NORTHERN BEACHES
COUNCIL

ATTACHMENT BOOKLET 5

ORDINARY COUNCIL MEETING

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ITEMS 8.9 - 9.2

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Item No	Subject		

REPORT

McCarrs Creek, Mona Vale and Bayview Flood Study Review

Client: Northern Beaches Council

Reference: 8A0433_RP-01_McCarrs Creek, Mona Vale and Bayview Flood Study Review

Revision: 04/Final For Council Adoption

Date: 07 July 2017

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Enhancing Society Together

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Foreword

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

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

The Policy provides for technical and financial support by the Government through the following sequential stages (refer to the Floodplain Risk Management Process overleaf):

1. Establish Floodplain Risk Management Committee (or Working Group)

Conducts a vital oversight role for the floodplain risk management process, acting as a focus and forum for discussion of key issues in formulating the management plan.

2. Flood Study

Determines the nature and extent of the flood problem.

3. Floodplain Risk Management Study

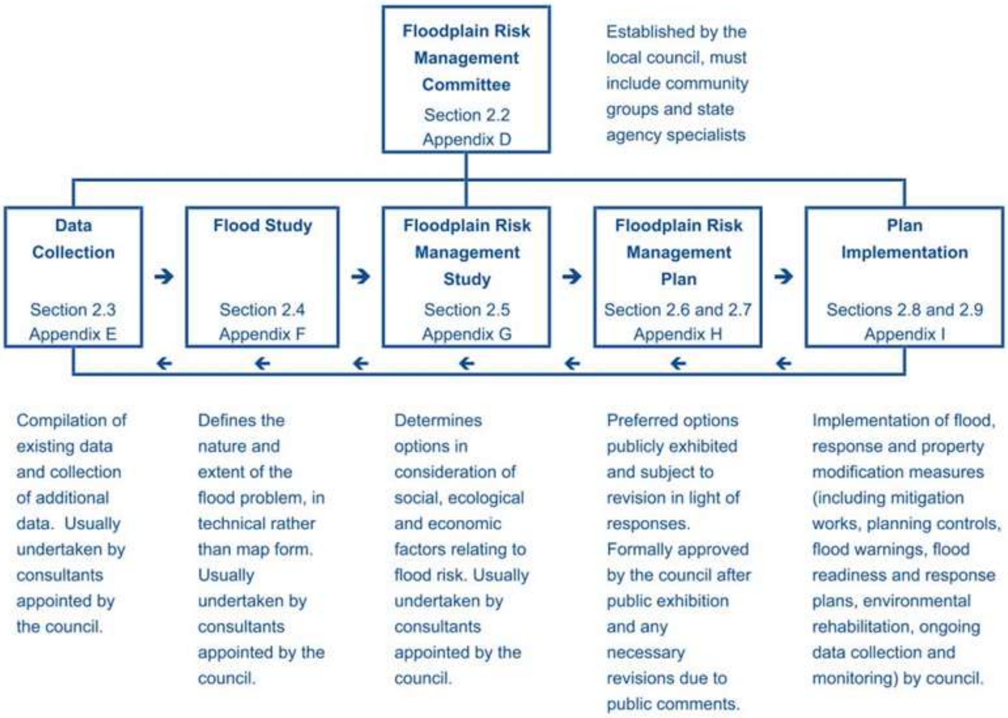
Evaluates management options for the floodplain in respect of both existing and proposed development.

4. Floodplain Risk Management Plan

Involves formal adoption by Council of a plan of management for the floodplain.

5. Implementation of the Plan

Construction of flood mitigation works to protect existing development, and use of flood risk management measures (such as development controls) to ensure new development is compatible with the flood hazard.



The Floodplain Risk Management Process (Floodplain Development Manual, 2005)

Glossary of Terms

annual exceedance probability (AEP)	AEP (measured as a percentage) is a term used to describe flood size. It is a means of describing how likely a flood is to occur in a given year. For example, a 1% AEP flood is a flood that has a 1% chance of occurring, or being exceeded, in any one year. It is also referred to as the '100 year ARI flood' or '1 in 100 year flood'. The term 100 year ARI flood has been used in this study. See also average recurrence interval (ARI).
Australian Height Datum (AHD)	National survey datum corresponding approximately to mean sea level.
attenuation	Weakening in force or intensity
average recurrence interval (ARI)	ARI (measured in years) is a term used to describe flood size. It is the long-term average number of years between floods of a certain magnitude. For example, a 100 year ARI flood is a flood that occurs or is exceeded on average once every 100 years. The term 100 year ARI flood has been used in this study. See also annual exceedance probability (AEP).
catchment	The catchment at a particular point is the area of land that drains to that point.
design flood	A hypothetical flood representing a specific likelihood of occurrence (for example the 100yr ARI or 1% AEP flood).
development	Existing or proposed works that may or may not impact upon flooding. Typical works are filling of land, and the construction of roads, floodways and buildings.
discharge	The rate of flow of water measured in tems of vollume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
flood	A relatively high stream flow that overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood behaviour	The pattern / characteristics / nature of a flood.
flood fringe	Land that may be affected by flooding but is not designated as floodway or flood storage.

flood hazard	The potential for damage to property or risk to persons during a flood. Flood hazard is a key tool used to determine flood severity and is used for assessing the suitability of future types of land use.The degree of flood hazard varies with circumstances across the full range of floods.
flood level	The height of the flood described either as a depth of water above a particular location (eg. 1m above a floor, yard or road) or as a depth of water related to a standard level such as Australian Height Datum (eg the flood level was 7.8 mAHD). Terms also used include flood stage and water level.
flood liable land	see flood prone land
floodplain	Land susceptible to flooding up to the probable maximum flood (PMF). Also called flood prone land. Note that the term flood liable land now covers the whole of the floodplain, not just that part below the flood planning level.
floodplain risk management study	Studies carried out in accordance with the Floodplain Development Manual (NSW Government, 2005) that assesses options for minimising the danger to life and property during floods. These measures, referred to as 'floodplain management measures / options', aim to achieve an equitable balance between environmental, social, economic, financial and engineering considerations. The outcome of a Floodplain Risk Management Study is a Floodplain Risk Management Plan.
floodplain risk management plan	The outcome of a Floodplain Risk Management Study.
flood planning levels (FPL)	The combination of flood levels and freeboards selected for planning purposes, as determined in Floodplain Risk Management Studies and incorporated in Floodplain Risk Management Plans. The concept of flood planning levels supersedes the designated flood or the flood standard used in earlier studies..
flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event. Under the merit policy, the flood prone definition should not be seen as necessarily precluding development. Floodplain Risk Management Plans should encompass all flood prone land (i.e. the entire floodplain).
flood stage	See flood level.
flood storage	Floodplain area that is important for the temporary storage of floodwaters during a flood.
flood study	A study that investigates flood behaviour, including identification of flood extents, flood levels and flood velocities for a range of flood sizes.

floodway	Those areas of the floodplain where a significant discharge of water occurs during floods. Floodways are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
freeboard	A factor of safety usually expressed as a height above the adopted flood level thus determing the flood planning level. Freeboard tends to compensate for factors such as wave action, localised hydraulic effects and uncertainties in the design flood levels.
high flood hazard	For a particular size flood, there would be a possible danger to personal safety, able-bodied adults would have difficulty wading to safety, evacuation by trucks would be difficult and there would be a potential for significant structural damage to buildings.
hydraulics	The term given to the study of water flow in rivers, estuaries and coastal systems.
hydrology	The term given to the study of the rainfall-runoff process in catchments.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
low flood hazard	For a particular size flood, able-bodied adults would generally have little difficulty wading and trucks could be used to evacuate people and their possessions should it be necessary.
m AHD	metres Australian Height Datum (AHD).
m/s	metres per second. Unit used to describe the velocity of floodwaters.
m^3/s	Cubic metres per second or 'cumecs'. A unit of measurement for creek or river flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.
overland flow path	The path that floodwaters can follow if they leave the confines of the main flow channel. Overland flow paths can occur through private property or along roads. Floodwaters travelling along overland flow paths, often referred to as 'overland flows', may or may not re-enter the main channel from which they left; they may be diverted to another water course.
peak flood level, flow or velocity	The maximum flood level, flow or velocity that occurs during a flood event.
probable maximum flood (PMF)	The largest flood likely to ever occur. The PMF defines the extent of flood prone land or flood liable land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with the PMF event are addressed in the current study.

probability	A statistical measure of the likely frequency or occurrence of flooding.
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek.
stage	See flood level.
topography	The shape of the surface features of land
velocity	The term used to describe the speed of floodwaters, usually in m/s.
water level	See flood level.

Executive Summary

BACKGROUND

Northern Beaches Council are responsible for land use planning within the Ingleside, Bayview and Mona Vale areas. The McCarrs Creek, Bayview and Mona Vale Flood Study covers 14 catchments (refer **Figure 1**), 11 of which drain into Pittwater Estuary (McCarrs Creek, Glen Cicada Creek, Gilwinga Drive, Browns Bay, BYRA, Loquat Valley, Fermoy Avenue, Bayview Park catchments, Cahill Creek including Mona Vale Main Drain, Yachtsman's Paradise and Edwin Ward Reserve catchments), 2 of which drain to the Pacific Ocean (Hill Crest catchment and the Mona Vale Golf Course Catchment).

The most relevant previous study, the Mona Vale and Bayview Flood Study, was undertaken by DHI in 1999 on behalf of Northern Beaches (Pittwater) Council using 1D MIKE11 hydraulic modelling. Since this previous flood study was carried out, significant changes in flood modelling capability have occurred, significant development across all the catchments has occurred, as well as the need to assess potential climate impacts.

The present Flood Study has been commissioned by Northern Beaches Council, with assistance from the NSW Office of Environment and Heritage (OEH). This study considers flooding from all sources: local storm runoff, creek flows as well as backwater flooding from tidal influences in the Pittwater estuary and Pacific Ocean.

This report details the results and findings of the Flood Study investigations. The key elements include:

- a description of the study area;
- a summary of available historical flood related data;
- establishment and calibration of the hydrologic and hydraulic models;
- the estimation of design flood behaviour for existing catchment conditions;
- sensitivity analysis of the model results to variation of input parameters;
- potential implications of climate change projections; and
- identification of the level of flood risk for individual properties in the catchment.

COMMUNITY CONSULTATION

A number of communication methods were employed in the community consultation process carried out for this study. This included distribution of a community consultation letter to over 4400 residents and businesses, the establishment of a web-page specifically for this study and an online questionnaire.

The primary aim of the consultation was to inform the community of the projects aims, objectives and timescales and to obtain historic flood information from the community that might benefit the study. In addition, the community consultation has in itself raised awareness of flooding issues across the study area.

A total of 48 responses were received to the online flood questionnaire of which 11 had experienced flooding. Residential flooding was reported in 8 separate events between 1988 and 2014 and included descriptions of flood mechanisms, flow paths, timing, depth, extent as well as flood photos and videos.

A Community Working Group was established including Councillors and representatives from the Community, State Emergency Services (SES), Sydney Water Corporation, Office of Environment and Heritage (OEH) and Roads and Maritime Services (RMS). The Working Group met regularly to discuss project progress and findings through the course of the Flood Study.

HYDROLOGIC AND HYDRAULIC MODELLING PROCESS

The hydrologic modelling was undertaken using a combination of the XP-RAFTS hydrological modelling software for some catchments and a direct rainfall approach within the hydraulic models for the majority of catchments. Hydraulic models were developed for all sub-catchments using a 1D/2D approach in the ESTRY/TUFLOW modelling suite. These models were calibrated to the April 1998 Event and verified against the October 1987 and January 1989 events.

The design rainfall events that were modelled were the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP design events and the Probable Maximum Precipitation (PMP). The temporal patterns for the design events were taken from Australian Rainfall and Runoff (AR&R) (Institute of Engineers Australia, 1987) and the Intensity-Frequency-Duration (IFD) data was taken from the Bureau of Meteorology's (BoM) internet-based tool. The PMP estimates were derived according to the BoM guidelines, the *Generalised Short Duration Method (BoM, 2003).*

OUTCOMES

The study outputs include design flood information such as peak flood levels and velocities, provisional flood hazard, preliminary hydraulic categorisation, preliminary flood planning extents and property classification according to Northern Beaches' Development Control Plan (DCP).

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1 Introduction

1.1 Background

Northern Beaches Council (Council) are responsible for local land use planning within the McCarrs Creek, Mona Vale and Bayview catchments, and intend to prepare a floodplain risk management study and plan for these catchments. As a step towards that ultimate aim, Council have commissioned this flood study, which covers all flood prone land in the suburbs of Mona Vale, Bayview, Church Point and Ingleside and considers mainstream, overland and tidal flooding.

Mona Vale, Bayview and Church Point are relatively low lying, urbanised centres in close proximity to the Pittwater estuary. All have heavily modified drainage networks. Ingleside is a steep, rural suburb with some residential development. Importantly it includes the Ingleside Land Release Area, where significant future development plans are scheduled within the study area.

1.2 Catchment Description

The study area is situated approximately 25 kilometres north of the Sydney CBD and encompasses the suburbs of Mona Vale, Bayview, Church Point and Ingleside over 14 sub-catchments totalling an area of 18.2 square kilometres. **Figure 1** shows the study area and the 14 sub-catchments.

The Bayview and Church Point portions of the study area are characterised largely by residential urban development, while the Ingleside area predominantly consists of rural-residential zones and the Ku-rin-gai Chase National Park. Land use in the Mona Vale area is predominantly urban residential with heavily industrial area in the immediate surrounds of the Mona Vale Main Drain. Two golf courses exist within the study area, in the lower portions of the Bayview and Mona Vale areas.

The majority of the 14 sub-catchments drain through traditional pit and pipe stormwater infrastructure and open channels and outlet north into the Pittwater Estuary. The Hillcrest and Mona Vale Golf Course catchments drain through similar stormwater infrastructure to the east and directly into the Pacific Ocean. In larger storm events, bypass flows from the Hillcrest catchment cross the sub-catchment boundaries and accumulate behind Barrenjoey Road, subsequently draining into the Mona Vale Main Drain. The Cahill Creek sub-catchment adjoins the downstream reaches of the Mona Vale Main Drain, eventually draining north to the Pittwater Estuary.

The terrain in the study area ranges from approximately 180 mAHD down to sea level, where the upstream portions of the sub-catchments are generally quite steep and range from 15 - 50% in grade. The lower areas of the Cahill Creek, Mona Vale Main Drain and Mona Vale Golf Course floodplains are generally flat with grades lower than 1%. The relatively natural catchments of McCarrs Creek and Cicada Glen Creek are characterised by steep bushland with longitudinal grades along the creek in the order of 1-5%.

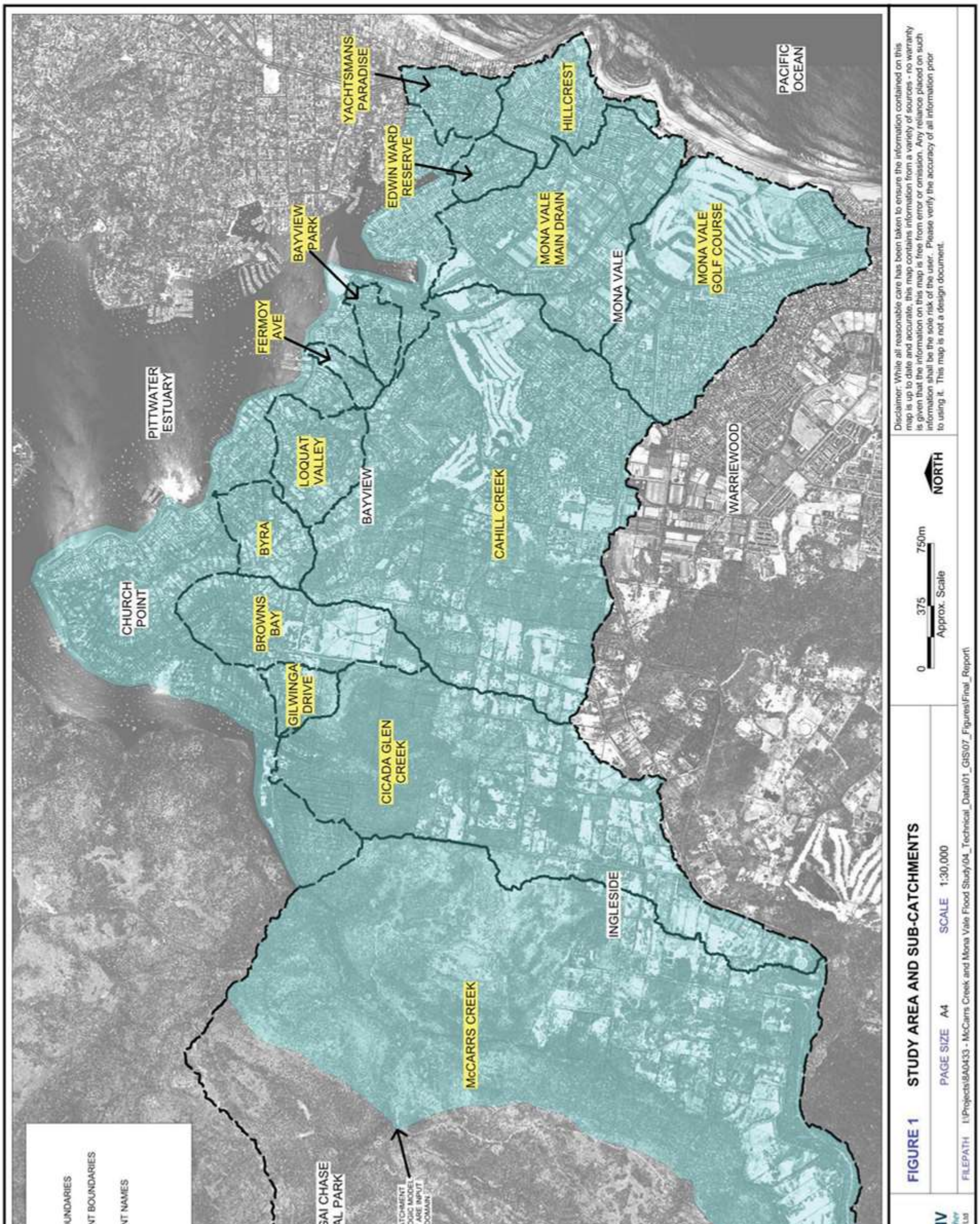
LEGEND
CADASTRAL BOUNDARIES
SUB-CATCHMENT BOUNDARIES
SUB-CATCHMENT NAMES
STUDY AREA
YACHTSMANS PARADISE
HILLCREST
PACIFIC OCEAN
EDWIN WARD RESERVE
MONA VALE MAIN DRAIN
MONA VALE
MONA VALE GOLF COURSE
BAYVIEW PARK
FERMOY AVE
PITTWATER ESTUARY
LOQUAT VALLEY
BAYVIEW
CAHILL CREEK
WARRIEWOOD
BYRA
CHURCH POINT
BROWNS BAY
GILWINGA DRIVE
CICADA GLEN CREEK
INGLESIDE
McCARRS CREEK
KU-RING-GAI CHASE NATIONAL PARK
WESTERN McCARRS CREEK CATCHMENT ONLY INCLUDED IN THE HYDROLOGIC MODEL. FLOWS FROM THIS CATCHMENT ARE INPUT TO THE HYDRAULIC MODEL DOMAIN
0
375
750m
Approx. Scale
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FIGURE 1
STUDY AREA AND SUB-CATCHMENTS
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Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a variety of sources - no warranty is given that the information on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document.

1.3 Study Objectives

The key objective of the Flood Study is to gain a comprehensive understanding of mainstream, overland and tidal flood risk in the above catchments. This study will form the basis of Councils future ability to undertake a Floodplain Risk Management Study and Plan and take sound flood related planning decisions for existing and future developments.

The study was developed for the 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP design events and the Probable Maximum Flood (PMF). The primary objectives of the study are:

- to determine the flood behaviour including design flood levels, velocities and flood extents within the 14 study catchments;
- to determine provisional residential flood planning levels and flood planning area;
- to assess the sensitivity of flood behaviour to potential climate change effects such as increases in rainfall intensities and sea level rise;
- to assess the floodplain categories in accordance with Council policy and undertake provisional hazard mapping; and
- to estimate the potential flood impact of the Ingleside Land Release.

This report details the results and findings of the Flood Study investigations. The key elements include:

- a description of the study area;
- a summary of available historical flood related data;
- establishment and calibration of the hydrologic and hydraulic models;
- the estimation of design flood behaviour for existing catchment conditions;
- sensitivity analysis of the model results to variation of input parameters;
- potential implications of climate change projections;
- to identify the level of flood risk for individual properties in the catchment; and
- description of the potential flood impact of the Ingleside Land Release.

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1.4 Justification for this Study

This Flood Study has been undertaken for the following reasons:

- None of the study catchments, with the exception of the Cahill Creek Catchment, have previously been subject to detailed flood modelling or investigation;
- The Mona Vale - Bayview Flood Study (2002), which studied the Cahill Creek Catchment, is over 10 years old and was undertaken using 1D hydraulic modelling only;
- Recent completion of the 2015 Pittwater Estuary Mapping of Sea Level Rise Impacts Study and the 2013 Pittwater Overland Flow Flood Study highlighted both potential flood risk across the study area and the incompleteness of current knowledge; and
- A need to understand the potential flood risk impacts from the Ingleside Land Release.

1.5 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 details the development of computer models.

Section 5 details the model calibration and validation process.

Section 6 presents the design flood conditions.

Section 7 discusses model sensitivity.

Section 8 reviews relevant literature relating to climate change within the study area.

Section 9 outlines appropriate development controls in the sub-catchments.

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2 Study Approach

2.1 Available Data

The data used for this study is presented and discussed in the following sections.

2.1.1 Previous Studies

Mona Vale - Bayview Flood Study, DHI (2002)

This report details the Flood Study undertaken by DHI on behalf of Northern Beaches (Pittwater) Council for the Mona Vale Main Drain and Cahill Creek sub-catchments. Hydrological modelling was undertaken using RDII, (DHI, 2001), which was an update to DHI's hydrological model, MOUSENAM. One-dimensional hydraulic modelling was undertaken using MIKE11, (DHI, 2001). Calibration of these models was undertaken for a storm event in April of 1998. Two events in January 1989 and October 1987 were used to verify the model calibration.

Pittwater Overland Flow Mapping and Flood Study, Cardno (2013)

This study identified properties and areas potentially affected by overland flow rather than "mainstream" flooding. A full dynamic two-dimensional (2D) SOBEK hydraulic model was used to define the overland flow behaviour under existing conditions and climate change scenarios. A range of flood events were considered, including the 5, 20, 100 year ARI and PMF events. Major hydraulic structures were included in the hydraulic modelling which used a 5 x 5 metre cell size.

2.1.2 Topographic Data

Airborne Light Detection and Ranging (LiDAR) survey of the catchment and its surrounds was provided for the study by Northern Beaches Council. This data was collected by two different sources in 2007. RHDHV also provided LiDAR for the study from their Land and Property Information (LPI) database. This dataset was collected in May of 2011.

The 2011 LiDAR dataset was utilised in this study as the time of survey allowed for more accurate representation of the current topographical features in the catchment. The accuracy of this dataset is reported as follows:

- Spatial Accuracy Horizontal = 0.8m
- Spatial Accuracy Vertical = 0.3m
- The accuracy of Aerial Laser Scanning (ALS) data can be influenced by the presence of open water or vegetation (tree shrub or canopy) at the time of the survey.

2.1.3 Pit and Pipe Data

Northern Beaches Council provided an asset database including the locations and dimensions of the majority of stormwater pits and pipes within the study area. The depths from the ground surface to pipe inverts were also included in the database for most entries.

2.1.4 Stream Flow Gauge

The Manly Hydraulics Laboratory (MHL) has been operating a flow gauge on the Darley Street Tributary of the Mona Vale Creek since July 2013. Details of this gauge are presented in **Table 2-1**, below.

Table 2-1: Details of the MHL flow gauge

Station Number	Station Name	Operating Authority	Location	Record Start Date	Record Close Date	Type
2134101	Darley Street, Mona Vale Stormwater	MHL	Mona Vale Main Drain Catchment. North Darley St.	2/07/13	Ongoing	Records discharge in l/s every 5 mins.

Since installation of the flow gauge, there have only been a number of very small events, limiting the gauge's usefulness for the purposes of this study. The largest event on record was equivalent to less than a 1 exceedance year (EY) event (i.e. less than a 1 year recurrence interval).

2.1.5 Historical Flood Level Data

Historical flood level data was obtained from previous reports provided by Northern Beaches Council. For the storm events in 1987, 1989 and 1999, surveyed flood mark information was sourced from the DHI (2002) Mona Vale - Bayview Flood Study. The tabulated flood mark data from this study is presented in **Section 5.1**.

2.1.6 Historical Rainfall Data

Table 2-2 presents the rainfall stations within the vicinity of the study area.

Table 2-2: Details of Rainfall Gauges Within the Vicinity of the Study Area

Station Number	Station Name	Operating Authority	Location	Elevation (m AHD)	Record Start Date	Record Close Date	Type
566145	Avalon Rain (Live)	MHL	Approx. 4km north of study area	-	27/06/94	Ongoing	TBR*/ Pluviometer
566146	Mona Vale Rain (Live)	MHL	Mona Vale Main Drain Catchment	-	27/06/94	Ongoing	TBR*/ Pluviometer
2134111	Narrabeen Creek / Warriewood Rain	MHL	Approx. 1.5km south of study area	-	15/05/98	18/9/2010	TBR*/ Pluviometer
66141	Mona Vale Golf Club	BoM	Mona Vale Golf Club	10	1/02/69	Ongoing	Daily
66183	Ingleside Animal Welfare League	BoM	Cicada Glen Creek Catchment	160	1/01/84	31/12/12	Daily
66059	Terry Hills	BoM	500m south of study area	199	3/01/08	Ongoing	1 min

**TBR – Tipping Bucket Recorder*

2.1.7 Previous Models

1D (MIKE 11) Hydraulics Model

A 1D MIKE11 hydraulic model was developed by DHI in 2002 as part of the Mona Vale and Bayview Flood Study. Some topography data has been extracted from the model and included in this study. The majority of data extracted from this model was situated on the Bayview Golf Course.

2D (SOBEK) Hydraulics Model

This model was developed by Cardno as part of the Pittwater Overland Flow Mapping and Flood Study, Cardno (2013). The SOBEK model uses a 5m x 5m grid with levels assigned by LiDAR data acquired in 2009. The model provided a useful initial cross check of flood results.

2.1.8 Detailed Survey

Detailed survey was gathered by Mepsteads Associates in 2014 as part of this study. A survey brief was prepared following the review of all available data and identification of critical data gaps. Given the size of the total study area, a compromise was made between the survey cost and appropriate

The survey covered a sample number of pits (up to 30) including pit cover, inlet levels, pipe sizes and inlet type. This sample survey was used to verify that the assumptions (outlined in **Section 4.2.5**) used on the pit and pipe asset database were reasonable. In addition, a number of culvert structures were surveyed as well as the thalweg (centreline) and overbanks of a number of open channels.

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2.2 Site Inspections

A number of site inspections were undertaken by RHDHV staff 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 such as embankments and kerbs that may have an impact on overland flooding behaviour;
- Confirmation of the location and configuration of the stormwater drainage pits and outlets;
- Land use types and vegetation characteristics; and
- Location of existing development and infrastructure on the floodplain.

This visual assessment was useful for defining hydraulic properties within the hydraulic model (such as hydraulic roughness) and ground-truthing of topographic features identified from survey.

2.3 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.

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

- Issue of an online questionnaire to obtain historical flood data and community perspective on flooding issues;
- Involvement of community representatives on the Floodplain Management Working Group; and
- Public exhibition of Draft the Report and community information session.

These elements are discussed in further detail in **Section 3**.

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2.4 Development of Computer Models

2.4.1 Hydrological Model

Traditionally, for the purpose of the Flood Study, a hydrologic model is developed to simulate the rate of storm runoff from the catchment. The output from the hydrologic model is a series of flow hydrographs at selected locations such as at stormwater drainage pit inlets, which form the inflow boundaries to the hydraulic model.

In recent years, the advancement in computer technology has enabled the use of the direct rainfall approach as a viable alternative. With the direct rainfall method the design rainfall is applied directly to the individual cells of the 2D hydraulic model.

This is particularly useful for overland flow studies where model results are desired in areas with very small contributing catchments. This study has adopted both a traditional approach (i.e. using a hydrologic and hydraulic model) and the direct-rainfall approach to model different parts of the study area. Details of both model's development are discussed in **Section 4.**

2.4.2 Hydraulic Model

Three TUFLOW hydraulic models (discussed in **Section 4.2**) were developed for this study. The models include:

- two-dimensional (2D) representation of the 14 sub-catchments, covering an area of approximately 18.6 km^2 (complete coverage of the total study area); and
- one-dimensional (1D) representation of the stormwater pipe network.

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

2.5 Calibration and Sensitivity Testing

The hydrodynamic model was primarily calibrated to the April 1998 flood event 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 severity.

The available historical information highlighted only one flood with sufficient data to potentially support a calibration process – the April 1998 event. However, flood information relating to the October 1989 and October 1987 events has also been used to aid the model calibration and validation process.

The calibration and validation of the model is presented in **Section 5**. A series of sensitivity tests were also carried out to evaluate the model. These tests were conducted to examine the performance of the models and determine the relative importance of different hydrological and hydrodynamic factors. The sensitivity testing of the model is detailed in **Section 7**.

2.6 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, which is sometimes referred to as the 100 year Average Recurrence Interval (ARI) flood, 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 Flood Study catchments, design floods were based on design rainfall estimates according to Australian Rainfall and Runoff (IEAust, 1987).

The design flood conditions form the basis for floodplain management in the catchments and in particular design flood planning levels for future development controls. The predicted design flood conditions are presented in **Section 6**.

2.7 Flood Model Results Presentation

Design flood result presentation was undertaken using output from the hydrodynamic model. Figures were produced showing estimated water depth and velocity for each of the design events. The figures present the peak value of each parameter. Provisional flood hazard and hydraulic categories derived from the hydrodynamic model results are also presented.

2.7.1 Map Filtering

Map filtering is a required component for producing flood mapping for this study as the direct rainfall model applies water to the entire domain of the model. In order to produce realistic flood extents, the criteria outlined in **Table 2-3** have been applied to the maps for events up to the 1% AEP Event. **Table** 2-4 presents the criteria applied to the maps for events larger than the 1% AEP Event. An outcome of the filtering process is that "puddles" may become evident within the flood extents. Puddles within the model results can occur for the following reasons:

1. The direct rainfall modelling approach is reliant on the model DEM to determine flood results. The LiDAR data utilised to create the model DEM is filtered by the data supplier, using an algorithm to remove buildings and vegetation from the survey. This filtering process can result in depressions in the DEM which do not reflect actual ground conditions.

2. Underground carparks may formulate puddles from the direct application of rainfall to these cells.

3. Legitimate depressions in the topography such as roadway sag points will collect flows, with no obvious signs of an overland flow path, nevertheless these areas are considered worthy of including in the flood maps.

The handling of puddle flood results is discussed in **Table 2-3** and **Table 2-4** and further below.

Table 2-3: Map Filtering Criteria for Events up to the 1% AEP Event

Filtering Criteria	Justification
Depth ≥ 0.15m	Depths above 0.15m are considered significant and contribute to the flood extent. Depths below 0.15m are only considered significant where flood waters have an associated significant velocity (refer below).
Depth below 0.15m with a velocity depth product > 0.3m²/s	Includes significant flowpaths under 0.15m of depth in the mapping.
Depth below 0.15m with a velocity depth product between 0.025m²/s and 0.3m²/s	These areas are considered local stormwater and were removed from the flood study mapping. The local stormwater extents were provided to Council for management thorugh the stormwater clause of the DCP.
"Puddles" less than 100m² removed from the flood extents	Excludes insignificant "puddles" from direct rain model results.

Table 2-4: Map Filtering Criteria for Events Greater than the 1% AEP Event

Filtering Criteria	Justification
Depth ≥ 0.15m	Depths above 0.15m are considered significant and contribute to the flood extent.
"Puddles" less than 200m² removed from the flood extents	Excludes insignificant "puddles" from direct rain model results.

Further minor editing of flood results was required following the map filtering outlined in **Table 2-3** and **Table** 2-4 to achieve the final flood results. The following additional measures were applied to model outputs:

- Puddles isolated around buildings were removed from the flood extents. These were attributed to the filtering of LiDAR data to remove buildings from the DEM. Areas similarly affected by the filtering of vegetation from the DEM were also removed from the flood extents unless an overland flow path was evident.
- Puddles isolated on underground carparks were removed from the flood extents unless significant flood depth on the adjoining roadway was observed. These areas were attributed to direct rainfall applied to the underground carpark down ramp rather than flooding.

The flood model outputs are described in **Section 6.3** and presented in **Appendix A**.

3 Community Consultation

3.1 Introduction

Community consultation is extremely important in the Flood Study process. A range of consultation and communication methods have been utilised with the following aims:

- Inform the community that the study is being undertaken and its aims and objectives;
- Utilise the communities flood knowledge within the Flood Study; and
- Inform and discuss the Flood Study results with the community and gain their confidence in the findings, and to raise awareness of flooding in the community.

3.2 Property Owner Letter and Online Survey

On 26 September 2014 Council sent all known residential and business addresses within the study area an initial community consultation letter. In total 4,443 letters were sent. A copy of the letter can be found in **Appendix B**.

The purpose of the letter was to inform the community of the study and its aims and objectives, and to request that members of the community submit flood information and knowledge to assist the formulation of the study. The letter also sought community representatives to be part of a McCarrs Creek, Mona Vale and Bayview flood study community working group.

To assist the community in submitting flood information and knowledge, an online questionnaire / survey was set-up using the 'Survey Monkey' software. A link to the survey was included in the letter and on Council's website. A total of 48 completed survey responses were received by 30th October 2014. This represents a 1% return rate to date. Most of the flood information that has been received is anecdotal in nature and therefore has been treated with caution and be subject to verification prior to adoption. A graphical summary of answers to key questions is provided in **Appendix B**.

The following flood related information was collated:

- A property on Eastview Road has experienced annual flooding since its current resident moved in 4 years ago. Flooding occurs under the house and is generally up to 7cm deep. The floodwater flows down the hill and floods the neighbour's property before exiting onto McCarrs Creek Road. The source of flooding is described as heavy rain combined with poor public drainage.
- A property on Minkara Road, Bayview was flooded in 1988. The floodwater flowed through the ground floor level of the property at a depth of approx. 5cm. Water inundated the property for 1 day. This is the only known flood event at the property in the past 26 years. The owner blames the flooding on Council for altering the footpath level outside the property. No flooding has been experienced since 1988 when the footpath level was adjusted by council.
- A property owner on Rednal Street, Mona Vale, who has lived there for 7 years alluded to possible tidal flooding of their garden in 2009 and 2011 but stated they were unsure if flooding had occurred at the dwelling.

- The garden and driveway of a property in Church Point have flooded every year since 2010. The owner has lived at the property for 15 years, which suggests no flooding occurred between 2000 – 2010. Floodwaters flow down the hill onto the property and pond for approx. 1 week. A total of 4 flood videos have been provided to Council.
- The garage of a property on Pittwater Road, Bayview experienced flooding in 2014. The floodwater flowed from the back to the front under the house and ponded for 2 days. The source of flooding is described as overland flow.
- Flooding in Pamela Reserve was reported to have occurred in 2012. The water overtopped the drainage pipe that runs through the park and flowed down the side of a property in Pamela Crescent, Bayview. Blockage by tree debris is reported to be the cause of flooding. The creek in the eastern part of the reserve was flowing fast.
- A property on Crescent Road, Newport experienced a near miss in 2013 and had to sandbag the front door and garage to prevent flow on the street from entering the property. The cause of flooding is reported to be a street drain with insufficient capacity.
- The garage, garden and driveway of a property on Seabeach Avenue has experienced flooding in 2008, 2010 and 2012. Flood depth in the garage is reported to be 20cm. The cause of flooding is described as poor maintenance of the Sea Road near Kennards.
- The owners of a property in Church Point, reported very fast overland flow in 2014 from neighbouring properties across the Council strip and onto the road. The flooding was approx. 25cm deep, 10m wide and flowed for 4 hours.
- A property on Rednal Street, Mona Vale, reported that a King tide caused tidal inundation of their backyard in 2014. This was the only flooding reported in the 3 years the owners have lived at the property.
- Properties along Pittwater Road, Mona Vale are reported to flood whenever there is heavy downpours. Water enters about 6 shop fronts, under the doors, up to a depth of 15-20cms. The flood mechanism is high tide preventing drainage and car wash from Pittwater Road. The water normally recedes with 2 hours.

3.3 Individual Stakeholder Engagement

The following individual project stakeholders have been contacted during the data collection stage of the project.

- **Bayview Golf Course** – Mr David Stone from Bayview Golf Course accompanied Paul Hart, Patrick Carolan and David Mepstead on a tour of the golf course on 9 September 2014. Mr Stone provided some topographic information of the golf course and indicated flood prone areas and flow directions. Mr Stone indicated that the golf course would be interested in participating in the McCarrs Creek, Mona Vale and Bayview flood working group.
- **Mona Vale Golf Course** – Mr Andy Hugill was contacted and access to the golf course arranged for the site visit on 9 September 2014. Flood photos of the golf course from February 1990 have been received via Council.
- **RMS** – RMS were contacted regarding the Mona Vale Road upgrade and widening project. Detailed design drawings of the scheme were received via RMS' design consultants GHD.

3.4 Website

Information on the Flood Study was posted on Councils website (link below) and feedback encouraged via a link to the online flood survey.

http://www.pittwater.nsw.gov.au/environment/natural_hazards/flooding/where_does_it_flood/mona_valebayview

3.5 Community Working Group

Council sought nominations for (via the property owner letter and website) and formed a Community Working Group.

The aim of the working group has been to act as a forum for the discussion of technical, social, economic and environmental issues in an advisory role to Council.

The working group members were:

- 2 x Councillors (Acting as Chairperson)
- Pittwater / Northern Beaches Council Officers (Manager, Catchment Management and Climate Change and
  A/Principal Officer, Floodplain Management)
- 2 x Citizen Representatives
- Bayview Golf Club
- Bayview Church Point Residents Association
- Mona Vale Chamber of Commerce
- NSW Office of Environment and Heritage (OEH)
- State Emergency Service – Warringah/Pittwater Unit and Sydney Northern Region
- Sydney Water
- Roads and Maritime Services

The group has met 3 times (so far) during the flood study, on the following dates:

- 12 February 2015. A presentation on the Flood Study aims and objectives and work thus far were given by Northern Beaches Council and Royal HaskoningDHV.
- 7 May 2015. A presentation on the hydrologic and hydraulic model build and calibration was given by Royal HaskoningDHV.
- 13 August 2015. A presentation on some initial draft Flood Study results was given by Royal HaskoningDHV.

3.6 Ground Truthing and Door Knocking

3.6.1 Ground Truthing Exercise

Preliminary flood maps were produced for the 10% and 1% AEP Events and the PMF Event, using the assumptions documented in this working paper. RHDHV staff undertook a ground truthing exercise with Council on the 6th May 2015 to verify these results against ground features. 14 areas of the floodplain were inspected across the study area. While flooding behaviour of the preliminary design events was generally found to be in line with expectations from the ground truthing exercise, a number of additional features were identified as part of this process which were included in the design event modelling.

3.7 Public Exhibition and Community Information Sessions

The draft flood study report was placed on public exhibition from the 29th February to the 8th of April, 2016. During this time, the community were encouraged to complete submissions to raise any concerns related to the flood study. Along with Council, RHDHV conducted one-on-one information sessions with residents to provide the public with further information and take on board comments from the public. Submissions were collated, resulting in some changes to the flood results presentation (outlined in **Section 2.7**) from the draft flood study results. A response to submissions memorandum was provided to Council with the revised flood results mapping, outlining the key changes for flood results and property affectation.

4 Model Development

For the purpose of a Flood Study, hydrologic and hydraulic models are commonly developed to assess a catchment's flood behaviour.

The **hydrologic model** simulates a catchment's rainfall-runoff processes, estimating stormwater flows that can be used for input into a hydraulic model.

The **hydraulic model** simulates the physical behaviour of water flowing in overland flow paths, watercourses and urban drainage networks and is a useful tool for estimating discharges, flood levels, flow velocities and flood hazard.

As outlined previously, recent developments in computer technology have enabled the efficient use of direct-rainfall modelling. This method combines the two modelling processes by applying rainfall directly to each cell in a two-dimensional hydraulic model. This study has adopted both a traditional approach (i.e. using a hydrologic and hydraulic model) and the direct-rainfall approach to model different parts of the study area (refer to **Section 4.2.1**).

The study area can be broken into three model areas (Refer **Figure 2**) based on catchment characteristics:

1. Model Area 1 – The 'Rural' Catchments. This area encompasses the McCarrs Creek and Cicada Glen Creek catchments, which are characterised as having little existing development area, with predominately rural lands, natural bushland and watercourses. A traditional modelling approach has been taken for these catchments, where both a hydrologic and hydraulic model have been developed using the XP-RAFTS and TUFLOW/ESTRY software packages respectively.

2. Model Area 2 – The 'Pittwater' Catchments. This area includes all of the small, steep highly urbanised catchments that drain into the southern foreshore of the Pittwater estuary. The direct-rainfall approach has been applied to these catchments, as it is an effective way of modelling overland flow paths and discharge to the drainage network in heavily urbanised areas. The TUFLOW/ESTRY software package was used for this area.

3. Model Area 3 – The 'Urban' Catchments. This model area consists of the majority of the study area, including the Cahill Creek and Mona Vale Main Drain floodplains and the Mona Vale Golf Course catchment. The direct-rainfall approach has been applied for this model area for the same reasons given above. The TUFLOW/ESTRY software package was also used for this area.

Royal HaskoningDHV

The following general steps have been undertaken in the development of the hydraulic model:

1. Delineation of the model topography catchment boundaries and drainage networks.
2. Inclusion of other physical characteristics such drainage features (i.e. bridges, stormwater pipes and channels and roughness values).
3. Review of hydrographic data from historic events for inclusion in the modelling (rainfall records, gauged flow and flood levels).
4. Calibration to a number of historic flood events (calibration refers to the adjustment of model parameters within reasonable limits, to best match modelled results to observed historical data).
5. Verification of the model against a number of historic flood events (verification refers to testing the models performance to other historic events without further adjustment to the model parameters).
6. Sensitivity Analysis of the model parameters to measure dependence of the results upon model assumptions.

Once model development is completed, it can be used for the following purposes:

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

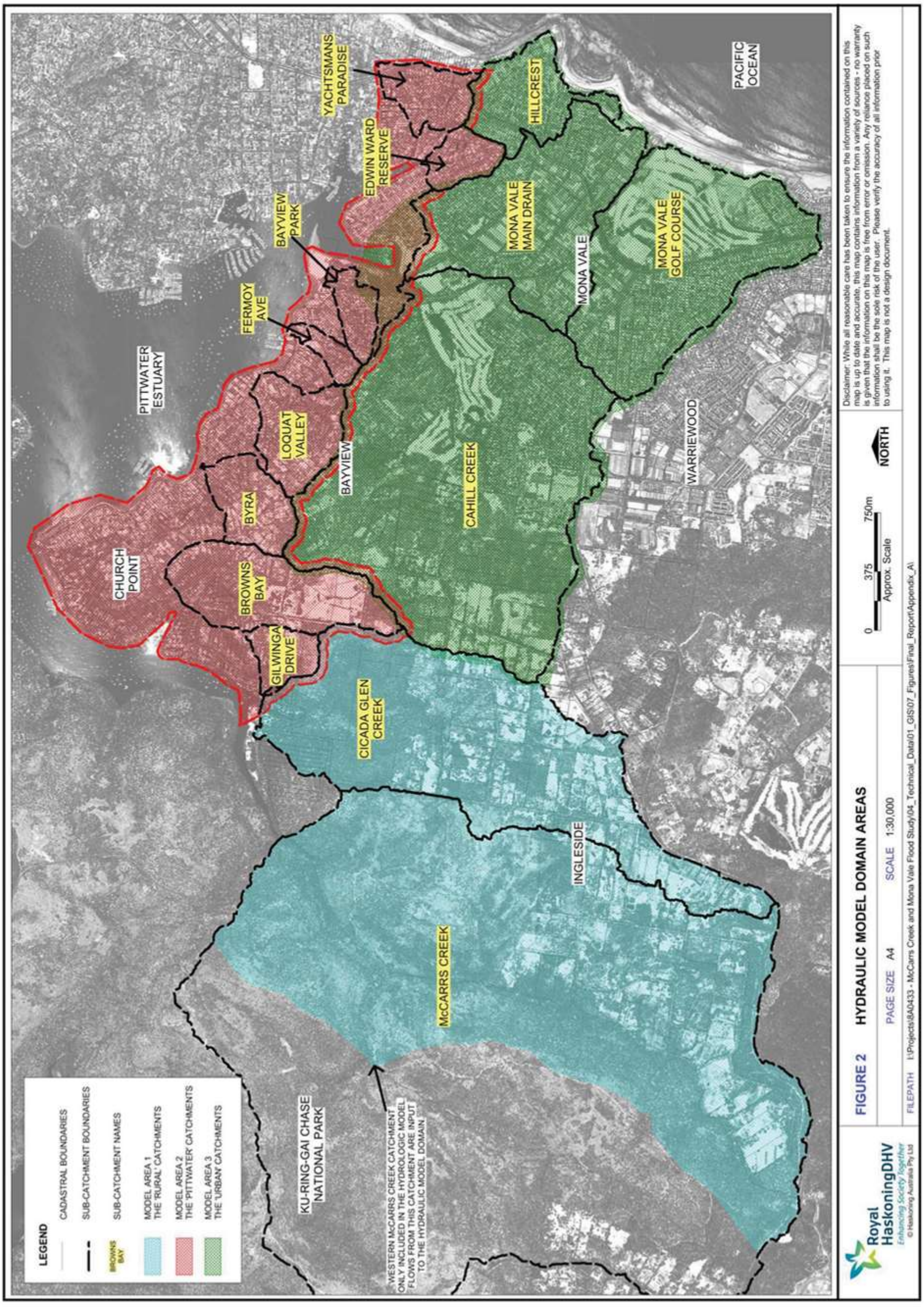
PACIFIC OCEAN
PITTWATER ESTUARY
YACHTSMANS PARADISE
EDWIN WARD RESERVE
BAYVIEW PARK
FERMOY AVE
HILLCREST
MONA VALE MAIN DRAIN
MONA VALE
MONA VALE GOLF COURSE
LOQUAT VALLEY
BAYVIEW
BYRA
CHURCH POINT
BROWNS BAY
GILWINGA DRIVE
CAHILL CREEK
WARRIEWOOD
CICADA GLEN CREEK
INGLESIDE
McCARRS CREEK
KU-RING-GAI CHASE NATIONAL PARK
WESTERN McCARRS CREEK CATCHMENT ONLY INCLUDED IN THE HYDROLOGIC MODEL FLOWS FROM THIS CATCHMENT ARE INPUT TO THE HYDRAULIC MODEL DOMAIN
LEGEND
CADASTRAL BOUNDARIES
SUB-CATCHMENT BOUNDARIES
SUB-CATCHMENT NAMES
MODEL AREA 1 THE 'RURAL' CATCHMENTS
MODEL AREA 2 THE 'PITTWATER' CATCHMENTS
MODEL AREA 3 THE 'URBAN' CATCHMENTS
Royal HaskoningDHV
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FIGURE 2
HYDRAULIC MODEL DOMAIN AREAS
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0 375 750m
Approx. Scale
NORTH
Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a variety of sources - no warranty is given that the information on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document.

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4.1 Hydrological Model

The hydrologic model simulates the rate at which rainfall runs off the catchment. The amount of rainfall runoff from the catchment is dependent on:

- The catchment slope, area roughness due to, vegetation or buildings and fences as well as, and other characteristics;
- Variations in the distribution, intensity and total depth of rainfall; and
- The antecedent conditions (dryness/wetness) of the catchment.

Hydrological modelling was undertaken using the XP RAFTS software package to establish inflow boundaries to the Model Area 1 TUFLOW model. A direct rainfall approach was adopted for Model Area 2 and Model Area 3. The hydrological parameters and approach for both of these methods is discussed in the following sections.

4.1.1 Catchment Delineation

The study area drains an area of approximately 18.6 km^2 through a number of channels, floodplains and drainage networks both north to the Pittwater estuary and east to the Pacific Ocean. The study area can be broken into 14 main sub-catchments (refer **Figure 2**), with some remaining minor overland flow areas in Model Area 2. **Table 4-1** lists these sub-catchments, their associated hydrologic/hydraulic model domain and provides the area each sub-catchment drains.

4.1.2 Rainfall Data

Rainfall information is the primary input and driver of the hydrological model. 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; and
- Temporal pattern – the temporal (time varying) spatial distribution of rainfall depth at a certain time intervals over the duration of the rainfall event.

Both of these properties can 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, significant assumptions regarding the temporal pattern may need to be made.

For design events, rainfall depths have been derived by the estimation of intensity frequency duration (IFD) design rainfall curves for the catchment by Engineers Australia. Standard procedures for derivation of these curves are outlined in AR&R (1987). AR&R (1987) also defines standard temporal patterns for use in design flood estimation.

4.1.3 Rainfall Losses and Catchment Roughness

The rainfall losses are a significant calibration parameter within the hydrologic/hydraulic model and have a major influence on peak flows and runoff volumes within the models. An initial and continuing loss model has been used in both the hydrological modelling and the direct rainfall approach to hydraulic modelling.

Initial losses describe the depth of rainfall that does not contribute to runoff in the initial part of a storm event due to interception and infiltration. These loss values help to describe the catchments antecedent conditions.

Continuing losses are the rate of rainfall that does not contribute to surface runoff once the initial loss has been satisfied, usually caused by ongoing previous surface infiltration.

The catchment and slope roughness parameters govern the speed with which the runoff will travel, influencing the hydrological response of the model. For calibration purposes, generally loss rate and catchment roughness parameters are adjusted to match observed flooding.

The catchment roughness and rainfall loss parameters adopted from the calibration process are discussed in **Section 3**.

4.2 Hydraulic Model

The overland flow regime in urban environments is generally characterised by complex varying flow paths. Road networks often convey a considerable portion of floodwaters due to the hydraulic efficiency of the impervious road surface compared with developed areas consisting of buildings and fences, which act to constrict or redistribute flows. Flow in urban environments is also conveyed through underground pipe networks that drain to downstream watercourses or bodies of water (such as the Pittwater estuary or out to sea). These drainage networks can often be the main escape route for floodwaters for some areas. Given this complex flooding environment, an integrated 1D/2D model approach is prudent for the study area.

TUFLOW/ESTRY is an integrated 1D/2D hydrodynamic model that is commonly used to analyse urban drainage systems. The following approach was applied to the TUFLOW model development:

- Surface flows were simulated within the model domain using TUFLOW's 2D unsteady flow algorithm. This simulation is informed by hydraulic roughness parameters and the model DEM, both of which were established over the study area.
- The pit and pipe drainage system was established in the model as a 1D ESTRY network. The 1D network is integrated (or linked) with the 2D model domain at the pit locations. This enables water to enter the pipe system from the 2D model (i.e. inflows into a pit) and in some cases surcharge from the pipe system to the 2D model domain.

4.2.1 Model Extents and Layout

Considerations for the hydraulic model development included:

- The physical nature of sub-catchments including land use, topography and drainage features;
- Controlling features such as embankments, culverts and bridges;
- The availability and location of calibration data;
- The level of accuracy required to meet the study's objectives; and
- Computational constraints.

As mentioned above, the study area has been broken into three model areas based on the similar nature of the sub-catchments within these model areas. It should also be noted that the only available calibration data for the study is contained within Model Area 3 (the 'Urban Catchments' around Mona Vale area).

Table 4-1 provides a description of each of the model areas and lists their sub-catchments and areas.

Table 4-1: Hydraulic Model Areas

Model Area		Sub-Catchments	Catchment Area	Total Hydraulic Model Area
			km^2	km^2
1	**The 'Rural' Catchments:** Characterised by predominantly natural, bushland catchments with some rural development. Natural watercourses are central to these catchments.	McCarrs Creek Cicada Glen Creek	9.9 2.3	7.6 *
2	**The 'Pittwater' Catchments:** Characterised by a number of small and steep, heavily urbanised catchments and overland flow paths that drain north into the Pittwater Estuary.	Gilwinga Drive Browns Bay BYRA Loquat Valley Fermoy Avenue Bayview Park Edwin Ward Reserve Yachtsman's Paradise	0.1 0.6 0.3 0.3 0.1 0.1 0.1 0.2	4.1 **
3	**The 'Urban' Catchments:** Consists of the larger urbanised catchments with generally flatter floodplains downstream. These catchments drain to both the Pittwater estuary and east to the Pacific Ocean.	Cahill Creek Mona Vale Main Drain Hillcrest Mona Vale Golf Course	3.4 1.1 0.4 1.4	6.9

* Western portion of McCarrs Creek Catchment is not included in hydraulic model.
** Model Area 2 also consists of small steep overland flow areas that are not considered significant sub-catchments for the purpose of this study.

A TUFLOW 2D domain model resolution of 3m was adopted for the study area. It should be noted that TUFLOW samples elevation points at the cell centres, mid-sides and corners, so a 3m cell size provides a Digital Elevation Model (DEM) resolution of approximately 1.5m. The 3m cell size was chosen for the study area as it provides the best compromise between computational efficiency and model accuracy for the study area.

4.2.2 Topography

A high resolution DEM has been developed utilising the following data:

- LiDAR data acquired in May of 2011 (acquired from LPI by RHDHV);
- Previously surveyed information acquired as part of the DHI Study (2002); and
- Detailed survey acquired by Mepsteads & Associates surveyors as part of this study (survey was completed in early 2015).

The DEM derived for this study was built using the LiDAR data as a base input to the TUFLOW model with all additional survey information incorporated using the software's Z-Shape functions. This allows model edits to be easily tracked, complexity to be added to the model over time and guarantees the editing of model cells irrespective of the grid origin and orientation (i.e. using breaklines). Where survey was difficult to collect due to dense vegetation, channel centrelines were lowered in the DEM by a small amount (up to 0.5m), to allow for extra channel capacity that is not represented in the filtered LiDAR data.

Figure 3, **Figure 4** and **Figure 5** show the resultant model DEM's for Model Areas 1, 2 and 3 respectively.

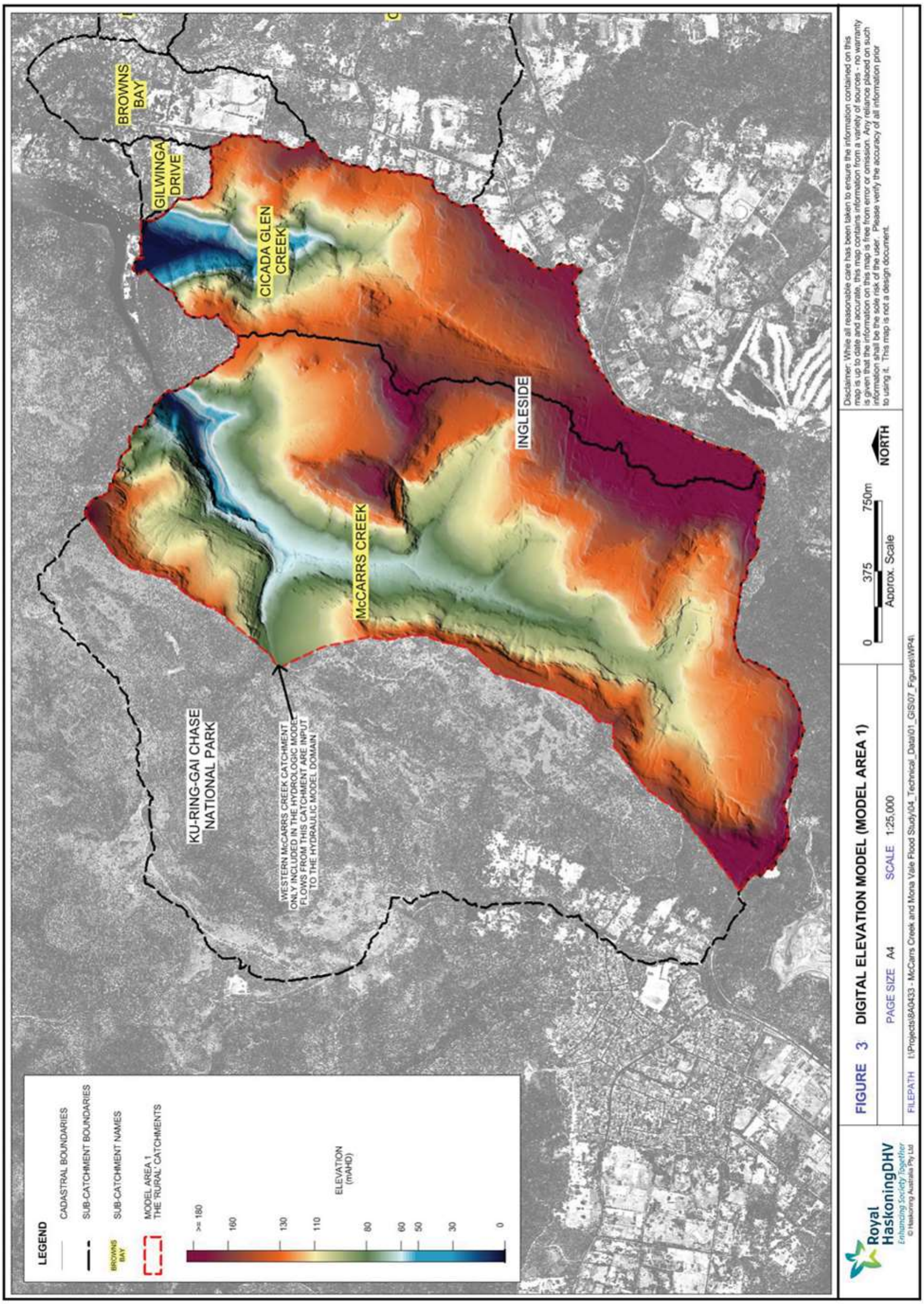
BROWNS BAY
GILWINGA DRIVE
CICADA GLEN CREEK
INGLESIDE
McCARRS CREEK
KU-RING-GAI CHASE NATIONAL PARK
WESTERN McCARRS CREEK CATCHMENT ONLY INCLUDED IN THE HYDROLOGIC MODEL FLOWS FROM THIS CATCHMENT ARE INPUT TO THE HYDRAULIC MODEL DOMAIN
LEGEND
CADASTRAL BOUNDARIES
SUB-CATCHMENT BOUNDARIES
SUB-CATCHMENT NAMES
MODEL AREA 1 THE 'RURAL' CATCHMENTS
ELEVATION (mAHD)
>= 180
160
130
110
80
60
50
30
0
0
375
750m
Approx. Scale
NORTH
Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a variety of sources - no warranty is given that the information on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document.
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FIGURE 3 DIGITAL ELEVATION MODEL (MODEL AREA 1)
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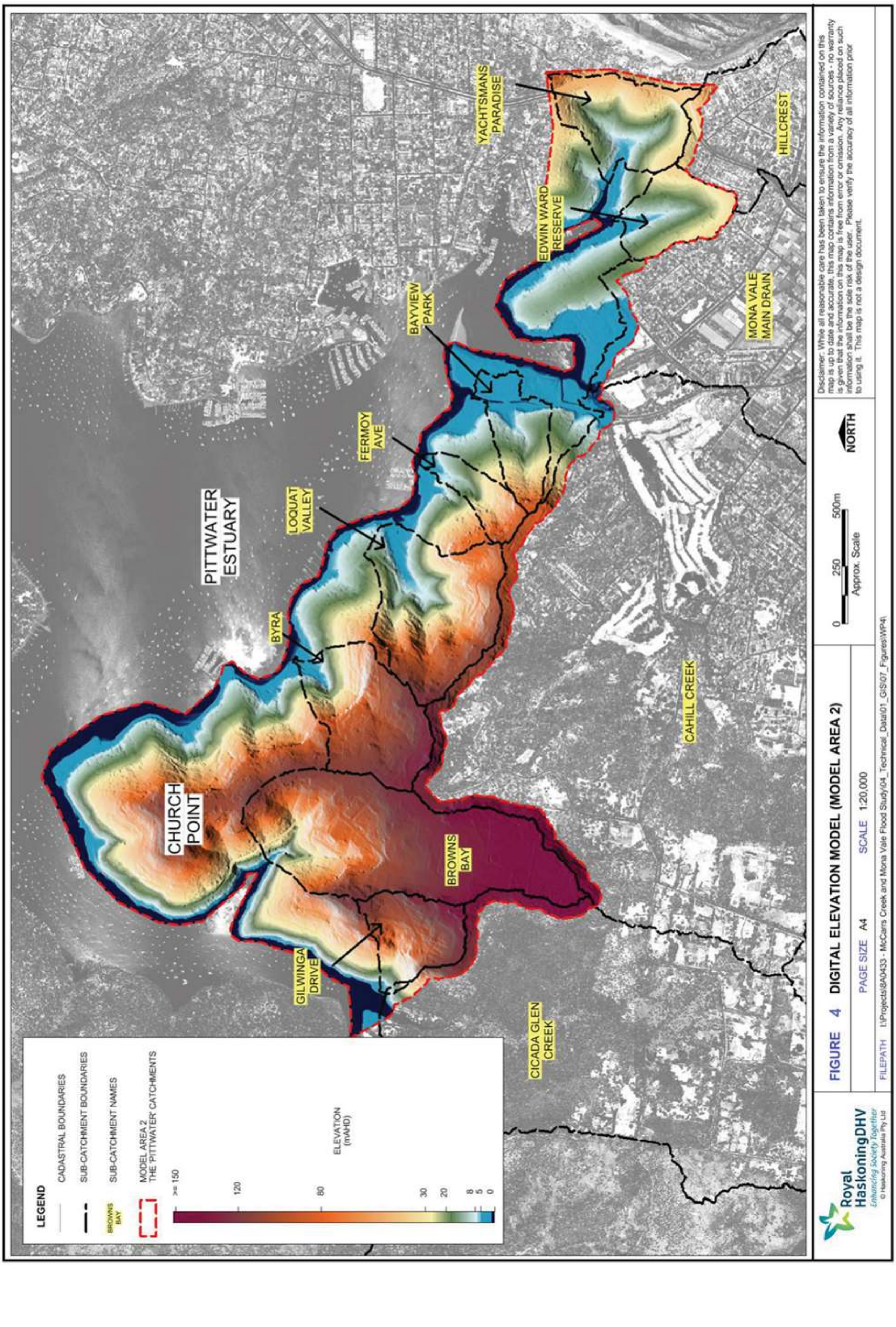
PITTWATER
ESTUARY
CHURCH
POINT
BROWNS
BAY
GILWINGA
DRIVE
BYRA
LOQUAT
VALLEY
FERMOY
AVE
BAYVIEW
PARK
EDWIN WARD
RESERVE
YACHTSMANS
PARADISE
HILLCREST
MONA VALE
MAIN DRAIN
CAHILL CREEK
CICADA GLEN
CREEK
LEGEND
CADASTRAL BOUNDARIES
SUB-CATCHMENT BOUNDARIES
SUB-CATCHMENT NAMES
MODEL AREA 2
THE 'PITTWATER' CATCHMENTS
ELEVATION
(mAHD)
>= 150
120
80
30
20
8
5
0
0
250
500m
Approx. Scale
NORTH
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Enhancing Society Together
FIGURE 4 DIGITAL ELEVATION MODEL (MODEL AREA 2)
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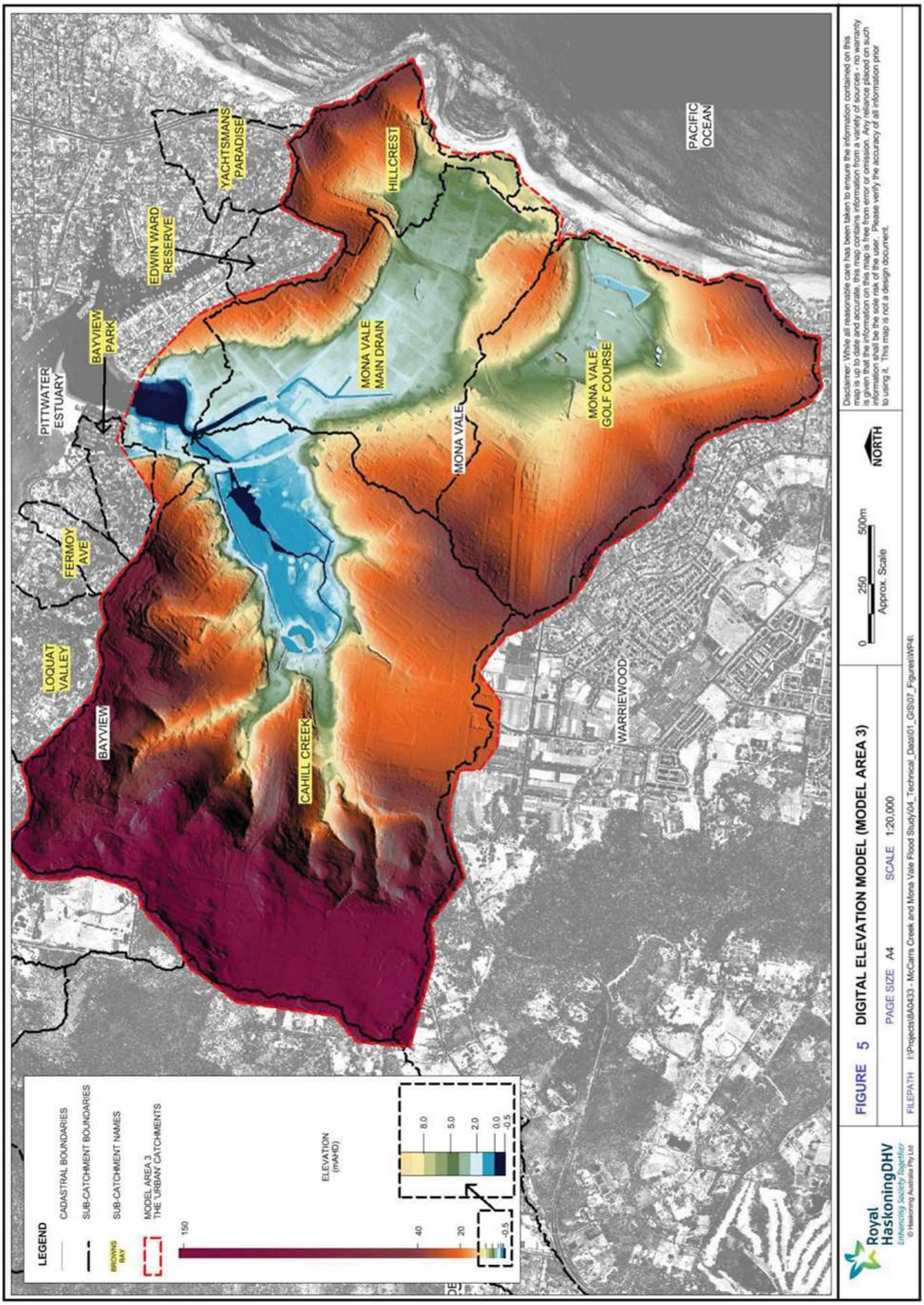

FIGURE 5 DIGITAL ELEVATION MODEL (MODEL AREA 3)

4.2.3 Hydraulic Roughness

The development of the hydraulic model required the assignment of different hydraulic roughness values to different areas of the model based on land-use types. Aerial photography and cadastral information have been used to delineate different land-uses (such as forested areas, cleared land, road reserve, residential allotments etc.) for modelling the variation in flow resistance.

The hydraulic roughness is one of the most important 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 are discussed in **Section 3**.

4.2.4 Modelling of Buildings

Both residential and industrial buildings can act to restrict overland flow, where the industrial buildings are likely to provide a greater disruption. To account for the flow disruption caused by buildings, the following assumptions were made for the hydraulic model:

- Residential dwellings were modelled using higher roughness values for the entire allotment (documented in Section **5.2.4**). This also accounts for flow disruptions associated with fences and other potential debris in residential allotments.
- Industrial buildings in the Mona Vale Main Drain catchment were excluded from the model grid (i.e. fully blocked out for flow) with independent calculations of flow input to the model to account for their excluded catchment area from the direct rainfall model.

4.2.5 Drainage System

The study requires the modelling of the trunk drainage system in each catchment. Council provided information where available on the existing drainage system. This data comprised a GIS layer of pit and pipe locations, along with surveyed details including pipe sizes, pit and pipe depths and pit inlet structures. No information was available for pipe invert levels or pit inlet levels and some local gaps in the data exist where survey of pit depths had not been possible.

Detailed survey was conducted for a number of pits and pipes in the downstream areas of each catchment as part of this study. This survey was used to verify the relative accuracy of assumptions made with the available GIS based pit and pipe data. The following assumptions were made to convert the GIS drainage information into a format reasonable for inclusion in the hydraulic model:

- Pit cover levels were assumed to be equal to the LiDAR surface level at the same location (survey of all pit cover levels in the study area was deemed inappropriate given the size of the study and its objectives).
- In areas where the depth to pipe invert was not available, depths were assumed to equal the pipe size plus an allowance for standard pipe cover (e.g. 600mm).
- These assumptions were then cross-checked against the DEM elevations to take account of any local topographic features and to maintain minimum cover levels. Assumed invert levels were also checked to maintain upstream and downstream pipe gradients, where appropriate.

For this study, the entire trunk drainage network was included in the hydraulic model, where this was defined as pipes with a larger diameter (or box culverts with a greater width) than 450mm. As the study area contains a number of locations that would drain poorly without the inclusion of the entire pipe network, some areas of the model included pipes smaller than 450mm.

The pipe network, represented as a 1D layer in the model, is dynamically linked to the 2D domain at specified pit locations for inflow and surcharge. Pit inlet capacities at each pit have been exaggerated in the model for the following reasons:

1. Only the trunk drainage system has been included in the hydraulic model therefore the exaggeration of pit inlets allows more flow to enter the trunk system in the downstream areas, where in reality it would already be in the underground network (that is, collected in upstream drainage network which is omitted from the model).

2. One of the study's objectives is to produce a map of pipe capacities within the trunk drainage system. By exaggerating the pit inlet capacities, the trunk system is assumed to be 'pipe constrained' and the true pipe capacity of each area of the trunk system can be established.

The modelled trunk drainage system, watercourses included in the modelling and the remaining drainage system (excluded from the model) are shown in **Figure 6** for the study area.

4.2.6 Boundary Conditions

The downstream model limit for each of the hydraulic model areas is as follows:

- Model Area 1 and 2 – The downstream model limit for the rural catchments and Pittwater foreshore models corresponds to the water level in the Pittwater estuary.
- Model Area 3 – Half of the 'Urban' model sub-catchments drain north to the Pittwater estuary and half drain east to the Pacific Ocean at Mona Vale Beach.

Tidal boundary conditions have been predicted for each of the calibration events using tidal constituents for the Pittwater area. For the design events, model boundaries are discussed in **Section 6.2**.

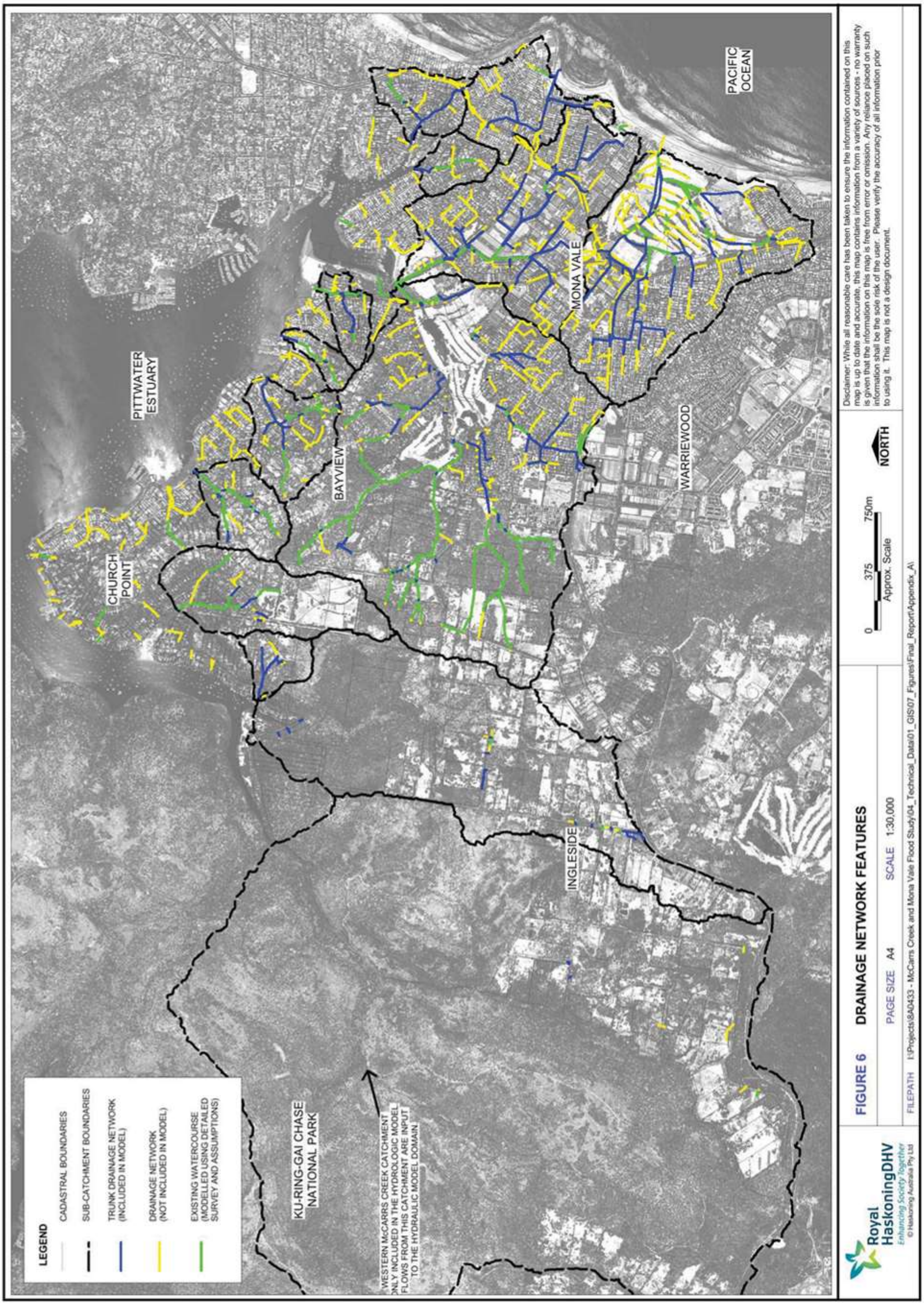
LEGEND
CADASTRAL BOUNDARIES
SUB-CATCHMENT BOUNDARIES
TRUNK DRAINAGE NETWORK (INCLUDED IN MODEL)
DRAINAGE NETWORK (NOT INCLUDED IN MODEL)
EXISTING WATERCOURSE (MODELLED USING DETAILED SURVEY AND ASSUMPTIONS)
PACIFIC OCEAN
PITTWATER ESTUARY
MONA VALE
BAYVIEW
CHURCH POINT
WARRIEWOOD
INGLESIDE
KU-RING-GAI CHASE NATIONAL PARK
WESTERN McCARRS CREEK CATCHMENT ONLY INCLUDED IN THE HYDROLOGIC MODEL FLOWS FROM THIS CATCHMENT ARE INPUT TO THE HYDRAULIC MODEL DOMAIN
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FIGURE 6
DRAINAGE NETWORK FEATURES
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SCALE 1:30,000
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Approx. Scale
NORTH
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5 Hydraulic Model Calibration

5.1 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.

Significant flooding in the study area has occurred on numerous occasions, with the most severe events in recent times including 1977, 1987, 1989, 1990 and 1998. These events were documented in the Mona Vale - Bayview Flood Study undertaken by DHI in 2002.

The Manly Hydraulics Laboratory (MHL) have been operating a flow gauge on the Darley Road Tributary of Mona Vale Creek since July 2013 and a tipping bucket rainfall gauge at Mona Vale since June 1994. Since installation of the flow gauge, there has only been a number of very small events, limiting the gauge's usefulness for calibration of the hydrological models. No new historical flood events have been identified as part of this study.

Table 5-1 identifies the three main events used for calibration/verification in the DHI Study (2002).

Table 5-1: Historical Rainfall Events (DHI, 2002)

Day/Month	Year	Total Depth	Total Duration	Estimated AEP
24 October	1987	99 mm	2 hours	5%
5/6 January	1989	154 mm	24 hours	<20%
10 April	1998	65 mm	1 hour	<5%

No stream flow gauges were operational in any of the three events noted in **Table 5-1**. Surveyed flood marks for these events were gathered as part of the previous DHI Study (2002). These are presented in **Table 5-2** and are located in **Figure 7** . As all of the surveyed flood marks available lie within Model Area 3, this model has been further developed during the calibration exercise. Parameter values chosen during this calibration process have been utilised in other parts of the study area for similar land use types.

Table 5-2: Historical Flood Marks (DHI, 2002)

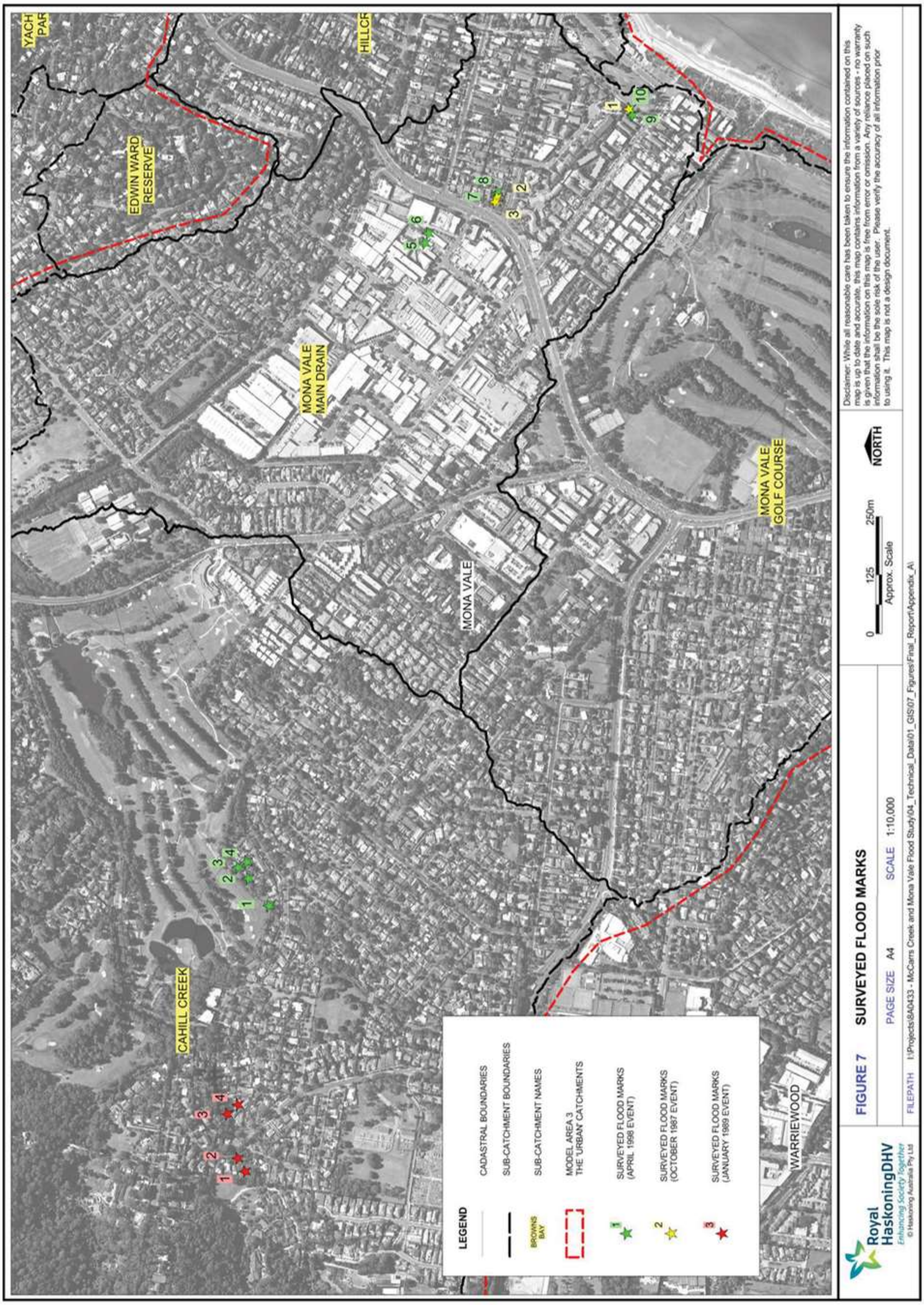
Street Name	Description	Year	Month	Date	Level (mAHD)
Barrenjoey Rd	Circular mark on back side fence	1998	**Apr***	**10**	**3.52**
Barrenjoey Rd	Line mark on back side fence	1987	Oct	24	3.68
Barrenjoey Rd	2cm above garage floor level	1998	**Apr***	**10**	**3.51**
Barrenjoey Rd	Top of brick foundation wall	1987	Oct	24	3.53
Parkland Rd	Ground level half way across back yard	1998	**Apr***	**10**	**1.82**
Parkland Rd	Level on tree on creek channel opposite back yard	1998	**Apr***	**10**	**1.42**
Parkland Rd	Water level on back fence	1998	**May***	**18**	**1.02**
Parkland Rd	Debris mark 1.5 brick courses up back of building	1998	**Apr***	**10**	**1.64**
Samuel St	Debris level on back fence	1989	Jan	5	5.71
Samuel St	Debris level on front wall near front door	1989	Jan	5	5.90
Old Samuel St	Debris level on garden shed	1989	Jan	5	7.54
Old Samuel St	Water level on fence between 4 & 6 Old Samuel St	1989	Jan	5	7.56
Darley St	Debris level on garage door	1998	**Apr***	**10**	**4.77**
Darley St	Debris level on side fence adjacent Apex Park	1998	**Apr***	**10**	**4.74**
Darley St	Water level in back yard near garages	1987	Oct	24	4.75

*Note: Values shown in **bold** were used for model calibration

Of the three main events presented in **Table 5-2**, the April 1998 event was chosen for hydraulic model calibration, with the verification exercise undertaken for the 1987 and 1989 events.

5.1.1 Accuracy of Flood Marks

The surveyed flood marks listed in **Table 5-2** have a relatively unknown level of accuracy. These marks were collected for the DHI study in 2002 predominately from photographs or anecdotal information of the historic events. The accuracy of this information could be affected by a number of factors such as debris marks being overstated from flood waves or misguided anecdotal information. As such, a match of +/- 150mm is considered a reasonable target for the observed and modelled flood levels in the calibration exercise.


EDWIN WARD RESERVE
MONA VALE MAIN DRAIN
MONA VALE
MONA VALE GOLF COURSE
CAHILL CREEK
WARRIEWOOD
LEGEND
CADASTRAL BOUNDARIES
SUB-CATCHMENT BOUNDARIES
SUB-CATCHMENT NAMES
MODEL AREA 3 THE 'URBAN' CATCHMENTS
SURVEYED FLOOD MARKS (APRIL 1998 EVENT)
SURVEYED FLOOD MARKS (OCTOBER 1987 EVENT)
SURVEYED FLOOD MARKS (JANUARY 1989 EVENT)
NORTH
0 125 250m
Approx. Scale
FIGURE 7
SURVEYED FLOOD MARKS
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5.2 April 1998 Model Calibration

A calibration run was undertaken for the model using the April 1998 flood event as this event had the most rainfall and flood level data available. All data for this event was sourced from the Mona Vale – Bayview Flood Study (DHI, 2002).

5.2.1 Recorded Flood Levels

Recorded flood levels for the April 1998 flood event (provided in the DHI flood study of 2002) were located in three different areas of the floodplain. In the Cahill Creek catchment, recorded peak flood levels were available for the rear of properties on Parkland Road adjoining the Bayview Golf Course. In the Mona Vale Main Drain catchment, peak flood levels were available for the properties in Darley Street East, Seabeach Avenue and Barrenjoey Road and in the light industrial areas adjacent to Polo Avenue.

5.2.2 Rainfall Data

Several pluviometers were installed in the Pittwater local government area in 1995. The rainfall records for these stations were used for both the temporal pattern and total rainfall depth aspects of the 1998 storm event. The Warriewood STP gauge temporal pattern was applied to the eastern sub-catchments of Model Area 3 and the Middle Creek gauge temporal pattern was applied to the western sub-catchments. **Figure 8** shows the derived rainfall isohyets for the April 1998 event.

5.2.3 Downstream Boundary Conditions

No recorded tailwater data was available for the 1998 event. As such, a tidal water level boundary was predicted for the period of the April 1998 storm event using available tidal constituents for Pittwater and was applied to both the ocean outlet of the Mona Vale Golf Course catchment and the Pittwater estuary.

The predicted Pittwater time series for the April 1998 event is presented in **Plate 5-1**.

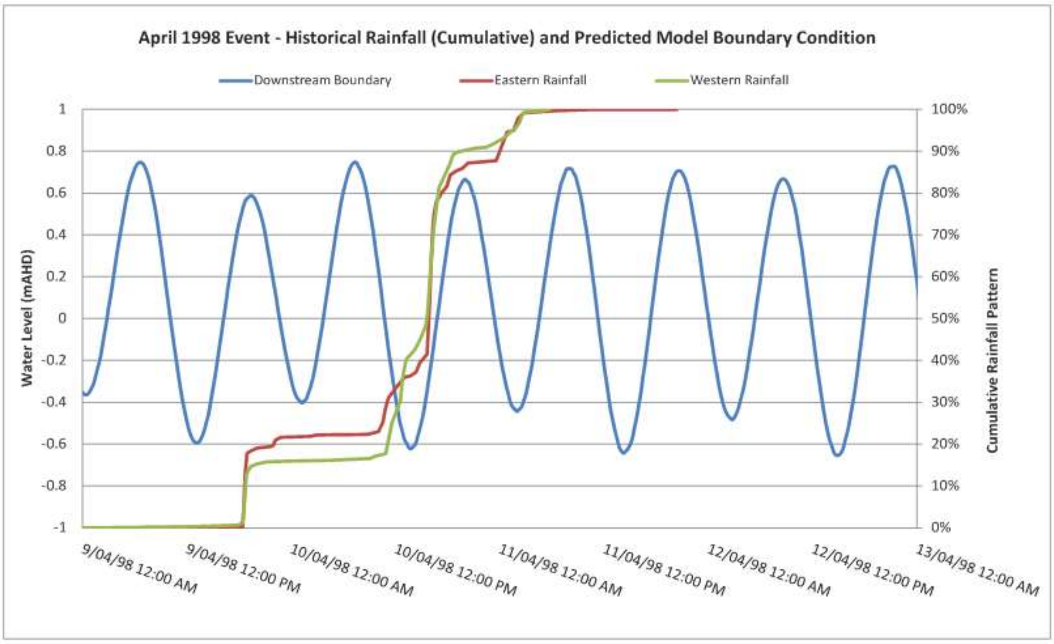

***Plate 5-1:** Recorded Rainfall Pattern and Predicted Model Boundary Condition (1998 Event)*

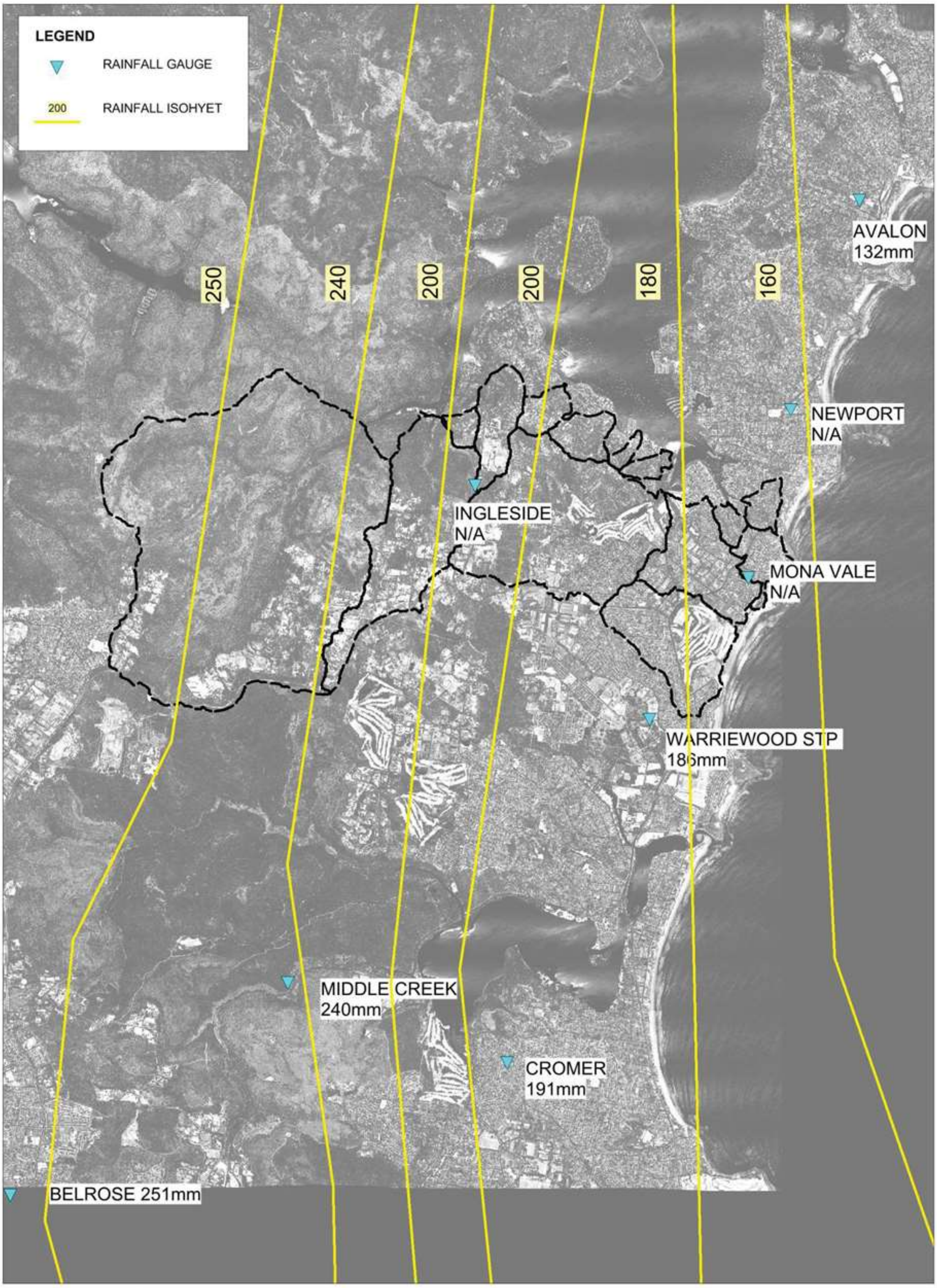

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FIGURE 8 **RAINFALL ISOHYETS (1998 EVENT)**

NORTH 0 0.75 1.5km Approx. Scale SCALE 1:30,000 PAGE SIZE A4

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5.2.4 Adopted Model Parameters

Initial estimates of rainfall losses and hydraulic roughness were assigned to different land uses in the study area following an initial site inspection. These parameters were then adjusted within reasonable limits to achieve a reasonable fit between modelled and historic flood levels. The land use areas adopted for the 1998 calibration event are shown in **Figure 9**. The associated rainfall losses and Manning's roughness values for these land use types are presented in **Table 5-3**.

Table 5-3: Model Material Types, Roughness and Rainfall Losses

Material Type		Hydraulic Roughness	Initial Loss	Continuing Loss
(-)		(n)	(mm)	(mm/hr)
1	Road Reserve	0.020	4	0.25
2	Rural Allotment	0.050	24	2.40
3	Medium Density Allotment	0.200	13	1.30
4	High Density Allotment	0.400	8.6	0.80
5	Industrial Areas	0.050	4	0.25
6	Densely Vegetated Areas	0.100	35	4.50
7	Grassed Areas	0.040	25	2.50
8	Open Water	0.020	0	0.00
9	Vegetated Allotment	0.100	31	4.10
10	Vegetated Channel	0.100	25	2.50
11	Concrete Lined Channel	0.025	1.5	0.00
12	Industrial Channel	0.100	1.5	0.00
13	Medium Density Allotment (Sandy Soil)	0.200	25	2.00
14	High Density Allotment (Sandy Soil)	0.400	20	1.50
15	Grassed Area (Sandy Soil)	0.040	30	2.50

Table 5-3 presents the adopted model parameters required to achieve calibration to the April 1998 flood event (discussed in **Section 5.2.5**). The following items are notable in the table:

- Residential allotments have the highest hydraulic roughness values (0.2 to 0.4) to account for flow disruptions caused by buildings and fences.
- Industrial areas have lower hydraulic roughness as the buildings in these parts of the floodplain have been blocked from the model DEM.
- Losses for material types 13-15 were desired based on need to reduce runoff flow volumes in the Mona Vale Main Drain and Hillcrest Catchments to match historical behaviour. The increase in rainfall losses for these material types is attributed to sandy soils in this area.

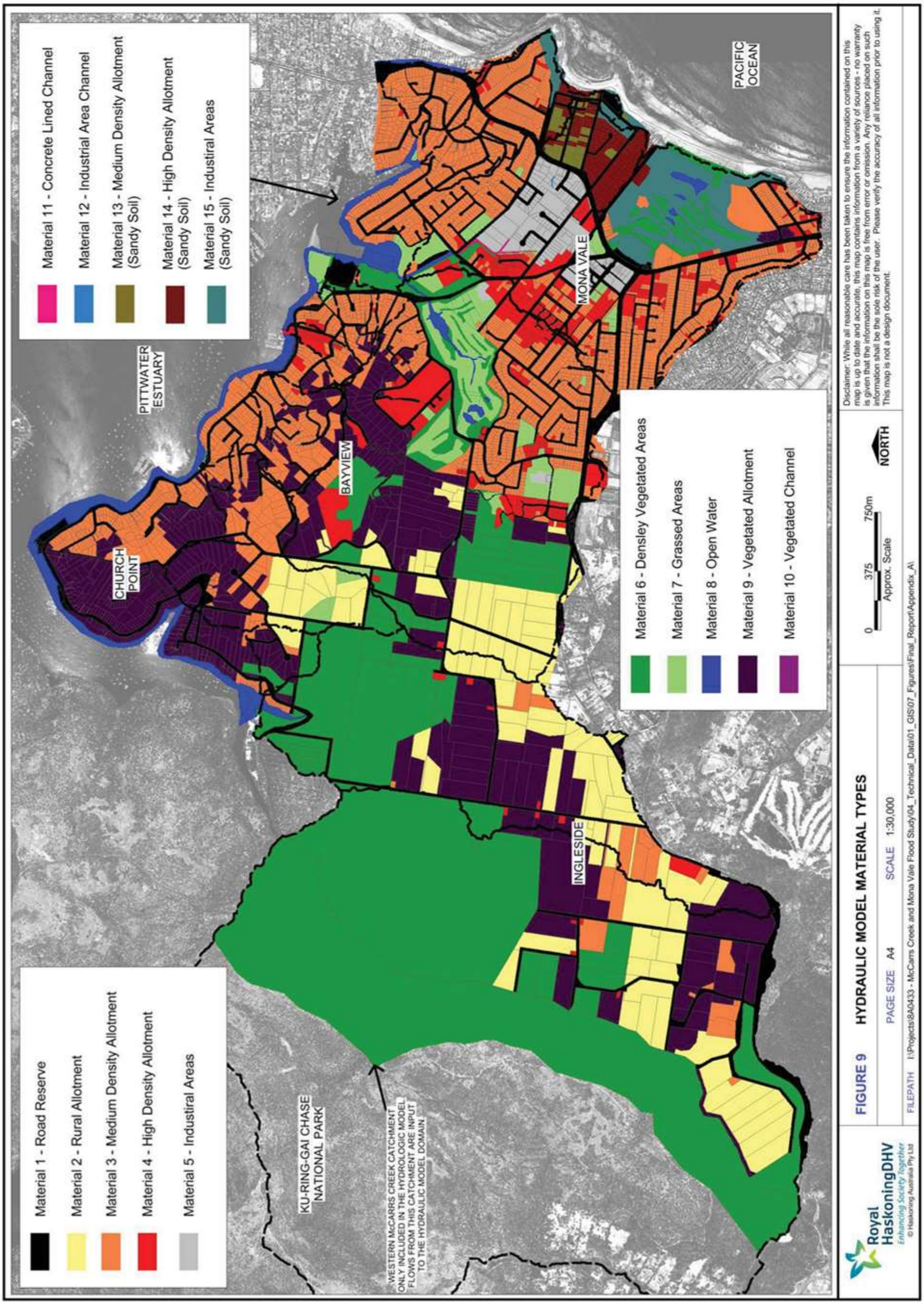
Material 1 - Road Reserve
Material 2 - Rural Allotment
Material 3 - Medium Density Allotment
Material 4 - High Density Allotment
Material 5 - Industrial Areas
Material 6 - Densley Vegetated Areas
Material 7 - Grassed Areas
Material 8 - Open Water
Material 9 - Vegetated Allotment
Material 10 - Vegetated Channel
Material 11 - Concrete Lined Channel
Material 12 - Industrial Area Channel
Material 13 - Medium Density Allotment (Sandy Soil)
Material 14 - High Density Allotment (Sandy Soil)
Material 15 - Industrial Areas (Sandy Soil)
PITTWATER ESTUARY
PACIFIC OCEAN
MONA VALE
BAYVIEW
CHURCH POINT
INGLESIDE
KU-RING-GAI CHASE NATIONAL PARK
WESTERN McCARRS CREEK CATCHMENT ONLY INCLUDED IN THE HYDROLOGIC MODEL. FLOWS FROM THIS CATCHMENT ARE INPUT TO THE HYDRAULIC MODEL DOMAIN
0
375
750m
Approx. Scale
NORTH
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FIGURE 9
HYDRAULIC MODEL MATERIAL TYPES
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5.2.5 Observed and Simulated Flood Behaviour

Comparisons between the recorded and predicted flood levels for the April 1998 flood event are presented in **Table 5-4**.

Table 5-4: 1998 Event Calibration Results

Flood Mark	Surveyed Level (m AHD)	Modelled Level (m AHD)	Difference (m)	Comment
1	**1.42**	**1.82**	**0.40**	**Flood mark considered unreliable***
2	1.82	1.71	-0.11	
3	**1.02**	**1.70**	**0.68**	**Flood mark considered unreliable ***
4	1.64	1.69	0.05	
5	3.16	3.07	-0.09	
6	3.22	3.24	0.02	
7	3.52	3.72	0.20	
8	3.51	3.72	0.21	
9	4.77	4.81	0.04	
10	4.74	4.80	0.06	

** given the vicinity of flood marks with different level*

Table 5-4 shows that the modelled flood level at 6 of the 10 flood marks is within the 150mm target range of the surveyed level, providing a good level of confidence in the models performance. Modelled levels at flood marks 7 and 8 are both 200m above the surveyed level, which is above the target level but not unacceptable. Flood marks 1 and 3 are considered unreliable given the vicinity of other nearby recorded flood marks with differing levels.

5.3 October 1987 Model Verification

A verification run was undertaken for the model using the October 1987 flood event, as this was a regionally significant event and produced the highest recorded flood levels in the Mona Vale Main Drain catchment. All data for this event was sourced from the Mona Vale – Bayview Flood Study (DHI, 2002).

5.3.1 Recorded Flood Levels

Recorded flood levels for the October 1987 flood event (DHI, 2002) were located within the Mona Vale Main Drain catchment upstream of the industrial areas. Peak flood levels were available for properties on Barrenjoey Road and Darley Street.

5.3.2 Rainfall Data

Only one pluviometer near the study area was available for the October 1987 event, the Warriewood STP. The temporal pattern of this gauge was applied to the entire domain of the hydraulic model and rainfall totals for each of the eastern and western sub-catchments were scaled using the rainfall Isohyets shown in **Figure 10**. These were derived from rainfall depths for the event from a number of daily rainfall gauges.

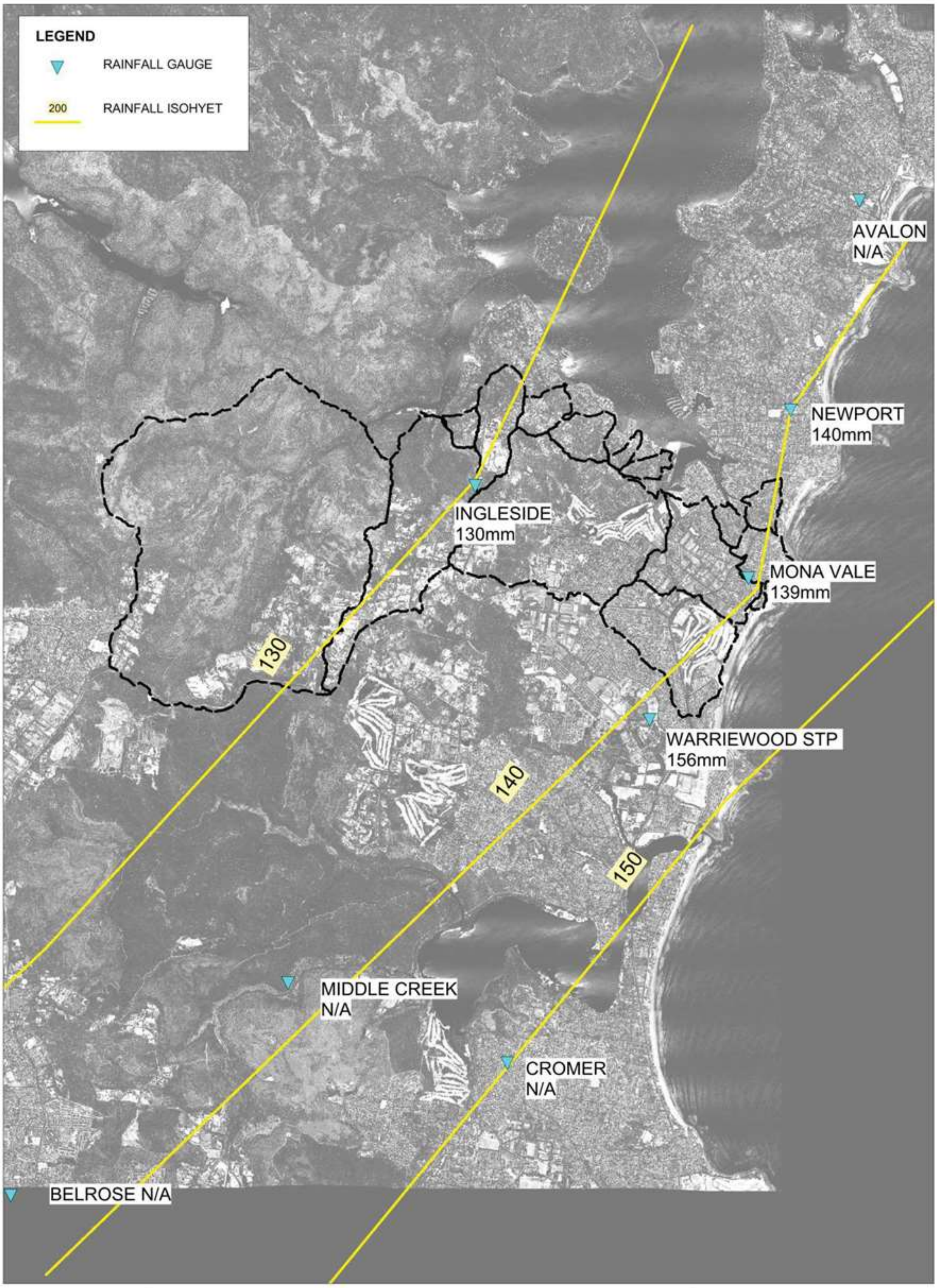

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FIGURE 10 **RAINFALL ISOHYETS (1987 EVENT)**

NORTH | 0 0.75 1.5km Approx. Scale | SCALE 1:30,000 | PAGE SIZE A4

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5.3.3 Downstream Boundary Conditions

No recorded tailwater data was available for the October 1987 event. As such, a tidal water level boundary was predicted for the period of the storm event using available tidal constituents for Pittwater and was applied to both the ocean outlet of the Mona Vale Golf Course catchment and the Pittwater estuary.

The predicted Pittwater time series for the October 1987 event is presented in **Plate 5-2**.

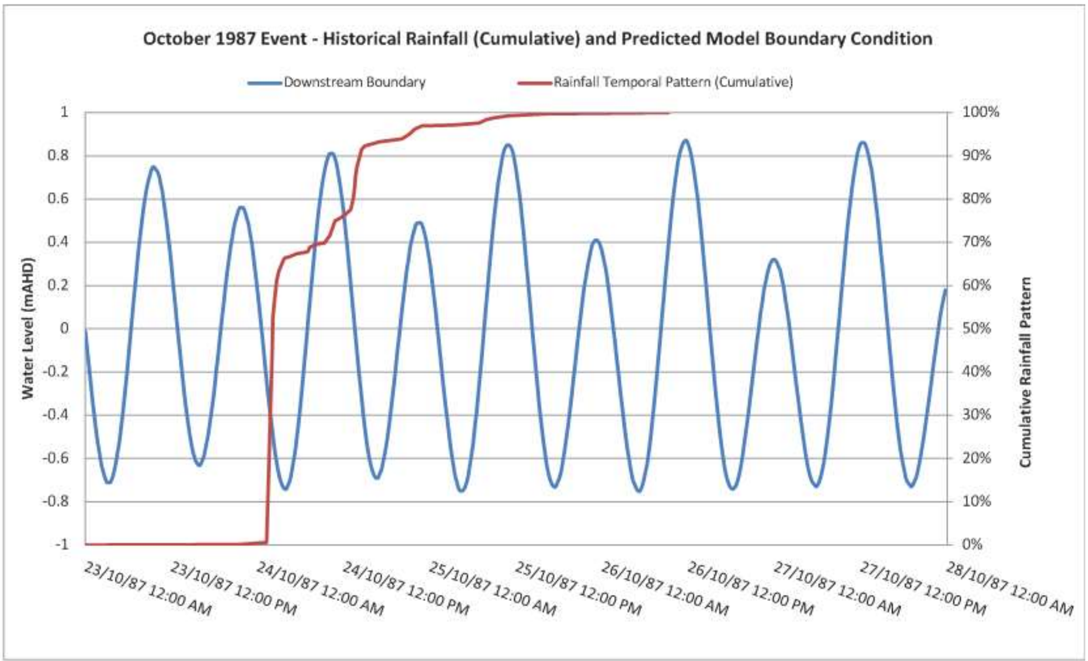

Plate 5-2: *Recorded Rainfall Pattern and Predicted Model Boundary Condition (1987 Event)*

5.3.4 Observed and Simulated Flood Behaviour

Comparisons between the recorded and predicted flood levels for the October 1987 flood event are presented in **Table 5-5.**

Table 5-5: 1987 Event Verification Results

Flood Mark	Surveyed Level (m AHD)	Modelled Level (m AHD)	Difference (m)	Comment
1	4.75	4.80	0.05	
2	**3.68**	**3.69**	**0.01**	**Flood Marks 2 and 3 have some discrepancy – modelled levels are both controlled by Barrenjoey Rd (and are the same)**
3	3.53	3.69	0.16	

Table 5-5 shows that for the 1987 flood event the model calibrates accurately, within or very close to the 150mm target accuracy, for all 3 surveyed levels.

5.4 January 1989 Model Verification

The January 1989 flood event was also used to verify the model calibration. No pluviograph data was available for this event, however it was still deemed appropriate to include this event in the model verification exercise as flood marks were available in the Cahill Creek catchment.

5.4.1 Recorded Flood Levels

Recorded flood levels for the January 1989 flood event (DHI, 2002) were located in the Cahill Creek catchment around the Samuel Street area. Little information is available for other areas suggesting that the event may not have been significant in other areas of the catchment.

5.4.2 Rainfall Data

A similar approach to the DHI Study (2002) was taken to derive rainfall for the 1989 verification event. The temporal pattern of the October 1987 event was adopted for this event as no pluviograph data was available and the two events were similar in magnitude. The rainfall Isohyets derived from the available daily rainfall gauges are shown in **Figure 11**.

5.4.3 Downstream Boundary Conditions

No recorded tailwater data was available for the October 1989 event. As such, a tidal water level boundary was predicted for the period of the storm event using available tidal constituents for Pittwater and was applied to both the ocean outlet of the Mona Vale Golf Course catchment and the Pittwater estuary.

The predicted Pittwater time series for the January 1989 event is presented in **Plate 5-3.**

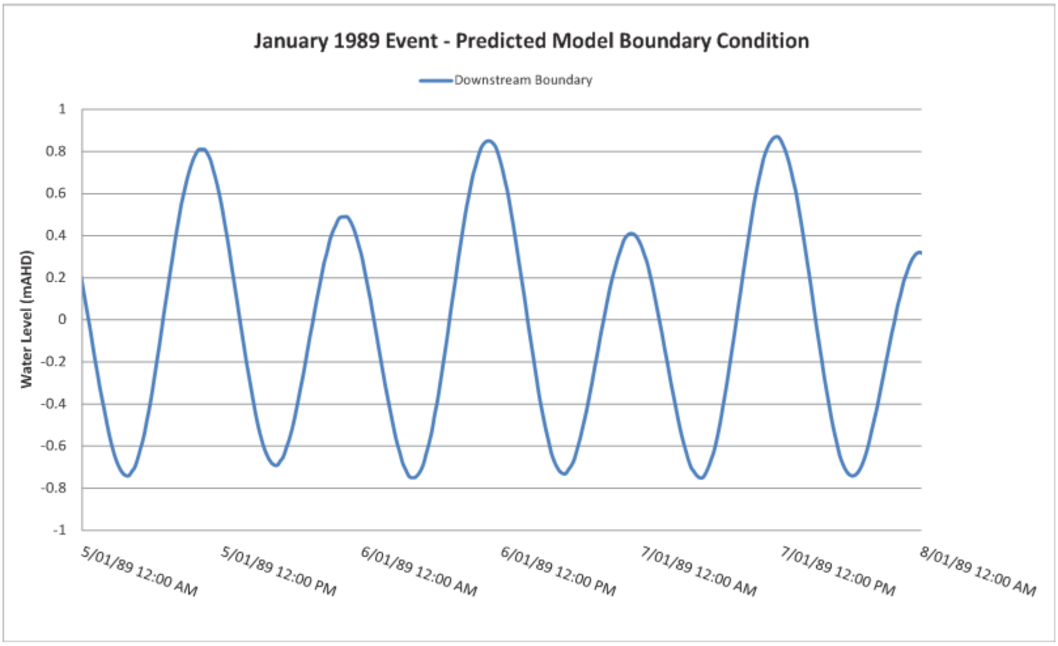

***Plate 5-3** Predicted Model Boundary Condition (1989 Event)*

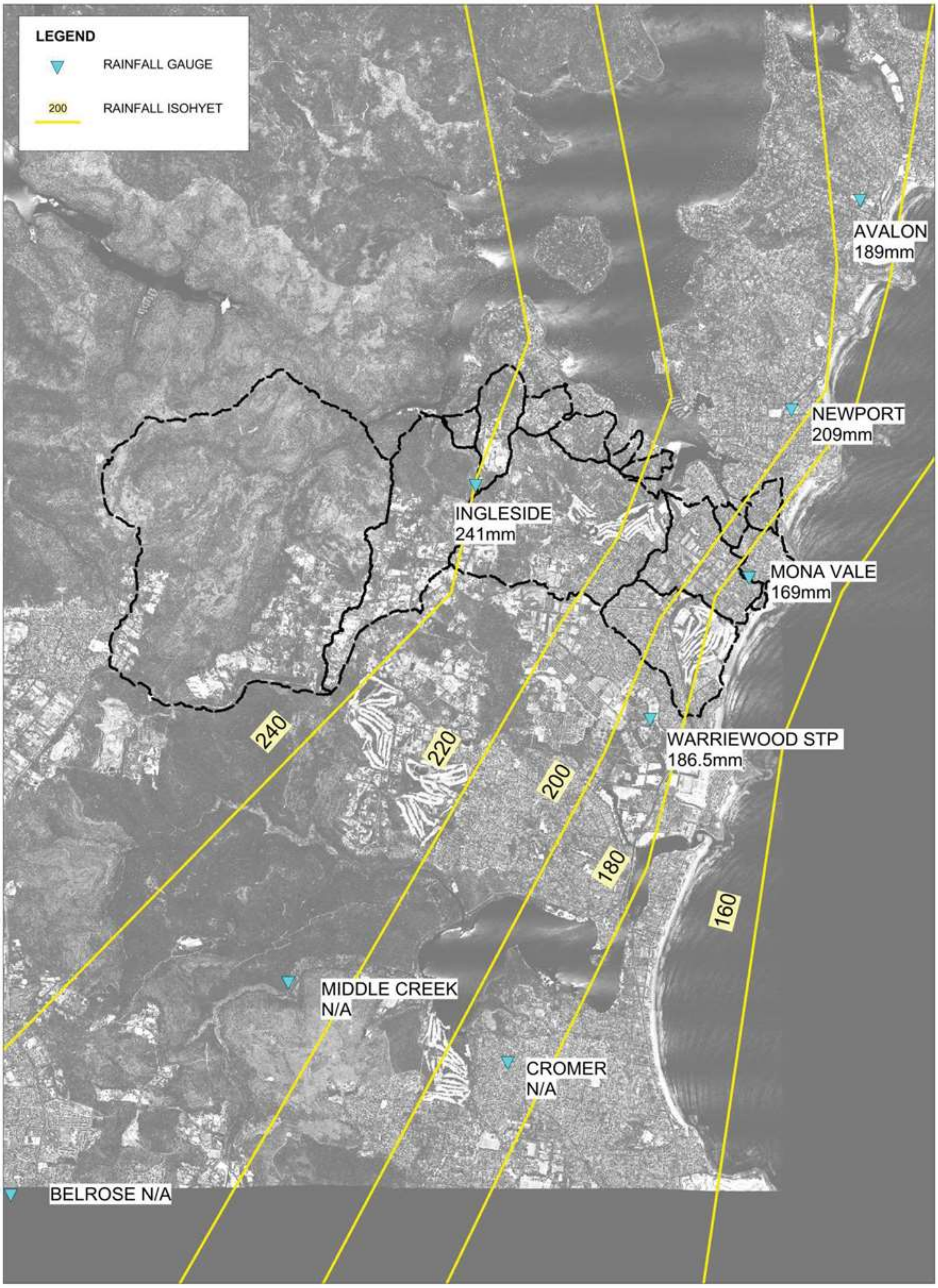

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FIGURE 11 **RAINFALL ISOHYETS (1989 EVENT)**

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5.4.4 Observed and Simulated Flood Behaviour

Comparisons between the recorded and predicted flood levels for the January 1989 flood event are presented in **Table 5-6**.

Table 5-6: 1989 Event Verification Results

Flood Mark	Surveyed Level (m AHD)	Modelled Level (m AHD)	Difference (m)	Comment
1	**7.54**	**8.23**	**0.69**	**Water level hard to match due to steep flood gradient in the model.**
2	7.56	7.59	0.03	
3	5.90	6.01	0.11	
4	5.71	5.77	0.06	

Table 5-6 shows that for the 1989 flood event the model calibrates accurately, within or very close to the 150mm target accuracy, for 3 of the surveyed levels (flood marks 2 – 4). Flood mark 1 is considered unreliable as the surveyed flood level is lower than flood mark 2, which is downstream of flood mark 1.

5.5 Calibration Summary

Hydraulic model calibration and verification has been achieved against a range of surveyed / observed flood marks across 3 historic flood events. The hydraulic models are considered to accurately representing the physical and hydraulic nature of the catchments and will provide a reasonable tool for estimating flooding in the design events. As historical flood data is not available for all catchments in the study area, sensitivity analysis of model parameters enables the model limitations to be understood. All sensitivity analyses carried out for this study are document in **Section 7**.

6 Design Event Modelling

6.1 Design Rainfall

Design rainfall parameters are derived from standard procedures defined in AR&R (1987) 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 Area is presented below.

6.1.1 Rainfall Depths

Design rainfall depths are based on the generation of intensity-frequency-duration (IFD) design rainfall curves utilising the procedures outlined in AR&R (1987). These curves provide rainfall depths for various design magnitudes (up to the 0.2% 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, 1987). 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 (100 year ARI and less) to extrapolate to the PMP. The PMP has been estimated using the Generalised Short Duration Method (GSDM) derived by the Bureau of Meteorology (2003).

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 0.25-hour, 0.5-hour, 0.75-hour, 1-hour, 1.5-hour, 2-hour, 3-hour, 4.5-hour, 6-hour and 9-hour durations.

Table 6-1 shows an excerpt of the average design rainfall intensities based on AR&R (1987) adopted for the modelled events and **Table 6-2** shows the adopted rainfall intensities for the PMF event.

Table 6-1: Average Design Rainfall Intensities (mm/hr) - AR&R 1987

Duration (hours)	Design Event Frequency				
	20% AEP	5% AEP	1% AEP	0.5% AEP	0.2% AEP
0.25	108.2	140.3	182.2	200.6	225.3
0.5	78.2	102.7	134.8	149.0	168.1
0.75	63.5	84.1	111.2	123.2	139.4
1	54.5	72.5	96.4	107.0	121.4
1.5	43.0	57.1	75.7	83.9	95.1
2	36.2	48.0	63.5	70.4	79.7
3	28.4	37.5	49.5	54.8	61.9
4.5	22.2	29.2	38.5	42.6	48.1
6	18.7	24.5	32.2	35.6	40.2
9	14.6	19.1	25.1	27.7	31.2

Table 6-2: Design Rainfall Intensities – PMF Event (mm/hr) – GSDM BoM 2003

Duration (hours)	0.25	0.5	0.75	1	1.5	2	2.5	3	4	5	6
Rainfall Intensity (mm/hr)	600	440	375	330	280	250	220	200	175	150	135

Areal Reduction Factor

The areal reduction factor takes into account the unlikelihood that larger catchments will experience rainfall of the same design intensity (eg 1% AEP) over the entire area. Areal reduction factors typically apply to catchments significantly larger than those considered in this Flood Study and no reduction factor is required even for the largest catchment in the study area (9.9km^2). This is confirmed from the historic catchment rainfall events which showed reasonably intense rainfall occurring over the entire catchment.

6.1.2 Temporal Patterns

The IFD data presented in **Table 6-1** provides for the average intensity 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 (1987).

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 for catchments of this size the same pattern across the catchment is generally adopted.

6.1.3 Rainfall Losses

The rainfall losses adopted for the design floods were the same as those used for model calibration and verification. Refer to **Table 5-3** of **Section 5** for the rainfall losses applied in model calibration.

6.2 Design Boundary Conditions

The downstream model limit for each of the hydraulic model areas is as follows:

- Model Area 1 and 2 – The downstream model limit for the rural catchments and Pittwater foreshore models corresponds to the water level in the Pittwater estuary.
- Model Area 3 – Half of the 'Urban' model sub-catchments drain north to the Pittwater Estuary and half drain east to the Pacific Ocean at Mona Vale Beach.

Each of the two boundary levels have been derived through a review of studies completed in the catchment.

6.2.1 Ocean Water Levels

The *Coastal Risk Management Guide* (DECCW, 2010a) is an authoritative source of design ocean water level information for NSW. DECCW (2010a) estimated that the 100 year ARI still water level (excluding wave setup) offshore of the Newcastle to Wollongong area (and thus including offshore of Pittwater LGA) was 1.44m AHD at present. Design water levels were also given for other AEP events (0.02%. 0.05%, 0.1%, 1%, 10% and 50%).

At a shoreline where there are breaking waves offshore, wave setup can increase still water levels. These levels are not specifically quantified in the latest coastline hazard study for Pittwater LGA (WorleyParsons, 2012), and have therefore been estimated from first principles.

Wave setup at a shoreline is typically about 15% of the breaking significant wave height. Based on Shand et al (2011), the 100 year ARI significant wave height offshore of Sydney for a 6 hour duration (a suitable duration to use to have the likelihood of coinciding with high tide) is 8.0m. Approximating this as a breaking wave height, this gives wave setup as 15% of this or 1.2m, and thus a total 100 year ARI water level including wave setup of 2.6m AHD could be assumed.

In the *Flood Risk Management Guide: incorporating sea level rise benchmarks in flood risk assessments* (DECCW, 2010b), it was noted that a conservative assumption for the 100 year ARI elevated water level at the ocean boundary for a catchment that drains directly to the ocean would be 2.6m AHD (that is, including wave setup effects). However, they noted that detailed site-specific analyses of elevated water levels at estuary entrances was appropriate, and may provide a potentially lower (less conservative) water level.

It is therefore reiterated that tailwater levels in the order of 2.6m AHD can only be potentially realised for stormwater outlets that discharge at back beach areas, which are landward of the surf zone. If outlets have a finite depth of water located seaward of the outlet in the design event, the magnitude of the water level including wave setup would be smaller than 2.6m AHD. It is also important to note that the 2.6m AHD water level including wave setup level does <u>not</u> propagate into the Pittwater waterway.

6.2.2 Estuary Water Levels

In the Pittwater estuary, there are variances in local water levels compared to the ocean, mainly due to local wind setup effects. Wave setup is also significantly lower in Pittwater estuary compared to offshore due to lower wave heights. There have been numerous studies investigating water levels in Pittwater estuary since 1991, and the latest study is Cardno (2011). Cardno (2011) determined design water levels at 37 locations around the Pittwater estuary (see **Figure A1** of **Attachment A**).

With reference to **Figure A1** and **Table A1**, locations 16 through 21 are within the study area. Given these locations, the Fork Junction on McCarrs Creek wind setup was applied to the estuary model boundaries as this gives the greatest possible wind setup in the study area.

6.2.3 Design Event Peak Levels

A tidal boundary was applied to the model with a peak level for each event as presented in **Table 6-2.**

Table 6-3: Peak Tailwater Levels for Design Events

Event	Pittwater Estuary Peak Level	Ocean Boundary Peak Level
	(mAHD)	(mAHD)
20% AEP Event	1.36	1.90
10% AEP Event	1.40	2.10
5% AEP Event	1.43	2.25
2% AEP Event	1.44	2.45
1% AEP Event	1.50	2.60
0.5% AEP Event	1.55	2.75
0.2% AEP Event	1.60	3.00
PMF Event	1.75	3.25

6.3 Design Results

6.3.1 Critical Storm Durations

A range of design event durations were simulated to determine the critical duration for flooding throughout the study area. Generally, shorter duration events are critical in the upstream, smaller and steeper sub-catchment areas. Longer duration events are critical in the lower catchment areas where storage effects become evident. The critical storm durations for the 1% AEP and PMF events are presented in **Figures 12 and 13**.

The design flood results are presented in a flood mapping series in **Appendix A**, which is comprised of an envelope of the critical storm shown durations in **Table 6-4**.

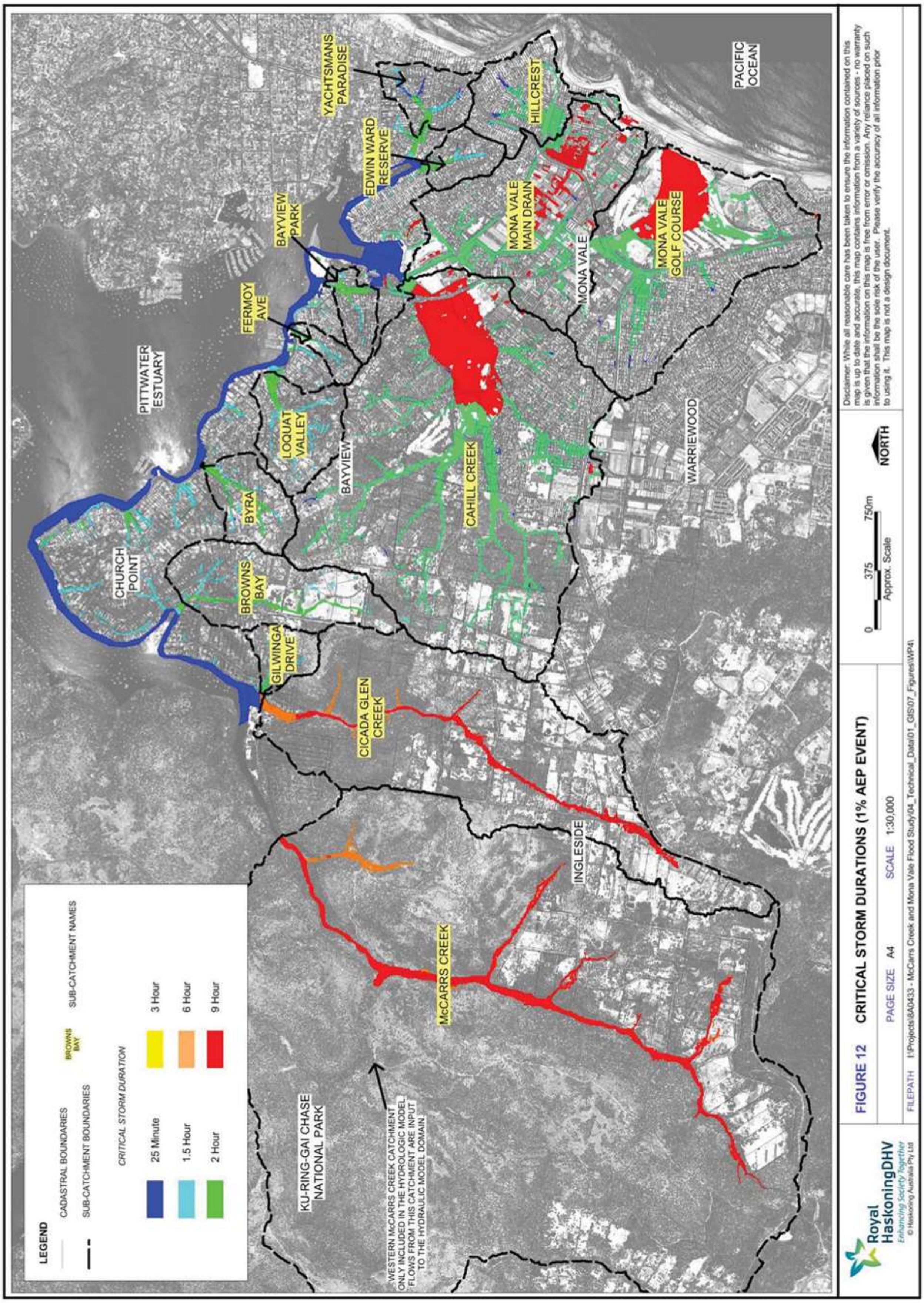

FIGURE 12 CRITICAL STORM DURATIONS (1% AEP EVENT)

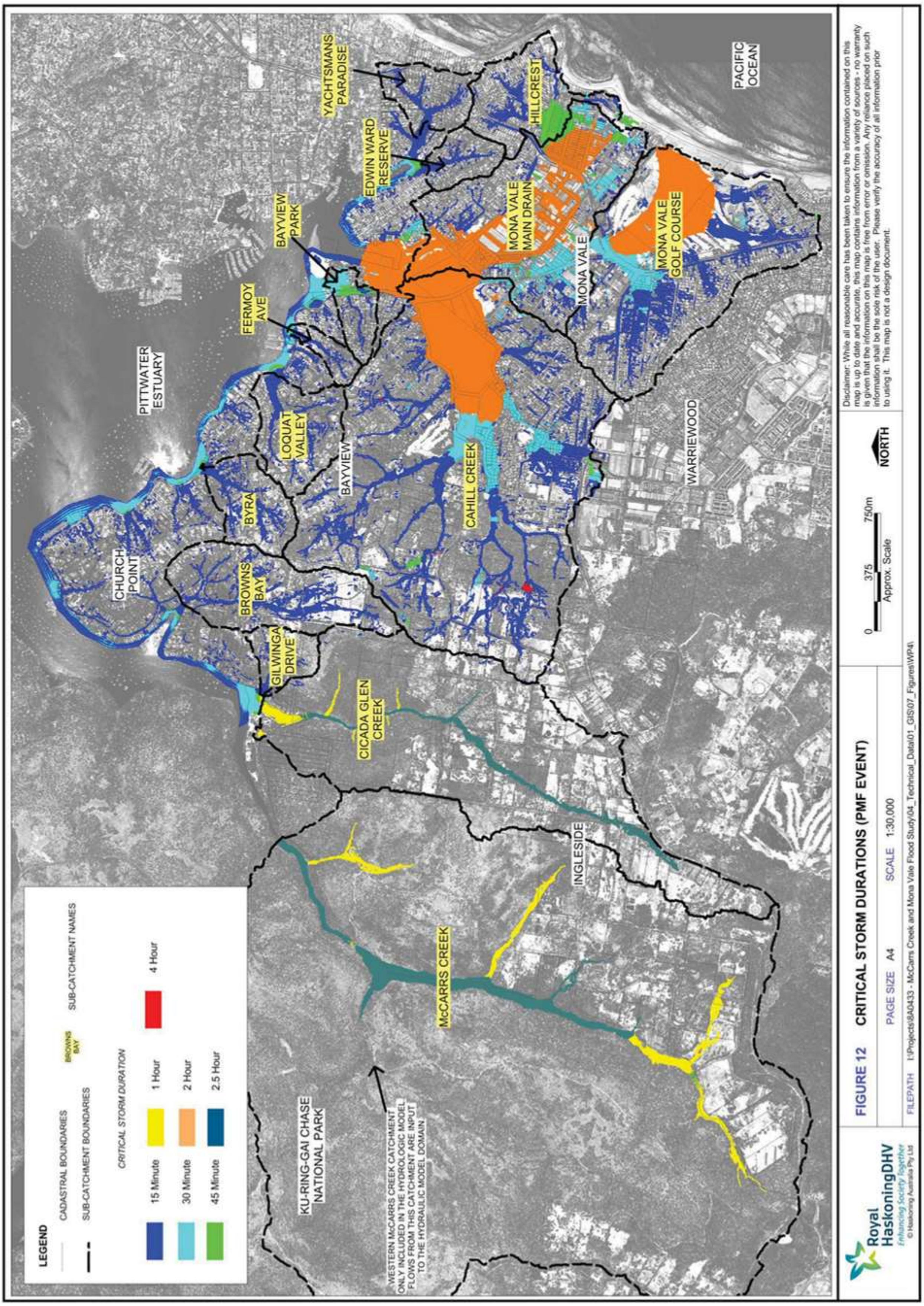

FIGURE 12 CRITICAL STORM DURATIONS (PMF EVENT)

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Table 6-4: Critical Storm Durations

Model Area	Critical Storm Durations
Model Area 1 – The 'Rural' Catchments	• 6 hour • 9 hour
Model Area 2 – The 'Pittwater' Catchments	• 25 minute • 1 hour • 1.5 hour • 2 hour • 3 hour
Model Area 3 – The 'Urban' Catchments	• 25 minute • 1 hour • 2 hour • 6 hour • 9hour

6.3.2 Peak Flood Depths

A summary of peak flood depths at key locations is shown in **Table 6-5** through **Table 6-7** below, and the placement of these locations is shown in **Figures 14** to **16**. Estimated peak flood depths and flood level labels are presented on **Figures A1** through **A8**. The values reported below are the maximum values from an envelope of scenarios as described in **Section 6.3.1**.

Table 6-5: Peak Flood Depths – Model Area 1 – The 'Rural' Catchments

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF Event
Model Area 1 – The 'Rural' Catchments – Peak Flood Depths (m)									
1	West Wirreanda Rd	0.85	0.89	0.93	0.96	0.99	1.03	1.06	1.62
2	East Wirreanda Rd	1.60	1.64	1.69	1.74	1.78	1.82	1.81	2.51
3	Wirreanda Rd North	1.20	1.30	1.42	1.52	1.60	1.69	1.78	3.16
4	Wirreanda Rd North	0.69	0.74	0.80	0.85	0.90	0.94	1.04	1.69
5	McCarrs Creek Rd	1.43	1.55	1.67	1.76	1.84	1.92	2.06	3.94
6	McCarrs Creek Rd	2.50	2.66	2.84	3.00	3.14	3.27	3.43	5.59
7	McCarrs Creek Rd	0.58	0.64	0.66	0.71	0.75	0.79	0.90	1.56
8	McCarrs Creek	1.02	1.13	1.25	1.37	1.47	1.57	1.53	3.42
9	Sophie Avenue	0.11	0.12	0.13	0.14	0.15	0.16	0.16	0.29
10	Chiltern Road	0.10	0.11	0.12	0.14	0.15	0.16	0.17	0.34
11	Glen Cicada Creek	1.28	1.31	1.35	1.38	1.41	1.44	1.54	1.90
12	Cicada Glen Rd	1.72	1.76	1.80	1.83	1.86	1.88	2.14	2.40
13	McCarrs Creek Rd	N/A	N/A	0.06	0.11	0.14	0.17	0.22	0.79

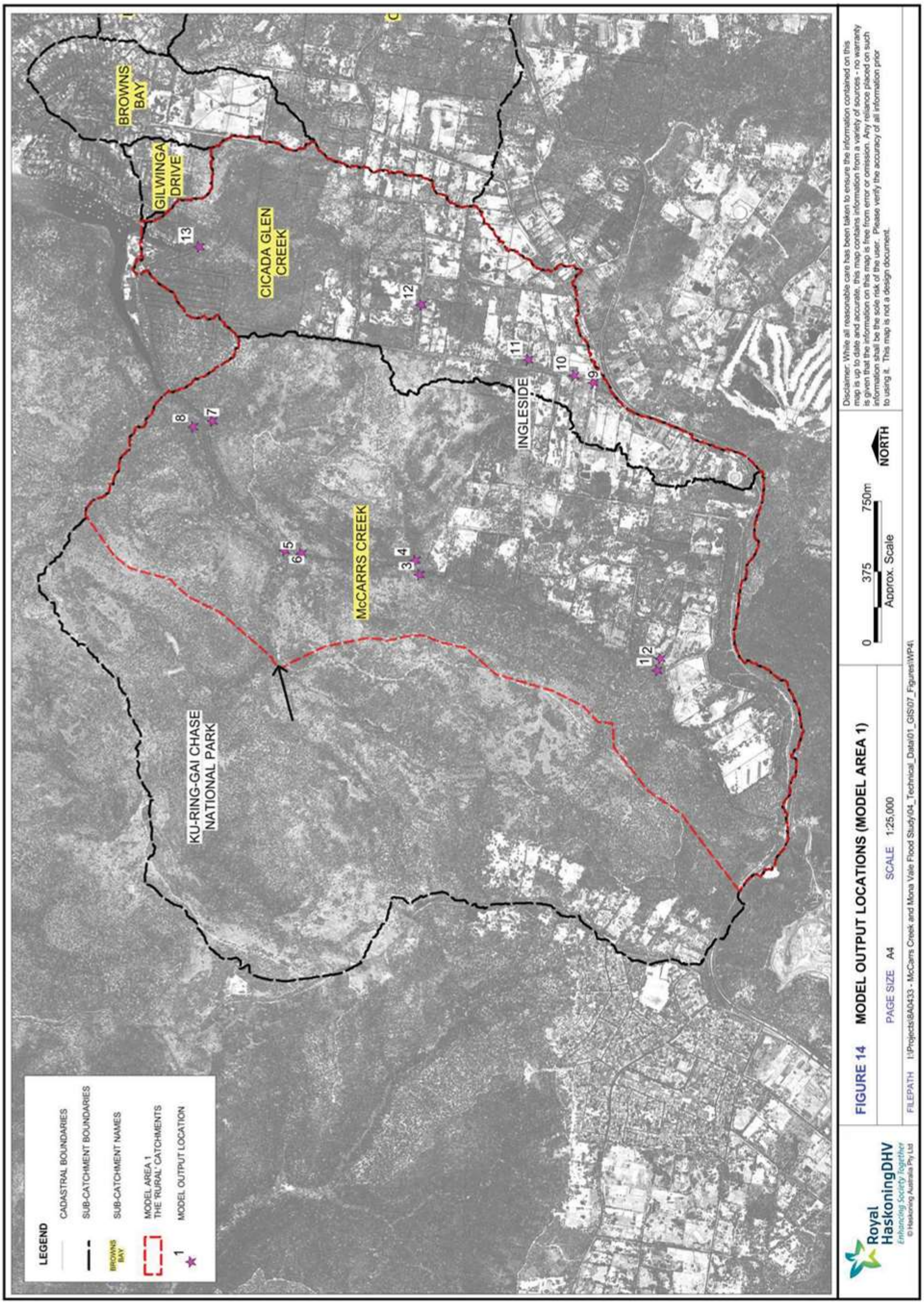
Table 6-6: Peak Flood Depths – Model Area 2 – The 'Pittwater' Catchments

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF Event
	Model Area 2 – The 'Pittwater' Catchments – Peak Flood Depths (m)								
1	McCarrs Creek Rd	0.14	0.15	0.17	0.21	0.22	0.24	0.28	0.41
2	Barcoola Place	0.35	0.37	0.40	0.42	0.42	0.43	0.47	0.52
3	Gilwinga Drive	0.11	0.16	0.22	0.24	0.29	0.32	0.34	0.48
4	McCarrs Creek Rd	0.12	0.16	0.20	0.24	0.26	0.29	0.31	0.67
5	McCarrs Creek Rd	N/A	0.06	0.07	0.08	0.09	0.10	0.11	0.15
6	Kananook Avenue	0.20	0.23	0.27	0.32	0.30	0.31	0.36	0.48
7	Kananook Avenue	0.11	0.13	0.15	0.18	0.18	0.20	0.23	0.28
8	Pittwater Rd	0.06	0.07	0.08	0.10	0.10	0.11	0.12	0.17
9	Pittwater Rd	0.15	0.18	0.21	0.24	0.25	0.28	0.31	0.41
10	Clive Crescent	0.07	0.08	0.09	0.09	0.11	0.12	0.11	0.17
11	Jendi Avenue	0.22	0.24	0.27	0.28	0.30	0.31	0.32	0.40
12	Jendi Avenue	0.08	0.09	0.13	0.15	0.16	0.17	0.19	0.29
13	Loquat Valley Rd	0.11	0.14	0.20	0.21	0.25	0.28	0.27	0.41
14	Kookaburra Close	N/A	0.15	0.16	0.17	0.16	0.17	0.17	0.20
15	Pittwater Rd	N/A	N/A	0.10	0.15	0.17	0.20	0.24	0.45
16	Pittwater Rd	0.08	0.08	0.09	0.10	0.11	0.11	0.12	0.16
17	Pittwater Rd	0.09	0.09	0.09	0.12	0.10	0.10	0.12	0.23
18	Gerroa Avenue	0.12	0.13	0.15	0.15	0.18	0.19	0.21	0.32
19	Pittwater Rd	0.26	0.33	0.41	0.48	0.54	0.58	0.64	0.95
20	Pittwater Rd	0.18	0.18	0.19	0.20	0.21	0.21	0.22	0.27
21	The Esplande	0.35	0.36	0.38	0.38	0.39	0.40	0.41	0.50
22	Rednal Street	0.71	0.36	0.39	0.41	0.44	0.46	1.70	0.79
23	Crescent Rd	0.23	0.24	0.25	0.27	0.27	0.27	0.30	0.44
24	Suncrest Avenue	0.17	0.18	0.19	0.20	0.22	0.23	0.25	0.32
25	Crescent Rd	0.18	0.19	0.22	0.24	0.26	0.29	0.31	0.46
26	Yachtsmans Paradise	0.68	0.74	0.81	0.86	0.89	0.94	0.99	1.33
27	Crescent Rd	0.16	0.18	0.20	0.21	0.23	0.24	0.26	0.40

Table 6-7: Peak Flood Depths – Model Area 3 – The 'Urban' Catchments

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF Event
Model Area 3 – The Urban Catchments – Peak Flood Depths (m)									
1	Peninsula Gdns Retirement	1.92	1.99	2.08	2.19	2.30	2.41	2.52	3.27
2	Old Samuel Street	0.36	0.48	0.60	0.74	0.88	1.01	1.15	2.02
3	Samuel Street	0.17	0.24	0.31	0.40	0.48	0.56	0.65	1.30
4	Parkland Road	0.18	0.26	0.35	0.46	0.57	0.65	0.78	1.54
5	Cabbage Tree Road	0.45	0.53	0.59	0.68	0.79	0.79	0.90	1.64
6	Annam Road	0.34	0.38	0.40	0.42	0.45	0.46	0.49	0.74
7	Annam Road	0.14	0.17	0.19	0.20	0.21	0.23	0.24	0.40
8	Annam Road	0.15	0.19	0.24	0.30	0.36	0.40	0.46	0.93
9	Cabbage Tree Road	0.07	0.18	0.27	0.39	0.51	0.62	0.80	1.72
10	Bayview Golf Course	0.88	0.99	1.08	1.20	1.32	1.46	1.64	2.54
11	Mona Vale Road	0.20	0.21	0.23	0.24	0.25	0.26	0.27	0.46
12	Samuel Street	0.38	0.43	0.46	0.49	0.51	0.52	0.54	0.75
13	Marie Crescent	0.81	0.95	1.08	1.22	1.34	1.43	1.56	2.37
14	Siobhan Place	0.28	0.29	0.34	0.53	0.63	0.72	0.82	1.51
15	Parkland Road	0.09	0.13	0.20	0.28	0.35	0.41	0.47	1.08
16	Waratah Street	0.08	0.09	0.10	0.11	0.11	0.11	0.12	0.27
17	Waratah Street	0.13	0.14	0.15	0.16	0.17	0.17	0.18	0.29
18	Cnr Maxwell St & Parkland Road	0.26	0.30	0.35	0.38	0.41	0.48	0.52	0.79
19	Wilmette Place	0.64	0.69	0.74	0.78	0.81	0.84	0.87	1.52
20	Grandview Parade	0.19	0.20	0.21	0.21	0.22	0.22	0.23	0.36
21	Orana Road	0.17	0.18	0.20	0.22	0.26	0.28	0.30	0.45
22	Bassett Street	0.33	0.41	0.51	0.61	0.69	0.75	0.83	1.33
23	Surfview Road	0.12	0.13	0.15	0.17	0.18	0.19	0.22	0.38
24	Seabeach Avenue	0.19	0.23	0.35	0.45	0.55	0.63	0.76	1.19
25	Heath Street	0.28	0.29	0.37	0.47	0.57	0.67	0.80	1.23
26	Polo Avenue	0.21	0.24	0.28	0.33	0.35	0.37	0.47	1.24

27	Tengah Crescent	0.47	0.56	0.68	0.76	0.82	0.86	0.92	1.70
28	Bassett Street	0.17	0.19	0.22	0.25	0.33	0.39	0.52	1.62
29	Mona Street	0.43	0.44	0.45	0.48	0.56	0.63	0.77	1.86
30	Barrenjoey Road	0.66	0.68	0.70	0.71	0.72	0.72	0.74	0.89
31	Barrenjoey Road	0.52	0.53	0.55	0.56	0.57	0.59	0.60	0.72
32	Brinawa Street	0.13	0.14	0.15	0.16	0.17	0.19	0.21	0.45
33	Brinawa Street	0.46	0.50	0.54	0.58	0.62	0.65	0.69	1.02
34	Vineyard Street	0.15	0.16	0.17	0.18	0.19	0.21	0.22	0.34
35	Cnr Mona Vale Rd & Pittwater Rd	0.32	0.34	0.37	0.39	0.41	0.44	0.47	0.64
36	Cnr Rowan St & Pittwater Rd	0.21	0.24	0.27	0.30	0.32	0.36	0.39	0.65
37	Pittwater Road	0.41	0.42	0.44	0.45	0.46	0.49	0.50	0.58
38	Mona Vale Golf Course	0.75	0.88	1.05	1.27	1.43	1.60	1.81	2.93


BROWNS BAY
GILWINGA DRIVE
CICADA GLEN CREEK
McCARRS CREEK
INGLESIDE
KU-RING-GAI CHASE NATIONAL PARK
LEGEND
CADASTRAL BOUNDARIES
SUB-CATCHMENT BOUNDARIES
SUB-CATCHMENT NAMES
MODEL AREA 1 THE 'RURAL' CATCHMENTS
MODEL OUTPUT LOCATION
0 375 750m
Approx. Scale
NORTH
FIGURE 14 MODEL OUTPUT LOCATIONS (MODEL AREA 1)
PAGE SIZE A4
SCALE 1:25,000
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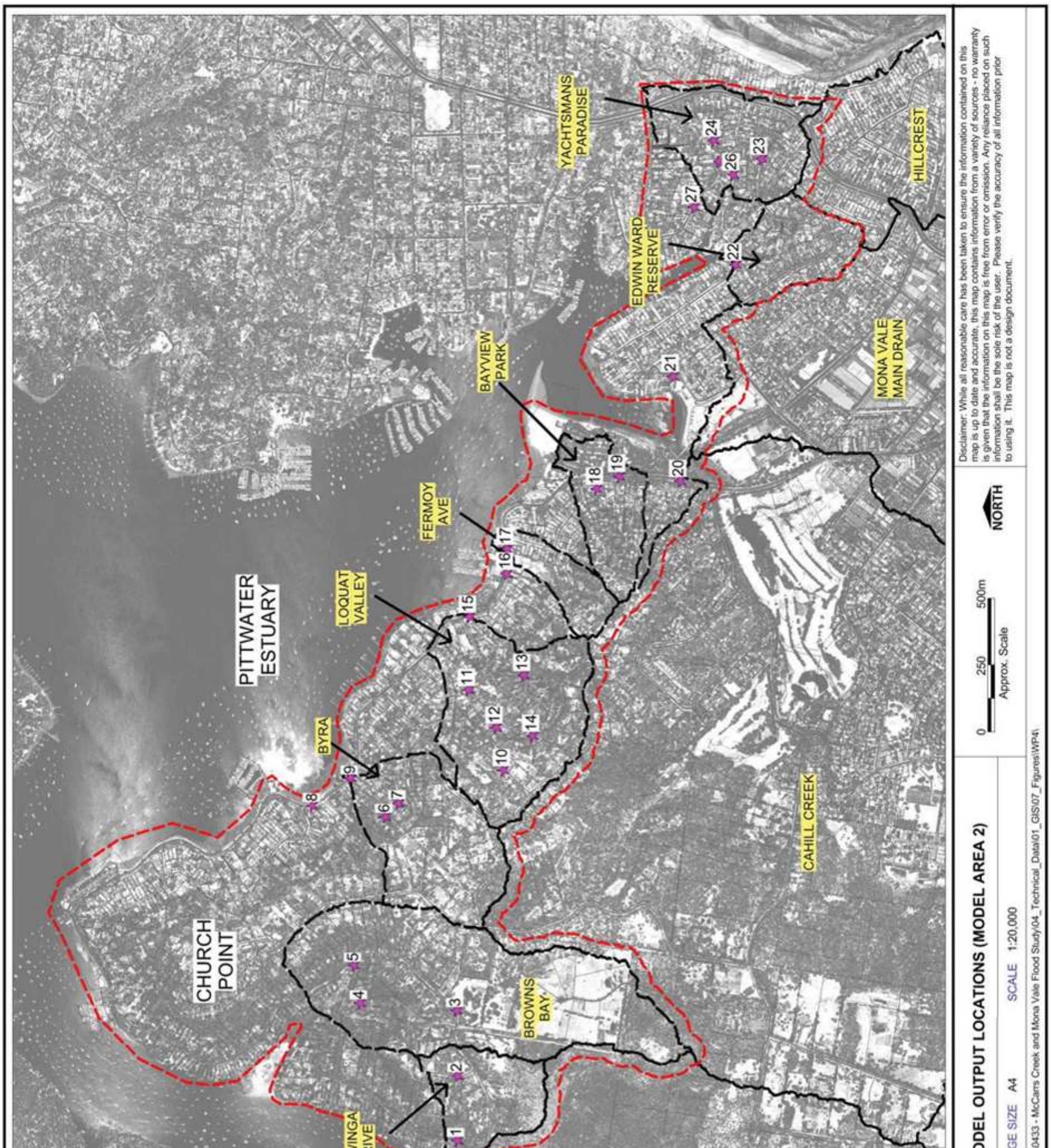
LEGEND
CADASTRAL BOUNDARIES
SUB-CATCHMENT BOUNDARIES
SUB-CATCHMENT NAMES
MODEL AREA 2
THE 'PITTWATER' CATCHMENTS
MODEL OUTPUT LOCATION
PITTWATER ESTUARY
CHURCH POINT
GILWINGA DRIVE
BROWNS BAY
BYRA
LOQUAT VALLEY
FERMOY AVE
BAYVIEW PARK
EDWIN WARD RESERVE
YACHTSMANS PARADISE
HILLCREST
MONA VALE MAIN DRAIN
CAHILL CREEK
CICADA GLEN CREEK
NORTH
0
250
500m
Approx. Scale
FIGURE 15
MODEL OUTPUT LOCATIONS (MODEL AREA 2)
PAGE SIZE A4
SCALE 1:20,000
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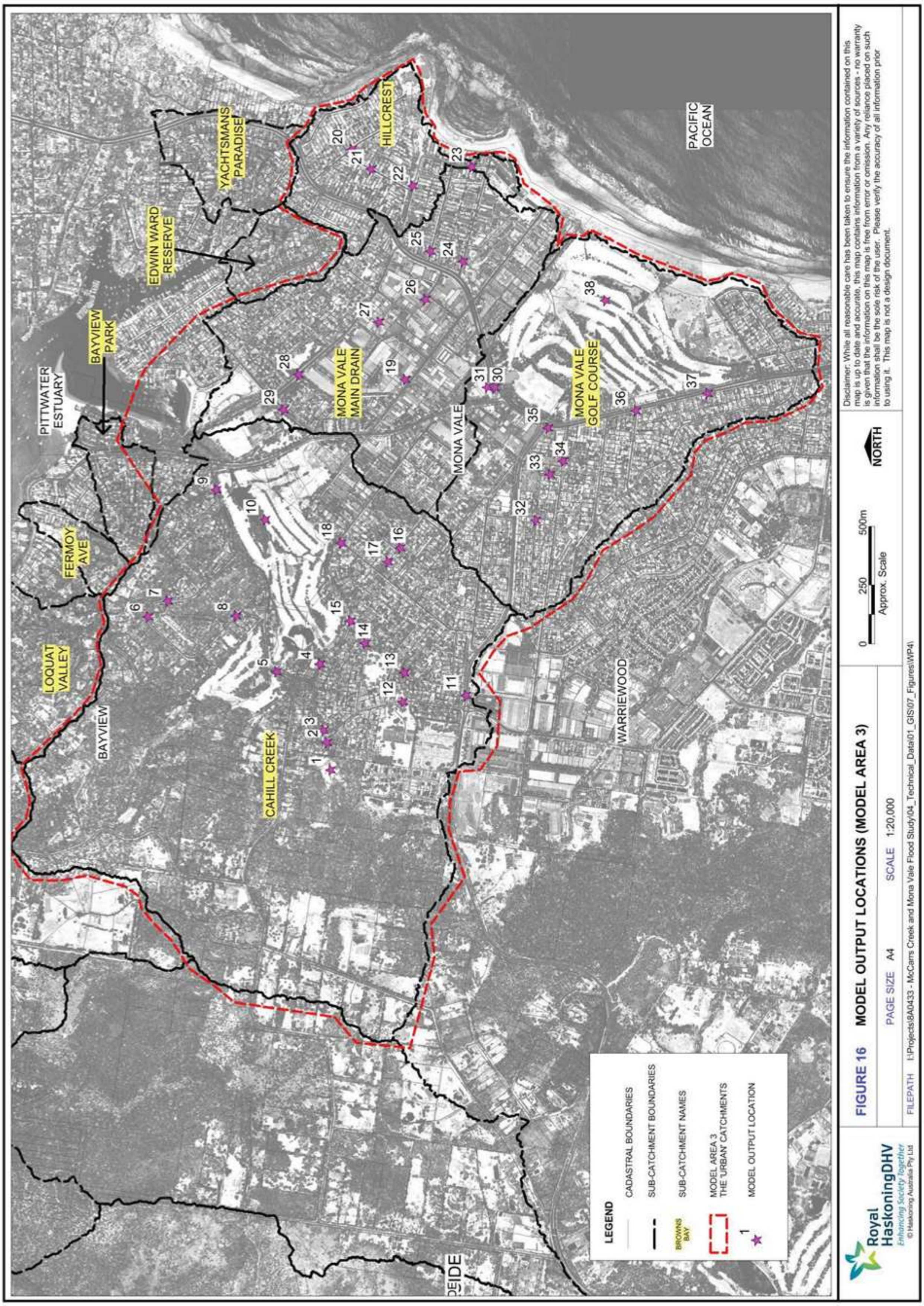
PACIFIC OCEAN
HILLCREST
YACHTSMANS PARADISE
EDWIN WARD RESERVE
BAYVIEW PARK
PITTWATER ESTUARY
MONA VALE MAIN DRAIN
MONA VALE
MONA VALE GOLF COURSE
FERMOY AVE
LOQUAT VALLEY
BAYVIEW
CAHILL CREEK
WARRIEWOOD
LEGEND
CADASTRAL BOUNDARIES
SUB-CATCHMENT BOUNDARIES
SUB-CATCHMENT NAMES
MODEL AREA 3 THE 'URBAN' CATCHMENTS
MODEL OUTPUT LOCATION
NORTH
0 250 500m
Approx. Scale
FIGURE 16 MODEL OUTPUT LOCATIONS (MODEL AREA 3)
PAGE SIZE A4 SCALE 1:20,000
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6.3.3 Peak Flood Velocities

A summary of peak flood velocities at key locations is shown in **Table 6-8** through **Table 6-10** below, and the placement of these locations is shown in **Figures 14** to **16**. Estimated peak flood velocity is presented on **Figures A9** to **A12**. The values reported below are the maximum values from an envelope of scenarios as described in **Section 6.3.1**.

Table 6-8: Peak Flood Velocities – Model Area 1 – The 'Rural' Catchments

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF Event
Model Area 1 – The Rural Catchments – Peak Flood Velocity (m/s)									
1	West Wirreanda Rd	0.31	0.35	0.41	0.45	0.49	0.54	0.59	1.36
2	East Wirreanda Rd	0.17	0.20	0.23	0.26	0.29	0.33	0.36	0.96
3	Wirreanda Rd North	1.47	1.50	1.54	1.56	1.59	1.61	1.65	2.08
4	Wirreanda Rd North	1.05	1.12	1.22	1.28	1.34	1.40	1.49	2.30
5	McCarrs Creek Rd	0.75	0.83	0.86	0.91	0.97	1.02	1.09	1.65
6	McCarrs Creek Rd	1.36	1.46	1.59	1.69	1.77	1.84	1.92	2.31
7	McCarrs Creek Rd	2.41	2.70	2.82	3.00	3.23	3.44	3.72	5.77
8	McCarrs Creek	2.73	2.93	3.16	3.33	3.50	3.66	3.84	5.98
9	Sophie Avenue	0.63	0.66	0.70	0.72	0.75	0.76	0.79	1.08
10	Chiltern Road	2.08	2.24	2.45	2.55	2.59	2.65	2.79	4.19
11	Glen Cicada Creek	0.23	0.26	0.30	0.35	0.39	0.43	0.48	1.38
12	Cicada Glen Rd	0.47	0.51	0.57	0.63	0.68	0.72	0.79	1.52
13	McCarrs Creek Rd	N/A	N/A	1.71	2.94	3.44	3.63	3.86	5.34

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Table 6-9: Peak Flood Velocities – Model Area 2 – The 'Pittwater' Catchments

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF Event
Model Area 2 – The Pittwater Catchments – Peak Flood Velocity (m/s)									
1	McCarrs Creek Rd	0.14	0.15	0.17	0.21	0.22	0.24	0.28	6.13
2	Barcoola Place	0.35	0.37	0.40	0.42	0.42	0.43	0.47	0.38
3	Gilwinga Drive	0.11	0.16	0.22	0.24	0.29	0.32	0.34	5.93
4	McCarrs Creek Rd	0.12	0.16	0.20	0.24	0.26	0.29	0.31	4.54
5	McCarrs Creek Rd	N/A	0.06	0.07	0.08	0.09	0.10	0.11	3.72
6	Kananook Avenue	0.20	0.23	0.27	0.32	0.30	0.31	0.36	1.10
7	Kananook Avenue	0.11	0.13	0.15	0.18	0.18	0.20	0.23	2.83
8	Pittwater Rd	0.06	0.07	0.08	0.10	0.10	0.11	0.12	3.77
9	Pittwater Rd	0.15	0.18	0.21	0.24	0.25	0.28	0.31	2.76
10	Clive Crescent	0.07	0.08	0.09	0.09	0.11	0.12	0.11	2.37
11	Jendi Avenue	0.22	0.24	0.27	0.28	0.30	0.31	0.32	0.86
12	Jendi Avenue	0.08	0.09	0.13	0.15	0.16	0.17	0.19	2.51
13	Loquat Valley Rd	0.11	0.14	0.20	0.21	0.25	0.28	0.27	2.24
14	Kookaburra Close	N/A	0.15	0.16	0.17	0.16	0.17	0.17	1.35
15	Pittwater Rd	N/A	N/A	0.10	0.15	0.17	0.20	0.24	2.46
16	Pittwater Rd	0.08	0.08	0.09	0.10	0.11	0.11	0.12	2.39
17	Pittwater Rd	0.09	0.09	0.09	0.12	0.10	0.10	0.12	1.79
18	Gerroa Avenue	0.12	0.13	0.15	0.15	0.18	0.19	0.21	2.39
19	Pittwater Rd	0.26	0.33	0.41	0.48	0.54	0.58	0.64	0.09
20	Pittwater Rd	0.18	0.18	0.19	0.20	0.21	0.21	0.22	0.92
21	The Esplande	0.35	0.36	0.38	0.38	0.39	0.40	0.41	0.12
22	Rednal Street	0.71	0.36	0.39	0.41	0.44	0.46	1.70	0.66
23	Crescent Rd	0.23	0.24	0.25	0.27	0.27	0.27	0.30	2.09
24	Suncrest Avenue	0.17	0.18	0.19	0.20	0.22	0.23	0.25	0.85
25	Crescent Rd	0.18	0.19	0.22	0.24	0.26	0.29	0.31	1.62
26	Yachtsmans Paradise	0.68	0.74	0.81	0.86	0.89	0.94	0.99	1.00
27	Crescent Rd	0.16	0.18	0.20	0.21	0.23	0.24	0.26	1.21

Table 6-10: Peak Flood Velocities – Model Area 3 – The 'Urban' Catchments

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF Event
Model Area 3 – The Urban Catchments – Peak Flood Velocity (m/s)									
1	Peninsula Gdns Retirement	0.63	0.63	0.61	0.59	0.58	0.61	0.64	1.06
2	Old Samuel Street	0.77	0.91	1.04	1.18	1.30	1.39	1.46	1.91
3	Samuel Street	0.87	1.12	1.32	1.52	1.69	1.82	1.92	2.23
4	Parkland Road	0.74	1.14	1.39	1.51	1.74	1.89	2.05	2.94
5	Cabbage Tree Road	1.46	1.44	1.77	1.95	2.04	2.10	2.19	2.79
6	Annam Road	0.28	0.32	0.37	0.39	0.42	0.44	0.47	0.75
7	Annam Road	0.44	0.50	0.55	0.59	0.62	0.68	0.72	1.13
8	Annam Road	1.35	1.48	1.54	1.64	1.79	1.82	1.98	3.13
9	Cabbage Tree Road	0.69	0.79	0.93	0.99	1.02	0.86	0.93	2.23
10	Bayview Golf Course	0.13	0.13	0.13	0.14	0.14	0.14	0.15	0.42
11	Mona Vale Road	N/A	0.16	0.20	0.24	0.27	0.31	0.35	0.51
12	Samuel Street	0.39	0.41	0.45	0.46	0.46	0.46	0.46	0.50
13	Marie Crescent	0.16	0.16	0.16	0.19	0.24	0.30	0.37	0.98
14	Siobhan Place	N/A	N/A	0.13	0.42	0.54	0.69	0.85	2.31
15	Parkland Road	0.42	0.56	0.87	1.23	1.41	1.57	1.70	2.14
16	Waratah Street	1.05	1.13	1.20	1.25	1.30	1.36	1.41	2.28
17	Waratah Street	1.00	1.08	1.11	1.19	1.29	1.40	1.49	1.92
18	Cnr Maxwell St & Parkland Road	1.15	1.21	1.34	1.44	1.51	1.59	1.69	2.54
19	Wilmette Place	0.22	0.23	0.25	0.21	0.22	0.25	0.28	0.91
20	Grandview Parade	0.25	0.27	0.29	0.31	0.32	0.34	0.37	0.67
21	Orana Road	2.14	2.37	2.64	2.81	2.81	2.96	2.97	3.71
22	Bassett Street	0.18	0.18	0.18	0.19	0.19	0.19	0.22	0.48
23	Surfview Road	0.30	0.34	0.37	0.38	0.41	0.43	0.45	0.79
24	Seabeach Avenue	N/A	N/A	0.14	0.18	0.19	0.21	0.23	0.43
25	Heath Street	0.12	0.13	0.16	0.18	0.20	0.21	0.22	0.37

26	Polo Avenue	0.27	0.26	0.27	0.26	0.26	0.27	0.37	1.09
27	Tengah Crescent	N/A	0.13	0.13	0.14	0.12	0.12	0.13	0.47
28	Bassett Street	0.24	0.32	0.38	0.43	0.50	0.53	0.57	0.78
29	Mona Street	N/A	N/A	N/A	0.10	0.10	0.12	0.13	0.27
30	Barrenjoey Road	0.14	0.15	0.18	0.19	0.20	0.21	0.21	0.27
31	Barrenjoey Road	0.59	0.61	0.63	0.63	0.63	0.64	0.65	0.97
32	Brinawa Street	1.75	1.85	1.97	2.07	2.16	2.25	2.31	3.18
33	Brinawa Street	0.35	0.35	0.37	0.40	0.40	0.41	0.42	0.42
34	Vineyard Street	0.87	0.88	0.93	1.00	1.07	1.12	1.21	2.09
35	Cnr Mona Vale Rd & Pittwater Rd	0.68	0.76	0.88	0.96	0.98	0.96	1.01	1.01
36	Cnr Rowan St & Pittwater Rd	0.96	0.98	0.98	0.98	0.98	0.98	0.98	1.19
37	Pittwater Road	0.16	0.16	0.17	0.17	0.19	0.19	0.22	0.40
38	Mona Vale Golf Course	0.26	0.29	0.33	0.36	0.39	0.42	0.46	0.72

6.3.4 Design Hydrographs

Design hydrographs were output from the model results for the 20%, 50% and 100% AEP Events and the PMF Event at numerous locations across the study area. Hydrographs for these events are presented in **Appendix C**.

6.3.5 Provisional Flood 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.

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 **Plate 6-1.**

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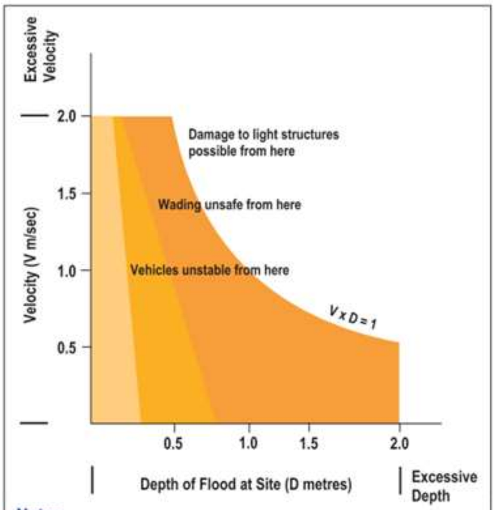
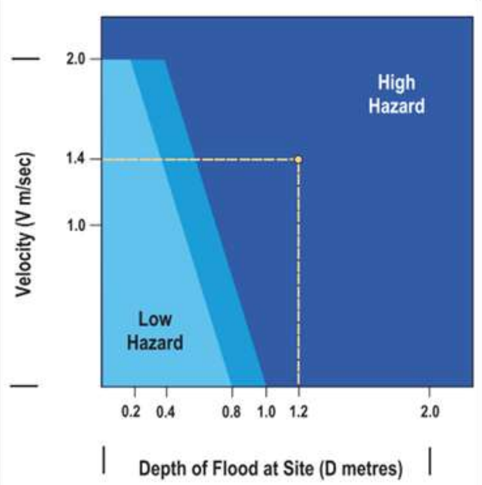


Notes

1. At velocities in excess of 2.0 m/s, the stability of foundations and poles can be affected by scour. Also, grass and earth surfaces begin to scour and can become rough and unstable
2. The velocity of floodwaters passing between buildings can produce a hazard, which may not be apparent if only the average velocity is considered. For instance, the velocity of floodwaters in a model test has risen from an average of 1 m/sec to 3 m/sec between houses.
3. Vehicle instability is initially by buoyancy.
4. At floodwater depths in excess of 2.0 meters and even at low velocities, there can be damage to light-framed buildings from water pressure, flotation and debris impact.

Derived from laboratory testing and flood conditions which caused damage.



Notes

The degree of hazard may be either -

- reduced by establishment of an effective flood evacuation procedure.
- increased if evacuation difficulties exist.

In the transition zone highlight by the median colour, the degree of hazard is dependant on site conditions and the nature of the proposed development.

Example:

If the depth of flood water is **1.2 m**
and the velocity of floodwater is **1.4 m/sec**
then the provisional hazard is **high**

Plate 6-1: Provisional Flood Hazard Categorisation (NSW Government, 2005)

The provisional hydraulic hazard is included in the mapping series for each simulated design event provided in **Appendix A**.

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

A number of approaches were considered when attempting to define flood impact categories across study catchments. Approaches to define hydraulic categories that were considered for this assessment included partitioning the floodplain based on:

- Peak flood velocity (m/s);
- Peak flood depth (m);
- Peak velocity * depth (sometimes referred to as discharge per unit width (m^2/s));
- Cumulative volume conveyed during the flood event (m^3); and
- Combinations of the above.

The definition of flood impact categories that was considered to best fit the application within study catchments was ultimately provided by Council and was based on a combination of velocity*depth, velocity and depth parameters. The adopted hydraulic categorisation is defined in **Table 6-11**.

The hydraulic category maps for the 1% AEP and PMF events are 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).

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Table 6-11: Hydraulic Categories

Floodway	Defined using the following criteria: Velocity * Depth > 0.3 OR Velocity > 0.5 m/s	Areas and flowpaths where a significant proportion of floodwaters are conveyed (including all bank-to-bank creek sections).
Flood Storage	Defined where Depth > 0.3 metres	Areas where floodwaters accumulate before being conveyed downstream. These areas are important for detention and attenuation of flood peaks.
Flood Fringe	Defined where Depth < 0.3 metres	Areas that are low-velocity backwaters within the floodplain. Filling of these areas generally has little consequence to overall flood behaviour.

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7 Model Sensitivity

Sensitivity analysis of model parameters is a required step in the development of a hydraulic model to understand the model's dependence upon model assumptions. Sensitivity analysis can also be undertaken to help understand proposed changes to modelling guidelines and the impacts of climate change. This section documents the sensitivity analysis undertaken as part of this Study.

7.1 Structure Blockages

The percentage of blockage applied to structures (culverts, bridges etc) in the hydraulic model can be a key parameter determining flood extent and levels. To test the sensitivity of the hydraulic model results to structure blockage, two test runs were undertaken applying 50% and 100% blockage to key culvert locations in the Urban Catchments hydraulic model for a 100 year return period event.

Plate 7-1 below is a 'difference map' showing the increase in flood level (m) under a 100% blockage scenario (and 50% blocked scenario in brackets) compared to a baseline scenario with no structure blockage.

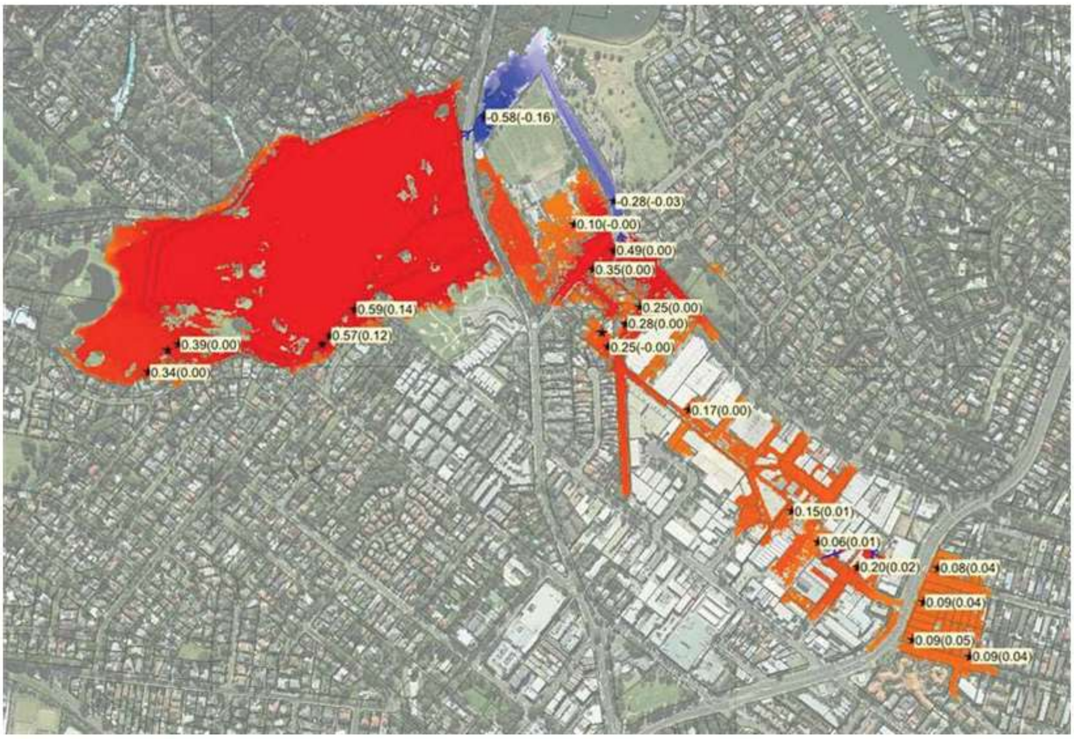

Plate 7-1: Structure Blockage Sensitivity Analysis Difference Map

Plate 7-1 shows that the 100% blocked scenario increases flood levels on properties by up to 600mm; and the 50% blocked scenario increases flood levels on properties by less than 150mm.

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The 100% blocked scenario is provided here for context regarding the sensitivity of blockages (i.e. a worst-case scenario). Increases of up to 150mm (seen in the 50% blocked scenario) could be considered to be a relatively insignificant impact on results as applied freeboard for flood planning levels is generally 500mm.

7.1.1 Design Run Recommendations

The following recommendations are made for the design runs based on sensitivity testing of blockage factors:

- Blockages of 20 – 50% could be used in the design runs for culverts without significantly influencing flood levels.
- The main culverts in the design models should have the following level of blockages applied:
- **30%** blockages for all culverts where open channels enter pipes.
- **50%** blockages for the open drain to culverted sections in the Mona Vale industrial complex. The potential for debris to collect in the open drains in this area is considered high.
- **0%** Blockages to inlet pits in the drainage system. The reason to exclude blockages from the drainage network is that:
  - Only the trunk drainage system is being modelled for this study (i.e. pipes greater than 450mm in diameter)
  - The methodology for modelling the drainage network is to assume that the system is not inlet constrained. This assumption is to correctly identify existing pipe capacities in the trunk drainage system (rather than constraints associated with the surface inlets).

7.2 Design Rainfall

Engineers Australia are currently undertaking an extensive revision of the 1987 AR&R guidelines. As part of this process, new IFDs are being generated from a longer and more extensive data set than were used in the 1987 IFDs. The revised IFD data set remains under review and is not yet intended for implementation in design flood studies. A comparison to the new IFD data set is provided here for context of the likely changes to the study when the new AR&R projects are finalised.

Plate 7-2 plots the 1987 IFD and the revised 2013 IFD data sets using the centroid of the McCarrs Creek catchment.

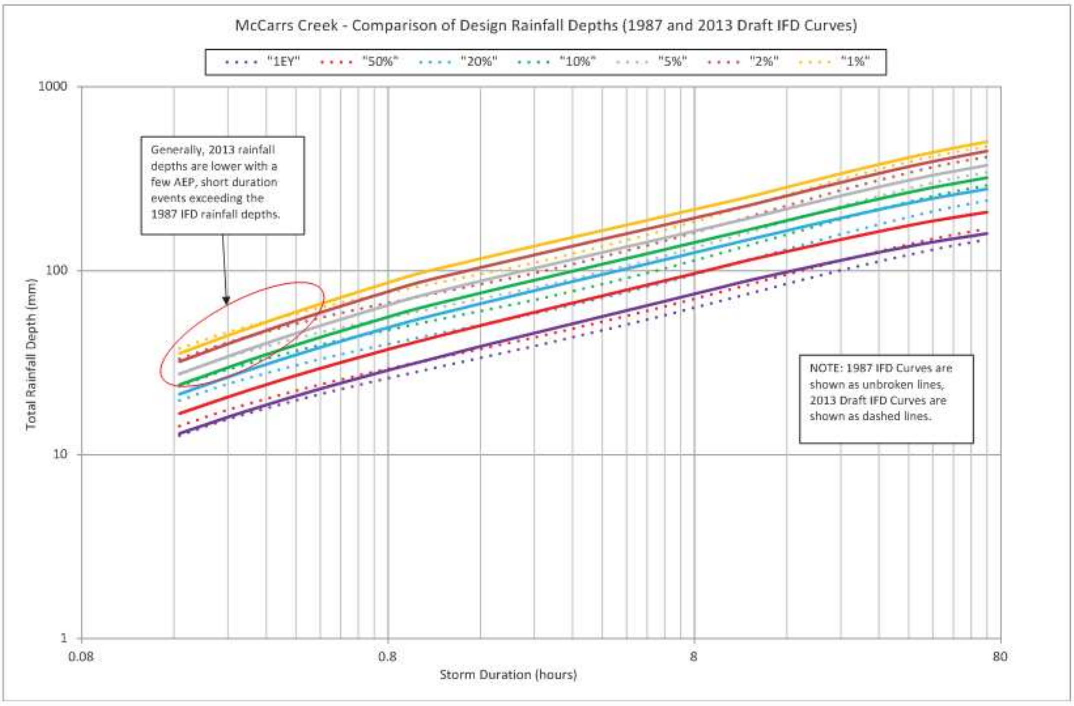

Plate 7-2: Comparison of Design Rainfall Depths at the McCarrs Creek Catchment

Plate 7-2 shows that for the McCarrs Creek Catchment, the 2013 draft IFD curves have generally lower design rainfall depths, averaging 13% less than the 1987 IFD curves. However, shorter duration events (<10mins) with a low Annual Exceedance Probability (AEP < 5%) are shown to have between 0 – 7% greater rainfall depths with the revised IFD curves. It is considered unnecessary to run a hydraulic model sensitivity of these events as the storm durations are too short for the size and nature of each of the catchments to be the critical duration storm.

8 Climate Change

8.1 Latest International Research on Climate Change Impacts

8.1.1 Annual Average Rainfall

Rainfall is the single most important climate variable for flood risk estimation. Several modelling studies are available to estimate changes in rainfall based on simulations from climate models. In mid-latitude and subtropical dry regions, mean precipitation is likely to decrease (IPCC 2013). Pittwater Council's Climate Change Risk Assessment (2012) also concluded that annual average rainfall is likely to decrease across the LGA.

Climate in Australia has a high natural variability, owing largely to the strong influence of the El Niño Southern Oscillation (ENSO), and especially rainfall is highly variable over Australia (Reisinger et al. 2014). Increases in precipitation have been found in north-western Australia since the 1950s, and declines in autumn/winter precipitation in south-western Australia since the 1970s and in south-east Australia since the 1990s (Reisinger et al. 2014). Apart from overall rainfall changes, the frequency of conditions suitable for thunderstorm occurrence has not been increasing in Australia, according to one study (Allen and Karoly 2013). For Australia, the evidence for past changes in extreme rainfall events (95th and 99th percentile) is mixed or insignificant (Reisinger et al. 2014), with for the east coast region, significant declines in total rainfall and extremes over the period 1950-2005 (Gallant et al, 2007).

8.1.2 Extreme Rainfall Events

With regard to heavy precipitation events, there are more land areas where heavy precipitation events have increased in frequency than areas where these have decreased (IPCC 2013). Extreme precipitation events will very likely become more intense and more frequent over mid-latitude land areas by the year 2100 (IPCC 2013). Pittwater Council's Climate Change Risk Assessment (2012) also concluded that rainfall event intensity will increase across the LGA.

It is important to note that changes in rainfall extremes in Australia have been observed for very small time intervals; i.e. sub-daily (Westra 2011; Westra and Sisson 2011; Jakob et al. 2011). This suggests that with further increasing temperatures, changes in rainfall may also occur at sub-daily time steps. Westra (2011) further notes that the spatial scale at which changes in rainfall occur, have not really been well addressed yet by research, and that while mean rainfall changes are related to circulation changes over larger areas, changes in intense rainfall may be occurring at smaller spatial scales. The same holds true for rainfall type (Westra, 2011); where mid-latitude storm types may move pole ward and become more important for Australia, while tropical cyclones become less frequent and tracks move southward.

Plate 8-1 illustrates according to two different ensemble simulation datasets the extent to which rainfall in December-February may change across Australia by the end of the century, albeit with considerable uncertainties for the Australian east coast. Future patterns of precipitation change according to a high climate change scenario (the RCP8.5 scenario; see left panel in **Plate 8-1** below) indicate that the east coast of NSW may see very small changes in total annual rainfall, while precipitation during December-February is expected to increase significantly (right panel) - (Irving et al 2012).

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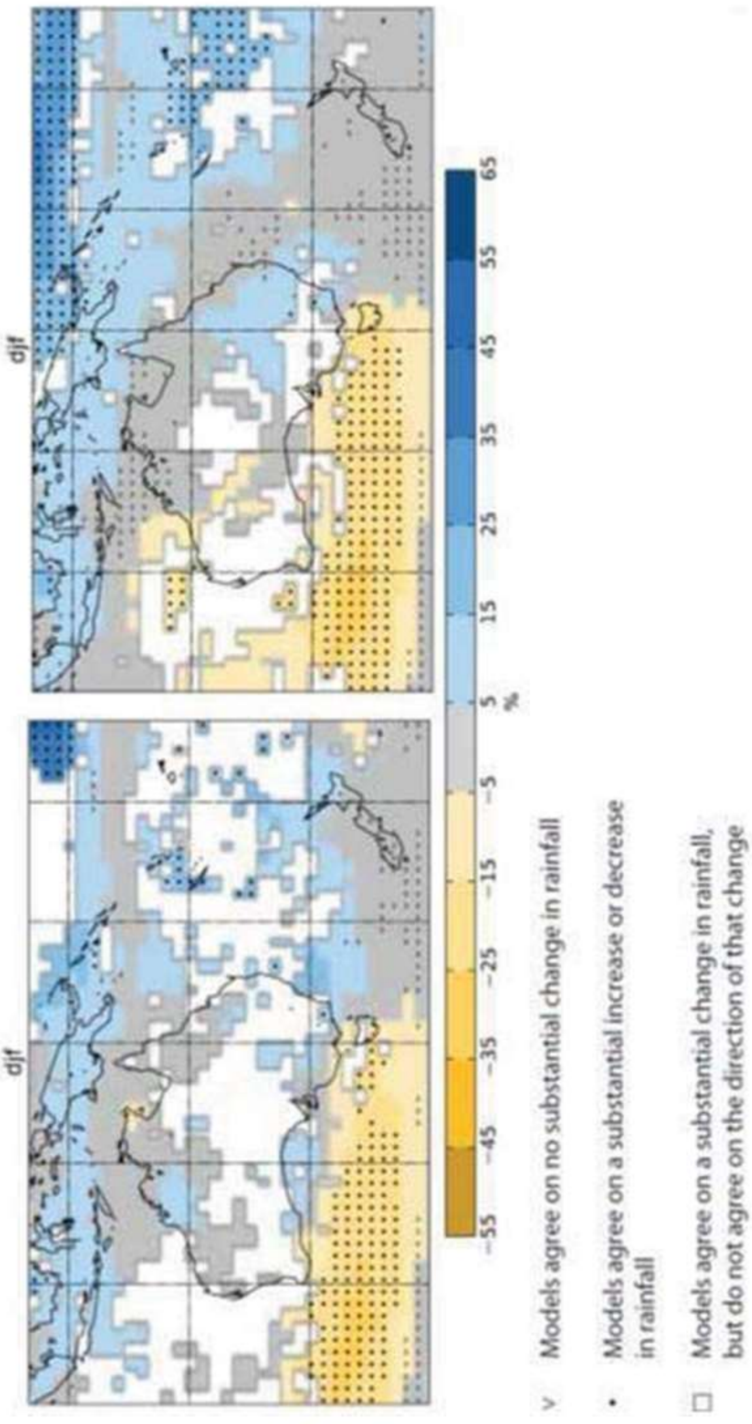

Plate 8-1: Expected Climate Change impacts in Australia based on IPCC Fifth Report

The finding that sub-daily rainfall amounts have increased alongside mixed trends in total rainfall (see above), leads to the implication that despite uncertainties in the change of annual and seasonal mean rainfall, intense rainfall events may occur more frequently in the future.

Projections of future extreme rainfall for Australia show possible increases in heavy rainfall events, substantially contributing to 5-day rainfall total and to annual rainfall totals (Alexander and Arblaster, 2009). Overall, the IPCC concludes that there is medium confidence in changes in current 20 year return period events and in short duration (sub-daily) extremes in most regions of Australia (Reisinger et al., 2014: Table 25-1).

8.1.3 Antecedent Conditions Considerations

There is little research on how climate change may affect antecedent conditions (principally soil moisture and evapotranspiration) that are important for the occurrence of flooding. In southern Australia there are indications that large scale circulation variability related to the Pacific-Decadal Oscillation (IPO) modulates soil moisture, thereby influencing flood occurrence (generally declining) through antecedent conditions, rather than through rainfall (Westra, 2011).

For instance, Micevski et al. (2003) demonstrate that during IPO negative phases, flood risk is substantially increased (up to a factor 2.0 x higher discharge). Flood conditions are expected to increase in the north of Australia, whereas in the south of Australia increasingly drier soil moisture conditions may compensate for changes in rainfall (Reisinger et al., 2014: Box 25-8). There is no research related specifically to Sydney on this topic.

Other processes that are less frequently considered include increased evaporation that could result in drier soil moisture conditions. A rapid change from a dry situation to a highly intense rainfall situation could influence runoff. Equally, drought conditions followed by extreme rainfall can exacerbate the amount of sediment discharged from the catchment. It could be recommended to monitor and assess both processes into the future, to inform modelling.

8.1.4 Sea Level Rise Considerations

The global mean sea-level increased by some 0.19 m between 1901 and 2010. For Australia, the rate of sea-level rise was 1.4 mm per year over the period 1900-2011 (Reisinger et al., 2014; Burgette et al., in press), slightly below the global average rate. Extreme sea-levels in Australia have risen at the same rate as the average sea level rise (Reisinger et al., 2014; Menendez and Woodworth, 2010).

Depending on the assumed emission scenario, global mean sea level is projected to rise by 0.53 to 0.97 m by 2100 (high emissions, RCP8.5) relative to the average of 1986-2005, or between 0.28 and 0.6 m (low emissions, RCP2.6) (IPCC, 2013).

Projected future sea-level rise along the Australian coast is expected to exceed the average historic rate, contributing to the trend in higher extreme sea- levels (Reisinger et al., 2014 IPCC, 2013). Studies suggest that with sea-level rise, the frequency of extreme sea-levels, as well as the number of exposed properties, may increase disproportionally along the Australian south-east coast (Reisinger et al., 2014; McInnes et al., 2011; McInnes et al.,2012), although other studies assume a proportionate increase (Wang et al., 2010).

For Australia, changes in future storms and cyclones are expected to play a minor role in changes in the occurrence of extreme sea-levels, compared to sea-level rise. A study using the CSIRO CCAM model found that the number of tropical cyclones may decrease strongly (by about 50%) by the end of the century (period 2051-2090 compared to 1971-2000), and a southward movement of genesis and decay regions (Abbs, 2012).

Finally, combinations of storm surge levels at the tail-end of the catchments, combined with intense rainfall from storm activity could potentially lead to peak water levels. It could be useful to assess the joint probabilities and intensities of these two processes, as a low-probability and high-impact event in a model.

8.2 NSW Government Policy Development on Climate Change

In NSW the 'Floodplain Development Manual: the management of flood liable land' (NSW Government, 2005), states that a flood study should address the possible implications of climate change on flood behaviour, including sea level rise, altered storm patterns and intensity and increased intensity and frequency of extreme events. The manual states the consequences of climate change on flood levels and behaviour should be analysed as part of a flood study either:

- Qualitatively based upon the broad range of floods being examined up to and including the PMF; or
- Sensitivity analysis in relation to rainfall intensity or downstream water level conditions for key flood events.

In 2007, more specific guidance was provided by the NSW Department of Environment and Climate Change (DECC, now Office of Environment and Heritage, OEH): 'Practical Consideration of Climate Change in Flood Investigations'. The guidelines recommend sensitivity analysis is considered for:

- Sea level rise – for low (0.18 m), medium (0.55 m) and high level impacts (up to 0.91 m); and
- Rainfall Intensities – for 10%, 20% and 30% increase in peak rainfall and storm volume.

The NSW Sea Level Rise Policy Statement (2009) provided by NSW DECC, now OEH, updated the best projections of sea level rise along the NSW coast, relative to 1990 mean sea levels, to be 0.4 m by 2050 and 0.9 m by 2100. It was acknowledged that higher rates were possible. The policy statement recommended these sea level rise benchmarks for use in flood risk assessments.

In 2012, the above sea level rise benchmarks were withdrawn by the NSW Government, following widespread concern that the coastal zone implications of their implementation were too onerous. The State Government instructed each Council to determine and implement its own benchmarks. In reality, and without any better science or guidance to follow, most NSW Councils have continued to adopt the 0.4 and 0.9 m sea level rise benchmarks.

Until relatively recently the table below provided the range of climate change scenarios typically modelled in NSW flood studies for each AEP event. Whilst being a comprehensive approach, this led to a significant number of events being run and subsequent modelling effort.

Table 8-1: Typical Matrix of Climate Change Scenarios adopted by NSW Coastal Councils

Scenario	Sea level rise (m)	Rainfall intensity increase
1	0.4	-
2	0.9	-
3	-	10%
4	-	20%
5	-	30%
6	0.4	10%
7	0.4	20%
8	0.4	30%
9	0.9	10%
10	0.9	20%
11	0.9	30%

More recently NSW practice has moved away from running all design events for all climate change cases. Instead it is now usual practice to only run a couple of events, the 1% AEP and a bigger and a smaller event. Consideration is currently being given in NSW and in the interim climate guidelines to putting more emphasis on how the probabilities of different events change rather than running extra climate change IFD runs. In most cases the relatively simple exercise of determining the percentage rainfall increase that would turn a 1% AEP event into a 0.5% (200 year) and 0.2% (500 year) will give a good picture of how changes in rainfall will affect risk management.

8.3 Adopted Tailwater Levels for different Sea Level Rise Scenarios

As outlined in **Section 6.2**, a number of Climate Change Sea Level Rise Boundary conditions were adopted based on a review of recent relevant literature. Different tailwater levels were adopted for either Pittwater estuary or Pacific Ocean (beach) outlet pipes.

Table 8-2: Adopted Tailwater Boundaries (Peak Level in Tidal Cycle)

Event	Pittwater Estuary Peak Level (mAHD)	Ocean Boundary Peak Level (mAHD)
1% AEP Event	1.50	2.60
2050 Climate Change Scenario (+0.33m)	1.83	2.93
2100 Climate Change Scenario (+0.83m)	2.35	3.43

8.4 Climate Change Model Scenarios

A total of six (6) climate change scenarios were simulated as outlined in **Table 8-3** below.

Table 8-3: Adopted Climate Change Scenarios to be modelled for this Study

Scenario	Rainfall	Tailwater
1	1% AEP Event + 10% Rainfall (simulated as 0.5% AEP Rainfall)	Current Conditions
2	1% AEP Event + 30% Rainfall (simulated as 0.2% AEP Rainfall)	Current Conditions
3	1% AEP Event	2050 Conditions
4	1% AEP Event	2100 Conditions
5	1% AEP Event + 30% Rainfall	2100 Conditions
6	PMF Event + 30% Rainfall	2100 Conditions

8.5 Climate Change Assessment Results

Results of the climate change simulations are presented in **Figures A16 – A23,** through a series of results maps and difference maps, highlighting the potential effects of climate change.

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9 Development Controls

9.1 Flood Planning Areas

Flood planning areas were calculated for the study area for three main areas, utilising freeboard to the 1% AEP flood results. These include:

- Area 1: Mainstream Flooding – For areas within defined watercourse channels, a 0.5m freeboard was applied and the flood surface was laterally extended until it intersected with the ground surface (i.e. were the planning level would intersect the watercourse overbank).
- Area 2: Major Overland Flow Paths – For overland flow areas greater than 0.3m deep a 5m horizontal buffer was applied to the modelled flood extent as freeboard.
- Area 3: Minor Overland Flow Paths – For overland flow areas less than 0.3m deep no freeboard was applied.

Flood planning areas are presented in **Figure A26**.

9.2 Council's Flood Categories

Council's Flood Control categories were updated during the course of the study to include the following:

- ***Low Flood Risk precinct*** refers to all *flood prone land* (i.e. within the PMF extent) not identified within the High or Medium flood risk precincts.
- ***Medium Flood Risk precinct*** means all *flood prone land* that is (a) within the 1% AEP Flood Planning Area; and (b) is not within the high flood risk precinct.
- ***High Flood Risk precinct*** means all *flood prone land* (a) within the 1% AEP Flood Planning Area; and (b) is either subject to a high hydraulic hazard, within the floodway or subject to significant evacuation difficulties (H5 and or H6 Life Hazard Classification).

Property classification mapping was undertaken utilising the filtered flood results. In addition to the map filtering (outlined in **Section 2.7.1**), properties were tagged where the flood extent encroached on the property boundary by more than 1m. Results of the property classification mapping are presented in **Figure A25**.

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Properties at Risk Analysis

A flood information database was produced for all of the study area catchments and contained the following:

- Address, lot and DP number;
- Land use (i.e. residential, commercial etc);
- Typical ground level (assumed from LiDAR);
- Maximum peak flood level and flood depth across the property for:
  - 20% AEP;
  - 10% AEP;
  - 5% AEP;
  - 2% AEP;
  - 1% AEP;
  - 0.5% AEP;
  - 0.2% AEP; and
  - PMF;
- Average flow velocity, flood hazard, flood risk (high or low) and hydraulic flood category for:
  - 1% AEP; and
  - PMF;
- Flood Planning Levels;
- Flood categories under Council's DCP, as discussed in **Section 9.1**; and
- Climate Change Levels.

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10 State Emergency Services (SES) Requirements

10.1 Duration of Inundation for Road Crossings

The maximum duration of inundation of flood waters over a number of road crossings was derived from the flood model results. To achieve this, the total duration that flood waters exceeded a cut-off value (0.15m) over the road crown was extracted from the time series results.

A summary of the maximum time of inundation a number of road crossings is shown in **Table 6-8** through **Table 6-10** below. The placement of these locations is shown in **Figure 14** to **16**. The values reported below are the maximum values from an envelope of scenarios as described in **Section 6.3.1**.

Table 10-1: Duration of Road Inundation – Model Area 1 – The 'Rural' Catchments

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF Event
Model Area 1 – The Rural Catchments – Duration of Inundation (hours)									
1	West Wirreanda Rd	13.6	13.7	13.9	14.0	14.1	14.2	14.2	7.9
2	East Wirreanda Rd	12.6	12.8	13.0	13.4	13.5	13.7	13.8	7.8
3	Wirreanda Rd North	11.8	11.9	12.2	12.4	12.6	12.7	12.8	7.2
4	Wirreanda Rd North	9.2	9.6	9.8	10.5	10.8	11.1	11.4	6.5
5	McCarrs Creek Rd	10.4	10.8	11.3	11.6	11.9	12.1	12.4	7.5
6	McCarrs Creek Rd	13.7	13.8	13.8	13.9	13.9	13.9	14.0	7.7
7	McCarrs Creek Rd	11.4	11.6	11.6	12.1	12.3	12.5	12.8	7.4
8	McCarrs Creek	7.5	8.2	8.8	9.4	9.8	10.2	10.6	7.2
9	Sophie Avenue	0.0	0.2	0.3	0.5	0.7	1.1	1.7	3.0
10	Chiltern Road	0.0	0.0	0.0	0.4	0.9	1.3	1.6	3.0
11	Glen Cicada Creek	14.4	14.5	14.6	14.6	14.6	14.6	14.7	8.0
12	Cicada Glen Rd	14.4	14.4	14.6	14.7	14.7	14.7	14.7	7.9
13	McCarrs Creek Rd	0.0	0.0	0.0	0.0	0.4	0.8	1.1	2.6

Table 10-2: Duration of Road Inundation – Model Area 2 – The 'Pittwater' Catchments

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF Event
Model Area 2 – The Pittwater Catchments – Duraiton of Inundation (hours)									
1	McCarrs Creek Rd	0.0	0.1	0.2	0.3	0.6	0.7	0.9	0.7
2	Barcoola Place	5.5	6.0	6.1	5.9	6.2	6.2	6.3	3.9
3	Gilwinga Drive	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.8
4	McCarrs Creek Rd	0.0	0.1	0.2	0.3	0.4	0.5	0.7	0.8
5	McCarrs Creek Rd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
6	Kananook Avenue	1.4	1.4	1.5	1.6	1.7	1.7	1.9	1.5
7	Kananook Avenue	0.0	0.0	0.1	0.2	0.2	0.3	0.3	0.7
8	Pittwater Rd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
9	Pittwater Rd	0.1	0.1	0.3	0.4	0.5	0.6	0.8	0.9
10	Clive Crescent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
11	Jendi Avenue	0.7	0.8	0.9	1.3	1.4	1.5	1.6	0.9
12	Jendi Avenue	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.6
13	Loquat Valley Rd	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.7
14	Kookaburra Close	4.8	4.8	4.8	4.7	4.9	4.9	4.9	3.2
15	Pittwater Rd	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.7
16	Pittwater Rd	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1
17	Pittwater Rd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
18	Gerroa Avenue	0.1	0.1	0.2	0.2	0.3	0.3	0.5	0.7
19	Pittwater Rd	1.2	1.7	2.1	2.4	2.6	2.7	2.9	2.1
20	Pittwater Rd	0.7	0.8	0.9	1.2	1.3	1.4	1.5	0.9
21	The Esplande	8.5	8.5	8.6	8.6	8.6	8.6	8.7	6.0
22	Rednal Street	1.1	1.2	1.5	1.9	2.0	2.1	2.3	1.0
23	Crescent Rd	0.9	1.0	1.1	1.3	1.4	1.4	1.5	0.8
24	Suncrest Avenue	0.2	0.2	0.4	0.6	0.7	0.7	0.9	0.7
25	Crescent Rd	0.2	0.2	0.3	0.4	0.5	0.7	0.8	0.8
26	Yachtsmans Paradise	2.3	2.4	2.6	2.7	2.8	2.9	2.9	1.2
27	Crescent Rd	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.7

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Table 10-3: Duration of Road Inundation – Model Area 3 – The 'Urban' Catchments

ID	Location	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF Event
Model Area 3 – The Urban Catchments – Duration of Inundation (hours)									
1	Peninsula Gdns Retirement	5.0	5.4	5.9	6.6	7.1	7.4	7.8	3.3
2	Old Samuel Street	2.0	2.3	2.7	3.5	4.1	4.8	5.4	3.4
3	Samuel Street	0.6	0.9	1.1	1.4	1.8	2.1	2.7	3.2
4	Parkland Road	0.7	1.1	1.2	1.6	1.8	2.2	2.8	3.1
5	Cabbage Tree Road	3.7	3.8	4.1	4.9	5.2	5.5	5.9	3.2
6	Annam Road	9.6	9.8	10.2	10.5	10.5	10.6	10.7	5.2
7	Annam Road	0.5	0.5	0.6	0.7	0.7	0.8	0.8	3.0
8	Annam Road	0.1	0.2	0.3	0.4	0.6	0.8	0.9	3.3
9	Cabbage Tree Road	1.2	2.3	3.1	4.0	4.5	5.0	5.6	4.6
10	Bayview Golf Course	6.3	6.7	7.2	7.9	8.3	8.8	9.2	6.6
11	Mona Vale Road	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4
12	Samuel Street	0.7	0.9	1.1	1.4	1.7	2.0	2.5	3.4
13	Marie Crescent	1.2	1.5	1.9	2.3	2.8	3.2	3.9	3.3
14	Siobhan Place	10.9	11.1	11.3	11.4	11.5	11.6	11.8	7.0
15	Parkland Road	12.0	12.2	12.4	12.7	12.8	12.9	12.9	8.4
16	Waratah Street	0.1	0.1	0.3	0.6	0.7	0.8	1.0	3.2
17	Waratah Street	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
18	Cnr Maxwell St & Parkland Road	0.0	0.0	0.0	0.1	0.1	0.1	0.2	1.9
19	Wilmette Place	2.7	3.1	3.4	3.8	4.2	4.5	4.7	3.3
20	Grandview Parade	13.8	13.9	14.0	14.1	14.2	14.2	14.3	9.9
21	Orana Road	0.5	0.6	0.9	1.1	1.3	1.6	1.7	3.3
22	Bassett Street	0.2	0.3	0.5	0.6	0.8	0.9	1.1	3.2
23	Surfview Road	2.4	2.8	3.4	4.1	4.7	5.3	6.3	4.2
24	Seabeach Avenue	0.0	0.0	0.0	0.1	0.1	0.2	0.3	2.9
25	Heath Street	3.3	5.0	4.3	5.0	6.1	6.8	7.4	4.8

26	Polo Avenue	10.7	11.1	11.2	11.5	11.7	11.9	12.1	8.2
27	Tengah Crescent	1.2	3.5	2.0	2.7	3.4	4.1	4.9	3.6
28	Bassett Street	2.4	3.4	4.1	5.0	6.0	6.9	7.4	5.2
29	Mona Street	0.6	1.0	1.5	2.2	3.0	3.9	4.4	3.4
30	Barrenjoey Road	12.4	12.8	13.0	13.4	13.5	13.7	13.8	9.8
31	Barrenjoey Road	12.1	12.2	12.3	13.0	13.3	13.5	13.7	9.8
32	Brinawa Street	6.0	6.5	7.0	8.2	8.7	9.3	10.2	5.6
33	Brinawa Street	0.0	0.0	0.0	0.1	0.1	0.2	0.2	2.3
34	Vineyard Street	6.5	7.0	7.4	8.0	8.2	8.4	8.5	3.4
35	Cnr Mona Vale Rd & Pittwater Rd	0.1	0.2	0.2	0.4	0.4	0.6	0.6	2.4
36	Cnr Rowan St & Pittwater Rd	5.5	5.9	6.4	7.0	7.2	7.5	7.7	3.4
37	Pittwater Road	0.5	0.6	0.8	0.9	1.1	1.3	1.5	3.3
38	Mona Vale Golf Course	7.0	7.4	7.8	8.2	8.3	8.5	8.6	3.4

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11 Acknowledgments

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- Members of the Community Working Group;
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- Residents that attended one on one consultation sessions;
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- Bureau of Meteorology;
- State Emergency Services; and
- Sydney Water Corporation.

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Appendix A – Preliminary Flood Depth Maps

List of Figures (Note: All maps have windows A, B and C)

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Appendix B – Community Consultation Information

07 July 2017

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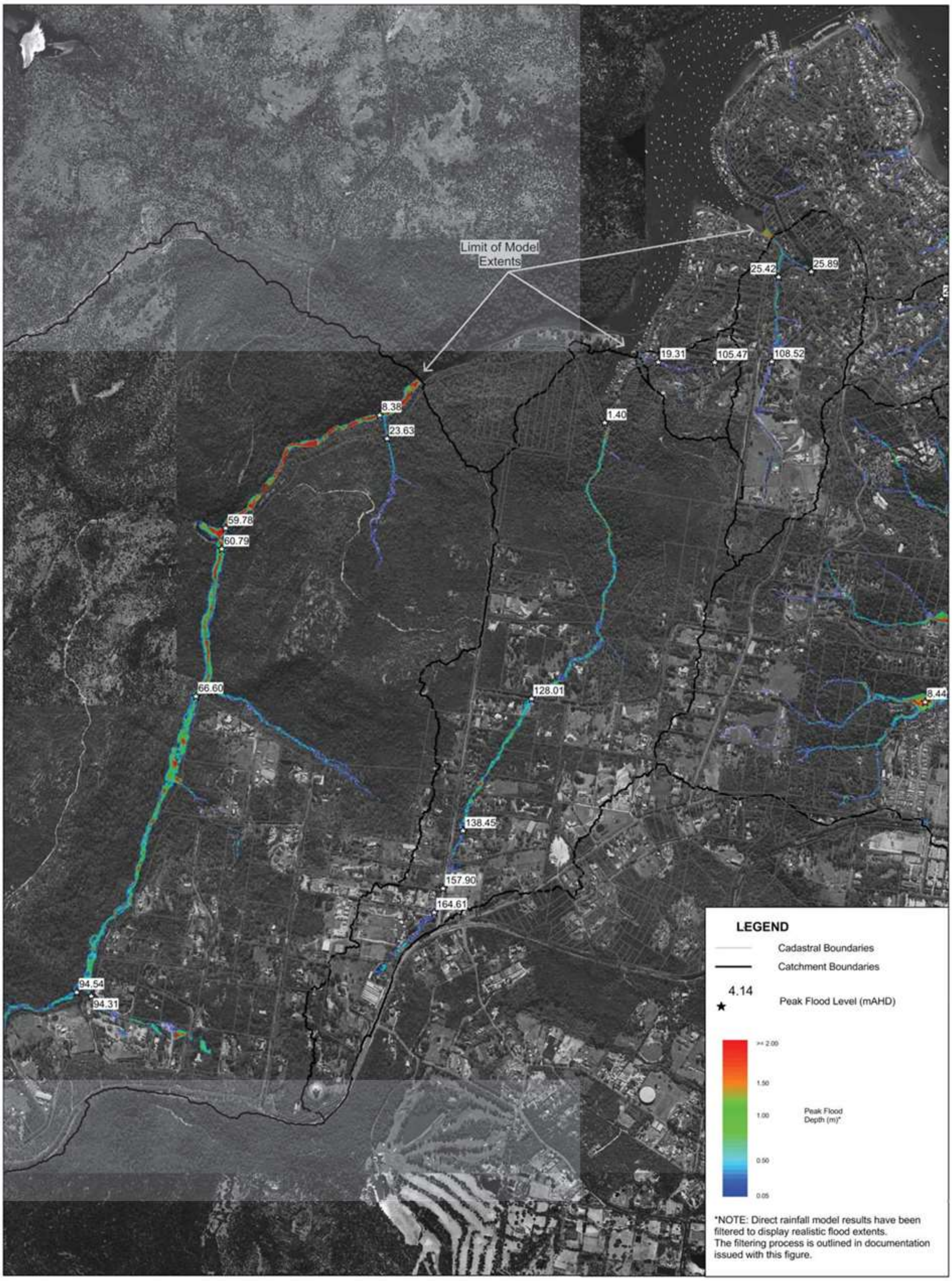
Appendix C – Design Hydrographs

07 July 2017



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NORTH	FIGURE A.1A PEAK FLOOD DEPTH (20% AEP EVENT)		
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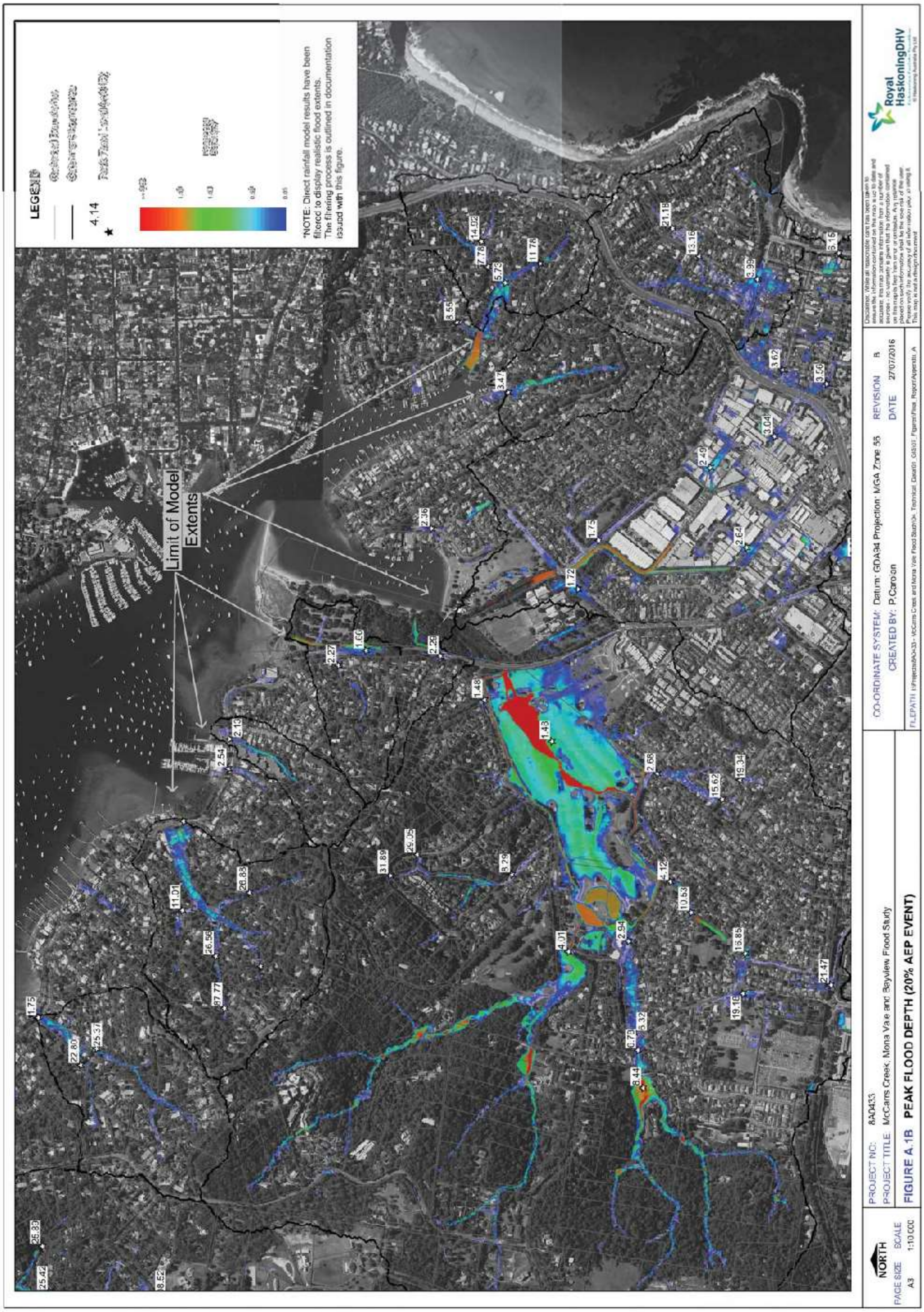
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FIGURE A.1B PEAK FLOOD DEPTH (20% AEP EVENT)
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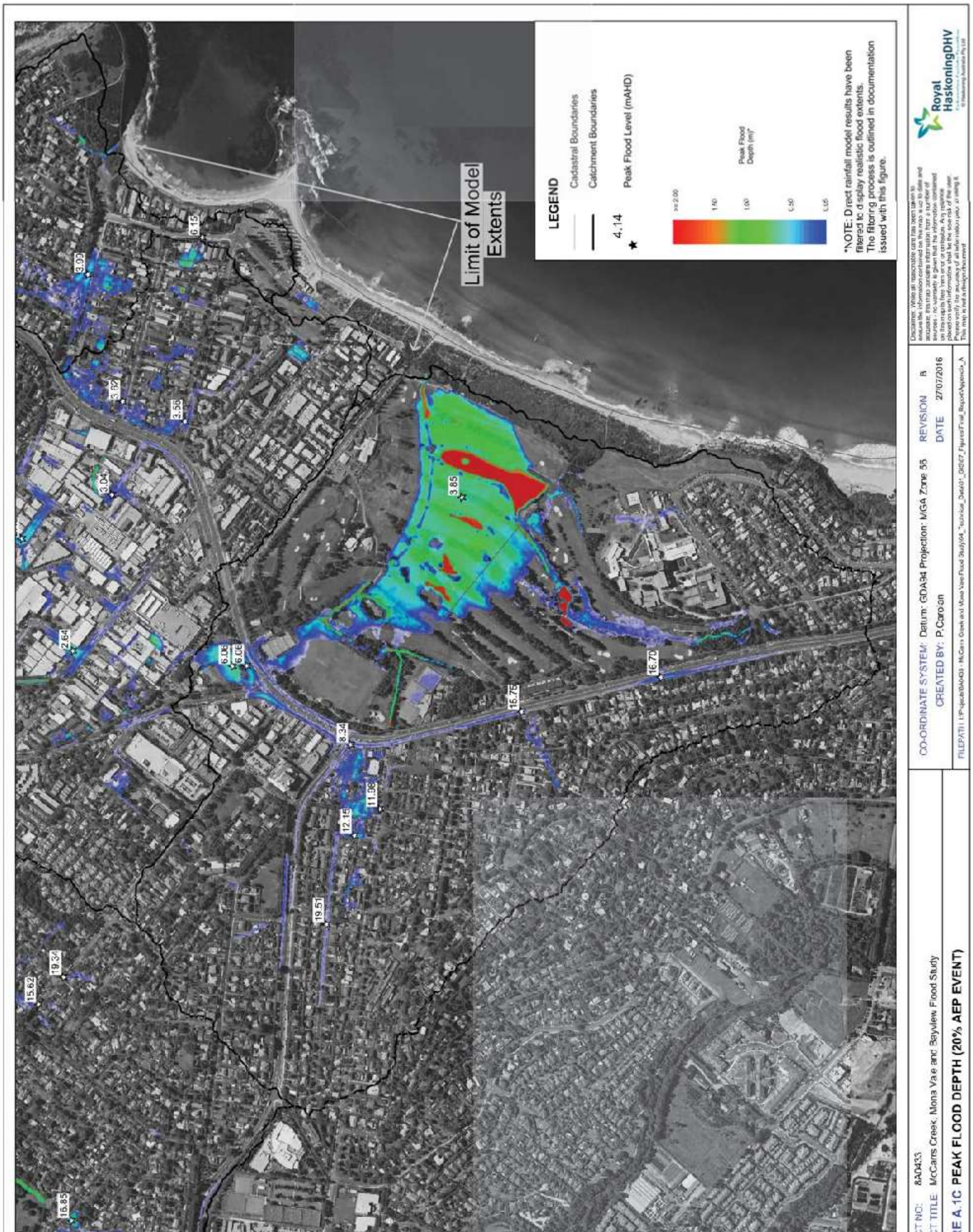
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Cadastral Boundaries
Catchment Boundaries
4.14 Peak Flood Level (mAHD)
Peak Flood Depth (m)*
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
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PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.1C PEAK FLOOD DEPTH (20% AEP EVENT)
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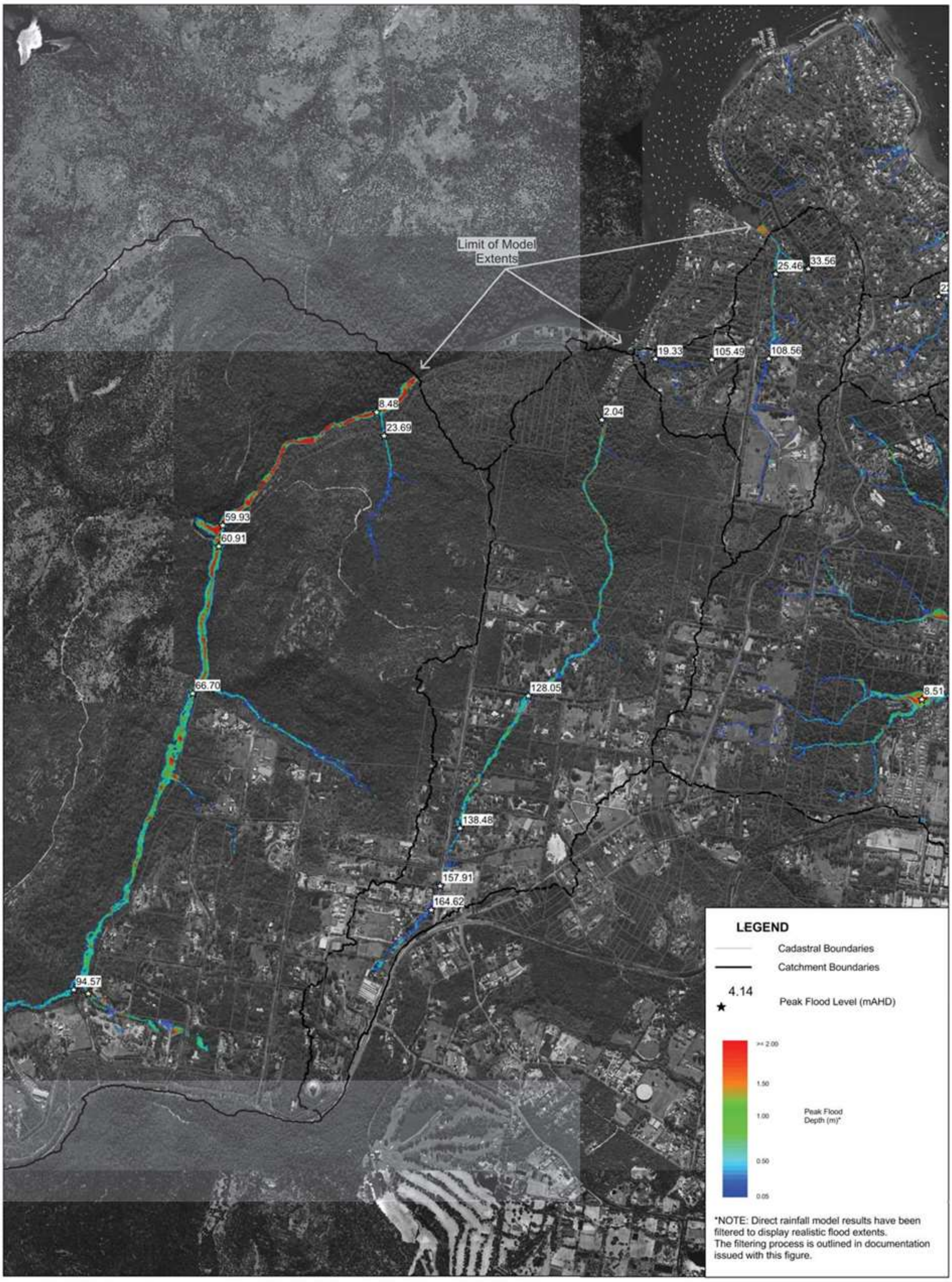

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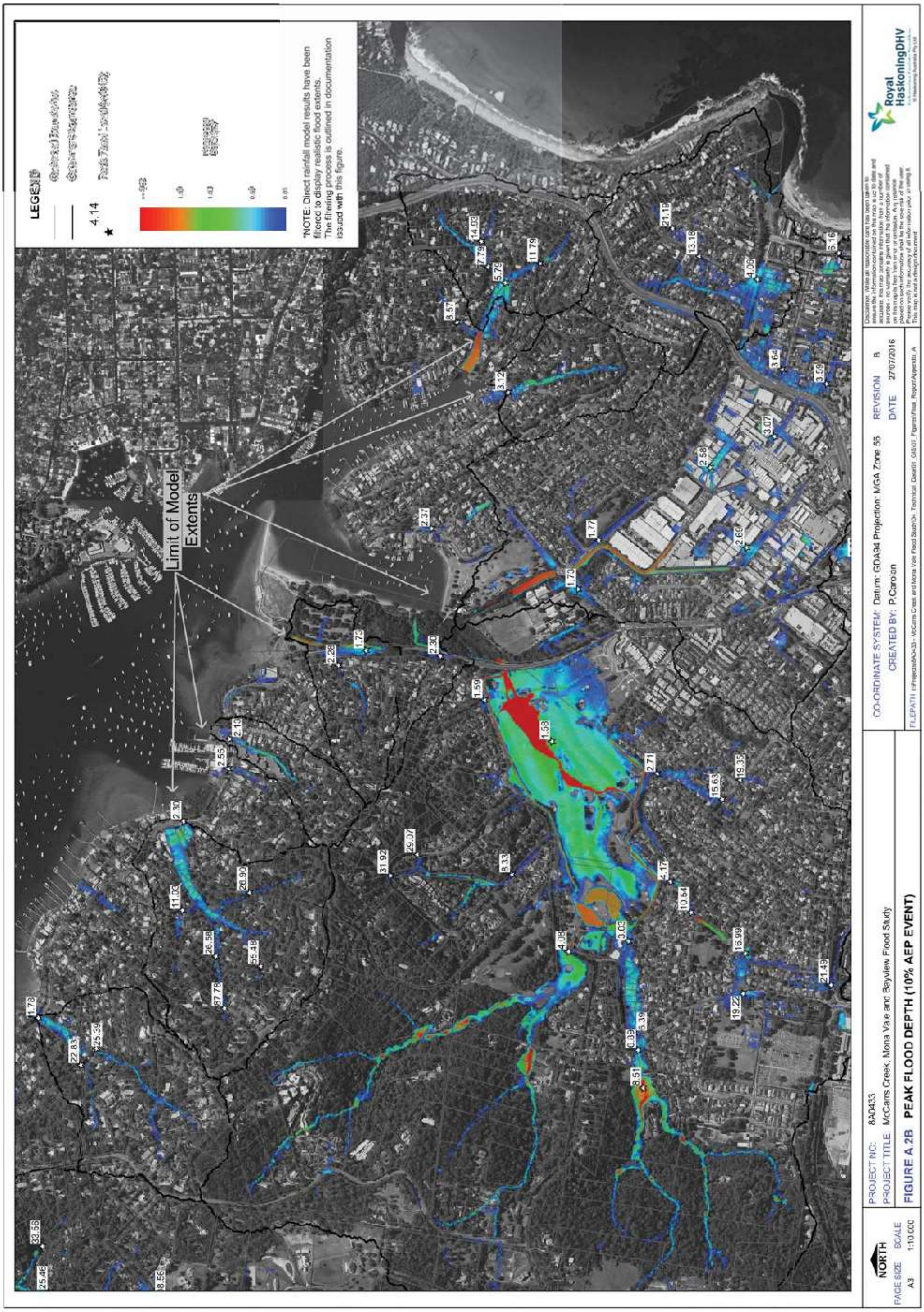
NORTHPAGE SIZE A3 SCALE 1:15,000	FIGURE A.2A PEAK FLOOD DEPTH (10% AEP EVENT) FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A	CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56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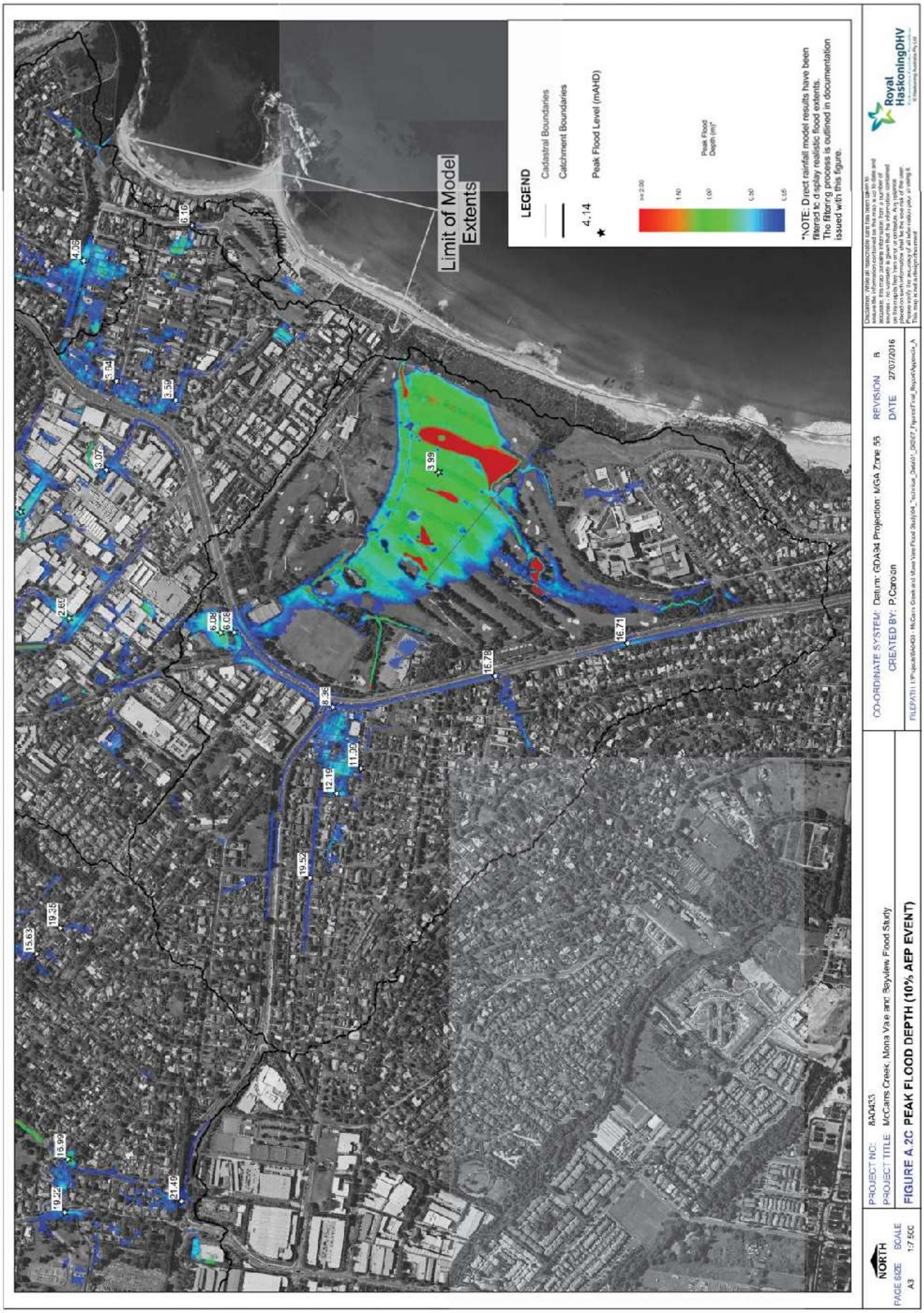
Limit of Model Extents
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Cadastral Boundaries
Catchment Boundaries
4.14 Peak Flood Level (mAHD)
Peak Flood Depth (m)*
>= 2.00
1.50
1.00
0.50
0.05
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
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DATE 27/07/2016
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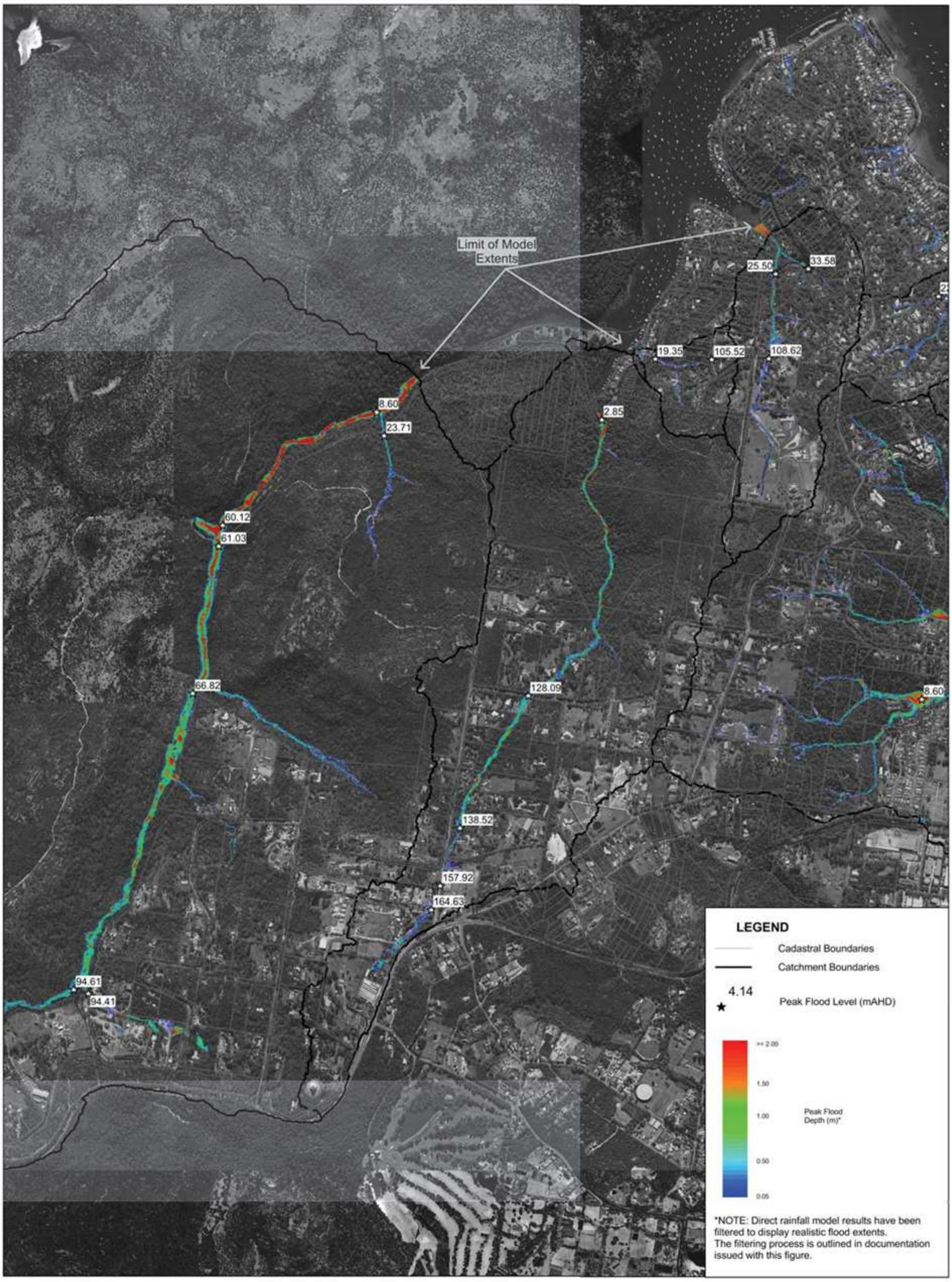

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FIGURE A.3A PEAK FLOOD DEPTH (5% AEP EVENT)

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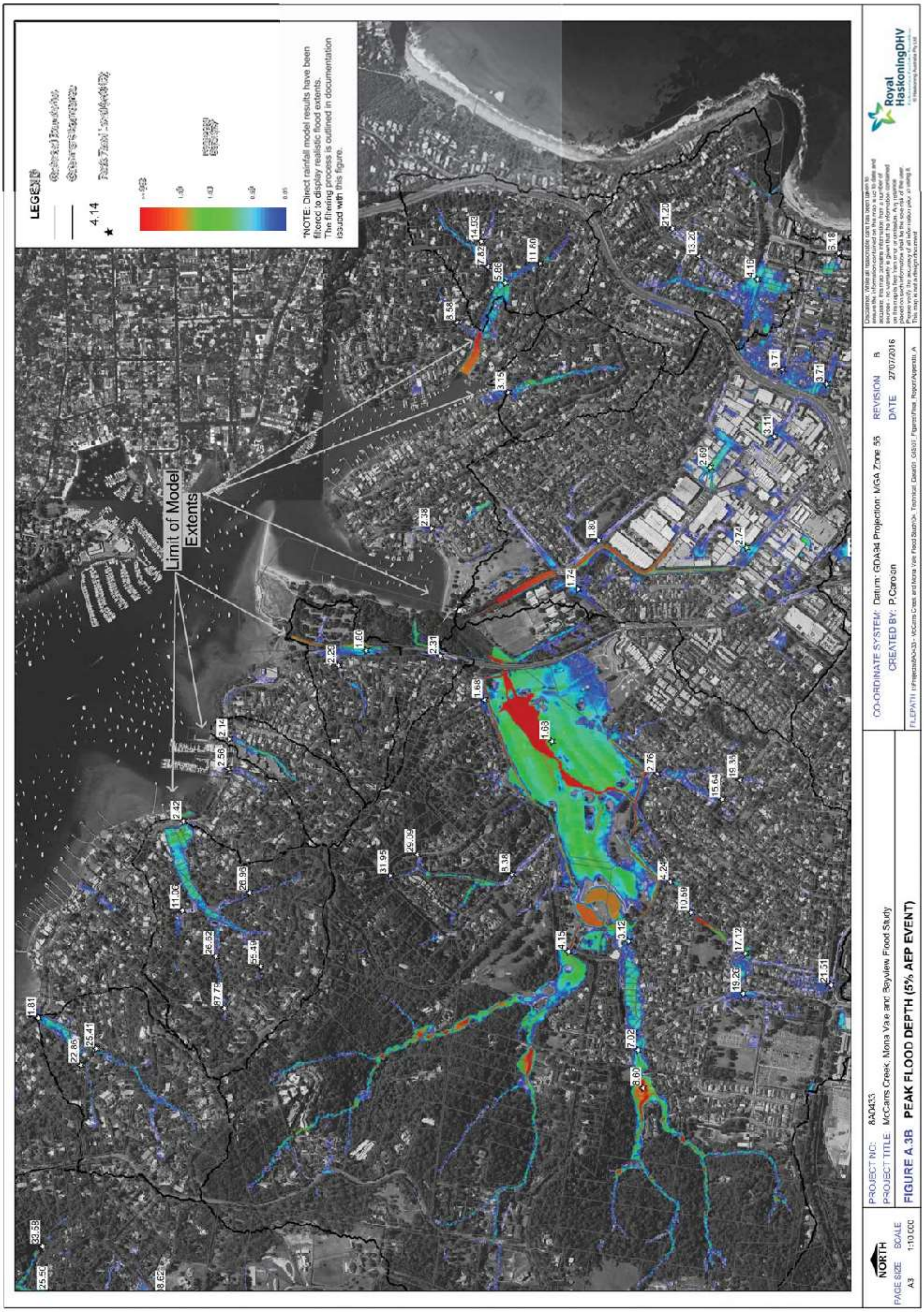
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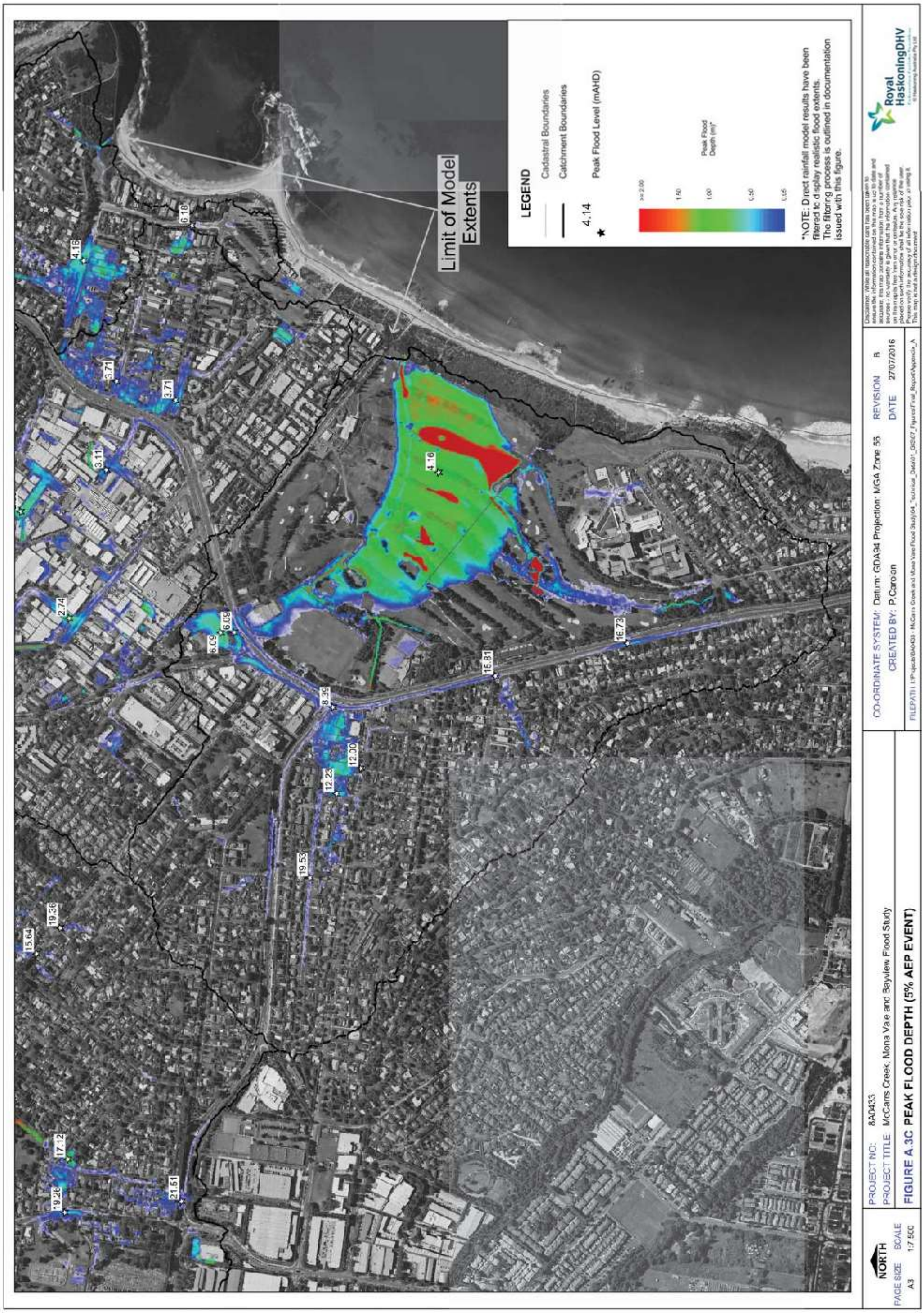
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Cadastral Boundaries
Catchment Boundaries
4.14 Peak Flood Level (mAHD)
Peak Flood Depth (m)*
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
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PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.3C PEAK FLOOD DEPTH (5% AEP EVENT)
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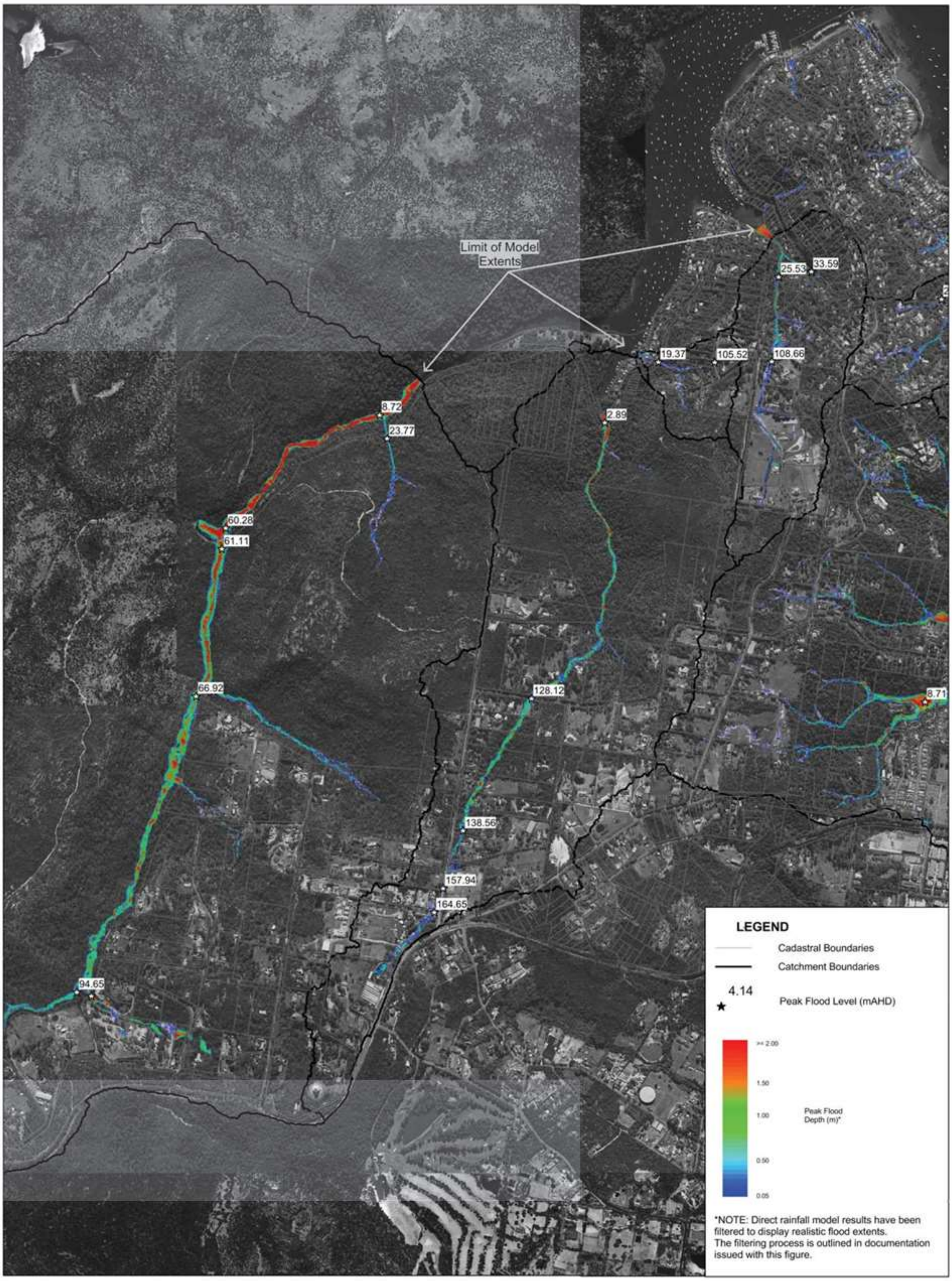

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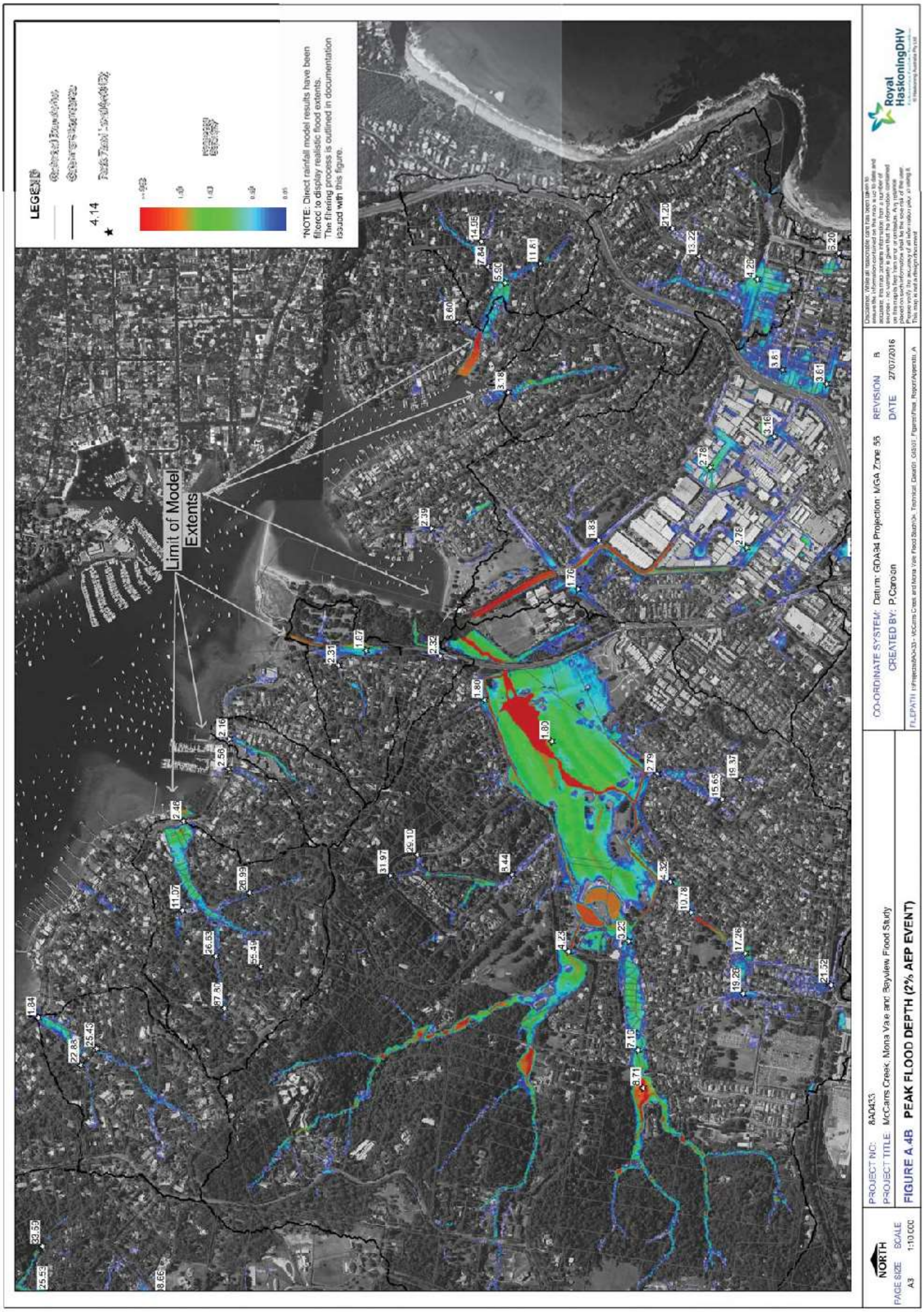
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REVISION B
CREATED BY: P.Carolan
DATE 27/07/2016
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
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NORTH
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Royal HaskoningDHV

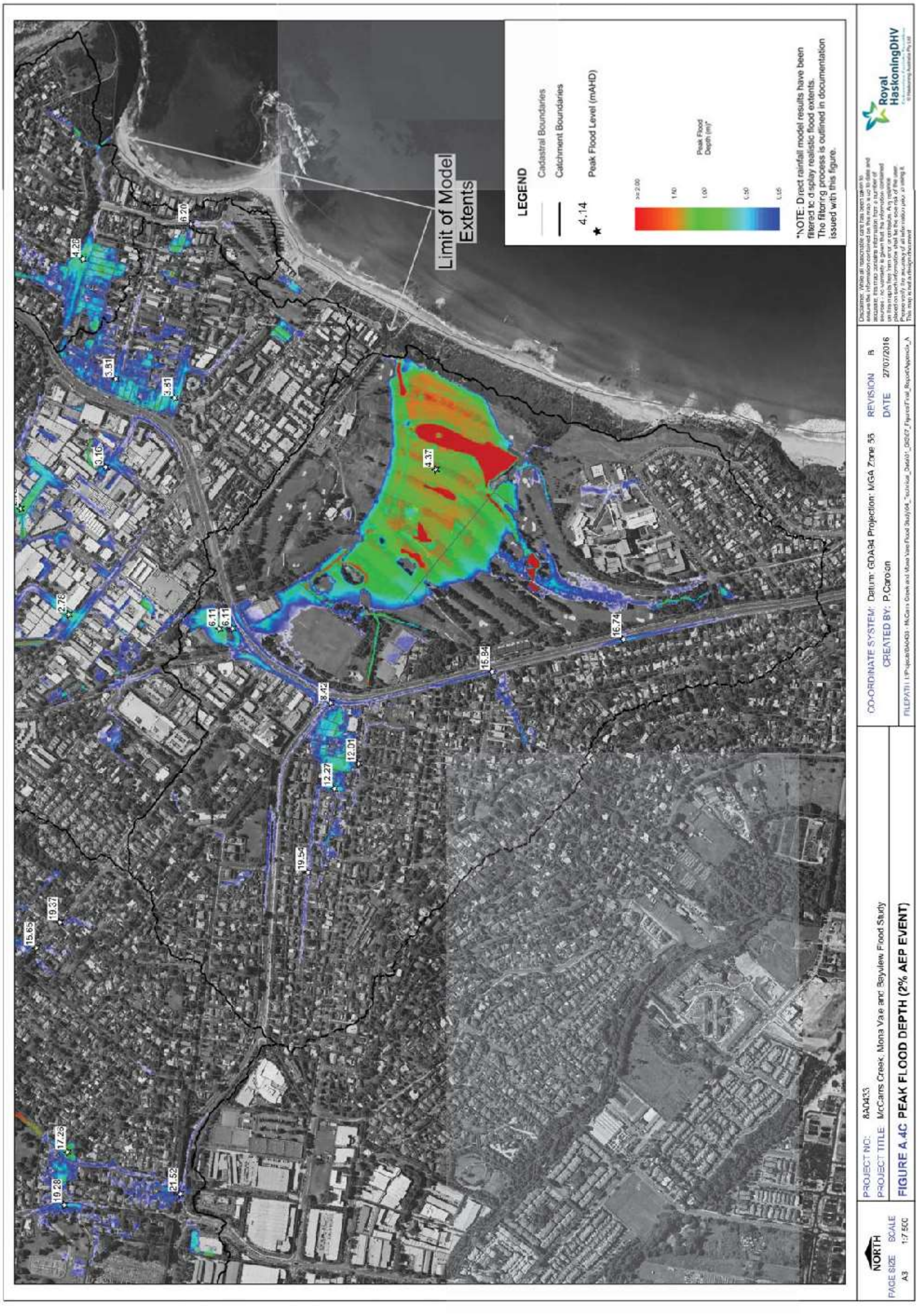
Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
4.14 Peak Flood Level (mAHD)
Peak Flood Depth (m)*
>= 2.00
1.50
1.00
0.50
0.05
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
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FIGURE A.4C PEAK FLOOD DEPTH (2% AEP EVENT)
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6.20
3.51
3.81
3.16
2.78
6.11
6.11
4.37
16.74
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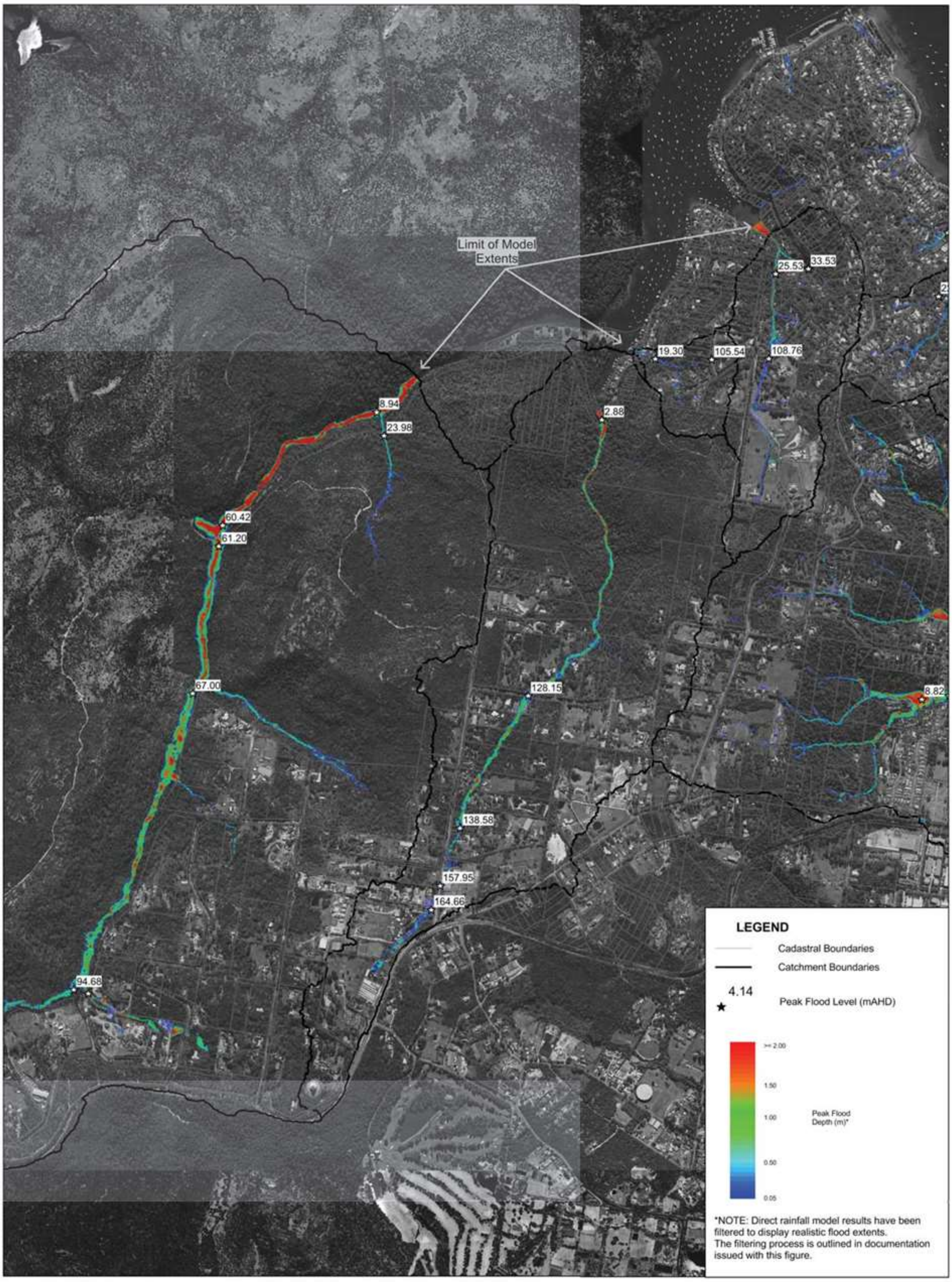
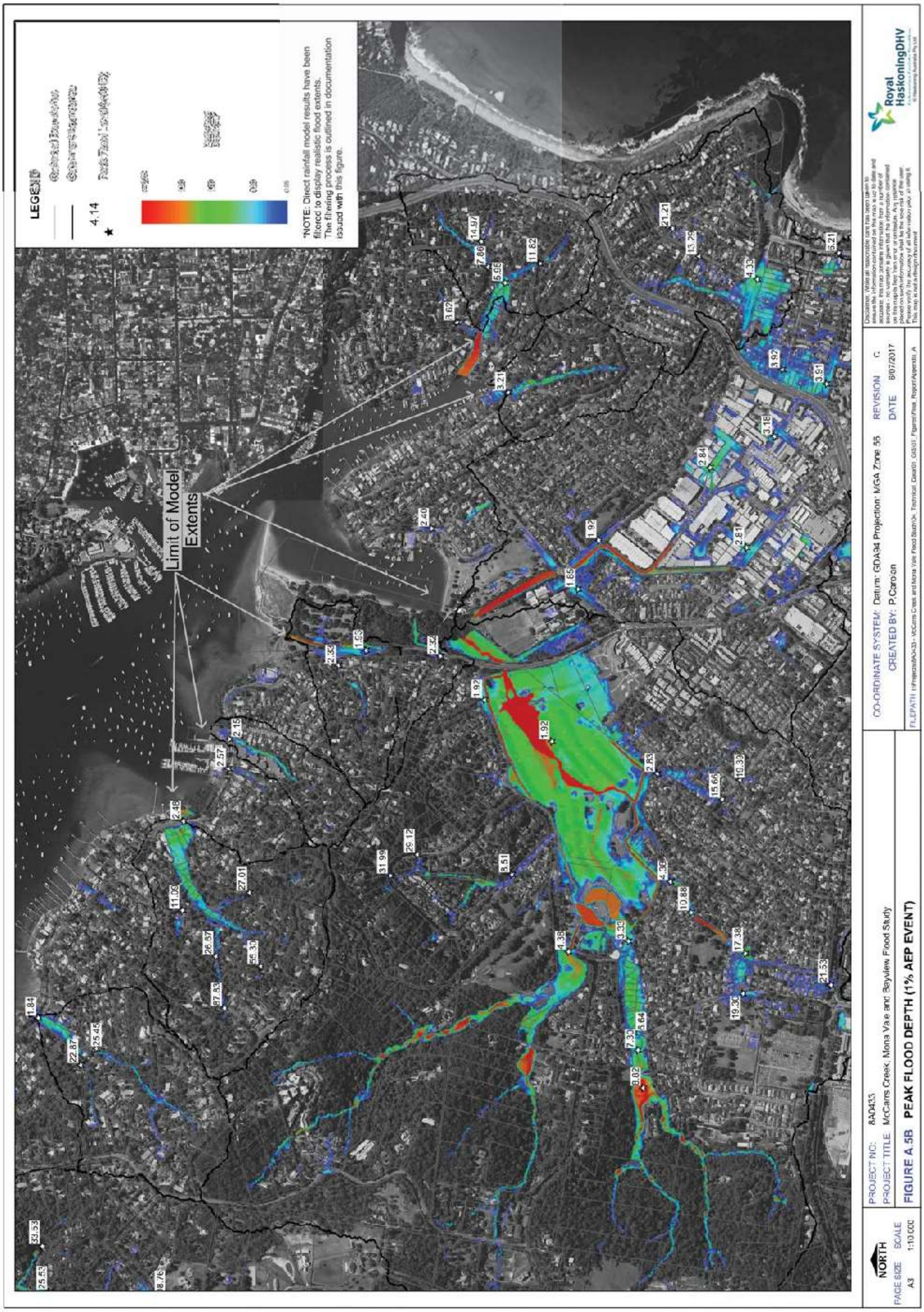
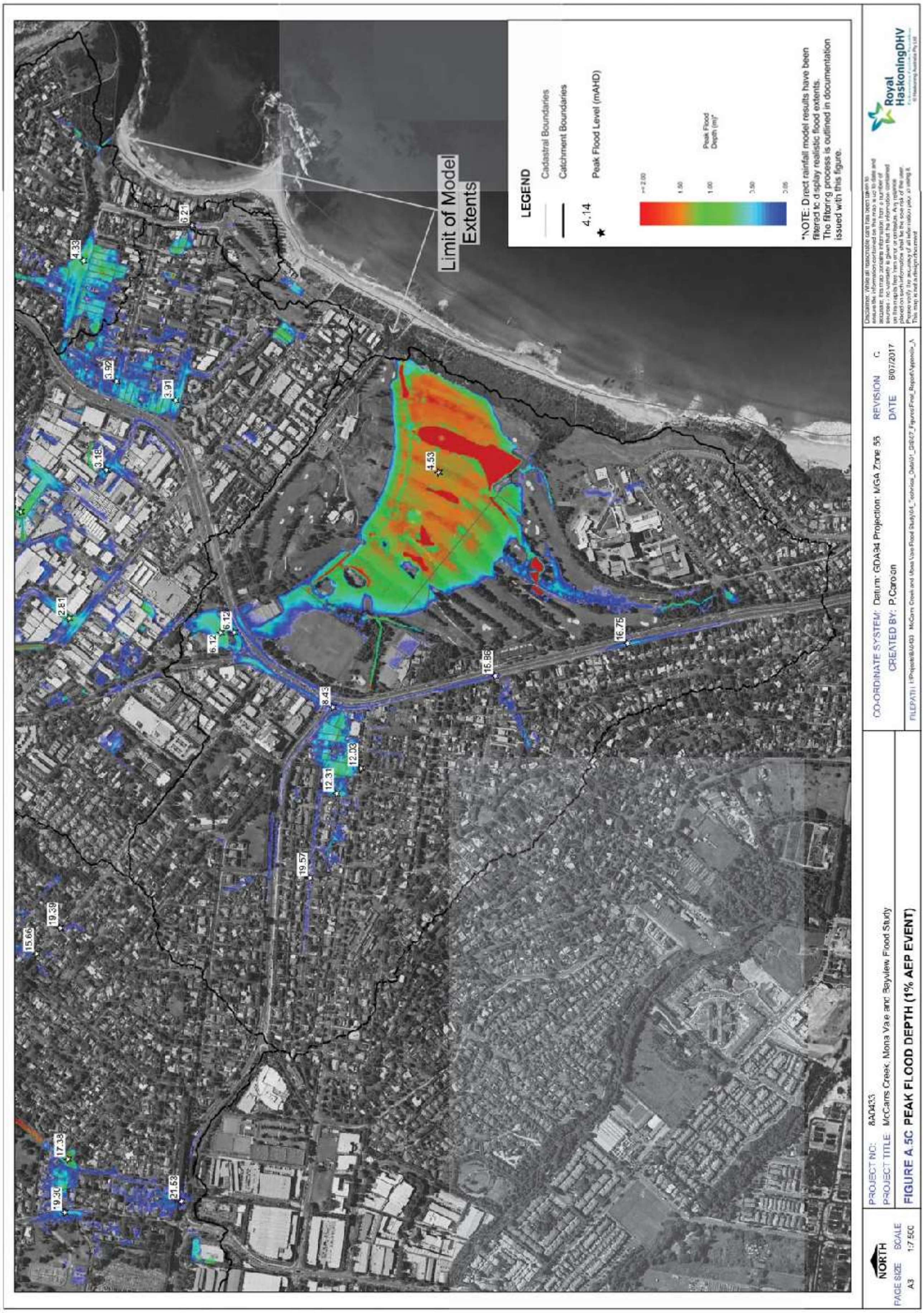
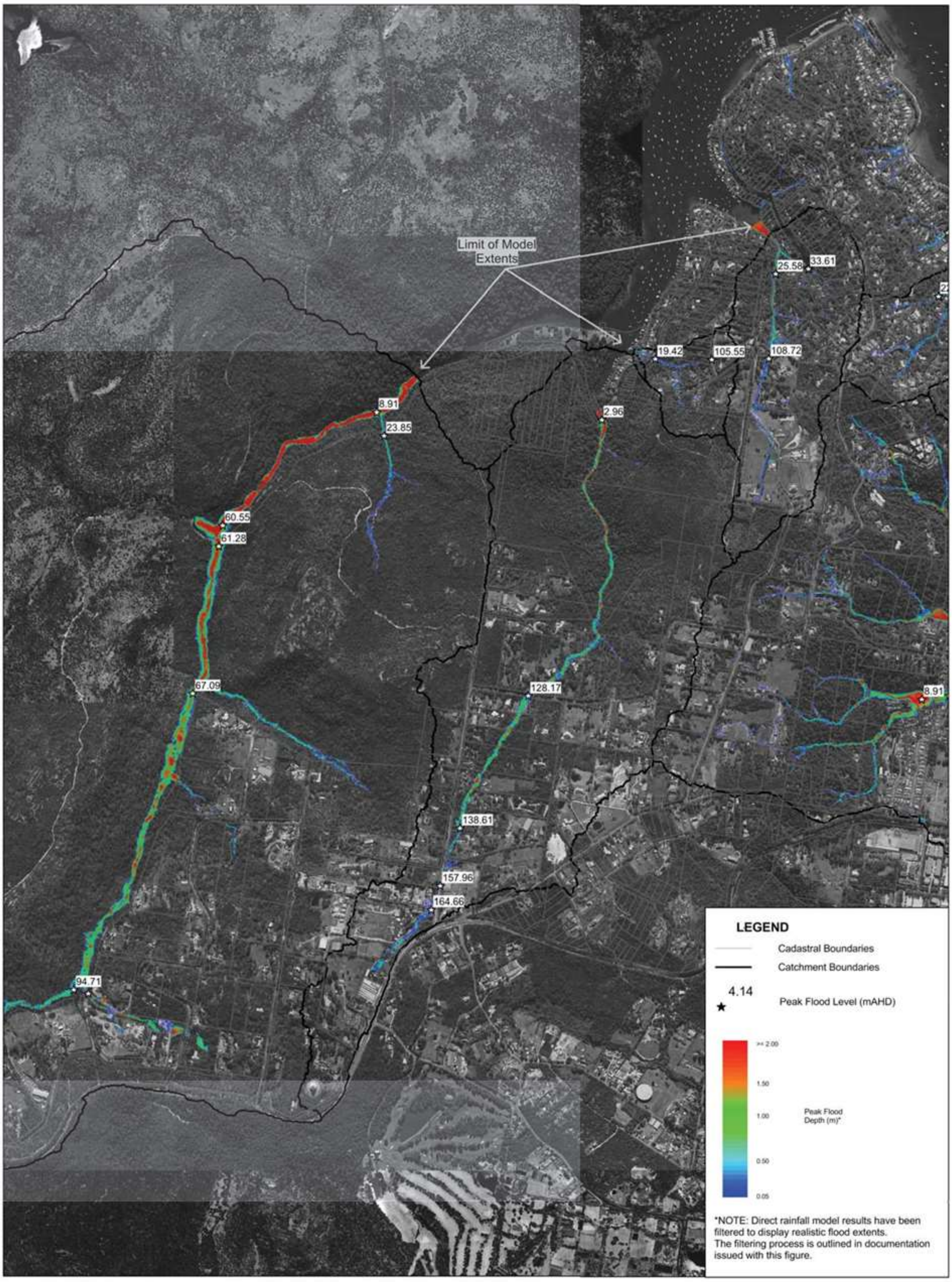
8.42
12.01
12.27
19.54
19.37
15.62
17.28
19.28
21.52



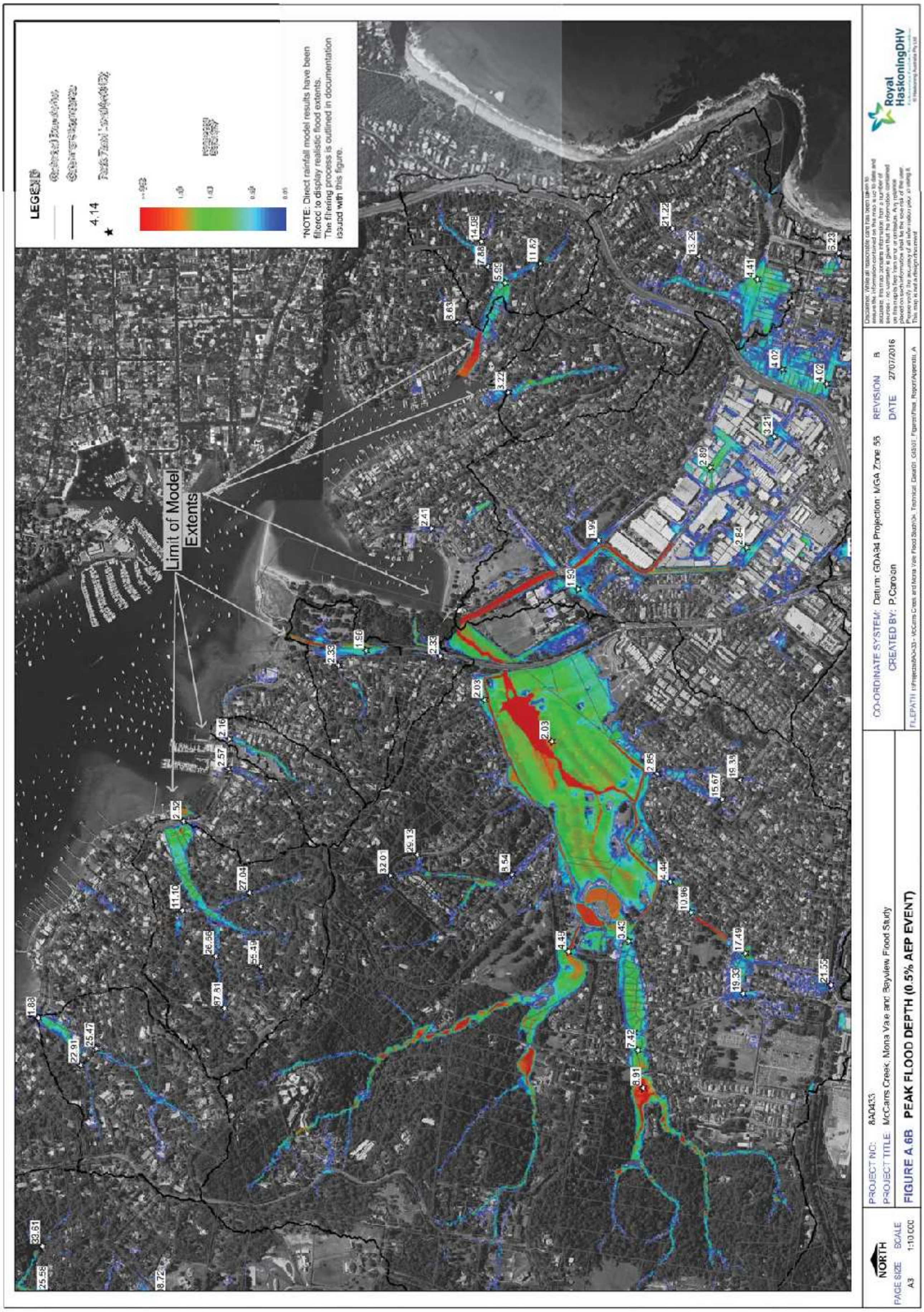
PROJECT NO: 8A0433 PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study		REVISION C DATE 6/07/2017 CREATED BY: P.Carolan	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document. Royal HaskoningDHV Enhancing Society Together
NORTH	FIGURE A.5A PEAK FLOOD DEPTH (1% AEP EVENT)		
PAGE SIZE A3 SCALE 1:15,000	FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A		CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

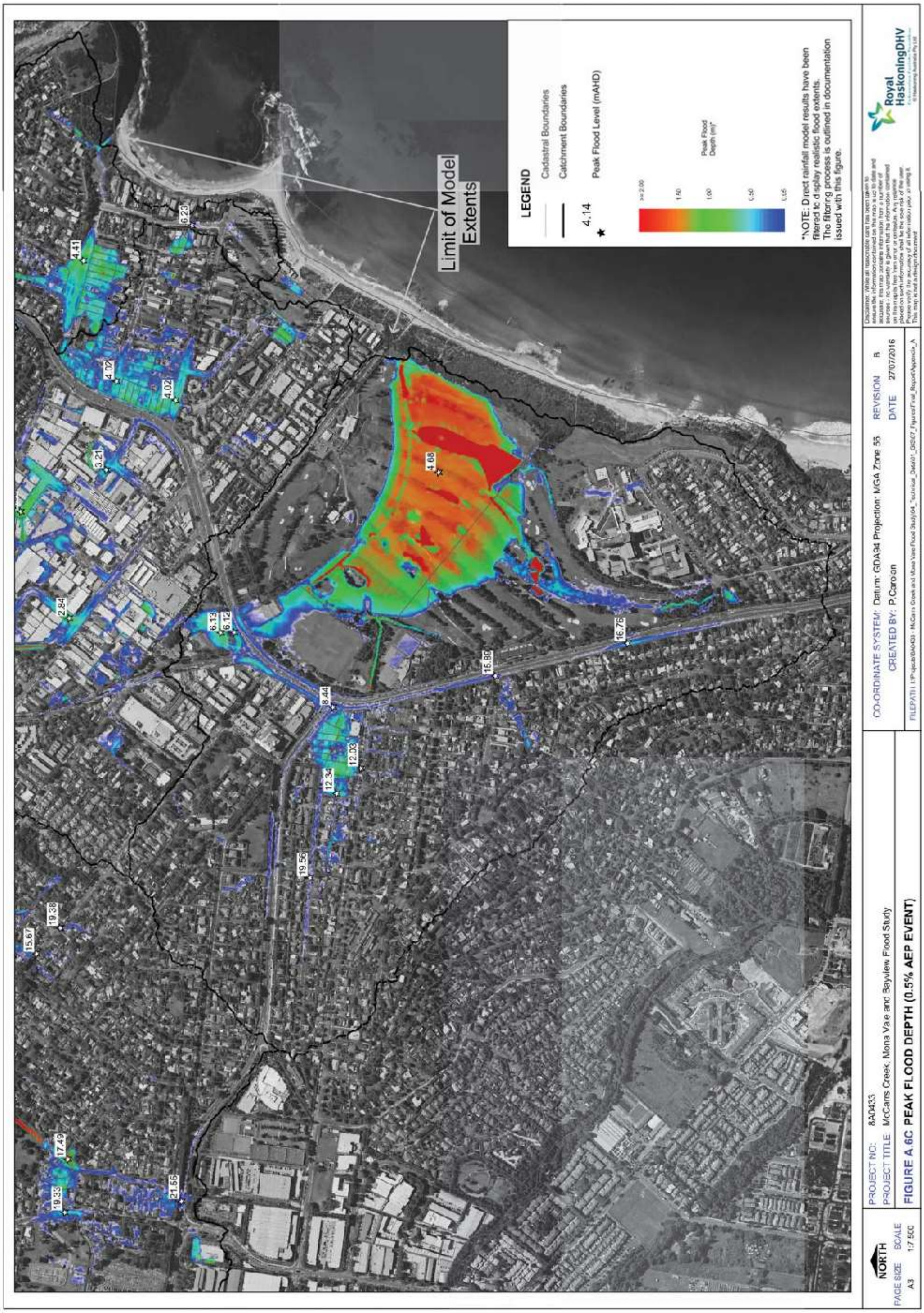

LEGEND
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
NORTH
PAGE SIZE A3
SCALE 1:10 000
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.5B PEAK FLOOD DEPTH (1% AEP EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 8/07/2017
Royal HaskoningDHV

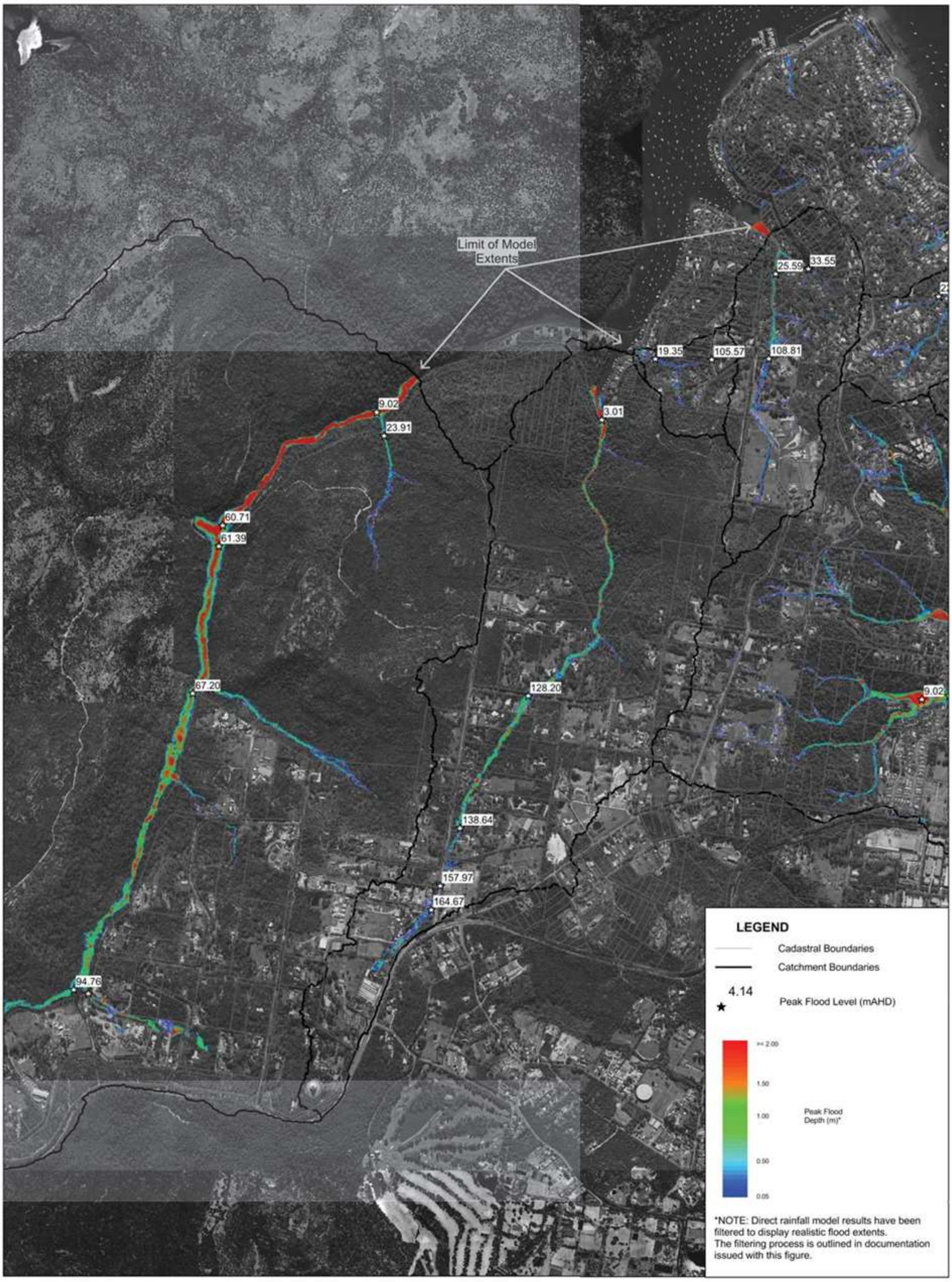

Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
4.14
Peak Flood Level (mAHD)
Peak Flood Depth (m)
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Royal HaskoningDHV
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 6/07/2017
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.5C PEAK FLOOD DEPTH (1% AEP EVENT)
NORTH
PAGE SIZE A3
SCALE 1:7,500



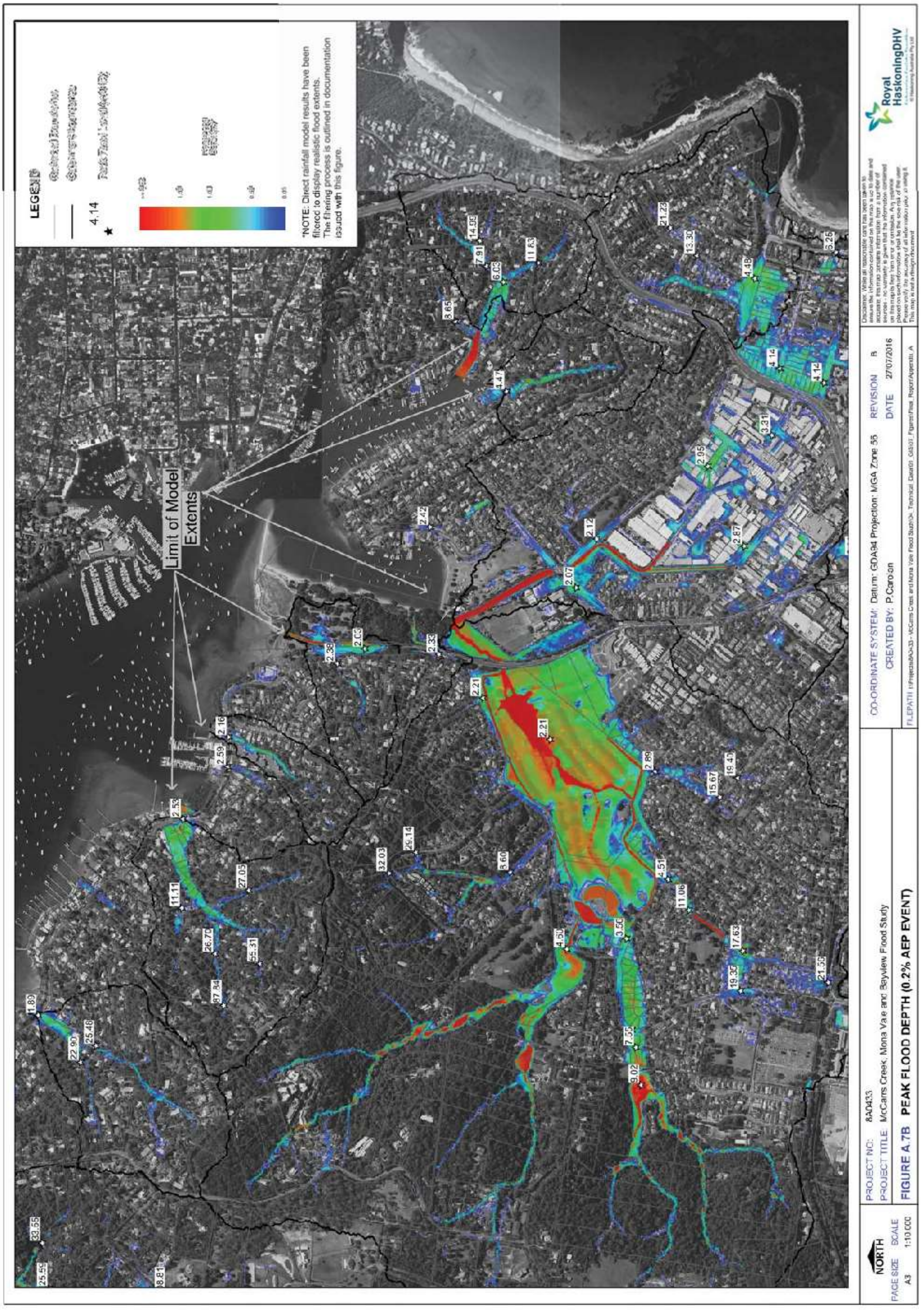
PROJECT NO: 8A0433 PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study	REVISION B DATE 27/07/2016 CREATED BY: P.Carolan	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document.	Royal HaskoningDHV Enhancing Society Together
NORTH PAGE SIZE A3 SCALE 1:15,000	FIGURE A.6A PEAK FLOOD DEPTH (0.5% AEP EVENT) FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A	CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56	


LEGEND
4.14
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.6B PEAK FLOOD DEPTH (0.5% AEP EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Caroon
REVISION B
DATE 27/07/2016
NORTH
PAGE SIZE A3
SCALE 1:10 000
Royal HaskoningDHV


LEGEND
Cadastral Boundaries
Catchment Boundaries
4.14 Peak Flood Level (mAHD)
Peak Flood Depth (m)*
>= 2.00
1.50
1.00
0.50
0.05
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Caroan
REVISION B
DATE 27/07/2016
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.6C PEAK FLOOD DEPTH (0.5% AEP EVENT)
NORTH
PAGE SIZE A3
SCALE 1:7,500
Royal HaskoningDHV



PROJECT NO: 8A0433 PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study		REVISION B DATE 27/07/2016 CREATED BY: P.Carolan	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document. Royal HaskoningDHV Enhancing Society Together © Haskoning Australia Pty Ltd
NORTH PAGE SIZE A3 SCALE 1:15,000	FIGURE A.7A PEAK FLOOD DEPTH (0.2% AEP EVENT)		
	FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A		CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56


LEGEND
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.7B PEAK FLOOD DEPTH (0.2% AEP EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Caro'an
REVISION B
DATE 27/07/2016
Royal HaskoningDHV
NORTH
PAGE SIZE A3
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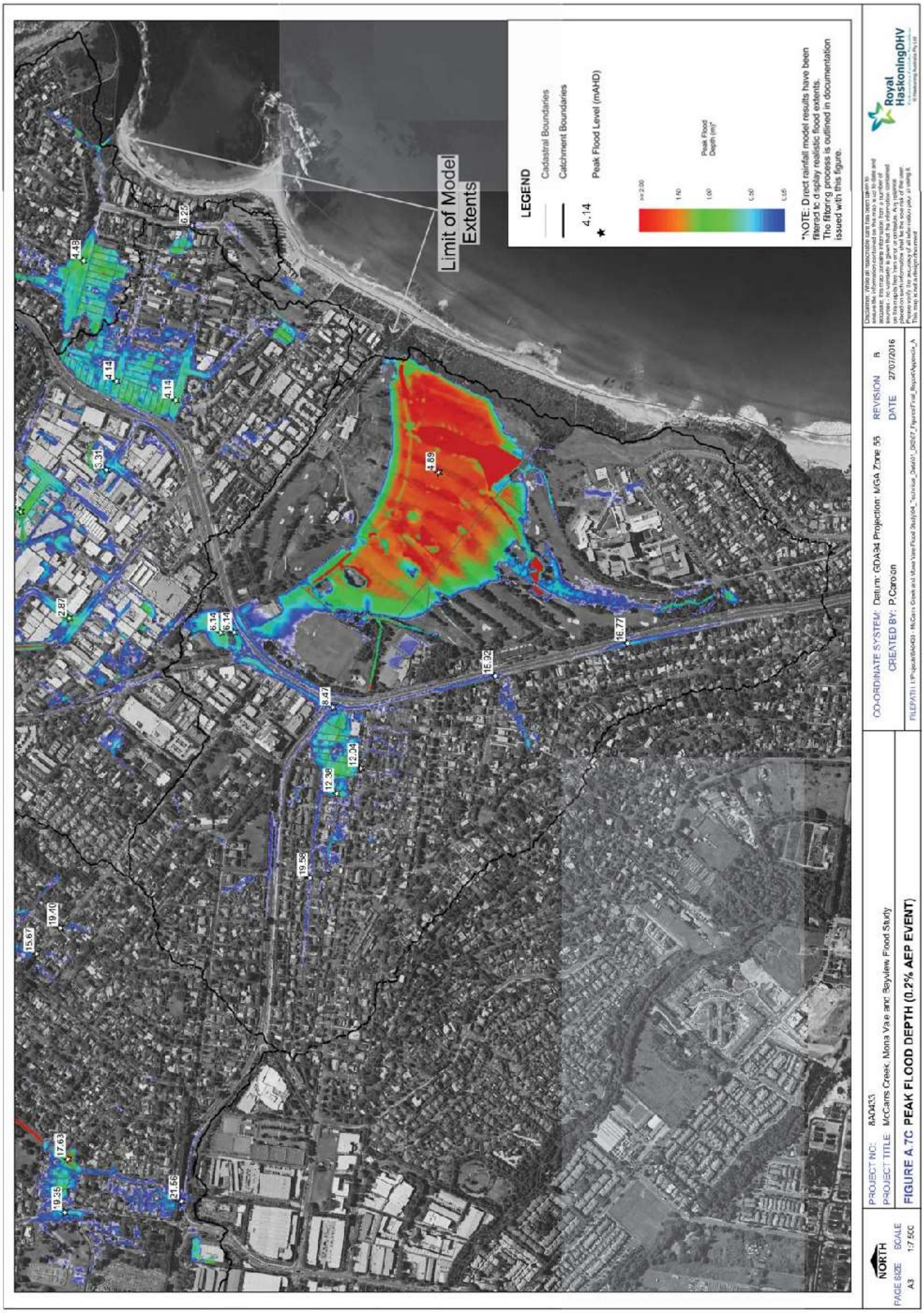
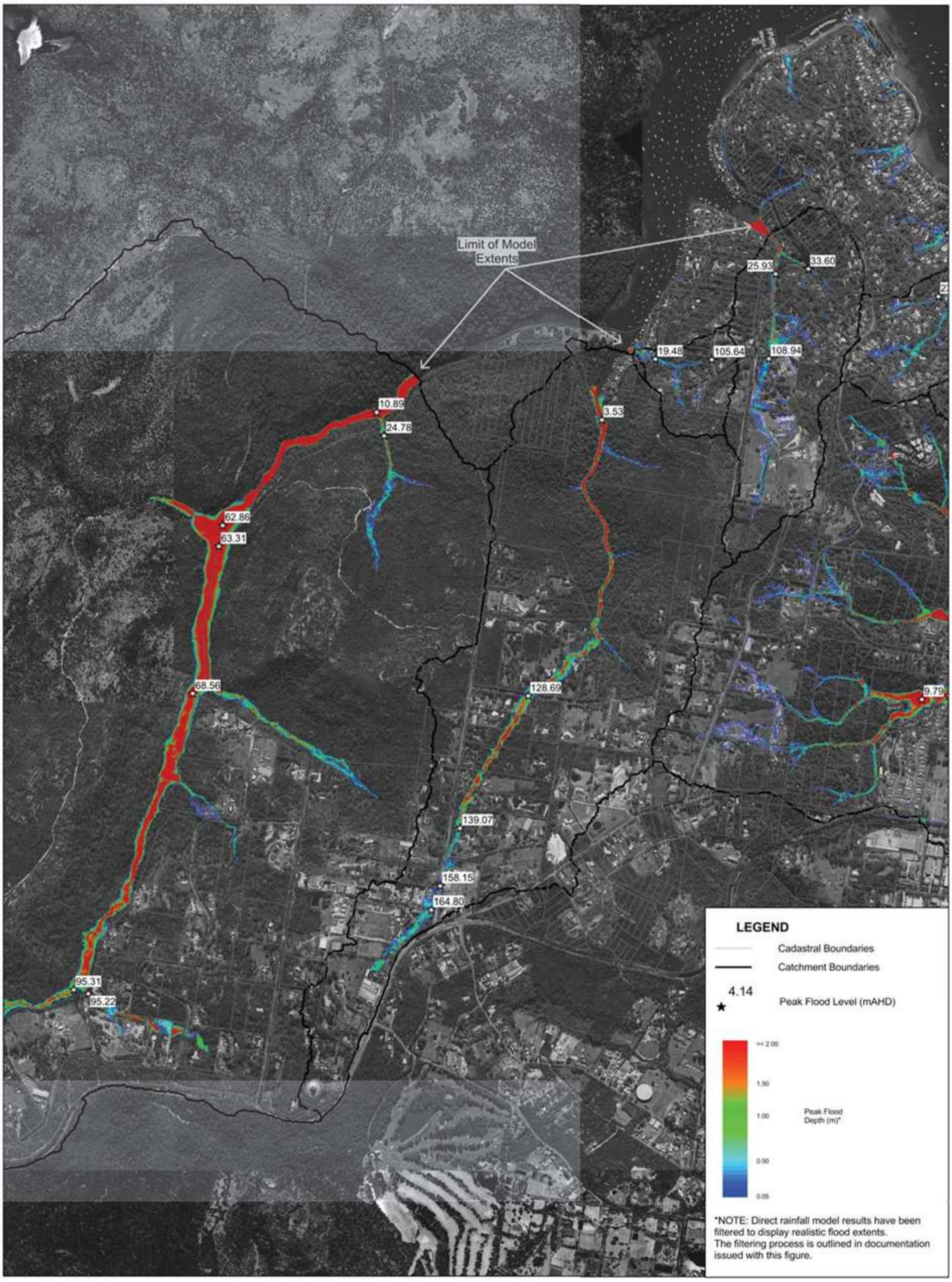
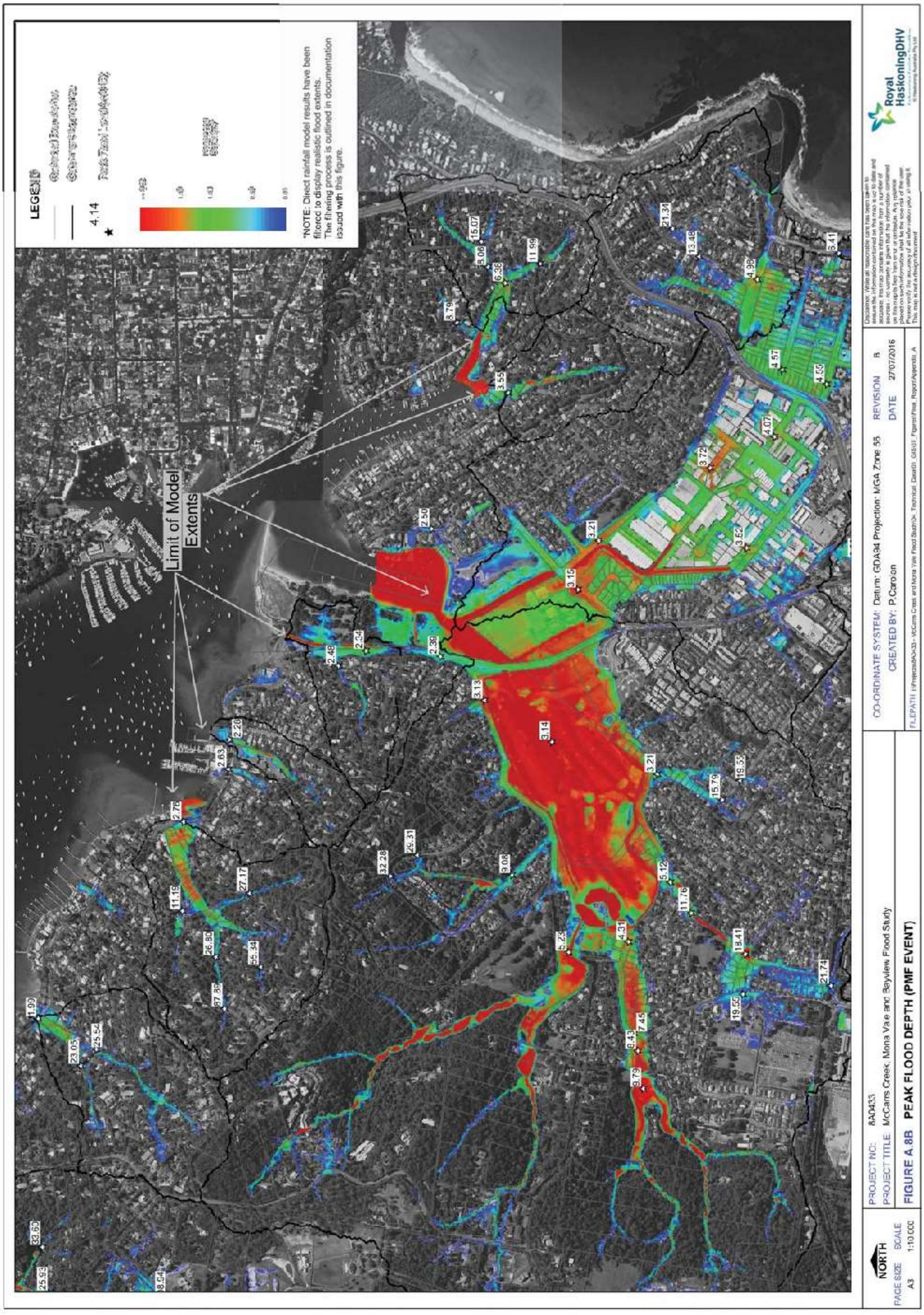
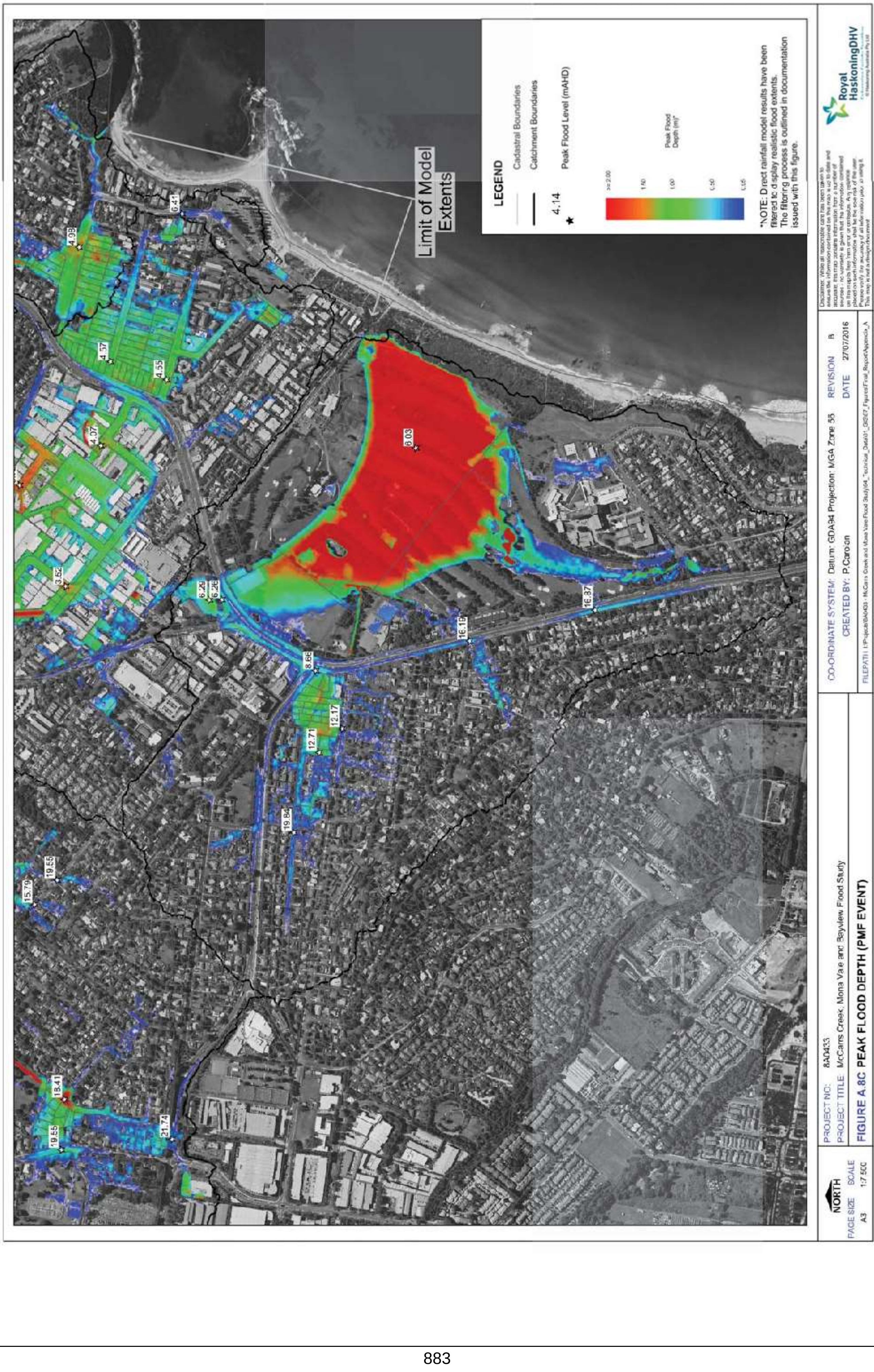
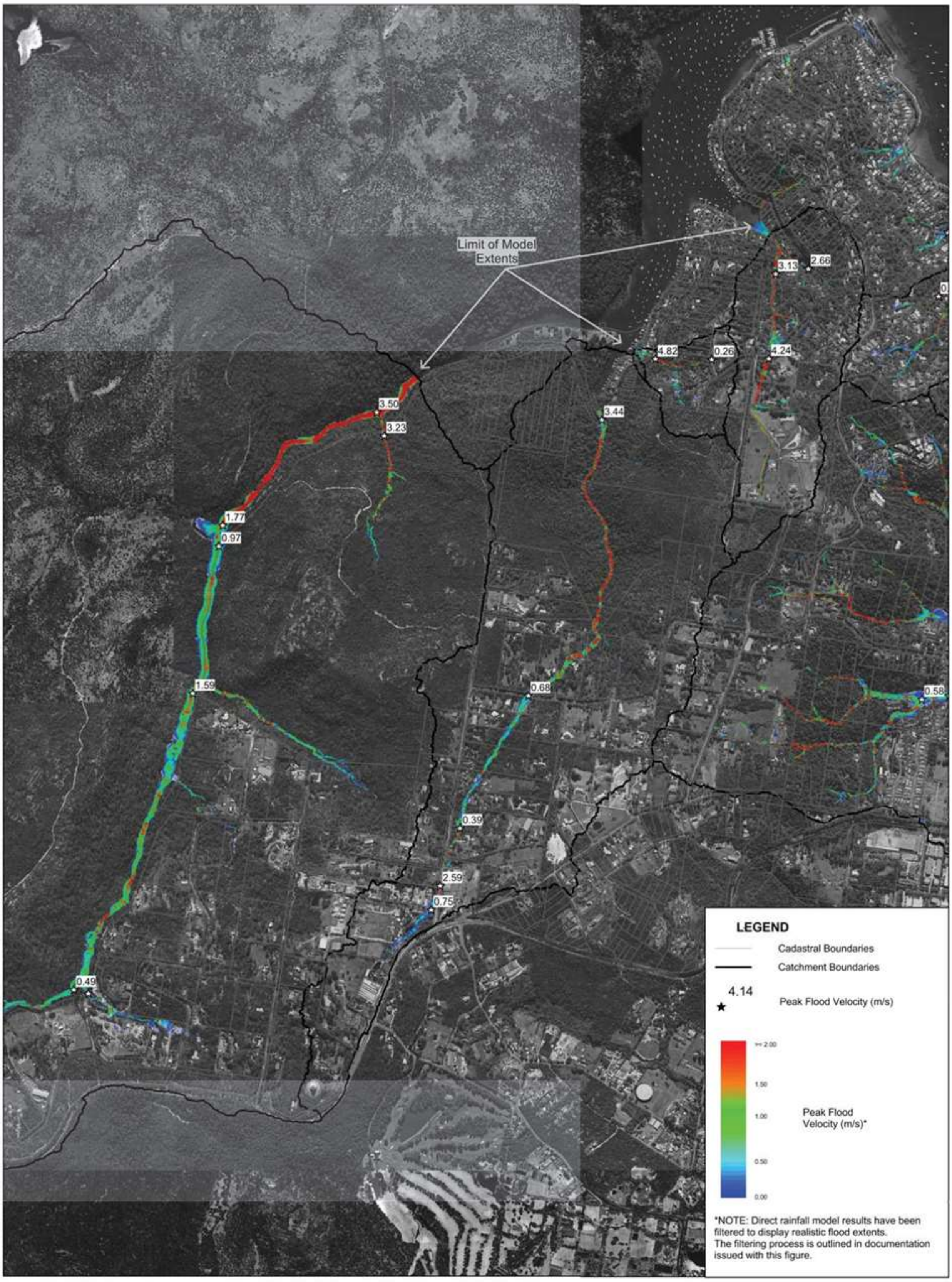

Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
4.14
Peak Flood Level (mAHD)
Peak Flood Depth (m)*
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
6.25
4.48
4.14
4.14
3.31
4.89
2.87
6.14
6.14
16.77
15.92
8.47
12.04
12.38
19.58
19.40
15.67
17.63
19.35
21.56
Royal HaskoningDHV
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION B
DATE 27/07/2016
FIGURE A.7C PEAK FLOOD DEPTH (0.2% AEP EVENT)
NORTH
PAGE SIZE A3
SCALE 1:7,500



PROJECT NO: 8A0433 PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study		REVISION B DATE 27/07/2016 CREATED BY: P.Carolan	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document. Royal HaskoningDHV Enhancing Society Together
NORTH	FIGURE A.8A PEAK FLOOD DEPTH (PMF EVENT)		
PAGE SIZE A3 SCALE 1:15,000	FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A		CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56


LEGEND
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.8B PEAK FLOOD DEPTH (PMF EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION B
DATE 27/07/2016
NORTH
PAGE SIZE A3
SCALE 1:10 000
Royal HaskoningDHV


LEGEND
Cadastral Boundaries
Catchment Boundaries
4.14
Peak Flood Level (mAHD)
Peak Flood Depth (m)*
>= 2.00
1.50
1.00
0.50
0.05
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
6.41
4.09
4.57
4.55
4.07
3.62
6.29
6.26
8.03
8.66
16.15
16.37
12.17
12.71
19.84
15.79
19.55
18.41
19.55
21.74
Royal HaskoningDHV
NORTH
PAGE SIZE A3
SCALE 1:7,500
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.8C PEAK FLOOD DEPTH (PMF EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Caroan
REVISION B
DATE 27/07/2016



PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
REVISION C DATE 6/07/2017
CREATED BY: P.Carolan

NORTH
PAGE SIZE A3 SCALE 1:15,000

FIGURE A.9A PEAK FLOOD VELOCITY (1% AEP EVENT)

FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A

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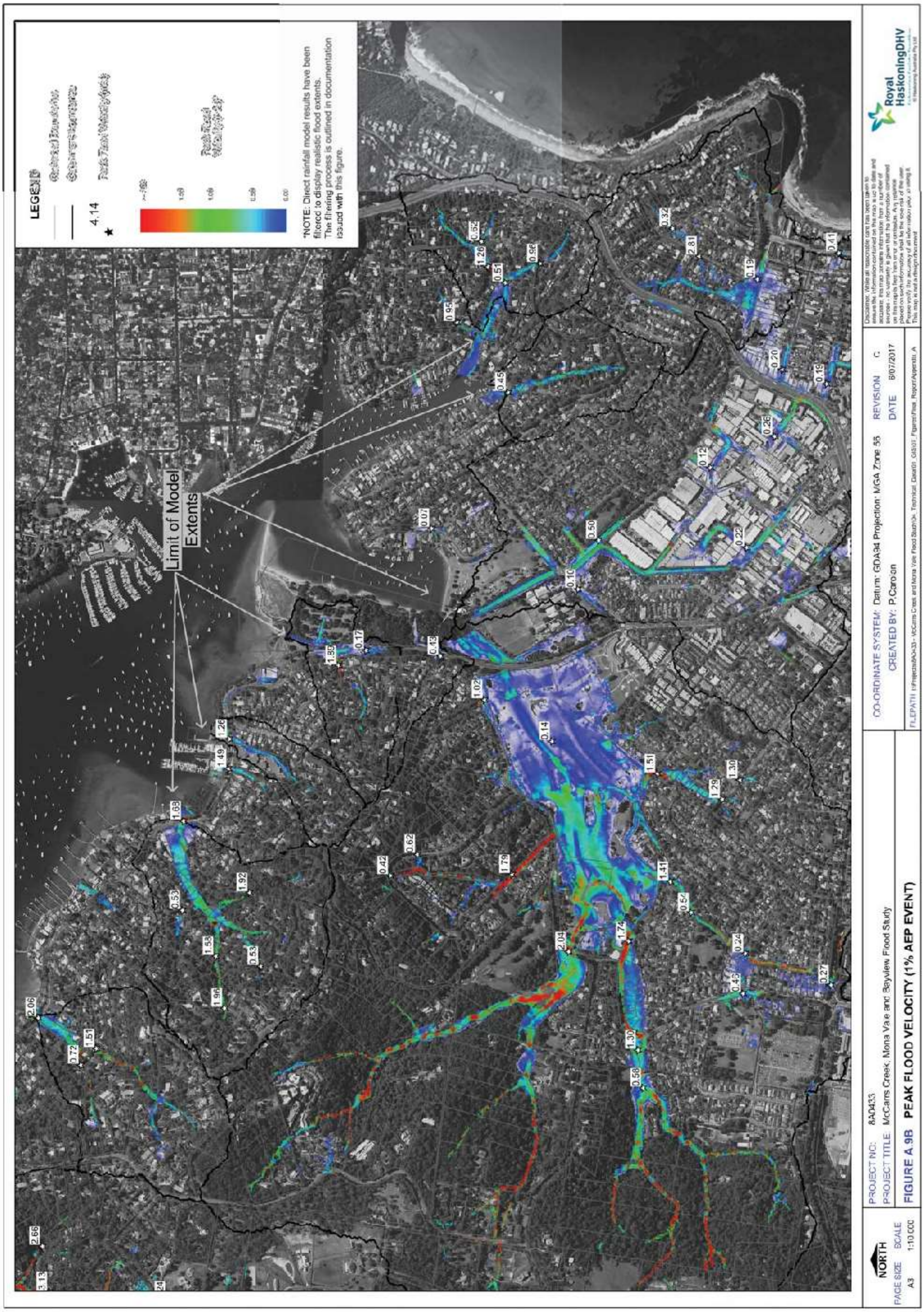
LEGEND
4.14
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
NORTH
PAGE SIZE A3
SCALE 1:10 000
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.9B PEAK FLOOD VELOCITY (1% AEP EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 6/07/2017
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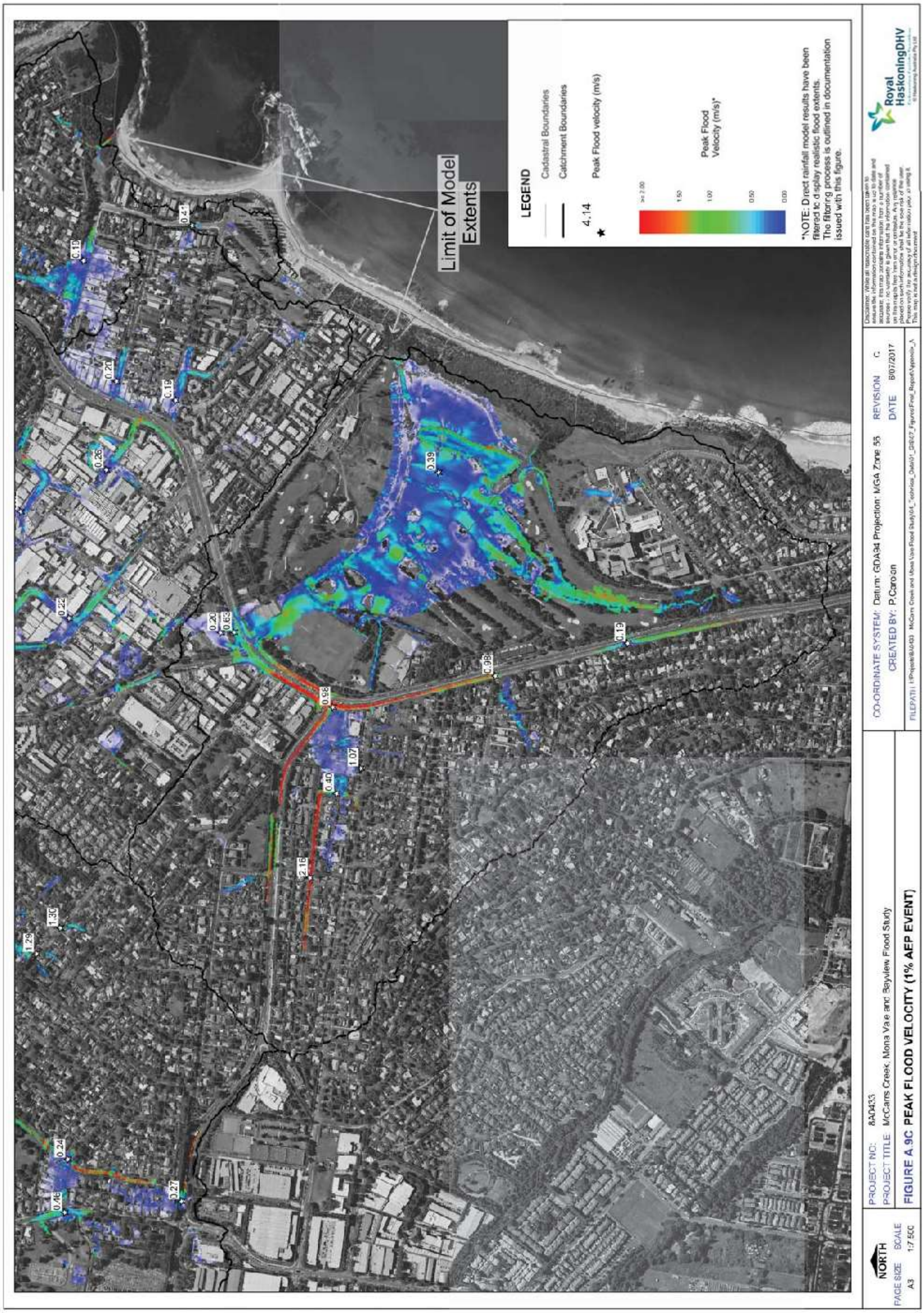
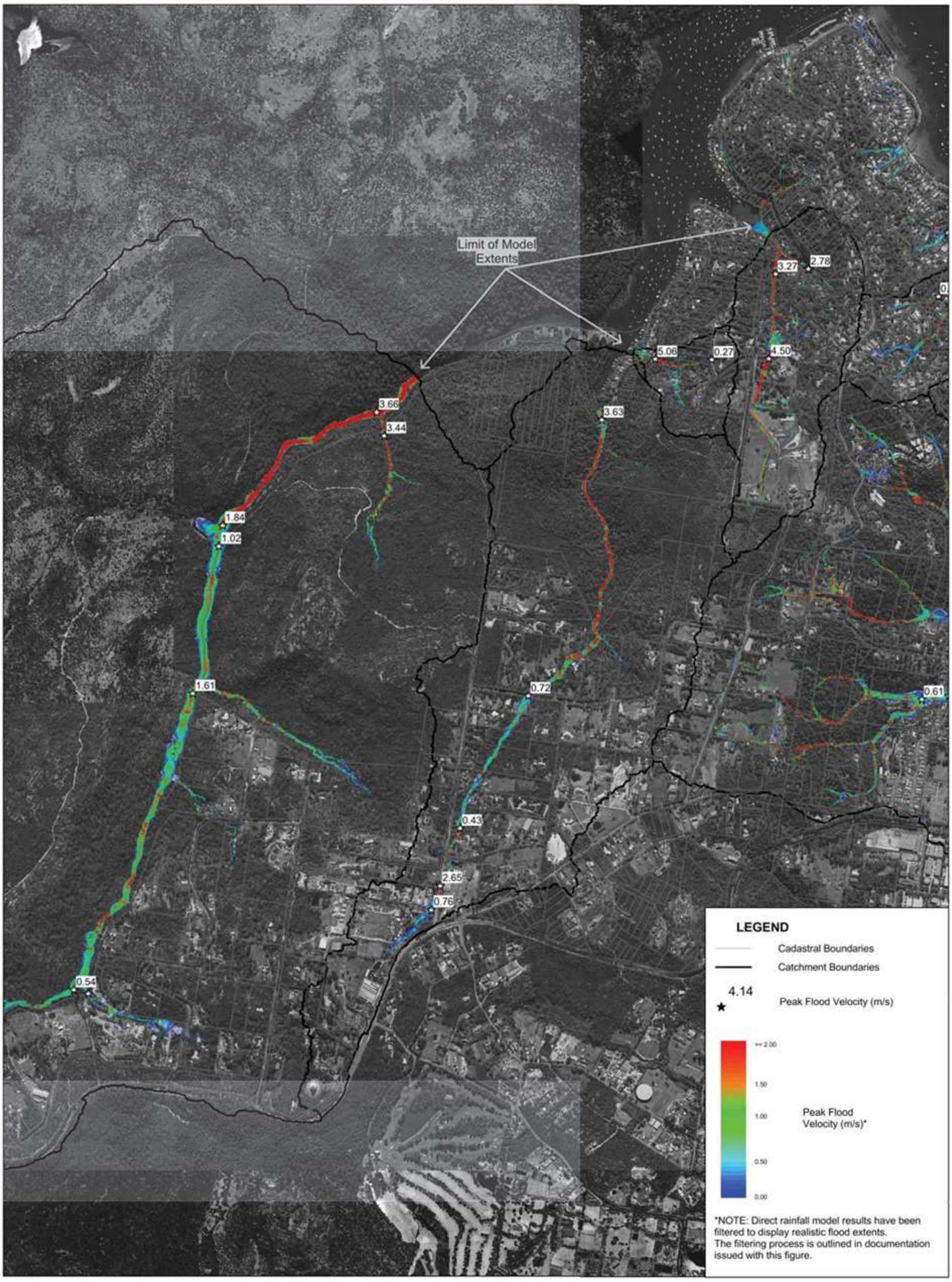
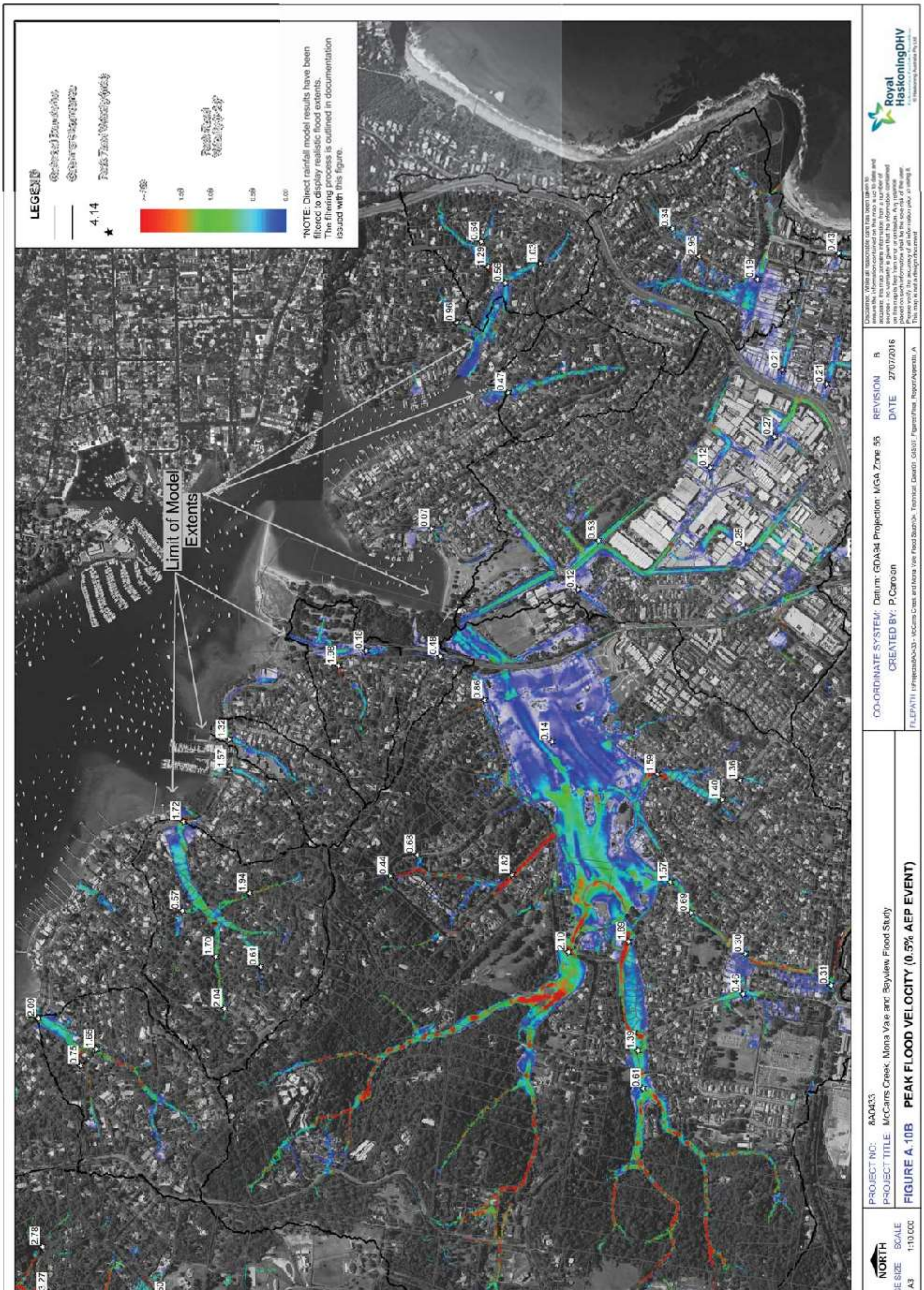
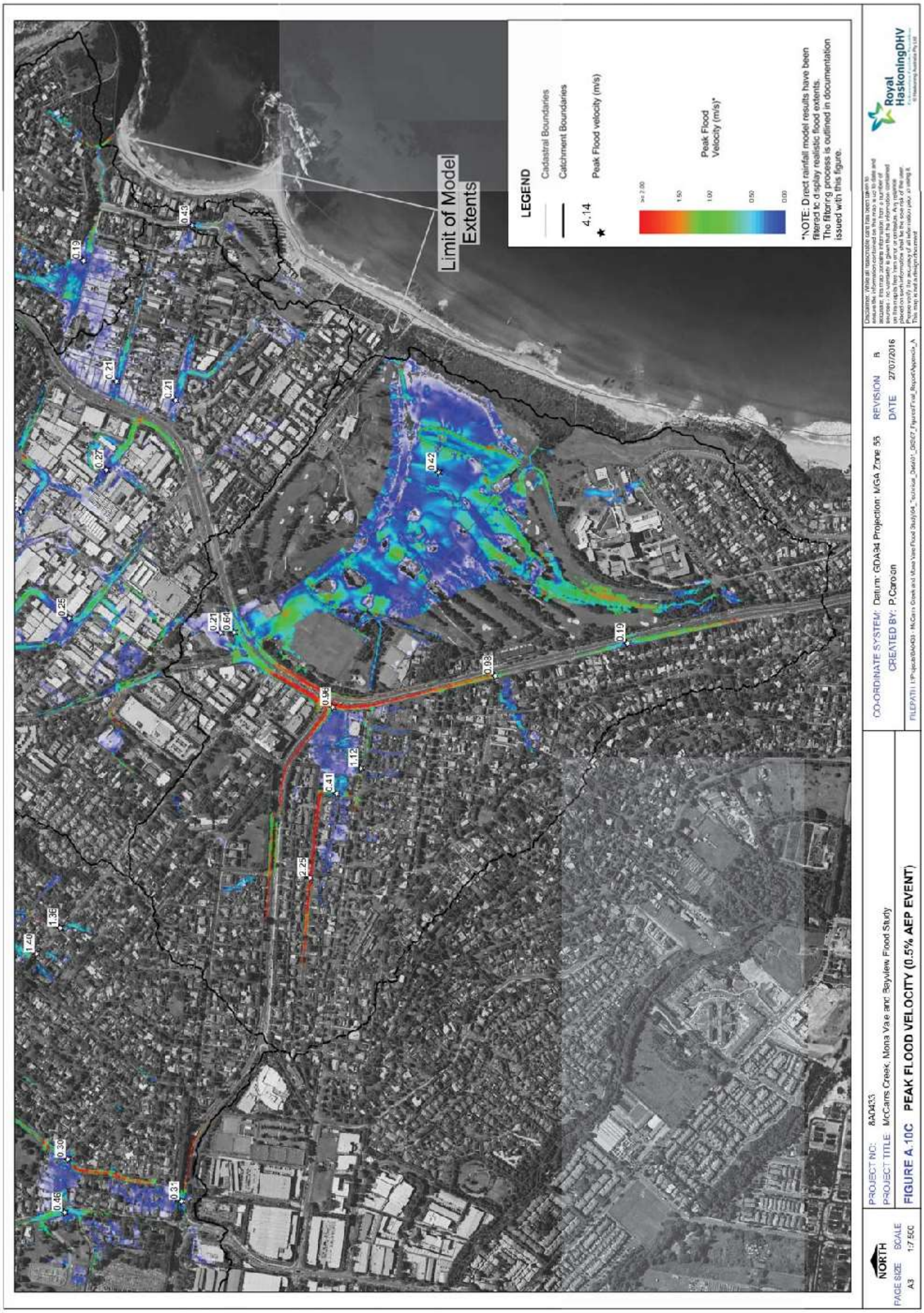
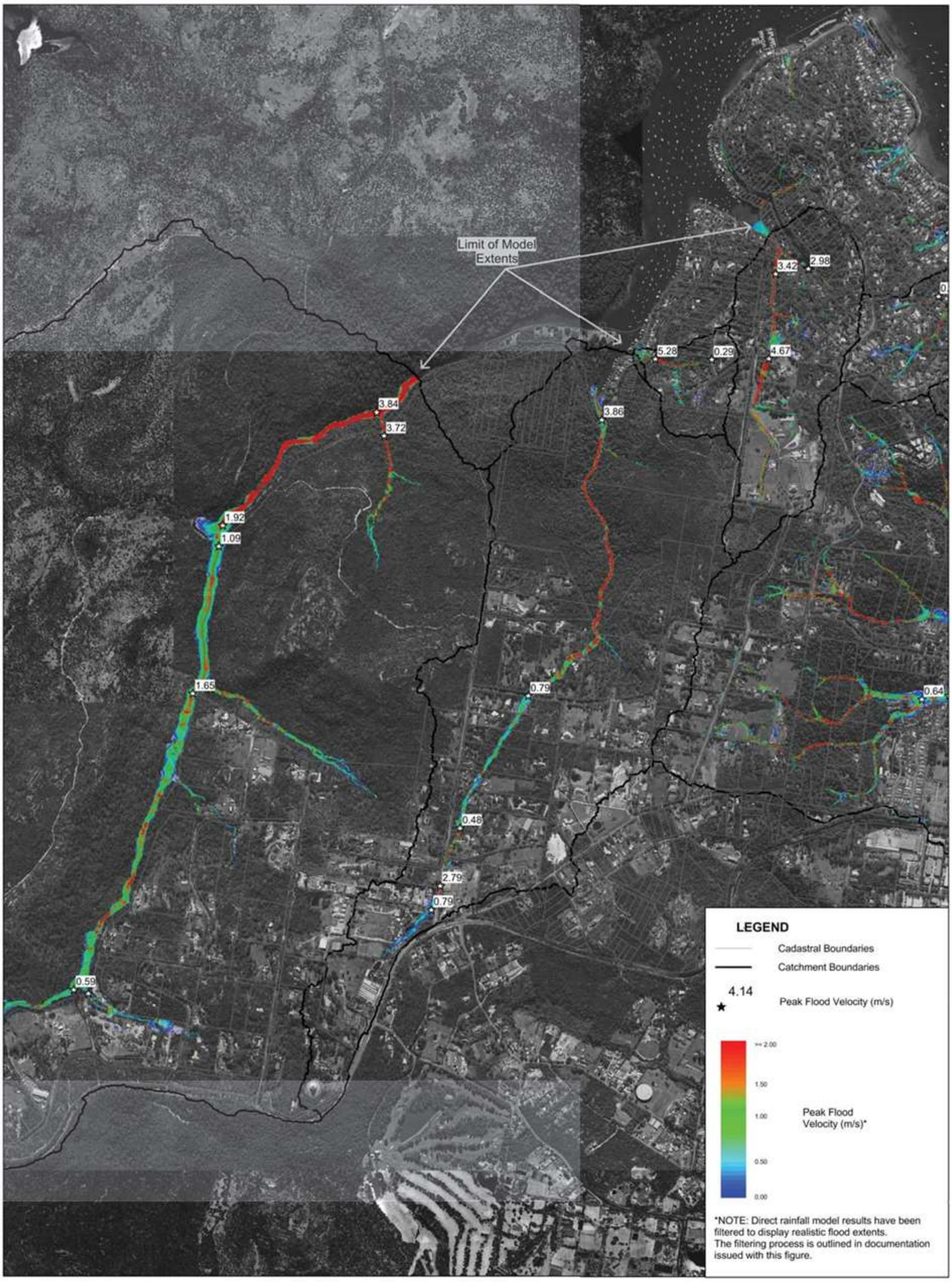

Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
4.14
Peak Flood velocity (m/s)
Peak Flood Velocity (m/s)*
1.50
1.00
0.50
0.00
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Royal HaskoningDHV
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.9C PEAK FLOOD VELOCITY (1% AEP EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
REVISION C
DATE 6/07/2017
NORTH
PAGE SIZE A3
SCALE



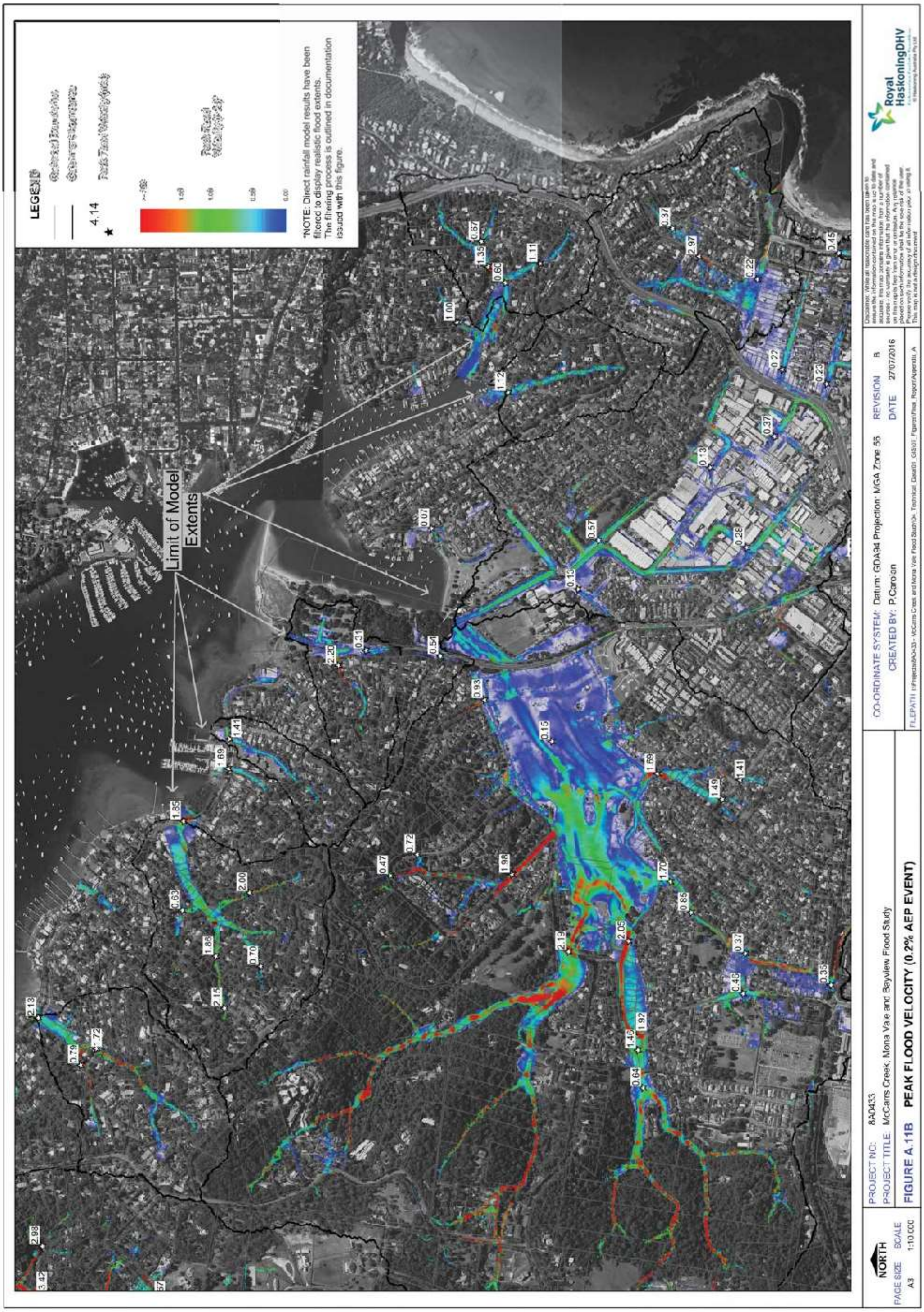
PROJECT NO: 8A0433 PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study	REVISION B DATE 27/07/2016 CREATED BY: P.Carolan	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document.
NORTH PAGE SIZE A3 SCALE 1:15,000	FIGURE A.10A PEAK FLOOD VELOCITY (0.5% AEP EVENT)	Royal HaskoningDHV Enhancing Society Together
	FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A	CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

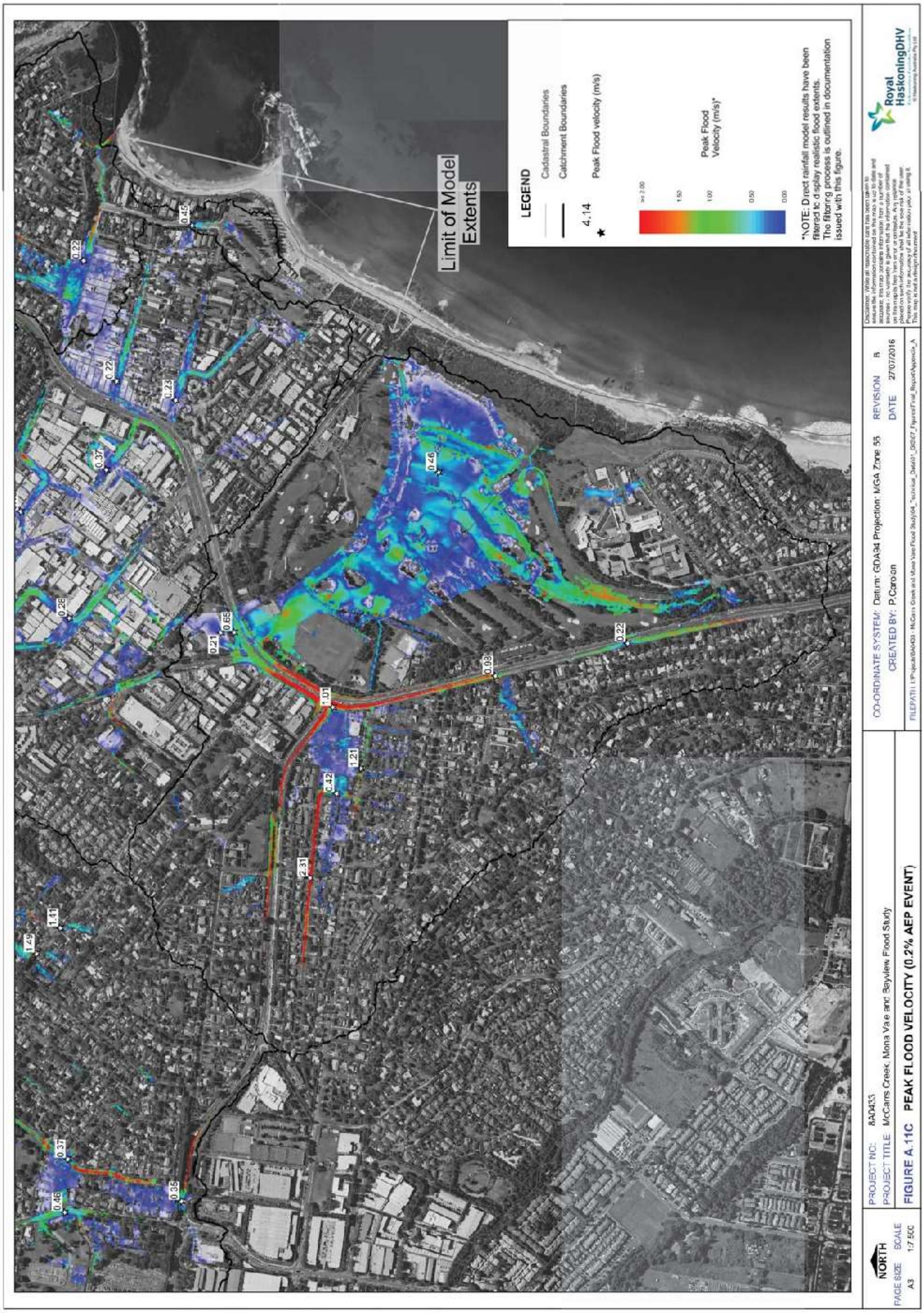

LEGEND
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.10B PEAK FLOOD VELOCITY (0.5% AEP EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION B
DATE 27/07/2016
NORTH
PAGE SIZE A3
SCALE 1:10 000
Royal HaskoningDHV

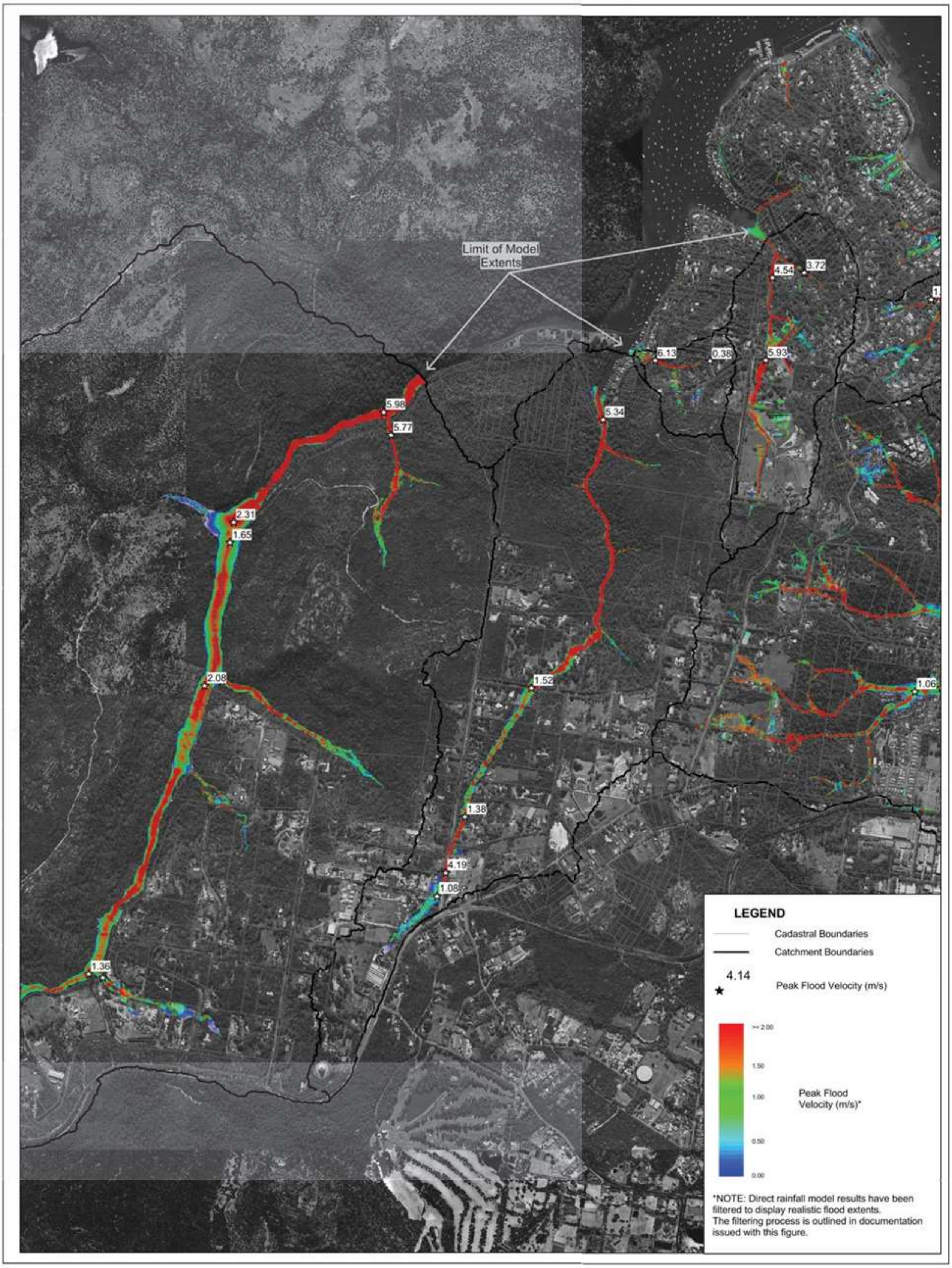

Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
Peak Flood velocity (m/s)
Peak Flood Velocity (m/s)*
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Royal HaskoningDHV
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.10C PEAK FLOOD VELOCITY (0.5% AEP EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Caroan
REVISION B
DATE 27/07/2016
NORTH
PAGE SIZE A3
SCALE 1:7,500



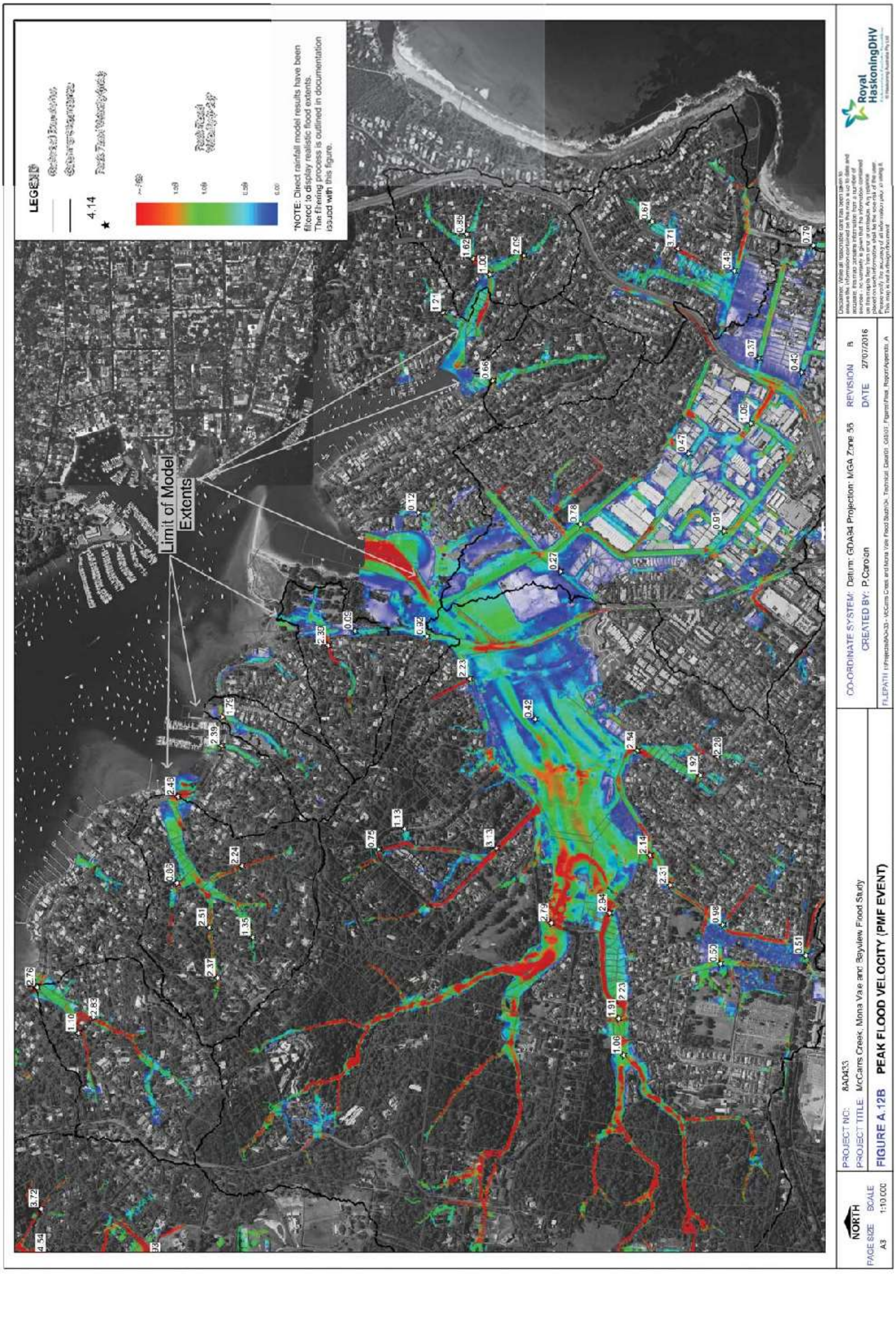
PROJECT NO: 8A0433		REVISION B DATE 27/07/2016	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document. Royal HaskoningDHV Enhancing Society Together
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study		CREATED BY: P.Carolan	
NORTH	FIGURE A.11A PEAK FLOOD VELOCITY (0.2% AEP EVENT)		
PAGE SIZE A3 SCALE 1:15,000	FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A		CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56


LEGEND
4.14
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.11B PEAK FLOOD VELOCITY (0.2% AEP EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION B
DATE 27/07/2016
NORTH
PAGE SIZE A3
SCALE 1:10 000
Royal HaskoningDHV


Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
4.14
Peak Flood velocity (m/s)
Peak Flood Velocity (m/s)*
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Royal HaskoningDHV
NORTH
PAGE SIZE A3
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.11C PEAK FLOOD VELOCITY (0.2% AEP EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
REVISION B
DATE 27/07/2016



PROJECT NO: 8A0433 PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study	REVISION B DATE 27/07/2016 CREATED BY: P.Carolan	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document. Royal HaskoningDHV Enhancing Society Together
NORTH PAGE SIZE A3 SCALE 1:15,000	FIGURE A.12A PEAK FLOOD VELOCITY (PMF EVENT) FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A	CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56


LEGEND
4.14
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
NORTH
PAGE SIZE A3
SCALE 1:10 000
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.12B PEAK FLOOD VELOCITY (PMF EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION B
DATE 27/07/2016
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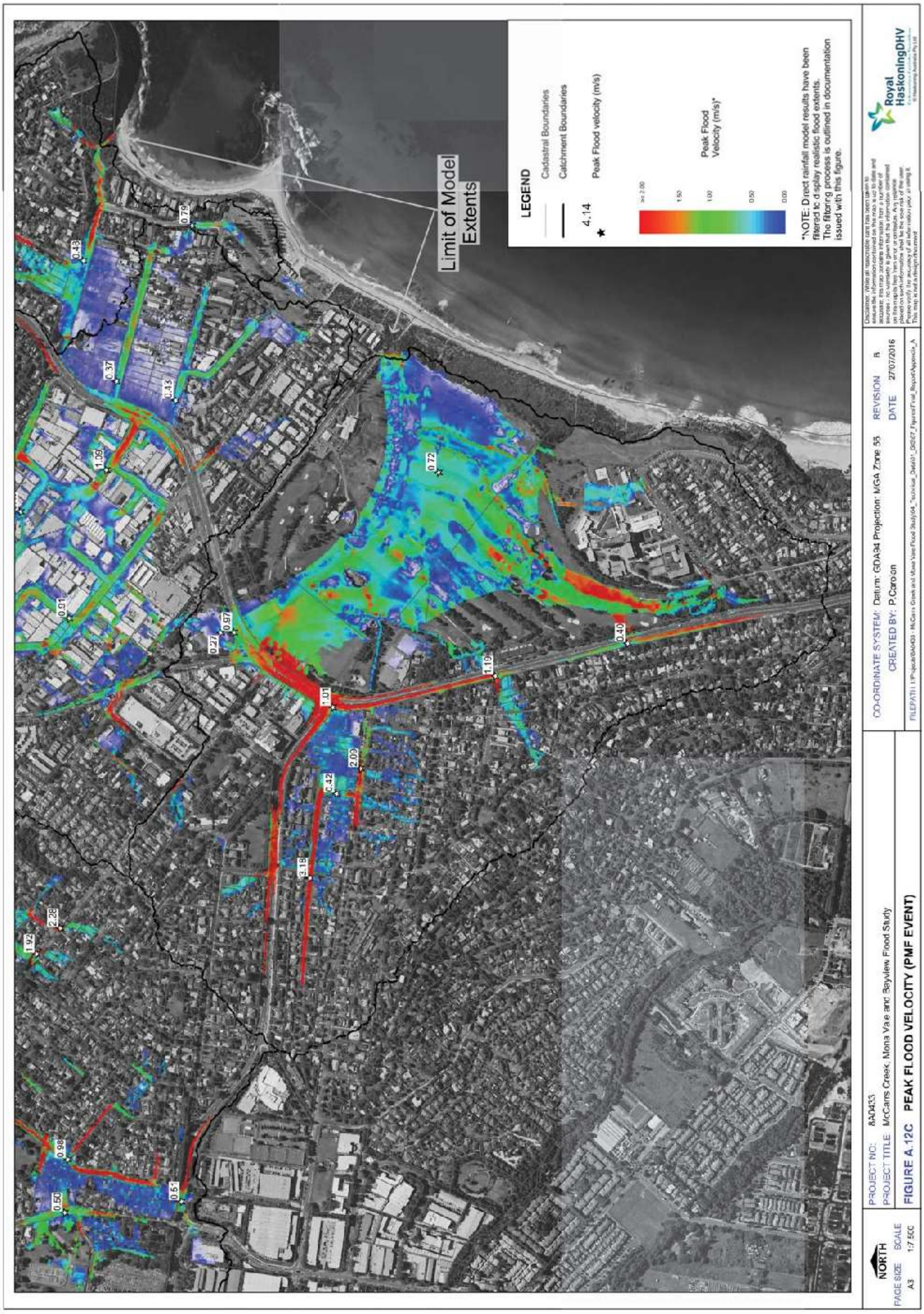
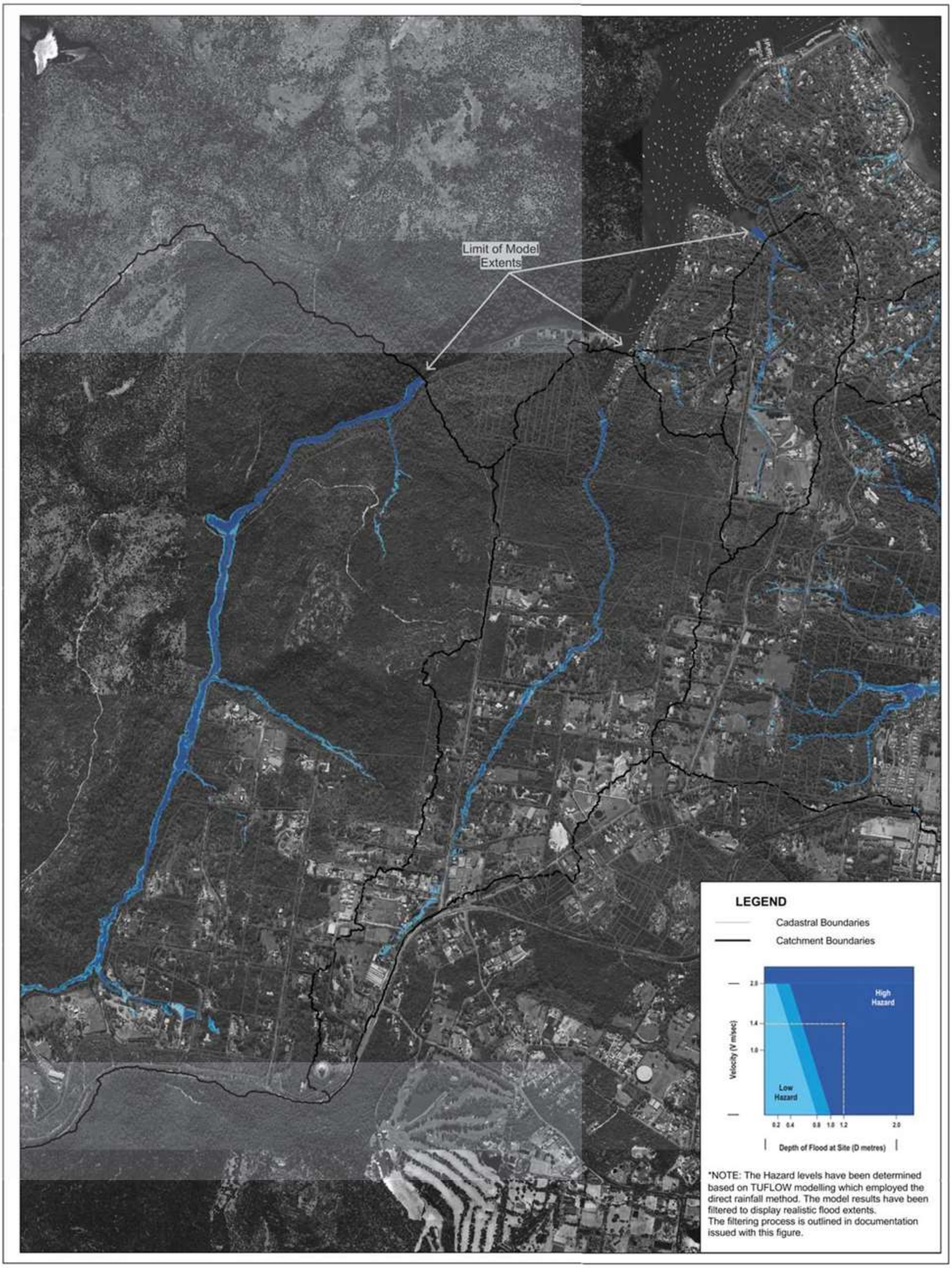

LEGEND
Cadastral Boundaries
Catchment Boundaries
Peak Flood velocity (m/s)
4.14
Peak Flood Velocity (m/s)*
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
Royal HaskoningDHV
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.12C PEAK FLOOD VELOCITY (PMF EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Caroian
REVISION B
DATE 27/07/2016
NORTH
PAGE SIZE A3
SCALE 1:7,500



PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study

REVISION C DATE 6/07/2017
CREATED BY: P.Carolan

NORTH
PAGE SIZE A3 SCALE 1:15,000

FIGURE A.13A PROVISIONAL FLOOD HAZARD (1% AEP EVENT)

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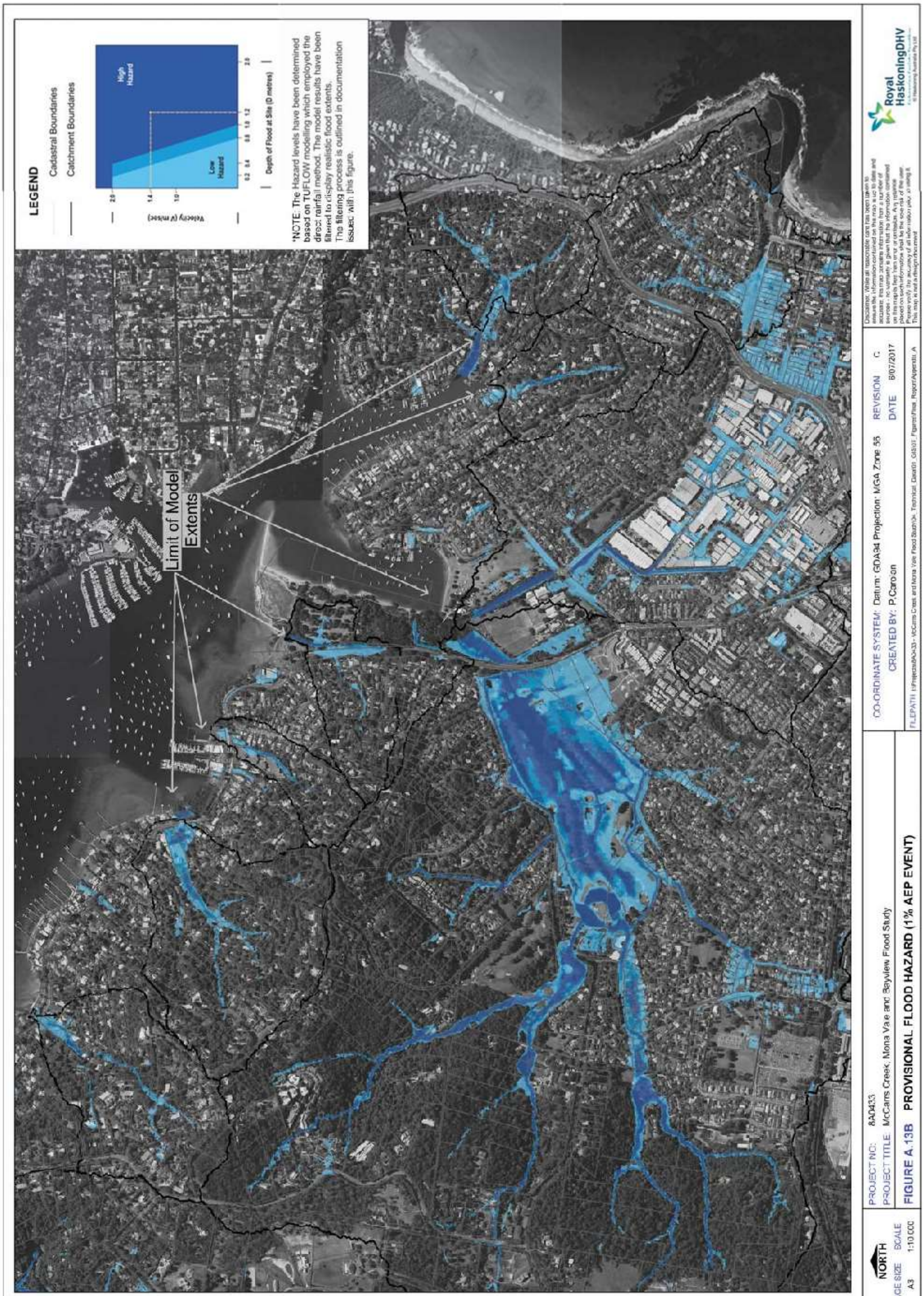
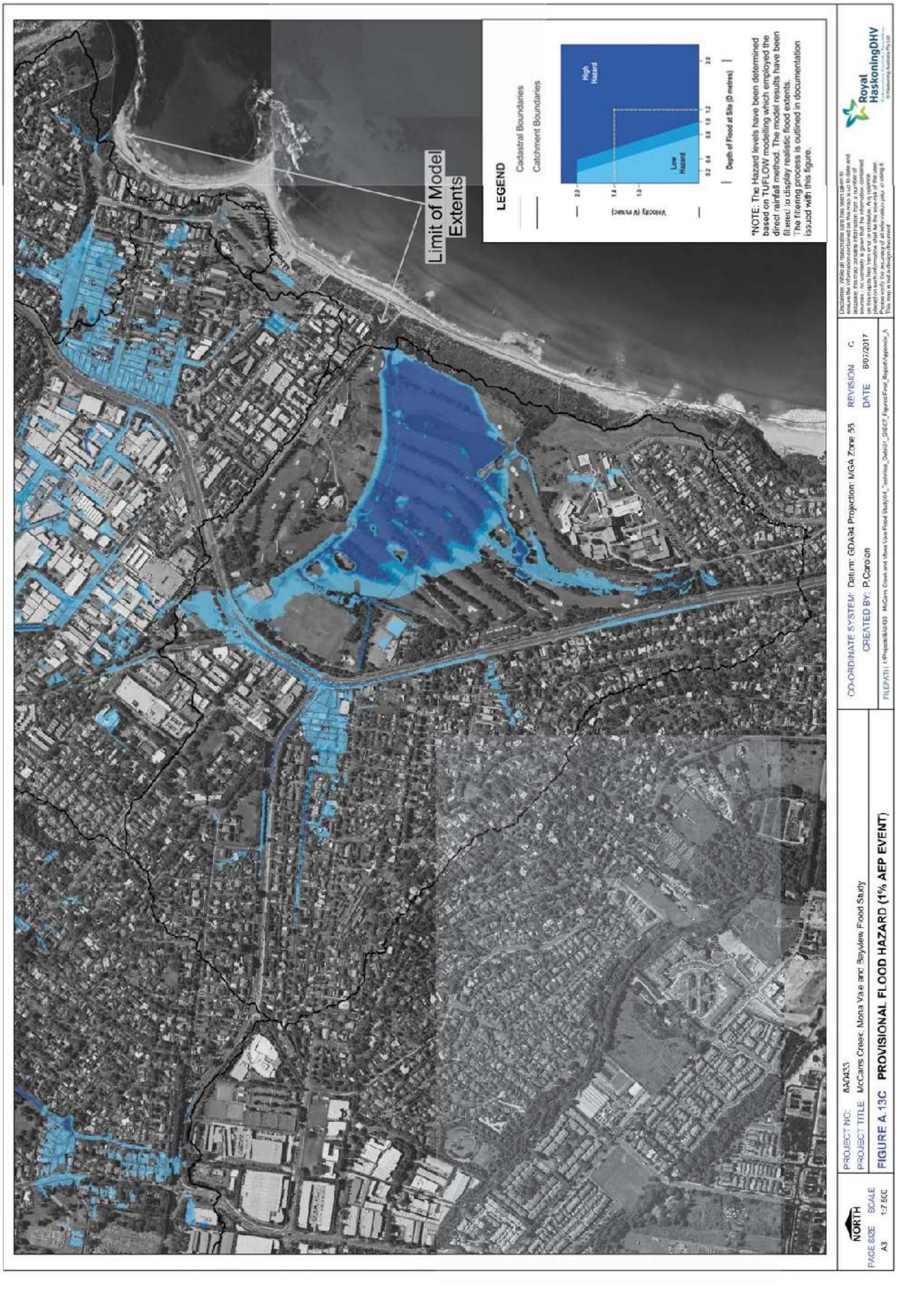
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56


LEGEND
Cadastral Boundaries
Catchment Boundaries
Velocity (V m/sec)
Depth of Flood at Site (D metres)
High Hazard
Low Hazard
*NOTE: The Hazard levels have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
NORTH
PAGE SIZE A3
SCALE 1:10 000
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.13B PROVISIONAL FLOOD HAZARD (1% AEP EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 6/07/2017
Royal HaskoningDHV


Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
High Hazard
Low Hazard
Velocity (V m/sec)
Depth of Flood at Site (D metres)
*NOTE: The Hazard levels have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
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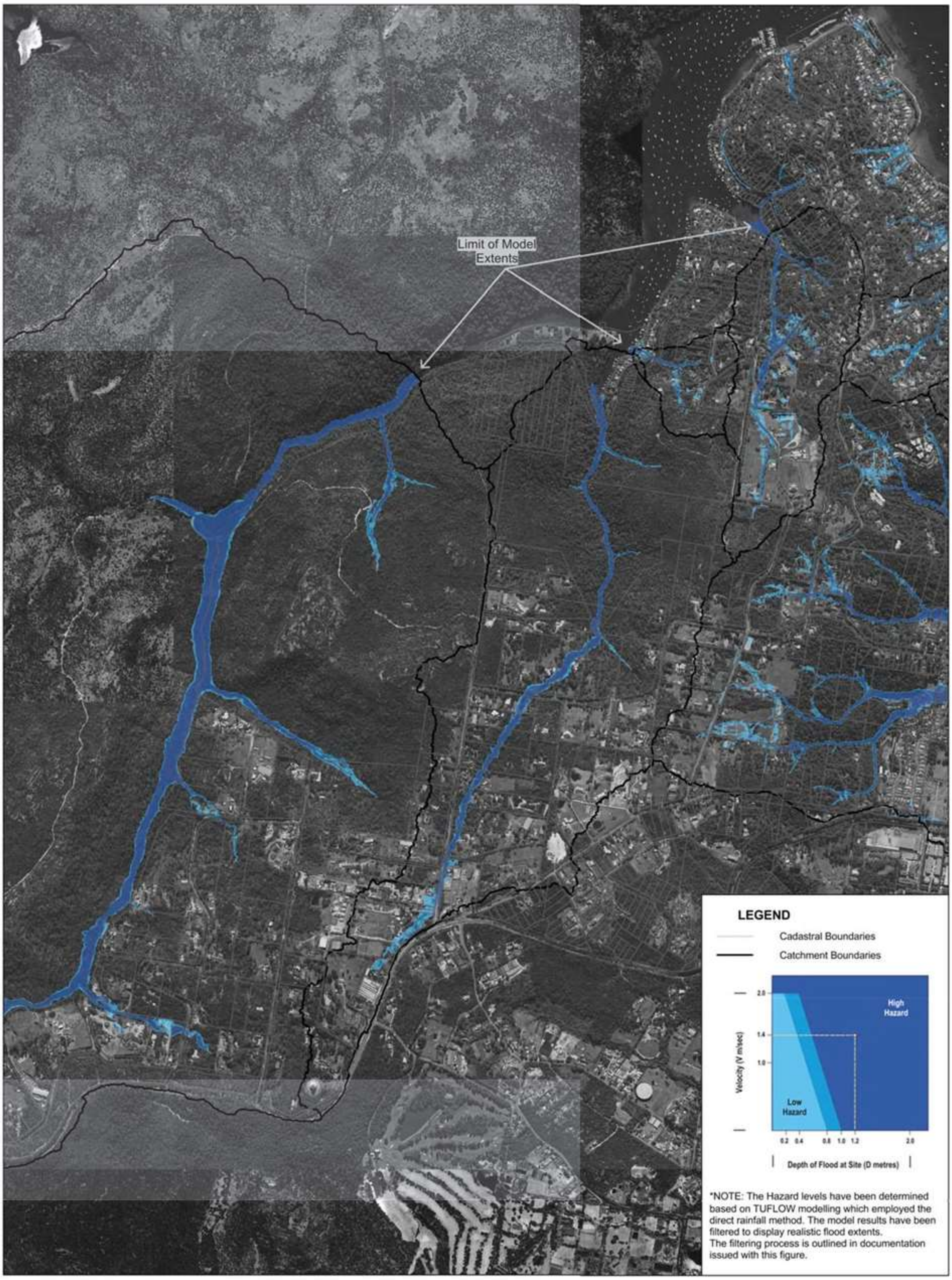
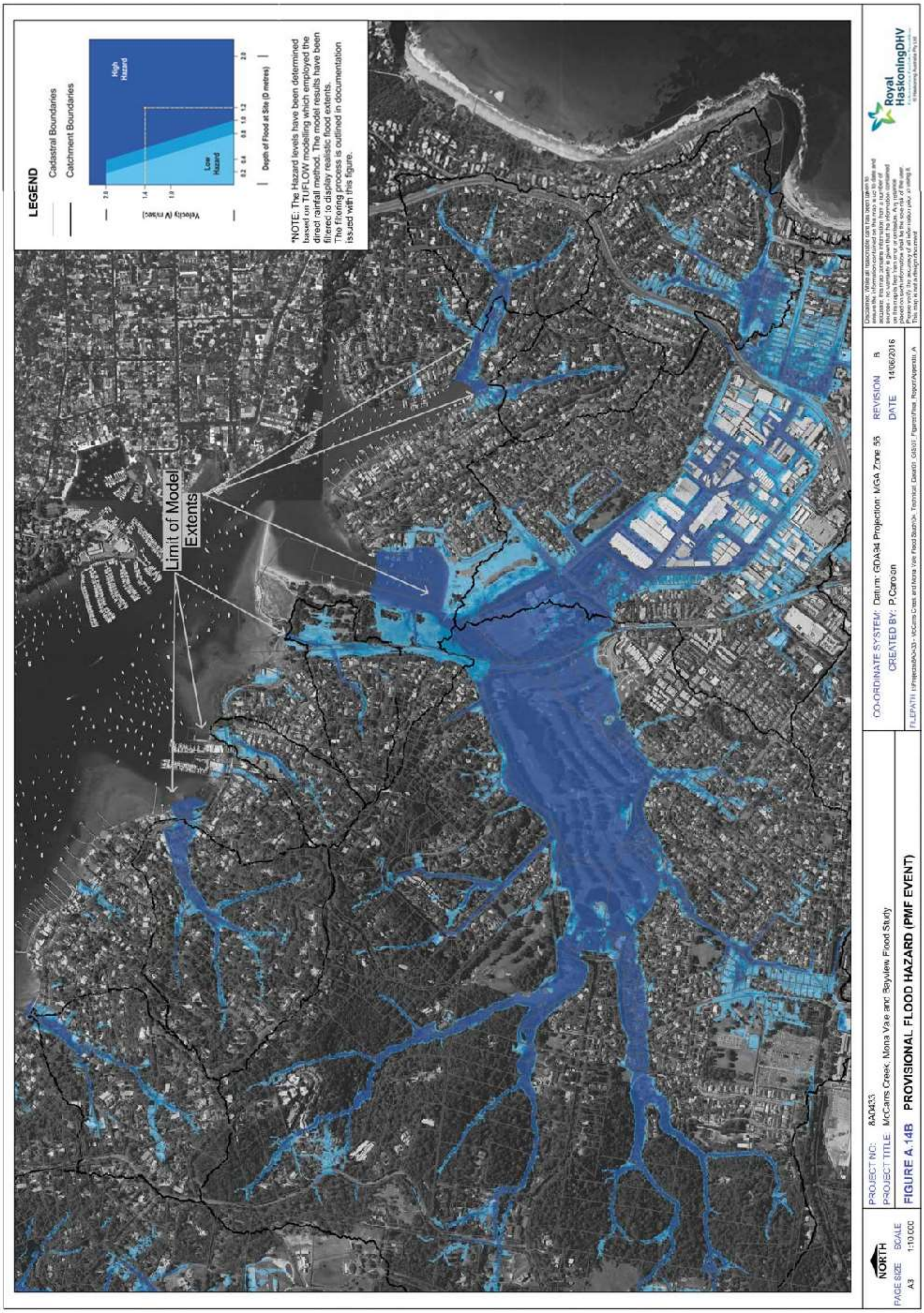
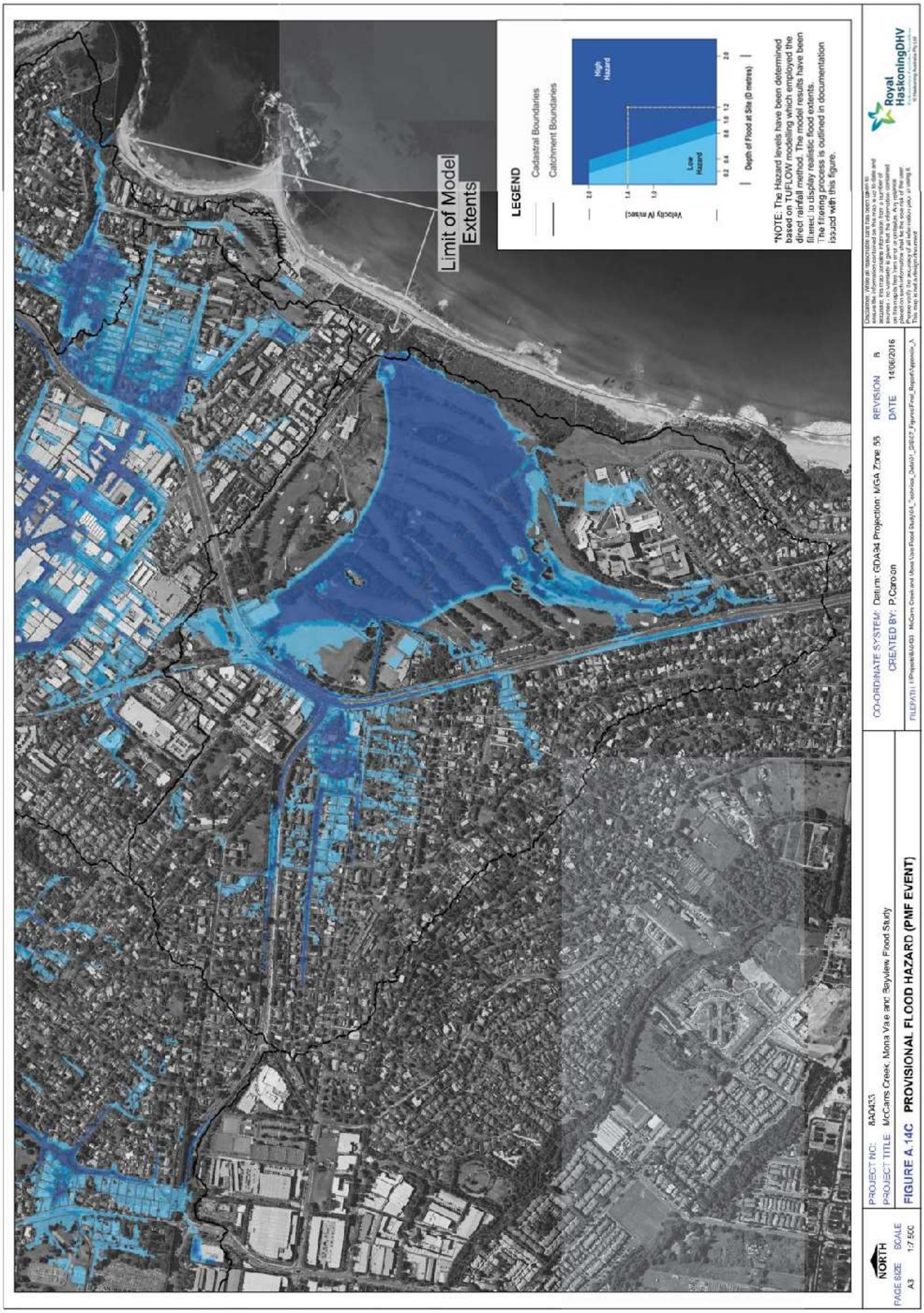
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 6/07/2017
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.13C PROVISIONAL FLOOD HAZARD (1% AEP EVENT)
NORTH
PAGE SIZE A3
SCALE 1:7 500

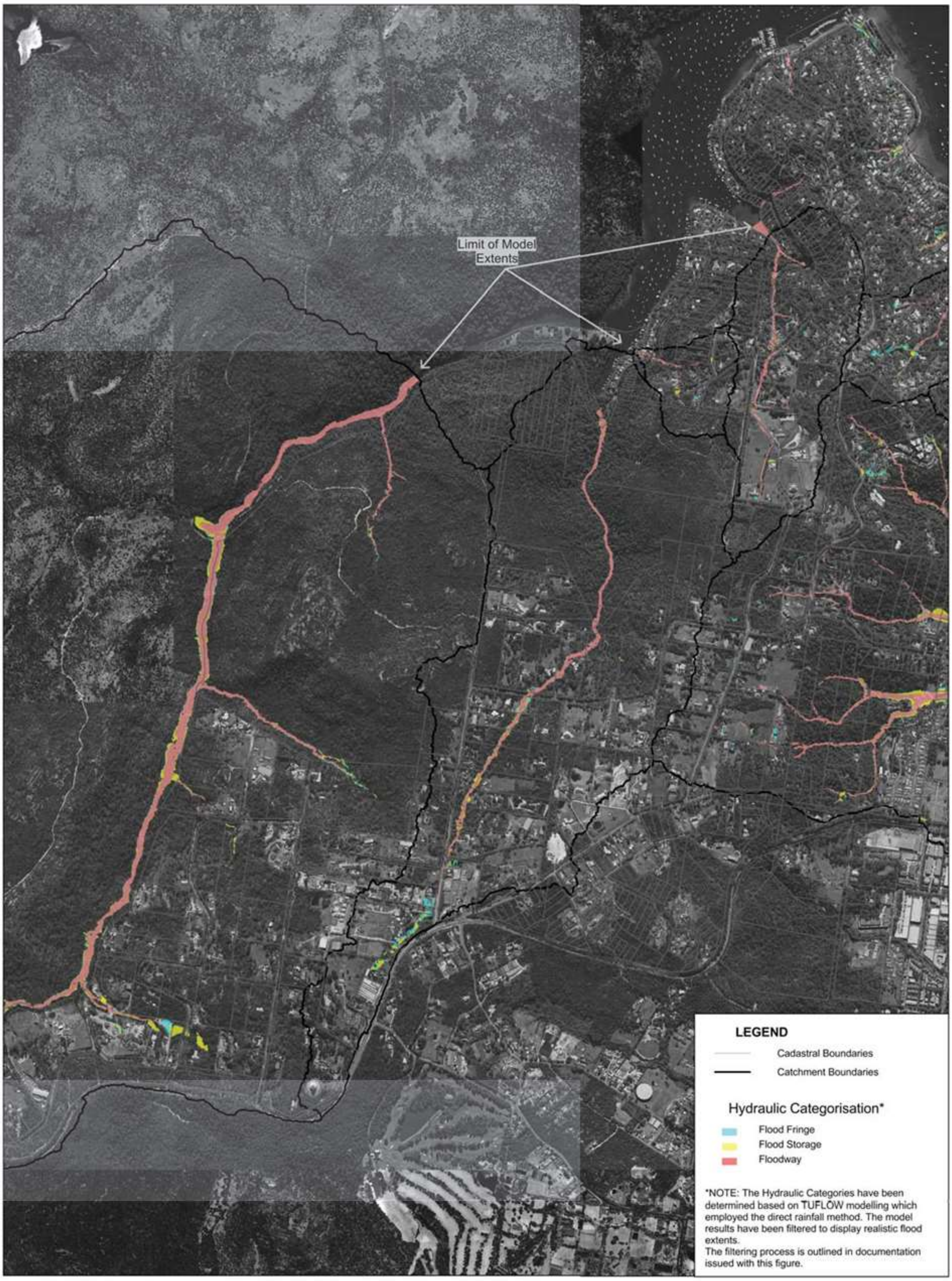


*NOTE: The Hazard levels have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.

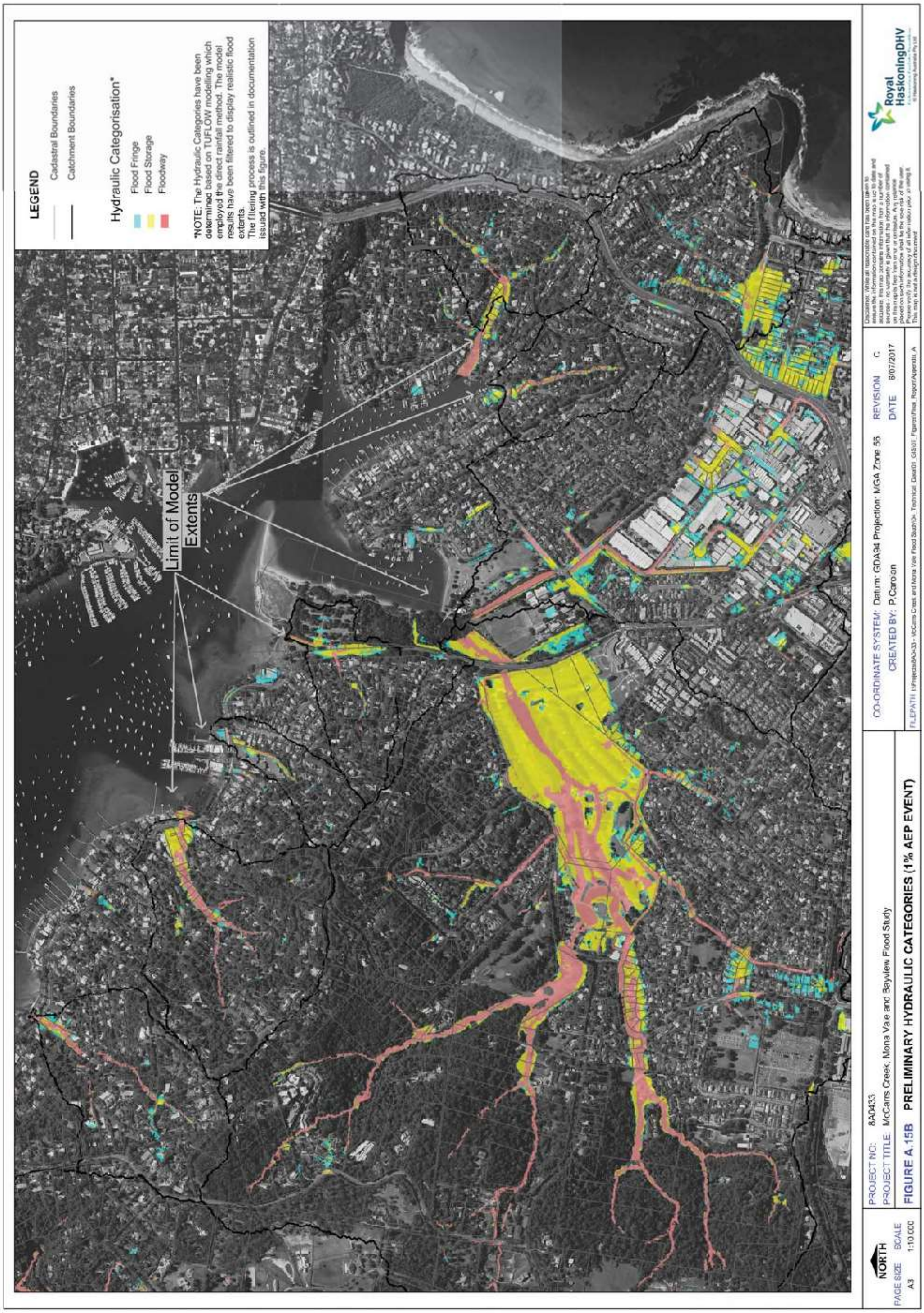
PROJECT NO: 8A0433 PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study		REVISION B DATE 14/06/2016 CREATED BY: P.Carolan	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document. Royal HaskoningDHV Enhancing Society Together
NORTH	FIGURE A.14A PROVISIONAL FLOOD HAZARD (PMF EVENT)		
PAGE SIZE A3 SCALE 1:15,000	FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A		CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

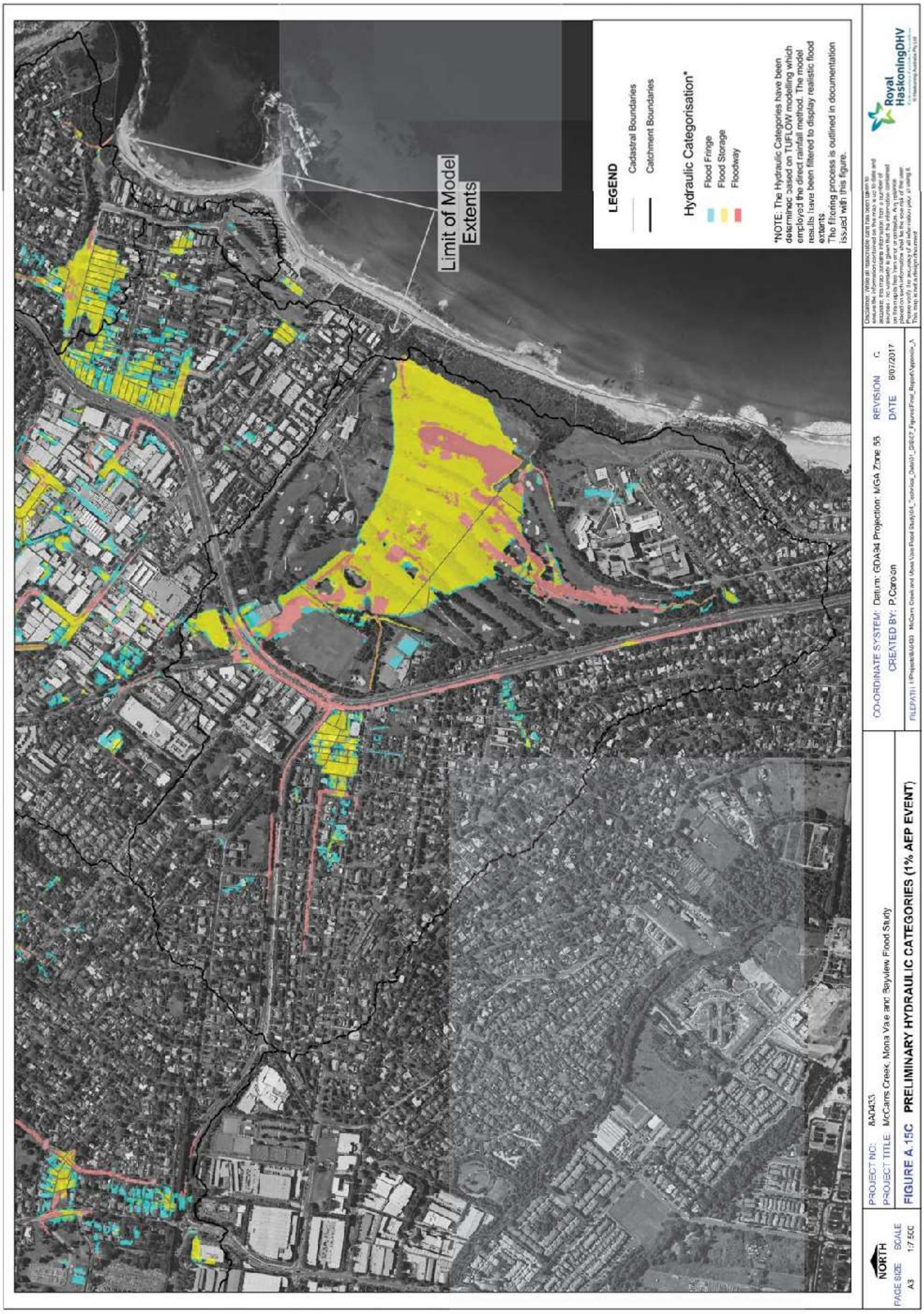

LEGEND
Cadastral Boundaries
Catchment Boundaries
High Hazard
Low Hazard
Velocity (V m/sec)
Depth of Flood at Site (D metres)
*NOTE: The Hazard levels have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
NORTH
PAGE SIZE A3
SCALE 1:10 000
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.14B PROVISIONAL FLOOD HAZARD (PMF EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION B
DATE 14/06/2016
Royal HaskoningDHV

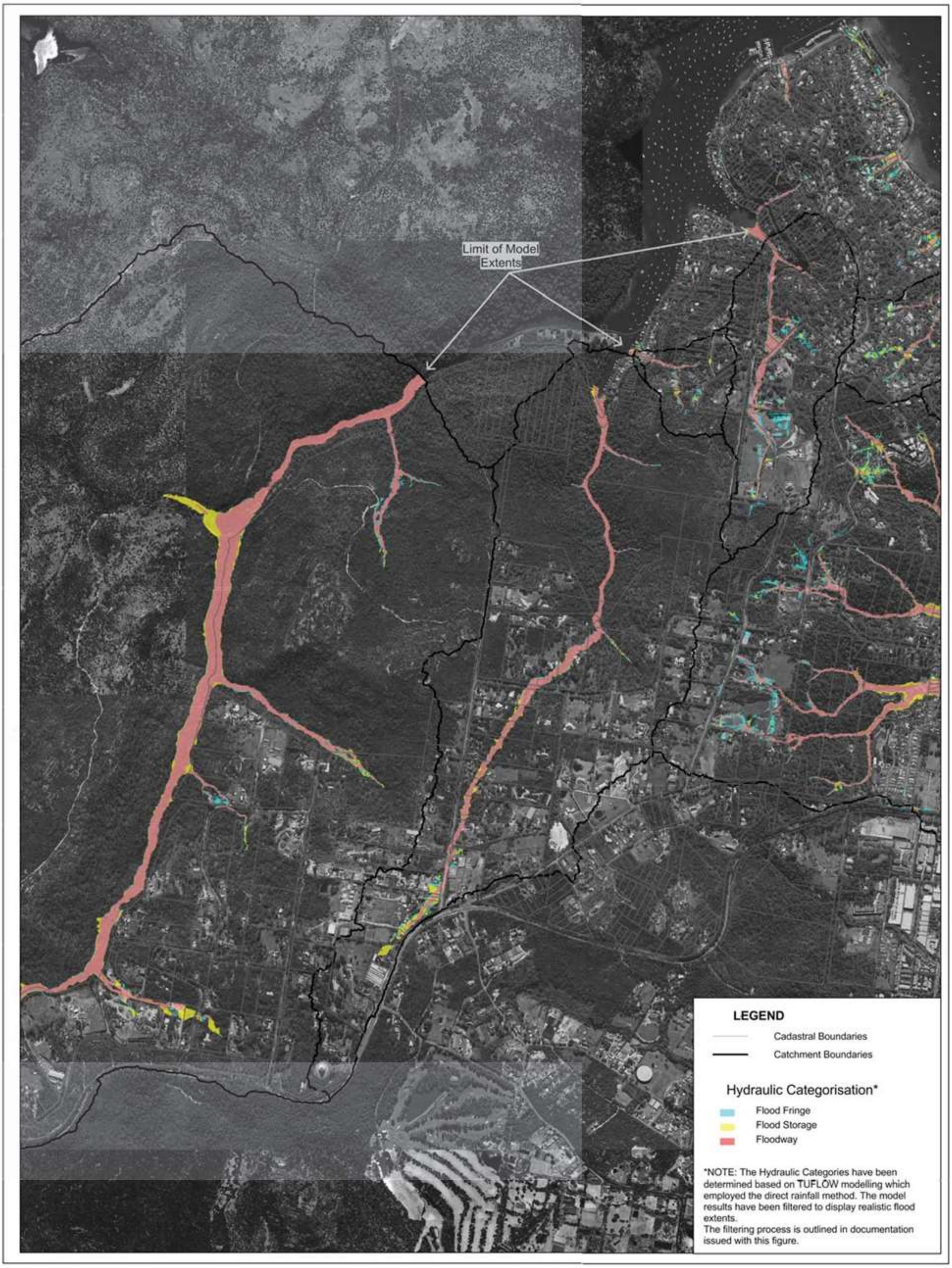

Limit of Model
Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
High Hazard
Low Hazard
Velocity (V m/sec)
Depth of Flood at Site (D metres)
*NOTE: The Hazard levels have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Royal HaskoningDHV
NORTH
PAGE SIZE A3
SCALE 1:7,500
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.14C PROVISIONAL FLOOD HAZARD (PMF EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Caroian
REVISION B
DATE 14/06/2016



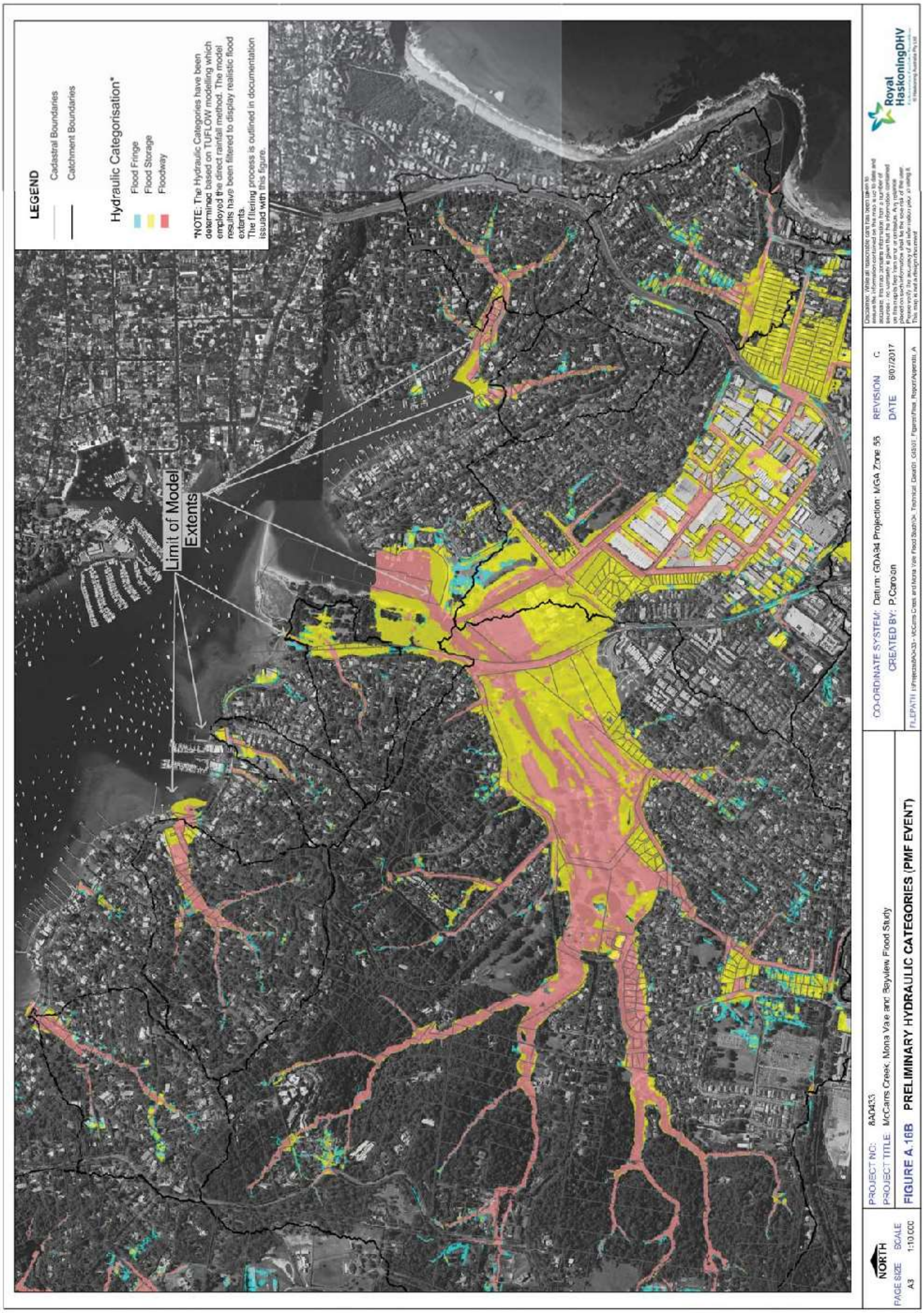
PROJECT NO: 8A0433 PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study		REVISION C DATE 6/07/2017 CREATED BY: P.Carolan	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document. Royal HaskoningDHV Enhancing Society Together © Haskoning Australia Pty Ltd
NORTH PAGE SIZE A3 SCALE 1:15,000	FIGURE A.15A PRELIMINARY HYDRAULIC CATEGORIES (1% AEP EVENT)		
	FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A		CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

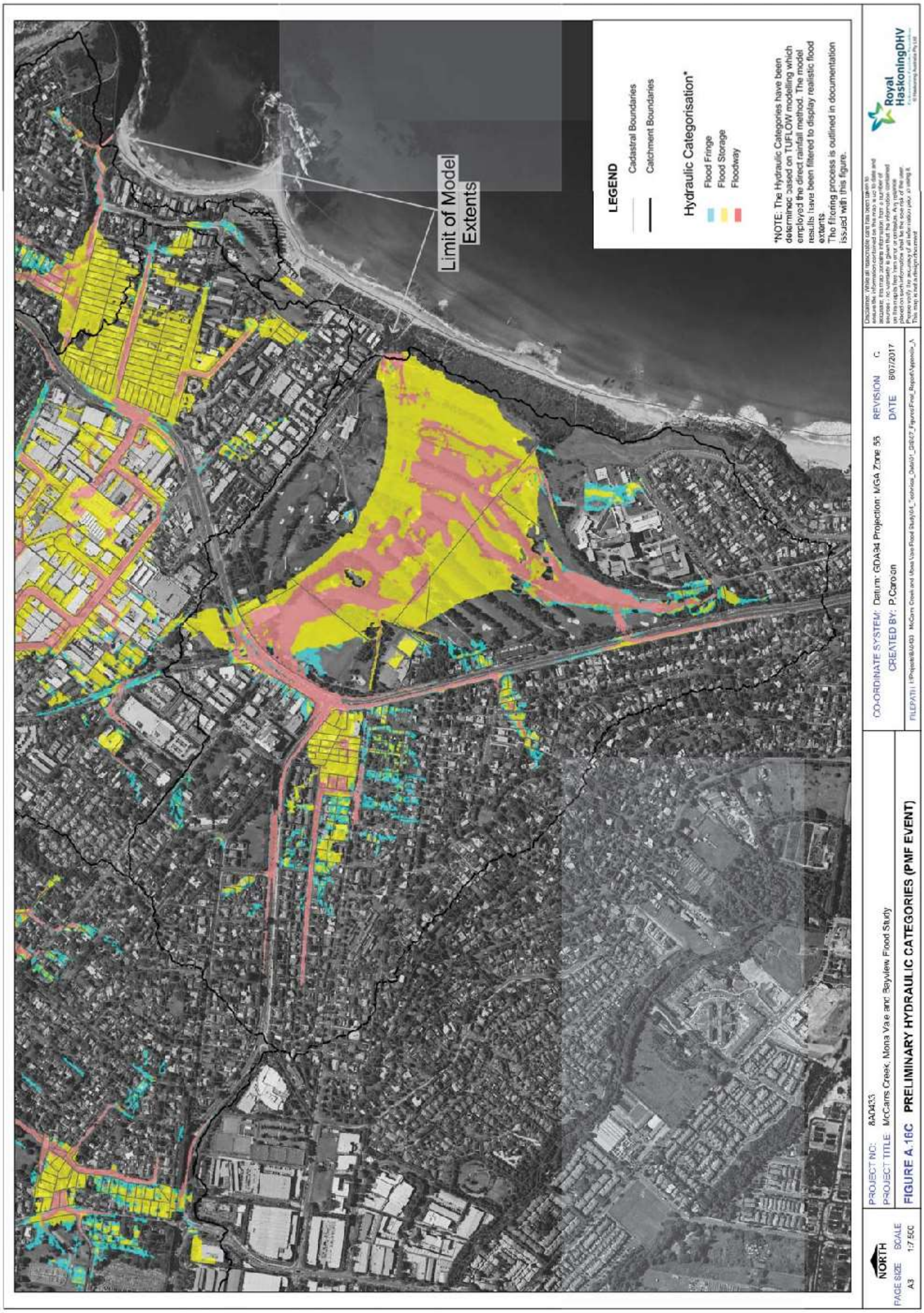

LEGEND
Cadastral Boundaries
Catchment Boundaries
Hydraulic Categorisation*
Flood Fringe
Flood Storage
Floodway
*NOTE: The Hydraulic Categories have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
NORTH
PAGE SIZE A3
SCALE 1:10 000
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.15B PRELIMINARY HYDRAULIC CATEGORIES (1% AEP EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 6/07/2017
Royal HaskoningDHV

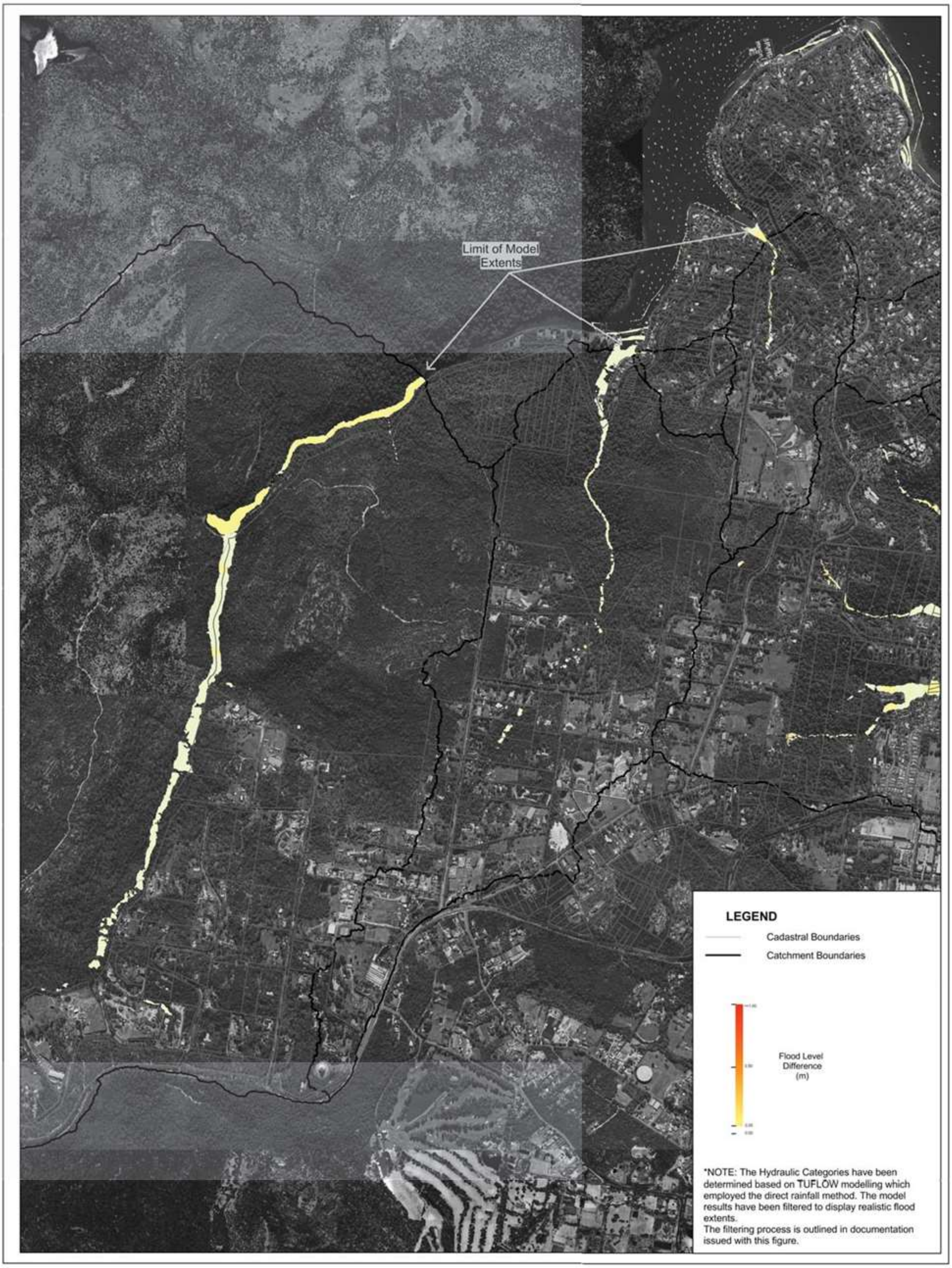

Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
Hydraulic Categorisation*
Flood Fringe
Flood Storage
Floodway
*NOTE: The Hydraulic Categories have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
Royal HaskoningDHV
NORTH
PAGE SIZE A3
SCALE 1:7,500
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.15C PRELIMINARY HYDRAULIC CATEGORIES (1% AEP EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 55
CREATED BY: P.Carolan
REVISION C
DATE 8/07/2017



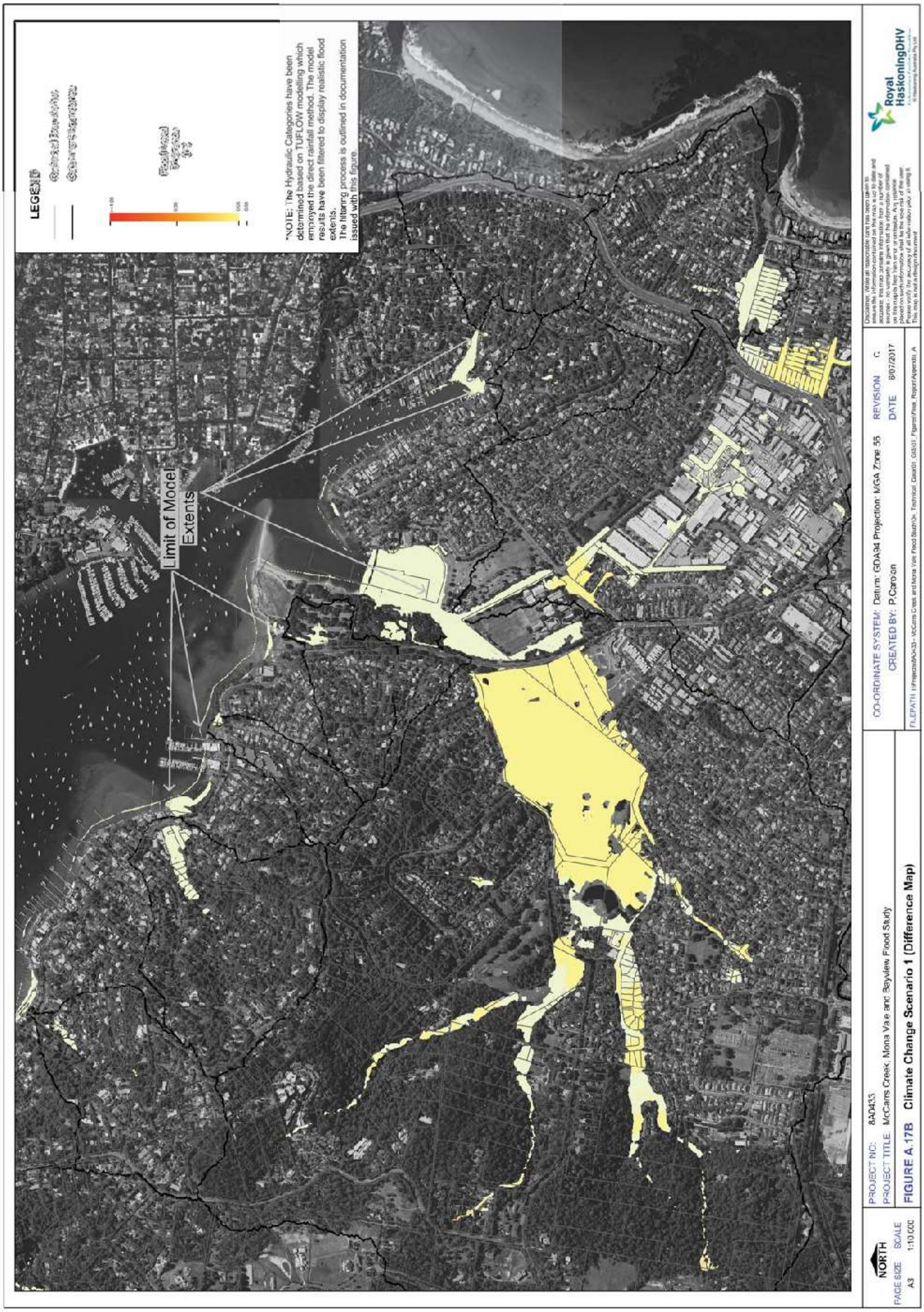
PROJECT NO: 8A0433 PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study	REVISION C DATE 6/07/2017 CREATED BY: P.Carolan	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document.
NORTH PAGE SIZE A3 SCALE 1:15,000	FIGURE A.16A PRELIMINARY HYDRAULIC CATEGORIES (PMF EVENT) FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A	Royal HaskoningDHV Enhancing Society Together CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

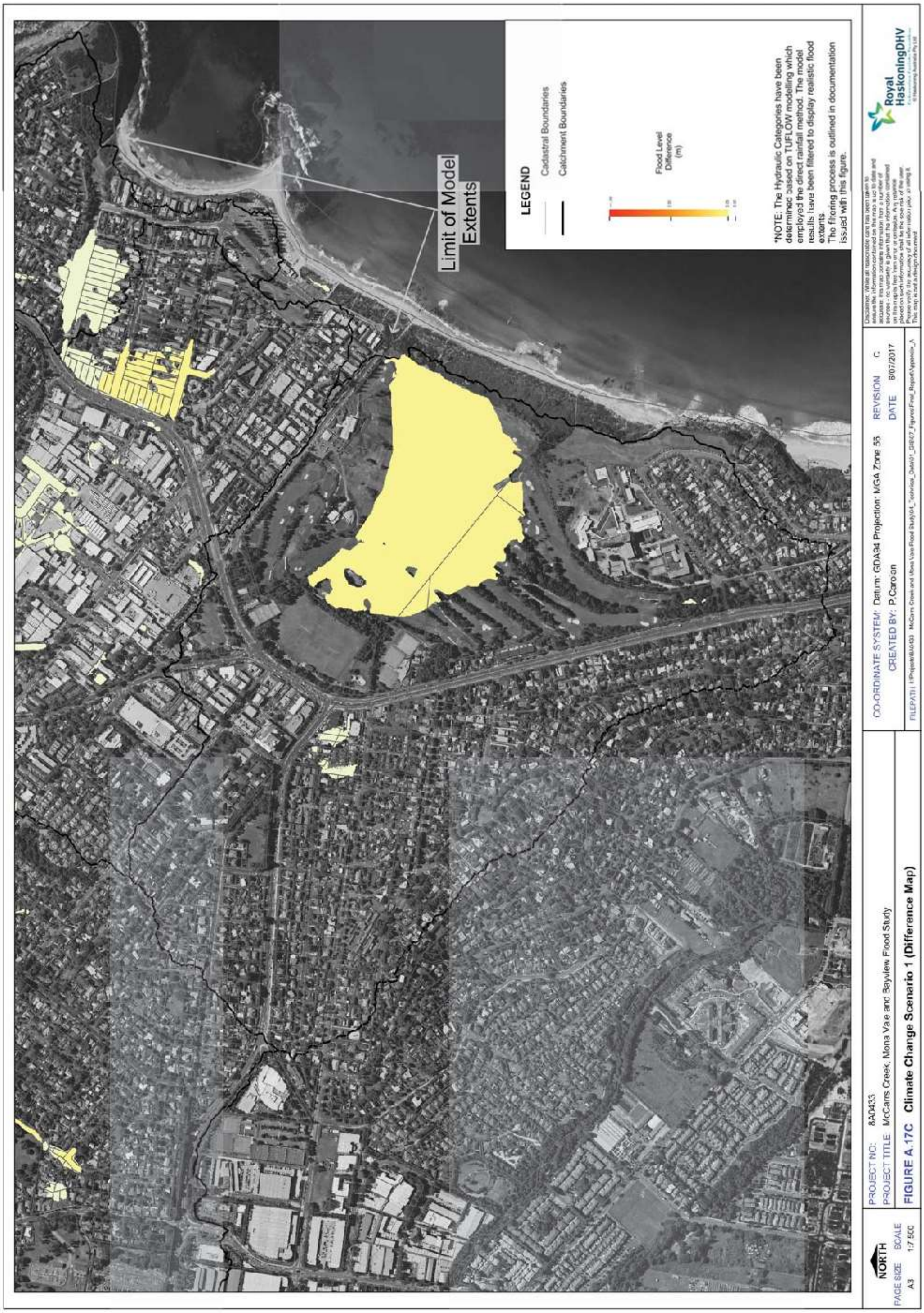

LEGEND
Cadastral Boundaries
Catchment Boundaries
Hydraulic Categorisation*
Flood Fringe
Flood Storage
Floodway
*NOTE: The Hydraulic Categories have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.16B PRELIMINARY HYDRAULIC CATEGORIES (PMF EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 8/07/2017
NORTH
PAGE SIZE A3
SCALE 1:10 000
Royal HaskoningDHV

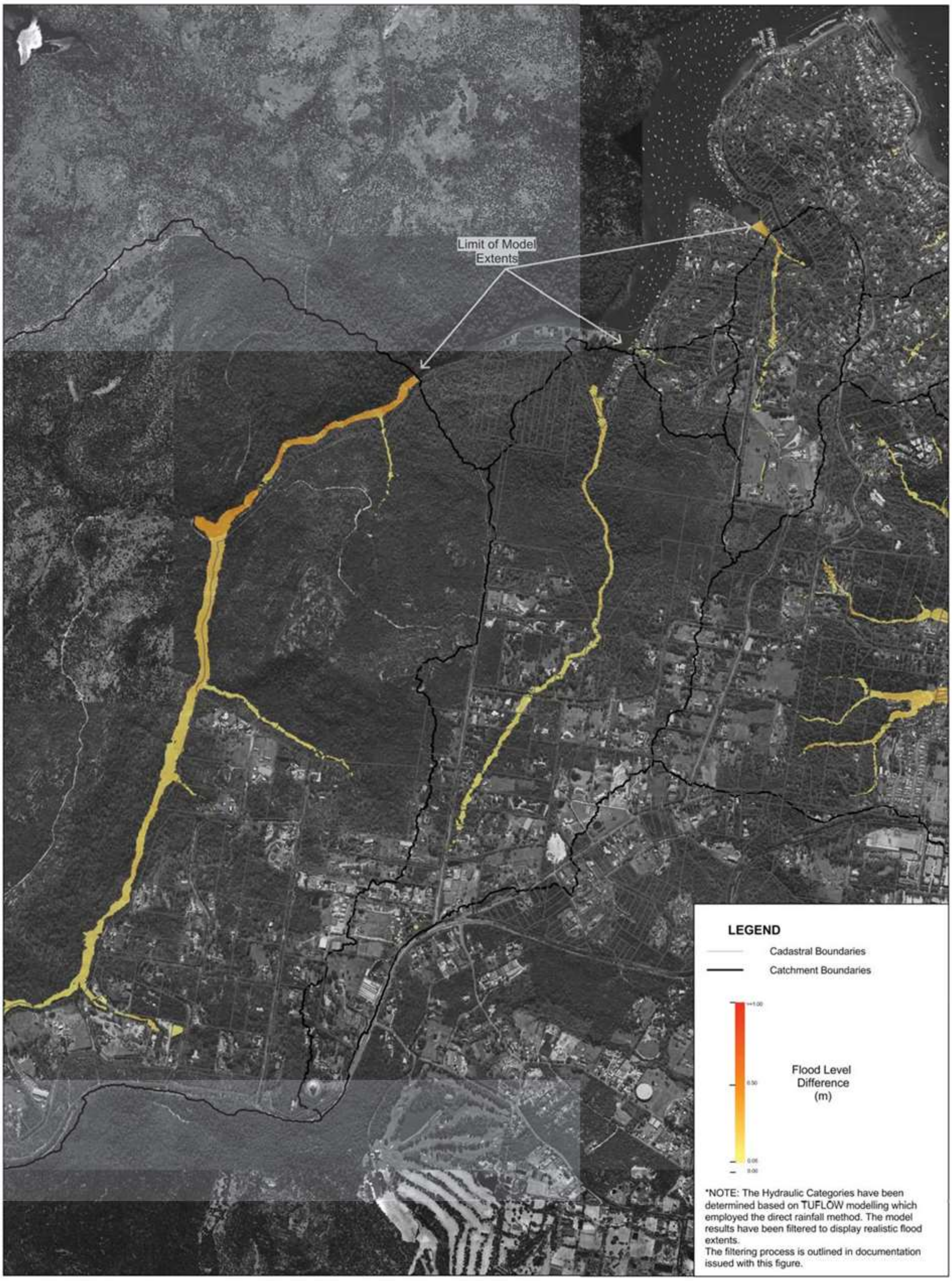

Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
Hydraulic Categorisation*
Flood Fringe
Flood Storage
Floodway
*NOTE: The Hydraulic Categories have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
Royal HaskoningDHV
NORTH
PAGE SIZE A3
SCALE 1:7,500
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.16C PRELIMINARY HYDRAULIC CATEGORIES (PMF EVENT)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Caroon
REVISION C
DATE 6/07/2017



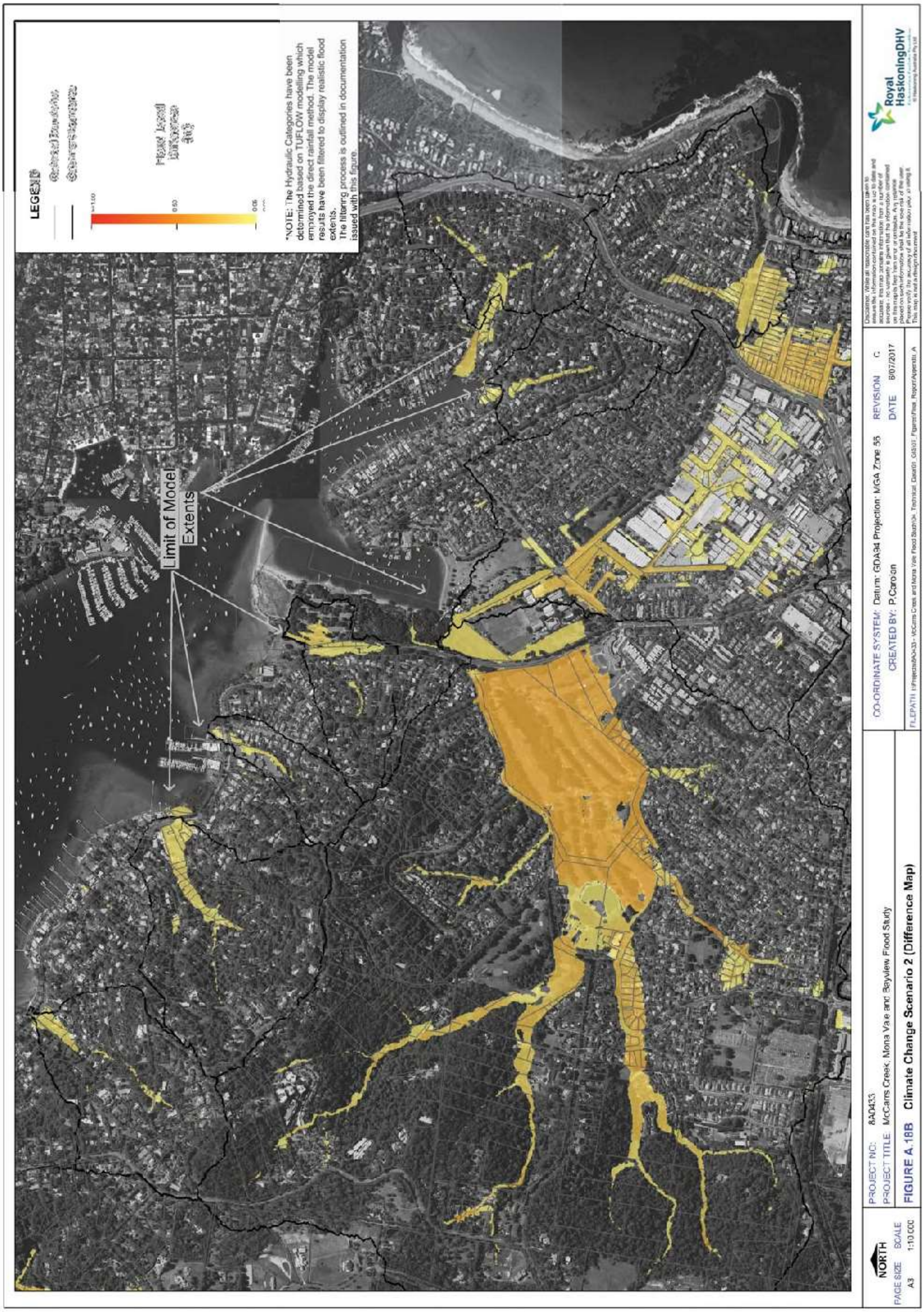
PROJECT NO: 8A0433 PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study		REVISION C DATE 6/07/2017 CREATED BY: P.Carolan	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document.
NORTH	FIGURE A.17A **Climate Change Scenario 1 (Difference Map)**		Royal HaskoningDHV Enhancing Society Together
PAGE SIZE A3 SCALE 1:15,000	FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A		CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

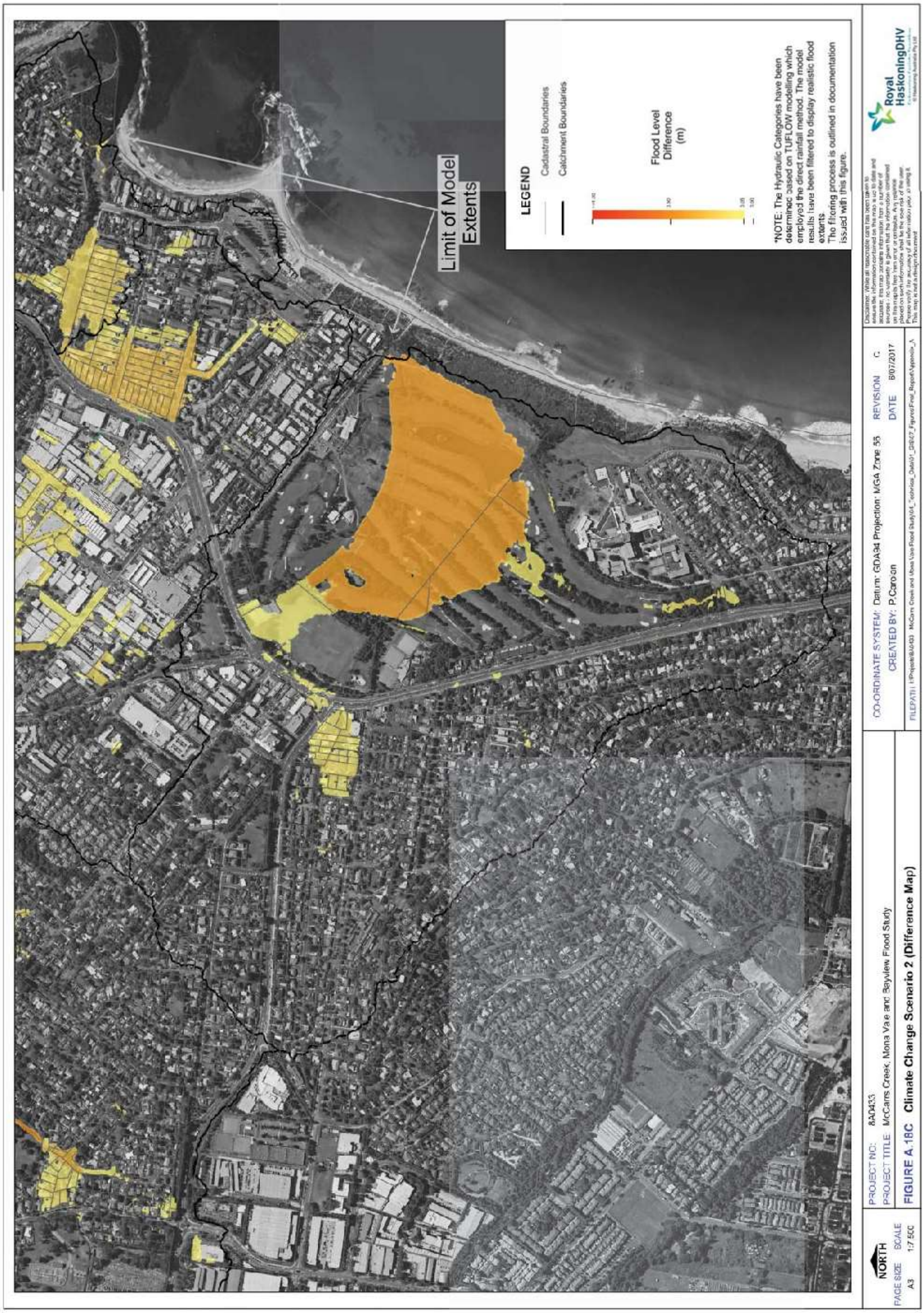

LEGEND
*NOTE: The Hydraulic Categories have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
NORTH
PAGE SIZE A3
SCALE 1:10 000
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.17B Climate Change Scenario 1 (Difference Map)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 6/07/2017
Royal HaskoningDHV

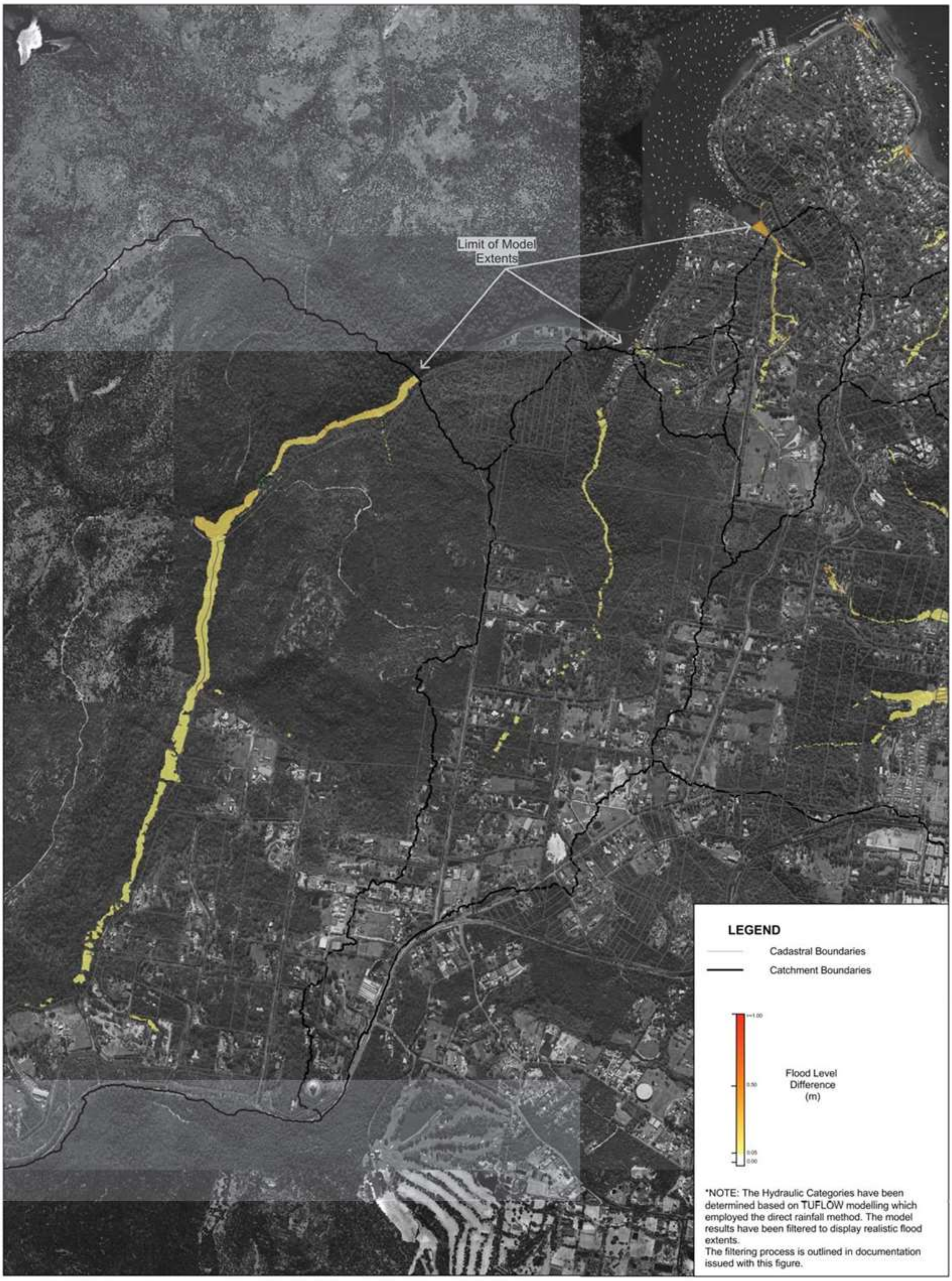

Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
Flood Level Difference (m)
*NOTE: The Hydraulic Categories have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
Royal HaskoningDHV
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.17C Climate Change Scenario 1 (Difference Map)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 8/07/2017
NORTH
PAGE SIZE A3
SCALE 1:7500



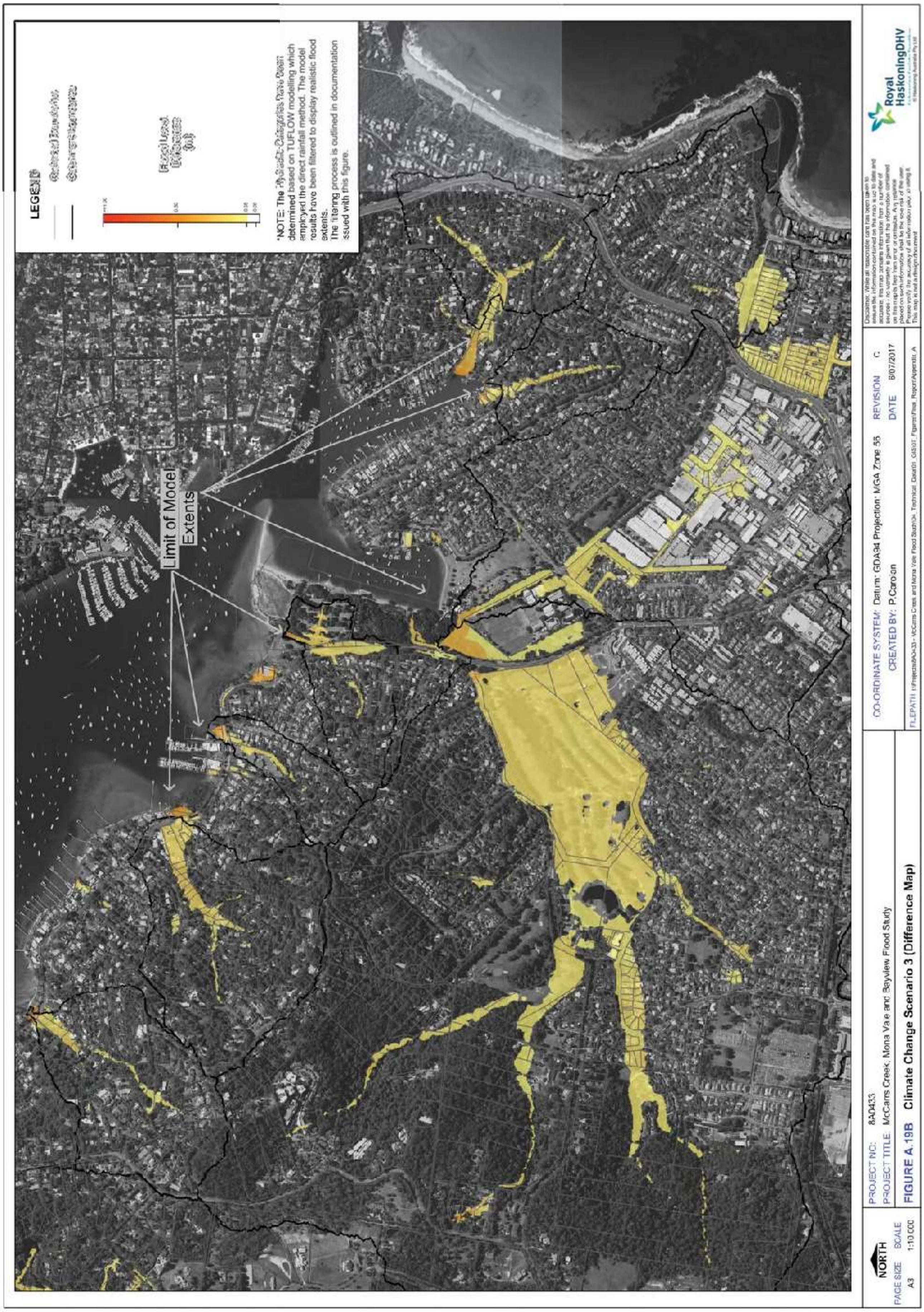
PROJECT NO: 8A0433 PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study		REVISION C DATE 6/07/2017 CREATED BY: P.Carolan	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document. Royal HaskoningDHV Enhancing Society Together © Haskoning Australia Pty Ltd
NORTH	FIGURE A.18A **Climate Change Scenario 2 (Difference Map)**		
PAGE SIZE A3 SCALE 1:15,000	FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A		CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56


LEGEND
*NOTE: The Hydraulic Categories have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.18B Climate Change Scenario 2 (Difference Map)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 6/07/2017
NORTH
PAGE SIZE A3
SCALE 1:10 000
Royal HaskoningDHV


Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
Flood Level Difference (m)
*NOTE: The Hydraulic Categories have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
Royal HaskoningDHV
NORTH
PAGE SIZE A3
SCALE 1:7,500
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.18C Climate Change Scenario 2 (Difference Map)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 55
CREATED BY: P.Carolan
REVISION C
DATE 8/07/2017



PROJECT NO: 8A0433 PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study	REVISION C DATE 6/07/2017 CREATED BY: P.Carolan	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document. Royal HaskoningDHV Enhancing Society Together
NORTH PAGE SIZE A3 SCALE 1:15,000	FIGURE A.19A Climate Change Scenario 3 (Difference Map) FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A	CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56


LEGEND
NOTE: The Hydraulic Categories have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
NORTH
PAGE SIZE A3
SCALE 1:10 000
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.19B Climate Change Scenario 3 (Difference Map)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 8/07/2017
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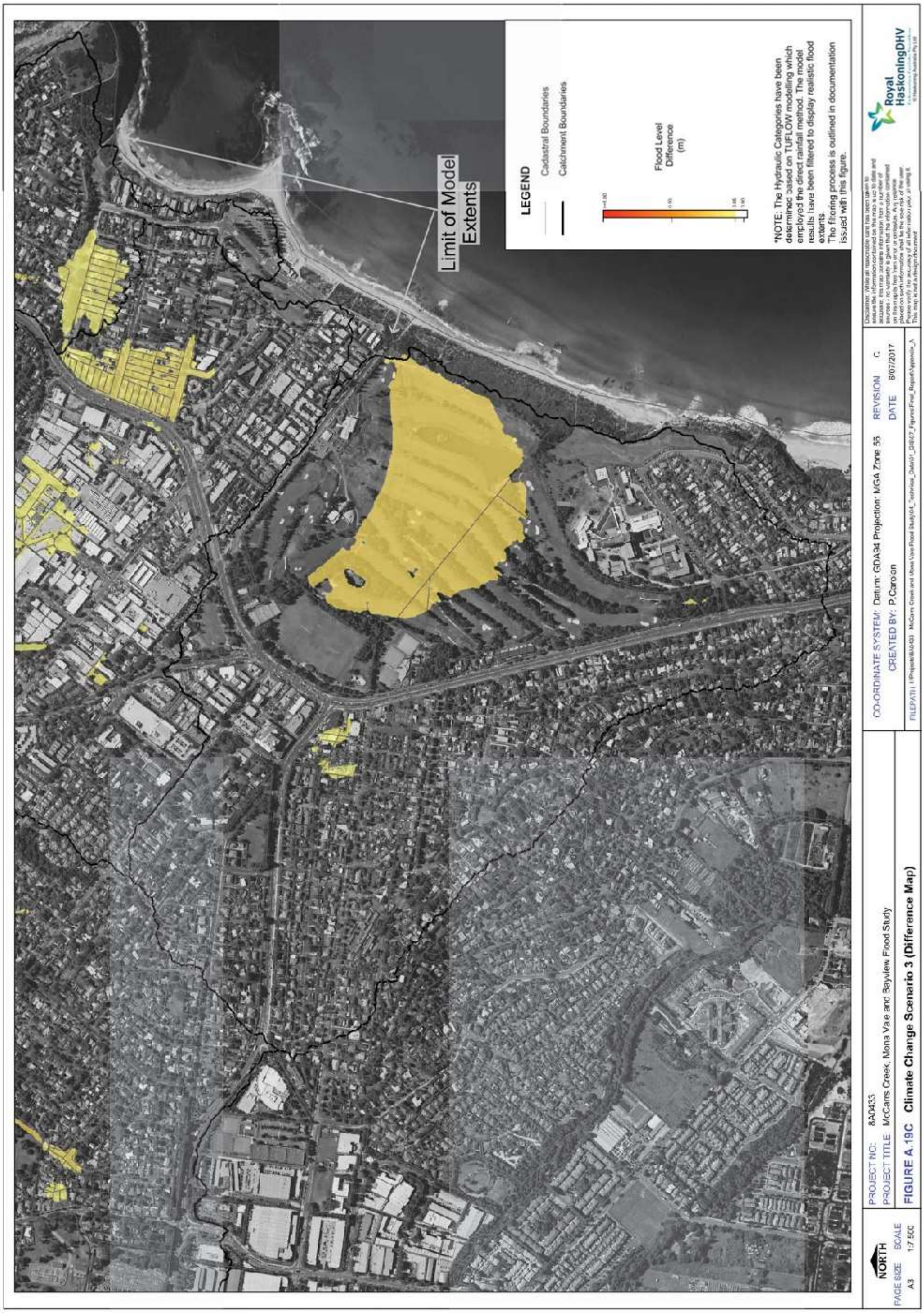
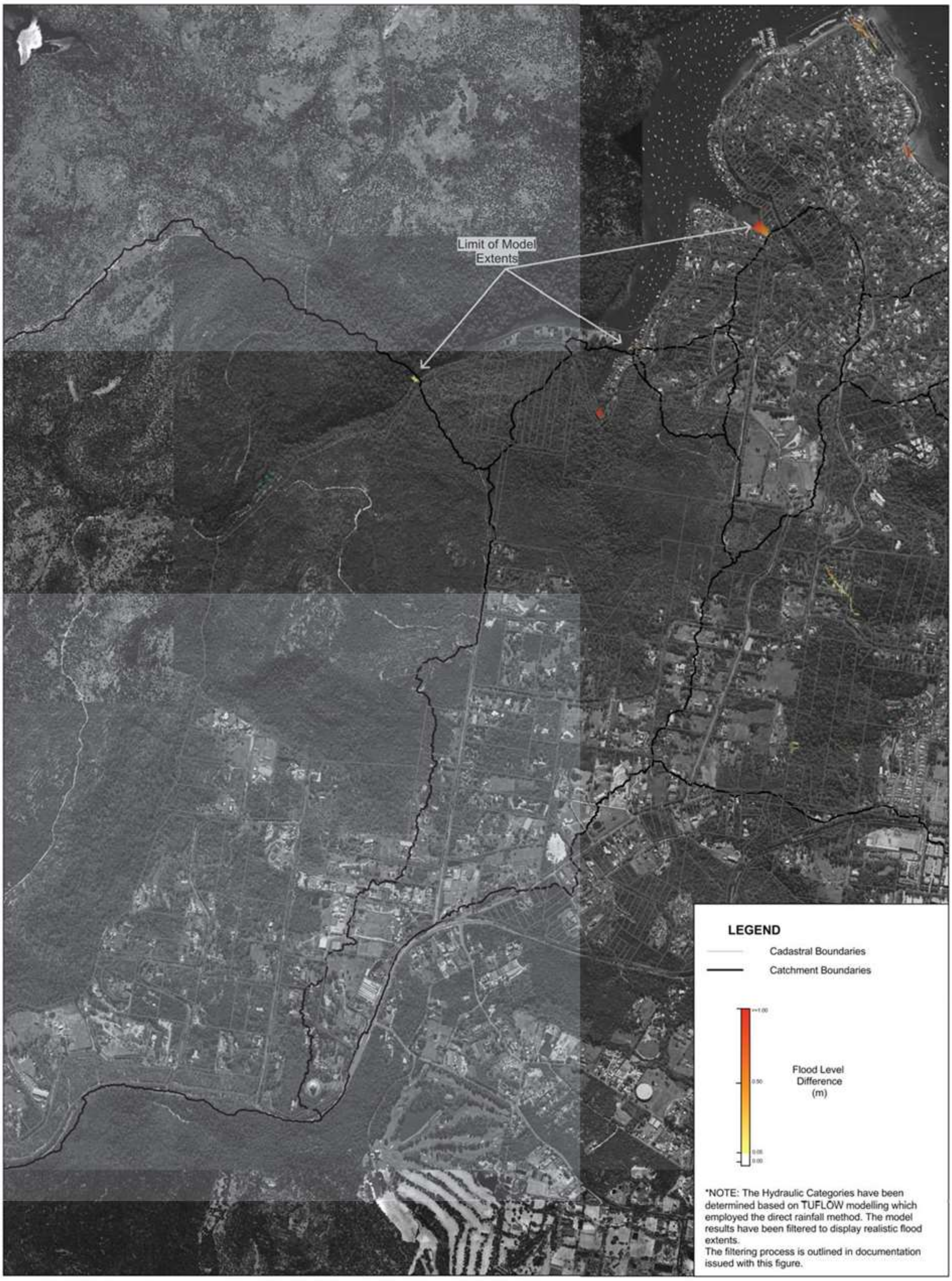

Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
Flood Level Difference (m)
*NOTE: The Hydraulic Categories have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
Royal HaskoningDHV
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 6/07/2017
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.19C Climate Change Scenario 3 (Difference Map)
NORTH
PAGE SIZE A3
SCALE 1:7500



PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
REVISION C DATE 6/07/2017
CREATED BY: P.Carolan

NORTH
PAGE SIZE A3 SCALE 1:15,000

FIGURE A.20A Climate Change Scenario 4 (Difference Map)

FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A

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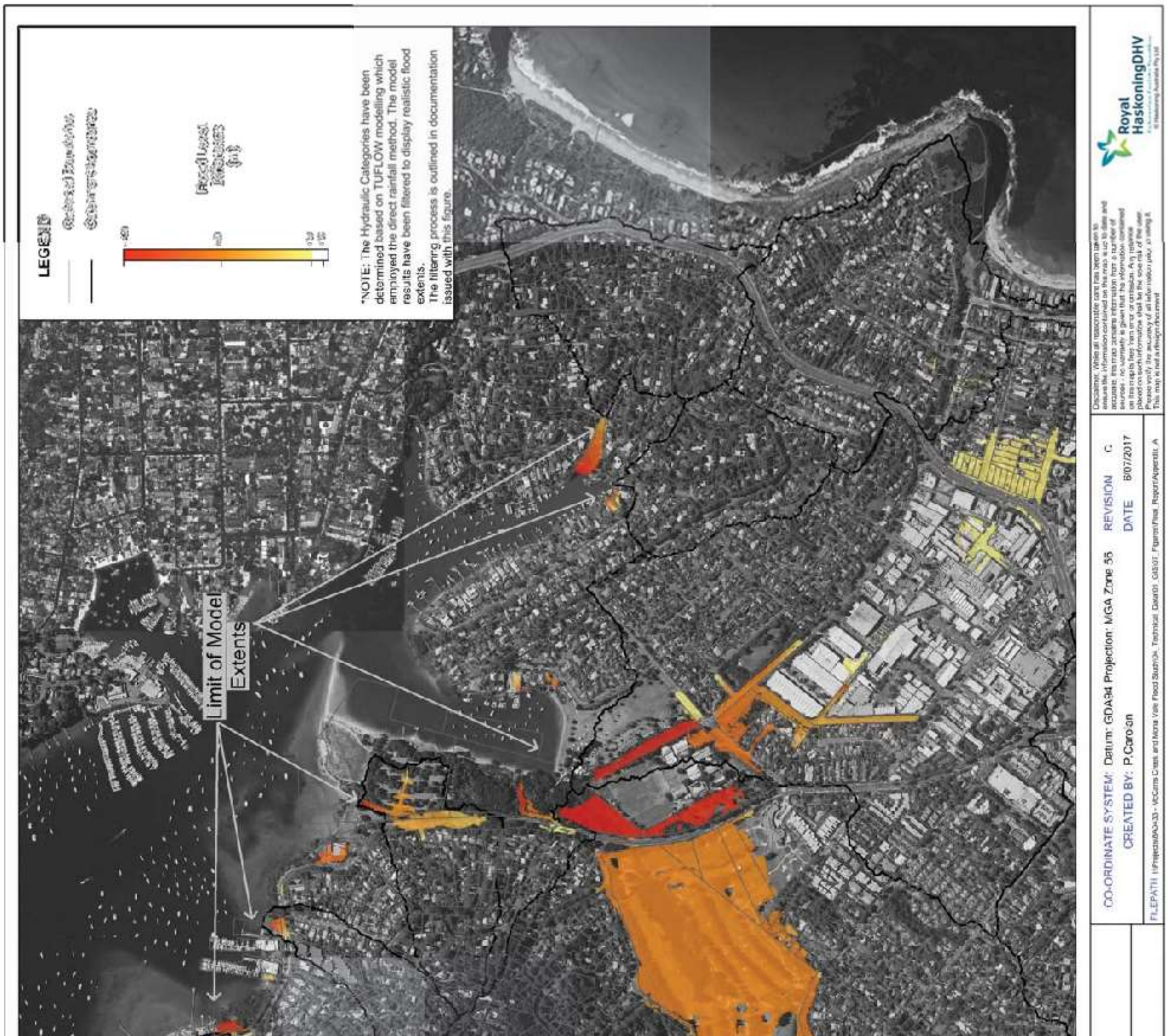
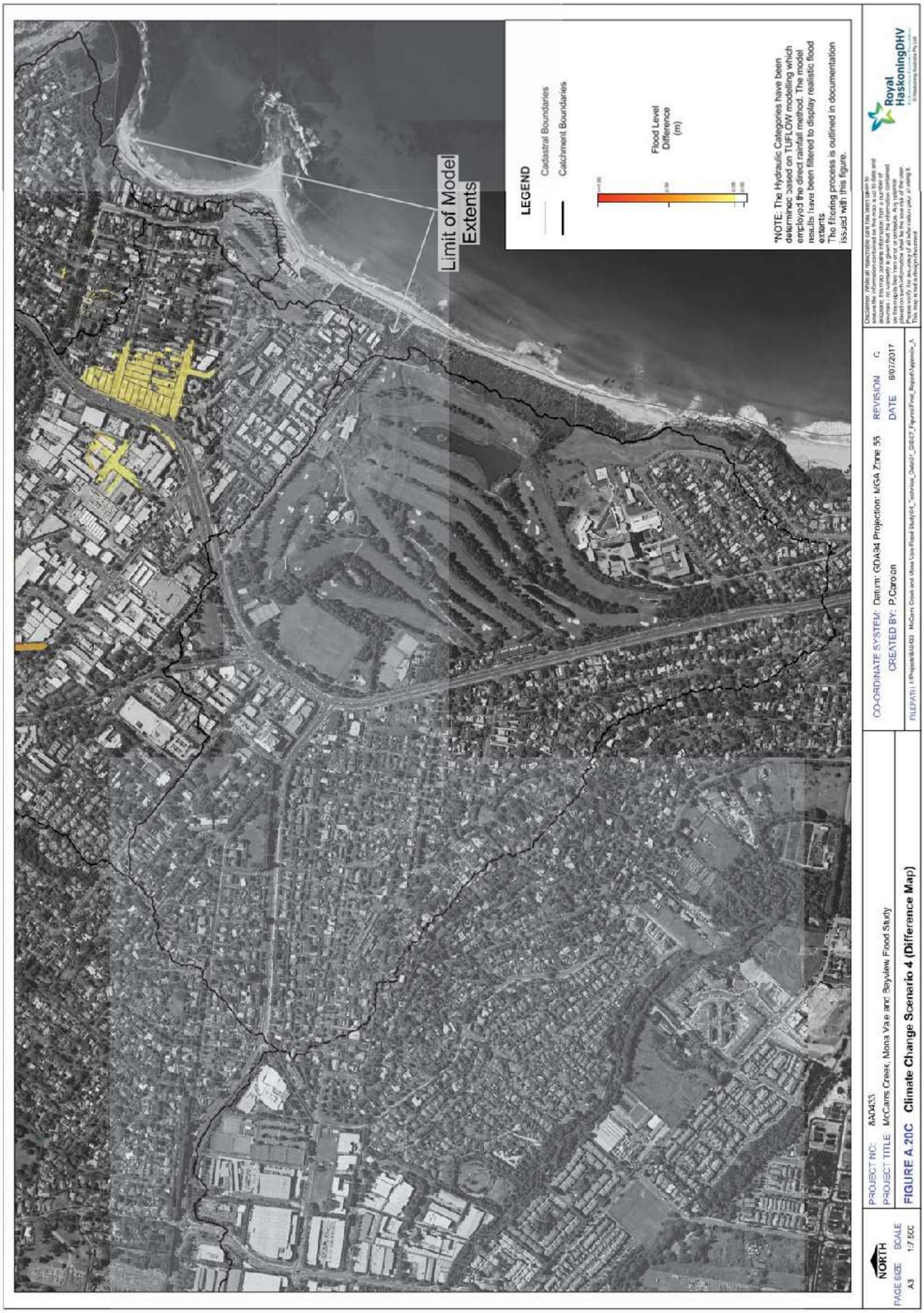
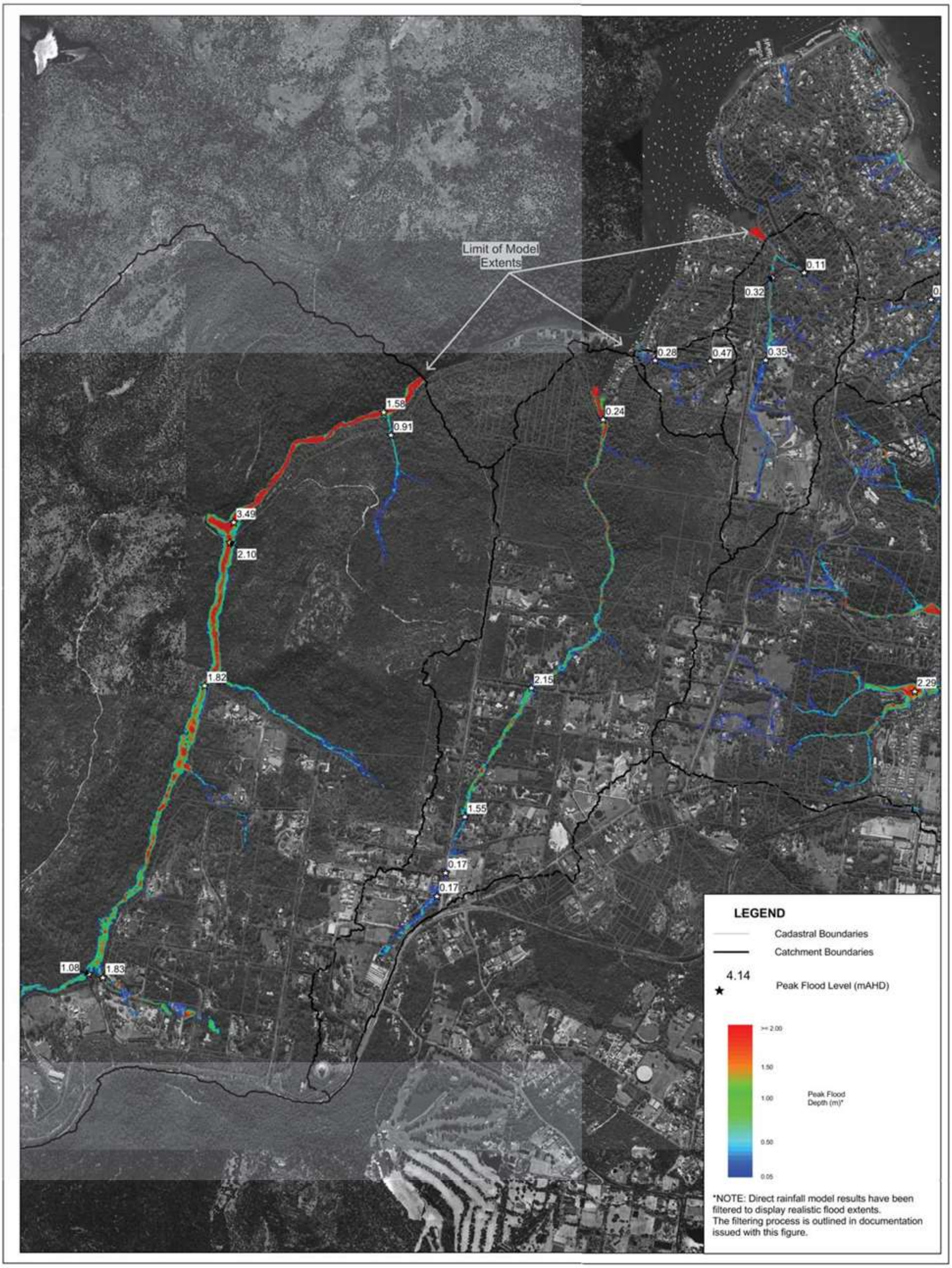

LEGEND
Limit of Model
Extents
*NOTE: The Hydraulic Categories have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
NORTH
PAGE SIZE A3
SCALE 1:10 000
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.20B Climate Change Scenario 4 (Difference Map)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 8/07/2017
Royal HaskoningDHV


Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
Flood Level Difference (m)
*NOTE: The Hydraulic Categories have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
Royal HaskoningDHV
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.20C Climate Change Scenario 4 (Difference Map)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
REVISION C
DATE 6/07/2017
NORTH
PAGE SIZE A3



PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study

REVISION C DATE 6/07/2017
CREATED BY: P.Carolan

NORTH

PAGE SIZE A3 SCALE 1:15,000

FIGURE A.21A PEAK FLOOD DEPTH (CC SCENARIO 5)

FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A

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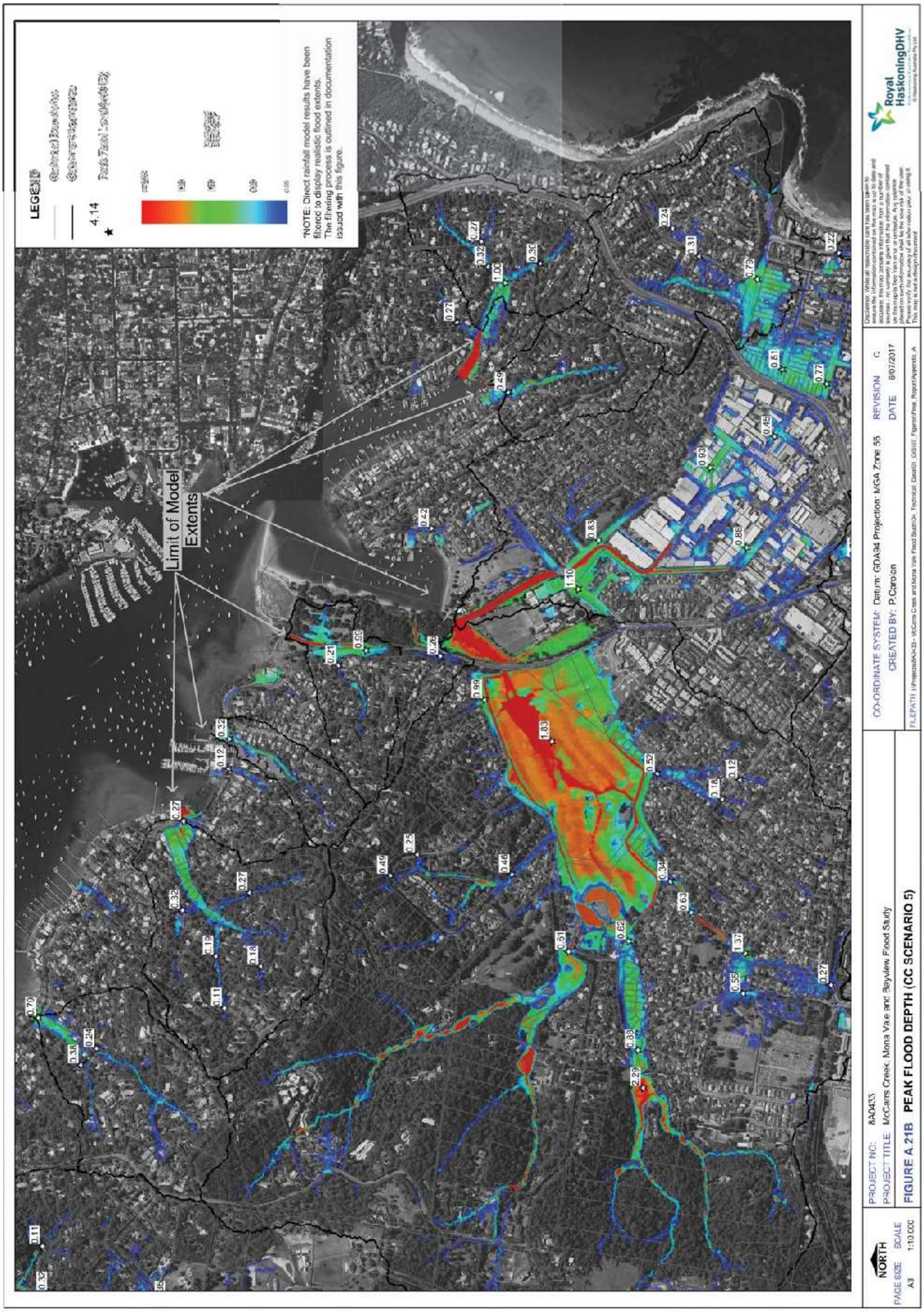
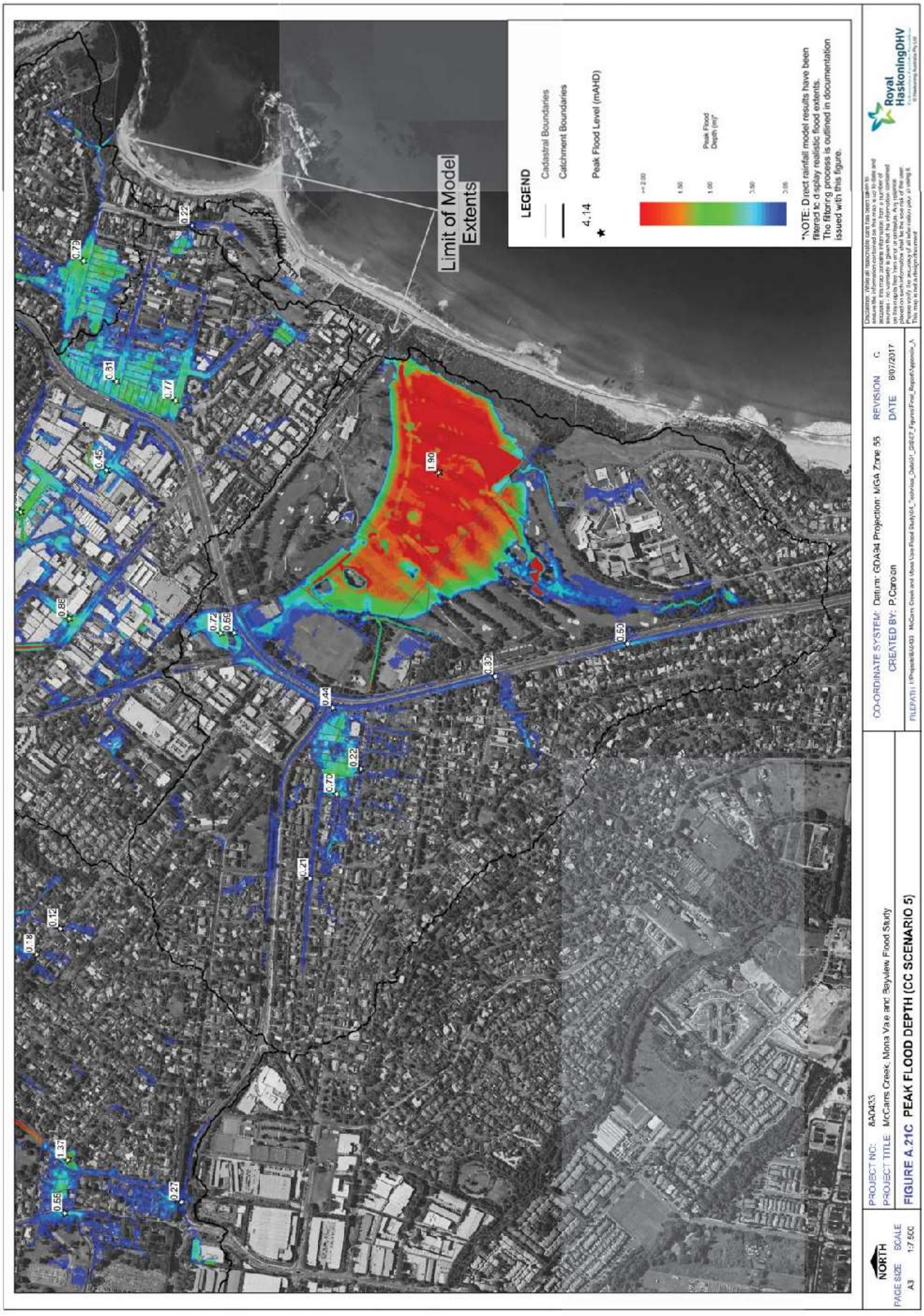
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56


LEGEND
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.21B PEAK FLOOD DEPTH (CC SCENARIO 5)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 6/07/2017
NORTH
PAGE SIZE A3
SCALE 1:10 000
Royal HaskoningDHV


Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
4.14 Peak Flood Level (mAHD)
Peak Flood Depth (m)*
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Royal HaskoningDHV
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.21C PEAK FLOOD DEPTH (CC SCENARIO 5)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Caroon
REVISION C
DATE 6/07/2017
NORTH
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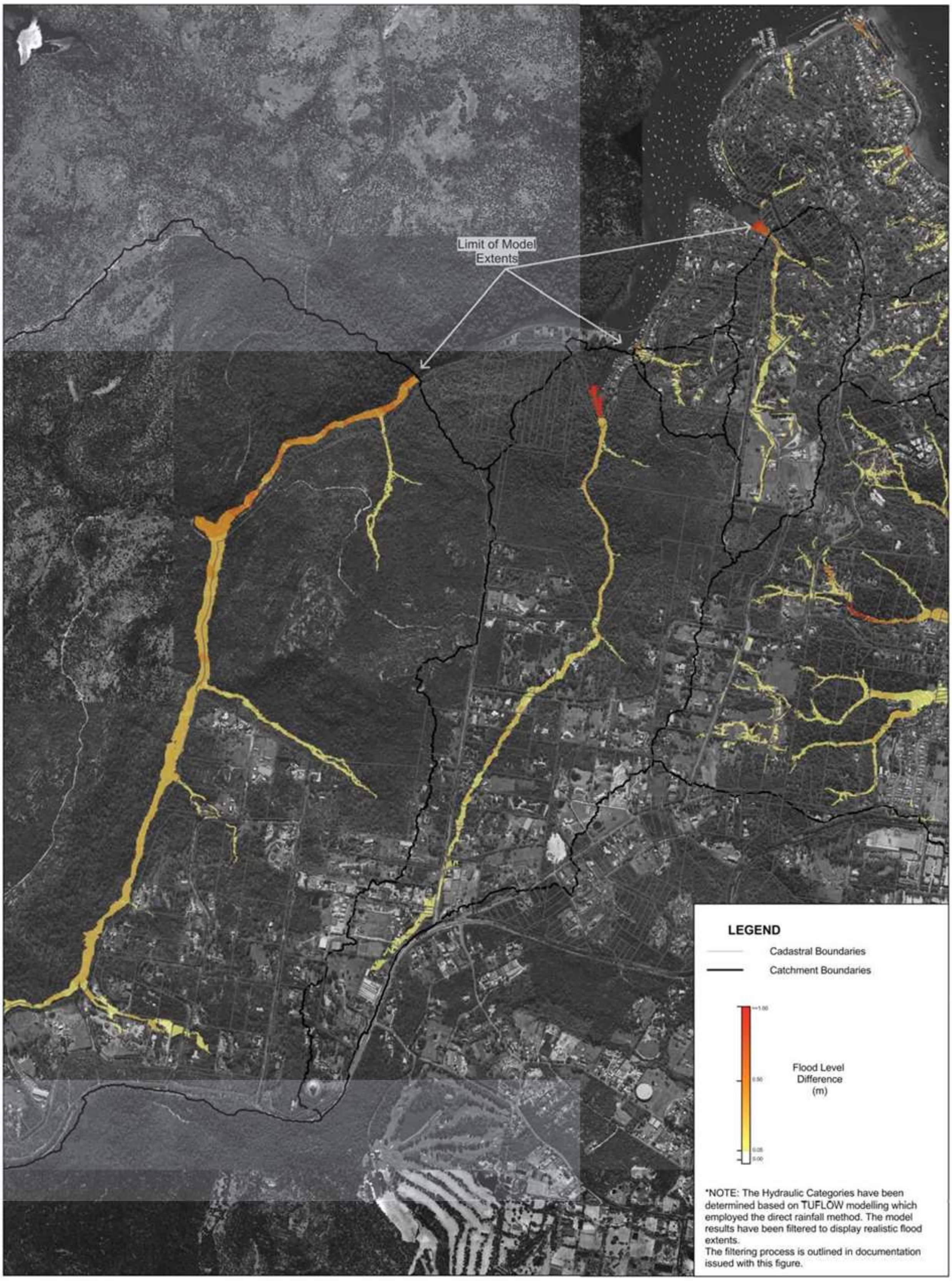
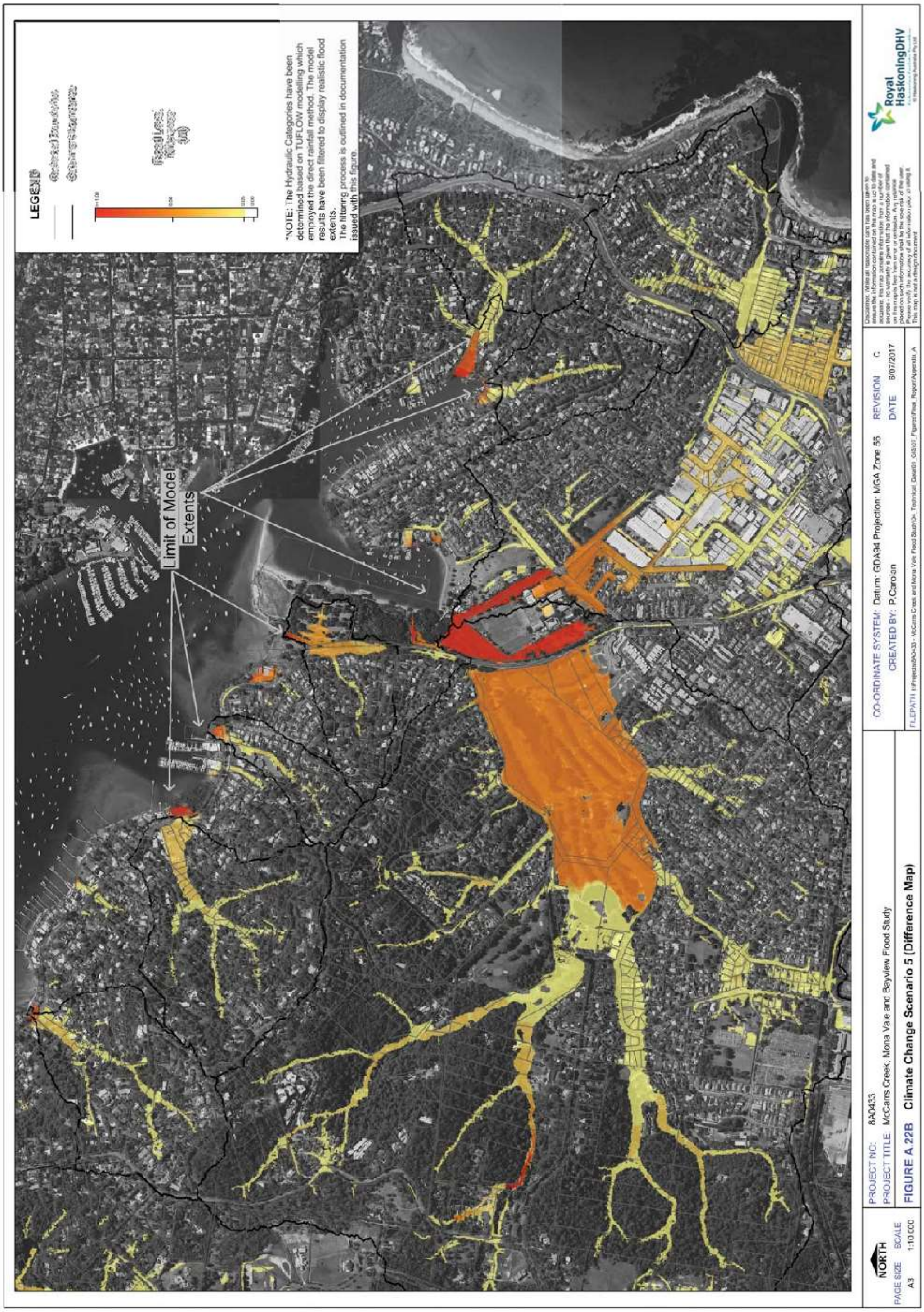
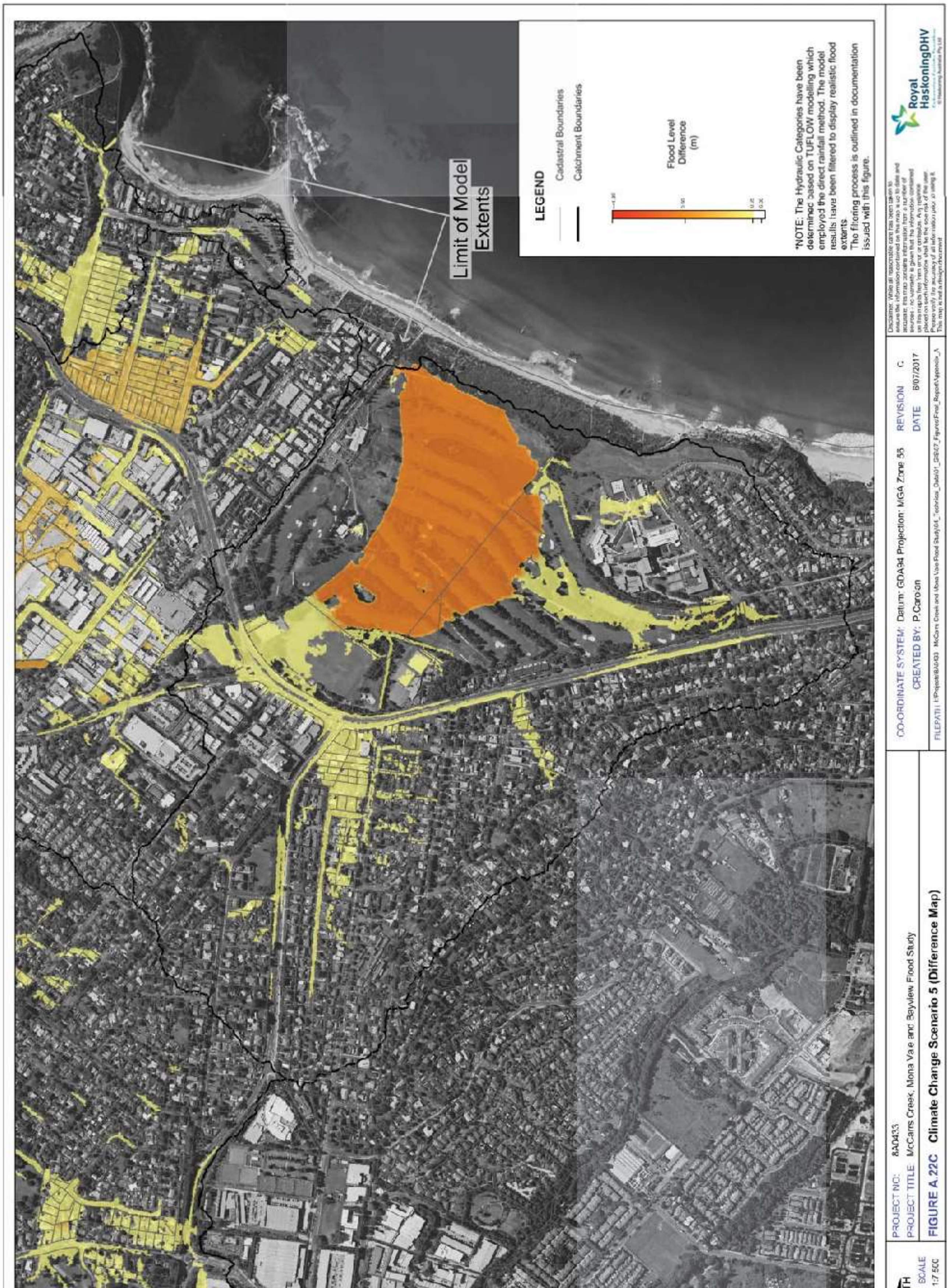
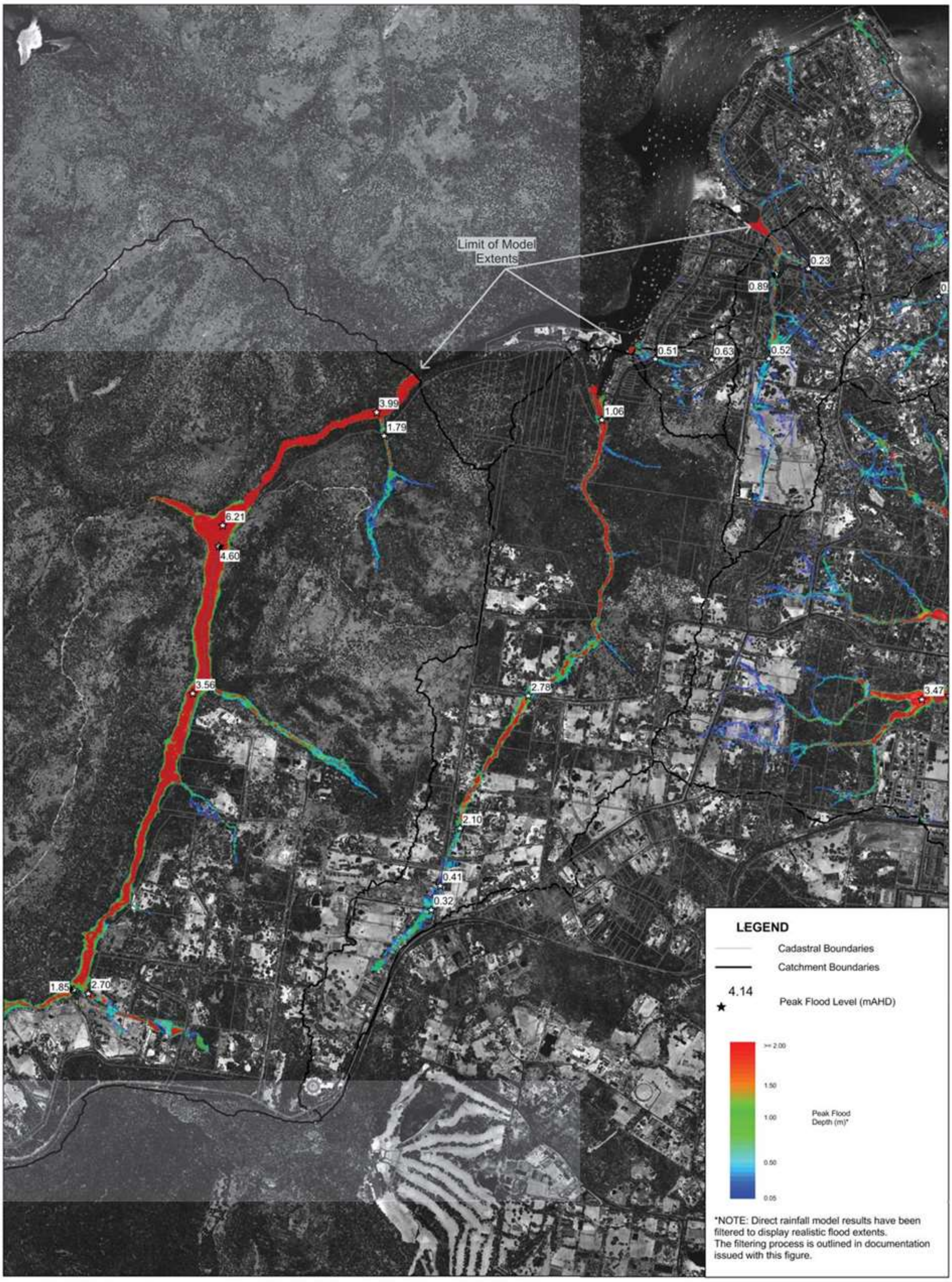


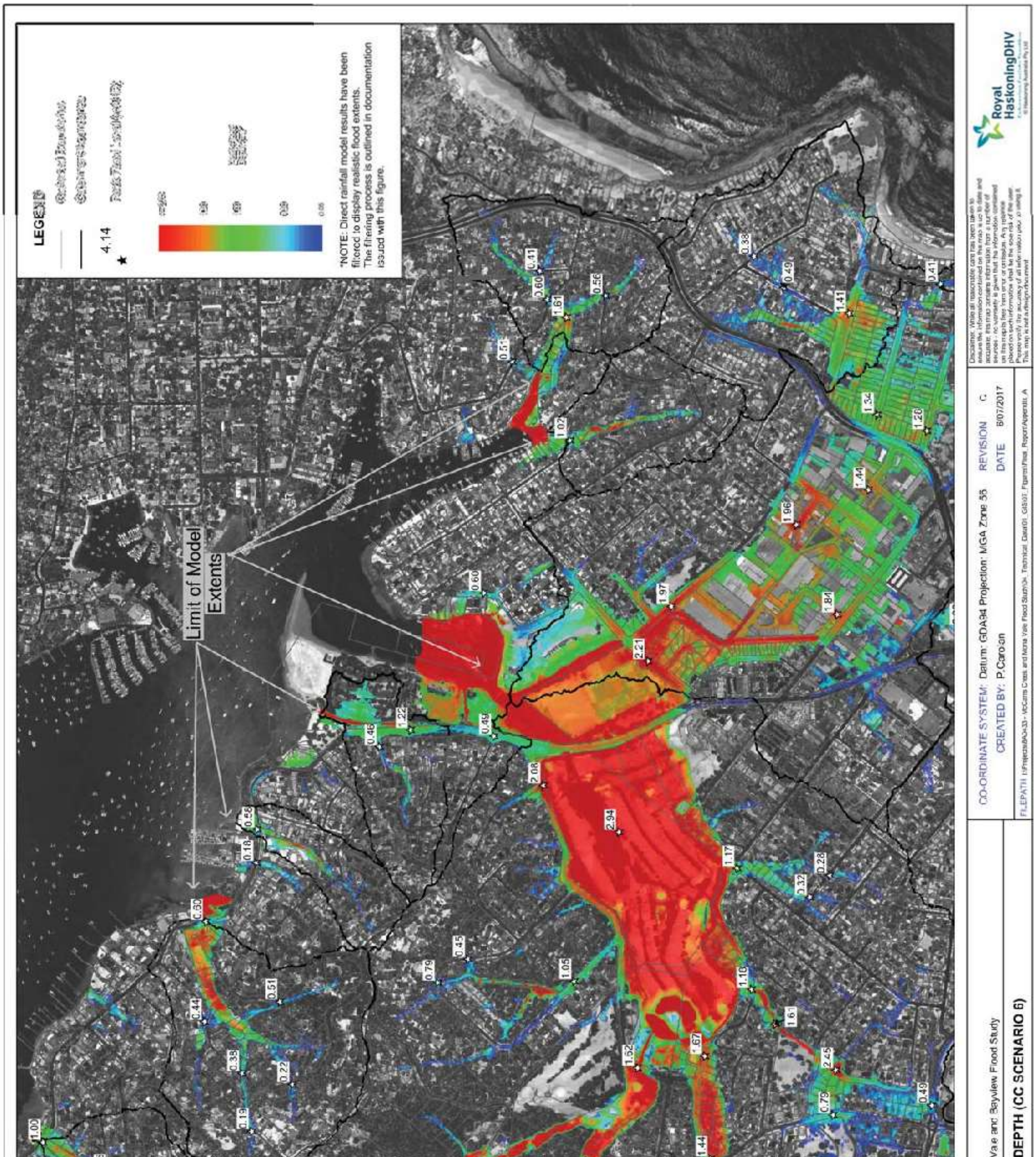
PROJECT NO: 8A0433 PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study	REVISION C DATE 6/07/2017 CREATED BY: P.Carolan	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document. Royal HaskoningDHV Enhancing Society Together
NORTH PAGE SIZE A3 SCALE 1:15,000	**FIGURE A.22A Climate Change Scenario 5 (Difference Map)** FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A	CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

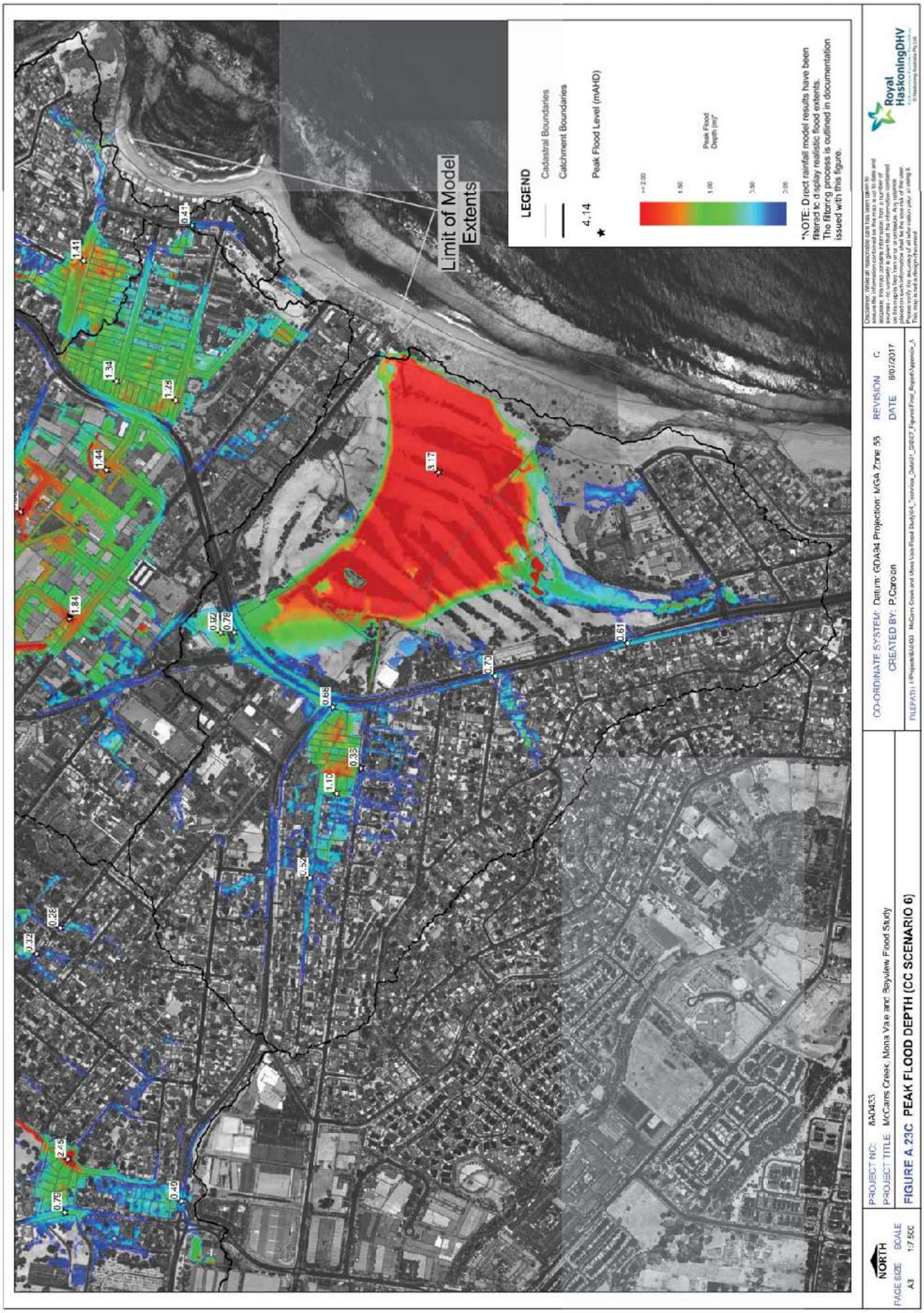

LEGEND
*NOTE: The Hydraulic Categories have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
NORTH
PAGE SIZE A3
SCALE 1:10 000
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.22B Climate Change Scenario 5 (Difference Map)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 8/07/2017
Royal HaskoningDHV

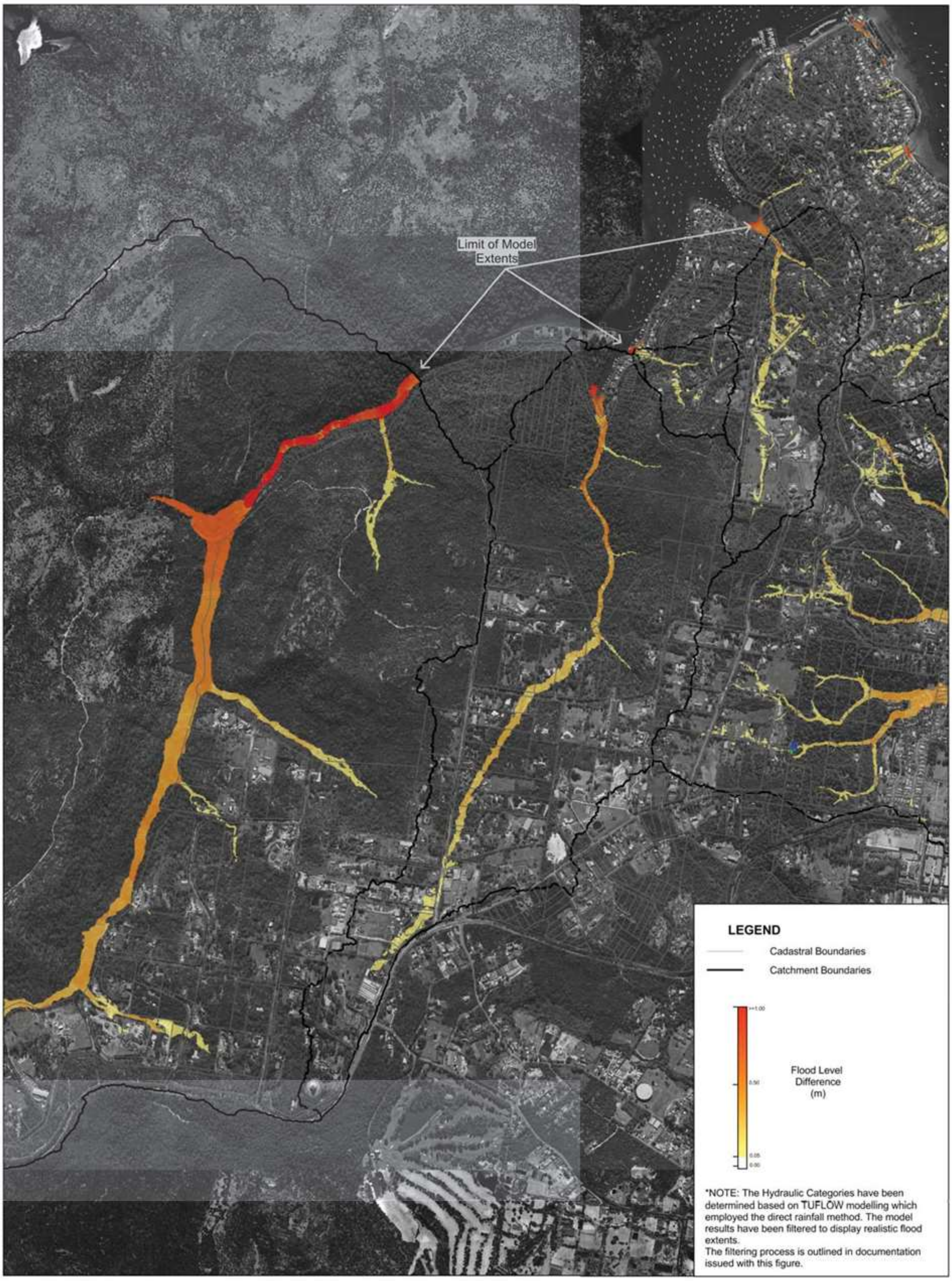

Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
Flood Level Difference (m)
*NOTE: The Hydraulic Categories have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
Royal HaskoningDHV
PAGE SIZE A3
SCALE 1:7,500
NORTH
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.22C Climate Change Scenario 5 (Difference Map)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 6/07/2017



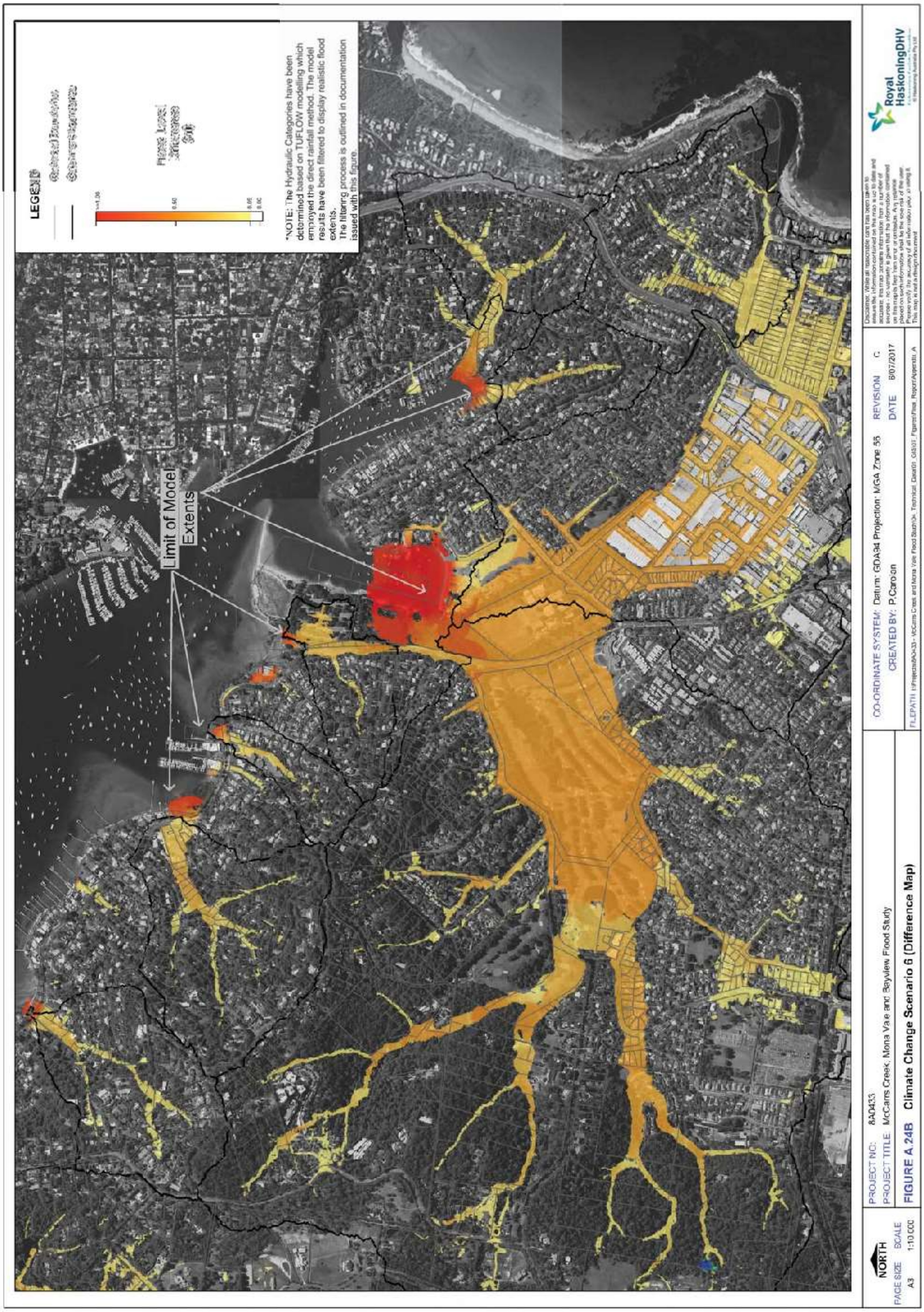
PROJECT NO: 8A0433		REVISION C DATE 6/07/2017	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document.
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study		CREATED BY: P.Carolan	Royal HaskoningDHV Enhancing Society Together
NORTH	FIGURE A.23A PEAK FLOOD DEPTH (CC SCENARIO 6)		
PAGE SIZE A3 SCALE 1:15,000	FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A		CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

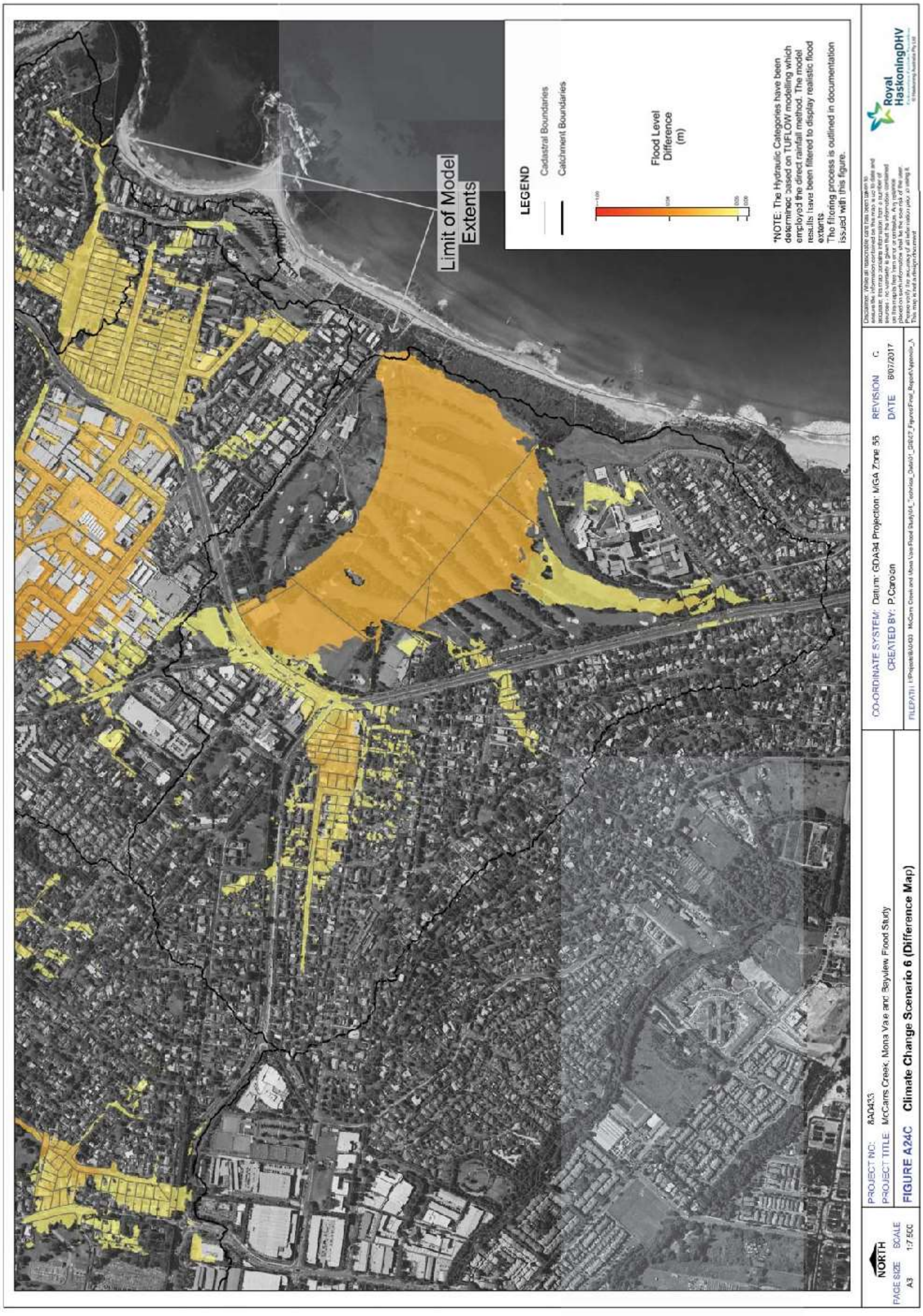

LEGEND
4.14
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.23B PEAK FLOOD DEPTH (CC SCENARIO 6)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Corcoran
REVISION C
DATE 6/07/2017
NORTH
PAGE SIZE A3
SCALE 1:10 000
Royal HaskoningDHV

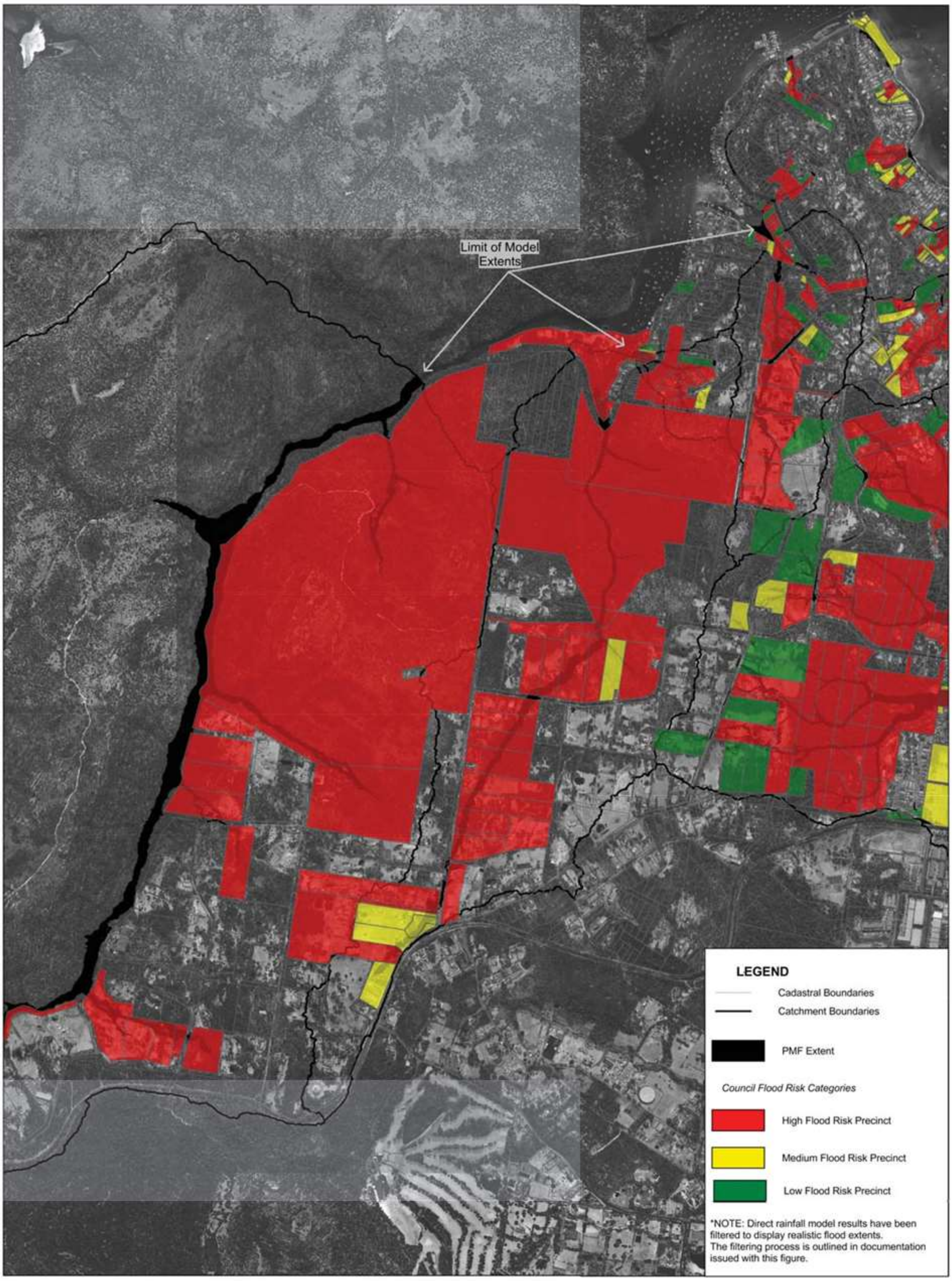

Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
4.14 Peak Flood Level (mAHD)
Peak Flood Depth (m)*
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
3.17
1.41
1.34
1.29
1.44
1.84
0.41
0.82
0.78
0.61
0.70
0.68
0.35
1.10
0.52
0.28
0.32
2.45
0.76
0.40
NORTH
PAGE SIZE A3
SCALE 1:7,500
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.23C PEAK FLOOD DEPTH (CC SCENARIO 6)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 8/07/2017
Royal HaskoningDHV



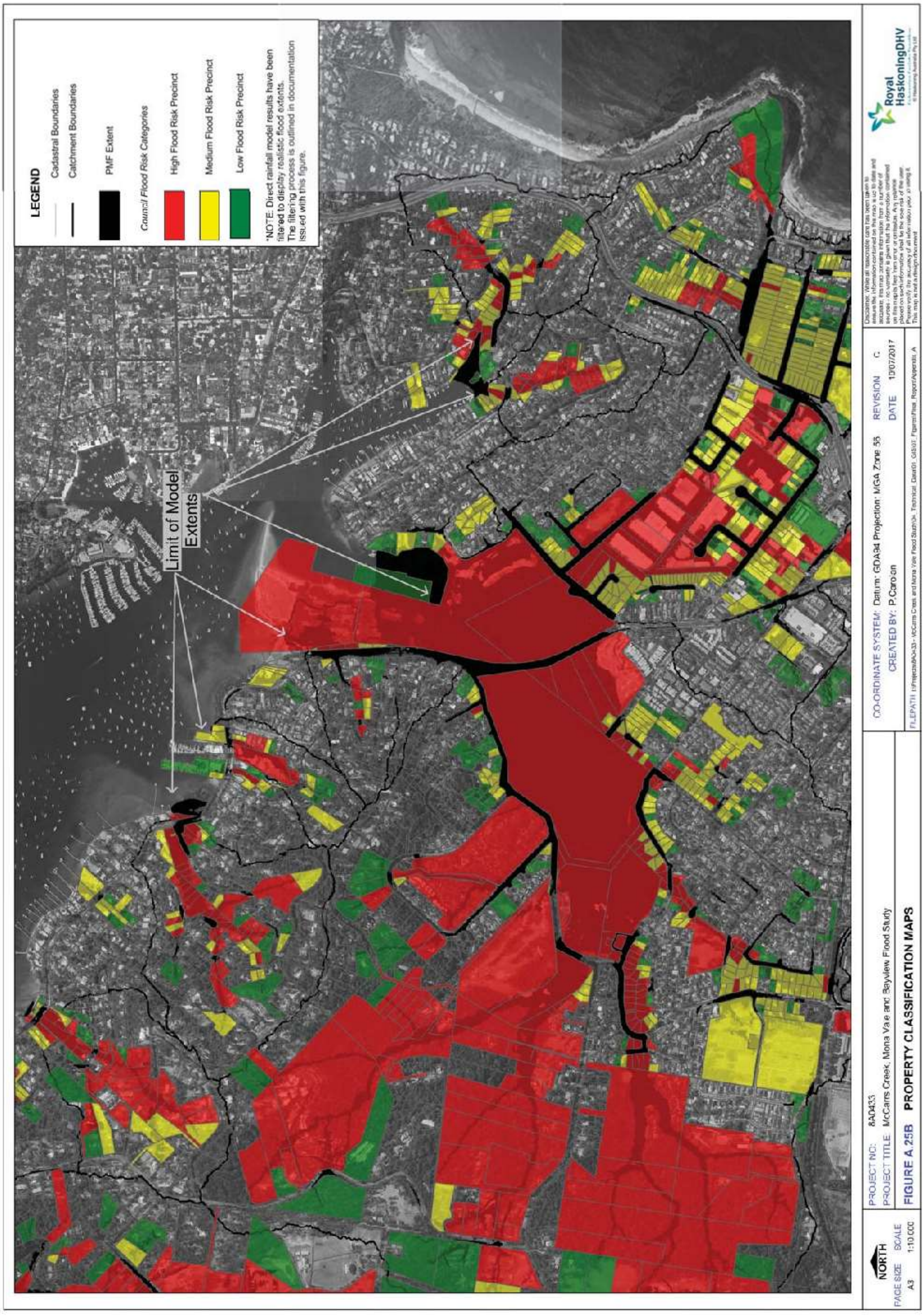
PROJECT NO: 8A0433 PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study	REVISION C DATE 6/07/2017 CREATED BY: P.Carolan	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document.
NORTH PAGE SIZE A3 SCALE 1:15,000	FIGURE A.24A Climate Change Scenario 6 (Difference Map) FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A	Royal HaskoningDHV Enhancing Society Together CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56

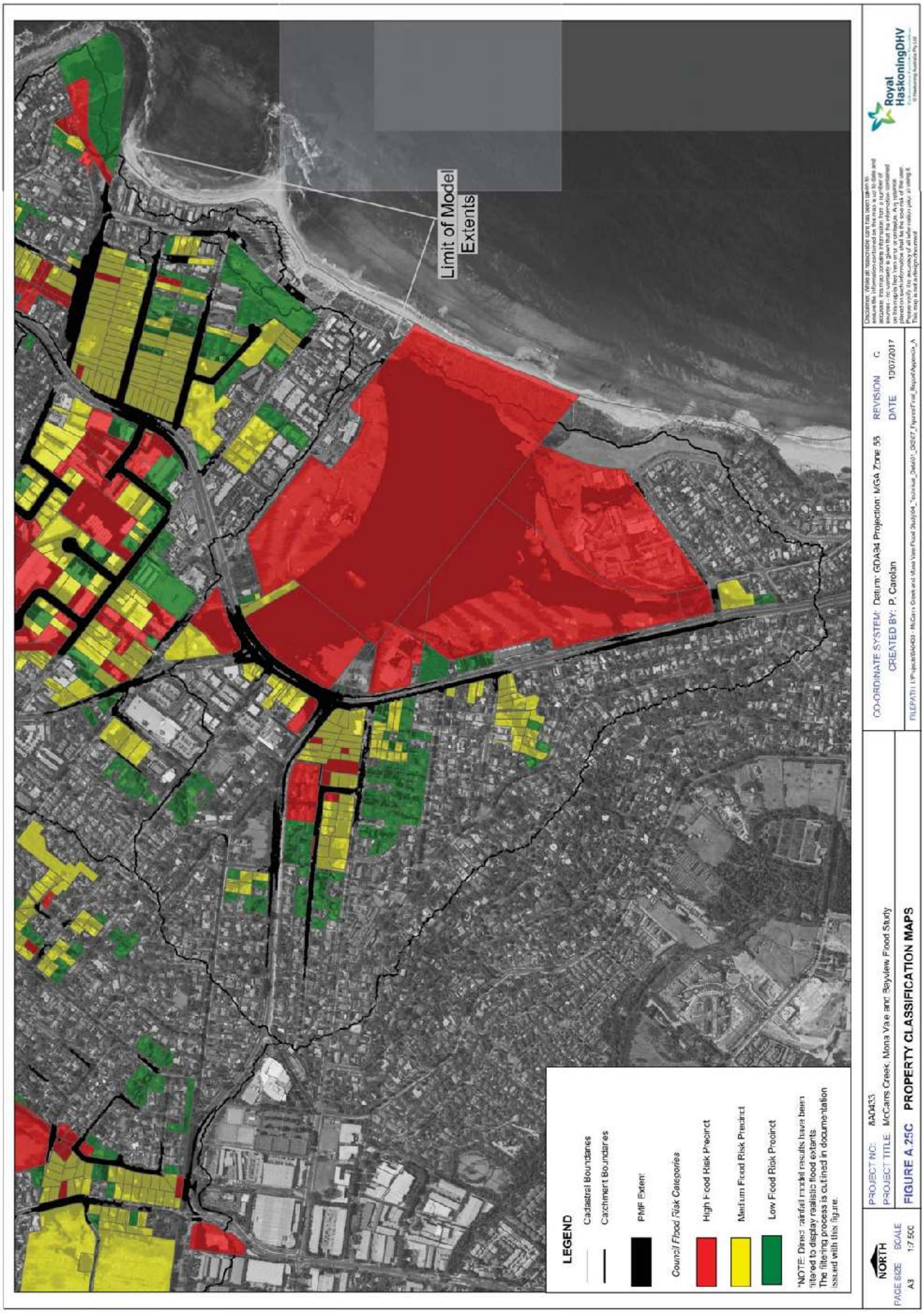

LEGEND
*NOTE: The Hydraulic Categories have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
NORTH
PAGE SIZE A3
SCALE 1:10 000
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.24B Climate Change Scenario 6 (Difference Map)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
REVISION C
Royal HaskoningDHV

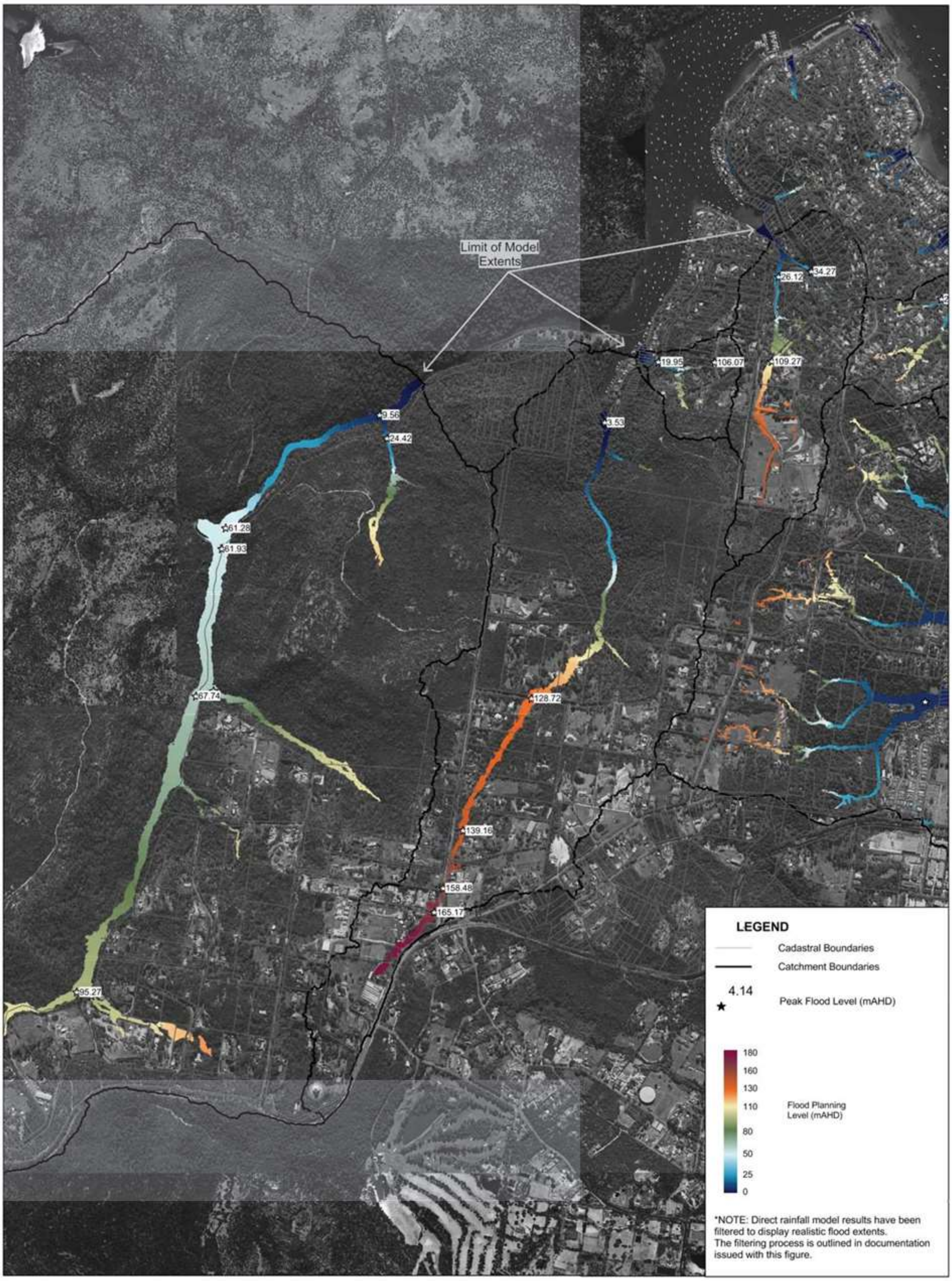

Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
Flood Level Difference (m)
*NOTE: The Hydraulic Categories have been determined based on TUFLOW modelling which employed the direct rainfall method. The model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
NORTH
PAGE SIZE A3
SCALE 1:7 500
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A24C Climate Change Scenario 6 (Difference Map)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Caroian
REVISION C
DATE 6/07/2017
Royal HaskoningDHV



PROJECT NO: 8A0433 PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study	REVISION C DATE 10/07/2017 CREATED BY: P.Carolan	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document. Royal HaskoningDHV Enhancing Society Together
NORTH PAGE SIZE A3 SCALE 1:15,000	FIGURE A.25A PROPERTY CLASSIFICATION MAPS	
FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A		CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56


LEGEND
Cadastral Boundaries
Catchment Boundaries
PMF Extent
Council Flood Risk Categories
High Flood Risk Precinct
Medium Flood Risk Precinct
Low Flood Risk Precinct
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
NORTH
PAGE SIZE A3
SCALE 1:10 000
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.25B PROPERTY CLASSIFICATION MAPS
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Caroan
REVISION C
DATE 10/07/2017
Royal HaskoningDHV


Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
PMF Extent
Council Flood Risk Categories
High Flood Risk Precinct
Medium Flood Risk Precinct
Low Flood Risk Precinct
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
NORTH
PAGE SIZE A3
SCALE 1:7,500
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.25C PROPERTY CLASSIFICATION MAPS
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P. Carolan
REVISION C
DATE 10/07/2017
Royal HaskoningDHV



PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study

REVISION C DATE 27/07/16
CREATED BY: P.Carolan

NORTH
PAGE SIZE A3 SCALE 1:15,000

FIGURE A.26A FLOOD PLANNING AREAS

FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document.

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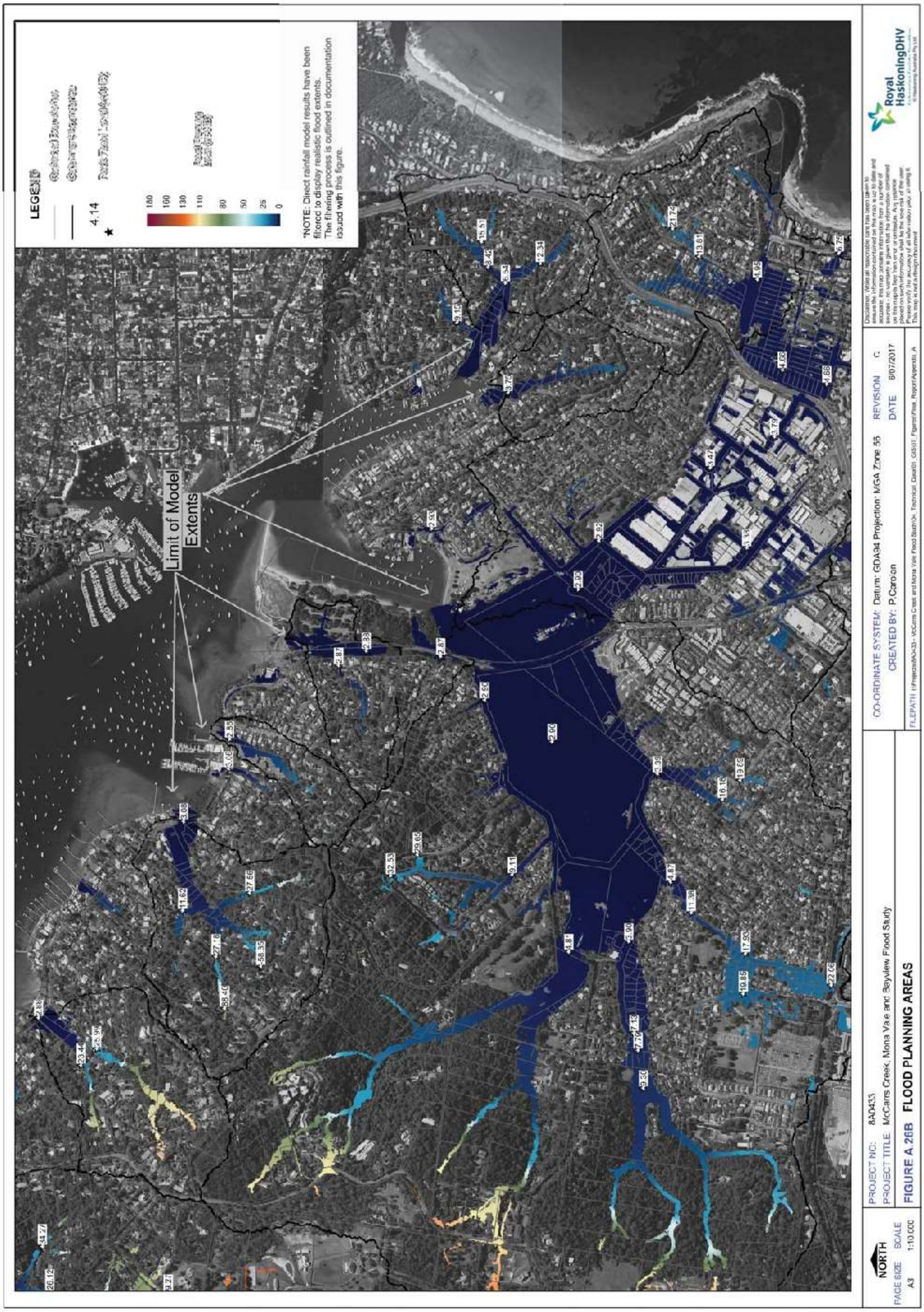
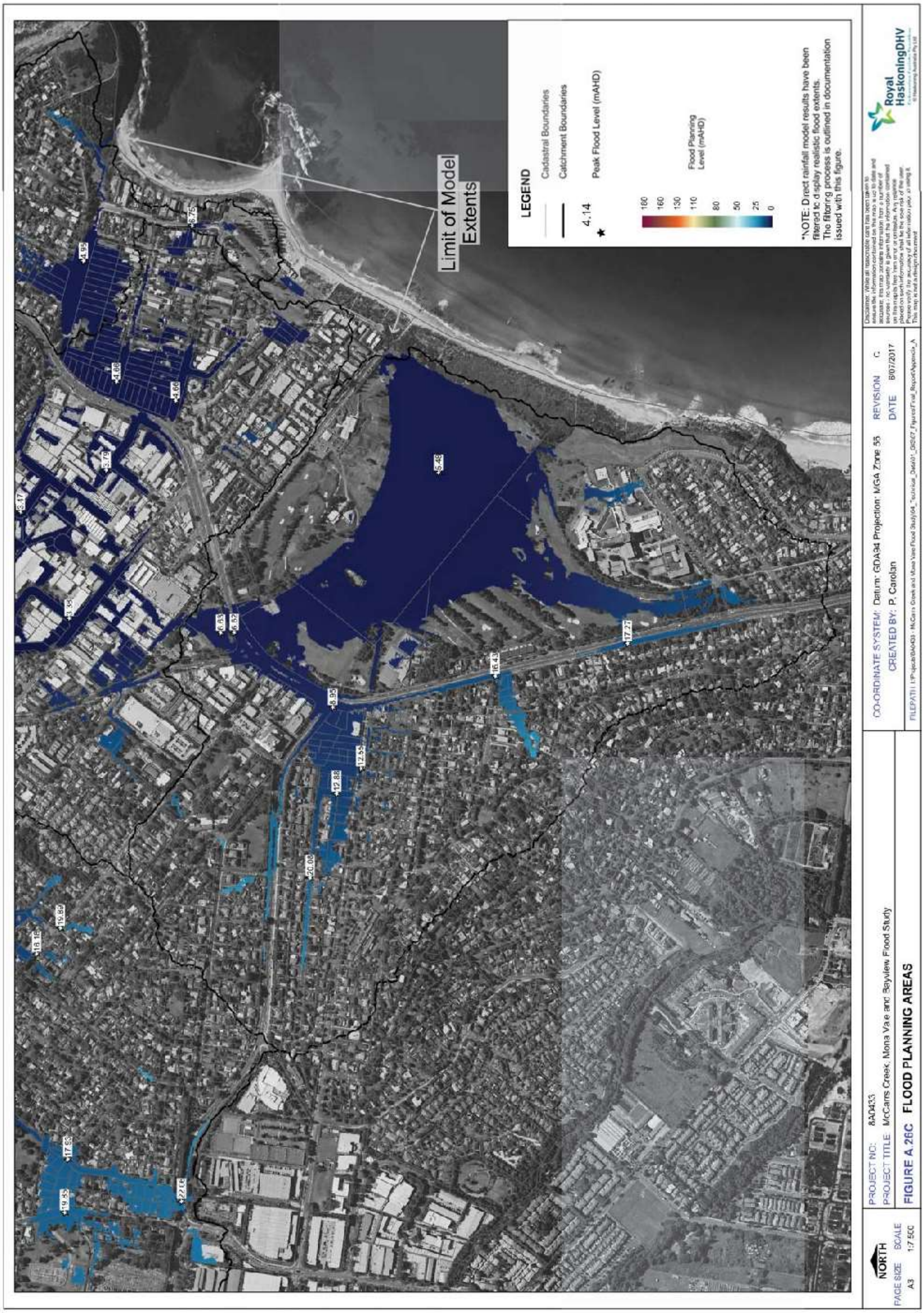
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56


LEGEND
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Limit of Model Extents
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.26B FLOOD PLANNING AREAS
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P.Carolan
REVISION C
DATE 8/07/2017
NORTH
PAGE SIZE A3
SCALE 1:10 000
Royal HaskoningDHV


Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
Peak Flood Level (mAHD)
Flood Planning Level (mAHD)
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with this figure.
Royal HaskoningDHV
PROJECT NO: 8A0433
PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.26C FLOOD PLANNING AREAS
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P. Carolan
REVISION C
DATE 6/07/2017
NORTH
PAGE SIZE A3
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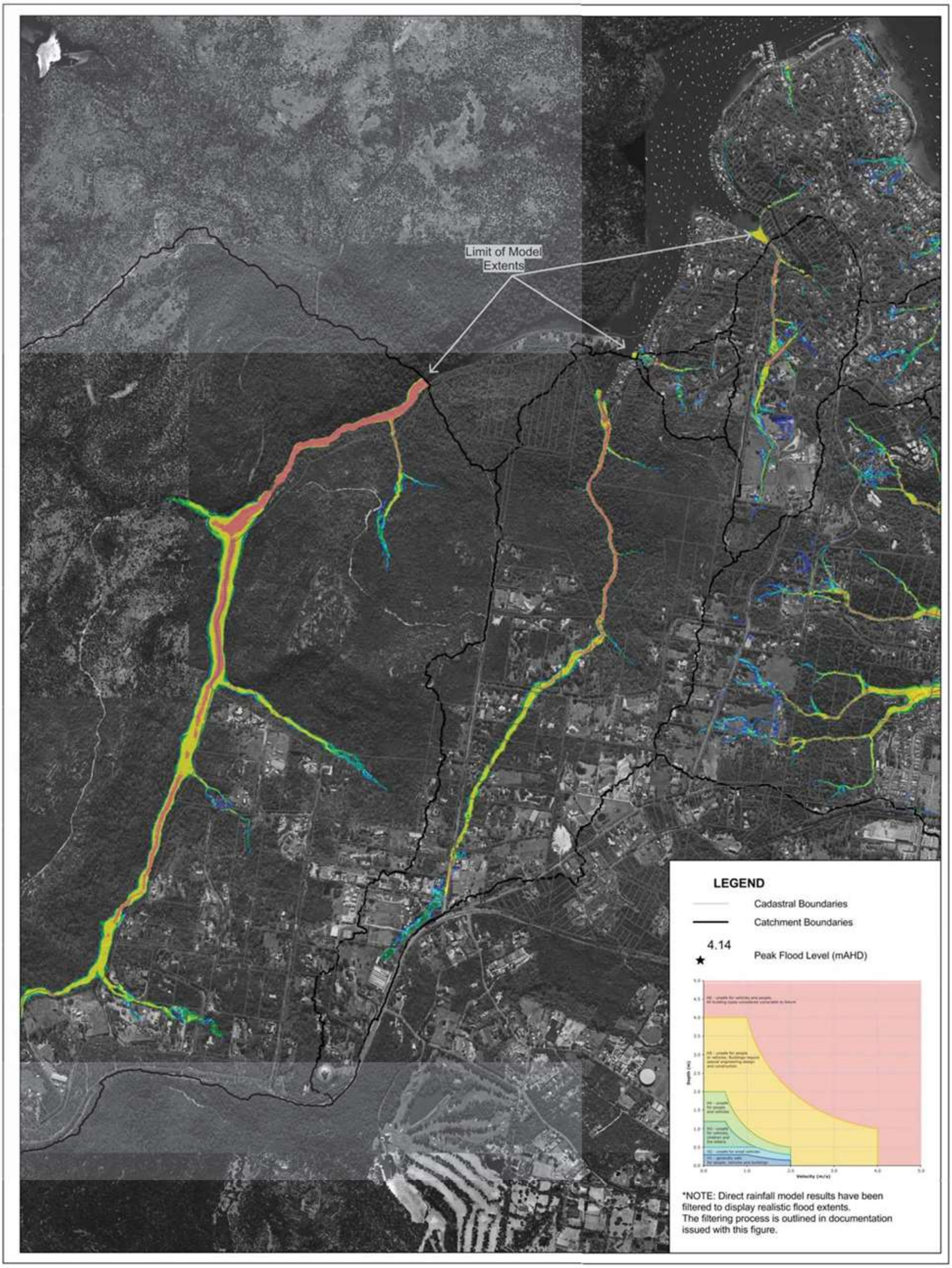
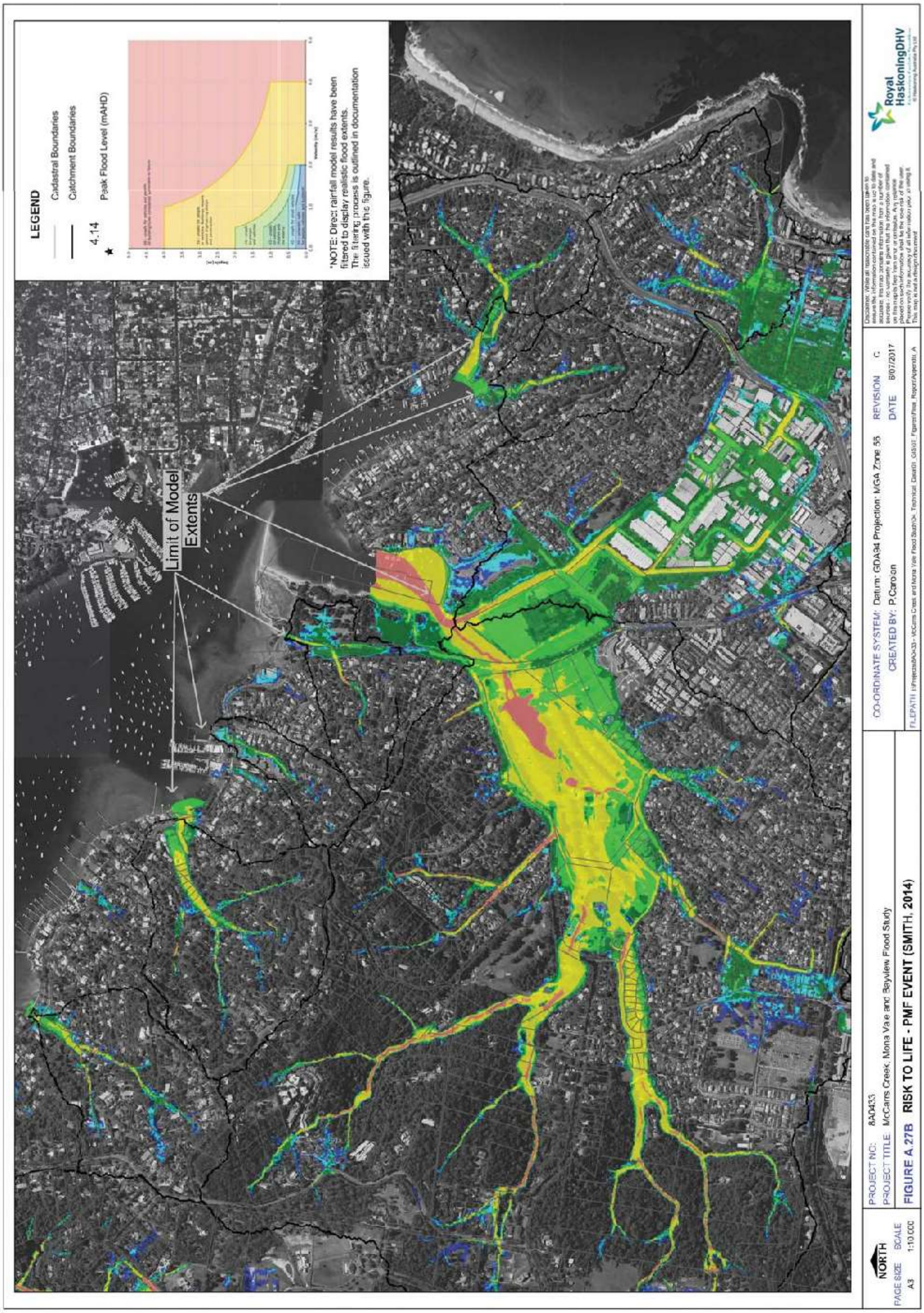
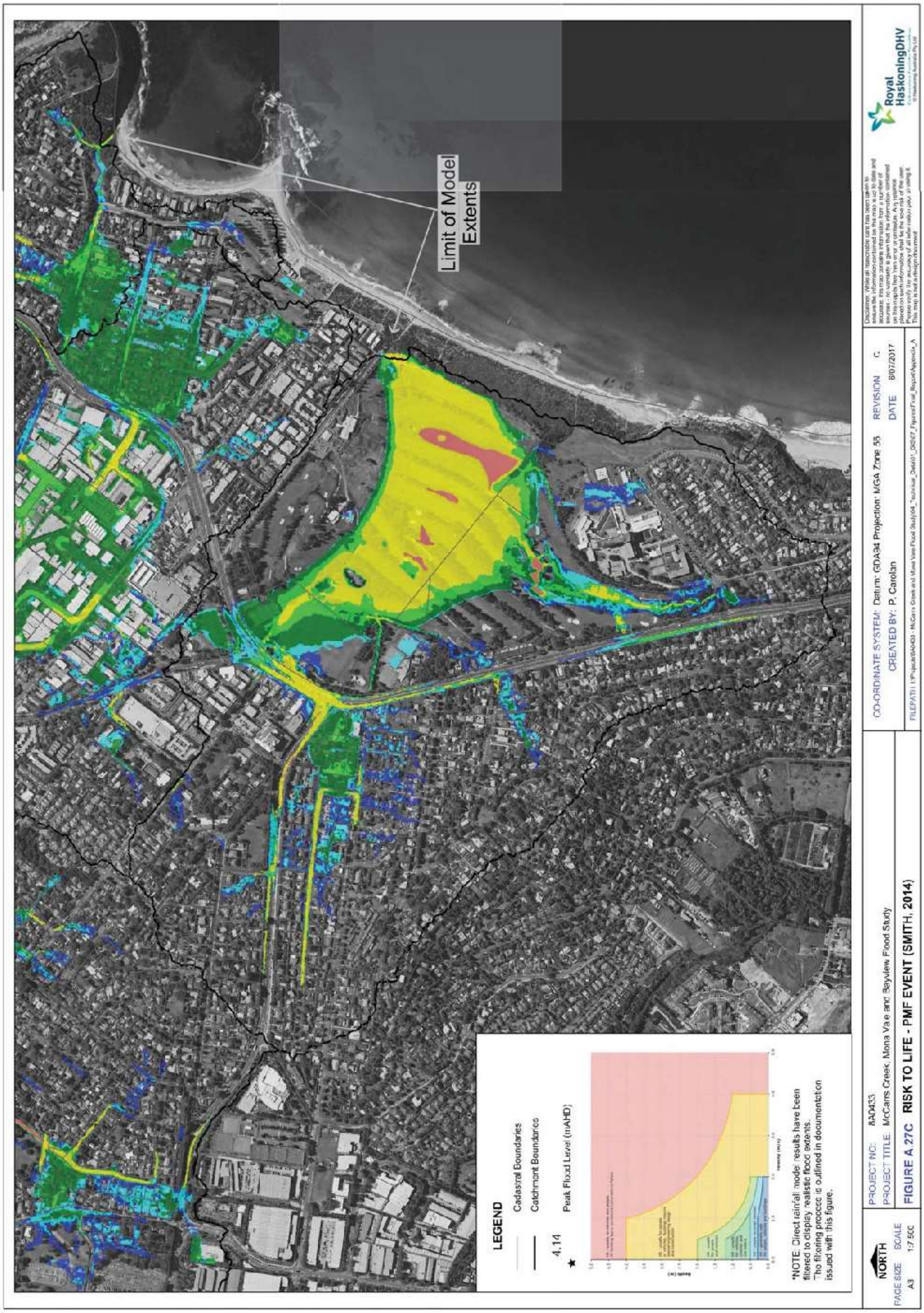


PROJECT NO: 8A0433 PROJECT TITLE: McCarrs Creek, Mona Vale and Bayview Flood Study		REVISION C DATE 8/08/16 CREATED BY: P.Carolan	Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, this map contains information from a number of sources - no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be the sole risk of the user. Please verify the accuracy of all information prior to using it. This map is not a design document.
NORTH PAGE SIZE A3 SCALE 1:15,000	FIGURE A.27A RISK TO LIFE - PMF EVENT (SMITH, 2014) FILEPATH I:\Projects\8A0433 - McCarrs Creek and Mona Vale Flood Study\04_Technical_Data\01_GIS\07_Figures\Final_Report\Appendix_A		Royal HaskoningDHV Enhancing Society Together CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56


LEGEND
Cadastral Boundaries
Catchment Boundaries
4.14
Peak Flood Level (mAHD)
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents. The filtering process is outlined in documentation issued with the figure.
Limit of Model Extents
NORTH
PAGE SIZE A3
SCALE 1:10 000
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.27B RISK TO LIFE - PMF EVENT (SMITH, 2014)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
REVISION C
Royal HaskoningDHV


Limit of Model Extents
LEGEND
Cadastral Boundaries
Catchment Boundaries
4.14 Peak Flood Level (mAHD)
*NOTE: Direct rainfall model results have been filtered to display realistic flood extents.
The filtering process is outlined in documentation issued with this figure.
NORTH
PAGE SIZE A3
SCALE 1:7 500
PROJECT NO: 8A0433
PROJECT TITLE McCarrs Creek, Mona Vale and Bayview Flood Study
FIGURE A.27C RISK TO LIFE - PMF EVENT (SMITH, 2014)
CO-ORDINATE SYSTEM: Datum: GDA94 Projection: MGA Zone 56
CREATED BY: P. Carolan
REVISION C
DATE 6/07/2017

September 2014

ADDRESS
ADDRESS
ADDRESS

Dear Sir/Madam

Re: MCCARRS CREEK, MONA VALE AND BAYVIEW FLOOD STUDY

Pittwater Council is undertaking a detailed flood study of the McCarrs Creek, Mona Vale & Bayview catchments to help identify flooding problem areas. With financial assistance from the NSW Government, Council has engaged consultants Royal HaskoningDHV to undertake the McCarrs Creek, Mona Vale & Bayview Flood Study.

The study will establish the basis for subsequent floodplain management activities to improve flood planning. These activities include setting design flood levels for development controls and managing potential climate change impacts.

We are seeking the community's help by collecting information, and photos on any flooding or drainage problems that you may have experienced in the past. Please take a minute or two to complete the community questionnaire/survey and provide responses wherever you can. Visit www.pittwater.nsw.gov.au/flooding for the online survey, or if you would like a paper copy posted to you please contact Council on 9970 1111. All information provided is confidential and used only for the purpose of the study.

We are also seeking community representatives to be part of a McCarrs Creek, Mona Vale and Bayview flood working group. The working group will act as a forum for the discussion of technical, social, economic and environmental issues in an advisory role to Council. The group is anticipated to meet at least four times between November 2014 and November 2015.

Your help is most appreciated. For further enquiries please contact Council at floodplain@pittwater.nsw.gov.au or phone 02 9970 1111.

Yours sincerely

Dr Melanie Schwecke
A/Principal Officer, Floodplain Management

McCarrs Creek, Mona Vale and Bayview Flood Study Review
– Community Questionnaire / Survey

Your views and experience are important to the flood study.

Pittwater Council is undertaking a detailed flood study of the McCarrs Creek, Mona Vale & Bayview catchments 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 complete the community questionnaire/survey and provide responses wherever you can. If you would like a paper copy posted to you please contact Council on 9970 1303.

All information provided is confidential and used only for the purpose of the study.

Name (optional)

Contact Details (phone / email) (optional)

What is your property address?

Is this property?

a) **A residential House**
b) **A residential Unit or apartment**
c) **A business premises**
d) **other**

How many storeys/floors does you property have?

How long have you lived at / owned this property?

Have you ever experienced flooding at this property? (YES / NO / Not Sure)

If YES

What date(s) did the flooding occur (1998, 1986?)

What parts of your home / property were inundated? (Inside the house? garage? garden / yard)

Do you know how deep the flooding was? If YES, could you provide the estimated depth in cm.

For how long were the flood waters on / in your property?

Was the flood water flowing through your property or ponding? If flowing please give any details you can about the velocity (how fast the water was flowing) and direction of flow?

Do you know what the source of the flooding was? (a creek? overland flow? tidal inundation?)

What do you think caused the flooding?

Do you have any flood water level marks (levels showing how high the flood water got in your property) at (or near) your property? (YES/NO/Not Sure). If yes where?

Do you have any photos, video's, newspaper articles or sketched maps showing the flooding?

If so could you send them to Council via email - floodplain@pittwater.nsw.gov.au, or contact Council staff on 9970 111 to arrange a time to meet at Mona Vale customer service for staff to copy the photos/videos

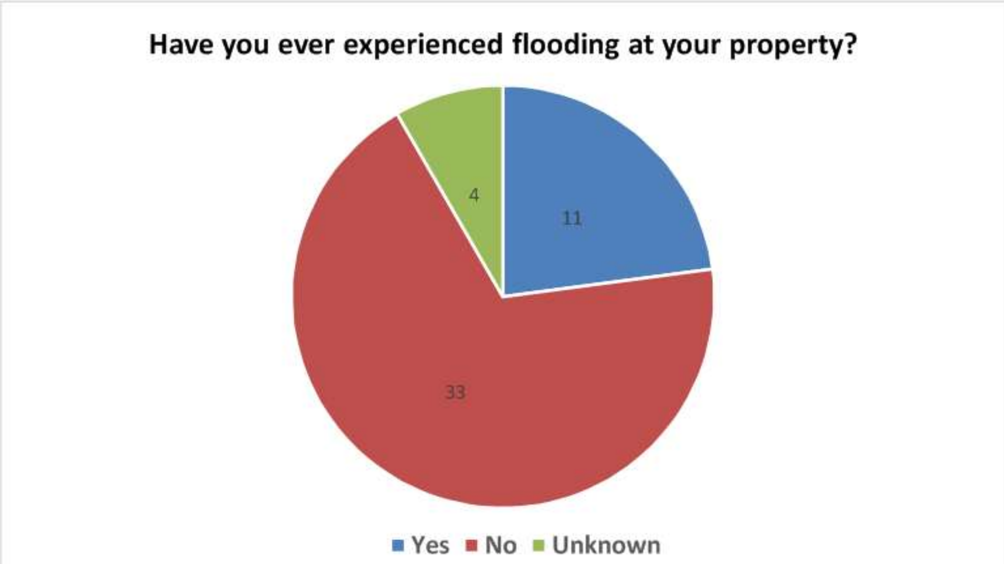
Can you estimate the level of you properties ground floor level above the natural ground level (cm)

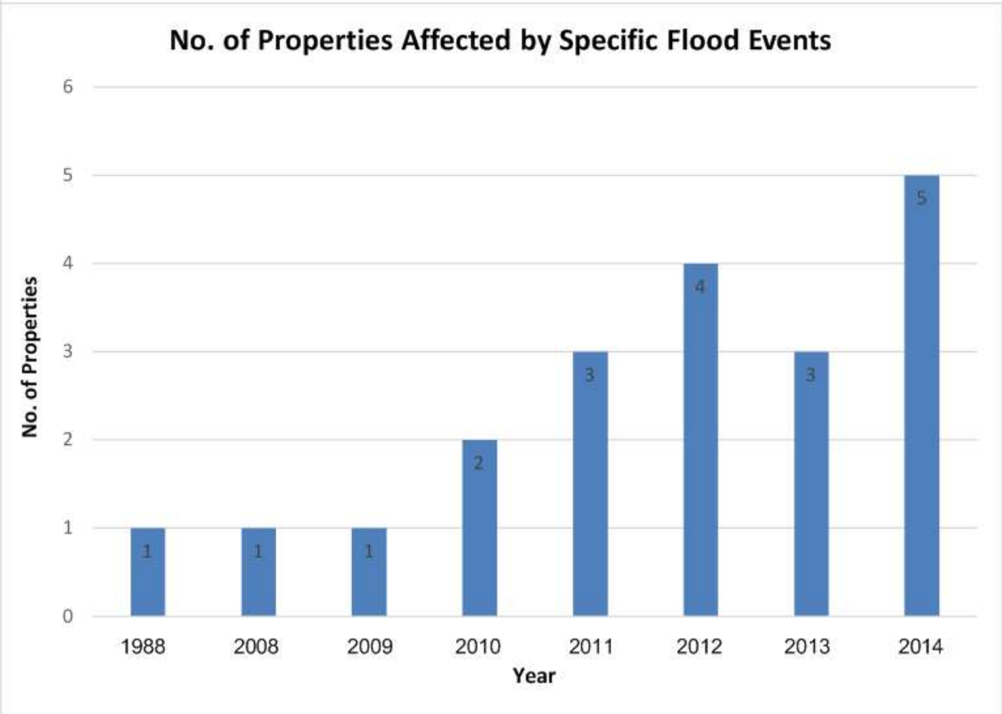
Please provide any other information related to flooding at (or near) your property

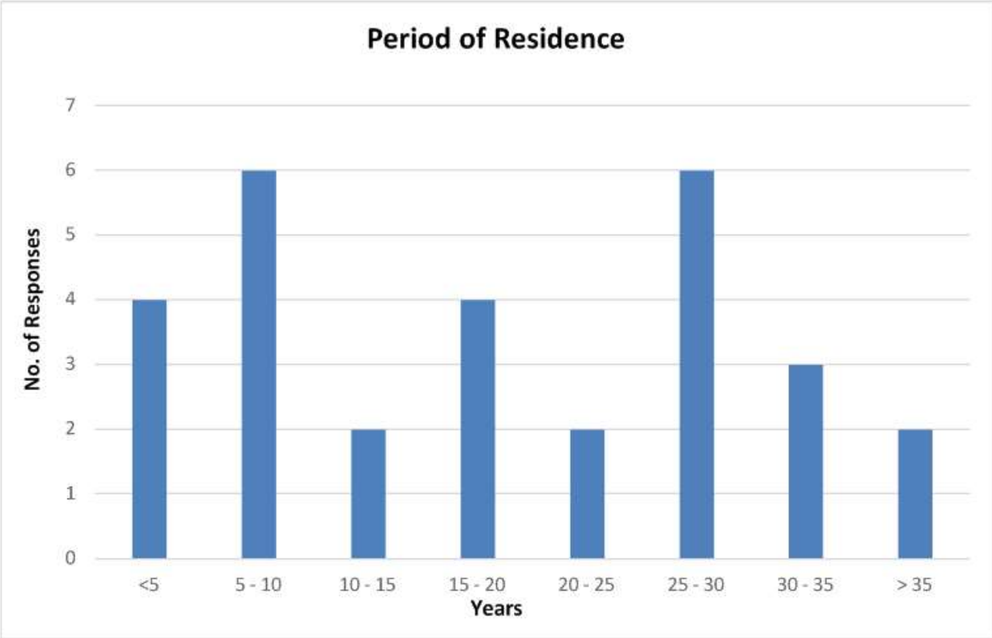
Thank you for your assistance in completing the community questionnaire/survey. If you have any further questions regarding the flood study please contact council on 9970 1111 or floodplain@pittwater.nsw.gov.au

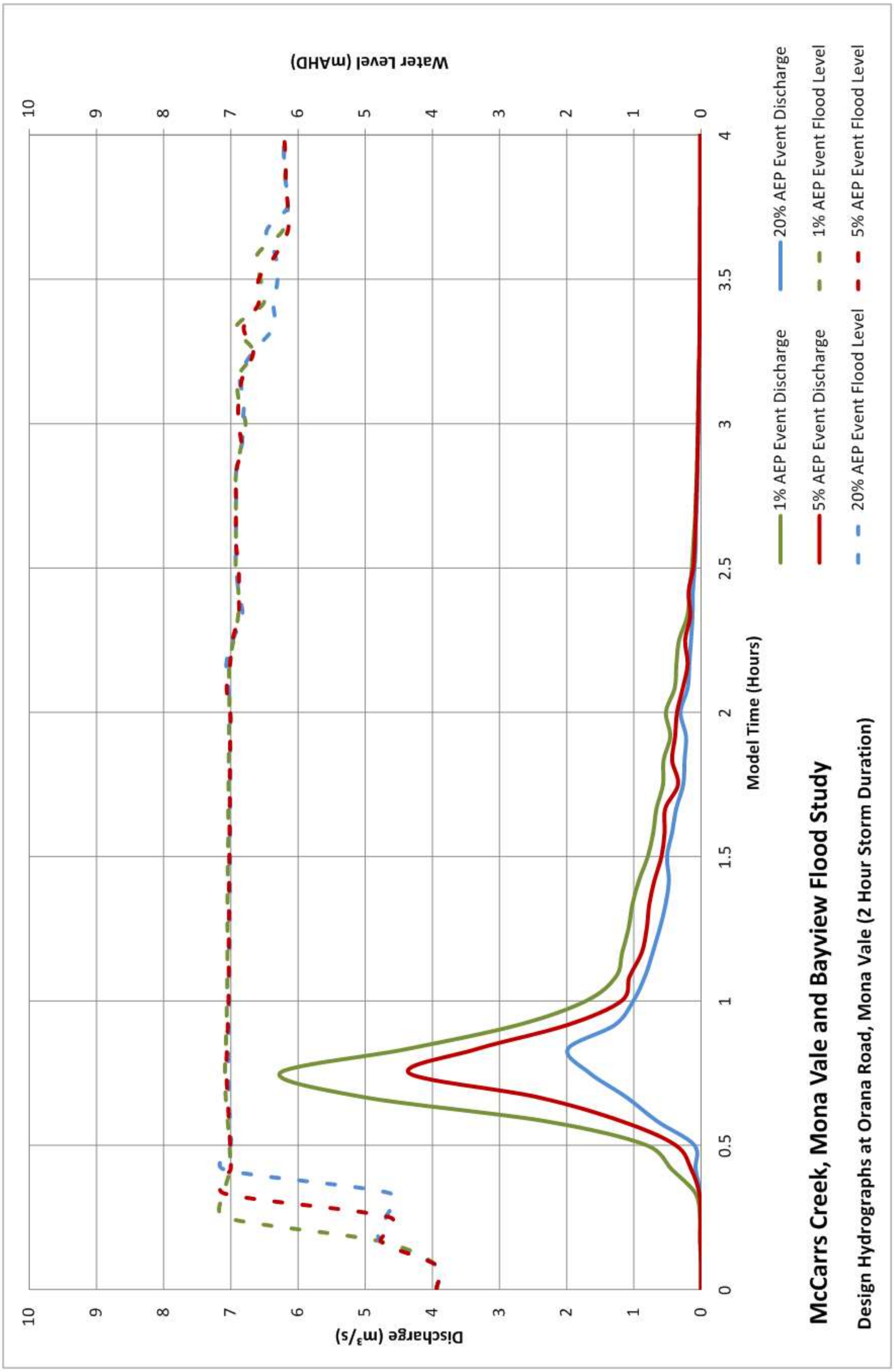
Royal HaskoningDHV
Enhancing Society Together

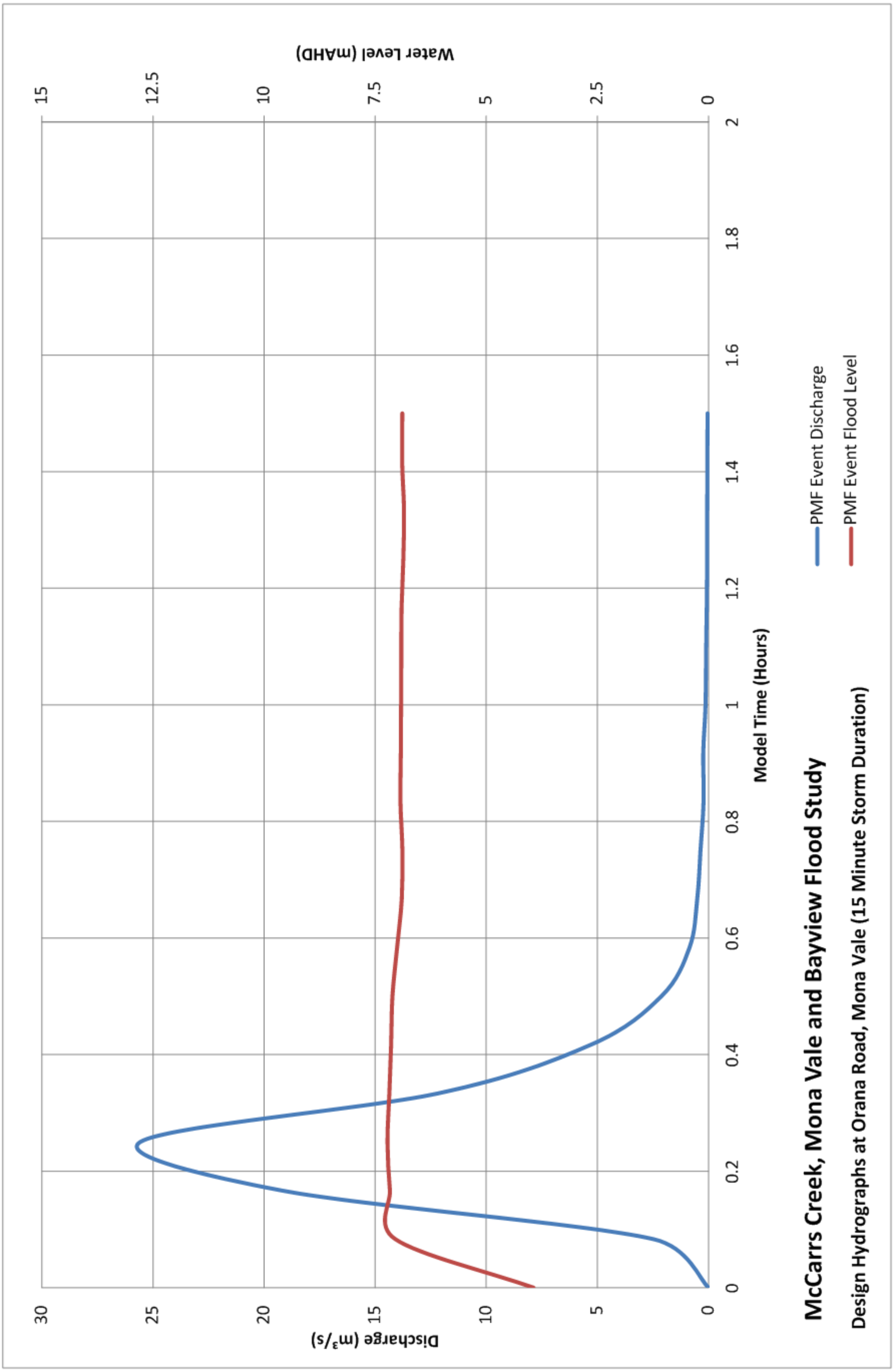
HASKONING AUSTRALIA PTY LIMITED
RIVERS, DELTAS & COASTS

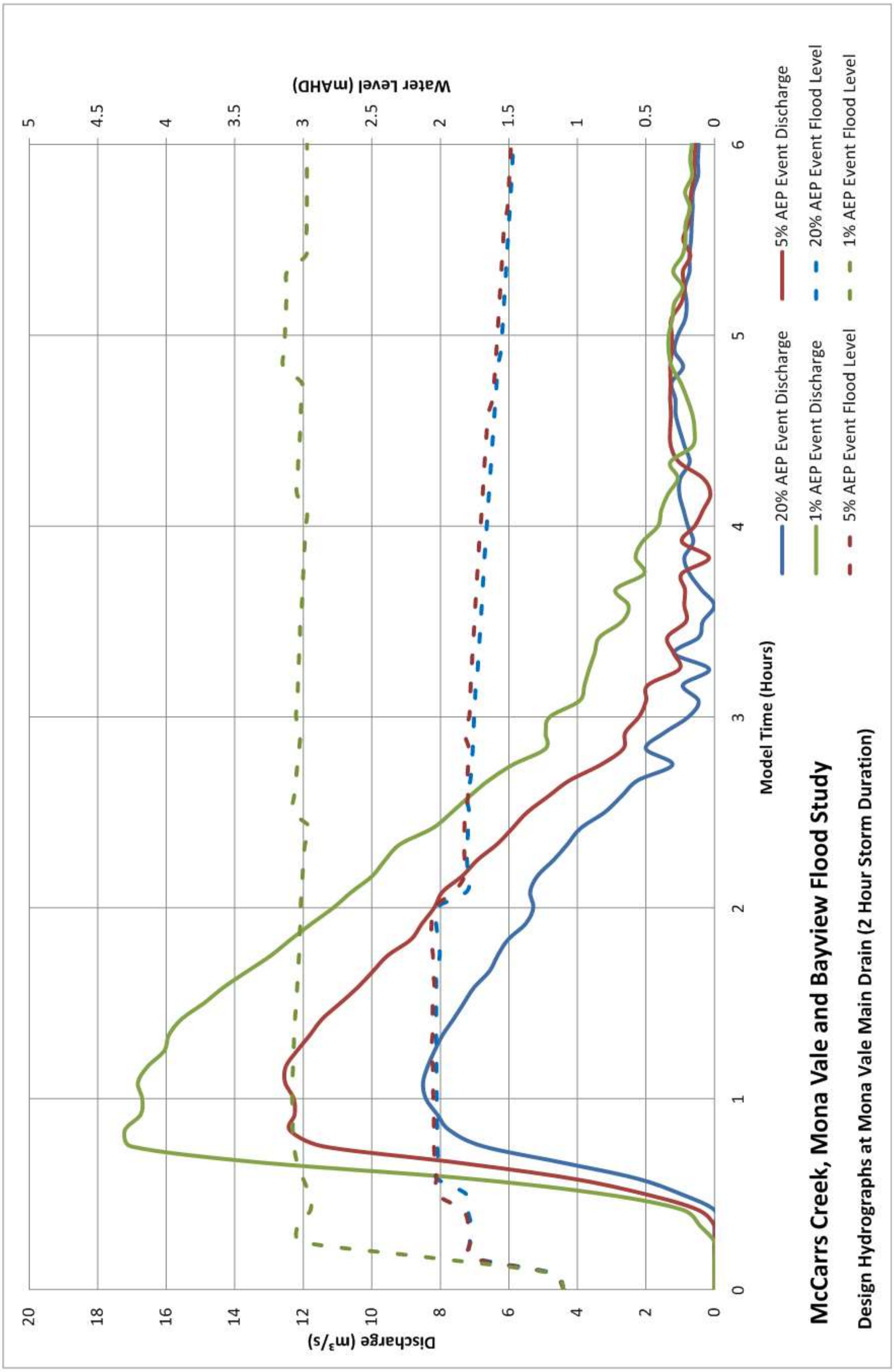





Period of Residence
No. of Responses
0
1
2
3
4
5
6
7
<5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
> 35
Years


McCarrs Creek, Mona Vale and Bayview Flood Study
Design Hydrographs at Orana Road, Mona Vale (2 Hour Storm Duration)
Discharge (m³/s)
Water Level (mAHD)
Model Time (Hours)
0
0.5
1
1.5
2
2.5
3
3.5
4
1% AEP Event Discharge
5% AEP Event Discharge
20% AEP Event Discharge
1% AEP Event Flood Level
5% AEP Event Flood Level
20% AEP Event Flood Level


McCarrs Creek, Mona Vale and Bayview Flood Study
Design Hydrographs at Orana Road, Mona Vale (15 Minute Storm Duration)
Discharge (m^3/s)
Water Level (mAHD)
Model Time (Hours)
0
5
10
15
20
25
30
2.5
7.5
12.5
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
PMF Event Discharge
PMF Event Flood Level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Model Time (Hours)
Discharge (m³/s)
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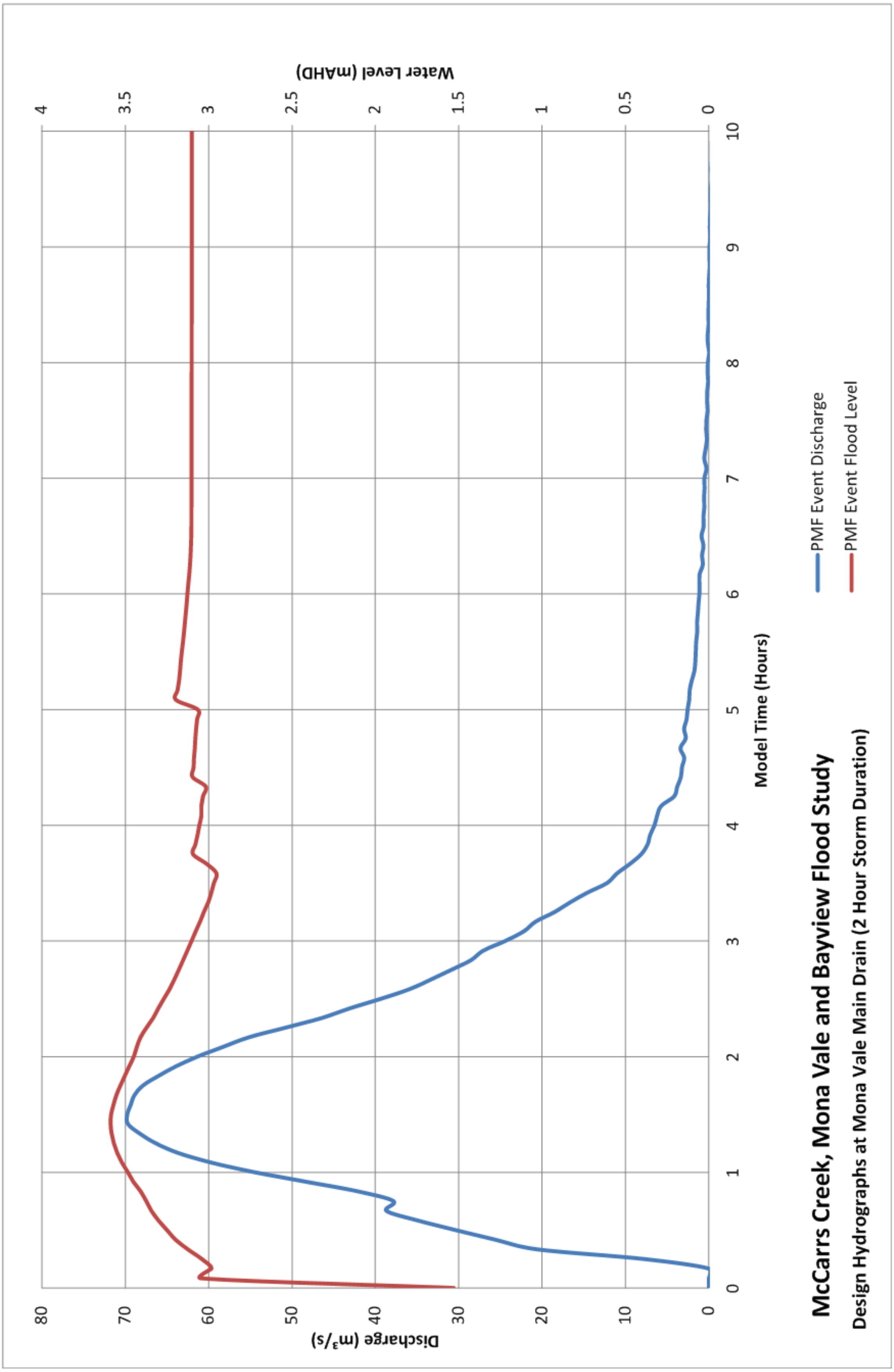
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Water Level (mAHD)
Model Time (Hours)
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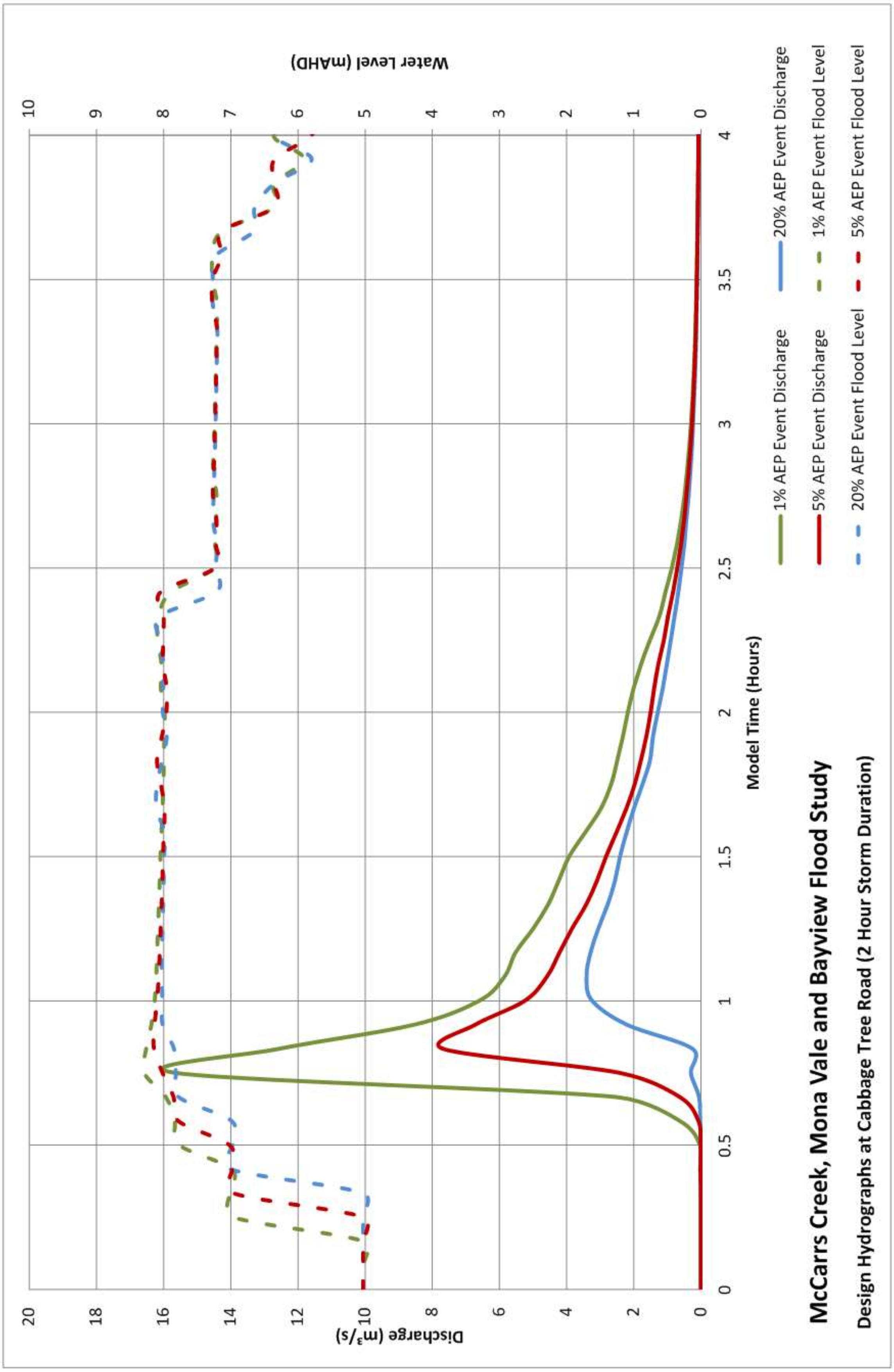
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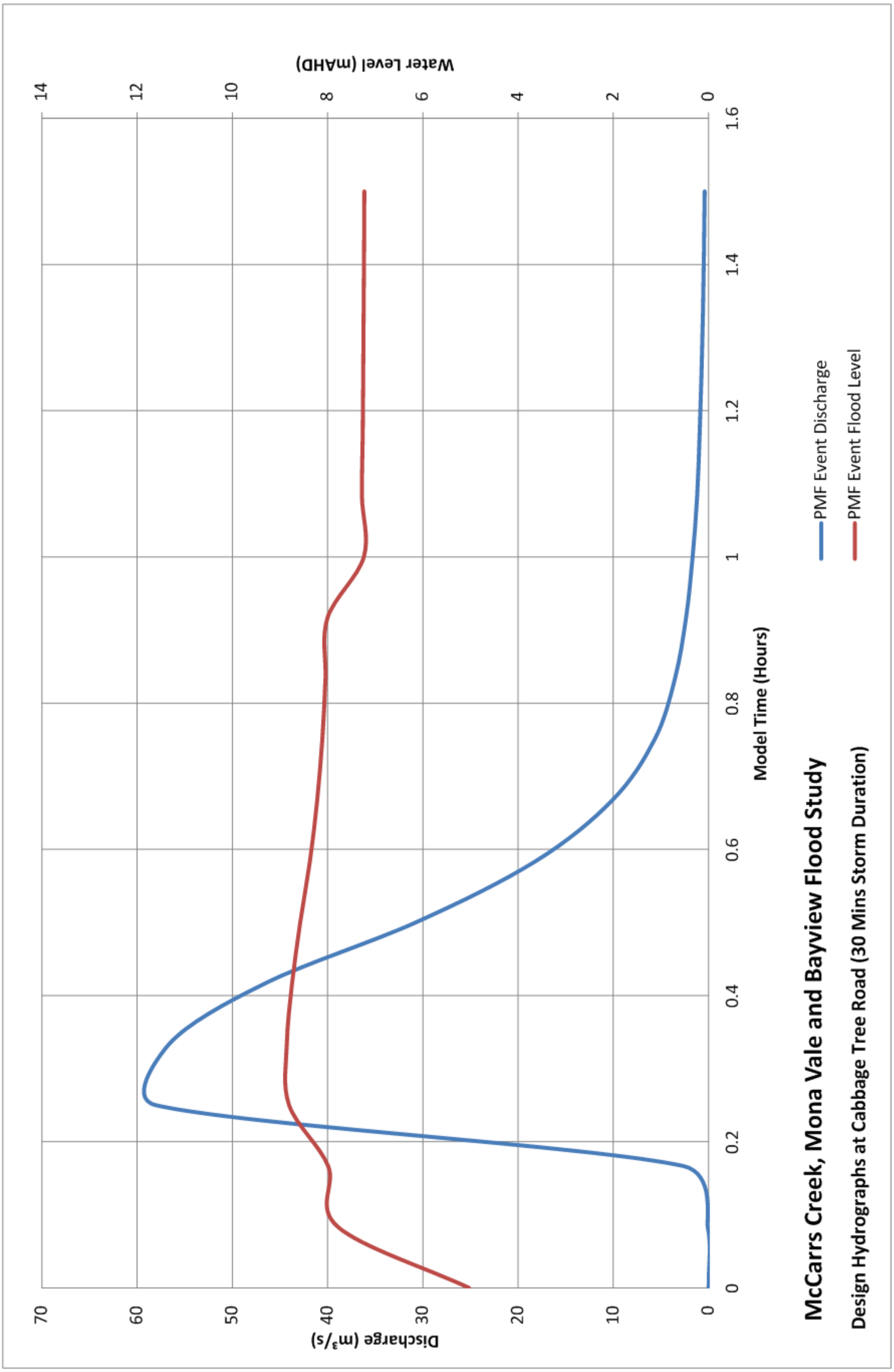
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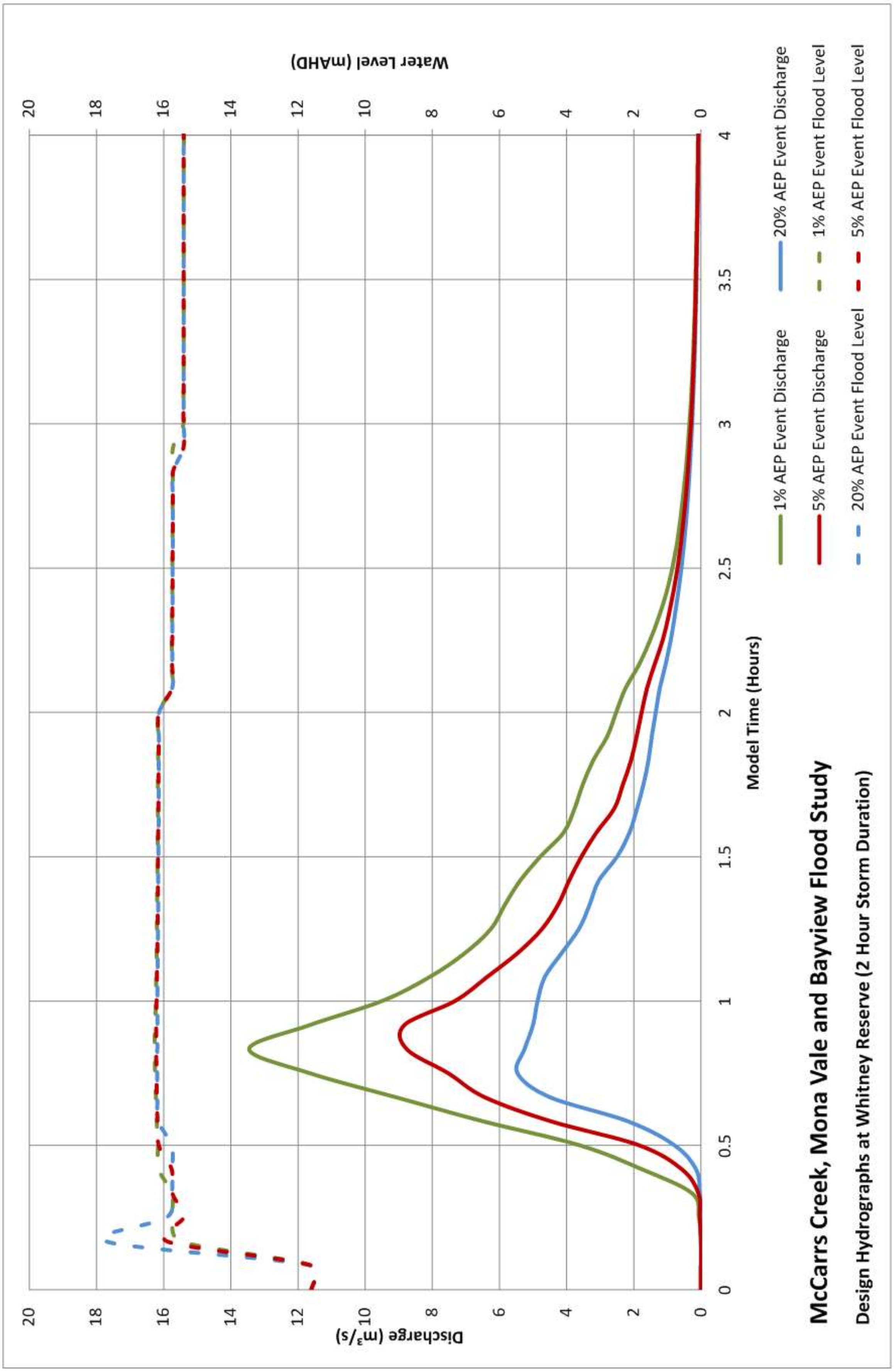
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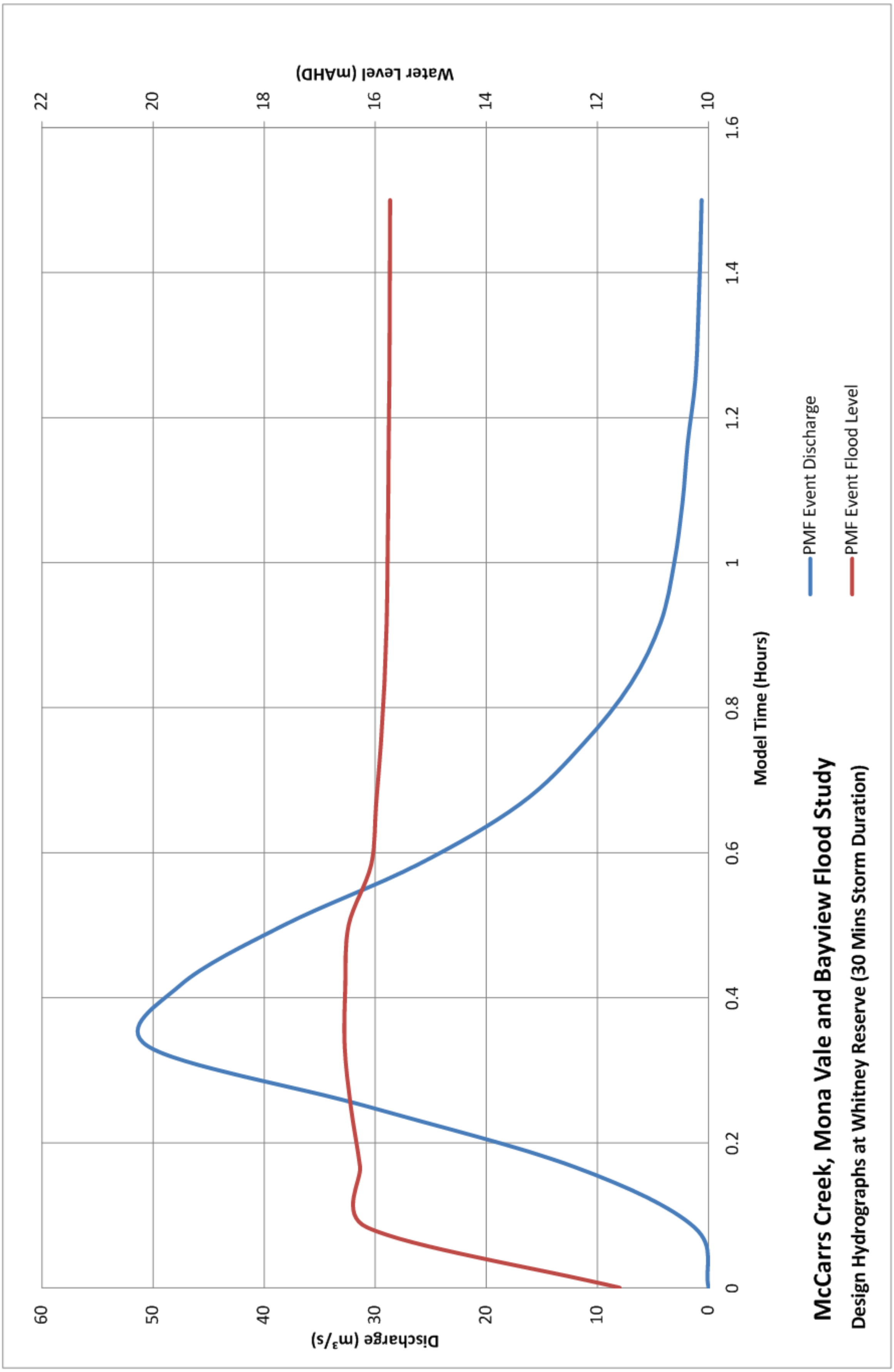
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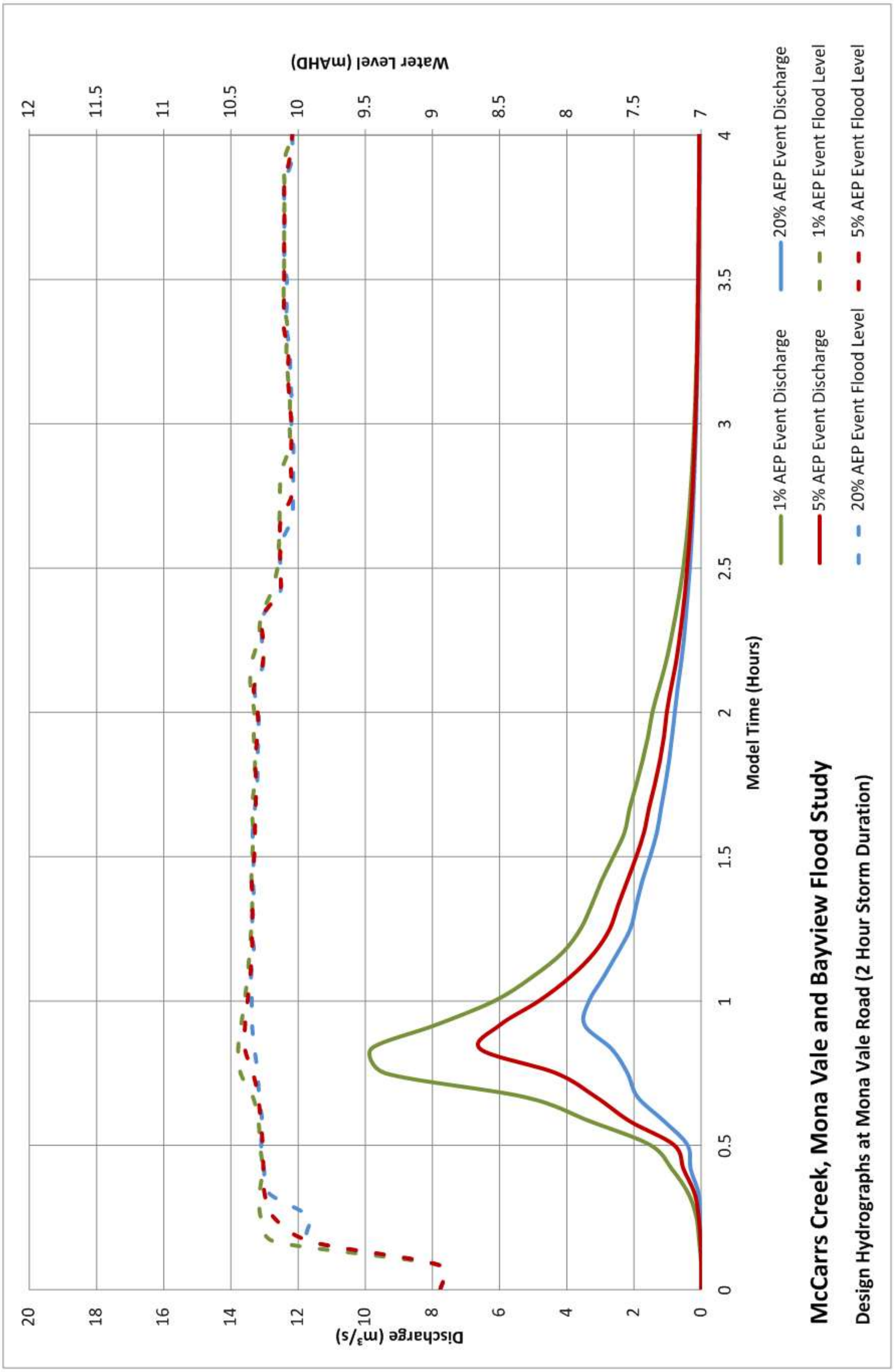
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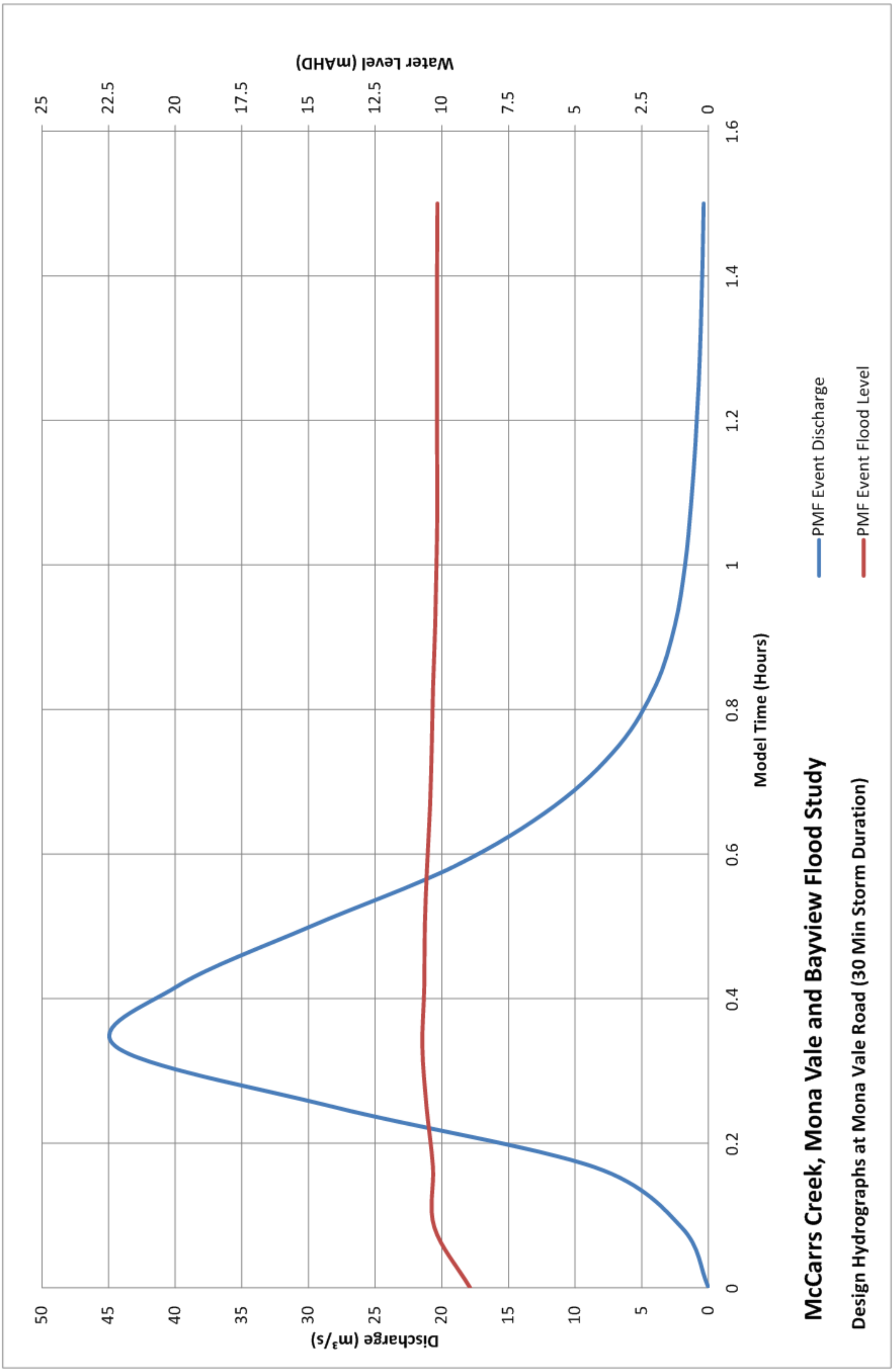
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Water Level (mAHD)
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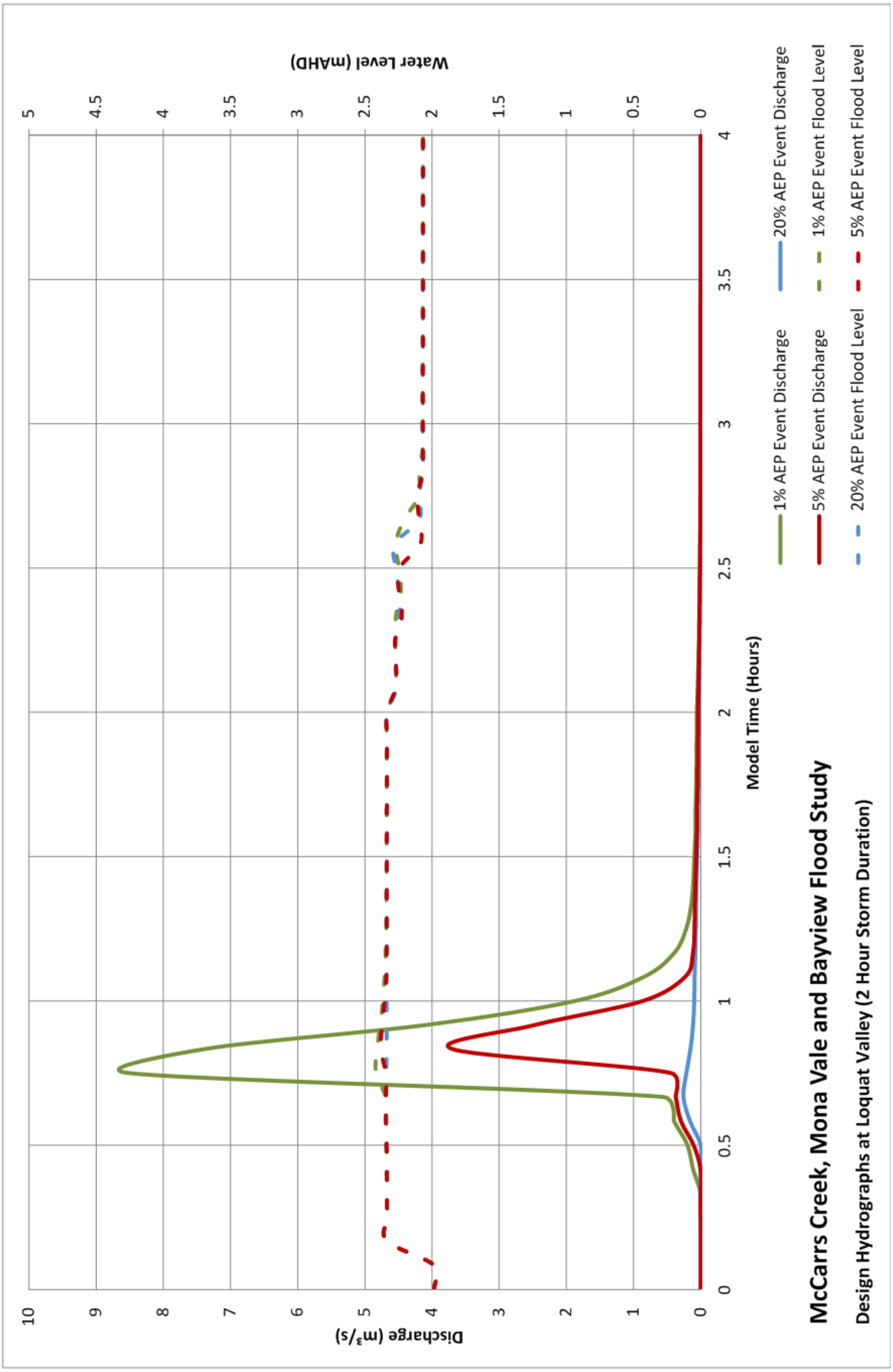
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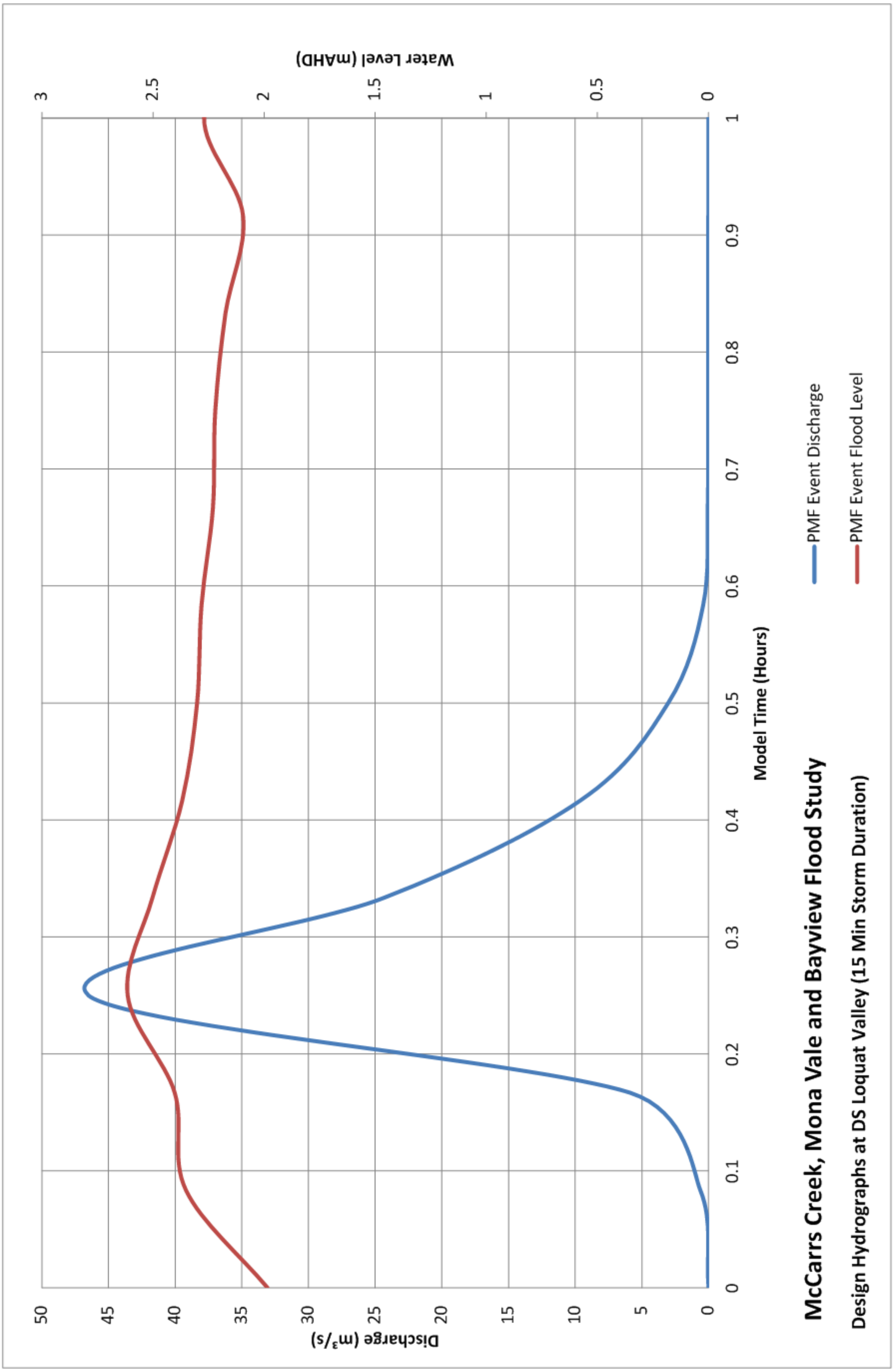
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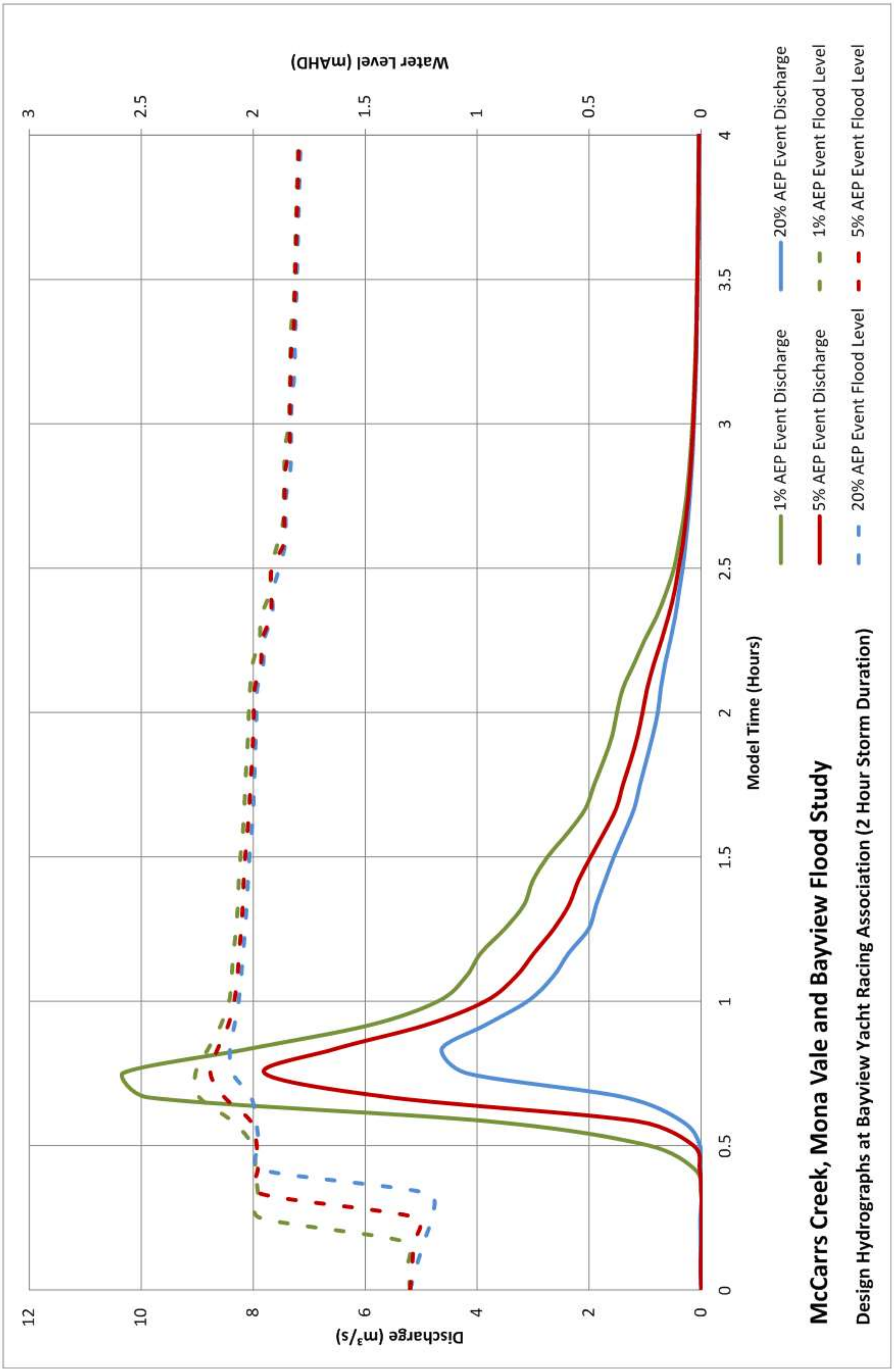
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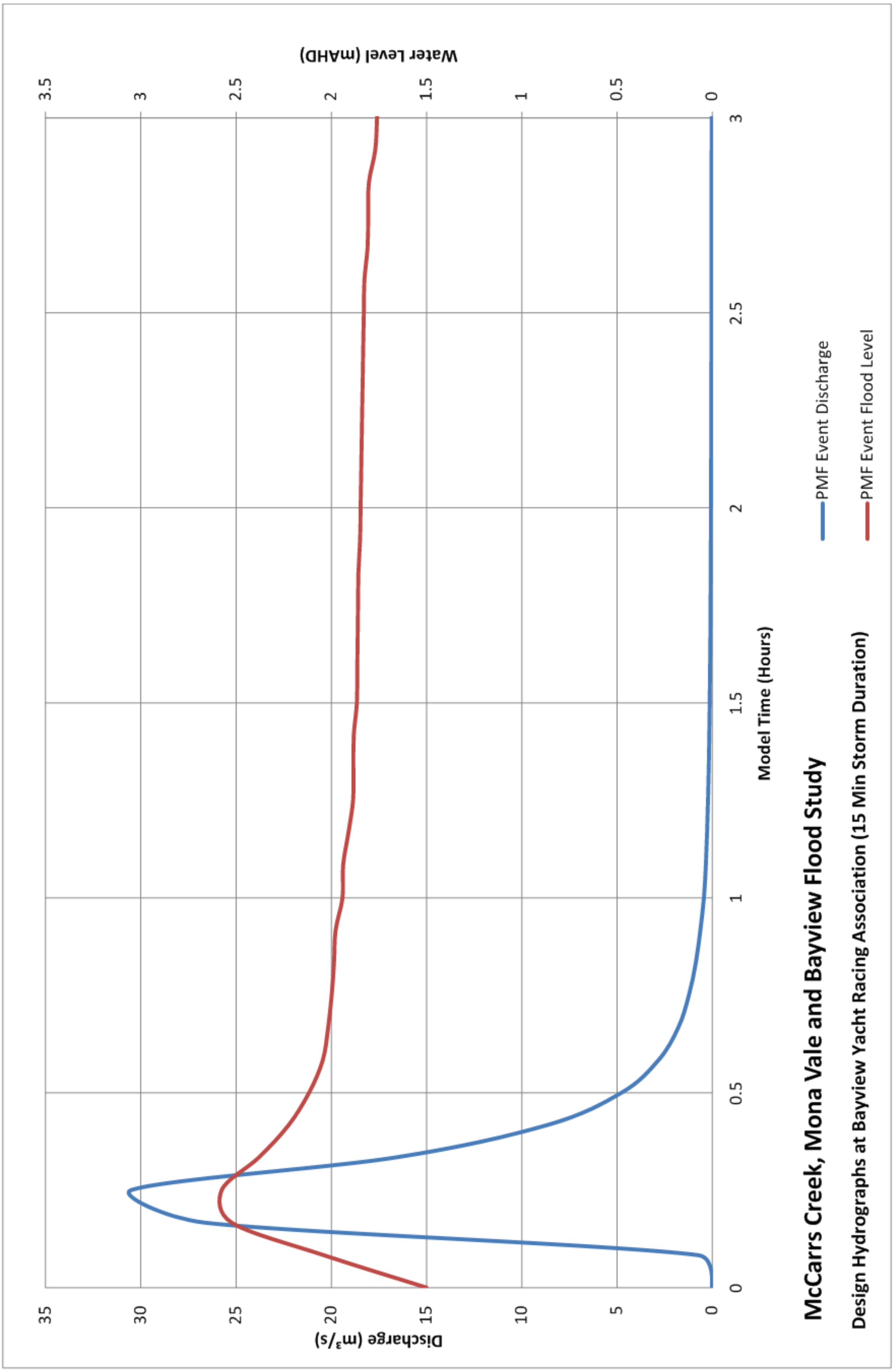
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Water Level (mAHD)
Model Time (Hours)
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Planning Proposal

30 Myoora Road, Terrey Hills

Transport Depot (Bus Parking Facility)

Submitted to Northern Beaches Council

On behalf of Forest Coach Lines Pty Ltd

May 2017

Suburban Town Planners

www.suburbantownplanners.com.au

Table of Contents

Summary - Reports/Documents.

This planning proposal for the proposed 'Transport Depot' (Bus Parking Facility) should be read in conjunction with the following plans and specialist's reports:

APPENDIX A: Detailed Survey Plans 1616-1, Overall Site Plan, 1616-2. Mr. Scott Taylor, Principal, Registered Surveyor. Scott Taylor & Associates.

APPENDIX B: Traffic Report, Mr. Ross Nettle, Principal, Transport and Traffic Planning Associates

APPENDIX C: Bushfire Assessment Report, Mr. Roger Fenwick, Bushfire Consultant, Principal, Bushfire Consultants.

APPENDIX D: Acoustic Report, Mr. Rodney Stevens, Principal, Rodney Stevens Acoustics

APPENDIX E: Letter from real estate agent re unavailability of a suitable site in other areas.

APPENDIX F: Planning Submission Application Form signed by Owners and Applicant of subject property.

APPENDIX G: Neighbour Notification Plan

APPENDIX H: Completed Application Form.

Summary - Expert Report's Conclusions.

Assessment of Traffic and Parking Implications by Mr. Ross Kettle of Transport, Traffic and Design Consultants.

Conclusion, Page 14: "This assessment has considered the potential traffic implications of the envisaged bus and bus driver consequential to modification of WLEP to permit this use.The assessment has concluded that:

- There will not be any adverse traffic implications,
- The proposed parking provisions will be adequate
- The vehicle access arrangements will be suitable and satisfactory."

Bushfire Assessment Report by Mr Roger Fenwick, Bushfire Consultant.

Conclusion, Page 6: "Approval of the proposal is recommended, with no bushfire related conditions. All works maybe to BAL-LOW under AS 3959-2009."

Acoustical Assessment Report by Mr. Rodney Stevens of Rodney Stevens Acoustics Pty Ltd.

Conclusion, Page 10: "The assessment has predicted the noise impact to the nearest residential dwellings. The noise modelling resulted in compliance to the NSW EPA INP requirements."

Planning Submission Proposal by Suburban Town Planners, Senior Town Planners, Phil Mudge and Melissa Neighbour.

Conclusion, Page 29: "This report has been prepared by Suburban Town Planners to support a Planning Proposal to Northern Beaches Council.

The Planning Proposal seeks to include 'Transport Depot' for a Bus Parking Facility, as an additional permitted use under the Warringah LEP 2011-2012, within the western portion of the site at 30 Myoora Road, Terrey Hills, on behalf of Forest Coach Lines over a 9,000sqm area.

This proposal has been prepared diligently in accordance with the recommendations/requirements of Pre - Planning Submission Proposal Meeting 2017-0028 held at NBC, Dee Why on the 4th April, 2017. As well, the document by the Department of Planning, How to prepare a Planning Submission has been diligently followed.

The proposal would deliver a much needed boost to bus transport services to the Northern Beaches/ Ingleside/ and the broader community of Northern Sydney, as well as providing additional employment and the subsequent economic and social benefit. This assessment has shown that the proposal is consistent with the relevant State and Local Strategies and Environmental Planning Instruments and that the environmental impacts of the development can be suitably managed.

In light of the benefits of the proposal we conclude that the Planning Proposal presents a suitable amendment to the LEP to allow Forest Coach Lines to deliver much-needed transport services to the greater Northern Sydney Region and should be supported by Council and processed through the Department of Planning Gateway System.

x-x-x-x-x-x-x-x-x-

1.0 Introduction

This report has been prepared by Suburban Town Planners on behalf of Forest Coach Lines (the proponent) in relation to a site at 30 Myoora Road, Terrey Hills. The site has dual frontage to Mona Vale Road and Myoora Road and is formally known as Lot 123 on DP752017.

This planning proposal has been prepared in accordance with section 55 of the Environmental Planning and Assessment Act 1979 (EP&A Act) and the guidelines prepared by the Department of Planning and Infrastructure entitled "A guide to preparing planning proposals", dated August 2016.

The planning proposal has had regard to the physical characteristics of the site, the social and economic context of the surrounding area, and addresses the key planning issues associated with the site and the strategic merit of its proposed rezoning to a level of detail appropriate to support a LEP Gateway determination by the Department of Planning & Environment (DP&E).

Forest Coach Lines (FCL) is the lead bus operator for the Sydney Metropolitan Bus Services Contract in region 14 with over 85 years' successful experience in offering quality and affordable transport to residents and visitors of Sydney North Shore. FCL operates 18 service routes and 129 school routes under the current government contract, providing charter services to more than 200 local schools and organisations.

FCL and the charter business are expanding significantly year on year with a growing bus fleet of approximately 10 buses per year in order to meet their current contracts and the transport demands of a rapidly growing area. In particular, the significant growth in transport demands are being driven by:

- The new Northern Beaches Hospital which is due to be completed in late 2018;
- FCL are striving to be fully prepared to provide the new Ingleside community with a first-class bus service and
- FCL have tendered for the major Epping to Chatswood Rail Replacement which is due to start in September 2018 and requires up to 39 buses for a 6-month period

The depot address of FCL is 4 Myoora Road, Terrey Hills which has a current capacity of 145 buses. A recently approved DA from Northern Beaches Council increased this from 131 buses to deal with capacity issues. FCL are now in a dire position as they urgently require additional land to park their growing bus fleet.

For the previous 24 months, FCL has been searching in the industrial zoned precincts of the Northern Beaches for suitable sites to park their buses. Despite these lengthy efforts, a suitable parcel of land or a building that could have been converted, was not found.

The proposed site for the additional bus parking facility is on 9,000sqm of land to be leased at 30 Myoora Road, Terrey Hills, located just 700 metres from the current bus depot. This property has an area of 16,340 square metres. This nearby location is an obvious benefit logistically in terms of convenience for staff, maintenance of the FCL fleet (which will all occur at the existing depot), and servicing Region 14 of the Sydney Metropolitan Bus Services Contracts.

Forest Coach Lines is a critical part of the required transport infrastructure to meet the strategic needs of the growing region. The new 'Transport Depot' (Bus Parking Facility), the subject of this planning proposal, is an essential expansion for this transport company to enable growth within the Terrey Hills area and the greater Sydney north region. By having an additional area for bus parking, FCL will be able to have a continued and increase significant positive social and economic impact.

The site is subject to the Warringah Local Environmental Plan 2011 (WLEP 2011). Under the WLEP 2011, the site is currently zoned as RU4, Primary Production Small Lots. A 'Transport Depot', or a property or part of a property used to park buses is a prohibited activity under the current RU4 land use table for the Zone. This planning proposal is requesting that the WLEP 2011 be amended to enable a 'Transport Depot' to become a Permitted Activity with consent. The request is made **specific to the 9,000sqm of land at the property, subject of this application,** and not as a general amendment to the WLEP 2011 to apply to the whole zoning.

This planning proposal report describes the site, the proposed changes to the WLEP 2011 and provides an environmental assessment. This report should be read in conjunction with the accompanying specialist reports which conclude that the proposed development will have no adverse traffic, parking, bushfire or acoustic implications. The report is written in accordance with the Department of Planning and Infrastructure's published "A guide to preparing planning proposals", dated August 2016.

The proposed development will allow Forest Coach Lines to continue to meet the growing demand for public transport servicing the North Shore and Northern Beaches, without imposing any significant or adverse impacts on the amenity of surrounding land.

2.0 The Site

2.1 Site Location

The site is located at 30 Myoora Road, Terrey Hills as shown in Figure 1.

Figure 1: Site Location

2.2 Site Description

The land at Lot 123 on DP752017 is approximately 1.634 hectares and generally rectangle in shape with frontage to Mona Vale Road and to Myoora Road.

This planning proposal relates to 9,000 sqm parcel of land (lease subject to Council approval) in the north-western corner of the site. Please The new 9,000 sqm proposed rezoned area will be setback 7.5 metres from Myoora Road boundary with an entrance of 6 metres at the north eastern corner, and an exit at the north western corner of Myoora Road. The parcel will be 156.905 deep and 57.36 wide. Figure 2 below is an aerial photo which shows the view of the site from Myoora Road. The red lines in Figure 2 denote the Lot 123 boundary and the pink lines denote the proposed 9,000 sqm lease area. Please also refer to the Detailed Survey Plan 1616-1 and Overall Site Plan 1616-2 contained in Appendix A.

Figure 2: View of site from Myoora Road.

2.3 Existing Development

The existing development on the site comprises:

i. Two (2) storey dual occupancy dwelling with frontage to Mona Vale Road
ii. One (1) storey office/ workers cottage
iii. Eleven (11) glass houses
iv. A number of outbuildings

2.4 Topography

The general area has a gentle slope from Mona Vale Road down to the west. The site itself slopes down slightly to the west.

2.5 Vegetation, Dam

There is no vegetation of significance located on the site, other than vegetation surrounding the dam at the Myoora Road frontage. There is no vegetation to remove otherwise. The dam will be emptied ecologically and filled with appropriate fill in accordance with standards.

2.6 Infrastructure and Services

The site is presently serviced by water, electricity, sewer, gas, and telecommunications.

2.7 Surrounding development

Immediately adjoining the subject site is a plant nursery and rural residential property at 313 Mona Vale Road and a rural residential property at 32 Myoora Road.

The wider precinct extending along the northern side of Mona Vale Road, generally between Myoora Road to the south-west and Cooyong Road to the north-east, is a mixed use precinct. It accommodates a diverse range of retail, commercial, light industrial, agricultural, and specialist uses including shops and restaurants, conference centres, motels, caravan parks, nurseries and landscape supply businesses, with a scattering of residential dwellings.

2.8 Land use zoning

The subject site is currently zoned RU4 Primary Production Small Lots under WLEP 2011, as shown hatched on Figure 3.

Figure 3: Extract of Land Zoning Map under WLEP 2011

The permitted land uses for the RU4 Primary Production Small Lots zone are:

Permitted without consent
Home-based child care; Home occupations

Permitted with consent
Animal boarding or training establishments; Aquaculture; Bed and breakfast accommodation; Building identification signs; Business identification signs; Child care centres; Community facilities; Dwelling houses; Environmental protection works; Extensive agriculture; Farm buildings; Home businesses; Home industries; Intensive plant agriculture; Landscaping material supplies; Plant

nurseries; Recreation areas; Respite day care centres; Roads; Roadside stalls; Rural supplies; Veterinary hospitals

Prohibited
Any development not specified in item 2 or 3

Further, Clause 18 of Schedule 1 Additional Permitted Uses applies to the site:

18 Use of certain land in the vicinity of Mona Vale and Myoora Roads, Terrey Hills:
(1) This clause applies to land in the vicinity of Mona Vale and Myoora Roads, Terrey Hills, shown as "Area 18" on the Additional Permitted Uses Map.

(2) Development for the purposes of educational establishments, garden centres, hospitals, hotel or motel accommodation, places of public worship, recreation areas, recreation facilities (indoor), recreation facilities (outdoor), registered clubs and restaurants or cafes is permitted with consent.

3.0 The Proposal Description

3.1 The Need for the 'Transport Depot' (Bus Parking Facility)

3.1.1 Background to Forest Coach Lines

The year 1928 saw brothers Trevor and Eric Royle migrate from their Welsh homeland to Australia. Like many newcomers to Australia, the two brothers strived for a more prosperous life in their new country.

For the first two years Trevor and Eric worked as farmhands in northern NSW. Returning to the Sydney area in 1930, they decided to buy a promising small suburban bus business from Mr E J Jones of Roseville. With this purchase the Royle brothers laid the foundations for Forest Coach Lines, now Sydney's longest established family-owned bus company. Forest Coach Lines (FCL) has grown to become the lead bus operator for the Sydney Metropolitan Bus Services Contract in region 14.

3.1.2 A growing business

The FCL Fleet size has rapidly increased over the last 5 years from 89 buses and coaches to the current 126 in total (refer to Figure 4 and 5). For the growth pressures outlined in the introduction this is set to increase and there will be over 20 replacement and growth buses added to the fleet in the next 4 financial years to help deliver better bus services to the public and meet the strategic transport needs of the region.

The charter business of FCL is larger than most other bus operations in Sydney due to the number of schools in the North Shore and FCL excellent customer services and successful operating experience in the past decades. In September 2016, FCL acquired Manly Coaches, which brought more customers and business opportunities. Currently with an average of over 100 daily movements and more decided school bus services, FCL charter business is expanding significantly year on year.

Figure 4: FCL Fleet Growth

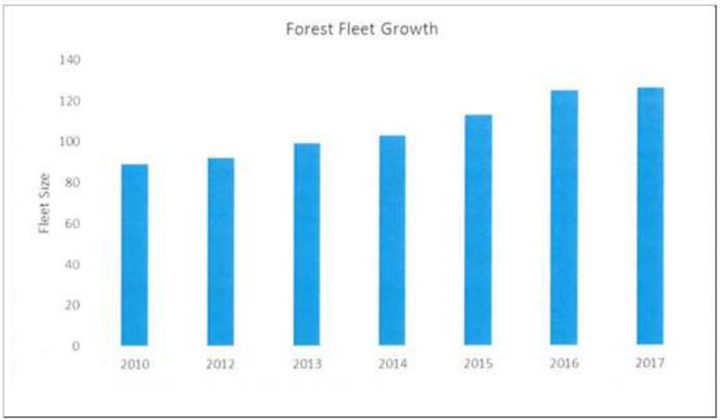
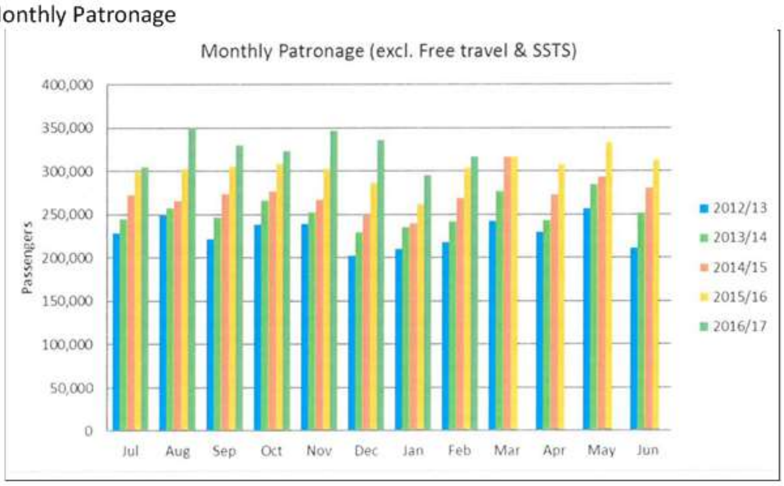


Figure 5: Monthly Patronage



3.1.3 Site Selection

Forest Coach Lines have been searching for the previous 24 months in the industrial zoned precincts of the Northern Beaches for suitable sites to park their growing fleet. Despite these lengthy efforts, a suitable parcel of land or a building that could have been converted, was not found. Please refer to the letter attached to this proposal from Nick Masselos, Real Estate consultant at Northern Beaches Commercial who has been working closely with FCL for the last two years in the search for a suitable site.

The proposed site for the additional 'Transport Depot' (Bus Parking Facility) is located just 700 metres from the current bus depot. This nearby location is an obvious benefit logistically in terms of convenience for staff, maintenance of the FCL fleet (which will all occur at the existing depot), and servicing Region 14 of the Sydney Metropolitan Bus Services Contracts.

As this submission indicates, the approval and rapid establishment of the site is essential to maintain the high level of service that the Northern Sydney area serviced by FCL have come to expect over the past 85 years.

3.2 Proposed Development

3.2.1 General Description

The proposed development seeks to use 9,000sqm of the subject site as a 'Transport Depot' for a Bus Parking Facility for a total of approximately 60 buses. The Facility will comprise of:

- Vehicle ingress driveway on the north-eastern corner of the site for entrance from Myoora Road to the right of way, and a vehicle egress driveway on the north-western corner of the site to exit the depot to Myoora Road. A request to NB Council will be made to remove existing vegetation along Myoora Road verge to ensure adequate sight distances
- It is proposed that approx. 6000 square metres will be asphalted and drained to cater in the first instance for 60 buses and driver's cars. Some driver parking will utilise empty bus bays, as is the procedure at the Bus depot at 4 Myoora Road, Terrey Hills, the headquarters of Forest Coach Lines.
- Drivers amenities facility – 10 metre x 4 Metre.

It is proposed to demolish the existing glasshouses and outhouses within the 9,000sqm area, to permit the staged asphalting of the parking area and movement of buses and other vehicles along the proposed right of way.

Details of the proposed development are provided more thoroughly in the documents and plans in the Appendix. Existing landscape setbacks to Mona Vale and Myoora Roads will be maintained as per existing controls for a consistent landscape frontage along the road frontage.

The FCL Depot at 4 Myoora Road will continue to be the site used for administration, servicing and cleaning of the entire FCL bus fleet, including those to be parked on the proposal site at 30 Myoora Road. There will be no servicing or cleaning of buses on the proposal site and the only servicing would be the contract cleaning of the small drivers' amenity and these cleaners will remove any rubbish. The large hardstand area will provide for the parking of any very infrequent maintenance vehicle.

3.2.2 Operational Characteristics

The proposed development is for on-site bus and car parking capacity associated with the use of the site as a Transport Depot (Bus Parking Facility). The site operations will be managed in accordance with the Forest Coach Lines Pty Ltd mandatory "Traffic Management Plan" which can be provided if required. The "Traffic Management Plan" provides detailed controls relating to the operation of the bus parking facility, including the responsibilities of Forest Coach Lines and its staff.

Below are the bus movements for 60 buses based on the FCL current roster operating at the 4 Myoora St Depot. This shows the approximate number of buses that will be arriving and leaving per hour of operation at the Transport Depot (Bus Parking Facility) at 30 Myoora Road.

Time Range	BUSES OUT of depot	BUSES INTO depot
0400-0500	0	0
0500-0600	8	0
0600-0700	22	0
0800-0900	20	9
1000-1100	1	8
1100-1200	1	2
1200-1300	2	2
1300-1400	3	3
1400-1500	18	2
1500-1600	10	1
1600-1700	2	6
1700-1800	5	6
1800-1900	2	14
1900-2000	1	10
2000-2100	0	6
2100-2200	0	4
2200-2300	1	3
2300-2400	1	1
2400-0100	0	2
0100-0200	0	1
0200-0300	0	1
0300-0400	0	0

3.2.3 Assessment of Impacts

This section outlines and assesses the likely amenity impacts as a result of the planning proposal and how they are proposed to be managed.

Access and Traffic

The Traffic Report, **APPENDIX B: Traffic Report, Mr. Ross Nettle, Principal, Transport and Traffic Planning Associates,** states that the sites "accesses will operate with a very satisfactory level of service and because the projected traffic generation will be so minor during the on-street peak periods, it is apparent that there will be no perceptible or unsatisfactory implications for the access intersections in the area."

A traffic survey was undertaken at the FCL access on Myoora Road to establish the access traffic activity during the weekday morning and afternoon peak periods. The Traffic report concluded that "there will not be any adverse traffic implications."

Noise impacts

The Acoustic Report, **APPENDIX D: Acoustic Report, Mr. Rodney Stevens, Principal, Rodney Stevens Acoustics** set out to determine the noise impact from the operation of the proposed Bus Depot to the nearest residential dwellings. The noise modelling and assessment resulted in compliance to the NSW EPA INP Requirements.

A comparison analysis was carried out of Sydney six bus depots to determine the distances between bus depots and surrounding residential dwellings. The images below are of the six bus depots showing residential dwellings that are within 100 metres of the depots, with each red line representing approximately 100m. Each bus depot is surrounded by residential dwellings and in some cases is located within entirely residential zones. By comparison the proposed bus facility over the subject site has 1 -2 residential dwellings located within a 100m radius, as shown in Figure 12 in the following set of figures.

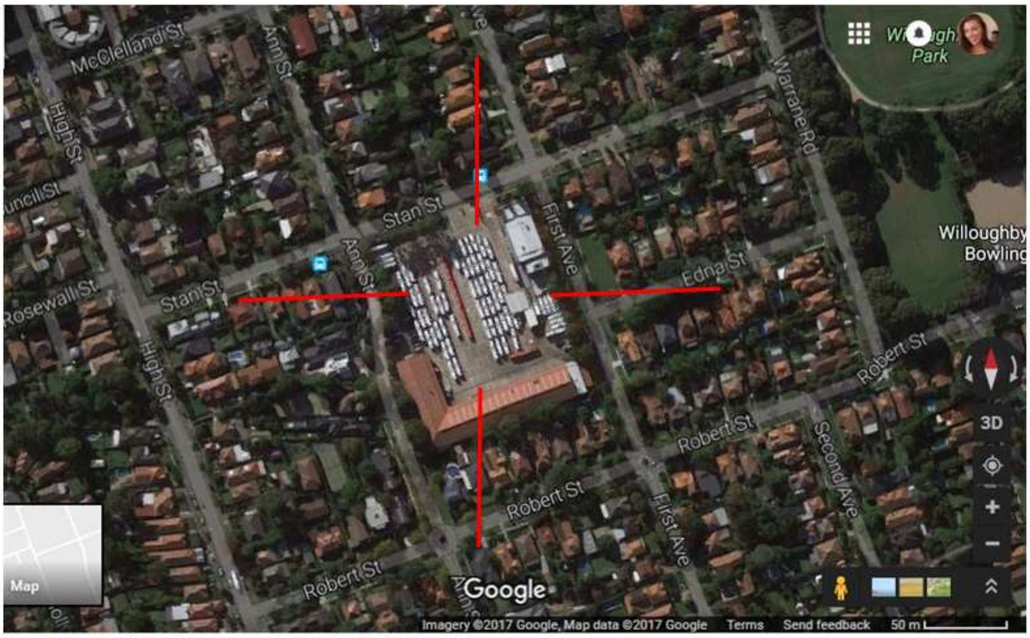


Figure 6: Willoughby Bus Depot (red lines represent approx. 100m)

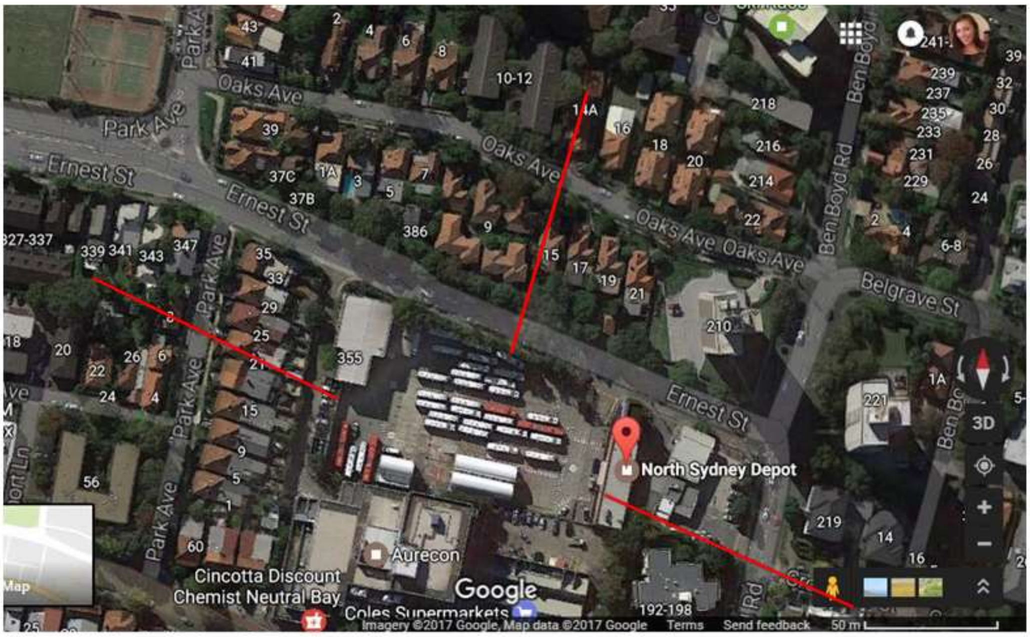


Figure 7: North Sydney Depot (red lines represent approx. 100m)

Figure 8: Burwood Depot (red lines represent approx. 100m)

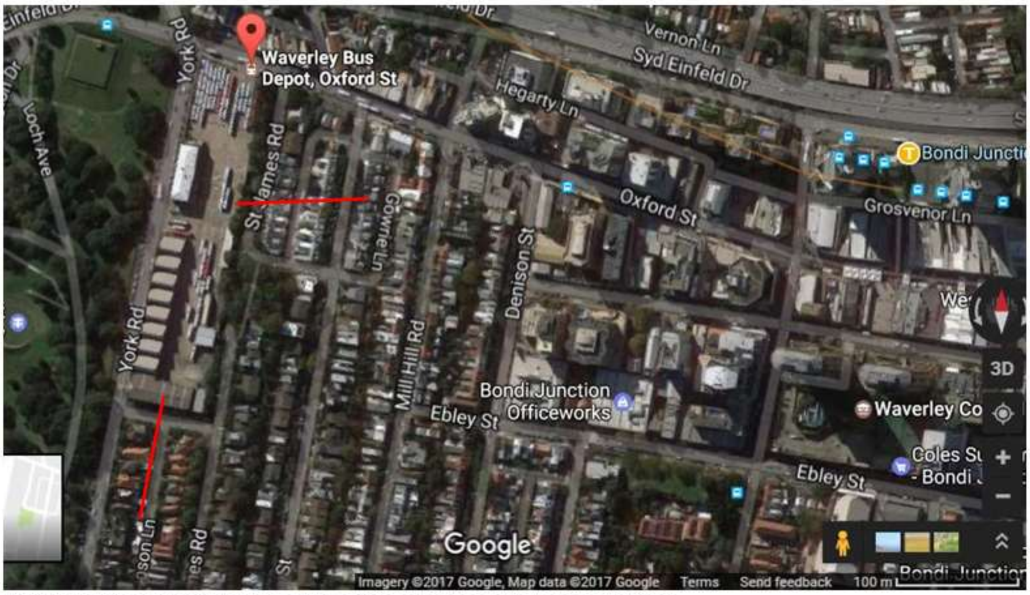


Figure 9: Waverley Bus Depot (red lines represent approx. 100m)

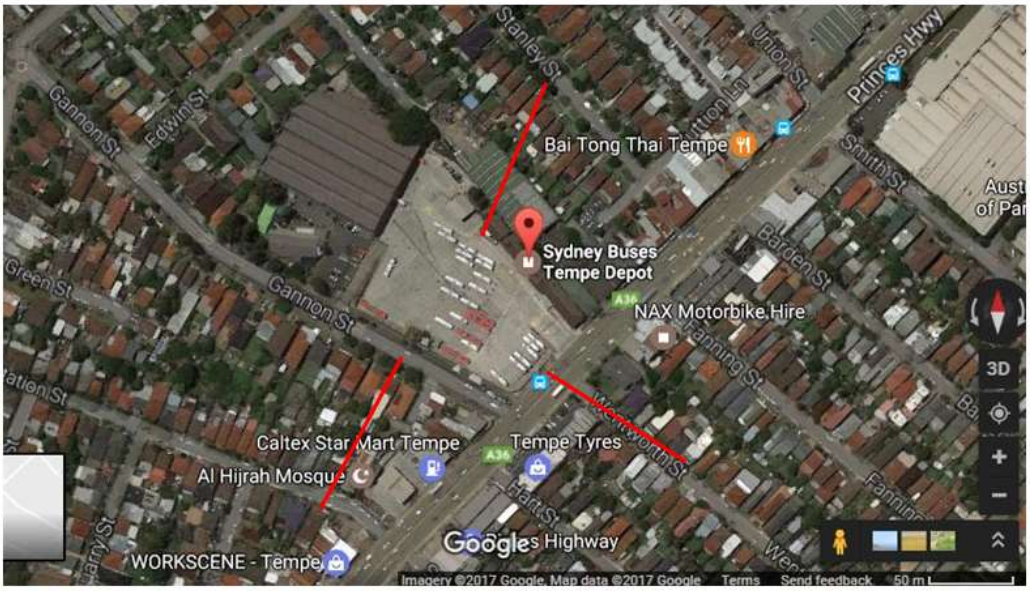


Figure 10: Tempe Bus Depot (red lines represent approx. 100m)

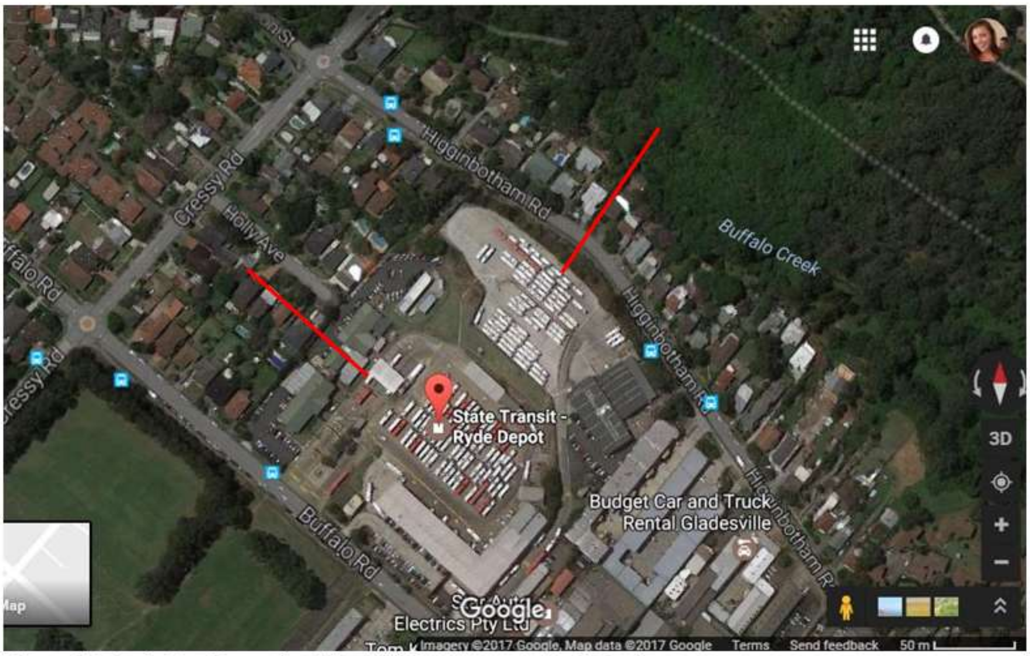


Figure 11: Ryde Bus Depot (red lines represent approx. 100m)

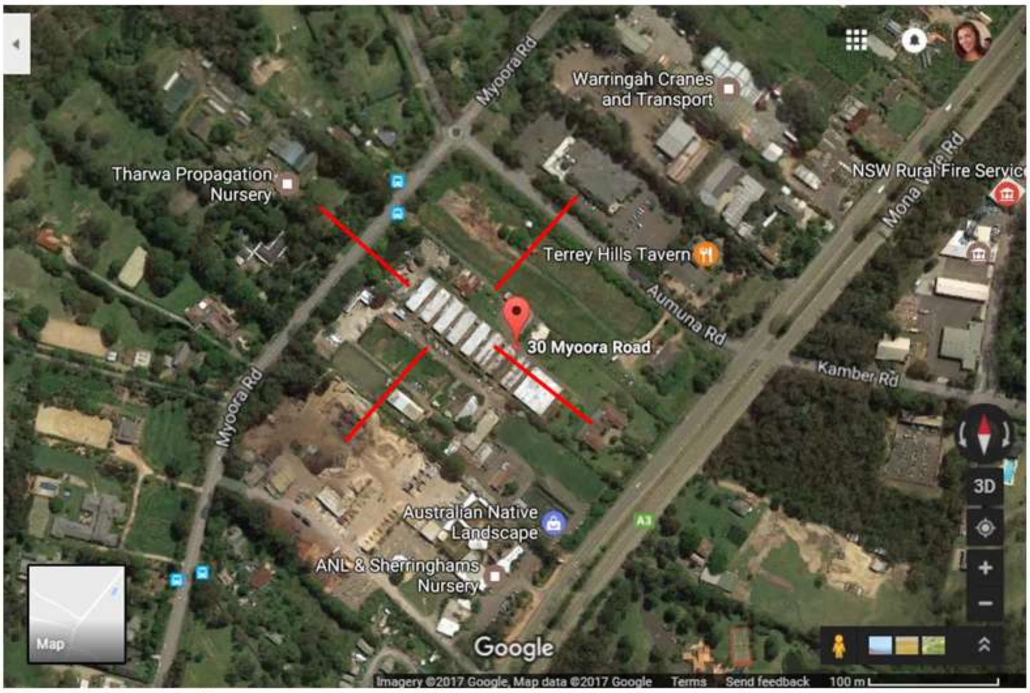


Figure 12: Proposed Transport Depot (red lines represent approx. 100m)

As a result of careful mitigation, the proposed development will have no adverse traffic, parking, bushfire or acoustic implications, as demonstrated by the accompanying specialist reports.

3.4 Environmental, Social and Economic Benefits

In general, investment in major projects can only be justified if the benefits of doing so exceed the costs. Such an assessment must consider all costs and benefits, and not simply those that can be easily quantified. As a result, the EP&A Act specifies that such a justification must be made having regard to biophysical, economic and social considerations and the principles of ecologically sustainable development.

In addition, one of the key objectives of the EP&A Act is to encourage "the promotion and co-ordination of the orderly and economic use and development of land". This and the other objectives of the Act recognise that the planning system needs to enable and facilitate the redevelopment of land in an economic manner, while balancing environmental and social impact and the public interest.

It is considered that this project would result in beneficial economic, environmental and social outcomes which are in the public interest. As stated in the Draft North District Plan "new transport infrastructure, can unlock a number of 'benefit streams', including direct transport benefits such as reduced travel times, and wider benefits such as reduced *congestion* and lower fuel consumption."

Specially this proposal would generate a net community benefit by increasing transport services which will improve access to jobs, schools, shops, hospitals and leisure activities. From an economic perspective, by improving access to centres and a range of services it increases prospects for economic growth and job creation. Increasing bus service availability will have indirect environmental benefits by reducing the number of cars on the road thereby reducing number of vehicle trips and lowering carbon emissions.

3.5 Proposed Amendments to WLEP 2011

The additional proposed use is for a Bus Parking Facility which falls under the definition in the WLEP 2011 of:

> ***transport depot*** *means a building or place used for the parking or servicing of motor powered or motor drawn vehicles used in connection with a business, industry, shop or passenger or freight transport undertaking.*

The proposed development for 'transport depot' is not permissible on the site under the current provisions of WLEP 2011.

It is proposed to retain the existing RU4 Primary Production Small Lots zoning on the site, and to permit the additional permitted use of '***transport depot'*** on the proposed to be leased 9,000sqm in the western portion of the site. The request is made **specific to the 9,000sqm of proposed lease land at the property** and the area of the site outside of the 9,000sqm leased portion would not have any additional permitted uses.

The additional permitted use of 'transport depot' would be included within Schedule 1 - Additional Permitted Uses of the WLEP 2011.

It is important to clarify that the operations for the proposed Land to be leased at the property is for the purposes of a Bus Parking Facility, and activities associated with running a Transport Depot will not be carried out on site. The FCL Depot at 4 Myoora Road will continue to be the main depot used for administration, servicing, refuelling and cleaning of the entire FCL bus fleet, including those to be parked on the proposal site at 30 Myoora Road. There will be no servicing, cleaning or refuelling of buses on the proposal site and the only servicing would be the contract cleaning of the small drivers' amenity and these cleaners will remove any rubbish. The large hardstand area will provide for the parking of any very infrequent maintenance vehicle.

4.0 Pre-lodgement meeting 2017 – 0028.

A predevelopment application meeting was held on Tuesday 4 April, 2017 at The Northern Beaches Council, Dee Why and attended by:

Attendees for Council:	Jeanne Thuez, Strategic Planner Neil Cocks, Manager Strategic Planning Rezvan Saket – Traffic Engineer
Attendees for applicant:	Phil Mudge – Principal Town Planner, Suburban Town Planners David Royle – Managing Director, Forest Coach Lines Melissa Neighbour - Senior Town Planner, Suburban Town Planners

4.1 Addressing Pre-DA Meeting Requirements

This section comprises of the key planning and application requirements extracted from the pre-lodgement meeting notes and provides a response to each.

5.1 Characterisation of use *(a) The proposed development would be characterised as comprising of a transport depot'(Coaches).* *(c) The definitions under WLEP 2011 for the proposed uses are:* ***transport depot*** *means a building or place used for the parking or servicing of motor powered or motor drawn vehicles used in connection with a business, industry, shop or passenger or freight transport undertaking.* *(d) The proposed development for 'transport depot' is not permissible on the site under the current provisions of WLEP 2011.*	Noted. Please refer to Section 3.5 of this Planning Proposal Report.
5.2 Key issues to be addressed *i. A traffic report is to be prepared by a qualified traffic consultant/engineer is to be submitted addressing the traffic implication on the surrounding road network, as well as access and egress to and from the site. The traffic report must include the following:* *o Traffic impact assessment .* *o Intersection analysis on surrounding intersections as required particularly on the intersection of Myoora Road and Mona Vale Road.* *o A parking plan in support of the proposed maximum number of buses and associated staff parking.*	Noted and addressed accordingly. Please refer to the Traffic Report submitted with this Proposal.
ii. Referral to Roads and Maritime Services (RMS) is require. In particular, regards to the traffic implication of the proposal on the road network and the intersection of Myroora road and Mona Vale Road.	Noted and addressed: Please Refer to the Report by Transport and Traffic Planning Associates as Appendix
iii. Strategic land-use justification for the proposal, addressing the unique characteristics of the site that would justify changes to permissible uses when compared to other sites in the locality.	Addressed. Please refer to Section 3.1 and 3.1.3.
iv. Potential impacts to the surrounding rural development and land uses.	Addressed. Please refer to Section 3.2.3.
v. Existing landscape setbacks to Mona Vale and Myoora Roads must be maintained as per existing controls for a consistent landscape frontage along the road frontage.	Complies – 7.5 metres Myoora Road. Proposed Depot does not front Mona Vale Road.

vi. Noise Report – Noise assessment of proposed use.	Addressed. Please refer to the Acoustic Report in the Appendix.
vii. Bushfire – Referral to RFS required.	Noted. Bushfire issues address in Bushfire Report. Please refer to the Appendix.
viii. Suitability of the proposed use on this site taking into consideration the adjacent and surrounding land uses.	Addressed. Please refer to Section 3.1 and 3.1.3.
CONCLUSION *(a) The proposal represents a change to the established function of land uses in the RU4 Primary Production Small Lots zone along Mona Vale and Myoora Roads. Any amendment to WLEP 2011 must provide a strong level of strategic justification to expand the permitted uses in this area.*	Noted. Please refer to Section 3.1.
(b) Traffic and access to the site are key considerations. Any application would be referred to RMS and other relevant agencies for their consideration.	Noted.
(c) Any future planning proposal must address the provision of required technical studies and supporting documents as outlined in Attachment 1.	Addressed.
(d) It is strongly recommended that the Applicant consults with neighbours regarding this proposal before finalising a planning proposal submission to Council.	Noted. This was carried out by Town Planner Phil Mudge…
(e) If you proceed with the planning proposal a Pre-lodgement Meeting would be recommended with the Development Assessment team to obtain more detailed assessment criteria and advice at the appropriate time.	A Pre-Lodgement Meeting was attended and resulted in this summary.
o ***Provision of Technical Studies and Supporting Documents*** *(a) The following studies and supporting documents shall be prepared to accompany the planning proposal at lodgement:* *i. A Planning Proposal prepared in accordance with the Department of Planning and Environment's Guide to Preparing Local Environmental Plan and Guide to Preparing Planning Proposals* *ii. A Traffic Report, prepared by a qualified traffic consultant/engineer including plan showing allocated staff parking and bus parking* *iii. Concept plans and/or drawings* *iv. A response to all matters outlined in these PLM notes*	Addressed accordingly. Please refer to the Appendix for consultants reports and plans.

o ***Additional Justification of the Planning Proposal*** *The planning proposal shall include:* *(a) Justification of the proposal against the Section 117 Ministerial Directions, including:* *i. 1.2 Rural Zones* *ii. 4.4 Planning for Bushfire Protection* *iii. 6.1 Approval and Referral Requirements* *iv. 6.3 Site Specific Provisions* *v. 7.1 Implementation of A Plan for Growing Sydney* *(b) An assessment demonstrating consistency with A Plan for Growing Sydney and the draft North District Plan.* *(c) A statement indicating the relationship with Council's Community Strategic Plan.* *(d) An assessment justifying any non-compliance with the Warringah Local Environmental Plan 2011, Warringah Development Control Plan 2011 and all relevant State Environmental Planning Policies.* *(e) An assessment of the likely amenity impacts as a result of the planning proposal and how they are proposed to be managed including the drafting of site specific provisions as necessary.*	Noted and addressed in Sections 5.0 and 3.0.

5.0 Strategic and Statutory Planning Framework

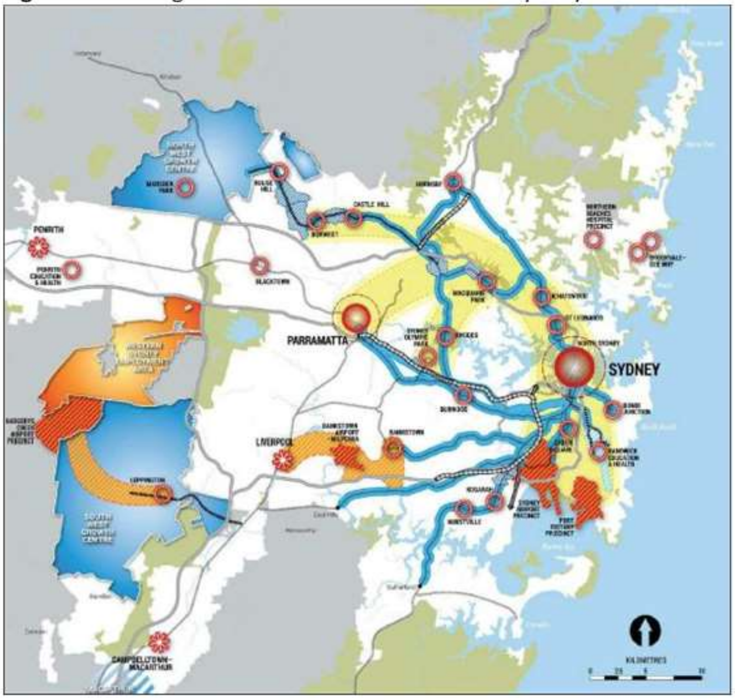
This chapter outlines the strategic and statutory planning framework within which the development outcomes for the land have been considered.

5.1 Strategic Planning Policies

5.1.1 A Plan for Growing Sydney

A Plan for Growing Sydney is the current strategic plan for the Sydney metropolitan area, and was released on 14 December 2014. The vision for the Plan is presented in Figure 13 below.

Figure 13: Strategic Plan for the Future Growth of Sydney



The Government's vision for Sydney is 'a strong global city, a great place to live'. To achieve this vision, the Government has set down goals that Sydney will be:

- a competitive economy with world-class services and transport;
- a city of housing choice with homes that meet our needs and lifestyles;
- a great place to live with communities that are strong, healthy and well connected; and
- a sustainable and resilient city that protects the natural environment and has a balanced approach to the use of land and resources.

To address these goals, the Plan proposes a range of goals, policy initiatives and strategic directions. The goals and directions relevant to this planning proposal are as follows:

- expand the Global Economic Corridor;
- grow strategic centres (including the Northern Beaches Hospital Precinct);
- grow a competitive economy with world-class services and transport; and
- protect our natural environment and biodiversity.

This planning proposal is consistent with ***A Plan for Growing Sydney***, in that it will:

- provide much needed transport infrastructure to service the 'global economic corridor' and the Northern Beaches Hospital Precinct;
- deliver additional much needed transport facilities to service northern Sydney's growing population, which will provide greater benefits to the overall productivity of Sydney;
- support the goal of growing a competitive economy by delivering world-class transport services;
- it will help to achieve the goal of "a great place to live with communities that are strong, healthy and well connected";
- it relates to a strategically well-located site which is readily accessible;
- it will grow Sydney's economy; and
- not have any significant environmental impacts.

5.1.2 Draft North District Plan

The Greater Sydney Commission's District Plans help set out how ***A Plan for Growing Sydney*** will apply to local areas. They outline how the Government will make decisions on public spaces, community facilities, housing, jobs, transport options, schools and hospitals to meet the needs of communities across Greater Sydney. The subject site is situated within the area that the ***Draft North District Plan*** applies.

The Planning Proposal has been addressed in relation to the vision, priorities and actions of the North District Plan.

In Section 3.1.1 Access to Jobs of the ***Draft North District Plan*** it states:

> *"On the Northern Beaches, access to jobs is relatively constrained. Addressing this challenge requires investigations of both east-west and north-south transit improvements and the attraction of local business investment and activity."*

The proposed development facilitated by this planning proposal supports the ***Draft North District Plan*** in that it will provide better and more frequent bus transport which will enable centres to be better connected and improve access to jobs.

Section 3.5 of the ***Draft North District Plan*** Focuses on "Prioritising Northern Beaches Hospital as the catalyst for a new centre". The proposed development will facilitate the development of this centre by providing better access to and from it.

In Section 3.6 and Section 3.7 it focuses on "Accessing a greater number of metropolitan jobs and centres within 30 minutes" and "Accessing local jobs, goods and services within 30 minutes" respectively. Specifically, within Section 3.7 it outlines "Transport for NSW is delivering and investigating opportunities to create better transport connections to strategic and district centres" including improving the frequency and performance of existing rapid bus routes.

The proposed development specifically assists in achieving this key priority of the ***Draft North District Plan*** and will improve the frequency of buses along key bus routes.

The transport services that will be provided by this Planning Proposal are therefore vital to unlocking the economic opportunities highlighted in the draft plan and for improving access to jobs. For the reasons outlined herein, the Planning Proposal is consistent with the ***Draft North District Plan.***

5.2 State Legislation

5.2.1 Environmental Planning and Assessment Act 1979

The Environmental Planning and Assessment Act 1979 (the EP&A Act) and the Environmental Planning and Assessment Act 2000 (EPA Reg) set out, amongst other things, the:

- requirements for rezoning land;
- requirements regarding the preparation of a local environmental study as part of the rezoning process;
- matters for consideration when determining a development application; and
- approval permits and/or licences required from other authorities under other legislation.

Ministerial directions under Section 117 of the EP&A Act set out a range of matters to be considered when preparing an amendment to a LEP.

The rezoning proposal has been prepared in accordance with the EP&A Act 1979 and EP&A Regulation 2000. The proposal's consistency with the relevant Section 117 Directions is demonstrated in Table 1 below.

Table 1 – Consistency with relevant Section 117 Directions

s.117 Direction Title	Direction Objective	Consistency of Planning Proposal
1.2 Rural Zones	The objective of this direction is to protect the agricultural production value of rural land	No, however inconsistency is justified as per clause (5) of Section 1.2* as the planning proposal is not over rural land of high quality agricultural value.
4.4 Planning for Bushfire Protection	The objectives of this direction are: (a) to protect life, property and the environment from bush fire hazards, by discouraging the establishment of incompatible land uses in bush fire prone areas, and (b) to encourage sound management of bush fire prone areas.	Yes. Please refer to the Bushfire Report contained in the Appendix.
6.1 Approval and Referral Requirements	The objective of this direction is to ensure that LEP provisions encourage the efficient and appropriate assessment of development.	Yes. The proposal does not include provisions that require the concurrence, consultation or referral of development applications to a Minister or public authority.
6.3 Site Specific Provisions	The objective of this direction is to discourage unnecessarily restrictive site specific planning controls.	No, the planning proposal does propose site specific planning controls as it is for a rezoning of 9,000sqm for a particular use being a 'Transport Depot' (Bus Parking Facility) on an existing lot. However inconsistency is justified as per clause (6) of Section 6.3* as the provisions of the planning proposal that are inconsistent are of minor significance.
7.1 Implementation of A Plan for Growing Sydney	The objective of this direction is to give legal effect to the planning principles; directions; and priorities for subregions, strategic centres and transport gateways contained in A Plan for Growing Sydney	Yes. The Planning Proposal demonstrates consistency with the relevant directions of A Plan for Growing Sydney. Please refer to Section 4.1.1 of this report.

* Section 117(2) of the Environmental Planning and Assessment Act 1979

5.2.2 State Environmental Planning Policies

The consistency of the planning proposal with relevant State Environmental Planning Policies (SEPPs) is addressed in the table below.

Table 2 - Consistency with relevant SEPPs

Environmental Planning Instrument	Consistency
SEPP 1 Development Standards	The planning proposal will not contradict or hinder application of this SEPP.

SEPP 4 Development Without Consent and Miscellaneous Exempt and Complying Development	Not applicable.
SEPP 6 Number of Storeys in a Building Consistent	The Planning Proposal does not propose controls for numbers of storeys.
SEPP 14 Coastal Wetlands	Not applicable
SEPP 15 Rural Landsharing Communities	Not applicable
SEPP 19 Bushland in Urban Areas	Not applicable
SEPP 21 Caravan Parks	Not applicable
SEPP 22 Shops and Commercial Premises	Not applicable
SEPP 26 Littoral Rainforests	Not applicable
SEPP 29 Western Sydney Recreation Area	Not applicable
SEPP 30 Intensive Agriculture	Not applicable
SEPP 32 Urban Consolidation (Redevelopment of Urban Land)	Not applicable
SEPP 33 Hazardous and Offensive Development	Not applicable
SEPP 36 Manufactured Home Estates	Not applicable
SEPP 39 Spit Island Bird Habitat	Not applicable
SEPP 41 Casino Entertainment Complex	Not applicable
SEPP 44 Koala Habitat Protection	Not applicable
SEPP 47 Moore Park Showground	Not applicable
SEPP 50 Canal Estate Development	Not applicable
SEPP 52 Farm Dams, Drought Relief and Other Works	Not applicable
SEPP 55 Remediation of Land.	Not applicable
SEPP 59 Central Western Sydney Economic and Employment Area	Not applicable
SEPP 60 Exempt and Complying Development	Not applicable.
SEPP 62 Sustainable Aquaculture	Not applicable
SEPP 64 Advertising and Signage	Not applicable
SEPP 65 Design Quality of Residential Flat Development	Not applicable
SEPP 70 Affordable Housing (Revised Schemes)	Not applicable
SEPP 71 Coastal Protection	Not applicable
SEPP (Affordable Rental Housing) 2009	Not applicable
SEPP (Building Sustainability Index: BASIX) 2004	Not applicable
SEPP (Exempt and Complying Development Codes) 2008	The Planning Proposal will not contain provisions that would be inconsistent with, or hinder the application of the SEPP.
SEPP (Housing for Seniors or People with a Disability) 2004	Not applicable
SEPP (Infrastructure) 2007	The Planning Proposal will not contain provisions that would be inconsistent with, or hinder the application of the SEPP.
SEPP (Kosciuszko National Park-Alpine Resorts) 2007	Not applicable
SEPP (Kurnell Peninsula) 1989	Not applicable
SEPP (Major Development) 2005	Not applicable
SEPP (Mining, Petroleum Production and Extractive Industries) 2007	Not applicable
SEPP (Miscellaneous Consent Provisions) 2007	Not applicable
SEPP (Penrith Lakes Scheme)	Not applicable
SEPP (Rural Lands) 2008	Not applicable
SEPP (SEPP 53 Transitional Provisions) 2011	Not applicable
SEPP (State and Regional Development) 2011	The proposal is not state or regional development significant infrastructure.

SEPP (Sydney Drinking Water Catchment) 2011	Not applicable
SEPP (Sydney Region Growth Centres) 2006	Not applicable
SEPP (Three Ports)	Not applicable
SEPP (Urban Renewal) 2010	Not applicable
SEPP (Western Sydney Employment Area) 2009	Not applicable
SEPP (Western Sydney Parklands) 2009	Not applicable
Deemed SEPPs	
SREP 8 (Central Coast Plateau Areas)	
SREP 9 Extractive Industry (No 2-1995)	Not applicable
SREP 16 Walsh Bay	Not applicable
SREP 18 Public Transport	Not applicable
SREP 20 Hawkesbury–Nepean River (No. 2-1997)	Not applicable
SREP 24 Homebush Bay Area	Not applicable
SREP 26 City West	Not applicable
SREP 30 St Marys	Not applicable
SREP 33 Cooks Cove	Not applicable
Sydney Regional Environmental Plan (Sydney Harbour Catchment)	Not applicable

5.3 Northern Beaches Council Planning Policies

5.3.1 Warringah LEP and DCP

The proposal's consistency with relevant local planning/development controls are detailed in the table below. It is noted that any controls related to detailed design and layout have not been addressed with this planning proposal and will be addressed with any future development application.

Applicable Provision	Complies?	Comment
Land adjacent to an arterial road	✓	Please refer to the Traffic Report contained in the Appendix.
Bushfire Prone Land	✓	Please refer to the Bushfire Report contained in the Appendix.
Minimum subdivision lot size – 20,000m2	✓	The Planning Proposal is not for subdivision.
– Maximum building height – 8.5 metres	✓	The Planning Proposal does not propose to amend this provision, nor does it propose
Land Slip Risk Map - Area A – Slope less than 5 degrees	✓	The development will not cause significant detrimental impacts because of stormwater discharge from the development site, and (c) The development will not impact on or affect the existing subsurface flow conditions.
Land with frontage to Mona Vale Road – 30 metres	✓	Proposed: The development will not impact of change the existing frontage to Mona Vale Road

5.3.2 Council's Warringah Community Strategic Plan

The Warringah **Community Strategic Plan** 2023 sets out the long-term aspirations of the Warringah community. The plan articulates 6 community outcomes and 22 objectives that sit beneath these outcomes. It also identifies the key pressures that the region is facing which pose a challenge to achieving the outcomes of the Plan.

Sustainable transport is identified as one of these key pressures and the Plan states that the "current public transport system does not adequately service all of Warringah" and "there are limited public transport options". Further, the Plan highlights that the increased demand for access to and from the northern beaches will create more congestion thereby limiting the capacity of the area to "attract employers who create the jobs and deliver the services we need, impacting on the quality of life in the community."

A key outcome of the Community Strategic Plan is to have "Connected Transport" and the plan outlines the "need to shift away from a high dependency on car-based travel to effectively connect with places where we work, learn and play."

This planning proposal will assist in alleviating the transport pressures that the region is facing by providing an increase in transport options that are available. It will provide more frequent bus services thereby directly aligning with the outcome of the Community Strategic Plan to achieve "Connected Transport".

6.0 Assessment of Planning Proposal against NSW Department of Planning and Infrastructure Guidelines

The following section includes an assessment against the requirements in A guide to preparing planning proposals published by the Department of Planning and Infrastructure in August 2016

6.1 Parts 1 and 2

Parts 1 and 2 of the guide have been covered in Section 3.0, which outlines the objectives and intended outcomes of the proposal, as well as how the intended outcomes can be achieved through amendments to the LEP.

6.2 Part 3 - Justification

6.2.1 Need for a Planning Proposal

01 - Is the planning proposal a result of any strategic study or report?

This planning proposal is not the result of any strategic study or report but rather it is a response to an urgent need for bus parking space on the Northern Beaches to enable Forest Coach Lines to meet and service the significant growth in transport needs of the greater Sydney north region.

02 - Is the planning proposal the best means of achieving the objectives or intended outcomes, or is there a better way?

Yes, the Planning Proposal is the best means. There is no better way.

The main objective and intended outcome of this planning proposal for a 'Transport Depot' (Bus Parking Facility) is to enable Forest Coach Lines to meet and service the rapidly growing transport demands of the greater Sydney north region. The current zoning does not allow the development for a 'Transport Depot' to be achieved, which, based on the social and economic benefit analysis and strategic need as outlined in this planning proposal, is shown to be an appropriate outcome for the site. The only way to permit a 'Transport Depot' (Bus Parking Facility) on Lot 123 is to amend the current planning controls in the manner requested in this planning proposal.

6.2.2 Relationship to strategic planning framework

03 - Is the planning proposal consistent with the objectives and actions of the applicable regional or sub-regional strategy (including the Sydney Metropolitan Strategy and exhibited draft strategies)?

The proposed development facilitated by this planning proposal supports the current metropolitan strategy contained in "A Plan for Growing Sydney". This is discussed further in Section 4.1.1.

04 - Is the planning proposal consistent with a council's local strategy or other local strategic plan?

The proposed development facilitated by this planning proposal supports the council's local strategy. This is discussed further in Section 4.1.1.

05 - Is the planning proposal consistent with applicable State Environmental Planning Policies?

Yes. An assessment of the planning proposal against applicable State Environmental Planning Policies (SEPPs) is provided in Table 2 in Section 4.2.2.

Q6 - Is the planning proposal consistent with applicable Ministerial Directions (s. 11 7 directions)?

The planning proposal is consistent with the relevant directions for planning proposals issued by the Minister for Planning under Section 117(2) of the EP&A Act. A full assessment is included in section 4.2.1 of this planning proposal report.

6.2.3 Environmental, social and economic impact

07 - Is there any likelihood that critical habitat or threatened species, populations or ecological communities, or their habitats, will be adversely affected as a result of the proposal?

No, the planning proposal will not result in any impact on critical habitat or threatened species, populations or ecological communities or their habitats.

08 - Are there any other likely environmental effects as a result of the planning proposal and how are they proposed to be managed?

Section 3.3.2 of this report discusses the environmental effects of the planning proposal and how they will be managed. It is concluded that the proposed development will have no adverse traffic, parking, bushfire or acoustic implications, as demonstrated by the accompanying specialist reports.

09 - Has the planning proposal adequately addressed any social and economic effects?

Yes. The proposed development will result in positive economic and social flow-on effects for the local area. The development will provide a much-needed transport service for the community and wider Northern Beaches region. This will strengthen and enhance the economy and the proposed development will hence support the overall viability of the Warringah LGA.

6.2.4 State and Commonwealth Interests

010 - Is there adequate public infrastructure for the planning proposal?

Yes. The site is located in an established urban area, adjoins two busy roads and has access to a range of existing utilities and services including a bus stop adjacent to the Myoora Road site frontage. Further investigations will be undertaken as part of the preparation of the Development Application material to ensure that appropriate contributions are made to public infrastructure.

011 - What are the views of State and Commonwealth public authorities consulted in accordance with the Gateway determination?

State and Commonwealth authorities will have the opportunity to provide comment on the planning proposal as part of its formal exhibition. Any future Development Application will be referred to the relevant authorities as required.

6.3 Part 4 - Mapping

Maps of the proposed amendments to the site will be prepared by Council to identify that the 9,000sqm portion of the site that is subject to the additional permitted use as described in Schedule 1 of the LEP.

6.4 Part 5 - Community Consultation

It is noted that confirmation of the public exhibition period and requirements for the planning proposal will be given by the Minister as part of the LEP Gateway determination.

Any future DA for the site would also be exhibited in accordance with Council requirements, at which point the public and any authorities would have the opportunity to make further comment on the proposal.

7.0 Conclusion

This report has been prepared by Suburban Town Planners to support a Planning Proposal to Northern Beaches Council.

The Planning Proposal seeks to include 'Transport Depot' for a Bus Parking Facility, as an additional permitted use under the Warringah LEP 2011-2012, within the western portion of the site at 30 Myoora Road, Terrey Hills, on behalf of Forest Coach Lines over a 9,000sqm area.

This proposal has been prepared diligently in accordance with the recommendations/requirements of Pre - Planning Submission Proposal Meeting 2017-0028 held at NBC, Dee Why on the 4th April, 2017. As well, the document by the Department of Planning, How to prepare a Planning Submission has been diligently followed.

The proposal would deliver a much needed bus transport service to the broader community, as well as providing additional employment and the subsequent economic and social benefit. This assessment has shown that the proposal is consistent with the relevant State and Local Strategies and Environmental Planning Instruments and that the environmental impacts of the development can be suitably managed.

In light of the benefits of the proposal we conclude that the Planning Proposal presents a suitable amendment to the LEP to allow Forest Coach Lines to deliver much-needed transport services and should be supported by Council and processed through the Department of Planning Gateway System.

Consistencies with State Environmental Planning Policies (SEPP) and Section 117 Direction

Consistency with SEPP's	Applicable	Consistent
SEPP No 1 – Development Standards	YES	YES
SEPP No 14 – Coastal Wetlands	NO	N/A
SEPP No 19 – Bushland in Urban Areas	YES	YES
SEPP No 21 – Caravan Parks	YES	YES
SEPP No 26 – Littoral Rainforests	NO	N/A
SEPP No 30 – Intensive Agriculture	YES	YES
SEPP No 33 – Hazardous and Offensive Development	YES	YES
SEPP No 36 – Manufactured Home Estates	NO	N/A
SEPP No 44 – Koala Habitat Protection	YES	YES
SEPP No 47 – Moore Park Showground	NO	N/A
SEPP No 50 – Canal Estate Development	YES	YES
SEPP No 52 – Farm Dams and Other Works in Land and Water Management Plan Areas	NO	N/A
SEPP No 55 – Remediation of Land	YES	NO
SEPP No 62 – Sustainable Aquaculture	YES	YES
SEPP No 64 – Advertising and Signage	YES	YES
SEPP No 65 – Design Quality of Residential Flat Development	YES	YES
SEPP No 70 – Affordable Housing (Revised Schemes)	YES	YES
SEPP 71 – Coastal Protection	NO	N/A
SEPP (Affordable Rental Housing) 2009	YES	YES
SEPP (Building Sustainability Index: BASIX) 2004	YES	YES
SEPP (Exempt and Complying Development Codes) 2008	YES	YES
SEPP (Housing for Seniors or People with a Disability) 2004	YES	YES
SEPP (Infrastructure) 2007	YES	YES
SEPP (Integration and Repeals) 2016	YES	YES
SEPP (Kosciuszko National Park—Alpine Resorts) 2007	NO	N/A
SEPP (Kurnell Peninsula) 1989	NO	N/A
SEPP (Mining, Petroleum Production and Extractive Industries) 2007	YES	YES
SEPP (Miscellaneous Consent Provisions) 2007	YES	YES

Consistencies with State Environmental Planning Policies (SEPP) and Section 117 Direction

SEPP (Penrith Lakes Scheme) 1989	NO	N/A
SEPP (Rural Lands) 2008	NO	N/A
SEPP (State and Regional Development) 2011	YES	YES
SEPP (State Significant Precincts) 2005	YES	YES
SEPP (Sydney Drinking Water Catchment) 2011	NO	N/A
SEPP (Sydney Region Growth Centres) 2006	NO	N/A
SEPP (Three Ports) 2013	NO	N/A
SEPP (Urban Renewal) 2010	NO	N/A
SEPP (Western Sydney Employment Area) 2009	NO	N/A
SEPP (Western Sydney Parklands) 2009	NO	N/A

Consistency with relevant Section 117 Directions

s.117 Direction	Direction Objective	Consistency of Planning Proposal
1.2 Rural Zones	To protect the agricultural production value of rural land.	No. The Planning Proposal is inconsistent with this s.117 direction as it does not meet the objective of the zoning.
4.4 Planning for Bushfire Protection	The objectives of this direction are: a) To protect life, property and the environment form bush fire hazards, by discouraging the establishment of incompatible land uses in bush fire prone areas b) To encourage sound management of bush fire prone areas.	Yes. A Bushfire Report was submitted with the Planning Proposal and the subject site is cleared with the exception of the Myoora Road property boundary.
6.1 Approval and Referral Requirements	To ensure that LEP provisions encourage the efficient and appropriate assessment of development.	Yes. The Planning Proposal is consistent with this direction as it does not require concurrence, consultation or referral of a Minister or public authority.
7.1 Implementation of *A Plan for Growing Sydney*	Is to give legal effect to the planning principles; directions; and priorities for sub regions, strategic centers and transport gateways contained in A Plan for Growing Sydney.	Yes. The Planning Proposal demonstrates some consistencies with the relevant directions of *A Plan for Growing Sydney.*

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Environmental Health

The Environmental Health Team reviewed the proposal and is mainly concerned with the issue of noise overnight in a location where residences are currently located in close proximity and there is a reasonable expectation of at least overnight residential amenity at this time. Had the proposal been for" business hours" operation there would be minimal concerns. The issues include:

1. **Potential water pollution issues** from the run off from pavement of the areas where busses are parked and serviced – information to be supplied and or condition for DA to deal with this.

2. **Light spill** from 1. Headlights leaving the site in particular properties adjacent in Myoora road 2. Illumination of the depot at night (32 and 28 Myoora Rd) – information to be supplied and or condition for DA. It is noted that the site is currently higher than the Myoora Road roadway; by reducing the access drive in height, and angling the drive way on exit direction light spill can be directed away from the dwellings opposite.

3. **Noise day time and evening**. An acoustic report has been prepared by Rodney Stevens Acoustics 10.5.17 which makes an assessment (only) of general compliance with the Environmental Noise Control Manual (EPA 1985) The presence of high vehicle noise from nearby industry and Mona Vale Road makes this issue of less concern.– information and or condition for DA

4. **The existing dwelling on this site is not part of the noise assessment**. Although not part of the development, as it is under ownership of the same owner and it is assumed all noise issues will be adequately resolved with the occupier of the Dwelling or the Dwelling not occupied.

5. **Noise at night is the most critical issue.** An acoustic report has been prepared by Rodney Stevens Acoustics 10.5.17 -which makes an assessment of **an anticipated noncompliance** with guidelines in regard to Night noise levels as received by a residential receiver at 21 Myoora Rd, by 3dBA (as this is an estimate of noise levels they may in fact be higher(or lower)) – any impact/tonal type noise could increase this deficit by an adjustment of +5dBA to 8dBA where a nuisance and could be more than justifiable.
   It is possible that acoustic treatments on the site (landscape and acoustic walls) may be able to deal with minimising a nuisance; however these have not been addressed at this time. – Information before any approval and or condition for DA (although a condition which cannot be complied with may create issues for Council).

   It is noted that the site is currently higher than the Myoora Road roadway, by reducing the access drive in height; cutting into the site, and with acoustic walls/batters, noise may be able to be reduced of exiting and entry.

6. **Noise from vehicle turning in and exiting** at the road way junction. Educating drivers (as proposed) sounds ideal but is difficult to enforce on a daily/nightly basis. The issue of noisy road vehicles is not a Council issue except where crossing the property boundary and the significant increase of heavy vehicle traffic flow due to an approval to intensify site use. Vehicles slowing, braking; to enter the site and accelerating as they leave is a significant issue compared to vehicles just driving past. **It is proposed that 12 buses will enter the site and 52 exit the site between 10pm and 7am a significant number**.

7. **Premises are currently unsewered**. If approval to pump to sewer can be obtained from Sydney Water this will solve any issue.(otherwise full details on how waste water will be

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dealt with ; such as upgrading the current onsite treatment system, which may need relocating) It is noted a drivers break area is to be provided.

8. No cleaning or maintenance on site is proposed; if this changes provision of a bunded under cover **washing and cleaning area** will be required. (Noise from this operation e.g. pressure cleaning , has not been addressed in the noise report and would increase night noise adversely)

9. Fumes from driving and idling buses are assumed to be diesel and depending on prevailing wind may be an issue at night when adjoining residents might reasonably have bedroom windows open. – information and or condition for DA.

10. Staff vehicle parking and staff noise has not been addressed and would increase the traffic flow onto the site slightly.

Natural Environment and Climate Change

The Catchments Team has no objection to the proposal. Although the dam is tagged by the LPI layer, it is not identified on the 1:25,000 Hornsby Topographical Map therefore it is not Integrated Development.

Council will require compliance with its Water Management Policy, including the provision of water quality treatment and pollution controls, however this will be reviewed at Development Application stage.

No biodiversity comments were received.

Transport & Civil Infrastructure

The Traffic Team does not have any objection on the proposed provision of a bus depot at 30 Myoora Road for the maximum of 60 buses and 55 staff car parking. I understand that the detail parking and internal circulation arrangements will be submitted as a subsequent Development Application.

I add that the traffic implication of the proposal on the intersection of Myoora Road / Mona Vale Road / Forest Way requires the RMS comments and approval.

Development Assessment

Notes from a meeting with Renee Ezzy, Senior Development Officer.

The Development Assessment Team does not support the proposal based on issues with the operation of the business at 4 Myoora Road, namely:

- Traffic and staff parking on site
- Physical movements of the buses
- The need to accommodate staff and buses separately.

It is considered that Forest Coach Lines should find a long term solution to their growth issues in an appropriately zoned location to accommodate the volume of staff and buses they require.