Public Works
Manly Hydraulics Laboratory

# KINCUMBER OVERLAND FLOW STUDY

## FINAL FLOOD STUDY REPORT

Report MHL2196
January 2014

prepared for
Gosford City Council

A division of the Department of Finance and Services

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# Foreword

The Kincumber Overland Flow Study has been prepared in accordance with the New South Wales Government's Floodplain Development Manual (2005). The manual guides implementation of the NSW Government's Flood Prone Land Policy (2005), which aims to reduce the impacts of flooding on communities and existing development, and to ensure that future development is compatible with flood risk.

Under the policy, primary responsibility for floodplain risk management rests with local government. Financial and technical assistance is provided to councils by the NSW Government's Office of Environment and Heritage (OEH).

The Floodplain Development Manual (NSW Government 2005) defines the following steps in the Floodplain Risk Management Process:

- Formation of a Floodplain Risk Management Committee
- Data Collection
- Flood Study Preparation
- Floodplain Risk Management Study Preparation
- Floodplain Risk Management Plan Preparation
- Floodplain Risk Management Plan Implementation.

Gosford City Council has engaged NSW Public Works Manly Hydraulics Laboratory to complete the Flood Study phase of this process to define existing flood behaviour within the study area. The outcomes of the study will provide the basis for the subsequent preparation of a Floodplain Risk Management Study and Plan.

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# 1. Introduction

## 1.1 Preamble

NSW Public Works Manly Hydraulics Laboratory was engaged by Gosford City Council (Council) to undertake the Kincumber Overland Flow Study. The purpose of the study is to define flood behaviour within the study area under existing conditions and provide a basis for the subsequent preparation of a Floodplain Risk Management Study and Plan.

The study is to provide a holistic assessment of flooding within the study area, including integrated investigation of overland and mainstream flood flows, and tidal inundation. Possible future variations in flood behaviour due to climate change are also addressed.

The study has been prepared to meet the objectives of the NSW Government Flood Prone Land Policy. Council has received financial assistance to complete the study under the Commonwealth and State National Disaster Resilience Grants Scheme.

A staged approach to the study has been adopted as outlined below:

- Stages 1-4 – Data Collection, Community Consultation and Hydrologic Modelling
- Stages 5-7 – Hydraulic Model Setup, Calibration and Validation
- Stages 8-9 – Design Flood Estimation and Mapping
- Stages 10-11 – Draft Hazard Categories and Flood Emergency Response Classification
- Stages 12-13 – Draft Flood Study Report
- Stage 14 – Final Flood Study Report.

This report constitutes Stage 14 – Final Flood Study Report.

## 1.2 Study Location

The Kincumber Overland Flow Study area is located in the east of the City of Gosford Local Government Area (LGA) on the NSW Central Coast. The study area encompasses an area of approximately 11 $km^2$, comprising several sub-catchments which drain into Kincumber Broadwater, as shown in Figure 1.1.

The suburb of Kincumber occupies the majority of the study area. Other suburbs include Kincumber South, Bensville and a small portion of Saratoga (Broadwater Drive and Weston Street).

## 1.3 Study Background

Development within the study area may be subject to flooding from three primary sources: elevated water levels in Brisbane Water and Kincumber Broadwater, mainstream flood flows escaping creeks, and overland flood flows.

Gosford City Council, in accordance with the NSW Government's Floodplain Risk Management Process, has requested a flood study to define flood behaviour within the Kincumber area, addressing in particular overland flows. Results will form the basis for a subsequent Floodplain Risk Management Study and Plan, which will identify options to minimise danger to personal safety, reduce flood damage to property, and ensure that future development is compatible with the flood risk.

Previous studies relating to flooding in the study area have included Kincumber Catchment Drainage Investigation (Webb, McKeown and Associates, 1999a), Bensville Urban Investigation Area Trunk Drainage Strategy Study (Webb, McKeown and Associates, 1999b), and Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar, 2010). The drainage studies investigated drainage system capacity, mainstream flooding and selected overland flow paths within portions of the current study area, while the Brisbane Water Foreshore Flood Study investigated flooding along the Brisbane Water shoreline including the foreshores of Kincumber Broadwater.

Results of the Kincumber Overland Flow Study update and supersede previous design flood levels determined in the Kincumber Catchment Drainage Investigation and Bensville Urban Investigation Area Trunk Drainage Strategy Study. The current study assesses flood behaviour due to local catchment flooding only and does not update estuary flood behaviour as assessed in the Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar, 2010).

## 1.4 Study Objectives

In summary, the flood study objectives were to:

- define flood behaviour under historic and existing catchment conditions in the study area, including mainstream and overland flow flooding
- determine flood conditions for the 20%, 10%, 2%, 1% and 0.5% Annual Exceedance Probability (AEP) and Probable Maximum Flood (PMF) design events
- provide information on:
  - flood levels, extents, velocities, flows and preliminary flood planning levels and areas
  - hydraulic categories, provisional hazard categories and preliminary true hazard categories
  - number of properties affected by 1% AEP flood extent and the depth of water over the property
  - tidal inundation extents for existing conditions and for conditions incorporating sea level rise

- undertake sensitivity analysis to assess the possible impacts of:
  - variation in hydrologic and hydraulic model parameters
  - blockages at critical infrastructure
  - changes in rainfall due to climate change
- contribute toward subsequent stages of the floodplain risk management process including provision of a computer model that can be used to assess flood mitigation options.

## 1.5 Study Methodology

The methodology employed in undertaking this study can be summarised as follows:

- site reconnaissance, compilation and review of available information
- identification of additional required data
- community consultation to collect information on historical flood behaviour, identify local flooding concerns and ensure community engagement through the floodplain management process
- set-up of hydrologic and hydraulic models
- calibration, verification and sensitivity testing of historic flood events
- modelling of design events for current conditions
- assessment of flooding impacts
- mapping, reporting and documentation of results.


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KINCUMBER OVERLAND FLOW STUDY
STUDY AREA

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Figure 1.1

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# 2. Site Description

Land use within the Kincumber Overland Flow Study area is primarily residential, with some commercial and industrial areas, and fringing rural zonings. Significant areas of bushland separate the suburbs of Kincumber, Kincumber South, Bensville and Saratoga.

The study area comprises several sub-catchments with a combined area of approximately 11 square kilometres. Drainage characteristics vary throughout the various study sub-catchments (see Figure 2.1), which drain into Kincumber Broadwater via a combination of overland flow, pipe and open channel networks, and small creeks and tidal waterways, the largest being Kincumber Creek. Kincumber Broadwater discharges through Cockle Channel to Brisbane Water which is connected to the Tasman Sea via Broken Bay.

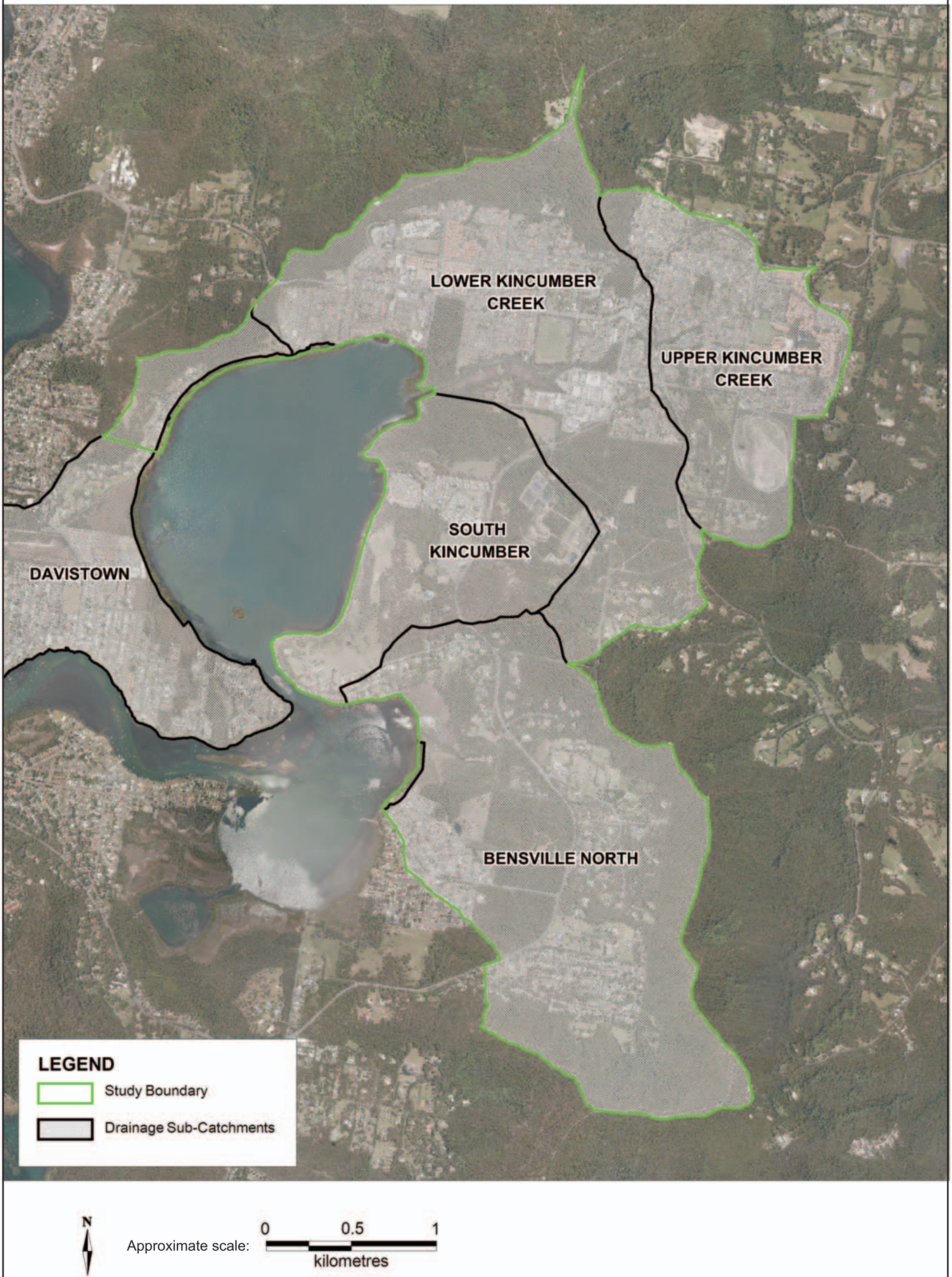
Upstream of Empire Bay Drive, Kincumber Creek is relatively narrow (approximately 4 m wide) and winding. The creek passes through five large culverts at Empire Bay Drive, widening and deepening moving downstream. The creek is approximately 10 m wide at Killuna Road prior to opening out at the Hawke Street boat ramp. Between this opening and Kincumber Broadwater the creek is up to 30 m wide with minimum bed elevations of around -1.5 m AHD.

The majority of the Lower Kincumber Creek sub-catchment is highly urbanised, with significant drainage infrastructure in place. Catch drains act to intercept runoff from Kincumber Mountain Reserve in the north of the catchment while large pit and pipe systems generally direct flow underground beneath developed areas. Within the Upper Kincumber Creek sub-catchment a retarding basin and Patrick Croke Oval act to attenuate flows from the north and west of the sub-catchment respectively and direct flows through underground pipe systems to the upper reach of Kincumber Creek. An open channel system directs flows from the south of the sub-catchment into Kincumber Creek near Water Street.

Runoff in the North Bensville sub-catchment is collected by pipe and open channel systems west of Empire Bay Drive, before passing through culverts under Empire Bay Drive and being directed to Kincumber Broadwater via two main creeks/open channels.

Properties within the Davistown sub-catchment are unlikely to experience significant rainfall-driven flooding issues due to the limited catchment area situated above the existing development.

The study area also includes low-lying foreshore areas which may be affected by high water levels in Brisbane Water. Such events may be driven by tidal and oceanic conditions, and/or large volumes of rainfall. Tidal gaugings undertaken by NSW Public Works MHL between February and May 2004 indicate that Kincumber Broadwater has a reduced tidal range in comparison with Brisbane Water at Booker Bay (MHL 2004).

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KINCUMBER OVERLAND FLOW STUDY
DRAINAGE SUB-CATCHMENTS

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Figure 2.1

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Kincumber Creek
near Killuna Road, Kincumber

Kincumber Creek
at Empire Bay Drive, Kincumber

Kincumber Creek upstream of
Empire Bay Drive, Kincumber

Retarding basin, Oberton Street, Kincumber

Patrick Croke Oval, Melville Street, Kincumber

Concrete-lined flow path between Cullens Road and Water Street, Kincumber

Concrete-lined open channel near Water Street, Kincumber

Large culverts crossing Empire Bay Drive near Bundaleer Crescent, Bensville

Creek crossing at Calool Street, Bensville

# 3. Data Collection

## 3.1 Topographic and Bathymetric Data

A raw LiDAR topographic point data set for the study area was provided by Council. A high resolution (1 m grid) digital elevation model (DEM) derived from the LiDAR data indicated that the point density and post-processing of the data was generally good. Elevation in the study area ranges from 0 m AHD to approximately 189 m AHD at Kincumber Mountain on the northern study boundary.

The following bathymetric and cross-sectional data was also provided by Council for use in the study:

- bathymetric point data for Kincumber Broadwater as used in the Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar 2010)
- cross-sectional survey data for Kincumber Creek upstream of Empire Bay Drive (WMA 2001)
- model cross-sectional data for minor creek upstream of Calool Street, Bensville, as used in the Bensville Urban Investigation Area Trunk Drainage Study (WMA 1999).

No previous bathymetric surveys of Kincumber Creek downstream of Empire Bay Drive could be found. As such, NSW Public Works MHL was engaged to undertake limited bathymetric survey of the creek. The survey was undertaken by boat on 13 November 2012 using Real Time Kinetic (RTK) GPS techniques to capture eight creek cross-sections and regular thalweg depths. Water surface levels measured by RTK were cross-checked against NSW Public Works MHL's Kincumber Creek water level gauge for consistency. The accuracy of the survey is estimated at ± 0.1 m vertical accuracy and ± 0.5 m horizontal accuracy.

The above data sets were used to derive a high resolution topographic and bathymetric DEM (1 m grid) of the study area as shown in Figure 3.1. During flood model development, further interpretation of the data was made based upon site observations and high resolution aerial photography to ensure that narrow features such as open channels were properly represented in the model DEM.

## 3.2 Council Data

### 3.2.1 Geographic Information

A selection of digitally available information was provided by Council in the form of GIS data sets. The data was provided by e-mail and electronic data transfer and assumed to be current for use in this study.

The following Council GIS data have been utilised in the study:

- Cadastre
- Aerial Photography
- LEP Zoning
- Drainage Sub-catchments
- Drainage Pipes
- Drainage Box Culverts
- Drainage Pits
- Drainage Headwalls.

### 3.2.2 Stormwater Drainage Network

During the course of model development, stormwater drainage GIS layers were found to be incomplete in a number of locations. Updated layers covering critical areas were provided by Council, while additional details were derived from works-as-executed plans and site observations. While effort has been made to properly represent all existing drainage structures in the model, the completeness of model drainage layers cannot be guaranteed. Information regarding internal drainage infrastructure was not available for some private developments including Kincumber Nautical Village.

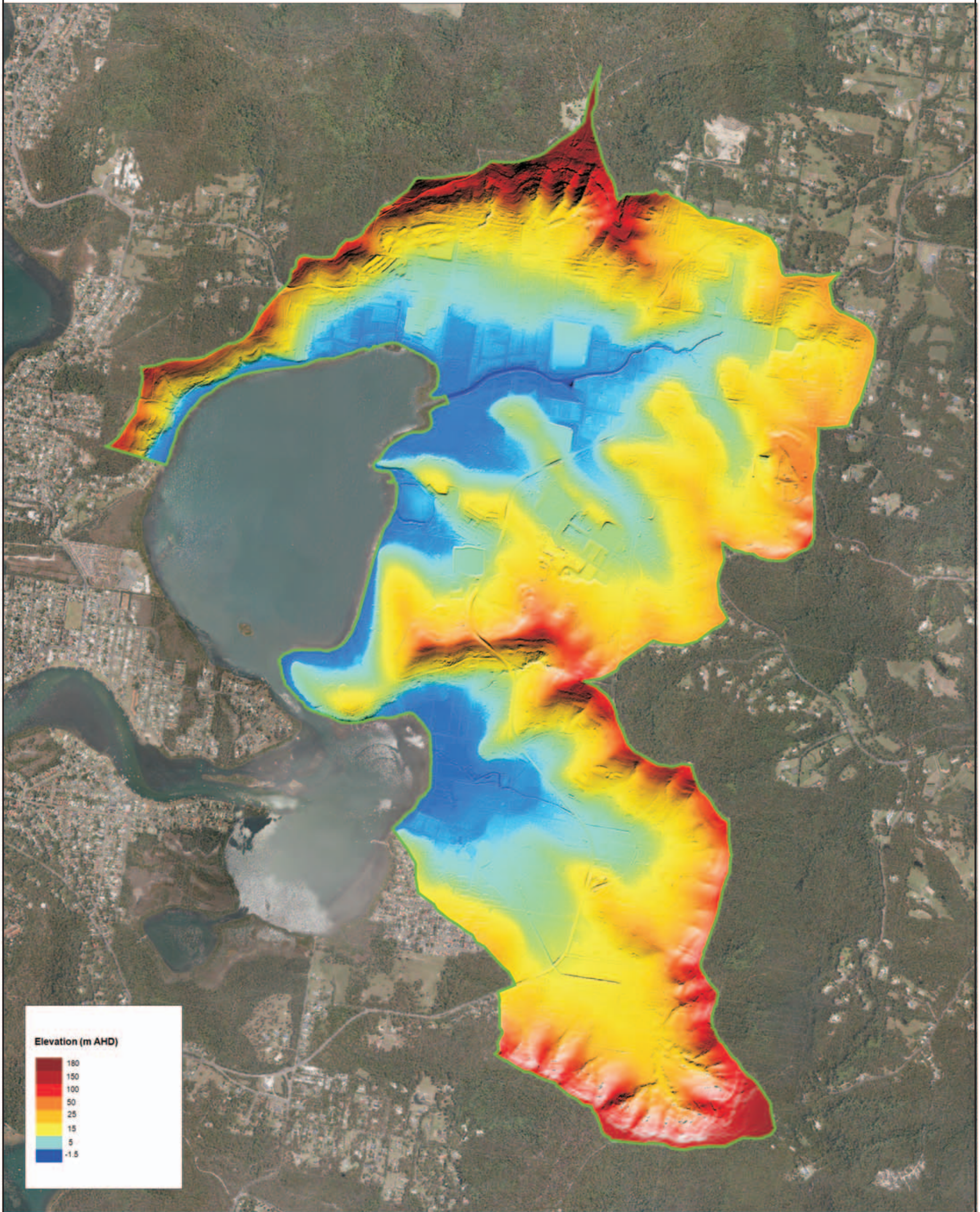
Additionally, details such as pit type, dimensions and depth were not available for all drainage pits. Model assumptions for such pits have been made based on GCC Design Specification for Survey, Road and Drainage Works (Gosford City Council 2008) and general site observations. In a number of instances NSW Public Works MHL made minor adjustments to the locations of pits, pipes and headwalls in GIS layers to conform with aerial photography, topographic information and site observations. Modelled pit depths were also adjusted in some instances to ensure connecting pipes were sloped in the correct direction.

## 3.3 Rainfall and Water Level Data

NSW Public Works MHL operates three continuous rainfall gauges (pluviometers) within the study area as well as a water level gauge in Kincumber Creek. Data from a pluviometer at Avoca, approximately 2.5 km east of the study area, and a water level gauge in Brisbane Water at Koolewong was also utilised. The locations of these gauges are shown in Figure 3.2. No additional gauges operated by other agencies were identified within the study area. Metadata for each gauge is presented in Table 3.1.

**Table 3.1 Gauge Metadata**

| Station Code | Station Name | MHL Client | Start/End Date | Data Type |
|---|---|---|---|---|
| 561148 | Kincumber Mountain | Gosford City Council | 2006–present | Continuous rainfall |
| 561144 | Bensville | Gosford City Council | 2006–present | Continuous rainfall |
| 561139 | Avoca Reservoir | Gosford City Council | 2005–present | Continuous rainfall |
| 561077 | Kincumber | OEH | 1987–present | Continuous rainfall |
| 212458 | Kincumber Creek GFWS | Gosford City Council | 2009–present | 15-minute water level |
| 212422 | Koolewong | OEH | 1985–present | 15-minute water level |




N

Approximate scale: 0 0.5 1 kilometres

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KINCUMBER OVERLAND FLOW STUDY
STUDY AREA TOPOGRAPHY

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Figure 3.1

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KINCUMBER OVERLAND FLOW STUDY
RAINFALL AND WATER LEVEL GAUGE LOCATIONS

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Figure 3.2

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# 4. Community Consultation

## 4.1 Community Consultation Program

A major part of the success of the floodplain management process lies in the effective engagement of the community in its development. Community consultation during this phase of the process has aimed to inform the community about the flood study and to garner information regarding historical flooding events, flooding concerns and ideas on potential floodplain management measures.

The primary components of the consultation process for this study have included:

- newspaper article informing the community of the study
- hosting of a project specific website by NSW Public Works MHL
- provision of information on Council's website
- distribution of an information pack and Community Survey form
- collation and review of Community Survey responses.

## 4.2 Community Flood Survey

### 4.2.1 Overview

In December 2012 a community survey form and supporting information pack was distributed by Council to land owners, residents and businesses within the study area, and was also made available online via Survey Monkey. The survey sought information regarding historical flooding events that may be useful in the calibration and validation of flood models, and also provided an opportunity for the community to contribute their concerns and ideas regarding the management of flooding issues. A copy of the survey form and information pack is included in Appendix B.

A total of 488 responses to the survey were received by Council and forwarded to NSW Public Works MHL along with any accompanying flood photography, while a further 56 responses were received online. Information regarding community flood experience derived from the completed surveys is summarised in Table 4.1.

**Table 4.1 Summary of Community Survey Responses**

| Number of Responses Received | Experienced Property Flooding | | |
|---|---|---|---|
| | No | Yes | House Flooded |
| 544 | 457 | 87 | 9 |

Of the 564 returned community surveys only 46 provided information regarding the date of flood events, of these very few provided specific dates. Flood events prominent in the community survey responses included May 1974, 1984, June 2007, 2010, 2011 (various), and January 2012.

#### 4.2.2 Consideration of Data for Model Calibration

Limited information appropriate for the purposes of flood model calibration was identified from the survey responses. Flood level information was adopted for calibration purposes only as anecdotal evidence, as levels were not substantiated by survey of flood marks or photographic evidence.

Flood level information derived from the survey responses and adopted for use in model calibration is further discussed in Section 6.3.5.

# 5. Numerical Model Development

## 5.1 Modelling Approach

Numerical computer models have been adopted as the primary means of investigating flood behaviour throughout the Kincumber Overland Flow Study area. When used carefully, modern computer models allow simulation of flood behaviour over large areas in a cost efficient and reliable manner.

For this study, the TUFLOW 2D/1D hydraulic modelling software package was selected. TUFLOW was considered suitable to replicate the complex 2D nature of overland flow patterns in the study catchments due to its ability to allow:

- accurate representation of overland flow paths in 2D
- integrated investigation and interaction of overland, mainstream and tidal components
- accurate representation of stormwater drainage components in 1D with dynamic linkage to the 2D model domain
- direct application of rainfall over the study area to simulate development of overland flows (as opposed to applying mainstream flows only)
- production of high quality, GIS compatible flood mapping outputs.

While hydrologic rainfall-runoff processes have been represented within TUFLOW using the direct rainfall approach, a separate hydrologic model has also been developed using the WBNM software to provide additional verification of the TUFLOW flood model operation.

## 5.2 Hydraulic Model

### 5.2.1 Model Extent and Layout

The 2D/1D hydraulic TUFLOW model developed covers all areas of the Kincumber Creek, South Kincumber, Bensville North and Davistown sub-catchments that may influence flood behaviour within the study area. This includes a sufficient distance from the shoreline into Kincumber Broadwater such that the tidal boundary condition does not exert unrealistic influence on flood behaviour within the study area.

The model consists of both a 2D domain and a dynamically linked 1D domain. The 2D domain model flows over the catchment topography using a square grid, while the 1D domain has been used to model drainage pits, pipes and culverts.

The adopted model layout is shown in Figure 5.1.

#### 5.2.2 2D Model Domain and Topography

The 2D hydraulic model domain covers an area of 1330 hectares with a 2 m square grid size, resulting in approximately 3,325,000 computational grid cells.

Each square grid cell contains information on ground surface elevation, hydraulic roughness and rainfall loss rates (see Section 5.2.4). The ground surface elevation is sampled at the centre, mid-sides and corners of each cell from a specified DEM. For a 2 m grid this results in DEM elevations being sampled every 1 m. This resolution was selected in order to accurately represent overland flow paths and open channels in 2D.

The DEM used to sample model ground surface topography was derived from provided LiDAR data. While this data is of a high quality, a lower data point density is achieved in heavily vegetated areas. In such areas DEM values may be interpolated across distances in excess of the TUFLOW grid size, potentially resulting in less accurate representation of smaller scale topographic features. Where topographic features likely to influence overland flow patterns (such as open channels and embankments) were identified within areas of sparser LiDAR coverage, 2D TUFLOW z-shapes were used to ensure that only relevant LiDAR data points were used to interpolate model ground elevations along the feature.

#### 5.2.3 Boundary Conditions

The model boundary conditions consist of the following:

- direct rainfall application over the 2D model domain
- a downstream tidal boundary within Kincumber Broadwater.

The selected location of the tidal boundary is shown in Figure 5.1. The boundary applies a specified time-varying water level and has been placed as far as practical from the downstream of the study area to limit the potential for instability and local forcing of water levels.

#### 5.2.4 Hydraulic Roughness

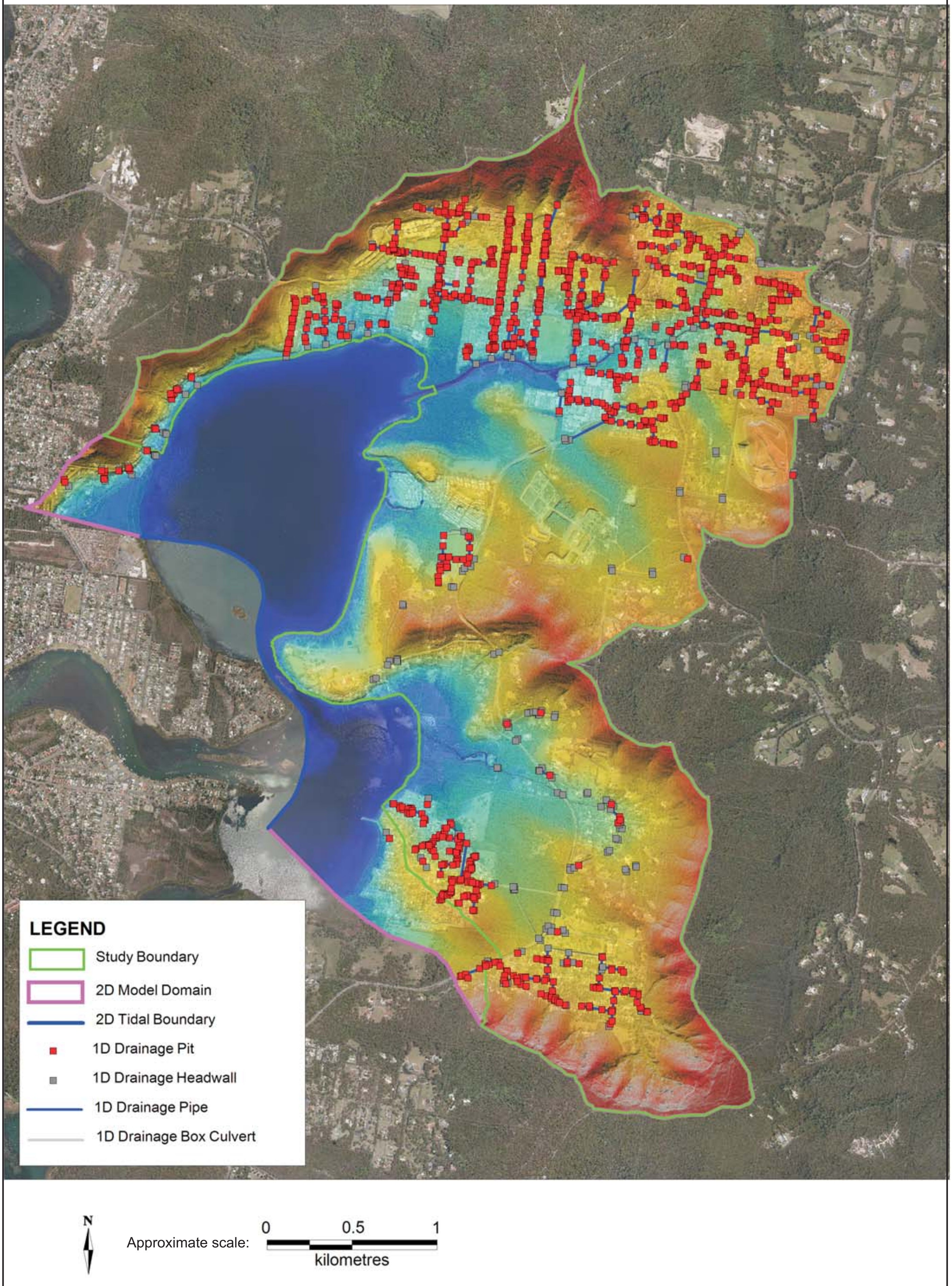
Hydraulic roughness coefficients (Manning's 'n') are used to represent the resistance to flow of different surface materials. Hydraulic roughness has a major influence on flow behaviour and is one of the primary parameters in hydraulic model calibration.

Spatial variation in hydraulic roughness is represented in TUFLOW by delineating the catchment into zones of similar hydraulic properties. The hydraulic roughness zones adopted in this study have been delineated based on consideration of Council LEP zoning, cadastral data, aerial photography and site observations. Factors affecting resistance to flow were of primary importance including surface material, vegetation type and density, and the presence and density of flow obstructions such as buildings, fences and garden beds. Manning's 'n' values assigned to each zone were determined based on site observations, with reference to standard values recommended by Chow (1959). As resistance to flow due to surface and form roughness varies with depth (e.g. Chow 1959, Institution of Engineers Australia 1987), variable depth-dependent hydraulic roughness values have been adopted for this study.

The delineation of hydraulic roughness zones applied in the TUFLOW model is shown in Figure 5.2, and associated Manning's 'n' roughness coefficients provided in Table 5.1. The higher Manning's values are applied at depths below the specified depth range of variable roughness, and the lower Manning's values applied at depths above the specified depth range. At flow depths within the range of variable roughness, applied Manning's values are determined by linear interpolation.

**Table 5.1  Adopted Manning's 'n' Hydraulic Roughness Coefficients**

| Material | Depth range of variable roughness (m) | Manning's 'n' |
|---|---|---|
| Estuary | 0.1–0.5 | 0.03–0.013 |
| Creek | 0.2–1.0 | 0.05–0.03 |
| Open channel – vegetated | 0.2–1.0 | 0.08–0.05 |
| Open channel - concrete | 0.1–0.5 | 0.035–0.02 |
| Residential – low density | 0.1–0.5 | 0.075–0.05 |
| Residential – medium density | 0.1–0.5 | 0.1–0.075 |
| Residential – high density | 0.1–0.5 | 0.4–0.2 |
| Commercial / Industrial | 0.3–1.5 | 0.15–0.075 |
| School Grounds | 0.3–1.5 | 0.15–0.06 |
| Open Space | 0.05–0.25 | 0.07–0.04 |
| Vegetation – medium density | 0.3–1.5 | 0.1–0.06 |
| Vegetation – high density | 0.5–2.5 | 0.1–0.08 |
| Tidal mudflat | 0.5–2.5 | 0.05–0.03 |
| Mangroves | 1.0–5.0 | 0.07–0.03 |

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KINCUMBER OVERLAND FLOW STUDY
TUFLOW MODEL SETUP

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Figure 5.1

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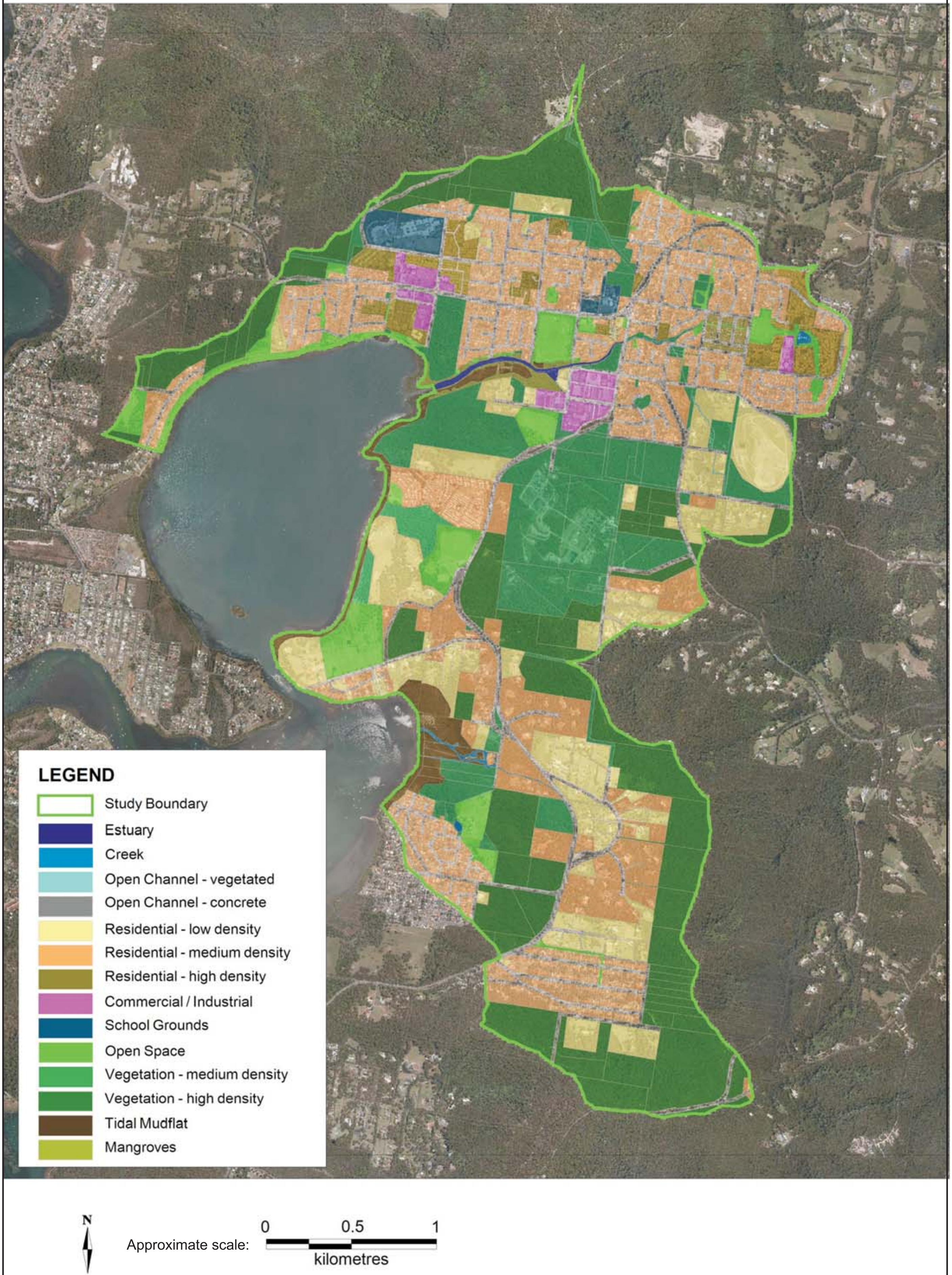


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KINCUMBER OVERLAND FLOW STUDY
HYDRAULIC ROUGHNESS ZONES

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Figure 5.2

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# 6. Model Calibration and Validation

## 6.1 Methodology

Model calibration is an essential step in the flood modelling process to confirm that the model can adequately simulate historical flood events. In order to carry out model calibration it is necessary to have available suitable recorded data sets against which to evaluate model results. Selection of appropriate historical events for model calibration is, therefore, largely dependent on the availability of relevant flood data.

The most reliable recorded flood data available in the study area is the Kincumber Creek water level record. Although recorded depth and flow data are not available higher in the catchment, calibration against the Kincumber Creek water level gauge would indicate that overall model behaviour in the Kincumber Creek catchment is reliable, and provide confidence in the model parameters and data being adopted throughout the study area. The Kincumber Creek water level record, together with recorded rainfall data, therefore act as the primary basis for model calibration, with anecdotal flood depth data collected through community consultation also utilised.

As no recorded flow data is available, NSW Public Works MHL undertook additional model verification through comparison of flow hydrographs computed by TUFLOW with those produced by a WBNM hydrologic model.

## 6.2 Event Selection

Suitable historical calibration and validation events were determined through considering the following criteria:

- the availability of Kincumber Creek water level and continuous rainfall data
- the historical significance of recorded rainfall
- the influence of recorded rainfall on Kincumber Creek water levels, and
- the availability of flood depth data collected through community consultation.

Review of the available historical information highlighted the 5 January 2012 event as the most suitable event for model calibration. This event was selected as the primary calibration event as it was the most significant rainfall event recorded since installation of the Kincumber Creek water level gauge in 2009, and it was one of the most commonly cited events in community survey responses. The 4 November 2010 event was selected for model validation as this was the second most significant rainfall event with Kincumber Creek water levels available.

It is noted that the highest water levels recorded in Kincumber Creek since 2009 - on 6 June 2012 (1.04 m AHD) and 16 May 2010 (0.95 m AHD) - were driven by elevated ocean conditions (a combination of high astronomical tide and storm surge). Rainfall was not a significant contributor to water levels during these events and therefore they were not considered for model calibration.

## 6.3 Model Calibration – 5 January 2012

### 6.3.1 5 January 2012 Event

The rainfall leading to flooding in Kincumber and Bensville on 5 January 2012 fell primarily over a duration of approximately 25 minutes, leading to a short spike in water level in Kincumber Creek. While the intensity of the rainfall event was significant, water levels in the creek remained relatively low due to coinciding neap tide conditions and the short duration of the event relative to the creek's critical storm duration of 90 minutes. The event was, however, cited as causing localised flooding in multiple responses to the community survey. A time-series plot of water level and rainfall data recorded during the event is presented in Figure 6.1.

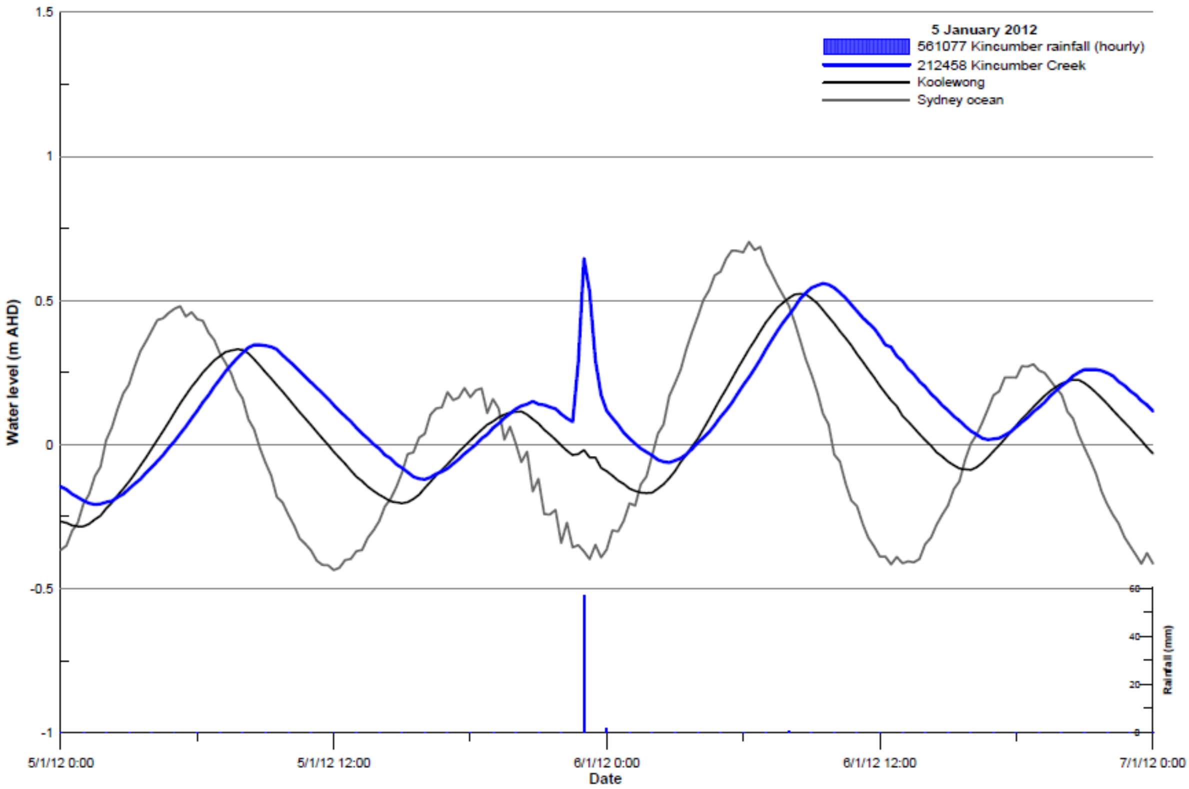



**Figure 6.1 5 January 2012 Event Time-Series**

### 6.3.2 Rainfall Data

Three continuous read gauges (pluviometers) were active within the study area on 5 January 2012, along with a further gauge in neighbouring Avoca. The cumulative rainfall recorded at these gauges during the 30-day period from 7 December 2011 to 6 January 2012 is shown in Figure 6.2.

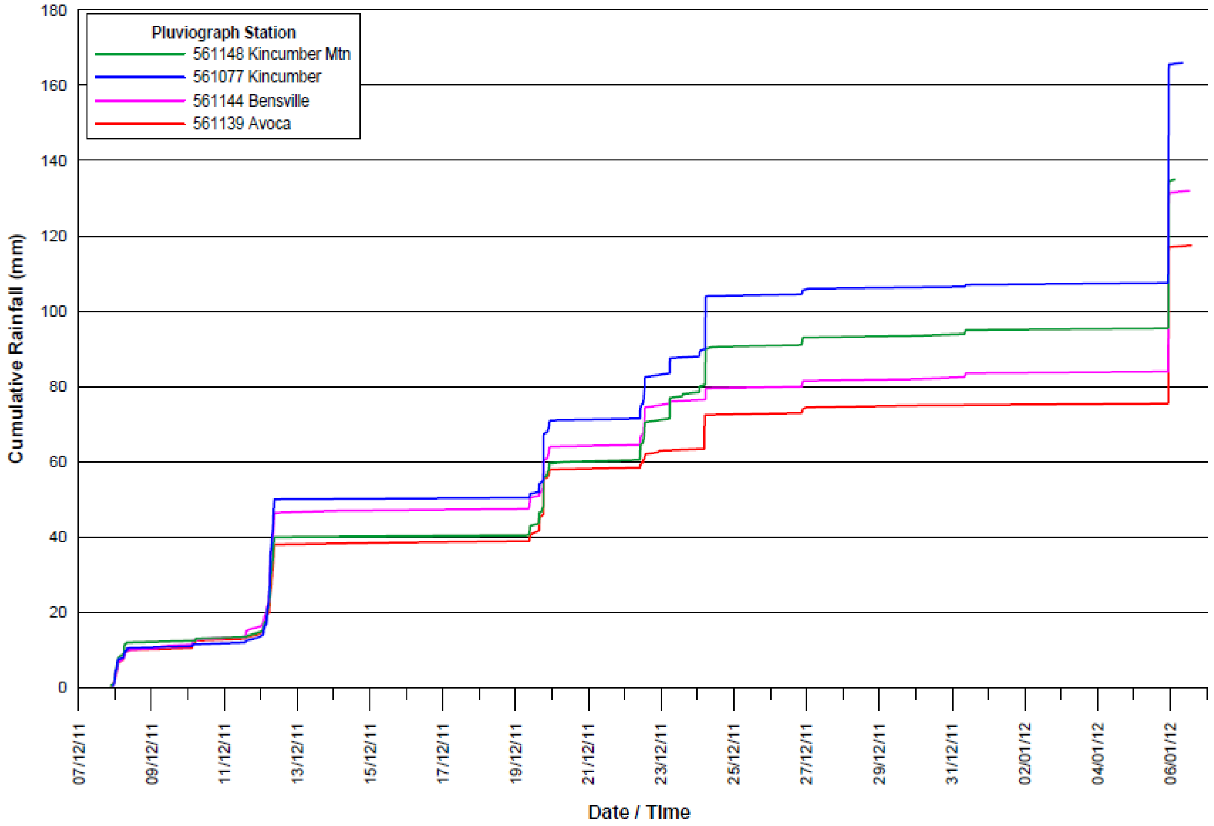



**Figure 6.2 30-Day Cumulative Rainfall to 6 January 2012**

Differences are evident in the rainfall records at each site. While these differences are likely to be the result of real spatial rainfall variability, it is notable that the Kincumber gauge recorded higher totals during a number of rainfall events including 5 January 2012. Rainfall hyetographs for each site depicting average rainfall intensity over the preceding 5-minute period on 5 January 2012 are shown in Figure 6.3.

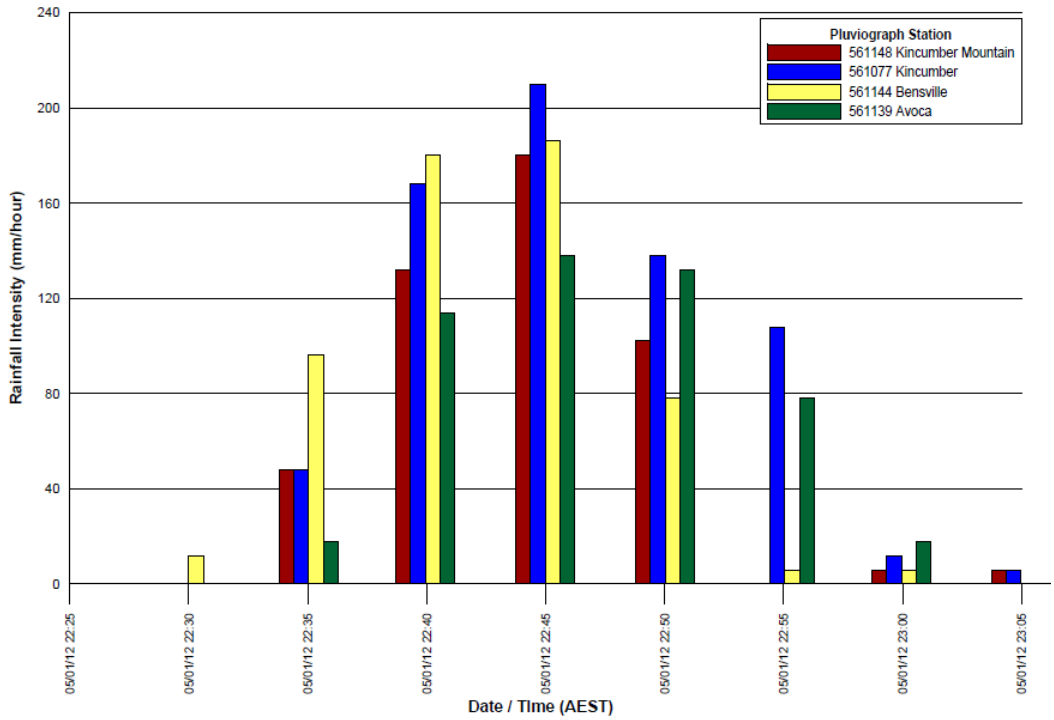



**Figure 6.3 5 January 2012 Rainfall Hyetograph**

The majority of recorded rainfall fell over a period of approximately 25 minutes from 10:30pm to 10:55pm Australian Eastern Standard Time (AEST) – i.e. 11:30pm to 11:55pm Australian Eastern Daylight-Saving Time (AEDT). A BoM Doppler radar image indicating the spatial distribution of rainfall intensity at 10:40pm AEST is shown in Figure 6.4. A pocket of 'heavy' rainfall is evident south-east of Gosford, in the vicinity of Kincumber. The BoM radar image loop indicates that the rainfall moved into the area from the south-west.

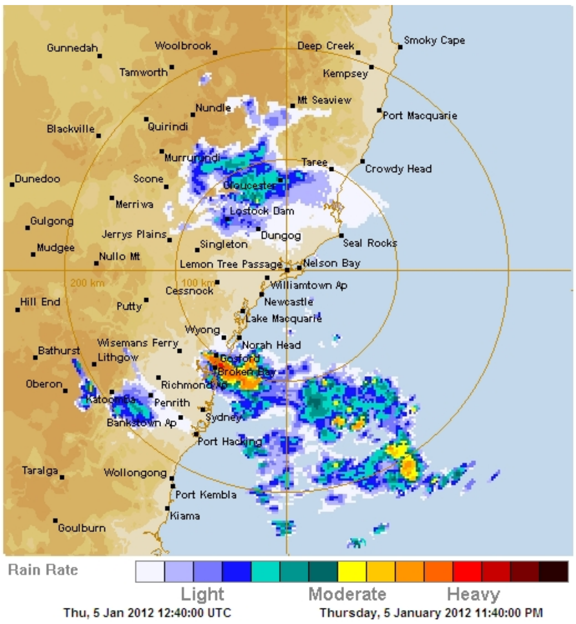



**Figure 6.4 Radar Image - 5 January 2012**
(Source: BoM)

### 6.3.3 Intensity-Frequency-Duration Analysis

In order to provide relative context to the intensity of the 5 January 2012 rainfall event, the maximum rainfall depth recorded over a given duration has been compared with design Intensity-Frequency-Duration (IFD) data for Kincumber, as shown in Figure 6.5. Tabulated comparisons to design rainfall depths are also presented in Table 6.1.

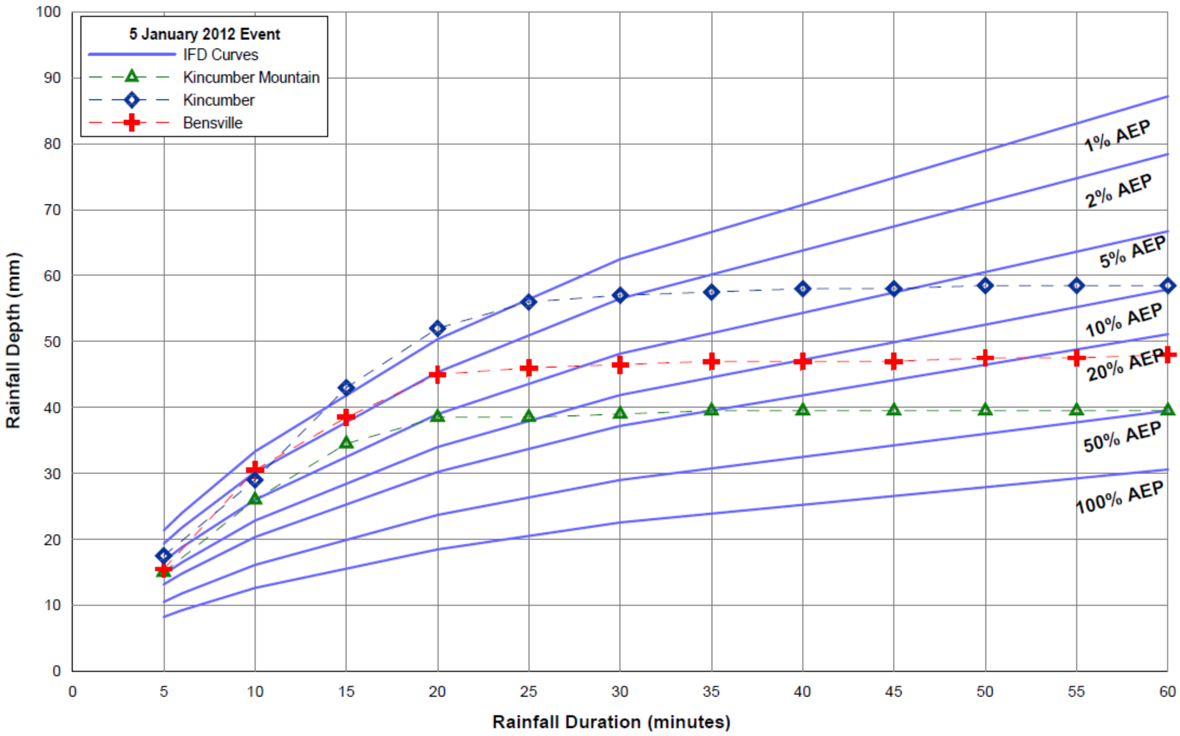



**Figure 6.5 IFD Comparison 5 January 2012**

**Table 6.1 Design Rainfall Comparison 5 January 2012**

| Duration (minutes) | Kincumber Mountain | | Kincumber | | Bensville | |
|---|---|---|---|---|---|---|
| | Recorded Rainfall Depth (mm) | % AEP | Recorded Rainfall Depth (mm) | % AEP | Recorded Rainfall Depth (mm) | % AEP |
| **10** | 26 | 5% AEP | 29 | ~2% AEP | 30.5 | 2% AEP |
| **20** | 38.5 | ~5% AEP | 52 | 1% AEP | 45 | ~2% AEP |
| **30** | 39 | 20% AEP | 57 | 2% AEP | 46.5 | 5-10% AEP |
| **60** | 39.5 | 50% AEP | 58.5 | 10% AEP | 48 | 20-50% AEP |

Based on the Kincumber gauge, the 5 January 2012 event was found to exceed the 1% AEP (100-year ARI) design rainfall curve for durations of 15 and 20 minutes. Rainfall at the Bensville gauge exceeded the 2% AEP design rainfall for durations of 10 to 20 minutes, while the maximum design rainfall exceeded at the Kincumber Mountain gauge was the 5% AEP (durations approximately 10 to 20 minutes).

### 6.3.4 Rainfall Loss Parameters

The translation of rainfall into runoff is directly influenced by the antecedent soil moisture conditions throughout the catchment. Rainfall losses are applied in hydrologic modelling to represent the amount of rainfall that does not contribute to runoff, primarily as a result of infiltration processes. The initial loss-continuing loss approach is widely accepted and was adopted in this study.

It should be noted that the initial loss-continuing loss model has been developed for use in traditional hydrologic models which do not consider losses associated with topographic features, for example depression storage. The direct rainfall approach used in this study applies rainfall directly to each model cell and generally results in initial losses associated with small ‘pits’ in the DEM. Research has shown that such losses can be of the same order as traditionally adopted initial loss values (Taaffe et al. 2011).

As shown in Figure 6.2, approximately 80-100 mm of rain had fallen over the study area during the 30 days leading up to the 5 January 2012 event. Considering antecedent conditions, and the storage associated with small ‘pits’ evident in heavily vegetated areas of the DEM, no initial losses were applied in the TUFLOW model for this event. A continuing loss value of 5.7 mm/hr was adopted for pervious areas, as per the mean derived loss rate for the Hunter region presented in Australian Rainfall and Runoff (AR&R, Institution of Engineers Australia 1987). No losses were applied to impervious or permanently wet areas (i.e. road, concrete channel, creek and estuary zones).

### 6.3.5 Kincumber Broadwater Tidal Boundary

NSW Public Works MHL’s water level gauges at Koolewong and Kincumber Creek were both operational during the 5 January 2012 event, however neither water level record is directly representative of tidal conditions in Kincumber Broadwater. Water levels in Kincumber Broadwater differ from those recorded at the gauge sites as follows:

- Koolewong – water levels in Kincumber Broadwater have been shown to have a slightly reduced tidal range in comparison to Brisbane Water at Koolewong, and exhibit a lag in tidal peaks of 45 minutes to 1 hour (MHL 2004).
- Kincumber Creek – catchment flows have a far stronger influence on water levels in Kincumber Creek in comparison to their effect on Kincumber Broadwater and Brisbane Water (e.g. Cardno Lawson Treloar 2010).

In order to develop a tidal condition representative of Kincumber Broadwater, a tidal prediction free from catchment flooding was created based on the Kincumber Creek water level record. The predicted tide was calculated using harmonic analysis after Foreman (1977). Minor adjustment of the tidal prediction was needed to match recorded tidal conditions in Kincumber Creek prior to flooding on 5 January 2012. The applied tidal boundary is included in Figure 6.7.

### 6.3.6 Kincumber Creek Bathymetric Condition

Results of preliminary calibration runs indicated that a key factor in model calibration against the Kincumber Creek water level gauge would be the stage-discharge relationship within the creek. The model stage-discharge relationship is governed primarily by creek bathymetry and hydraulic roughness, as well as tidal boundary conditions and over-bank topography.

Significant scour, particularly of sandy bed materials, can occur in channels subject to high velocity flood flows and may impact the conveyance of the channel. The potential occurrence and impact of scour in Kincumber Creek was therefore investigated.

It was found that in the 90 days prior to the bathymetric survey, undertaken on 13 November 2012, just 66 mm of rain had been recorded at the Kincumber gauge, compared with 319.5 mm in the 90 days prior to the 5 January 2012 event. Under the low flow, low energy conditions preceding the bathymetric survey, it is likely that accretion of sediment would have occurred. Based on observations of bed materials upstream of Empire Bay Drive, it is expected that deposited materials would comprise fluvial sand with some gravel and unconsolidated fines, as well as marine sands.

Modelled velocities in Kincumber Creek downstream of Empire Bay Drive for the January 2012 flood event peaked between 1.5 and 1.9 m/s along the channel thalweg, and remained above 1 m/s for over an hour in some locations. Reference to the modified Hjulström diagram (Miedema 2010) presented in Figure 6.6 indicates that velocities of 1 m/s can cause erosion of soils with particle sizes ranging from fine silt to pebble sized gravel. Velocities of the order modelled may also cause erosion of clays, particularly where unconsolidated or of low cohesion. Significant scour of the creek bed may therefore have occurred during the January 2012 event, particularly in the shallower channel section between Empire Bay Drive and the Hawke Street boat ramp

Two bathymetric conditions were therefore simulated as part of the model calibration:

- Kincumber Creek ‘surveyed bathymetry’ – model bathymetry in Kincumber Creek as per survey undertaken on 13 November 2012, with minor smoothing of small localised areas of apparent sediment accumulation
- Kincumber Creek ‘scoured bathymetry’ – ‘surveyed bathymetry’ lowered by 0.05 to 0.1 m between Empire Bay Drive and Hawke Street boat ramp; bathymetry lowered by 0.05 m between Hawke Street boat ramp and Kincumber Broadwater; minor areas lowered by up to 0.15 m.

As the depth at which barriers to scour (such as consolidated clay or bed rock) may occur is not known, only moderate bathymetric changes due to scour were adopted.

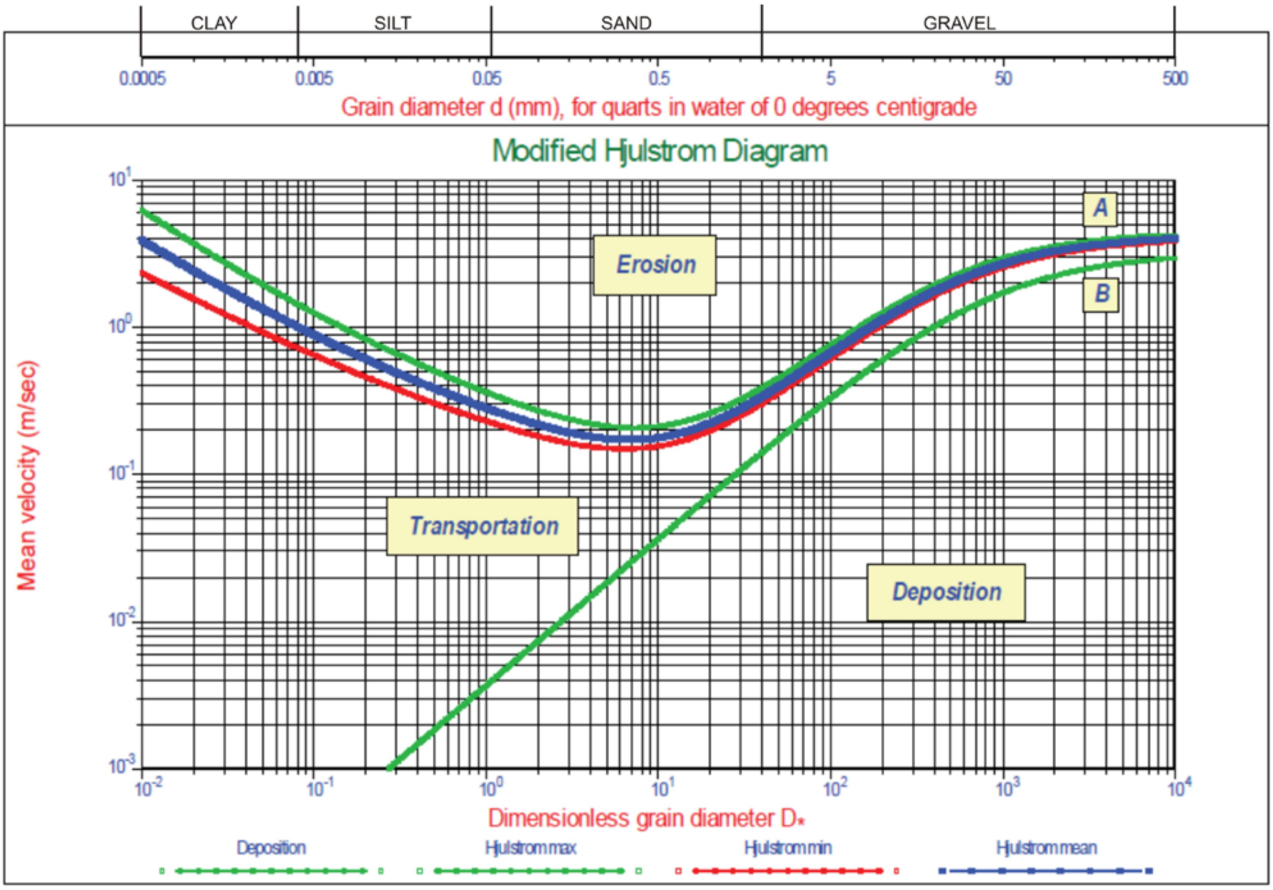



**Figure 6.6 Modified Hjulström Diagram**
**(Source: Miedema, 2010)**

### 6.3.7 Model Calibration Results

#### *6.3.7.1 Comparison with Kincumber Creek Water Level Record*

A comparison of recorded and simulated water levels in Kincumber Creek for the 5 January 2012 event is shown in Figure 6.7. The model results show differences from recorded water levels as follows:

- Peak water levels – while the timing of modelled and recorded flood peaks are in good agreement, the modelled flood peaks are higher than that recorded. This result may suggest differences in either stage-discharge relationship, timing of flow hydrographs, or total flow volume. As Kincumber Creek water levels were recorded only at 15-minute intervals during the event, the actual peak flood level may have been higher than recorded. Extrapolation of the rising and falling limbs of the recorded flood hydrograph provides an estimated flood peak of 0.72 m AHD.
- Catchment runoff response – after a minor lag in initial water level rise, the timing of the modelled flood peaks agree well with recorded levels. Following the flood peak, modelled water levels are slower to fall than recorded levels. Again, these results may suggest differences in either stage-discharge relationship, timing of flow hydrographs, or total flow volume.

As described above, the differences observed between simulated water levels and recorded water levels may be related to model stage-discharge relationship in Kincumber Creek, flow hydrograph timing, or total flow volume. Model inputs that influence these factors can be broken down as follows:

- stage-discharge relationship – creek bathymetry and overbank topography, Manning's roughness, tidal boundary conditions
- timing of flow hydrographs – spatial and temporal rainfall distribution, Manning's roughness, topography, model drainage structures, rainfall loss values
- total flow volume – rainfall distribution, rainfall loss values, topography (storage volume).

It is also possible that there are inaccuracies associated with recorded flood levels.

Given the results of flow hydrograph comparisons for this event (see Section 6.3.7.2), and the successful validation results (See Section 6.4) the primary uncertainties that may influence the results of the calibration are:

- the actual spatial and temporal rainfall distribution during the event, and
- actual bathymetric conditions in Kincumber Creek during the event.

If applied rainfall volumes were to be lowered (e.g. by excluding rainfall data from the Kincumber gauge or reducing the area over which it is applied) and model bathymetry in Kincumber Creek lowered to represent additional scouring, a better calibration result would be achieved. However, no data is available to better inform the actual rainfall distribution and bathymetric conditions occurring during the event.

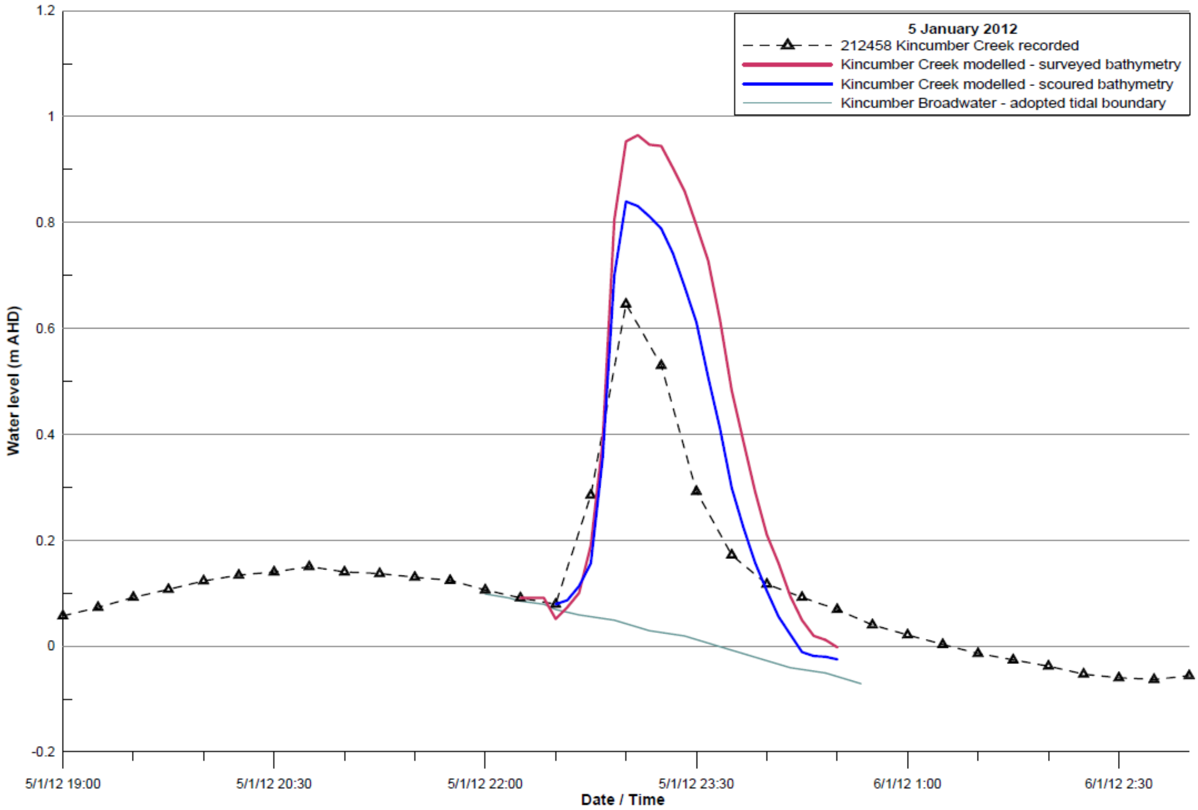



**Figure 6.7 Kincumber Creek Water Level Calibration - 5 January 2012**

#### *6.3.7.2 Comparison of TUFLOW and WBNM Flow Hydrographs*

As no recorded flow data is available in the study area, NSW Public Works MHL undertook additional model verification through comparison of flow hydrographs computed by TUFLOW with those computed by a WBNM hydrologic model. This provided both an additional means of calibrating model parameters, and a check on the proper operation of the direct rainfall method. A comparison of the resulting flow hydrographs at the Kincumber Creek gauge location is shown in Figure 6.8.

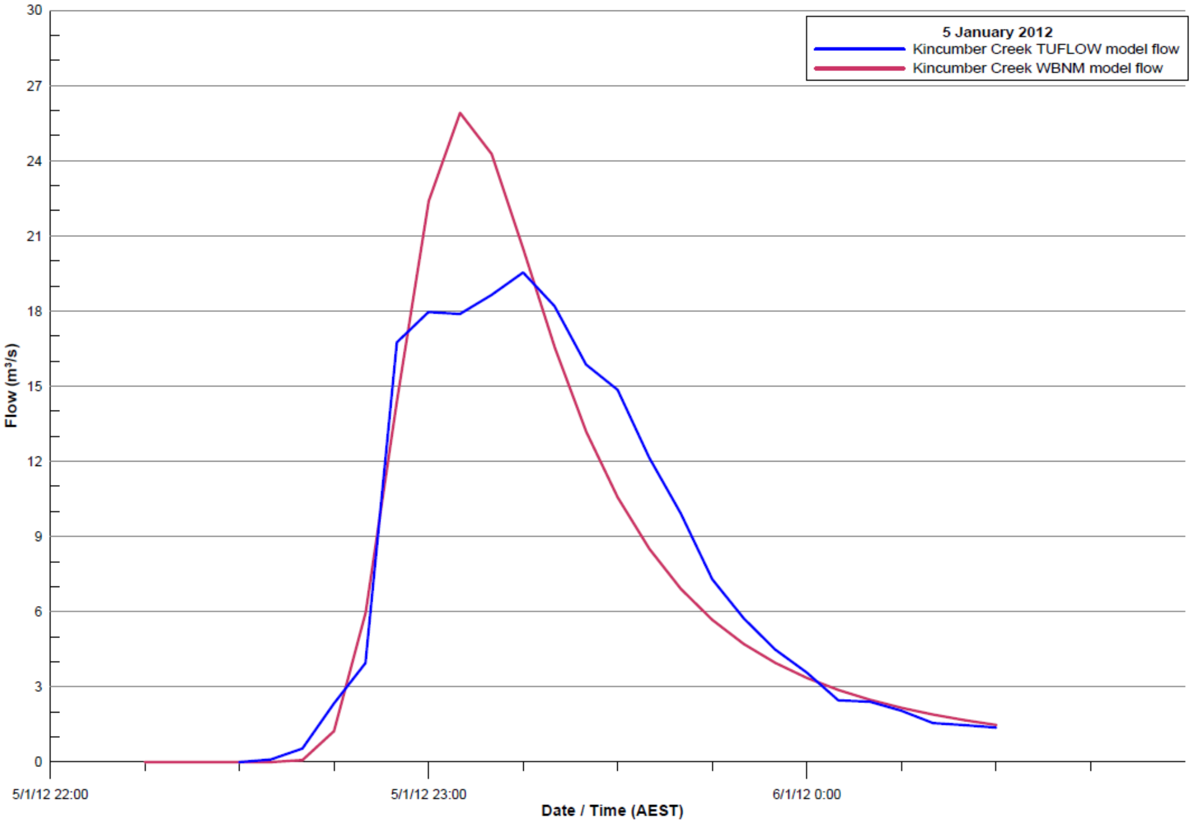



**Figure 6.8 Comparison of Model Flow Hydrographs - 5 January 2012**

The flow hydrographs simulated using WBNM and TUFLOW are in good agreement in terms of total volume and timing of flood flows. Differences in the hydrograph peak and receding-limb are related to storage areas (e.g. Patrick Croke Oval and Oberton Street retarding basin) which attenuate flows in the TUFLOW model but have not been specifically detailed in the WBNM model.

The results indicate that the different principles of operation in each model are converging on a common result. This provides confidence in the catchment runoff response of the TUFLOW model, and shows that volume is being conserved within the rainfall on the grid method.

#### *6.3.7.3 Comparison with Anecdotal Flood Depth Information*

Flood depth information gathered through the community consultation process served as additional anecdotal flood depth data during model calibration. Comparisons between model depth results and received community observations of flood depth for the 5 January 2012 event are presented in Table 6.2.

**Table 6.2 Anecdotal Calibration Results 5 January 2012**

| Location | Date Cited | Observed Flood Depth (m) | Simulated Flood Depth (m) |
|---|---|---|---|
| Calool Street, Bensville | 2012 | Undefined | 0.4 at road crossing |
| Hammond Close, Kincumber | 2012 | 0.1 | 0.11 |
| Humphreys Road, Kincumber South | 6 January 2012 | 0.02 (house) | 0.1 (in yard) |
| Kooreal Street, Kincumber | 2012 | 0.4 | 0.24 |
| Mathew Street, Kincumber | January 2012 | 0.1 | 0.1 |
| Algona Avenue, Kincumber | 5 January 2012 | 0.1 (ground)-1.0 (roadside ditch) | 0.06-0.5 |
| Algona Avenue, Kincumber | March 2012 | 0.1 | 0.11 |
| Wards Road, Bensville | 5 January 2012 | >0.2 | 0.2 |
| Wallan Road, Kincumber | November 2012 | 0.12 | 0.16 |

While results are difficult to compare due to uncertainties regarding the specific date, location and accuracy of observed flood depths, the results in Table 6.2 show a reasonable agreement between observed and simulated flood depths.

Local discrepancies in flood level may be influenced by structures such as fences, or blockage of pits and pipes, which it is unfeasible to model in specific detail throughout the study area. The effects of fences on broader scale flow patterns have been allowed for in determining Manning's roughness values for areas of residential land use. A further complication in comparisons is the uncertainty in determining actual spatial and temporal rainfall distribution for the event.

## 6.4 Model Validation – 4 November 2010

### 6.4.1 4 November 2010 Event

Rainfall in the study area on 4 November 2010 fell primarily over a duration of approximately 4 hours, with the bulk of the rainfall occurring between 7:30 pm and 9:30 pm. This lead to a sharp rise in Kincumber Creek water levels from 8:30 pm, peaking at around 9:15 pm. While the intensity of the rainfall event was less significant than 5 January 2012, higher creek water levels were reached, primarily due to the higher tide coinciding with the event. A time-series plot of water level and rainfall data recorded during the event is presented in Figure 6.9.

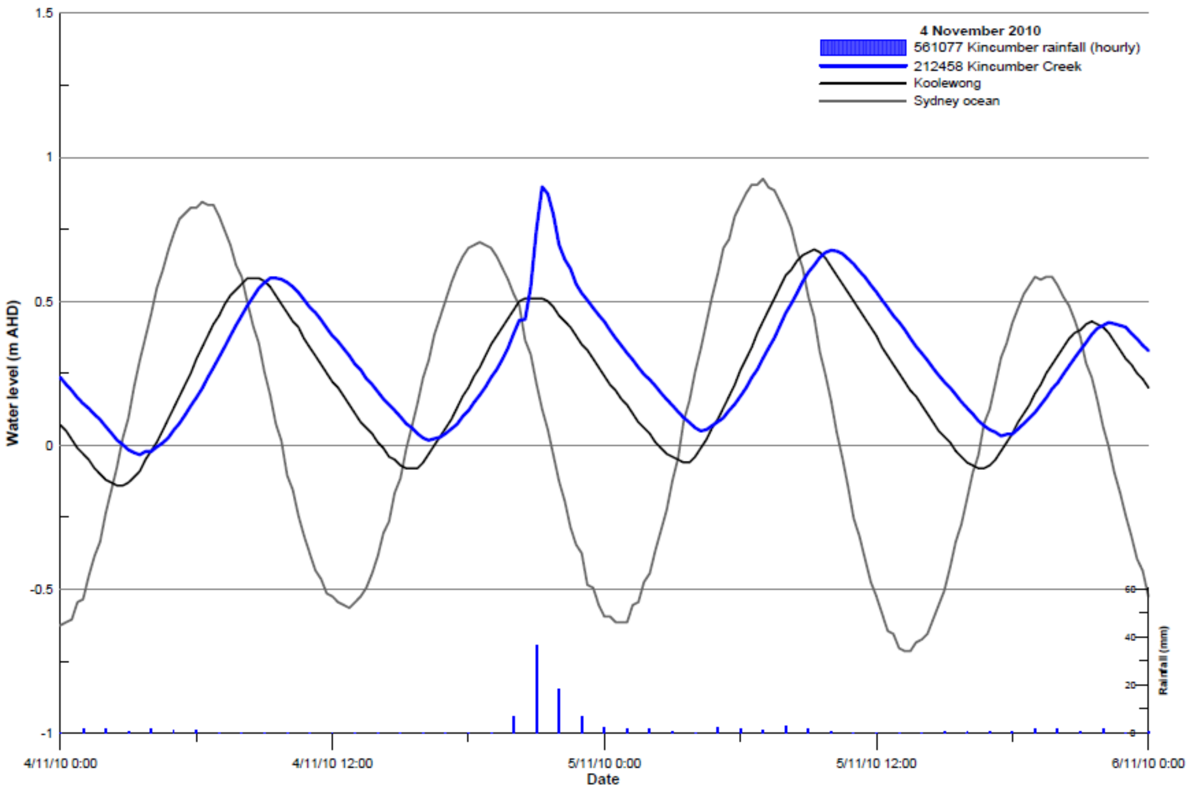



**Figure 6.9 4 November 2010 Event Time-Series**

### 6.4.2 Rainfall Data

Two pluviometers were active within the study area on 4 November 2010, along with the nearby gauge at Avoca Reservoir. No rainfall data was available from the Bensville gauge during this event. Rainfall hyetographs for the available sites depicting average rainfall intensity over the preceding 5-minute period on 4 November 2010 are shown in Figure 6.10.

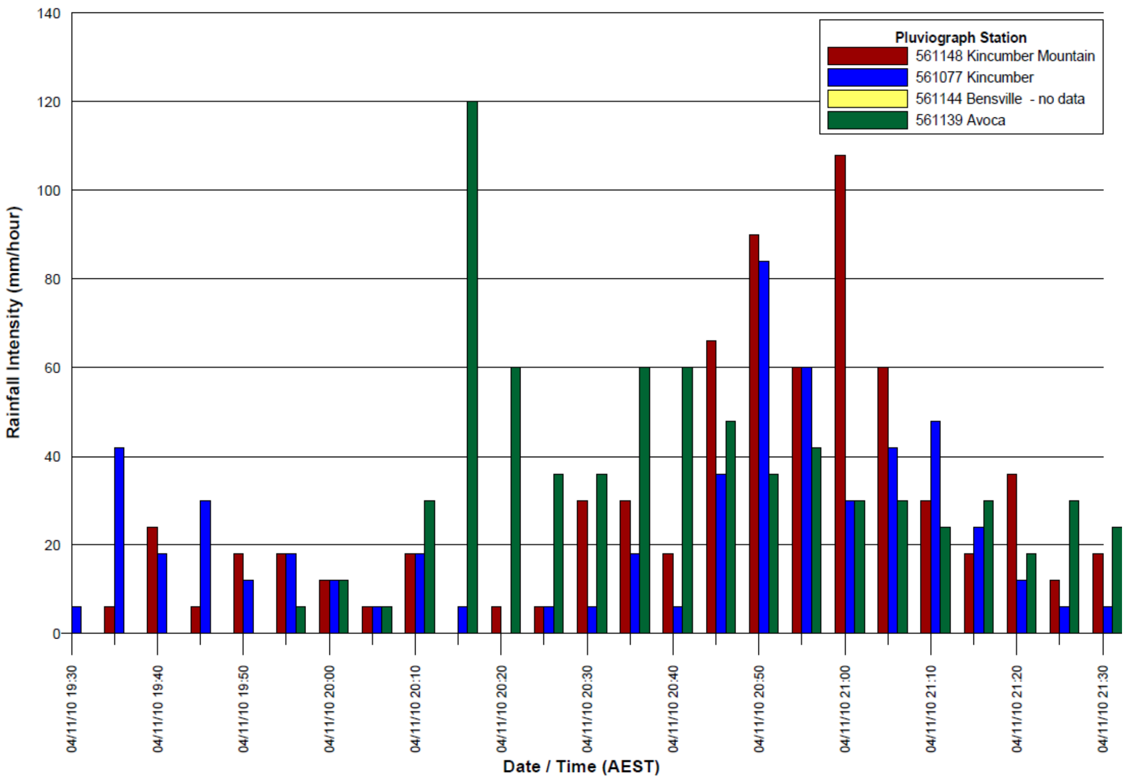



**Figure 6.10 4 November 2010 Rainfall Hyetograph**

### 6.4.3 Intensity-Frequency-Duration Analysis

In order to provide relative context to the intensity of the 4 November 2010 rainfall event, the maximum rainfall depth recorded over a given duration has been compared with design Intensity-Frequency-Duration (IFD) data for Kincumber, as shown in Figure 6.11 and summarised in Table 6.3.

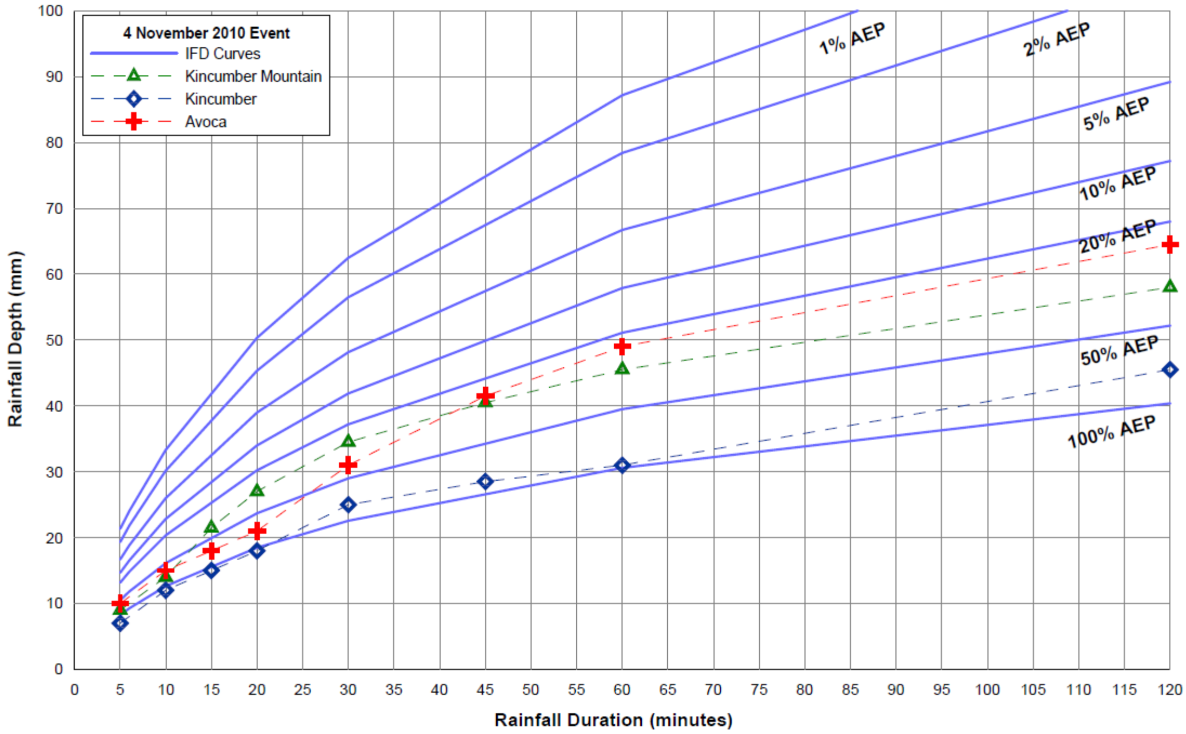



**Figure 6.11 IFD Comparison 4 November 2010**

**Table 6.3 Design Rainfall Comparison 4 November 2010**

| Duration (minutes) | Kincumber Mountain | | Kincumber | | Avoca | |
|---|---|---|---|---|---|---|
| | Recorded Rainfall Depth (mm) | % AEP | Recorded Rainfall Depth (mm) | % AEP | Recorded Rainfall Depth (mm) | % AEP |
| **10** | 14 | 50-100% AEP | 12 | ~100% AEP | 15 | 50-100% AEP |
| **20** | 27 | 20-50% AEP | 18 | ~100% AEP | 21 | 50-100% AEP |
| **30** | 34.5 | 20-50% AEP | 25 | 50-100% AEP | 31 | 20-50% AEP |
| **60** | 45.5 | 20-50% AEP | 31 | 100% AEP | 49 | 20-50% AEP |
| **120** | 58 | 20-50% AEP | 45.5 | 50-100% AEP | 64.5 | 20-50% AEP |

Recorded rainfall during the 4 November 2010 event approached the 20% AEP design rainfall curve over durations of 1 hour and 2 hours at the Avoca Reservoir gauge (outside the study area). Rainfall at Kincumber Mountain generally tracked between the 50% and 20% AEP design rainfall curves, while at the Kincumber gauge rainfall tracked closely to the 100% AEP design curve.

### 6.4.4 Rainfall Loss Parameters

As per the 5 January 2012 event, no initial losses were applied in the TUFLOW model for this event. A continuing loss value of 2.5 mm/hr was adopted for pervious areas. No losses were applied to impervious or permanently wet areas.

### 6.4.5 Kincumber Broadwater Tidal Boundary

NSW Public Works MHL's water level gauges at Koolewong and Kincumber Creek were both operational during the 4 November 2010 event. In order to develop a tidal condition representative of Kincumber Broadwater, a tidal prediction after Foreman (1977) was created based upon the Kincumber Creek water level record. Minor adjustment of the tidal prediction was needed to match recorded tidal conditions in Kincumber Creek prior to flooding on 4 November 2010. The applied tidal boundary is shown in Figure 6.12.

### 6.4.6 Kincumber Creek Bathymetric Condition

As per the calibration event (see Section 6.3.6), two bathymetric conditions were simulated as part of the model validation:

- Kincumber Creek 'surveyed bathymetry', and
- Kincumber Creek 'scoured bathymetry'.

In the 90 days prior to the 4 November 2010 event just 178.5 mm of rain had been recorded at the Kincumber gauge. Peak model velocities in Kincumber Creek downstream of Empire Bay Drive for this event were generally around 1.2 m/s along the channel thalweg, with localised peaks of up to 1.5 m/s.

Given the preceding low rainfall, sediment accretion may have occurred in the months prior to 4 November 2010. The lower velocities and higher tidal conditions during the event also show less potential to cause scour than the 5 January 2012 event.

### 6.4.7 Model Validation Results

#### *6.4.7.1 Comparison With Kincumber Creek Water Level Record*

A comparison of recorded and simulated water levels in Kincumber Creek for the 4 November 2012 event is shown in Figure 6.12. A strong correlation between simulated and recorded water levels has been achieved in terms of:

- Peak water levels – peak flood levels show a good agreement for this event. While the modelled flood peak occurs marginally later, the surveyed bathymetry scenario peak is within 0.04 m of the maximum recorded level.
- Catchment runoff response – the relative timing of the recorded and simulated water levels also show a strong agreement. The modelled flood hydrograph again shows a minor lag in initial creek level rise, with levels also receding slightly quicker. The difference in the falling-limb may be related to differences in the actual and applied downstream tidal boundary conditions.

The results of the 4 November 2010 validation event provide additional confidence in the ability of the developed TUFLOW model to simulate actual catchment flood behaviour. It can be seen that the bathymetric condition in Kincumber Creek had less influence on results than for the 5 January 2012 event. This is related primarily to the higher tidal boundary condition present during the 4 November 2010 event.

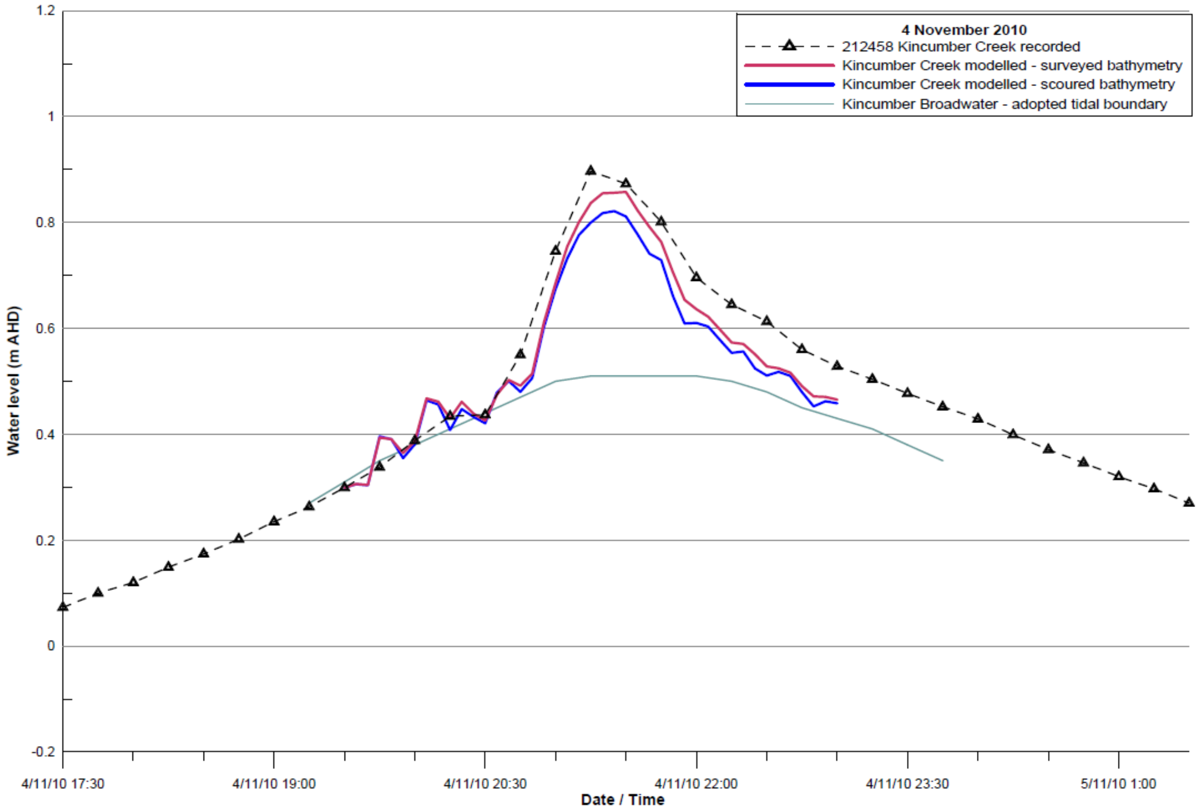



**Figure 6.12 Kincumber Creek Water Level Validation - 4 November 2010**

#### *6.4.7.2 Comparison of TUFLOW and WBNM Flow Hydrographs*

A comparison of flow hydrographs at the Kincumber Creek gauge location computed by TUFLOW and WBNM are shown in Figure 6.13.

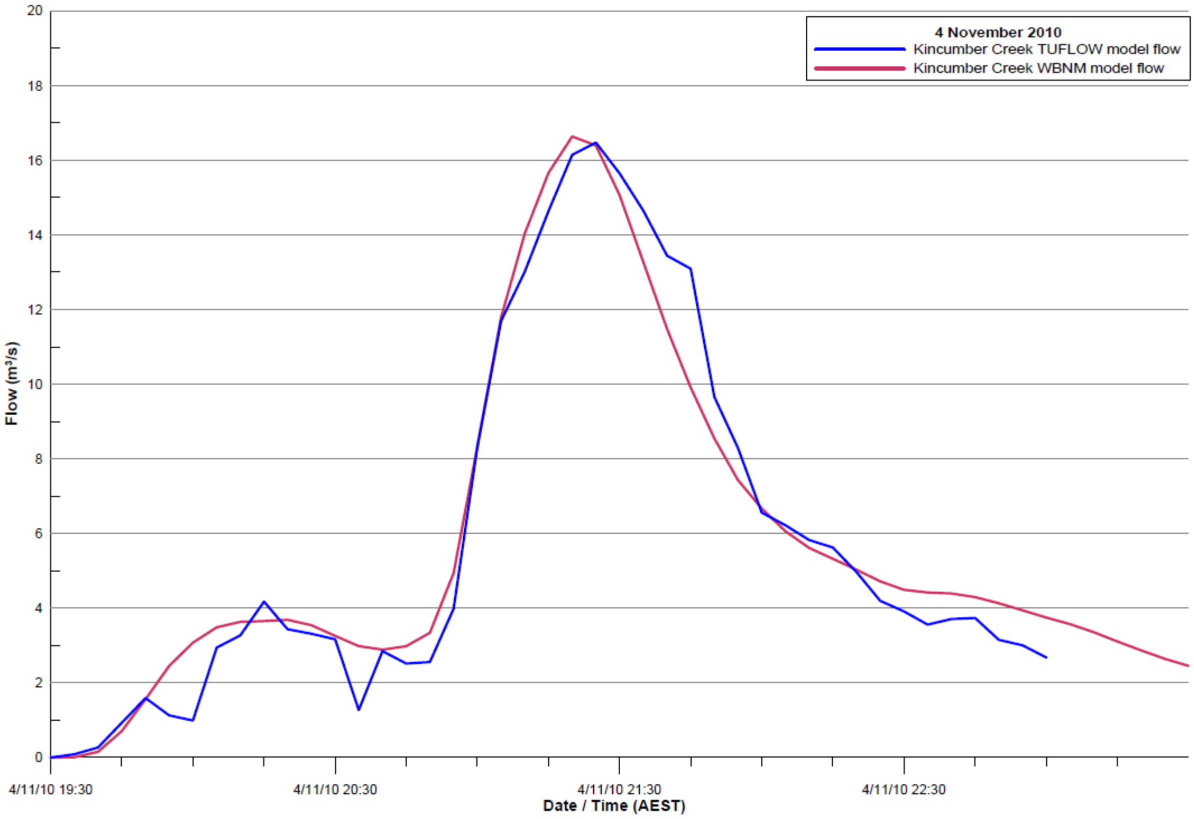



**Figure 6.13 Comparison of Model Flow Hydrographs - 4 November 2010**

The flow hydrographs simulated using WBNM and TUFLOW are in strong agreement in terms of total volume, timing of flood flows and peak flood flow. The results indicate that the different principles of operation in each model are converging on a common result. This provides additional confidence in the catchment runoff response of the TUFLOW model, and shows that volume is being conserved within the rainfall on the grid method.

## 6.5 Discussion of Model Calibration and Validation

Despite the differences in observed and simulated water levels in Kincumber Creek for the 5 January 2012 event, the developed TUFLOW flood model appears to have performed reasonably well. This is supported by good comparisons between simulated and recorded water levels for the November 2010 validation event, and agreement on catchment runoff response shown by flow hydrographs computed by TUFLOW and WBNM.

Discrepancies between simulated and recorded water levels appear to be related primarily to uncertainty regarding actual rainfall distribution, and actual bathymetric conditions in Kincumber Creek during the events. The improved results for the 4 November 2010 event in comparison to the 5 January 2012 event suggest that the influence of bathymetric conditions is reduced in the presence of higher tidal boundary levels. Given that the tidal boundary to be applied to design events (0.63 m AHD) is significantly higher than that coinciding with the 5 January 2012 event (maximum of 0.08 m AHD at the commencement of rainfall), adopted bathymetric conditions in Kincumber Creek will have a diminished influence in design event simulations.

# 7. Design Flood Estimation

## 7.1 Design Flood Events

Design flood conditions are estimated from hypothetical design rainfall events that have a given statistical probability of occurrence. The probability of a design event occurring can be expressed in terms of percentage Annual Exceedance Probability (AEP), and provides a measure of the relative frequency and magnitude of the flood event.

Flood conditions for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP and Probable Maximum Flood (PMF) design events have been investigated in this study.

## 7.2 Design Rainfall

### 7.2.1 Design Rainfall Intensities

Design rainfall depths for the 20% to 1% AEP events have been derived from standard procedures defined in AR&R (1987) for durations from 10 minutes to 6 hours.

The Probable Maximum Precipitation (PMP), used to derive the PMF conditions, has been estimated based on the Generalised Short Duration Method (GSDM) as defined by BoM (2003).

Rainfall depths for the 0.5% AEP event have been derived by interpolation between the 1% AEP and PMP rainfall depths using techniques described in AR&R (1987).

The derived average design rainfall intensities are presented in Table 7.1.

**Table 7.1 Average Design Rainfall Intensities**

| Duration (mins) | Design Event Average Rainfall Intensity (mm/hr) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 20% AEP | 10% AEP | 5% AEP | 2% AEP | 1% AEP | 0.5% AEP | PMP |
| **10** | 125.6 | 140.2 | 159.9 | 185.3 | 204.4 | 223.7 | - |
| **15** | 105.9 | 118.5 | 135.4 | 157.4 | 173.9 | 190.6 | - |
| **20** | 92.9 | 104.2 | 119.3 | 138.9 | 153.7 | 168.7 | - |
| **30** | 76.3 | 85.8 | 98.5 | 115.0 | 127.6 | 140.2 | 412.5 |
| **60** | 52.9 | 59.9 | 69.1 | 81.2 | 90.3 | 99.7 | - |
| **90** | 41.4 | 46.9 | 54.1 | 63.6 | 70.8 | 78.2 | 247.6 |
| **120** | 34.6 | 39.2 | 45.3 | 53.3 | 59.4 | 65.6 | - |
| **180** | 26.8 | 30.5 | 35.2 | 41.4 | 46.2 | 51 | - |
| **270** | 20.8 | 23.6 | 27.3 | 32.2 | 35.9 | 39.6 | - |
| **360** | 17.3 | 19.68 | 22.8 | 26.9 | 30.0 | 33.2 | - |

### 7.2.2 Temporal Rainfall Patterns

Temporal patterns are required to define the distribution of design rainfall over time throughout the duration of a design event. For the 20% to 0.5% AEP design flood events temporal rainfall patterns from AR&R (1987) were adopted. For the PMF, the GSDM temporal pattern (BoM 2003) was adopted.

### 7.2.3 Design Rainfall Losses

The initial loss-continuing loss approach was adopted in this study to represent losses in the rainfall-runoff process.

Zero initial losses have been applied in design modelling. This value has been determined in consideration of the following:

- Traditionally adopted initial loss values incorporate losses due to infiltration, initial storage and other processes. When using the direct rainfall approach with a high resolution DEM, as adopted in this study, losses associated with initial storage are well represented in the 2D domain. Research has shown that such losses can be of the same order as traditionally adopted initial loss values (Taaffe et al. 2011). Initial losses should therefore be lower in a direct rainfall model when compared with a traditional hydrologic model (Institution of Engineers Australia 2012).
- The design rainfalls applied are representative of intense bursts of rainfall. Such bursts generally occur within longer storm events (Institution of Engineers Australia 1987) and therefore it is likely that initial losses will have occurred prior to the start of the design storm burst.

Adopted continuing loss values of between 0 and 2.5 mm/hr have been applied in design modelling depending on the imperviousness of delineated TUFLOW hydraulic roughness zones. These values are consistent with standard recommended values for eastern NSW in AR&R (1987). The continuing loss is directly subtracted from applied model rainfall in TUFLOW.

### 7.2.4 Critical Duration

In order to determine critical storm durations for the study area a series of model runs were undertaken. The WBNM hydrologic model was run for the 1% AEP event for durations between 10 minutes and 6 hours. The critical storm duration required to produce maximum stream flows throughout the catchment was typically found to be 90 minutes. When investigating overland flow flooding, higher peak water levels may occur locally as the result of shorter storm durations, typically between 10 and 30 minutes.

The 1% AEP design event was run in TUFLOW for durations of 10, 30 and 90 minutes to determine the critical durations causing peak flood levels throughout the catchment. Critical durations throughout the study area for the 1% AEP design event are mapped in Figure 7.1.

For the 1% AEP. a duration of 90 minutes was found to be critical throughout the majority of the study area. The 30-minute storm duration was critical in some areas, generally higher in the catchment or in areas with a relatively small contributing catchment area. The 10-minute storm duration was not critical over any significant area. Design flood mapping presented in this report has adopted an ‘envelope’ approach, displaying the maximum of model results for 30-minute and 90-minute design event durations.

## 7.3 Design Boundary Condition – Kincumber Broadwater

The Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar 2010) recommends that the 1% probability of exceedance (PoE) water level is an appropriate downstream boundary condition for any local creek flood study that drains into Brisbane Water. This is based on the assumption that there is little correlation between rainfall-driven flooding in the study catchment and flooding in Brisbane Water.

The 1% PoE level of 0.63 m AHD for Kincumber Creek and Bensville, as determined by Cardno Lawson Treloar (2010), has been adopted in this study as the design boundary water level in Kincumber Broadwater. This 1% PoE level was determined by modelling the propagation of an offshore spring tidal signal with a peak level of 1 m AHD (the offshore tide which is exceeded only 1% of the time based on analysis of Fort Denison data) from Broken Bay into Kincumber Broadwater. As no tidal signal data associated with this level was available, a stationary level was applied. This approach to the design tidal boundary condition is consistent with previous flood studies undertaken for Gosford City Council.

## 7.4 Design Catchment Conditions

Design modelling has been undertaken for the following catchment conditions:

- ‘present’ levels of development as per data provided by Council in 2012
- hydraulic roughness as per that developed for the January 2012 calibration event
- drainage infrastructure as per GIS data layers provided by Council in 2012
- drainage lines and inlets assumed clear
- retarding basins assumed empty at start of design events.

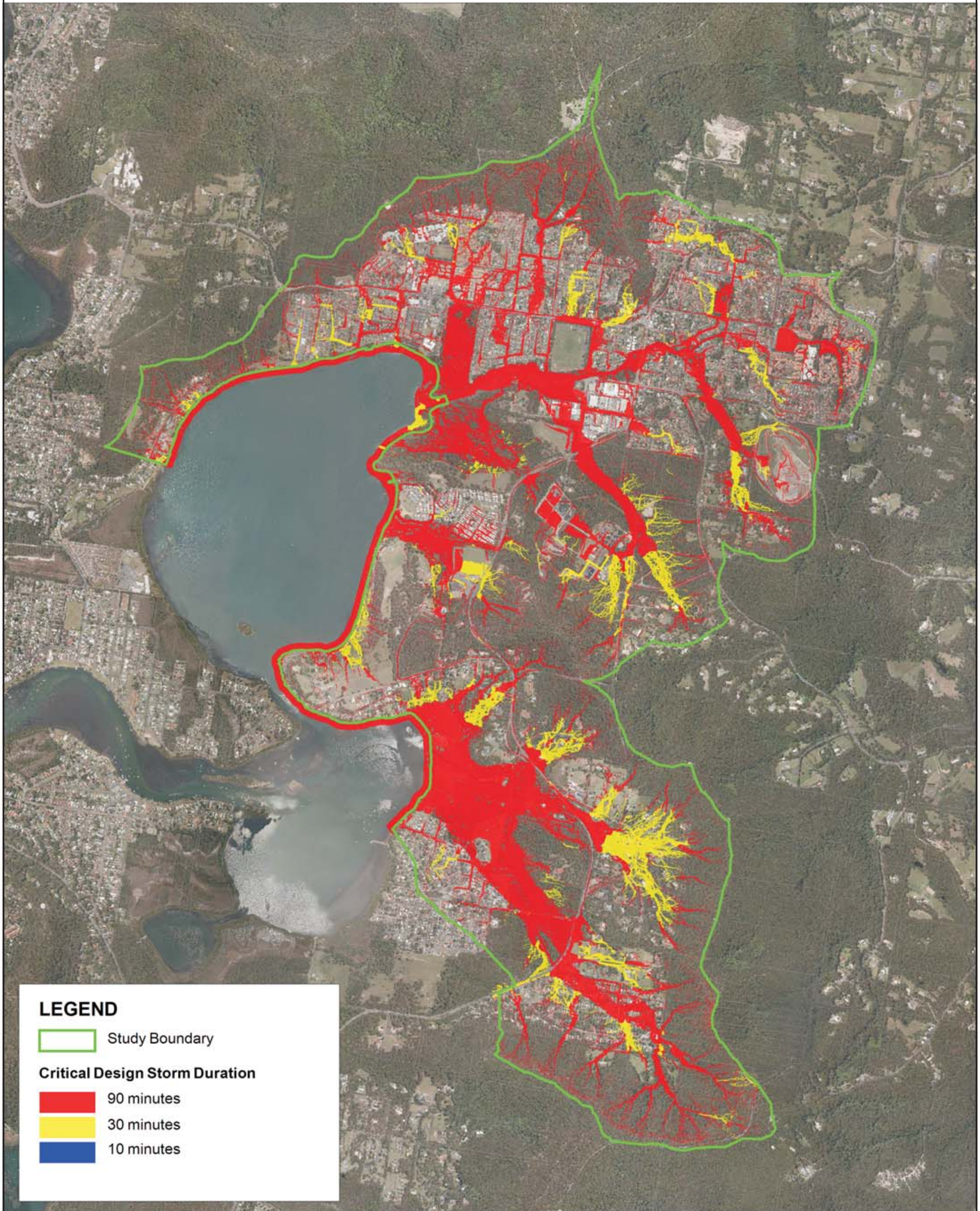
As discussed in Section 6.3.6, it is considered likely that accretion of sediment within Kincumber Creek would have occurred in the months prior to the bathymetric survey undertaken in November 2012. Given the magnitude of velocities simulated during the design flood events (see Appendix A) scour of the creek bed would be expected to occur, particularly during the less frequent events. The Kincumber Creek ‘scoured bathymetry’ (see Section 6.3.6) was therefore adopted for design event modelling. As the depth at which barriers to scour (such as consolidated clay or bedrock) may occur is not known, only moderate bathymetric changes due to scour were adopted.

## 7.5 Tidal Inundation

Tidal inundation, for the purposes of this study, refers to the inundation of low-lying land that may occur under normal ocean and estuary tidal conditions. Under current conditions a limited area may be subject to inundation from spring tides, however if significant sea level rise occurs in the future the extent and frequency of tidal inundation would increase.

Current tidal inundation has been determined using the mean of Highest High Water Solstice Spring (HHWSS) tides at Koolewong for the 20 years from 1990-2010 as presented in OEH Tidal Planes Analysis (MHL 2012). The HHWSS represents the highest tidal level occurring in a year due to astronomical drivers only (i.e. excludes storm surge, flooding and other contributors to total estuary levels) and the mean HHWSS is therefore analogous to the 100% AEP tidal level. Data from Koolewong has been utilised due to the length of data record available and proximity to Kincumber Broadwater. The mean HHWSS at Koolewong for the 20 years from 1990-2010 was 0.637 m AHD.

Tidal inundation extents have been determined by intersecting the HHWSS tidal plane with the model topography. The potential for tidal attenuation or amplification has therefore not been modelled, though any such effects would be expected to be minor.

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Approximate scale: 0 0.5 1 kilometres

Public Works
Manly Hydraulics Laboratory

KINCUMBER OVERLAND FLOW STUDY
1% AEP DESIGN EVENT
CRITICAL STORM DURATION

MHL Report 2196

Figure 7.1

DRAWING 2196-07-01.cdr

# 8. Design Flood Results and Mapping

## 8.1 Flood Mapping Approach

The use of the direct rainfall method in TUFLOW results in all active model cells being ‘wet’. Directly mapping all flood model results therefore produces a flood extent covering the entire model domain. To improve the presentation and interpretability of results the mapped flood extents for the design events were determined using a filtering methodology as described in Table 8.1.

**Table 8.1 Flood Mapping Filter**

| Criteria for Inclusion in Flood Mapping | Description |
|---|---|
| Depth ≥ 0.3 m | Includes all areas with significant depths of flooding (>0.3 m) in mapping |
| Depth ≥ 0.1 m<br>AND Velocity x Depth ≥ 0.01 $m^2/s$ | Includes depths between 0.1 m and 0.3 m but only where these have some flow component, therefore reducing the inclusion of small areas of still ponding |
| Depth ≥ 0.05 m<br>AND Velocity x Depth ≥ 0.025 $m^2/s$ | Includes shallower flows with some conveyance that may link areas of flooding with their source flowpaths. Small ‘islands’ of flooding displayed in mapping are thus likely to be the result of local ponding only |

This methodology was employed in order to include in flood mapping all areas with depths of 0.3 m and greater, areas with depths of between 0.1 m and 0.3 m whilst limiting the inclusion of small ponds, and additional areas of shallow flow conveyance.

## 8.2 Design Flood Peaks

Results of design flood modelling are presented in a series of flood maps in Appendix A, along with tabulated results at selected locations. This includes maps of peak flood level, depth, and velocity for the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and PMF design events.

It should be noted that maximum flood levels in foreshore areas and lower reaches of creeks may be caused by flooding of the Brisbane Water estuary due to large ocean storm events. The Kincumber Overland Flow Study assesses flood behaviour in the study area due to local catchment flooding only. Flood behaviour of the Brisbane Water estuary is described in Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar 2010).

## 8.3 Comparison with Previous Studies

A comparison of 1% AEP design event peak flood level results from the current study with those of previous studies undertaken in the study area is presented in Table 8.2.

**Table 8.2 Comparison of 1% AEP Peak Flood Levels with Previous Studies**

| Location | 1% AEP Peak Flood Level (m AHD) | | Previous Study Source |
|---|---|---|---|
| | Current Study | Previous Study | |
| Kincumber Creek DS of Erambie Road | 5.4 | 5.4 | WMA, 1999a* |
| Kincumber Creek near Koolkuna Close | 3.5 | 3.1 | WMA, 1999a* |
| Kincumber Creek near Pilluga Close | 3.2 | 2.9 | WMA, 1999a* |
| DS of Cullens Road | 7.4 | 7.4 | WMA, 1999a* |
| Lane between Cullens Road and Water Street | 6.1 | 6.0 | WMA, 1999a* |
| Intersection of Water Street and Wallan Road | 4.3 | 4.3 | WMA, 1999a* |
| DS of Calool Street | 2.02 | 2.00 | WMA, 1999b |
| DS of Empire Bay Drive near Bula Place | 12.28 | 11.96 | WMA, 1999b |
| US of Kallaroo Road | 9.99 | 9.97 | WMA, 1999b |
| DS of Kallaroo Road | 8.76 | 8.62 | WMA, 1999b |

* As per DRAWING No. 9/166/A1_02, dated 29/05/2001

The peak flood level comparisons in Table 8.2 show strong correlation between current and previous study results in some locations, while at other locations there is some variation. Much of this variation may be attributable to differences in modelling approach and software used, as well as other factors including differences in topographic data sets, changes in catchment land use and changes to drainage infrastructure.

## 8.4 Hydraulic Categories

Hydraulic categorisation is a useful tool in assessing the suitability of land use and development in flood-prone areas. The Floodplain Development Manual (NSW Government 2005) describes the following three hydraulic categories of flood-prone land:

- **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 0.1 m 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 impact on the flood pattern of flood levels.

These qualitative descriptions do not prescribe specific thresholds for determining the hydraulic categories in terms of model outputs, and such definitions may vary between floodplains depending on flood behaviour and associated impacts.

The Empire Bay Catchment Flood Study (Cardno Lawson Treloar 2010a) and Davis Town Catchment Flood Study (Cardno Lawson Treloar 2010b) defined hydraulic categories as per the criteria in Table 8.3.

**Table 8.3 Hydraulic Category Criteria**

| Hydraulic Category | Criteria | Description |
|---|---|---|
| **Floodway** | Velocity x Depth > 0.25 $m^2$/s AND Velocity > 0.25 m/s, OR Velocity > 1 m/s | Flowpaths and channels where a significant proportion of flood flows are conveyed |
| **Flood Storage** | Depth > 0.2 m, Not Floodway | Areas that temporarily store floodwaters and attenuate flood flows |
| **Flood Fringe** | Depth > 0.05 m, Not Floodway or Flood Storage | Generally shallow, low-velocity areas within the floodplain that have little influence on flood behaviour |

These criteria have been adopted for use in the Kincumber Overland Flow Study in consideration of the following:

- It is understood that Council wishes outputs from this study to be consistent with those from previous studies in the surrounding catchments.
- Flood behaviour in the Kincumber and Bensville catchments is generally comparable to that in the Empire Bay and Davis Town catchments. The presence of Kincumber Creek is the primary point of difference, however, the hydraulic definitions remain acceptable for application to the creek floodplain.

Hydraulic category mapping for the 1% AEP design event is presented in Appendix A.

## 8.5 Flood Hazard Categories

### 8.5.1 Provisional Hazard Categories

Flood hazard is a measure of the potential risk to life, limb and property posed by a flood. Flood hazard categories are defined in the Floodplain Development Manual (NSW Government 2005) as follows:

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

Provisional flood hazard categories for flood-prone land are generally determined based on relationships between simulated flood depths and velocities. These relationships are defined in Figures L1 and L2 in the Floodplain Development Manual (NSW Government 2005) and have been reproduced in Figure 8.1.

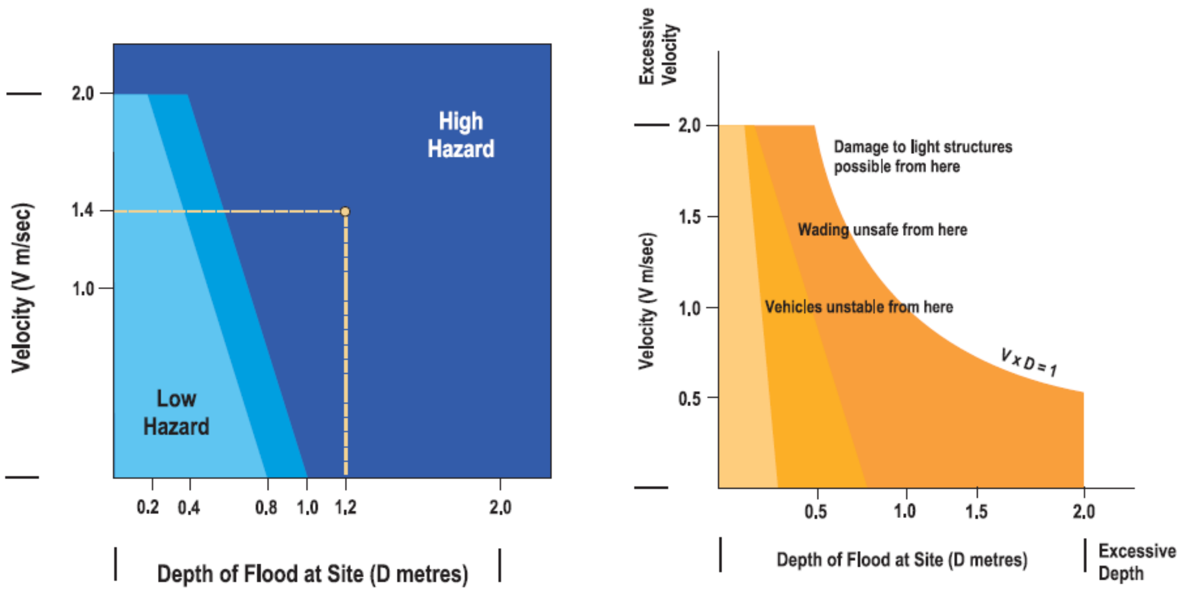


**Figure 8.1 Velocity-Depth Relationships for Provisional Hazard Categories**

(Source: NSW Government, 2005)

Provisional hazard categories have been determined for the 1% AEP design event and are presented in Appendix A. The 'transition zone' between high and low hazard is often assigned a high hazard category, but this should be determined as part of the Floodplain Risk Management Study based on factors such as those discussed in Section 8.5.2 below.

### 8.5.2 True Hazard Categories

True hazard categorisation requires the consideration of various factors in addition to provisional hazard categories including:

- effective warning time
- flood readiness
- rate of rise of floodwaters
- duration of flooding
- evacuation problems
- effective flood access, and
- type of development.

These factors are largely addressed through emergency response classification of communities, which was beyond the scope of this study. True hazard categories should therefore be established as part of the Floodplain Risk Management Study.

## 8.6 Property Affectation

The number of property parcels within the study area affected by various flood depths due to the 1% AEP design event are presented in Table 8.4. For the purposes of Table 8.4, parcels have been determined to be flood affected where at least 10% of the parcel was flooded, and the maximum flood depth was not less than 0.1 m. The parcel numbers provided have been divided into zonings as per the Gosford LGA LEP 2009. A number of analysed parcels are not currently developed and numbers may not reflect the number of developed properties that are flood affected.

**Table 8.4 1% AEP Property Affectation**

| Gosford LGA LEP Zoning 2009 | | Number of Parcels Affected | | | | |
|---|---|---|---|---|---|---|
| | | Max. Flood Depth 0.1–0.3 m | Max. Flood Depth 0.3–0.5m | Max. Flood Depth 0.5–1.0 m | Max. Flood Depth > 1.0 m | TOTAL |
| B1 | Neighbourhood Centre | 0 | 0 | 0 | 0 | **0** |
| B2 | Local Centre | 0 | 6 | 0 | 0 | **6** |
| DM | DM | 12 | 36 | 47 | 40 | **135** |
| E1 | National Parks and Nature Reserves | 0 | 0 | 1 | 1 | **2** |
| E2 | Environmental Conservation | 0 | 0 | 1 | 0 | **1** |
| E3 | Environmental Management | 0 | 0 | 0 | 0 | **0** |
| E4 | Environmental Living | 0 | 1 | 4 | 4 | **9** |
| E5 | Public Conservation | 0 | 2 | 4 | 3 | **9** |
| IN1 | General Industrial | 3 | 5 | 7 | 3 | **18** |
| R1 | General Residential | 0 | 1 | 0 | 0 | **1** |
| R2 | Low Density Residential | 526 | 275 | 137 | 55 | **993** |
| RE1 | Public Recreation | 3 | 7 | 12 | 35 | **57** |
| RE2 | Private Recreation | 0 | 0 | 0 | 0 | **0** |
| SP1 | Special Activities | 0 | 0 | 1 | 1 | **2** |
| SP2 | Infrastructure | 3 | 7 | 7 | 13 | **30** |
| **TOTAL** | | **547** | **340** | **221** | **155** | **1263** |

## 8.7 Preliminary Flood Planning Area

Flood planning areas and levels are an important practical tool in the management of floodplain risk through the application of development controls. These concepts are defined in the NSW Floodplain Development Manual (NSW Government 2005) as below:

- Flood planning levels (FPLs) - FPLs are the combinations of flood levels (derived from significant historical flood events or floods of specific ARIs) and freeboards selected for floodplain risk management purposes, as determined in risk management studies and incorporated in risk management plans.
- Flood planning area - The area of land below the FPL and thus subject to flood related development controls.

Traditionally, flood planning areas have often been determined by applying a freeboard of 0.5 m to the 1% AEP flood extent and extending this surface laterally until it intersects the surrounding topography. This method has generally been applied to land bordering lakes, rivers and creeks where flooding is confined to, or sourced from, a water body at an elevation below the surrounding land. When determining flood planning areas based on overland flows, however, the appropriateness of this method should be carefully considered on a site specific basis (see Figure 8.2).

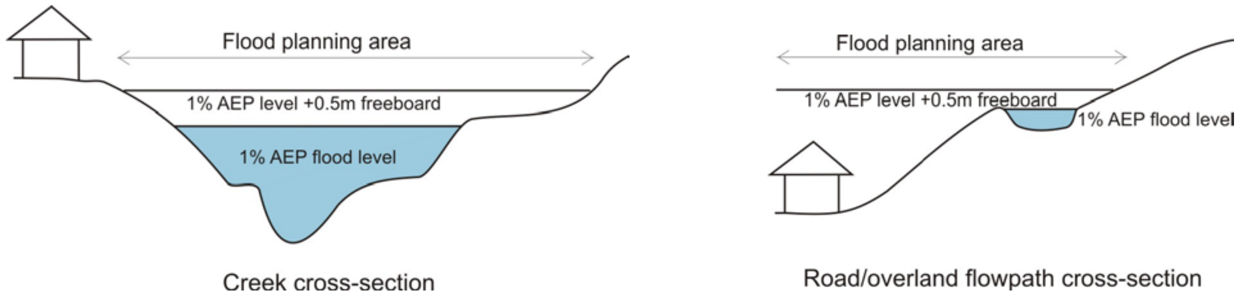


**Figure 8.2 Application of Freeboard to Creek Flow vs. Overland Flow**

The methodology used to derive the flood planning level and area should be technically sound and readily justifiable to the community. Consideration of multiple factors should therefore be made in determining an appropriate freeboard to be applied to the 1% AEP overland flow flood surface, and whether this should be extended laterally. These include:

- results of sensitivity analysis for the 1% AEP design flood
- flood hazard within the resulting flood planning area
- logic of resulting flood planning area based on ground truthing
- type of development (e.g. different freeboards may be applicable to garages, habitable floors and industrial buildings).

Results of sensitivity testing and climate change analysis for the 1% AEP design event show that even for a 30% increase in rainfall the largest simulated increases in peak flood level were approximately 0.3 m. This suggests that a freeboard of 0.3 m would appropriately allow for factors such as model accuracy, afflux due to blockages, and increased rainfall intensity due to climate change.

The following methodology was adopted to derive the preliminary flood planning area and level:

- **Preliminary Flood Planning Area** – The flood extent for the 1% AEP 90-minute design event with a 30% increase in rainfall intensity was taken as the maximum flood planning area extent. This provides a simple, logical and scientifically justifiable means of determining the lateral extent of the flood planning area.
- **Preliminary Flood Planning Level** – A freeboard of 0.3 m was applied to the 1% AEP design event level (for current conditions) within the Preliminary Flood Planning Area.

The resulting Preliminary Flood Planning Area with associated planning levels is presented in Appendix A.

It should be noted that the preliminary flood planning area developed in this study is based on local catchment runoff flooding only. Flooding associated with the Brisbane Water estuary may be critical in low-lying areas throughout the study area and should be considered in conjunction with local catchment flooding in determining a final flood planning level and area.

## 8.8 SES Information Requirements

The NSW Floodplain Development Manual requires studies and plans to incorporate information to facilitate the State Emergency Service (SES) in undertaking effective emergency response planning. The requirements for inclusion in a flood study, as outlined in the Floodplain Risk Management Guideline on SES Requirements from the FRM Process (DECC 2007), have been addressed in this study including:

- summary of historic flood information
- terrain elevation plan
- flood extent plans
- flood hazard plans
- flood category plans
- provision of flood model results to Council that define the variation in flood levels, extents and velocities over time.

From an emergency response perspective, flood behaviour in the study area is characterised by a rapid rise in flood waters in response to relatively short durations of high intensity rainfall. Flood-affected areas may experience flooding within as little as 15 minutes of an intense burst of rainfall (as simulated for the 1% AEP 90 minute duration storm event), providing limited opportunity for specific flood warnings or evacuation. Under simulated rainfall conditions - consisting of short duration high intensity rainfall bursts - floodwaters recede relatively quickly from their peaks (within an hour for the 1% AEP 90-minute event) indicating that emergency response measures such as resupply are unlikely to be required. Major roads including Avoca Drive and Empire Bay Drive may experience inundation due to storm events as common as the 20% AEP (1-in-5-year) design event, while a combination of the velocity and depth of flood flows on a number of other streets may pose threats to safety.

It should be noted that flooding of foreshore areas by high water levels in Brisbane Water estuary may require a different emergency response to the catchment-driven flooding investigated in this study. The slower processes driving such flooding may allow additional time for flood warning and evacuation, while affected areas may be subject to longer durations of flooding.

SES requirements from the floodplain risk management process will be further addressed through the Floodplain Risk Management Study and Plan phases.

## 8.9 Tidal Inundation

Current 100% AEP tidal inundation extents and depths (based on the mean HHWSS tidal level at Koolewong) are presented in Appendix A. Under current conditions, low-lying portions of a number of properties experience inundation due to the 100% AEP tide, however, development on these properties is located at elevations above the inundation extent.

## 8.10 Sensitivity Analysis

### 8.10.1 Blockage of Hydraulic Structures

Flood flows may transport with them various debris which have the potential to cause blockage of the hydraulic structures they encounter. Blockages reduce the flow capacity of hydraulic structures. This may result in an increase in flood levels upstream of the structure (afflux) and/or diversion of flows into alternative flow paths.

Australian Rainfall and Runoff Revision Project 11: Blockage of Hydraulic Structures (Institution of Engineers Australia, 2013) provides guidance on the consideration of blockages in determining design flood levels. Following the ‘Assessment Procedure for an AEP Neutral Blockage Level – Scheme A’, assessment of debris availability, debris characteristics and catchment characteristics indicated a ‘medium debris potential’, and a 90$^{th}$ percentile debris length of 1.5 m was assumed. The resulting ‘most likely’ blockage levels for these conditions are presented in Table 8.5.

**Table 8.5 Most Likely Blockage Levels**
(Institution of Engineers Australia 2013)

| Control Dimension | At-Site Debris Potential | | |
|---|---|---|---|
| | High | Medium | Low |
| **W < 1.5 m** | 100% | 50% | 25% |
| **W ≥ 1.5 m** | 20% | 10% | 0% |
| **W > 4.5 m** | 10% | 0% | 0% |

It was considered that structures with opening width of 1.5 m and greater are generally located downstream of significant flow paths capable of mobilising and transporting larger debris. A ‘high’ blockage level of 20% was therefore adopted for these structures. Sensitivity testing of the potential impact of structure blockages was thus undertaken for the 1% AEP 90-minute duration design event using the following blockage assumptions:

- 50% blockage of structures with opening width less than 1.5 m
- 20% blockage of structures with opening width 1.5 m and greater.

Changes in peak flood levels under assumed blockage conditions are presented in Appendix A and summarised in Table 8.6. The selected reporting locations in Tables 8.6 and 8.7 are presented in Appendix A, Figure A26.

Increases in peak flood levels due to the modelled blockage scenario were less than 0.05 m throughout the majority of the study area. Greater increases were observed locally, primarily in the Kincumber Creek catchment, with a number of additional properties being affected by flooding. The greatest impacts from blockage appear to be associated with increased overtopping of roadways and activation of alternative flowpaths.

**Table 8.6 1% AEP Peak Flood Level Sensitivity - Structure Blockage**

| Location | | Design Conditions | Blockage Scenario | |
|---|---|---|---|---|
| No. | Description | Flood Peak (m AHD) | Flood Peak (m AHD) | Difference (m) |
| 1 | Kincumber Creek near Samantha Crescent | 0.97 | 1.01 | 0.04 |
| 2 | Kincumber Creek near Davies Street | 1.20 | 1.18 | -0.01 |
| 3 | Kincumber Creek gauge near Killuna Road | 1.49 | 1.47 | -0.02 |
| 4 | Kincumber Creek DS of Empire Bay Drive | 2.23 | 2.22 | -0.01 |
| 5 | Empire Bay Dr at Kincumber Creek | 2.83 | 2.85 | 0.02 |
| 6 | Kincumber Creek US of Empire Bay Drive | 3.10 | 3.14 | 0.04 |
| 7 | Kincumber Creek near Wallan Road | 3.89 | 3.89 | 0.00 |
| 8 | Kincumber Creek near Erambie Road | 5.27 | 5.24 | -0.03 |
| 9 | Oberton St Retarding Basin | 9.04 | 9.09 | 0.05 |
| 10 | Flowpath near Castell Close | 11.10 | 11.11 | 0.01 |
| 11 | Flowpath near Bardo Road | 8.59 | 8.67 | 0.08 |
| 12 | Patrick Croke Oval | 13.67 | 13.95 | 0.28 |
| 13 | Intersection Wallan Road and Water Street | 4.17 | 4.18 | 0.01 |
| 14 | Access lane off Water Street | 5.46 | 5.46 | 0.00 |
| 15 | Open Channel near Water Street | 6.27 | 6.27 | 0.00 |
| 16 | Cullens Road | 8.52 | 8.53 | 0.01 |
| 17 | US of Cullens Road | 8.78 | 8.79 | 0.01 |
| 18 | Hawke Street near Kerta Road | 2.45 | 2.49 | 0.05 |
| 19 | Killara Street | 9.78 | 9.78 | 0.00 |
| 20 | Empire Bay Drive near industrial area | 3.47 | 3.48 | 0.01 |
| 21 | Bungoona Road near Avoca Drive | 5.07 | 5.19 | 0.12 |
| 22 | Property off Broula Close | 7.96 | 8.00 | 0.04 |
| 23 | Intersection Moro Close and Arakoon Street | 15.50 | 15.52 | 0.02 |
| 24 | Avoca Drive near Frost Reserve | 4.33 | 4.34 | 0.02 |
| 25 | Carlo Close | 9.89 | 9.89 | 0.01 |
| 26 | Intersection Serengeti Close and Arakoon Street | 23.57 | 23.58 | 0.01 |
| 27 | Calool Street | 1.97 | 1.97 | 0.00 |
| 28 | US of Empire Bay Drive near Bundaleer Crescent | 6.79 | 6.79 | 0.00 |
| 29 | Kallaroo Road | 9.68 | 9.69 | 0.02 |
| 30 | Empire Bay Drive near Bula Place | 14.34 | 14.35 | 0.00 |
| 31 | Yarram Road | 21.25 | 21.27 | 0.02 |

### 8.10.2 Hydraulic Roughness

The sensitivity of model results to hydraulic roughness was investigated by applying a 20% decrease and a 20% increase to adopted Manning's 'n' values for the 1% AEP 90-minute duration design event. Results of the sensitivity test are presented in Appendix A and summarised in Table 8.7.

**Table 8.7 1% AEP Peak Flood Level Sensitivity - Hydraulic Roughness**

| Location | | Design Conditions | 20% Decrease | | 20% Increase | |
|---|---|---|---|---|---|---|
| No. | Description | Flood Peak (m AHD) | Flood Peak (m AHD) | Difference (m) | Flood Peak (m AHD) | Difference (m) |
| 1 | Kincumber Creek near Samantha Crescent | 0.97 | 0.97 | 0.00 | 0.97 | 0.00 |
| 2 | Kincumber Creek near Davies Street | 1.20 | 1.19 | 0.00 | 1.20 | 0.00 |
| 3 | Kincumber Creek gauge near Killuna Road | 1.49 | 1.49 | 0.00 | 1.49 | 0.00 |
| 4 | Kincumber Creek DS of Empire Bay Drive | 2.23 | 2.22 | -0.01 | 2.24 | 0.01 |
| 5 | Empire Bay Drive at Kincumber Creek | 2.83 | 2.82 | 0.00 | 2.83 | 0.00 |
| 6 | Kincumber Creek US of Empire Bay Drive | 3.10 | 3.08 | -0.01 | 3.10 | 0.00 |
| 7 | Kincumber Creek near Wallan Road | 3.89 | 3.85 | -0.05 | 3.94 | 0.05 |
| 8 | Kincumber Creek near Erambie Road | 5.27 | 5.25 | -0.02 | 5.26 | -0.01 |
| 9 | Oberton Street Retarding Basin | 9.04 | 9.04 | 0.00 | 9.05 | 0.02 |
| 10 | Flowpath near Castell Close | 11.10 | 11.04 | -0.05 | 11.15 | 0.06 |
| 11 | Flowpath near Bardo Road | 8.59 | 8.60 | 0.01 | 8.59 | 0.00 |
| 12 | Patrick Croke Oval | 13.67 | 13.72 | 0.05 | 13.70 | 0.03 |
| 13 | Intersection Wallan Road and Water Street | 4.17 | 4.16 | -0.01 | 4.18 | 0.01 |
| 14 | Access lane off Water Street | 5.46 | 5.46 | -0.01 | 5.47 | 0.00 |
| 15 | Open Channel near Water Street | 6.27 | 6.26 | -0.01 | 6.27 | 0.01 |
| 16 | Cullens Road | 8.52 | 8.53 | 0.00 | 8.53 | 0.00 |
| 17 | US of Cullens Road | 8.78 | 8.78 | 0.00 | 8.79 | 0.01 |
| 18 | Hawke St near Kerta Road | 2.45 | 2.44 | 0.00 | 2.46 | 0.01 |
| 19 | Killara Street | 9.78 | 9.78 | 0.00 | 9.78 | 0.00 |
| 20 | Empire Bay Drive near industrial area | 3.47 | 3.47 | 0.00 | 3.46 | -0.01 |
| 21 | Bungoona Road near Avoca Drive | 5.07 | 5.08 | 0.01 | 5.06 | -0.01 |
| 22 | Property off Broula Close | 7.96 | 7.96 | 0.00 | 7.97 | 0.01 |
| 23 | Intersection Moro Close and Arakoon Street | 15.50 | 15.50 | 0.00 | 15.51 | 0.01 |
| 24 | Avoca Drive near Frost Reserve | 4.33 | 4.33 | 0.00 | 4.33 | 0.00 |
| 25 | Carlo Close | 9.89 | 9.88 | -0.01 | 9.89 | 0.01 |
| 26 | Intersection Serengeti Close and Arakoon Street | 23.57 | 23.57 | 0.00 | 23.57 | 0.00 |
| 27 | Calool Street | 1.97 | 1.93 | -0.04 | 1.99 | 0.02 |
| 28 | US of Empire Bay Drive near Bundaleer Crescent | 6.79 | 6.76 | -0.03 | 6.81 | 0.02 |
| 29 | Kallaroo Road | 9.68 | 9.71 | 0.04 | 9.68 | 0.00 |
| 30 | Empire Bay Drive near Bula Place | 14.34 | 14.35 | 0.00 | 14.34 | -0.01 |
| 31 | Yarram Road | 21.25 | 21.25 | 0.00 | 21.24 | 0.00 |

Peak flood levels for the 1% AEP design event were not found to be sensitive to a 20% decrease or increase in hydraulic roughness, with changes throughout the study area generally less than 0.05 m. For a 20% decrease in roughness, localised increases in peak flood level of 0.05 m to 0.1 m were observed on a number of roads and in Patrick Croke Oval, while decreases of 0.05 m to 0.1 m occurred along some major flowpaths. A 20% increase in roughness had less impact on peak flood levels, with localised increases greater than 0.05 m observed in only a few locations.

# 9. Climate Change Analysis

## 9.1 Potential Climate Change Impacts

Climate change is expected to result in increased rainfall intensity and sea level rise (SLR), both of which may have adverse flooding impacts on the study area.

### 9.1.1 Design Rainfall Intensity

The Floodplain Risk Management Guideline on Practical Consideration of Climate Change (DECC 2007) recommends that sensitivity analyses are undertaken for increases in rainfall intensity and volume of up to 30%. Sensitivity analysis of the 1% AEP 90-minute design event to a 30% increase in rainfall intensity due to climate change has therefore been undertaken. Comparison of the 1% AEP and 0.5% AEP events has also been undertaken, representing a 10% (actual rainfall increase of 10.36%) increase in rainfall.

### 9.1.2 Sea Level Rise

While there is a consensus among many scientists on the occurrence of sea level rise, projected increases vary considerably. The Floodplain Risk Management Guideline on Practical Consideration of Climate Change (DECC 2007) identifies, from relevant research, that sea level rise on the NSW coast is expected to be in the range of 0.18 m to 0.91 m by between 2090 and 2100.

Modelling by Cardno Lawson Treloar (2010) indicates that mean estuary level rise within Brisbane Water is expected to be equivalent to mean sea level rise. Changes in estuary morphology may also be expected in conjunction with sea level rise, however likely changes and associated timelines have not been quantified.

The sensitivity of catchment flooding impacts to sea level rise scenarios of 0.2 m and 0.9 m has been investigated in this study for the 1% AEP 90-minute design event.

## 9.2 Climate Change Results

### 9.2.1 Peak Flood Levels and Extents

Mapping of modelled climate change impacts on peak flood levels and flood extents is presented in Appendix B. A summary of peak flood levels for the increased rainfall and sea level rise climate change scenarios are presented in Tables 9.1 and 9.2 respectively. A number of locations where sea level rise had no influence on results have been omitted from Table 9.2. The selected reporting locations in Tables 9.1 and 9.2 are presented in Appendix A, Figure A26.

## Table 9.1 1% AEP Peak Flood Levels for Increased Rainfall Intensity

| Location | | Design Conditions | +10% Rainfall | | +30% Rainfall | |
|---|---|---|---|---|---|---|
| No. | Description | Flood Peak (m AHD) | Flood Peak (m AHD) | Difference (m) | Flood Peak (m AHD) | Difference (m) |
| 1 | Kincumber Creek near Samantha Crescent | 0.97 | 1.06 | 0.09 | 1.24 | 0.27 |
| 2 | Kincumber Creek near Davies Street | 1.20 | 1.29 | 0.10 | 1.46 | 0.26 |
| 3 | Kincumber Creek gauge near Killuna Road | 1.49 | 1.59 | 0.10 | 1.76 | 0.27 |
| 4 | Kincumber Creek DS of Empire Bay Drive | 2.23 | 2.31 | 0.08 | 2.46 | 0.23 |
| 5 | Empire Bay Drive at Kincumber Creek | 2.83 | 2.86 | 0.04 | 2.92 | 0.09 |
| 6 | Kincumber Creek US of Empire Bay Drive | 3.10 | 3.18 | 0.08 | 3.28 | 0.19 |
| 7 | Kincumber Creek near Wallan Road | 3.89 | 3.99 | 0.10 | 4.19 | 0.30 |
| 8 | Kincumber Creek near Erambie Road | 5.27 | 5.34 | 0.07 | 5.46 | 0.19 |
| 9 | Oberton Street Retarding Basin | 9.04 | 9.09 | 0.05 | 9.17 | 0.13 |
| 10 | Flowpath near Castell Close | 11.10 | 11.13 | 0.04 | 11.19 | 0.09 |
| 11 | Flowpath near Bardo Road | 8.59 | 8.61 | 0.02 | 8.78 | 0.19 |
| 12 | Patrick Croke Oval | 13.67 | 13.90 | 0.24 | 14.00 | 0.33 |
| 13 | Intersection Wallan Road and Water Street | 4.17 | 4.18 | 0.01 | 4.23 | 0.06 |
| 14 | Access lane off Water Street | 5.46 | 5.48 | 0.02 | 5.51 | 0.05 |
| 15 | Open Channel near Water Street | 6.27 | 6.30 | 0.03 | 6.34 | 0.07 |
| 16 | Cullens Road | 8.52 | 8.53 | 0.01 | 8.55 | 0.03 |
| 17 | US of Cullens Road | 8.78 | 8.81 | 0.03 | 8.87 | 0.08 |
| 18 | Hawke Street near Kerta Road | 2.45 | 2.50 | 0.06 | 2.58 | 0.13 |
| 19 | Killara Street | 9.78 | 9.80 | 0.02 | 9.83 | 0.05 |
| 20 | Empire Bay Drive near industrial area | 3.47 | 3.49 | 0.02 | 3.52 | 0.05 |
| 21 | Bungoona Road near Avoca Drive | 5.07 | 5.10 | 0.04 | 5.17 | 0.10 |
| 22 | Property off Broula Close | 7.96 | 8.00 | 0.04 | 8.04 | 0.08 |
| 23 | Intersection Moro Close and Arakoon Street | 15.50 | 15.52 | 0.02 | 15.55 | 0.05 |
| 24 | Avoca Drive near Frost Reserve | 4.33 | 4.35 | 0.03 | 4.39 | 0.07 |
| 25 | Carlo Close | 9.89 | 9.90 | 0.01 | 9.91 | 0.03 |
| 26 | Intersection Serengeti Close and Arakoon Street | 23.57 | 23.58 | 0.01 | 23.60 | 0.03 |
| 27 | Calool Street | 1.97 | 2.01 | 0.04 | 2.09 | 0.12 |
| 28 | US of Empire Bay Drive near Bundaleer Crescent | 6.79 | 6.83 | 0.04 | 6.90 | 0.11 |
| 29 | Kallaroo Road | 9.68 | 9.69 | 0.01 | 9.70 | 0.02 |
| 30 | Empire Bay Drive near Bula Place | 14.34 | 14.35 | 0.01 | 14.37 | 0.02 |
| 31 | Yarram Road | 21.25 | 21.29 | 0.04 | 21.36 | 0.11 |

**Table 9.2 1% AEP Peak Flood Levels for Sea Level Rise Scenarios**

| Location | | Design Conditions | +0.2 m SLR | | +0.9 m SLR | |
|---|---|---|---|---|---|---|
| No. | Description | Flood Peak (m AHD) | Flood Peak (m AHD) | Difference (m) | Flood Peak (m AHD) | Difference (m) |
| 1 | Kincumber Creek near Samantha Crescent | 0.97 | 1.08 | 0.11 | 1.60 | 0.63 |
| 2 | Kincumber Creek near Davies Street | 1.20 | 1.27 | 0.07 | 1.67 | 0.48 |
| 3 | Kincumber Creek gauge near Killuna Road | 1.49 | 1.52 | 0.04 | 1.79 | 0.31 |
| 4 | Kincumber Creek DS of Empire Bay Drive | 2.23 | 2.23 | 0.00 | 2.29 | 0.05 |
| 5 | Empire Bay Drive at Kincumber Creek | 2.83 | 2.83 | 0.00 | 2.83 | 0.00 |
| 6 | Kincumber Creek US of Empire Bay Drive | 3.10 | 3. 10 | 0.00 | 3.10 | 0.00 |
| 7 | Kincumber Creek near Wallan Road | 3.89 | 3.89 | 0.00 | 3.89 | 0.00 |
| 13 | Intersection Wallan Road and Water Street | 4.17 | 4.17 | 0.00 | 4.17 | 0.00 |
| 18 | Hawke Street near Kerta Road | 2.45 | 2.45 | 0.00 | 2.45 | 0.00 |
| 20 | Empire Bay Drive near industrial area | 3.47 | 3.47 | 0.00 | 3.46 | 0.00 |
| 24 | Avoca Drive near Frost Reserve | 4.33 | 4.33 | 0.00 | 4.33 | 0.00 |
| 27 | Calool Street | 1.97 | 1.97 | 0.00 | 1.97 | 0.00 |

It was found that, for a 1% AEP 90-minute duration design rainfall event with a 1% PoE tidal condition, the most significant potential climate change impacts in the study area are associated with an increase in rainfall intensity. In areas more heavily impacted by sea level rise, such as the Kincumber Broadwater foreshore and lower Kincumber Creek, it is likely that the occurrence of ocean storm-driven estuarine flooding in combination with sea level rise will have greater impacts than catchment-driven flooding of the same probability. These impacts have been investigated in the Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar 2010).

A 10% increase in rainfall was found to result in increases in water level of only a few centimetres on roadways and flowpaths. Greater increases were observed in areas of high flow concentration and areas that detain flows, such as Kincumber Creek (increases of around 0.1 m) and Patrick Croke Oval (0.23 m increase). The increase in flood extent associated with a 10% increase in rainfall is relatively minor.

Increases in modelled peak flood levels were more pronounced for a 30% increase in rainfall, with levels across a significant proportion of the flood extent rising by more than 0.05 m. From Table 9.2, flood levels in Kincumber Creek rose in the order of 0.2 m to 0.3 m from the current conditions, levels along flowpaths rose by between 0.05 m and 0.19 m, and levels on roads rose by 0.02 m to 0.13 m. The increase in the 1% AEP flood extent associated with a 30% increase in rainfall may impact a number of additional properties, particularly within the Kincumber Creek catchment.

Sensitivity results show that, even under a sea level rise scenario of 0.9 m, increases in the 1% AEP flood extent due to backwater effects (i.e. afflux due to a reduction in flow conveyance by downstream tidal conditions) are limited primarily to Kincumber Creek between Killuna Road and Empire Bay Drive. Other increases in the flood extent occurring along the Kincumber Broadwater foreshore and in lower Kincumber Creek are comparable to inundation extents that would be experienced under the associated tidal boundary level of 1.53 m AHD (current 1% PoE tidal level plus 0.9 m SLR) without the occurrence of catchment flooding. Increases in peak flood levels along the foreshore are in the same order as sea level rise, with the influence on peak flood level diminishing rapidly moving upstream.

The 100% AEP tidal inundation extent was not found to increase significantly under a 0.2 m sea level rise scenario. Under a 0.9 m sea level rise scenario, however, a number of additional properties in Saratoga, Kincumber, Kincumber South and Bensville would be affected.

### 9.2.2 Property Affectation

The influence of sea level rise on property flood affectation is presented in Table 9.3. The number of property parcels affected by flooding have been determined as described in Section 8.6. The increases in property affectation associated with sea level rise scenarios are indicated in brackets.

**Table 9.3 1% AEP Property Affectation for Sea Level Rise Scenarios**

| Scenario | Number of Parcels Affected | | | | |
|---|---|---|---|---|---|
| | Max. Flood Depth 0.1–0.3 m | Max. Flood Depth 0.3–0.5 m | Max. Flood Depth 0.5–1.0 m | Max. Flood Depth > 1.0 m | TOTAL |
| **Current Conditions** | 547 | 340 | 221 | 155 | **1263** |
| **0.2 m SLR** | 560 (+13) | 344 (+4) | 227 (+6) | 167 (+12) | **1298 (+35)** |
| **0.9 m SLR** | 565 (+18) | 349 (+9) | 237 (+16) | 175 (+20) | **1326 (+63)** |

### 9.2.3 Preliminary Flood Planning Areas

A comparison of Preliminary Flood Planning Areas for current conditions, 0.2 m sea level rise and 0.9 m sea level rise scenarios is presented in Appendix B. The methodology used to determine the flood planning areas is described in Section 8.7.

It can be seen that, using the methodology adopted, increases in the extent of flood planning areas due to sea level rise are generally limited to foreshore areas and the lower reaches of creeks. Minor additional increases may occur elsewhere associated with a reduction in the drainage system discharge capacity.

# 10. Conclusions and Qualifications

The objective of the Kincumber Overland Flow Study has been to define existing flood behaviour within the study area and provide a scientific basis for the subsequent preparation of a Floodplain Risk Management Study and Plan. Assessment of flood behaviour has been achieved through the establishment of a detailed flood model.

This Flood Study Report documents all stages of the study and provides key outputs including a full suite of design flood mapping and tabulated sensitivity results. This report and its outputs help to define flood behaviour within the study catchments and establish the basis for subsequent floodplain risk management activities.

The Kincumber Overland Flow Study has focused on defining flood behaviour driven by local catchment runoff. Flooding associated with the behaviour of the Brisbane Water estuary may be critical at some locations within the study area, and is described in the Brisbane Water Foreshore Flood Study (Cardno Lawson Treloar 2010). The outcomes of both studies should be considered in future floodplain risk management activities.

While all due effort has been made to ensure the reliability of flood model results, all models have limitations (e.g. Institution of Engineers 2012). The accuracy of any model is a function of the quality of the data used in the model development including topographical data, drainage structure data, and calibration data. Modelling is by nature a simplification of very complex systems, and results of flood model simulations should be considered as a best estimate only. There is, therefore, an unknown level of uncertainty associated with all model results that should be considered when utilising the outputs from this study.

Results of sensitivity testing for the 1% AEP design event showed that changes in peak flood level resulting from variation in hydraulic roughness and structure blockage were generally less than 0.1 m. Greater variations were observed due to increases in rainfall intensity and sea level rise. These results provide an indication of the model accuracy.

# 11. References

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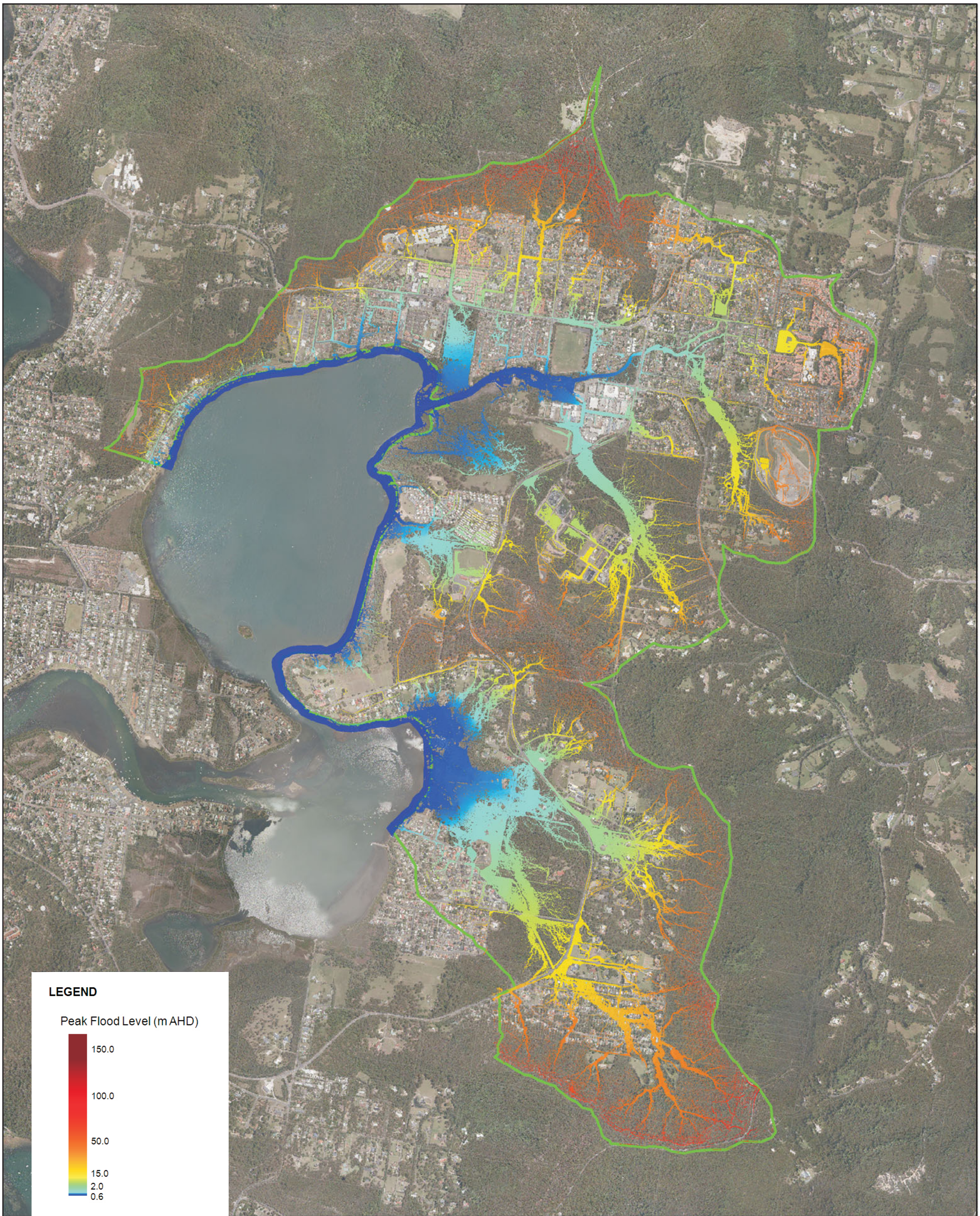
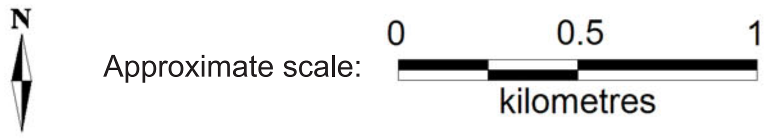
Webb, McKeown and Associates 1999b, *Bensville Urban Investigation Area Trunk Drainage Strategy Study*

# Appendix A

## Design Flood Mapping and Results

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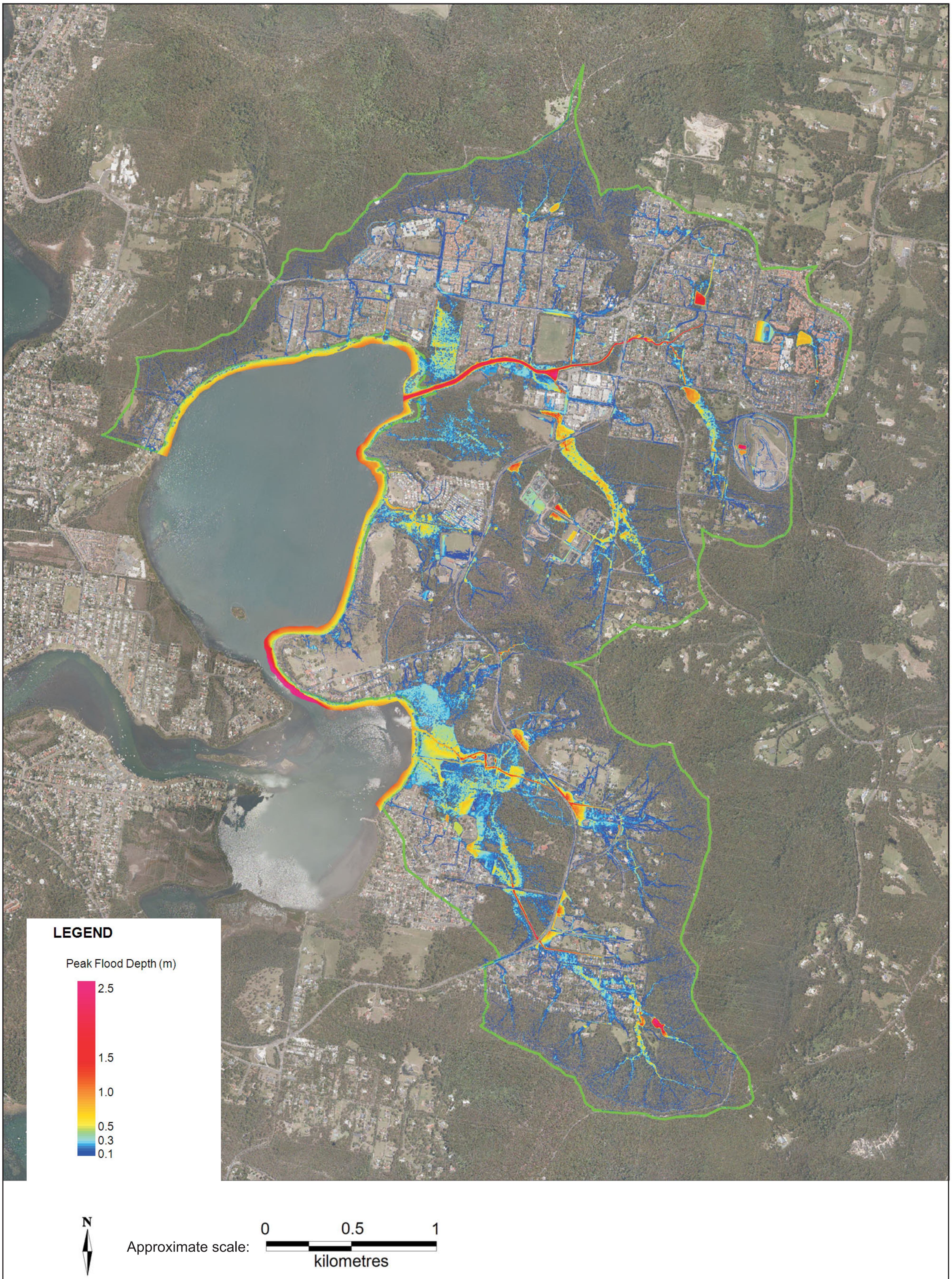
KINCUMBER OVERLAND FLOW STUDY
20% AEP PEAK FLOOD LEVEL

MHL Report 2196

Figure A1

DRAWING 2196-A1.cdr

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KINCUMBER OVERLAND FLOW STUDY
20% AEP PEAK FLOOD DEPTH

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Figure A2

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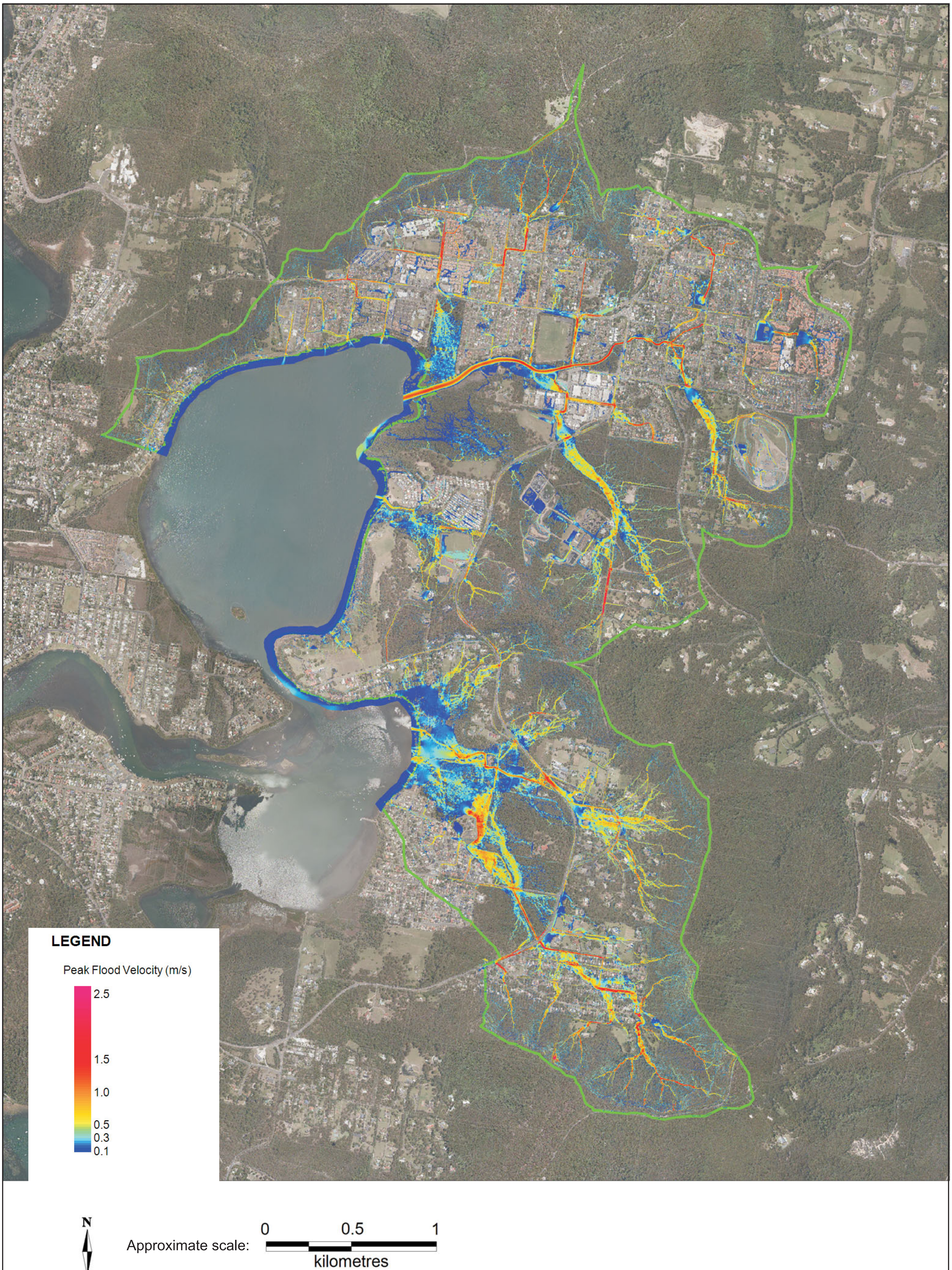


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KINCUMBER OVERLAND FLOW STUDY
20% AEP PEAK FLOOD VELOCITY

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Figure A3

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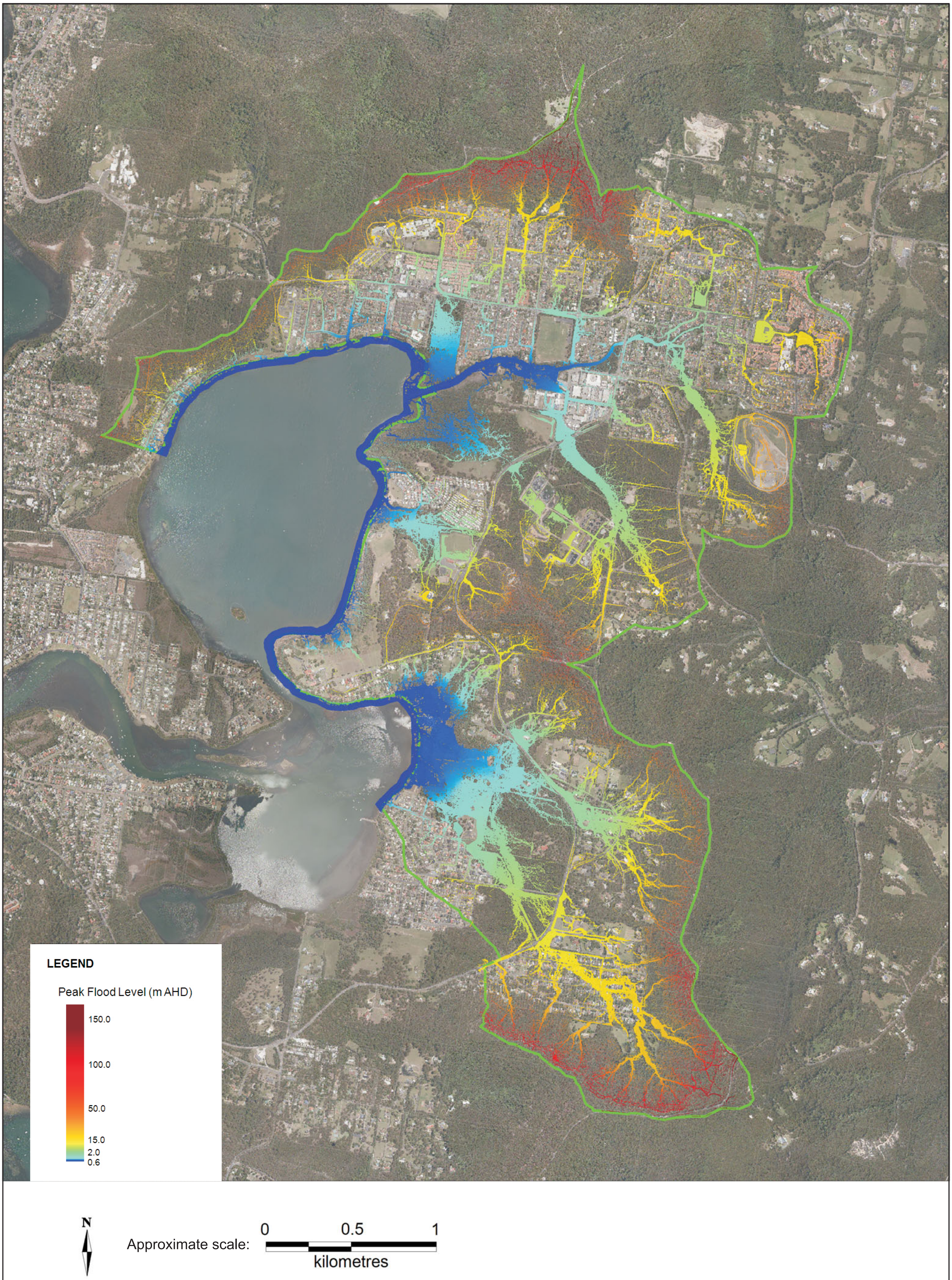


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KINCUMBER OVERLAND FLOW STUDY
10% AEP PEAK FLOOD LEVEL

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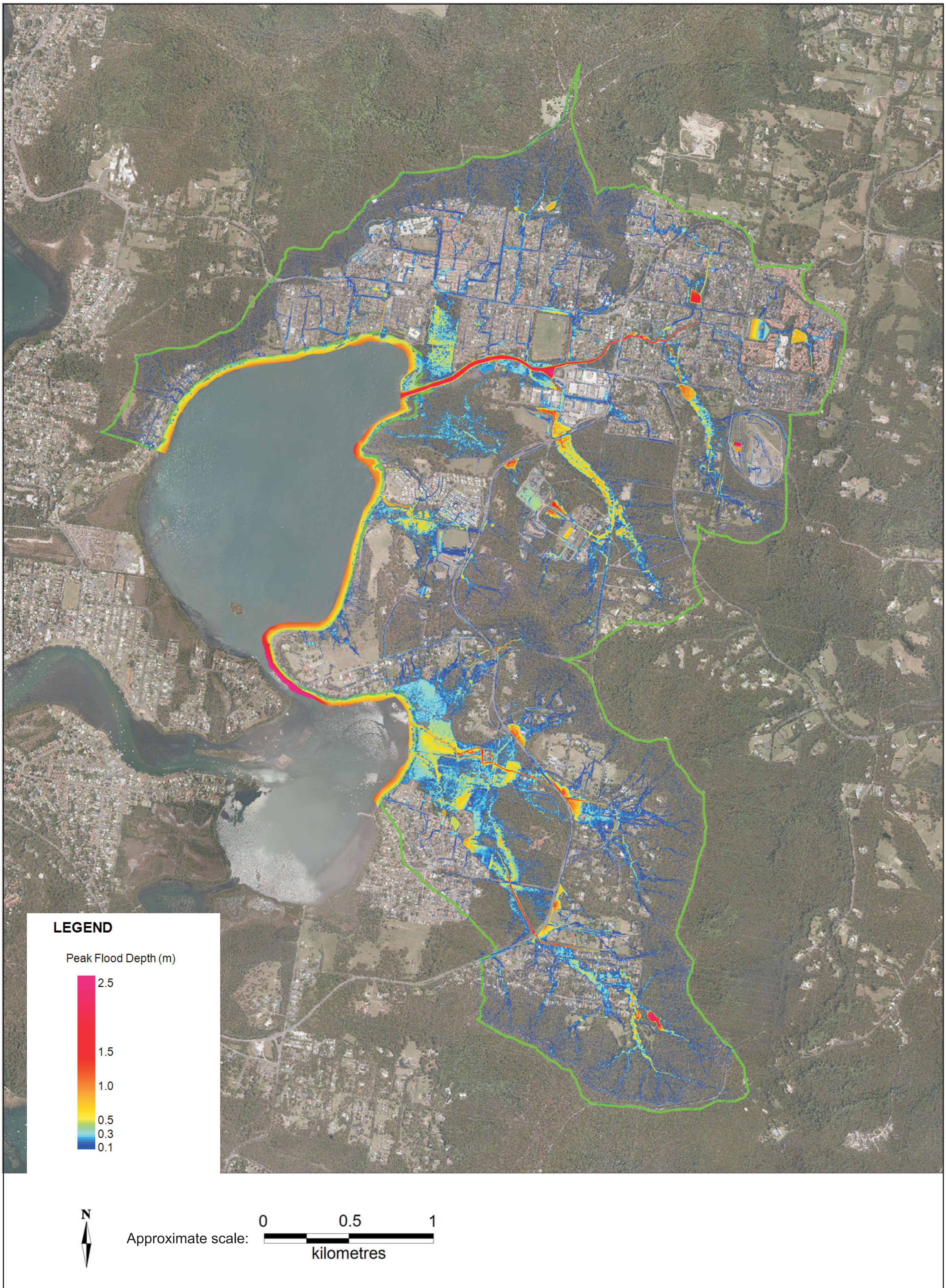
Figure A4

DRAWING 2196-A4.cdr

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KINCUMBER OVERLAND FLOW STUDY
10% AEP PEAK FLOOD DEPTH

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Figure A5

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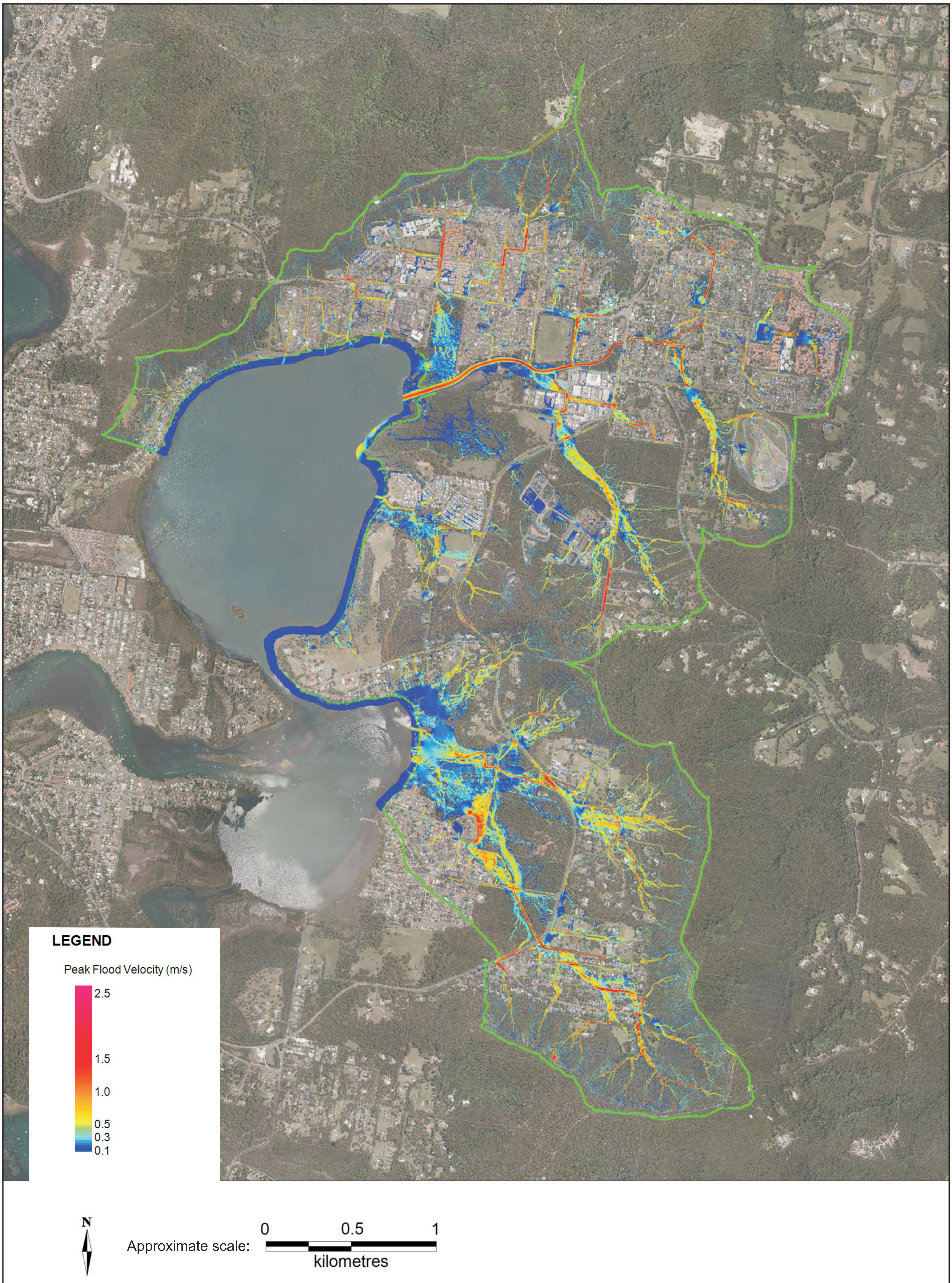


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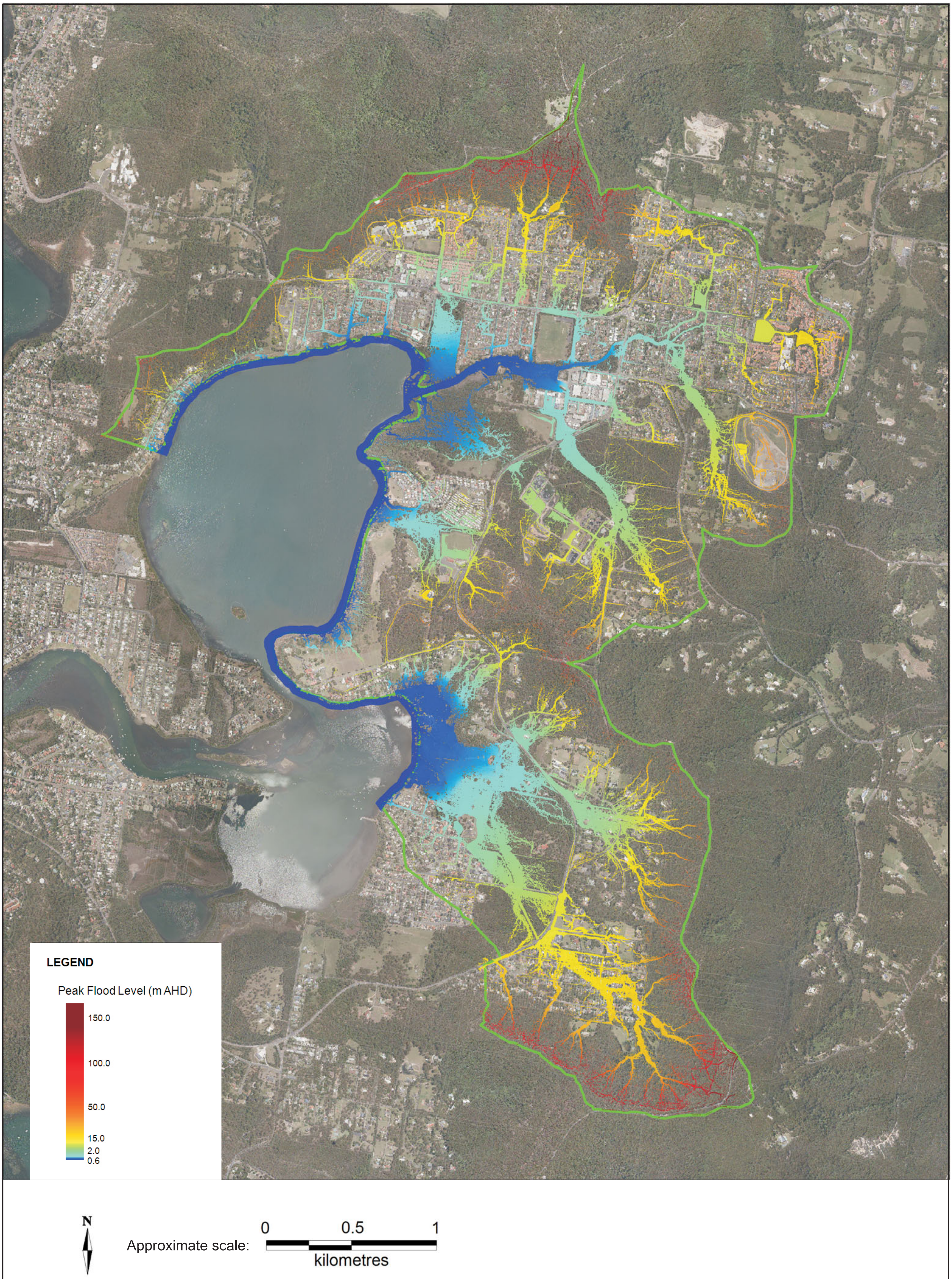
KINCUMBER OVERLAND FLOW STUDY
10% AEP PEAK FLOOD VELOCITY

MHL Report 2196

Figure A6

DRAWING 2196-A6.cdr

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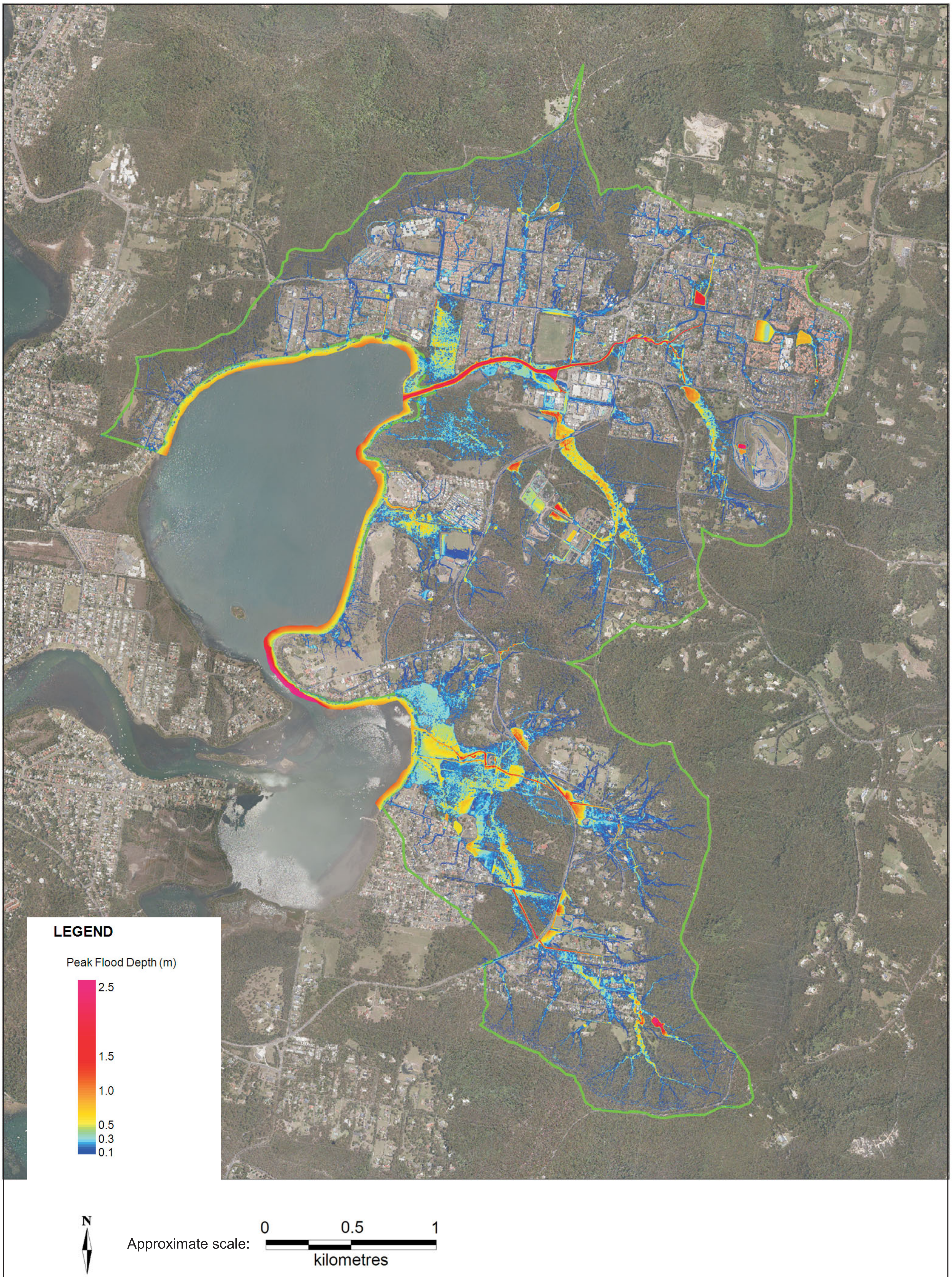
KINCUMBER OVERLAND FLOW STUDY
5% AEP PEAK FLOOD LEVEL

MHL Report 2196

Figure A7

DRAWING 2196-A7.cdr

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KINCUMBER OVERLAND FLOW STUDY
5% AEP PEAK FLOOD DEPTH

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Figure A8

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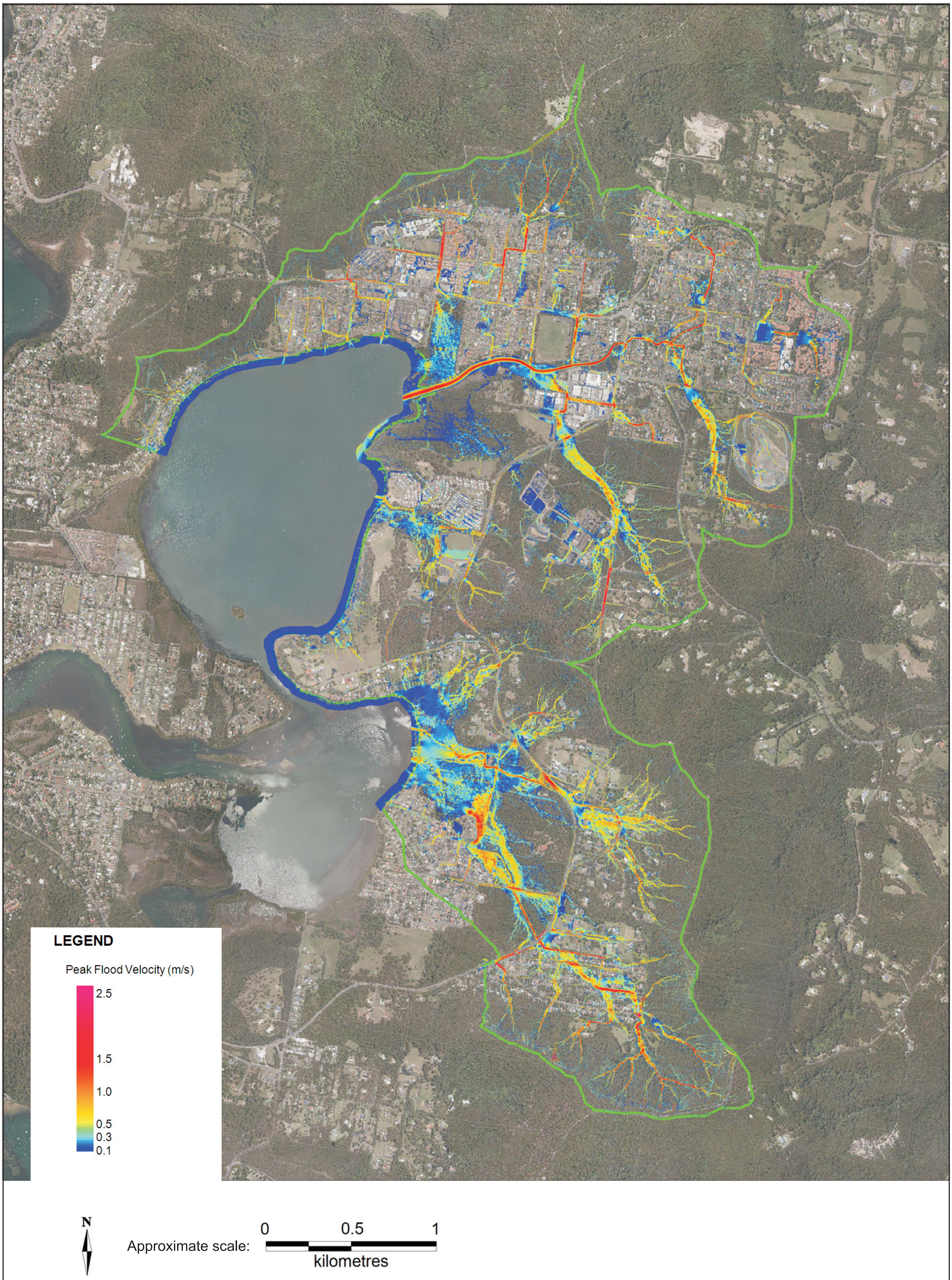


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KINCUMBER OVERLAND FLOW STUDY
5% AEP PEAK FLOOD VELOCITY

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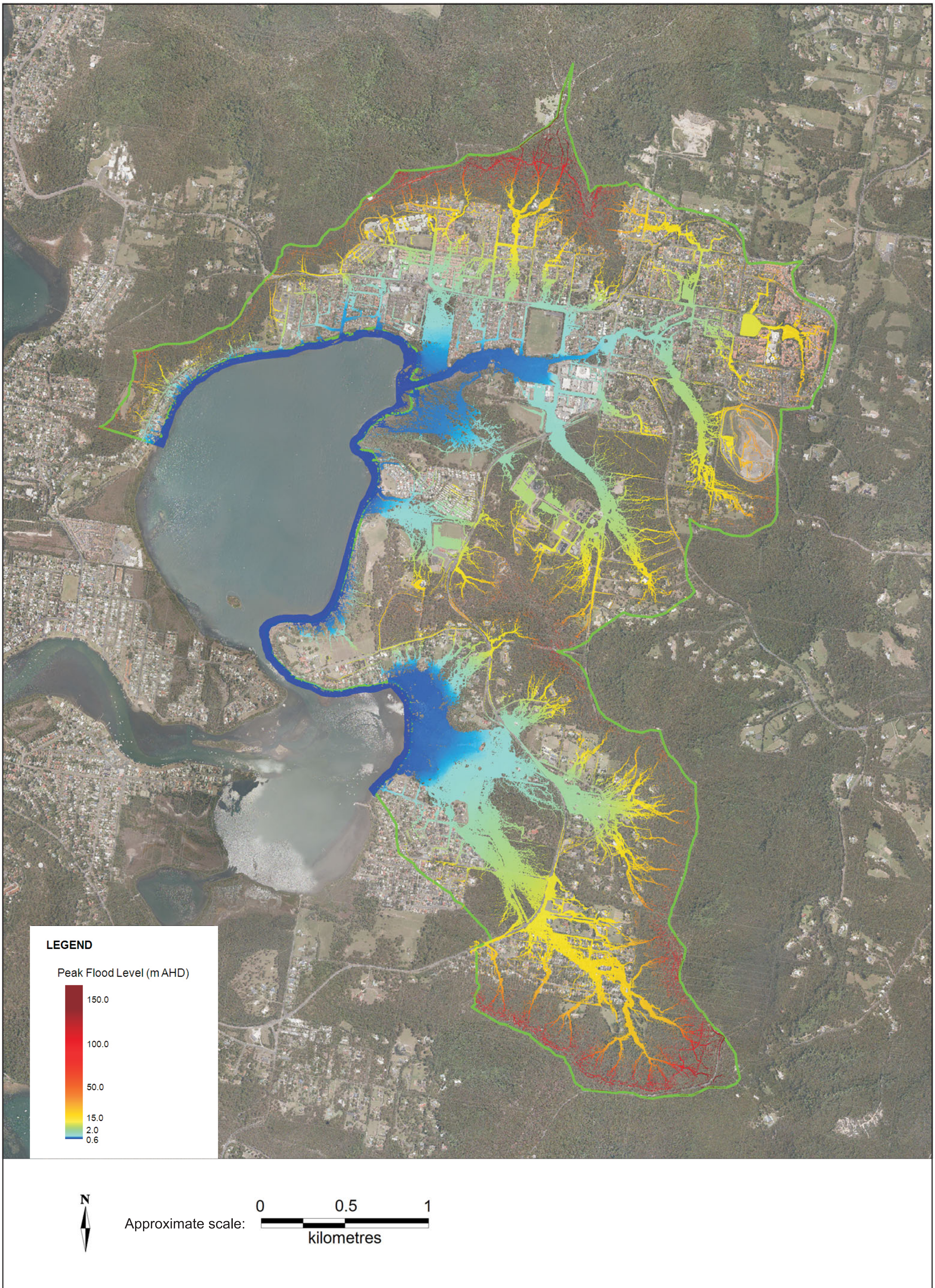
Figure
A9

DRAWING 2196-A9.cdr

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KINCUMBER OVERLAND FLOW STUDY
2% AEP PEAK FLOOD LEVEL

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Figure A10

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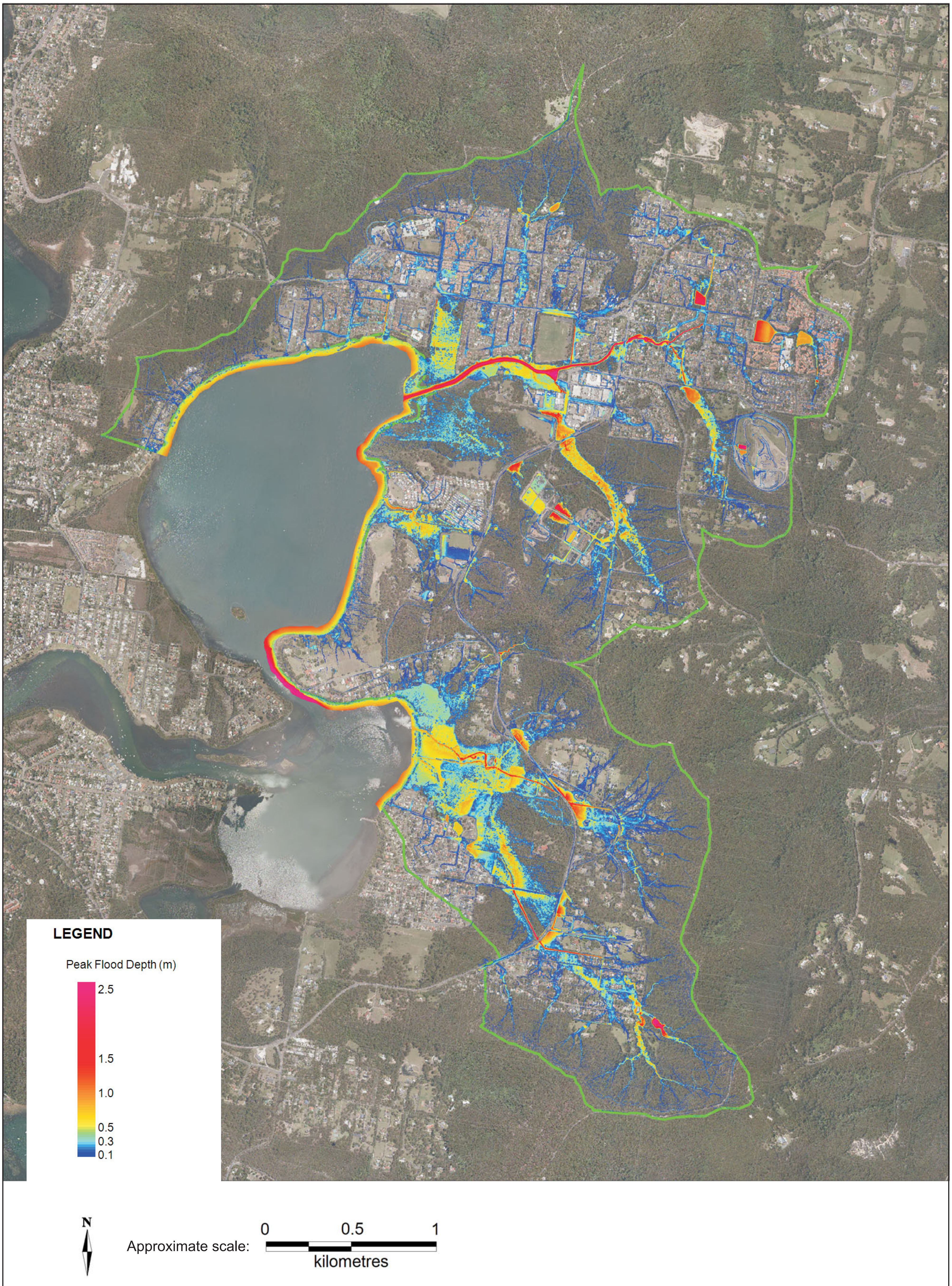


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KINCUMBER OVERLAND FLOW STUDY
2% AEP PEAK FLOOD DEPTH

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Figure A11

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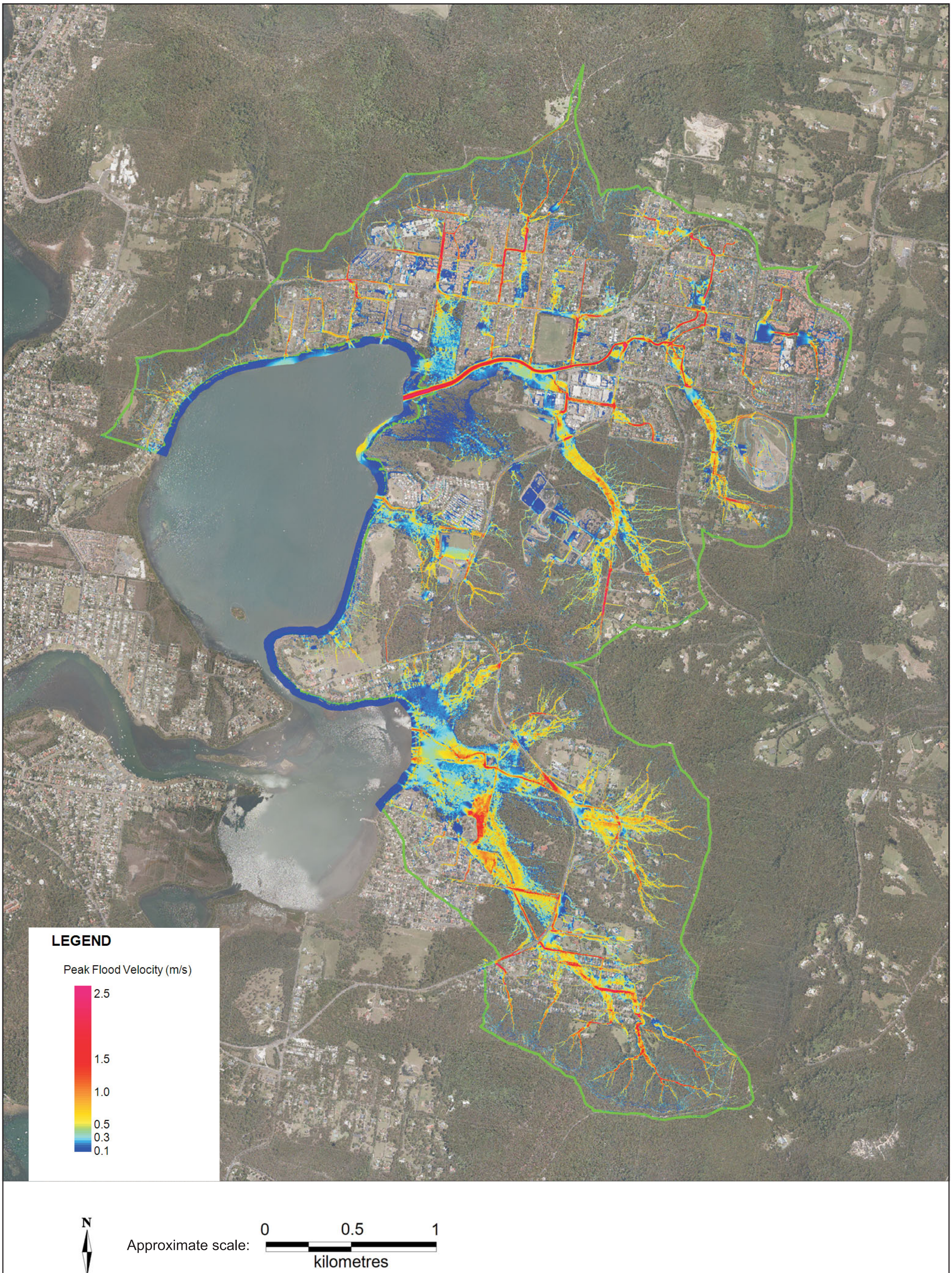


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KINCUMBER OVERLAND FLOW STUDY
2% AEP PEAK FLOOD VELOCITY

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Figure A12

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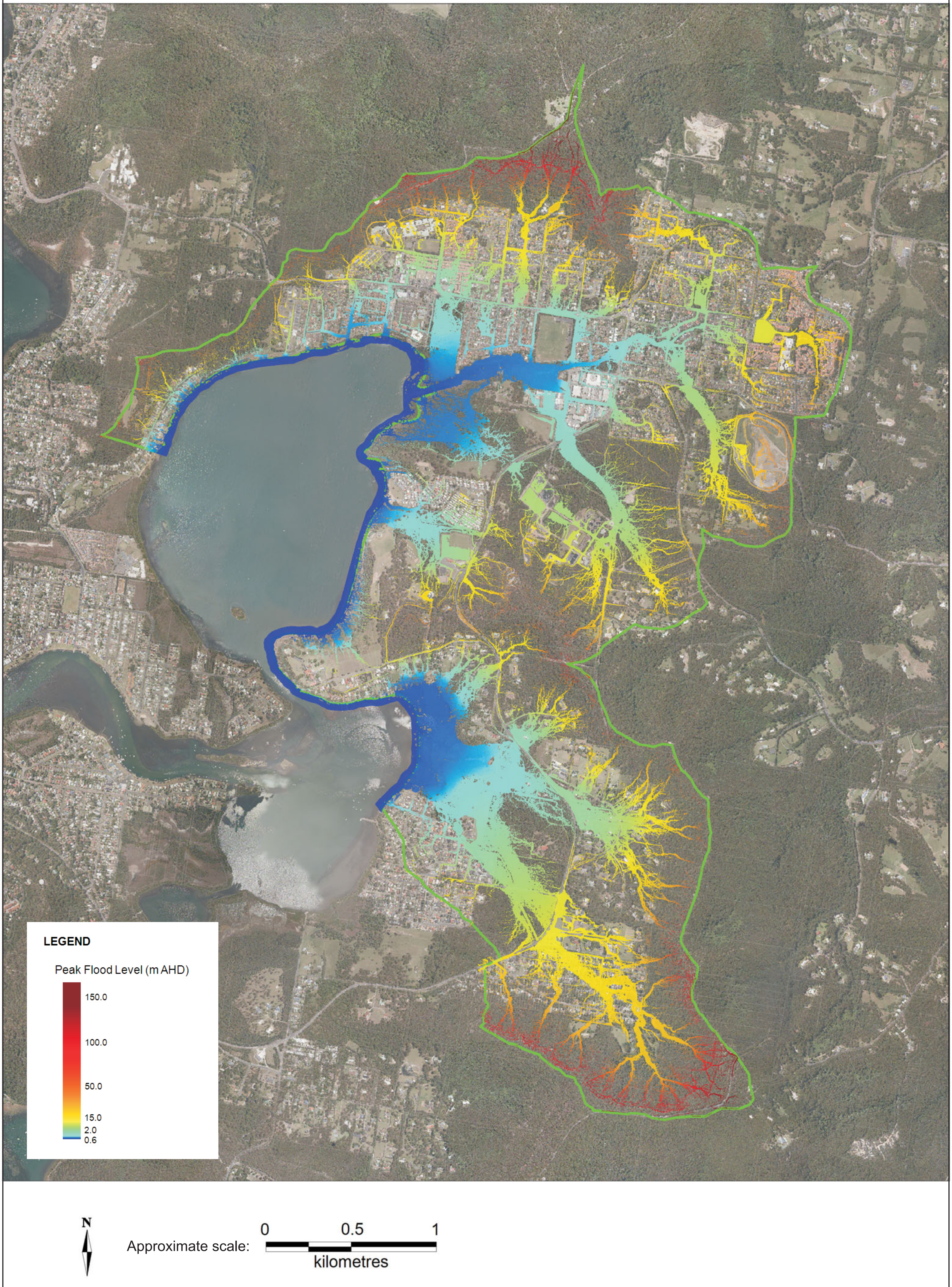


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KINCUMBER OVERLAND FLOW STUDY
1% AEP PEAK FLOOD LEVEL

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Figure A13

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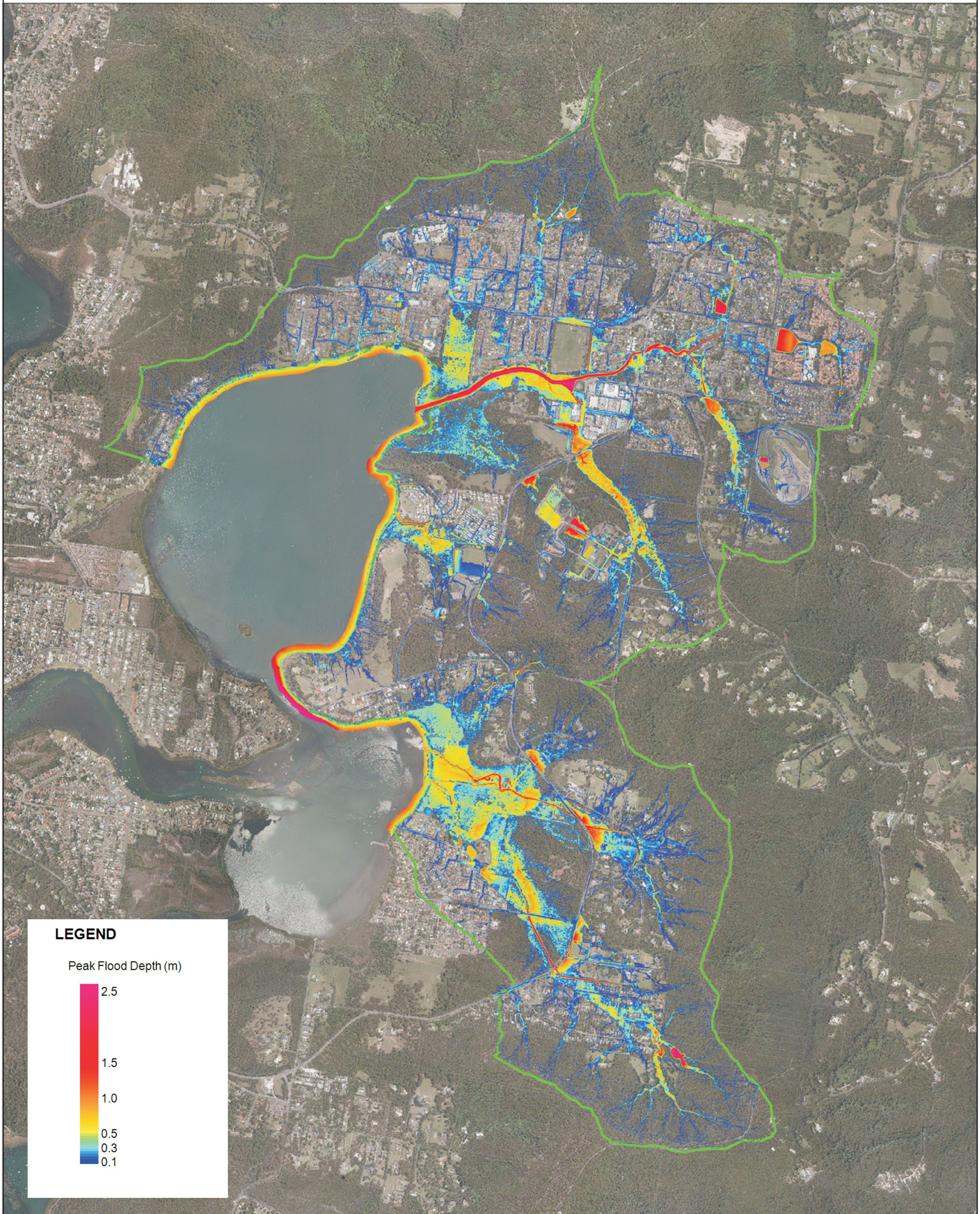


N

Approximate scale: 0 0.5 1 kilometres

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KINCUMBER OVERLAND FLOW STUDY
1% AEP PEAK FLOOD DEPTH

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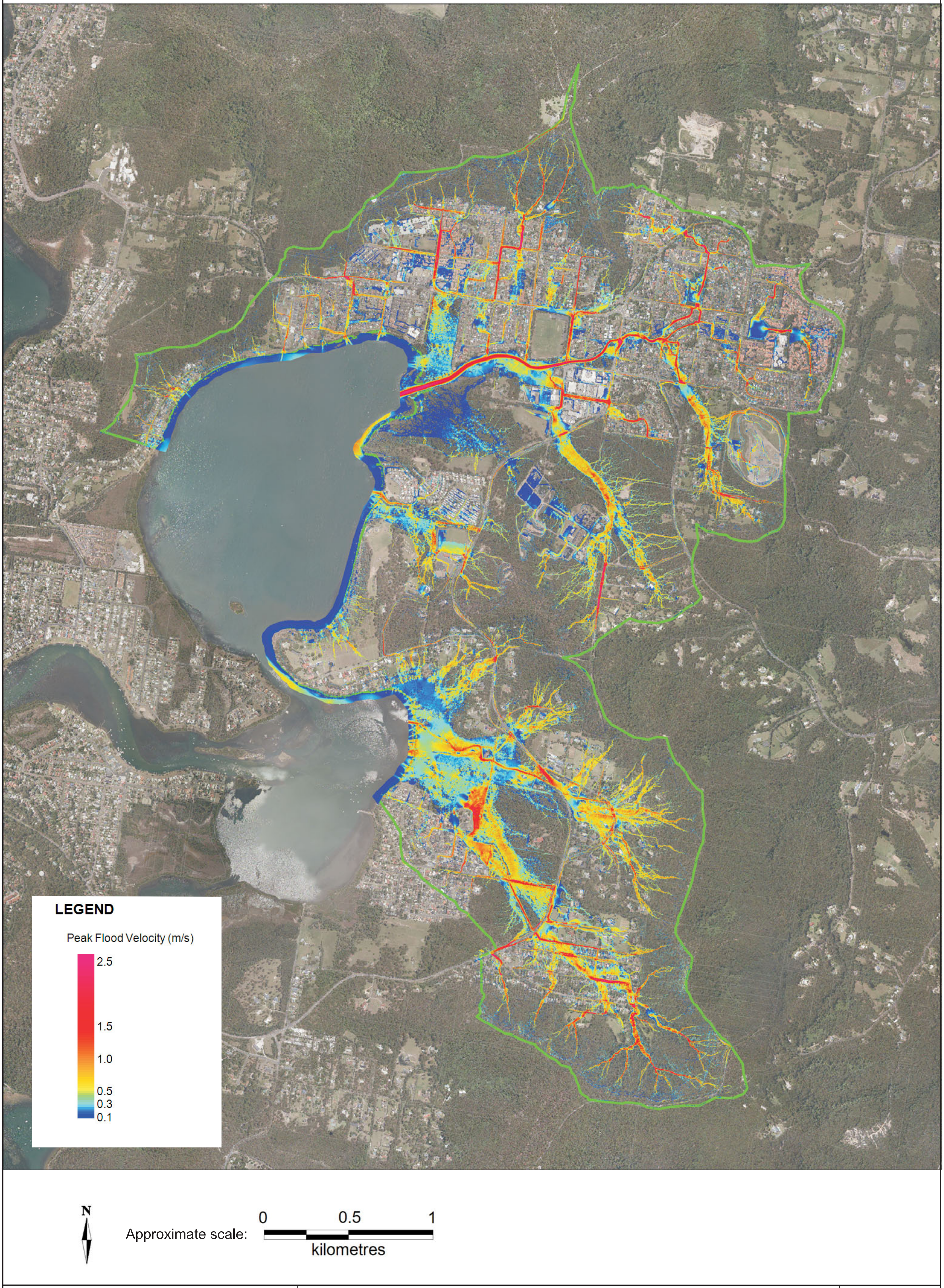
Figure A14

DRAWING 2196-A14.cdr

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KINCUMBER OVERLAND FLOW STUDY
1% AEP PEAK FLOOD VELOCITY

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Figure A15

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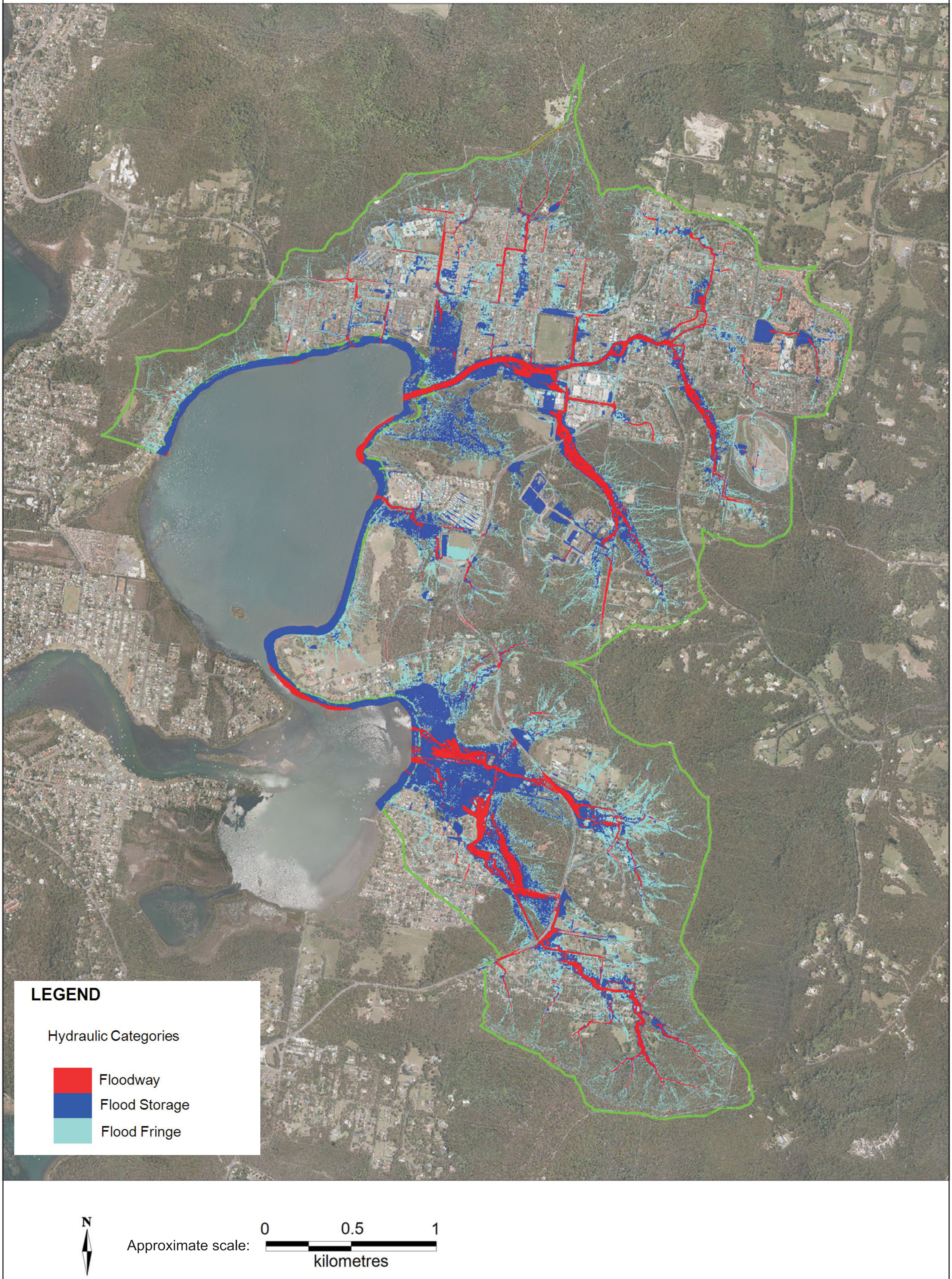


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KINCUMBER OVERLAND FLOW STUDY
1% AEP HYDRAULIC CATEGORIES

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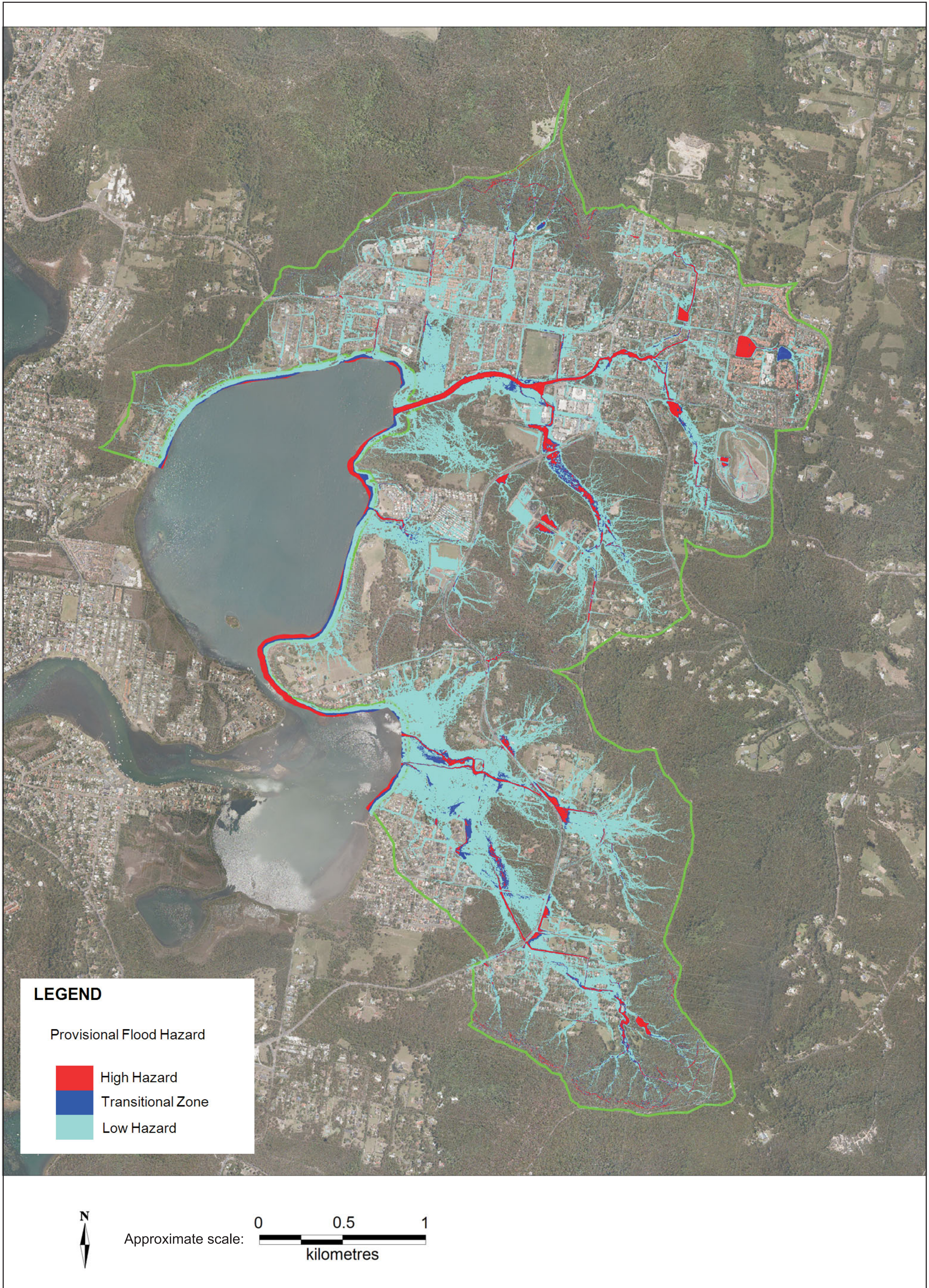
Figure A16

DRAWING 2196-A16.cdr

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KINCUMBER OVERLAND FLOW STUDY
1% AEP PROVISIONAL HAZARD CATEGORIES

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Figure A17

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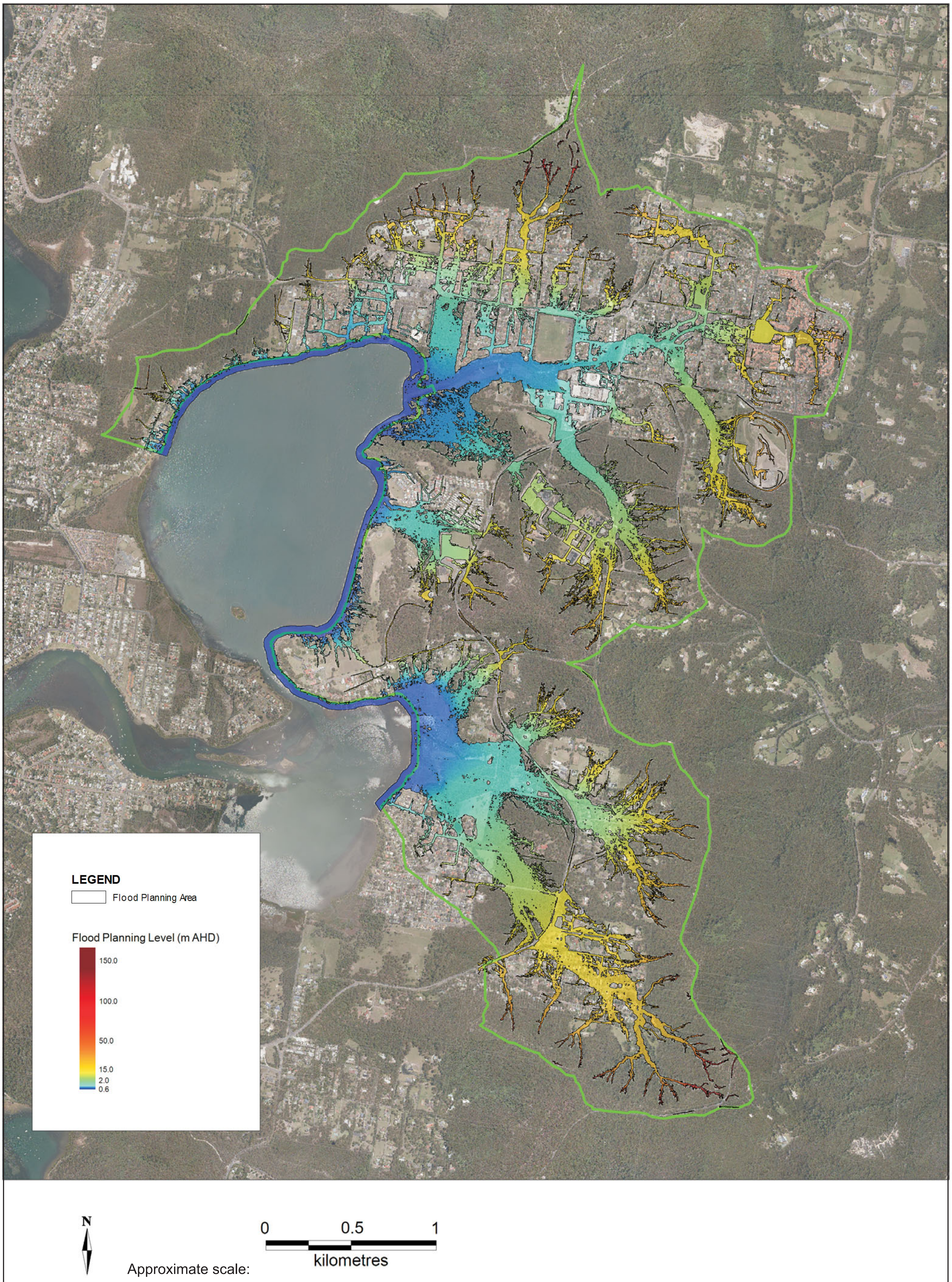


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KINCUMBER OVERLAND FLOW STUDY
PRELIMINARY FLOOD PLANNING LEVEL AND AREA

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Figure A18

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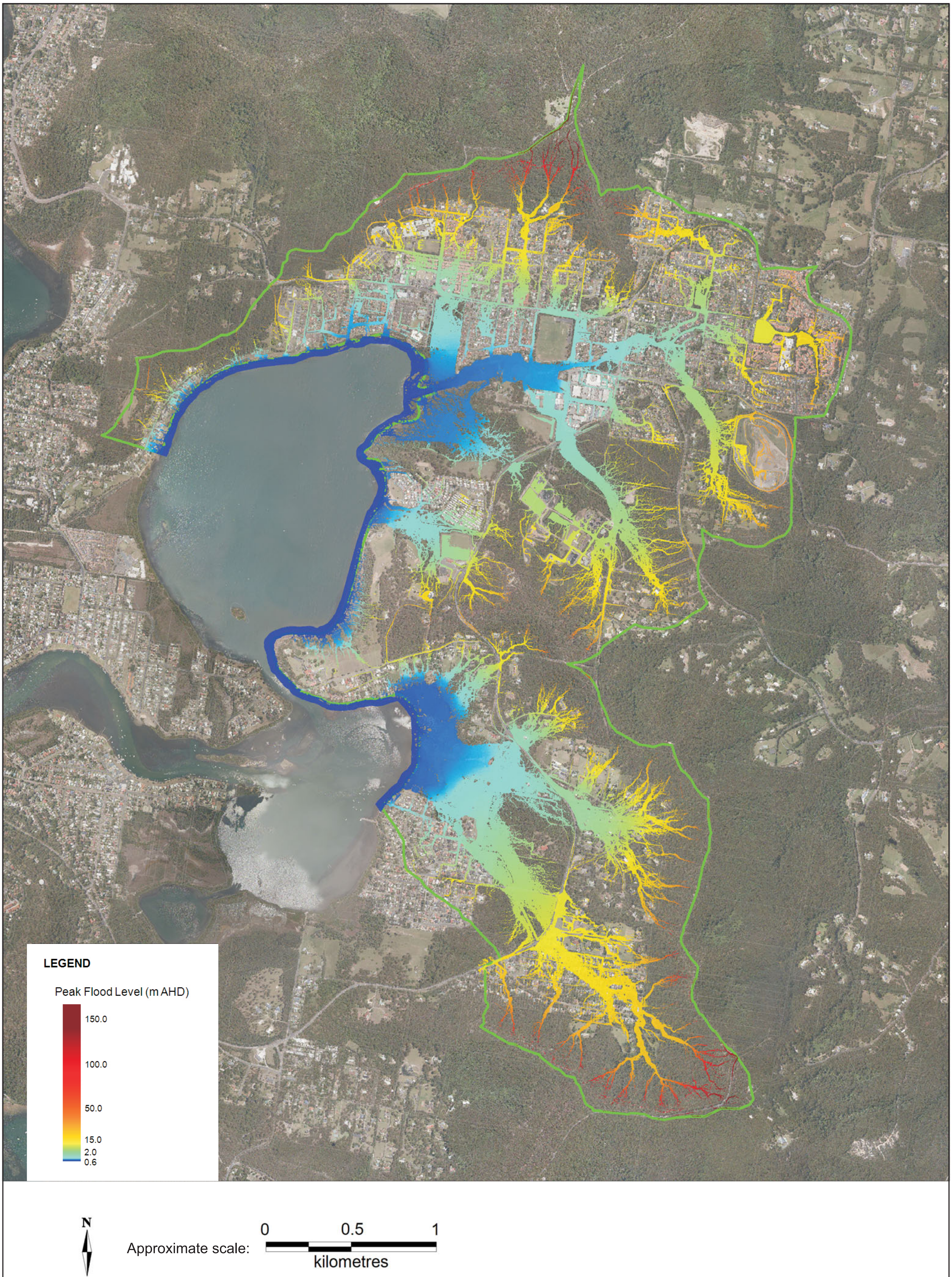


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KINCUMBER OVERLAND FLOW STUDY
0.5% AEP PEAK FLOOD LEVEL

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Figure A19

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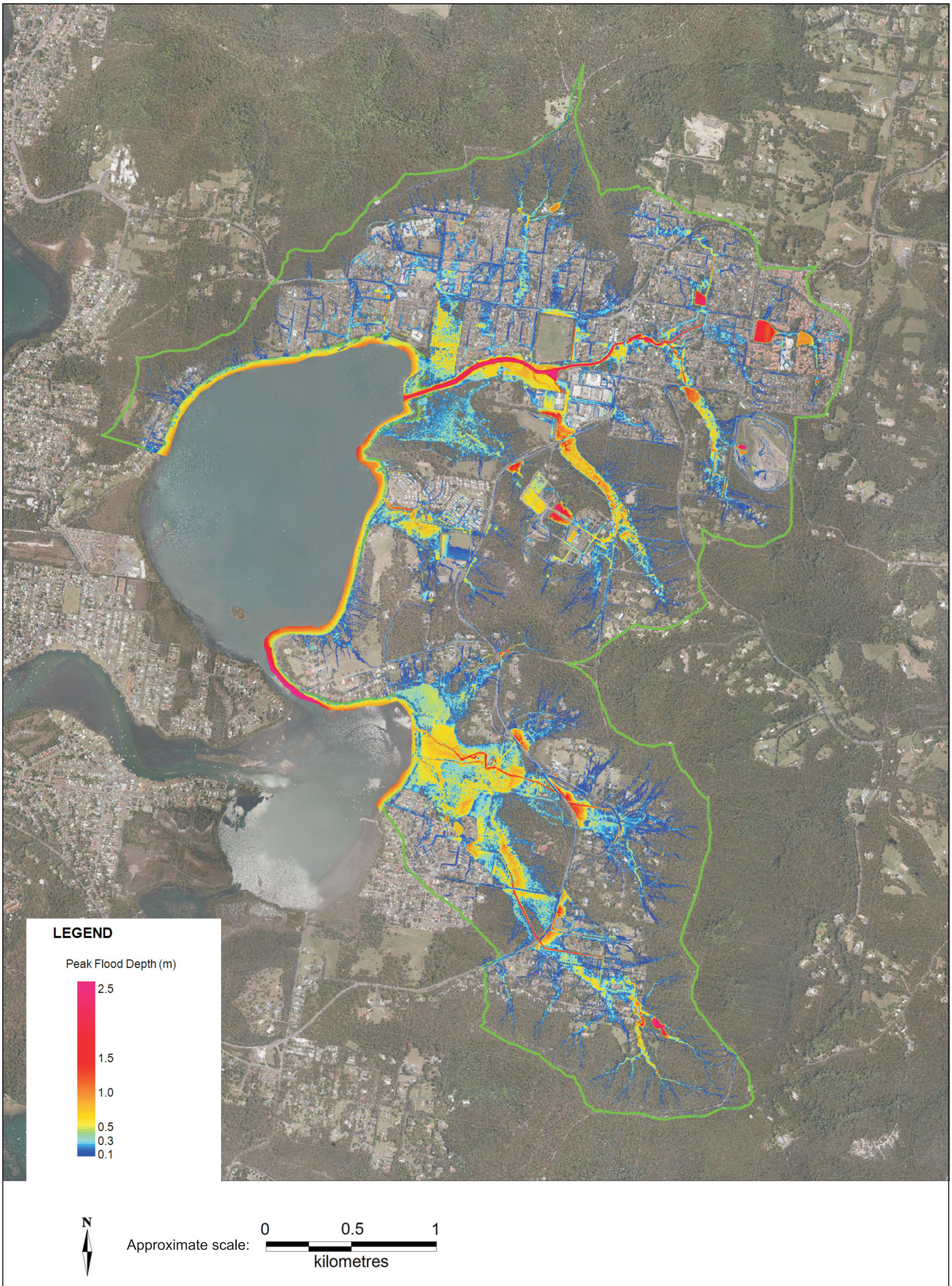


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KINCUMBER OVERLAND FLOW STUDY
0.5% AEP PEAK FLOOD DEPTH

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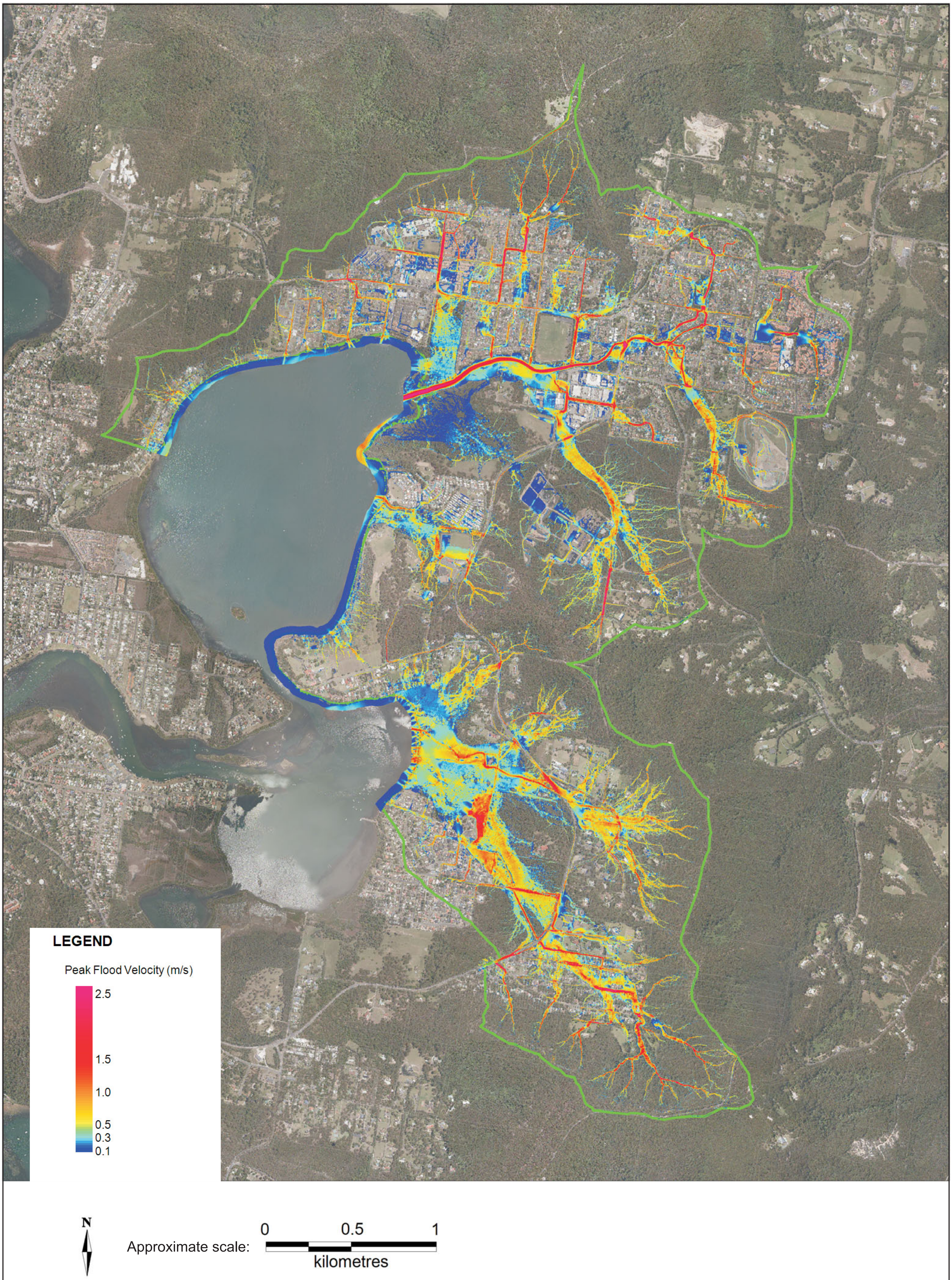
Figure A20

DRAWING 2196-A20.cdr

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KINCUMBER OVERLAND FLOW STUDY
0.5% AEP PEAK FLOOD VELOCITY

MHL Report 2196

Figure A21

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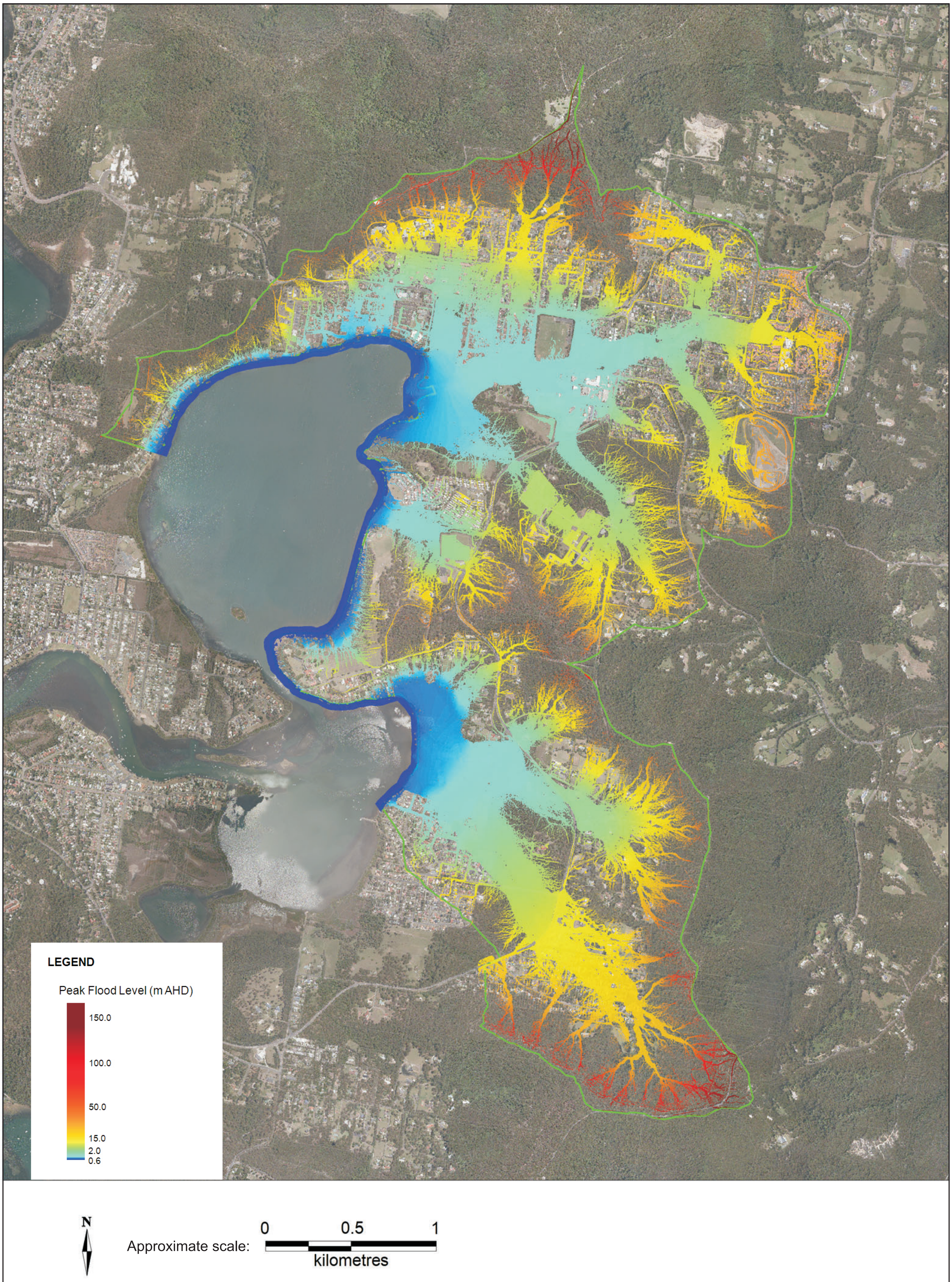


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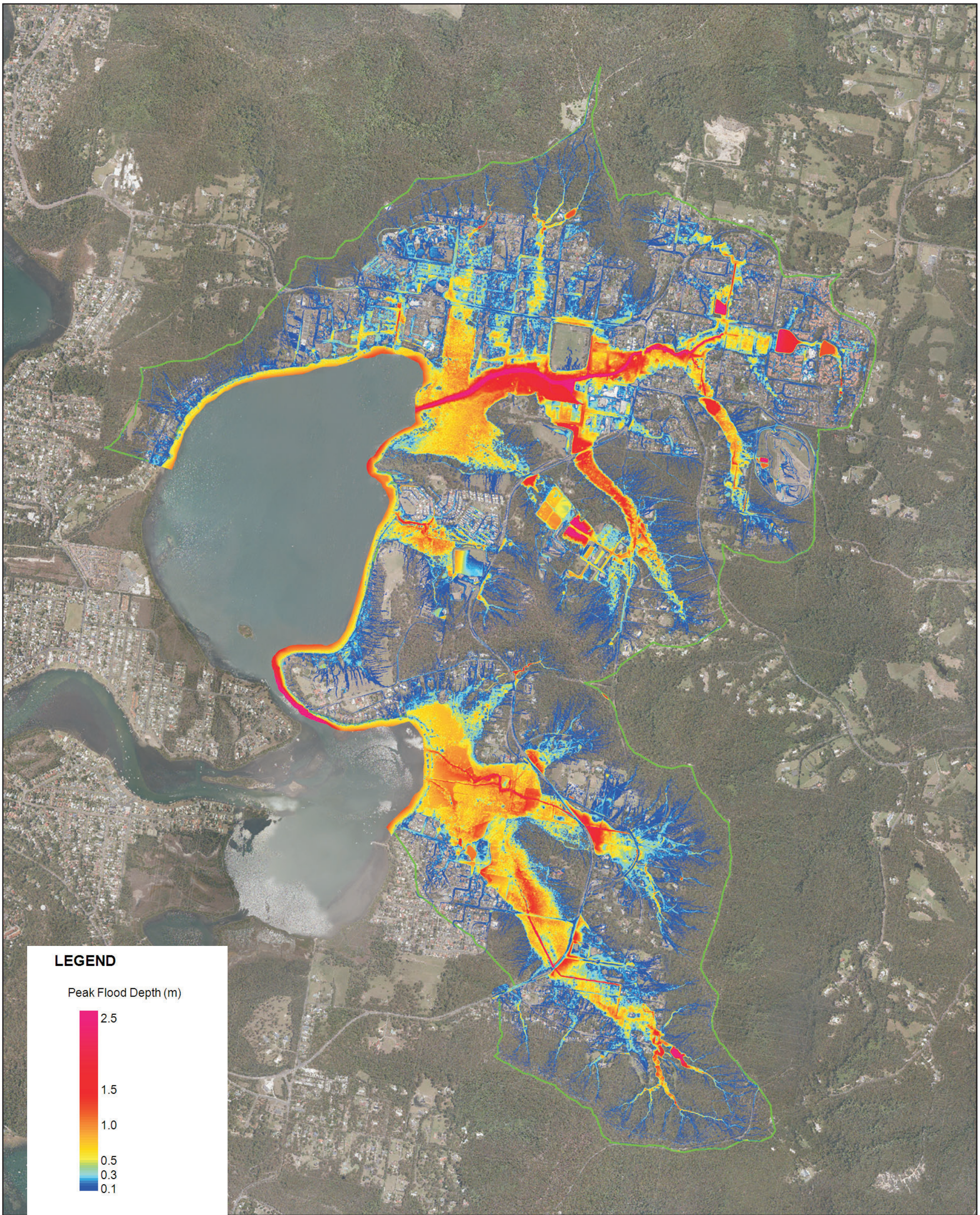
KINCUMBER OVERLAND FLOW STUDY
PMF PEAK FLOOD LEVEL

MHL Report 2196

Figure A22

DRAWING 2196-A22.cdr




N

Approximate scale: 0 0.5 1 kilometres

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KINCUMBER OVERLAND FLOW STUDY
PMF PEAK FLOOD DEPTH

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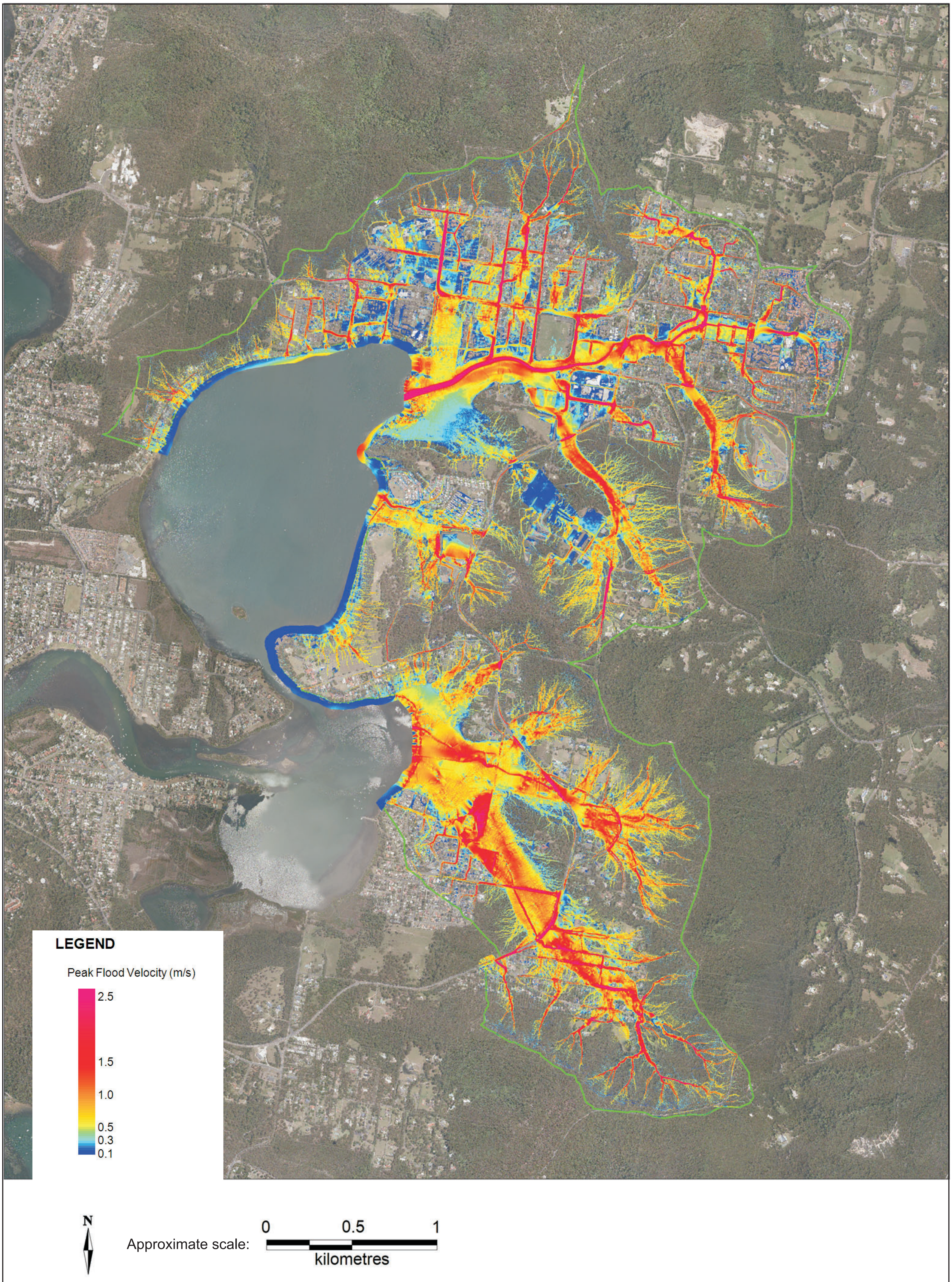
Figure A23

DRAWING 2196-A23.cdr

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KINCUMBER OVERLAND FLOW STUDY
PMF AEP PEAK FLOOD VELOCITY

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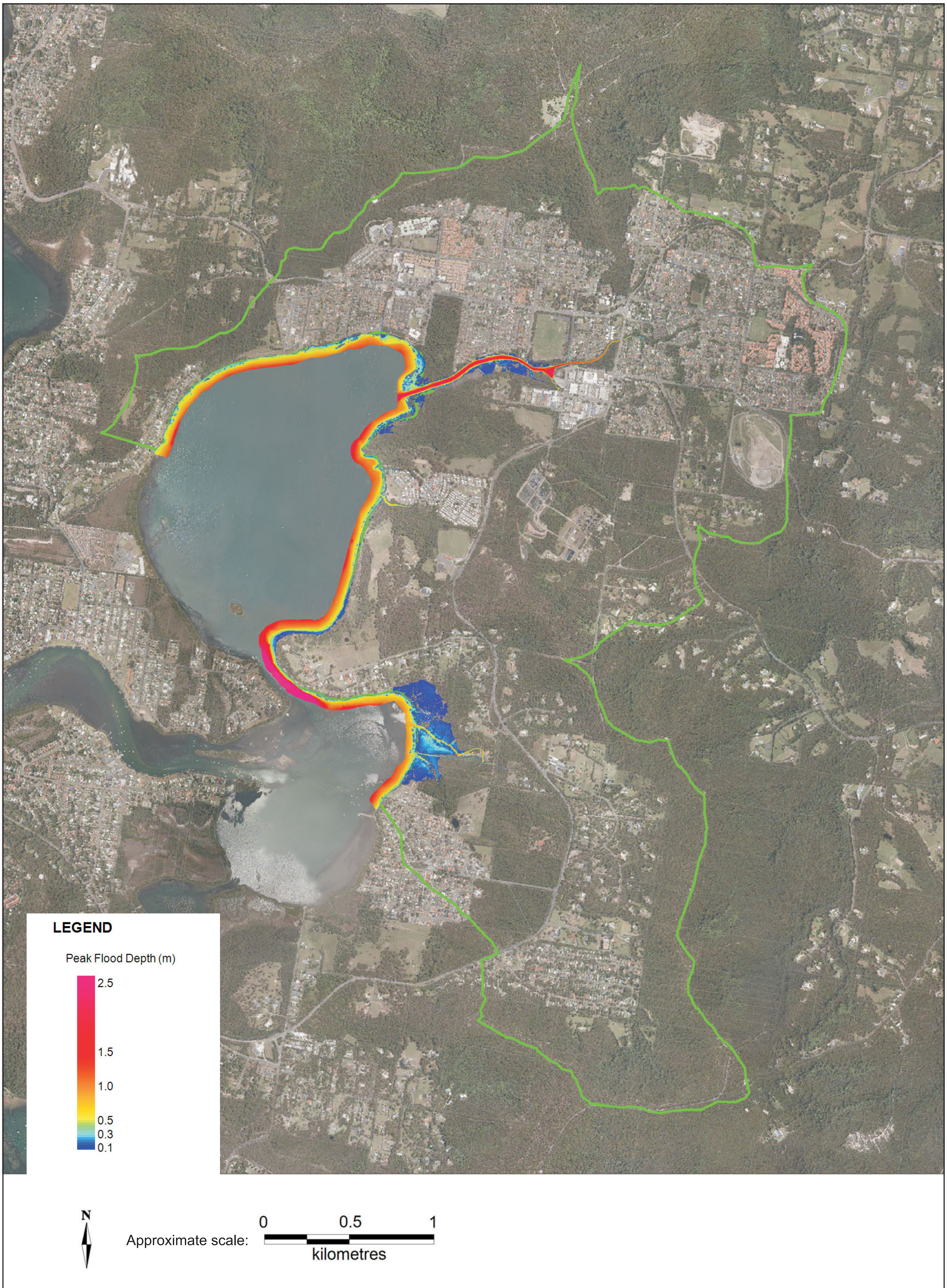
Figure A24

DRAWING 2196-A24.cdr

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KINCUMBER OVERLAND FLOW STUDY
100% AEP TIDAL INUNDATION - DEPTH

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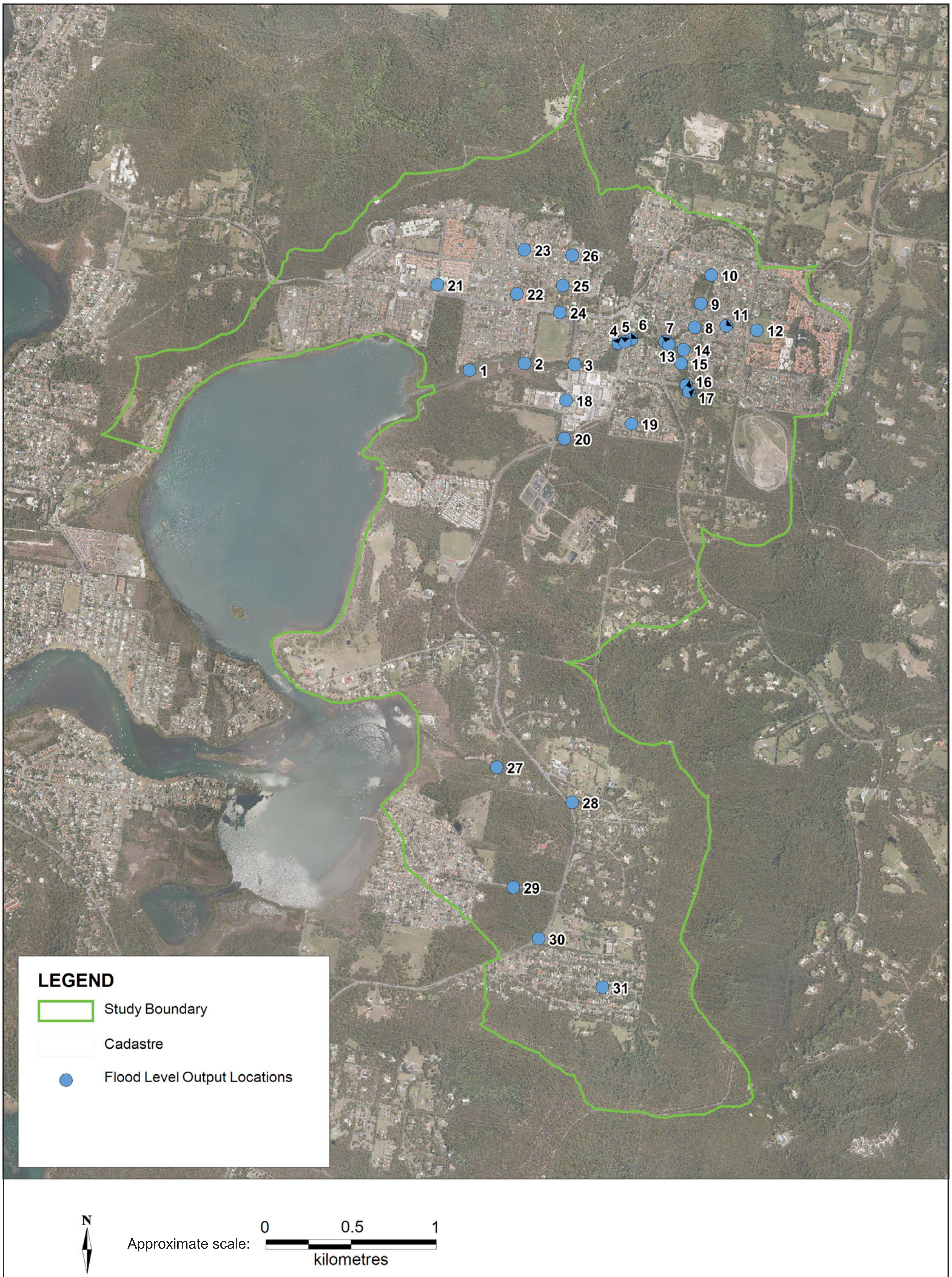
Figure A25

DRAWING 2196-A25.cdr

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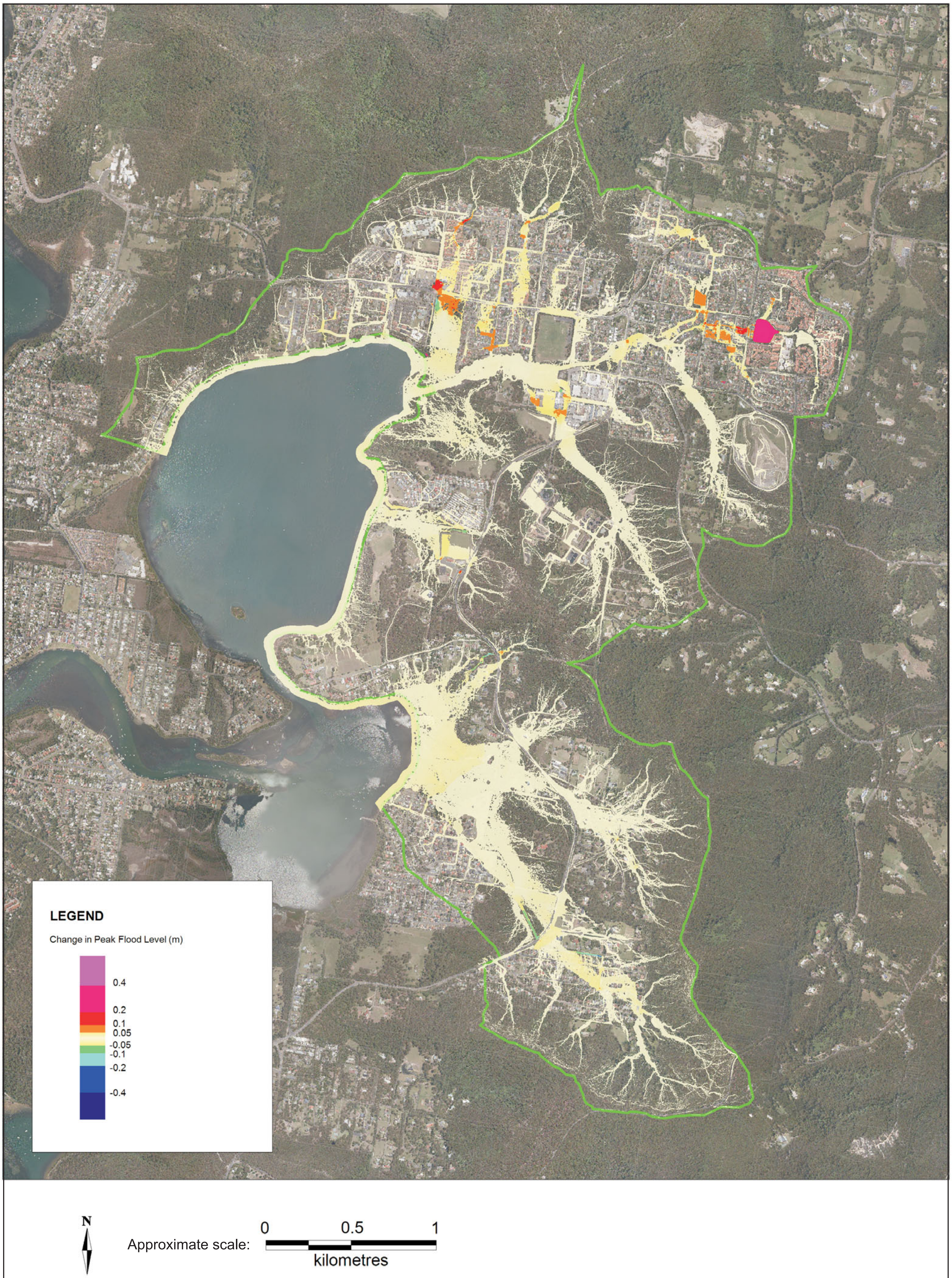
KINCUMBER OVERLAND FLOW STUDY
FLOOD LEVEL OUTPUT LOCATIONS

MHL Report 2196

Figure A26

DRAWING 2196-A26.cdr

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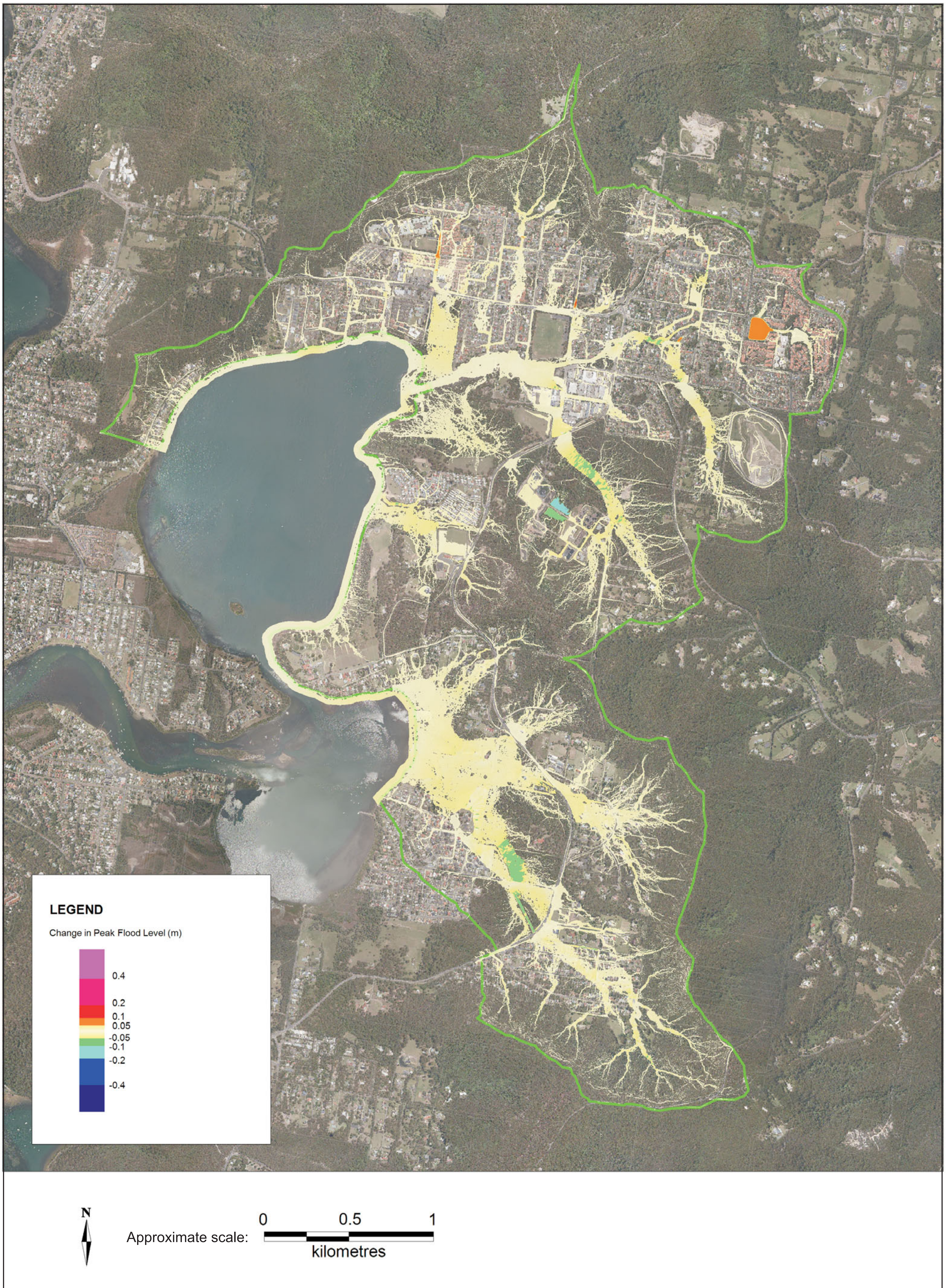
KINCUMBER OVERLAND FLOW STUDY
STRUCTURE BLOCKAGE SENSITIVITY
1% AEP EVENT

MHL Report 2196

Figure A27

DRAWING 2196-A27.cdr

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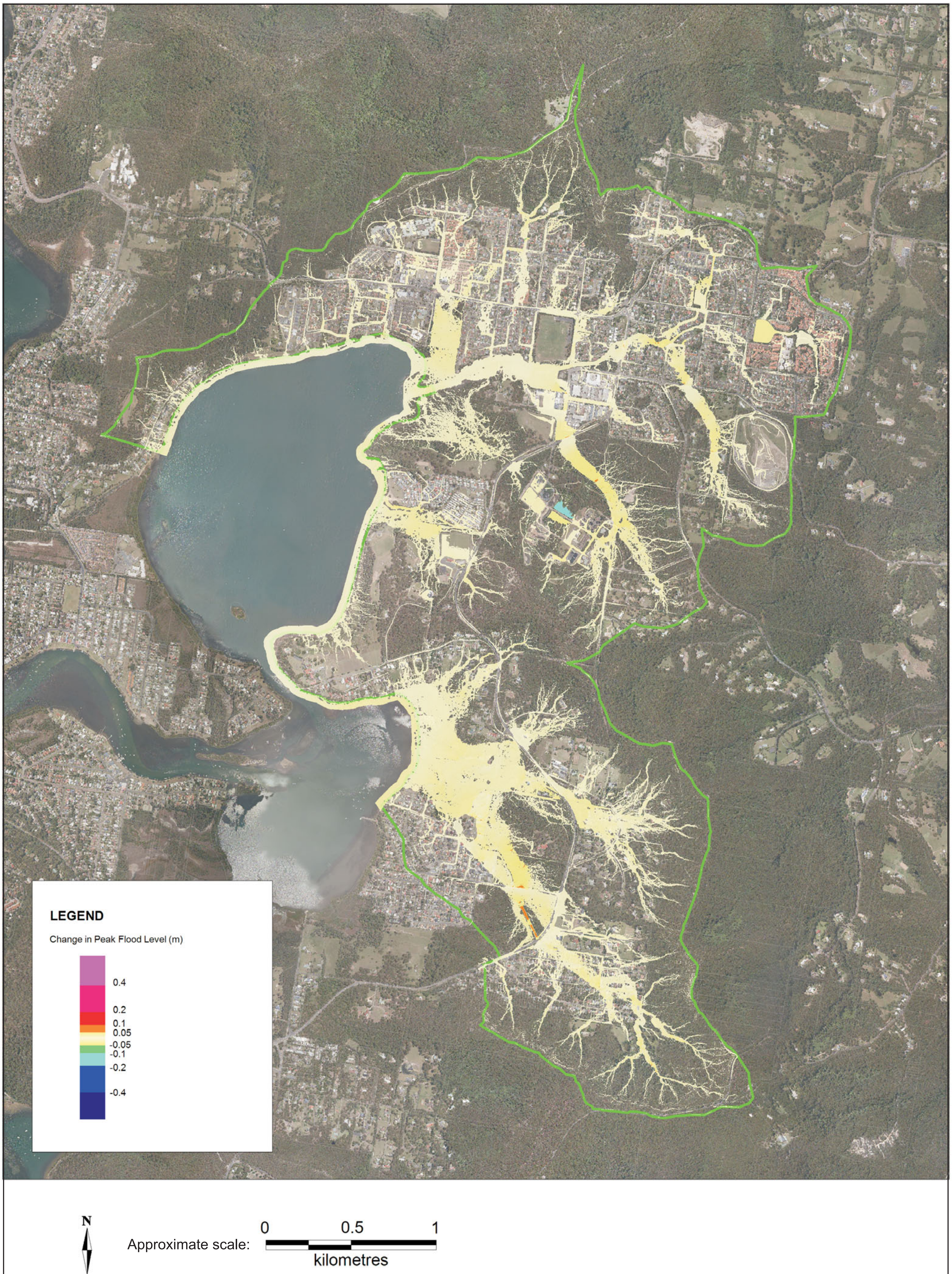
KINCUMBER OVERLAND FLOW STUDY
20% DECREASED HYDRAULIC ROUGHNESS
1% AEP EVENT

MHL Report 2196

Figure A28

DRAWING 2196-A28.cdr

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KINCUMBER OVERLAND FLOW STUDY
20% INCREASED HYDRAULIC ROUGHNESS
1% AEP EVENT

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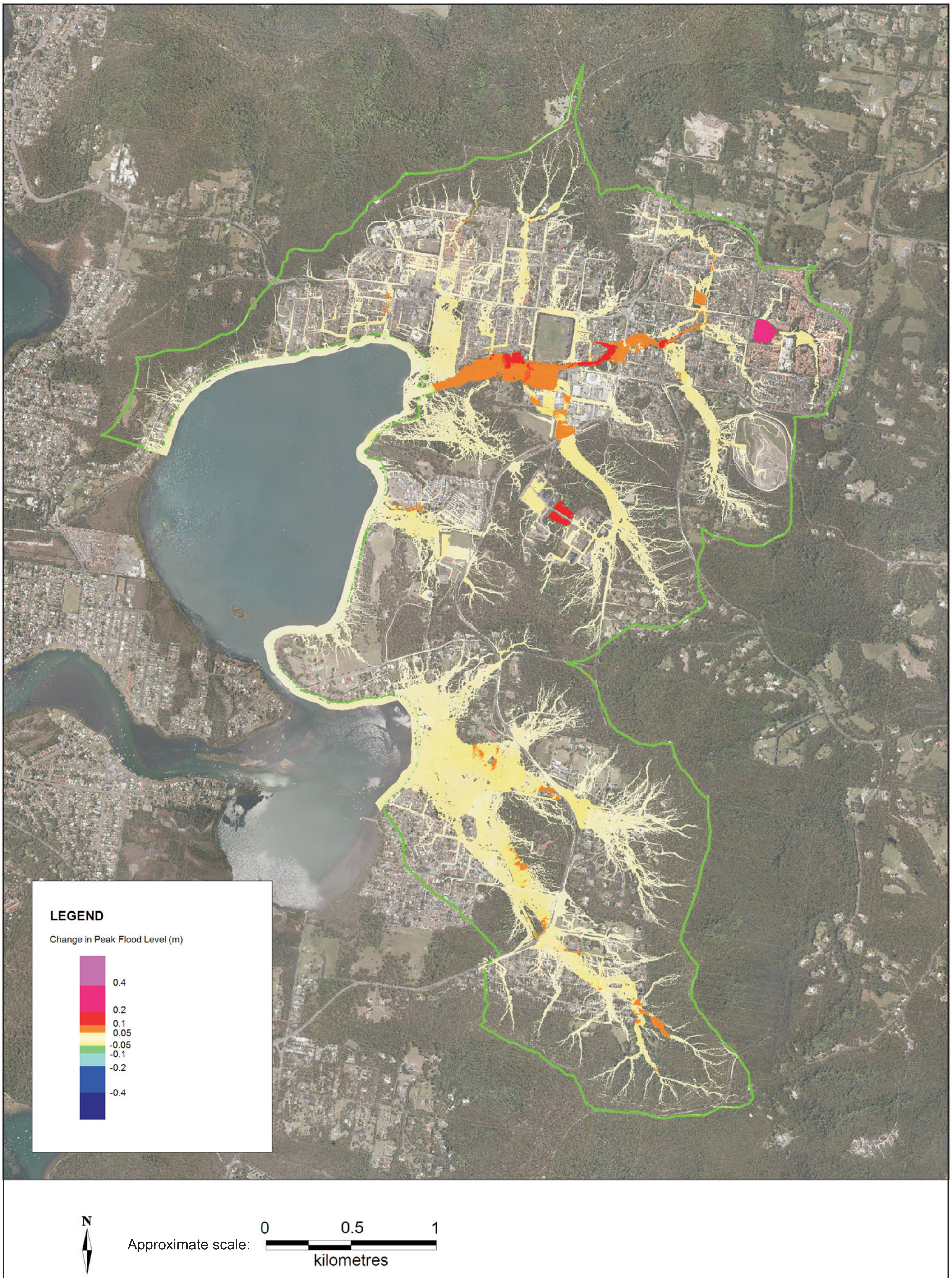
Figure A29

DRAWING 2196-A29.cdr

# Appendix B

## Climate Change Impact Mapping

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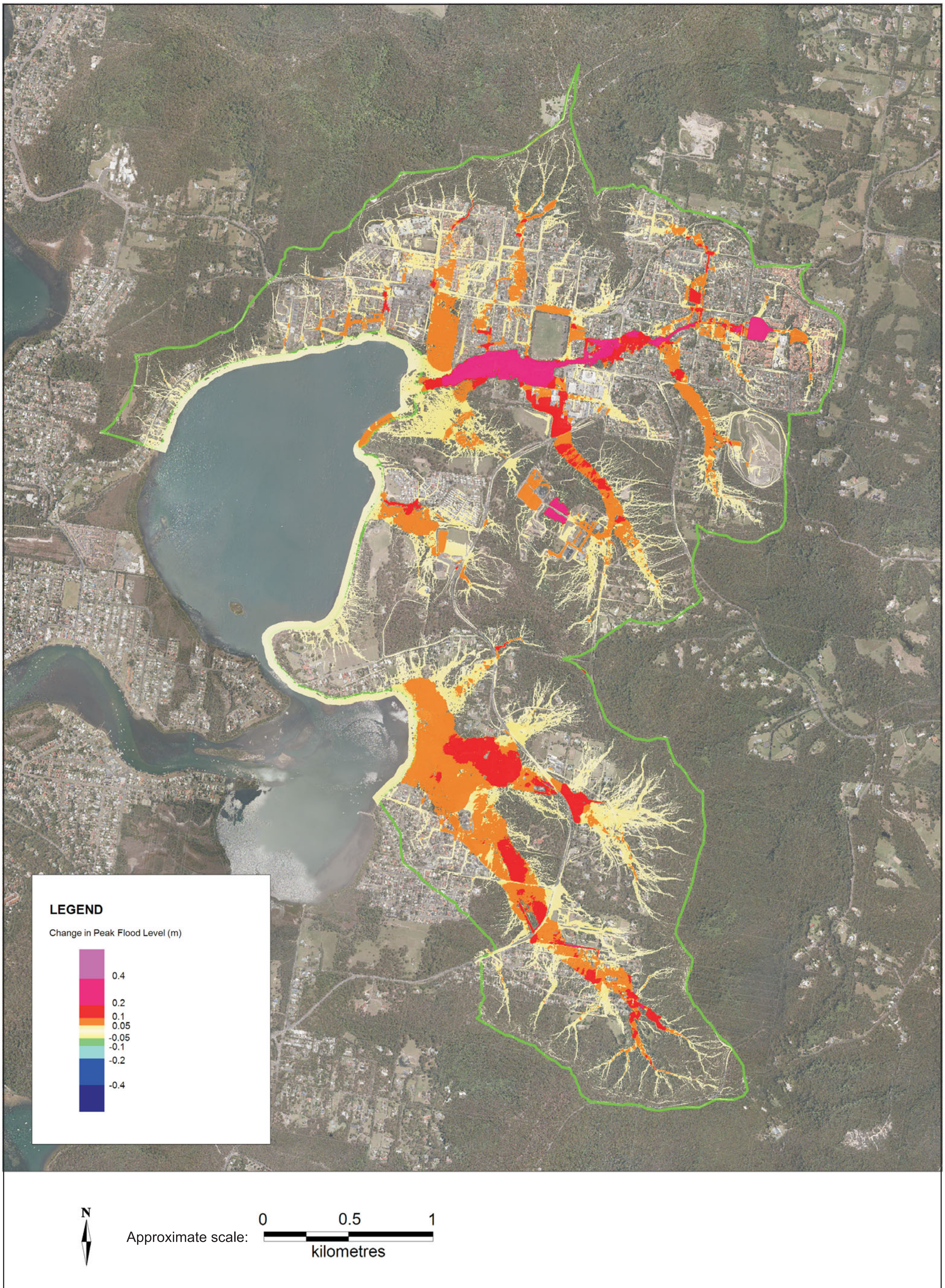
KINCUMBER OVERLAND FLOW STUDY
10% RAINFALL INTENSITY INCREASE
1% AEP EVENT

MHL Report 2196

Figure B1

DRAWING 2196-B1.cdr




NSW GOVERNMENT

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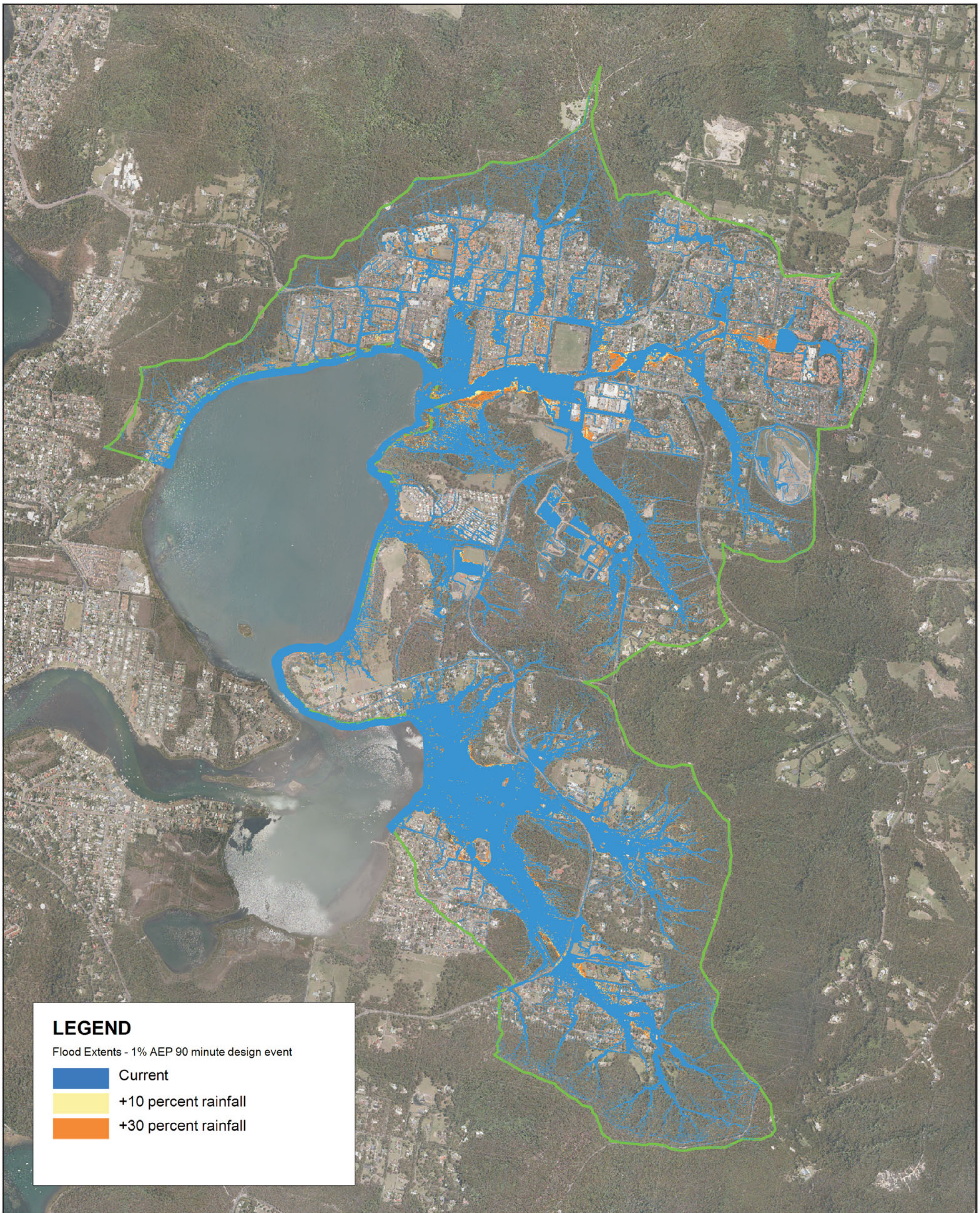
KINCUMBER OVERLAND FLOW STUDY
30% RAINFALL INTENSITY INCREASE
1% AEP EVENT

MHL Report 2196

Figure B2

DRAWING 2196-B2.cdr




N

Approximate scale: 0 0.5 1 kilometres

Public Works
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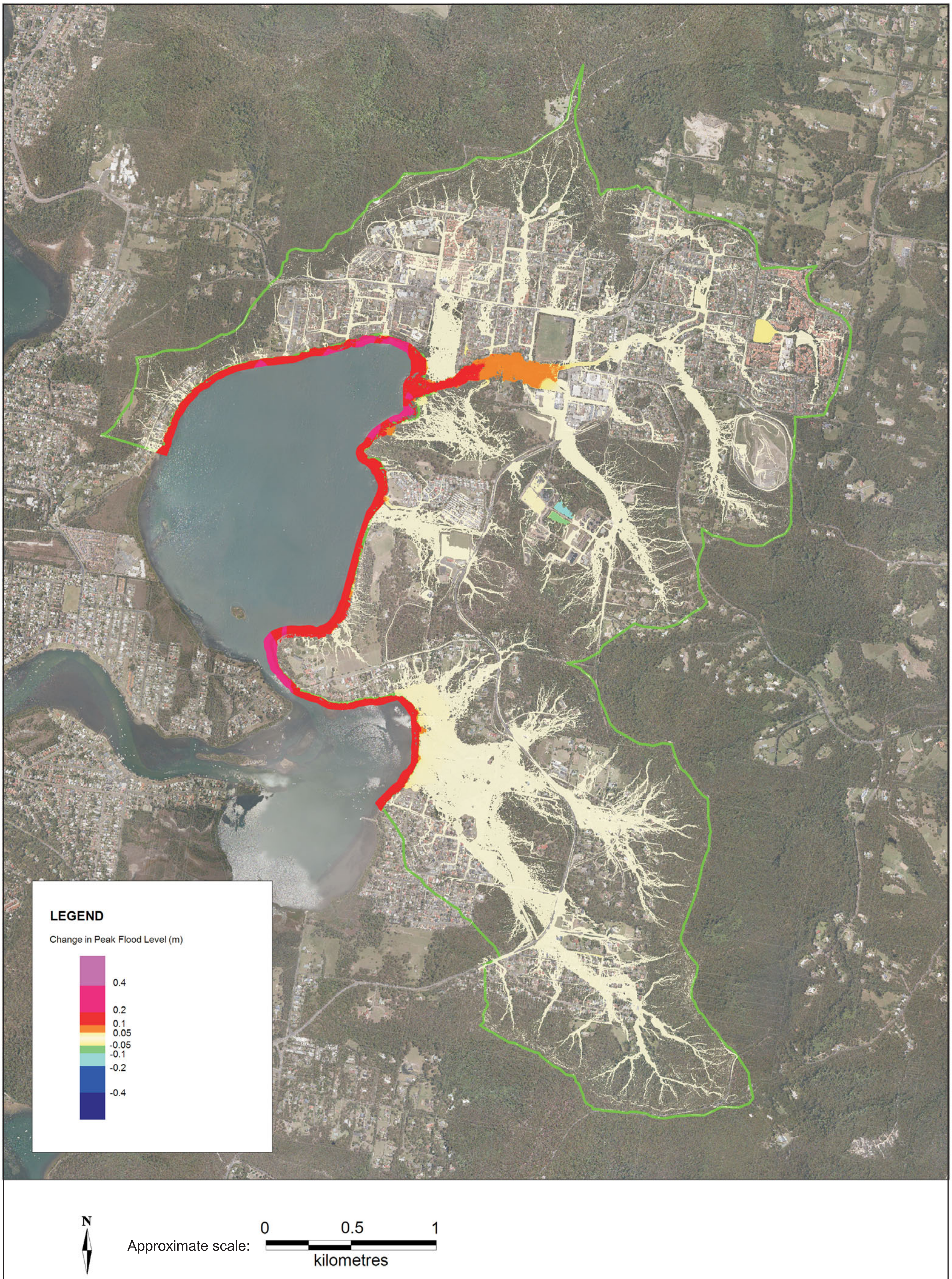
KINCUMBER OVERLAND FLOW STUDY
RAINFALL INTENSITY INCREASE FLOOD EXTENTS
1% AEP EVENT

MHL Report 2196

Figure B3

DRAWING 2196-B3.cdr



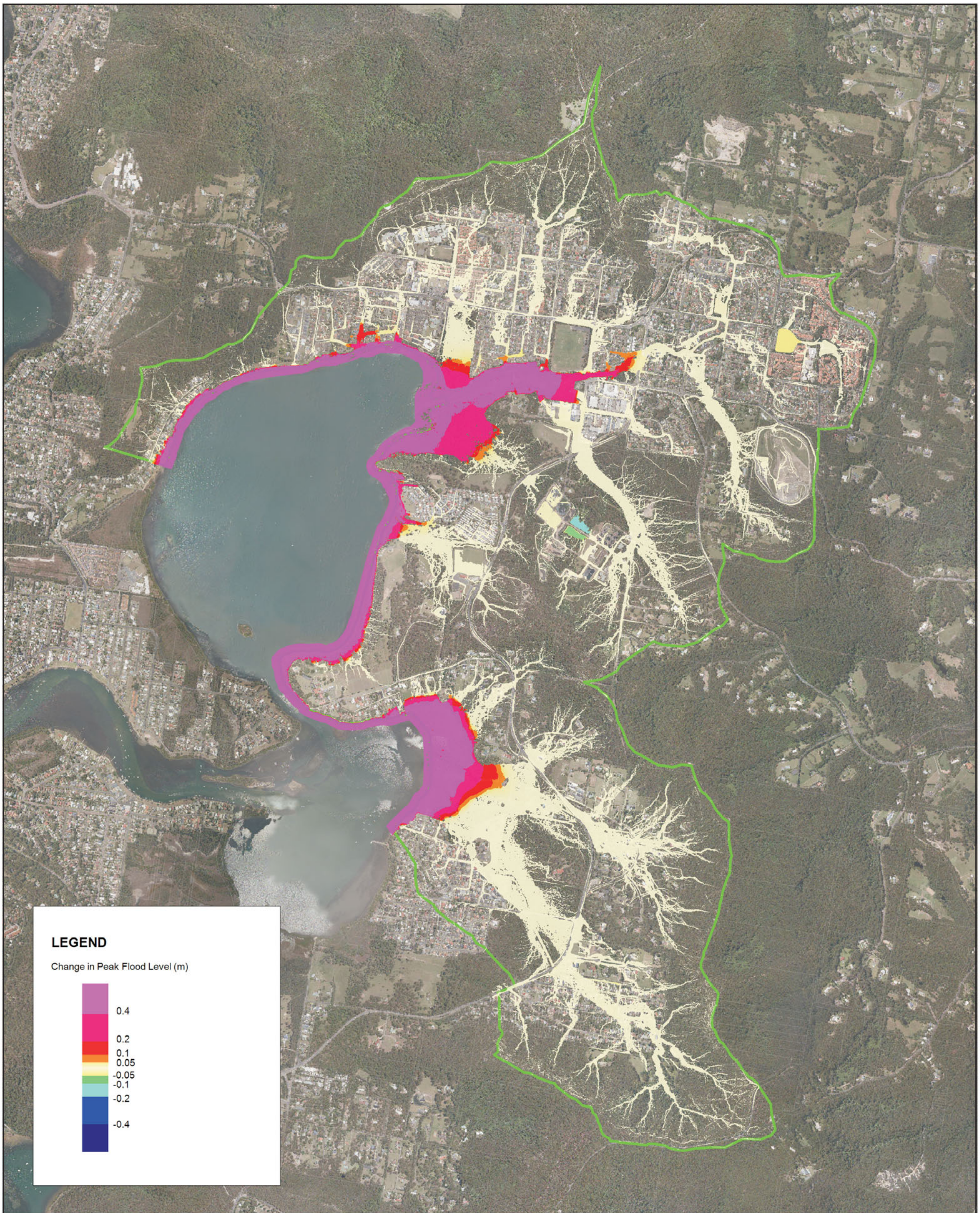

NSW GOVERNMENT Public Works Manly Hydraulics Laboratory

KINCUMBER OVERLAND FLOW STUDY
0.2m SEA LEVEL RISE SCENARIO
1% AEP EVENT

MHL Report 2196

Figure B4

DRAWING 2196-B4.cdr




N

Approximate scale: 0 0.5 1 kilometres

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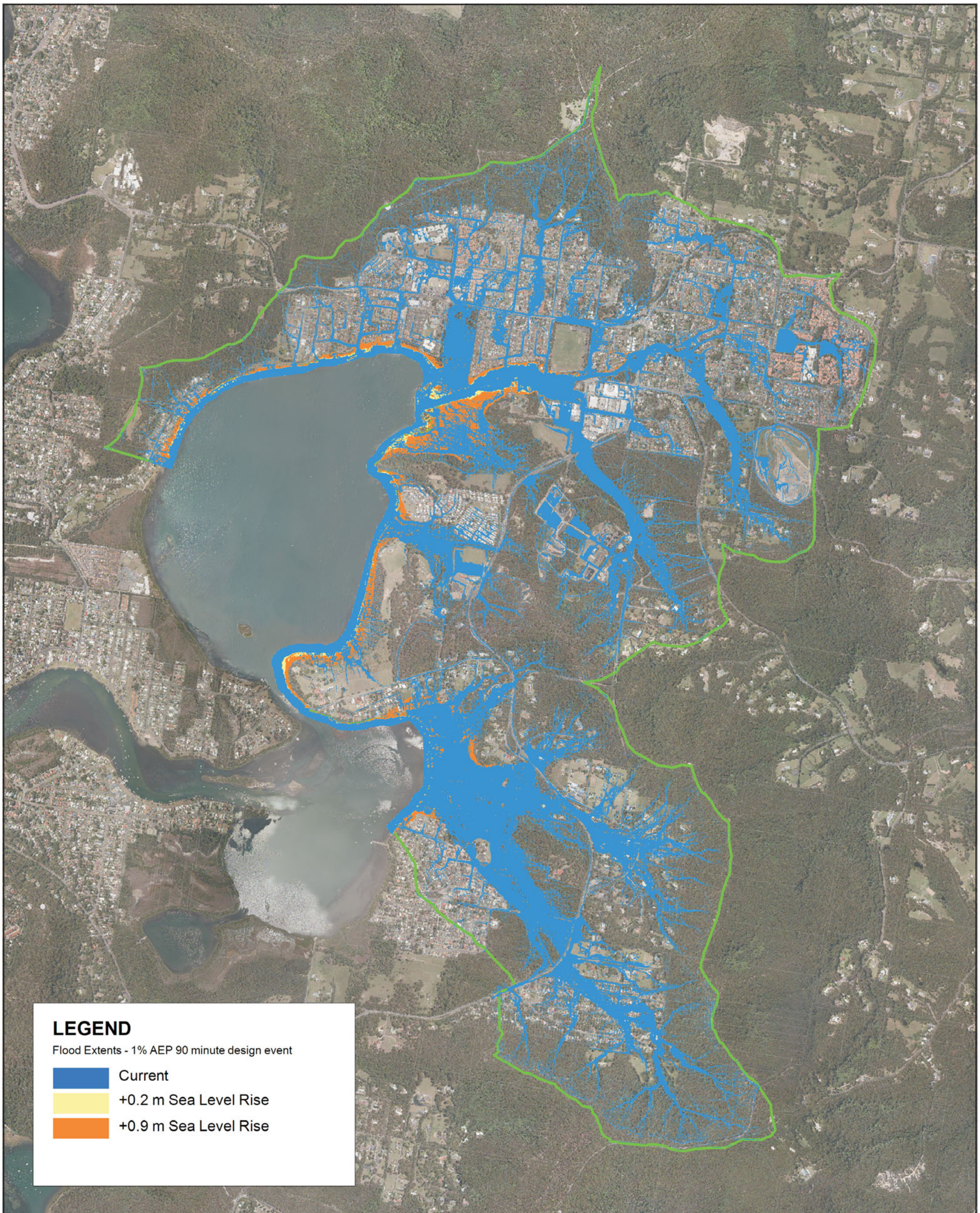
KINCUMBER OVERLAND FLOW STUDY
0.9m SEA LEVEL RISE SCENARIO
1% AEP EVENT

MHL Report 2196

Figure B5

DRAWING 2196-B5.cdr




N

Approximate scale: 0 0.5 1 kilometres

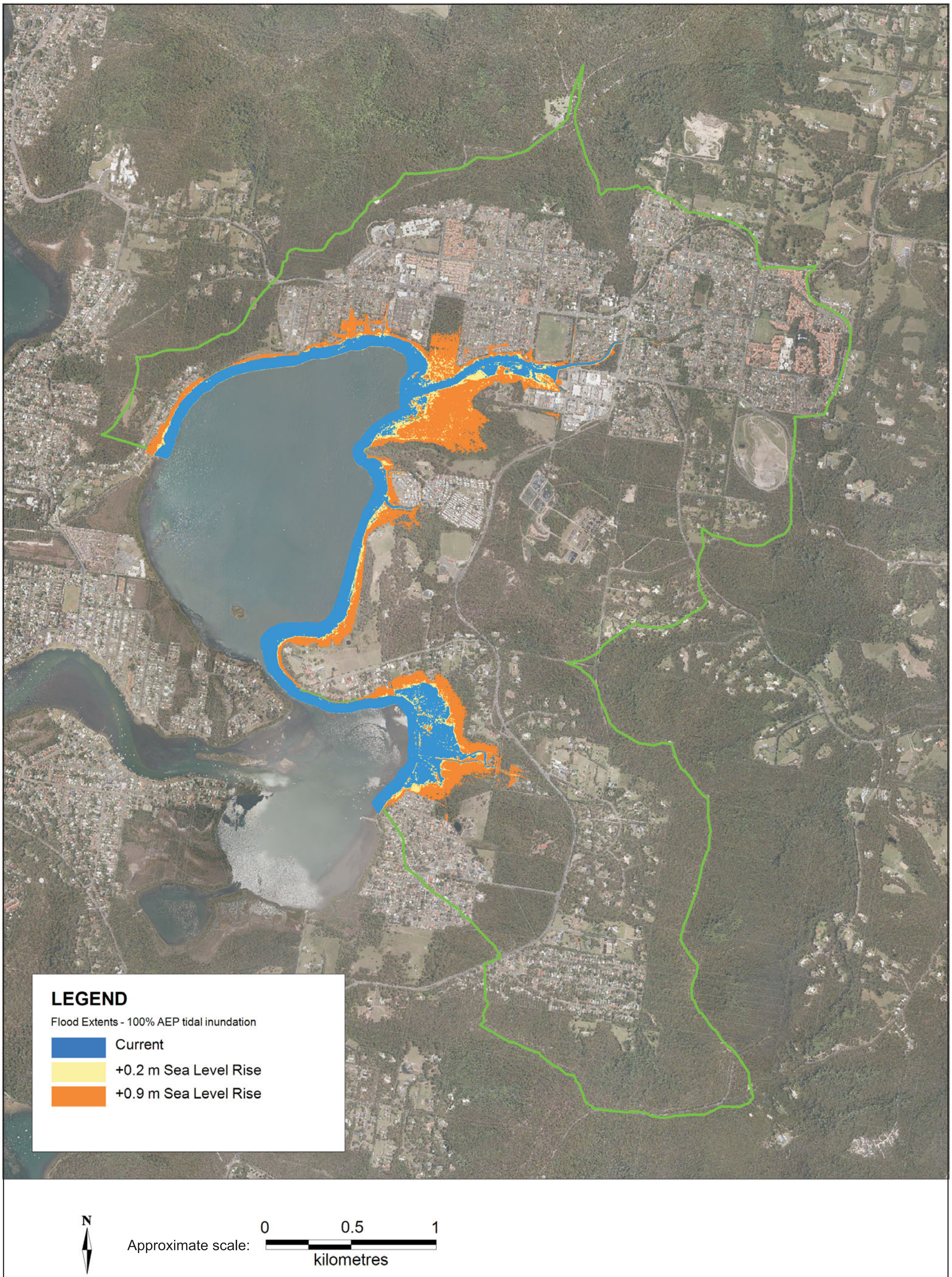
Public Works
Manly Hydraulics Laboratory

KINCUMBER OVERLAND FLOW STUDY
SEA LEVEL RISE SCENARIO FLOOD EXTENTS
1% AEP EVENT

MHL Report 2196

Figure B6

DRAWING 2196-B6.cdr



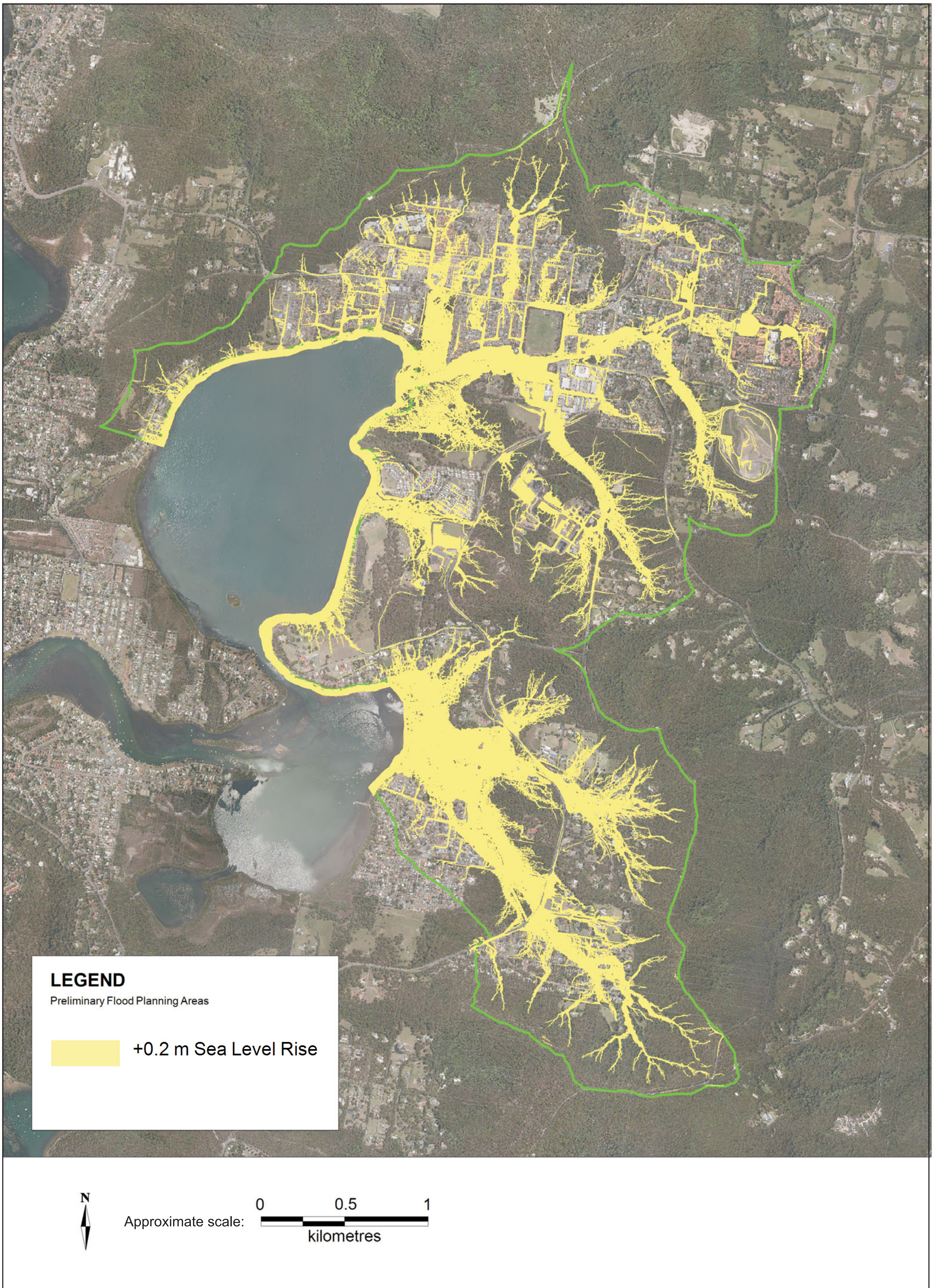

Public Works
Manly Hydraulics Laboratory

KINCUMBER OVERLAND FLOW STUDY
SEA LEVEL RISE SCENARIO TIDAL INUNDATION
100% AEP TIDE

MHL Report 2196

Figure B7

DRAWING 2196-B7.cdr

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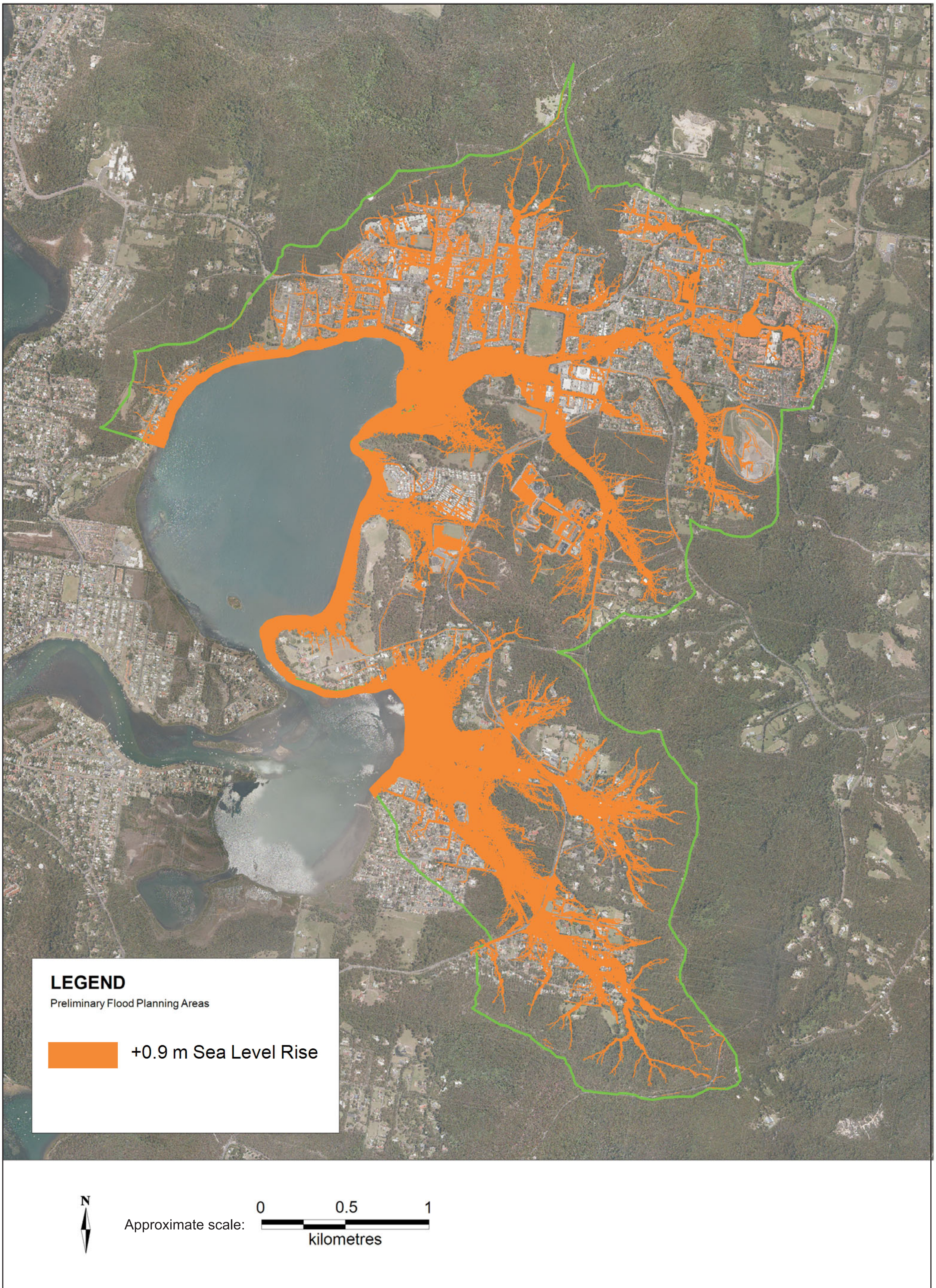
Manly Hydraulics Laboratory

KINCUMBER OVERLAND FLOW STUDY
PRELIMINARY FLOOD PLANNING AREA
0.2m SEA LEVEL RISE SCENARIO

MHL Report 2196

Figure B8

DRAWING 2196-B8.cdr

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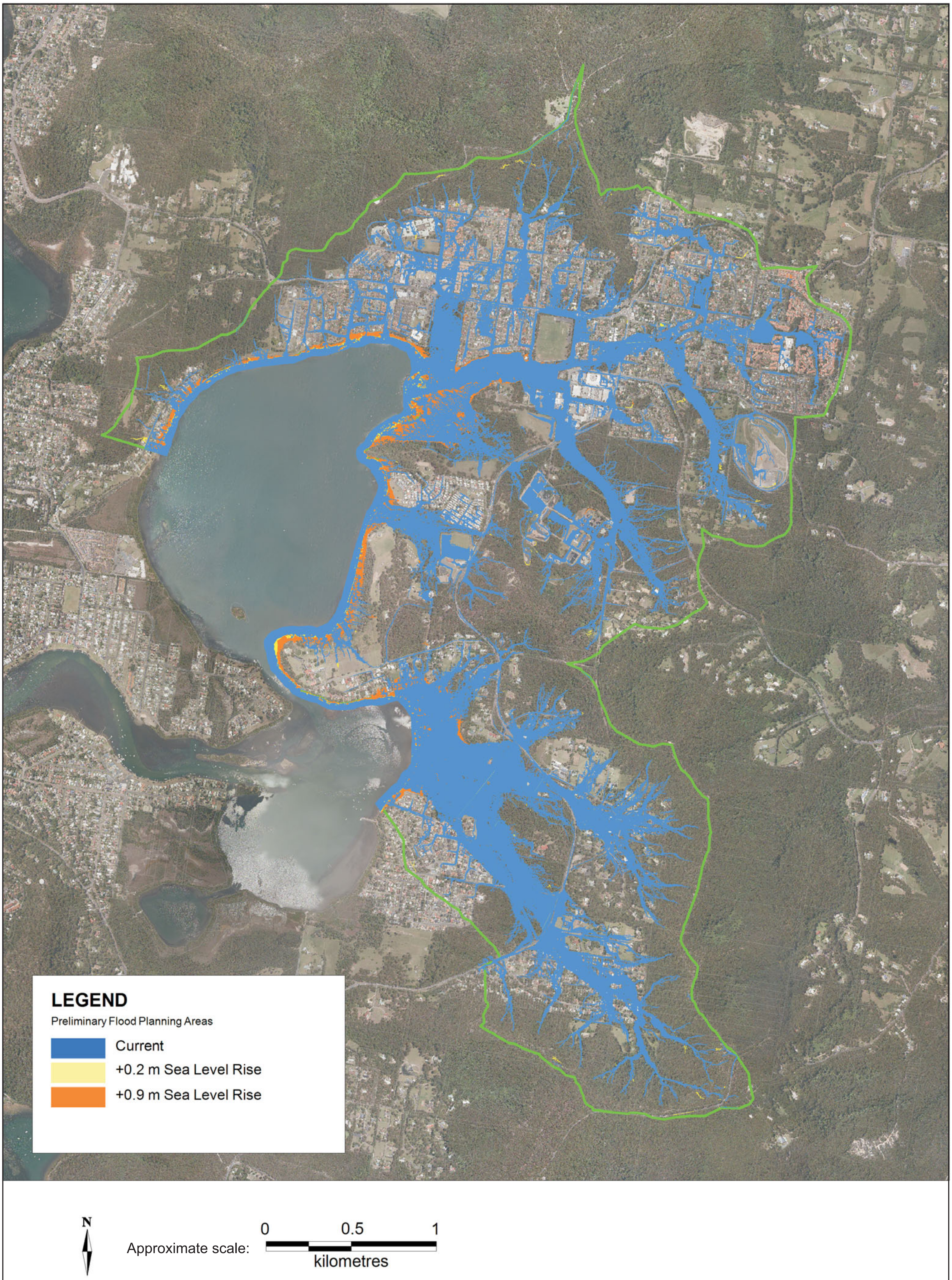
KINCUMBER OVERLAND FLOW STUDY
PRELIMINARY FLOOD PLANNING AREA
0.9m SEA LEVEL RISE SCENARIO

MHL Report 2196

Figure B9

DRAWING 2196-B9.cdr

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KINCUMBER OVERLAND FLOW STUDY
COMPARISON OF FLOOD PLANNING AREAS
FOR SEA LEVEL RISE SCENARIOS

MHL
Report 2196

Figure
B10

DRAWING 2196-B10.cdr

## Appendix C

## Community Consultation
## Community Survey Form and Information Pack

4304 7087

12738228
Robert Baker:s
29 November 2012

Dear Sir/Madam

**Kincumber Local Catchment Flood Study - Community Questionnaire**
**Property:**

Council has engaged Manly Hydraulics Laboratory (MHL) to prepare a flood study in order to gain understanding of local flooding behaviour within the Kincumber-Bensville Catchment. This information will be used to develop future planning strategies and assist with upgrading infrastructure.

The purpose of this letter is to seek input from you regarding any flooding experiences that you have observed in and around your local catchment. Accordingly, we would appreciate it if you could complete the enclosed questionnaire and return, using the enclosed reply-paid envelope, by **9 January 2013**. If you prefer, you can complete and submit this questionnaire online:

https://www.surveymonkey.com/s/KincumberFloodQuestionnaire

All information will be treated in accordance with Council's Privacy Policy.

For the duration of the project, which is expected to be completed by March 2013, you can refer to the MHL website for further information on flood risk management planning in the Kincumber local area (http://new.mhl.nsw.gov.au/users/Kincumber), or contact Mr Bronson McPherson MHL Project Manager on (02) 9949 0244 or Bronson.McPherson@mhl.nsw.gov.au.

Yours faithfully

*Robert Baker*

Robert Baker
**Senior Flooding & Drainage Planning Engineer**
**Environment & Planning**

## KINCUMBER OVERLAND FLOW FLOOD STUDY
## COMMUNITY SURVEY

### Background Information

Under the NSW Government's Flood Prone Land Policy (2005), Council has a responsibility for floodplain risk management. Council has received a grant from the Natural Disaster Resilience Grants Scheme to undertake the **Kincumber Overland Flow Flood Study** and has engaged a consultant, **NSW Public Works Manly Hydraulics Laboratory**, to carry out the work.

The study is to cover an area of approximately 11 $km^2$, including the suburbs of **Kincumber, Kincumber South, Bensville and part of Saratoga** in the east of Gosford City Council Local Government Area (LGA).

Council invites residents to provide any historical flood information that could assist in the preparation of the Flood Study. The information provided will help the Consultant and Council understand local flooding problems and may assist in later floodplain management activities. **This Community Survey is voluntary**. An online version of the survey can be found at https://www.surveymonkey.com/s/KincumberFloodQuestionnaire.

For further information, please see: http://new.mhl.nsw.gov.au/users/Kincumber/

* * * * * * * * *

### COMMUNITY SURVEY FORM

To complete this survey, please tick the appropriate boxes and make comments where required. **You may tick more than one box if applicable.** Please return the completed survey in the enclosed reply-paid envelope by 9 January 2013.

**Attention: Robert Baker, Senior Flooding and Drainage Planning Engineer**

***For any specific information relating to the* Kincumber Overland Flow Flood Study**
**please contact Mr Bronson McPherson - Project Manager**
**Manly Hydraulics Laboratory, 110b King Street Manly Vale NSW 2093**
**Phone: (02) 9949 0244, Email: Bronson.McPherson@mhl.nsw.gov.au, or Fax: (02) 9948 6185**

**CONTACT INFORMATION** (This information will only be used to complete the Flood Study.)

Name:……………………………………………………………………………………………………………

Address:…………………………………………………………………………………………………………

Address of your Property (if different from the address above)

……………………………………………………………………………………………………………………

Telephone:………………………………………………Email: ………………………………………………

**1 What is the type of property? (please tick one)**

☐ Residential ☐ Vacant land ☐ Industrial
☐ Commercial ☐ Farming/Rural ☐ Other (Please specify)…………………………

**2 If residential, what is the residential status of property? (please tick one)**

☐ Owner-occupied
☐ Leased to tenants
☐ Other (Please specify)…………………………………………

**3 If commercial, what is the status of property? (please tick one)**

☐ Owner-operated business
☐ Leased to tenants
☐ Other (Please specify)…………………………………………

**4 If owner-occupied or owner-operated business, how long have you lived or operated a business at this address?**

| 0-5 years | 6-10 years | 10-20 years | More than 20 years |
|---|---|---|---|
| | | | |

**5 As far as you are aware, has your property ever been affected by flooding?**

☐ Yes (if you answered YES, please complete the table overleaf)
☐ No (If you answered NO, please go to question 7)

| **Date/s** your property has been affected by floods, if known? (Date, Month, Year) (if more than one, please list all dates) | **Event Date** ____________ | **Event Date** ____________ | **Event Date** ____________ | **Event Date** ____________ |
|---|---|---|---|---|
| What **part/s of your property** were affected by flooding (select more than one if appropriate)<br>**1 = Ground**<br>**2 = Garage/Shed**<br>**3 = Main Building**<br>**4 = Other (please specify)** | | | | |
| **Depth of Flooding** (in cms)<br>Please provide details of the location of this depth (e.g. a sketch) | | | | |
| **Duration of Flooding** (Hours/Days) | | | | |
| **What was the velocity (speed) of the flood waters at the peak/worst of the flooding?**<br>1 = Stationary<br>2 = Walking Pace<br>3 = Running Pace | | | | |

6 (a) **What was the source of the floodwaters?**

☐ Creek (floodwaters rising in the creek)
☐ Kincumber Broadwater (levels rising in lake)
☐ Water flowing down the roads
☐ Ponding of water within property
☐ Ponding of water on roads
☐ Overflow from neighbouring properties
☐ Other (Please describe)……………………………………………………………………………….................

(b) **Are there any flood marks on or near your property?**
☐ Yes ☐ No
If you answered Yes, do we have your permission for surveyors to access your property and will surveyors be able to do so? (Please ensure you have completed the contact details above so we can contact you)
☐ Yes ☐ No

(c) **Do you have or know of any photographs or records of these flood events?**
☐ Yes ☐ No
If Yes, would it be possible for Council to make copies of this data to contribute to the Flood Study?
☐ Yes ☐ No
If Yes, please indicate if the holder of this information is someone other than you.

..........................................................................................................................................

7 **Have you measured rainfall levels on or near your property?**
☐ Yes ☐ No
If you answered Yes, are you willing to make this information available to us? (Please ensure you have completed the contact details above so we can contact you)
☐ Yes ☐ No

## COMMENTS

8 **Do you have any suggestions for resolving the flooding or drainage problems in your area or do you have any comments you wish to make in addition to the questions in the survey?** Please attach additional pages for any further information, if needed.

..........................................................................................................................................
..........................................................................................................................................
..........................................................................................................................................
..........................................................................................................................................

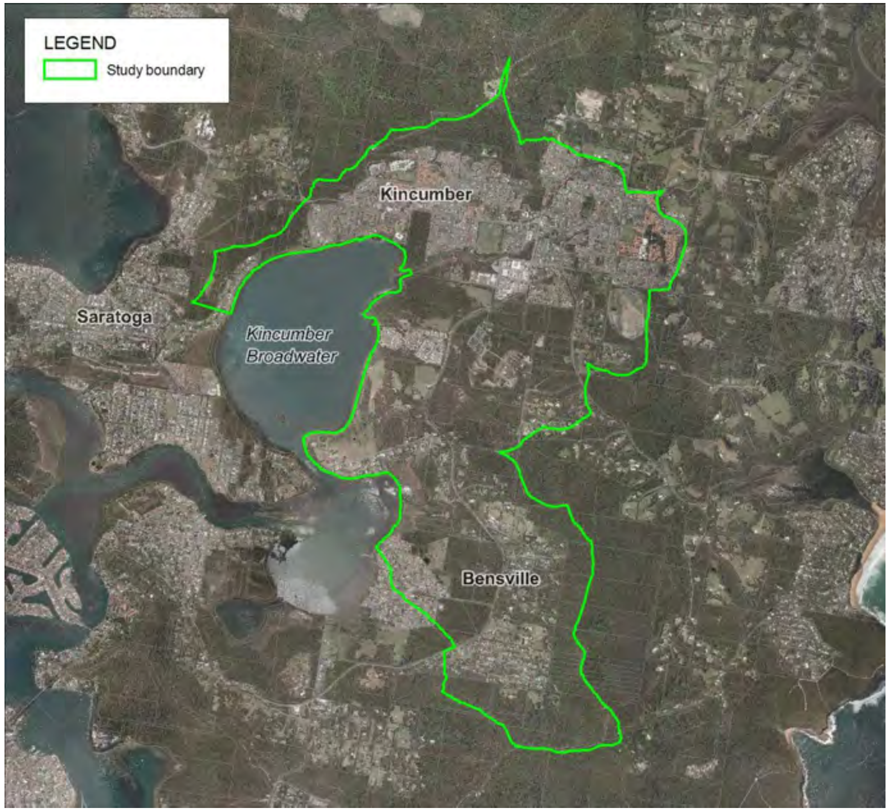
Thank you for your time in completing this Community Survey

# Kincumber

# Overland Flow Flood Study

## Community Newsletter December 2012

**Gosford City Council is undertaking a flood study to identify flood risks within the Kincumber and Bensville catchments. The study will cover the area shown below.**




## Who is involved?

Under the NSW Government's Flood Prone Land Policy, Local Government has a responsibility for management of flood prone land.

Gosford City Council has received financial assistance under the Natural Disaster Resilience Grants Scheme and has engaged consultants from NSW Public Works' Manly Hydraulics Laboratory to undertake the study.

Technical assistance will be provided by the NSW Office of Environment and Heritage.

## What are the flood risks?

Flooding in the Kincumber and Bensville catchments can come from three main sources: high creek levels; high water levels in Kincumber Broadwater; and excess stormwater flowing overland.

The dominant cause of creek and overland flooding is intense rainfall, while foreshore flooding from Kincumber Broadwater can be driven by elevated ocean conditions (tide and storm surge), long durations of rainfall, and local wind waves.

This study will focus on flooding from creeks and overland flow paths caused by heavy rainfall, and will consider the influence of water levels in Kincumber Broadwater on such flooding. Investigation of foreshore flooding from Kincumber Broadwater has previously been investigated in the Brisbane Water Foreshore Flood Study, 2010.

## What are the study outcomes?

The primary objective is to define flood behaviour across the study area including determining flood levels, depths, velocities and their distribution. Flood maps showing predicted extents of flood inundation will be produced.

A range of flood magnitudes will be assessed from frequent events to extremely rare events. This will allow the potential severity and frequency of flooding at any location to be established.

Study results and mapping will be based on flood simulations by detailed computer models developed specifically for the study area. Historical information such as rainfall and peak flood levels can be used to calibrate the computer models, ensuring that they are representative of real local flood behaviour.

The results of the current flood study will form the basis of a future Floodplain Risk Management Study and Plan. The study and plan will assist Council in determining strategies to manage flood risks to existing and future development. This may include measures such as: adoption of development control levels; flood mitigation works; improved flood warning and emergency response.

## How can I contribute?

Community involvement is essential to the success of the floodplain risk management process. It enables the community to contribute local knowledge of flood behaviour, along with their concerns and ideas for flood management; and allows information to be effectively conveyed back to the community.

Please take a few minutes to complete and return the enclosed Community Survey. Alternatively, an online version is available here: https://www.surveymonkey.com/s/KincumberFloodQuestionnaire

All survey information is confidential and will be used only for floodplain risk management purposes.

Historical flood information from the survey will help develop understanding of flood behaviour across the study area. Where reliable dates, flood depths and locations (or flood photography) are provided, these can be compared against model results and help improve model accuracy. Results of the survey will also be stored for future reference when considering potential floodplain management measures.

Further opportunities for community involvement will be provided at later stages of the floodplain management process.

## Where can I find out more?

For more information, and to keep updated on the progress of the Kincumber Overland Flow Flood Study, please see the following links:

**Study website**

http://new.mhl.nsw.gov.au/users/Kincumber/

**Gosford City Council website**

http://www.gosford.nsw.gov.au/flooding

## Appendix D

## Report Addendum
## Assessment of Proposed Drainage Works

# Appendix D – Assessment of Proposed Drainage Works

## D.1 Introduction

In association with the Kincumber Overland Flow Study, NSW Public Works' Manly Hydraulics Laboratory (NSWPW) was requested by Gosford City Council (Council) and the NSW Office of Environment and Heritage (OEH) to assess proposed drainage works in the Kincumber drainage catchment using the existing TUFLOW flood model. This report addendum provides a description of the work undertaken and a summary of results.

## D.2 Numerical Model Development

### D.2.1 Existing Hydraulic Model

The TUFLOW flood model as developed for use in the Kincumber Overland Flow Study (see Section 5) provided the basis for assessing the impact of proposed drainage works on flood levels. Modifications to the 1D stormwater drainage model layers and the model topography were made as described below.

### D.2.2 Proposed Stormwater Drainage Works Modifications

Information regarding proposed drainage works was provided by OEH and Council in the following forms:

- Kincumber Drainage Catchment Proposed Works plan
- Proposed Pipes and Culverts GIS layer (PropPipesCulverts - 130115.shp)
- Proposed Pits and Headwalls GIS layer (PropPitsHW - 130115.shp)
- Kincumber Drainage Upgrade – Stage 2 General Arrangement Plans (7023_100-122.pdf and 7023_124-148.pdf).

The provided GIS layers were converted into a form compatible for use with TUFLOW, with reference to available drainage plans. In some instances NSWPW made minor adjustments to the locations or surface elevations of pits and pipes in GIS layers to conform to the model digital elevation model (DEM). Modifications to existing model drainage layers were also made to reflect the proposed drainage arrangement. The proposed detention basin embankment was digitised into the model from provided design plans and cross-sections, and a proposed catch drain was represented in the model based upon typical cross-sections. The resulting model drainage and embankment layout is shown in Figure D1.

## D.3 Results

Peak flood level results for the 1% AEP 90-minute duration design event simulation with proposed drainage works are presented in Figure D2. The impact of proposed drainage works on peak flood levels has been assessed through comparison of these results with those for the 1% AEP 90-minute duration design event under current conditions (i.e. existing drainage infrastructure only). The simulated change in peak flood level and change in flood extent associated with the proposed works are shown in Figures D3 and D4 respectively. A summary of results at key locations (see Figure A26) is provided in Table D1.

**Table D1 1% AEP Peak Flood Levels for Increased Rainfall Intensity**

| Location | | Current Conditions | | With Proposed Drainage Works | |
|---|---|---|---|---|---|
| **No.** | **Description** | **Flood Peak (m AHD)** | **Peak Depth (m)** | **Flood Peak (m AHD)** | **Difference (m)** |
| 22 | Property off Broula Close | 7.96 | 0.55 | 7.80 | -0.16 |
| 23 | Intersection Moro Close and Arakoon Street | 15.50 | 0.32 | 15.26 | -0.24 |
| 24 | Avoca Drive near Frost Reserve | 4.33 | 0.43 | 4.13 | -0.20 |
| 25 | Carlo Close | 9.89 | 0.39 | 9.72 | -0.17 |
| 26 | Intersection Serengeti Close and Arakoon Street | 23.57 | 0.40 | 23.51 | -0.06 |

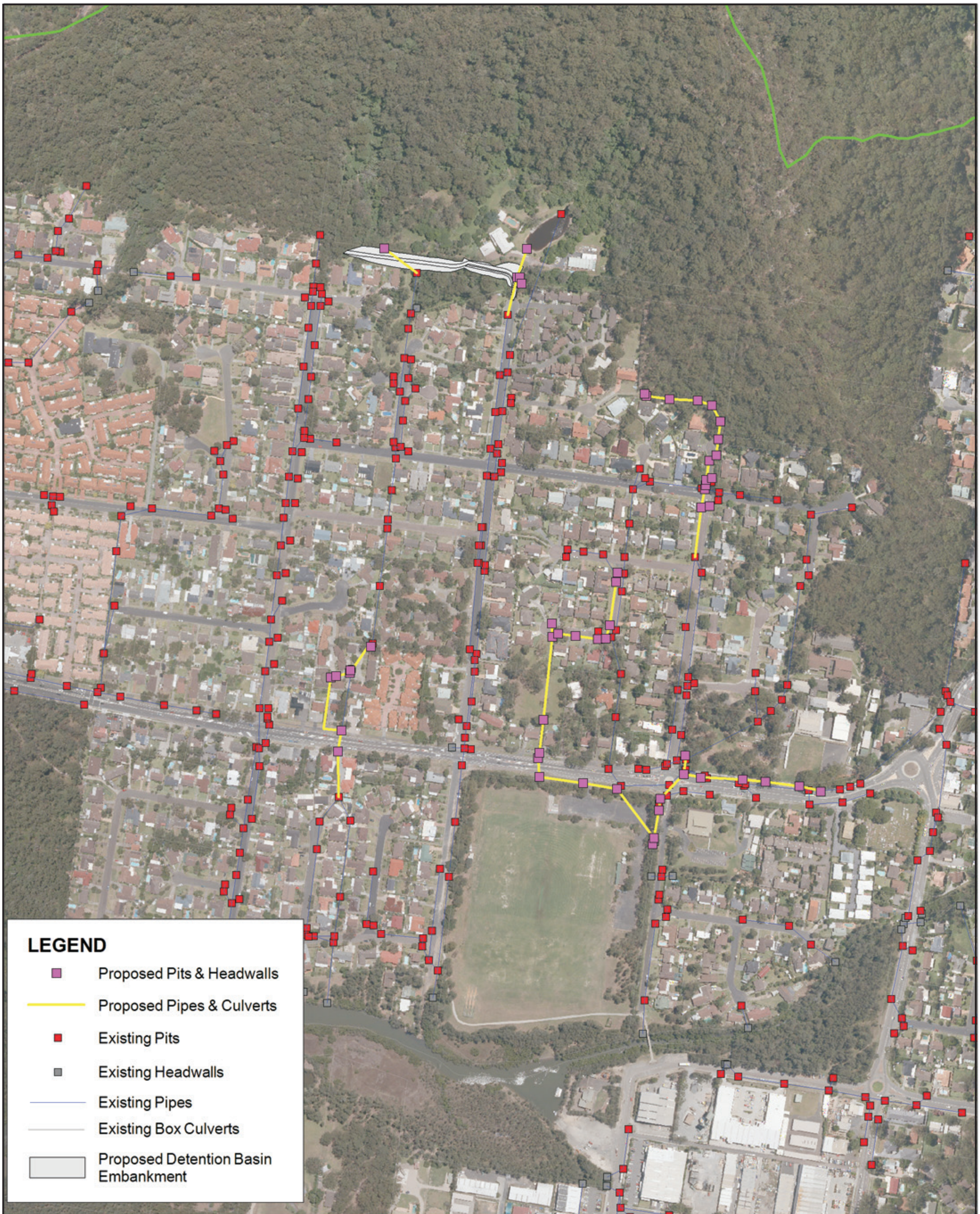
Based on the results of model simulations for the 1% AEP 90-minute duration design event, the impacts of the proposed drainage works, as modelled, can be summarised as follows:

- The introduction of a detention basin between the northern ends of Davies and Tilba streets had a major impact in reducing modelled flood flows downstream including:
  - decreases in flood levels of up to 40 cm along Moro Close
  - decreases in flood levels of 10 to 20 cm along Arakoon Street
  - overland flow between Arakoon Street and Wilma Street is largely eliminated
  - the extent of overland flow between Wilma Street and Avoca Drive is reduced, with flood levels decreased by 10 to 20 cm
  - flood levels along Tilba Street reduced by 5 to 10 cm
  - decreases in flood levels of 2 to 5 cm evident as far west as Bungoona Road and as far south as Warrana Road.
- Introduction of an additional low level outlet from the existing detention basin north-east of Davies Street along with additional drainage infrastructure lower in the catchment also influenced the above results.
- The peak modelled flood surface level in proposed detention basin was 24.0 m AHD.
- Introduction of a catch drain, pits and piping north of Serengeti Close and Joalah Road reduced easement flows into Serengeti Close. As a result, overland flow depths between Arakoon Street and Carlo Close were reduced by up to 8 cm.
- Additional pits and pipes in the vicinity of Carlo Close, in combination with the catch drain mentioned above, resulted in decreases in flood levels of up to 19 cm along Carlo Close and adjacent properties.
- Additional pits and box culverts along Empire Bay Drive adjacent to Frost Reserve resulted in decreases in peak flood levels of up to 20 cm. A reduction in overland flows from Carlo Close also contributed to this result.
- Minor localised increases in flood levels of around 3 cm were observed in some locations associated with increased discharges to open channels or surcharging from existing pits.

## D.4 Limitations

While all due effort has been made to ensure the reliability of flood model results, all models have limitations (e.g. Institution of Engineers 2012). Modelling is by nature a simplification of very complex systems, and results of flood model simulations should be considered as a best estimate only.

A 2D grid size of 2 m was adopted in the developed flood model resulting in sampling of the terrain elevation at a resolution of 1 m. Ground features at a scale smaller than this (e.g. kerb and guttering, catch drains) may not therefore be accurately represented in the model. Kerb and guttering may have a locally important influence on the amount of runoff captured by proposed drainage works. There is, therefore, an unknown level of uncertainty associated with model results that should be considered when utilising the outputs from this study.




N

Approximate scale: 0 100 200 metres

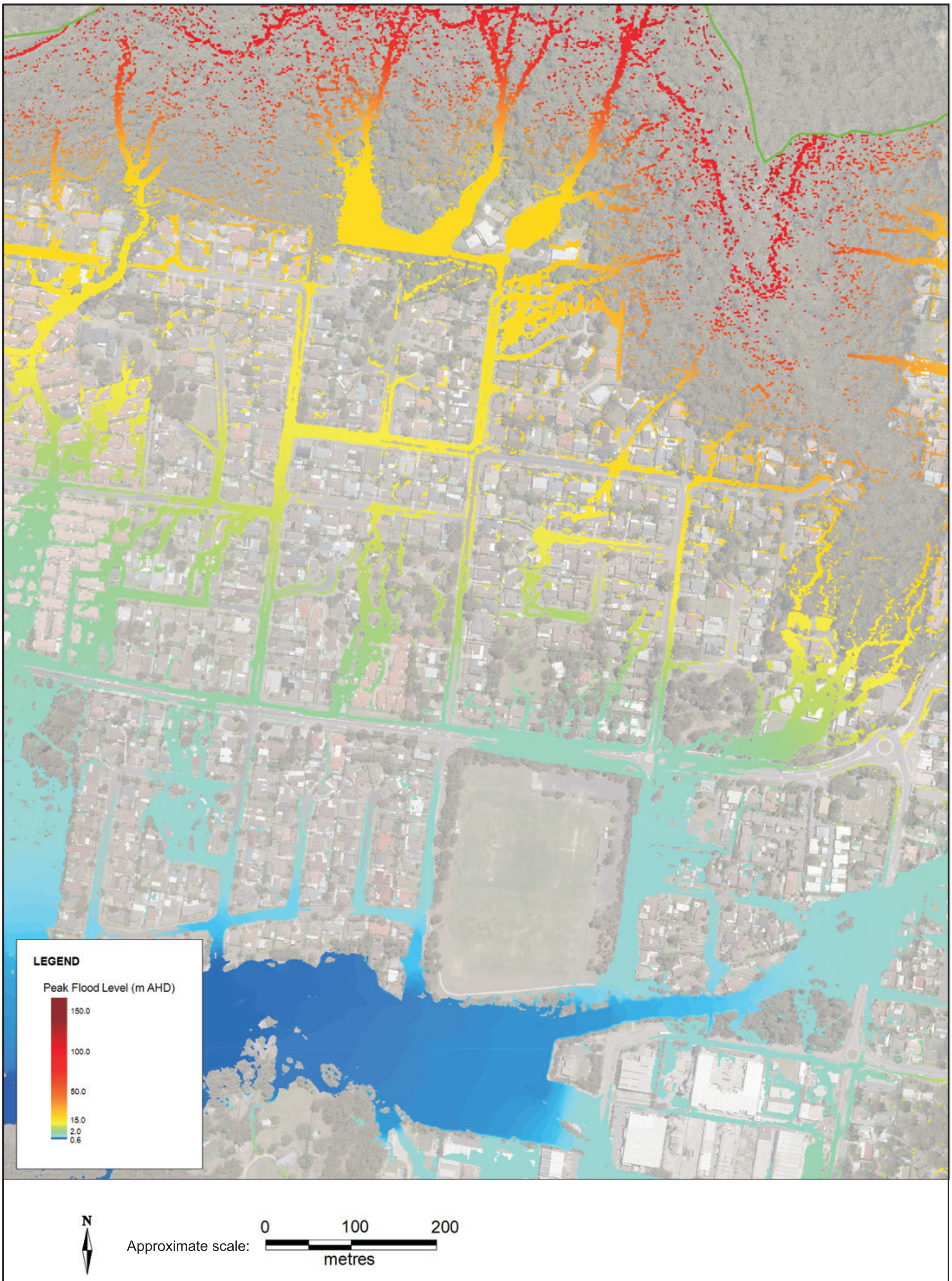
Public Works
Manly Hydraulics Laboratory

KINCUMBER CATCHMENT
PROPOSED DRAINAGE WORKS

MHL Report 2196

Figure D1

DRAWING 2196-D1.cdr

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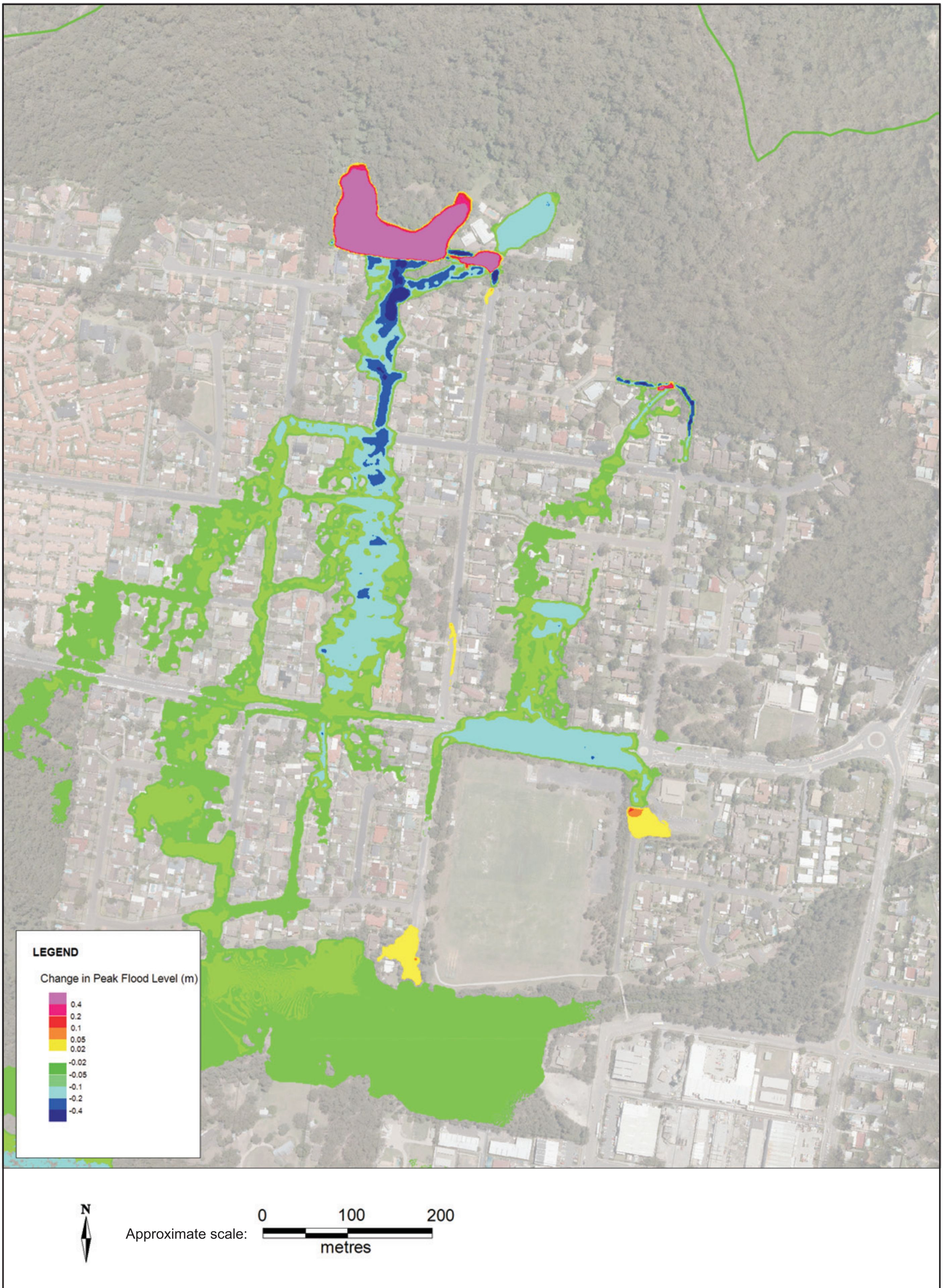
KINCUMBER CATCHMENT
PROPOSED DRAINAGE WORKS
PEAK FLOOD LEVEL

MHL Report 2196

Figure D2

DRAWING 2196-D2.cdr

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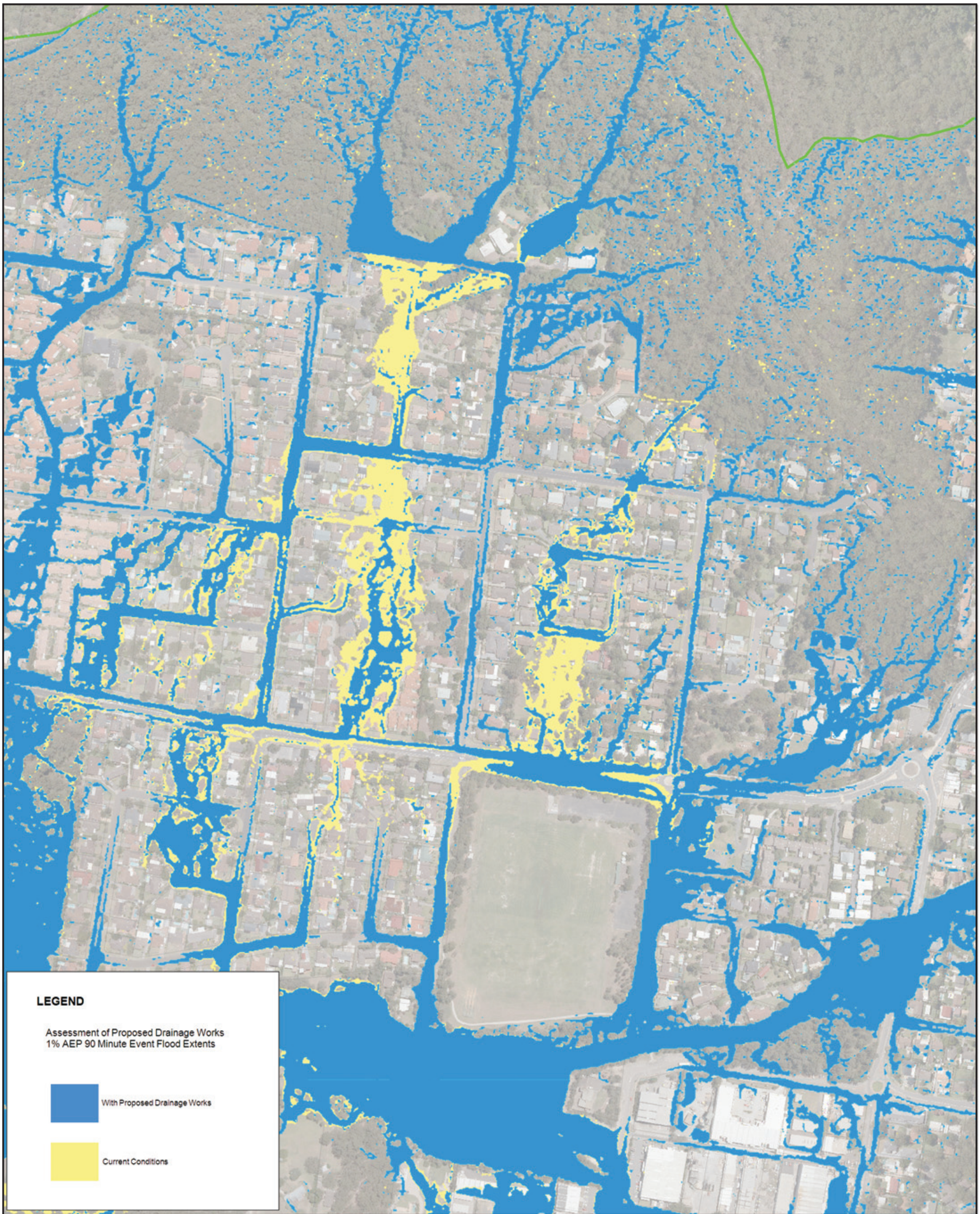
KINCUMBER CATCHMENT
PROPOSED DRAINAGE WORKS
CHANGE IN PEAK FLOOD LEVEL

MHL Report 2196

Figure D3

DRAWING 2196-D3.cdr




N

Approximate scale: 0 100 200 metres

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KINCUMBER CATCHMENT
PROPOSED DRAINAGE WORKS
CHANGE IN FLOOD EXTENTS

MHL Report 2196

Figure D4

DRAWING 2196-D4.cdr

Public Works
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