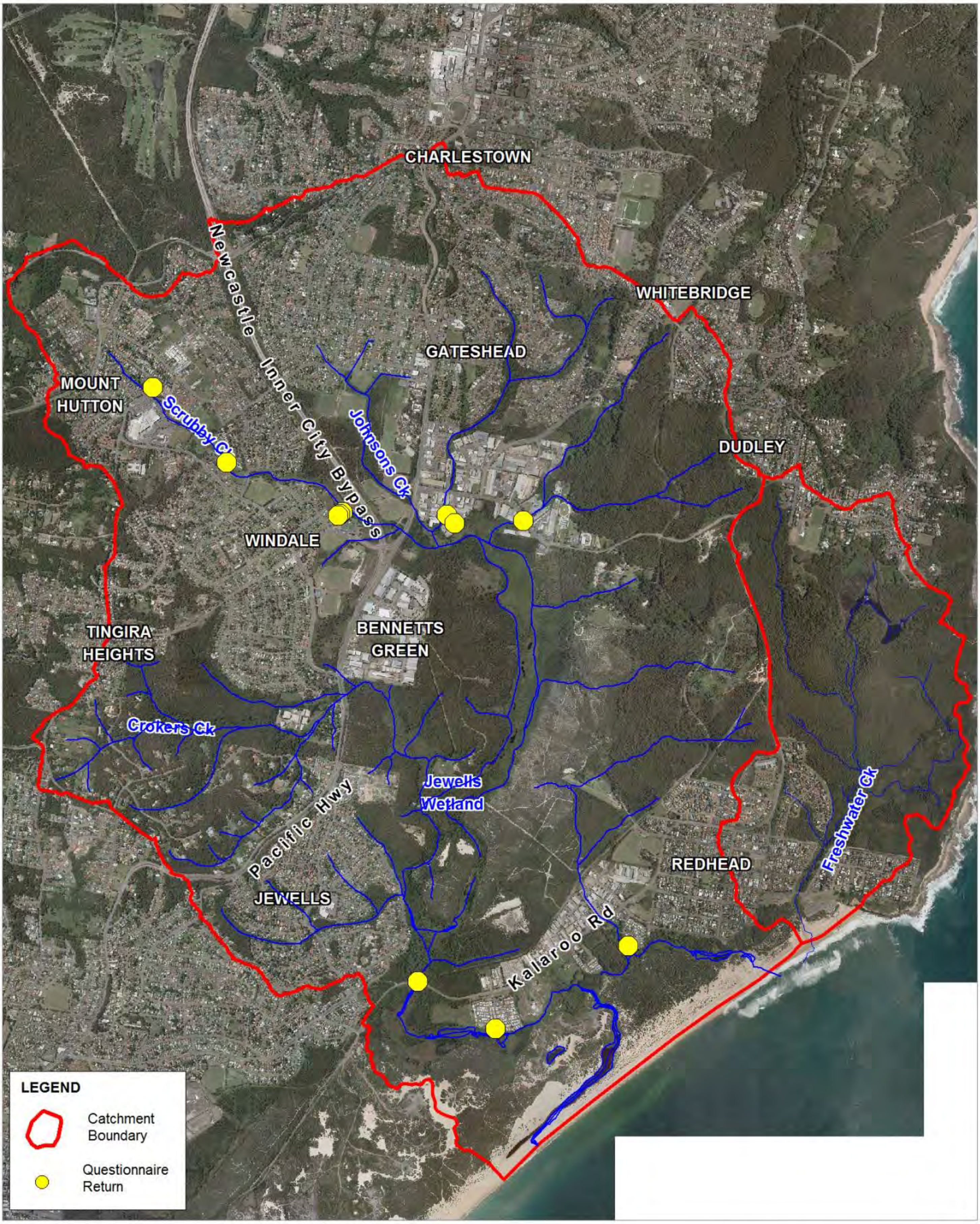
3.2 Community Questionnaire

In June 2012, a short questionnaire was sent to potentially flood affected landowners, residents and businesses located within the study area. Council distributed the questionnaire to some 270 properties, with Council receiving 15 responses. Of these responses, 10 had relevant information relating to flooding in the Jewells Wetland catchment. The distribution of these responses in the catchment is shown in Figure 3-1.

The questionnaire asked residents to provide as much information as possible in regard to historical flood events within the catchment. A copy of the questionnaire is included in Appendix C. Provided hereunder is a summary of the key information provided in the responses.

Historical Flooding

- Years of flooding – respondents were asked to acknowledge dates of previous flood events within the catchment from personal experience. The majority of respondents confirmed experience of the most recent significant flood events in the catchment being June 2007. Additional flood events noted by individual respondents included the 1988 and 1990 events.
- Flood marks – a key objective of the flood questionnaires was to obtain peak flood level reference points for model calibration purposes. Information received was largely in the form of anecdotal reports of flooding and some photographs predominantly for the June 2007 flood event. Ten historical flood marks were identified for the June 2007 event and were later surveyed to obtain peak flood levels.



Title:

Distribution of Questionnaire Returns

Figure: 3-1

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Questionnaire_Returns.WOR

Following collation and review of all returned questionnaires, follow up consultation was undertaken with relevant respondents of the questionnaire. The objective of this follow up consultation was to confirm details of flood marks so that they could be incorporated into the field survey.

Staff from BMT WBM and Council‟s survey team undertook specific site inspections and discussion with residents to confirm observations of flooding and other anecdotal flooding reports. The majority of information provided by residents related to June 2007 flooding. Further details of the flood behaviour provided by the residents and its use in the model calibration process are presented in Section 6.2.4.

3.3 Public Exhibition

The Draft Jewells Wetland Flood Study was placed on public exhibition for a 4-week period to 01 August 2013. Landowners, residents and businesses were invited to participate in the study by providing comment on the Draft report. During this period, community members have the opportunity to review the flood study and provide feedback on the study approach and findings.

Two formal submissions were received from:

- NSW Roads and Maritime Services; and
- Community Environment Network Inc.

Copies of the submissions received are provided in Appendix C for reference. No additional information or modifications to the study were considered required in response to the submissions.

4 ADDITIONAL SURVEY

The following sections outline the additional survey data collected to supplement the existing data and enable the establishment of a suitable two-dimensional model representation for the contributing channels of Jewells Wetland. Survey output is provided in Appendix D for reference.

4.1 Channel Cross Sections

The effectiveness of aerial data capture is often limited in the vicinity of the main creek alignment due to the presence of water and dense vegetation. In these instances cross-section surveys are required to accurately define the shape of the watercourse.

Figure 4-1 shows the location of cross sections that were surveyed by Council to provide additional waterway information for the Jewells Wetland catchment.

The majority of the surveyed cross sections were located within the reaches including the lower Jewells Wetland downstream of Kalaroo Road and the reach of Scrubby Creek through Windale. The cross section locations also coincide with the location of major hydraulic structures as discussed in Section 4.2. The distribution and average spacing of cross sections was defined to provide an appropriate level of detail to develop the hydraulic model.

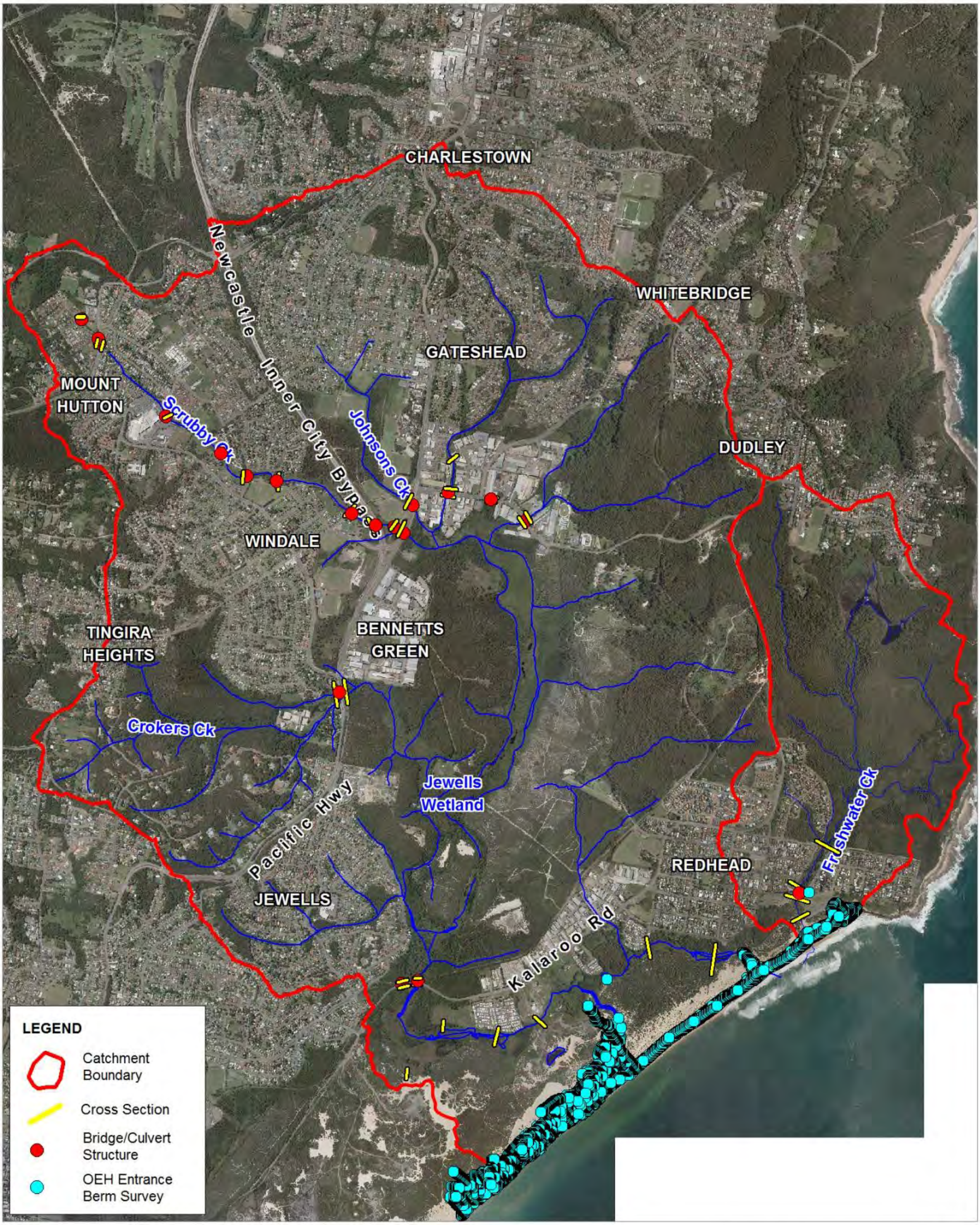
The ground survey also provides the opportunity to assess the relative accuracy of the LiDAR data. Due to access difficulties, Council survey team were unable to survey cross sections across the majority of the Jewells Wetland area. It is acknowledged that in these heavily vegetated areas, the limitations of the LiDAR would be most pronounced. Discrepancy in the LiDAR representation of the actual bed level condition in the Jewells Wetland area is unlikely to have a major influence on the design flood conditions in the broader study area. The Jewells Wetland area provides for a significant temporary storage of floodwater in the system. In major events the typical water depths are in excess of 2m. The LiDAR data typically provides for reasonable representation of the bulk storage in the wetland area, albeit with the accuracy of the absolute bed level not known. Given the broader inundation across the floodplain and the storage volume within this part of the system, additional detail of the low-flow channel areas would not impact on the flood results.

In the other areas of the catchment, particularly where there is the main concentration of potentially affected development, comparison of the surveyed data points from Council ground survey compares well with the LiDAR representation.

4.2 Structures

There are numerous hydraulic structures on the main channels within the study area for which limited existing survey detail was available. Accordingly, the ground survey undertaken by Council included the survey of numerous structures to provide the structure details required to build the hydraulic model such as dimensions, waterway areas and invert levels.

Nineteen (19) structures in total were surveyed including bridges and culverts on main channel and tributary alignments. Further structure details and their respective model configuration are presented in Section 5.2.3.



Title:

Location of Additional Survey

Figure: 4-1

Rev: A

N

0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Additional_Survey.WOR

4.3 Historical Flood Marks

Details of historical flood marks were sought as part of the community questionnaire (refer Section 3). The historical flood marks generally comprise recorded marks (from photographic evidence or points reconstructed from the memories of community members) and the levels which these marks represent need to be known in order to utilise them in the hydraulic model calibration and verification process. As such, identified flood marks across the catchment were surveyed.

4.4 Beach Berm and Entrance Survey

The Office of Environment and Heritage (OEH) provided additional ground survey of the entrance, with spot heights detailing the profile of the entrance channel, berm and coastal dune system around the outlet of Crokers Creek. The survey included flood debris lines which are believed to be from the June 2007 flood event. Further discussion of the debris marks is provided in the model calibration (refer to Section 6).

5 MODEL DEVELOPMENT

Computer models are the most accurate, cost-effective and efficient tools to assess a catchment"s flood behaviour. For this study, two types of models were used:

- A hydrologic model of the entire Jewells Wetland Lake catchment; and
- A hydraulic model covering the floodplain area of the major tributary channels including Scrubby Creek, Johnsons Creek, Crokers Creek, and other smaller local watercourses.

The **hydrologic model** simulates the catchment rainfall-runoff processes, producing the river/creek flows which are used in the hydraulic model.

The **hydraulic model** simulates the flow behaviour of the channel and floodplains, producing flood levels, flow discharges and flow velocities.

Both of these models were calibrated interactively.

Information on the topography and characteristics of the catchments, watercourses and floodplains are built into the models. Recorded historical flood data, including rainfall, flood levels and river flows, are used to simulate and validate (calibrate and verify) the models. The models produce as output, flood levels, flows (discharges) and flow velocities.

Development of a hydraulic model follows a relatively standard procedure:

1. Discretisation of the catchment, watercourses, floodplain, etc.
2. Incorporation of physical characteristics (river cross-sections, floodplain levels, structures etc.).
3. Establishment of hydrographic databases (rainfall, river flows, flood levels) for historic events.
4. Calibration to one or more historic floods (calibration is the adjustment of parameters within acceptable limits to reach agreement between modelled and measured values).
5. Verification to one or more other historic floods (verification is a check on the model"s performance without further adjustment of parameters).
6. Sensitivity analysis of parameters to measure dependence of the results upon model assumptions.

Once model development is complete it may then be used for:

- Establishing design flood conditions;
- Determining levels for planning control; and
- Modelling development or management options to assess the hydraulic impacts.

5.1 Hydrological Model

The hydrologic model simulates the rate at which rainfall runs off the catchment. The amount of rainfall runoff and the attenuation of the flood wave as it travels down the catchment are dependent on:

- The catchment slope, area, vegetation and other characteristics;
- Variations in the distribution, intensity and amount of rainfall; and
- The antecedent conditions (dryness/wetness) of the catchment.

These factors are represented in the model by:

- Sub-dividing (discretising) the catchment into a network of sub-catchments inter-connected by channel reaches representing the creeks and rivers. The sub-catchments are delineated, where practical, so that they each have a general uniformity in their slope, landuse, vegetation density, etc.;
- The amount and intensity of rainfall is varied across the catchment based on available information. For historical events, this can be very subjective if little or no rainfall recordings exist.
- The antecedent conditions are modelled by varying the amount of rainfall which is “lost” into the ground and “absorbed” by storages. For very dry antecedent conditions, there is typically a higher initial rainfall loss.

The output from the hydrologic model is a series of flow hydrographs at selected locations such as at the boundaries of the hydraulic model. These hydrographs are used by the hydraulic model to simulate the passage of the flood through the Jewells Wetland catchment.

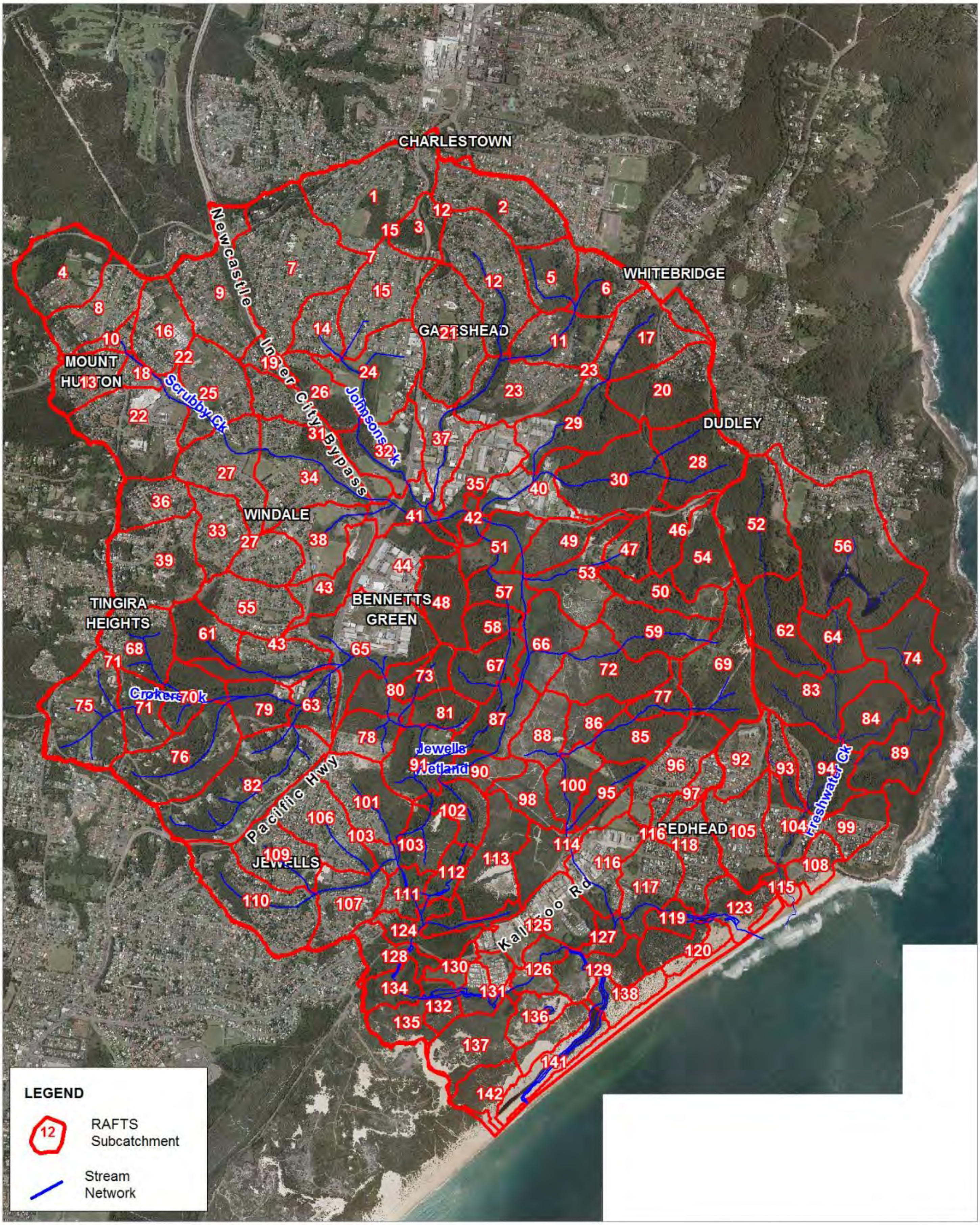
The XP-RAFTS software was used to develop the hydrologic model using the physical characteristics of the catchment including catchment areas, ground slopes and vegetation cover as detailed in the following sections.

5.1.1 Flow Path Mapping and Catchment Delineation

The Jewells Wetland catchment drains an area of approximately 22km^2 to the coastal entrance at the Tasman Sea. For the hydrological model this area has been delineated into 142 sub-catchments as shown in Figure 5-1. The sub-catchment delineation provides for generation of flow hydrographs at key confluences or inflow points to the hydraulic model.

Table 5-1 summarises the key catchment parameters adopted in the XP-RAFTS model, including catchment area, vectored slope and PERN (roughness) value estimated from the available topographic information and aerial photography. The adopted PERN values considered the proportion of different land surface coverage in each sub-catchment such as forested catchment, cleared floodplain, urban development, waterway etc.

For sub-catchments with higher proportions of urban development, lower PERN values have been adopted to reflect the increased responsiveness of the urban land use types. These urban sub-catchments have also been modelled using a second sub-catchment approach, where the impervious areas are treated separately. The PERN value for these impervious areas has been set to 0.015 accordingly.



Title:
RAFTS Model Sub-catchment Layout

Figure: 5-1

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 0.75 1.5km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\RAFTS_Layout.WOR

Table 5-1 RAFTS Sub-catchment Properties

Catchment Label	Area (ha)	Slope (%)	Impervious %	Catchment Label	Area (ha)	Slope (%)	Impervious %
1	41.5	4.8	50	72	25.5	1.6	1
2	27.8	4.8	50	73	7.7	4.1	1
3	11.2	11.7	50	74	24.8	1.6	1
4	26.3	6.1	23	75	31.3	7.7	41
5	14.7	7.8	16	76	31.7	6.2	45
6	14.4	11.7	17	77	8.0	3.0	1
7	53.8	2.2	49	78	11.9	3.3	13
8	20.5	4.3	43	79	12.9	2.5	13
9	32.1	3.0	57	80	11.5	0.5	1
10	4.6	3.4	48	81	9.5	3.2	1
11	20.1	3.1	26	82	44.0	3.4	54
12	35.0	4.8	47	83	26.9	3.3	2
13	14.6	3.9	45	84	15.1	6.5	1
14	12.5	0.7	50	85	14.7	1.8	1
15	26.7	2.1	49	86	9.4	1.2	1
16	19.0	3.3	50	87	17.1	1.1	1
17	23.9	5.5	29	88	13.3	1.4	1
18	4.8	2.2	50	89	21.1	2.6	1
19	5.6	2.6	70	90	9.1	0.7	1
20	26.6	7.4	15	91	17.6	0.9	1
21	33.4	2.5	50	92	14.3	3.8	42
22	35.1	2.9	42	93	7.6	6.5	35
23	27.3	1.4	36	94	20.5	4.9	11
24	27.8	1.4	27	95	9.8	1.0	1
25	23.6	3.0	50	96	20.5	1.6	30
26	13.5	1.3	11	97	7.1	3.1	50
27	26.5	2.2	50	98	10.5	1.3	1
28	25.6	9.2	3	99	12.8	9.0	31
29	26.0	2.9	22	100	12.4	0.8	1
30	30.8	5.4	1	101	22.2	2.1	25
31	17.6	1.6	55	102	12.2	0.8	1
32	20.8	1.1	26	103	16.1	1.2	10
33	16.4	3.4	47	104	12.7	2.7	34
34	33.1	1.1	42	105	22.6	2.3	44
35	19.6	1.4	70	106	25.0	2.7	53
36	13.8	5.3	36	107	18.8	2.0	50
37	17.7	1.0	90	108	8.5	7.0	31
38	18.8	1.7	50	109	19.1	3.8	50
39	31.8	3.8	38	110	31.7	3.7	51
40	19.1	1.1	66	111	8.4	0.4	15
41	11.5	0.8	38	112	7.2	0.3	1
42	4.3	1.5	1	113	23.6	0.4	1
43	14.9	1.0	57	114	17.6	0.7	10

Catchment Label	Area (ha)	Slope (%)	Impervious %	Catchment Label	Area (ha)	Slope (%)	Impervious %
44	21.1	1.4	65	115	3.5	1.6	3
45	12.9	5.2	50	116	20.6	1.6	40
46	11.4	6.2	1	117	19.0	1.0	37
47	9.5	10.2	1	118	19.6	1.6	48
48	15.9	4.1	1	119	5.8	0.4	1
49	13.5	3.1	5	120	5.3	0.0	0
50	15.0	3.6	1	121	8.6	1.3	1
51	14.4	1.2	5	122	6.7	0.2	4
52	32.3	6.9	5	123	12.7	1.1	12
53	19.9	2.4	1	124	13.7	0.6	8
54	16.8	10.5	1	125	24.6	0.7	42
55	20.6	3.4	44	126	9.2	1.0	19
56	65.7	1.4	14	127	5.9	0.5	1
57	9.7	0.8	1	128	10.7	2.0	11
58	8.7	3.6	1	129	14.6	1.4	1
59	20.9	3.9	1	130	5.0	0.9	13
60	18.3	2.5	30	131	8.0	1.0	20
61	14.6	6.6	12	132	7.0	2.3	1
62	23.8	3.5	1	133	4.3	1.2	50
63	12.5	2.2	44	134	8.6	0.3	1
64	13.3	7.9	1	135	9.7	0.3	1
65	38.0	1.7	58	136	9.6	0.0	1
66	18.8	1.2	1	137	20.0	0.9	1
67	15.3	1.6	1	138	10.0	0.7	0
68	20.4	10.4	20	139	8.4	1.6	1
69	29.6	5.3	1	140	0.1	1.7	0
70	13.1	4.5	1	141	13.6	0.0	0
71	13.8	13.4	11	142	11.0	3.0	1

5.1.2 Rainfall Data

Rainfall information is the primary input and driver of the hydrological model, which simulates the catchment"s response in generating surface run-off. Rainfall characteristics for both historical and design events are described by:

- Rainfall depth – the depth of rainfall occurring across a catchment surface over a defined period (e.g. 270mm in 36hours or average intensity 7.5mm/hr); and
- Temporal pattern – describes the distribution of rainfall depth at a certain time interval over the duration of the rainfall event.

Both of these properties may vary spatially across the catchment.

The procedure for defining these properties is different for historical and design events. For historical events, the recorded hyetographs at continuous rainfall gauges provide the observed rainfall depth and temporal pattern. Where only daily read gauges are available within a catchment, assumptions regarding the temporal pattern may need to be made.

For design events, rainfall depths are most commonly determined by the estimation of intensity-frequency-duration (IFD) design rainfall curves for the catchment. Standard procedures for derivation of these curves are defined in AR&R (2001). Similarly AR&R (2001) defines standard temporal patterns for use in design flood estimation.

The rainfall inputs for the historical calibration/validation events are discussed in further detail in Section 6 and design events discussed in Section 7.

5.2 Hydraulic Model

BMT WBM has applied the fully 2D software modelling package TUFLOW. The 2D model has distinct advantages over 1D and quasi-2D models in applying the full 2D unsteady flow equations. This approach is necessary to model the complex interaction between rivers, creeks and floodplains and converging and diverging of flows through structures. The channel and floodplain topography is defined using a high resolution DEM for greater accuracy in predicting flows and water levels and the interaction of in-channel and floodplain areas.

5.2.1 Topography

The ability of the model to provide an accurate representation of the flow distribution on the floodplain ultimately depends upon the quality of the underlying topographic model. For the Jewells Wetland catchment, a 2m by 2m gridded DEM was derived from the LiDAR survey and hydrographic survey datasets provided by Council.

As discussed in Section 4.1, additional cross section survey of the watercourses was required to supplement the existing cross sections and LiDAR data and provide the necessary detail on channel shape and dimensions for representation in the hydraulic model. The channel topography has been incorporated into the linked 1D- 2D model representation.

The LiDAR data was acquired in June 2007. Since that time, there have no major broad scale land form changes that would significantly alter the floodplain. The most significant recent infrastructure is the completion of the Fernleigh Track cycleway which traverses the lower end of the catchment just upstream of Kalaroo Road. The section of the track within the study area between Jewells Station and Belmont was completed in 2011. The track has largely been constructed on the former rail formation. This formation was picked up the LiDAR data such that the general embankment is incorporated in the model configurations for both pre- and post- cycleway completion. New culvert structures are incorporated in the cycleway at the main waterway crossings near the Kalaroo Road crossing.

5.2.2 Extents and Layout

Consideration needs to be given to the following elements in constructing the model:

- Topographical data coverage and resolution;
- Location of recorded data (e.g. levels/flows for calibration);

- Location of controlling features (e.g. dams, levees, bridges);
- Desired accuracy to meet the study"s objectives; and
- Computational limitations.

With consideration to the available survey information and local topographical and hydraulic controls, a linked 1D-2D model was developed extending from the coastal entrance at the downstream limit, upstream along all major tributary routes to the upper catchment. The model incorporates the mainstream alignments of Scrubby Creek, Johnsons Creek and Crokers Creek. The model layout is presented in Figure 5-2.

5.2.3 Hydraulic Roughness

The development of the TUFLOW model requires the assignment of different hydraulic roughness zones. These zones are delineated from aerial photography and cadastral data identifying different land-uses (e.g. forest, cleared land, roads, urban areas, etc.) for modelling the variation in flow resistance. The hydraulic roughness is one of the principal calibration parameters within the hydraulic model and has a major influence on flow routing and flood levels. The roughness values adopted from the calibration process is discussed in Section 6.

5.2.4 Structures

There are a number of bridge and culvert crossings over the main channel alignments and tributaries within the model extents as detailed in Table 5-2 (refer to Figure 5-2 for locations). These structures vary in terms of construction type and configuration, with varying degrees of influence on local hydraulic behaviour. Incorporation of these major hydraulic structures in the models provides for simulation of the hydraulic losses associated with these structures and their influence on peak water levels within the study area.

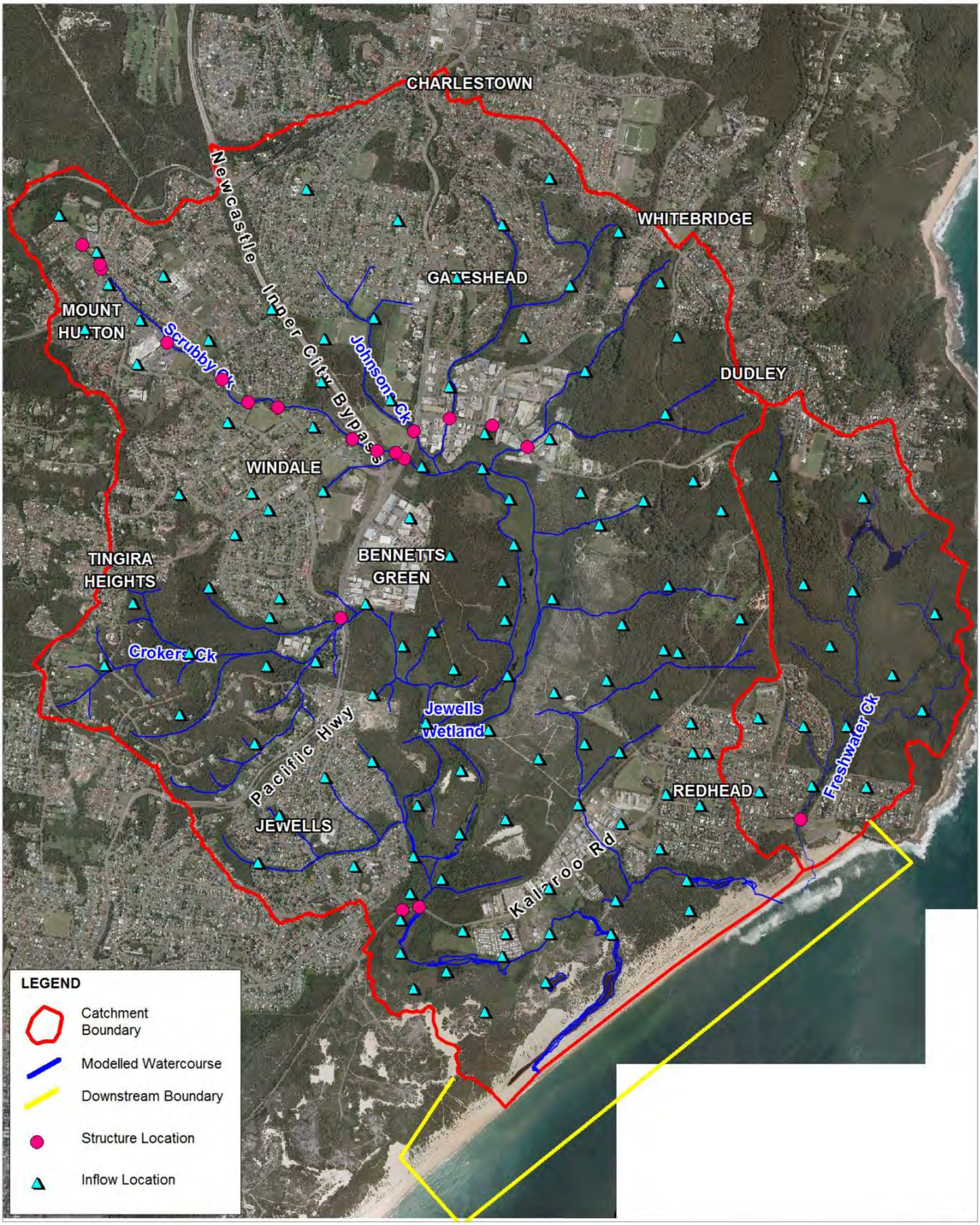
The larger bridge structures have been modelled as flow constrictions within the 2D domain. Culverts, which are typically smaller, have been modelled using 1D structures, embedded within the 2D domain.

5.2.5 Boundary Conditions

The model boundary conditions are derived as follows:

- Inflows - the catchment runoff is determined through the hydrological model and is applied to the TUFLOW model as flow vs. time inputs. These are applied at the upstream modelled watercourse limits and also as distributed inflows along the modelled watercourse reaches.
- Downstream Water Level– the downstream model limit corresponds to the water level in the Tasman Sea.

The model domain has been extended some distance offshore in the coastal zone to enable the simulation of the scouring and outflow processes occurring for the entrance breakouts. Marine LiDAR bathymetric data (OEH, 2008) was utilised to extend the model to a distance of approximately 500m from the beach. The adopted water levels for the downstream boundary condition for the calibration and design events are discussed in Section 6 and Section 7 respectively.



Title:

Tuflow Model Layout

Figure: 5-2

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 0.75 1.5km

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Tuflow_Layout.WOR

Table 5-2 Major Hydraulic Structures within the Model Area

ID	Location	Structure
S1	Cycleway Bridge 1 (Crokers Creek)	Concrete bridge (approx. 20m span)
S2	Cycleway Bridge 2 Kalaroo Road	Concrete bridge (approx. 3m span)
S3	Kalaroo Road (Crokers Creek)	Box culvert (3 x 2.1m x 1.2m)
S4	Pacific Highway (Crokers Creek)	Box culvert (3 x 3.0m x 1.5m)
S5	Oakdale Road 1 (Un-named Tributary)	Box culvert (2 x 3.0m x 2.1m)
S6	Oakdale Road 2 (Un-named Tributary)	Box culvert (2 x 1.8m x 1.3m)
S7	Pacific Highway (Johnsons Creek)	Box culvert (3 x 2.1m x 1.5m)
S8	Pacific Highway (Scrubby Creek)	Box culvert (5 x 1.2m x 1.8m)
S9	Old Pacific Highway Access Road (Scrubby Creek)	Box culvert (2 x 1.2m x 2.4m)
S10	Inner City Bypass (Scrubby Creek)	Box culvert (approx.. 5 x 3.0m x 1.5m)
S11	Footbridge Inner City Bypass (Scrubby Creek)	Concrete bridge (approx. 50m span)
S12	Footbridge (Scrubby Creek)	Concrete bridge (approx. 15m span)
S13	Merrigum Street (Scrubby Creek))	Concrete bridge (approx. 15m span)
S14	Footbridge (Scrubby Creek)	Concrete bridge (approx. 15m span)
S15	Footbridge (Scrubby Creek)	Concrete bridge (approx. 20m span)
S16	Warners Bay Road (Scrubby Creek)	Box culvert (3 x 1.2m x 0.6m)
S17	Cowmeadow Road Footbridge (Scrubby Creek)	Pipe culvert (3 x 0.75m)
S18	Progress Road (Scrubby Creek)	Concrete culvert (double 0.9m pipe)

5.2.6 Entrance Geomorphology

The entrance geometry was defined through a combination of available information in the LiDAR data and survey. The crest level of the entrance berm is a dynamic condition, though it is understood that Crokers Creek is typically closed. Entrance berm levels can vary from a fully open scoured condition following an entrance breakout event up to around 2.5m AHD during drier conditions with significant coastal storm activity. The modelled entrance berm geometry for both the calibration process and design flood conditions is discussed further in Section 6 and Section 7 respectively.

The ability to model morphological changes in the Wetland entrance during a flood event is critical for this study, as it incorporates changes to the effectiveness of the entrance in conveying water out of the Wetland during the flood event. The changing entrance shape as the entrance scour develops affects peak water levels in the Wetland during a flood.

The Van Rijn formulation of sand transport is generally accepted as being currently the most feasible and accurate method for estimating sand transport. However, it must be noted that sand transport is a complex interaction of processes that is still not fully understood. In order to account for these uncertainties, it is necessary to make approximations related to a number of the process interactions. Although these approximations are unavoidable, the Van Rijn method is still considered appropriate and has been combined with the TUFLOW hydraulic model to achieve realistic time-varying entrance shoal and beach berm levels and the accompanying simulated flood discharges.

The geomorphologic module within TUFLOW was used for this study to model the entrance scour during flood events. The model allows the integration of scouring processes at the entrance in terms of cross-sectional conveyance capacity. The scouring rate is based on inter-related parameters: flood flows, initial water levels, downstream ocean water levels and, of greatest importance, the original lagoon entrance/berm geometry.

Quantification of sand transport rates is achieved by the use of two unifying and fundamental concepts:

(i) The combined action of currents and waves mobilises the bottom sands and sets them into motion; and

(ii) The bottom sediment, once mobilised, is moved in the direction of the prevailing net current. The net current can be the result of factors such as river flow, tides, wind, wave radiation stresses or asymmetry in the oscillatory wave motion, or a combination of these.

Inputs to the geomorphologic model include:

- D50 (median grain size of a representative sand sample): 0.25 mm;
- D90: 0.50 m (grain size which is exceeded by 10% of a representative sand sample);
- Fall Velocity (settling velocity of sand grains through water within a representative sand sample: 0.035 m/s);
- Sand Grain Density: 2650 kg/m^3; and
- Water Density: 1035 kg/m^3.

6 MODEL CALIBRATION

6.1 Selection of Calibration Events

The selection of suitable historical events for calibration of computer models is largely dependent on available historical flood information. Ideally the calibration and validation process should cover a range of flood magnitudes to demonstrate the suitability of a model for the range of design event magnitudes to be considered.

As discussed in Section 3, a number of responses from the community questionnaire provide for valuable anecdotal reports of flooding conditions experienced in the June 2007 event, as well as flood marks (many supported by photographic evidence) which have been subsequently surveyed to establish actual flood level.

The records for the June 2007 event provide the most comprehensive coverage of the catchment of all the historical events identified. The model calibration process therefore is based principally on the historical data available for the June 2007 event. Whilst not as extensive as the June 2007 event in terms of availability of data, the data available for the April 1988 and February 1990 events provides the opportunity for validating the developed model to other actual events experienced in the catchment.

The available data, modelling approach and model results for each of these events are discussed in further detail in the following sections.

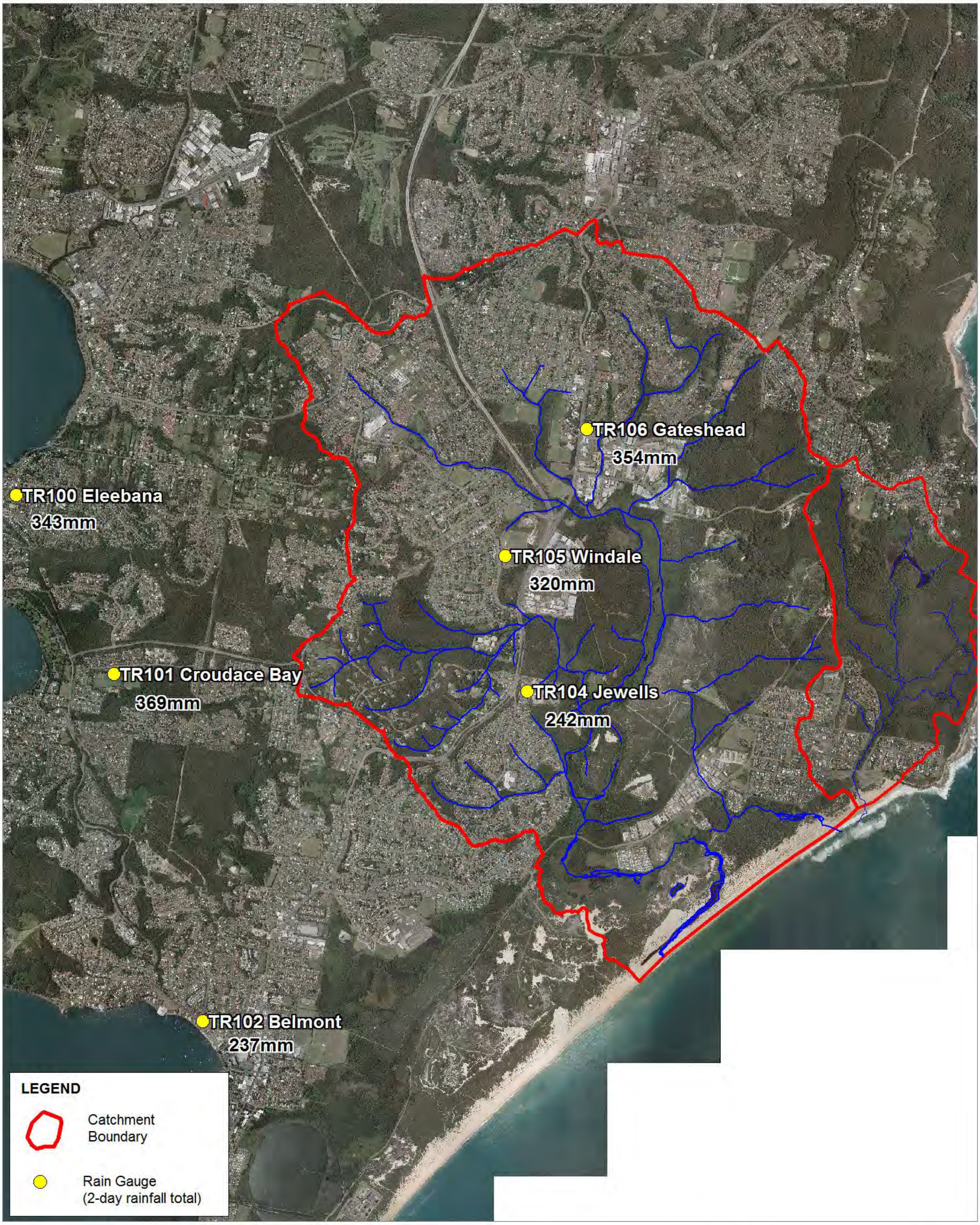
6.2 June 2007 Model Calibration

6.2.1 Rainfall Data

The distribution of rainfall gauge locations in the vicinity of Jewells Wetland catchment was shown in Figure 2-2 with their respective periods of record shown in Table 2-1. There are a number of pluviometer stations operated by Hunter Water located within the Jewells Wetland catchment and within nearby locations. Many of the stations failed during the severe weather conditions experienced during the June 2007 event. Significantly, three of the pluviometers located within the Jewells Wetland catchment remained operable and provide a continuous time series of rainfall throughout the event.

Figure 6-1 shows the location of Hunter Water pluviometer rainfall gauges that remained operable. The June 2007 storm was localised and intense, with rainfall depths and temporal patterns exhibiting significant spatial variation. This variation can be seen by comparing the effective daily totals recorded at the gauges over the period of two days (recorded to 9:00am on the 8th and 9th June 2007).

The rainfall totals show a distinct variation between gauges. Most pronounced is the lower rainfall totals recorded for Jewells and Belmont. The Gateshead, Windale, Eleebana and Croudace Bay totals are all of the order of 300mm, whereas the recorded totals at Jewells and Belmont are substantially lower at 210mm.



Title:

June 2007 Rain Gauge Distribution and Recorded Rainfall

Figure: **6-1**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 1 2km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Rain_Gauges_2007.WOR

Table 6-1 Daily Rainfall Totals from Local Gauges for the June 2007Event

Gauge Location	24 hr Total (mm) (to 9am 08/06/07)	24 hr Total (mm) (to 9am 09/06/07)
Gateshead	45	309
Windale	36	284
Jewells	32	210
Eleebana	45	298
Croudace Bay	41	328
Belmont	28	209

Rainfall radar data is available for this event from the BoM Newcastle radar station at Lemon Tree Passage. The radar record obtained has 10 minute rainfall intensity data which can be collated to approximate rainfall depths over time. Figure 6-2 represents the variation in rainfall for the June 2007 event in the vicinity of the Jewells Wetland catchment. Higher rainfall depth is indicated by the orange-red zones decreasing in depth through yellow to blue for the lower rainfall depth zones. The red line shows an approximate delineation of zone to higher/lower rainfall which is generally reflected in the gauge totals.

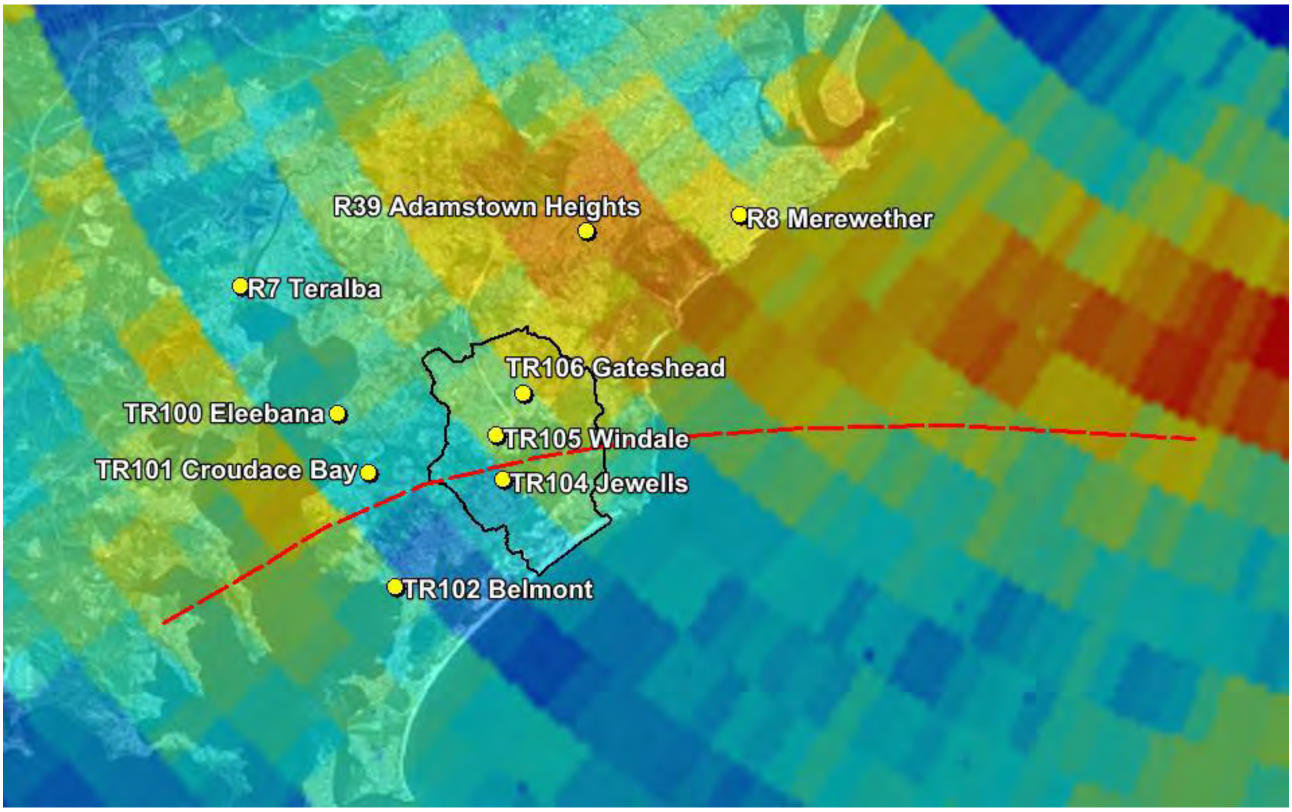


Figure 6-2 Spatial Variation in Rainfall Depth from BoM Rainfall Radar

The 30 minute interval rainfall data recorded at the Gateshead, Windale and Jewells gauges located in the catchment is presented in Figure 6-3. The temporal pattern for each of the gauge locations is very similar, albeit with the lower rainfall at the Jewells gauge evident over the main storm burst period (3pm – 6pm 8th June). The hyetographs indicates over 130mm of rainfall in the two hour period from 3:30pm to 5:30pm.

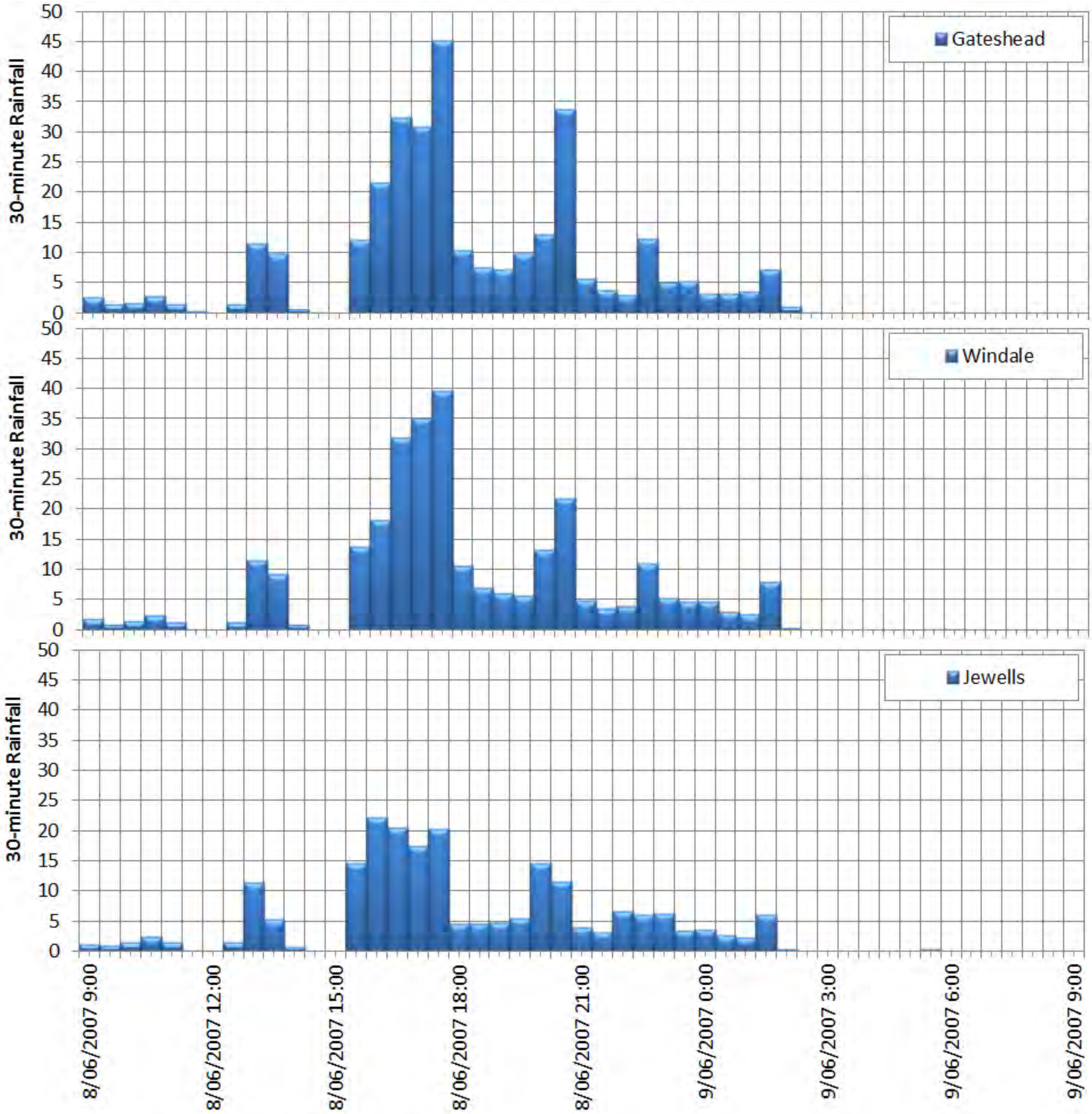


Figure 6-3 Rainfall Hyetographs for the June 2007 Calibration Event

To gain an appreciation of the significance of the June 2007 event, the recorded rainfall depths for various storm durations is compared with the design IFD data for the Jewells Wetland catchment as shown in Figure 6-4 and Figure 6-5 for the Gateshead and Jewells gauges respectively. The derived depth vs. duration profile for the June 2007 event from the recorded gauge data at Gateshead shows it generally tracking well above the design1% AEP (100-year ARI) rainfall for durations up to 36 hours. The Jewells data also tracks to a 1% AEP event up to the 12-hour duration.

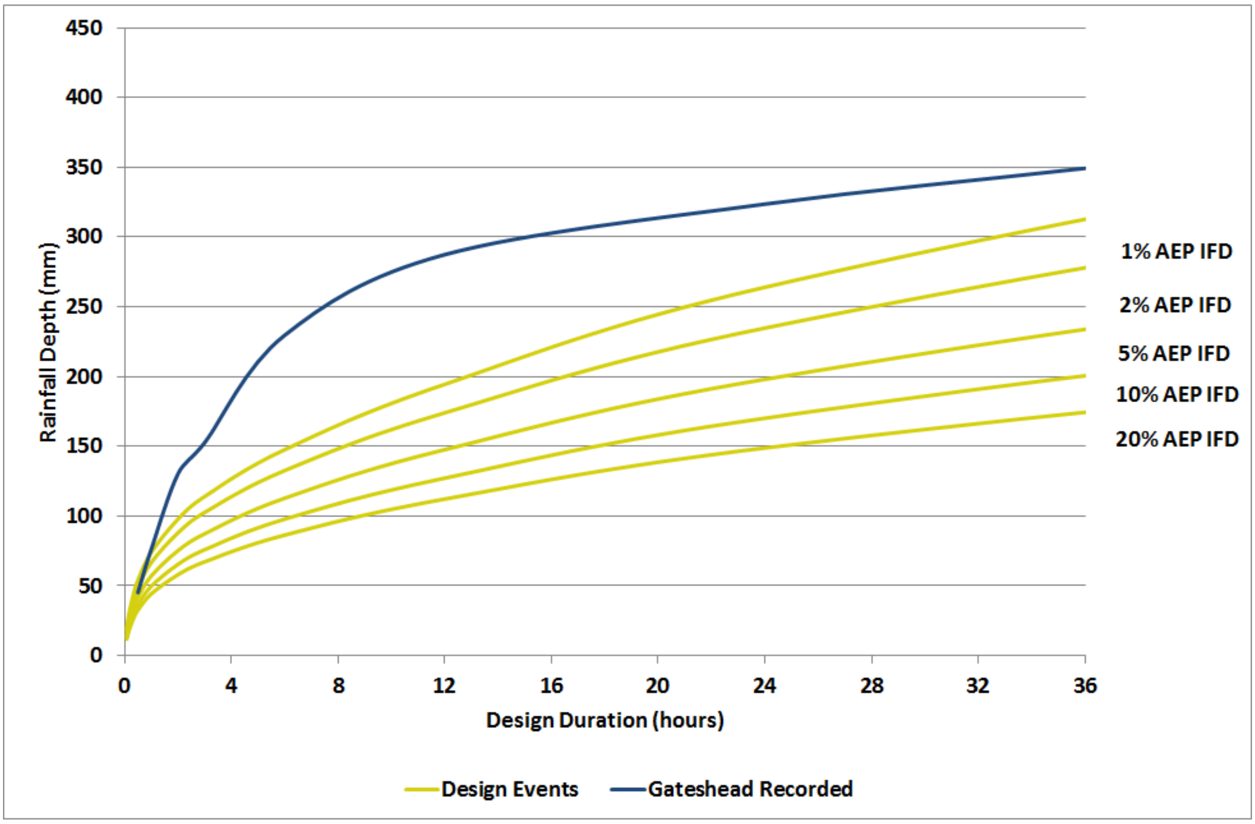


Figure 6-4 Comparison of Gateshead June 2007 Rainfall with IFD Relationships

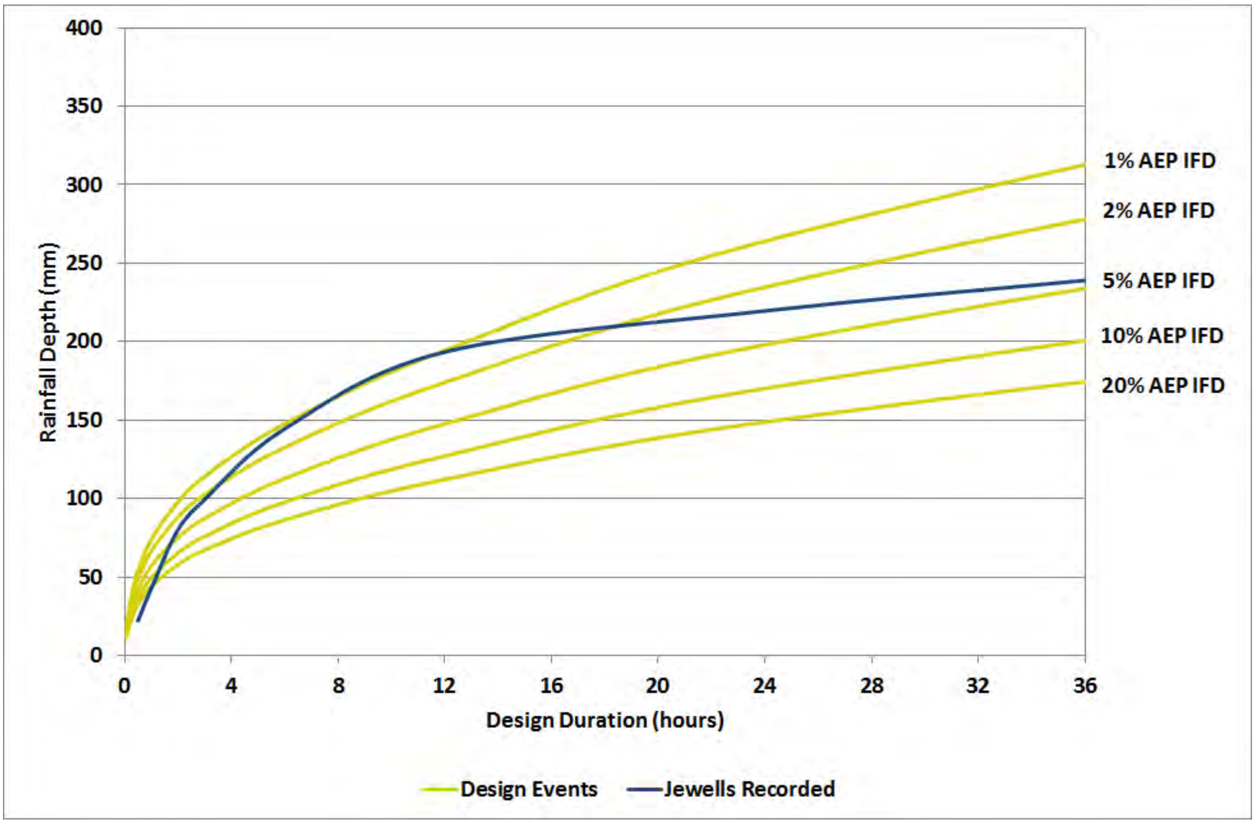


Figure 6-5 Comparison of Jewells June 2007 Rainfall with IFD Relationships

6.2.2 June 2007 Entrance Berm Geometry

The modelled geometry of the entrance berm can impact on the response of modelled levels to catchment inflows and tides. Ideally, for full calibration of the entrance dynamics, survey data of the berm heights before and after the event would be available. However, this data was not directly available for the June 2007 event.

The LiDAR and aerial imagery used in the study was collected as part of the NSW Central and Hunter Coast LiDAR project with data collection completed in January 2007. Accordingly, the data within the LiDAR is expected to provide a reasonable representation of the broader entrance conditions prior to the June 2007 event. It is unlikely that in the time period following the LiDAR data collection up to the June 2007 event that there was another breakout event that may have substantially changed the entrance condition.

A detail of the LiDAR based topography and aerial imagery is shown in Figure 6-6. The entrance is effectively closed with a berm level of the order of 2.5m. This level is reflected in the berm crest (near the beach face) and also by the indicative standing water level in the entrance channel behind the berm, picked up by the LiDAR.

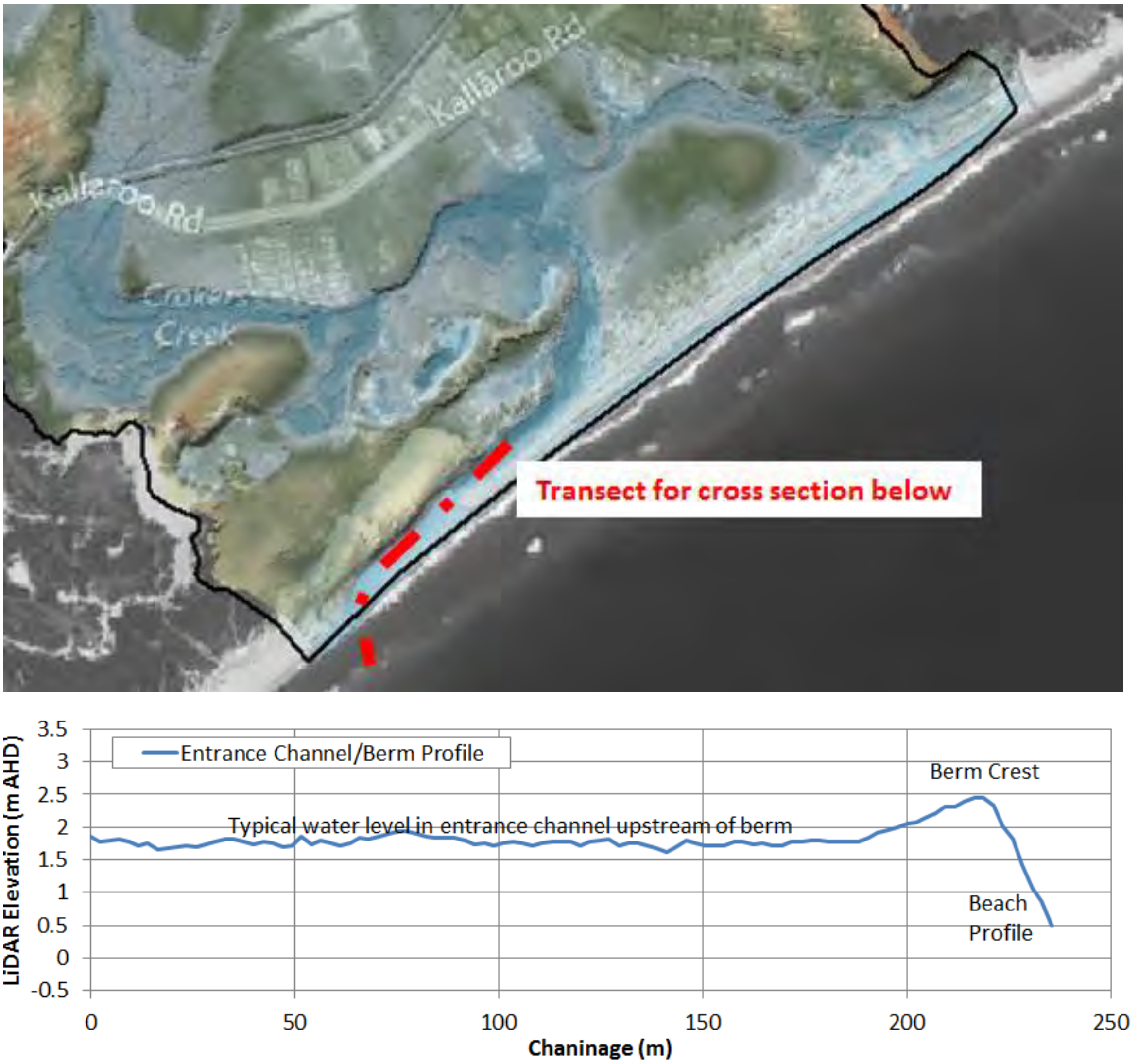


Figure 6-6 Detail of Berm Elevation

6.2.3 Adopted Model Parameters

The model calibration centred on the adjustment of the sub-catchment PERN values and rainfall losses (hydrological model parameters) and the Manning‟s „n‟ values for the floodplain and channel (hydraulic model parameter).

The final values adopted, as shown in Table 6-2 were found to give a good result in representing the recorded water levels identified from the surveyed flood marks.

Table 6-2 June 2007 Model Calibration Parameters

Parameter	Value	Comment
Initial Loss (mm)	10	Initial loss was not a significant influence on the model results, given the lengthy modelled period and large rainfall depth preceding the main storm burst.
Continuing Loss (mm/hr)	2.5	Similar to adopted design continuing loss rate as recommended in AR&R (2001).
PERN Forested Cleared Urban (pervious) Urban (impervious)	 0.10 0.06 0.035 0.015	The PERN factors are used to adjust the catchment routing factor to allow for catchment roughness. Catchment average values were estimated based on representative land use/ground coverage.
Bx (storage routing parameter)	1.0	The adopted value was applied globally for the entire catchment and provided the best fit of catchment response in terms of flow magnitude and timing.
Manning‟s n (channel)	0.02 – 0.08	Variable adjusted locally (within reasonable bounds) to provide best fit for peak water level profiles. Variability largely reflects degree of channel vegetation, channel size and sinuosity.
Manning‟s n (floodplain)	0.02 – 0.12	Variable adjusted locally (within reasonable bounds) to provide best fit for peak water level profiles. Variability largely reflects land use on the floodplain (cleared, forested, roads, urban lots)
Entrance berm median grain size (mm)	0.25	A median grain size of 0.25mm is appropriate for this coastal area.

6.2.4 Observed and Simulated Flood Behaviour June 2007

There were a number of surveyed flood marks available for the June 2007 event. Flood marks at approximately 10 locations were surveyed across the study area, mainly along the alignment of Scrubby Creek in the upper catchment and in the lower reaches of Crokers Creek downstream of Kalaroo Road.

Figure 6-7 presents a long section of modelled peak water levels from the entrance to the upper reaches of Scrubby Creek for the June 2007 event, with comparison to the available flood marks. The modelled bed elevation is also included for reference.

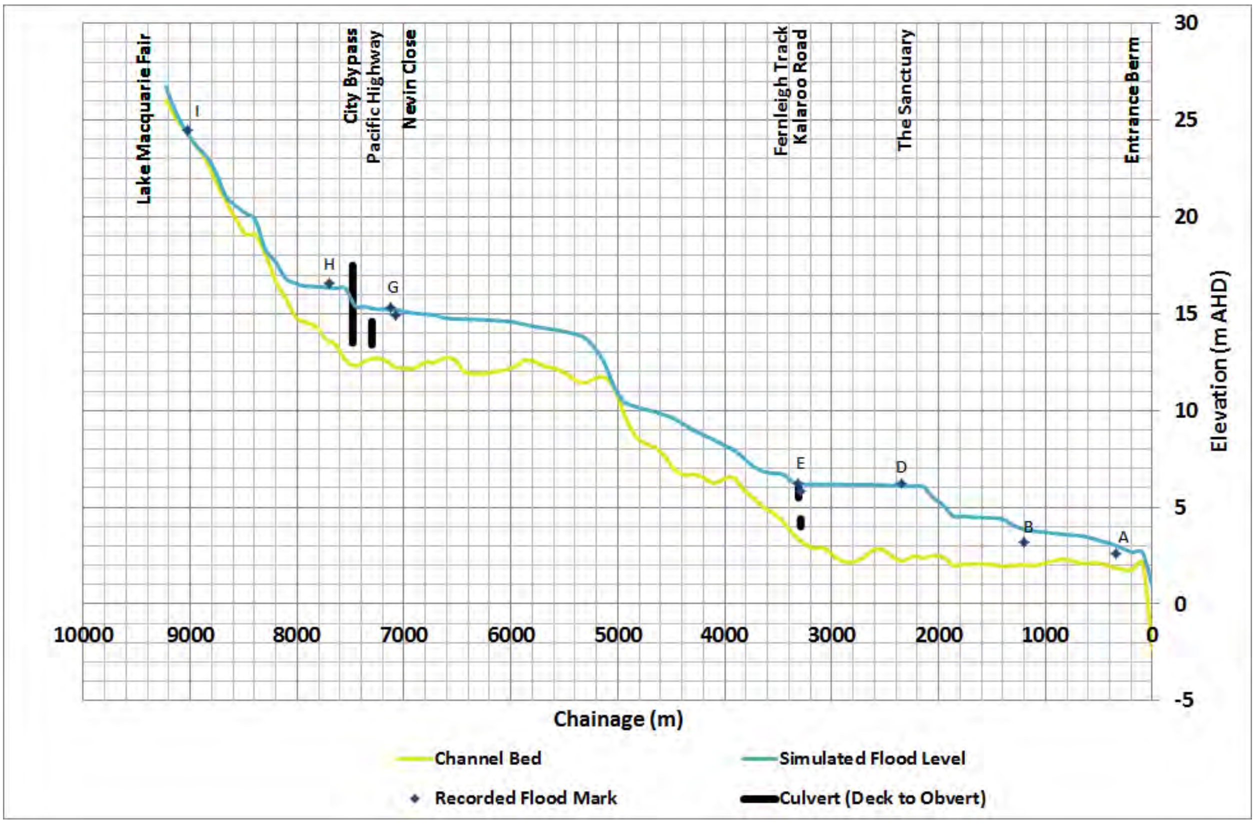


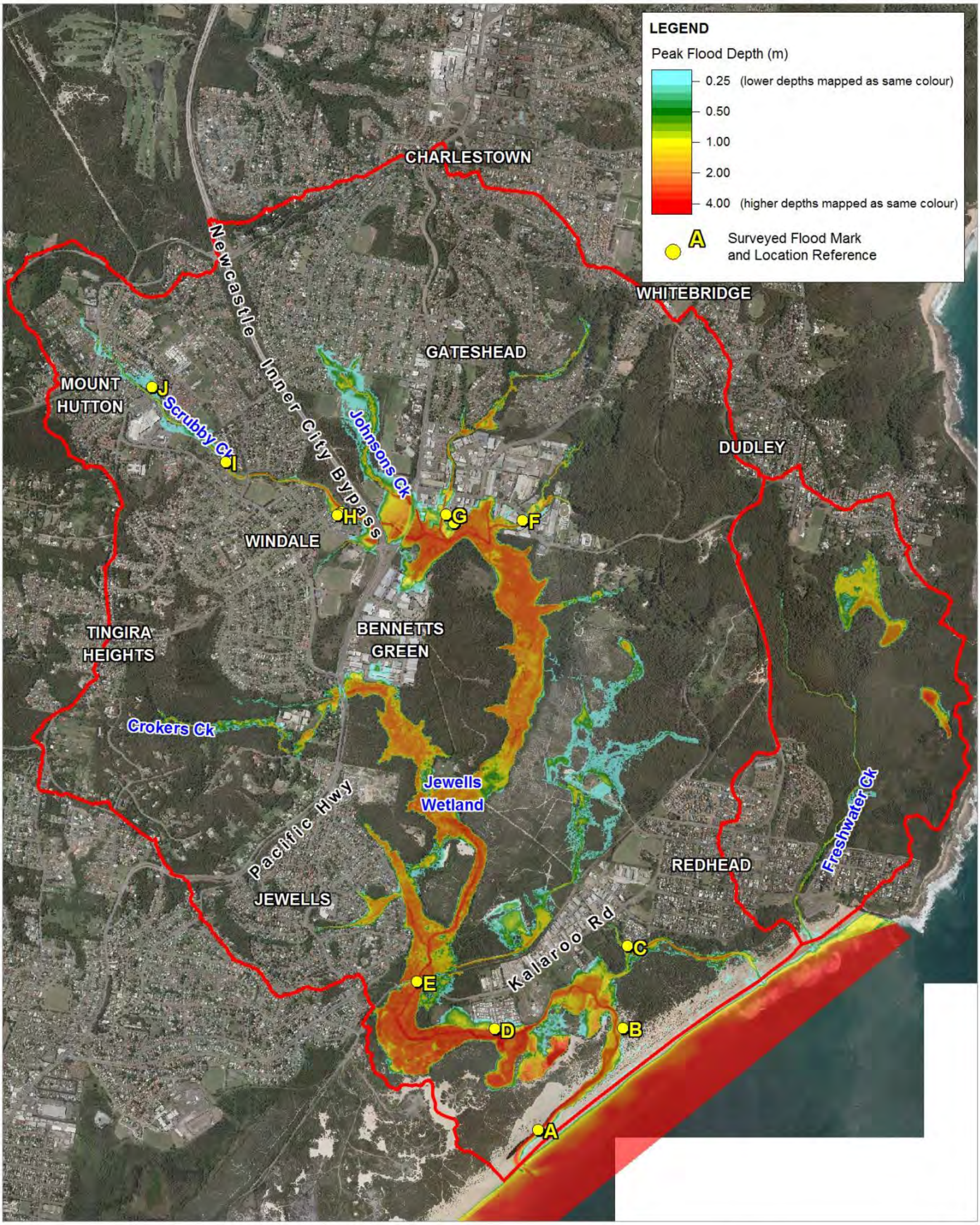
Figure 6-7 Long Section of Modelled Peak Flood Levels for the June 2007 Event

The results show a good match to the surveyed flood marks, with the majority of modelled peak water levels being within 0.3m of the survey data. There is some inherent uncertainty related to the surveyed levels of flood marks. Local conditions can often indicate flood levels that are above or below the general representative flood level of the broader area. However, the overall predicted flood peak is considered a good representation of the observed conditions.

Figure 6-8 shows the modelled flood depths in the catchment for the June 2007 event. The locations at which flood levels have been recorded are shown for reference. A comparison of the recorded and modelled peak flood levels at each of the surveyed flood mark locations is shown in Table 6-3.

The results of the model simulation of the June 2007 event shows a good comparison to the recorded peak flood levels at all of the locations. The difference between the recorded and modelled flood level is typically between 0.1m – 0.3m, which is within the typical target calibration range for studies of the nature.

Further detail on the recorded flood level and general flooding conditions at each of the locations is provided below. The details of the flood mark survey undertaken by Council including location references, levels and landholder comments is also included in Appendix D for reference.



Title:

Model Calibration for June 2007 Event

Figure: 6-8

Rev: A

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\June2007_Calibration.WOR

Table 6-3 Comparison of Recorded and Simulated Flood Levels June 2007

Location	Recorded Level (m AHD)	Simulated Level (m AHD)
A – Entrance Channel	2.6	2.8
B – Entrance Channel	3.2	3.8
C – Redhead Beach Holiday Park	3.8	4.1
D – The Sanctuary, Kalaroo Road	6.2	6.1
E – Kalaroo Road Crossing	5.8	6.2
F – Oakdale Road, Gateshead	14.9	15.1
G – Nevin Close, Gateshead	14.9 15.3	15.1 15.3
H – Lake Street, Windale	16.6	16.4
I – Wilsons Road, Mt Hutton	24.0 24.6	23.7 24.6
J – Helen Street, Mt Hutton	29.2	29.1

Location A and B – Entrance Channel

OEH undertook a detailed survey of the beach berm and entrance channel in December 2011. Included in this survey were levels of debris marks along the top of the berm/channel. Whilst is not certain, the debris may have been generated from the June 2007 event. There does not appear to have been other events, fluvial or coastal, in recent times to deposit this debris to these levels. Figure 6-9 shows a sample photograph of the debris line surveyed by OEH along the entrance channel alignment.

Figure 6-9 Photograph of Debris Surveyed by OEH

The general surveyed level of the debris lines agrees fairly well with simulated peak water level profile, including a rapid decrease in level from Location B to Location A towards the entrance.

These flood marks have not directly been utilised to calibrate the models given the uncertainty in their origin. Nevertheless, the modelled peak flood level shows a fair comparison with the observed levels of the general debris lines.

Location C – Redhead Beach Holiday Park, Kalaroo Road

This site is located along one of the secondary higher level outlet channels (referred to as Second Creek) from the Jewells Wetland. The outlet has a fairly limited capacity given the narrow channel width between the sand dunes and the extent of vegetation. Residents on the channel edge experienced high water levels in June 2007 event. An approximate flood level of 3.8m AHD was estimated from the flood mark survey undertaken by Council surveyors following the resident questionnaire response. The simulated flood level of 3.9m AHD compares reasonably well at this location.

Properties are located very close to the channel in this area, with typical ground levels on the properties immediately adjacent to the channel of the order of 4m AHD. Accordingly, for the June 2007 event floodwaters rose to peak levels close to threatening property. Figure 6-10 shows a photograph provided by a resident of floodwaters within the channel close to peak flood conditions.

Figure 6-10 Flood Photograph at Location C

Location D – The Sanctuary, Kalaroo Road

This site is located along the main outlet channel of Jewells Wetland. A flood photo taken at the site is presented in Figure 6-11. The photo was taken some time after the peak of the event, however, peak flood levels were recorded via the water level line/debris mark on the garage as shown in Figure 6-12. The garage building is the same building shown in both photographs.

Figure 6-11 Flood Photo at Location D

Figure 6-12 Photograph of Peak Flood Level Watermark at Location D

An approximate peak flood level of 6.2m AHD was estimated from the flood mark survey obtained by Council. It is noted this is substantially higher than flood level recorded at Location C and the debris marks at Locations A and B at the coastal entrance. This significant change in peak water level is well simulated in the model as shown on the peak flood level profile in Figure 6-7. This is a result of the hydraulic control imposed by the natural constriction in the channel just downstream of the site (evident on the flood depth map shown in Figure 6-8). Accordingly, there is a sound agreement between recorded and simulated flood levels at this location.

Through discussions with residents at the site, it was also noted that during the June 2007 event floodwater was spilling over the former rail embankment upstream of Kalaroo Road. Further discussion on this general area is provided below.

Location E –Kalaroo Road Crossing

The backwater influence of the channel constriction discussed above extends back to Kalaroo Road as shown in the long section profile. With Kalaroo Road having an invert level of around 4m AHD, the June 2007 event resulted in signifcant flood depths over the road. A questionnaire response indicated a depth of 1.5m at the crossing, however considering the peak flood level record at the Sanctuary downstream, depths of the order 2m would have been experienced at the peak of the event. It is likley the 1.5m depth observation was not at the peak of the event.

The top of former rail embankment (now the Fernleigh Track cycleway) upstream of Kalaroo Road had an approximate level of 6.2m AHD. The model simulation provides for peak flood levels of ~6.3m AHD with a shallow depth of flow over the embankment, consistent with the anecdotal flooding report.

Location F –Oakdale Road Gateshead

A business owner on the downstream side of the Oakdale Road culvert crossing indicated depth of flow across the road of the order of 1m deep, with the creek approximately 0.3m from the point of spilling. The creek adjacent to the property is shown in Figure 6-13, consisting of a concrete lined section of channel. The top of channel is therefore well defined with a level of approximtaely 15.2m AHD., and indicative June 2007 flood level in the channel of ~14.9m AHD.

The model simulation provides for a peak flood depth over the road of approximately 0.6m. The simulated water levels downstream of the crossing are higher (~0. 4m) than the reports given by the occupier providing for a simulated spilling from the channel and minor inundation of ground levels at the property.

Location G – Nevin Close Gateshead

Two business owners from the industrial estate provided flood levels for the June 2007 event that resulted in inundation to on-site buildings. Figure 6-14 and Figure 6-15 shows the observed water line/debris marks that have been surveyed by Council to establish peak flood levels.. Flooding in this vicnity is due to the combined influence of peak flood conditions in the Jewells Wetland immeditely downstream of the site, and also from the local catchment flows conveyed through the major stormwater drianage channels through the Gateshead Industrial Estate.

Figure 6-13 Photograph of Channel at Location F

Figure 6-14 Photograph of Peak Flood Level Watermark at Location G

The recorded flood marks of 15.3m AHD and 14.9m AHD compare reasonable well with the respective model simulation peak levels of 15.3m AHD and 15.1m AHD. This lower end of Nevin Close is susceptible to flooding, noting however the June 2007 event as discussed represents a major flood condition.

Figure 6-15 Photograph of Peak Flood Level Watermark at Location G

Location H – Lake Street Windale

Properties at the lower end of Lake Street were subject to inundation in the June 2007 event. A flood photo of the site is presented in Figure 6-16 which shows floodwater inundation at the property and the proximity to high flows in the adjacent Scrubby Creek. The photograph is not taken at the peak of the event. A higher water mark (debris line) is evident on the fence. Peak flood levels have been able to be veirifed through peak water level lines recorded at the properties such as shown in Figure 6-17.

Numerous flood marks recorded at three neighbouring properties confirmed the peak flood level to be of the order of 16.6m AHD. The model simulation provides for a flood level of 16.5m AHD providing a good representation of the actual flooding conditions at this location. As shown in Figure 6-8, the properties are located in a slight depression on the right bank floodplain of Scrubby Creek, with the flood inundation extents widening accordingly in the vicinity of the property before returning to a narrower floodplain reach just upstream of the Inner City Bypass.

Similar orders of flooding have been experienced at the properties for other major historical events including the April 1998 and Fenruary 1990 events. Respective 1998 and 1990 flood levels based on Councils records are 16.5m AHD and 16.0m AHD.

Figure 6-16 Flood Photograph at Location H (source Newcastle Herald)

Figure 6-17 Photograph of Peak Flood Level Watermark at Location H

Location I – Wilsons Road Mt Hutton

Residents of property adjacent to Scrubby Creek provided details of the extent of flooding which were surveyed to obtain a peak flood height of the order of 24.6m AHD which has been replicated in the model. This area is immediately downstream of Lake Macquarie Fair where the concrete lined channel transitions to an earth channel. No property was inundated at this location with the flood inundation limited to the open floodplain area.

Location J – Helen Street Mt Hutton

The backyards of residences on Helen Street are immediately ajacent to the Scrubby Creek channel. The June 2007 flood event exceeded the capacity of the channel providing for inundation of adjacent property. One questionnare respondent provided details of the extent of inundation on the property which was to determine the peak flood level of approximately 29.2m AHD. This level was approximately 0.4m below the floor level of the residence. The model simulation of the June 2007 event provides for inundation of the backyards of properties along Helen Street with the simulated peak flood level of 29.1m AHD corresponding to the recorded flood mark.

Residents also noted that the properties are located within a natural depression, confirmed in review of the LiDAR data. In major flood events where channel capacity is exceeded, this part of the floodplain becomes inundated. Council"s historical flood records provided for flood levels of 29.2m AHD and 28.9m AHD on neighbouring properties for an event in 1966. These are similar levels to the June 2007 event.

6.3 February 1990 Model Validation

The February flood has been used as a model validation event, given the availability of rainfall and peak flood level data. The data available for the event is not as extensive as that available for June 2007, however, the limited data provides an opportunity to test the calibrated model.

6.3.1 Rainfall Data

The Hunter Water rainfall gauge network provides extensive coverage across the region, however, the network was largely established subsequent to the February 1990 flood event. The closest pluviometer stations that recorded the event are the Maryville and Barnsley BoM stations. Both of these stations are located approximately 12km from the Jewells Wetland catchment.

In addition to the Maryville and Barnsley continuous rainfall record, there are a number of daily rainfall gauges in the vicinity of the catchment area for which records are available. The recorded daily totals (for the 24 hours to 9am) from February 2nd – 5th 1990 for the available rainfall gauges are summarised in Table 6-4).

Table 6-4 Recorded Rainfall February 1990 Event

Gauge Location	2nd February 1990 (mm)	3rd February 1990 (mm)	4th February 1990 (mm)	5th February 1990 (mm)
Mount Hutton	18.6	277	144.4	19.6
Merewether (Burwood Beach WWTP)	27	265	167	2.4
Cockle Creek	28.6	270	150	11.2
Belmont WWTP	14	249	126	12
Maryville	25.2	286.6	177.6	0.8
Barnsley	23	239	150.5	10

As shown in Table 6-4, there was extensive rainfall across the local area over a 4-day recording period. The majority of the rain fell in the 24-hours to 9:00am on the 3rd February, however, this was followed by further substantial falls recorded on the 4th February.

The Mount Hutton gauge is located within the Jewells Wetland catchment and accordingly maybe considered representative of the catchment area rainfall. However, there is a general consistency in the recorded totals across the gauges shown in Table 6-4, such that there is no major variation in the spatial rainfall distribution.

Hunter Water had also installed other pluviometers in the Newcastle region including one at Charlestown. The original pluviometer records have not been found, however, an extract from the Winding Creek Flood Mitigation Study (Hunter Water Corporation, 1992) provides a trace of the recorded cumulative rainfall for the event as shown in Figure 6-18. The Charlestown pluviometer trace has been digitised from this chart, however, given the consistency with the other pluviometers, there would appear to be a general consistency in the regional rainfall.

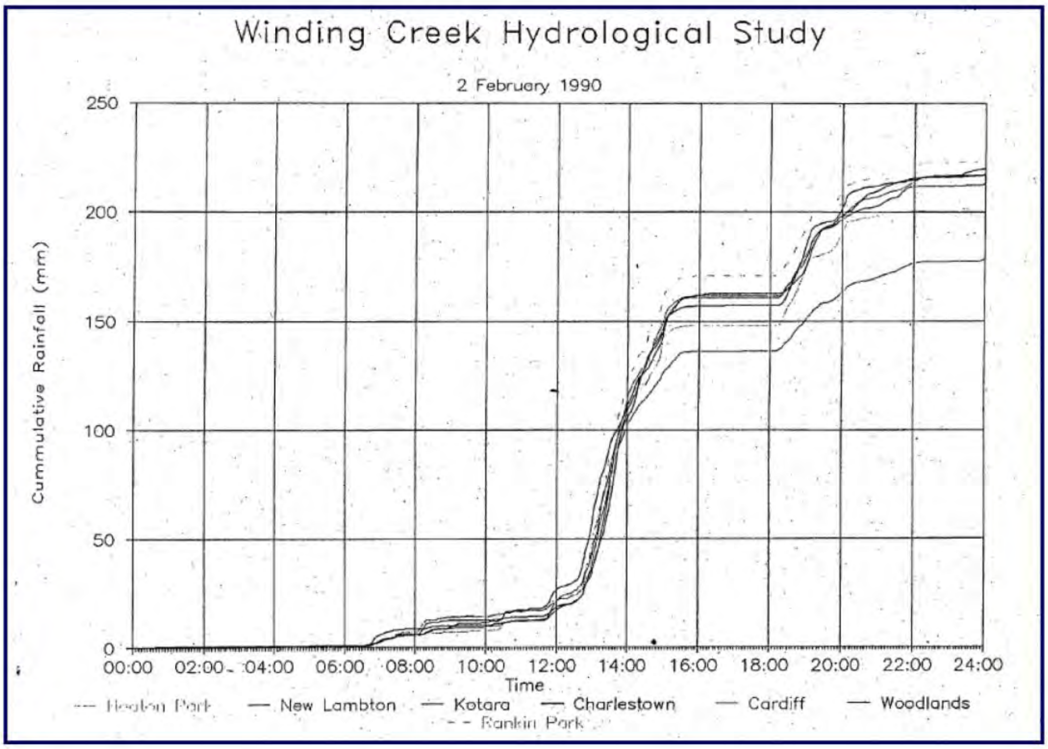


Figure 6-18 February 1990 Pluviometer Records (HWC, 1992)

The 30 minute interval rainfall data recorded at the Barnsley, Charlestown and Maryville gauges is presented in Figure 6-19. The temporal pattern for each of the gauge locations is very similar, albeit with a more intense rainfall at the Maryville gauge evident over the main storm burst period (12pm – 3pm 2nd February). The Maryville hyetograph indicates some 118mm of rainfall in the three hour period to approximately 3pm. A similar intense rainfall burst is also shown for the Charlestown gauge. It is this intense burst rather than the gradual accumulation of rainfall over the longer durations that provides for the flood conditions in the Jewells Wetland. This is particularly the case in the reaches of Scrubby Creek and Johnsons Creek from which the majority of flood data for the February 1990 relates.

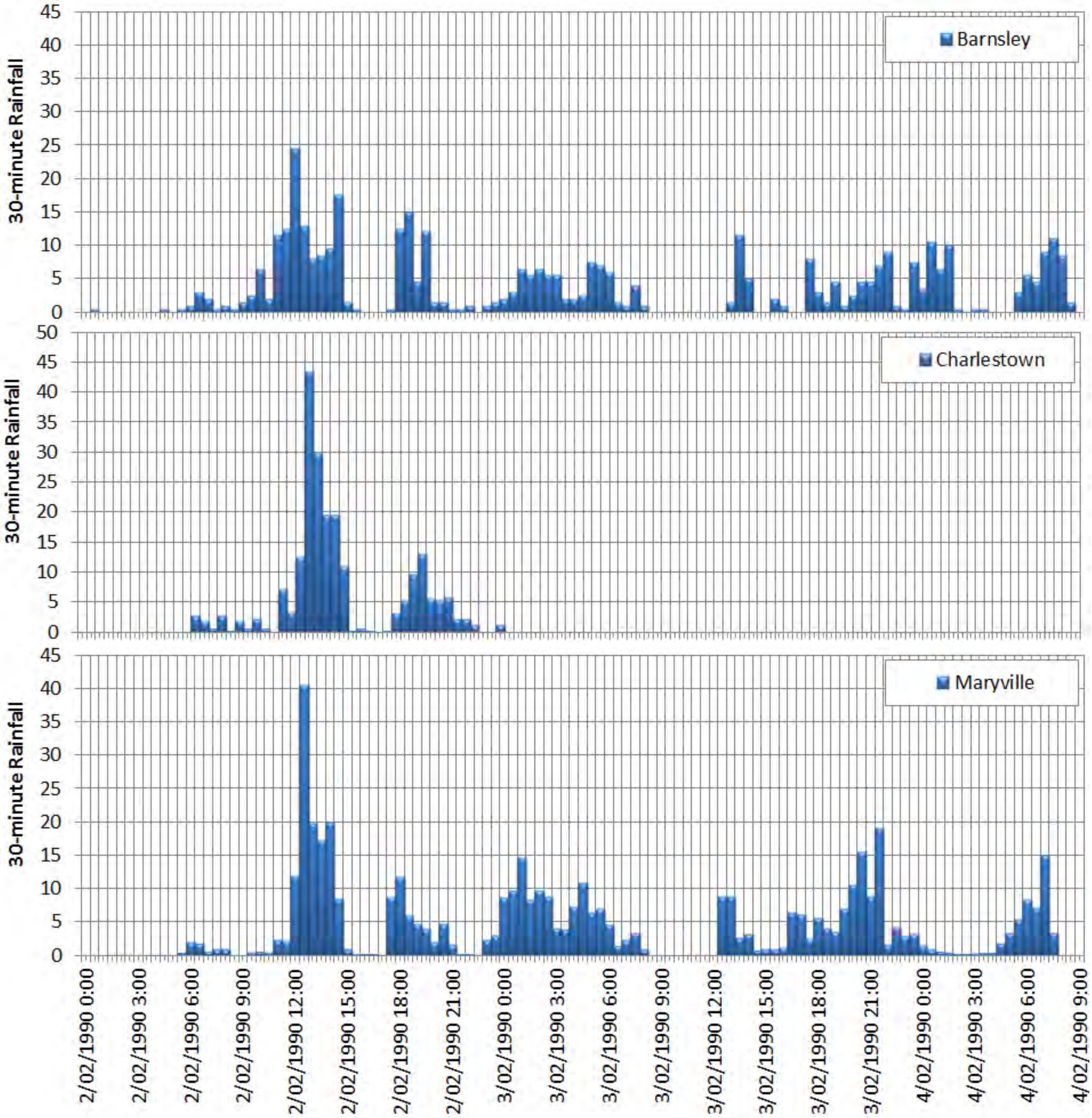


Figure 6-19 Rainfall Hyetographs for the February 1990 Validation Event

To gain an appreciation of the significance of the February 1990 event, the recorded rainfall depths for various storm durations is compared with the design IFD data for the Jewells Wetland catchment as shown in Figure 6-20. The derived depth vs. duration profile for the February 1990 event (from the recorded daily data at Mount Hutton scaled using the Maryville temporal pattern) shows it generally tracking well above the design 1% AEP (100-year ARI) rainfall for durations up to 48 hours. The Jewells data also tracks to a 1% AEP event for the 3-hour duration. As noted, it is this short high intensity rainfall providing for the critical flood condition in the upper reaches of the tributary catchments. The longer duration higher volume rainfall may provide more significant flooding in the lower catchment area in the main flood storage areas of the Jewells Wetland.

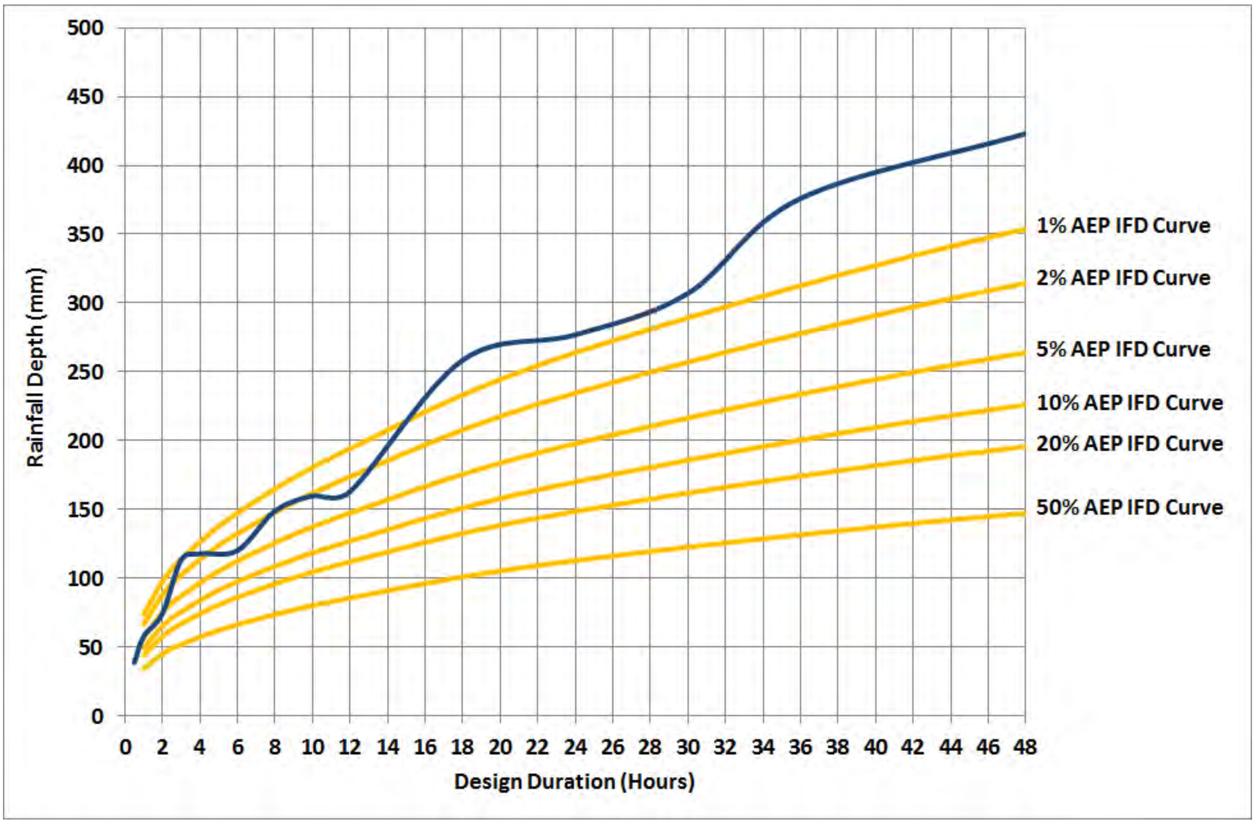


Figure 6-20 Comparison of Jewells February 1990 Rainfall with IFD Relationships

6.3.2 February 1990 Entrance Berm Geometry

The condition of the entrance prior to the February 1990 event is unknown. In the absence of data, the existing condition as generally represented by the 2007 LiDAR capture, the OEH 2011 survey and additional ground survey acquired for the study.

The entrance condition is unlikely to have any significant impact on the modelled flood condition in the areas for comparison of historical flood level data.

6.3.3 Observed and Simulated Flood Behaviour February 1990

The adopted model parameters from the June 2007 event calibration as summarised in Table 6-2 have been applied directly for the February 1990 event validation.

There were a number of surveyed flood marks available for the February 1990 event from Council"s existing historical flood record database. These flood marks are clustered in a number of keys areas including:

- Gateshead West – residential area at the upper reaches of Johnsons Creek. Subsequent to the 1988 and 1990 events, significant stormwater drainage improvements were undertaken in this area. The location of the affected area to which the available flood marks relate is not in the current study area.

- Lake Street Windale – residential properties at the end of Lake Street corresponding to the same locations were flood marks have also been recorded for the June 2007 and April 1988 events.
- Gateshead Industrial Estate – a number of flood marks are clustered in the industrial estate between Oakdale Road and Nevin Close.
- Ocean Breeze Caravan Park – Council‟s records hold a few peak flood level records for the event at the caravan park of Kalaroo Road.

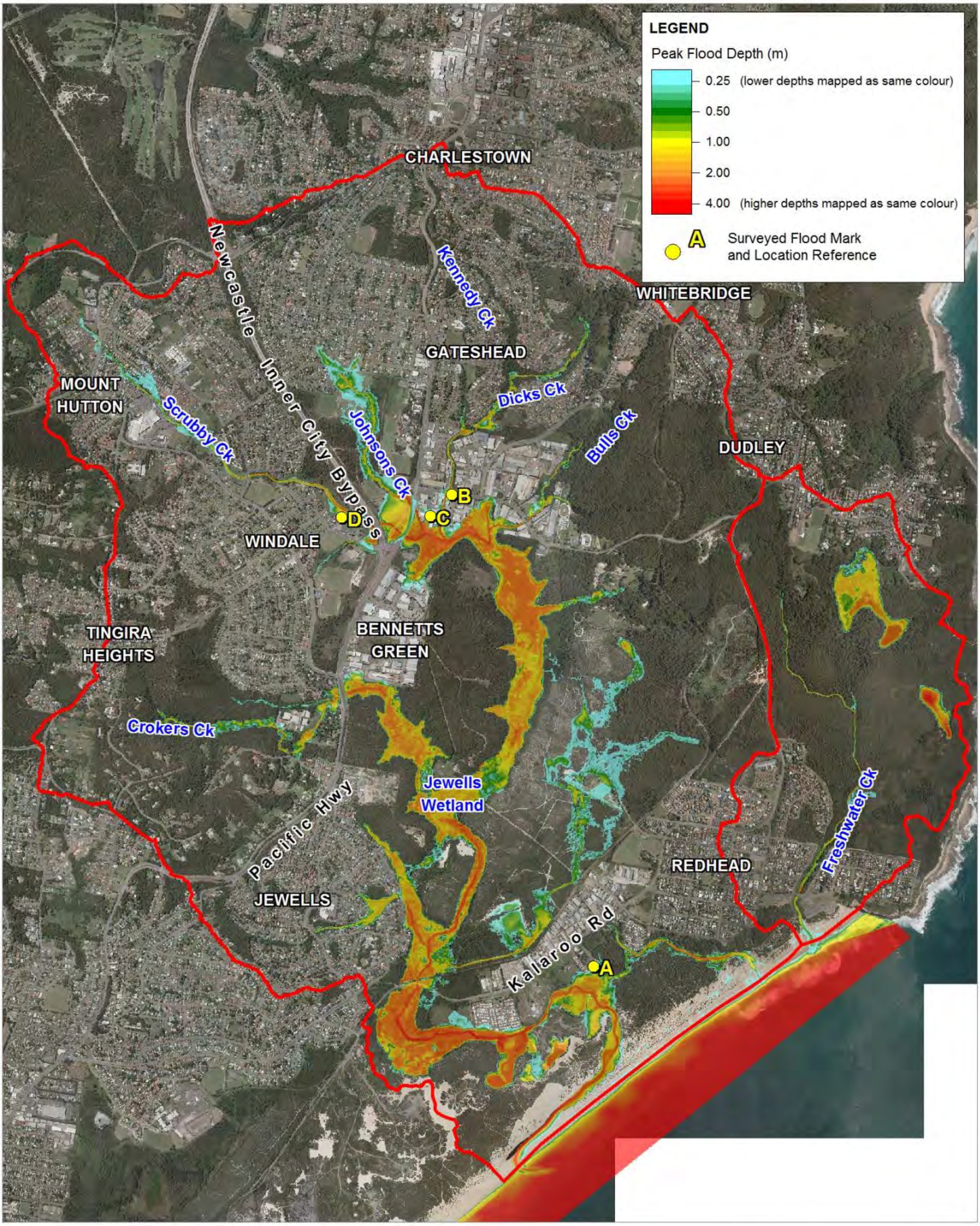
Figure 6-21 shows the modelled flood depths in the catchment for the February 1990 event. The locations at which flood levels have been recorded are shown for reference. A comparison of the recorded and simulated peak flood levels at each of the surveyed flood mark locations is shown in Table 6-5.

Table 6-5 Comparison of Recorded and Simulated Flood Levels February 1990

Location	Recorded Level (m AHD)	Simulated Level (m AHD)
A – Ocean Breeze Caravan Park	3.2 3.3	4.1
B – Oakdale Road, Gateshead	15.0	15.1
C – Nevin Close/Arnhem Close, Gateshead	14.3 14.5 14.7	14.7
D – Lake Street, Windale	15.9 16.0	15.7

With the exception of the Ocean Breeze Caravan Park, the simulated peak flood levels provide a reasonable comparison to the recorded levels (typically within +/-0.3m). The simulated levels in the Ocean Breeze Caravan Park vicinity can be heavily influenced by the overall creek and entrance channel condition. Flood levels of the order of those recorded would suggest very less constrained channel compared to the adopted current conditions. It would be unlikely to be able to establish the actual conditions for the February 1990 event in the absence of detailed survey data.

There is some spread in the levels recorded around the Nevin Close and Arnhem Close industrial area in Gateshead. The simulated level provides a good match to the highest observed flood levels. Similarly for Lake Street Windale, the model provides a reasonable simulation of the peak flood level condition.



Title:

Model Calibration for February 1990 Event

Figure: 6-21

Rev: A

N

0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Feb1990_Calibration.WOR

6.4 April 1988 Model Validation

The April 1998 event has been used as a model validation event, given the availability of rainfall and peak flood level data. The data available for the event is not as extensive as that available for June 2007, however, the limited data provides a further opportunity to test the calibrated model.

6.4.1 Rainfall Data

As noted previously, the extensive Hunter Water rainfall gauge network was not in operation in 1988. The only pluviometer station within a reasonable distance of the Jewells catchment that recorded the event is the Mayville station. This station is located approximately 12km from the Jewells Wetland catchment.

In addition to the Maryville continuous rainfall record, there are a number of daily rainfall gauges in the vicinity of the catchment area for which records are available. The recorded daily totals (for the 24 hours to 9am) from April 28th – 30th 1988 for the available rainfall gauges are summarised in Table 6-6).

Table 6-6 Recorded Rainfall April 1988 Event

Gauge Location	28th April 1988 (mm)	29h April 1988 (mm)	30th April 1988 (mm)
Mount Hutton (Auklet Road)	134	50	45
Cockle Creek	62	53	46
Bolton Point	32	54	38
Maryville	40	48	46
Newcastle Nobbys Signal Station	8	51	48
Swansea	39	36	59

As shown in Table 6-6, the recorded total at Mount Hutton on the 28th April 1988 is standout total. Whilst there are a limited number of operating gauges in the region, the recorded totals suggest the April 1988 event was particularly localised.

The Mount Hutton gauge is located within the Jewells Wetland catchment and accordingly maybe considered representative of the catchment area rainfall. However, given other gauges in the locality recorded significantly less rainfall, there is potentially a major variation in the spatial rainfall distribution, even across the Jewells Wetland catchment.

The 30 minute interval rainfall data recorded at the Maryville gauge is presented in Figure 6-22. A short but intense period of rainfall is evident at the Maryville gauge over the main storm burst period around 9pm 27th April. The Maryville hyetograph indicates some 34mm of rainfall in a 1.5-hour period. This represents the bulk of the rainfall recorded in the 24hours to 9am 28th April of 40mm as shown in Table 6-6. Significantly, the Maryville gauge received very little other rainfall within that 24-hour period, with large periods of no rainfall.

Whilst the Mount Hutton gauge had significantly higher rainfall, it is likely the main storm event was similar to Maryville, being a short intense burst over around 1.5-hours. Scaling the Maryville temporal pattern to the recorded 134mm at Mount Hutton provides for a main storm burst of around 113mm in 1.5-hours at Mount Hutton.

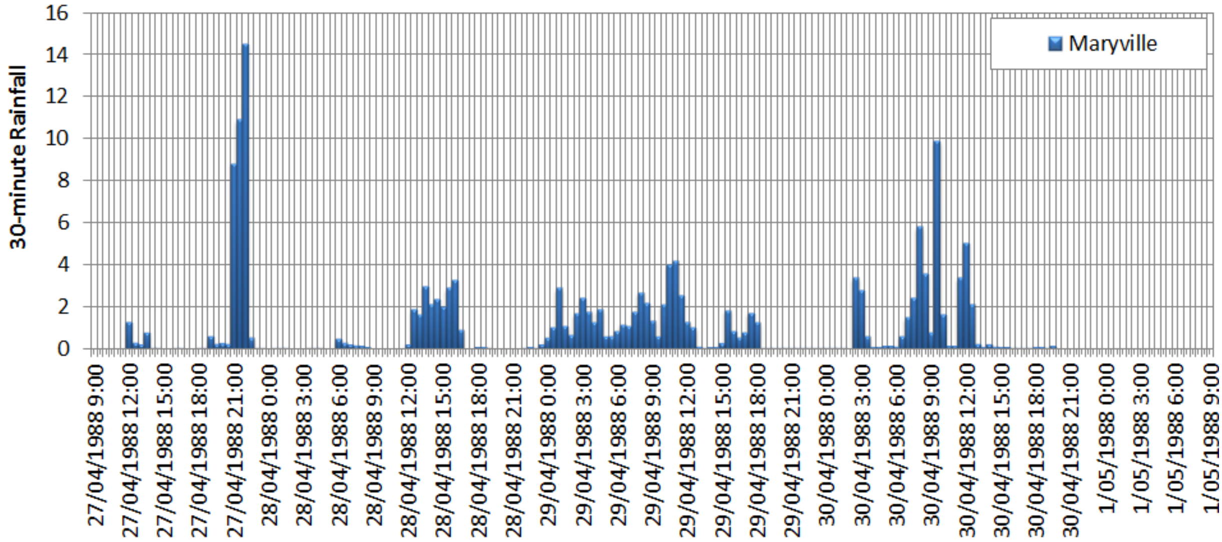


Figure 6-22 Rainfall Hyetographs for the April 1988 Validation Event

To gain an appreciation of the significance of the April 1988 event, the recorded rainfall depths for various storm durations is compared with the design IFD data for the Jewells Wetland catchment as shown in Figure 6-23. The derived depth vs. duration profile for the April 1988 event (from the recorded daily data at Mount Hutton scaled using the Maryville temporal pattern) shows it tracking well above the design 1% AEP (100-year ARI) rainfall for short durations up to 3 hours. Only a small amount of rainfall was recorded after the initial 1-5hour rainfall burst, accordingly there is little increase in the cumulative rainfall over the longer duration as shown in Figure 6-23.

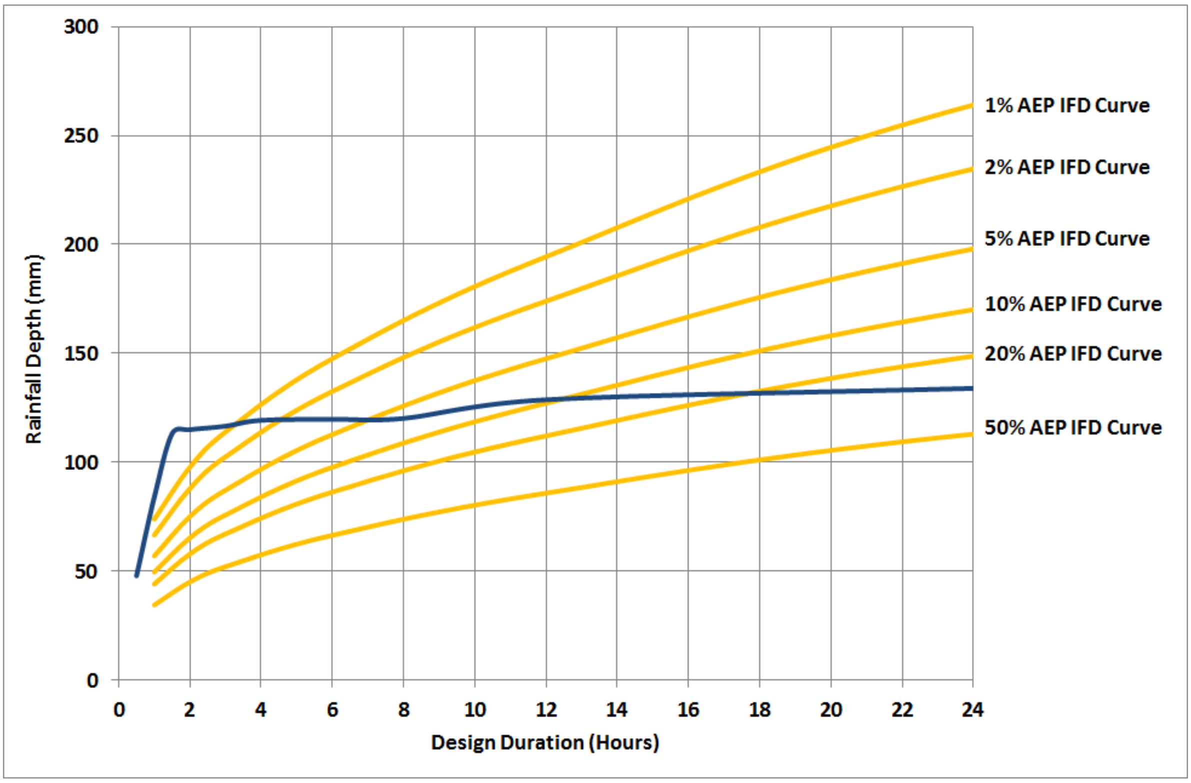


Figure 6-23 Comparison of Jewells April 1988 Rainfall with IFD Relationships

BMT WBM

6.4.2 April 1988 Entrance Berm Geometry

As with the February 1990 event, the condition of the entrance prior to the April 1988 event is unknown. In the absence of data, the existing condition as generally represented by the 2007 LiDAR capture, the OEH 2011 survey and additional ground survey acquired for the study.

The entrance condition is unlikely to have any significant impact on the modelled flood condition in the areas for comparison of historical flood level data.

6.4.3 Observed and Simulated Flood Behaviour April 1988

The adopted model parameters from the June 2007 event calibration as summarised in Table 6-2 have been applied directly for the April 1988 event validation.

There were a number of surveyed flood marks available for the April 1988 event from Council‟s existing historical flood record database. These flood marks are clustered in a number of keys areas including:

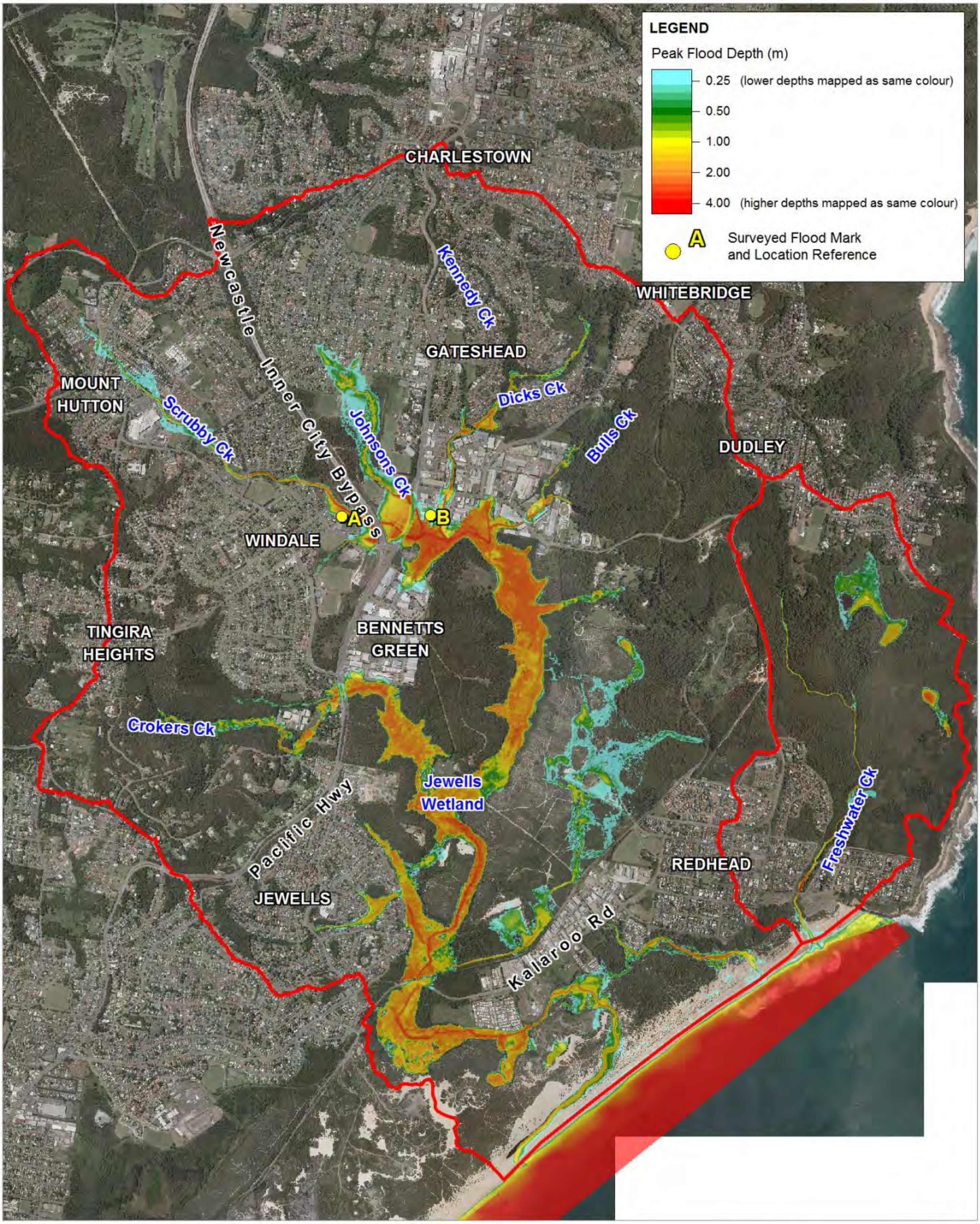
- Gateshead West – residential area at the upper reaches of Johnsons Creek. Subsequent to the 1988 and 1990 events, significant stormwater drainage improvements were undertaken in this area. The location of the affected area to which the available flood marks relate is not in the current study area.
- Lake Street Windale – residential properties at the end of Lake Street corresponding to the same locations where flood marks have also been recorded for the June 2007 and February 1990 events.
- Gateshead Industrial Estate – a number of flood marks are clustered in the industrial estate mainly at Arnhem Close.

Figure 6-24 shows the modelled flood depths in the catchment for the April 1988 event. The locations at which flood levels have been recorded are shown for reference. A comparison of the recorded and simulated peak flood levels at each of the surveyed flood mark locations is shown in Table 6-7.

Table 6-7 Comparison of Recorded and Simulated Flood Levels February 1990

Location	Recorded Level (m AHD)	Simulated Level (m AHD)
A – Lake Street, Windale	16.5	16.5
B – Arnhem Close, Gateshead	14.5	15.2

The simulated peak flood level matches the observed conditions at Lake Street Windale. This peak flood level condition is similar to that experienced for the June 2007 event.



Title:
Model Calibration for April 1988 Event

Figure: 6-24

Rev: A

N

0 0.75 1.5km

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Apr1988_Calibration.WOR

The Arnhem Close levels are overestimated by the model. This is likely to be as a result of the adopted rainfall. The rainfall derived from the Mount Hutton Auklet Road gauge was applied across the entire Jewells Wetland catchment. The location of the gauge is such that it is expected to provide a good representation of the rainfall in the upper reaches of Johnsons Creek and Scrubby Creek, hence the good representation of the peak flood condition at Lake Street Windale.

The storm event was very localised as represented by the distribution of rainfall across the gauges shown in Table 6-6. Accordingly, it is likely there is a spatial variation in rainfall across the Jewells catchment. A large proportion of the catchment contributing to the Gateshead Industrial area emanates from the Charlestown/Whitebridge localities. Rainfall in these catchments for the April 1988 event was most likely lower than that recorded at Mount Hutton. There is insufficient data to generate a spatial rainfall distribution for the Jewells catchment. However, it is estimated that a rainfall reduction of the order of 10-20mm would be sufficient to match the observed flood conditions at Arnhem Close, Gateshead.

6.5 Use of Model for Design Flood Simulation

The developed hydrological (RAFTS) and hydraulic (TUFLOW) models were calibrated to the observed June 2007 event conditions and subsequently applied to the April 1988 and February 1990 events as a validation exercise. Overall the models have been found to provide a sound representation of historical flood conditions as discussed in the previous sections. Accordingly, the models are considered appropriate for undertaking the design event modelling.

In applying the models for design purposes, the following points of issue are noted:

- Calibration accuracy – typically the calibration achieved the desired level of accuracy (e.g. peak flood +/-0.3m) with all model parameters kept within normal bounds. In simulating historical events it is noted there can be considerable uncertainty in the spatial and temporal distribution of rainfall across the catchment. Often this is defined on the basis of limited point information provided from available rainfall gauge data. Additionally, many of the recorded historical flood marks, principally for the April 1988 and February 1990 events, cannot be verified in terms of what was measured, timing etc. As noted in some instances there is a significant variation in recorded flood level between adjacent property flood marks.
- Entrance conditions – the condition of the entrance channel immediately prior to the calibration events was unknown. Peak flood conditions in the lower part of the system (i.e. wetland area downstream of Kalaroo Road) are potentially influenced by the entrance condition. Further, the channel connectivity in the lower wetland area is difficult to ascertain. Access is limited given the extensive dense vegetation coverage. In major flood events where significant flow is conveyed through the wetland, the channel connectivity and conveyance of main channel reaches represented in the model can impact on peak flood conditions.
- Post 2007 model changes – the major topographical changes between calibration events are the construction of the Inner City Bypass and the Fernleigh Track cycleway. In moving from the calibrated June 2007 model, only the Fernleigh Track construction requires a model update. In the most part, the previous rail embankment has been retained for the track. The principal updates required are local modifications to the embankment crest level and associated culvert structures at the main waterway crossing of Crokers Creek just upstream of Kalaroo Road.

- Design rainfall estimates – As shown in Figure 6-4, Figure 6-20 and Figure 6-23, the June 2007, February 1990 and April 1988 events all represent a significant rainfall event. Dependent on the relevant duration, each event has been shown to track at or above the corresponding 1% AEP design rainfall. Accordingly, in simulating the design flood conditions, a number of areas will have a design 1% AEP condition lower than what has been previously experienced. In some instances, such as Lake Street Windale, the design 1% AEP condition will have been exceeded multiple times.

7 DESIGN FLOOD CONDITIONS

Design floods are hypothetical floods used for planning and floodplain management investigations. They are based on having a probability of occurrence specified as Annual Exceedance Probability (AEP) expressed as a percentage.

Refer to Table 7-1 for a definition of AEP.

Table 7-1 Design Flood Terminology

AEP	Comments
0.5%	A hypothetical flood or combination of floods which represent the worst case scenario with a 0.5% probability of occurring in any given year.
1%	As for the 0.5% AEP flood but with a 1% probability.
2%	As for the 0.5% AEP flood but with a 2% probability.
5%	As for the 0.5% AEP flood but with a 5% probability.
10%	As for the 0.5% AEP flood but with a 10% probability.
20%	As for the 0.5% AEP flood but with a 20% probability.
50%	As for the 0.5% AEP flood but with a 50% probability.
Extreme Flood / PMF[1]	A hypothetical flood or combination of floods which represent an extreme scenario.

1 A PMF (Probable Maximum Flood) is not necessarily the same as an Extreme Flood.

In accordance with Council"s brief, the design events to be simulated include the 50% AEP, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and PMF event. The 1% AEP flood is generally used as a reference flood for development planning and control.

In determining the design floods it is necessary to take into account:

- Design rainfall parameters (rainfall depth, temporal pattern and spatial distribution). These inputs drive the hydrological model from which design flow hydrographs will be extracted as inputs to the hydraulic model;
- Design entrance channel geometry. As discussed, the entrance condition is a significant feature in terms of flood water level controls in the lower catchment. As outlined in the State Government"s *Flood Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessments* (DECCW, 2010), both closed and open entrance scenarios are to be modelled;
- Design downstream ocean boundary levels. A fully scoured entrance condition will provide for the critical case for ocean flooding, whilst for closed condition and intermediate scouring, coincident fluvial and tidal conditions may dictate flooding;

- The impact of future climate change on berm heights, ocean levels and catchment inflows.

7.1 Simulated Design Events

A suite of design event scenarios was defined that is most suitable for future floodplain management planning in the Jewells Wetland catchment. Consideration was given to flood events driven by both catchment and ocean processes. The potential impact of climate change on flood behaviour within the catchment has also been considered.

7.1.1 Design Flood Events

A range of design events was defined to model the behaviour of coincident flooding from both catchment and ocean sources within the Jewells Wetland catchment including the 50% AEP, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and PMF events. An overview of adopted model conditions for these design events is presented in Table 7-2. The adopted ocean boundary conditions are discussed in Figure 7-2.

Table 7-2 Design Model Runs for Coincident Flood Events

Design Flood	Rainfall	Berm Geometry	Ocean Boundary Peak Water Level (m AHD)
50% AEP	50% AEP	Closed (2.5m AHD Berm Saddle)	1.7 (50% AEP)
50% AEP	50% AEP	Open (-0.5m AHD)	1.7 (50% AEP)
20% AEP	20% AEP	Closed (2.5m AHD Berm Saddle)	1.9 (20% AEP)
20% AEP	20% AEP	Open (-0.5m AHD)	1.9 (20% AEP)
10% AEP	10% AEP	Closed (2.5m AHD Berm Saddle)	1.9 (20% AEP)
10% AEP	20% AEP	Open (-0.5m AHD)	2.1 (10% AEP)
5% AEP	5% AEP	Closed (2.5m AHD Berm Saddle)	2.1 (10% AEP)
5% AEP	10% AEP	Open (-0.5m AHD)	2.25 (5% AEP)
2% AEP	2% AEP	Closed (2.5m AHD Berm Saddle)	2.25 (5% AEP)
2% AEP	5% AEP	Open (-0.5m AHD)	2.45 (2% AEP)
1% AEP	1% AEP	Closed (2.5m AHD Berm Saddle)	2.25 (5% AEP)
1% AEP	5% AEP	Open (-0.5m AHD)	2.60 (1% AEP)
0.5% AEP	0.5% AEP	Closed (2.5m AHD Berm Saddle)	2.45 (2% AEP)
0.5% AEP	2% AEP	Open (-0.5m AHD)	2.75 (0.5% AEP)
PMF	PMP	Closed (2.5m AHD Berm Saddle)	2.60 (1% AEP)

7.1.2 Climate Change

The NSW Government has published guidelines on the practical consideration of climate change (DECC, 2007). For the Jewells Wetland catchment a range of design events was defined to model the potential impacts of future climatic change within the study catchment. There are three outcomes of current climate change predictions which may have a significant impact on flood behaviour within the Jewells Wetland catchment:

- Future sea-level rise;
- Elevated berm heights, themselves a function of sea-level rise;
- Increased extreme rainfall intensities.

The outcomes of these climate change considerations will help understand the potential changes in future flood behaviour and how to best plan for future development within the catchment. The design events for which climate change impacts were considered were therefore focussed on the main planning event – 1% AEP event. An overview of adopted model conditions for these climate change events is presented in Table 7-3.

Table 7-3 Design Model Runs for Climate Change Flood Events

Scenario	Rainfall	Berm Geometry	Ocean Boundary Peak Water Level (m AHD)
1% AEP 2050	1% AEP	Closed (2.9m AHD Berm Saddle	2.65 (5% AEP +0.4m)
1% AEP 2050	1% AEP	Closed (3.4m AHD Berm Saddle)	3.15 (5% AEP +0.9m to 2100
1% AEP 2050	1% AEP+10% increase	Closed (2.5m AHD Berm Saddle)	2.25 (5% AEP)
1% AEP 2050	1% AEP+10% increase	Closed (2.9m AHD Berm Saddle)	2.65 (5% AEP +0.4m)
1% AEP 2100	1% AEP+10% increase	Closed (3.4m AHD Berm Saddle)	3.15 (5% AEP +0.9m)
1% AEP 2100	1% AEP+20% increase	Closed (2.5m AHD Berm Saddle)	2.25 (5% AEP)
1% AEP 2100	1% AEP+20% increase	Closed (2.9m AHD Berm Saddle)	2.65 (5% AEP +0.4m)
1% AEP 2100	1% AEP+20% increase	Closed (3.4m AHD Berm Saddle)	3.15 (5% AEP +0.9m)
1% AEP 2100	1% AEP +30% increase	Closed (2.5m AHD Berm Saddle)	2.25 (5% AEP)
1% AEP 2100	1% AEP +30% increase	Closed (2.9m AHD Berm Saddle)	2.65 (5% AEP +0.4m)
1% AEP 2100	1% AEP +30% increase	Closed (3.4m AHD Berm Saddle)	3.15 (5% AEP +0.9m)

7.2 Design Rainfall

Design rainfall parameters are derived from standard procedures defined in AR&R (2001) which are based on statistical analysis of recorded rainfall data across Australia. The derivation of location specific design rainfall parameters (e.g. rainfall depth and temporal pattern) for the study catchment is presented below.

7.2.1 Rainfall Depths

Design rainfall depth is based on the generation of intensity-frequency-duration (IFD) design rainfall curves utilising the procedures outlined in AR&R (2001). These curves provide rainfall depths for various design magnitudes (up to the 1% AEP) and for durations from 5 minutes to 72 hours.

The Probable Maximum Precipitation (PMP) is used in deriving the Probable Maximum Flood (PMF) event. The theoretical definition of the PMP is "the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of year" (AR&R, 2001). The ARI of a PMP/PMF event ranges between 10^4 and 10^7 years and is beyond the "credible limit of extrapolation". That is, it is not possible to use rainfall depths determined for the more frequent events (1% AEP and less) to extrapolate the PMP. The PMP has been estimated using the Generalised Short Duration Method (GSDM) derived by the Bureau of Meteorology.

A range of storm durations were modelled in order to identify the critical storm duration for design event flooding in the catchment. Design durations considered included the 1-hour, 1.5-hour, 2-hour, 3-hour, 4.5-hour, 6-hour, 9-hour, 12-hour, 18-hour, 24-hour durations.

Table 7-4 shows the average design rainfall intensities based on AR&R adopted for the modelled events.

Table 7-4 Average Design Rainfall Intensities (mm/hr)

Duration (hours)	Design Event Frequency				
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
1	44.2	49.7	57.1	66.7	74
2	29	32.7	37.6	44	48.9
3	22.4	25.3	29.1	34.2	38
4.5	17.2	19.5	22.4	26.3	29.3
6	14.4	16.3	18.8	22.1	24.6
9	11.1	12.6	14.6	17.2	19.1
12	9.35	10.6	12.3	14.5	16.2
18	7.30	8.32	9.67	11.4	12.8
24	6.2	7.09	8.25	9.78	11
48	4.08	4.71	5.5	6.55	7.37
72	3.1	3.58	4.2	5.02	5.66

7.2.2 Temporal Patterns

The IFD data presented in Table 7-4 provides for the average intensity (or total depth) that occurs over a given storm duration. Temporal patterns are required to define what percentage of the total rainfall depth occurs over a given time interval throughout the storm duration. The temporal patterns adopted in the current study are based on the standard patterns presented in AR&R (2001).

The same temporal pattern has been applied across the whole catchment. This assumes that the design rainfall occurs simultaneously across each of the modelled sub-catchments. The direction of a storm and relative timing of rainfall across the catchment may be determined for historical events if sufficient data exists, however, from a design perspective the same pattern across the catchment is generally adopted.

7.2.3 Rainfall Losses

The hydrologic model parameters adopted for the design floods were based on the initial and continuing loss model, with a continuing loss of 2.5mm/h as recommended in AR&R (2001). For the initial loss AR&R recommends values between 10mm and 35mm for eastern NSW. For the initial and continuing rainfall losses, values of 15mm and 2.5mm/h were used. These are consistent with the recommended ranges for design event losses in AR&R (2001).

7.2.4 Climate Change Impact on Design Rainfall

Current guidelines predict that a likely outcome of future climatic change will be an increase in extreme rainfall intensities. Climate Change in New South Wales (CSIRO, 2004) provides projected increases in annual extreme rainfall intensities for north-east NSW of 5% for both the years 2030 and 2070. The spring extreme rainfall intensities are projected to increase by 10% for the year 2070. These figures are based on a 2.5% AEP 24h duration rainfall event.

The climate change sensitivity tests considered increases in design rainfall intensity of 10%, 20% and 30% in accordance with Practical Consideration of Climate Change Guideline for Floodplain Risk Management (DECC, 2007).

7.3 Design Ocean Boundary

Design ocean boundaries for use in flood risk assessments are recommended by Appendix A of the Flood Risk Management Guide (DECCW, 2010). This appendix was formerly Guideline 5 of Ocean Boundary Conditions for Hydraulic Flood Modelling. The design ocean boundaries from Figure 3 of this document are presented in Figure 7-1.

The design peak water levels for ocean derived flood events consistent with Figure 7-1 are 2.25m AHD for the 5% AEP event and 2.6m AHD for the 1% AEP event. These levels include the following considerations:

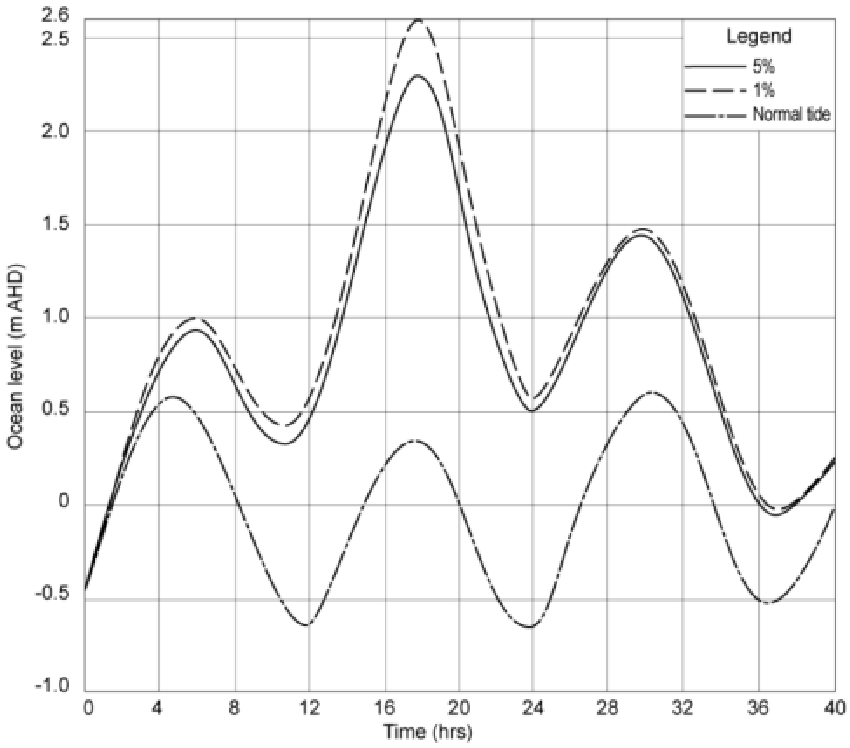
- Barometric pressure set up of the ocean surface due to the low atmospheric pressure of the storm;
- Wind set up due to strong winds during the storm “piling” water upon the coastline;
- Astronomical tide, particularly the HHWSS; and

- Wave set up.

The appropriate design peak water levels to be used for the remaining design events were then derived through use of a log graph, presented in Figure 7-2. The peak flood levels are also provided in Table 7-5.

The temporal pattern of the design boundaries for ocean derived flood events was based on the recommended water level hydrograph for ocean design events as shown in Figure 7-1. This water level hydrograph provides for a storm surge allowance superimposed on a normal tide condition.

The timing of the peak water level was adjusted to coincide with the peak catchment inflow. The water levels were then scaled accordingly to match those from Table 7-5. The design ocean boundaries used in this study are presented in Figure 7-3.



Source: Figure3, Appendix A, Draft Flood Risk Management Guide (DECCW, 2010)

Figure 7-1 OEH Recommended Design Ocean Boundaries

Table 7-5 Adopted Design Peak Ocean Water Levels

Event Magnitude	Water Level (m)
50% AEP	1.7
20% AEP	1.9
5% AEP	2.25
2% AEP	2.45
1% AEP	2.60
0.5% AEP	2.75

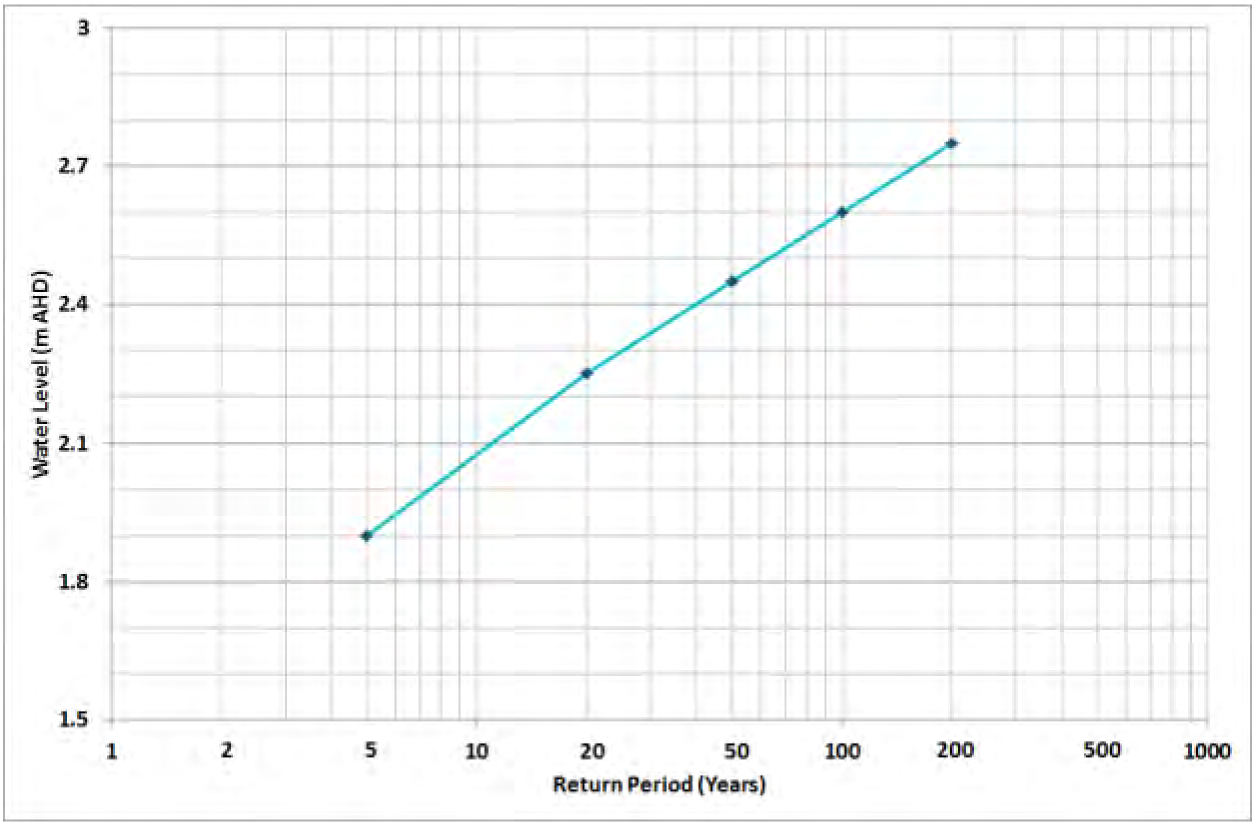


Figure 7-2 Design Peak Ocean Water Level Derivation

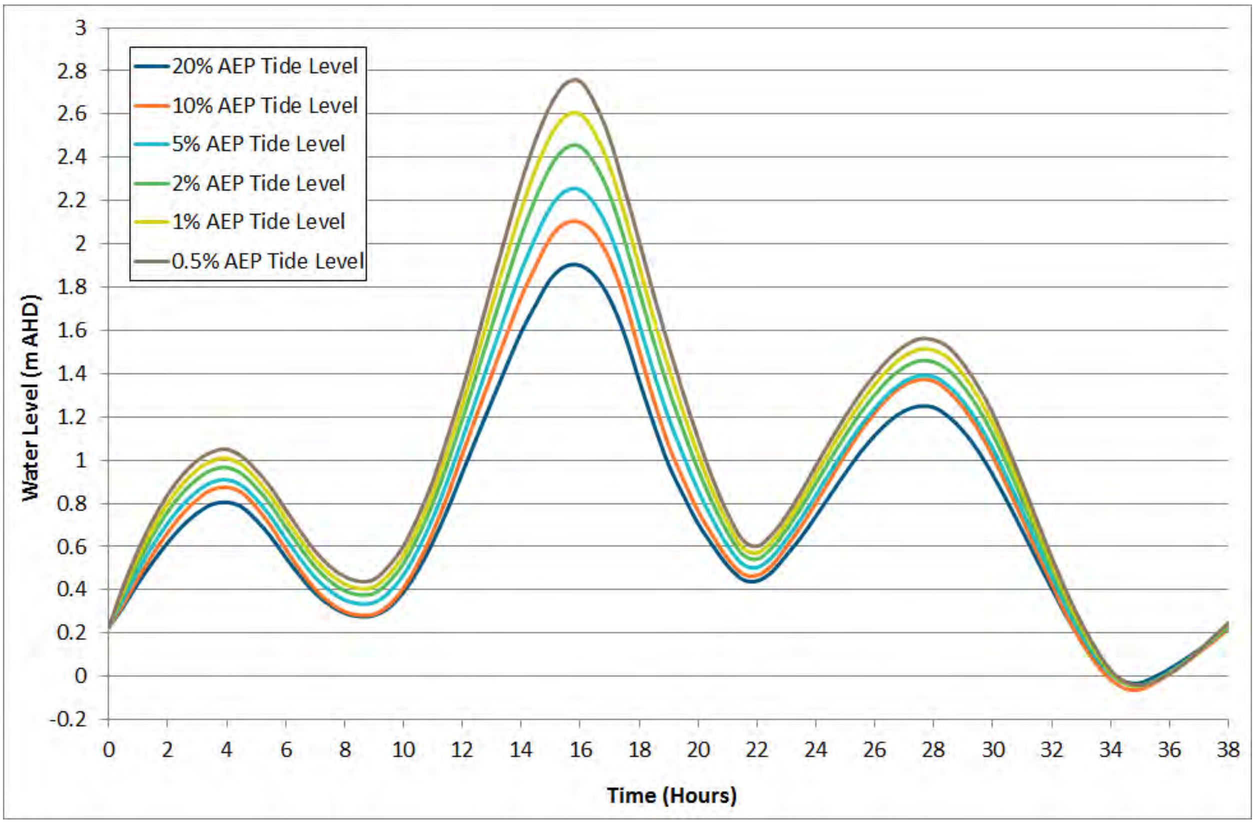


Figure 7-3 Design Boundaries for Ocean Derived Flood Events

7.4 Design Berm Geometry

The design berm geometry can have a significant influence on modelled flood levels in the lower reaches of the Jewells Wetland catchment. In defining the entrance condition for the design flood analysis, consideration is given to the geometry of the berm for open and closed conditions, for existing and future scenarios considering potential sea level rise influences.

7.4.1 Catchment Derived Flood Events

The berm saddle height adopted for the catchment derived flooding design events is 2.5m AHD. The design berm geometry was based on the LiDAR survey data, in which the berm crest elevation was around 2.0m AHD. The model elevations in the entrance have been raised by 0.5m to provide a crest elevation of 2.5m. For the 1% AEP event, additional model scenarios have been undertaken to test the sensitivity of the berm condition adopting both a 3m and 4m berm saddle height.

7.4.2 Ocean Derived Flood Events

For the ocean derived flood events Appendix A of the Flood Risk Management Guide (DECCW, 2010) calls for a largely unrestricted entrance condition. This has been represented through the lowering of the model elevations in the entrance channel, providing an open entrance with a bed elevation of -0.5m AHD.

7.4.3 Climate Change

There are no government guidelines concerning the impact of future climatic change of entrance berm geometries. A change in entrance berm processes is likely to result from the predicted sea level rise and changes to coastal storm intensity. From this change, a net upward shift in typical berm heights at the entrance may be expected commensurate with sea level rise estimates.

For the purposes of this study a berm height increase of 0.4m and 0.9m has been adopted in line with the adopted sea level rise scenarios. This gives a berm saddle height for catchment derived flood events of 2.9m AHD corresponding to 0.4m sea level rise, and 3.4m AHD corresponding to 0.9m sea level rise. For the open entrance condition adopted for ocean derived flood events the bed elevation has been raised to -0.1m AHD and 0.4m AHD for 0.4m and 0.9m sea level rise scenarios respectively.

The Lake Macquarie Coastal Processes and Hazards Definition Study (BMT WBM, 2011) included an assessment of shoreline recession due to sea level rise. This coastal recession has been represented in the climate change scenarios by shifting the berm position westwards by appropriate distances.

7.5 Initial Water Levels

Initial water levels in the Jewells Wetland water body have been set to the same level at the berm saddle height for the closed entrance condition scenarios. For the baseline design condition, this represents an initial water level of 2.5m AHD.

For open entrance conditions, the initial water levels have been set to a level similar to the sea level at the onset of the event. There is little flood storage capacity available in the lake, which peaks at a similar level to the peak sea level and is not sensitive to the initial water level.

For the climate change scenarios, initial water levels in Jewells Wetland have been raised by 0.4m and by 0.9m for the respective scenarios.

8 DESIGN FLOOD RESULTS

A range of design flood conditions were modelled, the results of which are presented and discussed below. The simulated design events included the 50% AEP, 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP and 0.5% AEP for both catchment derived and ocean derived flooding. The PMF flood event has also been modelled.

The impact of future climate change on flooding in Jewells Wetland was also considered for both catchment derived and ocean derived flood events, focussing on the 1% AEP flood event.

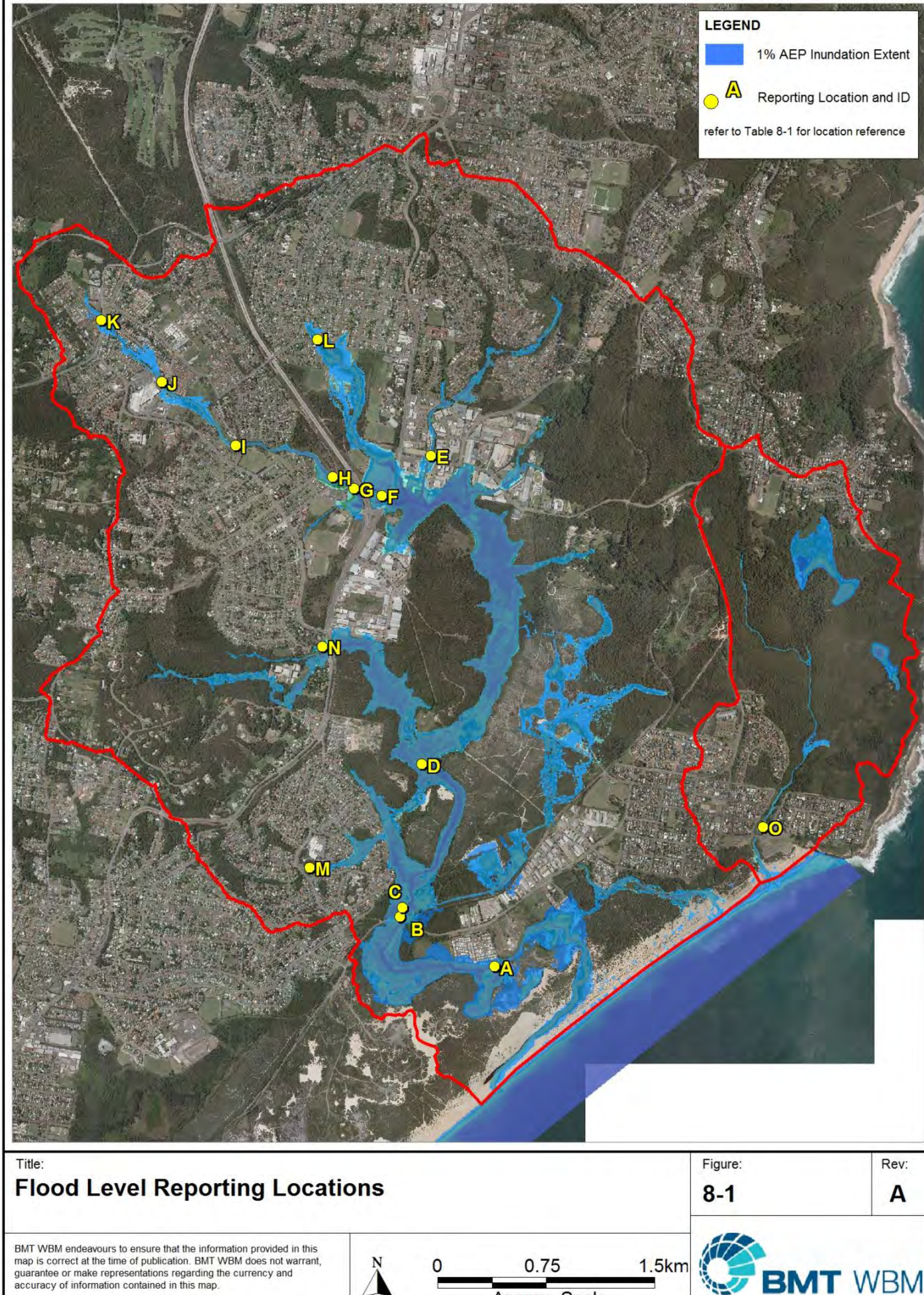
8.1 Peak Flood Level Conditions

Predicted flood levels at selected locations (as presented in Figure 8-1) are shown in Table 8-1 and Table 8-2 for catchment derived and ocean derived events respectively. Flood levels for the ocean derived events are only reported in Table 8-2 for the reporting locations in the lower part of the catchment. The modelled design scenarios were summarised in Table 7-2.

Table 8-1 Simulated Design Peak Flood Levels (m AHD) for Catchment Events

ID	Location	Flood Event Frequency							
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMF
A	The Sanctuary	4.1	4.7	4.9	5.3	5.6	5.7	5.9	8.1
B	U/S Kalaroo Road	5.2	5.2	5.3	5.5	5.8	5.9	6.1	8.5
C	U/S Fernleigh Track	5.3	5.6	5.8	6.0	6.2	6.3	6.5	8.5
D	Jewells Wetland	8.6	8.9	9.1	9.3	9.5	9.6	9.7	11.9
E	U/S Oakdale Road	14.5	14.8	14.9	15.1	15.2	15.3	15.4	17.4
F	U/S Pacific Hwy (SC)	14.3	14.6	14.8	14.9	15.1	15.2	15.2	17.4
G	U/S Inner City Bypass	14.6	14.9	15.0	15.2	15.5	15.7	16.0	18.4
H	Lake Road Windale	14.9	15.3	15.4	15.6	15.8	16.0	16.1	18.4
I	U/S Merrigum St	20.0	19.9	20.0	20.2	20.3	20.5	20.6	23.2
J	Lake Macquarie Fair	26.4	26.6	26.7	26.8	26.9	27.0	27.0	28.0
K	U/S Warners Bay Rd	34.9	35.2	35.5	35.9	36.0	36.1	36.1	36.6
L	U/S Willow Road	21.8	21.9	21.9	22.0	22.0	22.0	22.1	22.7
M	D/S Ntaba Rd	7.7	8.0	8.1	8.1	8.2	8.2	8.3	9.1
N	U/S Pacific Hwy (CC)	9.9	10.1	10.2	10.5	10.7	10.8	10.9	12.3
O	U/S Beach Rd	5.3	5.6	5.8	6.2	6.6	7.1	7.6	11.7

The catchment flooding events are the dominant flooding mechanism in the Jewells Wetland catchment across the full range of design flood magnitudes. The influence of the ocean condition is limited to the very downstream end of the system. The design 1% AEP ocean boundary condition of 2.6m AHD is only slightly higher than the adopted berm height condition of 2.5m AHD for the catchment derived events. An open entrance condition is adopted in simulating the ocean derived events to enable the propagation of a storm surge upstream into the lower wetland area. However, it



Title:

Flood Level Reporting Locations

Figure: 8-1

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Reporting_Locations.WOR remains the assumed coincident catchment flood condition dominating peak flood levels in the majority of the lower catchment.

Table 8-2 Simulated Design Peak Flood Levels (m AHD) for Ocean Events

ID	Location	Flood Event Frequency						
		50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP
A	The Sanctuary	3.7	4.5	4.5	4.9	5.2	5.2	5.6
B	U/S Kalaroo Road	5.4	5.3	5.3	5.4	5.5	5.5	5.7
C	U/S Fernleigh Track	5.3	5.6	5.6	5.7	6.0	6.0	6.2
D	Jewells Wetland	8.6	8.9	8.9	9.1	9.3	9.3	9.5
O	U/S Beach Rd	5.3	5.6	5.6	5.8	6.0	6.0	6.3

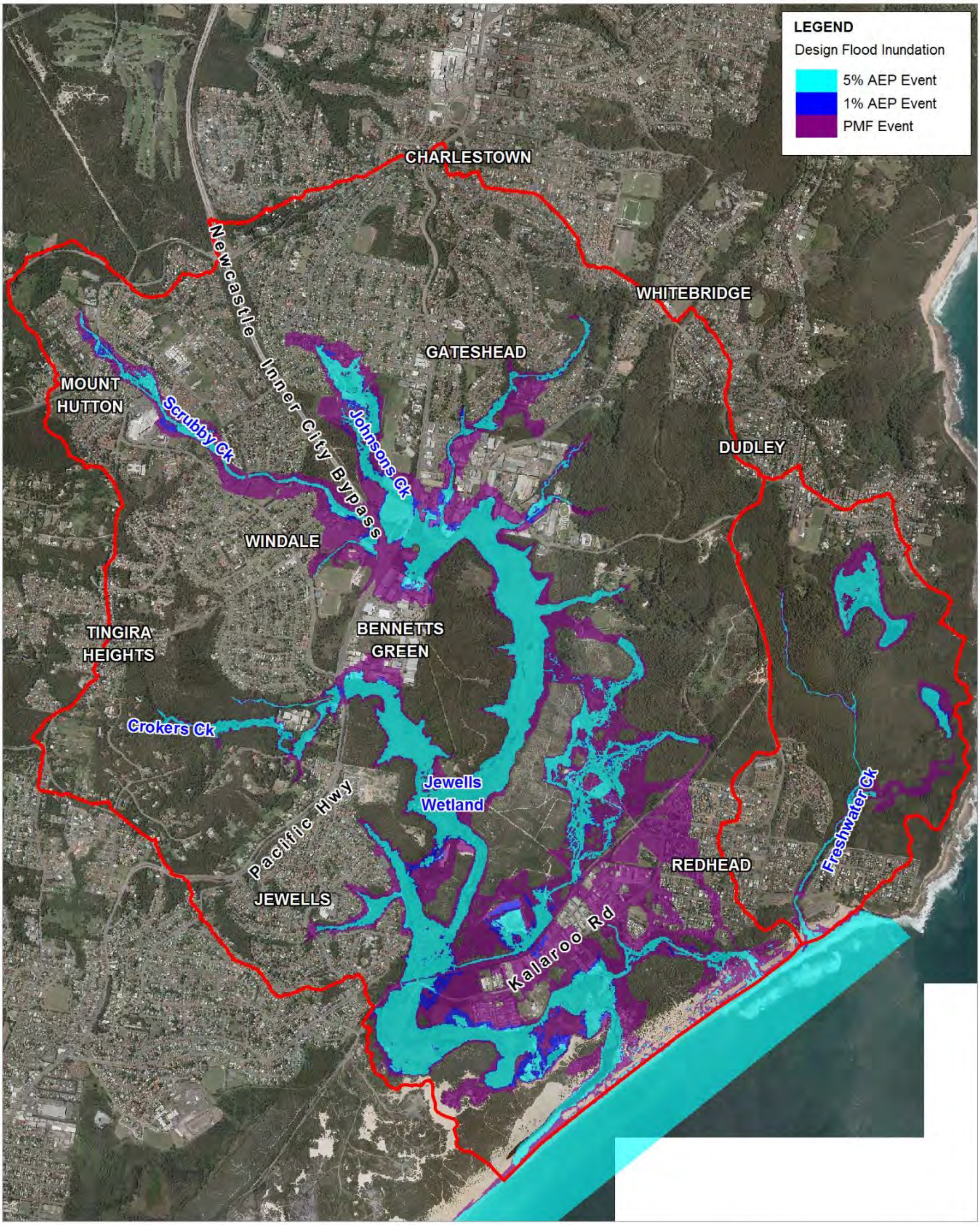
Figure 8-2 shows the design flood inundation extents for the 5% AEP, 1% AEP and PMF events. The flood extents for the 5% AEP event and 1% AEP event are broadly similar. The inundation extents for the PMF event show a much increased area at risk to flooding, especially in the following locations:

- Development areas downstream of Kalaroo Road, in particular the Sanctuary and the Redhead Holiday Park;
- The industrial/commercial estates of Gateshead and Bennetts Green; and
- Residential property adjacent to Scrubby Creek at Windale.

For events up to the 1% AEP magnitude the flooding within the catchment is largely restricted to undeveloped floodplain areas. There appears to be no extensive areas subject to significant inundation at the 1% AEP level. The most significant at risk properties are largely those as identified in the June 2007 event that were subject to inundation.

At the PMF level, there is some overtopping of the Fernleigh Track providing for overland flooding in some of the developed areas of Redhead.

The critical duration for the peak 1% AEP flood levels across the catchment is shown in Figure 8-3. Typically in the upper reaches of all the tributary channels the critical duration was the 2-hour event. In the lower catchment encompassing the broader Jewells Wetland where there is more significant temporary flood storage, the critical duration was typically the longer duration 9-hour event. The main Freshwater Creek channel has limited temporary flood storage such that the critical duration along the entire reach is given by the short duration 2-hour event.



Title:

Design Flood Inundation Extents

Figure: 8-2

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

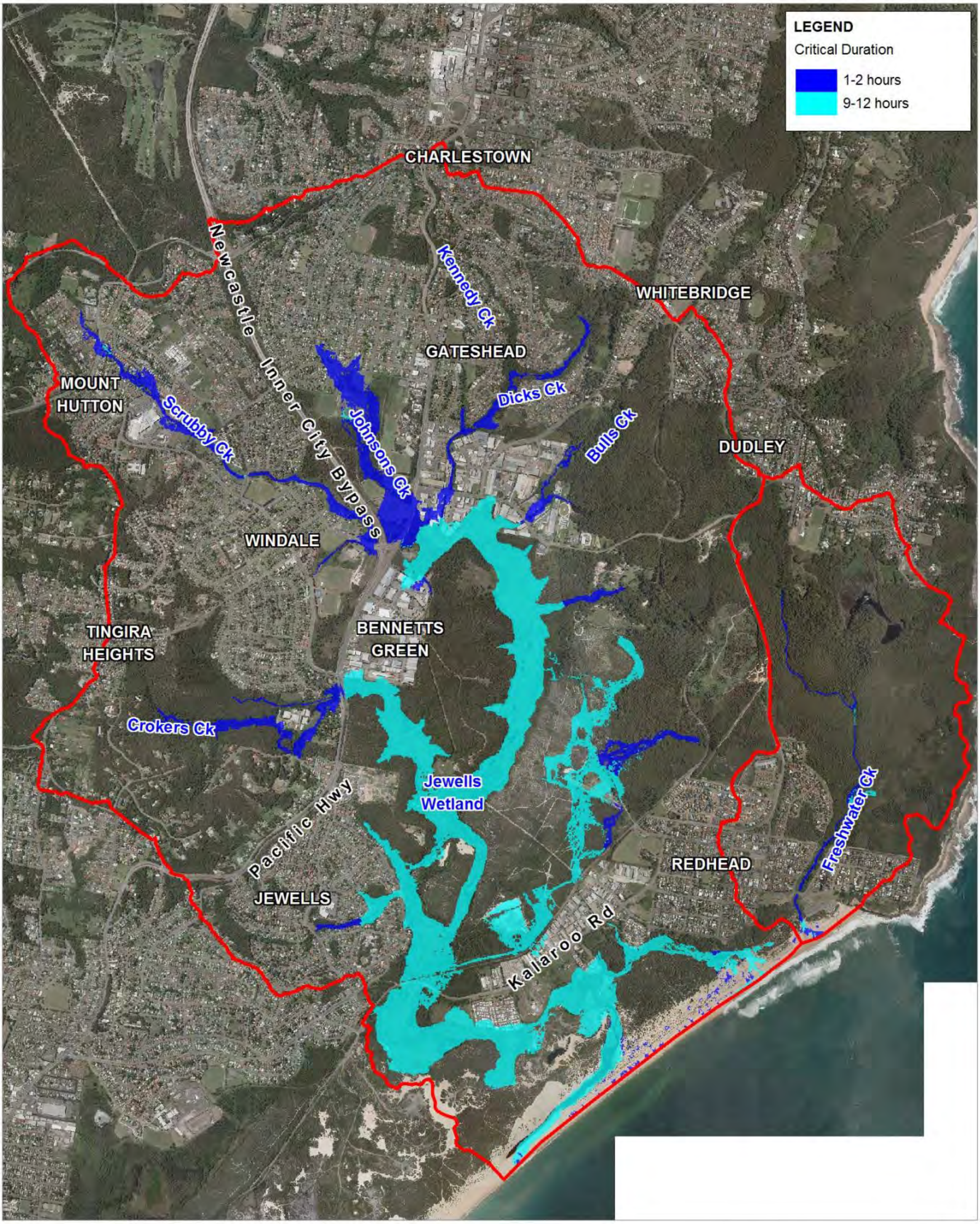
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Inundation_Extents.WOR



Title:

Design Flood Critical Duration

Figure: 8-3

Rev: A

N

0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Critical_Duration.WOR

A longitudinal profile showing predicted flood levels through the catchment are shown in Figure 8-4. The profile extends from the ocean boundary on the main Crokers Creek outlet upstream through the broader Jewells Wetland area to the confluence of Scrubby Creek and Johnsons Creek in the vicinity of the Gateshead Industrial area. The profile then extends upstream of the Pacific Highway along the alignment of Scrubby Creek up to Lake Macquarie Fair.

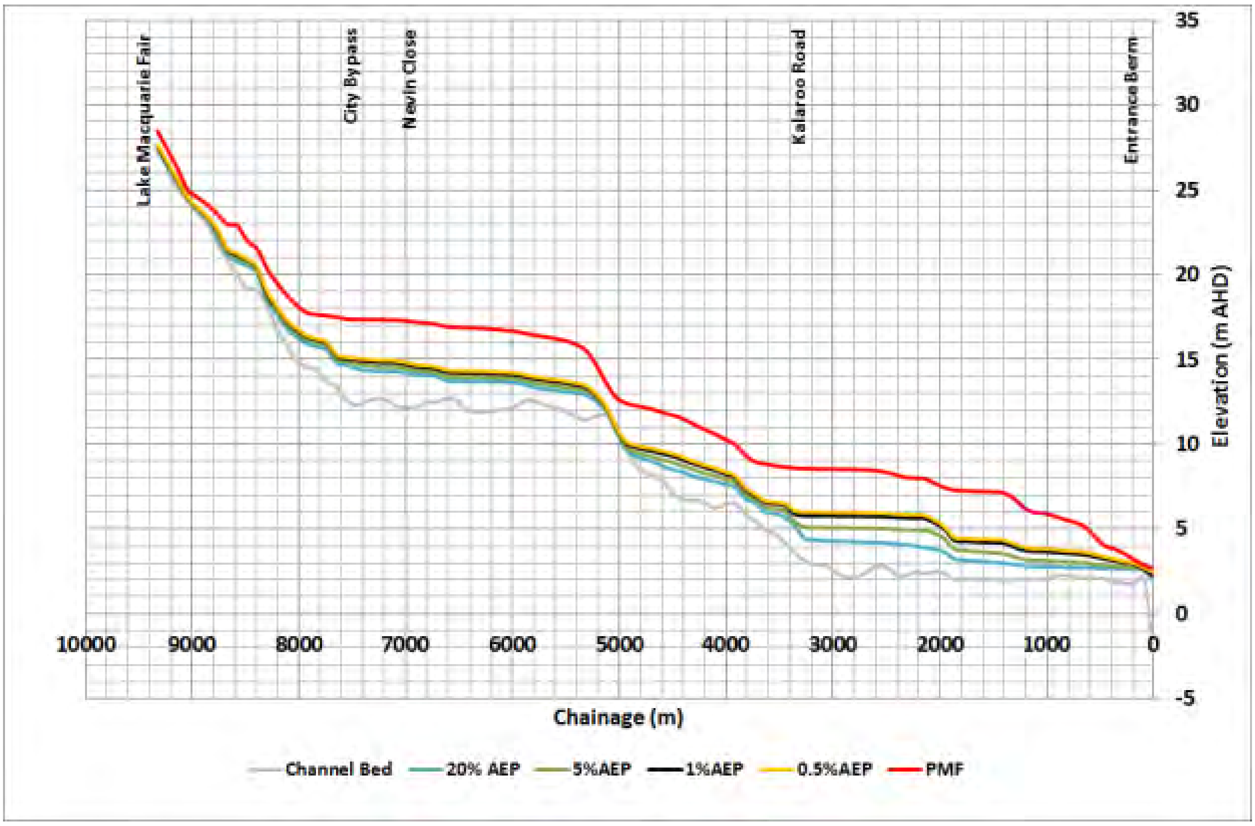


Figure 8-4 Catchment Event Peak Flood Level Profiles

Further design flood level profiles along all main tributary channels is provided in Appendix B. Comparison profiles are also provided between simulated design events and the historical flood events simulated in the model calibration/validation process.

8.2 Flood Flows

The flood flow hydrographs for the modelled events are presented in Figure 8-5 to Figure 8-8 for the following locations on the key tributaries: Crokers Creek at Kalaroo Road, Scrubby Creek at the Pacific Highway, Johnsons Creek at the Pacific Highway and Freshwater Creek at Beach Road. The hydrographs are shown for the 9-hour duration storm, representative of the peak flow condition in the majority of the catchment area. They peak at around 6 hours after the onset of the storm.

Shown for reference is the simulated June 2007 hydrograph for comparison to the simulated design event conditions. As noted in Section 6.2, the June 2007 event typically exceeds the design 1% design flood condition throughout the catchment. The June 2007 event also represented a longer duration than the representative 9-hour design condition.

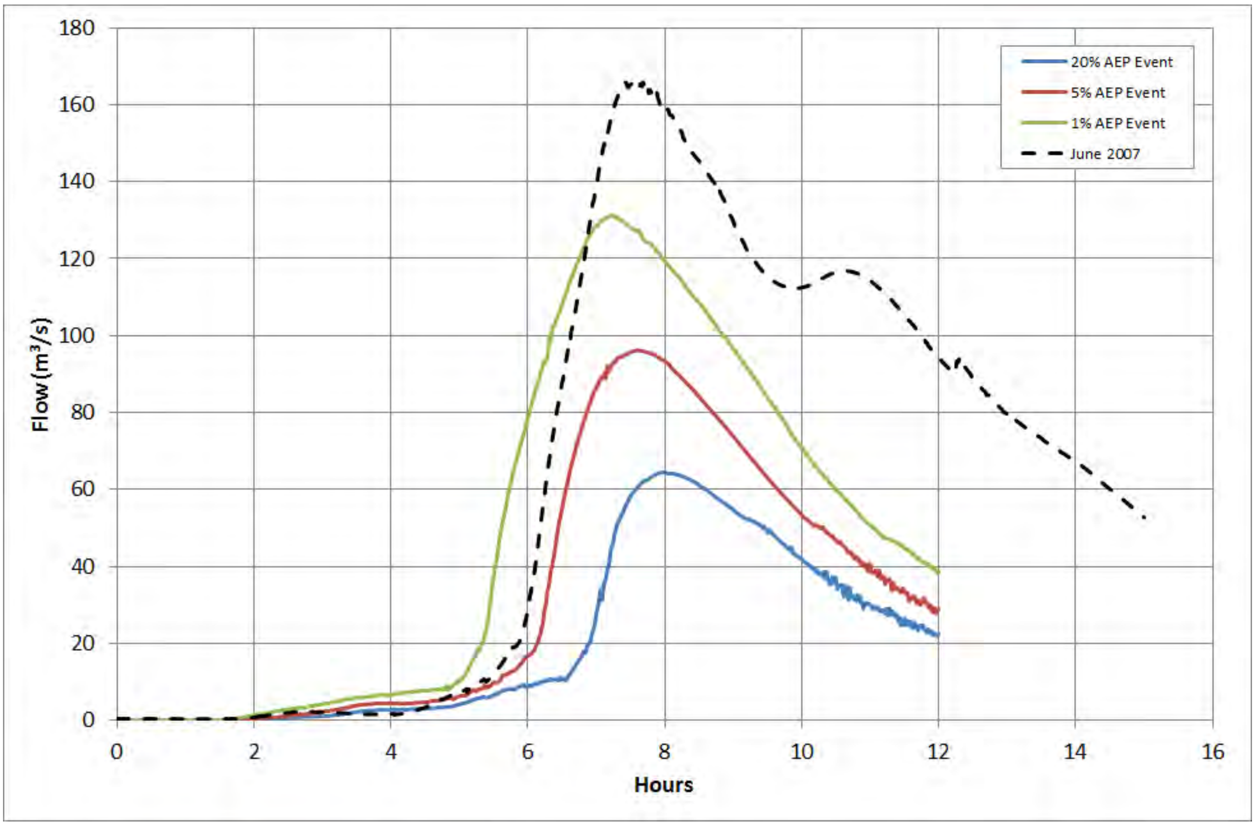


Figure 8-5 Modelled 9-hour Duration Event Hydrographs Crokers Creek at Kalaroo Road

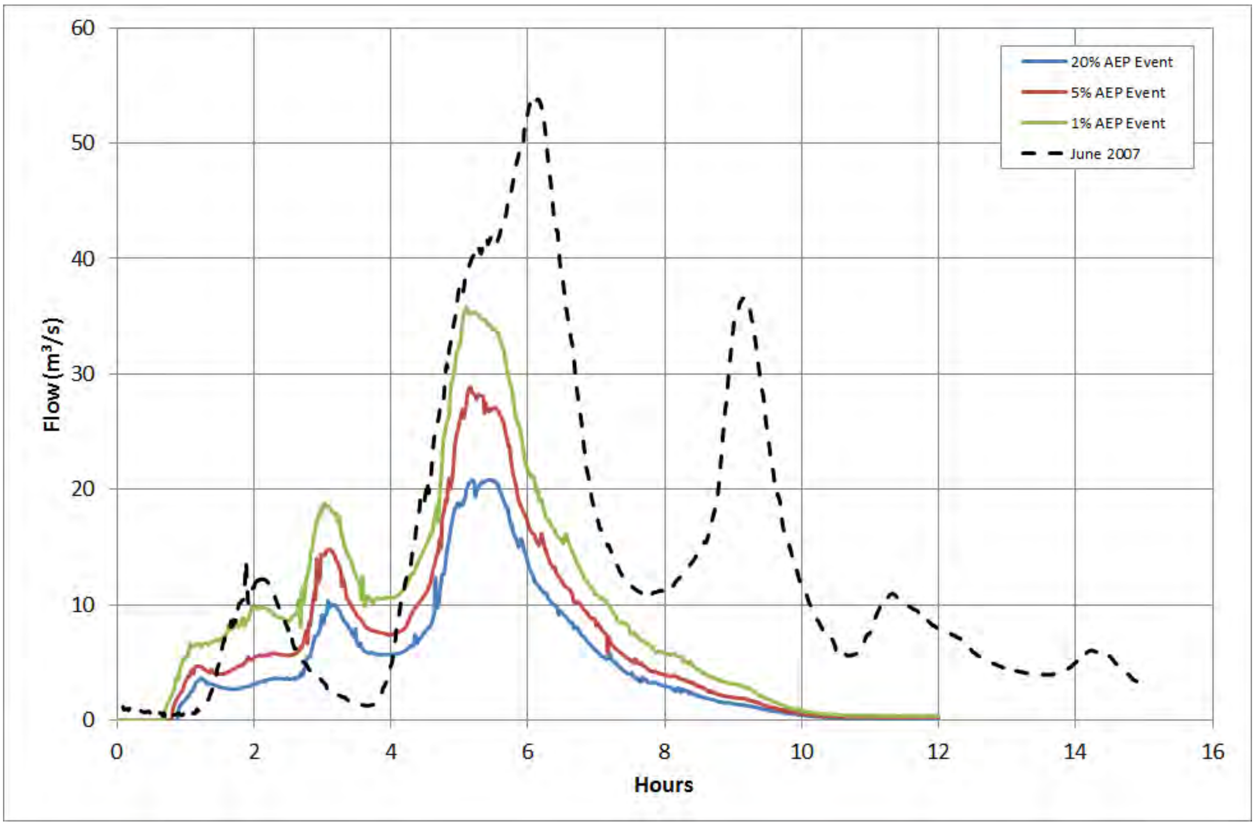


Figure 8-6 Modelled 9-hour Duration Event Hydrographs at Scrubby Creek at Pacific Highway

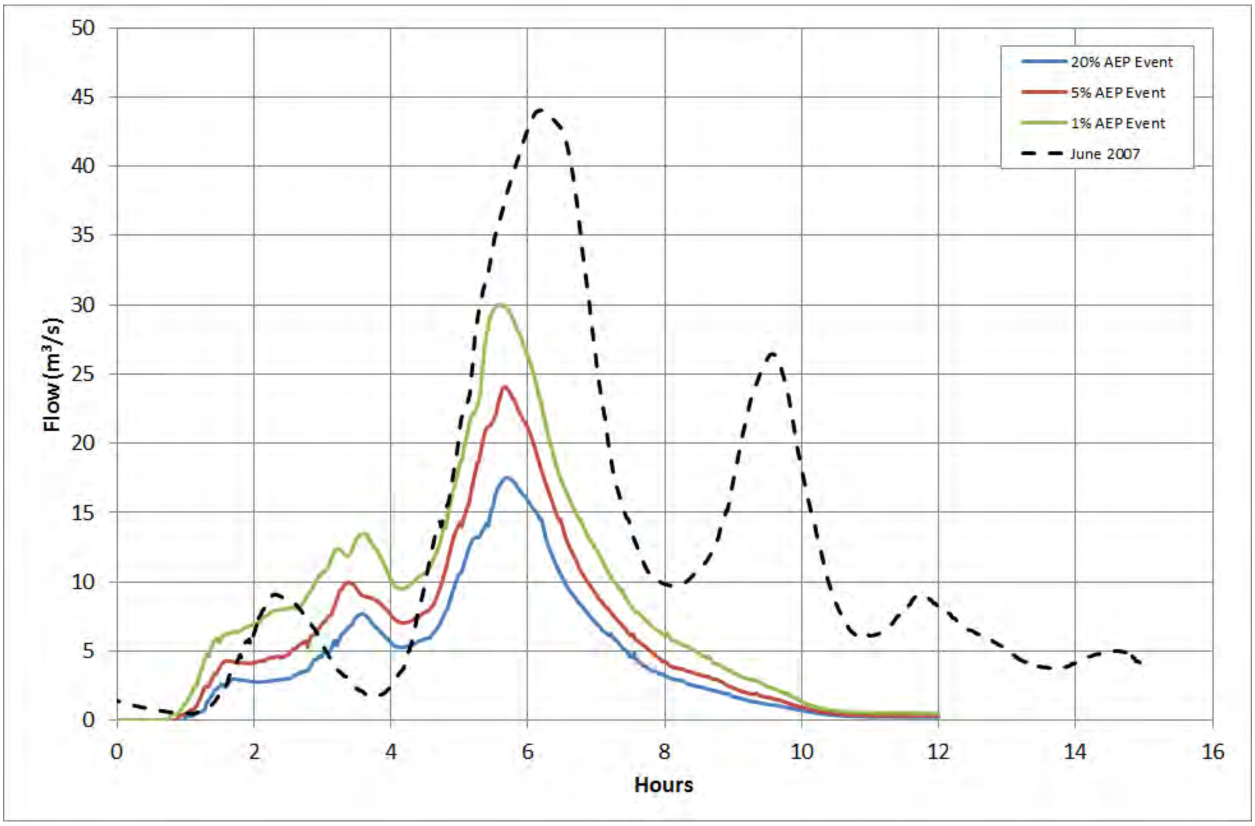


Figure 8-7 Modelled 9-hour Duration Event Hydrographs at Johnsons Creek at Pacific Highway

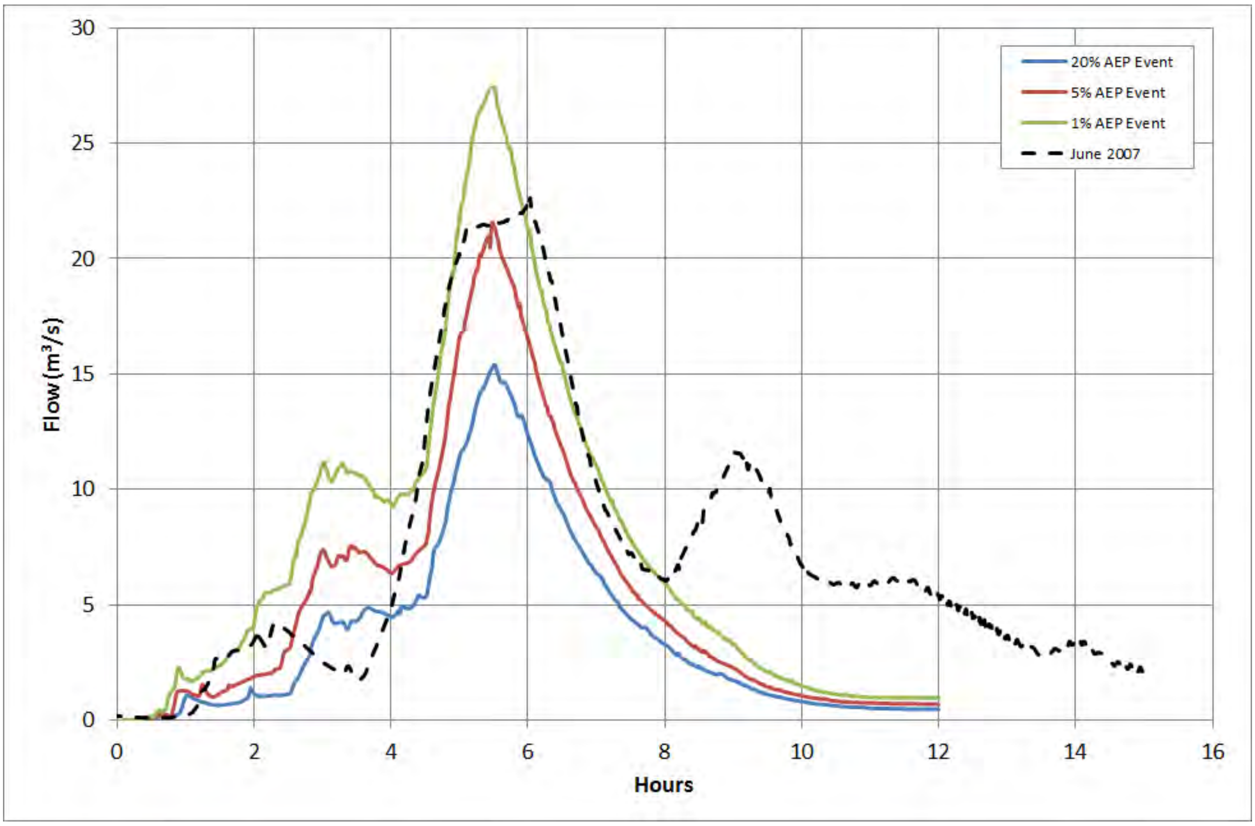


Figure 8-8 Modelled 9-hour Duration Event Hydrographs at Freshwater Creek at Beach Road

Peak in channel flood velocities are typically around 1.5m/s to 2.5m/s, being lower in the floodplain areas. Flood velocities on the developed floodplain areas are typically less than 0.5m/s, but may be locally high around control structures and on roadways.

8.3 Hydraulic Categorisation

There are no prescriptive methods for determining what parts of the floodplain constitute floodways, flood storages and flood fringes. Descriptions of these terms within the Floodplain Development Manual (NSW Government, 2005) are essentially qualitative in nature. Of particular difficulty is the fact that a definition of flood behaviour and associated impacts is likely to vary from one floodplain to another depending on the circumstances and nature of flooding within the catchment.

The hydraulic categories as defined in the Floodplain Development Manual are:

- **Floodway -** Areas that convey a significant portion of the flow. These are areas that, if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.
- **Flood Storage -** Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%.
- **Flood Fringe -** Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

A number of approaches were considered when attempting to define flood impact categories across the study catchment. The approach that was adopted derived a preliminary floodway extent from the velocity * depth product (sometimes referred to as unit discharge). The floodway extent was then locally adjusted where appropriate. The peak flood depth was used to define flood storage areas. The adopted hydraulic categorisation is defined in Table 8-3.

Preliminary hydraulic category mapping is included in Appendix A. It is also noted that mapping associated with the flood hydraulic categories may be amended in the future, at a local or property scale, subject to appropriate analysis that demonstrates no additional impacts (e.g. if it is to change from floodway to flood storage).

8.4 Provisional Hazard

The NSW Government"s Floodplain Development Manual (2005) defines flood hazard categories as follows:

- **High hazard** – possible danger to personal safety; evacuation by trucks is difficult; able-bodied adults would have difficulty in wading to safety; potential for significant structural damage to buildings; and
- **Low hazard** – should it be necessary, trucks could evacuate people and their possessions; able-bodied adults would have little difficulty in wading to safety.

Table 8-3 Hydraulic Categories

Floodway	Velocity * Depth > 0.5	Areas and flowpaths where a significant proportion of floodwaters are conveyed (including all bank-to-bank creek sections).
Flood Storage	Velocity * Depth < 0.5 and Depth > 0.5 metres	Areas where floodwaters accumulate before being conveyed downstream. These areas are important for detention and attenuation of flood peaks.
Flood Fringe	Velocity * Depth < 0.5 and Depth < 0.5 metres	Areas that are low-velocity backwaters within the floodplain. Filling of these areas generally has little consequence to overall flood behaviour.

The key factors influencing flood hazard or risk are:

- Size of the Flood
- Rate of Rise - Effective Warning Time
- Community Awareness
- Flood Depth and Velocity
- Duration of Inundation
- Obstructions to Flow
- Access and Evacuation

The provisional flood hazard level is often determined on the basis of the predicted flood depth and velocity. This is conveniently done through the analysis of flood model results. A high flood depth will cause a hazardous situation while a low depth may only cause an inconvenience. High flood velocities are dangerous and may cause structural damage while low velocities have no major threat.

Figures L1 and L2 in the Floodplain Development Manual (NSW Government, 2005) are used to determine provisional hazard categorisations within flood liable land. These figures are reproduced in Figure 8-9.

The provisional hydraulic hazard is included in the mapping series provided in Appendix A.

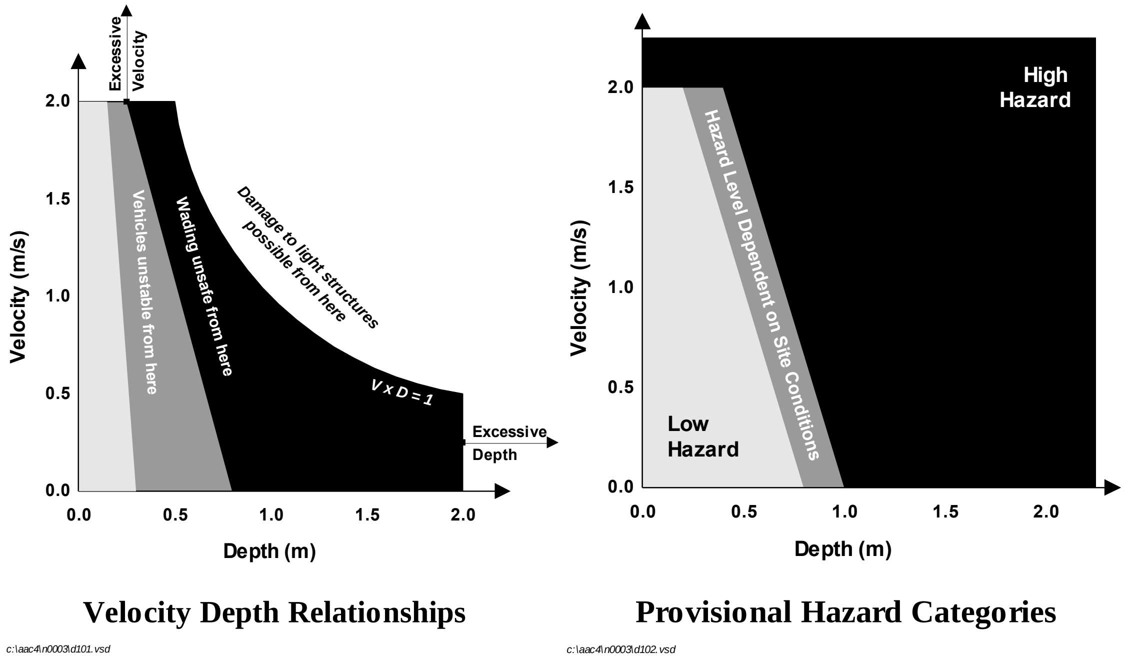


Figure 8-9 Provisional Flood Hazard Categorisation

8.5 Sensitivity Tests

8.5.1 Entrance Conditions

The design flood conditions adopted a 2.5m minimum berm height at the outlet of the entrance channels. For the 5% AEP and 1% AEP events the impact of adopting minimum berm height of 3.0m AHD and 4.0m AHD were assessed. Figure 8-10 and Figure 8-11 show the results of this assessment for the 5% AEP event and the 1% AEP event respectively. The berm profiles are those at the onset of the event, during which the geomorphologic model scours the berm as the flood is conveyed out through the entrance channels.

The peak flood level results of each event show a similar level of impact. The impact of the adopted berm height does not extend more than around 2km upstream of the entrance. This location is well downstream of Kalaroo Road and just downstream of The Sanctuary.

The adoption of a nominal berm height to establish design flood levels therefore only has an influence limited to the far downstream end of the catchment. In setting design flood levels for development control in the lower reaches impacted by the berm, consideration can be given to the adoption of flood levels based on a more conservative (higher) initial berm level.

The limited influence of the berm on peak flood level conditions upstream would suggest that entrance works to manage the berm height or to maintain an open entrance condition would have little benefit in reducing major flood risk.

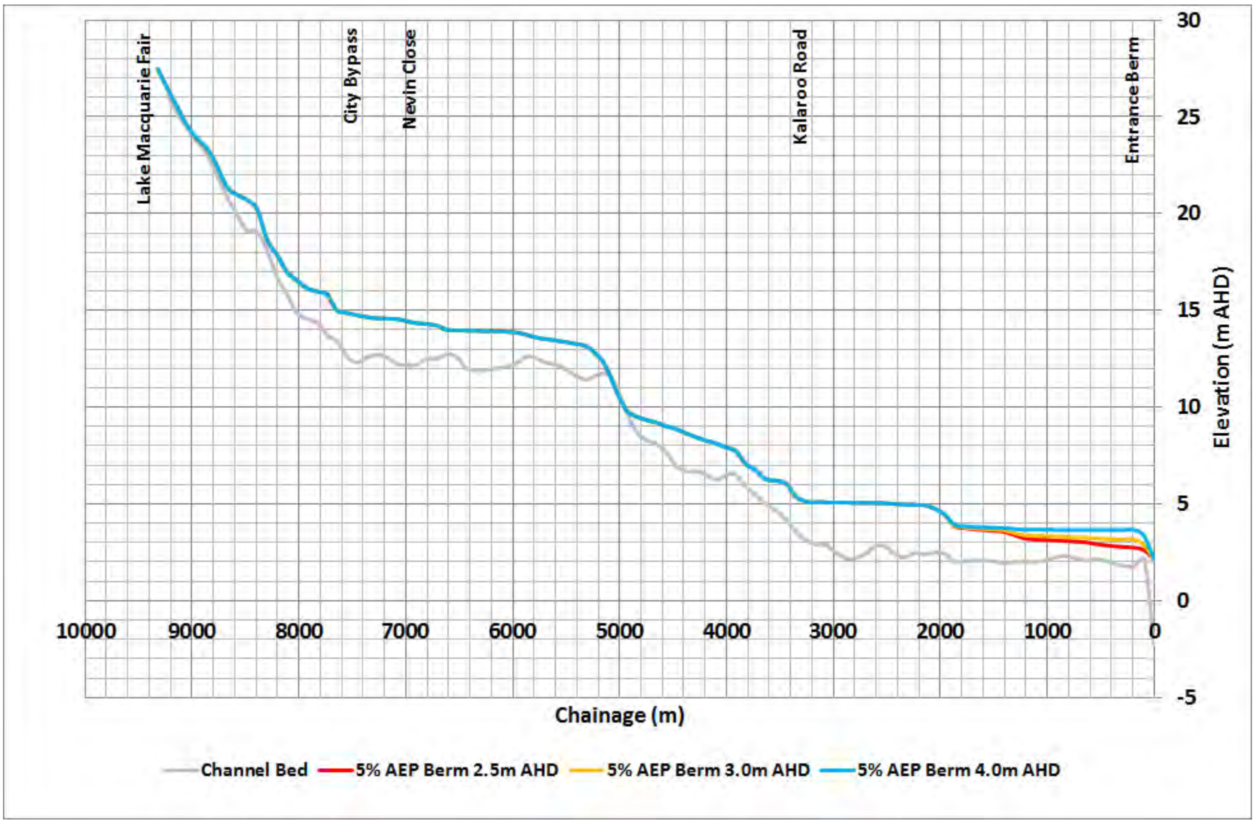


Figure 8-10 Sensitivity of the 5% AEP Peak Flood Levels to the Entrance Berm Height

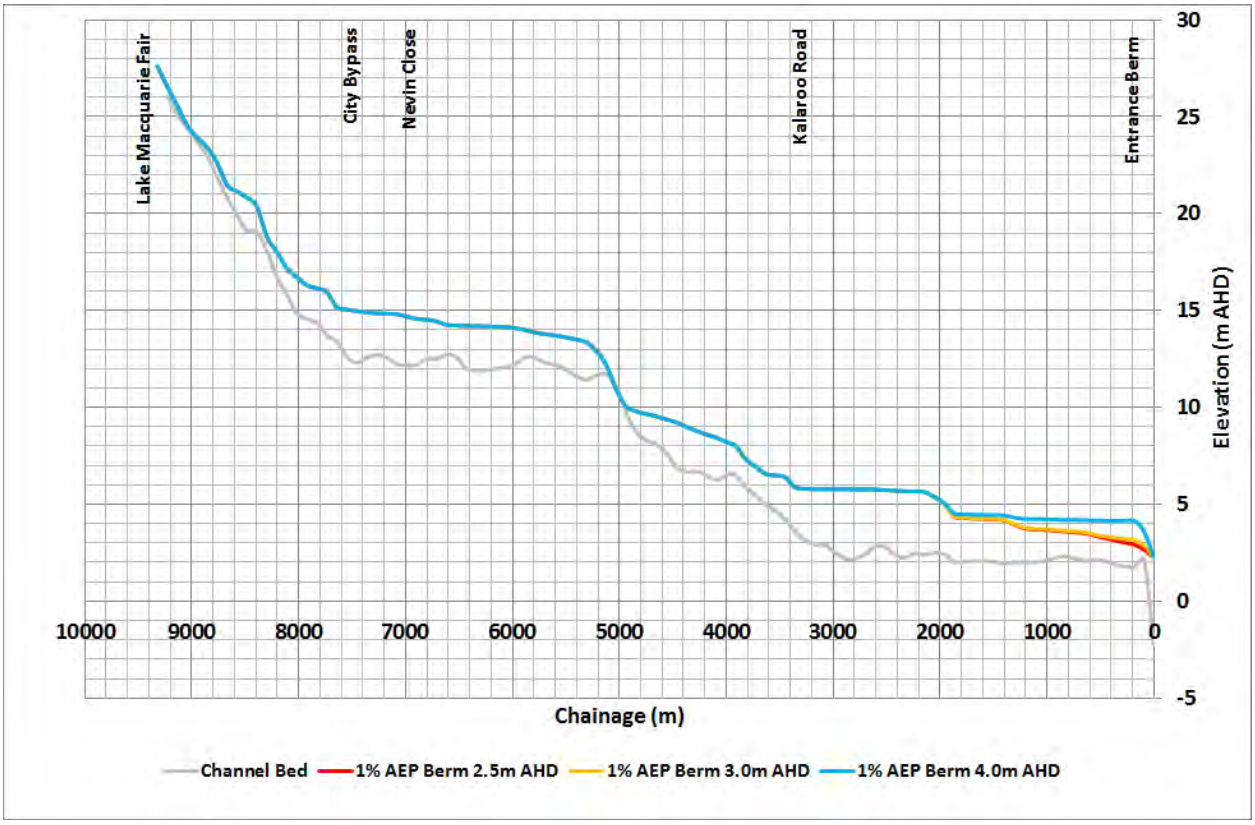


Figure 8-11 Sensitivity of the 1% AEP Peak Flood Levels to the Entrance Berm Height

8.5.2 Channel and Floodplain Roughness

The sensitivity of modelled peak flood levels to the adopted Manning‟s „n‟ roughness values were tested for the 1% AEP catchment event also. Sensitivity tests on the hydraulic roughness (Manning‟s „n‟) were undertaken by applying a 25% decrease and a 25% increase in the adopted values for the baseline design conditions. Whilst a calibration process has been undertaken with respect to available data, and adopted design parameters are within typical ranges, the inherent variability/uncertainty in adopted parameters warrants consideration of the relative impact on design flood conditions.

Figure 8-12 shows the results of this assessment. The impact of increasing the adopted Manning‟s „n‟ values typically raises peak flood levels by 0.2m to 0.3m. Reducing the adopted Manning‟s „n‟ values typically lowers peak flood levels by 0.2m to 0.3m. The main area of influence is typically in the vegetated channel sections.

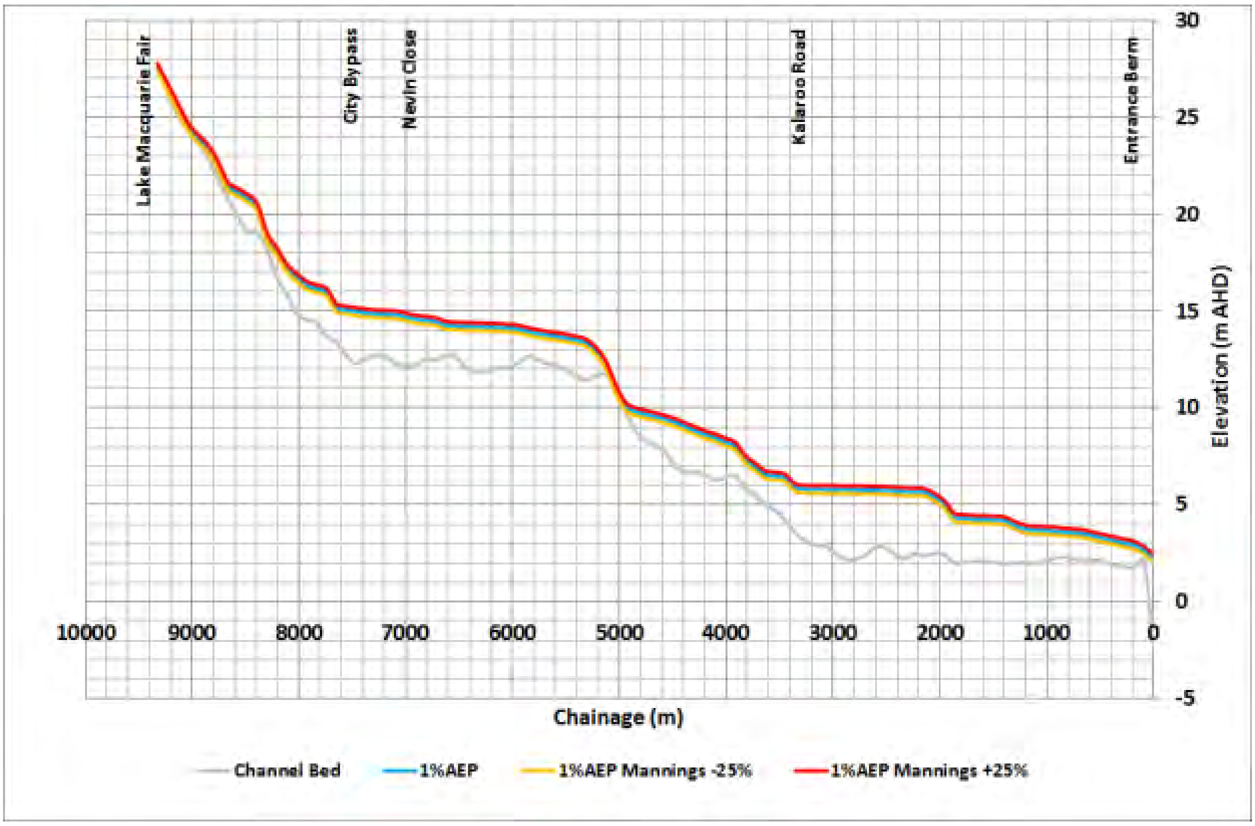


Figure 8-12 Sensitivity of Peak Flood Levels to Changes in Roughness

In most part the increase in flood levels do not provide extensive changes to the flood inundation extents, albeit higher levels potentially on individual properties. Freeboard provisions, particularly for building floor levels, are typically included in flood planning levels and would be expected to accommodate most increase in flood levels attributed to higher roughness values. In highly sensitive areas, maintenance of vegetation growth in channels may be an effective solution to manage these potential flood level increases. Future floodplain risk management studies in the catchment would be expected to consider potential for ongoing stream maintenance programs.

8.5.3 Initial Water Level

The sensitivity of modelled peak flood levels to the adopted initial water level values were tested for the 1% AEP catchment event also. The baseline conditions adopted an initial water level of 2.5m AHD, the same elevation as the adopted entrance berm height. This assumes that the available wetland storage behind the entrance berm is full at the onset of the flood event. The sensitivity test adopted a lower initial water level of 1.5m AHD for the storage area behind the berm. The initial water level condition was found to have minimal impact (<0.02m) on the peak design flood condition. This can be attributed to the relatively small volume of flood storage in the lower wetland area compared to the overall flood volumes conveyed through the catchment in major flood events. Any storage available at the onset of a major flood event is taken up very quickly and has minimal influence on attenuating the major flows through the system.

8.5.4 Climate Change Scenarios

The design conditions for assessing potential climate change impacts were discussed in Section 7.

- Increases in design rainfall intensity of 10%, 20% and 30%;
- Sea level rise of 0.4m and 0.9m providing for:
  - Direct Increase in ocean boundary water levels (refer Figure 7-3 for base conditions)
  - Direct increase in berm height (above baseline 2.5m AHD minimum berm)

The impact of changes to design rainfall intensity and sea level rise scenarios were considered individually and in combination as discussed below. The climate change scenarios modelled were summarised in Table 7-3.

8.5.4.1 Increased Rainfall Intensity

Figure 8-13 shows the long section profile through the catchment comparing the peak flood water levels for the baseline catchment flooding condition and the rainfall intensity tests. The results are also tabulated in Table 8-4 at the reporting locations. Rainfall intensity increases of 10%, 20% and 30% were applied to the baseline 1% AEP 9hr duration catchment flood condition (note the critical duration varies across the catchment such that the peak 1% AEP flood level shown in Table 8-4 may vary from the levels presented in Table 8-1).

A 10% increase in design rainfall intensity provides for increases in level of up to 0.2m , with the average change in level around 0.1m. A 20% increase in design rainfall intensity provides for increases in level of up to 0.3m , with the average change in level around 0.2m. A 30% increase in design rainfall intensity provides for increases in level of up to 0.5m , with the average change in level around 0.3m.

To gain some perspective on the rainfall intensity increases, the 10% increase in the 1% AEP design rainfall provides for similar levels to the 0.5% AEP design flood condition as shown in Table 8-1. Given the relative increase in flood levels is typically small (<0.2m), it is anticipated that existing freeboard provisions could accommodate small increased in flood level as a result in rainfall intensity increase. It is noted that the IFD rainfall estimates are currently under review as part of the AR&R

update. Potential changes in design rainfall intensity as part of these updates warrants consideration in future floodplain risk management investigations in the catchment.

Table 8-4 Modelled Peak Flood Levels (m AHD) with Rainfall Increase

ID	Location	Design Event			
		1% AEP	1% AEP+10%	1% AEP+20%	1% AEP+30%
A	The Sanctuary	5.7	5.9	6.1	6.3
B	U/S Kalaroo Road	5.9	6.1	6.3	6.4
C	U/S Fernleigh Track	6.3	6.5	6.6	6.7
D	Jewells Wetland	9.6	9.7	9.8	9.9
E	U/S Oakdale Road	15.2	15.3	15.4	15.4
F	U/S Pacific Hwy (SC)	15.1	15.2	15.2	15.3
G	U/S Inner City Bypass	15.5	15.7	15.8	16.0
H	Lake Road Windale	15.7	15.9	16.0	16.1
I	U/S Merrigum St	20.1	20.2	20.2	20.3
J	Lake Macquarie Fair	26.7	26.7	26.7	26.8
K	U/S Warners Bay Rd	35.5	35.8	35.9	36.0
L	U/S Willow Road	21.9	21.9	22.0	22.0
M	D/S Ntaba Rd	7.8	7.9	8.0	8.0
N	U/S Pacific Hwy (CC)	10.7	10.8	10.9	10.9

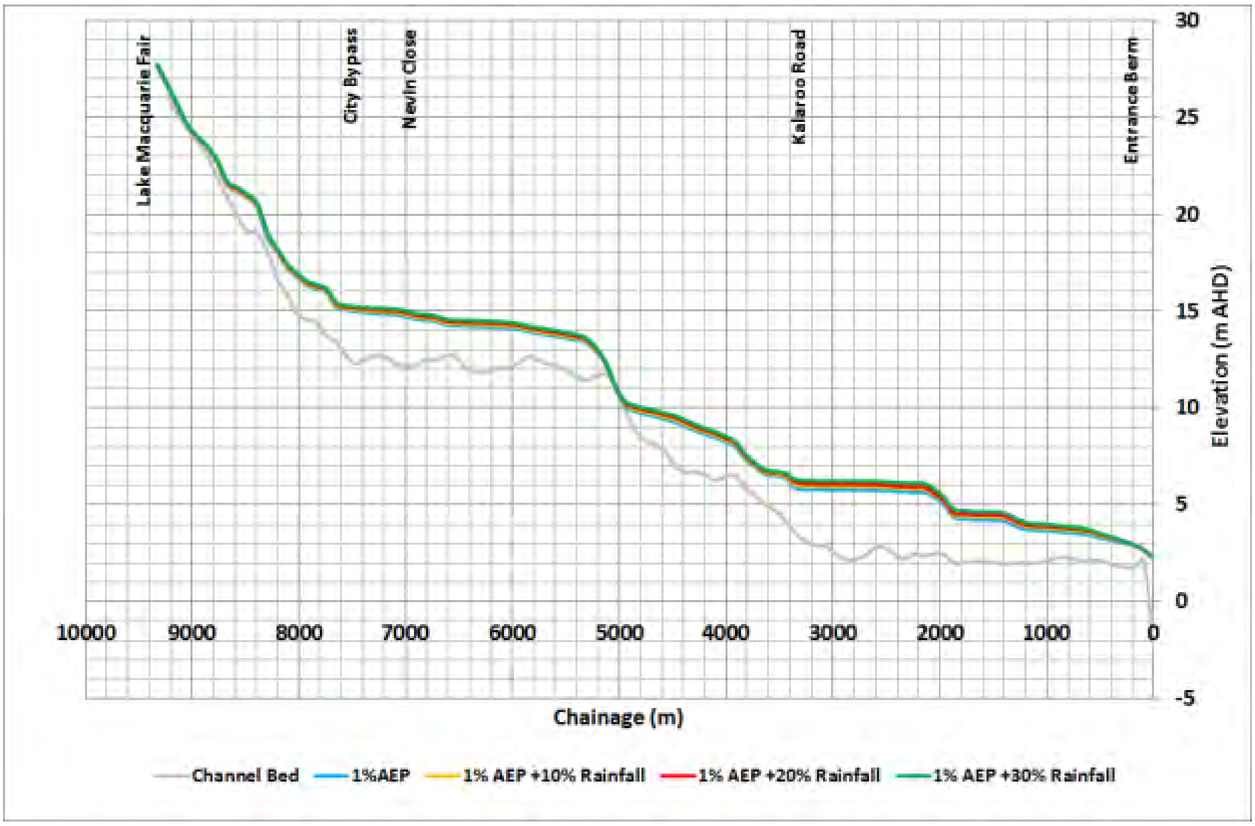


Figure 8-13 Sensitivity of 1% AEP Peak Flood Levels to Increased Rainfall Intensity

8.5.4.2 Sea Level Rise

Figure 8-14 shows the long section profile through the catchment comparing the peak flood water levels for the baseline condition and the sea level rise scenarios of 0.4m and 0.9m. . As with the impact of berm increase discussed previously, the extent of the impact of sea level scenarios on peak flood levels is limited to the lower end of the catchment downstream of The Sanctuary. The catchment flooding condition is so dominant in the area given the local topographical controls, that the influence of the ocean boundary condition is relatively limited in extent. In comparing the results with berm height sensitivity assessment, much of the change in peak flood condition for the sea level rise scenario can be attributed to the corresponding increase in berm height. The peak flood levels at the reporting locations for the sea level rise sensitivity test is summarised in Table 8-5.

8.5.4.3 Combined Rainfall Increase and Sea Level Rise

The combination of rainfall intensity increase and sea level rise provide impacts over and above the individual scenarios, but limited again in extent to the lower reaches. The influence of the berm height and ocean boundary water levels is limited to downstream of The Sanctuary. Accordingly, the peak flood level results presented previously in Table 8-4 for the rainfall intensity increases are applicable to the combined rainfall/sea level rise scenarios. Figure 8-15 shows the long section profile through the catchment comparing the peak flood water levels for the baseline condition and the sea level rise scenarios of 0.4m and 0.9m.

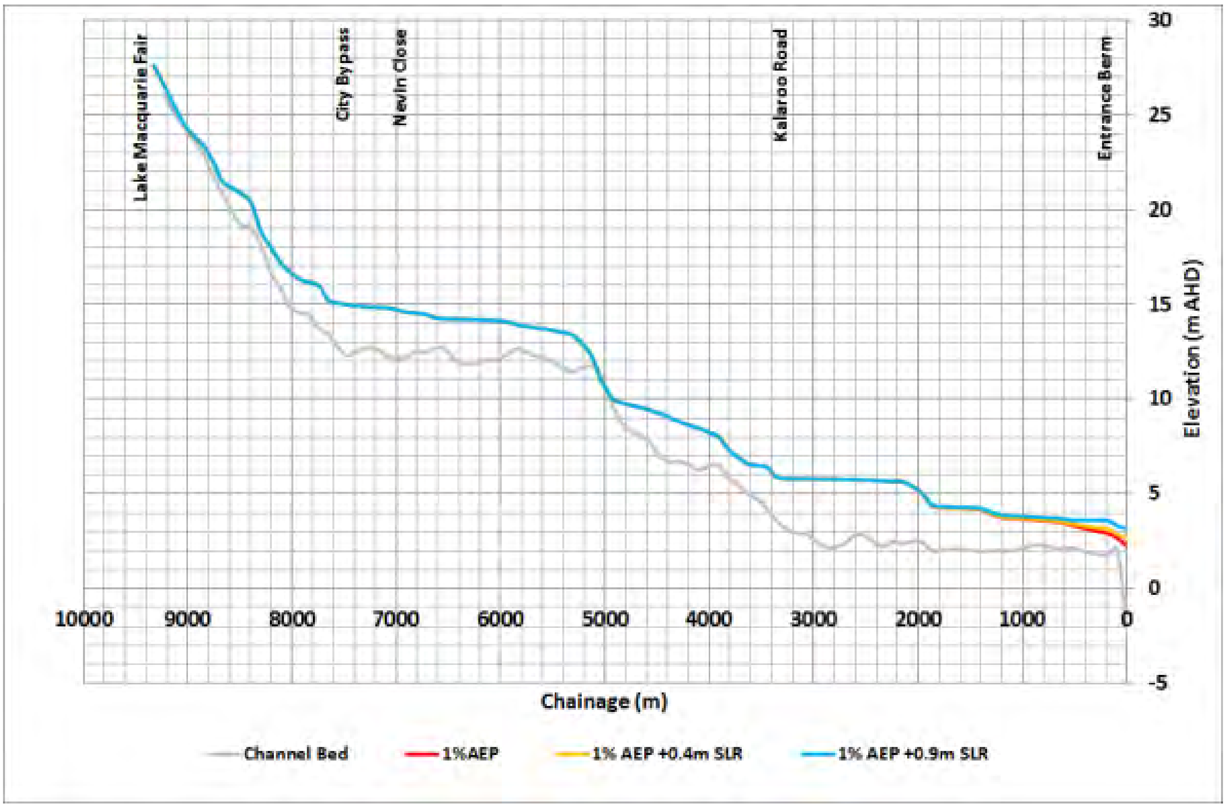


Figure 8-14 Sensitivity of 1% AEP Peak Flood Levels to Sea Level Rise

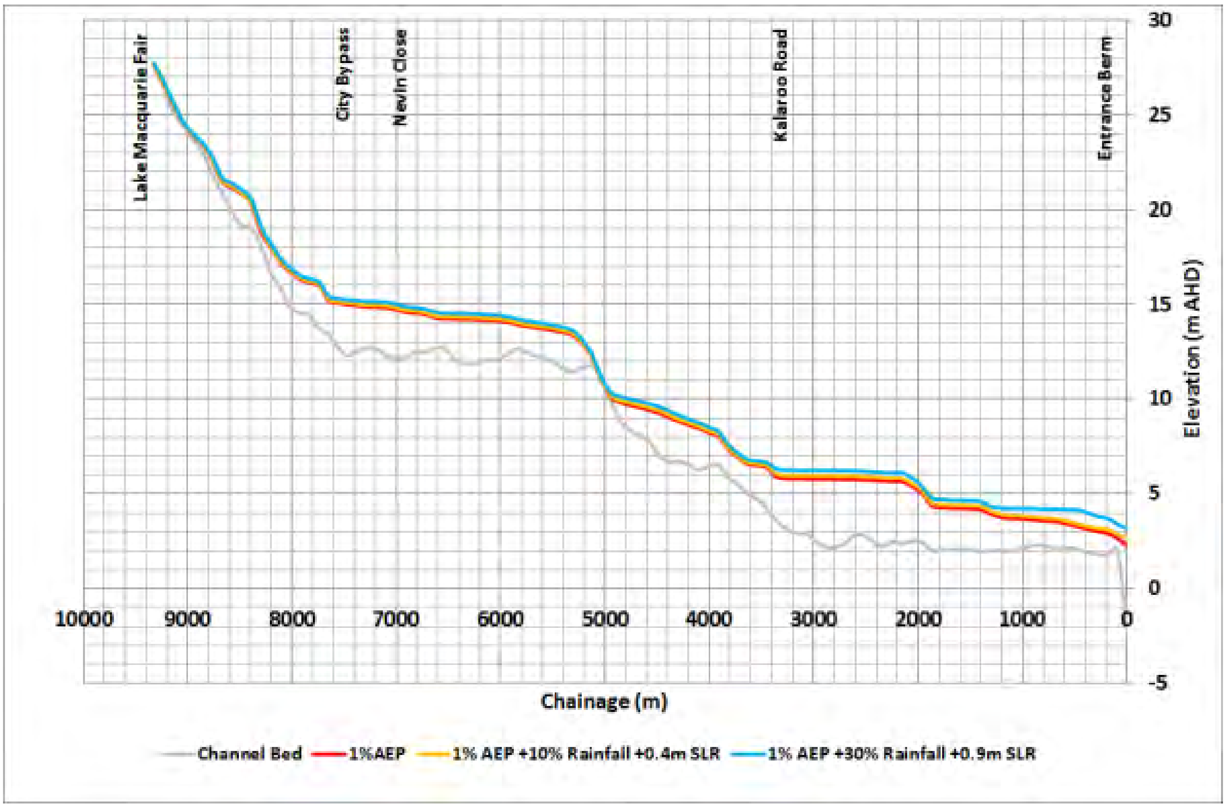


Figure 8-15 Sensitivity of 1% AEP Peak Flood Levels to Sea Level Rise & Rainfall Increase

The peak flood levels at the reporting locations for the sea level rise plus rainfall intensity increase sensitivity test is summarised in Table 8-5.

Table 8-5 Modelled Peak Flood Levels (m AHD) with Sea Level Rise and Rainfall Increase

ID	Location	Design Event				
		1% AEP	1% AEP+0.4m SLR	1% AEP+0.9m SLR	1% AEP+10% +0.4m SLR	1% AEP+30% + 0.9m SLR
A	The Sanctuary	5.7	5.7	5.7	5.9	6.3
B	U/S Kalaroo Road	5.9	5.9	5.9	6.1	6.4
C	U/S Fernleigh Track	6.3	6.3	6.3	6.5	6.7
D	Jewells Wetland	9.6	9.6	9.6	9.7	9.9
E	U/S Oakdale Road	15.2	15.2	15.2	15.3	15.4
F	U/S Pacific Hwy (SC)	15.1	15.1	15.1	15.2	15.3
G	U/S Inner City Bypass	15.5	15.5	15.5	15.7	16.0
H	Lake Road Windale	15.7	15.7	15.7	15.9	16.1
I	U/S Merrigum St	20.1	20.1	20.1	20.2	20.3
J	Lake Macquarie Fair	26.7	26.7	26.7	26.7	26.8
K	U/S Warners Bay Rd	35.5	35.5	35.5	35.8	36.0
L	U/S Willow Road	21.9	21.9	21.9	21.9	22.0
M	D/S Ntaba Rd t	7.8	7.8	7.8	7.9	8.0
N	U/S Pacific Hwy (CC)	10.7	10.7	10.7	10.8	10.9

As discussed, the influence of the ocean boundary condition including allowances for increases under sea level rise condition, does not extend any significant distance upstream (refer Figure 8-14). This is reflected in the results in Table 8-5 which show no influence of the boundary at the reporting locations, including the most downstream reference point at The Sanctuary.

9 CONCLUSIONS

The objective of the study was to undertake a detailed flood study of the Jewells Wetland catchment and establish models as necessary for design flood level prediction.

In completing the flood study, the following activities were undertaken:

- Collation of historical and recent flood information for the study area;
- Development of computer models to simulate hydrology and flood behaviour in the catchment;
- Calibration of the developed models using the available flood data, primarily relating to the June 2007 event with further validation to the April 1988 and February 1990 events; and
- Prediction of design flood conditions in the catchment and production of design flood mapping series.

Responses to the community questionnaire undertaken as part of the community consultation for the project provided valuable historical flood information to assist in the model development and calibration process. A good model calibration was achieved with the available data, confirming the appropriateness of the model for design flood simulation.

The catchment flooding is typically characterised by a series of well-defined flow paths along the creek alignments of the main tributaries of Jewells Wetland. Despite this flow definition, some development has encroached on the floodplain areas of some of the tributary catchments. This is particularly the case for parts of the suburbs of Gateshead and Windale.

The flood study will form the basis for the subsequent floodplain risk management activities, being the next stage of the floodplain risk management process. The key locations to consider during this process have been identified as:

- Properties in Windale adjacent to Scrubby Creek
- Properties within the Gateshead industrial area; and
- Properties in the lower catchment downstream of Kalaroo Road.

For some parts of the catchment, the recorded rainfall for the historical events of April 1988, February 1990 June 2007 have approached or exceeded the design 1% AEP design rainfall condition. This may require further consideration for the selection of appropriate flood planning levels. It is noted that updates to design rainfalls are currently being undertaken as part of the review of Australian Rainfall & Runoff.

Increases in flood risk in association with potential climate change have been assessed in the study. The impact of sea level rise has a limited influence on peak flood conditions in the catchment, with only the very bottom end of the catchment well downstream of Kalaroo Road influenced by the sea level rise condition. However, the threat of increased rainfall intensity associated with climate change impacts would result in increases in flood levels throughout the catchment. The sensitivity of flood levels in these areas due to climate change influences should be taken into consideration in floodplain risk management activities.

10 REFERENCES

BMT WBM (2011) *Coffs Harbour Coastal Processes and Hazards Definition Study*

Commonwealth Scientific and Industrial Research Organisation (CSIRO) (2004) *Climate Change in New South Wales Part 2: Projected changes in climate extremes.*

Commonwealth Scientific and Industrial Research Organisation (CSIRO) (2007) *Projected Changes in Climatological Forcing for Coastal Erosion in NSW.*

Department of Environment and Climate Change (DECC) (2007) *Floodplain Risk Management Guideline: Practical Consideration of Climate Change.*

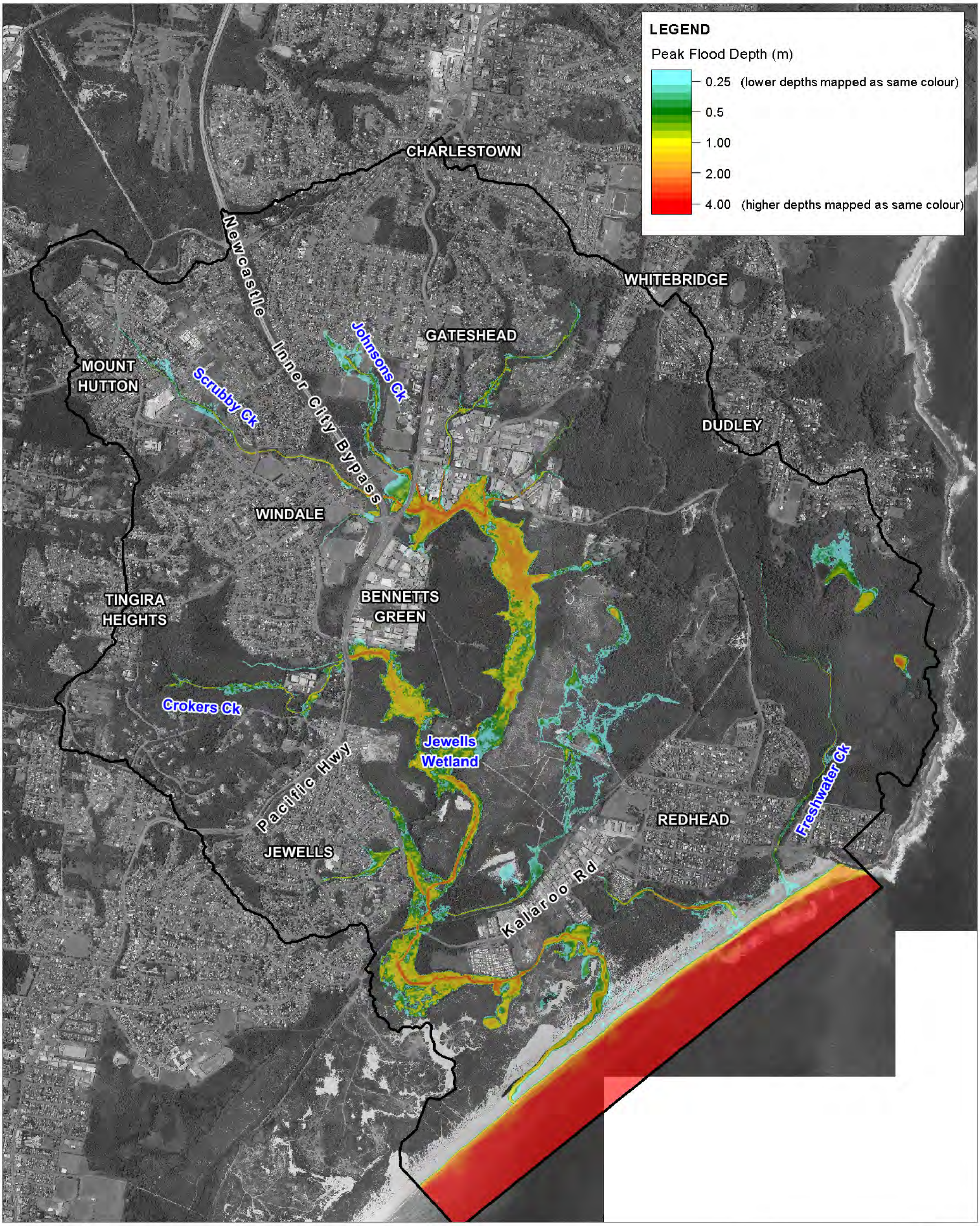
Department of Environment, Climate Change and Water (DECCW) (2010) *Coastal Risk Management Guide: Incorporating sea level rise benchmarks in coastal risk assessments.*

Department of Environment, Climate Change and Water (DECCW) (2010) *Flood Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessments.*

Department of Environment, Climate Change and Water (DECCW) (2009) *NSW Sea Level Rise Policy Statement.*

NSW Department of Infrastructure, Planning and Natural Resources (DIPNR) (2005) *Floodplain Development Manual.*

APPENDIX A: DESIGN FLOOD MAPPING



Title:

Peak Flood Depth - 50% AEP Event

Figure: 50%_AEP_d

Rev: A

N

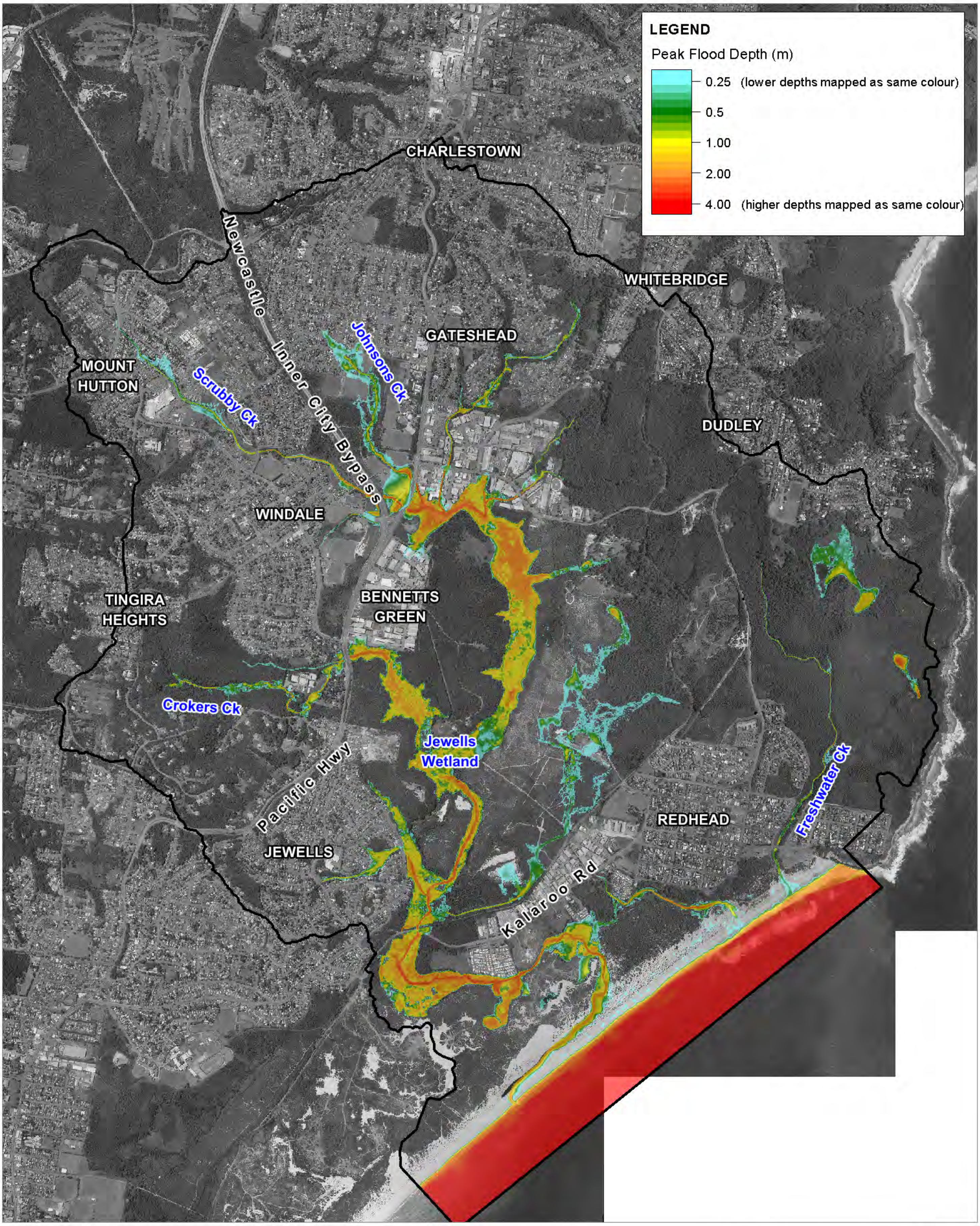
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_50%AEP_d.WOR



Title:

Peak Flood Depth - 20% AEP Event

Figure: 20%_AEP_d

Rev: A

N

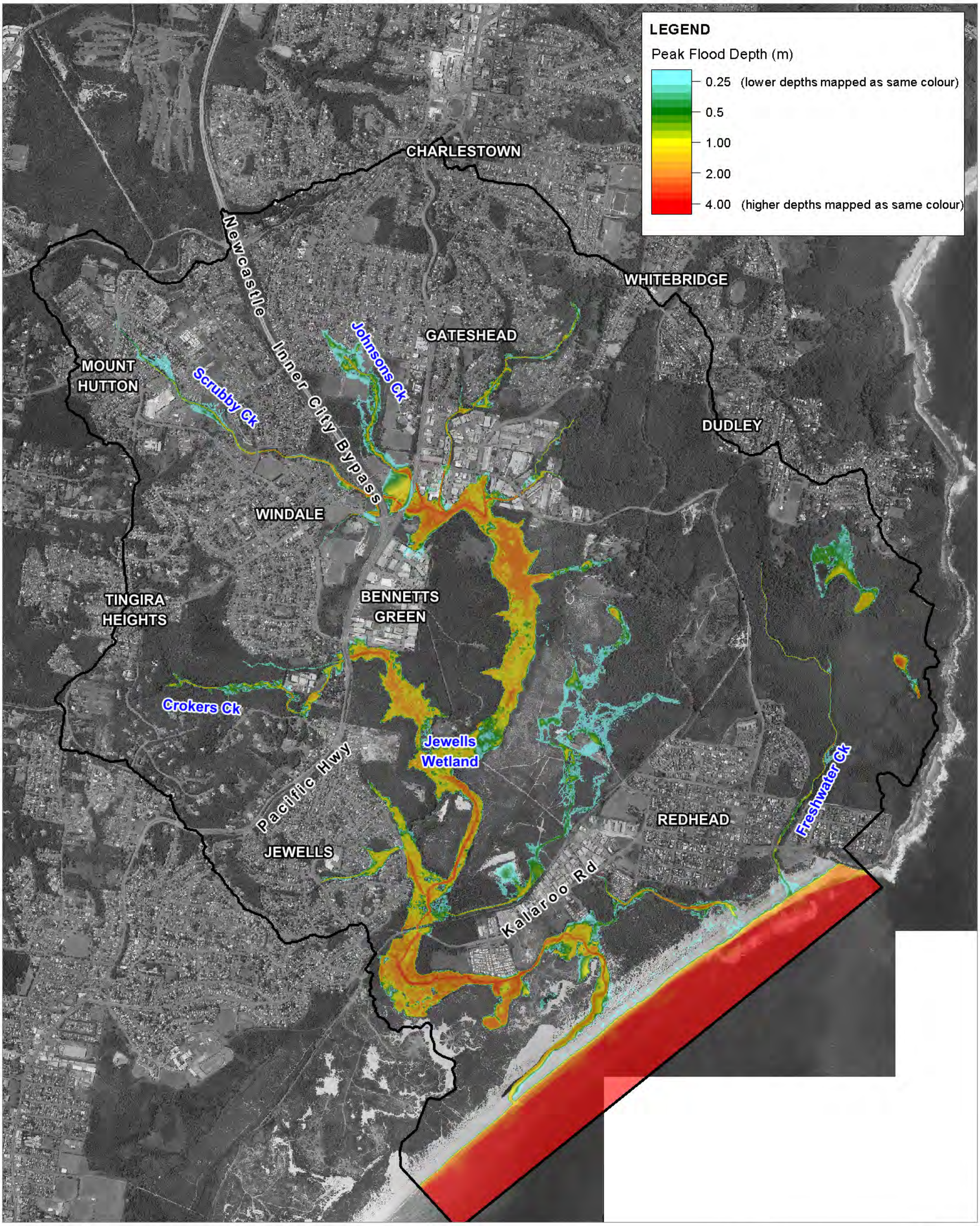
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_20%AEP_d.WOR



Title:

Peak Flood Depth - 10% AEP Event

Figure: 10%_AEP_d

Rev: A

N

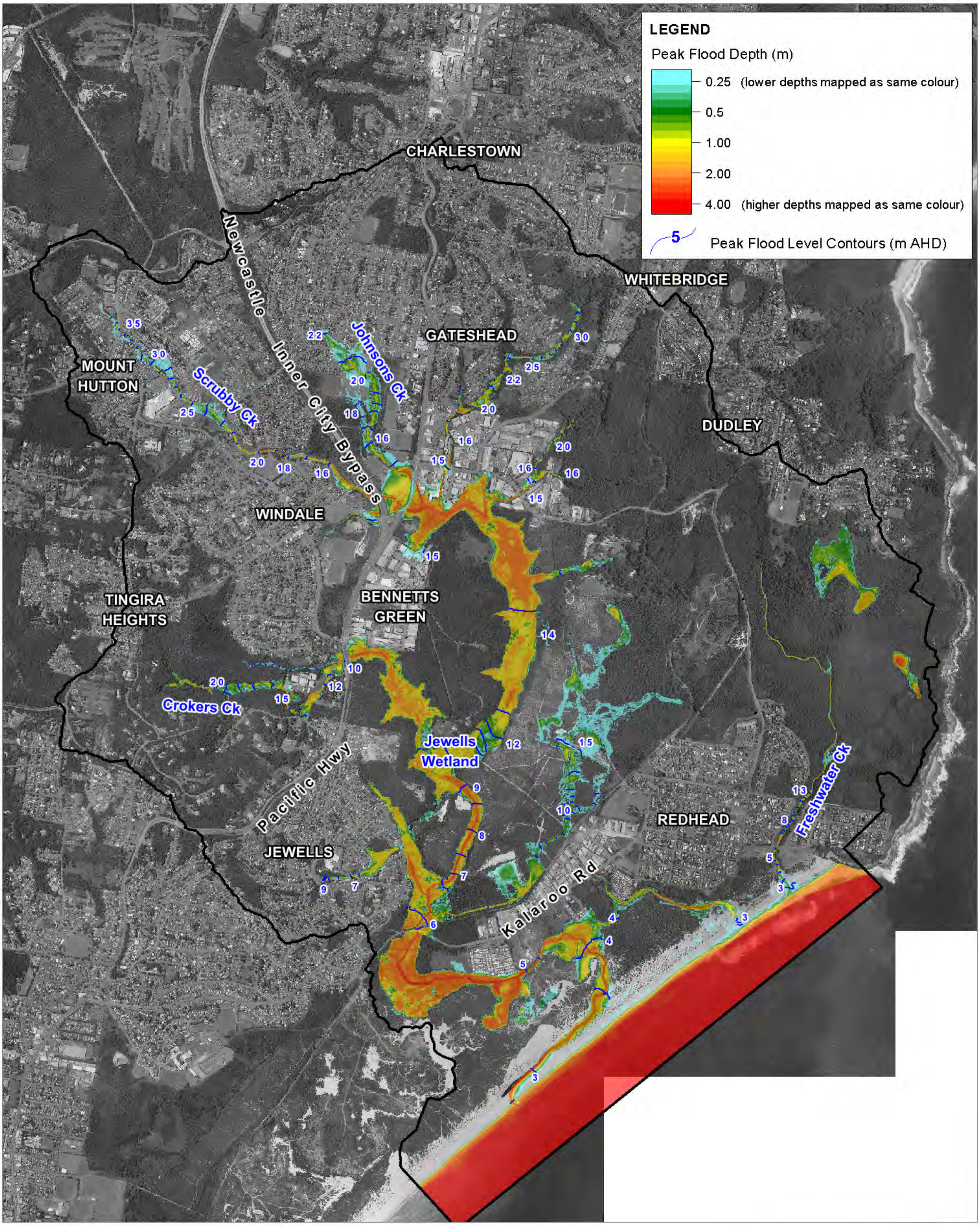
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_10%AEP_d.WOR



Title:

Peak Flood Depth - 5% AEP Event

Figure: 5%_AEP_d

Rev: A

N

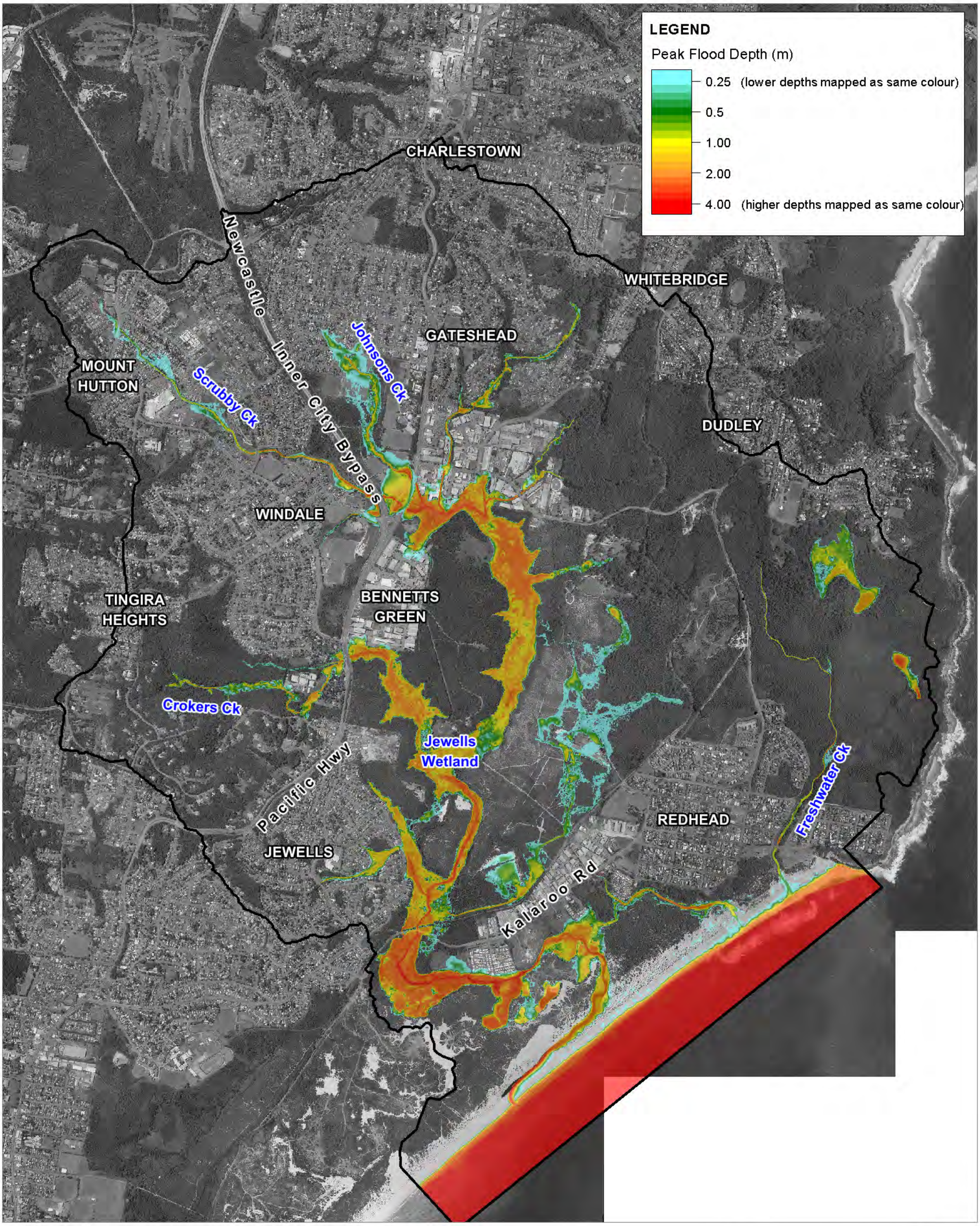
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_5%AEP_d.WOR



Title:

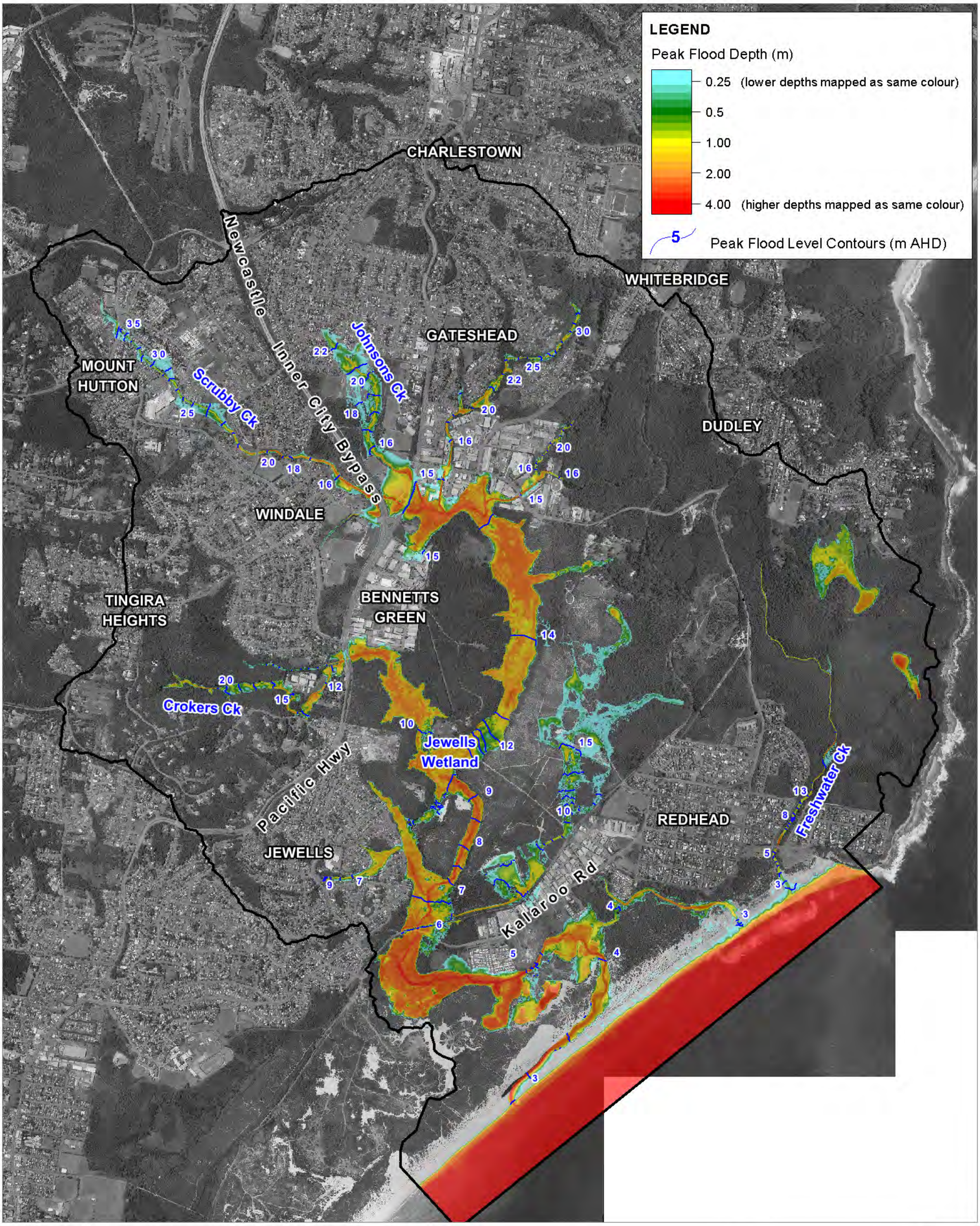
Peak Flood Depth - 2% AEP Event

Figure: **2%_AEP_d**

Rev: **A**

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_2%AEP_d.WOR



Title:

Peak Flood Depth - 1% AEP Event

Figure: 1%_AEP_d

Rev: A

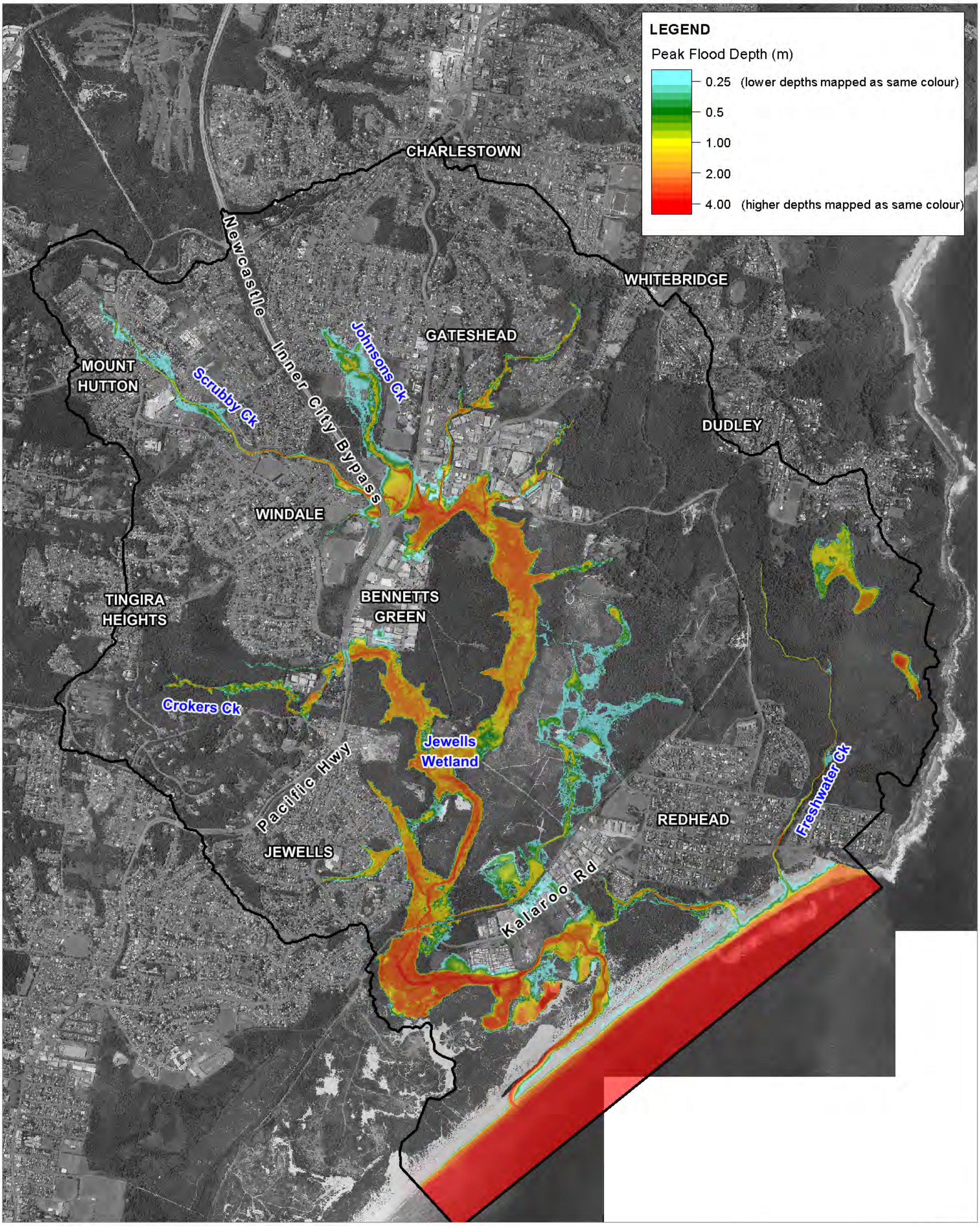
N

0 0.75 1.5km

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_1%AEP_d.WOR



Title:

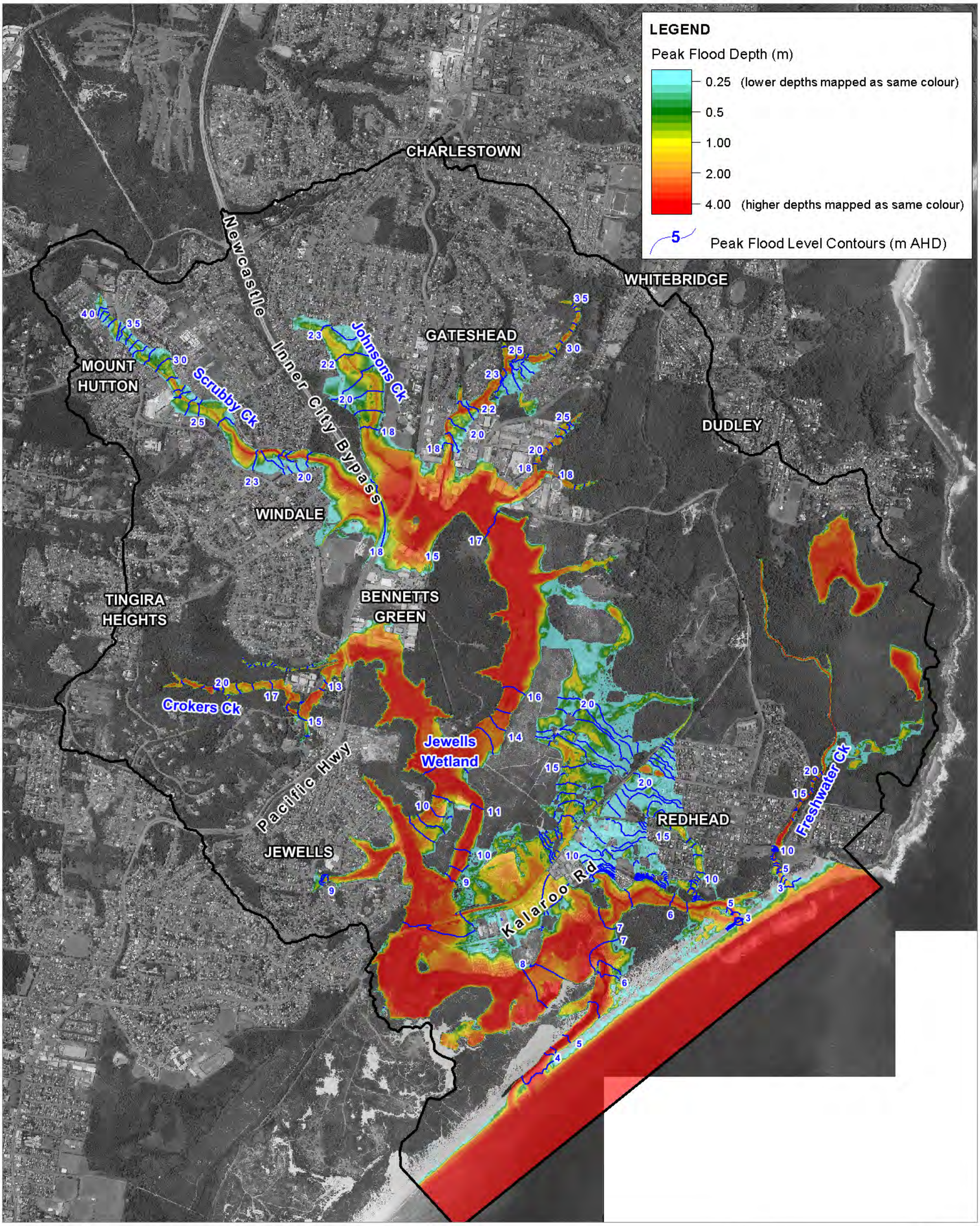
Peak Flood Depth - 0.5% AEP Event

Figure: 0.5%_AEP_d

Rev: A

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_0-5%AEP_d.WOR



Title:

Peak Flood Depth - PMF Event

Figure: PMF_d

Rev: A

N

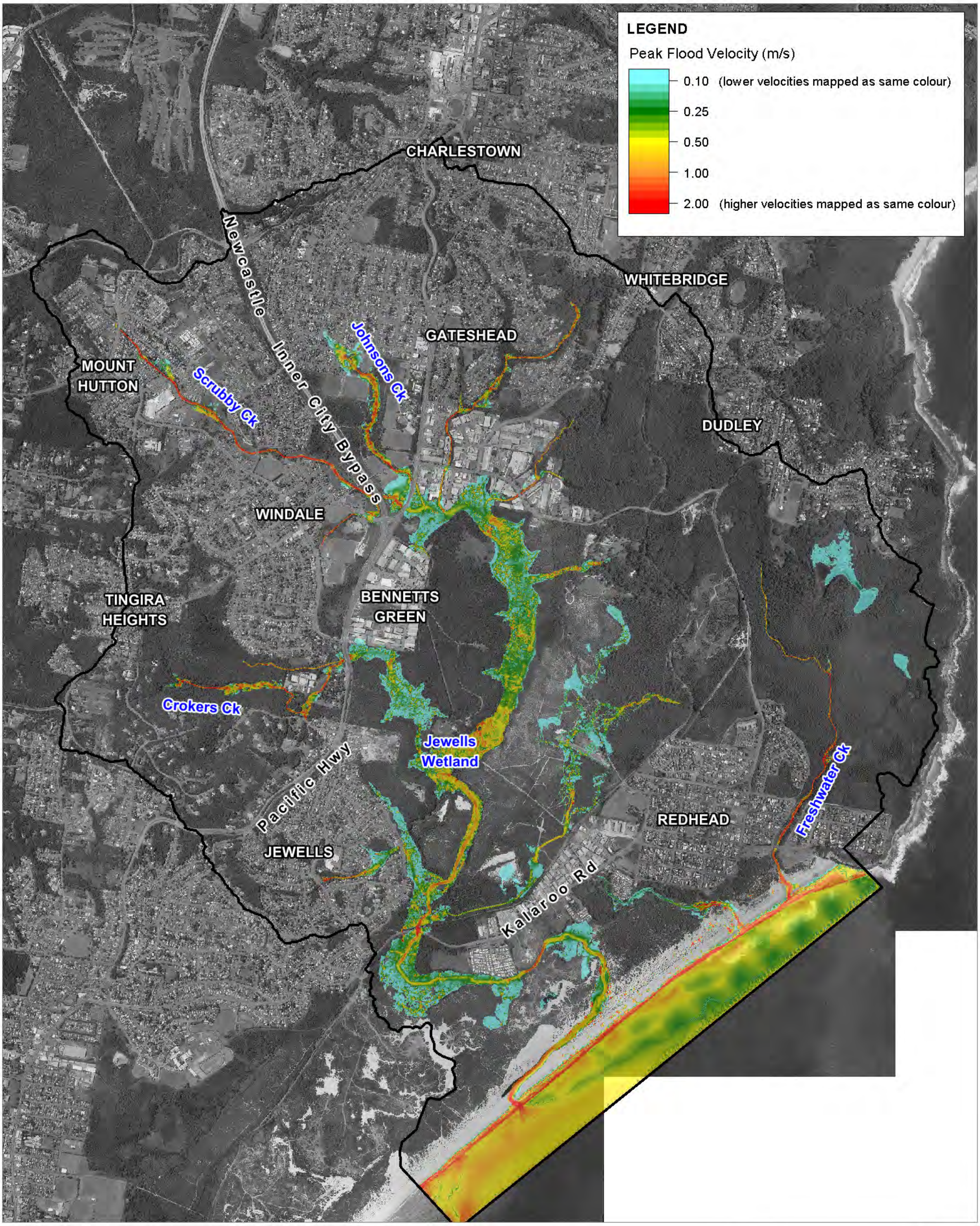
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_PMF_d.WOR



Title:

Peak Flood Velocity - 50% AEP Event

Figure: 50%_AEP_v

Rev: A

N

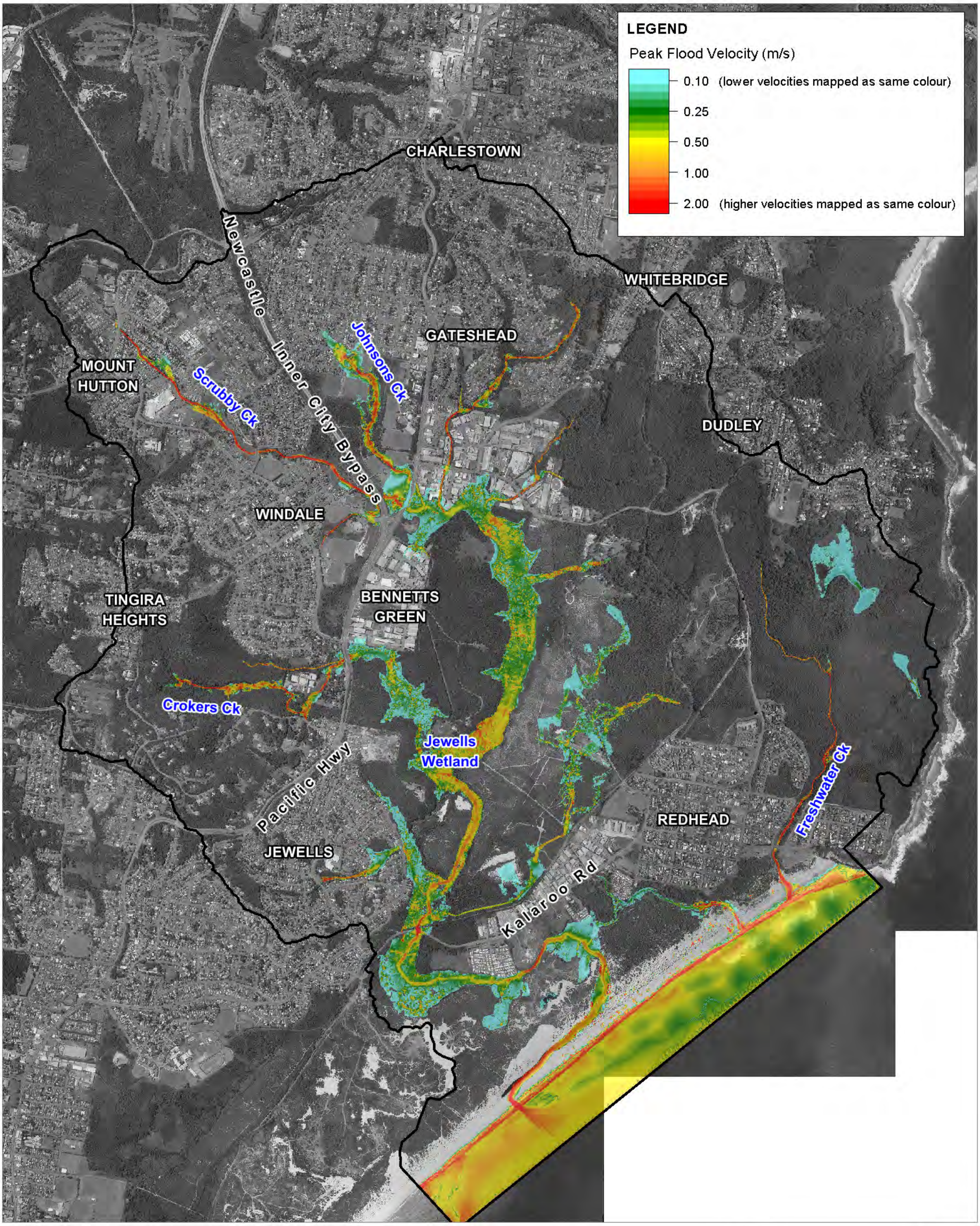
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_50%AEP_v.WOR



Title:

Peak Flood Velocity - 20% AEP Event

Figure: 20%_AEP_v

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

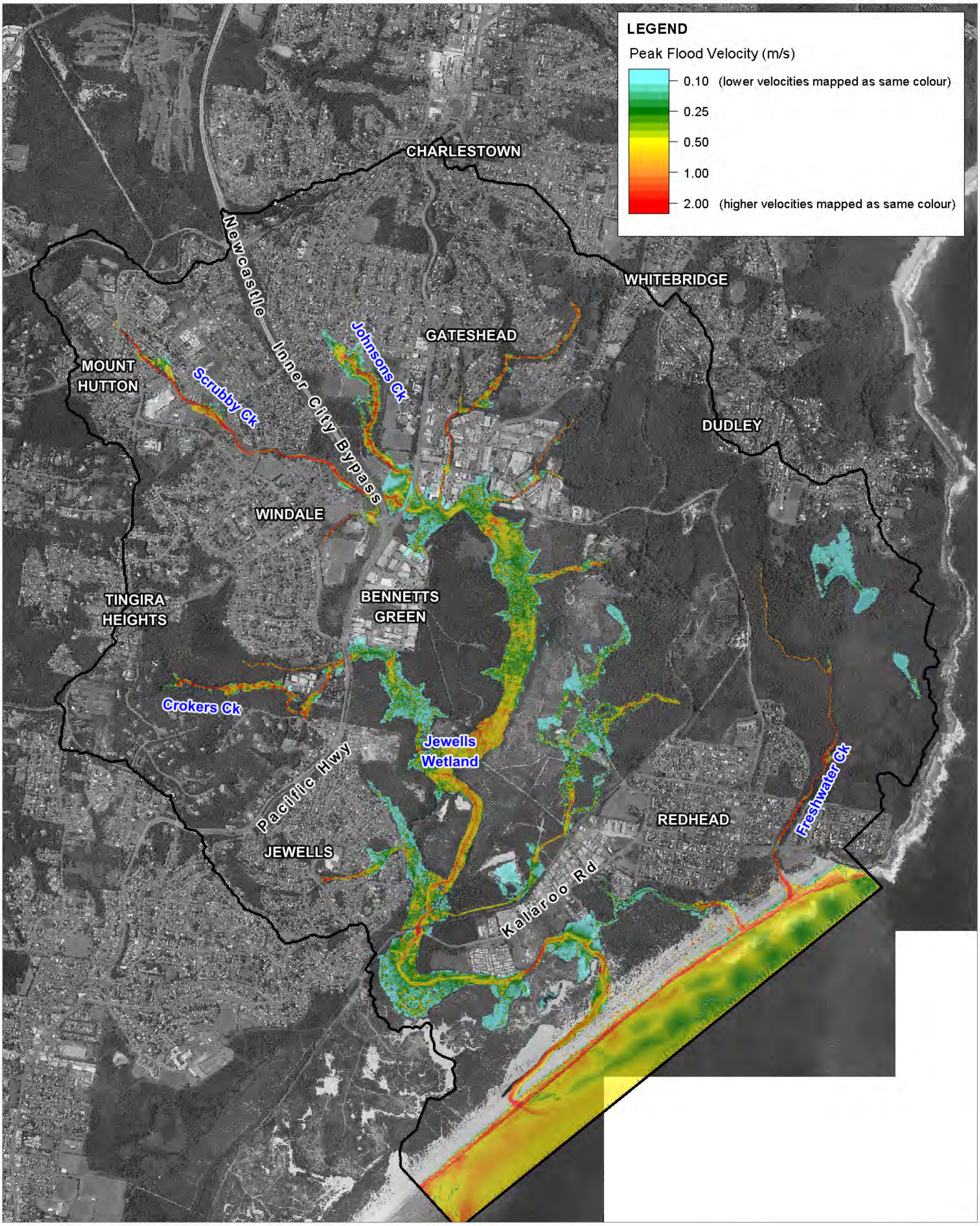
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_20%AEP_v.WOR



Title:

Peak Flood Velocity - 10% AEP Event

Figure: 10%_AEP_v

Rev: A

N

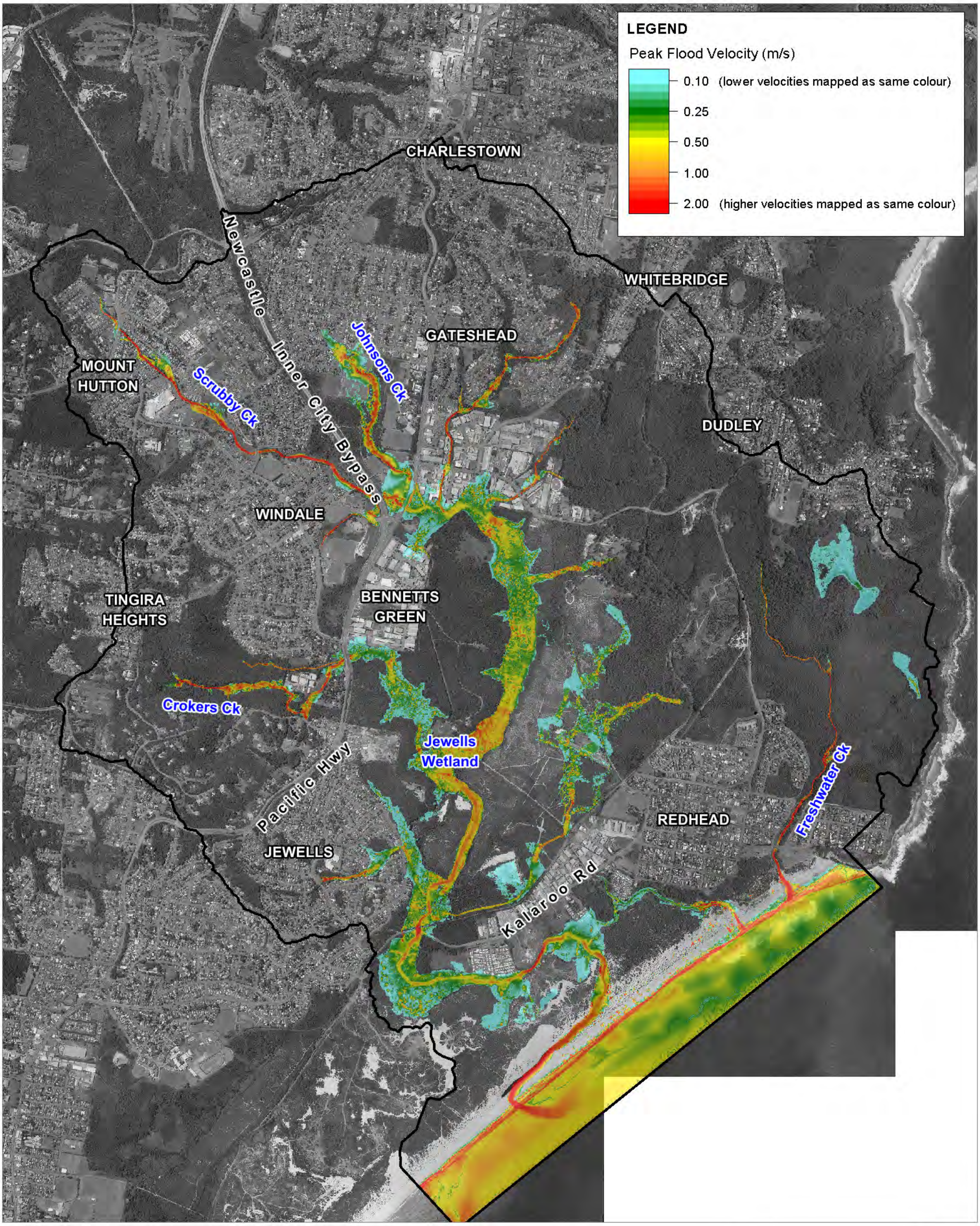
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_10%AEP_v.WOR



Title:

Peak Flood Velocity - 5% AEP Event

Figure: 5%_AEP_v

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

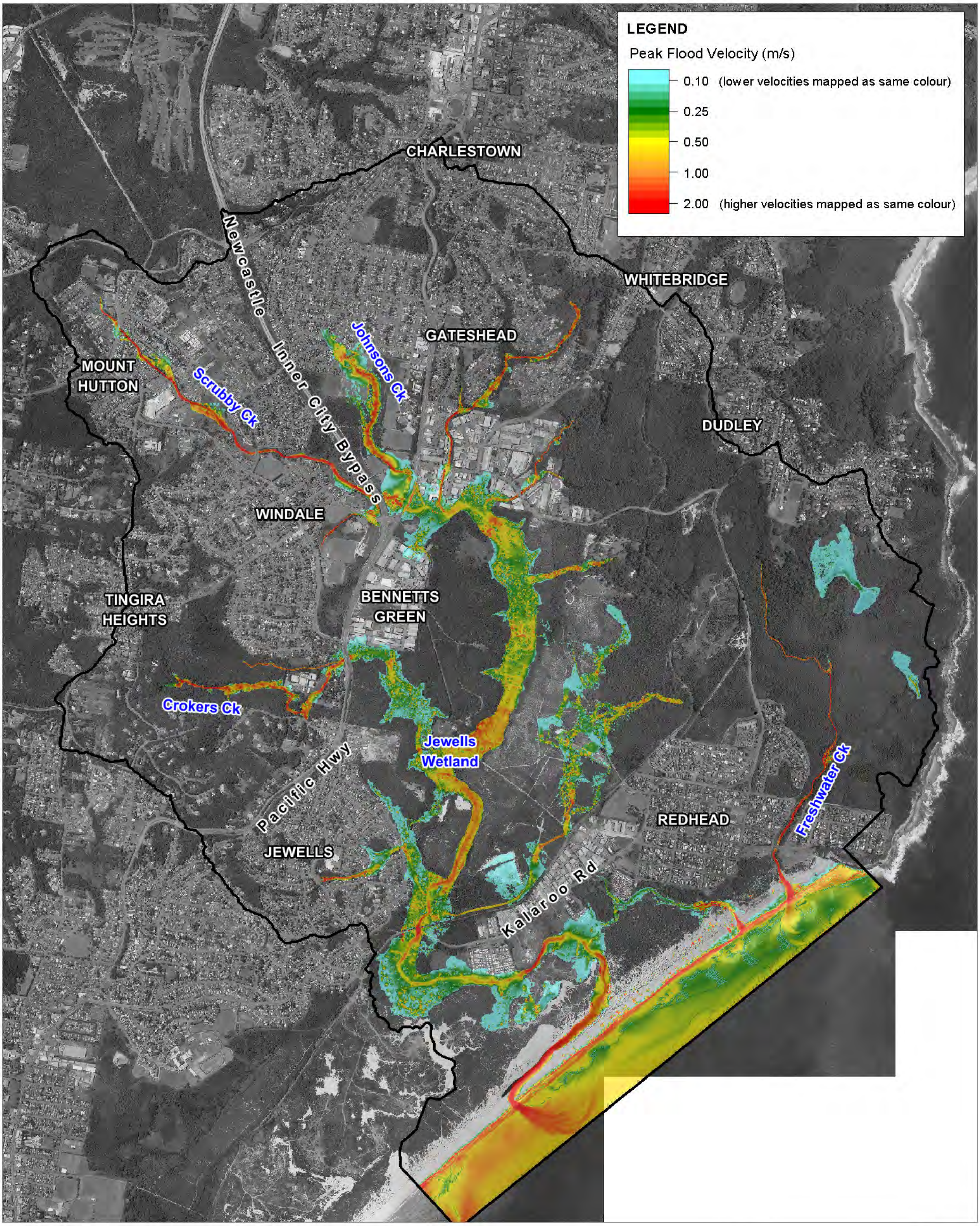
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_5%AEP_v.WOR



Title:

Peak Flood Velocity - 2% AEP Event

Figure: 2%_AEP_v

Rev: A

N

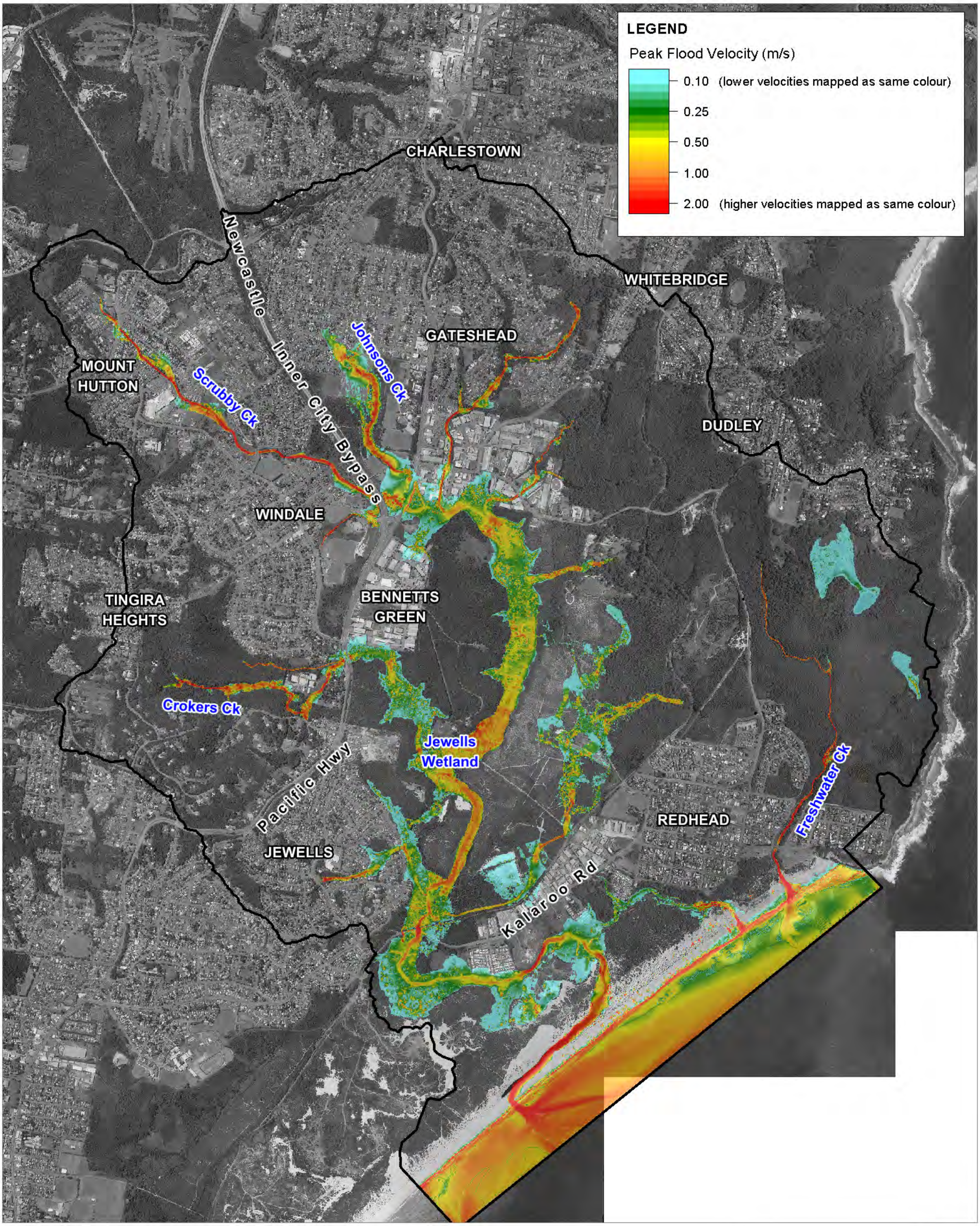
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_2%AEP_v.WOR



Title:

Peak Flood Velocity - 1% AEP Event

Figure: 1%_AEP_v

Rev: A

N

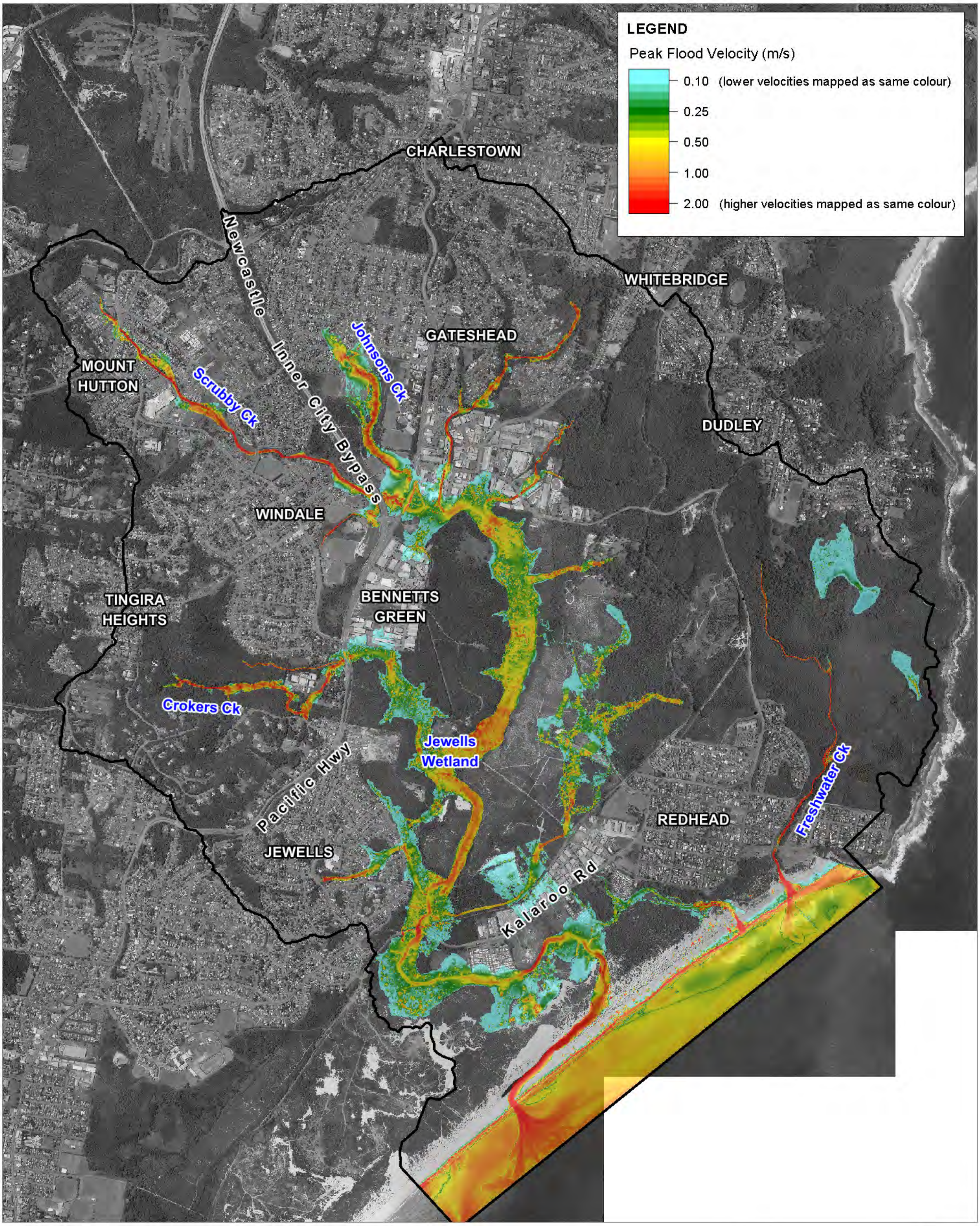
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_1%AEP_v.WOR



Title:

Peak Flood Velocity - 0.5% AEP Event

Figure: 0.5%_AEP_v

Rev: A

N

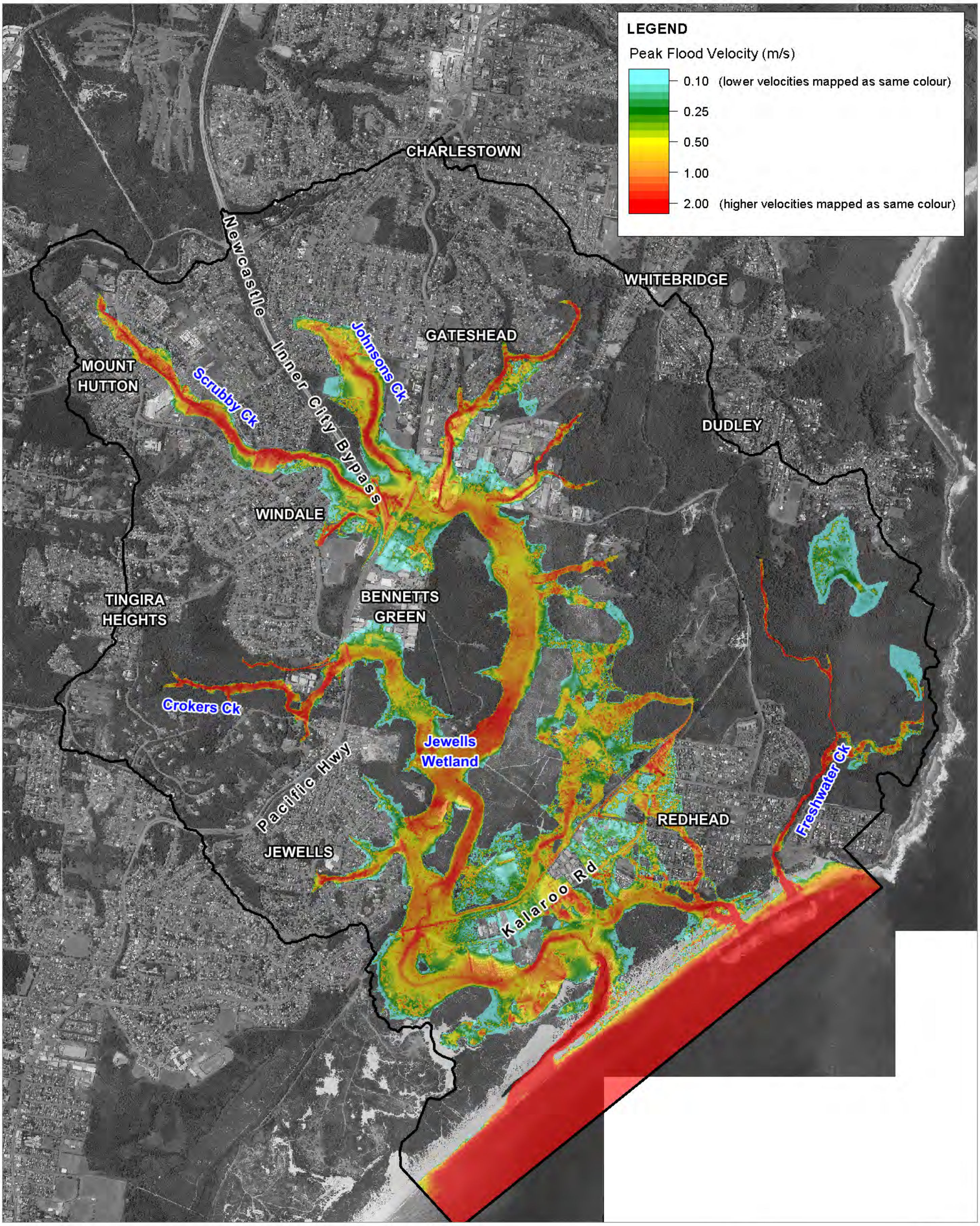
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_0-5%AEP_v.WOR



Title:

Peak Flood Velocity - PMF Event

Figure: PMF_v

Rev: A

N

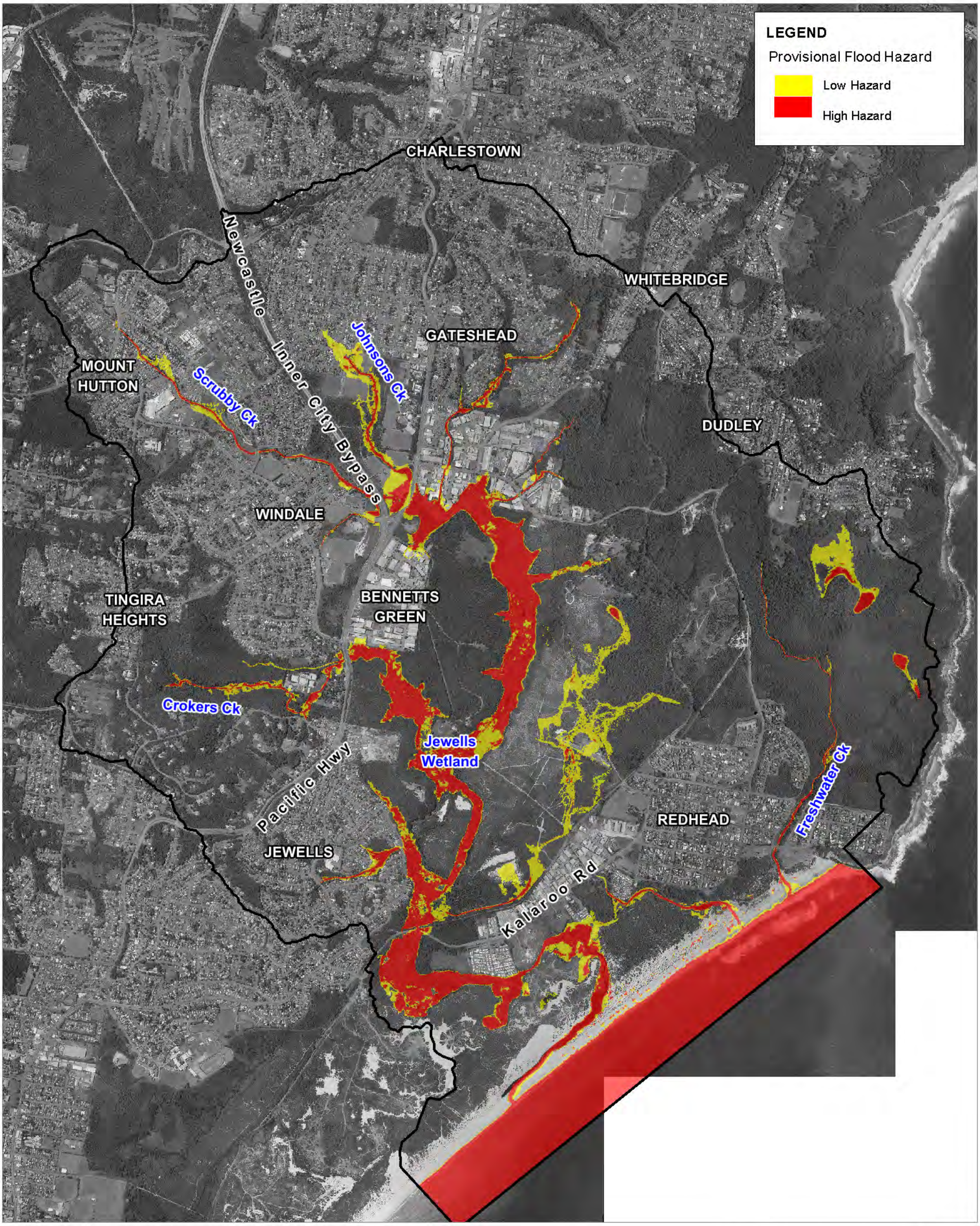
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_PMF_v.WOR



Title:

Provisional Flood Hazard - 20% AEP Event

Figure: 20%_AEP_z

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

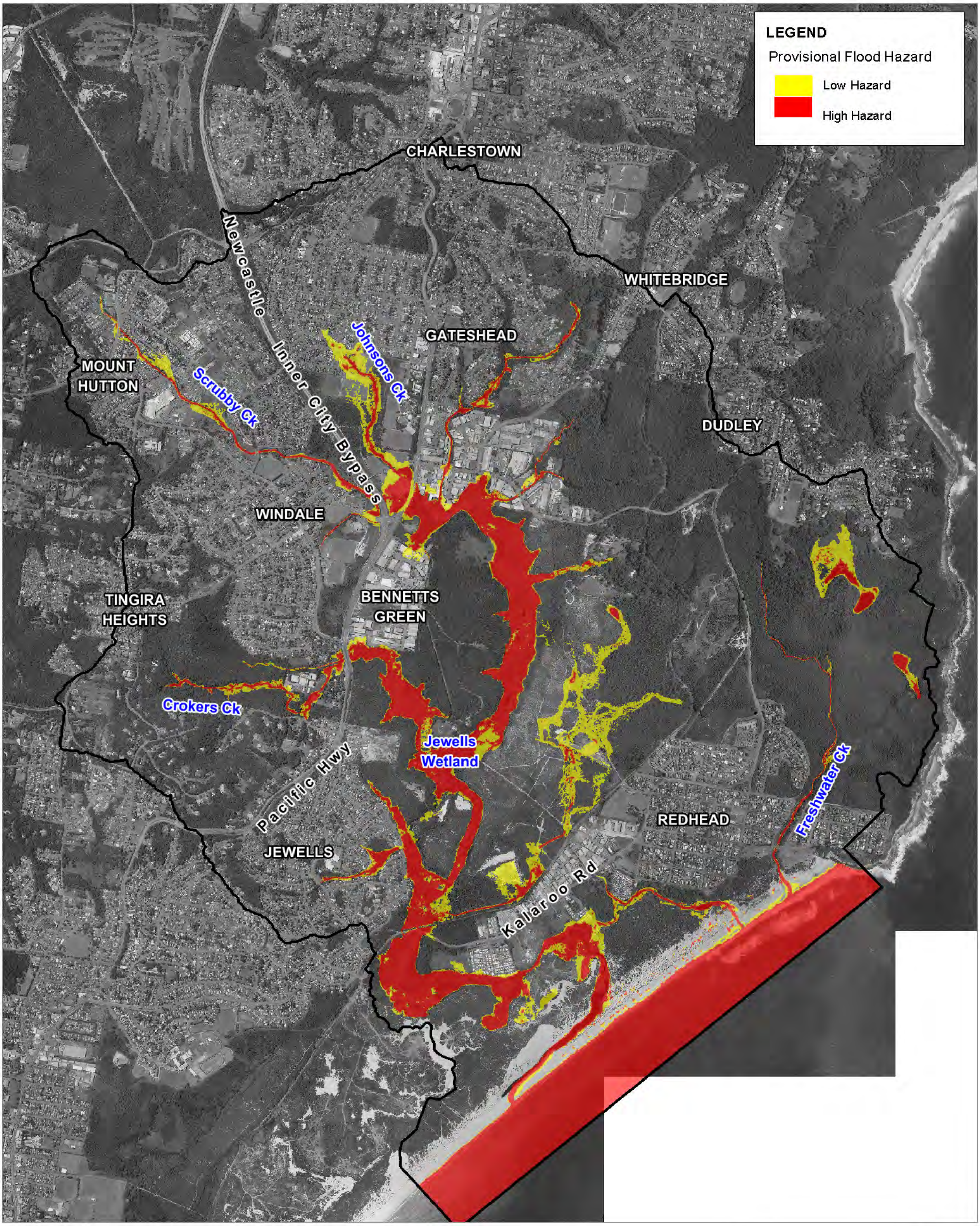
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_20%AEP_z.WOR



Title:

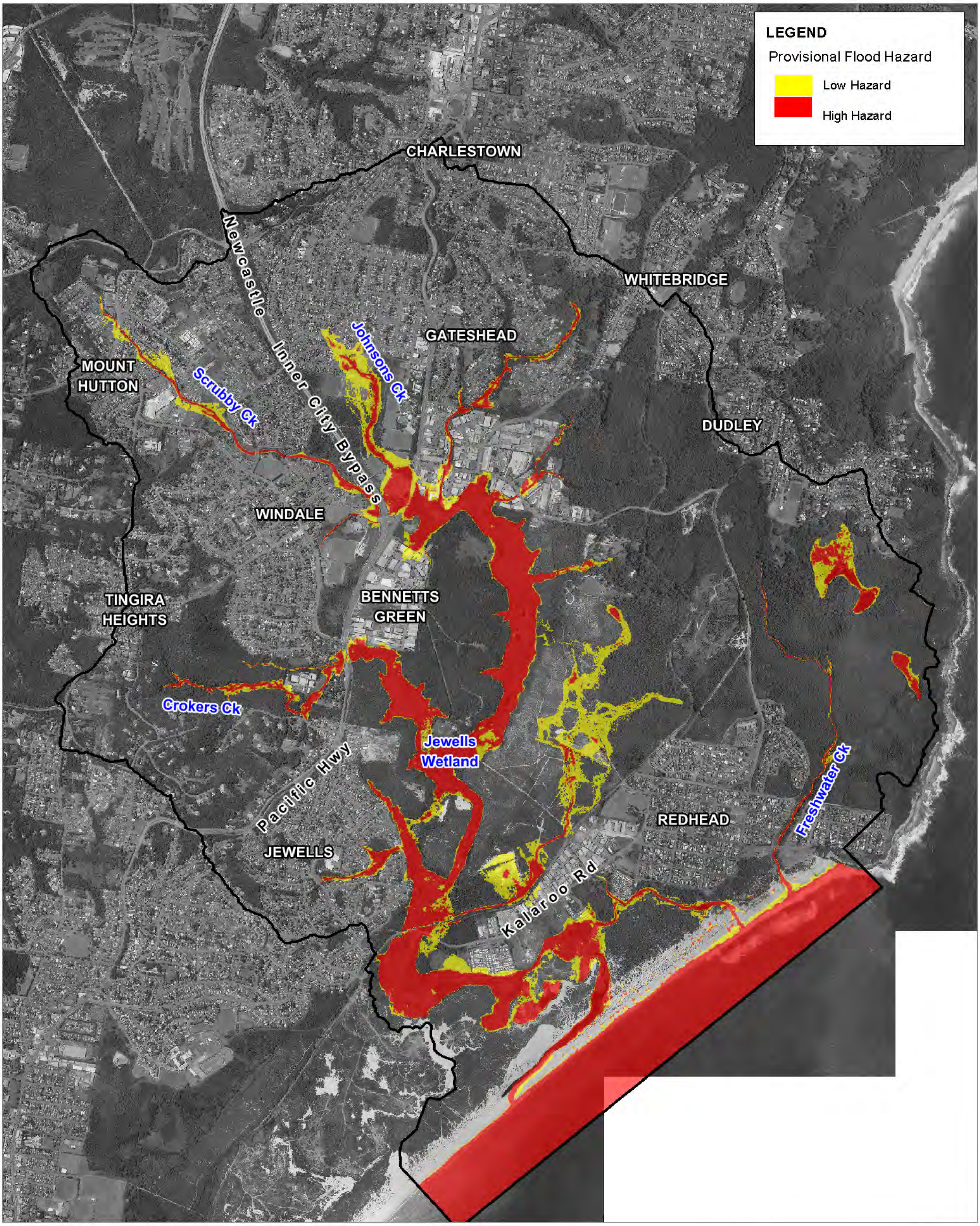
Provisional Flood Hazard - 5% AEP Event

Figure: 5%_AEP_z

Rev: A

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_5%AEP_z.WOR



Title:
Provisional Flood Hazard - 1% AEP Event

Figure: 1%_AEP_z

Rev: A

N

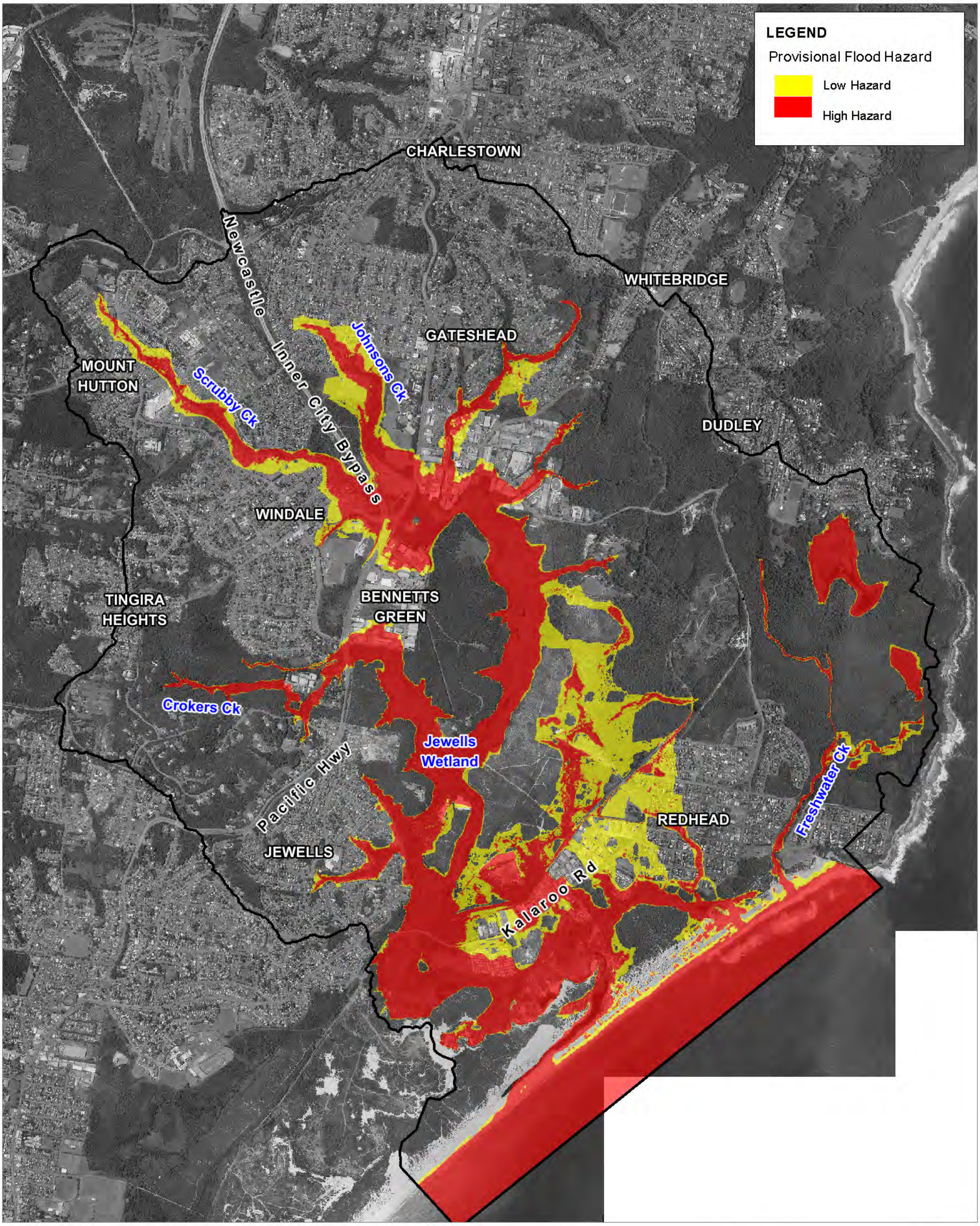
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_1%AEP_z.WOR



Title:

Provisional Flood Hazard - PMF Event

Figure: PMF_z

Rev: A

N

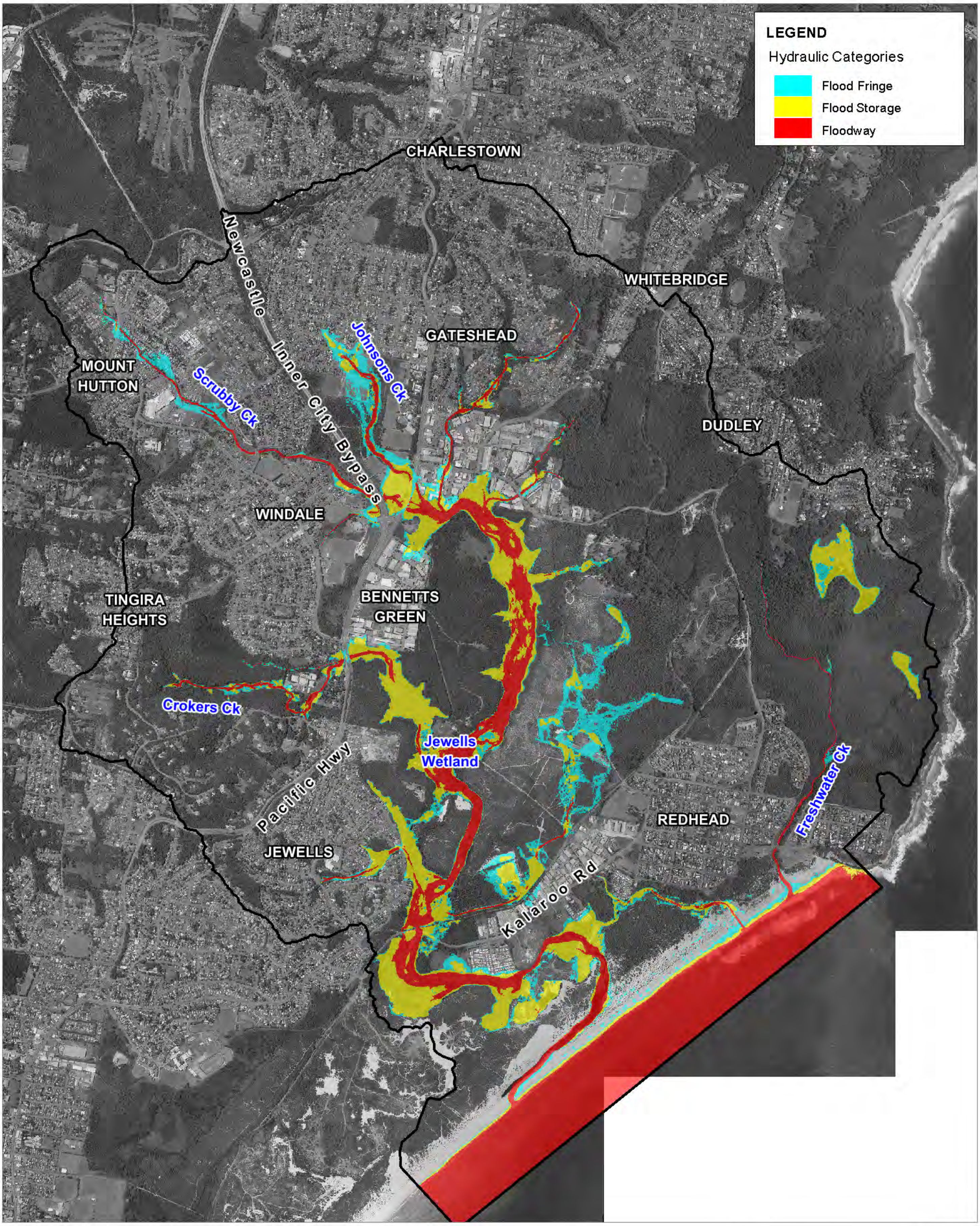
0 0.75 1.5km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_PMF_z.WOR



Title:
Hydraulic Categories - 1% AEP Event

Figure: **1%_AEP_hc**

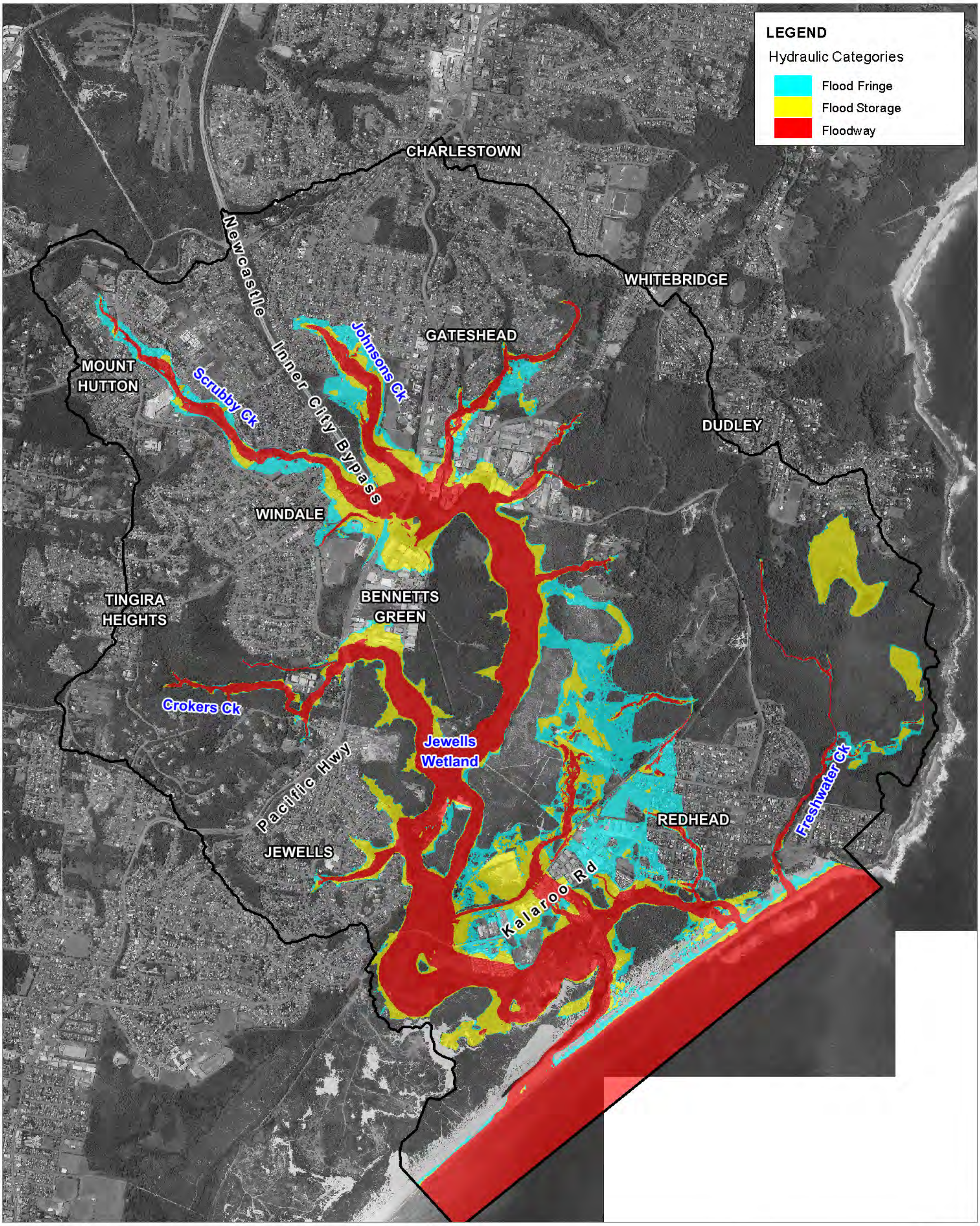
Rev: **A**

N

0 0.75 1.5km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_1%AEP_hc.WOR



Title:

Hydraulic Categories - PMF Event

Figure: PMF_hc

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 0.75 1.5km

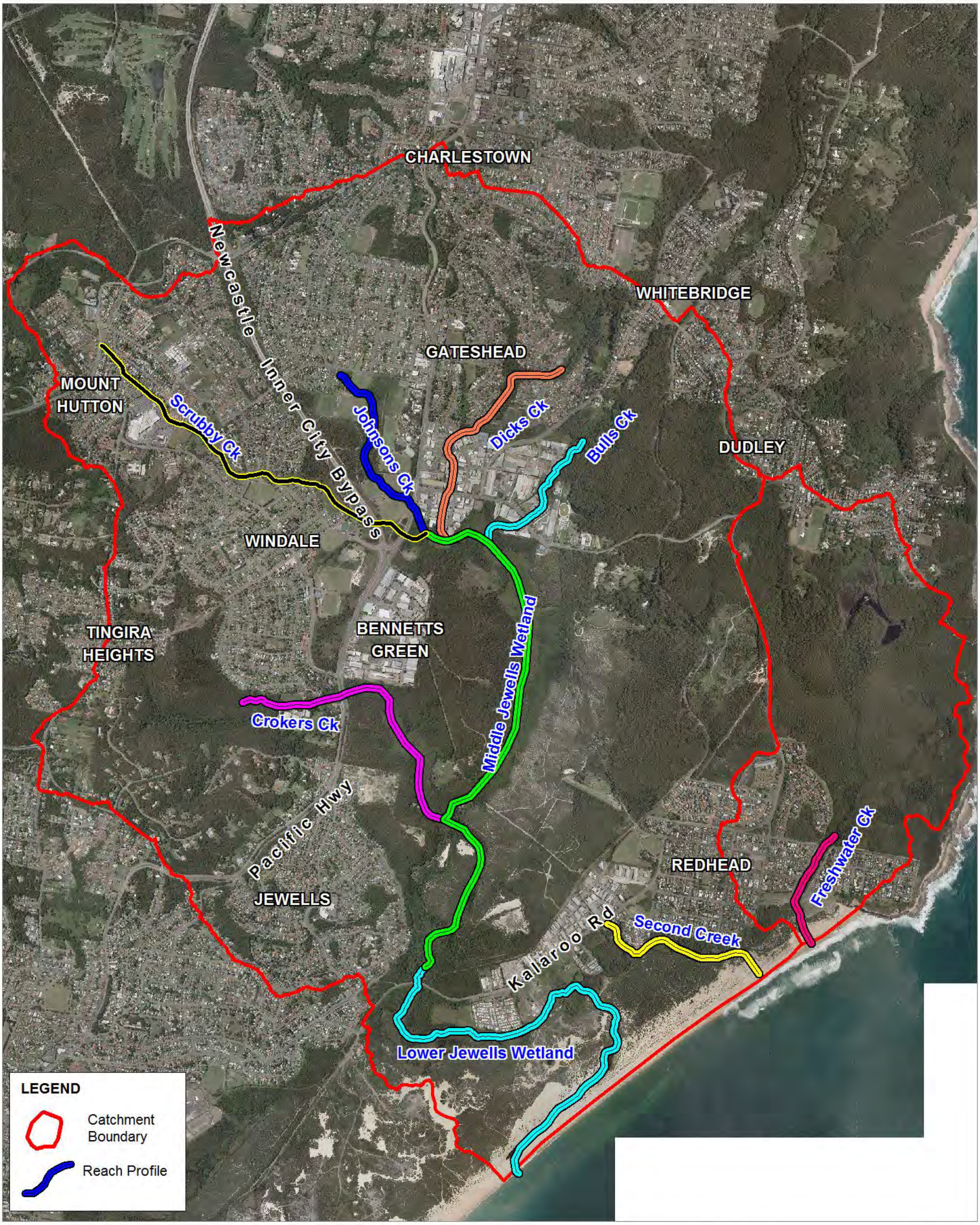
Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Mapping_PMF_hc.WOR

APPENDIX B: DESIGN FLOOD PROFILES



Title:

Creek Longsection Profiles

Figure: **B-1**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

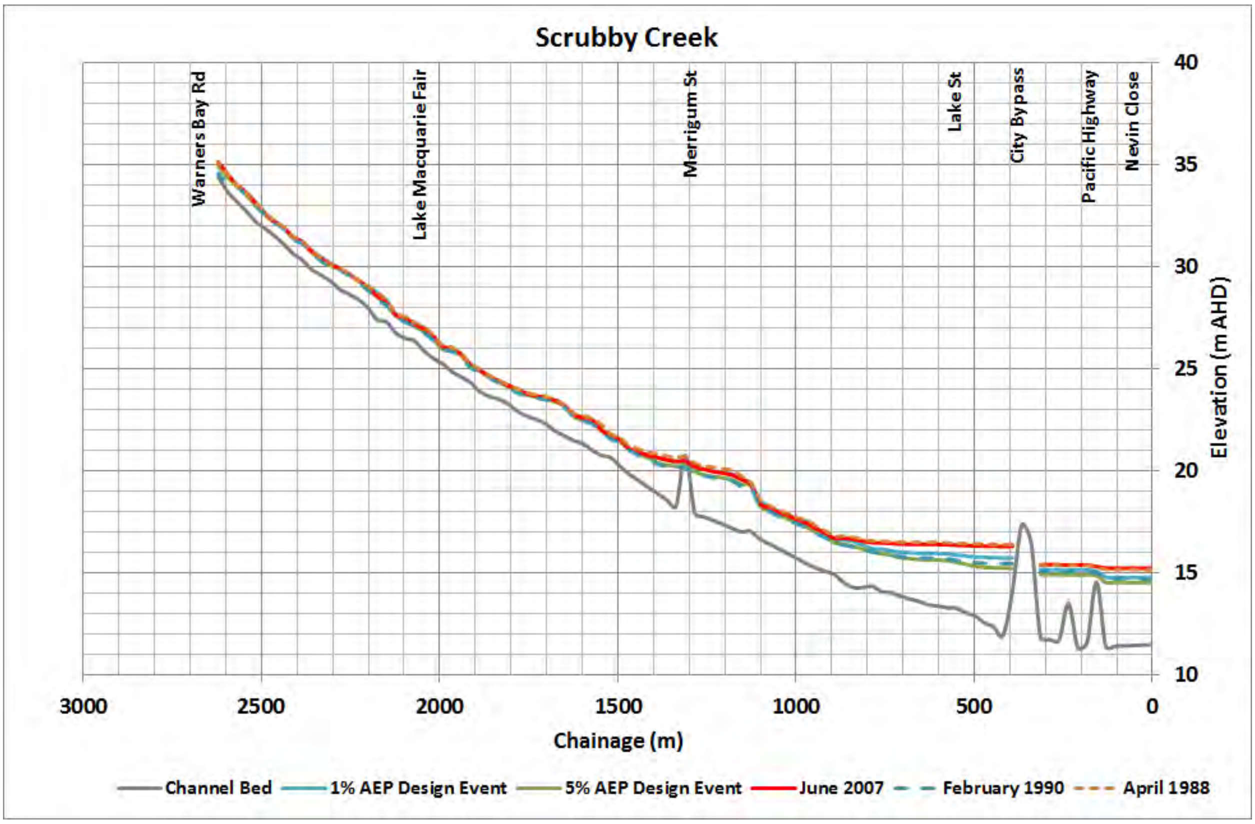
0 0.75 1.5km

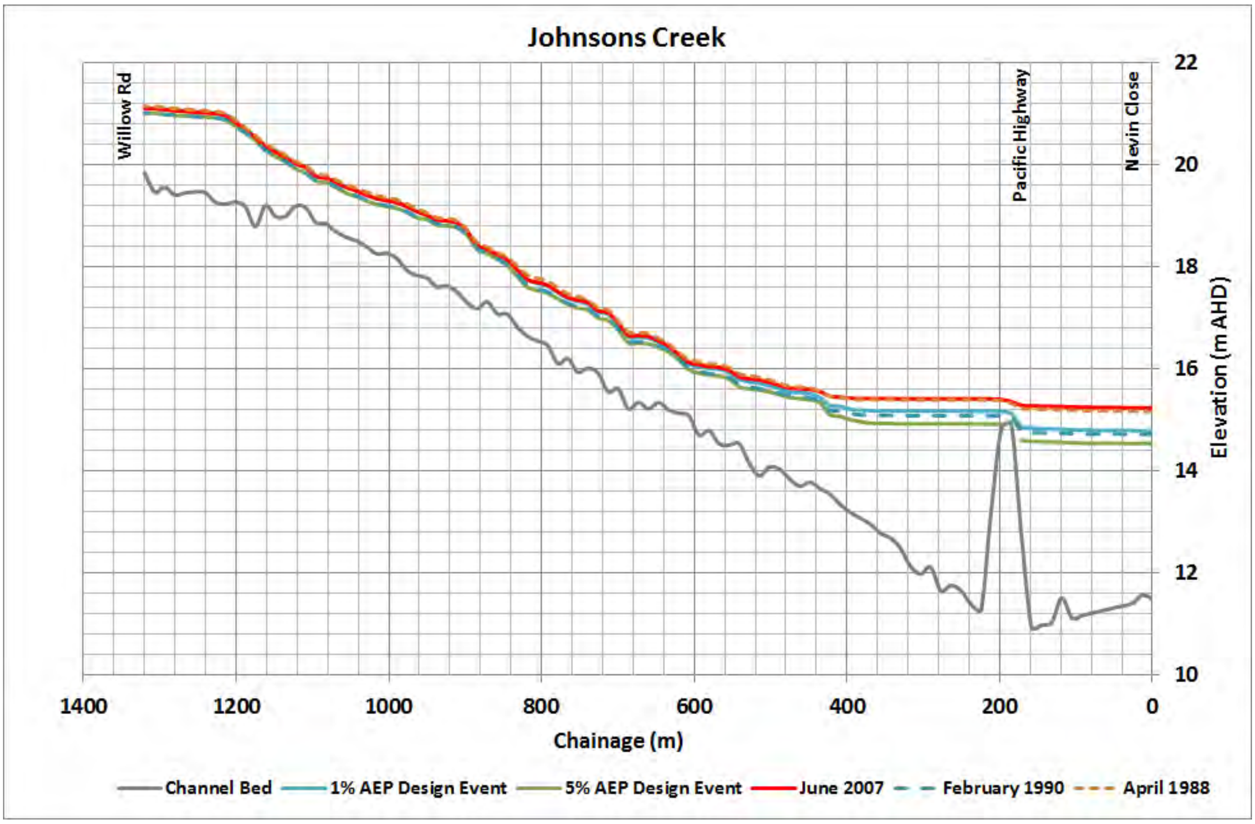
Approx. Scale

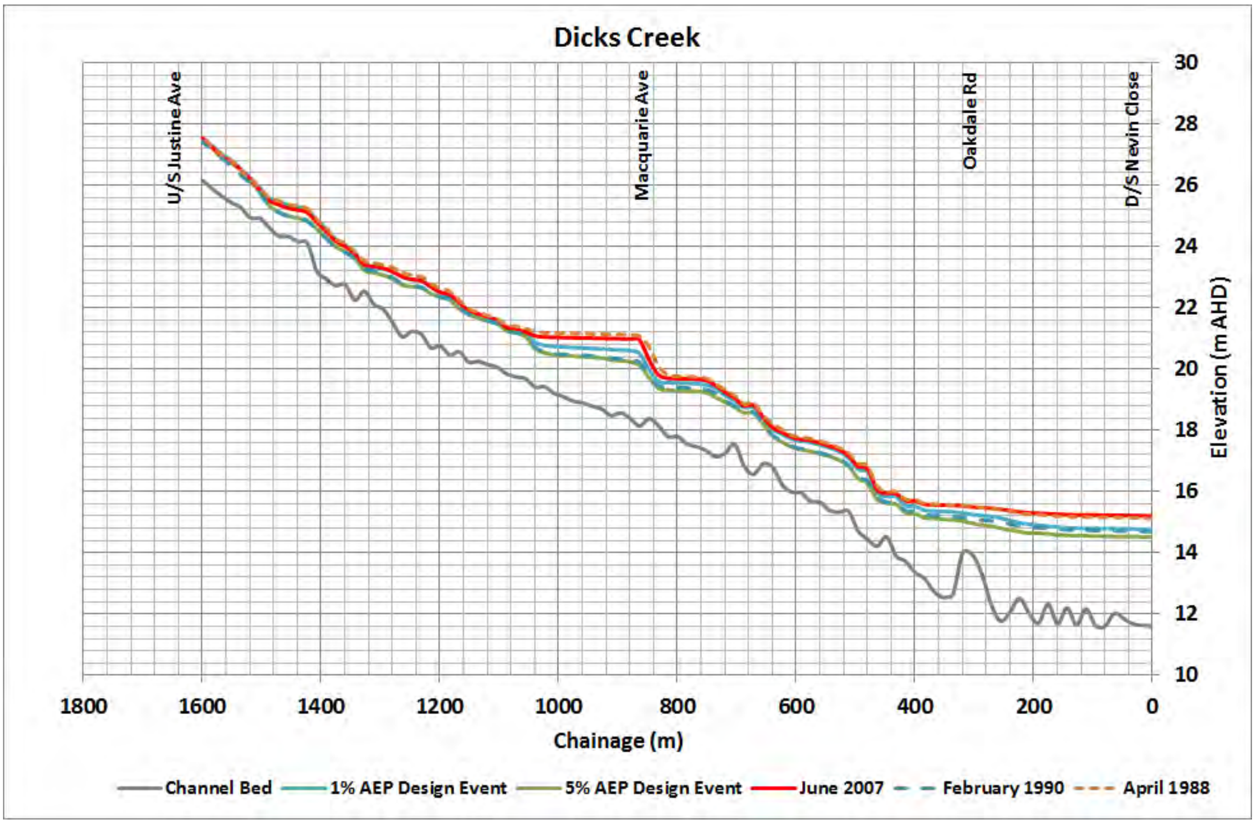
BMT WBM

www.bmtwbm.com.au

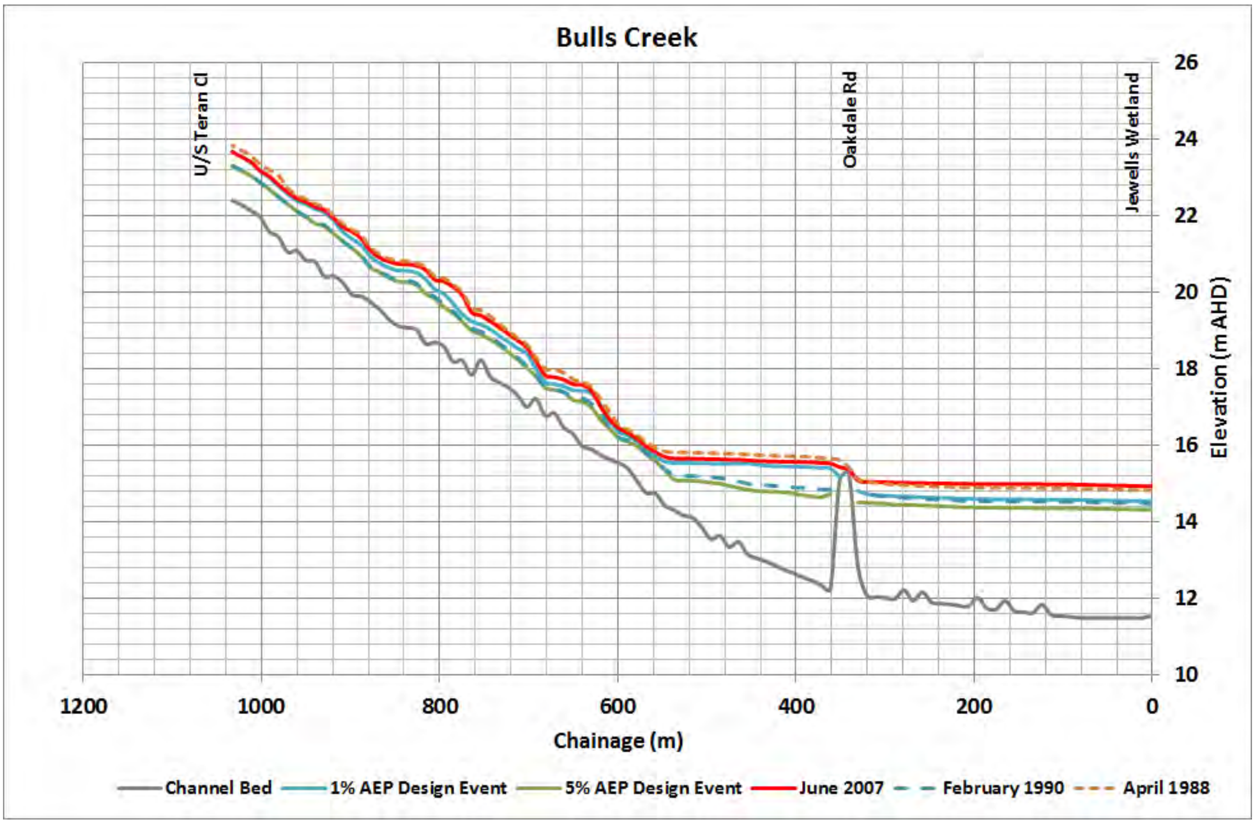
Filepath : K:\N2242_Jewells_Wetland_Flood_Study\MI\Workspaces\Locality_Plan.WOR


Scrubby Creek
Warners Bay Rd
Lake Macquarie Fair
Merrigum St
Lake St
City Bypass
Pacific Highway
Nevin Close
Elevation (m AHD)
Chainage (m)
Channel Bed
1% AEP Design Event
5% AEP Design Event
June 2007
February 1990
April 1988

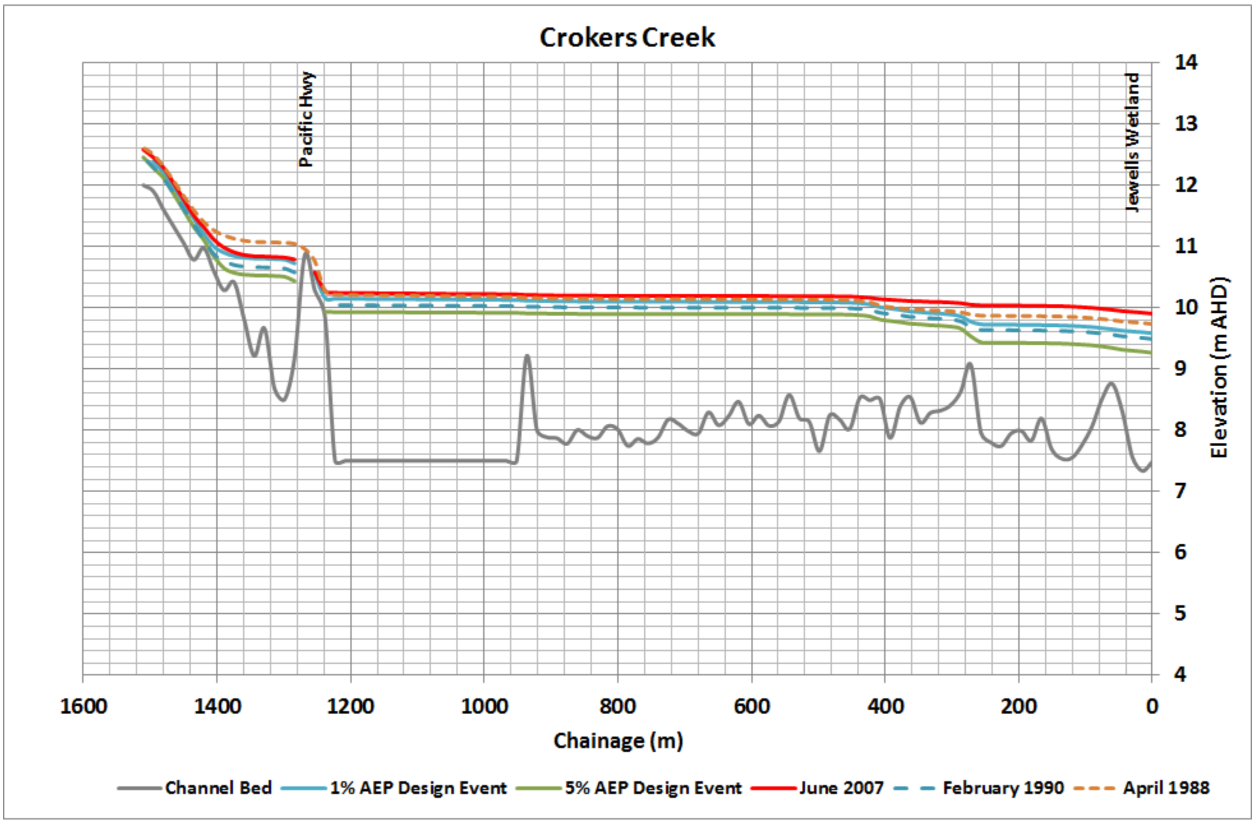

Johnsons Creek
Willow Rd
Pacific Highway
Nevin Close
Elevation (m AHD)
Chainage (m)
Channel Bed
1% AEP Design Event
5% AEP Design Event
June 2007
February 1990
April 1988

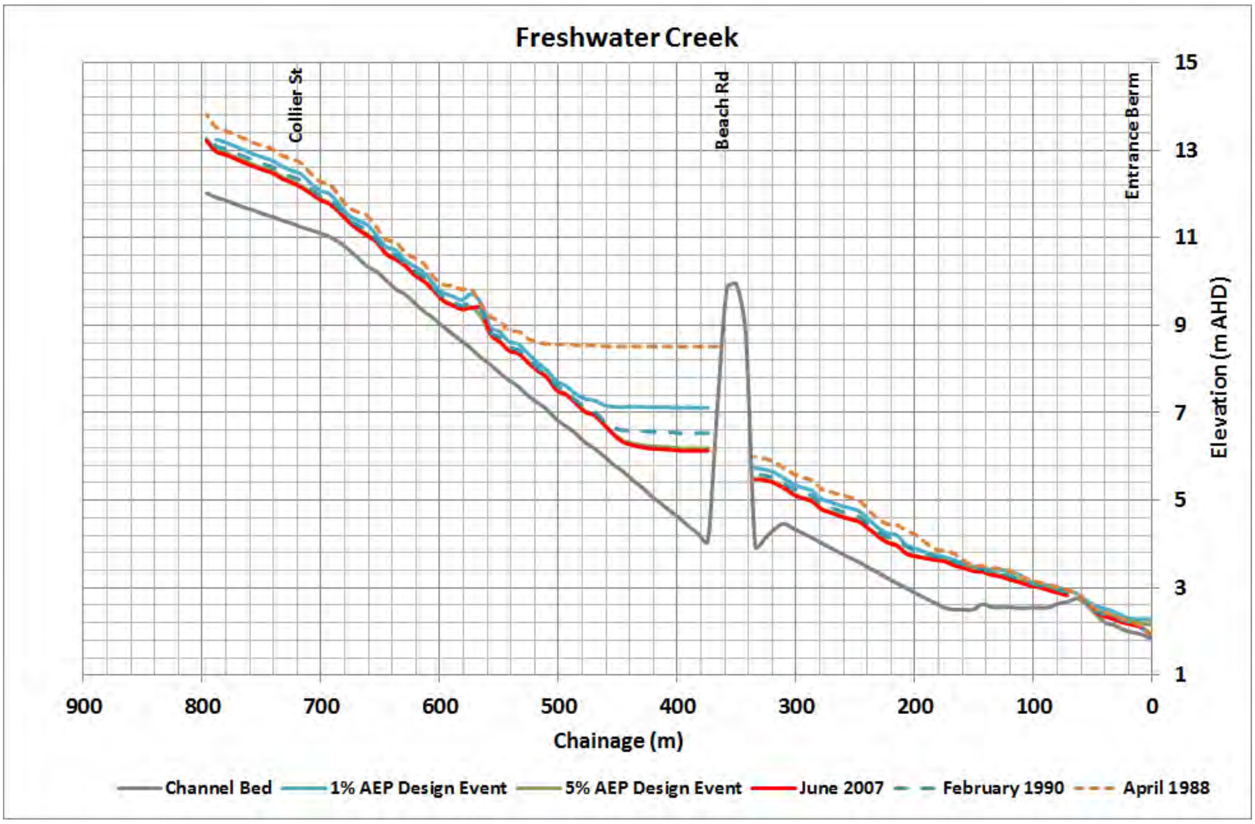


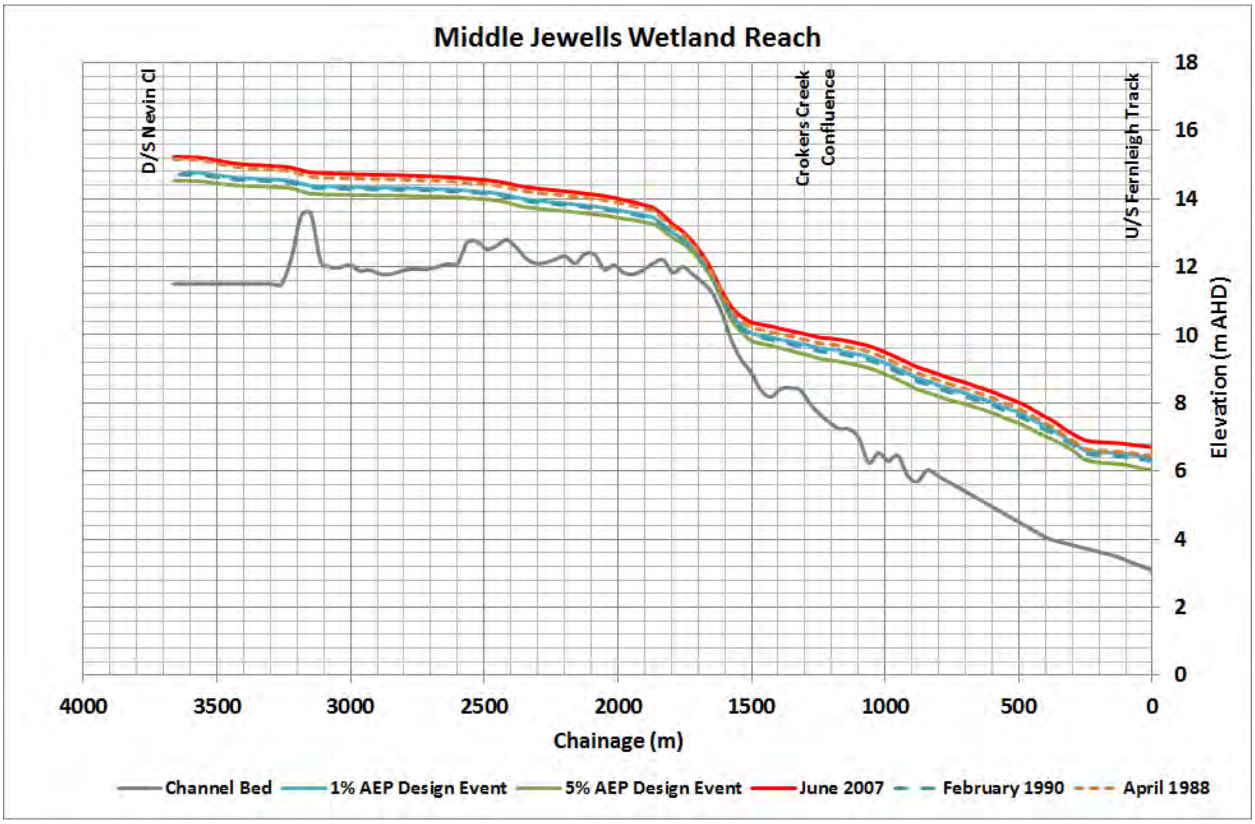
Dicks Creek
U/S Justine Ave
Macquarie Ave
Oakdale Rd
D/S Nevin Close
Elevation (m AHD)
Chainage (m)
Channel Bed
1% AEP Design Event
5% AEP Design Event
June 2007
February 1990
April 1988

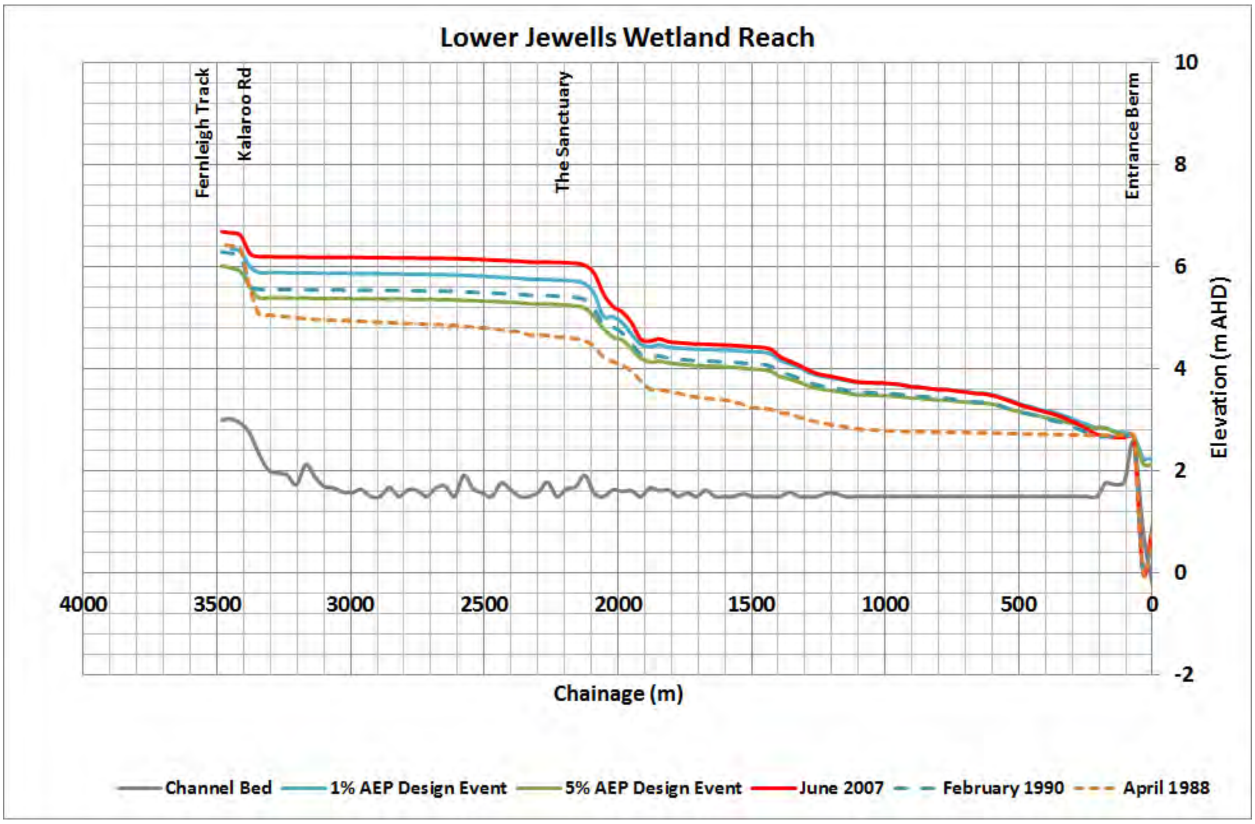


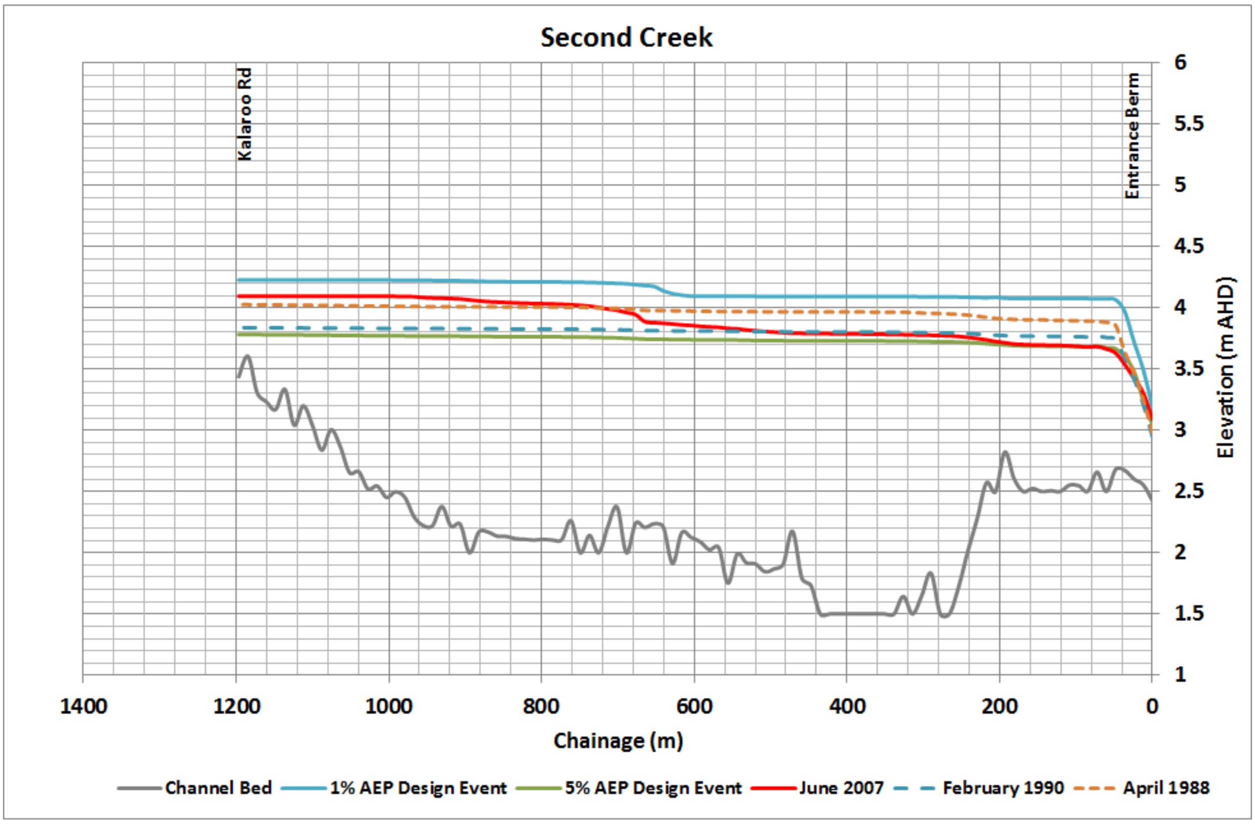
Bulls Creek
U/S Teran Cl
Oakdale Rd
Jewells Wetland
Elevation (m AHD)
Chainage (m)
Channel Bed
1% AEP Design Event
5% AEP Design Event
June 2007
February 1990
April 1988


Crokers Creek
Pacific Hwy
Jewells Wetland
14
13
12
11
10
9
8
7
6
5
4
Elevation (m AHD)
1600
1400
1200
1000
800
600
400
200
0
Chainage (m)
Channel Bed
1% AEP Design Event
5% AEP Design Event
June 2007
February 1990
April 1988


Freshwater Creek
Collier St
Beach Rd
Entrance Berm
15
13
11
9
7
5
3
1
Elevation (m AHD)
900
800
700
600
500
400
300
200
100
0
Chainage (m)
Channel Bed
1% AEP Design Event
5% AEP Design Event
June 2007
February 1990
April 1988


Middle Jewells Wetland Reach
D/S Nevin Cl
Crokers Creek Confluence
U/S Fernleigh Track
Elevation (m AHD)
Chainage (m)
Channel Bed
1% AEP Design Event
5% AEP Design Event
June 2007
February 1990
April 1988


Lower Jewells Wetland Reach
Fernleigh Track
Kalaroo Rd
The Sanctuary
Entrance Berm
Elevation (m AHD)
Chainage (m)
Channel Bed
1% AEP Design Event
5% AEP Design Event
June 2007
February 1990
April 1988


Second Creek
Kalaroo Rd
Entrance Berm
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
Elevation (m AHD)
1400
1200
1000
800
600
400
200
0
Chainage (m)
Channel Bed
1% AEP Design Event
5% AEP Design Event
June 2007
February 1990
April 1988

APPENDIX C: COMMUNITY CONSULTATION MATERIAL

1. **Community Questionnaire**
2. **Public Exhibition Responses**

safe & healthy *living*

PREPARING FOR OUR CHANGING ENVIRONMENT

Lake Macquarie City Council

Jewells Wetland Flood Study

Community Questionnaire July 2012

YOUR VIEWS AND EXPERIENCES ARE IMPORTANT TO THE STUDY

Lake Macquarie City Council is undertaking a detailed flood study of the Jewells Wetland catchment to help identify flooding problem areas. We are seeking the community's help by collecting information on any flooding or drainage problems that you may have experienced in the past. Please take a minute or two to read through these questions and provide responses wherever you can. Please return this form to Council in the enclosed envelope (no stamp required).
All information is confidential and used only for the purposes of the study.

Date Due: 30 July 2012

CONTACT AND PROPERTY DETAILS

Name:...

Address:...

....

Phone or email:..

Please tick your type of property:

☐ House ☐ Unit/Flat/Apartment ☐ Business

☐ Other (please specify) ....

....

How long have you been at this property?

.... i.e. years

PREVIOUS FLOODING EXPERIENCE

Have you ever experienced flooding at this property?

☐ Yes ☐ No

If yes, what dates or years did this happen?

....

....

Are you able to indicate the depth that flood waters reached on your property or elsewhere such as roads?

....

....

....

....

....

....

Do you think your property could be flooded in the future?

☐ Yes ☐ No

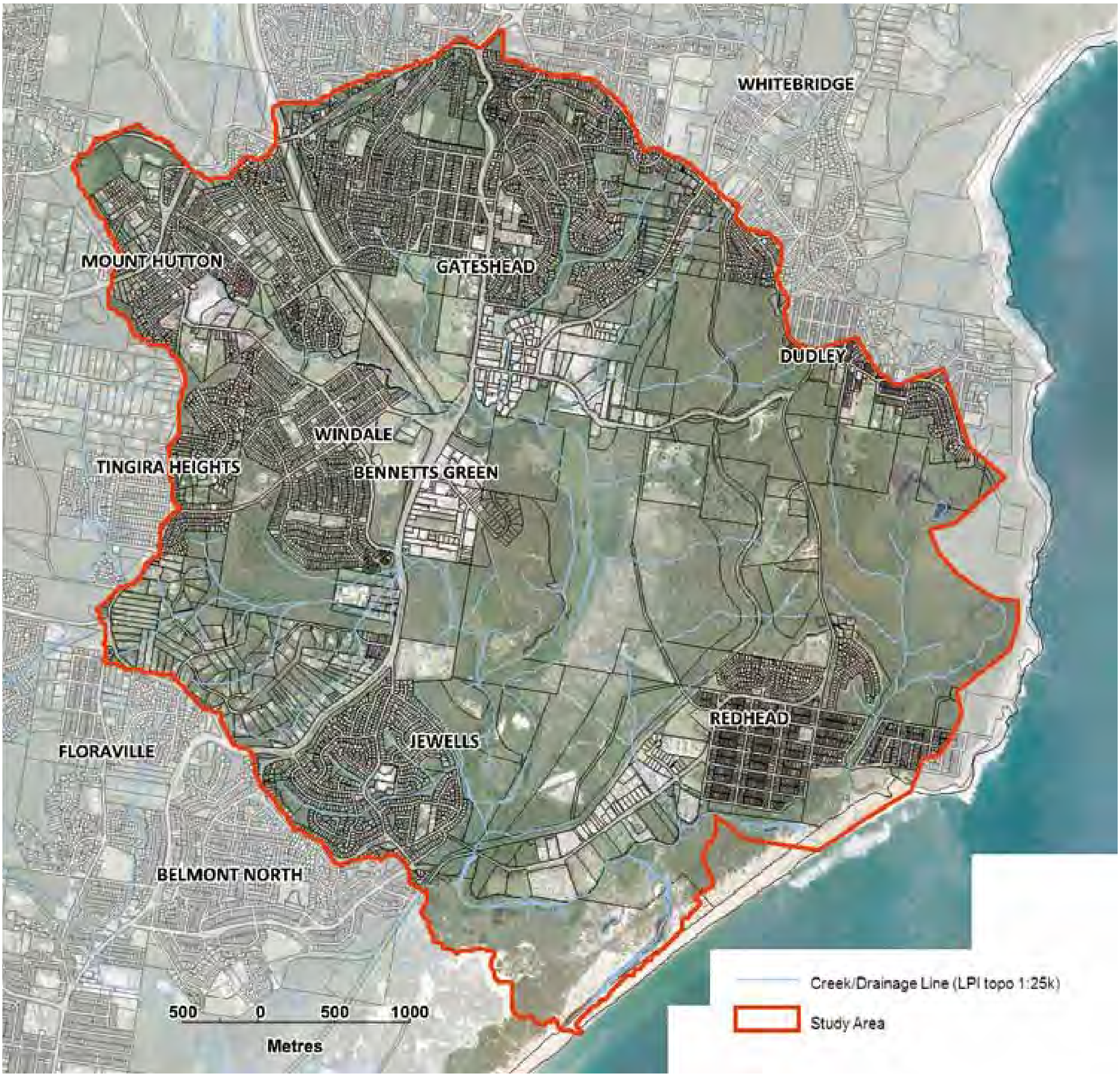
A map is provided on the reverse. Please mark up your property or known flooding areas. Additional space is provided to add other comments.

PHOTOGRAPHS AND VIDEO

Do you have any photographs or videos of flooding that you are willing to share with Council? (will be returned).

☐ Yes ☐ No

Photographs and videos can be returned with the questionnaire or emailed to the address below.
If you have any questions please contact Senior Floodplain Management Officer, Greg D Jones on **4921 0333**
or email: **council@lakemac.nsw.gov.au**



PLEASE PROVIDE ANY ADDITIONAL COMMENTS OR INFORMATION THAT YOU THINK WILL HELP THE STUDY

....

....

....

....

....

....

Thank you for your assistance in completing this survey.

Community Environment Network Inc.

An alliance of community and environment groups from Lake Macquarie, Wyong and Gosford.

[redacted]
Deputy Chair
Community Environment
Network
[redacted]
Cooranbong
NSW 2265

[redacted]

Lake Macquarie City Council
Box 1906
Hunter Region Mail Centre
NSW 2310

July 29, 2013

Jewells Wetland Flood Study
Submission from Community Environment Network

Dear Sir,
The Lake Macquarie Planning Committee which is part of the Community Environment Network corresponds by email to its members to evaluate planning proposals in Lake Macquarie and endeavors to make informed submissions to Council on environmental, social and economic issues.
The committee has had the opportunity to review the **Jewells Wetland Flood Study May 2013.**

CEN commends LMCC for the following initiatives:

1. Adopting a whole of catchment approach to the study of Jewells Wetland.
   Wetlands are valuable storages for flood water in a flood event. Wetlands disperse their accumulated water slowly and therefore reduce the risk of flash flooding events. Wetlands should be protected for these services they provide to the human population.

2. The Jewels Wetland Study gives evidence of placing a high value on its biodiversity.
   Wetlands provide a variety of habitats for flora from herbs to flowering plants to shrubs and trees, and breeding areas for fauna from macro invertebrates to fish, reptiles and aquatic and marine birds. Wetlands are nature's kidneys and need to be protected to preserve the water quality in the Gateshead, Windale, Bennetts Green and Jewells area.

3. The proposed strategies in the Flood Study will provide effective environmental management of Jewells Wetland.

4. The proposed strategies will help to minimize and mitigate the impact of sea level rise on peak flood conditions in the catchment.

5. This study will be an effective tool in identifying potential works to reduce existing flooding.

6. With predicted sea level rise this study will be a very useful tool in identifying flood risk and flood levels in future developments.

7. This study will also be an effective tool for city planners to give a rigorous assessment of proposed future developments and changes in land use in the Jewels Wetland catchment and likely impacts on storm water flows and areas prone to flooding.

8. The Jewells Wetland Study will be an important tool in setting appropriate flood levels for development control.

9. The Study will be an important tool in improving flood emergency response and recovery.

10. The Council and BMT WBM Pty Ltd are to be commended for their endeavors in engaging the community in this flood study:

- Actively seeking flood stories, and photographic evidence of flood events from the residents
- Placing this study on public exhibition from May till August 2013 for public comment.
- Mailing a copy of the Jewells Wetland Flood Study CD to Community Environment Network for comment.

Thank you for giving the community opportunity to respond to this study.

Yours sincerely

Deputy Chair – Community Environment Network

Transport
Roads & Maritime Services

8 July 2013

SF2012/009266/2
CR2013/004747

General Manager
Lake Macquarie City Council
Box 1906 Hunter Region Mail Centre
NSW 2310

Attention: Ms Alice Howe

EXHIBITION OF DRAFT JEWELLS WETLAND FLOOD STUDY, MAY 2013

Dear Ms Howe

I refer to your letter dated 20 June 2013, (your reference: F2011/04755), regarding the subject exhibition of the draft flood study forwarded to Roads and Maritime Services (RMS) for comment.

RMS Responsibilities

Transport for NSW and RMS primary interests are in the road network, traffic and broader transport issues. In particular, the efficiency and safety of the classified road network, the security of property assets and the integration of land use and transport.

RMS Response and Requirements

RMS has reviewed the information provided and has no objections to or requirements for the draft flood study as it is considered the proposed land use as a wetlands will have no impact on the classified road network.

Should you require further advice please contact me on [redacted].

Yours sincerely

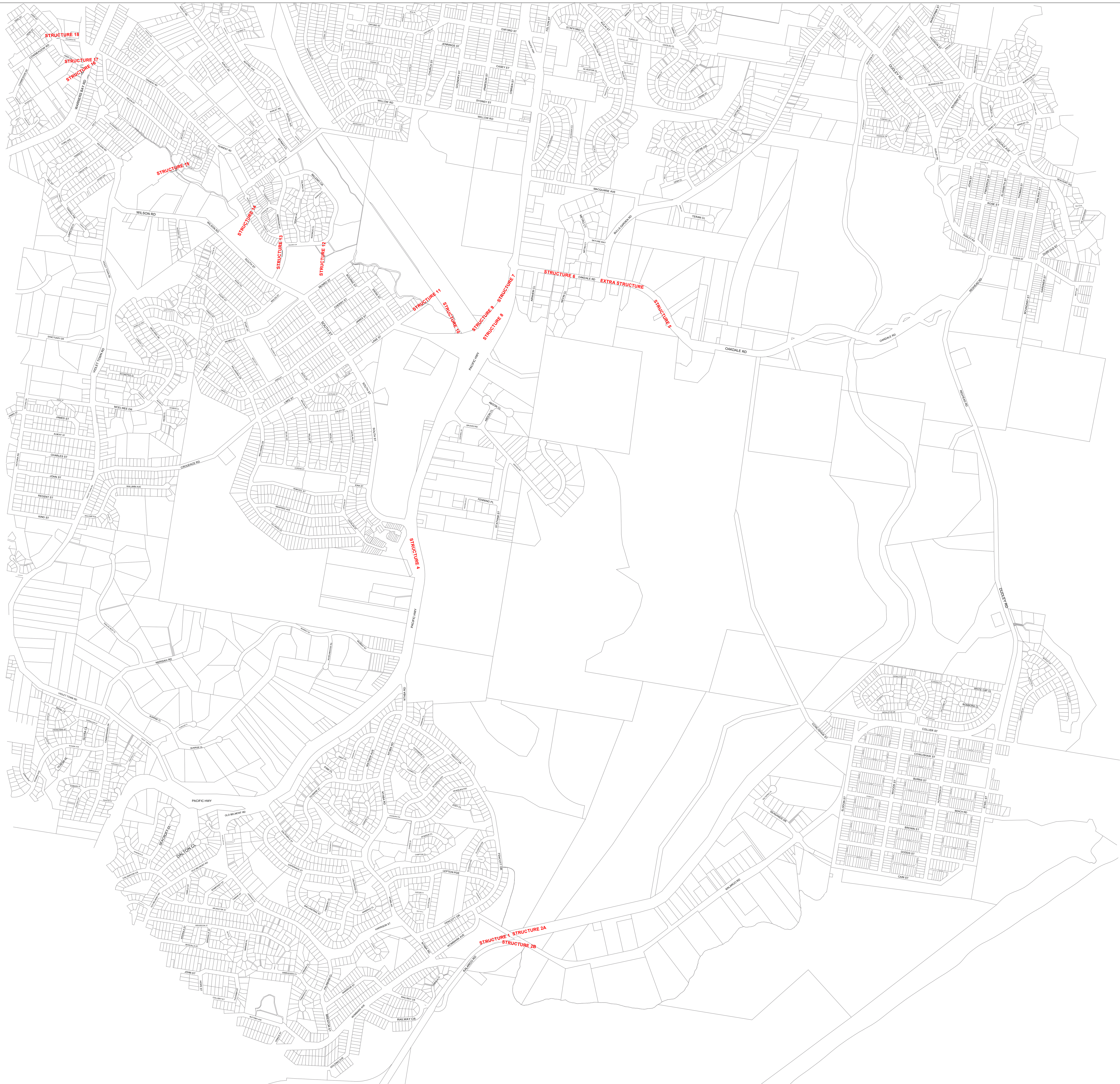
[redacted]

Manager, Land Use Development
Hunter Region

Roads & Maritime Services

59 Darby Street, Newcastle NSW 2300 | Locked Bag 2030 Newcastle NSW 2300 DX7813 Newcastle
T 02 4324 0240 | **F** 02 4324 0342 | **E** [redacted] **www.rmservices.nsw.gov.au** | **13 22 13**

APPENDIX D: ADDITIONAL SURVEY DATA



VERSION	DATE	COMMENTS	CHK BY	APP'D BY
2	27/7/12	STAGE 2	CMR	PWT
1	9/6/12	STAGE 1	CMR	PWT

CAD FILES: JEWE3477

DRAWN BY: I.NAYLOR

DESIGNED BY:

SURVEYED BY: I.NAYLOR

THIS DRAWING IS AN UNCONTROLLED COPY UNLESS STATED OTHERWISE

SCALE

PLAN 1:10000

HEIGHT DATUM	COORDINATES	ORIG. SHEET SIZE
AHD	MGA	A1

WORK TO FIGURED DIMENSIONS - DO NOT SCALE. CHECK DIMENSIONS AND LEVELS ON JOB BEFORE ORDERING MATERIALS OR COMMENCING WORK. THIS DRAWING IS SUBJECT TO

CLIENT :

Lake Macquarie City Council

PREPARED BY :

CITY PROJECTS ~ SURVEY ~

126-138 MAIN ROAD
SPEERS POINT
PHONE (02)49210 333
FAX (02)49210 535

PROJECT NAME

FLOOD STUDY

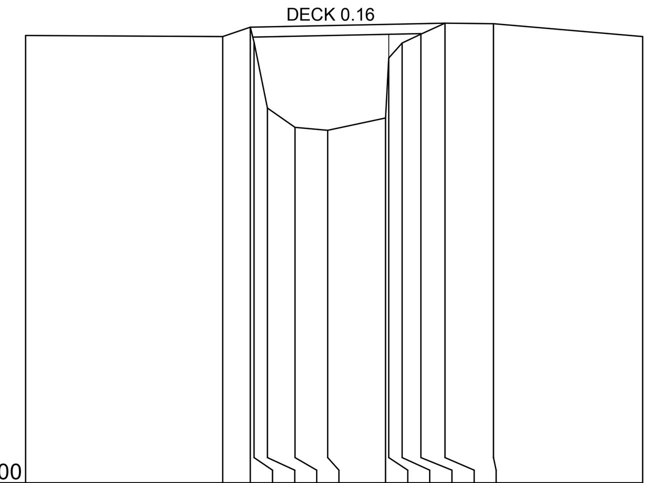
DRAWING TITLE

COVER PLAN (STRUCTURE LOCATIONS)

PROJECT ADDRESS & DETAILS

JEWELLS WETLAND AND UPPER TRIBUTARIES

FOLDER NO:	SHEET:	DRAWING No:	VERSION
PM12\0029\04\01	1 OF 5 SHEETS	3477	2

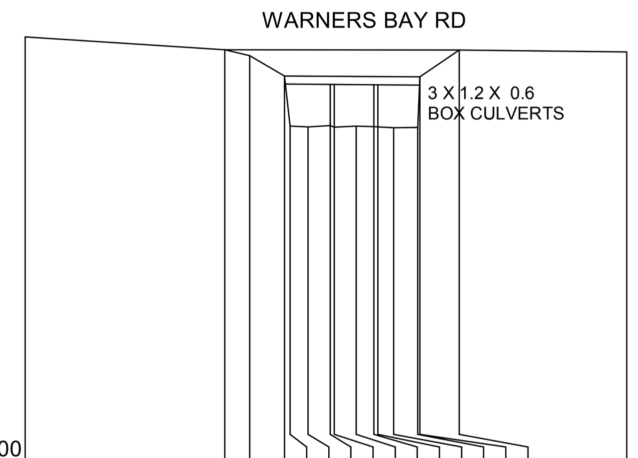


Datum R.L. 28.00

NATURAL	35.07	35.05	35.20	34.96	33.92	33.62	33.57	33.77	34.72	34.95	35.09	35.27	35.26	35.05
Chainage	0.00	6.23	7.11	7.23	7.65	8.52	9.56	11.38	11.49	11.91	12.50	13.26	14.80	19.51

STRUCTURE 16
FOOT BRIDGE

STRUCTURE 16
FOOT BRIDGE

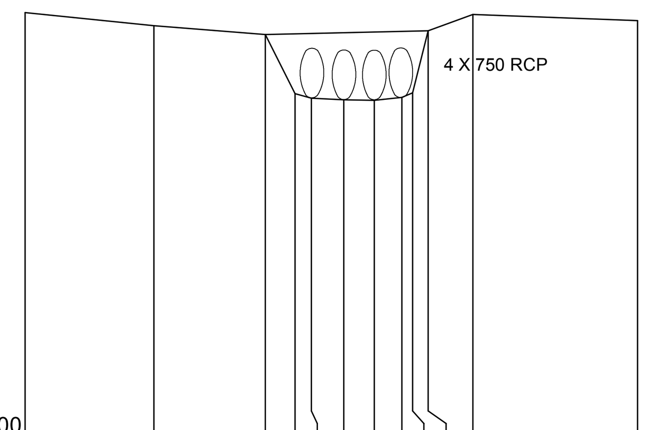


Datum R.L. 29.00

NATURAL	35.68	35.48	35.39	35.06	34.27	34.26	34.28	34.26	34.27	34.26	34.26	34.25	34.25	35.05	35.47	35.45
Chainage	0.00	6.32	7.10	8.20	8.38	8.95	9.65	9.78	10.47	11.03	11.16	11.66	12.42	12.49	13.73	19.03

STRUCTURE 16
WARNERS BAY RD CULVERT

STRUCTURE 16
WARNERS BAY RD CULVERT

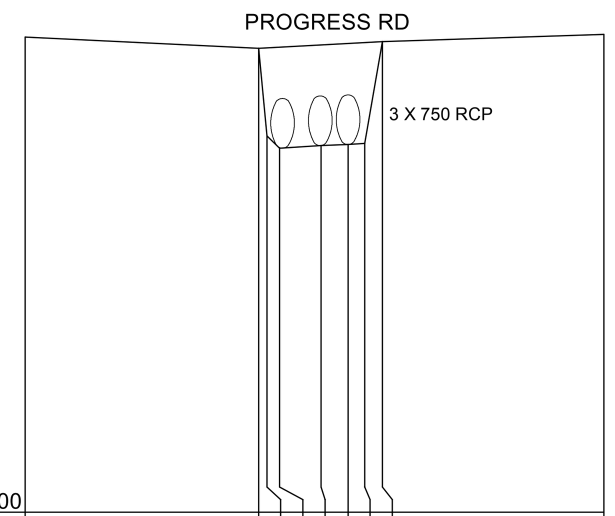


Datum R.L. 29.00

NATURAL	35.70	35.49	35.35	34.42	34.35	34.32	34.31	34.36	34.43	35.41	35.67	35.58
Chainage	0.00	4.07	7.60	8.53	9.05	10.07	11.04	11.91	12.25	12.74	14.15	19.36

STRUCTURE 16
FOOT CROSSING

STRUCTURE 16
FOOT CROSSING

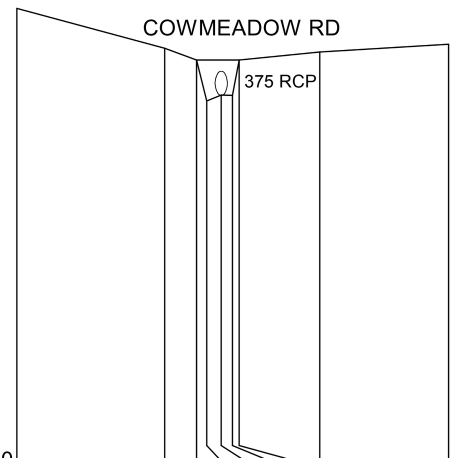


Datum R.L. 33.000

NATURAL	40.512	40.331	38.948	38.753	38.795	38.811	38.829	40.438	40.554
Chainage	0.000	7.378	7.644	8.043	9.354	10.204	10.736	11.290	18.297

STRUCTURE 18 UP STREAM
PROGRESS RD CULVERT

STRUCTURE 18 UP STREAM
PROGRESS RD CULVERT

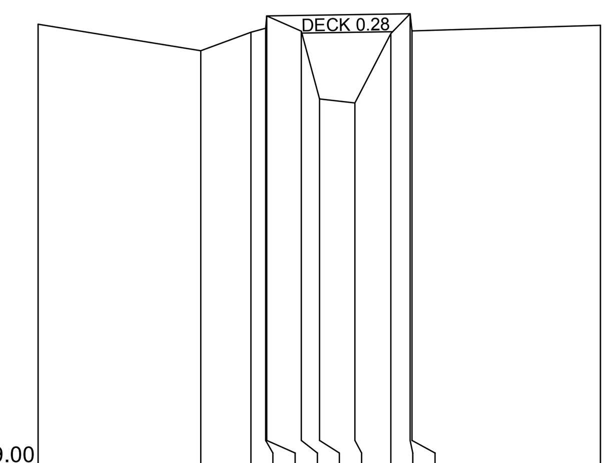


Datum R.L. 29.000

NATURAL	36.31	35.68	35.50	34.85	34.94	34.94	35.50	35.63	35.75
Chainage	0.00	4.67	5.68	6.01	6.46	6.82	7.03	9.57	13.65

STRUCTURE 17
COWMEADOW RD INLET PIPE

STRUCTURE 17
COWMEADOW RD INLET PIPE



Datum R.L. 29.00

NATURAL	35.98	35.56	35.85	35.92	36.11	35.87	34.80	34.74	35.83	36.15	35.87	35.96
Chainage	0.00	5.14	6.72	7.18	7.21	8.31	8.88	10.01	11.13	11.75	11.81	17.76

STRUCTURE 17
COWMEADOW RD FOOT BRIDGE

STRUCTURE 17
COWMEADOW RD FOOT BRIDGE

VERSION	DATE	COMMENTS	CHK BY	APP'D BY
2	27/7/12	STAGE 2	CMR	PWT
1	9/6/12	STAGE 1	CMR	PWT

CAD FILES: JEWE3477
DRAWN BY: I.NAYLOR
DESIGNED BY:
SURVEYED BY: I.NAYLOR

THIS DRAWING IS AN UNCONTROLLED COPY UNLESS STATED OTHERWISE

SCALE
CROSS SECTION HORIZONTAL 1:200
VERTICAL 1:100

HEIGHT DATUM AHD | COORDINATES MGA | ORIG. SHEET SIZE A1

CLIENT :
Lake Macquarie City Council

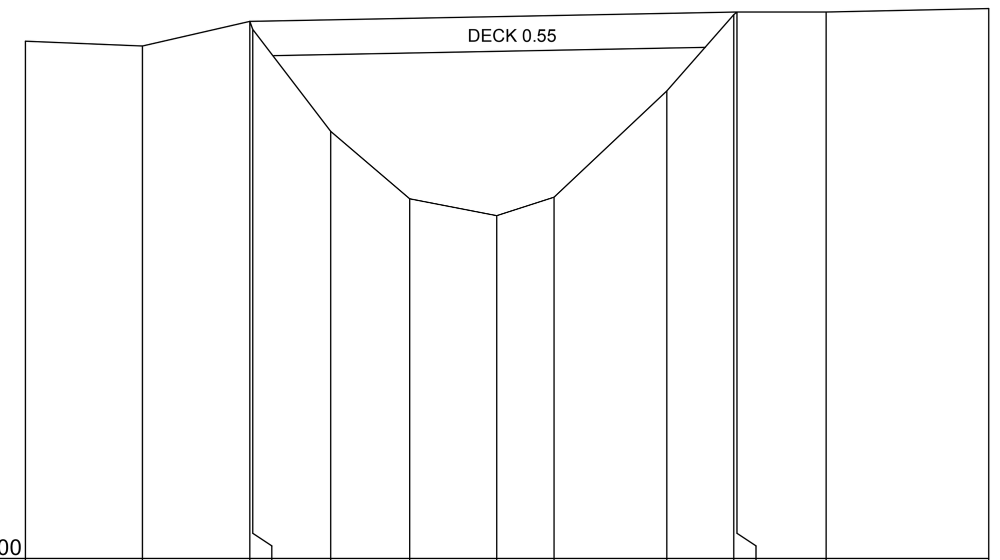
PREPARED BY :
CITY PROJECTS ~ SURVEY ~
126-138 MAIN ROAD
SPEERS POINT
PHONE (02)49210 333
FAX (02)49210 535

PROJECT NAME
FLOOD STUDY

DRAWING TITLE
CROSS SECTIONS

PROJECT ADDRESS & DETAILS
JEWELLS WETLAND AND UPPER TRIBUTARIES

FOLDER NO: PM12\0029\04\01
SHEET: 5 OF 5 SHEETS
DRAWING No: 3477
VERSION 2

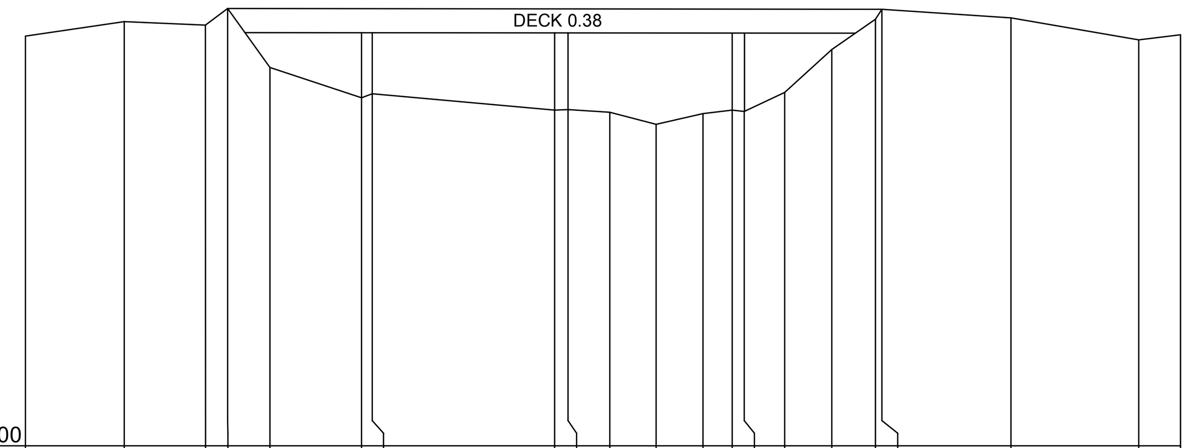


Datum R.L. 11.00

Chainage	NATURAL
0.00	19.18
3.70	19.11
7.09	19.50
7.19	19.37
9.66	17.76
12.15	16.69
14.90	16.43
16.71	16.72
20.28	18.40
22.40	19.61
22.50	19.65
25.31	19.65
30.46	19.70

STRUCTURE 12 UP STREAM
FOOT BRIDGE

STRUCTURE 12 UP STREAM
FOOT BRIDGE



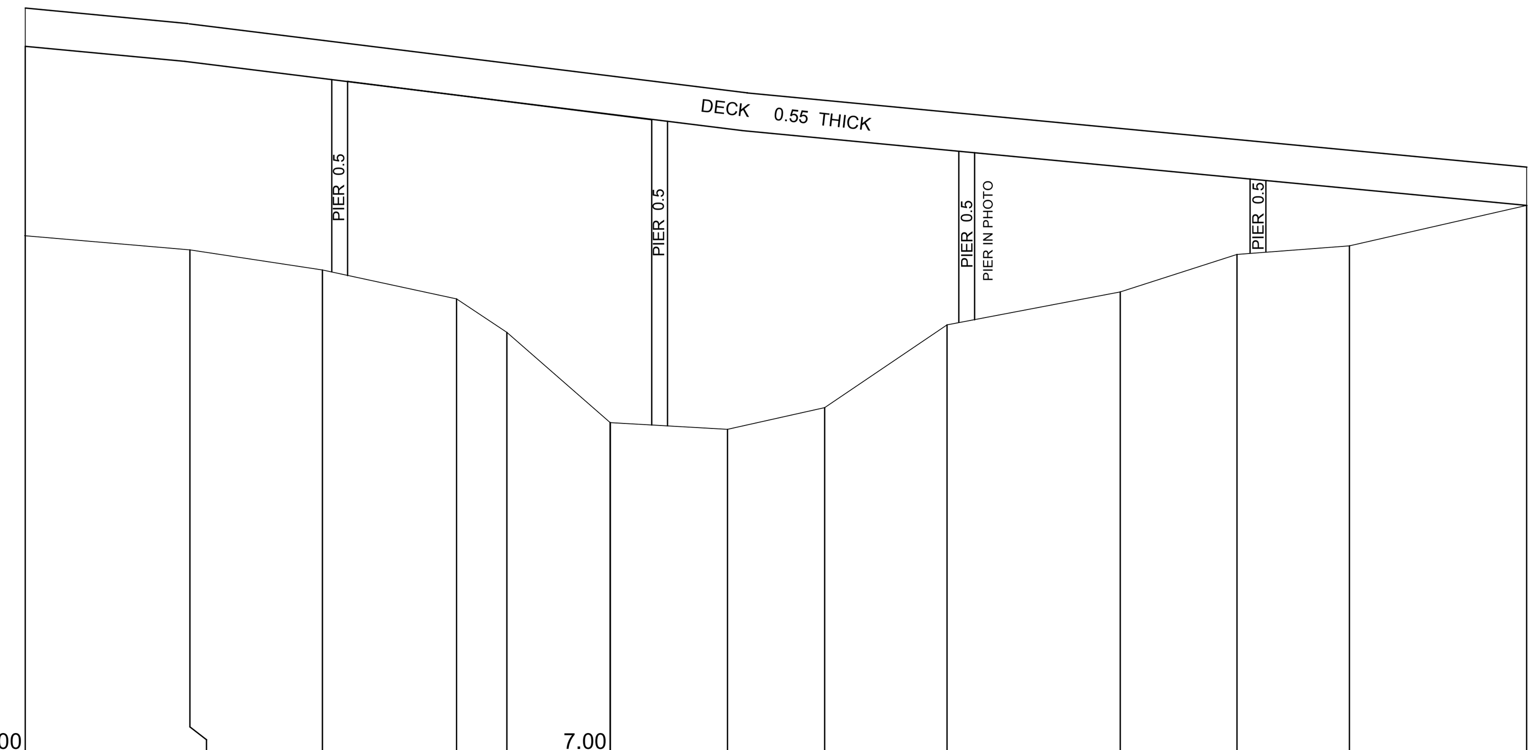
Datum R.L. 20.00

Chainage	NATURAL
0.00	26.47
3.13	26.70
5.70	26.63
6.39	26.91
7.73	25.98
10.60	25.49
10.99	25.57
16.75	25.30
17.15	25.31
18.48	25.27
19.94	25.08
21.42	25.26
22.34	25.30
22.73	25.28
24.00	25.58
25.50	26.26
26.88	26.74
27.08	26.89
31.16	26.76
35.20	26.41
36.52	26.49

STRUCTURE 15 UP STREAM
FOOT BRIDGE

STRUCTURE 15 UP STREAM
FOOT BRIDGE

FOOT BRIGDE OVER
NEWCASTLE BYPASS



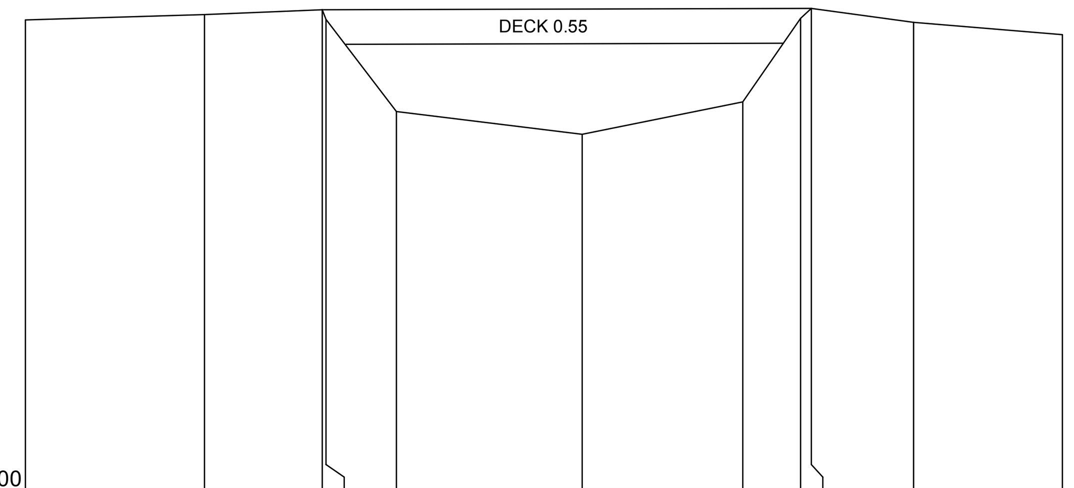
Datum R.L. 7.00

7.00

Chainage	NATURAL
0.00	18.16
5.20	14.94
9.39	14.62
13.64	14.16
15.23	13.64
18.49	12.21
22.21	12.10
25.28	12.45
29.15	13.75
34.62	14.28
38.32	14.87
41.87	15.00
47.48	15.64

STRUCTURE 11 UP STREAM
FOOT BRIDGE

STRUCTURE 11 UP STREAM
FOOT BRIDGE



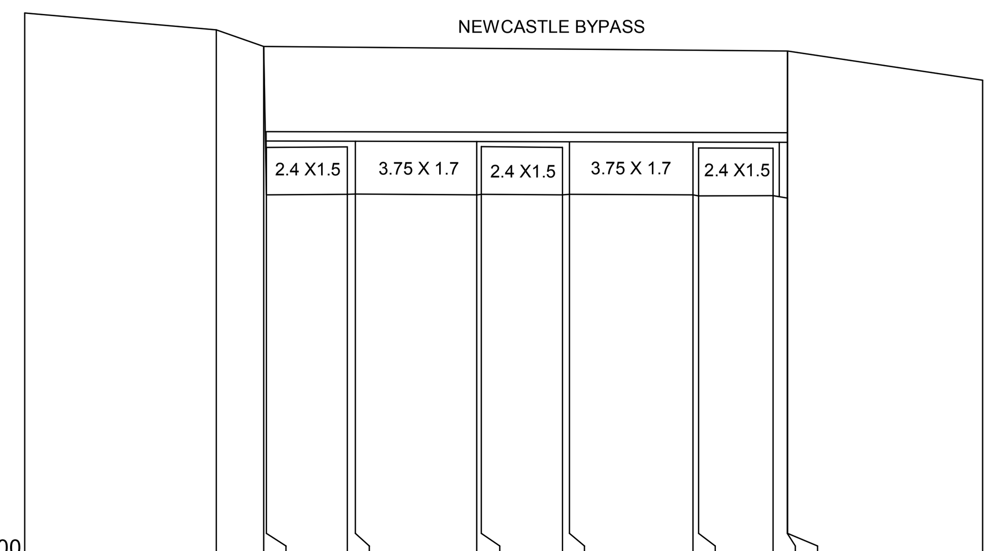
Datum R.L. 15.00

Chainage	NATURAL
0.00	22.42
5.66	22.51
9.39	22.59
9.51	22.44
11.74	20.98
17.61	20.62
22.69	21.13
24.52	22.45
24.86	22.61
28.09	22.39
32.80	22.19

STRUCTURE 14 UP STREAM
FOOT BRIDGE

STRUCTURE 14 UP STREAM
FOOT BRIDGE

NEWCASTLE BYPASS



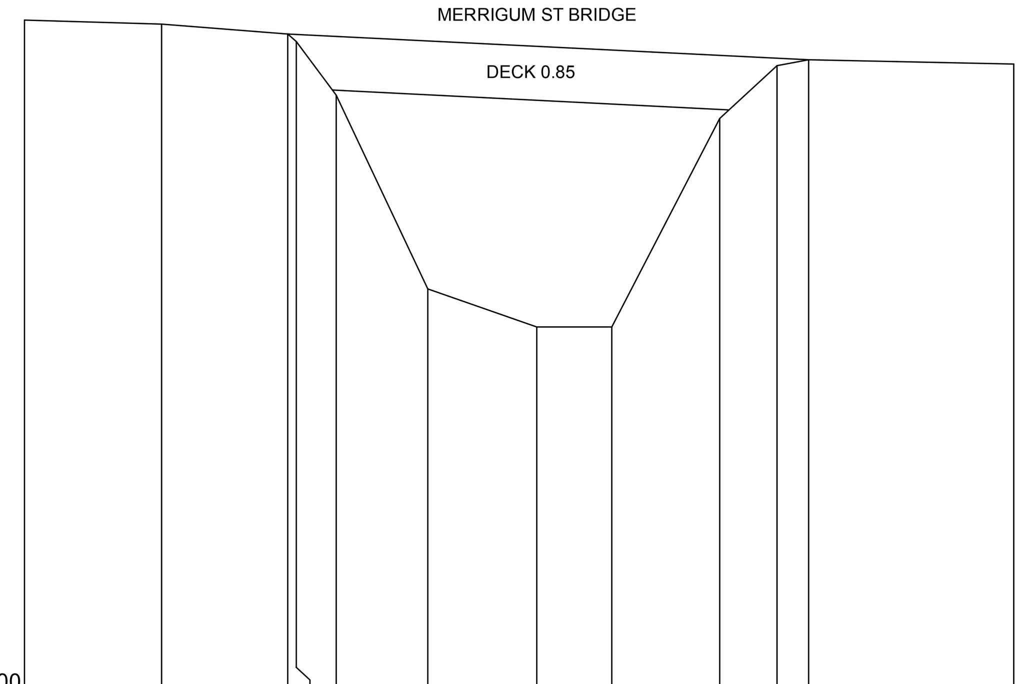
Datum R.L. 6.00

Chainage	NATURAL
0.00	14.62
6.05	14.36
7.55	14.10
7.65	11.75
10.15	11.76
10.45	11.77
14.35	11.75
14.44	11.76
16.99	11.75
17.21	11.76
21.11	11.75
21.30	11.73
23.65	11.74
24.09	11.70
24.10	14.02
30.27	13.56

STRUCTURE 10 UP STREAM
CULVERT

STRUCTURE 10 UP STREAM
CULVERT

MERRIGUM ST BRIDGE



Datum R.L. 12.00

Chainage	NATURAL
0.00	22.62
4.33	22.56
8.32	22.40
8.59	22.28
9.85	21.44
12.75	18.38
16.20	17.78
18.57	17.77
21.97	21.07
23.79	21.90
24.79	22.00
31.27	21.93

STRUCTURE 13 UP STREAM
MERRIGUM ST BRIDGE

STRUCTURE 13 UP STREAM
MERRIGUM ST BRIDGE

VERSION	DATE	COMMENTS	CHK BY	APP'D BY
2	27/7/12	STAGE 2	CMR	PWT
1	9/6/12	STAGE 1	CMR	PWT

CAD FILES: JEWE3477

DRAWN BY: I.NAYLOR | DESIGNED BY: | SURVEYED BY: I.NAYLOR

THIS DRAWING IS AN UNCONTROLLED COPY UNLESS STATED OTHERWISE

SCALE

CROSS SECTION HORIZONTAL 1:200
VERTICAL 1:100

HEIGHT DATUM	COORDINATES	ORIG. SHEET SIZE
AHD	MGA	A1

CLIENT :

Lake Macquarie City Council

PREPARED BY :

CITY PROJECTS ~ SURVEY ~

126-138 MAIN ROAD
SPEERS POINT
PHONE (02)49210 333
FAX (02)49210 535

PROJECT NAME

FLOOD STUDY

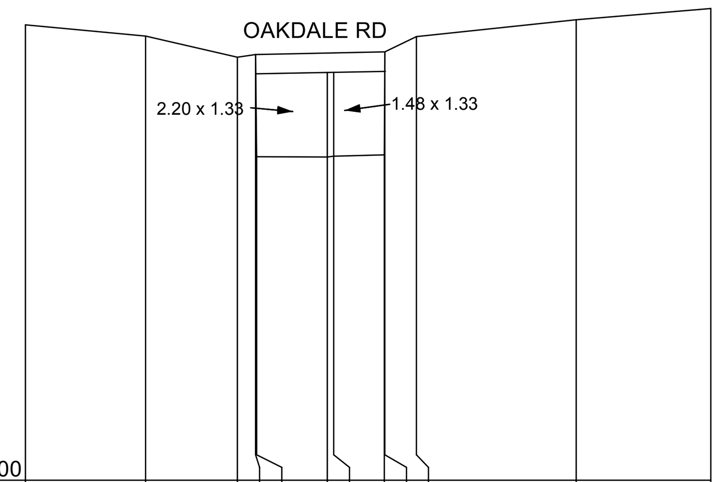
DRAWING TITLE

CROSS SECTIONS

PROJECT ADDRESS & DETAILS

JEWELLS WETLAND AND UPPER TRIBUTARIES

FOLDER NO: PM12\0029\04\01 | SHEET: 4 OF 5 SHEETS | DRAWING No: 3477 | VERSION 2

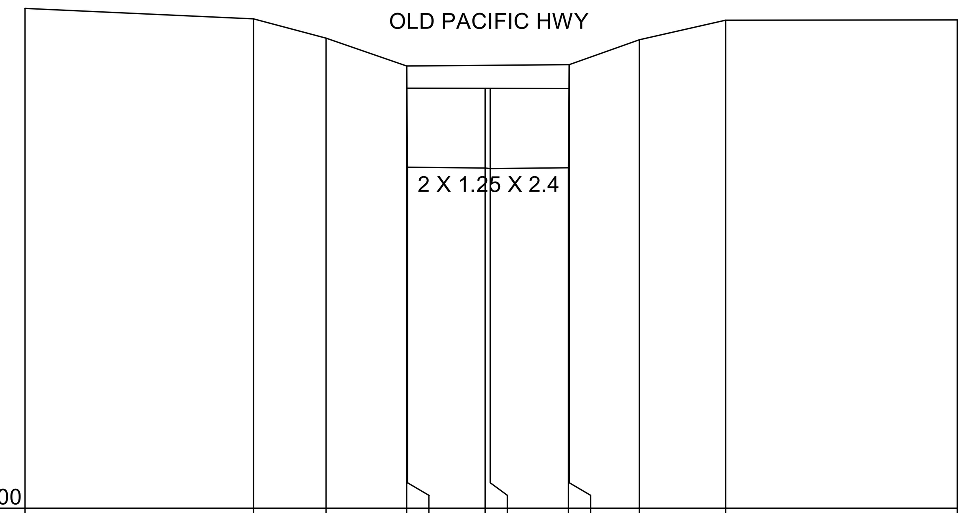


Datum R.L. 7.00

Chainage	NATURAL
0.00	14.20
3.80	14.02
6.71	13.69
7.28	13.73
7.31	12.12
9.55	12.11
9.76	12.13
11.36	12.14
11.37	13.78
12.37	14.02
17.42	14.28
21.69	14.46

STRUCTURE 6
OAKDALE RD/ CULVERT

STRUCTURE 6
OAKDALE RD/ CULVERT

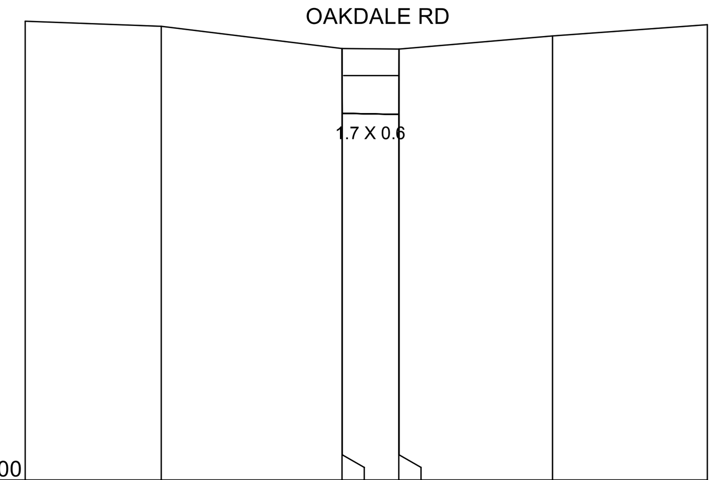


Datum R.L. 6.00

Chainage	NATURAL
0.00	13.90
7.22	13.73
9.52	13.43
12.06	12.99
12.09	11.39
14.55	11.38
14.70	11.37
17.18	11.38
17.20	13.01
19.42	13.40
22.15	13.71
29.47	13.72

STRUCTURE 9
MINOR ACCESS ROAD CULVERT

STRUCTURE 9
MINOR ACCESS ROAD CULVERT

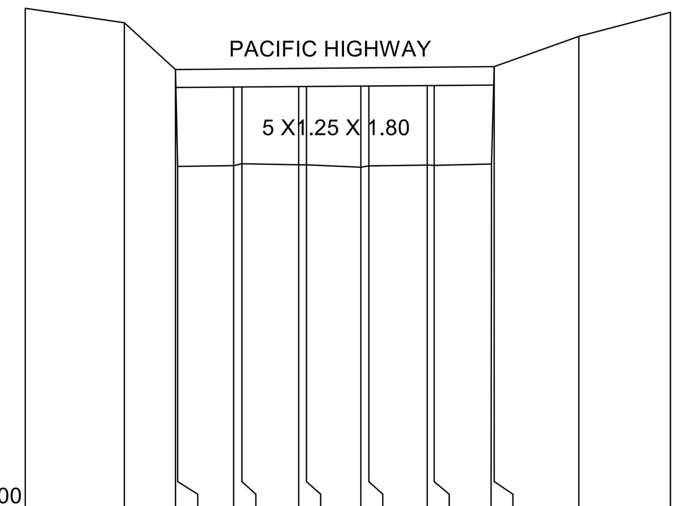


Datum R.L. 7.00

Chainage	NATURAL
0.00	14.25
4.30	14.17
10.02	13.82
10.03	12.80
11.81	12.78
11.82	13.81
16.67	14.02
21.57	14.20

EXTRA STRUCTURE
OAKDALE RD/ CULVERT

EXTRA STRUCTURE



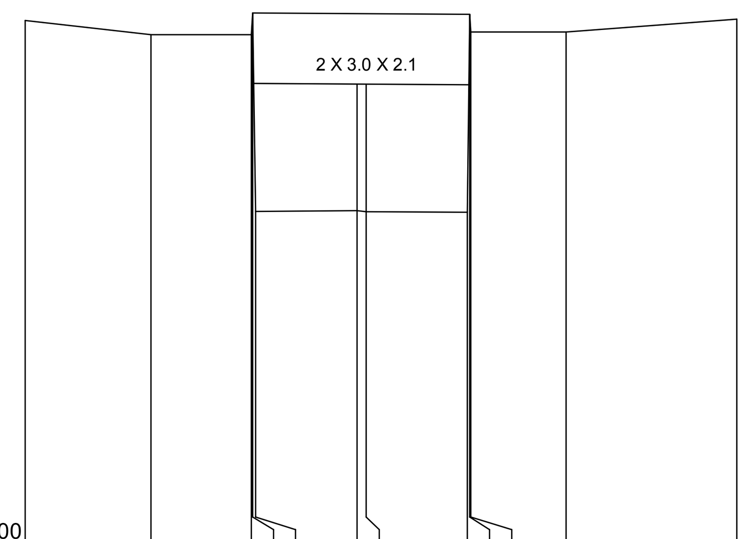
Datum R.L. 6.00

Chainage	NATURAL
0.00	13.89
3.13	13.66
4.75	12.92
4.82	11.39
6.59	11.40
6.85	11.43
8.64	11.41
8.89	11.41
10.60	11.38
10.86	11.39
12.70	11.41
12.93	11.40
14.74	11.42
14.82	12.97
17.50	13.45
20.39	13.83

STRUCTURE 8
PACIFIC HIGHWAY CULVERT

NO PHOTO AVALABLE

STRUCTURE 8



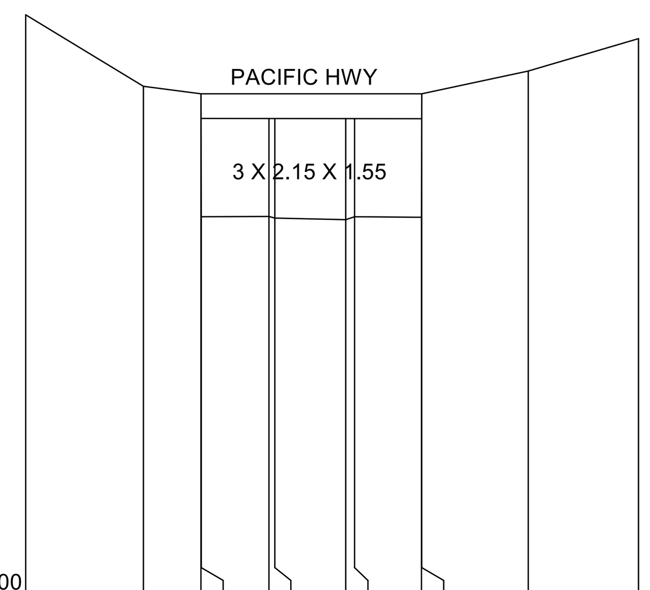
Datum R.L. 7.00

Chainage	NATURAL
0.00	15.25
3.98	15.03
7.15	15.02
7.19	15.37
7.29	12.23
10.50	12.24
10.78	12.22
13.99	12.22
14.06	15.34
14.09	15.06
17.11	15.07
22.51	15.27

Scale Horizontal 1:200 Vertical 1:100

STRUCTURE 5
OAKDALE RD/ CULVERT

STRUCTURE 5
OAKDALE RD/ CULVERT



Datum R.L. 5.00

Chainage	NATURAL
0.00	14.14
3.73	13.01
5.55	12.89
5.55	10.95
7.69	10.95
7.92	10.93
10.13	10.90
10.40	10.95
12.52	10.94
12.53	12.89
15.90	13.25
19.39	13.76

STRUCTURE 7
PACIFIC HIGHWAY CULVERT

STRUCTURE 7
PACIFIC HIGHWAY CULVERT

VERSION	DATE	COMMENTS	CHK BY	APP'D BY
2	27/7/12	STAGE 2	CMR	PWT
1	9/6/12	STAGE 1	CMR	PWT

CAD FILES: JEWE3477
DRAWN BY: I.NAYLOR
DESIGNED BY:
SURVEYED BY: I.NAYLOR

THIS DRAWING IS AN UNCONTROLLED COPY UNLESS STATED OTHERWISE

SCALE
CROSS SECTION HORIZONTAL 1:200
VERTICAL 1:100

HEIGHT DATUM AHD | COORDINATES MGA | ORIG. SHEET SIZE A1

WORK TO FIGURED DIMENSIONS - DO NOT SCALE. CHECK DIMENSIONS AND LEVELS ON JOB BEFORE ORDERING MATERIALS OR COMMENCING WORK. THIS DRAWING IS SUBJECT TO

CLIENT :
Lake Macquarie City Council

PREPARED BY :
CITY PROJECTS ~ SURVEY ~

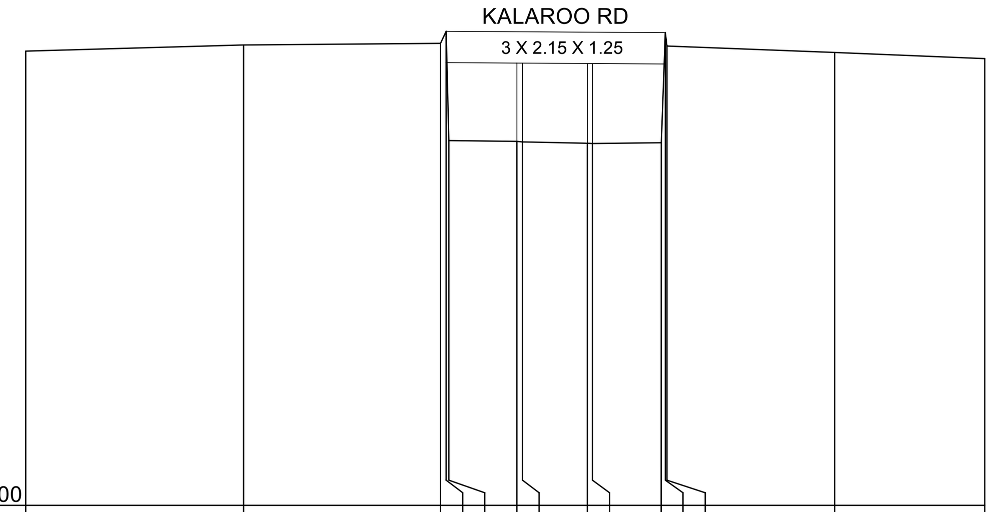
126-138 MAIN ROAD
SPEERS POINT
PHONE (02)49210 333
FAX (02)49210 535

PROJECT NAME
FLOOD STUDY

DRAWING TITLE
CROSS SECTIONS

PROJECT ADDRESS & DETAILS
JEWELLS WETLAND AND UPPER TRIBUTARIES

FOLDER NO: PM12\0029\04\01
SHEET: 3 OF 5 SHEETS
DRAWING No: 3477
VERSION 2

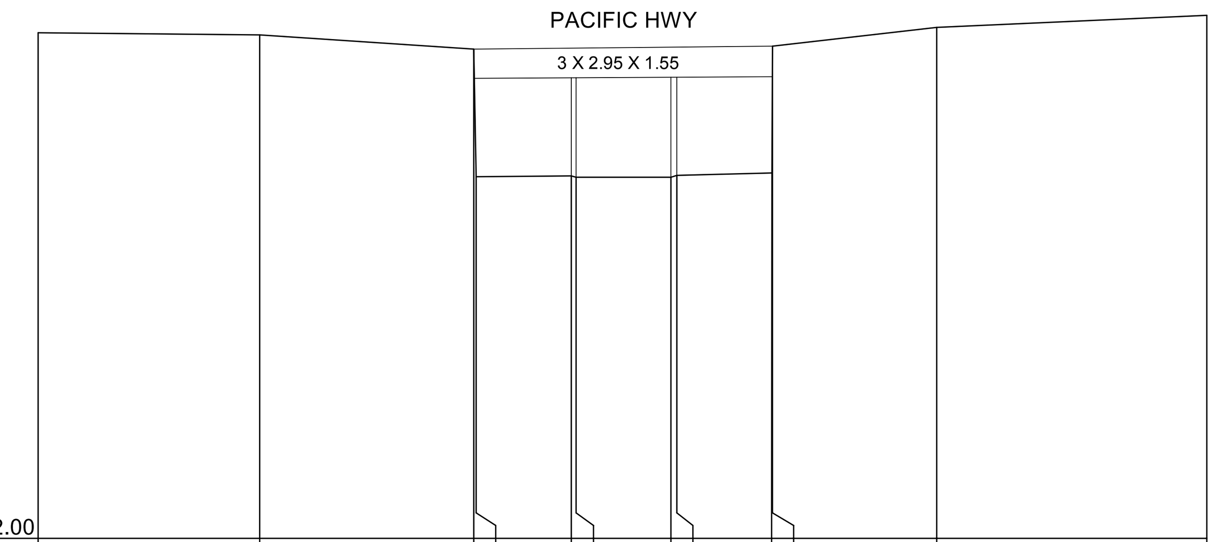


Datum R.L. -3.00

Chainage	NATURAL
0.00	4.18
6.89	4.28
13.11	4.30
13.28	4.49
13.37	2.77
15.52	2.75
15.70	2.75
17.75	2.72
17.90	2.72
20.07	2.73
20.21	4.47
20.26	4.26
25.56	4.16
30.31	4.06

STRUCTURE 2B
KALAROO RD

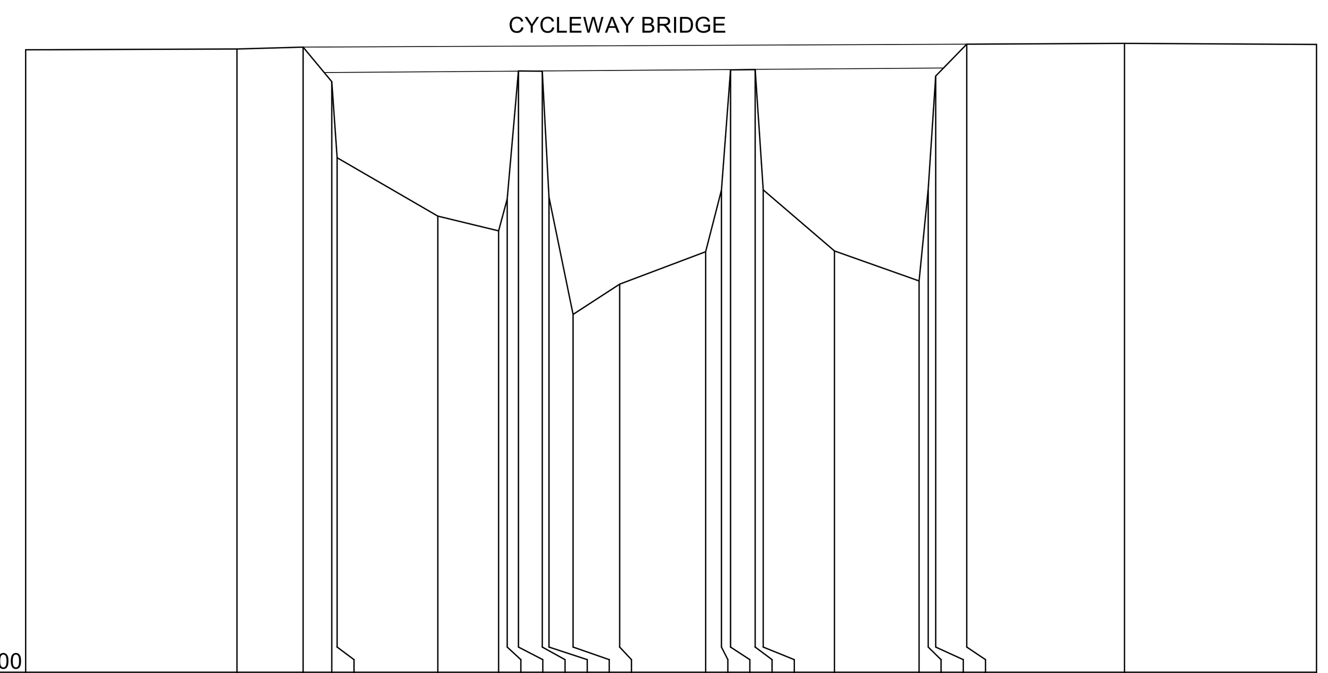
STRUCTURE 2B
KALAROO RD



Datum R.L. 2.00

Chainage	NATURAL
0.00	9.98
7.00	9.95
13.76	9.73
13.84	7.71
16.84	7.72
17.00	7.70
19.99	7.70
20.18	7.73
23.17	7.75
23.20	9.77
28.39	10.07
36.92	10.26

STRUCTURE 4
PACIFIC HIGHWAY SOUTH BOUND



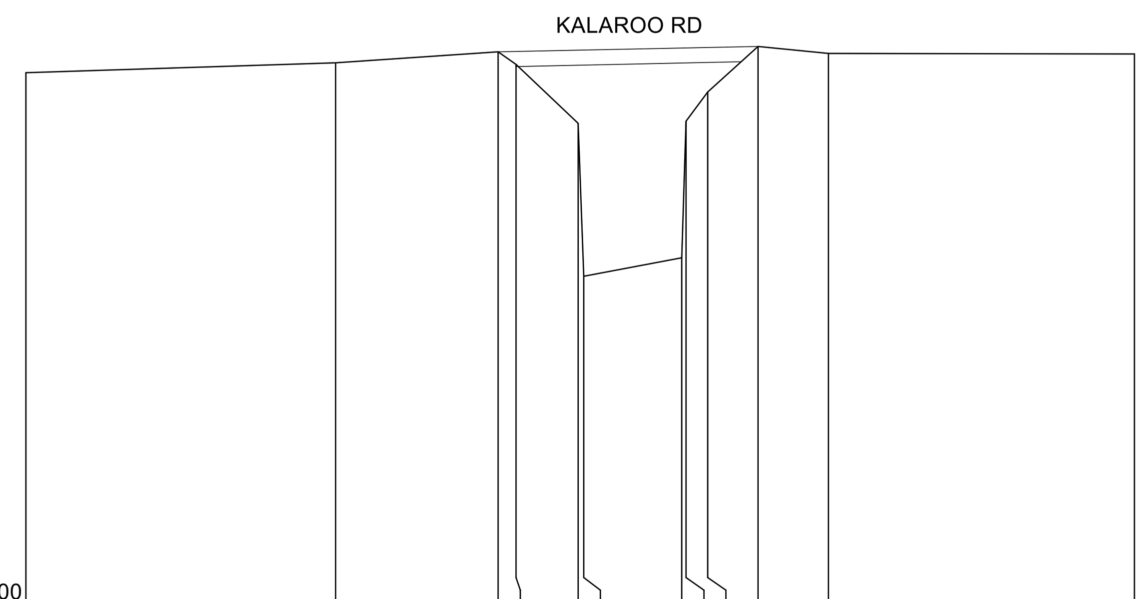
Datum R.L. -4.00

Chainage	NATURAL
0.00	5.84
6.68	5.85
8.76	5.88
9.67	5.33
9.85	4.13
13.03	3.21
14.95	2.98
15.22	3.48
15.58	5.50
16.33	5.50
16.54	3.51
17.30	1.66
18.77	2.13
21.49	2.65
21.99	3.62
22.28	5.52
23.06	5.53
23.32	3.63
25.56	2.66
28.24	2.19
28.53	3.63
28.76	5.42
29.75	5.93
34.74	5.94
40.81	5.92

STRUCTURE 2A
CYCLEWAY BRIDGE

STRUCTURE 2A
CYCLEWAY BRIDGE

STRUCTURE 4
PACIFIC HIGHWAY SOUTH BOUND



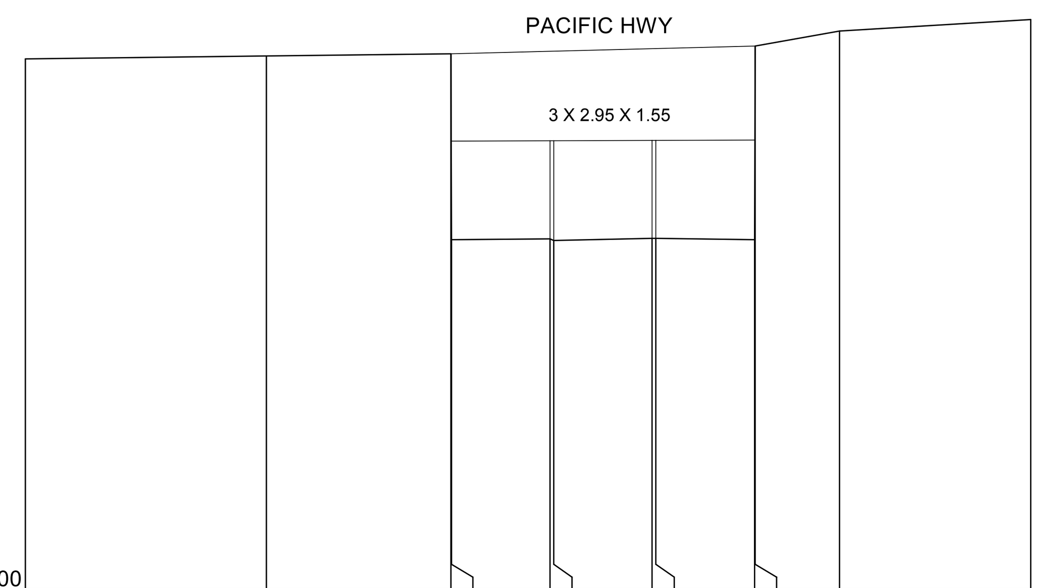
Datum R.L. -2.00

Chainage	NATURAL
0.00	6.38
9.80	6.54
14.94	6.71
15.51	6.51
17.47	5.58
17.65	3.16
20.75	3.45
20.88	5.62
21.56	6.08
23.16	6.80
25.39	6.68
35.07	6.68

Scale Horizontal 1:200 Vertical 1:100

STRUCTURE 1
KALAROO RD

STRUCTURE 1
KALAROO RD



Datum R.L. 2.00

Chainage	NATURAL
0.00	10.39
7.63	10.44
13.45	10.47
13.47	7.53
16.59	7.55
16.71	7.52
19.82	7.55
19.94	7.55
23.06	7.53
23.08	10.59
25.75	10.83
31.78	11.01

STRUCTURE 4
PACIFIC HIGHWAY NORTH BOUND

NO PHOTO AVALIBLE

STRUCTURE 4

VERSION	DATE	COMMENTS	CHK BY	APP'D BY
2	27/7/12	STAGE 2	CMR	PWT
1	13/7/12	STAGE 1	CMR	PWT

CAD FILES: JEWE3477
DRAWN BY: I.NAYLOR
DESIGNED BY:
SURVEYED BY: I.NAYLOR

THIS DRAWING IS AN UNCONTROLLED COPY UNLESS STATED OTHERWISE

SCALE
CROSS SECTION HORIZONTAL 1:200
VERTICAL 1:100

HEIGHT DATUM	COORDINATES	ORIG. SHEET SIZE
AHD	MGA	A1

CLIENT :
Lake Macquarie City Council

PREPARED BY :
CITY PROJECTS ~ SURVEY ~

126-138 MAIN ROAD
SPEERS POINT
PHONE (02)49210 333
FAX (02)49210 535

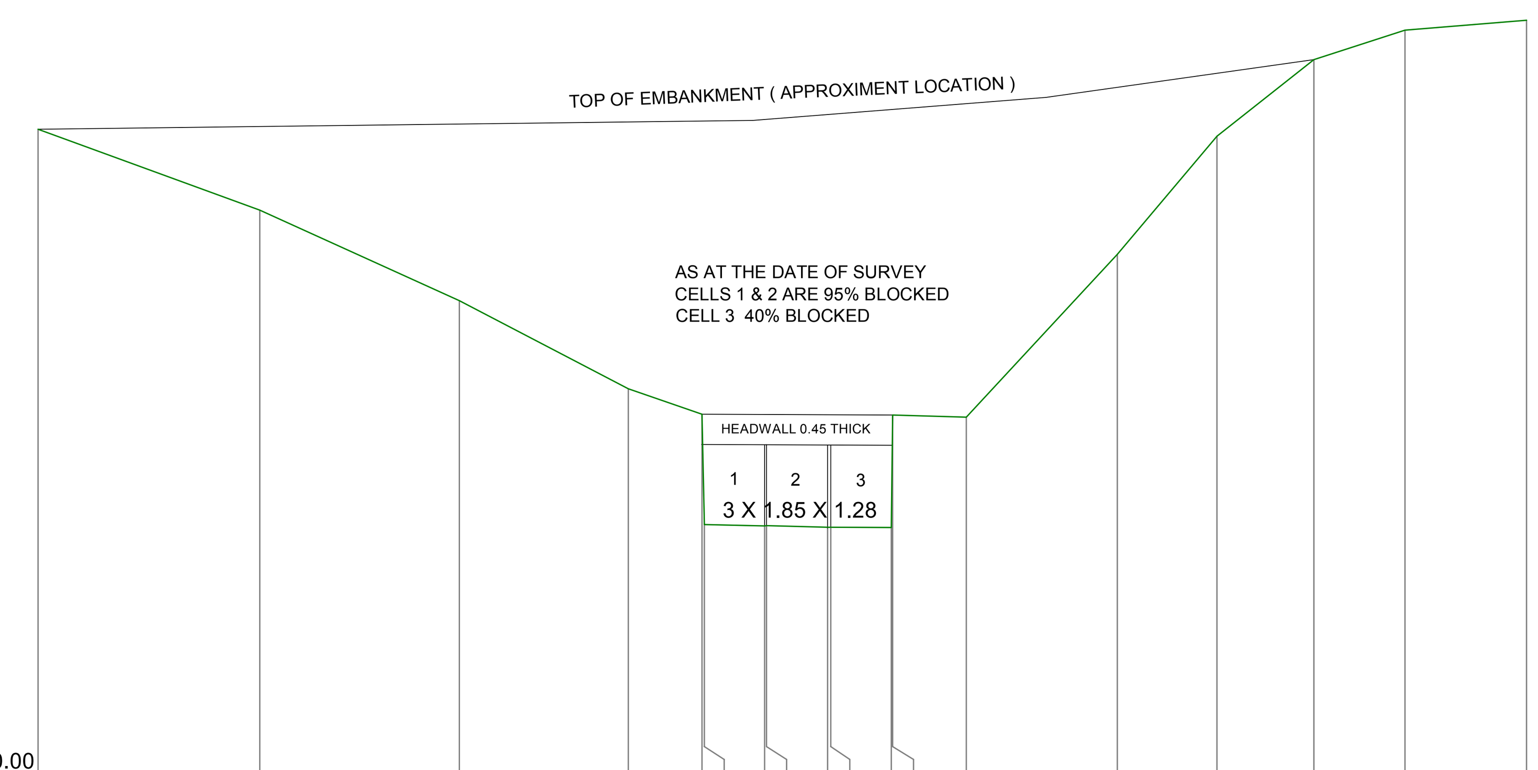
PROJECT NAME
FLOOD STUDY

PROJECT ADDRESS & DETAILS
JEWELL WETLANDS AND UPPER TRIBUTARIES

DRAWING TITLE
CROSS SECTIONS

FOLDER NO: PM12\0029\04\01
SHEET: 2 OF 5 SHEETS
DRAWING No: 3477
VERSION 2

SECTION 2 LOOKING DOWN STREAM



Datum R.L. 0.00

NATURAL	10.16	8.88	7.45	6.06	5.65	3.91	3.89	3.89	3.87	3.87	3.87	5.64	5.61	8.18	10.05	11.26	11.72	11.88
Chainage	0.00	7.01	13.32	18.66	20.99	21.07	22.97	23.03	24.96	25.06	26.98	27.02	29.34	34.12	37.27	40.34	43.21	47.06

Scale Horizontal 1:200 Vertical 1:100

SECTION 2 LOOKING DOWN STREAM

VERSION	DATE	COMMENTS	CHK BY	APP'D BY
1	11/9/12		CMR	PWT

CAD FILES: REDH3569.CCX
DRAWN BY: I.NAYLOR
DESIGNED BY:
SURVEYED BY: I.NAYLOR

SCALE
PLAN 1:2000
CROSS SECTION HORIZONTAL 1:200
VERTICAL 1:100

HEIGHT DATUM AHD
COORDINATES MGA
ORIG. SHEET SIZE A1

CLIENT : Lake Macquarie City Council

PREPARED BY :
CITY PROJECTS ~ SURVEY ~
126-138 MAIN ROAD
SPEERS POINT
PHONE (02)49210 333
FAX (02)49210 535

PROJECT NAME
FLOOD STUDY

PROJECT ADDRESS & DETAILS
FRESHWATER CREEK REDHEAD

DRAWING TITLE
PLAN & CROSS SECTIONS

FOLDER NO: F2011/04755
SHEET: 1 OF 1 SHEETS
DRAWING No: 3569
VERSION 1

OEH 2011 Entrance and Beach Survey

Surveyed data points incorporating entrance channel, beach profile and debris marks

BMT WBM

BMT WBM Brisbane	**Level 8, 200 Creek Street Brisbane 4000** **PO Box 203 Spring Hill QLD 4004** **Tel +61 7 3831 6744 Fax +61 7 3832 3627** **Email bmtwbm@bmtwbm.com.au** **Web www.bmtwbm.com.au**
BMT WBM Denver	**14 Inverness Drive East, #B132** **Englewood Denver Colorado 80112 USA** **Tel +1 303 792 9814 Fax +1 303 792 9742** **Email denver@bmtwbm.com** **Web www.bmtwbm.com.au**
BMT WBM Mackay	**Suite 1, 138 Wood Street Mackay 4740** **PO Box 4447 Mackay QLD 4740** **Tel +61 7 4953 5144 Fax +61 7 4953 5132** **Email mackay@bmtwbm.com.au** **Web www.bmtwbm.com.au**
BMT WBM Melbourne	**Level 5, 99 King Street Melbourne 3000** **PO Box 604 Collins Street West VIC 8007** **Tel +61 3 8620 6100 Fax +61 3 8620 6105** **Email melbourne@bmtwbm.com.au** **Web www.bmtwbm.com.au**
BMT WBM Newcastle	**126 Belford Street Broadmeadow 2292** **PO Box 266 Broadmeadow NSW 2292** **Tel +61 2 4940 8882 Fax +61 2 4940 8887** **Email newcastle@bmtwbm.com.au** **Web www.bmtwbm.com.au**
BMT WBM Perth	**Suite 3, 1161 Hay Street West Perth 6005** **Tel +61 8 9328 2029 Fax +61 8 9486 7588** **Email perth@bmtwbm.com.au** **Web www.bmtwbm.com.au**
BMT WBM Sydney	**Level 1, 256-258 Norton Street Leichhardt 2040** **PO Box 194 Leichhardt NSW 2040** **Tel +61 2 9713 4836 Fax +61 2 9713 4890** **Email sydney@bmtwbm.com.au** **Web www.bmtwbm.com.au**
BMT WBM Vancouver	**401 611 Alexander Street Vancouver** **British Columbia V6A 1E1 Canada** **Tel +1 604 683 5777 Fax +1 604 608 3232** **Email vancouver@bmtwbm.com** **Web www.bmtwbm.com.au**