Manly to Seaforth Flood Study

Flood Study Report

NA49913018

Prepared for
Northern Beaches Council

22 February 2019

Cardno
Shaping the Future

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Foreword

The NSW Government Flood Prone Land Policy is directed towards providing solutions to existing flood problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the policy, the management of flood prone land is the responsibility of Local Government. The State Government subsidises flood management measures to alleviate existing flooding problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. The Commonwealth Government also assists with the subsidy of floodplain management measures.

The Policy identifies the following floodplain management 'process' for the identification and management of flood risks:

1. Formation of a Committee -

    Established by a Local Government Body (Local Council) and includes community group representatives and State agency specialists.

2. Data Collection -

    The collection of data such as historical flood levels, rainfall records, land use, soil types etc.

3. Flood Study -

    Determines the nature and extent of the flood problem.

4. Floodplain Risk Management Study –

    Evaluates floodplain management measures in respect of both existing and proposed development.

5. Floodplain Risk Management Plan –

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

6. Implementation of the Plan –

    This may involve the construction of flood mitigation works (e.g. culvert amplification, overland flowpath modification) to protect existing or future development. It may also involve the use of Environmental Planning Instruments to ensure new development is compatible with the flood hazard.

The process is iterative, and following the implementation of the plan, it is important that ongoing monitoring and evaluation is undertaken.

This Flood Study has been prepared for Northern Beaches Council by Cardno, and addresses Parts 2 and 3 of the Floodplain Management process. This Study was funded by Northern Beaches Council, the New South Wales Government, and the Commonwealth Government (under the Natural Disaster Mitigation Program).

Prior to the formation of Northern Beaches Council on 12th May 2016 this study was called the Manly LGA Flood Study.

Executive Summary

Cardno was commissioned by Northern Beaches Council to undertake the Flood Study for urban catchments, which comprises the suburbs of Clontarf and Balgowlah Heights and parts of Seaforth, Balgowlah, Fairlight, and Manly. Prior to the formation of Northern Beaches Council on 12th May 2016 this study was called the Manly Local Government Area (LGA) Flood Study.

In 2012, a Flood Study was completed for the Manly Lagoon Catchment, which is north of this study area.

This study incorporated community consultation throughout and included a community questionnaire distributed to the community to gain an understanding of flood awareness and experience in the catchment. It comprised 10 questions that were mailed to approximately 5,500 properties within the study area.

A set of four detailed 1D/2D models have been developed to describe flooding behaviour in the study area using SOBEK model software. The models incorporate 1D elements (pits and pipes) and a 2D surface of grid cell size 2.5 m x 2.5 m.

The models were validated with three historical storms; February 2010, June 2013 and October 2013. The 2010 event was in the order of a 10% - 5% Annual Exceedance Probability (AEP) event whilst the other two events were estimated to be between a 50% and 20% AEP.

The SOBEK model rain on grid hydrology was also verified against a traditional hydrological model (XP-RAFTS). The match between the XP-RAFTS model and the SOBEK model for timing, volume and peak flow was very good, with virtually identical timings and volumes recorded.

Using the established models, the study has determined flood behaviour for the 20%, 10%, 2%, 1%, 0.5% AEP and PMF design events. The primary flood characteristics reported include flood depths, flood levels, velocities, flow rates and provisional flood hazard for flood-affected areas.

A number of scenarios to test the sensitivity of impacts of blockage and climate change have also been considered.

The outcomes of this study can be used for future planning and studies to investigate various management and flood mitigation options for the existing catchment conditions and will assist in evaluating long-term flood management strategies now that existing flood risks have been defined in this study.

This Flood Study has been prepared to facilitate the Floodplain Risk Management Study (FRMS) for the study area.

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Glossary

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded each year (one in a hundred chance); it would be quite rare but it would be relatively large. The 1% AEP event is equivalent to a 1 in 100 year Average Recurrence Interval (ARI) event.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that periods between exceedances are generally random
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Creek Rehabilitation	Rehabilitating the natural 'biophysical' (i.e. geomorphic and ecological) functions of the creek.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. E.g. some roads may be designed to be overtopped in the 1 in 1 year or 100%AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal

	inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers. These include structural flood modifications to change the way floods behave, property modification options to improve property resilience to floods and emergency response modification options to improve the response of emergency services and the community during flood events.
Floodplain management options	The measures which might be feasible for the management of a particular area. A variety of floodplain management measures are often reviewed for a catchment, although only some will ultimately prove to be successful. These successful measures become floodplain management options, which are assessed in further detail.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the “Standard flood event” of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with

	naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Overland Flow	Overland flow is excess rainfall runoff that runs across the land before it enters a watercourse / constructed drainage system or after rising to

	the surface, such as the capacity is exceeded. The term overland flow is used interchangeably in this report with “flooding”.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from Probable Maximum Precipitation (PMP). PMP is the greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For further explanation see Annual Exceedance Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

* Terminology in this Glossary have been derived or adapted from the NSW Government Floodplain Development Manual, 2005, where available.

Abbreviations

AAD	Average Annual Damage
AEP	Annual Exceedance Probability
ARI	Average Recurrence Intervals
BoM	Bureau of Meteorology
DCP	Development Control Plan
FPL	Flood Planning Levels
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
GIS	Geographic Information System
ha	Hectare
IFD	Intensity Frequency Duration
km	Kilometres
km^2	Square kilometres
LEP	Local Environment Plan
LGA	Local Government Area
m	Metre
m^2	Square metre
m^3	Cubic Metre
mAHD	Metres to Australian Height Datum
mm	Millimetre
m/s	Metres per second
NSW	New South Wales
OEH	Office of Environment & Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SES	State Emergency Service

1 Introduction

Cardno was commissioned by Northern Beaches Council to undertake the Flood Study for urban catchments, which comprises the suburbs of Clontarf and Balgowlah Heights and parts of Seaforth, Balgowlah, Fairlight, and Manly. Prior to the formation of Northern Beaches Council on 12th May 2016 this study was called the Manly LGA Flood Study.

The study has been undertaken to define the existing flooding behaviour of the catchment due to overland flooding.

1.1 Study Context

The NSW Floodplain Management process progresses through six steps in an iterative process:

1. Formation of a Floodplain Management Committee
2. Data Collection
3. Flood Study
4. Floodplain Risk Management Study
5. Floodplain Risk Management Plan
6. Implementation of the Overland Flow / Floodplain Risk Management Plan

This document addresses Stages 2 and 3 of the process.

1.2 Study Objectives

The objectives of the Flood Study were to:

- Undertake a review of available data;
- Consult with the community to collect their observations on historic flood events and current flooding issues;
- Development of a hydrological / hydraulic model for the study area;
- Calibrate / validate the hydrological / hydraulic model;
- Define the existing flood behaviour of the study area for a range of flood events;
- Undertake sensitivity testing to confirm the selected model parameters; and
- Determine flood planning areas.

Results of the flood modelling will be output as electronic files suitable for incorporation into Council's Geographic Information System (GIS).

1.3 Study Location

The study area is located within the Northern Beaches Council LGA and includes the suburbs of Clontarf and Balgowlah Heights and parts of Seaforth, Balgowlah, Fairlight, and Manly. The land-use is predominantly residential with Manly Hospital, some retail, and the Manly central business district. It has several beaches including Manly Beach, North Steyne Beach, Queenscliff Beach, Shelley Beach, and Clontarf Beach as well as large areas of bushland including Sydney Harbour National Park and Dobroyd Head.

Generally, the study area covers about 10.7 km^2 and is the southern part of the former Manly Local Government Area (LGA) that drains to Middle Harbour, North Harbour, and the Tasman Sea at numerous locations. It excludes the areas of the former LGA which are in the Manly Lagoon catchment which was part of a separate flood study.

1.4 About This Report

This Report has been prepared to document the Study objectives, methodology and outcomes.

- Section 1 Introduction – introduces the study.
- Section 2 Review and Compilation of Data – summarises the data used to inform the flood model.
- Section 3 Community Consultation – presents the community consultation undertaken.
- Section 4 Flood Model Establishment – provides information as to how the flood model was developed.
- Section 5 Flood Model Validation – provides information as to how the flood has been validated.
- Section 6 Existing Flood Behaviour – presents the flood behaviour as determined by the flood model.
- Section 7 Sensitivity Modelling - a discussion around sensitivity of the model by varying parameters.
- Section 8 Scenario Modelling – presents the scenarios modelled.
- Section 9 Conclusion
- Section 10 References
- Section 11 Qualifications

This report has adopted Annual Exceedance Probability (AEP) terminology to define flood events. Historically, Average Recurrence Intervals (ARI) terminology has been used to describe flood events but can lead to confusion with regard to the frequency of an event occurring. Therefore, an AEP terminology is most appropriate in conveying flood information to the community. **Table 1-1** correlates the AEP terminology with the ARI terminology.

Table 1-1 ARI to AEP Conversion

ARI (Average Recurrence Interval)	AEP (Annual Exceedance Probability)
1 Year	1EY (ie 1 Exceedance per Year)
2 Year	50%
5 Year	20%
10 Year	10%
20 Year	5%
50 Year	2%
100 Year	1%
200 Year	0.5%

2 Review and Compilation of Data

2.1 Previous Reports and Studies

Flood behaviour in the study area has not previously been defined as part of a detailed flood study or flood modelling. Previous studies that relate closely to this Flood Study are:

- Climate Change Action for the Manly LGA 2008-2038 – Manly Council (Cardno, 2008). This report identified impacts of climate change (sea level rise, catchment flooding, and oceanic inundation) on the LGA. A prioritised action list for a variety of adaptive measures was prepared.
- Raglan Street Catchment Manly, Investigation into Possible Stormwater Upgrades – Manly Council (Cardno 2008a). This report identified the capacity of the piped stormwater system in this area was less than the 1 in 1 year Average Recurrence Interval event resulting in unsafe overland flow conditions.
- Manly Flat Area Drainage Strategy Study – Manly Council (Lyall & Macoun, 1989). This report identified potential elevated flood risks from reduced stormwater network performance due to high tailwater conditions and low elevations.

Furthermore, the Manly Lagoon Flood Study (BMT WBM, 2012) modelled flood behaviour in the catchment to the north of the study area.

2.2 Council GIS Data

Geographic Information System (GIS) data was provided by Council for the study including cadastre, land use zones, suburb boundaries, sub catchment boundaries, and stormwater pits and pipes. Council also supplied an aerial photo of the catchment (circa 2009) and ground elevations from Airborne Laser Scanning (ALS / LiDAR) collected by AAM Hatch in 2007/2008 (from Sydney Coastal Councils Group).

2.3 Survey Information

2.3.1 Pit and Pipe Survey

Cardno completed a detailed survey of the stormwater pit and pipe network in the study area to confirm information for the purposes of this study and as an updated database of Council's assets. About 2,500 pits and their connecting pipes were surveyed. Pit and pipe GIS layers were issued in August 2013. **Table 2-1** and **Table 2-2** show the pit and pipe types the number of assets surveyed for each class.

Table 2-1 Pit Survey

Pit Types	Number
Junction Pit	469
Headwall	116
Pipe Outlet	100
Kerb Inlet with Single Grate	183
Kerb Inlet with Double Grate	699
Single Grate	218
Double Grate	64
Letterbox Pit	44
Gross Pollutant Trap	9
Kerb Inlet Only	175
Kerb Outlet	32
Blind Pits	388

Other	9
Total	*2506*

The definition of a "blind pit" is where a pit appears to exist but there is no structure or lid visible at the surface. In these instances the pit may not be visible due to further construction after pit installation or the pit may have been sealed over by road pavement.

Table 2-2 Pipe Survey

Pit Types	Number
Pipe	2083
Box Culvert	98
Open Channel	43
Unknown	167
Total	*2391*

2.3.2 Detailed Ground Survey

Following an extensive site inspection process of some 40 sites (shown on **Figure 2-1**) and review of ALS data, it was found that in several locations that further detailed ground survey was required. Additional survey was required at the following five sites which was subsequently undertaken by Cardno surveyors.

Kangaroo Lane, Manly – Site 5

Preliminary model results showed ponding in Kangaroo Lane. This seems reasonable as Kangaroo Lane would be a local low point with the escarpment to the east and a slight ridgeline running along Pittwater Road. The issue at this location relates to the preliminary Digital Terrain Model (DTM) established based on the supplied ALS data.

ALS is generally processed to remove records of buildings, trees, and other non-terrain data scanned. Due to the steep escarpment adjacent to Kangaroo Lane, a number of trees have not been removed from the data. This creates bulges in the escarpment for the DTM compared to what was observed on the site visit.

Additional survey was undertaken here to improve the DTM at the toe of the escarpment and to better align the DTM to pit survey data.

Bower Street, Manly – Site 11

A significant natural flowpath was observed running east into a 900mm diameter pipe located under Bower Street and the adjacent reserve. Though the DTM defines the low point upstream of Bower Lane, additional survey was undertaken to inform the interaction of the flowpath with the pipe inlet such that it can be properly modelled.

North Harbour Reserve, Balgowlah – Site 14

A major natural flowpath was observed heading east towards North Harbour Reserve with a wing-walled inlet structure located upstream of North Harbour Reserve diverting flow into a 900mm pipe under the reserve. This is potentially a complex system with flow readily able to divert around the wing walls. Therefore, this inlet structure and the surrounding area could be surveyed in more detail to better account for this inlet in the model.

Brimbecom Reserve, Balgowlah – Site 18

A minor flowpath was observed to follow the property boundary to the east of the reserve before diverting into a pipe. A bund across the natural flowpath has been constructed which is not identified in the DTM. The top and base levels of the bund was surveyed to enable better modelling of the inlet characteristics at this location.

Bligh Crescent, Seaforth – Site 36

A minor flowpath was observed which would convey flow in a southerly direction before crossing under Bligh Crescent through a small diameter culvert. Excess flows from this culvert would be conveyed down Bligh Crescent and pond on the road with the natural flowpath continuing under a private driveway of several residences. Additional survey was undertaken to better define the potential flow behaviour in the model.

The low-lying area of Clontarf contains a large concrete structure running in a westerly direction, most likely housing a large pipeline. This would act as a blockage of overland flow. Survey was undertaken along the top of the structure to evaluate the impact it has upon flows.

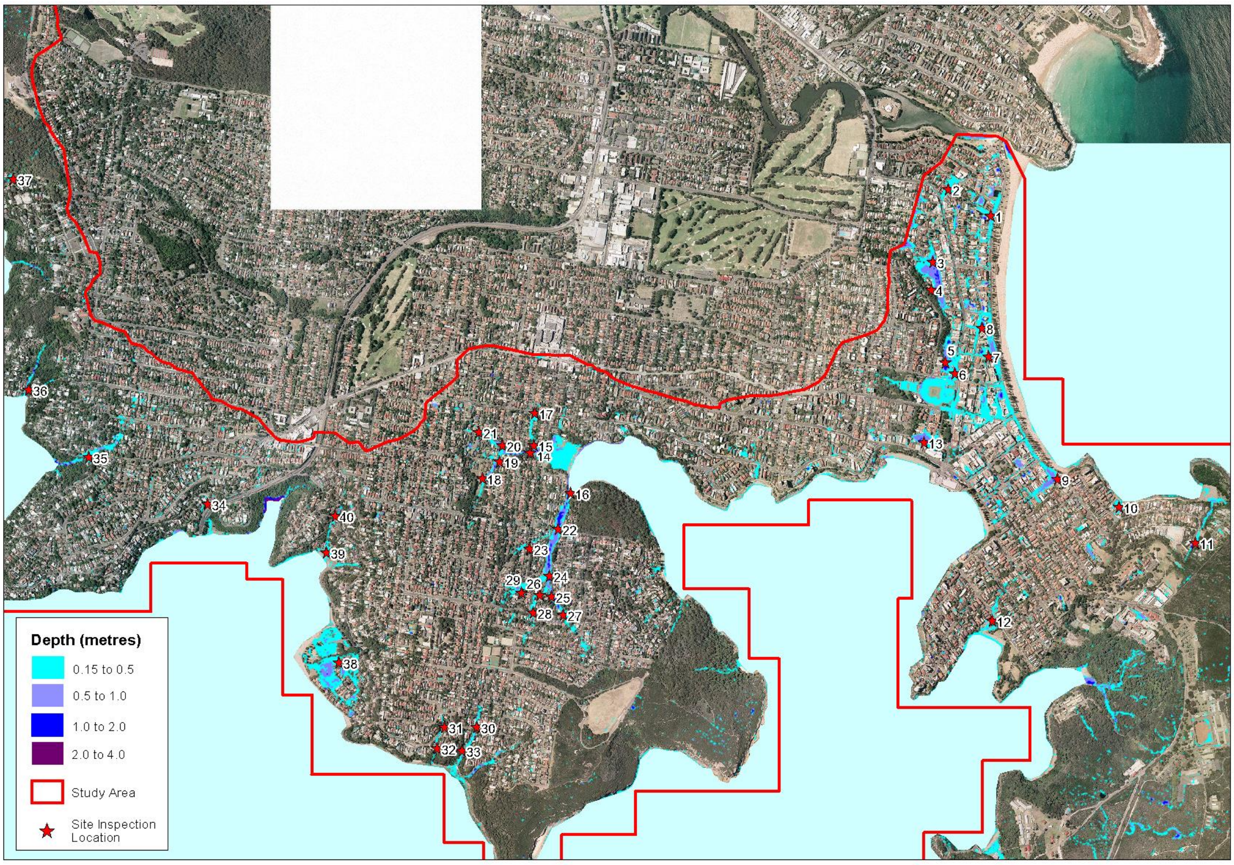

Figure 2-1 Site Inspection Locations

2.4 Site Inspections

A field inspection was undertaken by Cardno to familiarise with local conditions and identify any features requiring additional detailing for the establishment of the flood model. Additional ground survey of specific sites was completed to provide suitable data for the study.

Council inspected the study area, primarily in the CBD, to confirm flow paths between buildings and arcades / accesses that were not visible.

2.5 Historic Flood Information

The study area has experienced a number of large flood events and information was provided by Council including a report by Council's library historian and photographs of previous flood events from Council staff.

2.6 Rainfall and Gauge Data

There are four pluviometer rainfall gauges operated by Manly Hydraulics Laboratory (MHL) which record rainfall at frequent time intervals suitable for flood modelling in the vicinity of the study area. The location of these gauges are shown in **Figure 2-2**.

Figure 2-2 Pluviometer Locations

The time period of rainfall records for the four rain gauges is summarised in **Table 2-3**. Due to recording errors and malfunction of the gauges there are periods where no data is recorded within these record periods.

Table 2-3 Rainfall Data Record Length of Rainfall Gauges

Rainfall Gauge	Record Commenced	Extent of Record Collected
Manly CBD	13/05/2013	29/10/2014
Spit Bridge	14/08/2013	29/10/2014
Manly Dam	27/11/1995	29/10/2014
North Manly	31/05/1994	29/10/2014

3 Community Consultation

Community consultation is an important component of the Flood Study, with one of the key objectives of the study to ensure that the community can clearly understand potential flood risks within the catchment. The NSW Government *Floodplain Development Manual* (2005) details a framework and process for implementing the Flood Prone Land Policy. Following the completion of the Flood Study, a Floodplain Risk Management Study and Plan is to be completed which reviews potential options for flood management and mitigation. The resultant Plan is a strategic framework for Council to implement policies and undertake works. Community involvement throughout the process is important to ensure the community's concerns are considered and for acceptance of the final recommendations of the process.

Primary components of the consultation process include a questionnaire and public exhibition period discussed further in this section.

3.1 Project Website and Mailout

Cardno assisted Council in establishing a project website that provided an overview of the objectives of the study and advised of upcoming consultation activities. A primary component of the consultation process for the Flood Study is the initial mailout that includes a guide to advise the objectives of the study and a questionnaire enquiring about a range of flood related issues. The community guide and questionnaire (included in **Appendix D**) were distributed to approximately 5,500 properties identified in a preliminary estimation of the catchment floodplain.

The nine Precinct Groups of the former Manly Council were also advised of the Flood Study.

3.2 Community Questionnaire

A questionnaire was distributed to the community to gain an understanding of flood awareness and experiences in the catchment. It comprised ten questions about flood experiences and was mailed to approximately 5,500 properties within the study area. The questionnaire was also available via a link to Survey Monkey (https://www.surveymonkey.com/s/ManlyLGAFS) published on the project website. A copy of the questionnaire is included in **Appendix D.**

A total of 204 responses were received during the four week reply period, 35 of which were completed online and 169 returned as hardcopies. This represents a response rate of 4%.

Responses received for the questions are summarised in the following sections.

3.2.1 Question 1 – Contact Details

Contact details for respondents were requested (but not essential) to enable correspondence to further discuss responses in detail and to facilitate future contact as the flood study progresses.

3.2.2 Question 2 – Property Type

What is the property type?

- Residential, commercial, industrial

Due to the high proportion of residential properties within the study area, over 99% of respondents described their property as residential.

3.2.3 Question 3 – Time at Residence

How long have you lived and worked at this property?

Table 3-1 lists the responses for the years that the respondent has lived / worked in the catchment. Time of residence is an important criterion for evaluation of the responses that follow. Specifically, a resident may have lived in the catchment for a couple of years and thus may not have experienced a flood event in the catchment due to no significant storms occurring within their relatively short time in the area.

Submissions for this question indicated that 31% of respondents have been in the catchment for less than five years which may have an effect on awareness of local flooding, with more recent arrivals to the area potentially not having an awareness of historical flood events. Notably, 25% have lived in the area for more than 20 years.

Table 3-1 Time of Residence

Period of Residence	Number of Responses	Percentage
0 to 5 years	64	31%
6 to 10 years	35	17%
11 to 15 years	26	13%
16 to 20 years	27	13%
More than 20 years	52	25%
Total	*204*	-

3.2.4 Question 4 – Property Occupancy

What is the status of the property?

- Owner-occupied, leased

Of the respondents, 85% identified that they were the owner of the property, while only 15% identified as tenants (**Table 3-2**). Seven respondents recorded their property as both owner and tenant occupied (i.e. apartment buildings).

It is noted that tenant occupied residences are in general less likely to have resided in the catchment for a long period and may have limited awareness of local flooding.

Table 3-2 Type of Occupancy

Period of Residence	Number of Responses	Percentage
Owner Occupied	178	85%
Tennant Occupied	31	15%
Other Occupied	0	0%
Total	*209*	-

3.2.5 Question 5 – Awareness of Flooding

What is your level of awareness of flooding having occurred in the study area?

- Aware / personal knowledge, some awareness, no prior knowledge

Responses to Question 5 regarding awareness of flooding are a guide for general flood exposure in the catchment. However, responses can be influenced by a resident's location and time in the catchment, as well as the period since the last major storm event. This information can be applied to the next stage of the Floodplain Management Process, where options are considered, such as the implementation of education campaigns to raise awareness of flooding both generally and in relation to specific hazardous locations in the catchment.

Of the respondents, 50% indicated they are aware of potential flooding in the catchment (**Figure 3-1**), which is an important objective of the study of defining flood behaviour to enable the community to be informed about potential risks. Based on analysis of the survey results, awareness of flooding in the catchment does not directly relate to the years residing in the catchment as it is also dependent on the respondent's location in the catchment and floodplain extent.

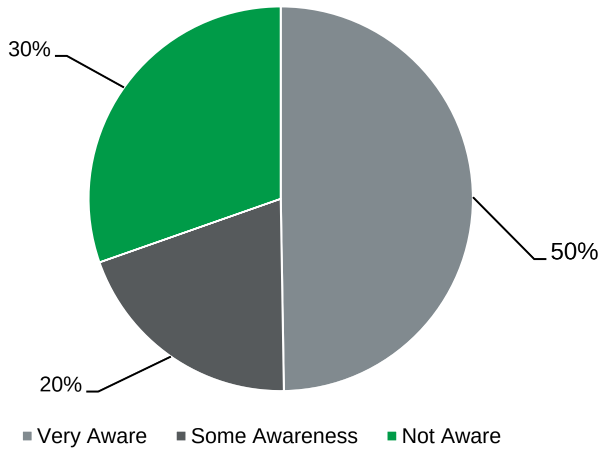

Figure 3-1 Flood Awareness of Respondents

3.2.6 Question 6 – Property Inundation

Have you ever experienced flooding at the address you specified above from streets, channels or creeks?

- Front or back yard, shed or garage, residential (below floor level), residential (above floor level), commercial (below floor level), commercial (above floor level), industrial

The degree of affectation by flooding at particular properties is relevant to the flood model calibration / validation process as it identifies the actual impact advised by the resident to compare to the flood model outcome. Responses to Question 6 also indicate the general exposure within the catchment to flood risk and property damage in particular areas.

The highest percentage of property inundation was in the front/backyard with 42% followed by residential (below floor) with 25% (**Figure 3-2**).

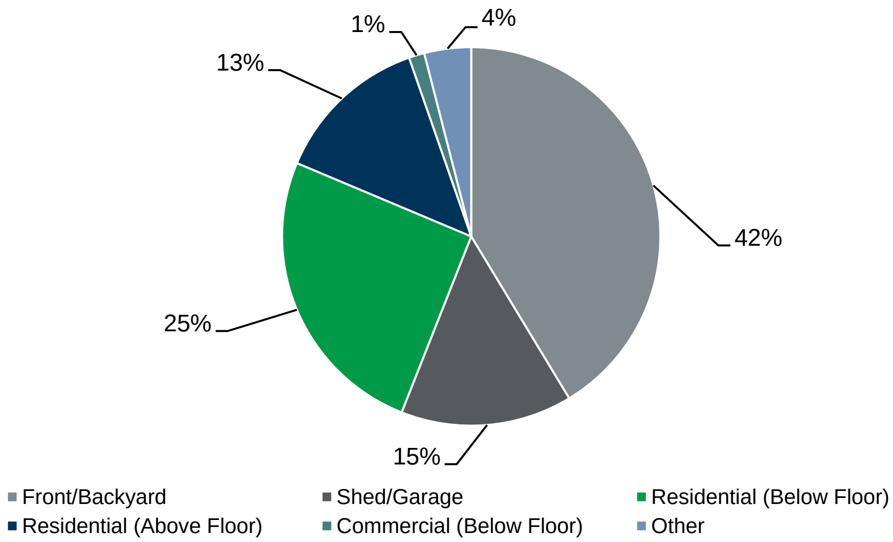

Figure 3-2 Property Inundation

Locations reported by residents as having previously experienced above-floor flooding included:

- College Street, Reddall Street, The Crescent and North Steyne in Manly;
- Battle Boulevard and Ponsonby Parade in Seaforth; and
- Monash Crescent in Clontarf and Gourlay Avenue in Balgowlah.

Approximate dates of inundation are listed in **Table 3-3.**

Table 3-3 Property Inundation Dates

Date of Flood Event
12-13 February 2010
March 2011
16 March 2012
11 June 2012
2 June 2013
28 October 2013
April 2014

Photographs or flood marks from previous storm events assist in the model calibration / validation process supplementing the descriptions provided. Photographs may also be relevant for local historians. Several photographs, reports and letters relating to specific flood events and the associated property damage were provided by survey respondents for use by the study team.

3.2.7 Question 7 – Flooding in the Catchment

If you have experienced flooding elsewhere in the study area, what other areas have you seen flooded?

- Residential or commercial areas, roads or footpaths, parks

This question provides an indication of flooding identified elsewhere within the catchment, such as roadways and other public open space areas that may be transited or otherwise used by members of the public. Similar to Question 6, this information is relevant for the flood model calibration / validation process, and it also assists in capturing data on issues with emergency management and evacuation. **Table 3-4** summarises the responses provided regarding other (non-residential) locations affected by flooding.

Table 3-4 Flooding in the Catchment

Area	Number of Responses	Locations Affected by Flooding	
Residential/ Commercial	17	Bower St, Manly (2)	Bonner Av, Manly
		Monash Cr, Clontarf	Cove Av, Manly
		Smith St, Manly (2)	Alan Av, Seaforth
		Pine St, Manly	Addison Rd, Manly
		Beatty St, Balgowlah Heights	Victoria Pde, Manly
		North Harbour St, Balgowlah	Harbour View St, Clontarf
		Ashburner St, Manly	Collingwood St, Manly
		Montpelier Pl, Manly	

Area	Number of Responses	Locations Affected by Flooding	
Roads/Foot Paths	94	Addison Rd, Manly (7)	Lakeside Cres, North Manly
		Alexander St, Manly	Lauderdale Ave, Fairlight
		Allenby St / Holmes Ave Intersection Clontarf	Malvern Ave, Manly
		Ashburner St, Manly	Monash Cres, Clontarf
		Balgowlah Rd, Manly (3)*	North Steyne, Manly
		Belgrave St, Manly	Ogilvy St, Clontarf
		Bonner Ave, Manly (4)	Pacific Pde, Manly
		Campbell Pde, Manly Vale	Pacific St, Manly
		Carlton St, Manly	Pittwater Rd / Raglan St Intersection, Manly (7)
		Central Ave, Manly	Reddall St, Manly
		Collingwood St, Manly	Rolf St, Manly
		Collins Beach Rd, Manly	Seaforth Cres, Seaforth
		Condamine St, Balgowlah	Smith St, Manly
		Craig Ave, Manly	Sydney Road, Seaforth
		Denison St, Manly	Victoria Pde, Manly
		Golf Pde, Manly	Wentworth St / South Steyne Intersection, Manly
		Kangaroo Ln, Manly	Wilyama Ave, Fairlight
Parks	24	Pittwater Rd Sports Grounds	Manly Oval
		North Harbour Reserve	Kangaroo Reserve
		Ivanhoe Park	Nolan Reserve*
		Manly District Park	Keirle Park*
		Manly Golf Course*	Lagoon Park
Other	5	Clarence Street Waterfall, Balgowlah	Manly Centre, Manly
		Condamine St, Balgowlah (2)*	Kangaroo Ln, Manly

*indicates survey responses received that do not appear in the study area.

3.2.8 Question 8 – Flood Experience

Have you ever been inconvenienced by a flood event? *- Daily routine was affected, safety threatened, access to property was affected, property or contents were damaged, business unable to operate*

Question 8 provides an indication of the impacts of flooding to residents in the catchment.

Flood experience responses are summarised in **Figure 3-3** and listed below:

- 51 respondents recorded that their daily routine was affected due to flooding;
- 7 respondents were concerned for their safety;
- 26 had access to their property affected;
- 24 respondents had their property damaged; and
- 1 experienced difficulties in operating their business.

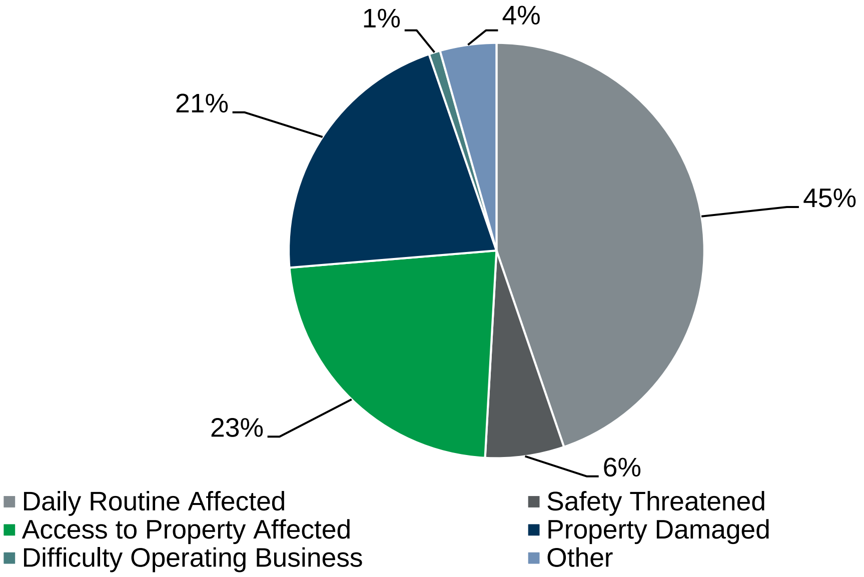

Figure 3-3 Flood experience

3.2.9 Question 9 – Drain and Culvert Blockage

Have you noticed any stormwater drains, creeks, channels, bridges and/or culverts blocked during a flood event? *- Yes, no (include details)*

Responses to Question 9 serve several purposes. For model calibration / validation, residents may advise of flooding impacts worse than modelled which may be the result of blockage to stormwater inlets and conduits. The responses may identify particular locations requiring maintenance to remove debris or locations that are particularly susceptible to blockages during storm events.

A total of 101 respondents advised that drains or culverts were blocked (**Table 3-5**), generally by organic matter and rubbish.

Table 3-5 Blocked Drains / Culverts

Location	Comments
2 Battle Blvd, Seaforth	Drainage pit blocked 100%
36 Seaforth Cres, Seaforth	Culverts blocked 90%
4 Palmerstone Pl, Seaforth	Drains blocked 80%
40 Smith St, Manly	Drains blocked 100%
70 Seaforth Cres, Seaforth	Drains blocked 80%
Alan Ave, Seaforth	Drains blocked 80%
Balgowlah Rd, Manly	Drains blocked 50%
Balgowlah Rd / Rolf St, Manly*	Drains blocked 100%
Beatrice St, Clontarf	Drains blocked 100%
Belgrave St, Manly	Drains blocked 20%
Bower St, Manly	Drains blocked 20%
Central Ave / Raglan St Intersection, Manly	Drains blocked 80-100%
Central Ave / Sydney Rd Intersection, Manly	Drains blocked 50%
Condamine St / Lower Beach St, Balgowlah	Drains blocked 20%
Darley Rd, Manly	Drains blocked 20%
George St, Manly	Drains blocked 80%
Kangaroo Ln, Manly	Drains blocked 20-100%
Lauderdale St, Fairlight	Drains blocked 50-80%
Lower Beach St / North Harbour St Corner, Balgowlah	Drains blocked 80%
Malvern Ave, Manly	Drains blocked 20-50%
North Steyne, Manly	Drains blocked 80-90%
Ogilvy Road, Clontarf	Drains blocked 100%
Pacific St, Manly	Drains blocked 100%
Raglan St, Manly	Drains blocked 20%
Raglan St / Pittwater Rd Intersection, Manly	Drains blocked 80-100%
Sydney Rd, Manly	Drains blocked 20%

*indicates survey responses received that do not appear in the study area.

3.2.10 Question 10 – Additional Comments.

> *If you have any other information you would like to provide to inform the Manly LGA flood study, please provide details.*

Respondents were asked if they wished to provide additional information to inform the Flood Study.

Responses identified the following issues of concern:

- Potential impact of flooding of the proposed car park under Manly Oval;
- The impact of high tides and rising sea levels on flooding; and
- Quality of stormwater runoff.

3.3 Flood Study Working Group

Council established the Flood Study Working Group in March 2015 to provide a forum for discussion and recommendation on matters relating to the Flood Study. The working group consists of a Councillor, Council staff, community representatives and state government agency representatives (including State Emergency Service).

3.4 Draft Report Public Exhibition

Public exhibition of the Draft Manly to Seaforth Flood Study is required by the Local Government Act (1993, Section 402). This section stipulates that Council must exhibit the draft plan for public comment for a period of at least 28 days, and that submissions must be considered by the council before the plan is endorsed or amended.

The Draft Report of the Manly to Seaforth Flood Study was endorsed for public exhibition at the Council meeting on the 17 April 2018. The exhibition period ran from the 11th June to the 13th July 2018. The report was made available online and in hardcopy at all Council libraries and customer service centres. Three one on one sessions were hosted on the 19th, 21st and 23rd June 2018 at Manly Town Hall and Seaforth Village Community Centre. Approximately 40 people attended over the 3 days. At the completion of the public exhibition period, the Have Your Say webpage had had 676 visits. 58 submissions were received, including written submissions and submissions provided to staff at one on one sessions and over the phone.

Generally the submissions related to the following issues:

- Potential impacts on property values and insurance costs resulting from flood notification of property;
- Potential inaccuracies in the flood mapping as it is based on a computer model of the catchment with aerial laser scanning (ALS) for establishing ground elevations;
- Residents have lived at the property for many years but haven't experienced flood inundation of their property in actual storm events;
- Specific site conditions that affect overland flow paths and flood inundation are not represented in the modelled extents;
- Maintenance of the stormwater drainage network (pits and pipes) is required;
- Requests for review of the flood mapping to exclude their property from being listed as flood affected; and,
- The report is highly technical and it is difficult to understand the implications of the study.

The submissions were reviewed and responses prepared to each submission provided to Council for responding to the community. The following are the general response to the above main issues:

- The study report is a technical document detailing the flood modelling methodology to define flood behaviour in the catchment and mapping the resultant flood extents. The study aims to identify potential flood risks to help plan and respond to potential flooding and in turn help the community to make informed decisions about potential risks, property development and insurance considerations. Future studies such as the Floodplain Risk Management Study will investigate potential mitigation options for flood hotspots identified in the flood study.
- Council discussed the report outcomes with respondents to clarify the document and implications.
- A storm event of a 1% AEP magnitude has not occurred in the catchment in recent history. A PMF event is extremely rare with an estimated chance of 0.000001% of occurring in any year. The storm event of 12 February 2010 used for the flood model validation was estimated as a 5%-10% AEP event. As such, residents may not have experienced larger events that are relevant to flood planning.

- ALS ground elevations are widely used as a suitable representation of ground level in flood studies of a catchment-wide scale (like this study). An accuracy of about +/-150mm is quoted for ALS to actual detailed field survey (which is not feasible for a study of this scale).
- The flood model is of catchment-wide scale with a 2.5m x 2.5m grid cell size and thus does not represent all specific localised hydraulic controls, such as kerb lines that may redirect shallow flow. Similarly, constrictions to flow, such as houses, buildings, and walls were not explicitly modelled in the study. These were represented with model parameters that allow consideration of their impact on flood behaviour.
- The stormwater drainage network of pits and pipes is designed to convey runoff in minor events, typically only up to the 20% AEP event and does not have capacity to convey all runoff in a large storm event such as the 1% AEP. Managed overland flow paths such as roadways form part of the drainage system in major storm events.
- This study identifies the flood extent and behaviour in the catchment. Potential mitigation measures and maintenance of the stormwater drainage system would be reviewed as part of a future floodplain risk management study.

Flood inundation mapped at some of the submission properties were reviewed where requested. The review comprised confirming the model setup suitably represented the actual conditions on the site, such as checking the ALS and model grid as well as ground-truthing at some sites. Mapped flood inundation was revised at some properties as there was a definitive reason the mapping was not accurate (such as small isolated ponds in lowpoints that weren't entirely correct or a retaining wall which limited flood extents that was not represented in the model). In other cases the mapping was unchanged as the local on ground topography and catchment characteristics matched the parameters of the flood model. A consistent flood mapping approach was thus maintained across the study area.

4 Flood Model Establishment

The hydraulic model is developed by collating data into the modelling software (SOBEK) to produce a simulation of the on-ground conditions. Elements of the adopted configuration for parameters to the Manly to Seaforth Flood Study SOBEK models are described.

4.1 Model Terrain

The catchment area to be modelled is digitised as a grid surface where the grid size is an important consideration for hydraulic modelling. A smaller grid size enables greater definition of overland flowpaths, such as flows between buildings and along roads, however a large number of cells is thus required to define a particular study area. A smaller grid cell enables a shorter computational time-step, particularly for areas with higher velocities (such as some of the steep slopes in the study area), which in turn results in longer run times.

A terrain grid (also referred to as a ‘topographic’ grid) for each SOBEK model was developed to represent ground elevations based on ALS data using a grid cell size of 2.5m x 2.5m. **Table 4-1** provides a summary of the number of active grid cells in each of the four SOBEK models.

Table 4-1 Model Zone Grid Cells Number

Model Zone	A	B	C	D
Grid Cells (millions)	0.50	0.75	0.45	0.55

4.2 Buildings

There are three common methods used to define buildings in a hydraulic model:

1. Raising of buildings, to represent a complete obstruction to the flow;
2. Utilising a high roughness across the footprint of the building; or
3. Using an averaged roughness across the entire property.

The key challenge with the first method is whether the grid size is sufficiently small enough to define the flowpaths between buildings. A grid size of 2.5m x 2.5m would result in the flowpaths between buildings of 2.5m wide or less being artificially blocked. While many buildings in the study area have flowpaths between them larger than this, there would still be a number of flowpaths blocked.

The second method does not fully block the flow but significantly reduces the conveyance through the building footprints. It also has the advantages of providing an allowance for storage. In addition, the second method does not require manually reviewing all buildings within the flowpath to ensure that the flowpaths between the buildings are modelled appropriately. The challenge with this method is that it still requires the outlines of the buildings to be defined.

The third method is applying a roughness to the entire property, which effectively averages the roughness values for the building, garden areas and other property features. When building outlines are not available, this is effectively the only option. It is important to note that the impact of this approach will average out to some degree the velocities across the property.

As part of the validation all three methods of building representation were utilised. Based on the outputs of the validation model, it was identified that a high roughness on the footprint of the building (method 2) provided the most representative flow paths and water levels when compared to recorded flood impacts in the study area. In the option of raising buildings (method 1), key flow paths, particularly in high density areas were blocked, which did not represent actual flooding behaviour. In the option of averaged roughness of entire properties (method 3), flow paths were not well represented, compared to when modelling with a high roughness of individual building footprints.

4.3 Pits and Pipes

A comprehensive pit and pipe network survey was undertaken prior to the commencement of the hydraulic modelling phase of this study. Detailed information was therefore available on the size, location and invert level of the drainage network within the study area.

Pits and pipes have been incorporated into the model as one-dimensional elements. The pit and pipe network is shown in **Figure 4-1** with the general catchment elevations.

Junction pits (that is street pits with sealed lids and no inlet) have been modelled as closed thus excluding flow from entering the pipe system. Stormwater pits with an inlet component (that is a kerb lintel or grate opening) are modelled as having unlimited entry. Inlet capacity is therefore restricted to the conveyance capacity of the stormwater pipe. Sensitivity of the flood model to stormwater network blockage is reviewed in **Section 8**

4.4 Roughness

The flow of runoff across a surface is dependent on the nature of the specific surface, whether it is rough (inhibiting flow) or smooth (allowing smoother flow). Hydraulic modelling requires mapping of the ground surface to classify the variations in roughness for the particular land use. A roughness map of the study area was developed using the 2011 aerial photography and land use zoning details supplied by Council.

Figure 4-2 shows the roughness layout applied in the 2D model. There is no standard reference that provides guidelines on estimating the roughness for overland flow in 2D models in urban areas. Previous experience of calibrating model catchments with similar land uses and topography provides a suitable guide to determine the roughness values. The roughness values adopted for the 2D are listed in **Table 4-2.**

Table 4-2 Model Roughness Values

Classification	Adopted Roughness Value
Open Space	0.04
Roads	0.02
Coastline	0.04
Bushland	0.08
Ocean	0.02
Residential/Urban Areas	0.10
Buildings	0.50

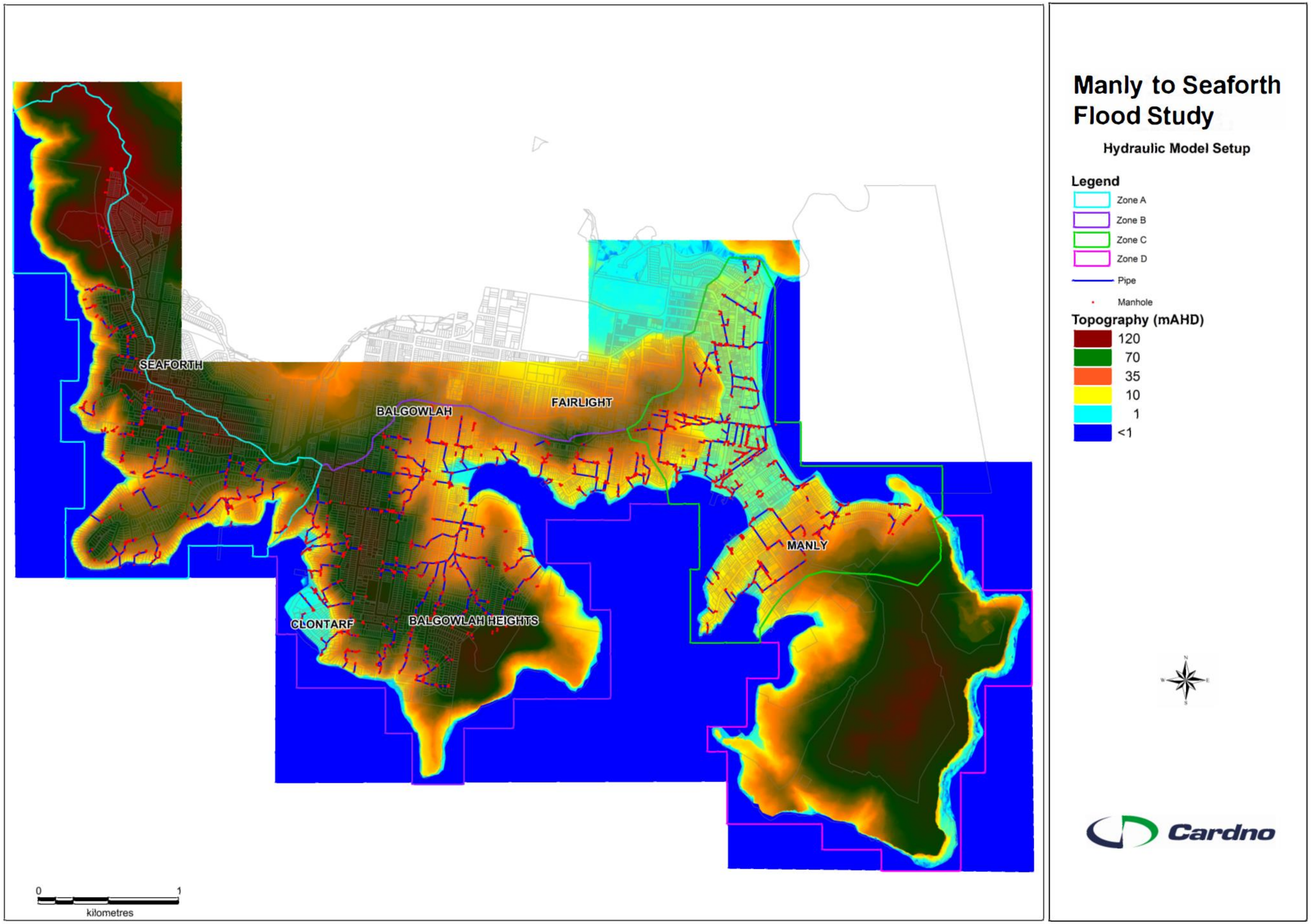

Figure 4-1 Hydraulic Model Setup

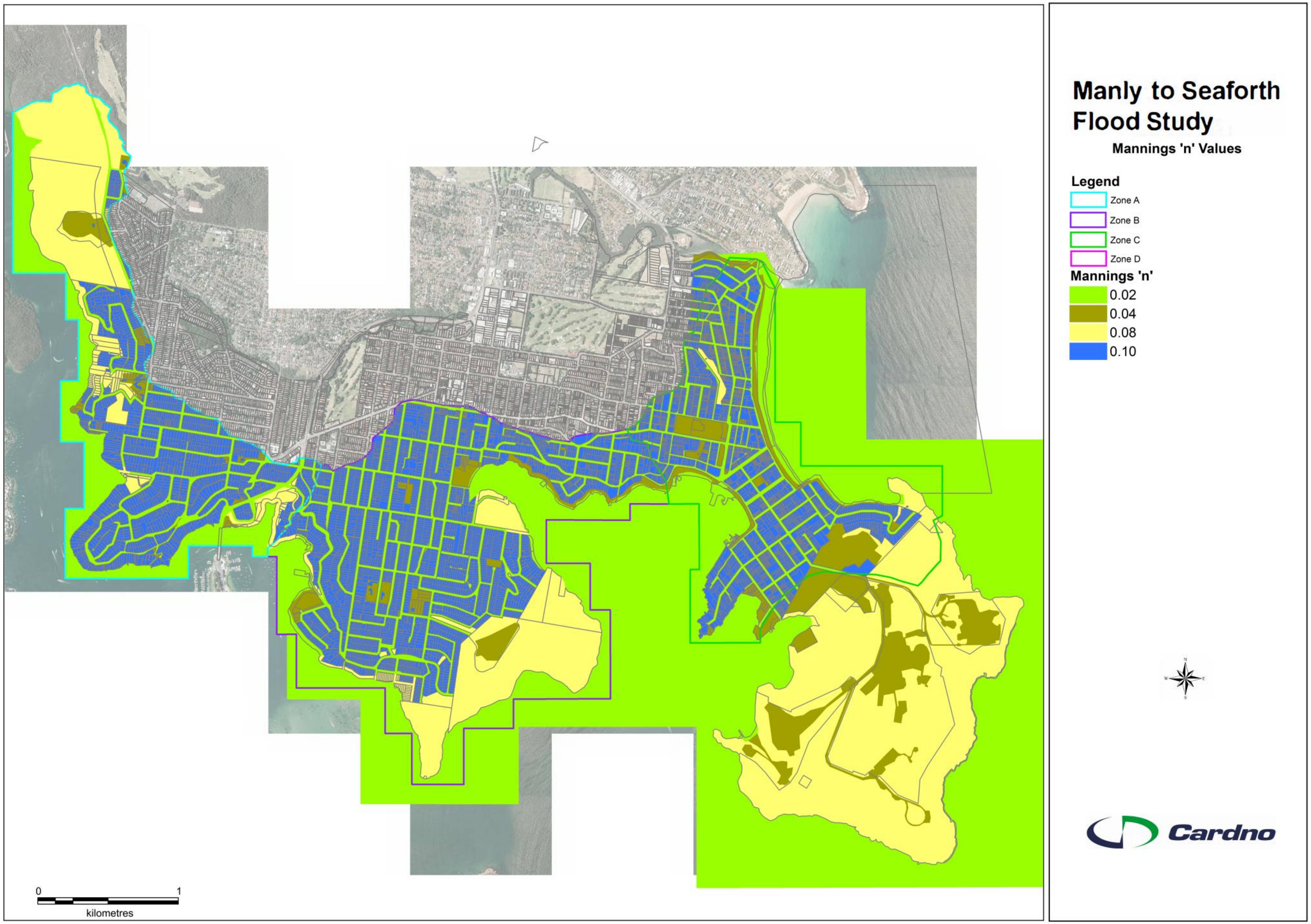

Figure 4-2 Roughness Values

4.5 Downstream Boundary

The study area discharges into Middle Harbour, North Harbour and the Tasman Sea at many different outlet locations along the foreshore. The majority of the areas influenced by sea level in the study area are limited to the direct foreshore. Therefore, the influence on boundary conditions for the overland flow study is likely to be primarily around the foreshore areas, where overland flowpaths and drainage pipes interact with the foreshore areas.

The ocean / harbour water level varies depending on the tide and atmospheric conditions. A storm event in the catchment may coincide with a range of harbour levels, such as low or high tide. As a conservative estimate, a 5% AEP peak design ocean water level of 1.40m AHD is adopted as the downstream boundary level for the design events except for the PMF (which has a 1% AEP level of 1.45m AHD) as shown in **Table 4-3**.

Table 4-3 Adopted Tailwater Levels

Design Storm Event	Tailwater Level (m AHD)
20% AEP	1.40
10% AEP	1.40
2% AEP	1.40
1% AEP	1.40
0.5% AEP	1.40
PMF	1.45

4.6 Manly Oval Detention Basin

The flood model was updated in 2016 to include the newly constructed underground stormwater detention system beneath Manly Oval. The reason for the construction of underground storage was to reduce the flood risk at the Raglan and Pittwater Road intersection of the Manly CBD.

The storage beneath Manly Oval was incorporated into the existing model based on conceptual design plans using the following methodology:

- A 525mm diameter diversion pipe was inserted into the model connected to the existing drainage asset running along the western boundary of the oval.
- The diversion pipe was connected to a large underground pipe with the equivalent storage volume of 573m^3. This storage volume was estimated using concept design plans supplied by Manly Council.
- The storage was connected back into the existing drainage system at Belgrave Street via an overflow pipe.

The flood model was validated without the inclusion of the underground stormwater detention system because past flood events used for the validation occurred prior to the storage being constructed.

5 Flood Model Validation

5.1 Historic Storm Events

5.1.1 Event Data

Validation of the flood model has been completed based on hydrologic modelling using an alternative model and photographs and historical data sourced from Council and responses from the community consultation. No specific event flood levels are available nor stream gauges (which record time-series of flowrates or water levels) are operated within the study area to enable calibration of the flood model. Available data for recent storms is summarised in **Table 5-1**. In addition to these descriptions, general comments on flooding within the catchment based on community feedback have been reviewed.

Table 5-1 Summary of Available Historical Storm Event Data

Rainfall Event	Available Photos	Locations of Photos	Historical Data	Quality of Data
12-13 February 2010	18 photos available (6 time stamped)	Raglan Street Kangaroo Lane	Yes, 4 noted event, 2 descriptions	Good, comment on location and depth of flooding
September 2010	5 photos available (none time stamped)	Raglan Street	No	
21 January 2012	8 photos available (none time stamped)	Raglan Street Kangaroo Lane	No	
10-11 June 2012	Yes, submission ID 149	Ponsonby Parade	Yes, 4 noted event, 1 description	Good, comment on overfloor flooding for Ponsonby Parade
2 June 2013	No photos available		Yes, 4 noted event, 2 descriptions	Average, notes flood streets and locations
28 October 2013	No photos available		Yes, 3 noted event, 3 descriptions	Good, one notes duration of flooding, another the depth in car park

5.1.2 Selected Storms

Four major storms that have occurred within the above recording periods that were specifically identified to a significant extent in the community consultation:

- 12-13 February 2010;
- 10-11 June 2012;
- 2 June 2013; and
- 28 October 2013.

5.1.3 Available Rainfall Data

Rainfall data recorded at the MHL gauges for these storms has been summarised in **Table 5-2**. **Figure 5-1** to **Figure 5-4** show the recorded temporal pattern for these events.

Table 5-2 Summary of Available Rainfall Data for Recent Storms

Rainfall Event	Rainfall Gauge with Recorded Data	Total Rainfall Amount (mm)
12-13 February 2010	Manly Dam	83
10-11 June 2012	Manly Dam North Manly	124 119
2 June 2013	Manly CBD Manly Dam North Manly	69.5 61.5 68.0
28 October 2013	Spit Bridge Manly Dam North Manly	15.0 58.0 63.5

Figure 5-1 Rainfall Distribution 12/02/2010

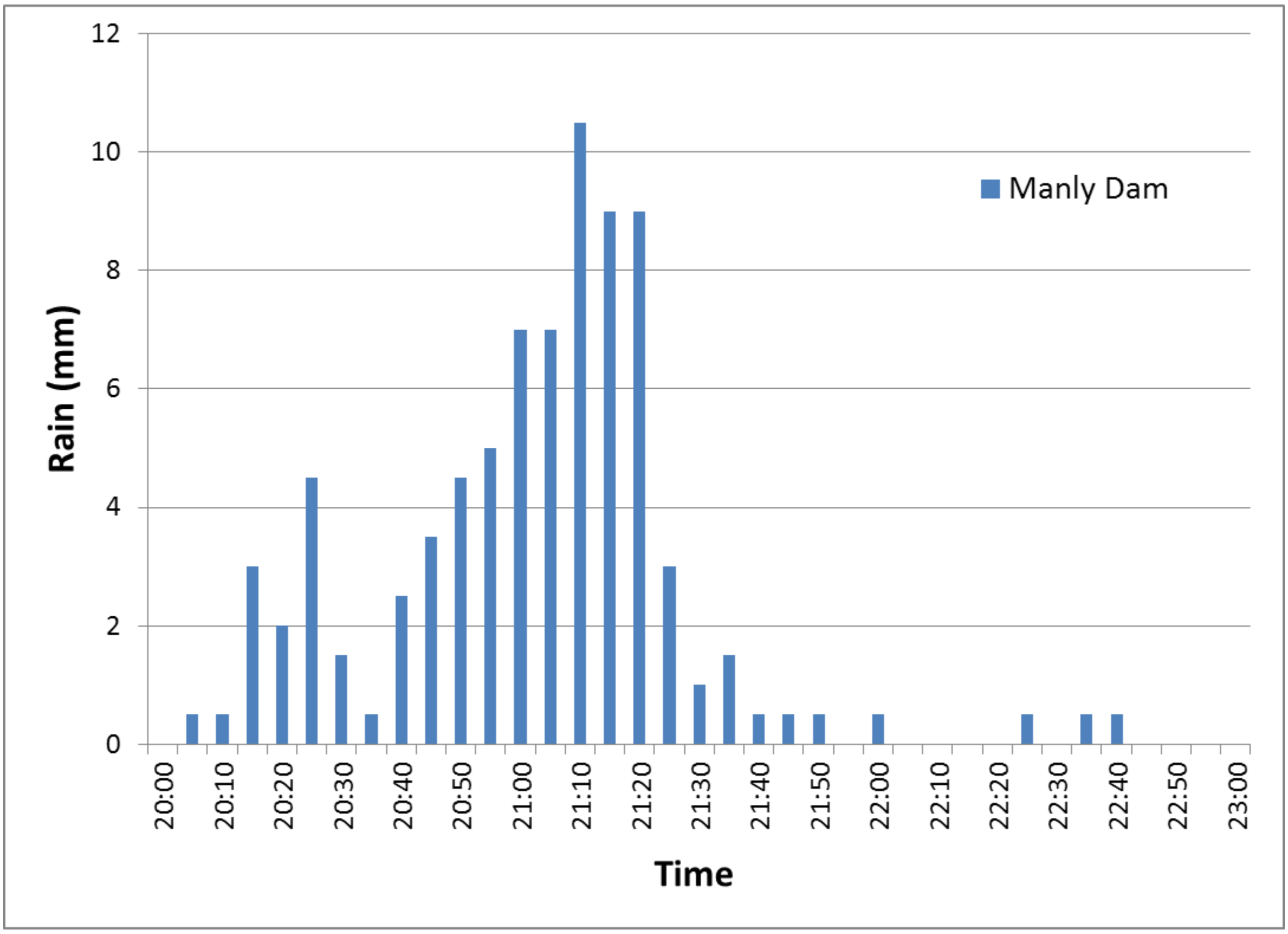

Figure 5-2 Rainfall Distribution 10/06/2012-11/06/2012

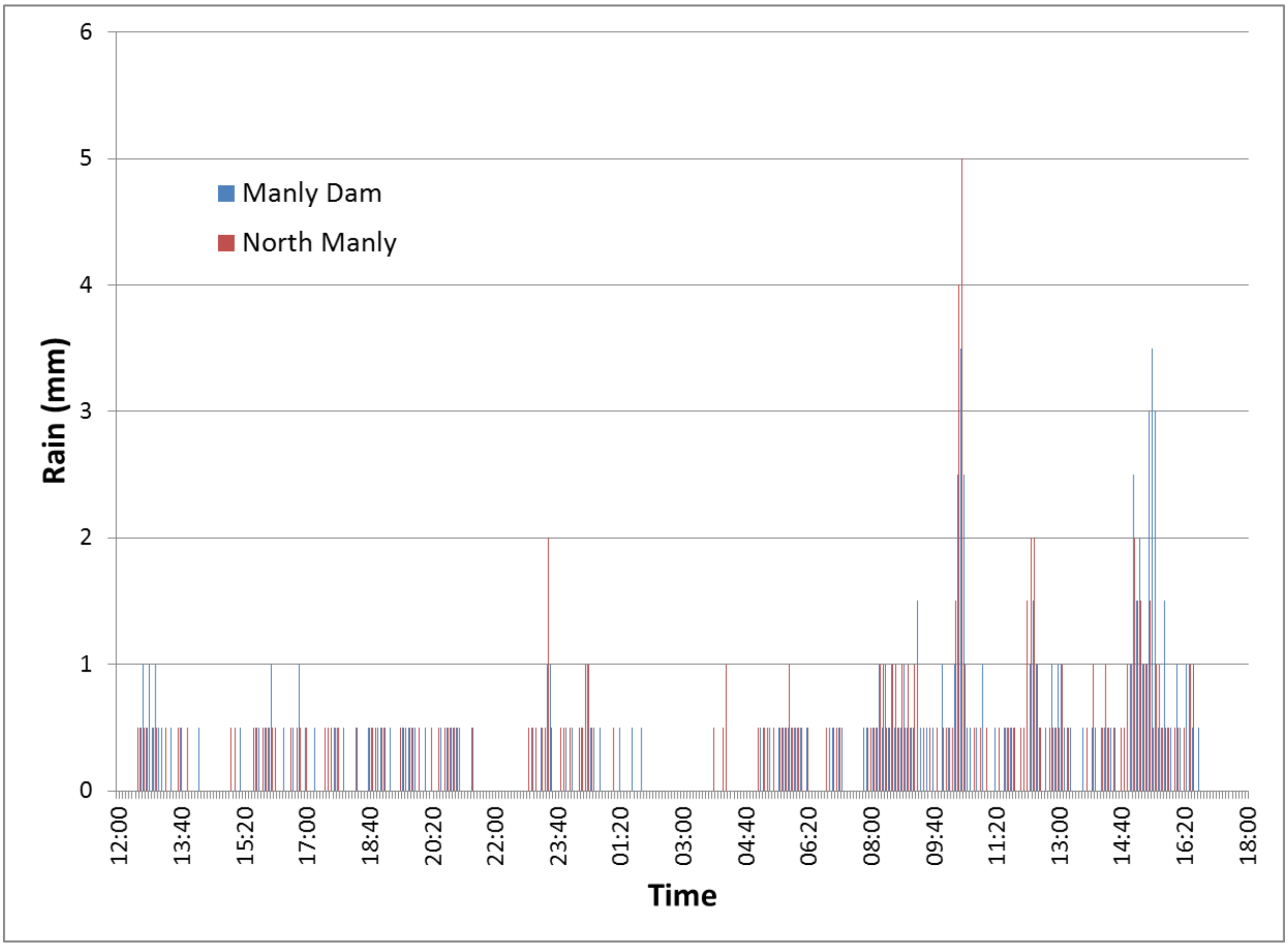

Figure 5-3 Rainfall Distribution 2/06/2013

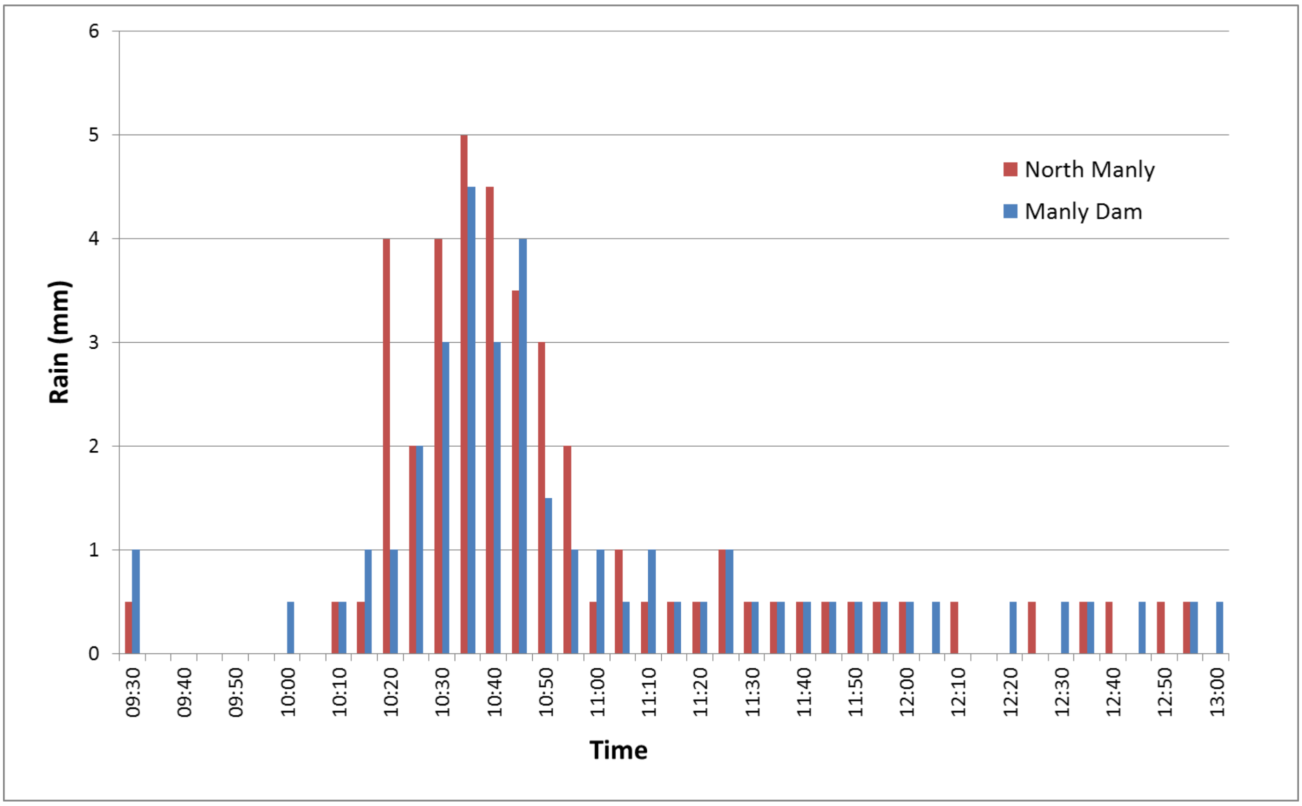

Figure 5-4 Rainfall Distribution 28/10/2013

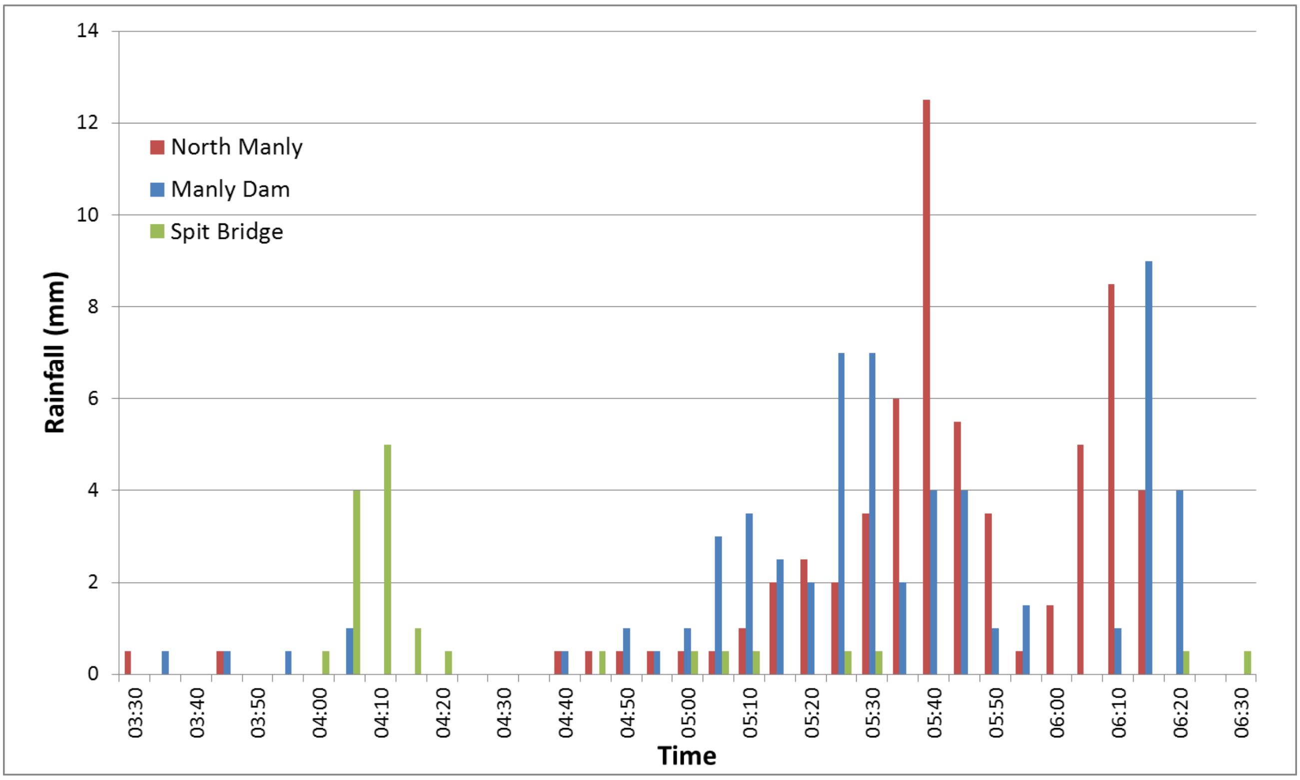

Table 5-3 summarises the estimated Average Recurrence Interval (ARI) for the 2010 and 2013 events for various durations. Of note is the spatial variation experienced across the region. This is particularly apparent within the 28/10/2013 event where the rainfall recorded at Spit Bridge rainfall station is 25% of the recorded rainfall at Manly Dam and North Manly. This implies rainfall in this region may vary greatly across the catchment area during high intensity storm events. **Table 5-3** does not provide a summary of the June 2012 event. This event was a long period of consistent rainfall (shown in **Figure 5-2**). While the rainfall total was high, because of the length of the storm, an ARI of less than 1 year for all durations (up to 72 hours) was estimated for this event.

Table 5-3 Equivalent ARI Estimates

Event	Gauge	Details	Duration (minutes)		
			30	60	90
12 February 2010	Manly Dam	Intensity (mm/hr)	92	64	51
		Approx. ARI	10yr~20yr	10yr~20yr	10yr~20yr
2 June 2013	Manly CBD	Intensity (mm/hr)	56	35	25
		Approx. ARI	2yr	1yr~2yr	1yr~2yr
	Manly Dam	Intensity (mm/hr)	36	23	18
		Approx. ARI	<1yr	<1yr	<1yr
	North Manly	Intensity (mm/hr)	46	30	23
		Approx. ARI	1yr~2yr	1yr	1yr
28 October 2013	Manly Dam	Intensity (mm/hr)	52	41	35
		Approx. ARI	1yr~2yr	2yr~5yr	2yr~5yr
	North Manly	Intensity (mm/hr)	66	54	40
		Approx. ARI	2yr~5yr	5yr	2yr~5yr
	Spit Bridge	Intensity (mm/hr)	22	12	9.3
		Approx. ARI	<1yr	<1yr	<1yr

5.2 Hydraulic Model Validation

The three events described within the table above were run and reviewed against the historical data provided by the community. The modelled peak depths for the three validation events, February 2010, June 2013, and October 2013 events are shown in **Appendix A**.

The following pages show a comparison of photography of the February 2010 flood event versus the modelled results. In general, the results show a good correlation between the observed flooding and the modelled flooding. Photographs from the September 2010 and January 2012 event were also reviewed.

The hydraulic model has replicated the extents well where major overland flow was observed within the catchment. Within the Manly CBD, there is a good reproduction of recorded flooding issues against modelled flood inundation. Within the west of the study area, however, several sites which have reported flooding have not shown inundation in the modelled events potentially due to specific local conditions (such as debris blockages) that may have occurred at the time . The flood model was validated against past flood events that occurred prior to the Manly Oval Underground Flood Storage being constructed. Therefore, the model without the inclusion of the underground stormwater detention system was used for model validation.

Thirty-two (32) residents provided responses detailing previous flooding in and around their properties. Twenty (20) of the submissions matched the flood extents and depths that were simulated by the validation modelling. Four (4) comments related to flooding that was not identified in the validation events modelling because it was expected to originate from local depressions and drainage areas that are too small to be highlighted in the model. Six (6) comments related to flooding that was likely to be caused by blocked drains or stormwater asset issues that have since been upgraded so was not expected to be identified in the validation events modelling. These validation locations are not specifically listed in this report as they were confidential submissions from the community consultation.

5.2.1 February 2010 Event

Figure 5-5 Central Ave in Feb 2010 Event - Looking Towards Post Office (Source - Manly Council)

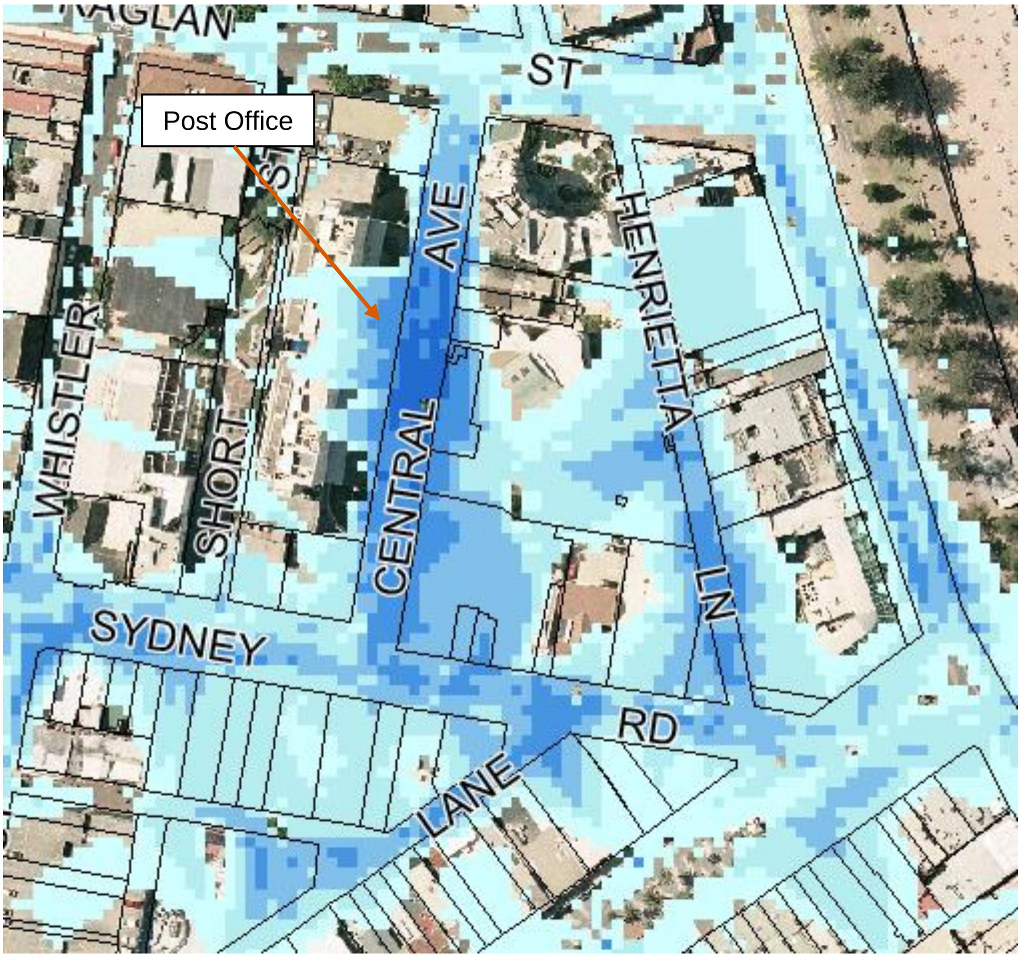

Figure 5-6 Feb 2010 Event Validation Flood Extent - Central Avenue

Flooding through this area estimated within the model is representative of the flood impact experienced as flood depths of approximately 0.5 m are present within the model along the roadway.

5.2.2 September 2010

Figure 5-7 is a photograph from Manly Council showing inundation at the intersection of Raglan Street and Belgrave Street during the September 2010 event. This event was not specifically modelled but the storm events that were modelled show inundation at this location.

Figure 5-7 Intersection of Raglan Street and Belgrave Street in September 2010 Event (Source - Manly Council)

5.2.3 January 2012

The 21 January 2012 storm event was not specifically modelled however photographs from Manly Council showing inundated areas were available (refer to **Figure 5-8**, **Figure 5-9** and **Figure 5-10**). The flood modelling (of the other events) also shows flood inundation occurring at these locations.

Figure 5-8 Intersection of Sydney Road and Belgrave Street in 2012 Event (Source - Manly Council)

Figure 5-9 Kangaroo Lane (near Raglan Street) in 2012 Event (Source - Manly Council)

Figure 5-10 Raglan Street (near Intersection with Belgrave Street) in 2012 Event (Source - Manly Council)

5.2.4 Summary

The hydraulic model was considered to accurately represent known flood events for the catchment based on the validation events. Maps showing the peak depths modelled for the three validation events, February 2010, June 2013, and October 2013 events are included in **Appendix A**. Generally a good match of the modelled flood extent is shown compared to the reported flooding inundation.

5.3 Hydrologic Verification

As the Direct Rainfall (rain-on-grid) methodology (discussed in Section 4.1) is still relatively new to the industry, it was verified against a traditional hydrological model. The verification was undertaken by comparing the runoff flow hydrographs of a 1% AEP event from the Direct Rainfall Model (SOBEK) with the results from a traditional hydrological model (XP- RAFTS).

It is not always expected that the two models will exactly match (in fact, two separate traditional hydrological models with similar parameters can produce significantly different results). However, where there are differences some interpretation of the results can be made, and the models can be checked as to why this is the case.

The comparison was undertaken on relatively small sub-catchments, as the larger the sub-catchment, it is more likely that significant hydraulic controls, such as culverts, would not be included in the hydrological model. In addition, the primary aim of this comparison is to ensure that the timing and peak flows from the direct rainfall hydraulic model (SOBEK) are reasonable, with the focus on the runoff areas rather than the mainstream areas. The comparison is also useful to testing appropriate roughness and loss parameters in the hydraulic model for generating catchment runoff.

Two sub-catchments within the study area were modelled in XP-RAFTS to assess the flows generated in the SOBEK model. The sub-catchments, shown in **Figure 5-11**, are located in the upper areas of the catchment.

Figure 5-11 XP-RAFTS Catchments

Modelled sub-catchment parameters are listed in 29**Table 5-4**. For the purposes of the verification, the fraction impervious has been generalised in both the XP-RAFTS model and within the SOBEK model.

Table 5-4 XP-RAFTS Subcatchment Parameters

Catchment	Area (Ha)	Fraction Impervious (%)	Vectored Slope (%)
C1	5.63	50	15
C2	7.99	50	8.4

Figure 5-12 and **Figure 5-13** show the flow hydrographs modelled in SOBEK and XP-RAFTS for the two sub catchments. An adopted soil infiltration loss rate of 10 mm initial and 1 mm continuing is applied to the hydraulic model. This is an area-weighted loss rate designed to reflect the average losses that are experienced over the area.

The match between the XP-RAFTS model and the SOBEK model for timing, volume and peak flow is very good, with virtually identical timings and volumes recorded. The SOBEK model results in a slightly higher peak flow than the XP-RAFTS model which is likely due to slight variances in the roughness and equal area slope assumptions. The SOBEK model is therefore considered to suitably estimate flow runoff compared to the traditional hydrology model.

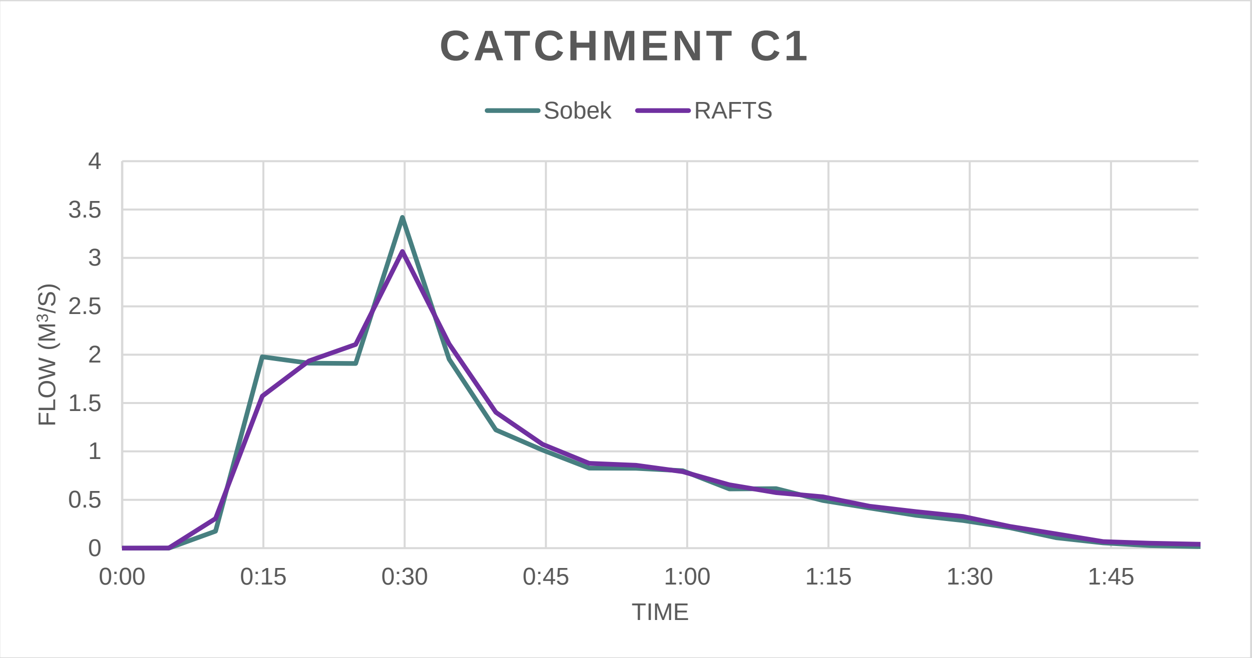

Figure 5-12 Catchment C1 Validation Results

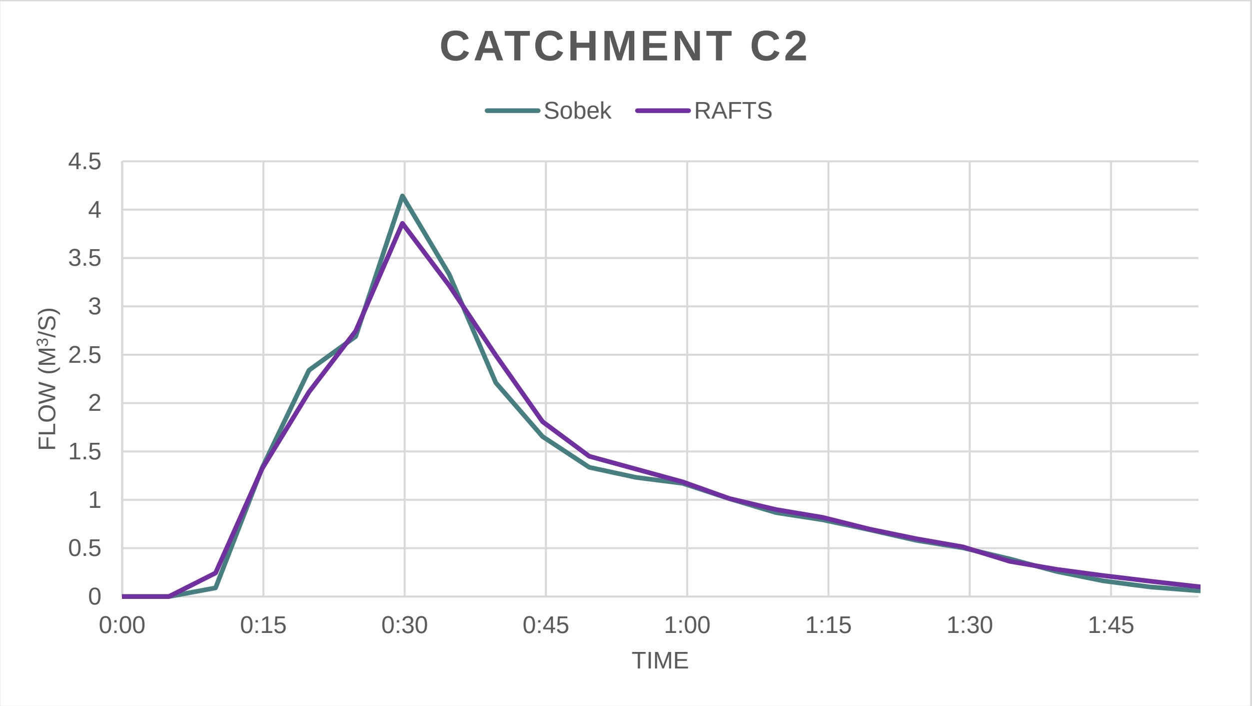

Figure 5-13 Catchment C2 Validation Results

6 Existing Flood Behaviour

6.1 Model Scenarios

Flood behaviour was modelled in SOBEK for the 20%, 10%, 2%, 1%, 0.5% AEP and PMF design flood events. Model runs were carried out for the rainfall event durations of 15 minutes, 20 minutes, 25 minutes, 30 minutes, 45 minutes, 60 minutes, 90 minutes, 2 hours and 3 hours for all AEP events.

Critical durations for peak flood levels in the study area vary depending on the location and flood characteristics for specific locations. These are listed in **Table 6-1**. Generally, shorter duration events result in higher peak water levels at the upstream and higher elevation areas whilst longer duration events are critical in main flow paths and ponding areas.

Table 6-1 Event Critical Durations

Annual Exceedance Probability	Critical Duration
20% to 0.5% AEP	90 to 120 minutes
PMF	15 to 90 minutes

6.2 Result Maps

Peak water level, depth, and velocity in the study area are determined based on the peak value for each grid cell from all durations modelled in a particular AEP event. As the direct rainfall approach is used, every 2D cell is inundated with some flood depth. A filter is applied to clarify the results and highlight primary flow paths excluding locations of minor localised runoff depths. The flood extents of figures showing design events, sensitivity and scenarios are filtered, such that:

- For PMF event - Depths less than 0.15 m are removed and ponded areas/islands of less than 200 m^2 are removed;
- For all other AEP events - Depths less than 0.15 m are removed except flows with a velocity-depth product greater than $0.3m^2/s$ are included. Ponded areas/islands of less than 100 m^2 are removed.

Maps of flood results have been prepared for each of the four modelled zones on individual figures. These are included in **Appendix B**:

- **Figures 1-4**: Flood Peak Inundation Extents (20%, 10%, 2%, 1%, 0.5% AEP and PMF)
- **Figures 5-16**: Peak Flood Water Levels (20% AEP, 1% AEP and PMF)
- **Figures 17-28**: Peak Flood Depths (20% AEP, 1% AEP and PMF)
- **Figures 29-40**: Peak Flood Velocities (20% AEP, 1% AEP and PMF)
- **Figures 41-52**: Hydraulic Categories (20% AEP, 1% AEP and PMF)
- **Figures 53-64**: Provisional Flood Hazard (20% AEP, 1% AEP and PMF)
- **Figures 65-72**: Hazard Vulnerability Classification (1% AEP and PMF)

6.3 Discussion of Results

An analysis of the 20% and 1% AEP results was undertaken and the following significant flood affected areas were identified. Note the below identified locations are not the only areas which are subject to inundation but highlight some areas which are severely impacted. Only regions significantly impacted by the 20% AEP have been highlighted as these locations are most likely to be frequently affected by flood inundation.

6.3.1 Manly

- In the 20% AEP the drainage system in this location has insufficient capacity to cater for the catchment runoff. Due to the presence of a low point in the topography at the corner of Gilbert Street and Eustace Street an area of significant ponding is formed. Depths in excess of 600 mm are recorded within the roadway in the 20% AEP event. In the 1% AEP event the extent of this flooding increases significantly, affecting properties along West Promenade and resulting in depths in excess of 1000 mm.
- Kangaroo Lane and Pittwater Road north of Raglan Street also have significant flood affectation in the 20% AEP. Similarly this is due to a local depression within the topography which results in an area of ponded floodwater. Depths in excess of 1100 mm are present along Kangaroo Lane in the 20% AEP. In the 1% AEP event, the region of ponded floodwater increases to cover the intersections of Pittwater Road and Raglan Street and Pittwater Road and Sydney Road. This results in a peak flood level of about 5.85 m AHD at this intersection which is a peak depth of 600 mm on Raglan Street.
- Central Avenue in the 20% AEP suffers from inundation of up to 550 mm. In the 1% AEP the region is further impacted, with depths in excess of 600 mm. Flooding in this region is contributed to by overland flow entering the area from Sydney Road. The flood impacts within this location are due to the drainage system present being inadequately sized to cater for the volume of runoff present in the region. Furthermore, due to downstream boundary conditions, an increase in capacity of the drainage system may not reduce flood impacts.
- Smith Street, located at the bottom of the cliffs behind Kangaroo Street, is impacted by significant ponding in the 20% AEP event (similar to flooding behaviour in Kangaroo Lane). This is due to the underground system having insufficient capacity to drain the region. In the 1% AEP event the area of affectation extends over the corner of Smith Street and Pine Street, resulting in the inundation of multiple properties.
- The corner of North Steyne and Pacific Street suffers from inundation in the 20% AEP when the underground drainage network in the region is exceeded. The water ponds up in the roadway and carpark in this area until there is sufficient capacity in the drainage network to discharge into the ocean. In the 1% AEP event the extent of this flooding increases, resulting in impacts up to the corner of Ceramic Lane and North Steyne.

6.3.2 Balgowlah and Balgowlah Heights

- A prominent flow path is present between New Street and Lower Beach Street. This flow path travels primarily through properties until it reaches North Harbour Reserve where it then discharges into Jilling Cove. This flow path is present due to the underground drainage network having insufficient capacity to cater for the 20% AEP event. This flowpath affects several properties but in the majority of cases it is through the back of properties and does not affect many buildings. In the 1% AEP event the flow path width increases resulting in more properties being affected.
- Another flow path is present which begins near the corner of Glenside and Ernest Street. This flow path travels primarily through properties, also passing through Nanbaree Reserve. The flow path then continues through properties until it discharges into Jilling Cove. This flow path is present due to the underground drainage network having insufficient capacity to cater for the 20% AEP event. This flow path affects several properties with many buildings identified as potentially impacted.

6.3.3 Clontarf

- At the corner of Monash Crescent and Holmes Avenue there is a significant area of ponding in the 20% AEP event. This is due to the drainage network in the region being under capacity as well as the properties at the corner being lower than the roadway. As a result of these issues when runoff can no longer enter the drainage system, the properties to the north of Monash Crescent become inundated. Depths up to 650 mm are present in the 20% AEP, with this increasing to 950 mm in the 1% AEP event.

6.4 Hydraulic Categories

As per The Floodplain Development Manual (NSW Government, 2005), hydraulic category mapping has been produced for the categories:

- Floodways;
- Flood Storage; and
- Flood Fringe.

Floodways are areas of the floodplain where a significant discharge of water occurs during floods that are often, but not always, aligned with naturally defined channels. They are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Flood Storages are parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. Flood Fringe is the remaining area of flood-prone land after floodway and flood storage areas have been defined.

Hydraulic categories were determined using an in-house developed program which utilises model results from velocity and depth in addition to post processing to ensure categories are contiguous. Hydraulic category mapping figures are shown in **Appendix B**.

6.5 Provisional Hazard

6.5.1 General

Flood hazard can be defined as the risk to life and limb caused by a flood. The hazard caused by a flood varies both in time and place across the floodplain. The Floodplain Development Manual (NSW Government, 2005) describes various factors to be considered in determining the degree of hazard. These factors are:

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

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

6.5.2 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters and is based strictly on hydraulic considerations.

Historically, the criteria for these relationships have been taken from the NSW Floodplain Development Manual (Appendix L; NSW Government, 2005). The Manual defines two major categories for provisional hazard – high and low. A High Hazard refers to flood conditions that pose a possible danger to personal safety, evacuation by trucks would be difficult, able-bodied adults would have difficulty wading to safety, and there is a potential for significant structural damage to buildings. A Low Hazard refers to flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks and able-bodied adults would have little difficulty wading to safety. The Transition Zone the degree of hazard is dependent on the site conditions and the nature of the proposed development. The FDM hazard relationship is shown in **Figure 6.1**. **Figures 53 to 64** in **Appendix B** show the provisional flood hazard for the 20% AEP, 1% AEP, and PMF) event.

Recently, a new method of hazard categorisation has been developed by the revised Australian Rainfall and Runoff (AR&R) guideline (2016) (Book 6: Flood Hydraulics, Section 7.2.7). The classification is still based on depth and velocity, but utilises six categories based on the stability of children, adults, the elderly and vehicles in floodwaters:

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles, children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

The AR&R hazard curves are shown in **Figure 6.2**. **Figures 65 to 72** in **Appendix B** show the hazard categorisation for the 1% AEP and PMF events based on the AR&R classification.

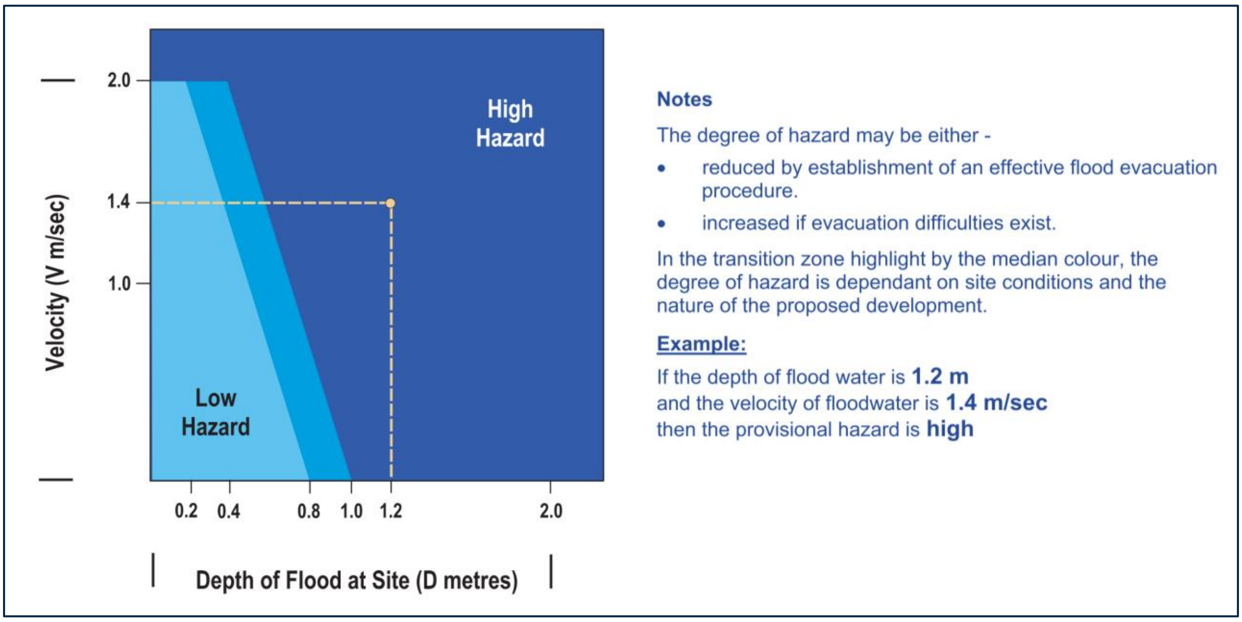

Figure 6-1 Provisional Hazard Categories from Appendix L of the Floodplain Development Manual

High provisional hazard is shown at several independent areas in the study area for the 20% AEP storm event. Streets with occurrences of high provisional hazard in the 20% AEP event include Kangaroo Lane, Jackson Street, and New Street.

In the 1% AEP design event, areas with a high hazard classification (of H3 to H6, which describe unsafe conditions for vehicles and people) occur along the main flow paths to the channels and in trapped low points on roads. Roads with this high hazard classification include: Smith Street, Manly; Kangaroo Lane, Manly; Gilbert Street, Manly; Ashburner Street, Manly; College Street, Manly; Bower Lane, Manly; Central Avenue, Manly; Raglan Street, Manly; Pittwater Road, Manly; North Steyne, Manly; Woodland Street, Balgowlah; Condamine Street, Balgowlah; New Street East, Balgowlah; Valley Road, Balgowlah Heights; Sandy Bay Road, Clontarf; Castle Circuit, Seaforth; and Bligh Crescent, Seaforth. Properties may also be inundated with high hazard classification on Smith Street, Manly; Kangaroo Lane, Manly; Gilbert Street, Manly; Ashburner Street, Manly; Woodland Street, Balgowlah; and Valley Road, Balgowlah Heights.

In a PMF design event, all flow paths are inundated to a greater severity and the hazard classification often increases by one level on the H1-H6 scale. Major roads affected by a high hazard classification include Manly Road, Seaforth (near the Spit Bridge) and Sydney Road, Manly (near the CBD).

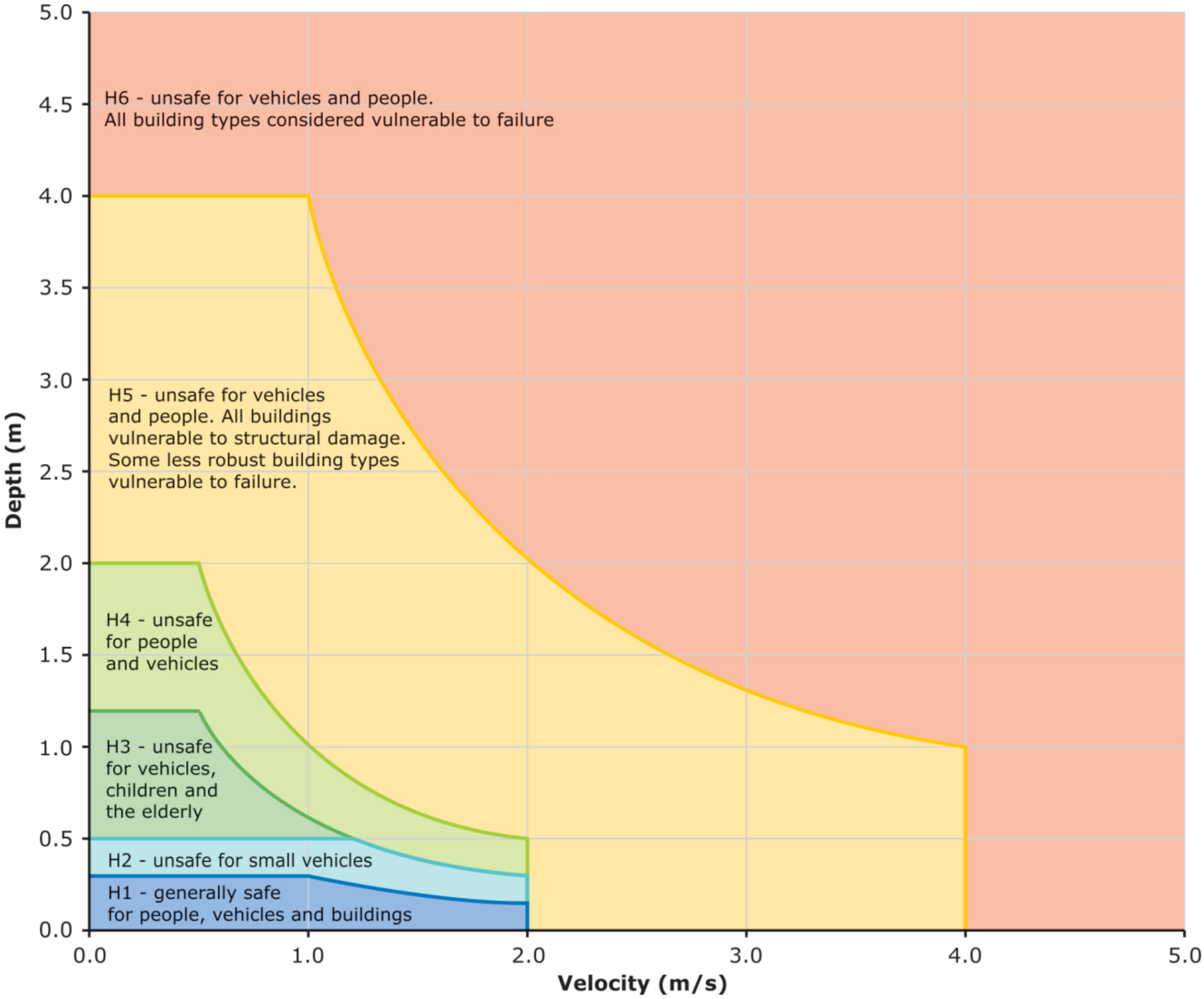

Figure 6-2 Provisional Hazard Categories from AR&R

7 Sensitivity Modelling

The sensitivity of the model was analysed to determine the range of uncertainty in the model results for changes in key parameters. The following variables were tested for the 1% AEP 120 minute duration catchment derived flood event (or PMF 90 minute duration for open-ocean elevated water level Case 3):

- Catchment roughness – increased and decreased by 20%
- Catchment rainfall – increased and decreased by 20%
- Tailwater level – increased by 0.4m and 0.9m, which also represents an analysis of sea level rise
- Open-ocean elevated water level

7.1 Catchment Roughness

Values of the hydraulic roughness parameter applied to the model in the 2D grid were increased and decreased by 20% for the sensitivity analysis. For this assessment, the roughness was not adjusted in the 1D channels, pipes and culvert elements.

Differences of the peak water level were compared to the base model with the roughness values increased by 20% and decreased by 20%. **Figures 73 to 78** in **Appendix C** show the differences throughout the study area.

The impact of 2D roughness values on the results of the modelling are generally relatively low with a negligible average and median level difference. Larger differences occur at isolated locations. Increases and decreases are observed in both scenarios, due to the either additional or less resistance of the roughness changes.

Event peak water levels changes generally within the range of -0.1m to +0.1m are noted:

- For channels draining to Jilling Cove (from Woodland Street South, Balgowlah and Ernest Street, Balgowlah Heights)
- Near Holmes Avenue, Allenby Street, and Monash Crescent, Seaforth
- In streets near Manly Beach generally bounded by Ashburner Street, Gilbert Street, and Ceramic Lane as shown on **Figures 75 and 78**.

7.2 Catchment Rainfall

The average rainfall intensity for the 1% AEP, 120 minute duration storm was increased and decreased by 20% for the sensitivity analysis.

Differences of the peak water level were compared to the base model for the rainfall increases and decrease. **Figures 79 to 84** in **Appendix C** show the differences throughout the study area.

Impacts due to variations in rainfall intensity are widespread across the study area, although there are certain areas that are more significantly affected than others.

The average change is generally low within the flood extent. Larger differences occur at isolated locations, which generally coincide with larger flow paths and storage areas.

7.3 Tailwater Level

Tailwater levels were increased by 0.4m and 0.9m. **Figures 85 to 87** in **Appendix C** show the area of affectation as a result of these changes. This analysis also represents an analysis of sea level rise scenarios, being +0.4m representing the year 2050 and +0.9m representing the year 2100 (DECCW, 2010). Isolated locations in foreshore areas show increase of flood extent as a result of the change in tailwater level. There are very limited areas where the tailwater level increase influences the flood depths that are not directly linked to the foreshore.

7.4 Open-Ocean Elevated Water Level

Elevated ocean levels may occur during storm events at ocean fronting areas (eg Manly Beach and Shelley Beach) due to the effects of wave runup and wind setup in an oceanic storm event. Three sensitivity cases are modelled for elevated ocean levels based on OEH (2015) which lists combinations of catchment flooding and oceanic inundation scenarios as listed in **Table 7-1**. The peak of the elevated ocean condition may not specifically coincide with the peak of the catchment rainfall thus this condition has been run as a sensitivity.

Table 7-1 Open-Ocean Elevated Water Level Sensitivity Scenarios

Case	Catchment Rainfall	Ocean Boundary Tailwater (m AHD)	Harbour Boundary Tailwater (m AHD)	Figure
1	1% AEP 120 minute duration	2.30	1.40	88
2	2% AEP 120 minute duration (noting 5% AEP was not a modelled design event)	2.60	1.45	89
3	PMF 90 minute duration	2.60	1.45	90

Case 1 (1% AEP 120 minute duration rainfall with 5% AEP elevated tailwater levels per Table 7-1) was compared to the 1% AEP peak water level results with a tailwater level of 1.40m AHD. The sensitivity assessment is focussed on identifying whether the elevated tailwater level results in increased peak water levels on properties. Peak water level increases of up to 0.01m are estimated in scattered locations across Manly as shown on **Figure 88**. An increase of up to 0.03m is estimated in Smith Street and Pine Street for the elevated tailwater condition due to reduced conveyance in the drainage pipe network. Properties in this area are estimated to have an inundation depth of 0.2m to 0.7m for the design tailwater boundary condition (discussed in **Section 4.5**).

Case 2 (2% AEP 120 minute duration rainfall with 1% AEP elevated tailwater levels per Table 7-1) was compared to the 1% AEP peak water level results with a tailwater level of 1.40m AHD. In Case 2, no increase is estimated to peak flood levels compared the design tailwater boundary condition. A reduction in the peak flood level for the elevated ocean level model is shown in many areas where shorter duration catchment rainfall durations dominate.

Case 3 (PMF 90 minute duration rainfall with 1% AEP elevated tailwater levels per Table 7-1) was compared to the 1% AEP peak water level results (peak of all durations) with a tailwater level of 1.45m AHD. A reduction in the peak flood level for the elevated ocean level model is shown in many areas where shorter duration catchment rainfall durations dominate. Peak flood levels are estimated to increase by up to 0.01m at Collingwood Street/Pacific Street, Smith Street / Pine Street, Carlton Street, The Corso / South Steyne, in Manly.

In conclusion, the ocean water level sensitivity analysis results indicate that the adopted design tailwater boundary conditions are suitable for the purposes of this study.

8 Scenario Modelling

A series of scenarios were modelled to determine the catchment flood behaviour under these possible conditions. The following variables were tested:

- Conduit blockage – 50% blocked (for the 1% AEP event) and 100% blocked (for the 20% AEP event)
- Climate change – catchment rainfall increased by 10%, 20% and 30% for the 1% AEP 120 minute catchment derived flood event without sea level rise (increased tailwater)
- Climate change – increased rainfall by 30% combined with increased tailwater of 0.9m for the 1% AEP 120 minute catchment derived flood event

Sea Level Rise on catchment derived flood events is represented by **Figures 85 to 87** in **Appendix C**, which also show the sensitivity analysis of tailwater level.

8.1 Conduit Blockage

Stormwater pits can potentially block through a number of factors, including the build-up of leaf litter, parked cars and garbage bins. Blockages to culverts and bridges within the study area can occur by the accumulation of debris washed down from upstream. This debris, from observations in other similar catchments, can include vegetation and trees, cars and garbage bins.

Blockage to stormwater drainage conduits was modelled for a 50% blockage in the 1% AEP event and 100% blockage in the 20% AEP event. This effectively removes the capacity of all pipes within the system. A notable increase in flood level in the vicinity of North Steyne and Denison Street is observed with flood levels increasing 0.35m and 0.5m for the 50% Blockage and 100% Blockage events respectively. Minor increases in flood depth are observed throughout the remainder of the study area and can be viewed in **Figures 91 to 96** in **Appendix C**.

8.2 Climate Change – Rainfall

The average rainfall intensity for the 1% AEP 120 minute duration storm was increased by 10%, 20% and 30% for the analysis.

Differences of the peak water level were compared to the base model for the rainfall increases. **Figures 97 to 99** in **Appendix C** show the differences throughout the study area. Impacts due to variations in rainfall intensity are widespread across the study area, although there are certain areas that are more significantly affected than others. The average change is generally low within the flood extent. Larger differences occur at isolated locations, which generally coincide with larger flow paths and storage areas.

8.3 Climate Change – Rainfall and Sea Level Rise

To test the combination of sea level rise and increased rainfall intensity, tailwater levels were increased by 0.9m and the average rainfall intensity was increased by 30% as this is seen as the worst-case scenario. **Figures 100 to 103** in **Appendix C** show the differences throughout the study area. Within areas that are not directly linked to the foreshore, increases in depths are generally less than 0.1 metres, with a few isolated locations of depth increases of up to 0.2 metres.

9 Flood Planning

Following the prediction of flood behaviour using modelling, the results were used to generate flood planning information. Information used for flood planning purposes includes the following:

- 1% AEP flood levels plus freeboard defines the Flood Planning Levels.
- The Flood Planning Levels are used to define the Flood Planning Area.
- The PMF.

The Flood Planning Area and the PMF extent are shown on **Figures 104 to 107** in **Appendix C**. The Figures also show shallow flows identified as local stormwater, which have depths less than 150 mm and a Velocity Depth product of between 0.025 m^2/s and 0.3 m^2/s during a 1% AEP storm. The local stormwater flow areas do not define the Flood Planning Area, but are included to show the flow paths of stormwater during a 1% AEP flood event.

10 Conclusion

Flood modelling has been undertaken for urban catchments that comprise parts of the suburbs of Seaforth, Balgowlah, Clontarf, Balgowlah Heights, Fairlight, and Manly.

A direct rainfall approach (rainfall-on-grid) has been used to model flood behaviour using SOBEK modelling software. Three significant rainfall events were used to validate the model against available historical data.

Validation of the hydrologic component of the flood model was undertaken using XP-RAFTS.

The validated flood model was used to asses a range of flood events, namely:

- 20% AEP;
- 10% AEP;
- 2% AEP;
- 1% AEP;
- 0.5% AEP;
- The PMF.

Each event was run for a number of durations ranging from the 15 minute event up to the 3 hour event in order to determine the critical duration for the study area. Flood peak inundation extents have been determined for each AEP event whilst the peak flood water level, peak flood depths and velocities, hydraulic categories and provisional flood hazard has been determined for the 20% AEP, 1% AEP and the PMF.

11 References

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12 Qualifications

This report has been prepared by Cardno for Northern Beaches Council and as such should not be used by a third party without proper reference.

The investigation and modelling procedures adopted for this study follow industry standards and considerable care has been applied to the preparation of the results. However, model set-up and validation depends on the quality of data available. The flow regime and the flow control structures are complicated and can only be represented by schematised model layouts.

Hence there will be a level of uncertainty in the results and this should be borne in mind in their application.

The report relies on the accuracy of the survey data and pit and pipe data at the time of survey.

Study results should not be used for purposes other than those for which they were prepared.

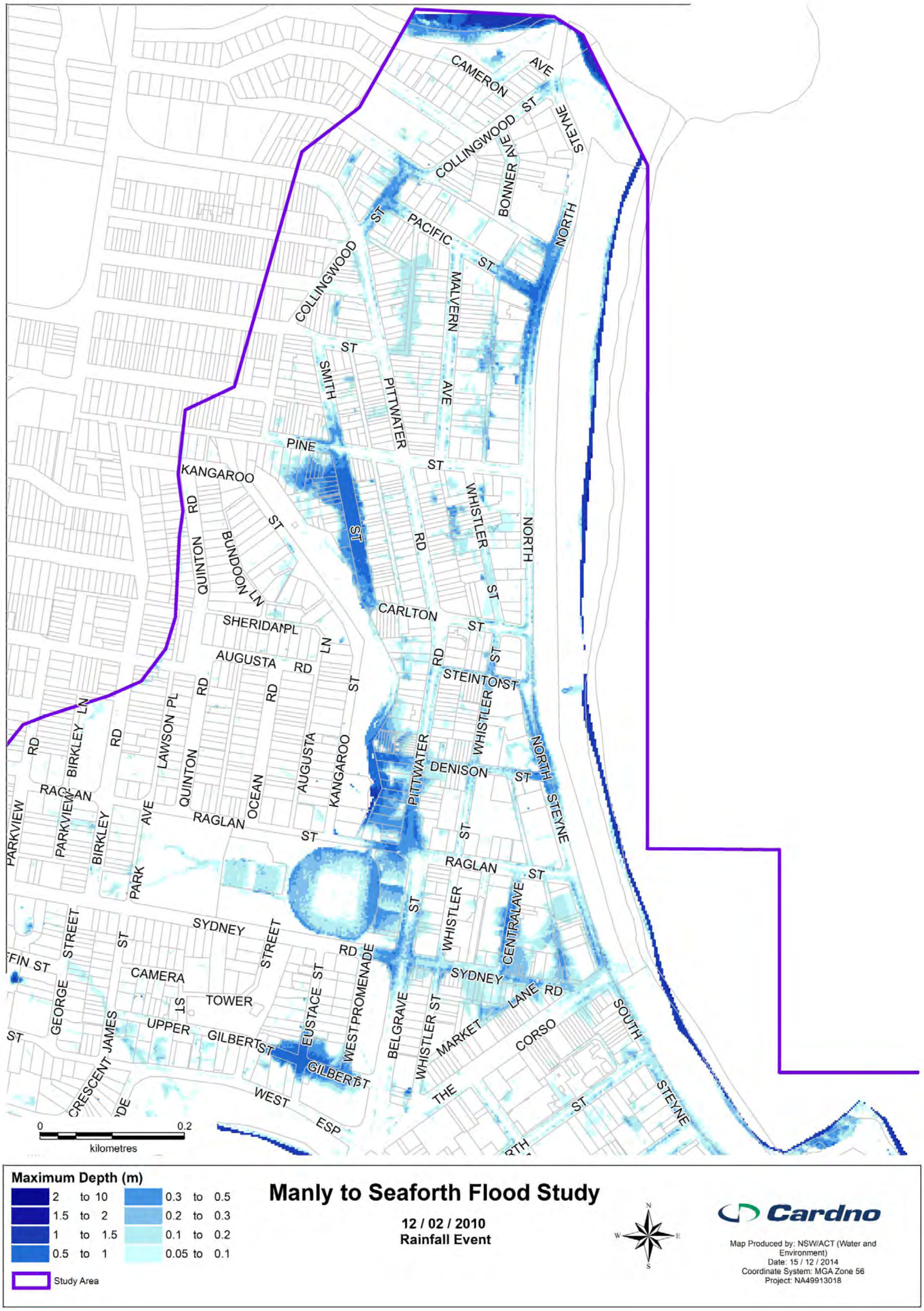
Flood Study Report

APPENDIX

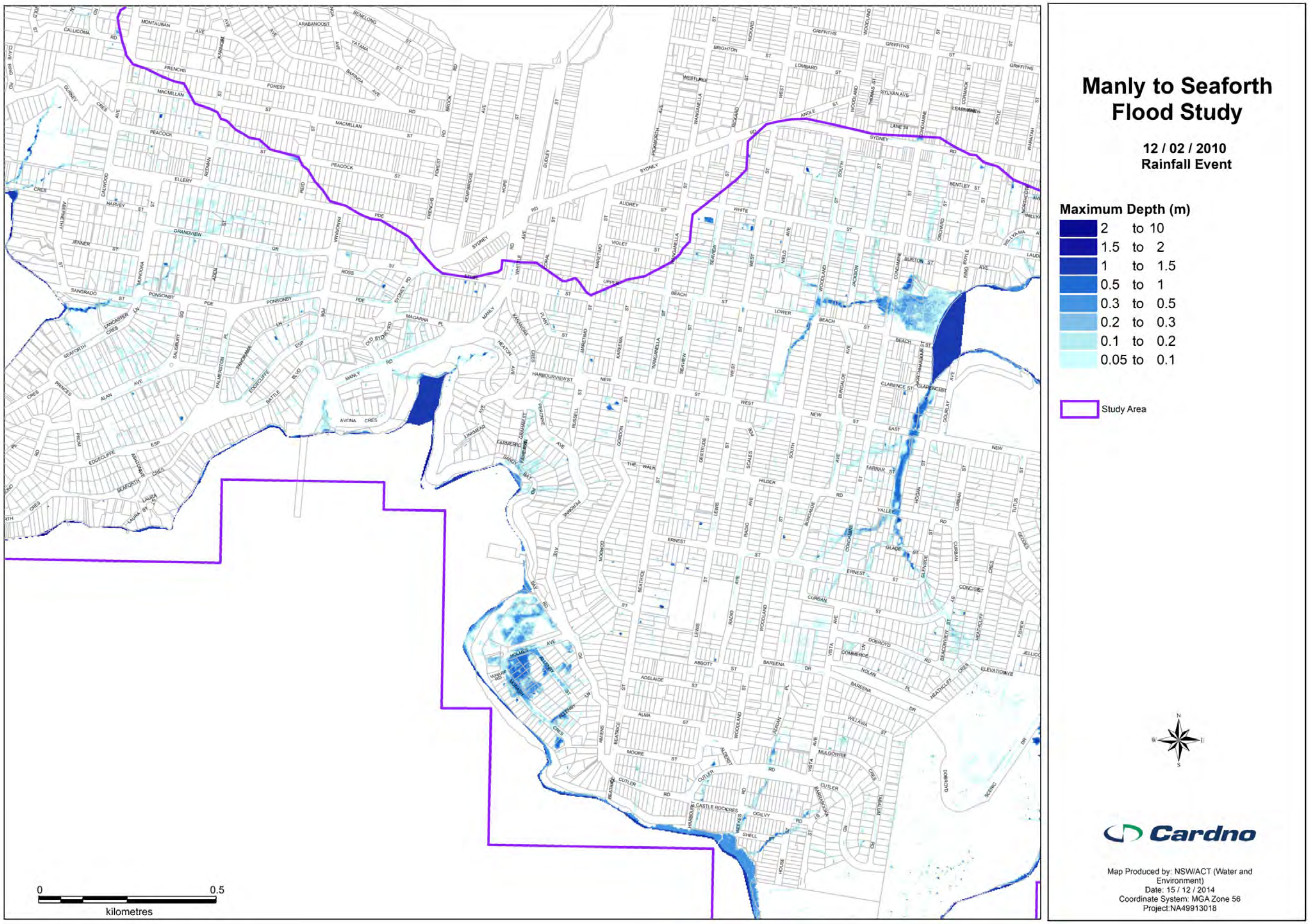
A

VALIDATION FIGURES

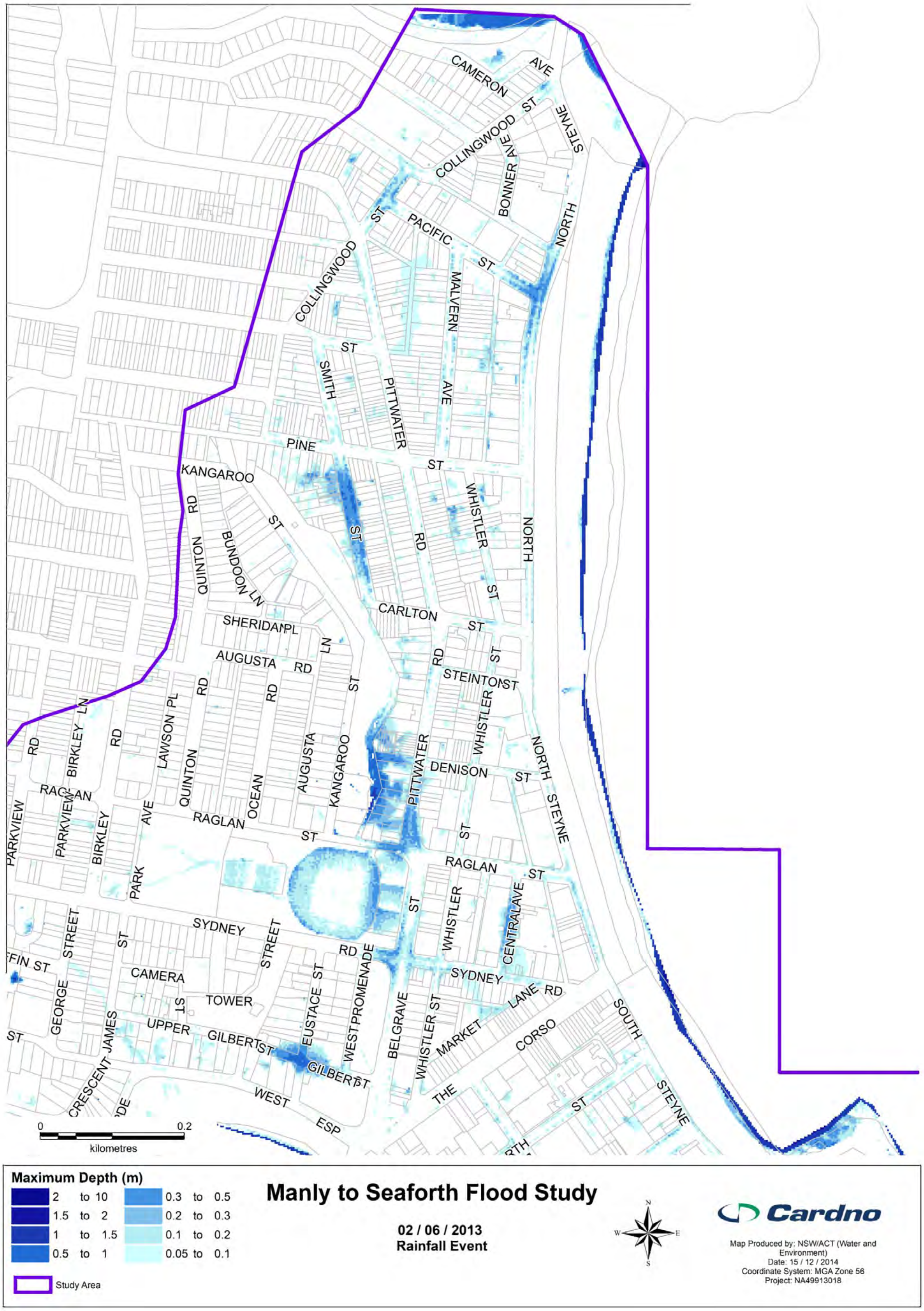
Cardno
Shaping the Future



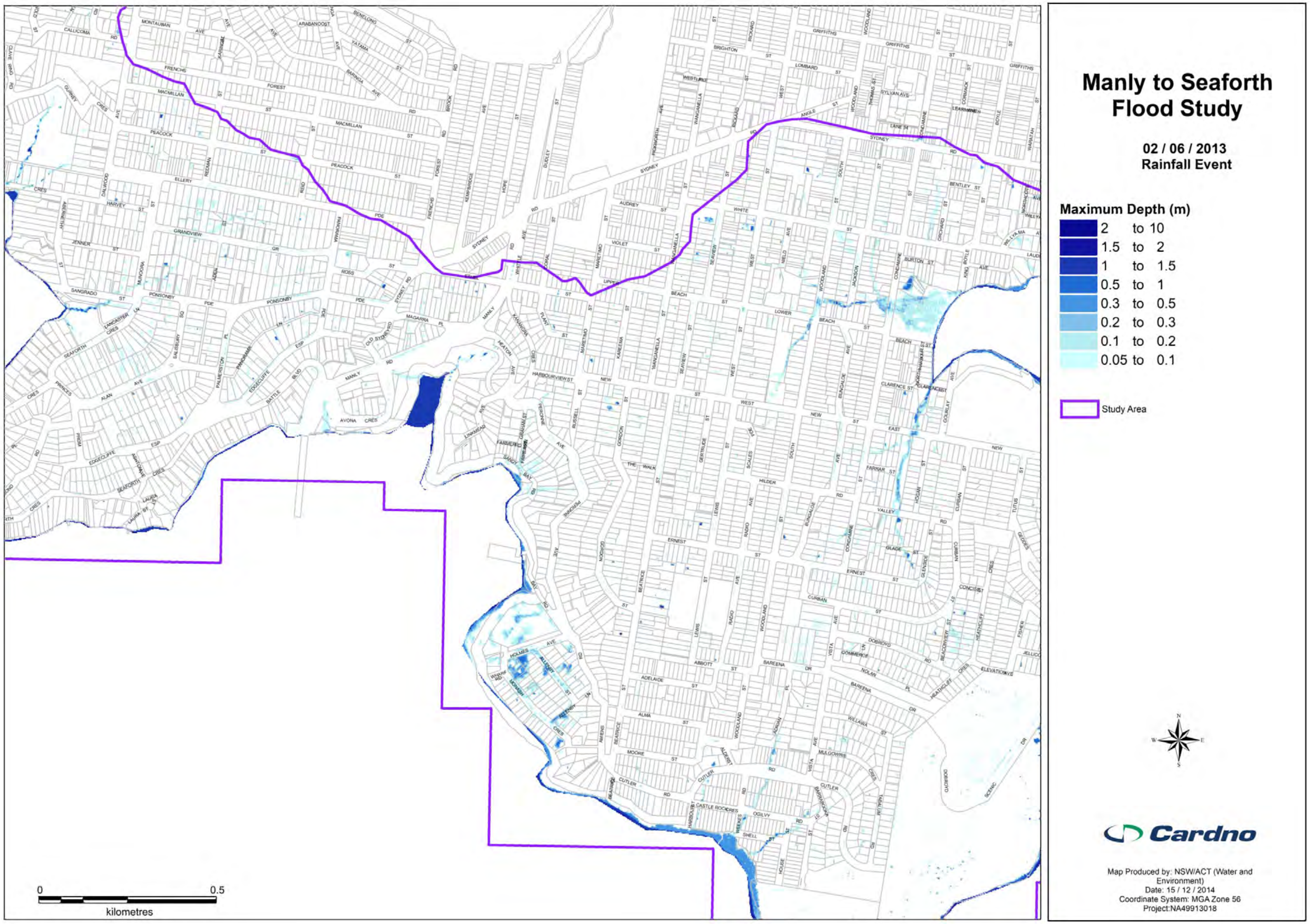
Validation Event Hydraulic Model Results 12/02/2010, East Model Area



Validation Event Hydraulic Model Results 12/02/2010, West Model Area



Validation Event Hydraulic Model Results 2/06/2013, East Model Area



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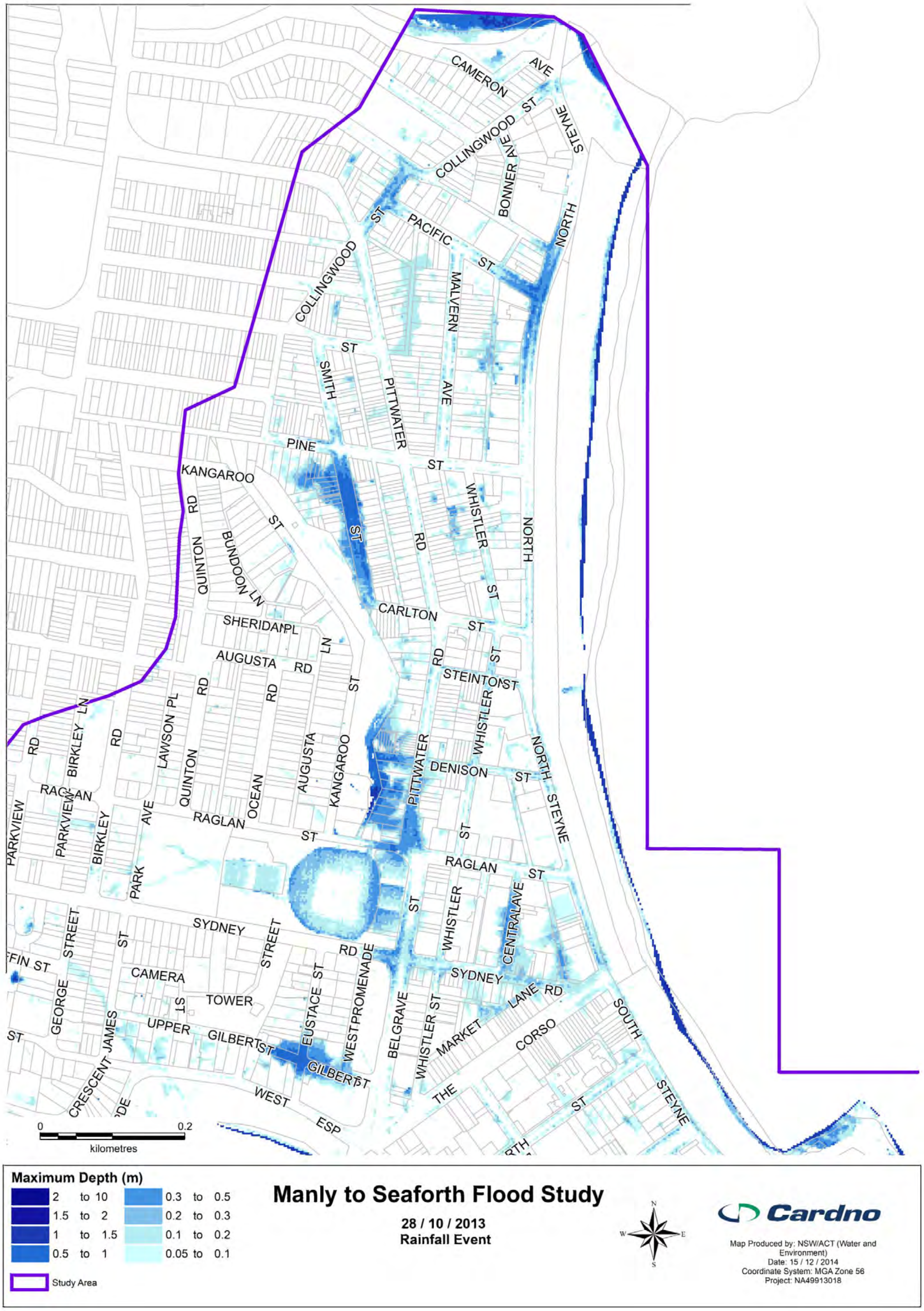
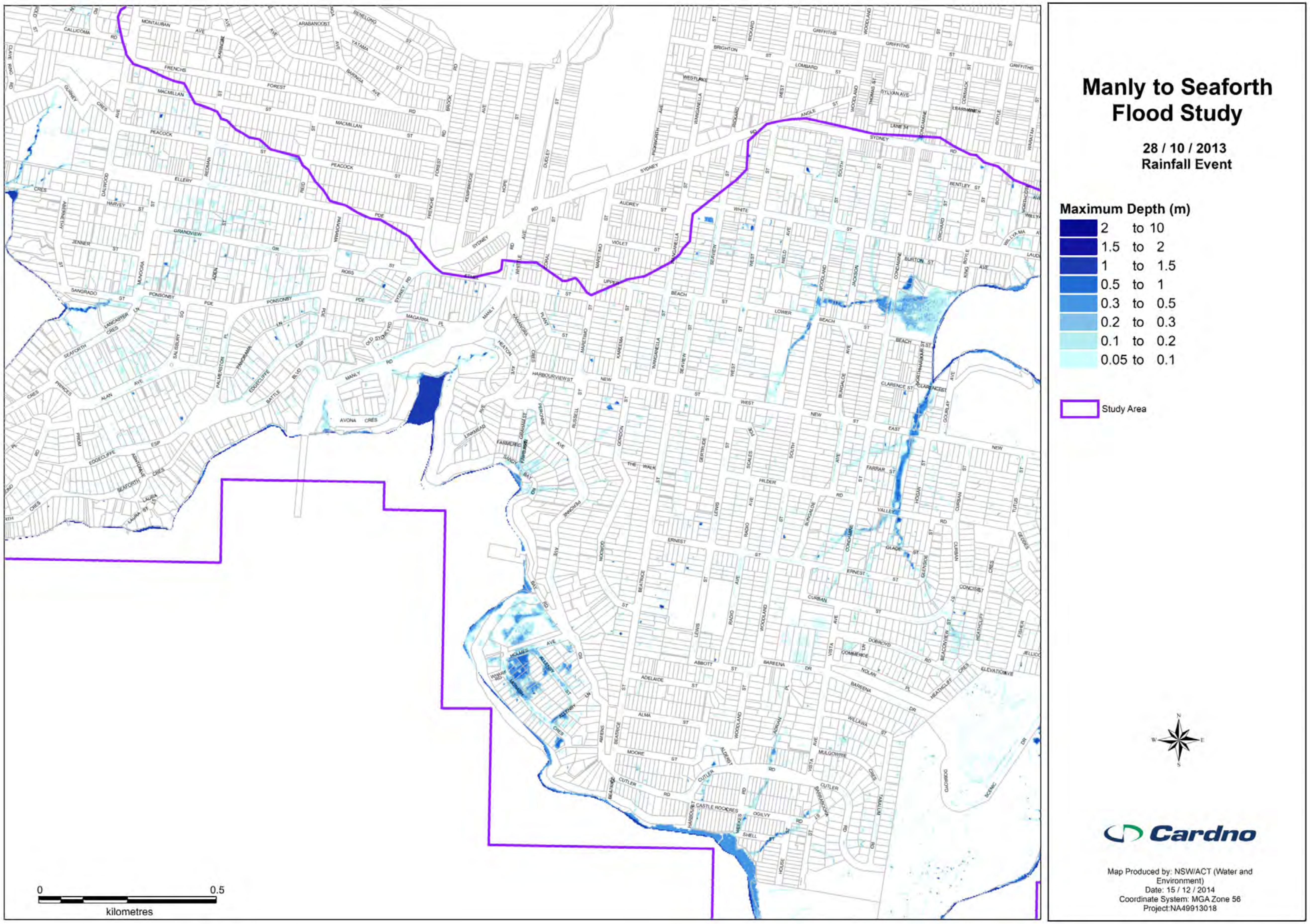


Validation Event Hydraulic Model Results 28/10/2013, East Model Area



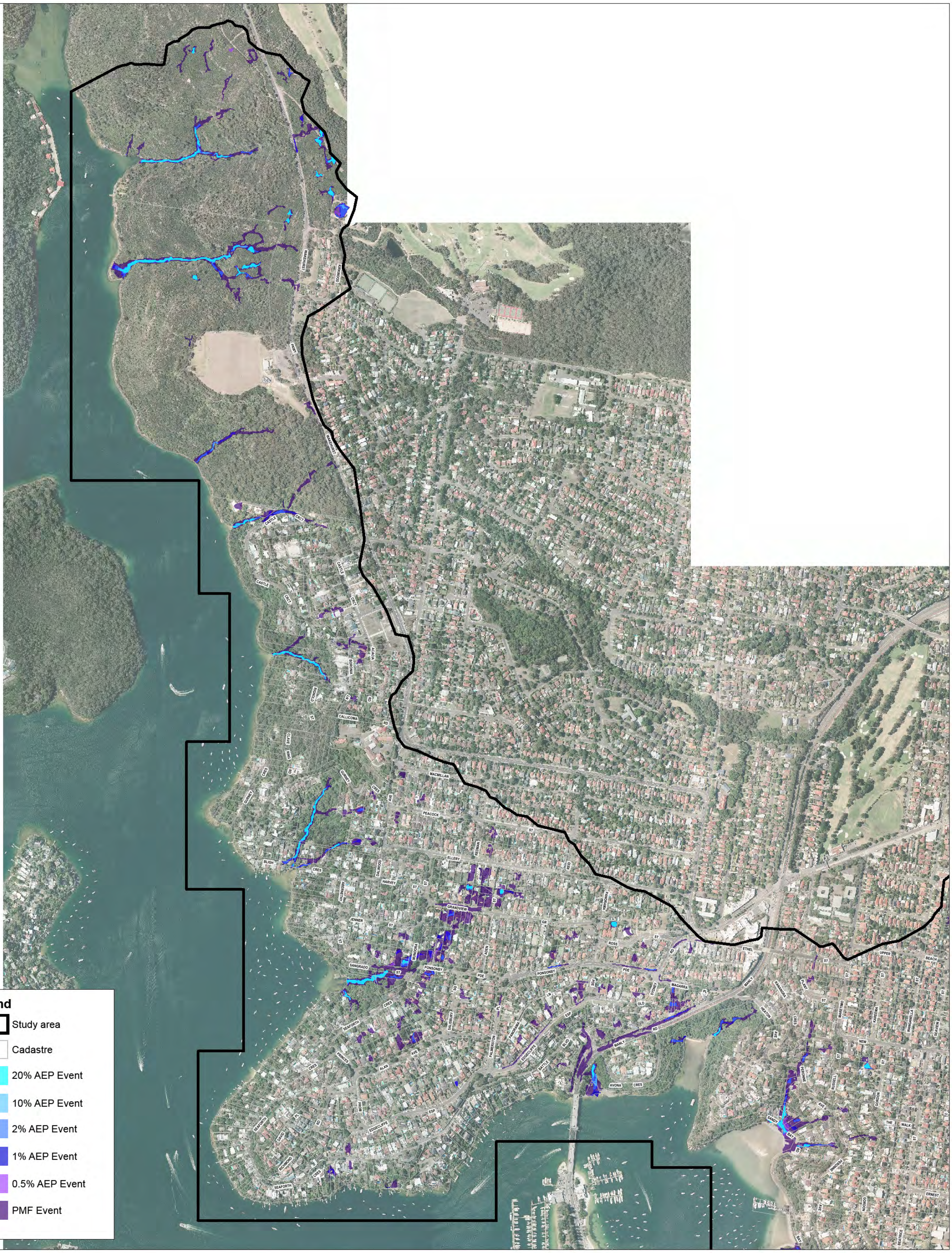
Validation Event Hydraulic Model Results 28/10/2013, West Model Area

APPENDIX

B

DESIGN EVENT FIGURES

Cardno
Shaping the Future



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0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
Peak Flood Inundation Extent
Map 1/4

Figure 1

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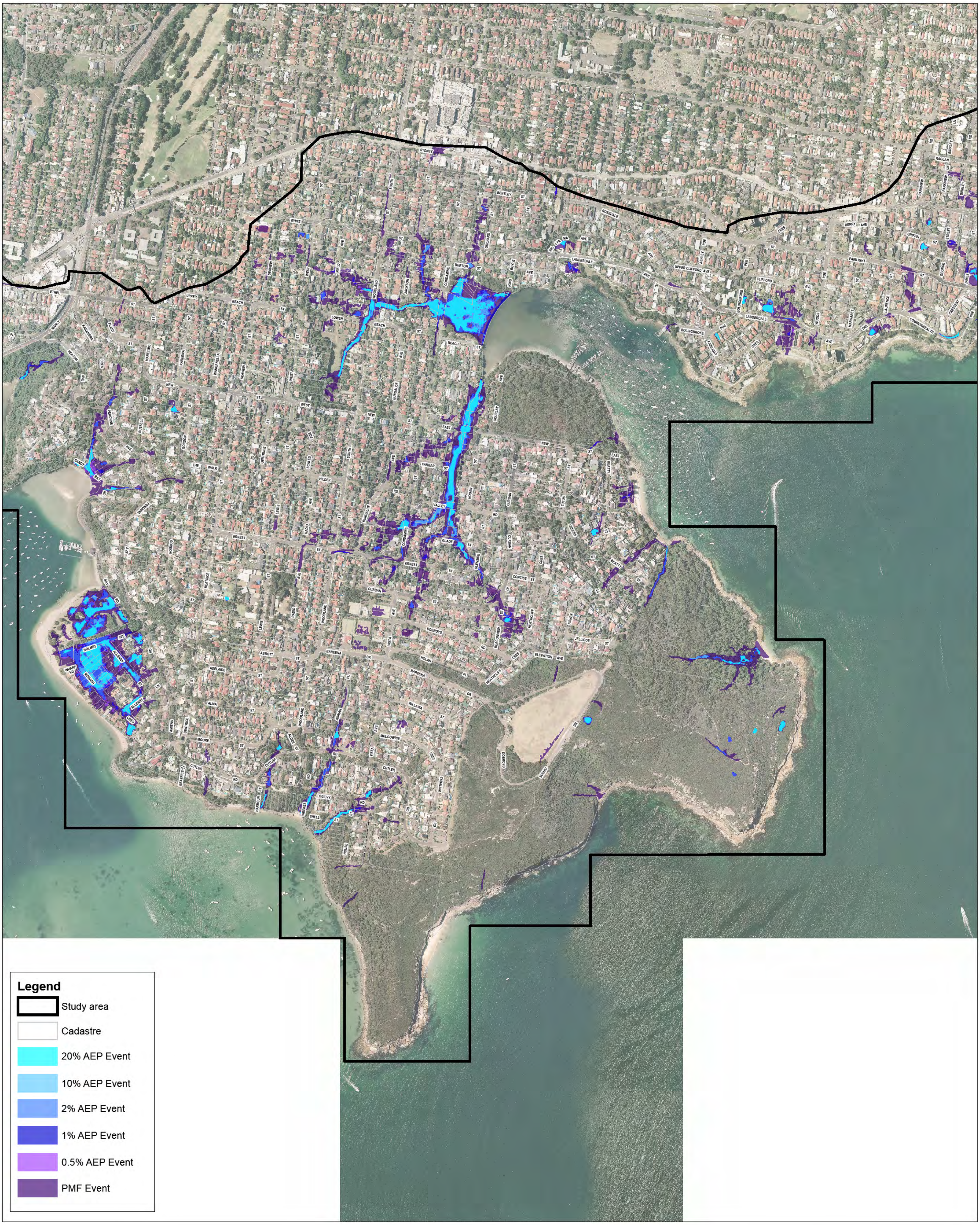

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Kilometers

Manly to Seaforth Flood Study
Peak Flood Inundation Extent
Map 2/4

Figure 2

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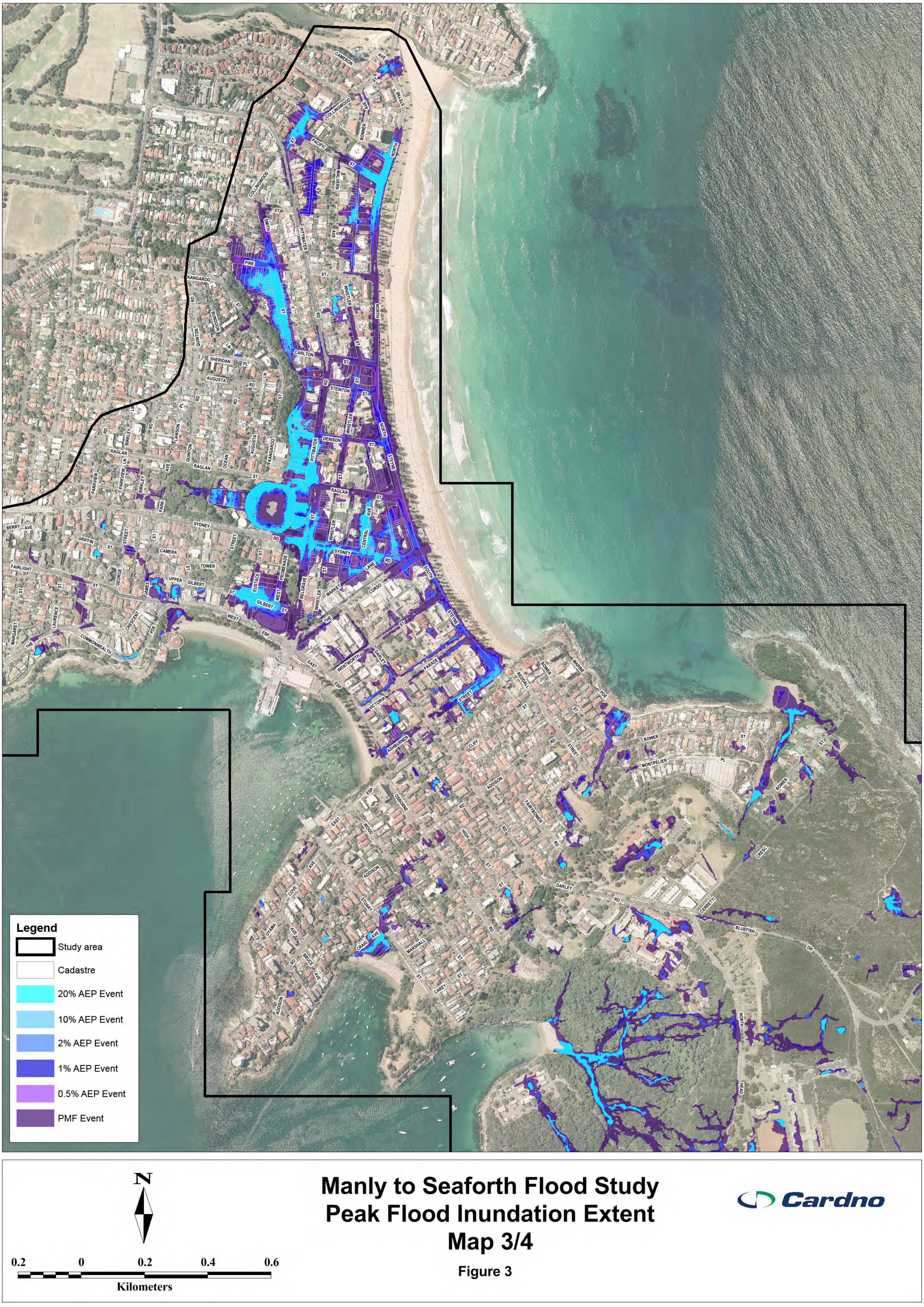
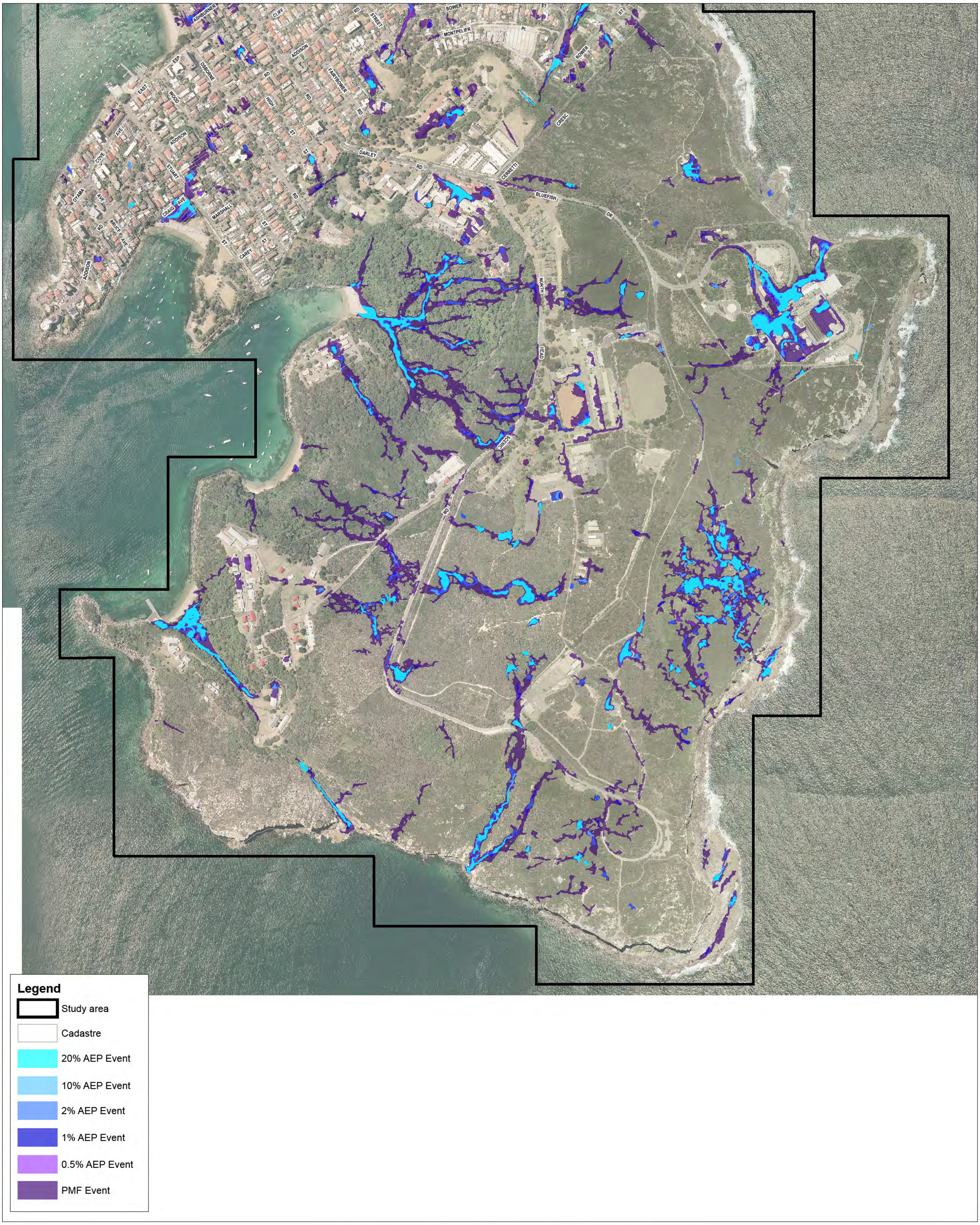


Manly to Seaforth Flood Study
Peak Flood Inundation Extent
Map 3/4

Figure 3

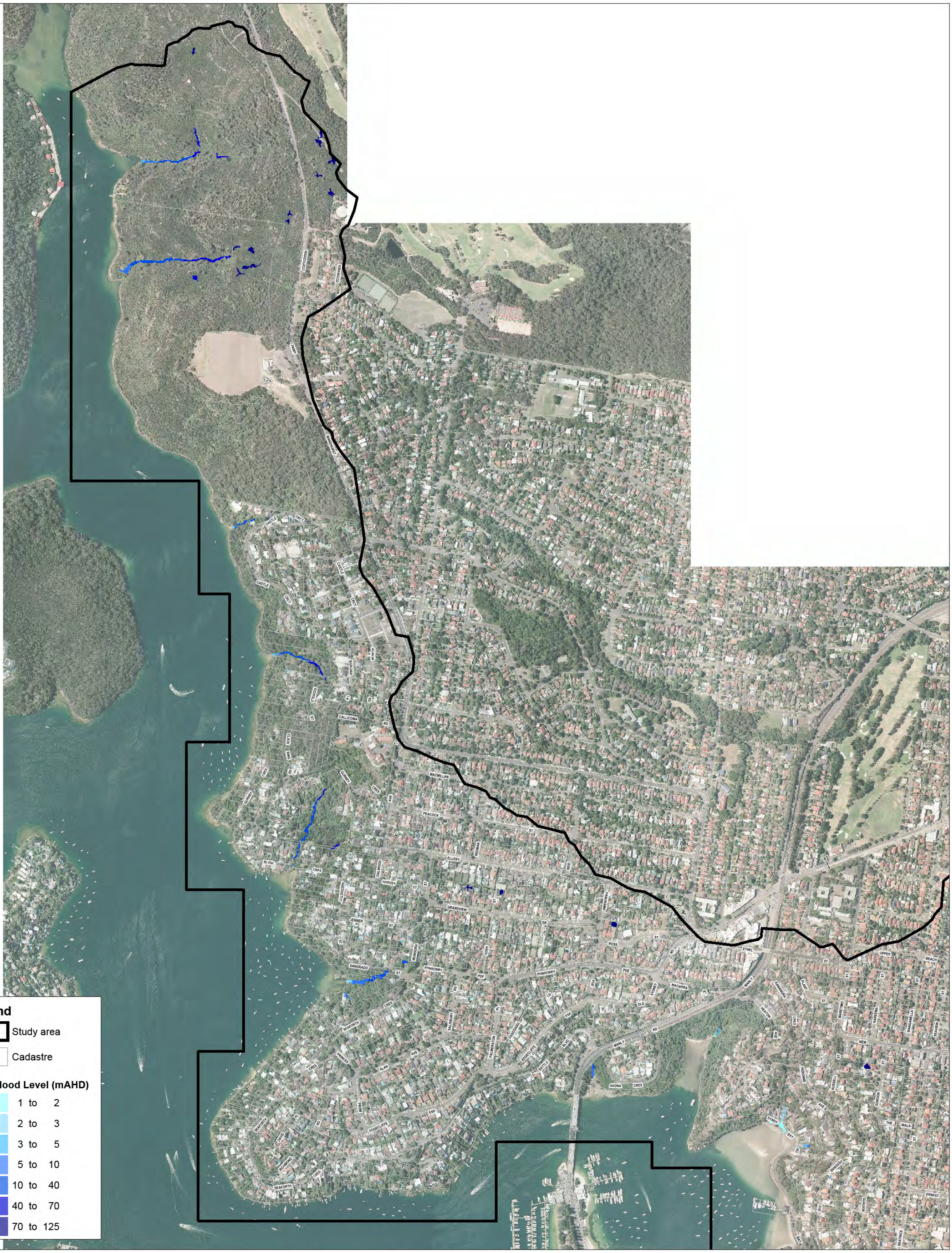
Cardno



Manly to Seaforth Flood Study
Peak Flood Inundation Extent
Map 4/4

Figure 4

Cardno



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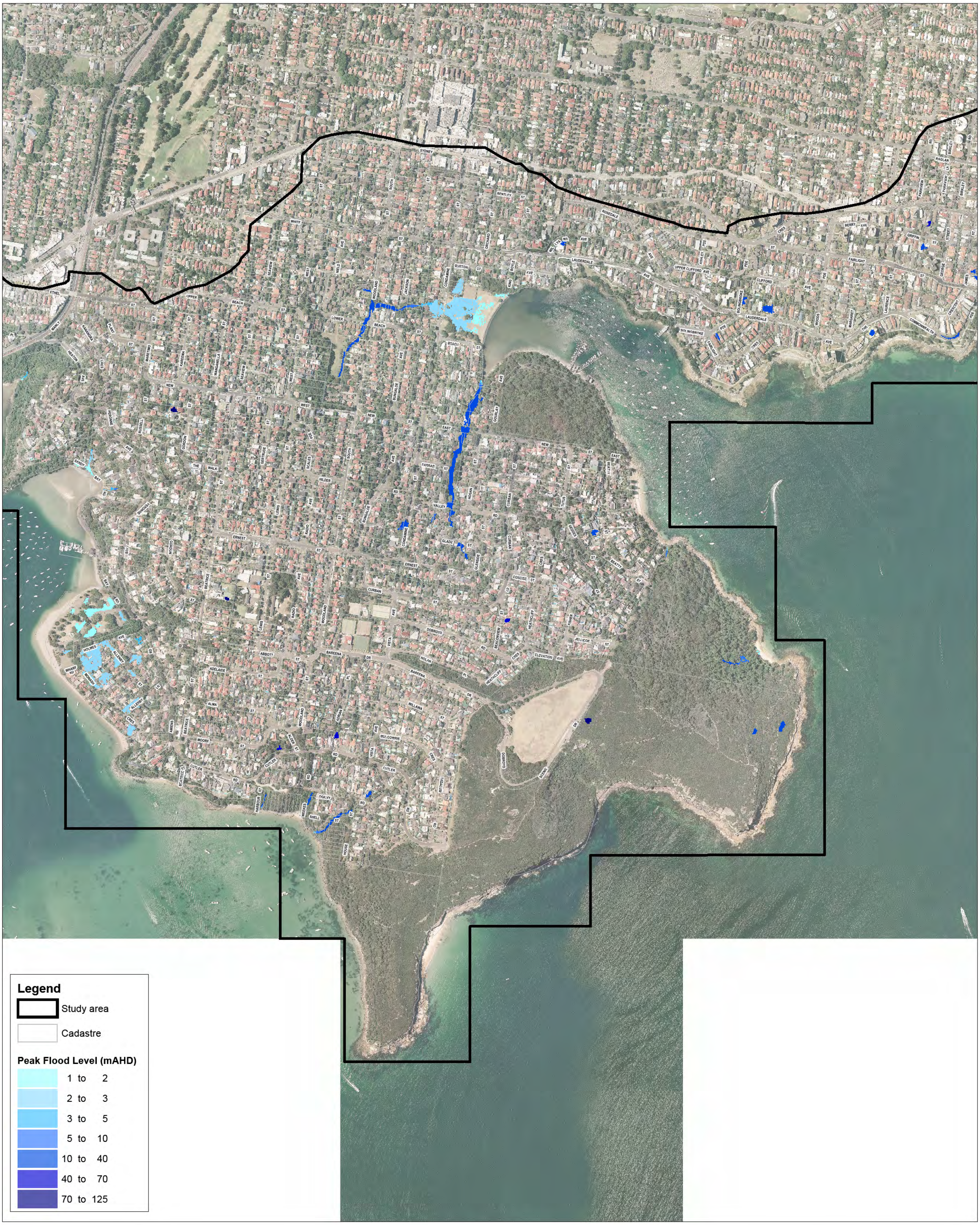
Kilometers

Manly to Seaforth Flood Study
20% Peak Flood Water Level
Map 1/4

Figure 5

Cardno



N

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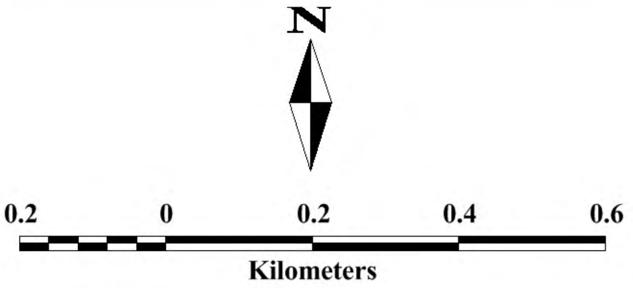
Kilometers

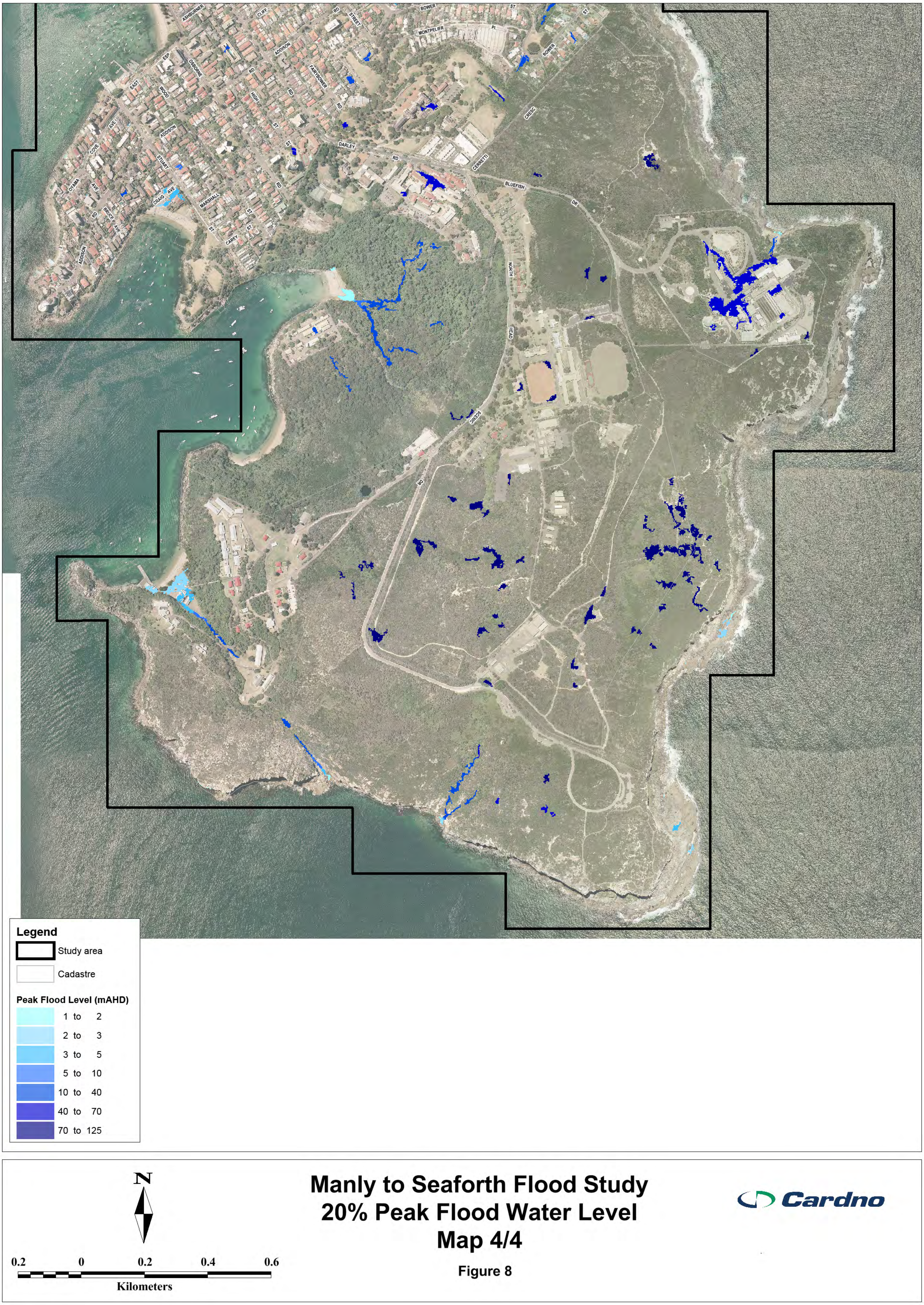
Manly to Seaforth Flood Study
20% Peak Flood Water Level
Map 2/4

Figure 6



Manly to Seaforth Flood Study
20% Peak Flood Water Level
Map 3/4

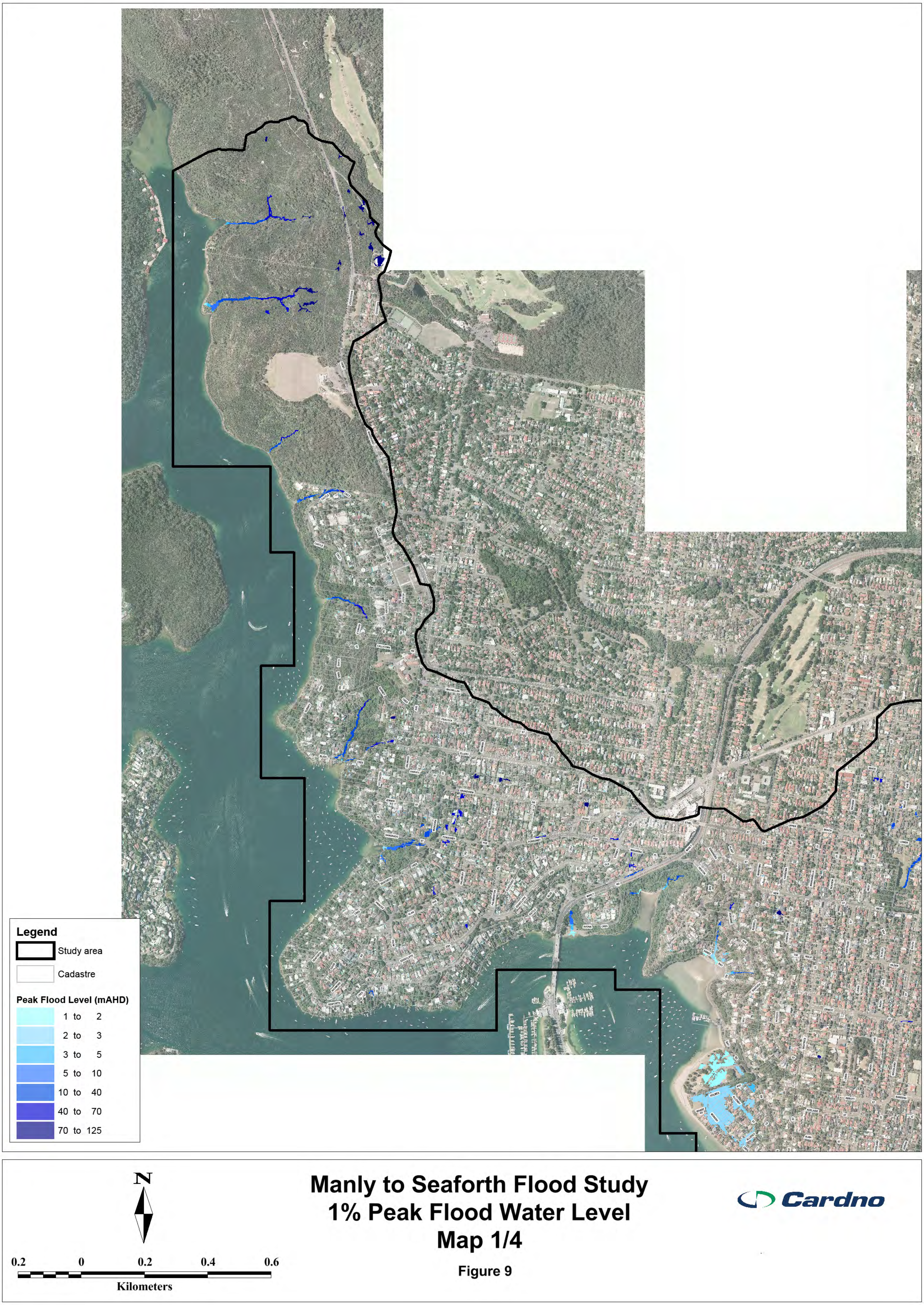
Figure 7



Manly to Seaforth Flood Study
20% Peak Flood Water Level
Map 4/4

Figure 8

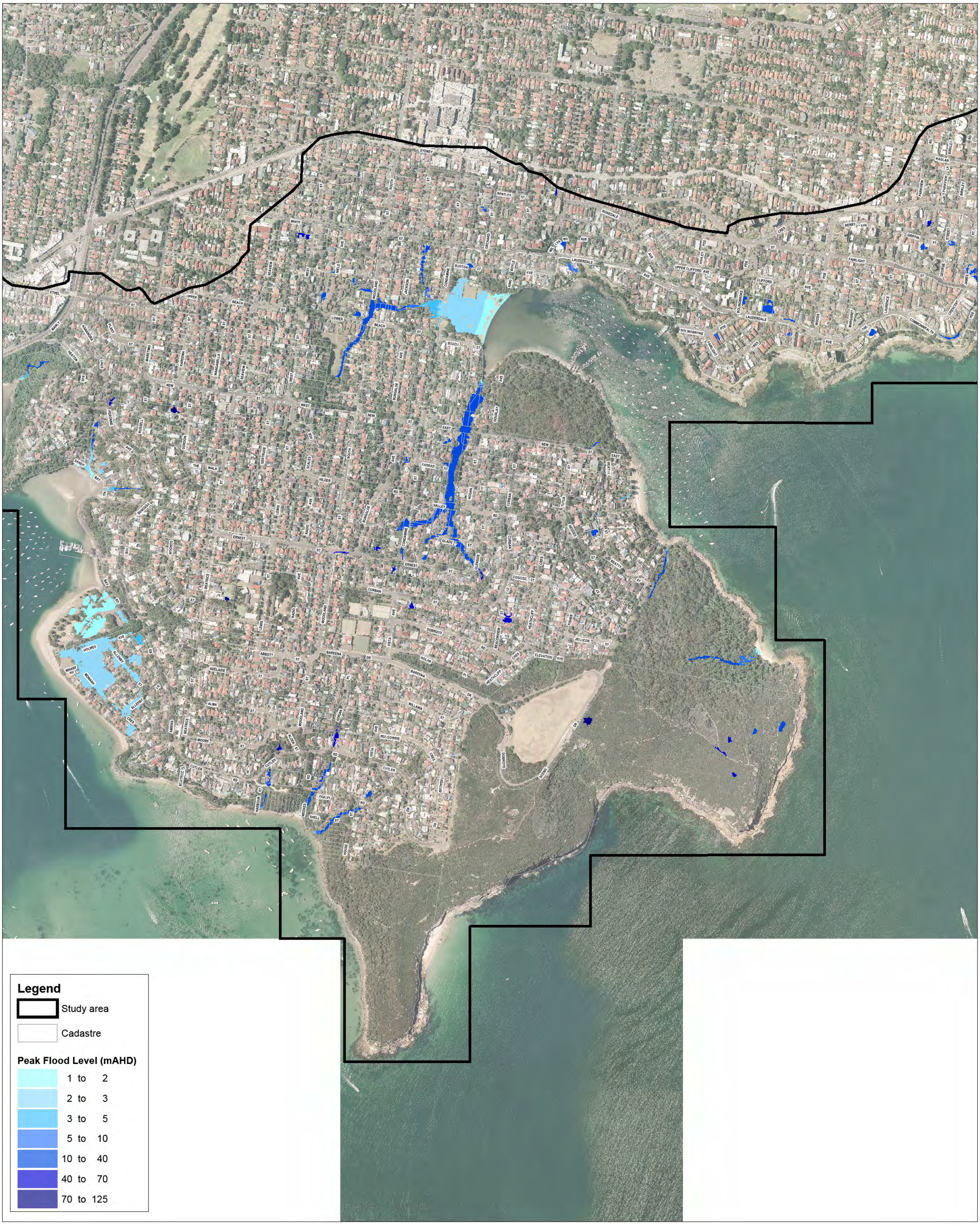
Cardno



Manly to Seaforth Flood Study
1% Peak Flood Water Level
Map 1/4

Figure 9

Cardno



N

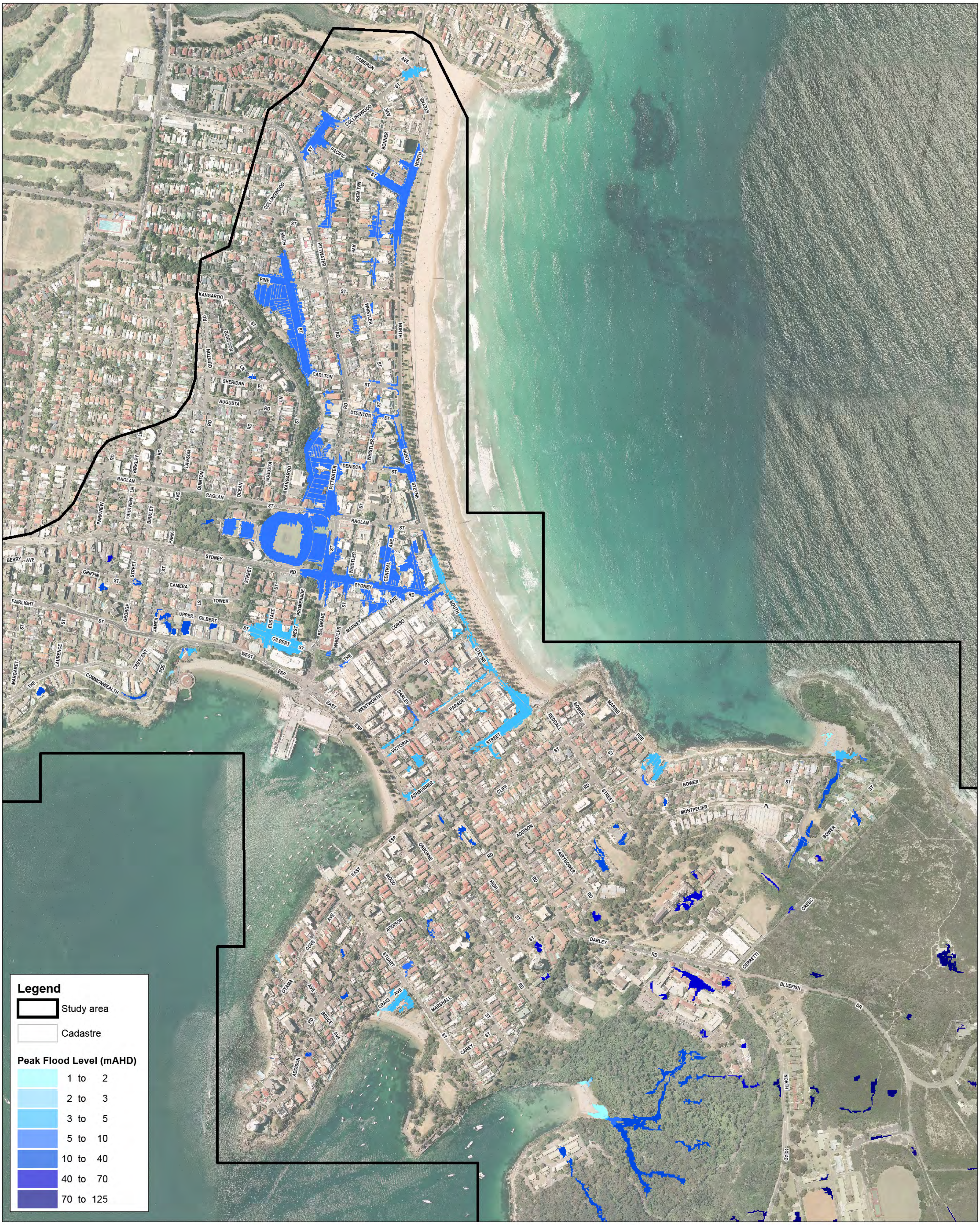
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
1% Peak Flood Water Level
Map 2/4

Figure 10

Cardno



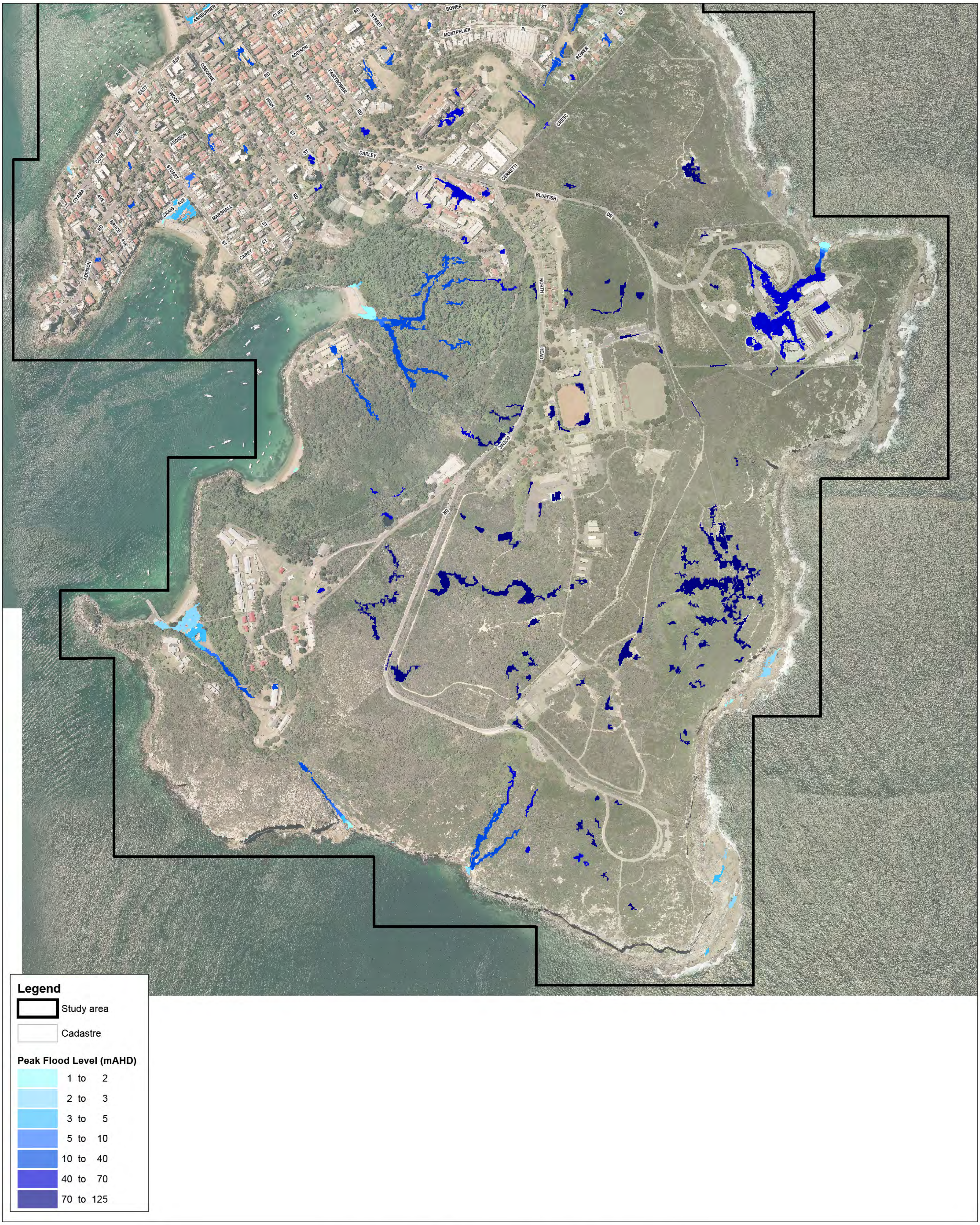
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
1% Peak Flood Water Level
Map 3/4

Figure 11

Cardno



N

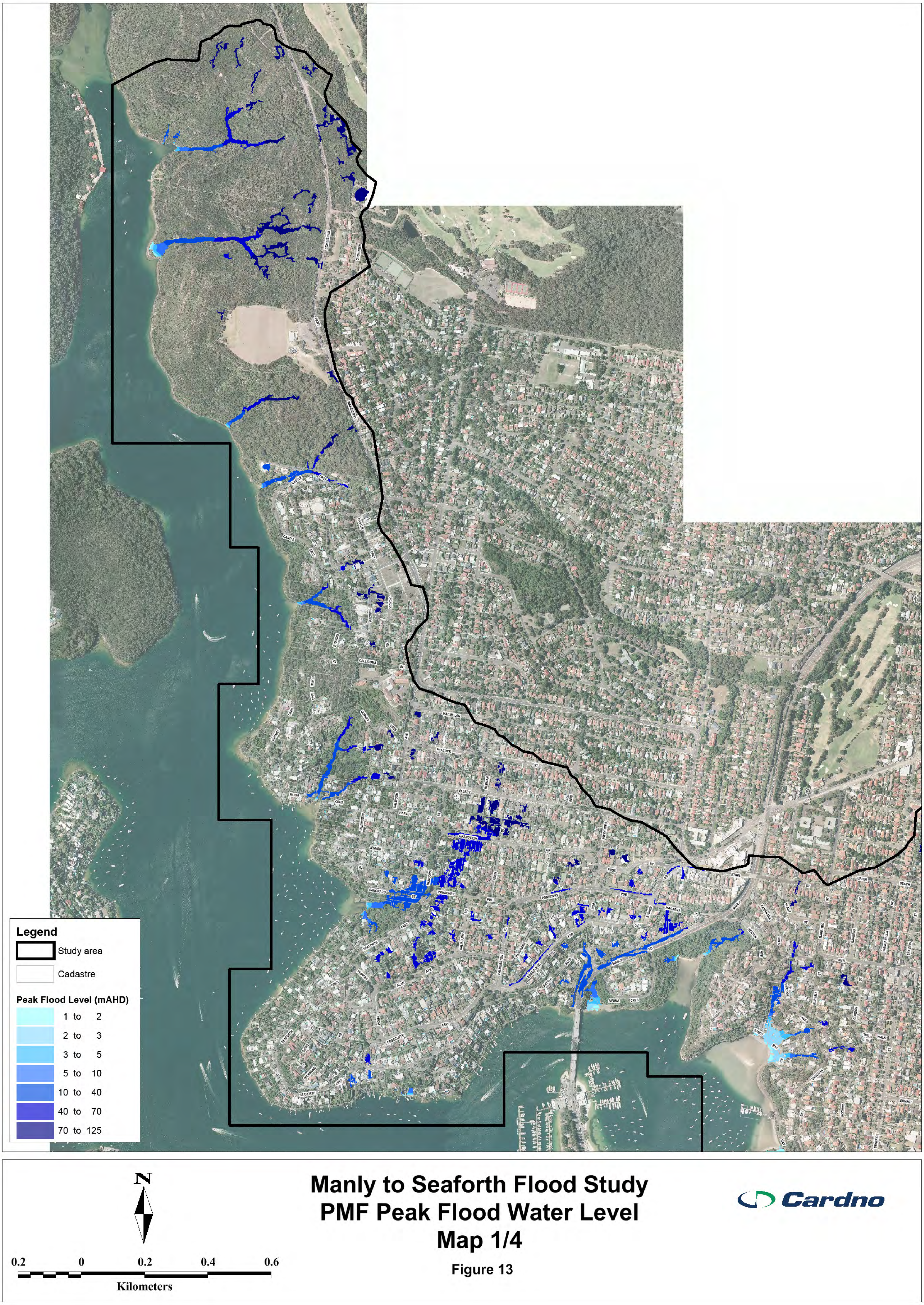
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
1% Peak Flood Water Level
Map 4/4

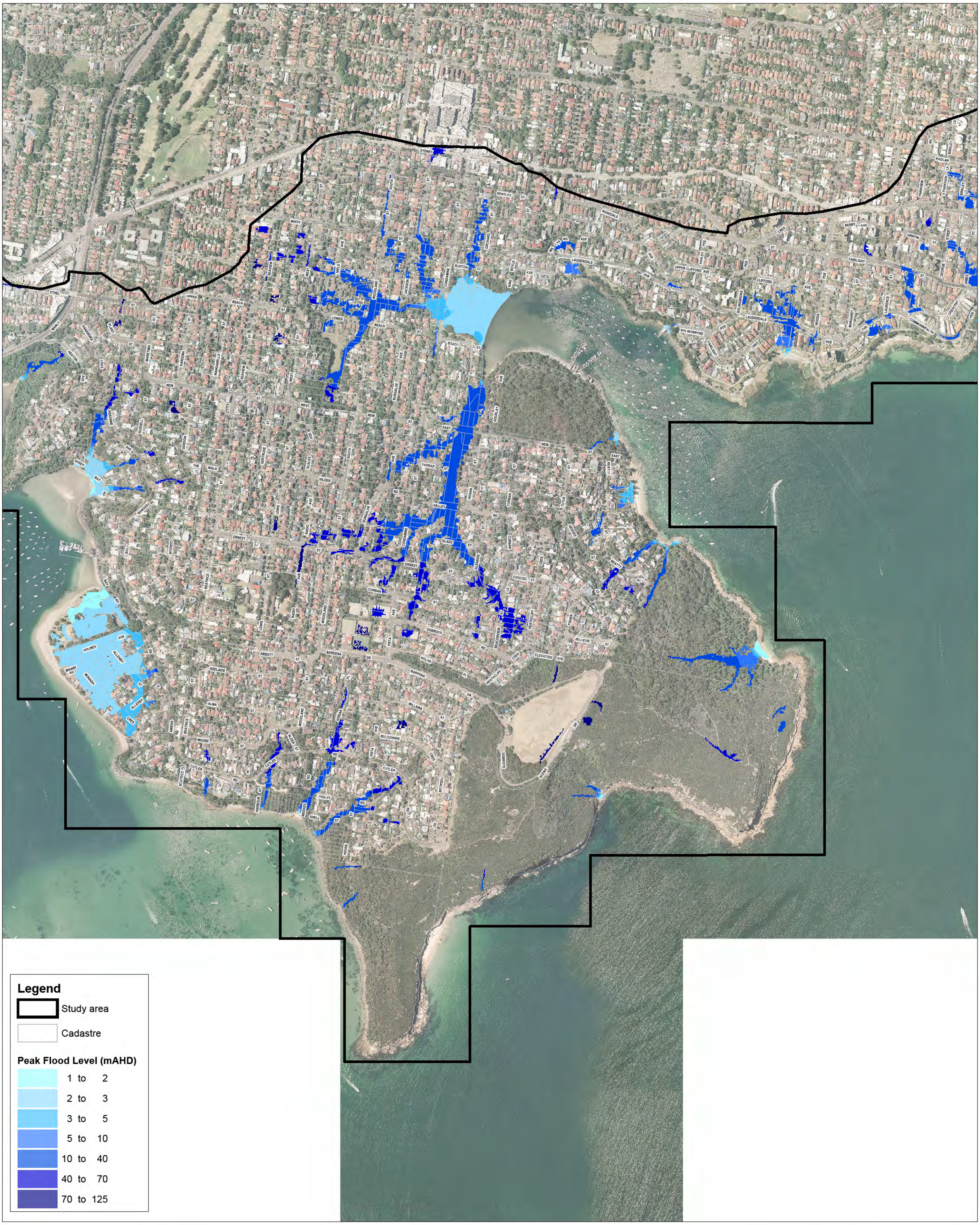
Figure 12

Cardno



Manly to Seaforth Flood Study
PMF Peak Flood Water Level
Map 1/4

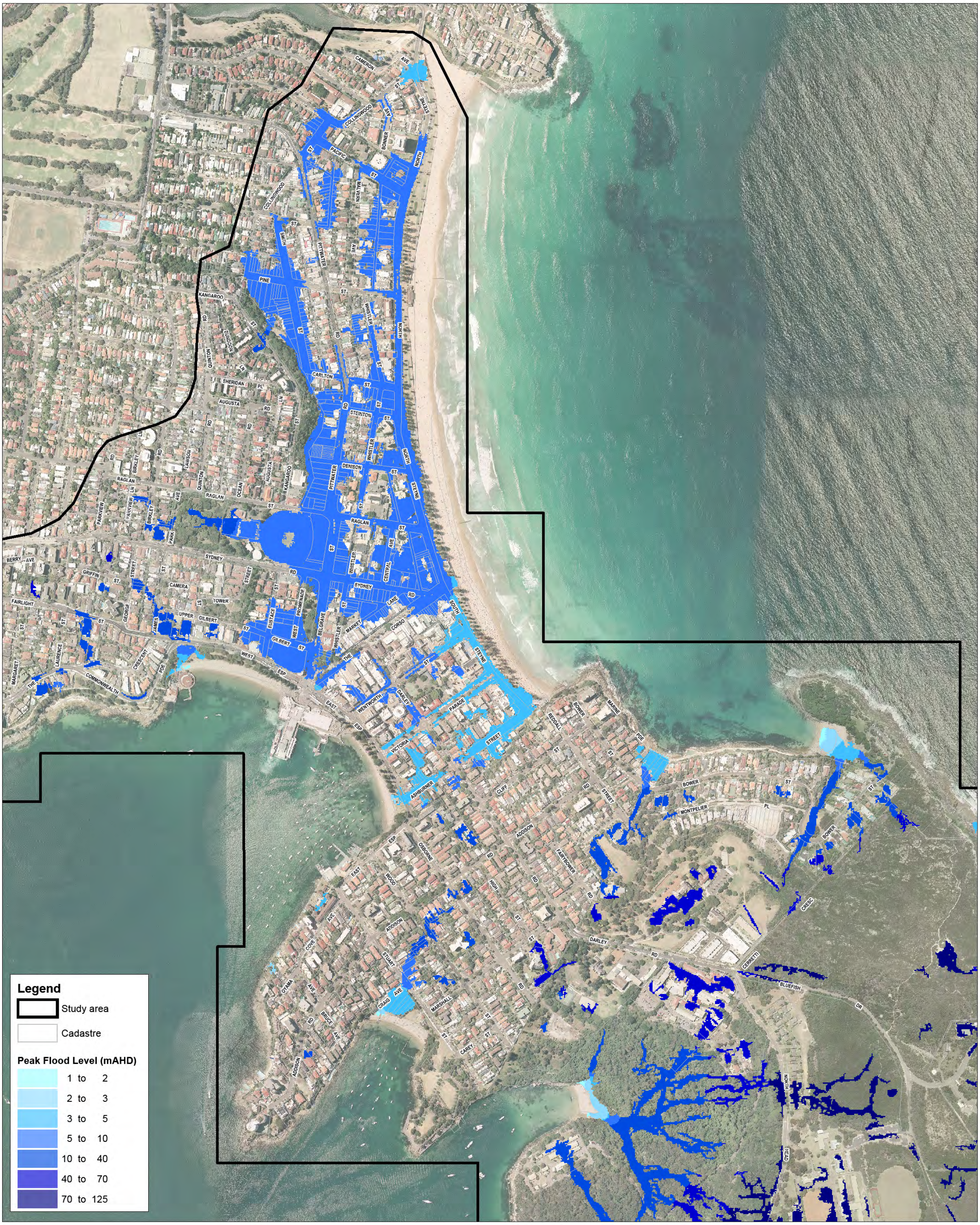
Figure 13



Manly to Seaforth Flood Study
PMF Peak Flood Water Level
Map 2/4

Figure 14

Cardno



N

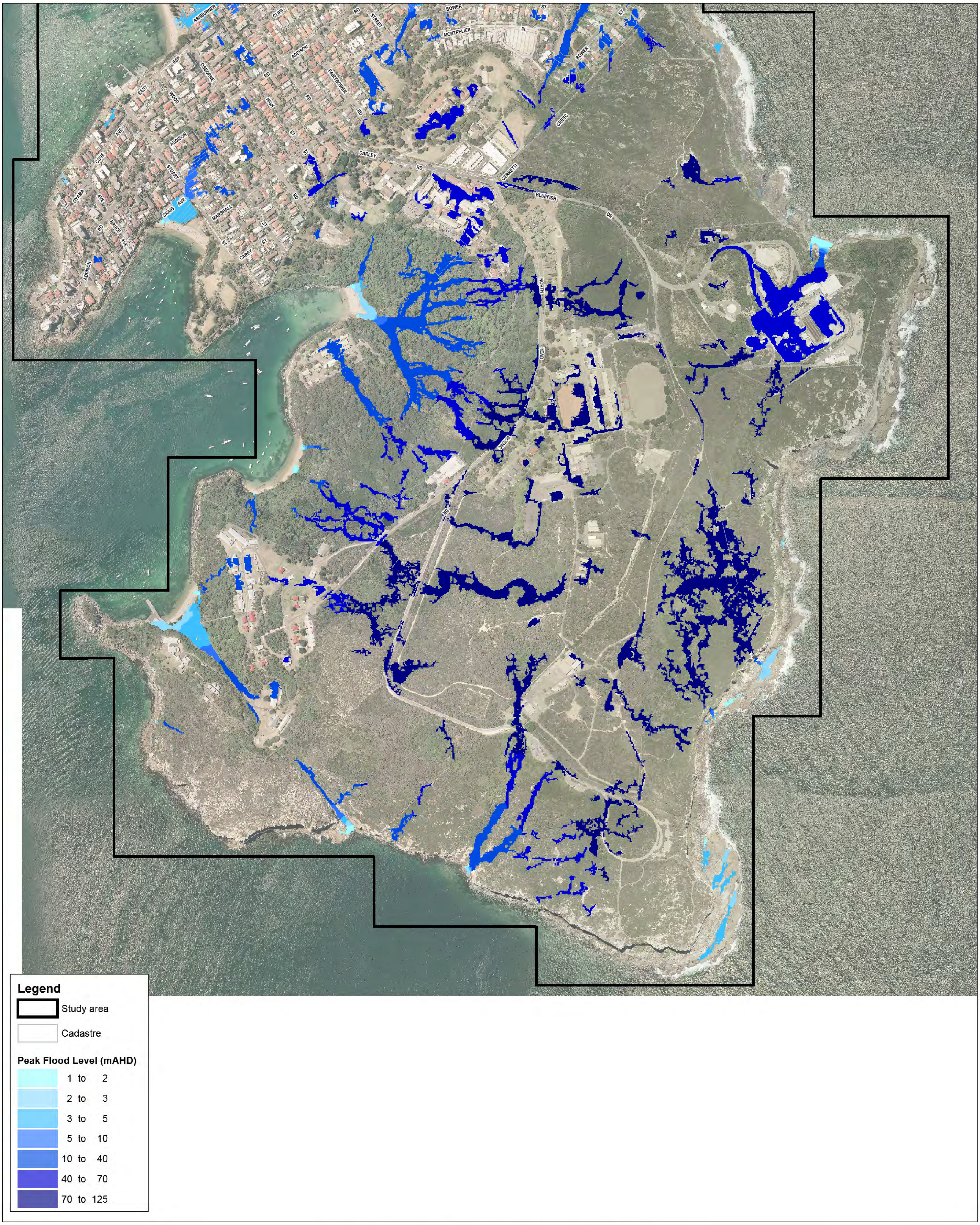
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
PMF Peak Flood Water Level
Map 3/4

Figure 15

Cardno



N

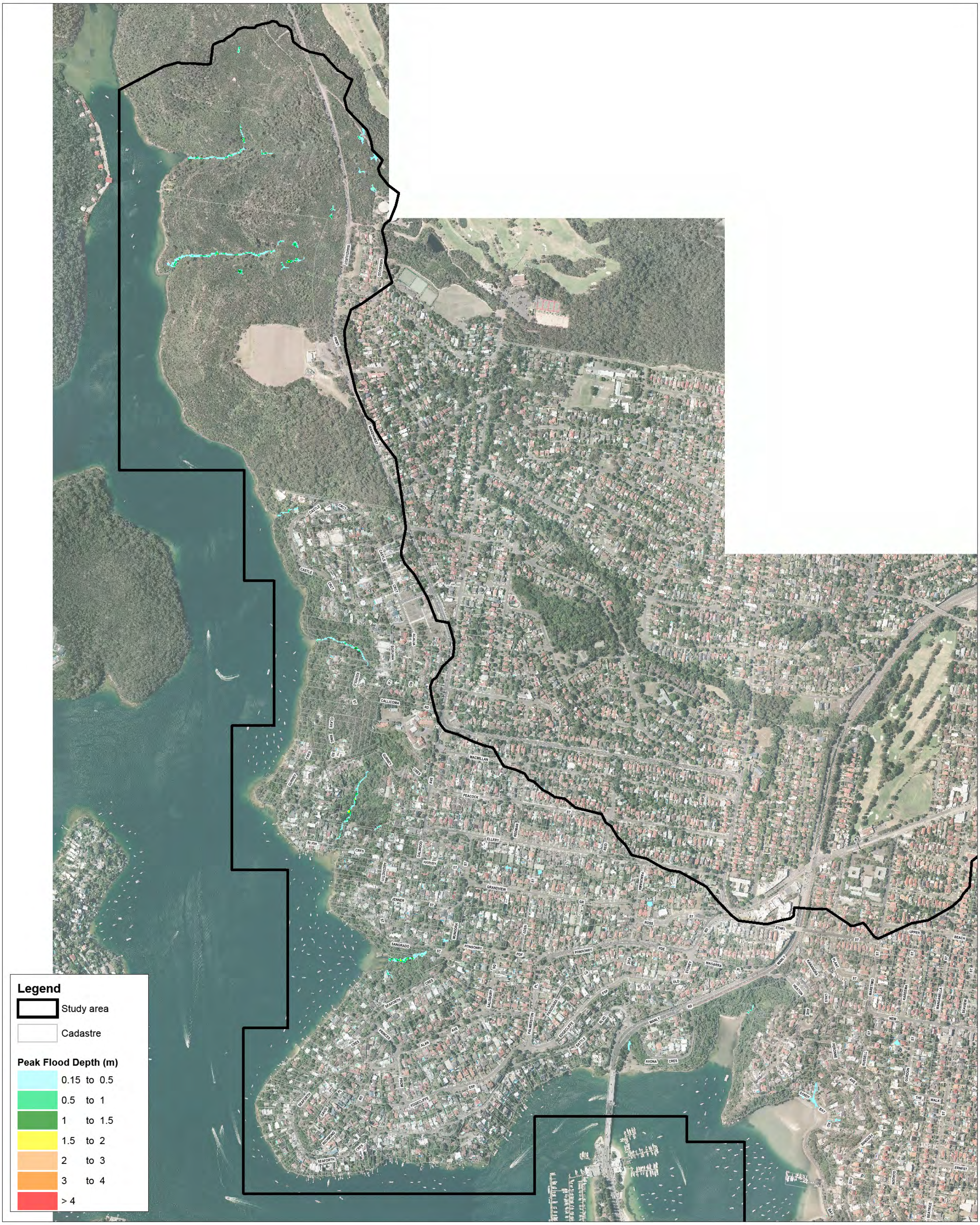
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
PMF Peak Flood Water Level
Map 4/4

Figure 16

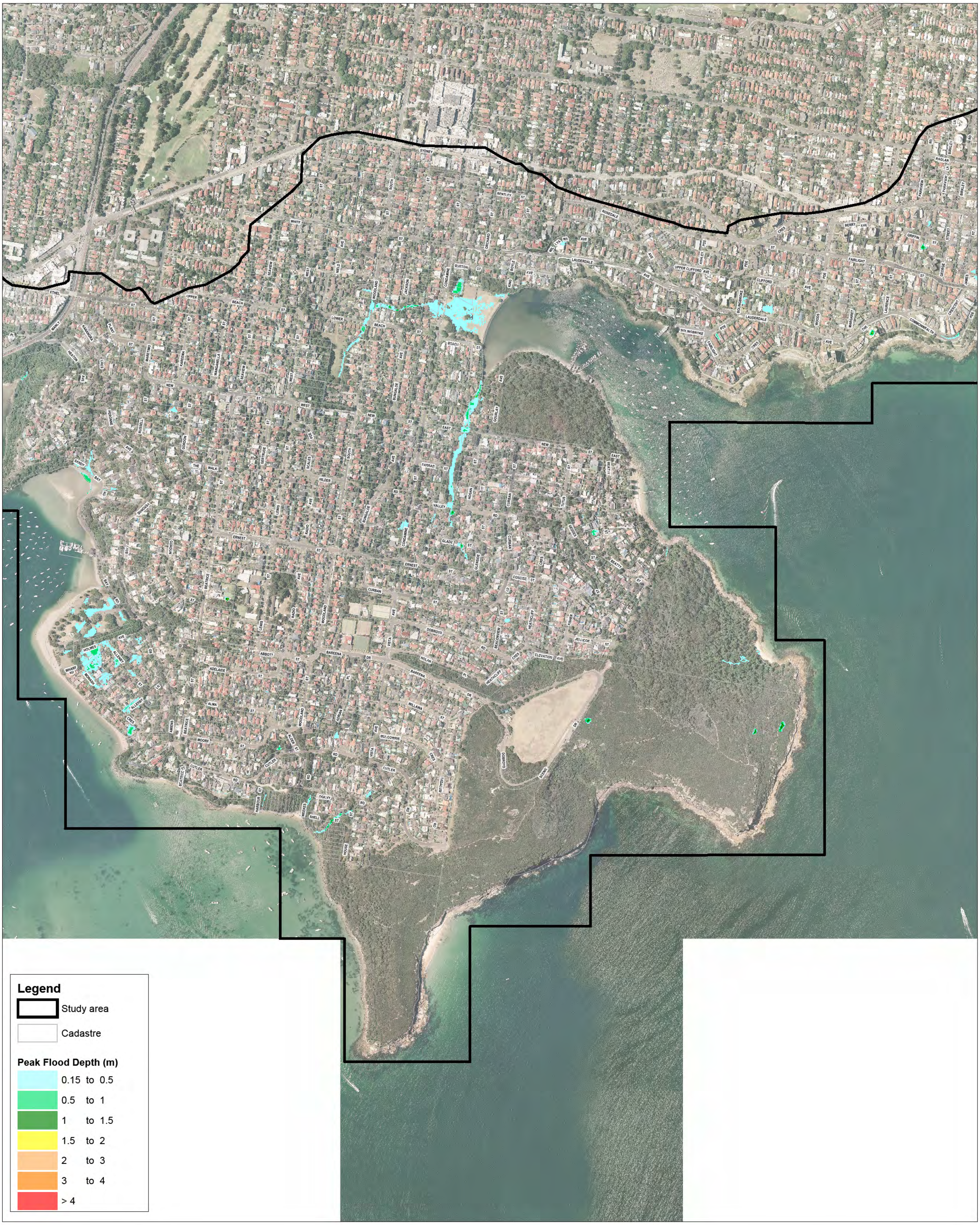
Cardno



Manly to Seaforth Flood Study
20% Peak Flood Depths
Map 1/4

Cardno

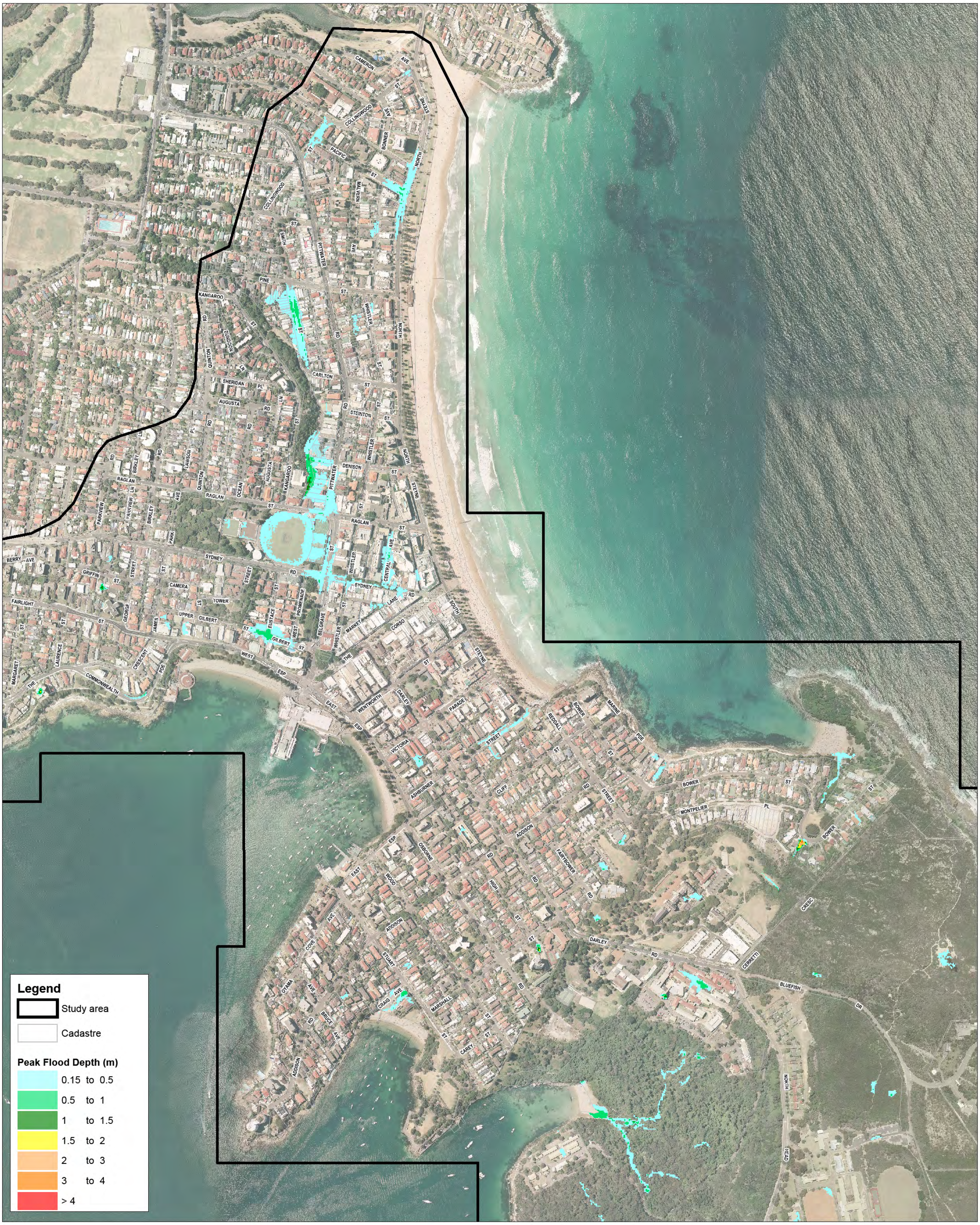
Figure 17



Manly to Seaforth Flood Study
20% Peak Flood Depths
Map 2/4

Figure 18

Cardno



N

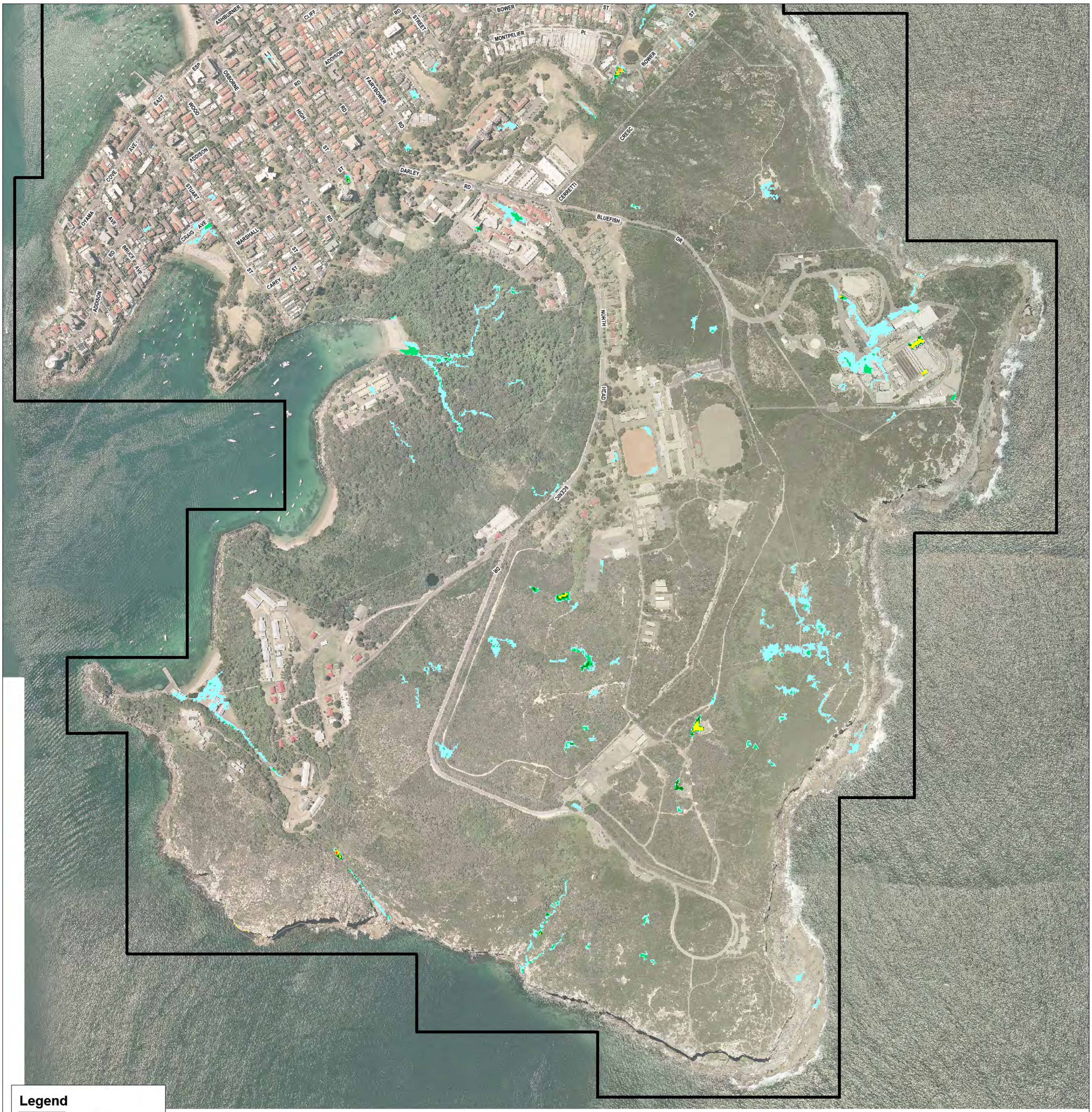
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
20% Peak Flood Depths
Map 3/4

Cardno

Figure 19



Legend

Study area

Cadastre

Peak Flood Depth (m)

0.15 to 0.5

0.5 to 1

1 to 1.5

1.5 to 2

2 to 3

3 to 4

> 4

N

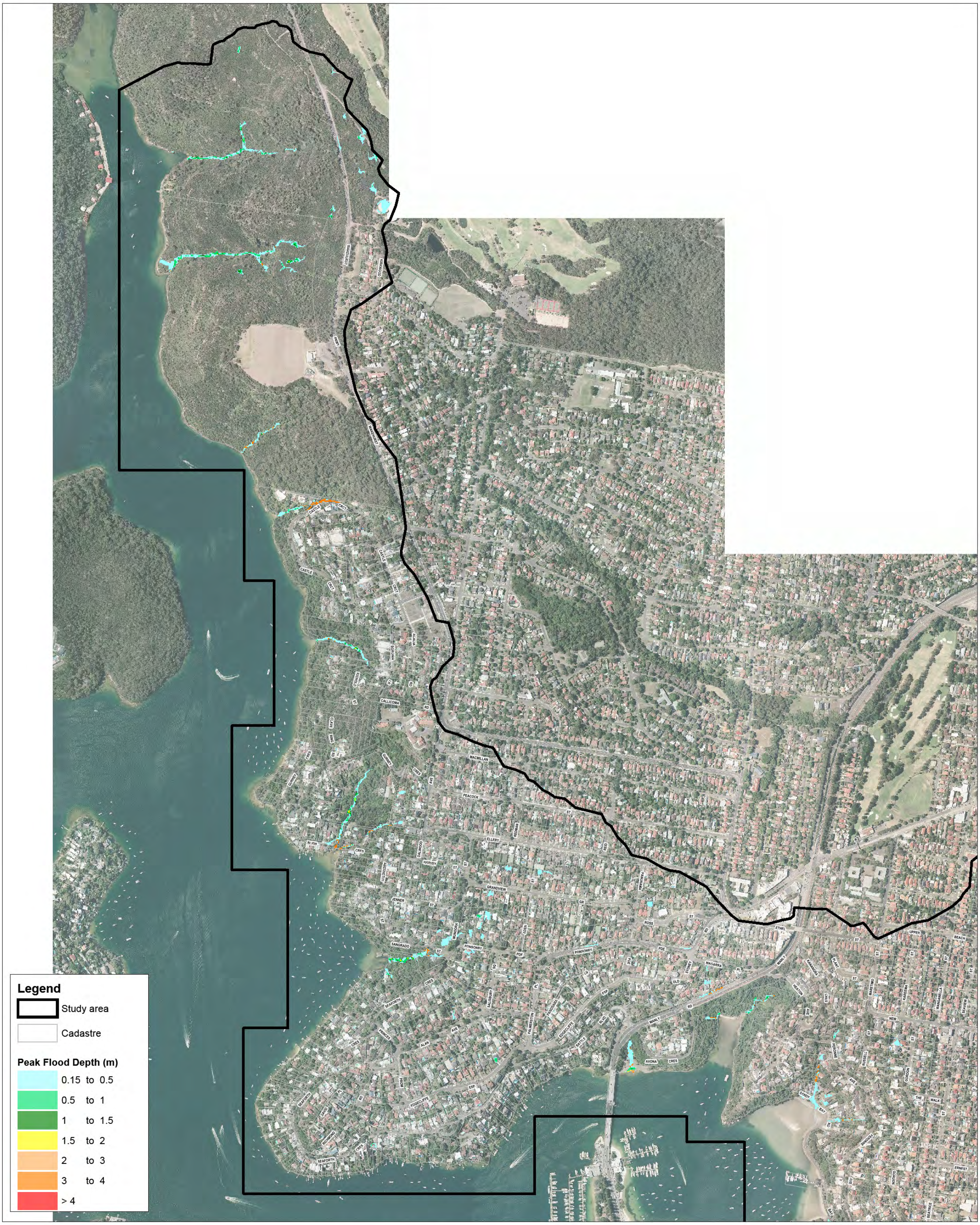
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
20% Peak Flood Depths
Map 4/4

Figure 20

Cardno



N

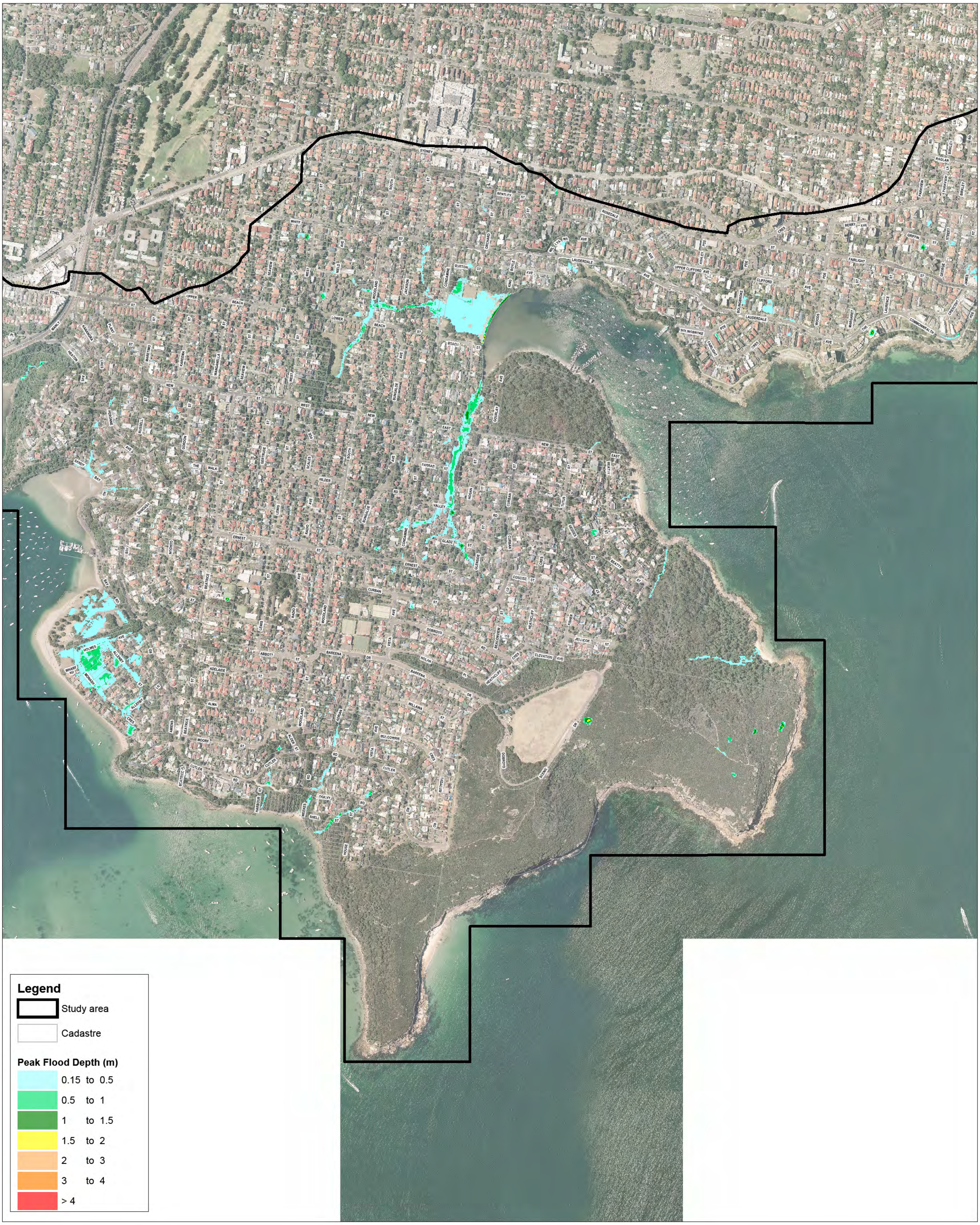
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
1% Peak Flood Depths
Map 1/4

Cardno

Figure 21



N

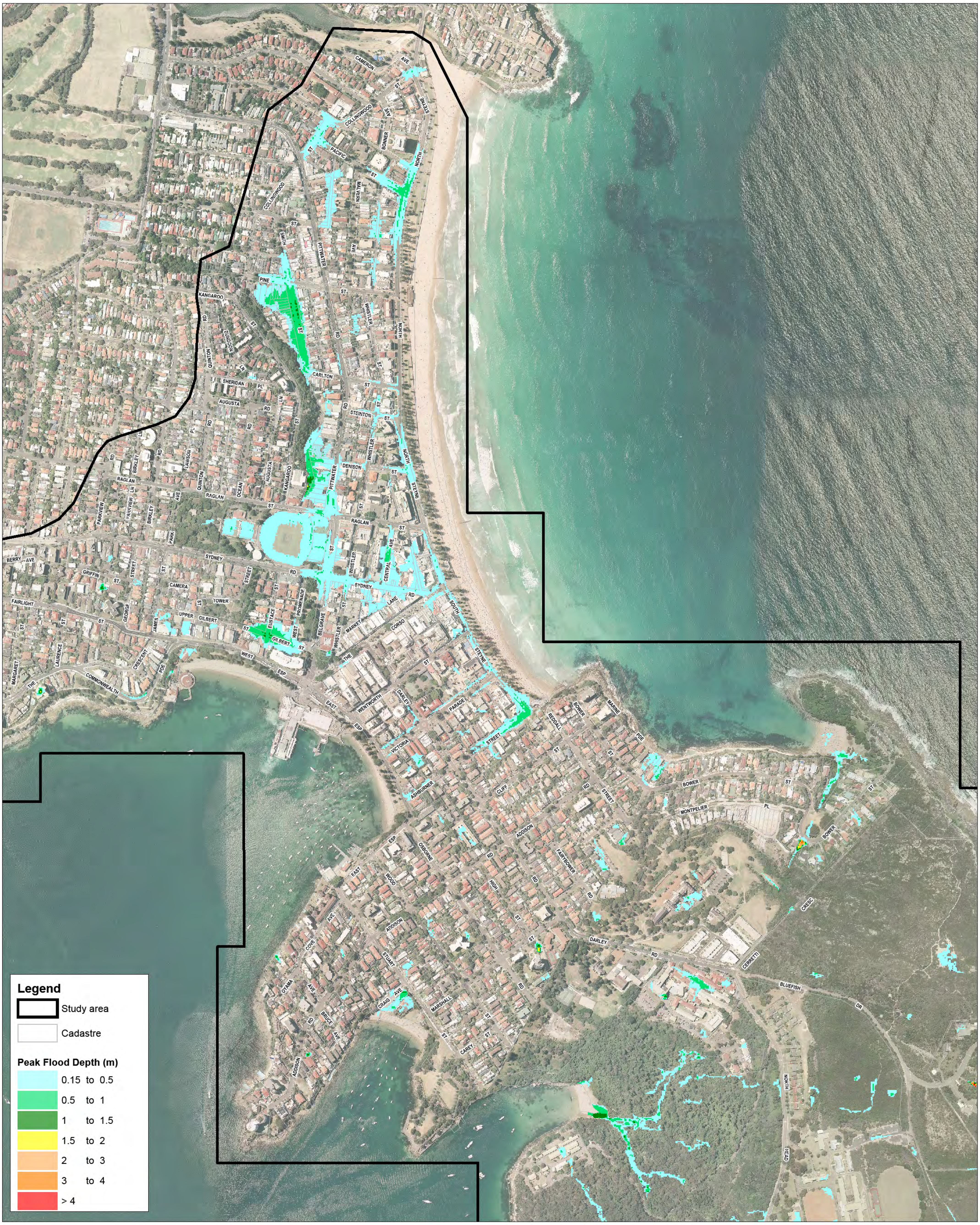
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
1% Peak Flood Depths
Map 2/4

Figure 22

Cardno



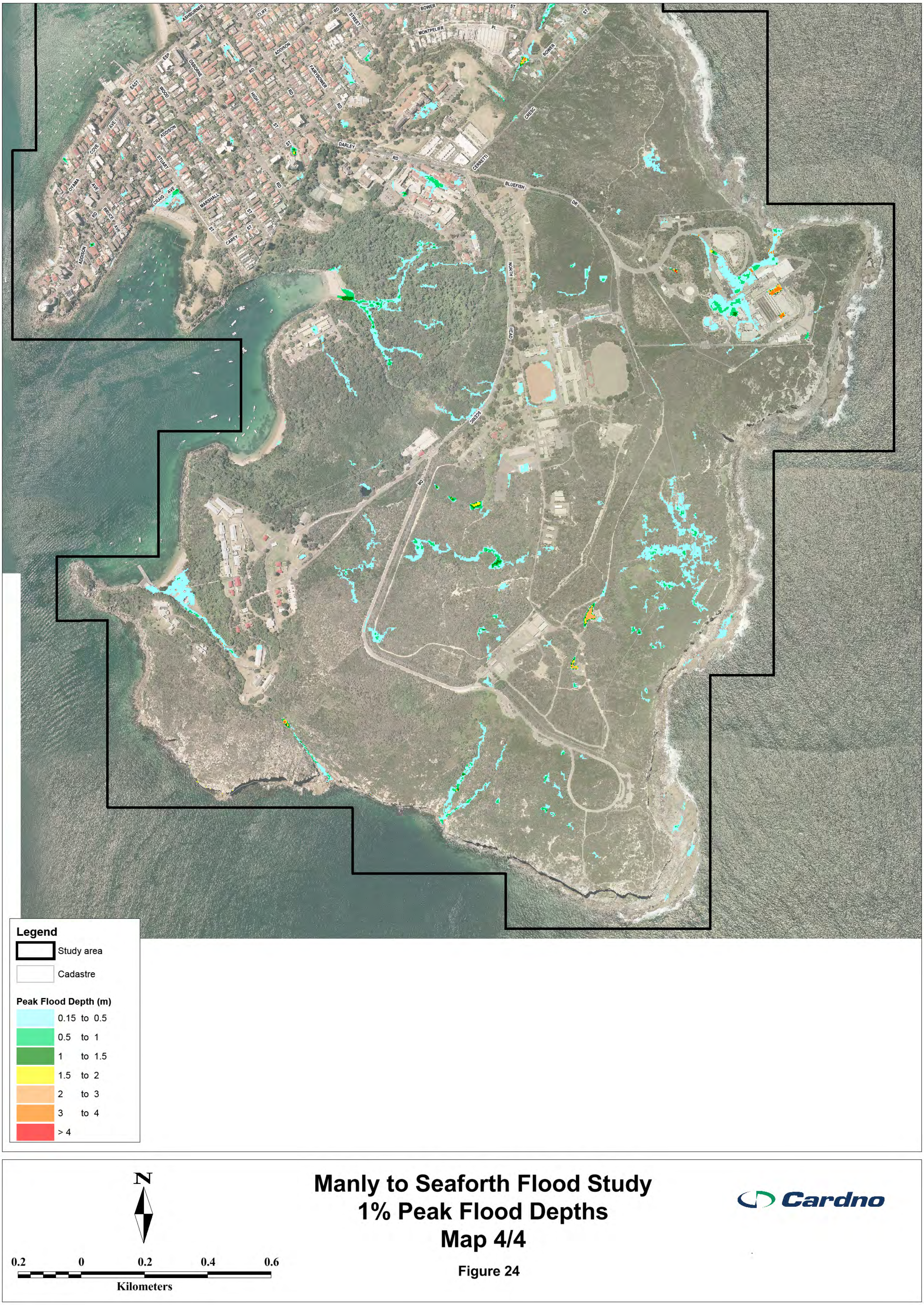
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
1% Peak Flood Depths
Map 3/4

Figure 23

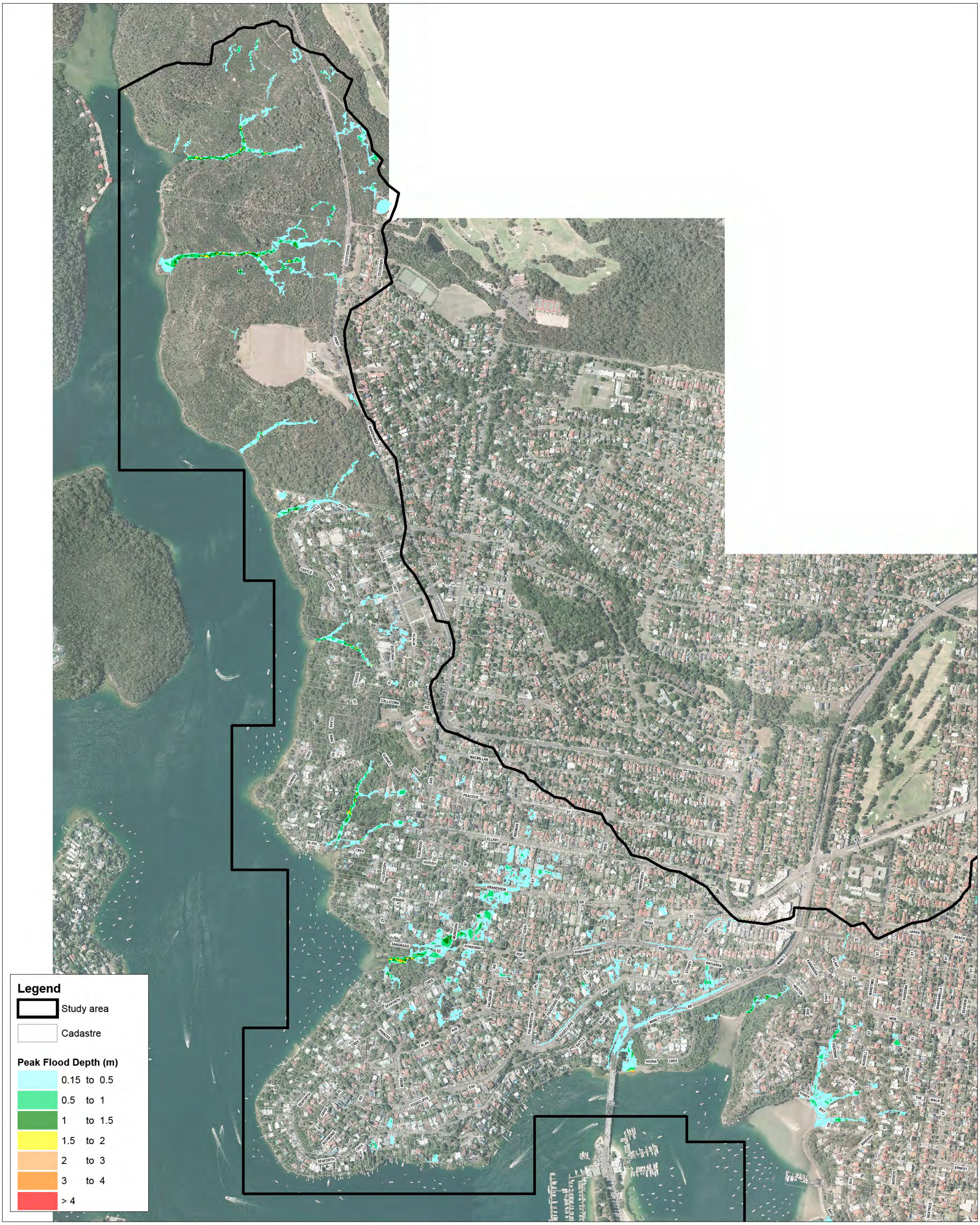
Cardno



Manly to Seaforth Flood Study
1% Peak Flood Depths
Map 4/4

Figure 24

Cardno



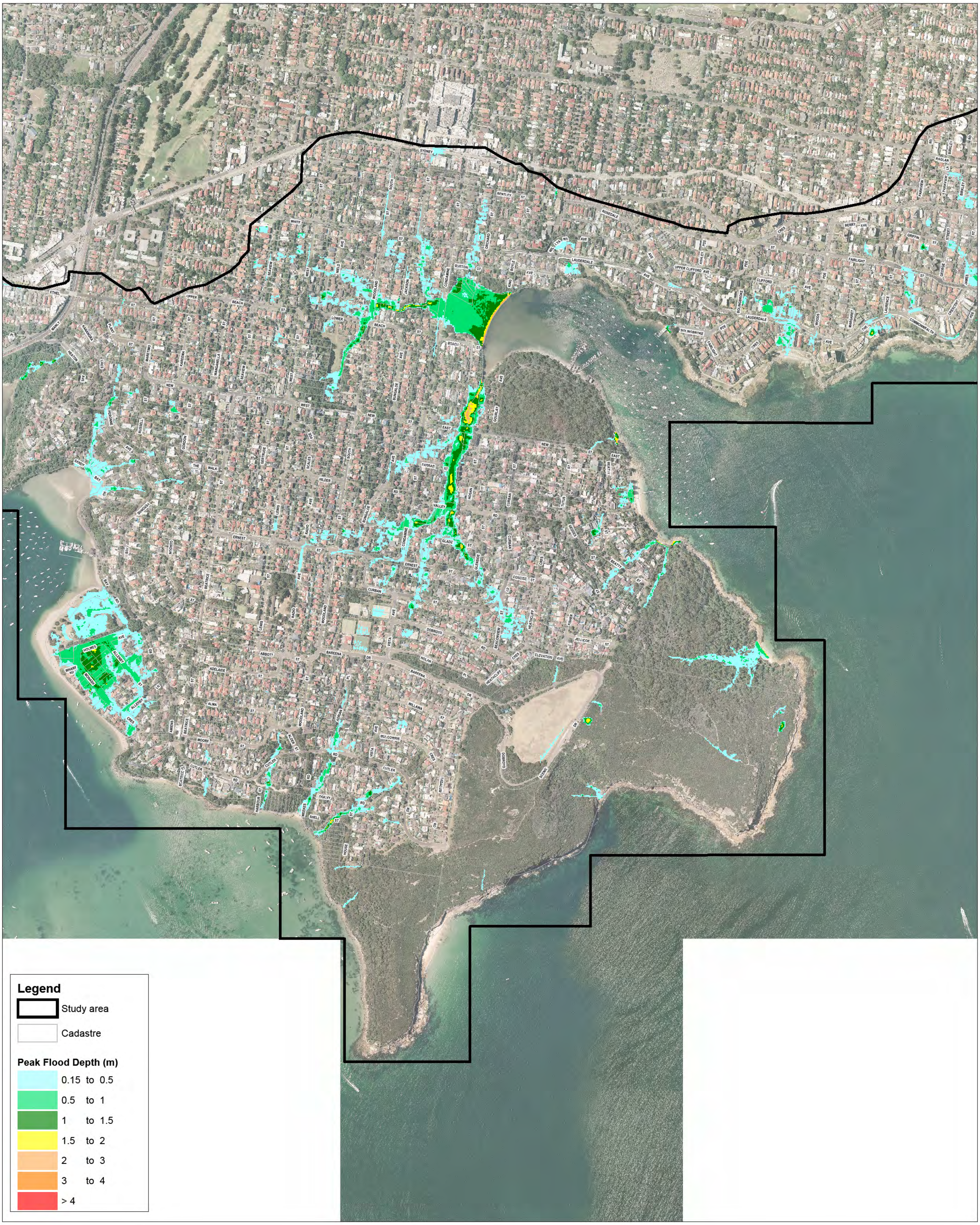
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
PMF Peak Flood Depths
Map 1/4

Figure 25

Cardno



N

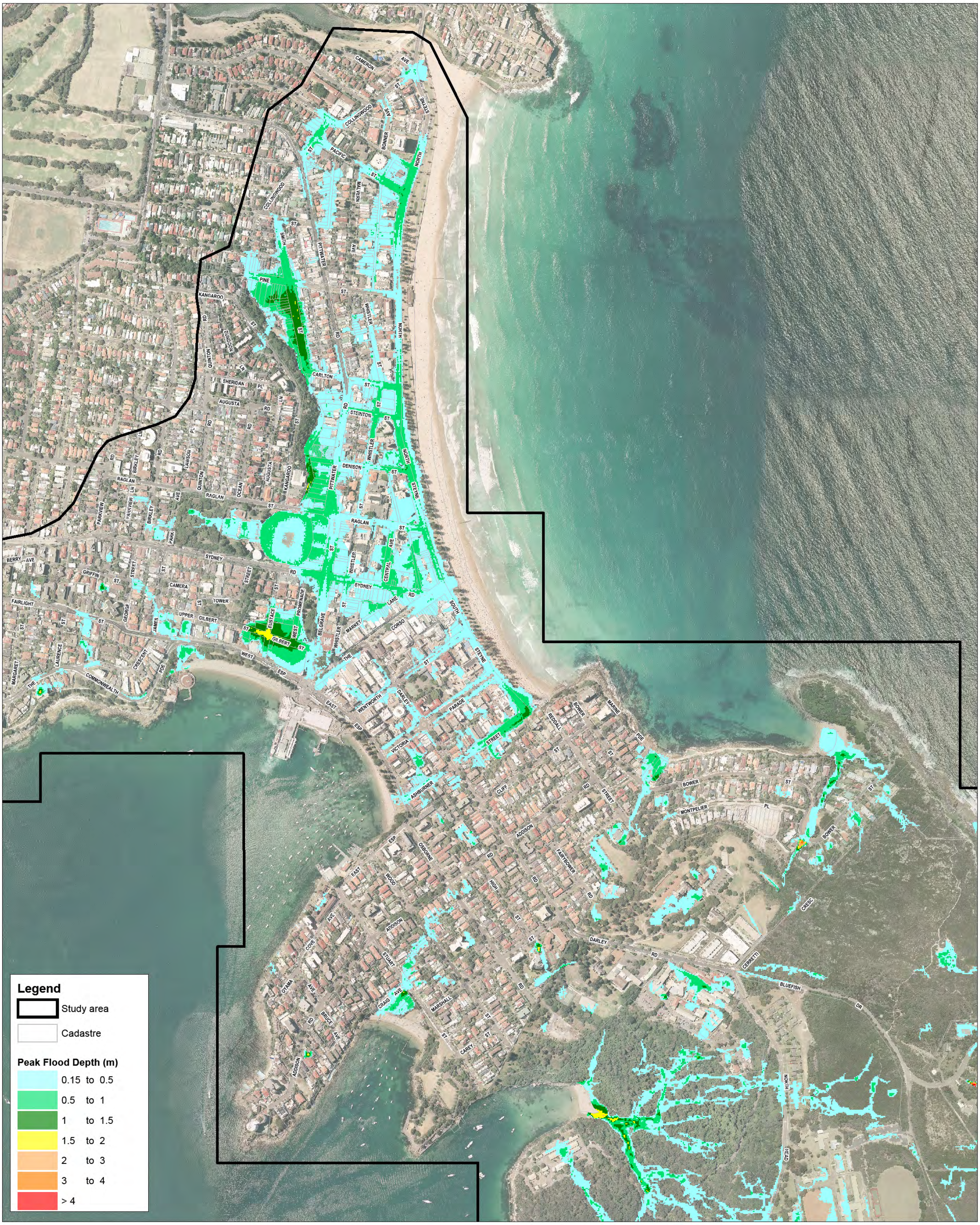
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
PMF Peak Flood Depths
Map 2/4

Figure 26

Cardno



N

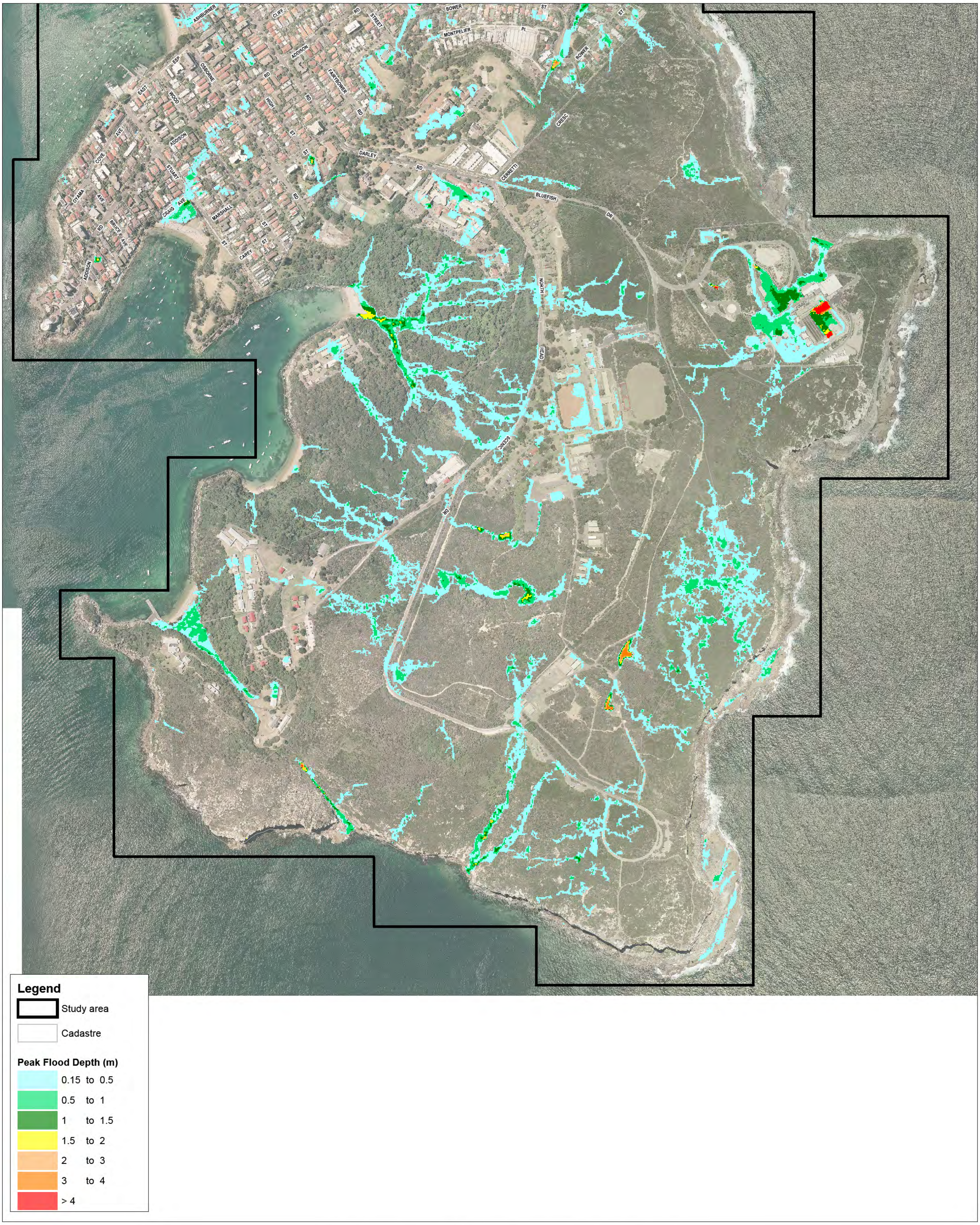
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
PMF Peak Flood Depths
Map 3/4

Figure 27

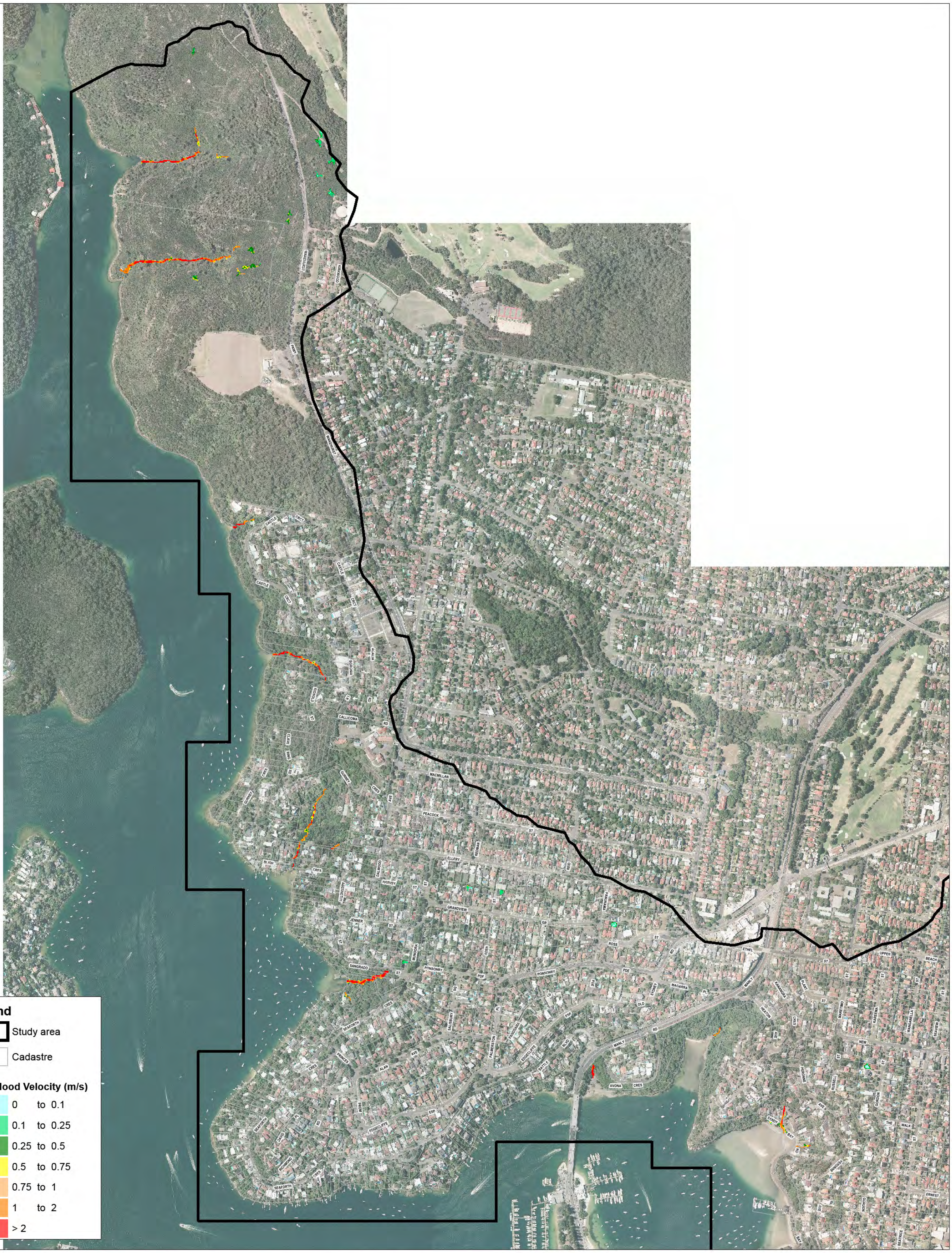
Cardno



Manly to Seaforth Flood Study
PMF Peak Flood Depths
Map 4/4

Figure 28

Cardno



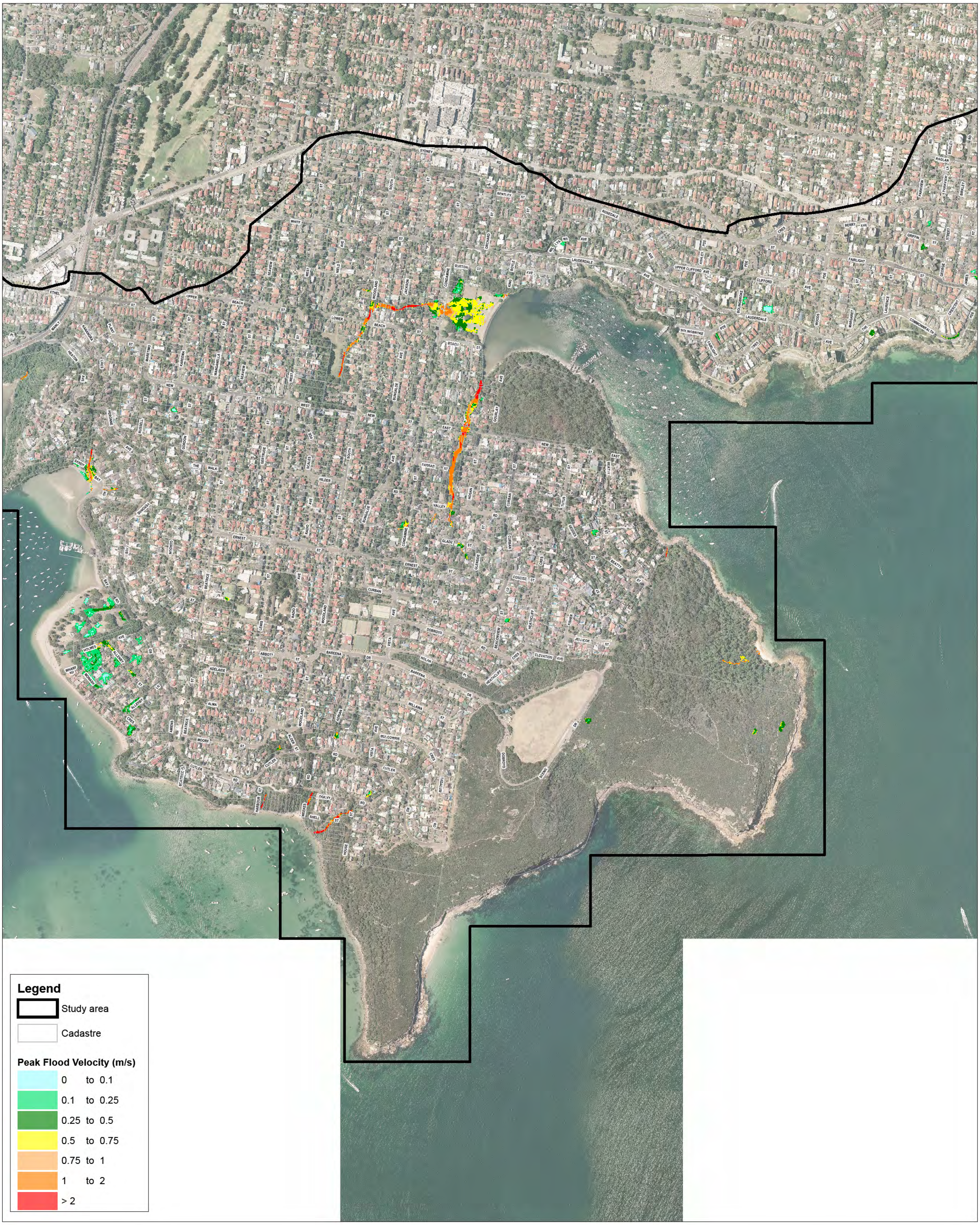
N

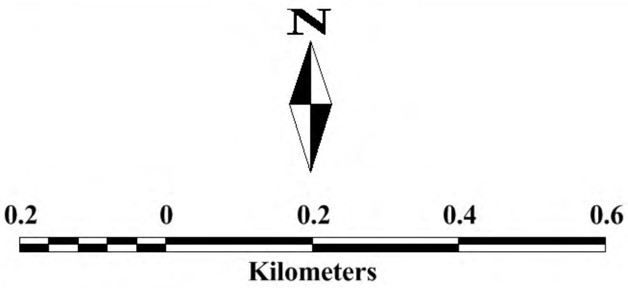
0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
20% Peak Flood Velocity
Map 1/4

Figure 29

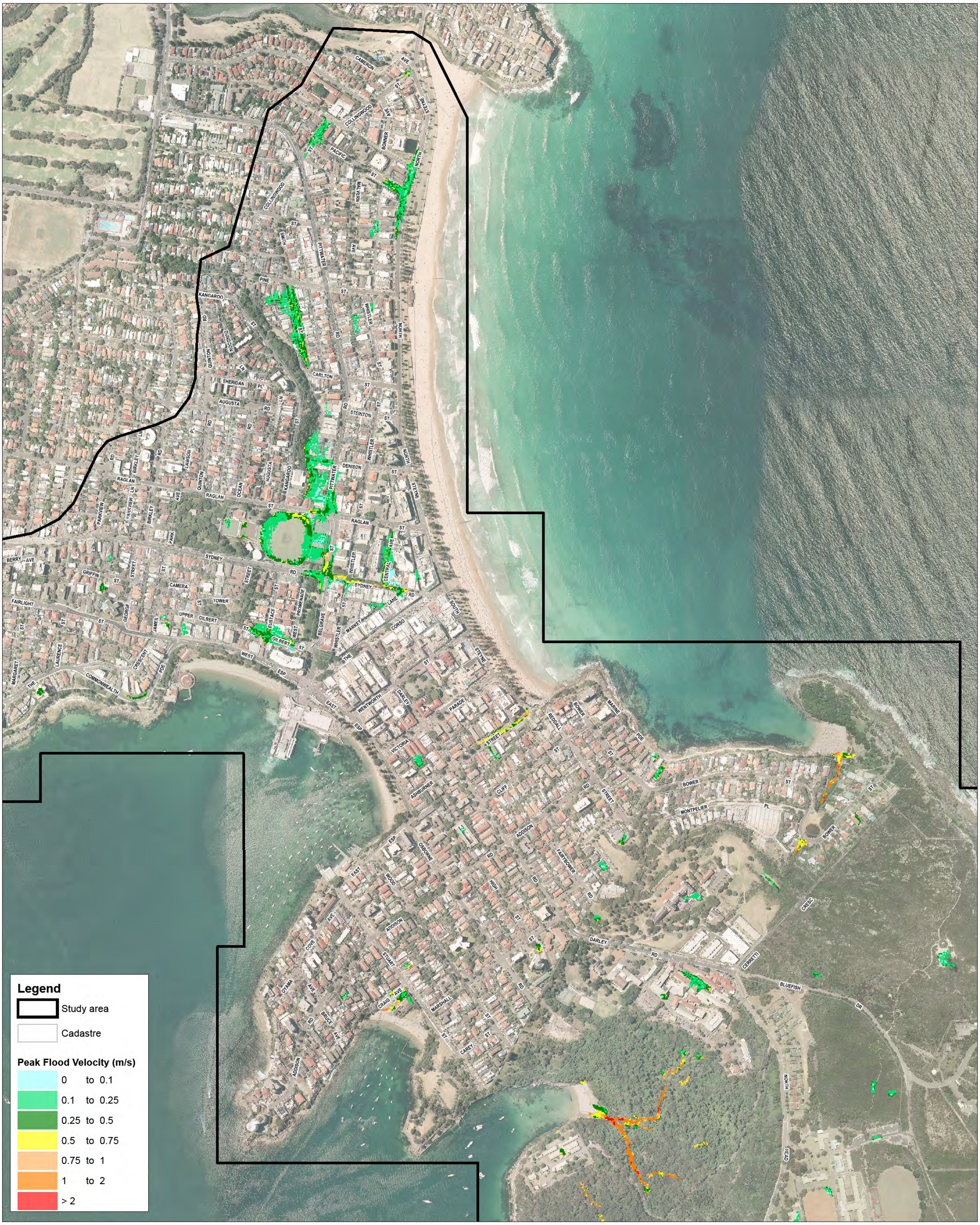
Cardno





Manly to Seaforth Flood Study
20% Peak Flood Velocity
Map 2/4

Figure 30



N

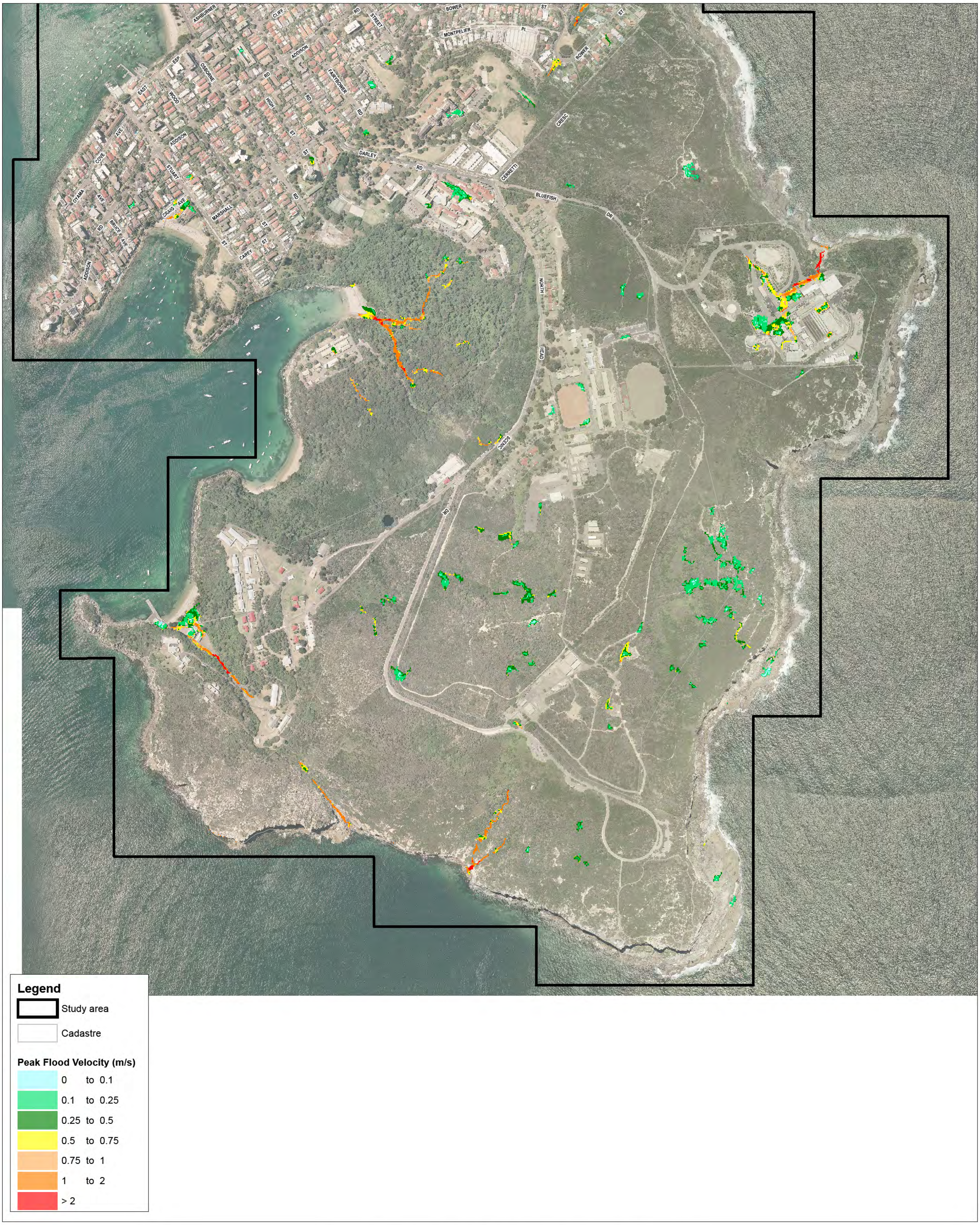
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
20% Peak Flood Velocity
Map 3/4

Cardno

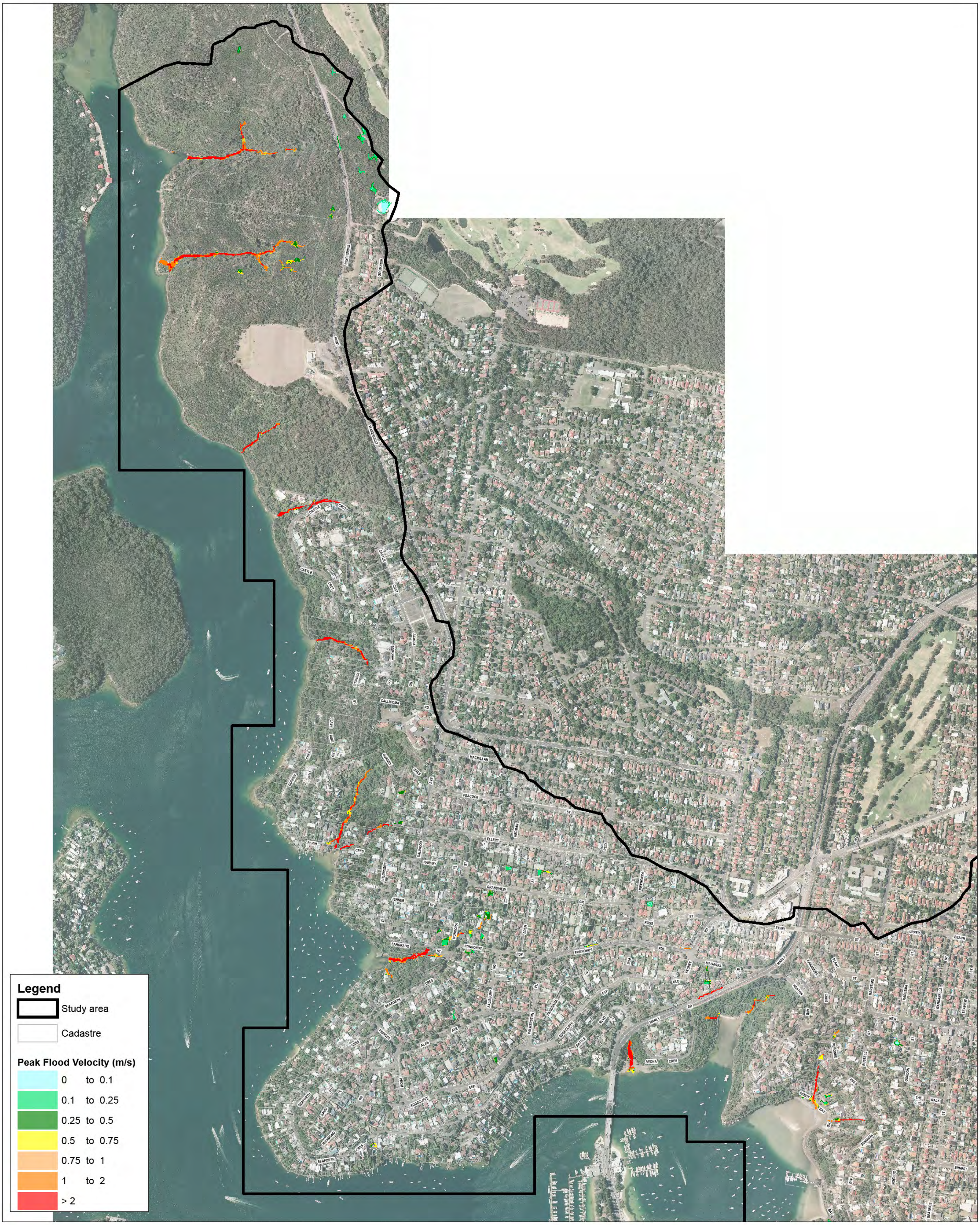
Figure 31



Manly to Seaforth Flood Study
20% Peak Flood Velocity
Map 4/4

Cardno

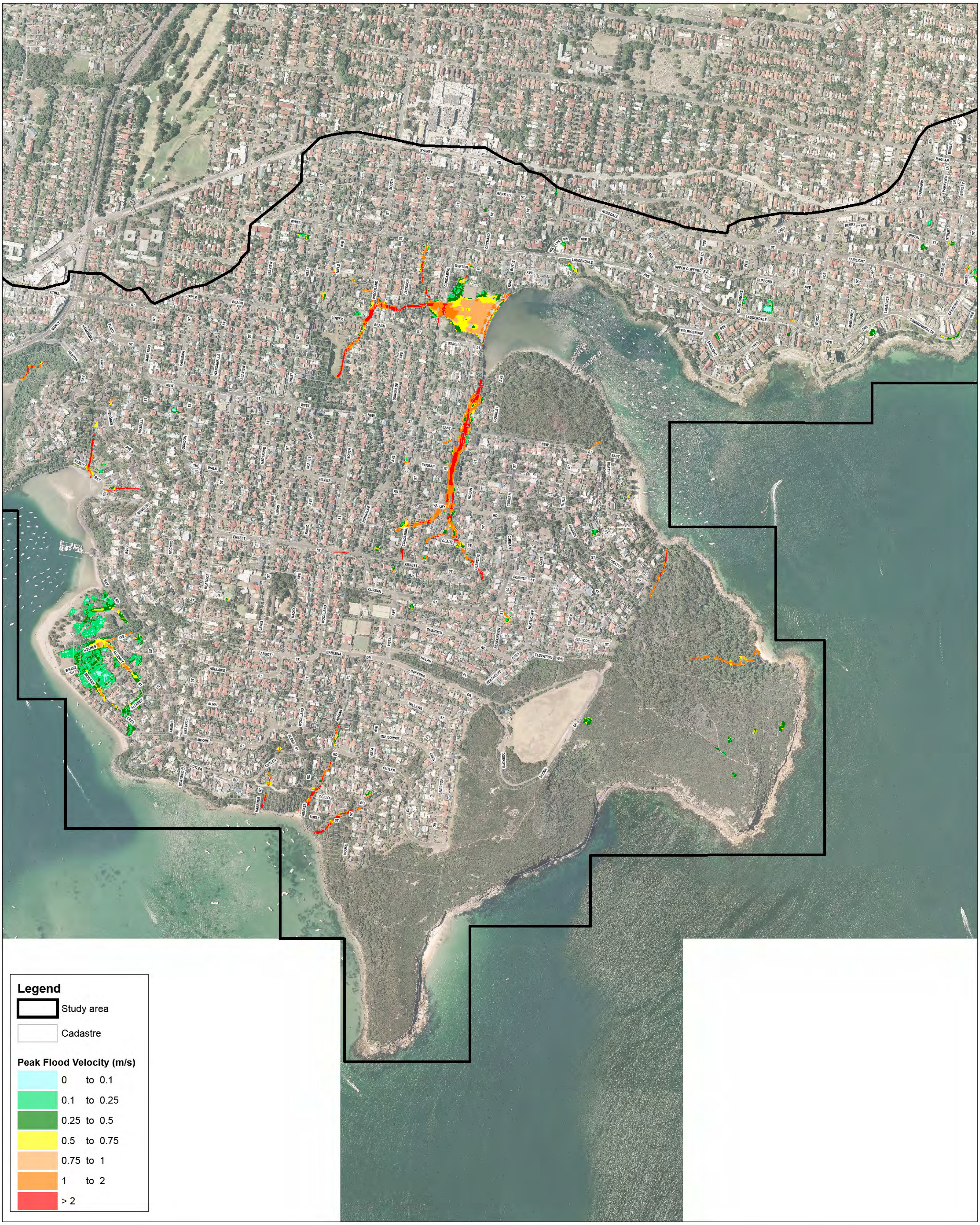
Figure 32



Manly to Seaforth Flood Study
1% Peak Flood Velocity
Map 1/4

Cardno

Figure 33



N

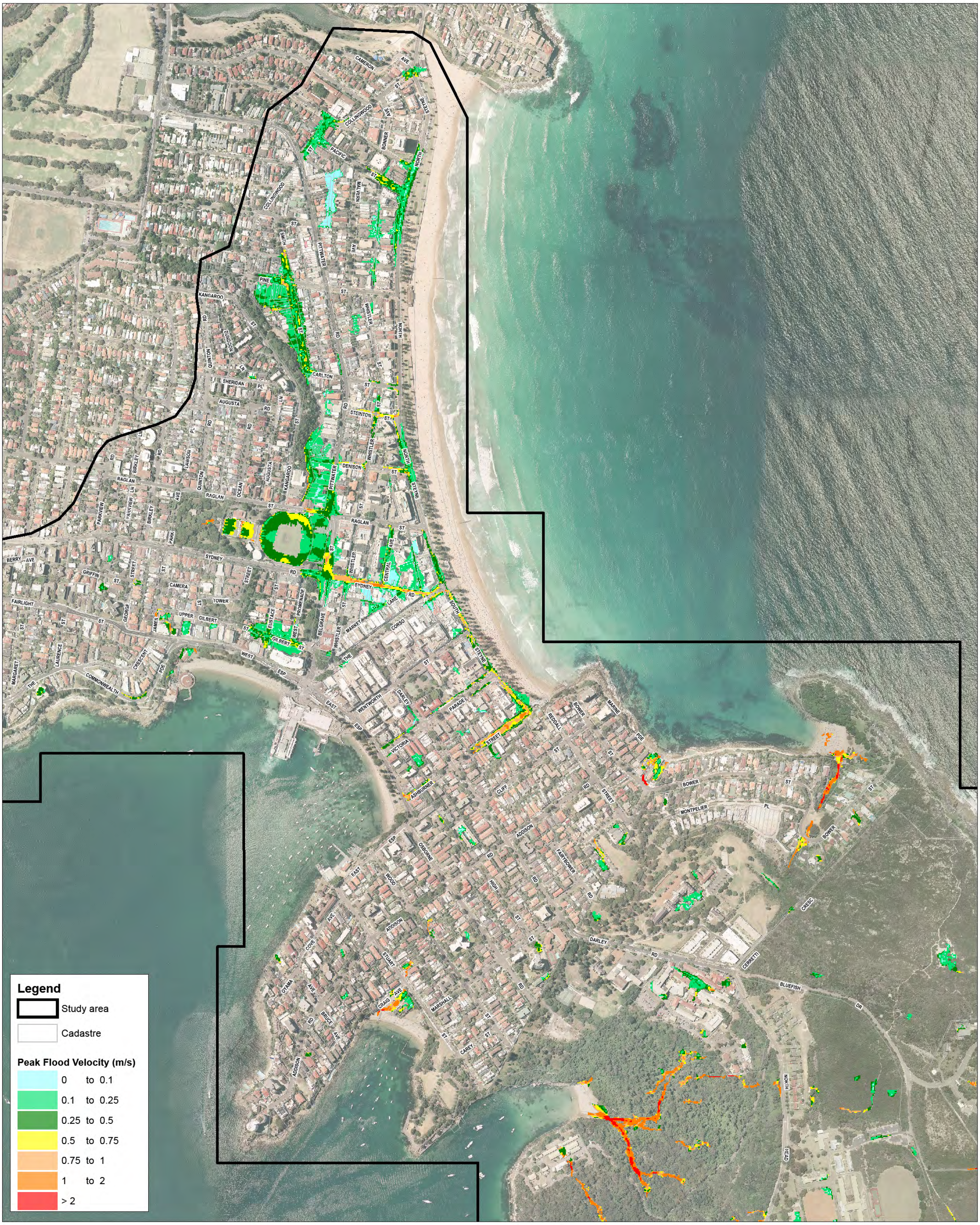
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
1% Peak Flood Velocity
Map 2/4

Figure 34

Cardno



N

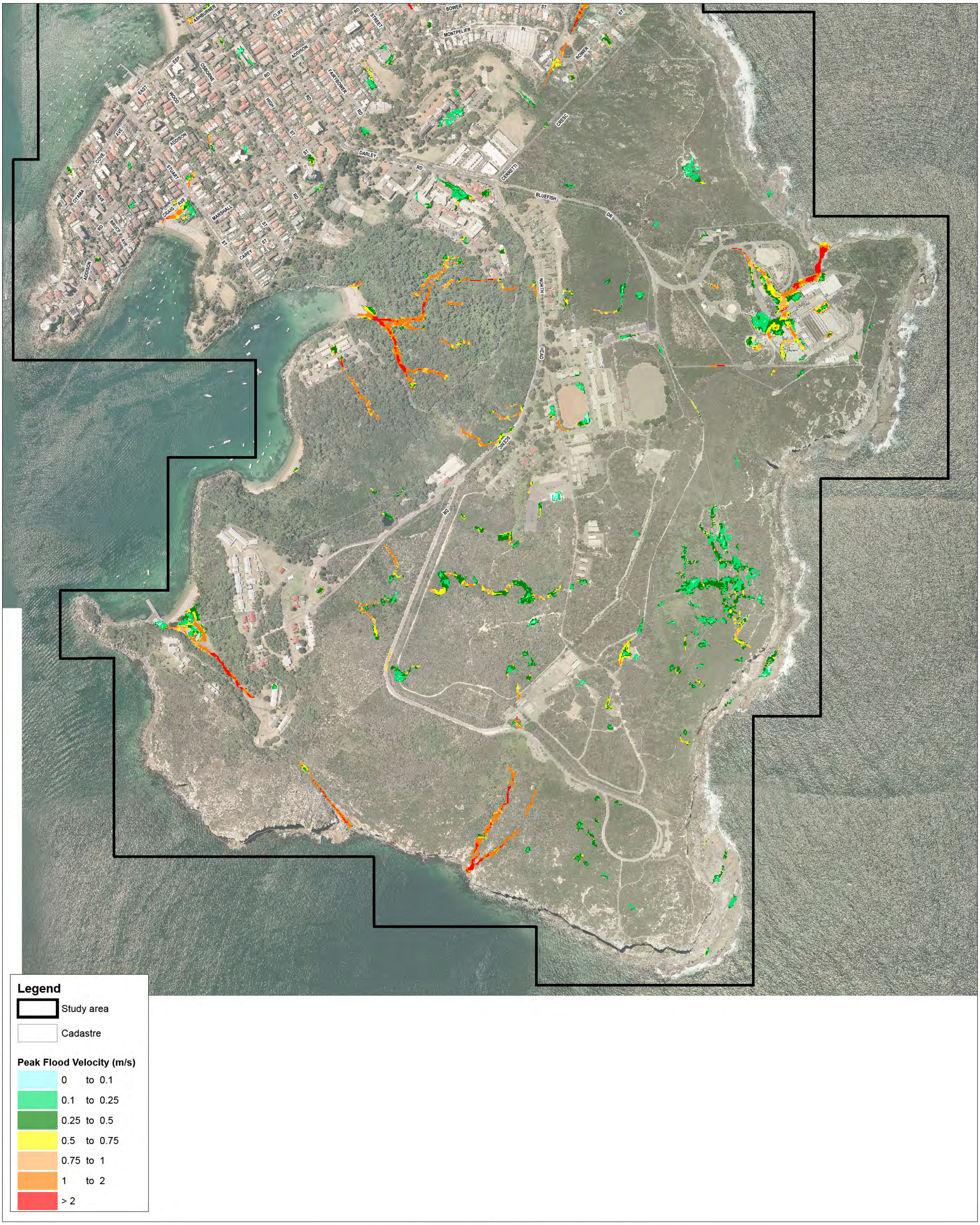
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
1% Peak Flood Velocity
Map 3/4

Cardno

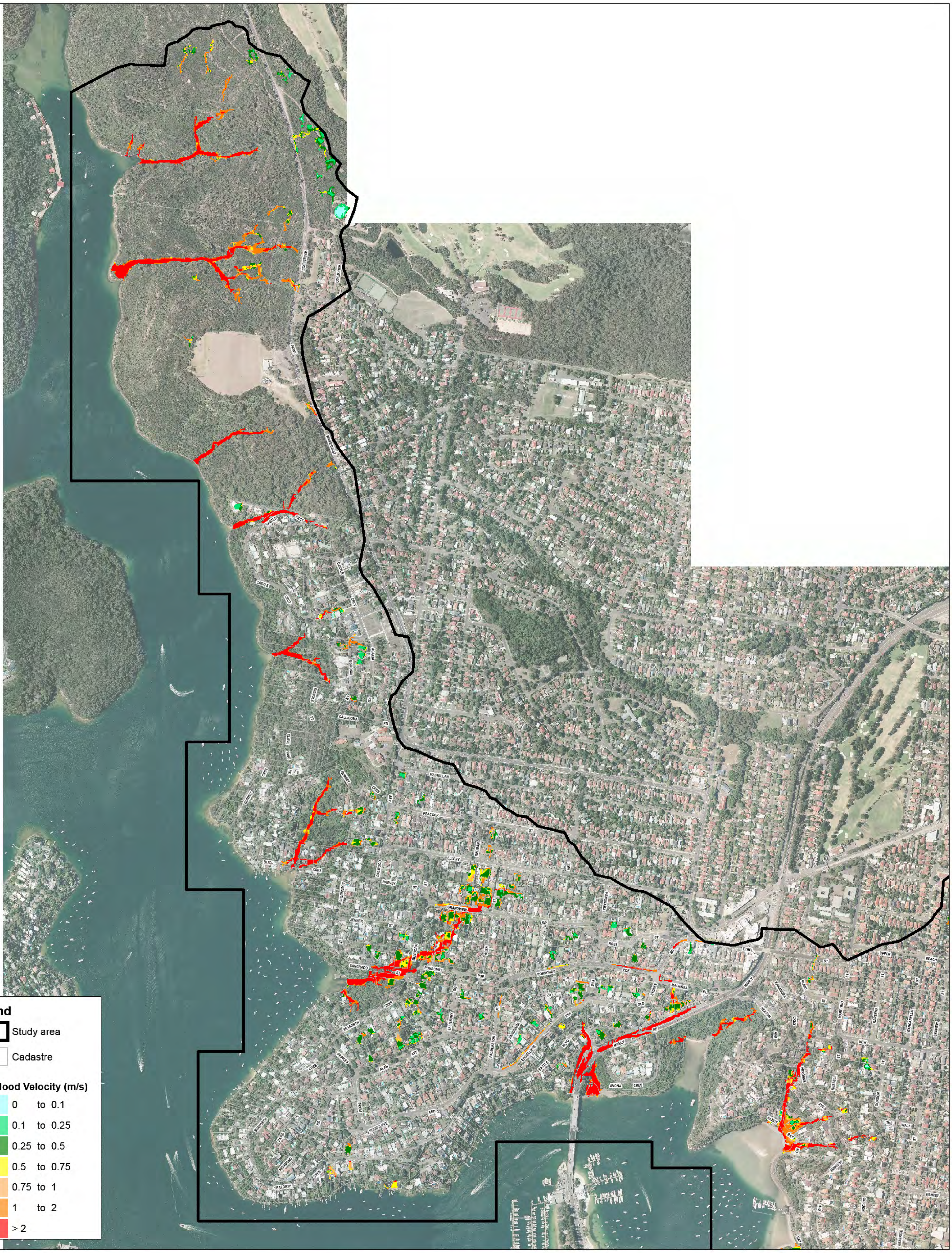
Figure 35



Manly to Seaforth Flood Study
1% Peak Flood Velocity
Map 4/4

Figure 36

Cardno



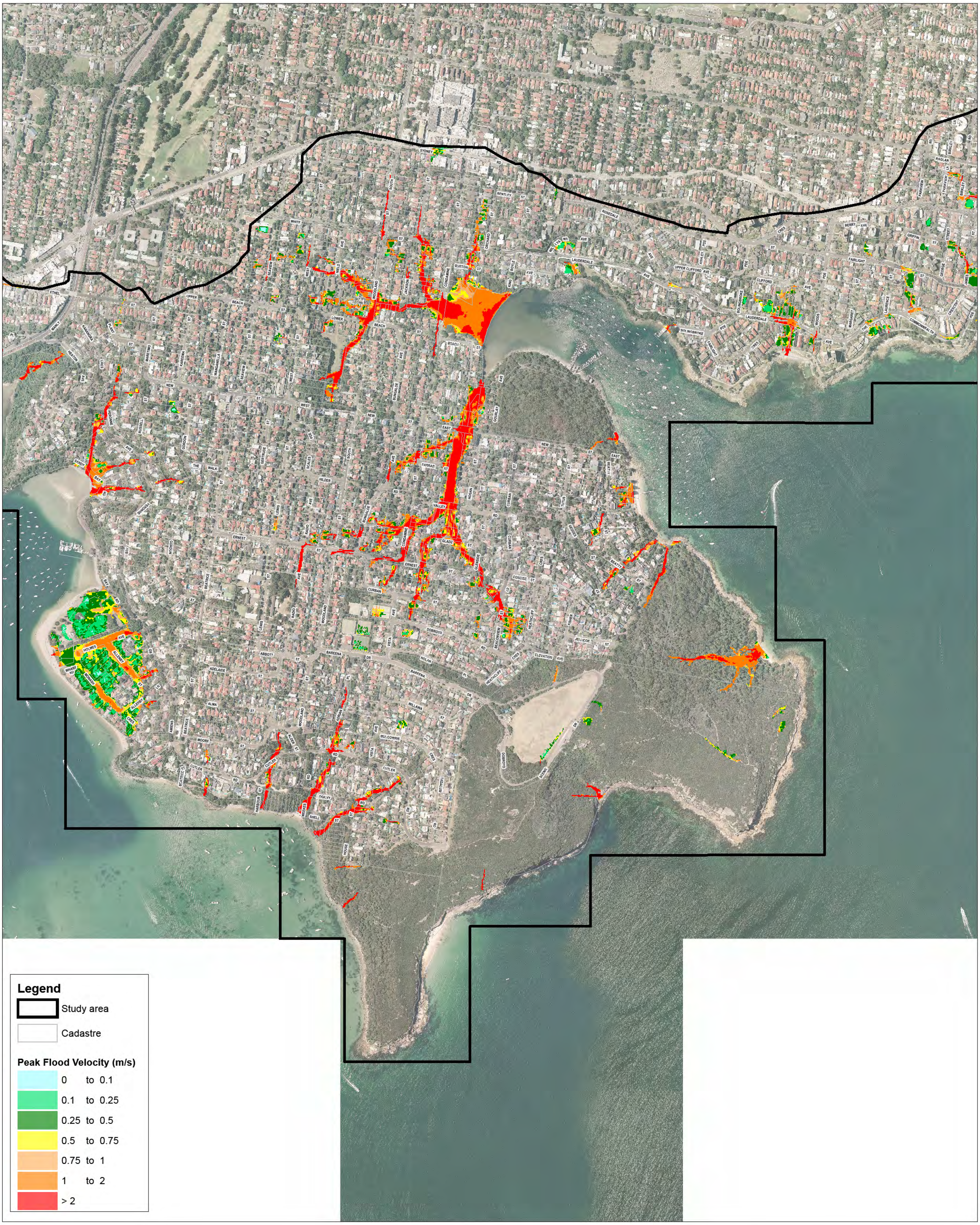
Manly to Seaforth Flood Study
PMF Peak Flood Velocity
Map 1/4

N

0.2 0 0.2 0.4 0.6
Kilometers

Cardno

Figure 37



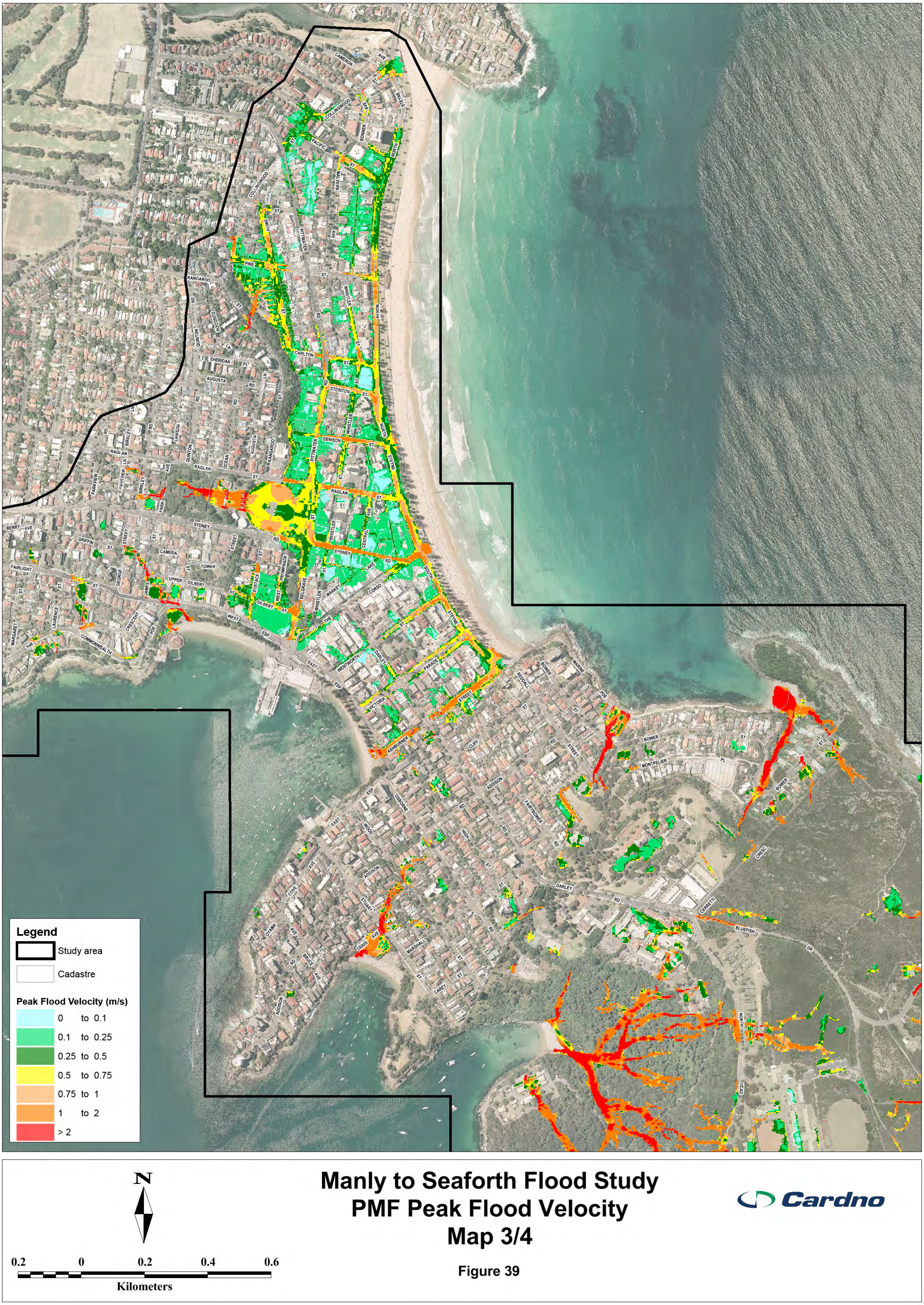
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
PMF Peak Flood Velocity
Map 2/4

Figure 38

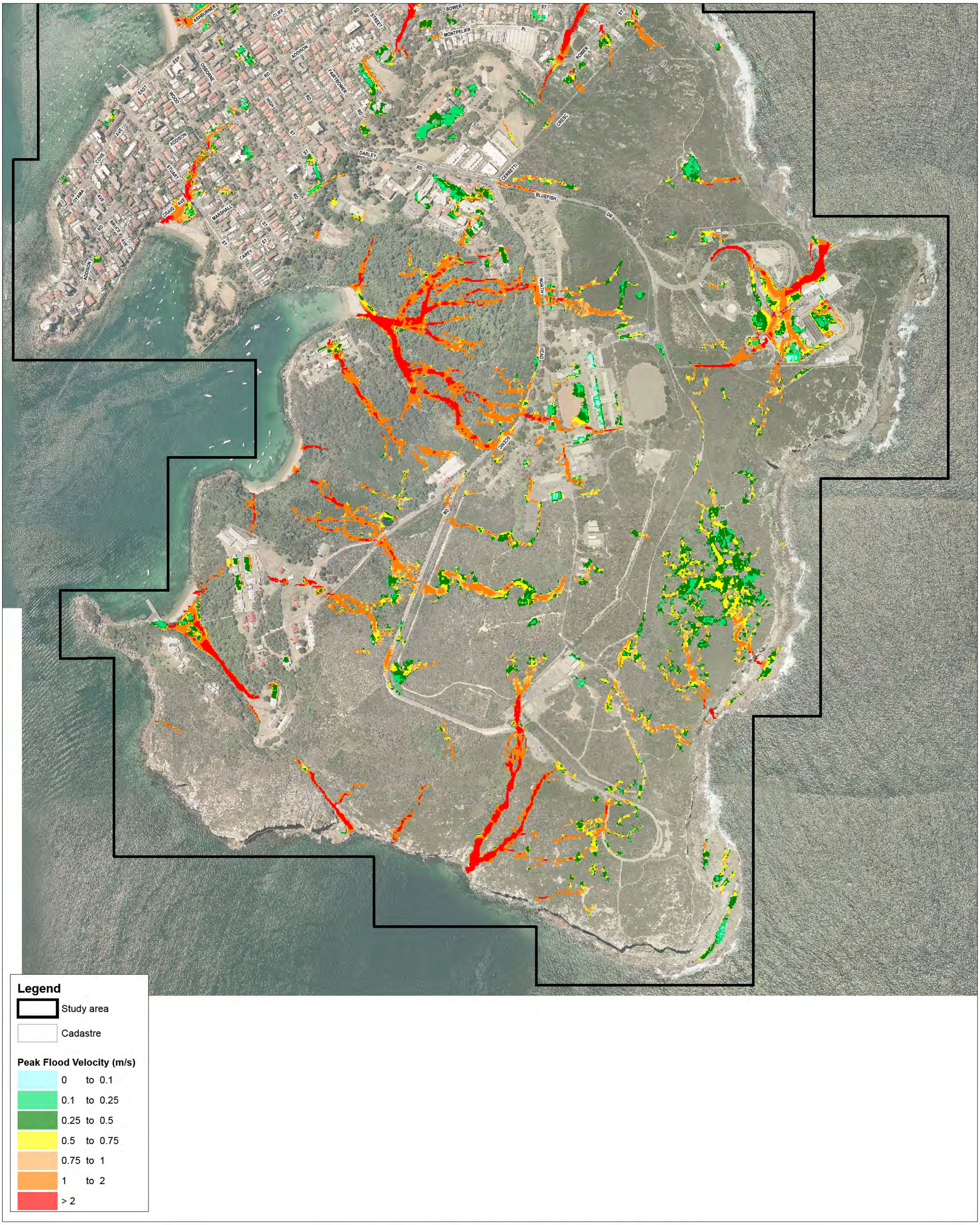
Cardno



Manly to Seaforth Flood Study
PMF Peak Flood Velocity
Map 3/4

Cardno

Figure 39



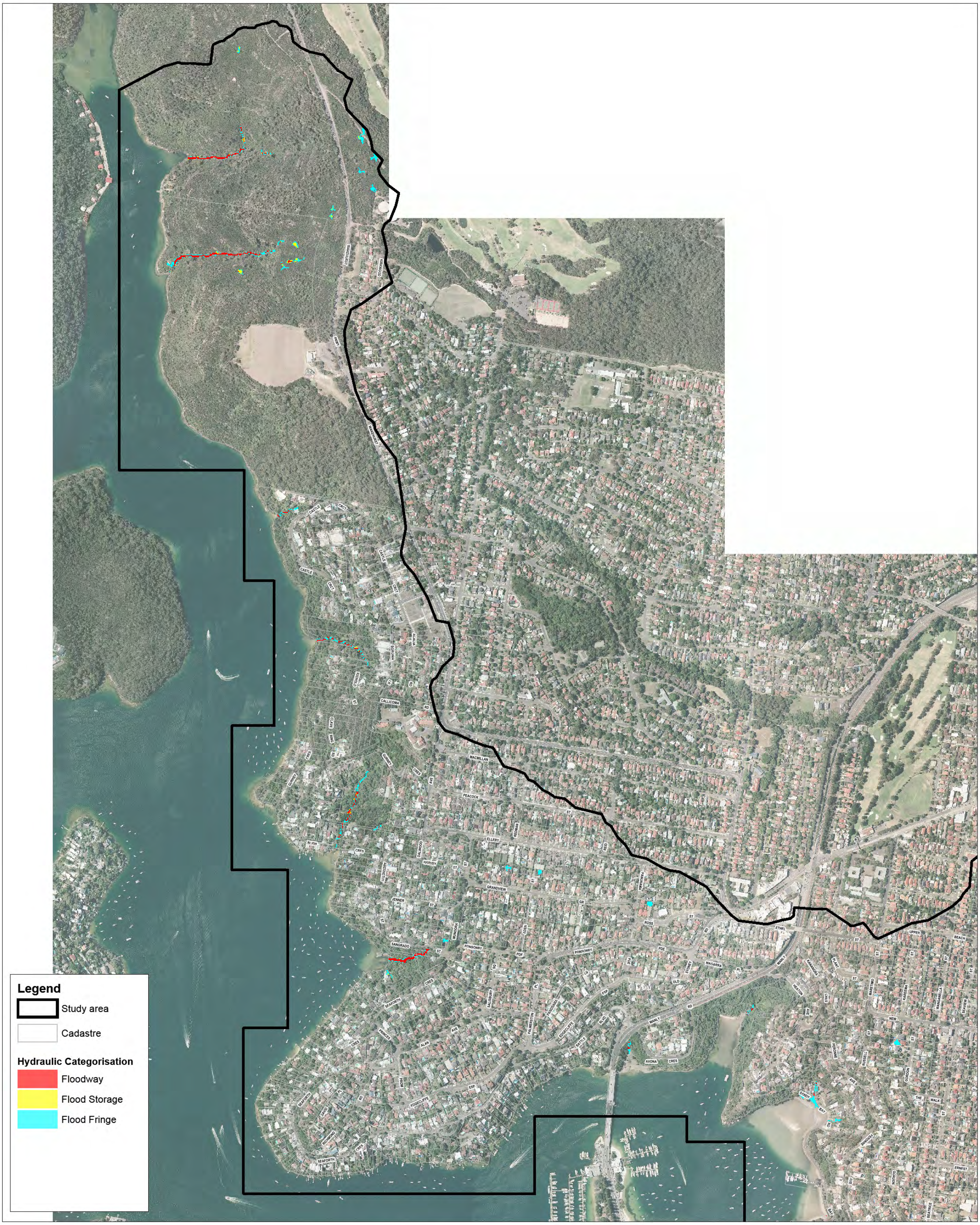
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
PMF Peak Flood Velocity
Map 4/4

Figure 40

Cardno



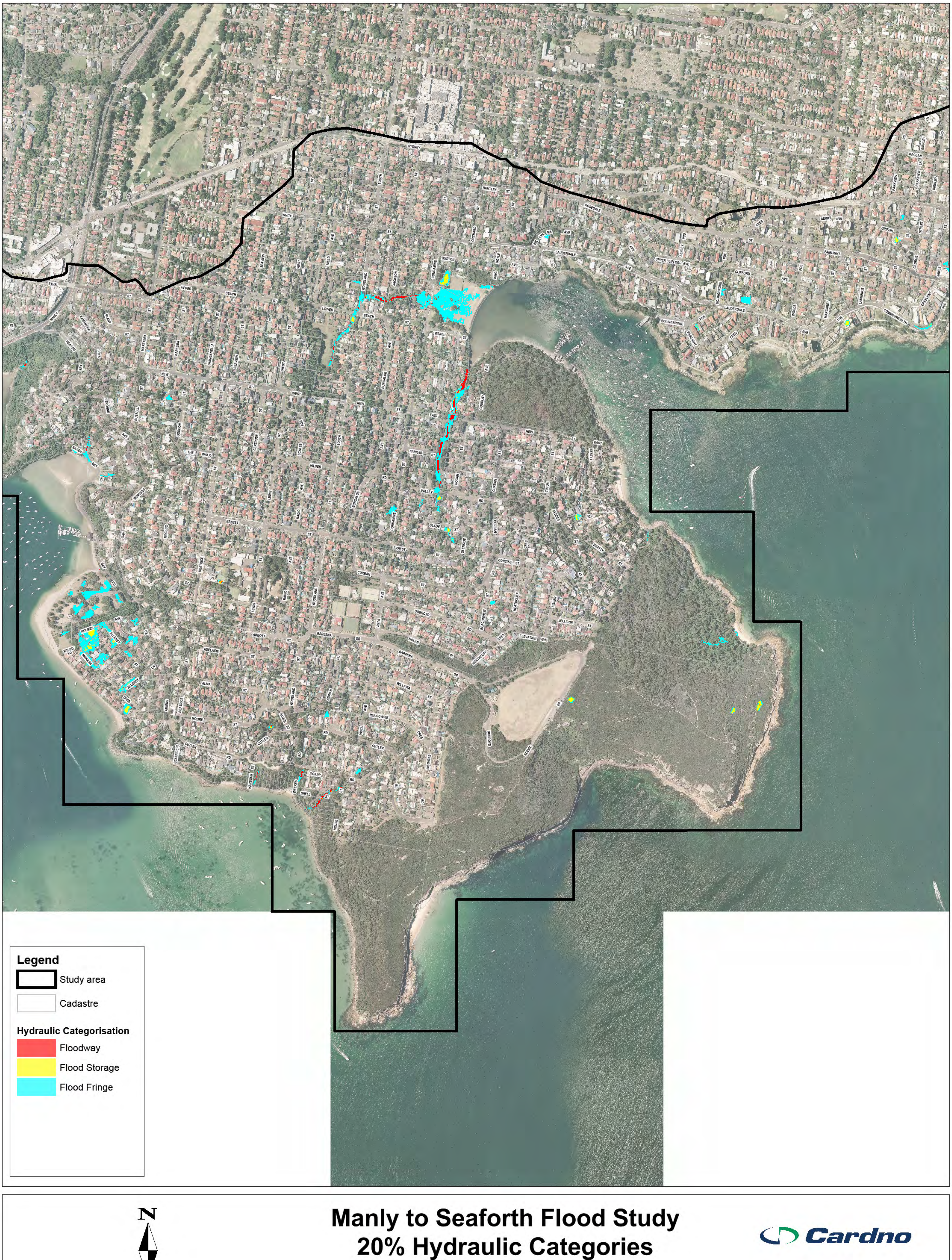
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
20% Hydraulic Categories
Map 1/4

Figure 41

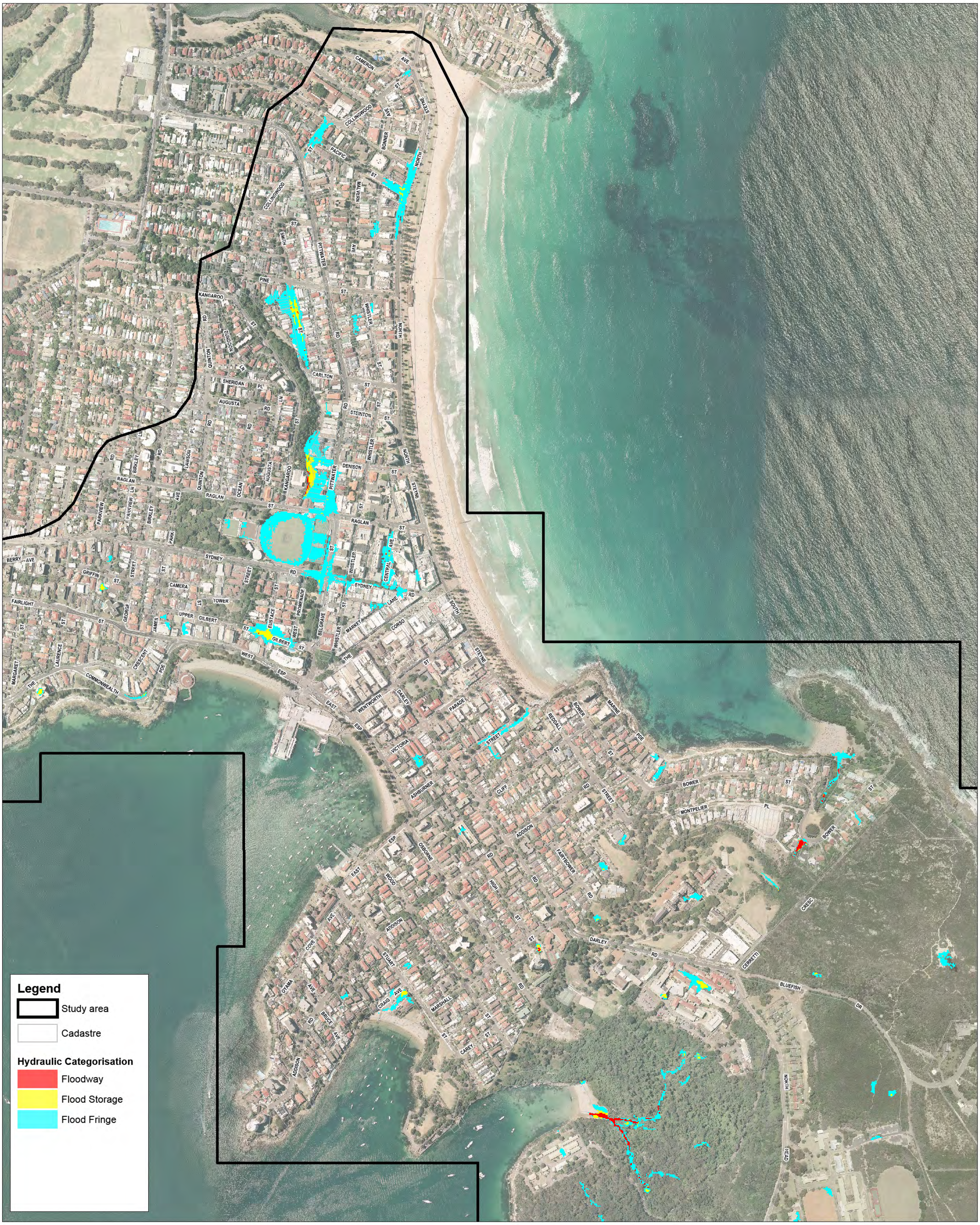
Cardno



Manly to Seaforth Flood Study
20% Hydraulic Categories
Map 2/4

Figure 42

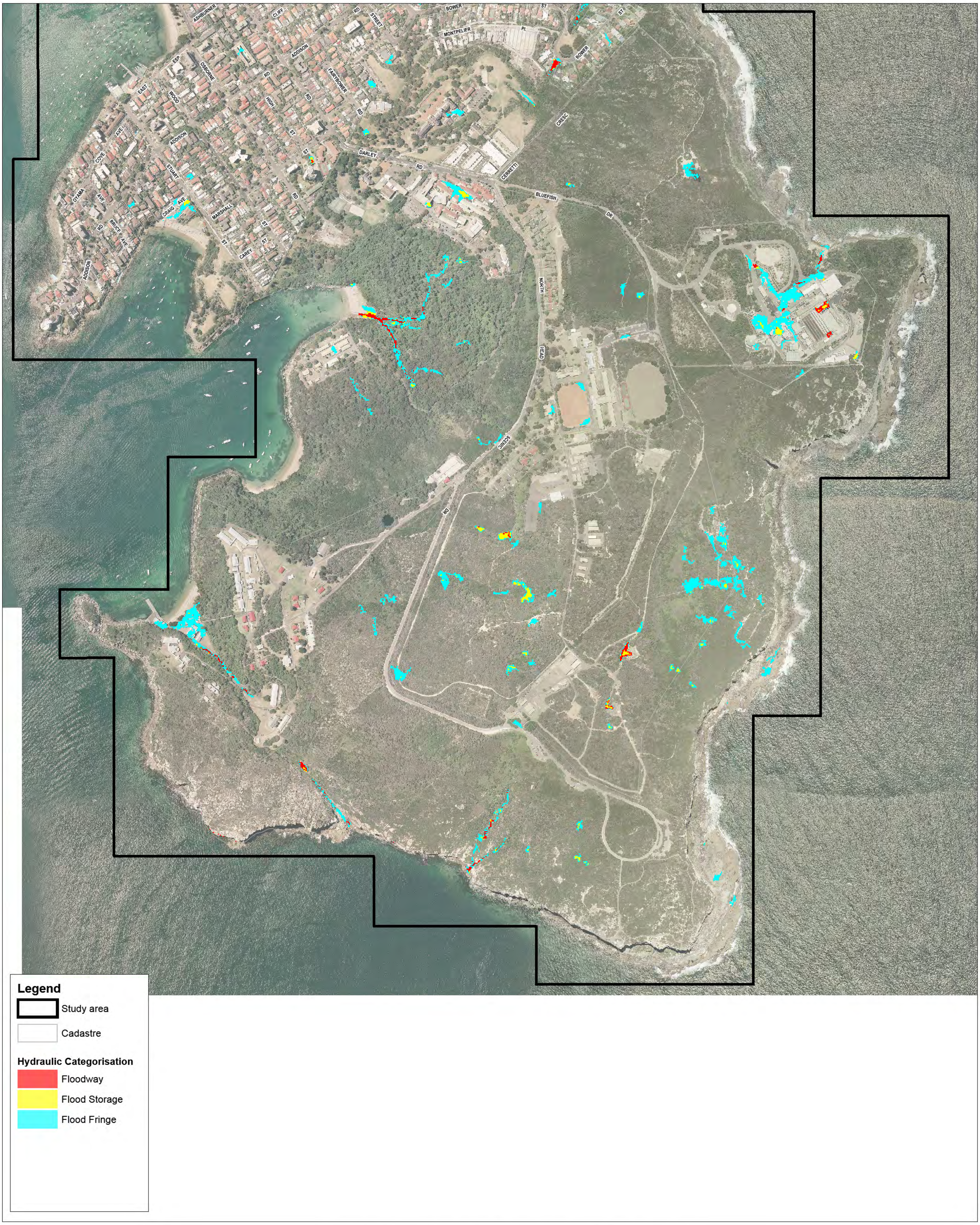
Cardno



Manly to Seaforth Flood Study
20% Hydraulic Categories
Map 3/4

Cardno

Figure 43



N

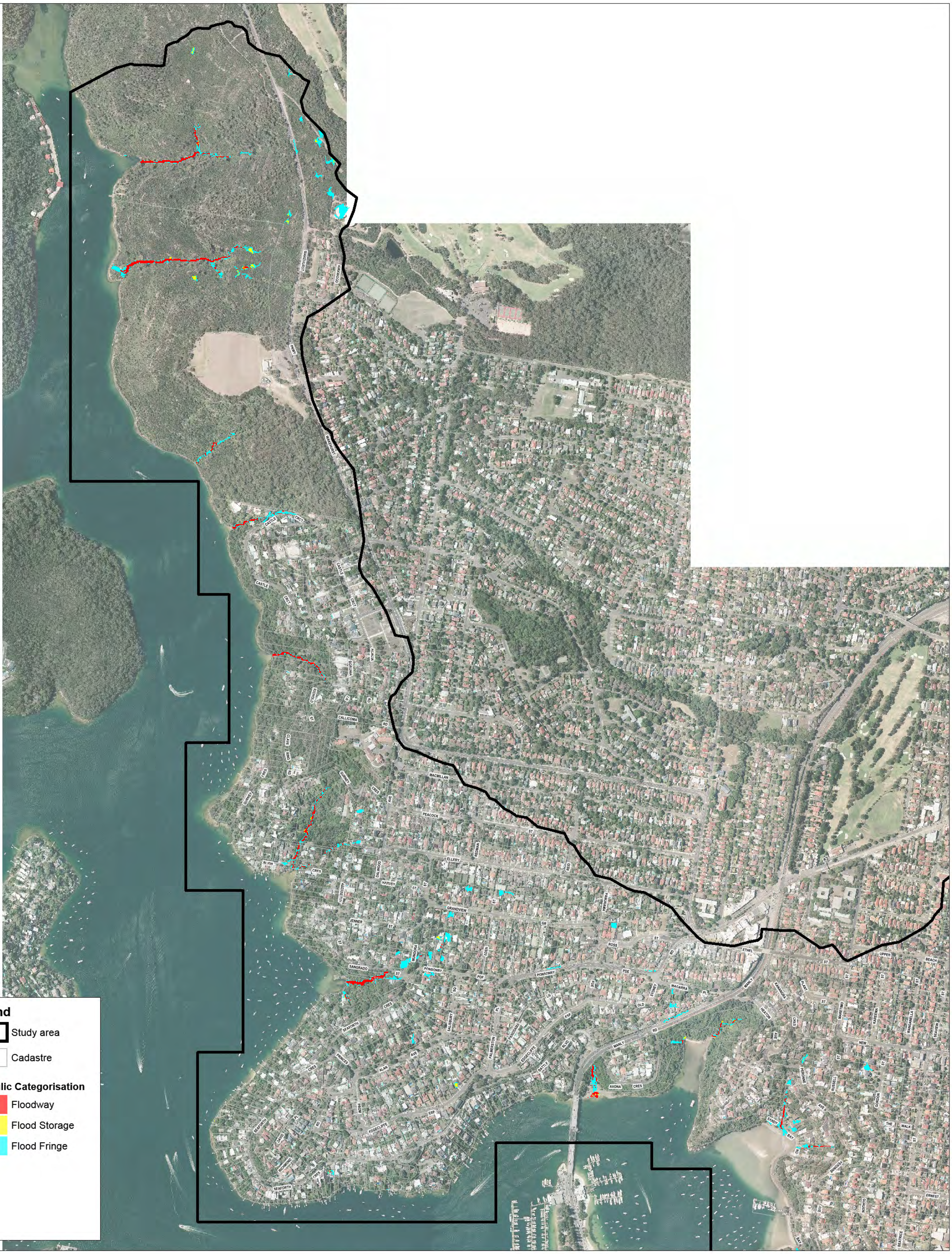
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
20% Hydraulic Categories
Map 4/4

Figure 44

Cardno



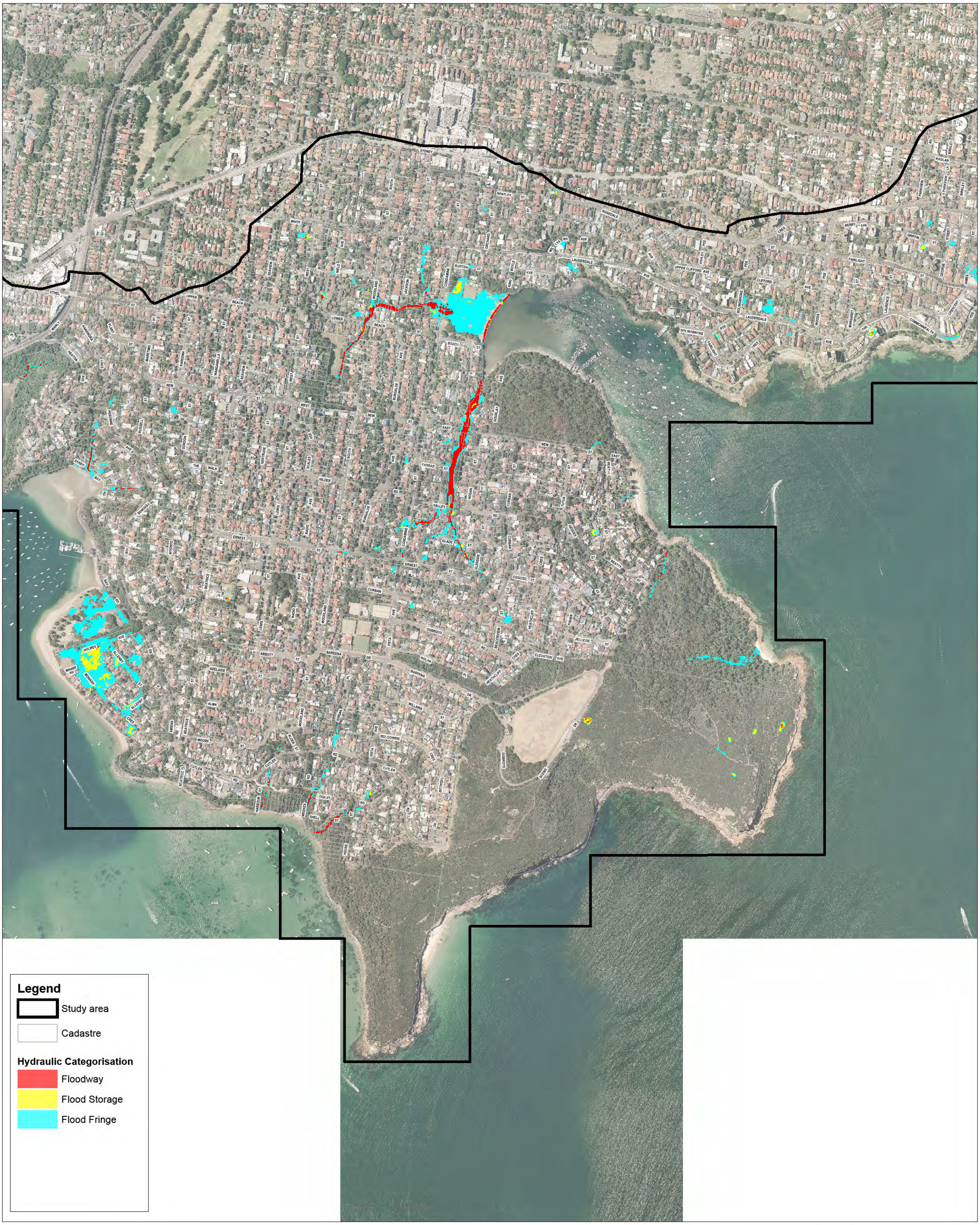
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
1% Hydraulic Categories
Map 1/4

Figure 45

Cardno



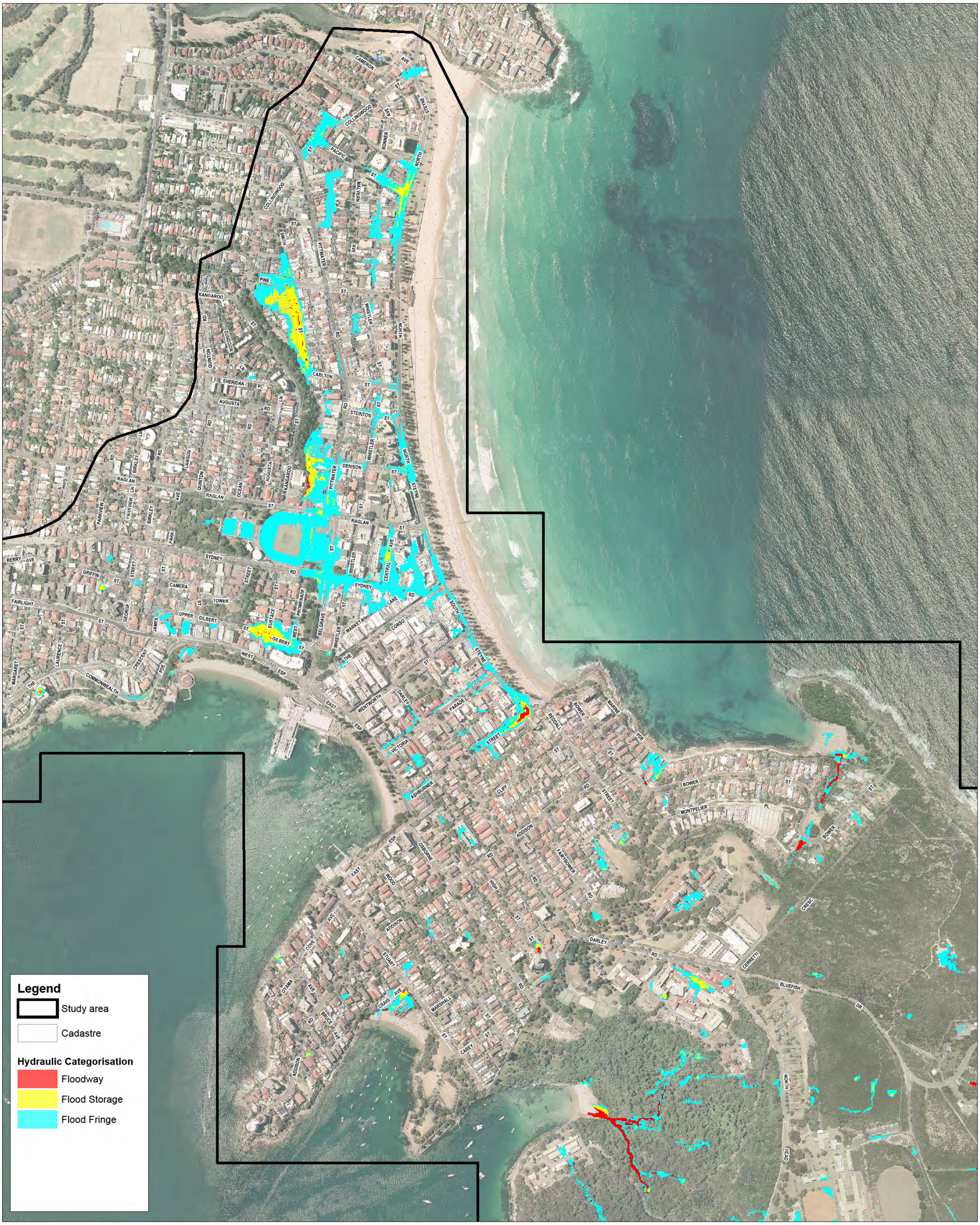
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
1% Hydraulic Categories
Map 2/4

Figure 46

Cardno



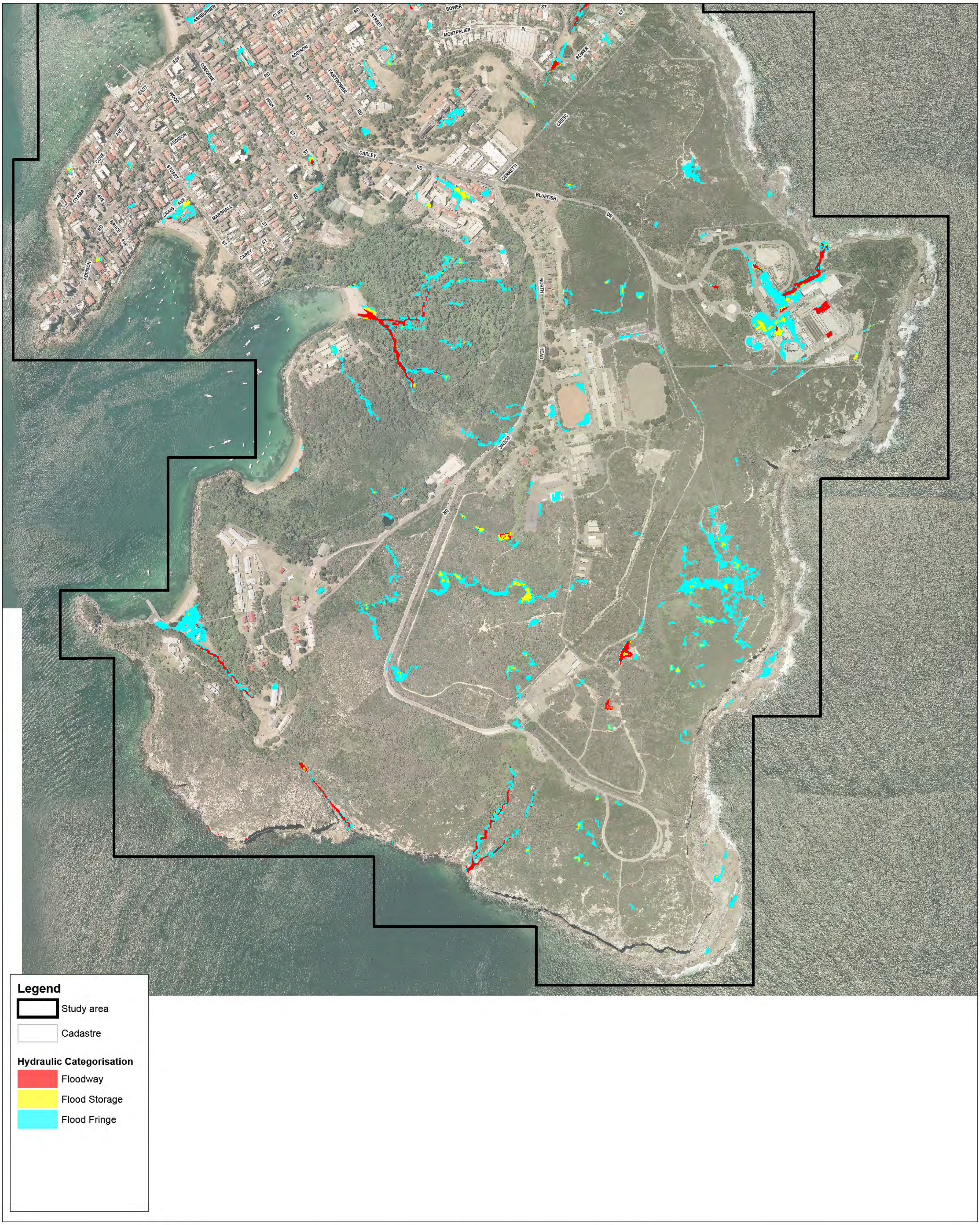
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
1% Hydraulic Categories
Map 3/4

Figure 47

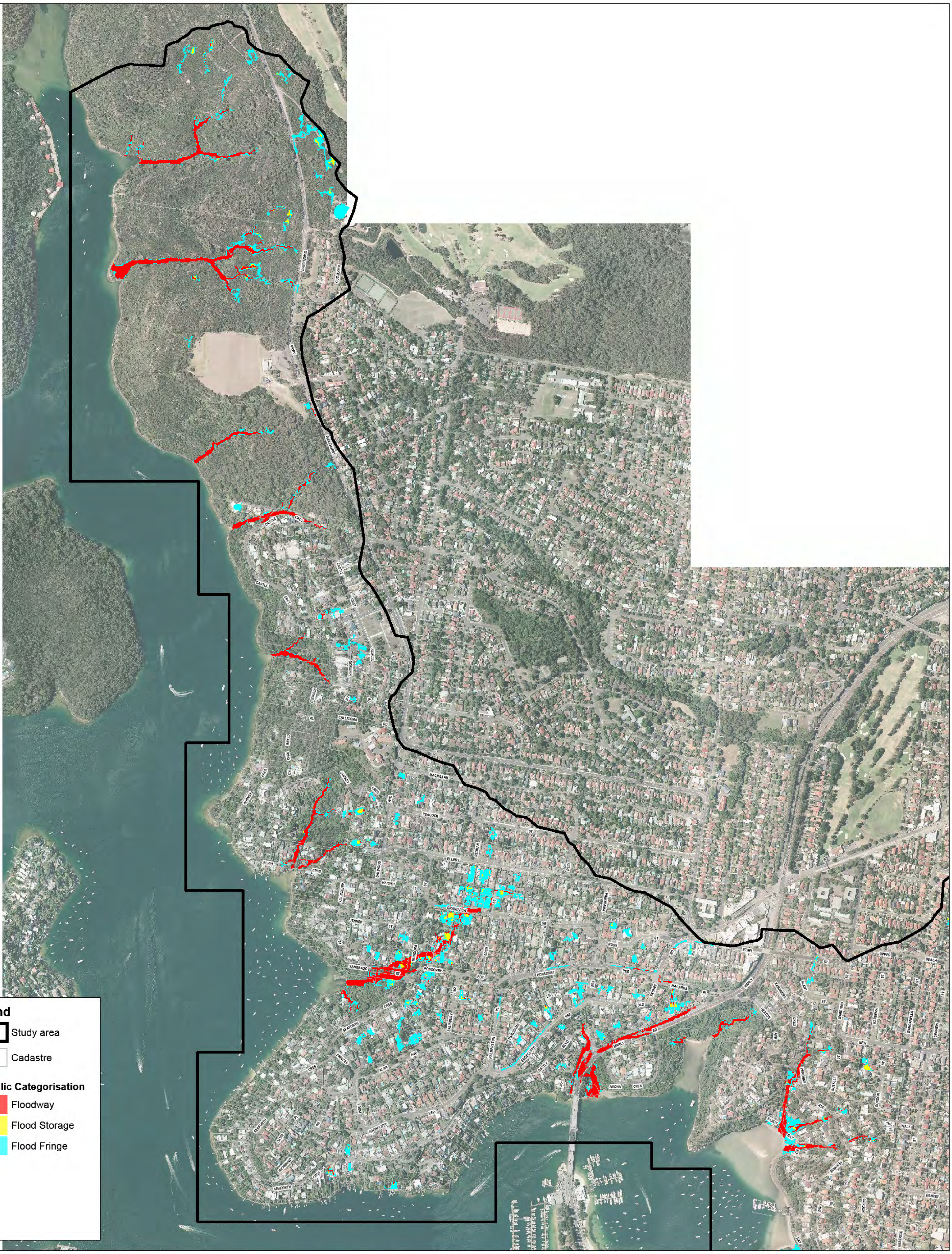
Cardno



Manly to Seaforth Flood Study
1% Hydraulic Categories
Map 4/4

Figure 48

Cardno



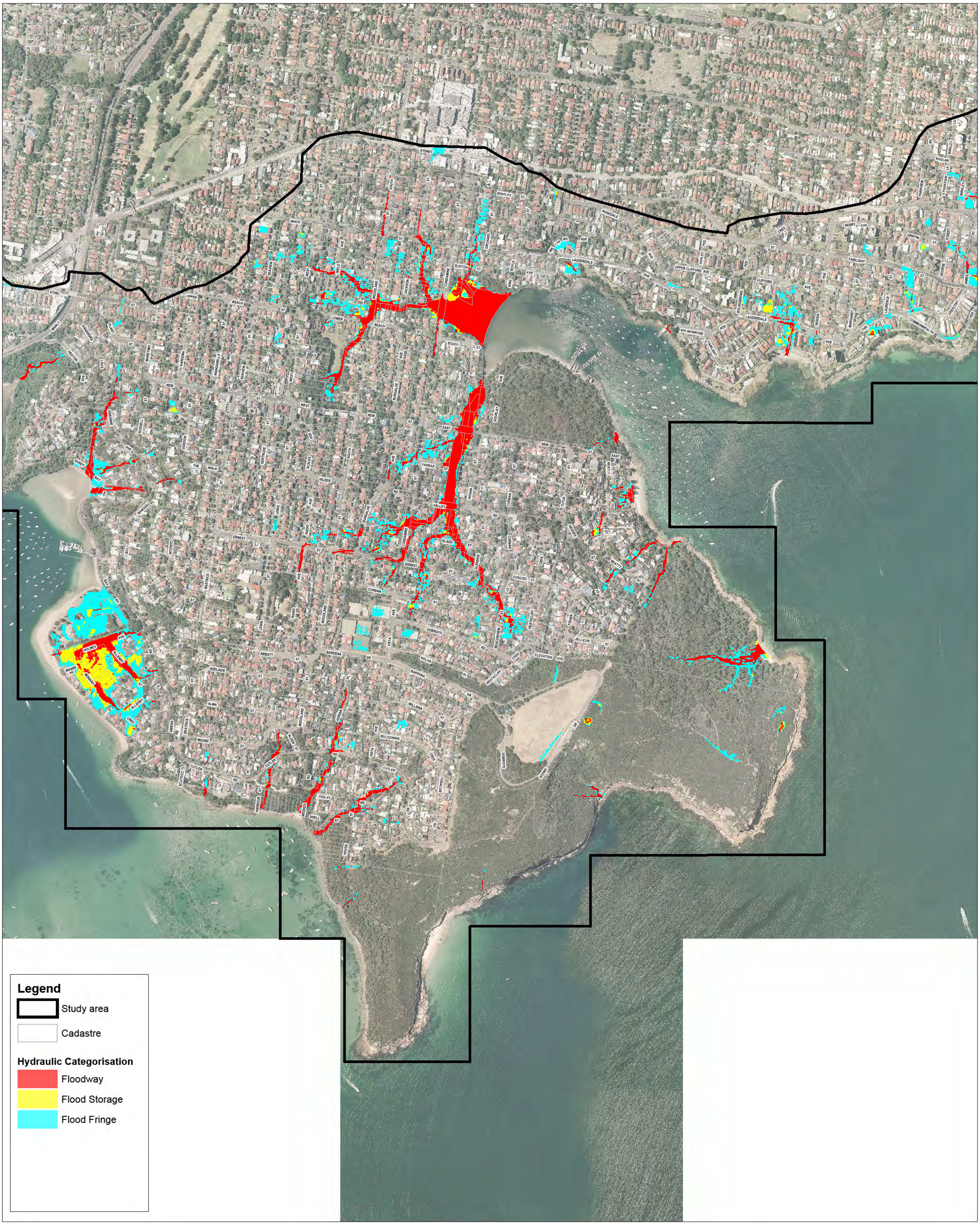
N

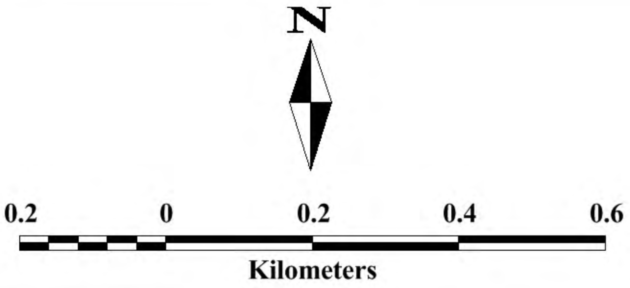
0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
PMF Hydraulic Categories
Map 1/4

Figure 49

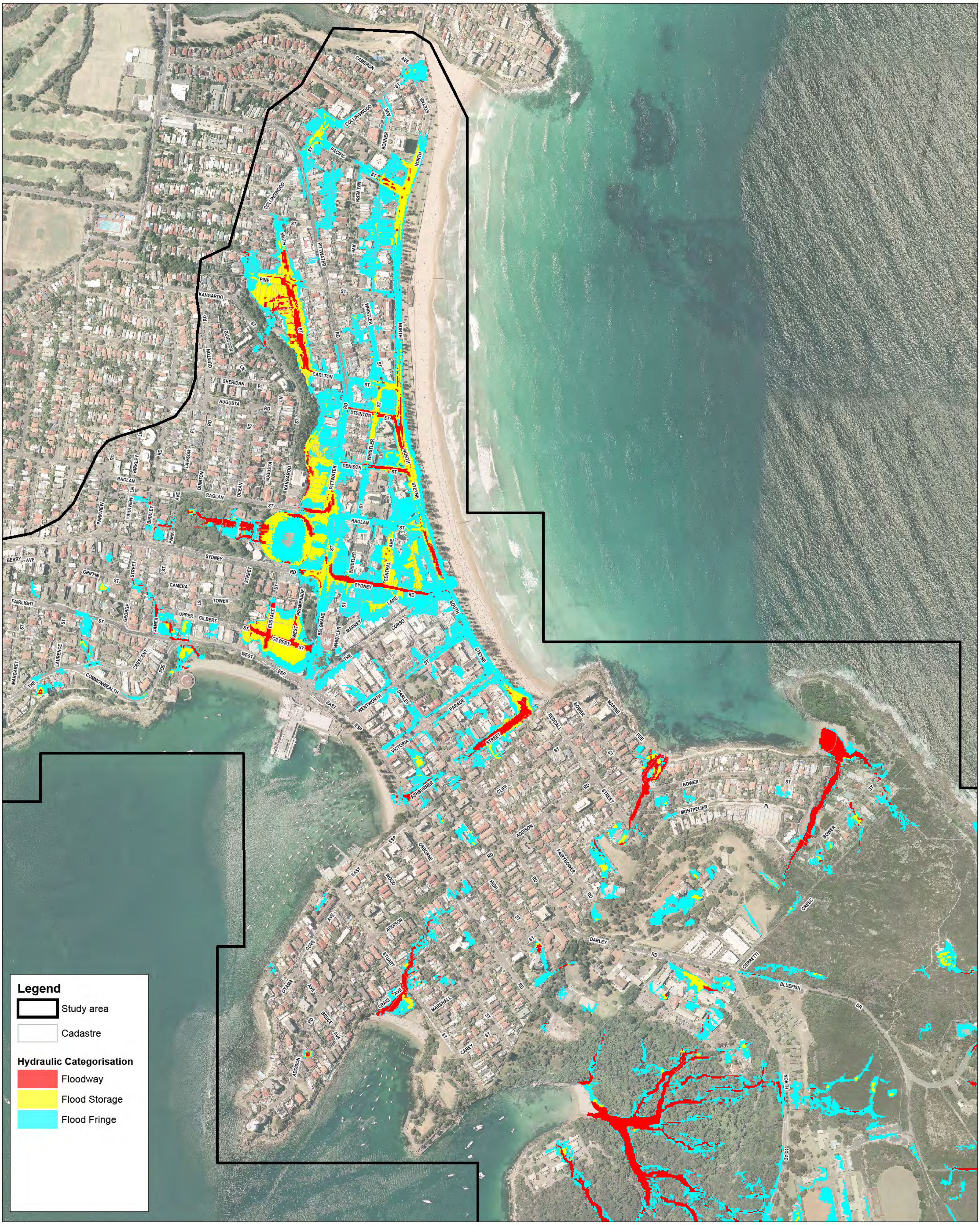
Cardno





Manly to Seaforth Flood Study
PMF Hydraulic Categories
Map 2/4

Figure 50



N

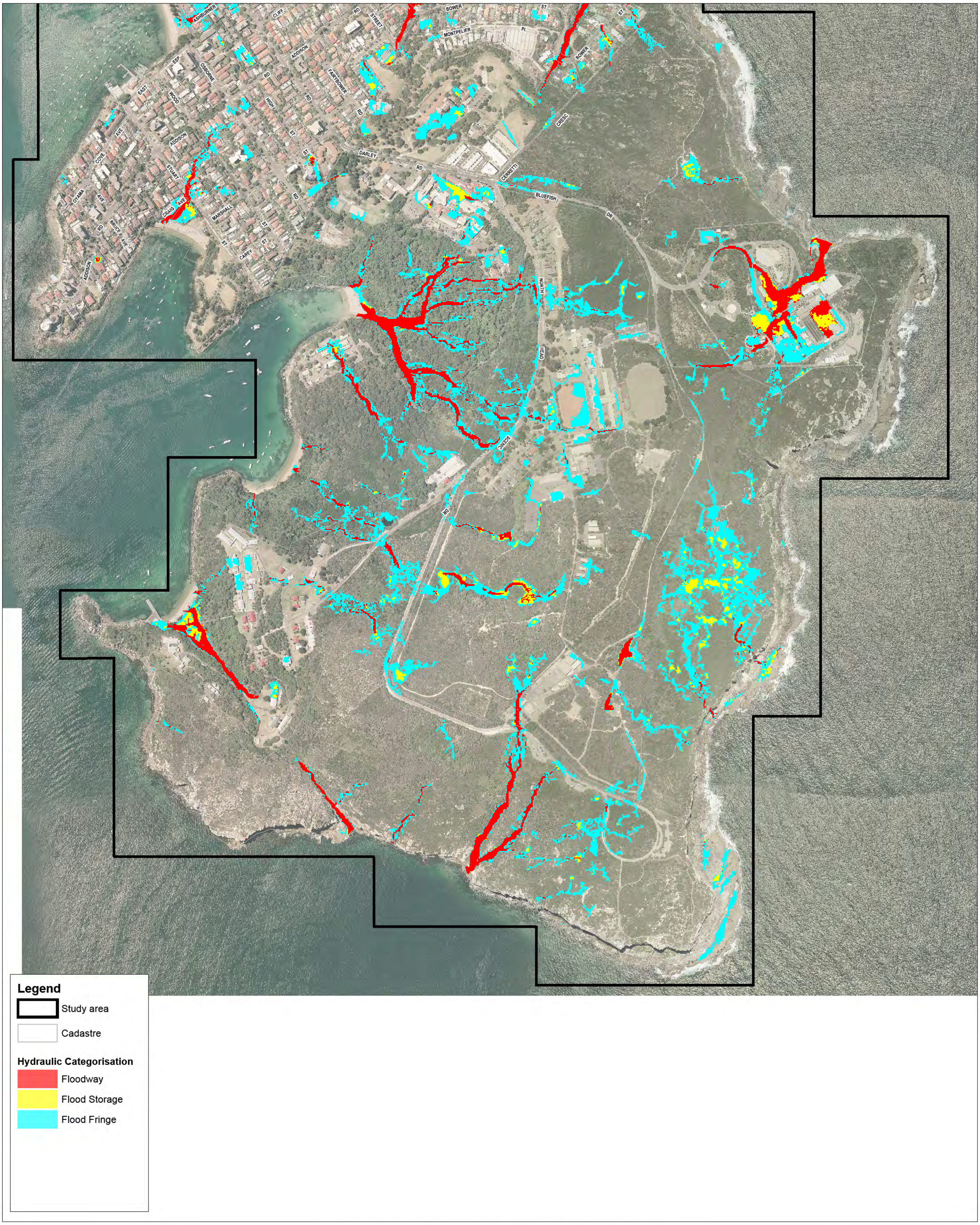
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
PMF Hydraulic Categories
Map 3/4

Figure 51

Cardno



N

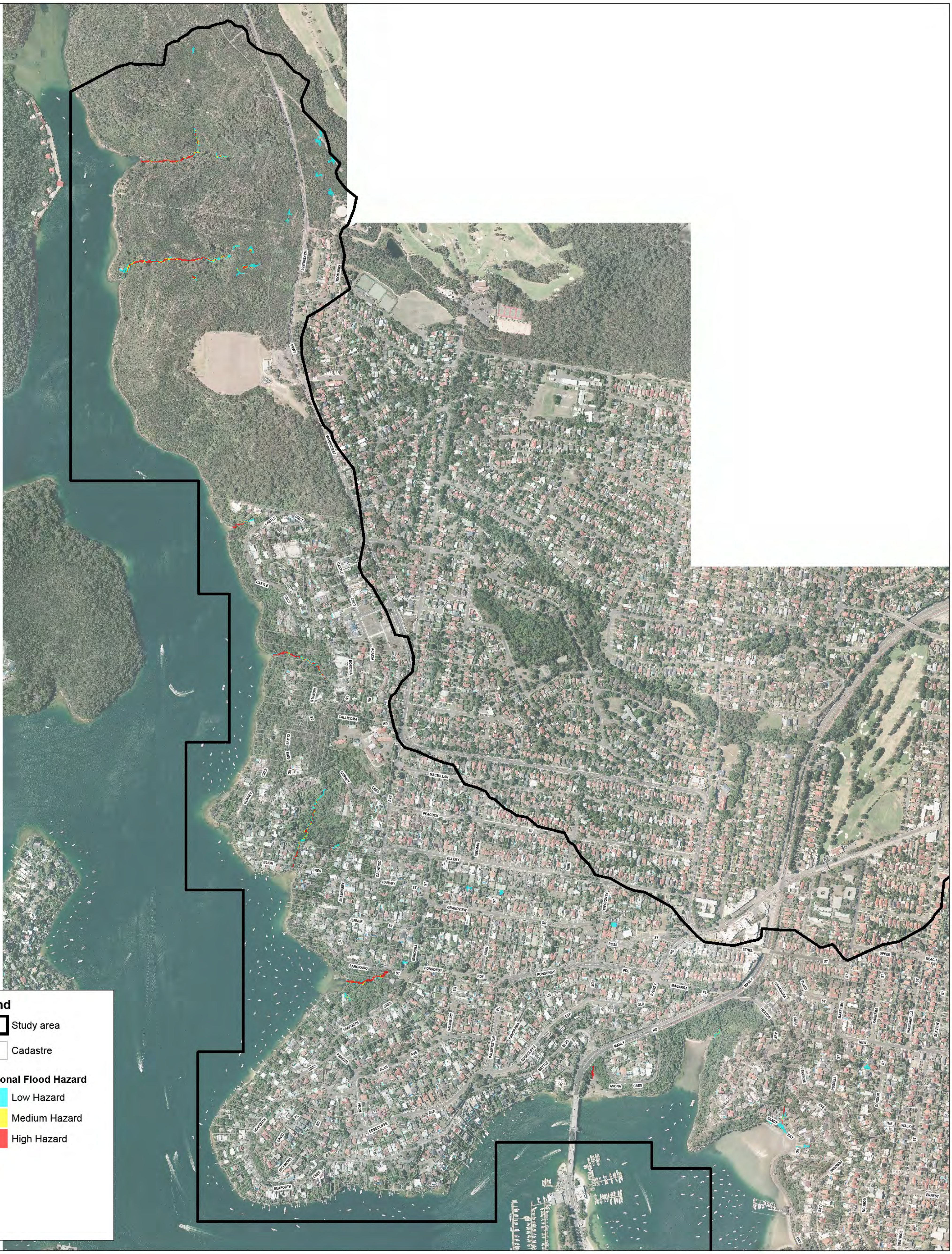
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
PMF Hydraulic Categories
Map 4/4

Figure 52

Cardno



N

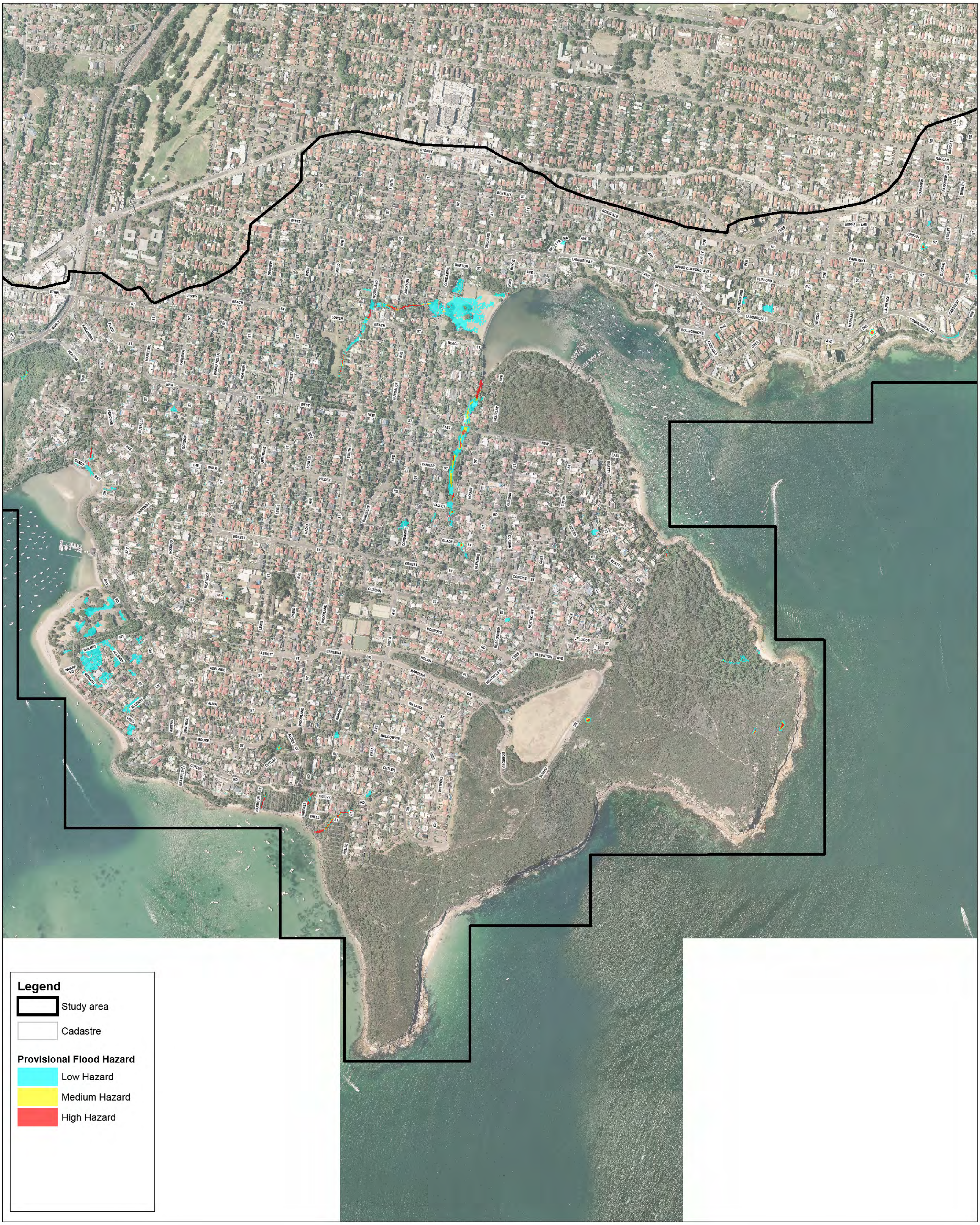
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
20% Provisional Flood Hazard
Map 1/4

Figure 53

Cardno



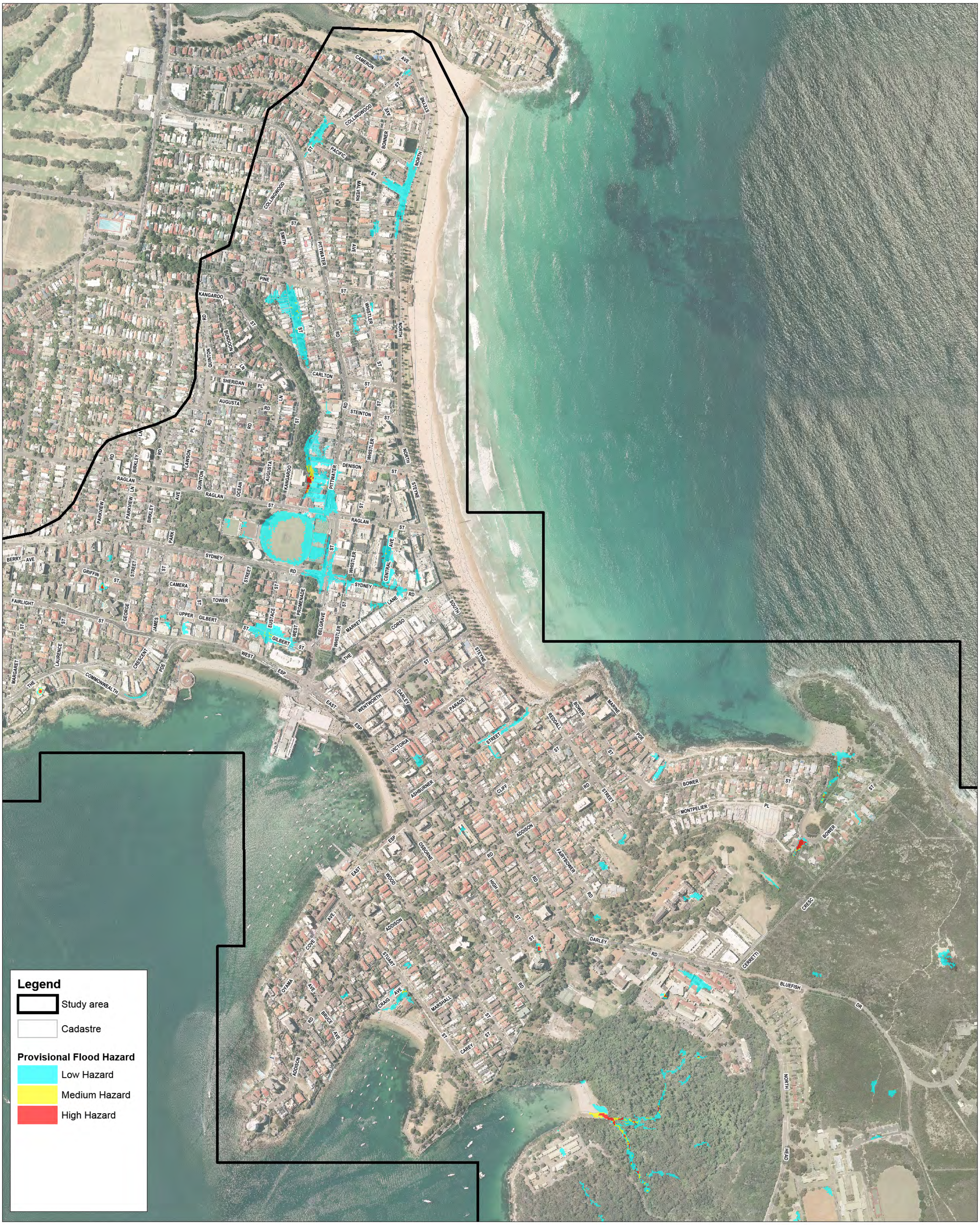
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
20% Provisional Flood Hazard
Map 2/4

Figure 54

Cardno



N

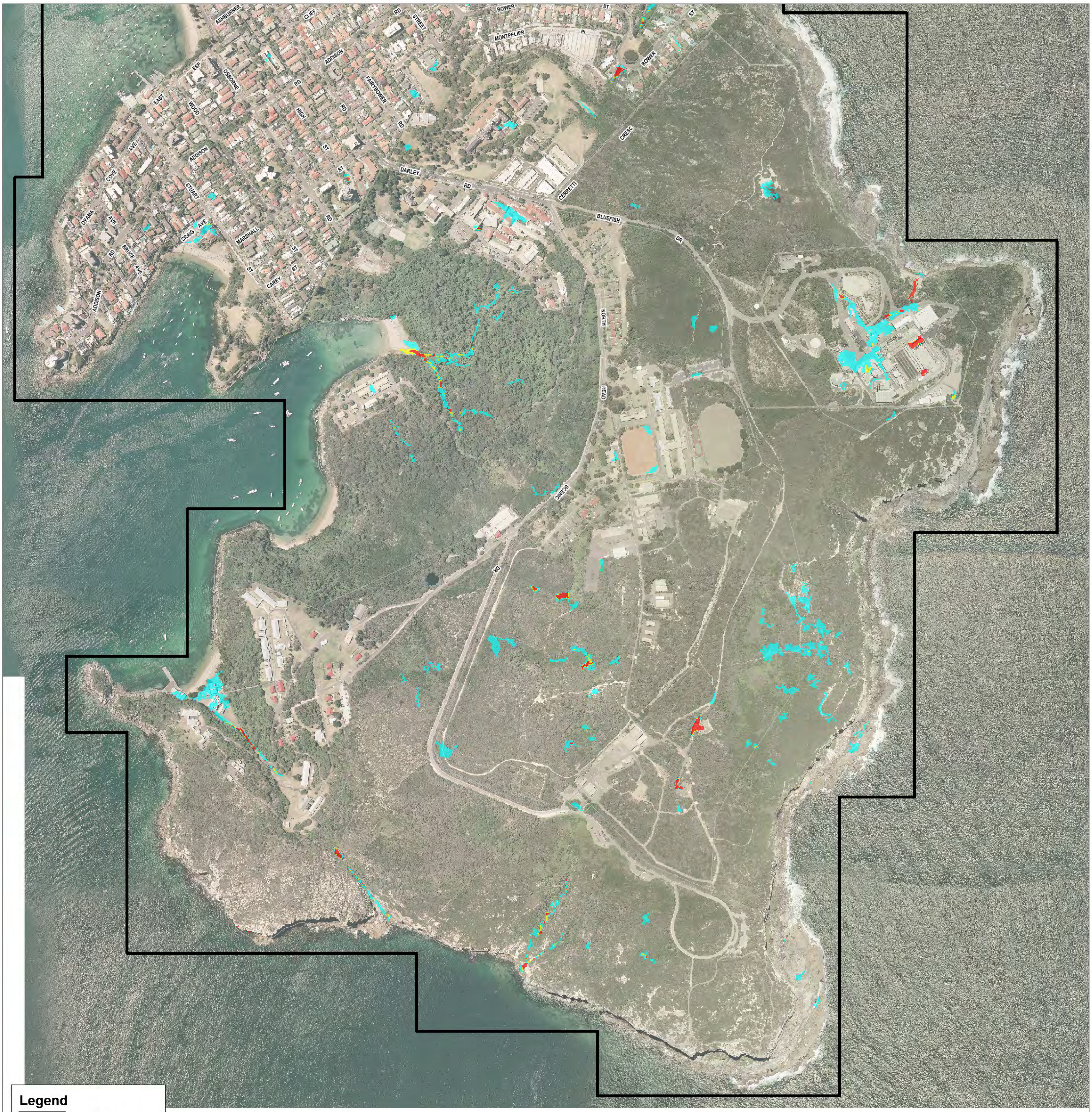
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
20% Provisional Flood Hazard
Map 3/4

Figure 55

Cardno



Legend

Study area

Cadastre

Provisional Flood Hazard

Low Hazard

Medium Hazard

High Hazard

N

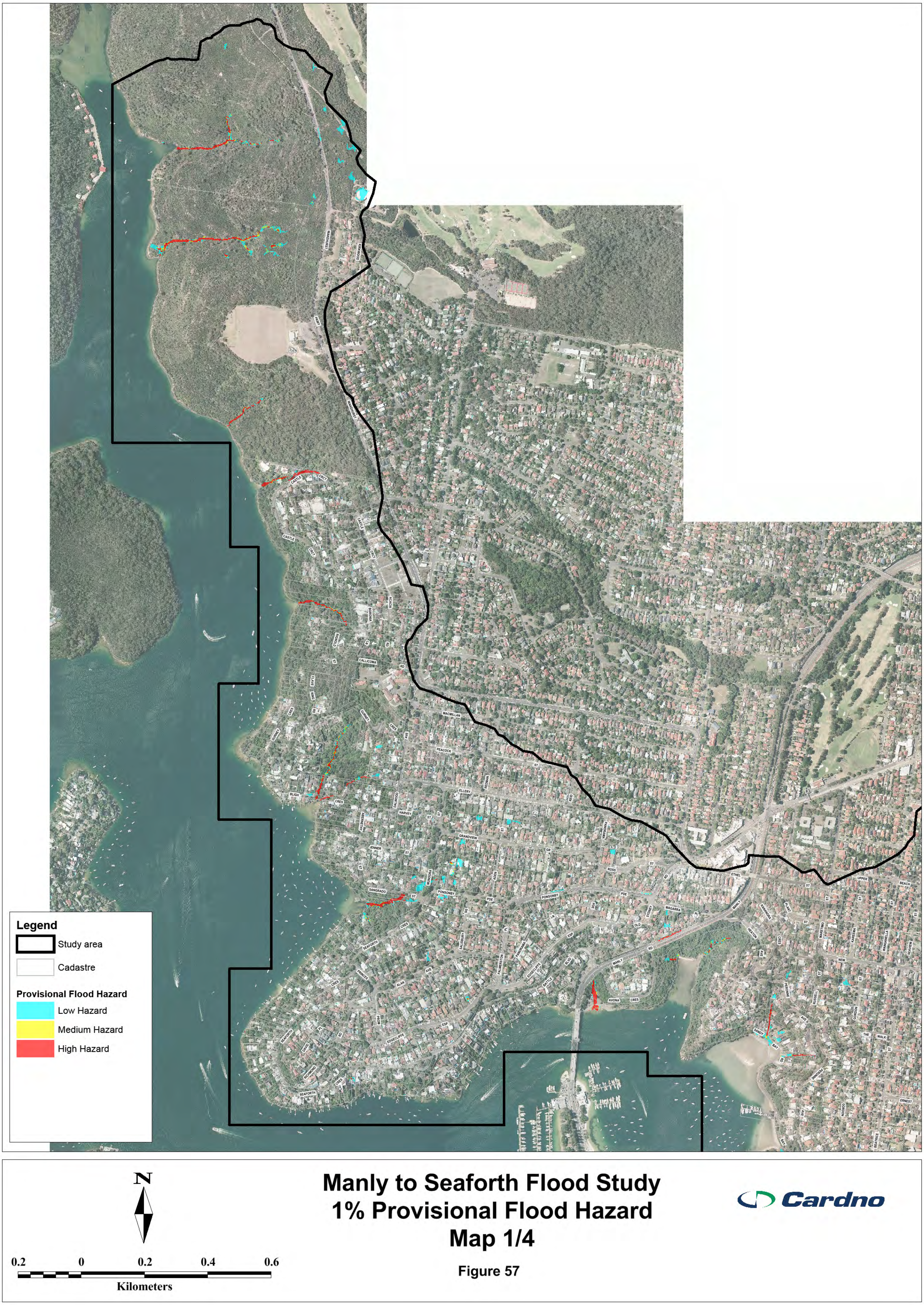
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
20% Provisional Flood Hazard
Map 4/4

Figure 56

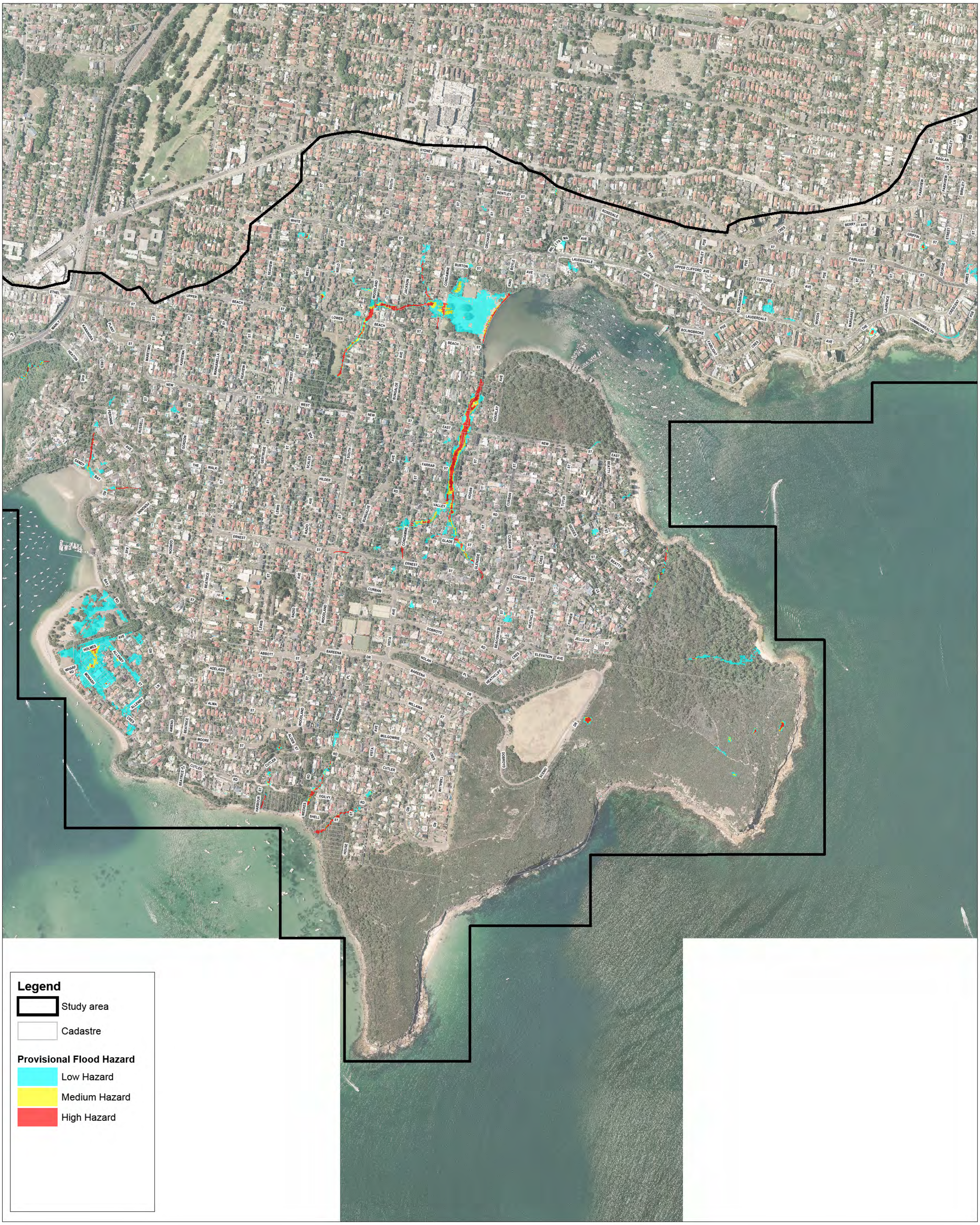
Cardno



Manly to Seaforth Flood Study
1% Provisional Flood Hazard
Map 1/4

Cardno

Figure 57



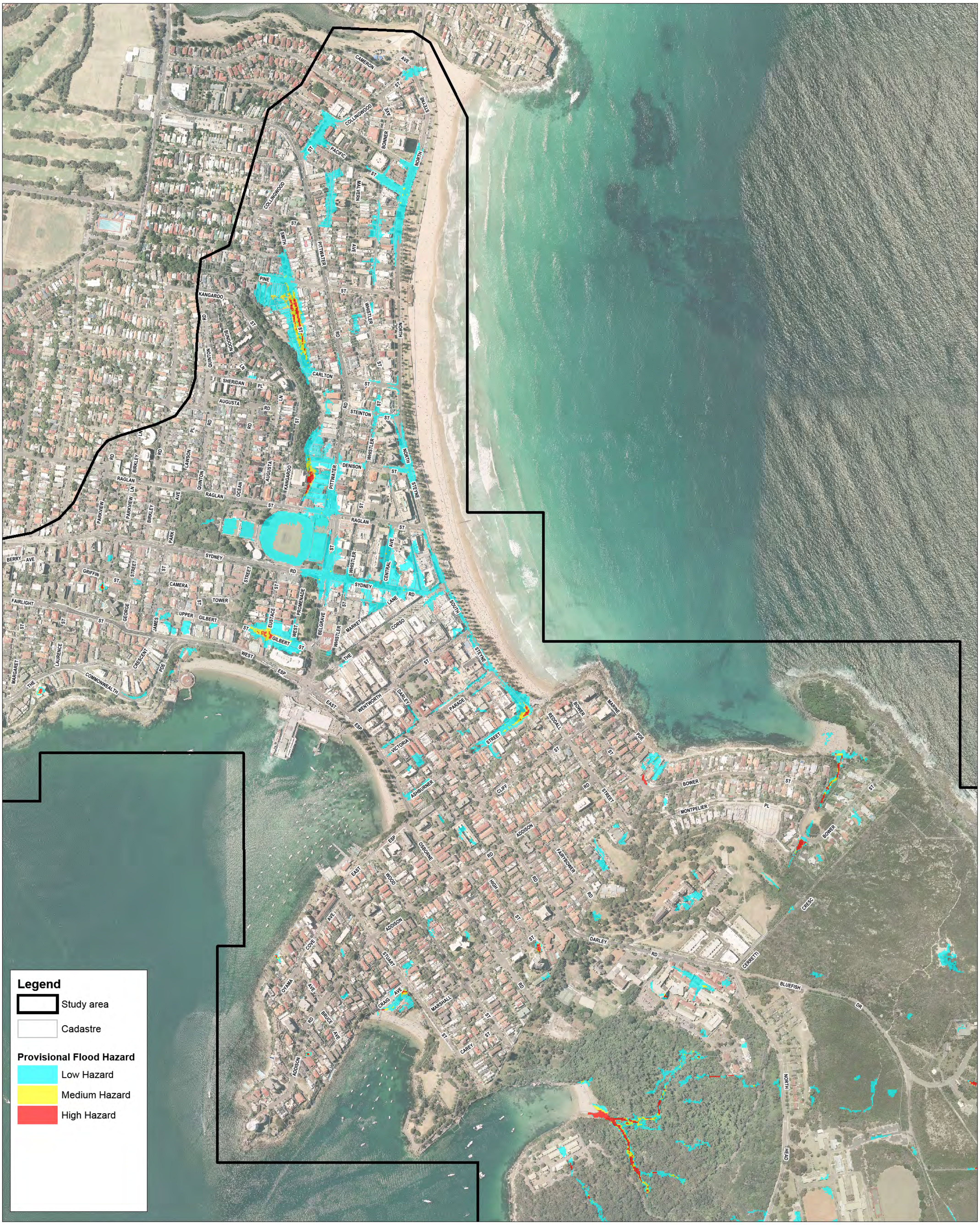
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
1% Provisional Flood Hazard
Map 2/4

Figure 58

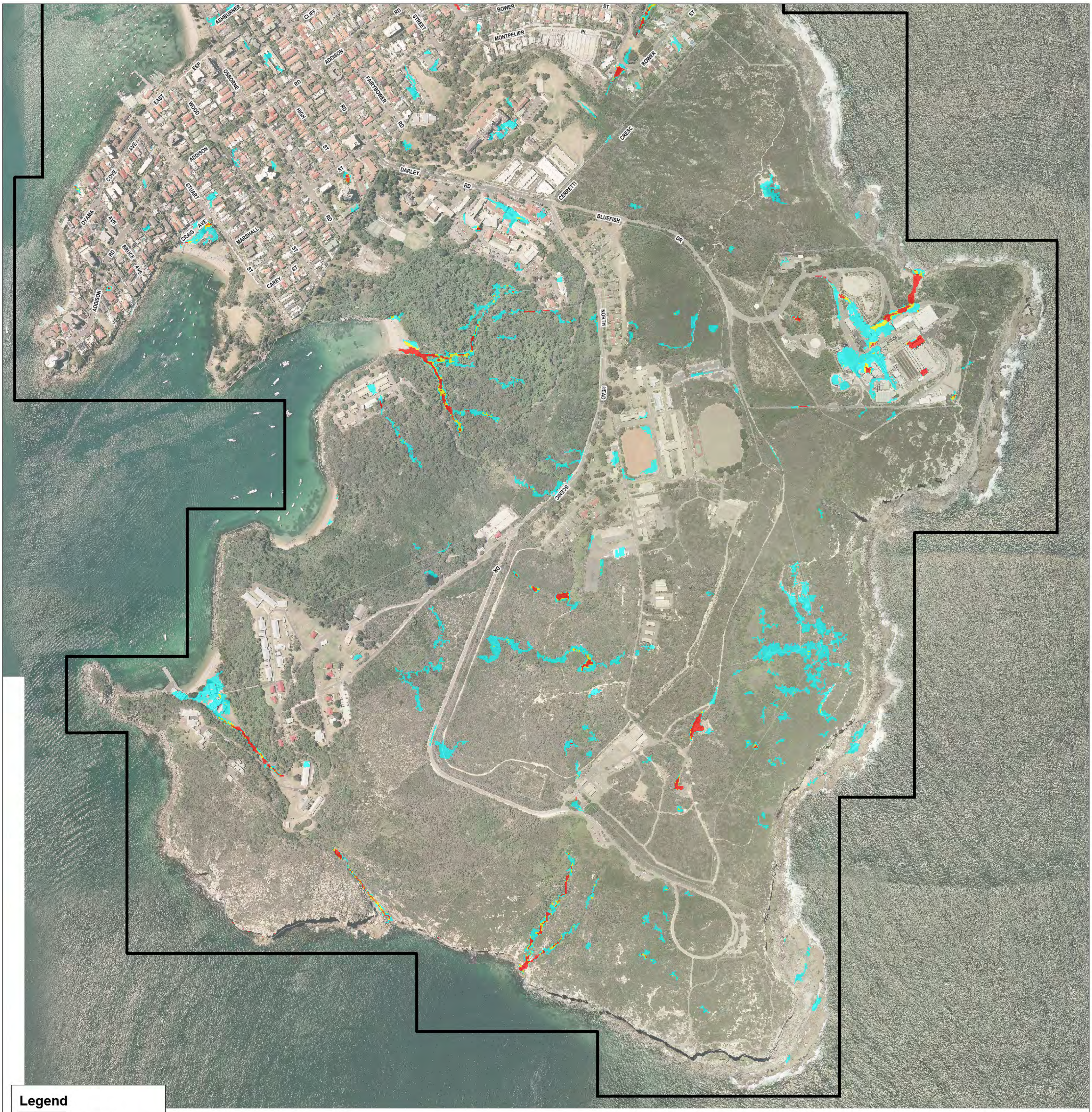
Cardno



Manly to Seaforth Flood Study
1% Provisional Flood Hazard
Map 3/4

Figure 59

Cardno



Legend

Study area

Cadastre

Provisional Flood Hazard

Low Hazard

Medium Hazard

High Hazard

N

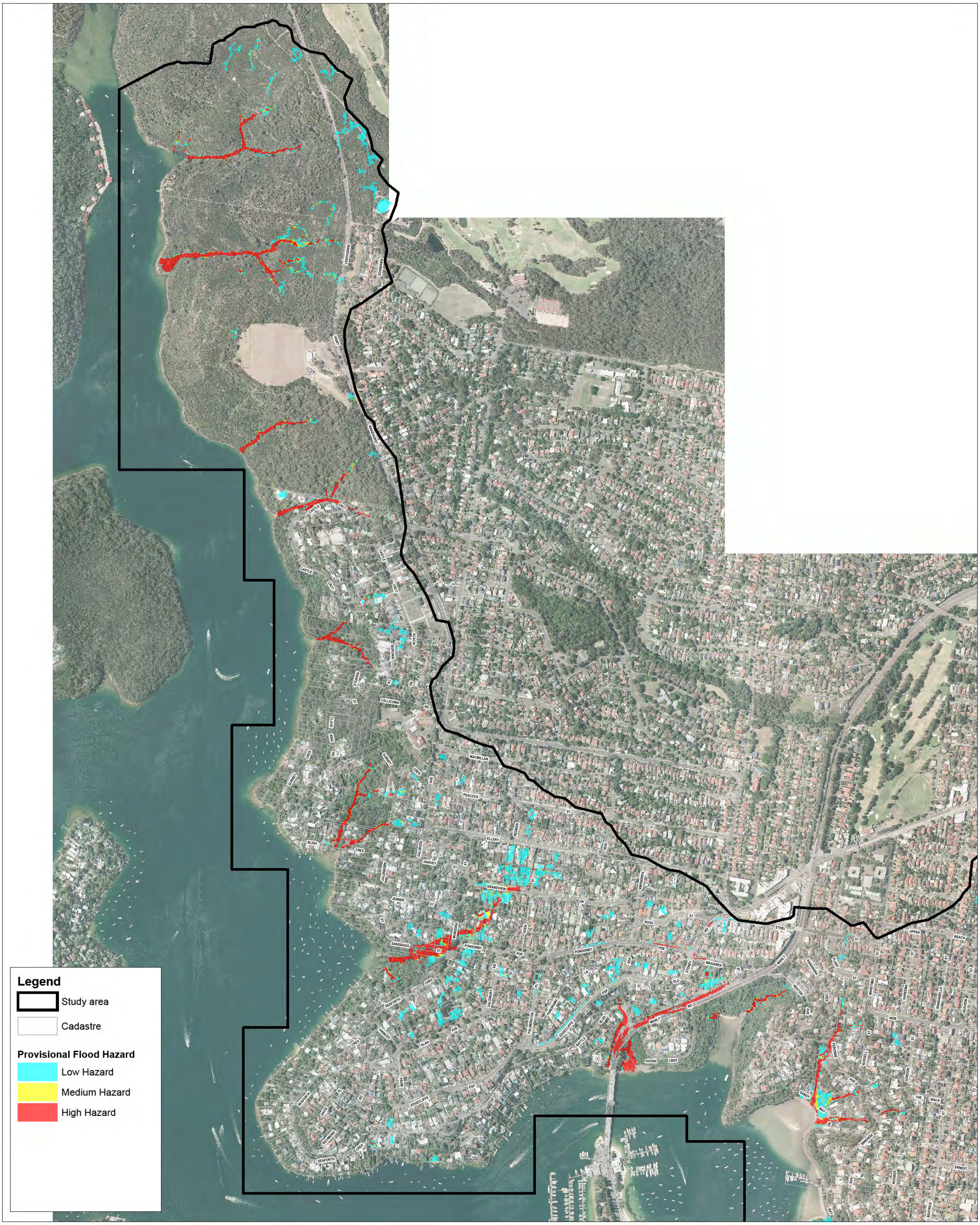
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
1% Provisional Flood Hazard
Map 4/4

Figure 60

Cardno



N

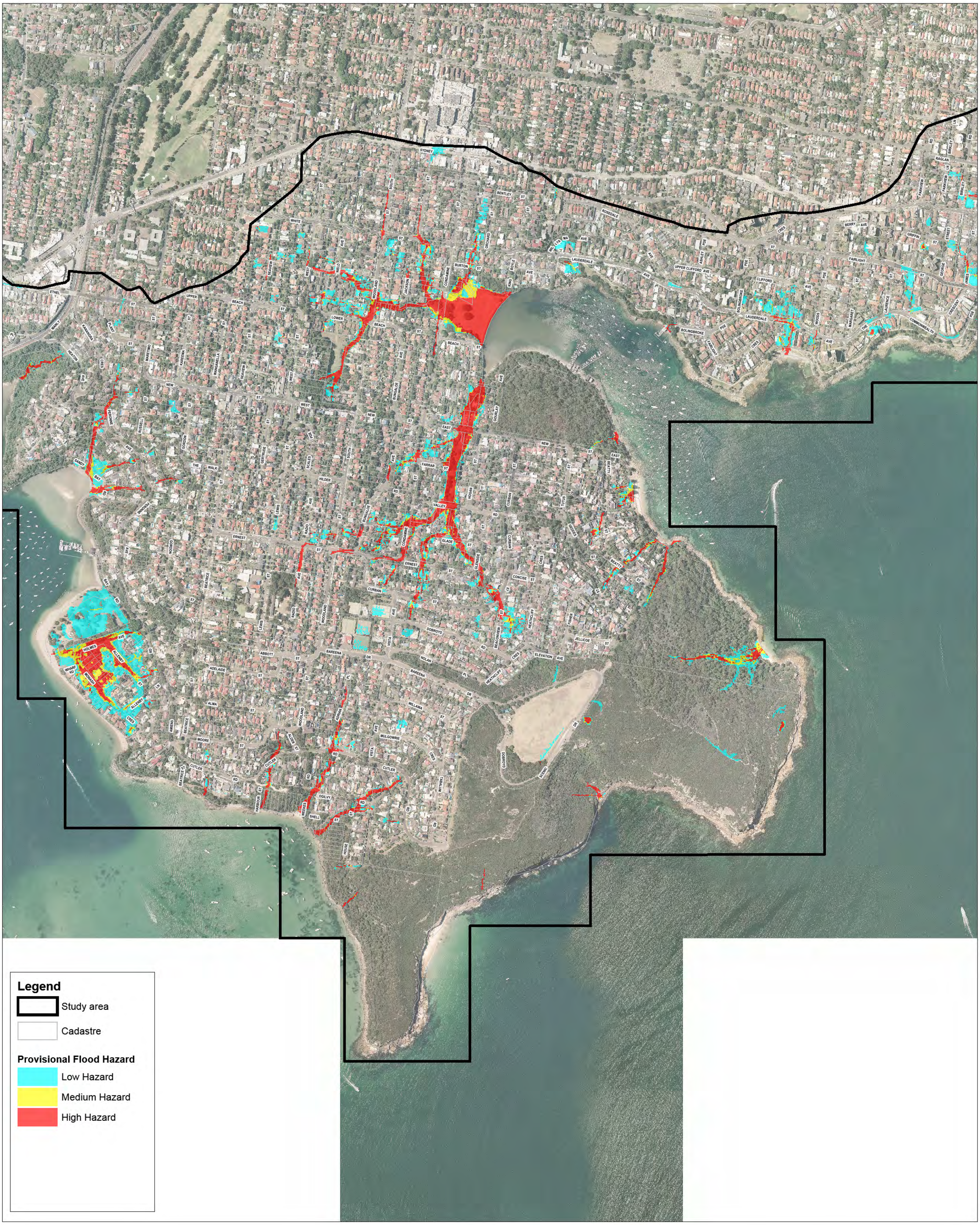
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
PMF Provisional Flood Hazard
Map 1/4

Figure 61

Cardno



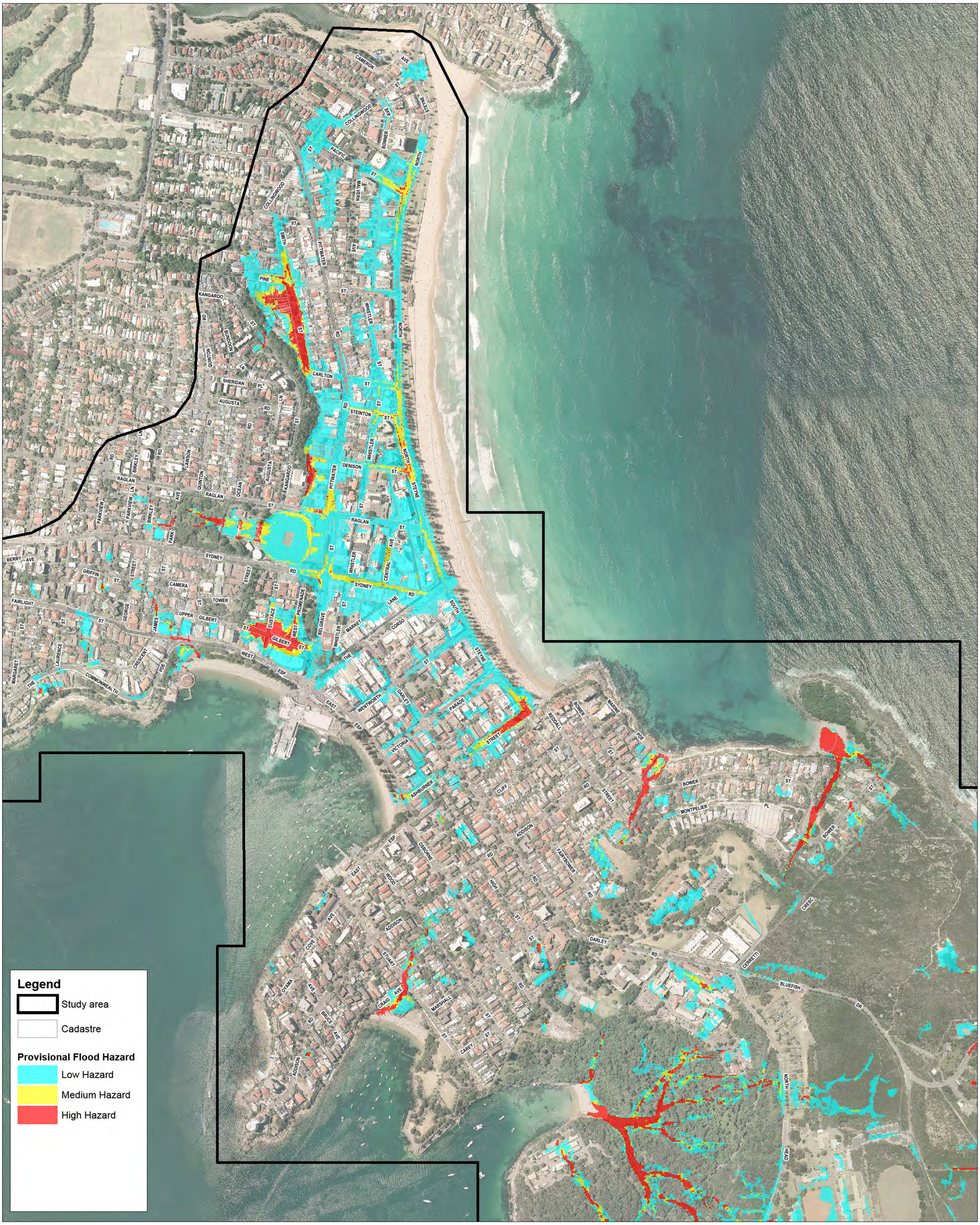
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
PMF Provisional Flood Hazard
Map 2/4

Figure 62

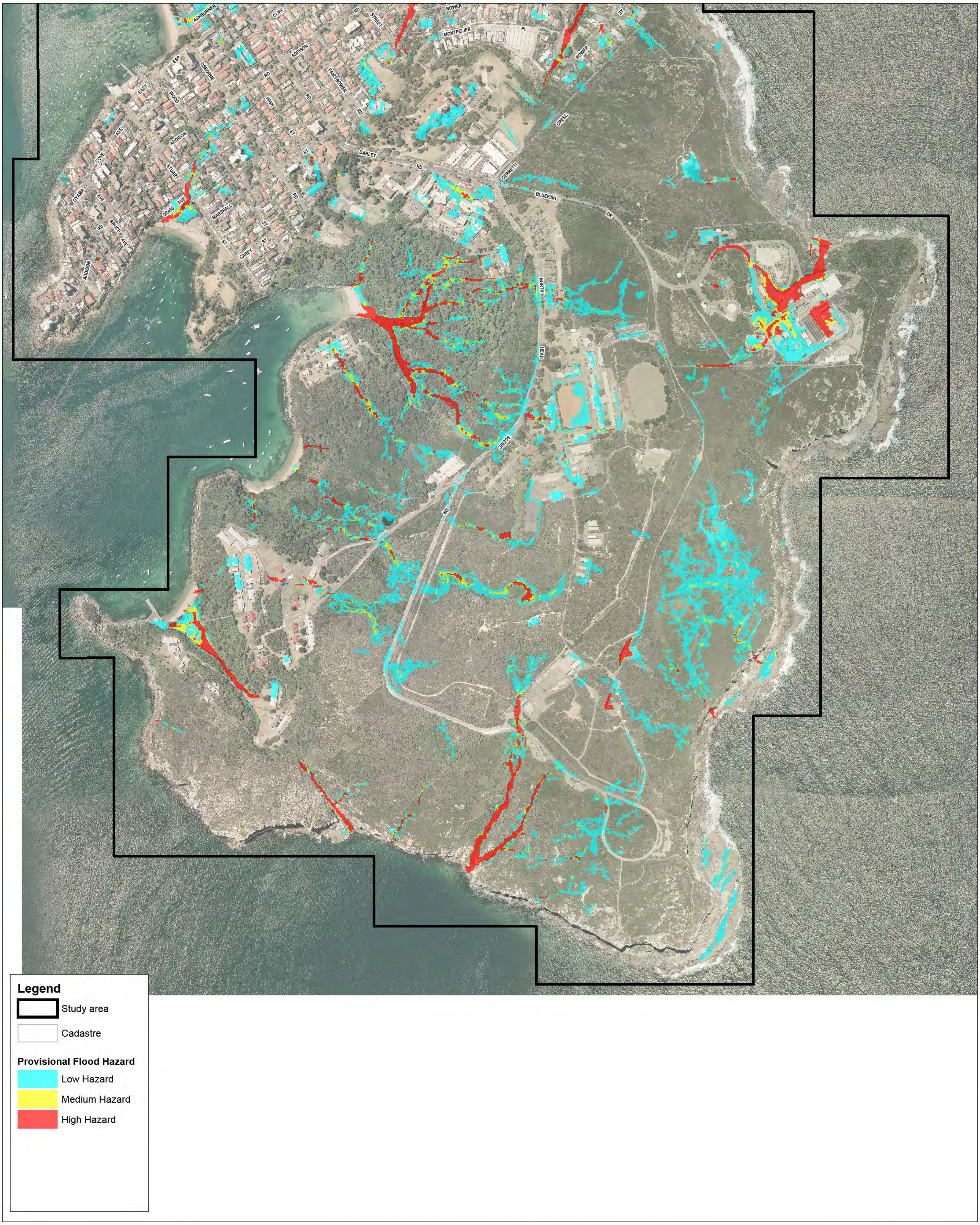
Cardno



Manly to Seaforth Flood Study
PMF Provisional Flood Hazard
Map 3/4

Figure 63

Cardno



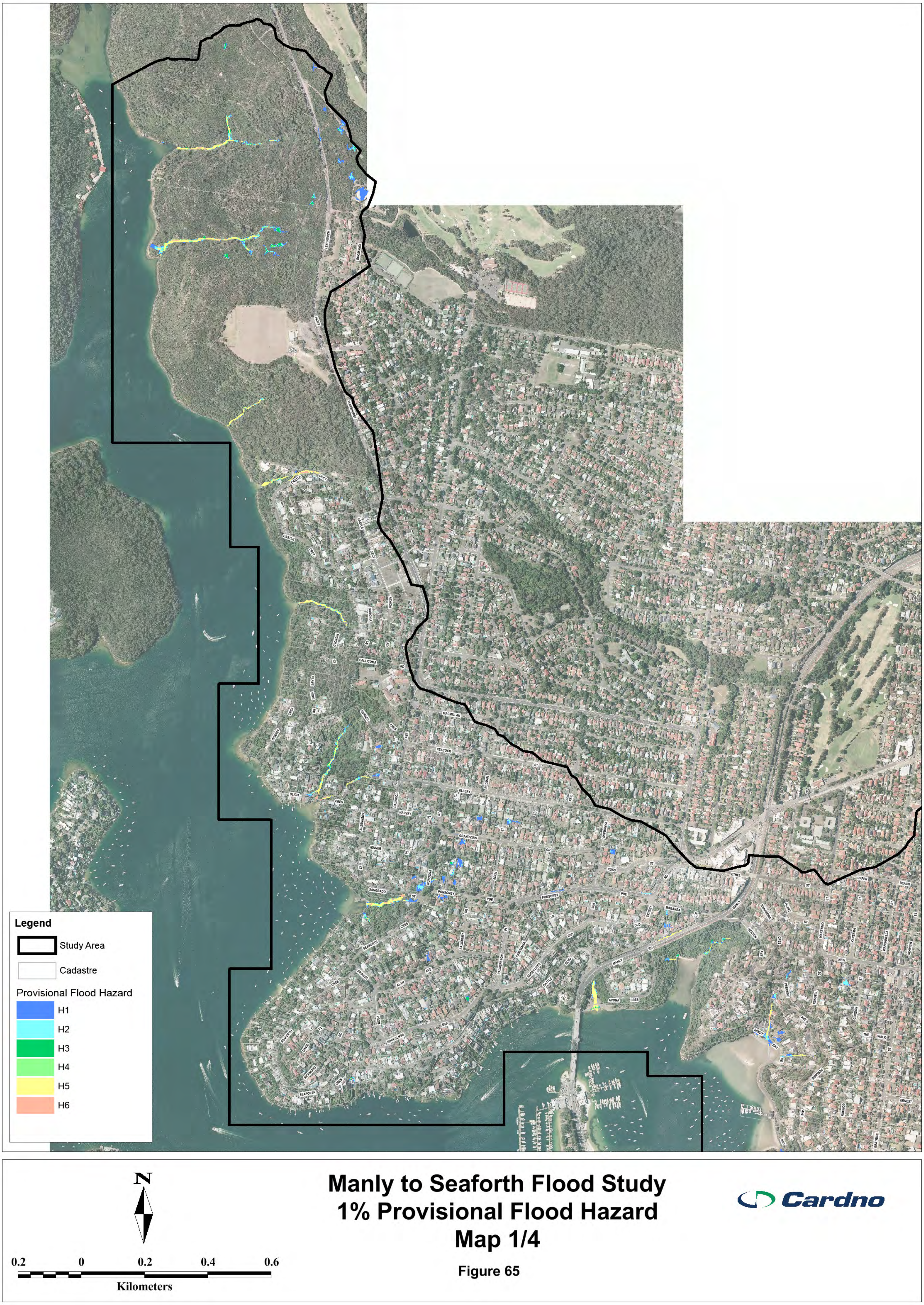
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
PMF Provisional Flood Hazard
Map 4/4

Figure 64

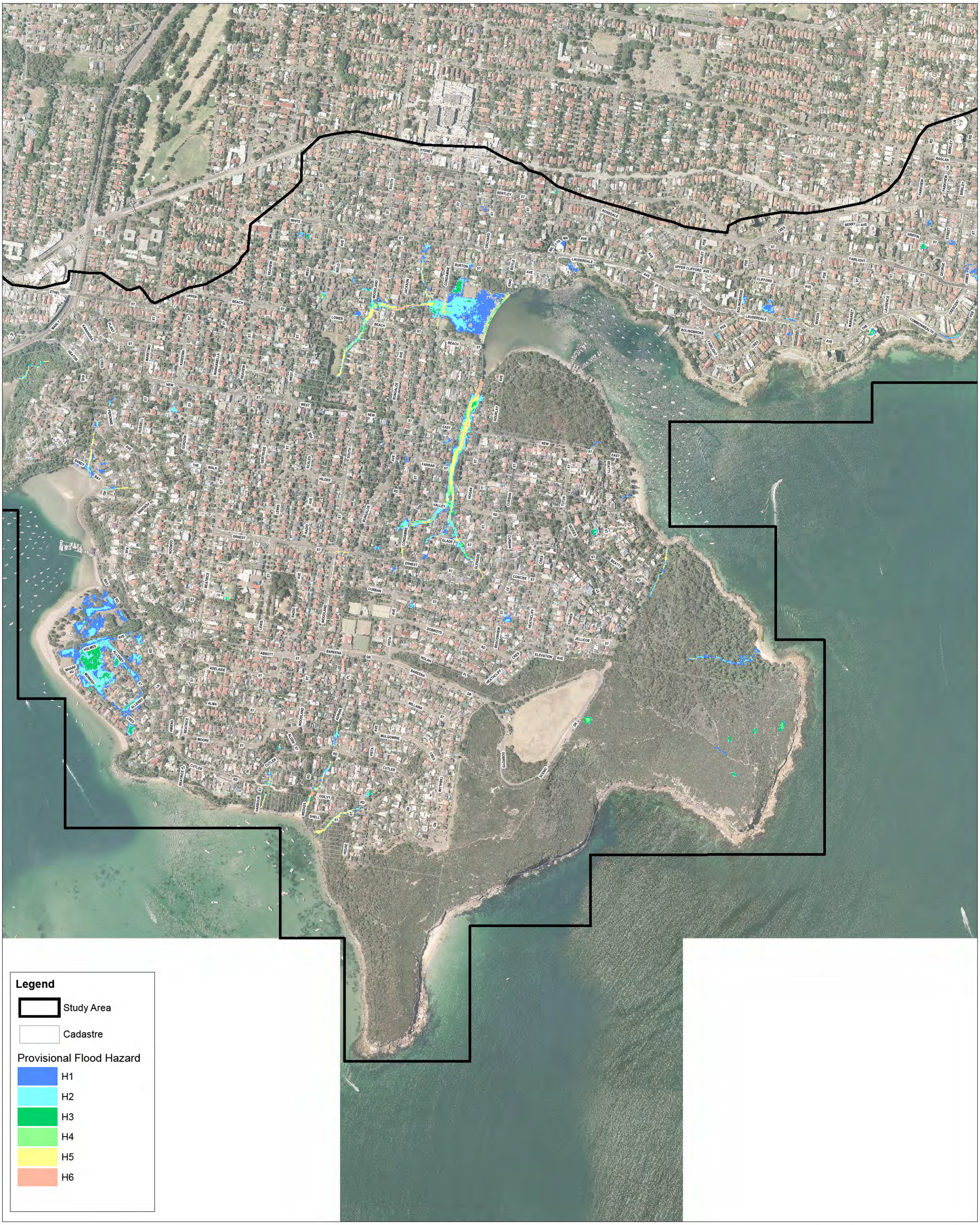
Cardno



Manly to Seaforth Flood Study
1% Provisional Flood Hazard
Map 1/4

Figure 65

Cardno



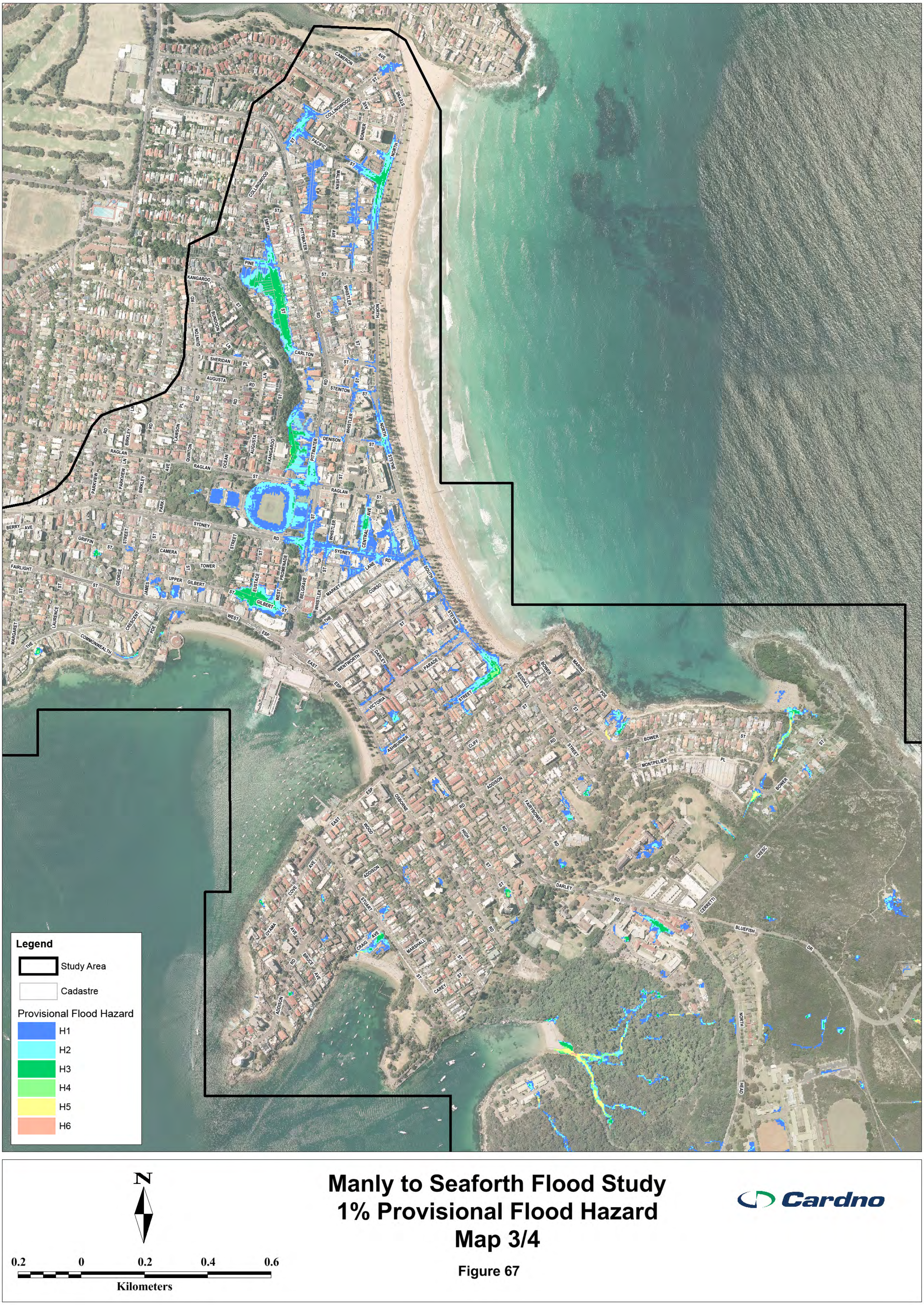
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
1% Provisional Flood Hazard
Map 2/4

Figure 66

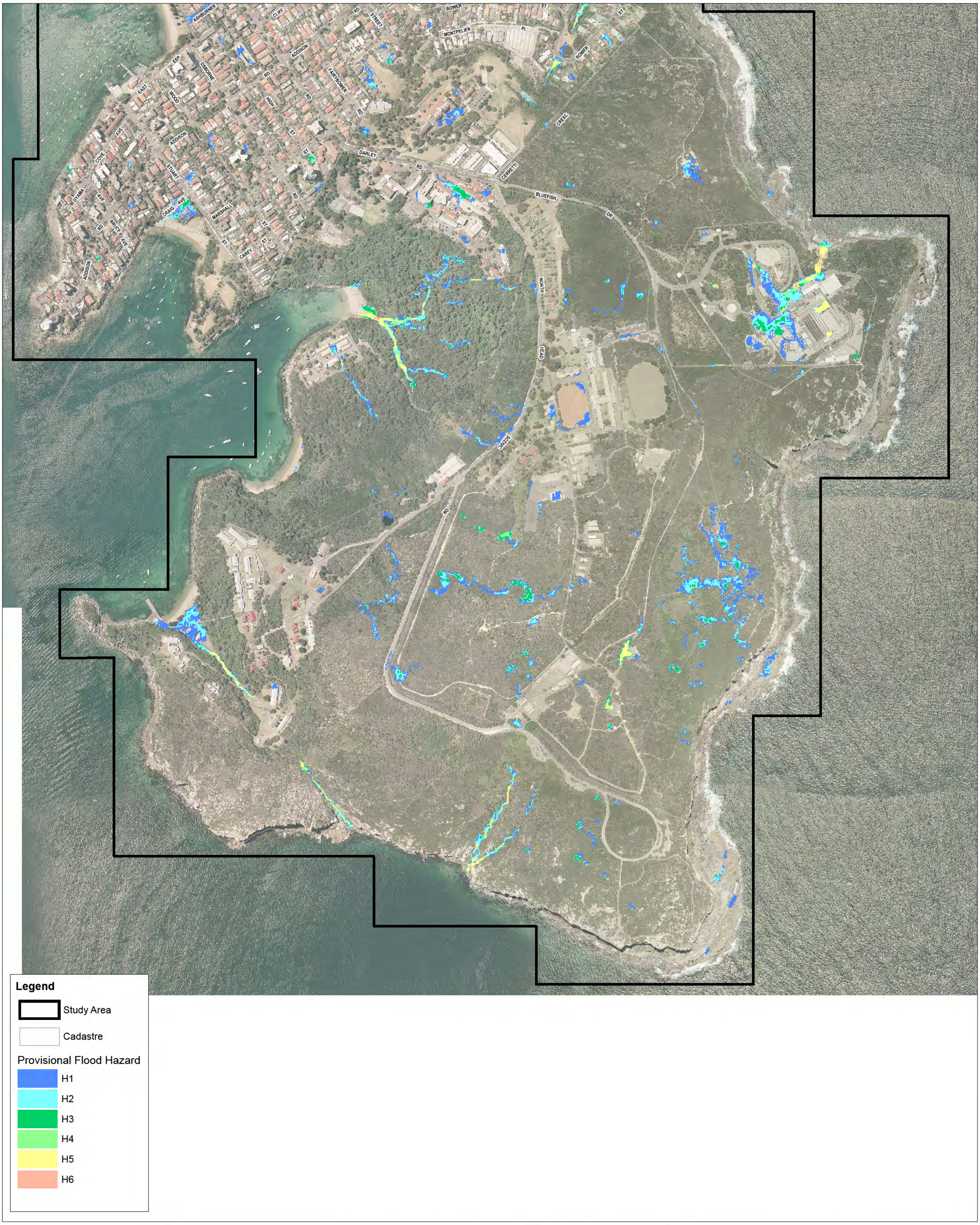
Cardno



Manly to Seaforth Flood Study
1% Provisional Flood Hazard
Map 3/4

Figure 67

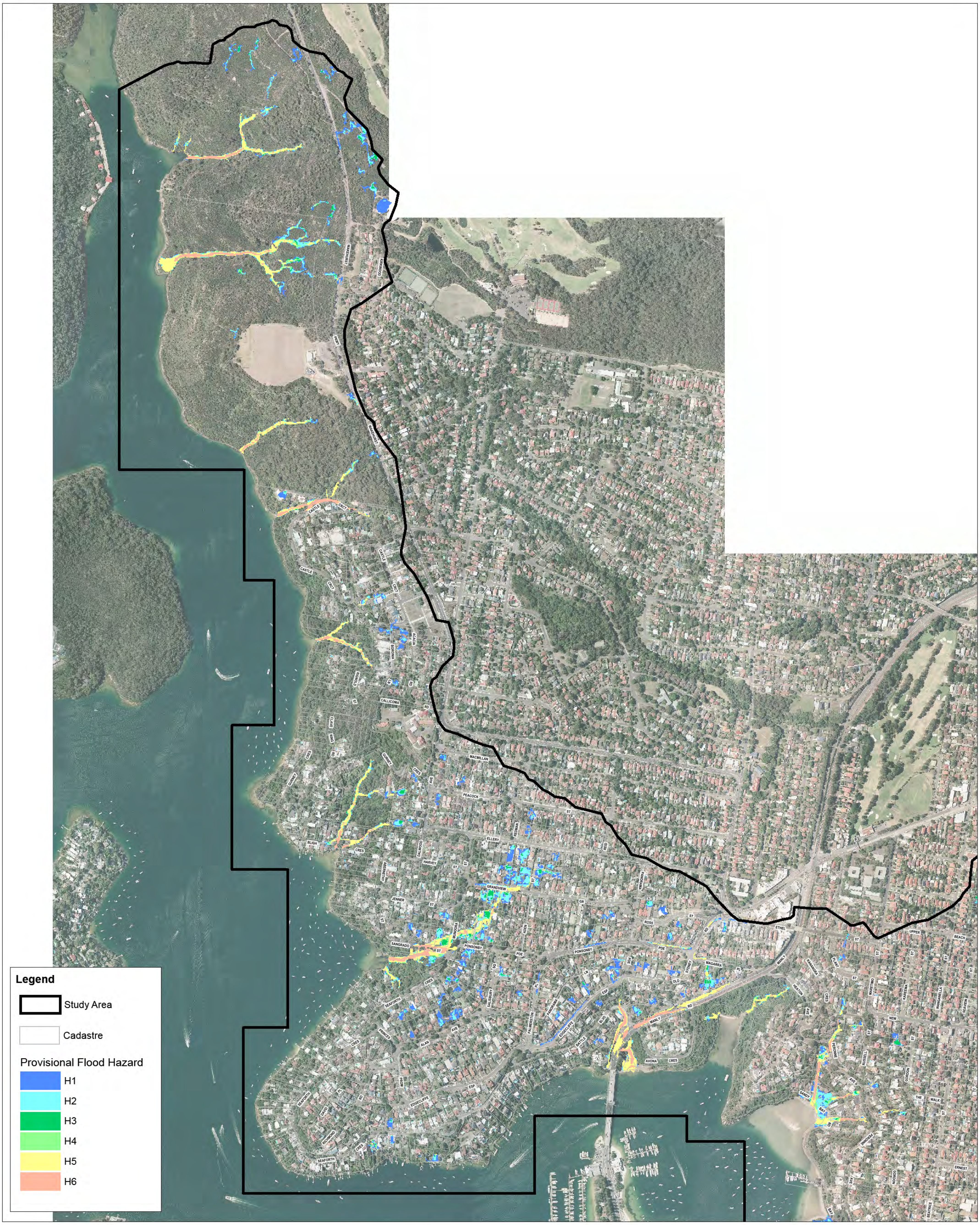
Cardno



Manly to Seaforth Flood Study
1% Provisional Flood Hazard
Map 4/4

Figure 68

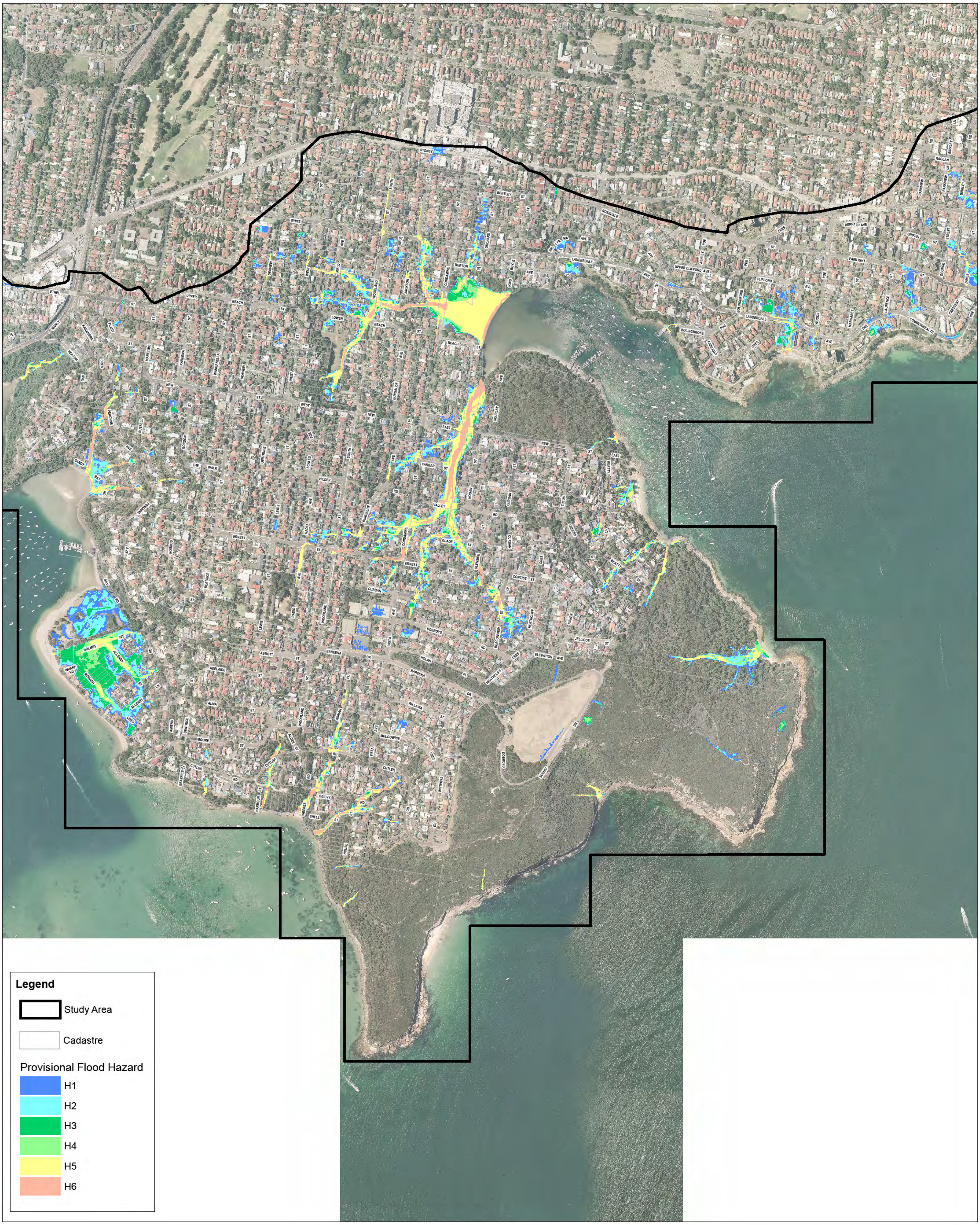
Cardno



Manly to Seaforth Flood Study
PMF Provisional Flood Hazard
Map 1/4

Figure 69

Cardno



N

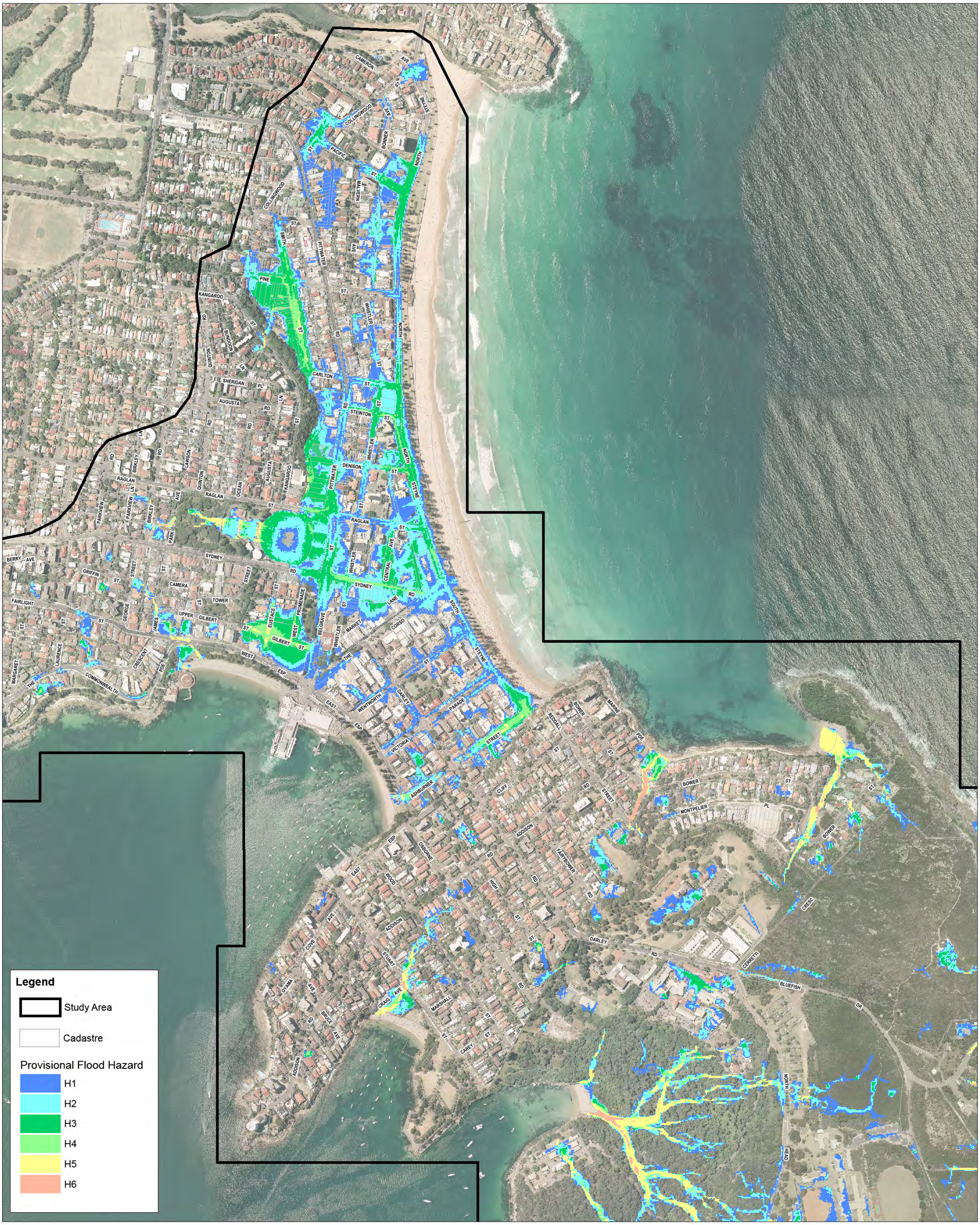
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
PMF Provisional Flood Hazard
Map 2/4

Figure 70

Cardno



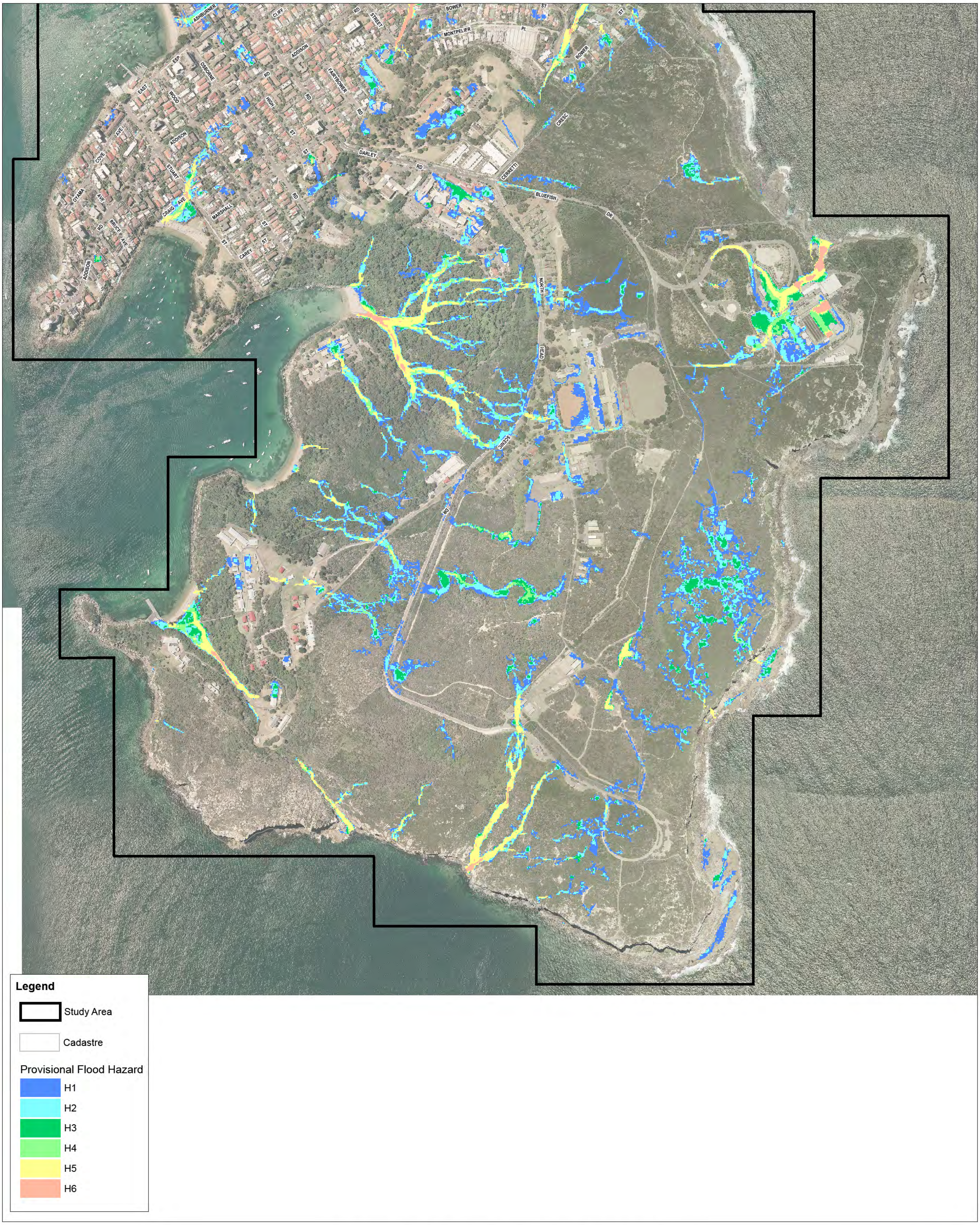
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
PMF Provisional Flood Hazard
Map 3/4

Figure 71

Cardno



N

0.2 0 0.2 0.4 0.6

Kilometers

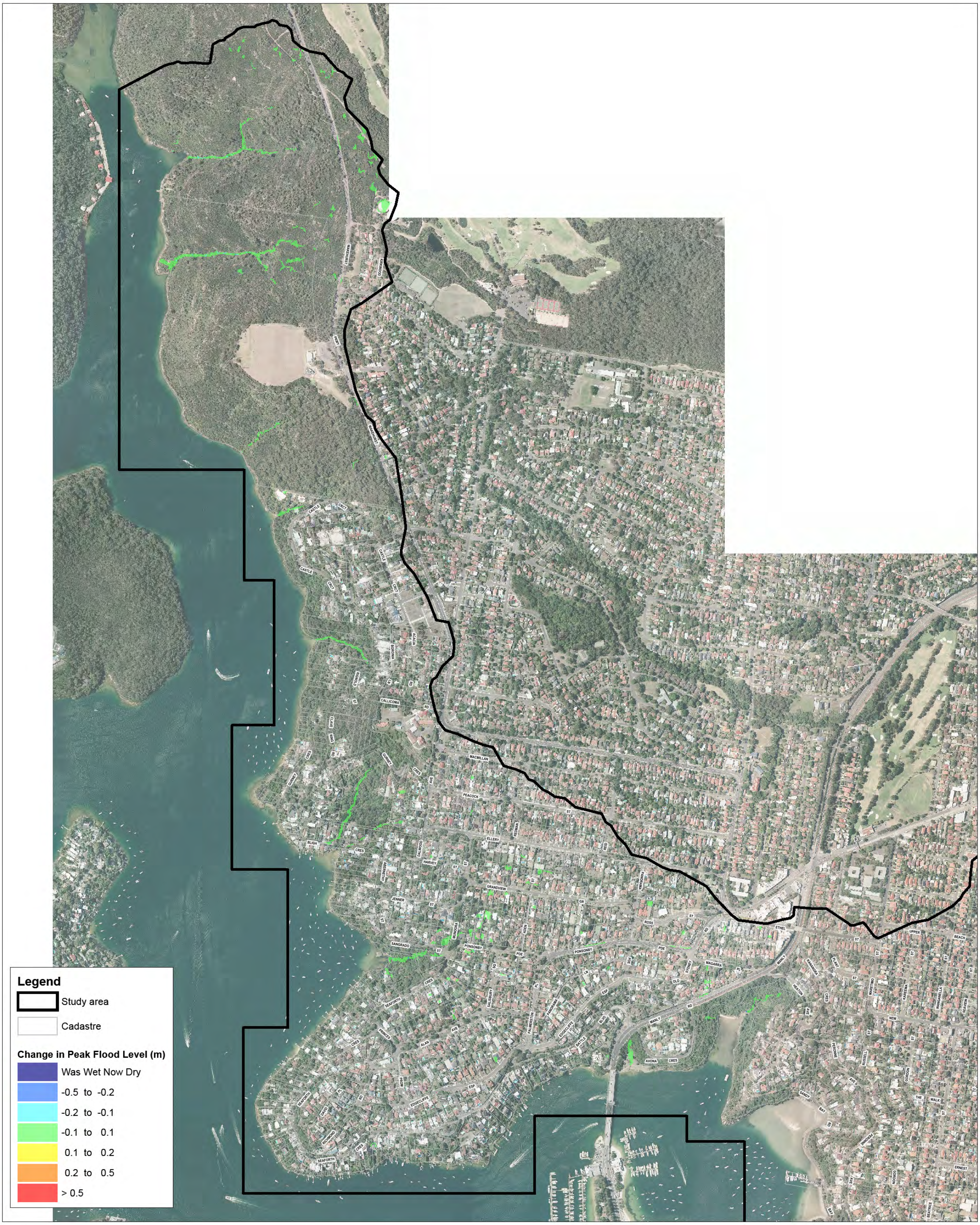
Manly to Seaforth Flood Study
PMF Provisional Flood Hazard
Map 4/4

Figure 72

Cardno

APPENDIX C

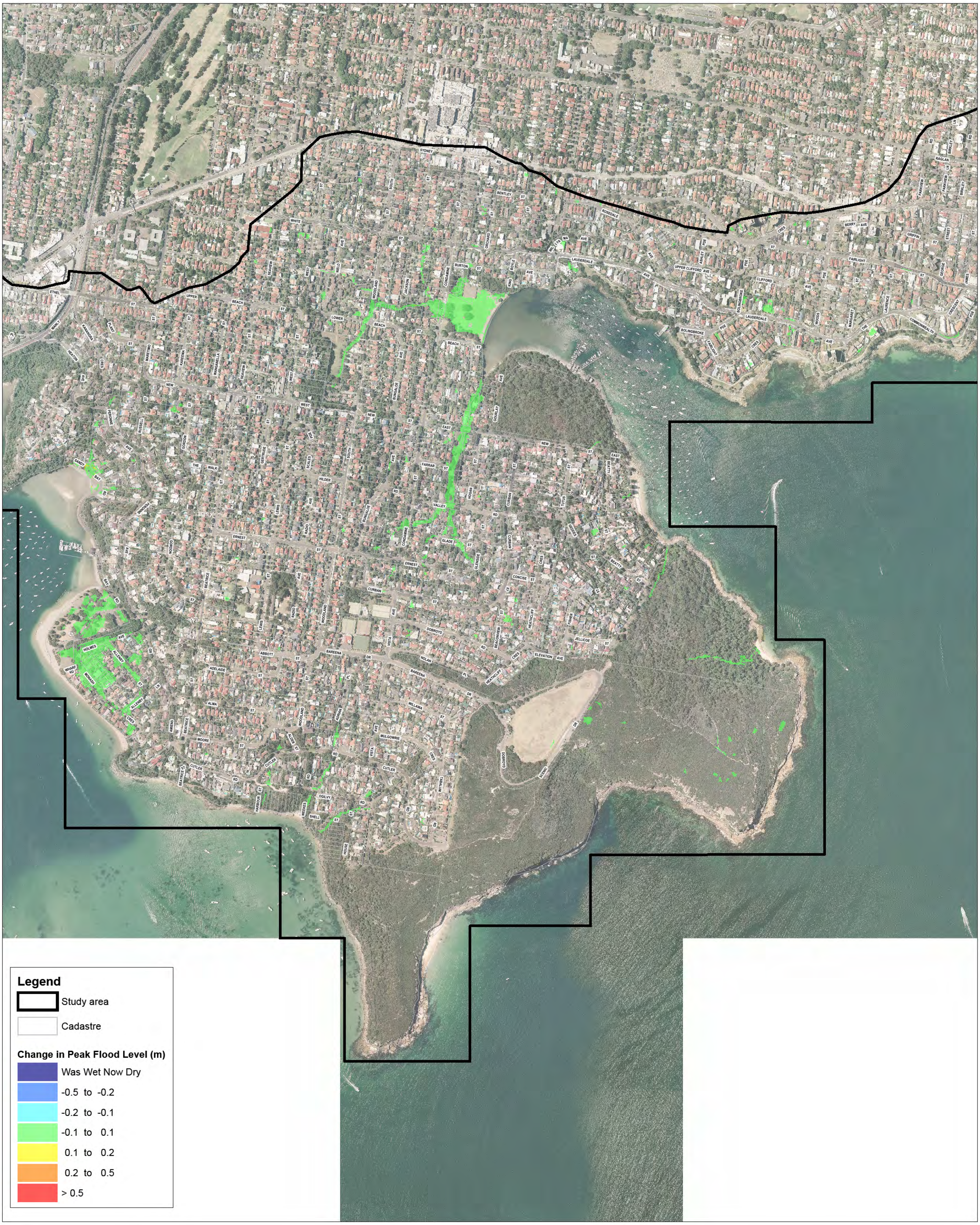
SENSITIVITY FIGURES



Manly to Seaforth Flood Study
Change in Peak Flood Level
20% Decreased Roughness
Map 1/3

Figure 73

Cardno



N

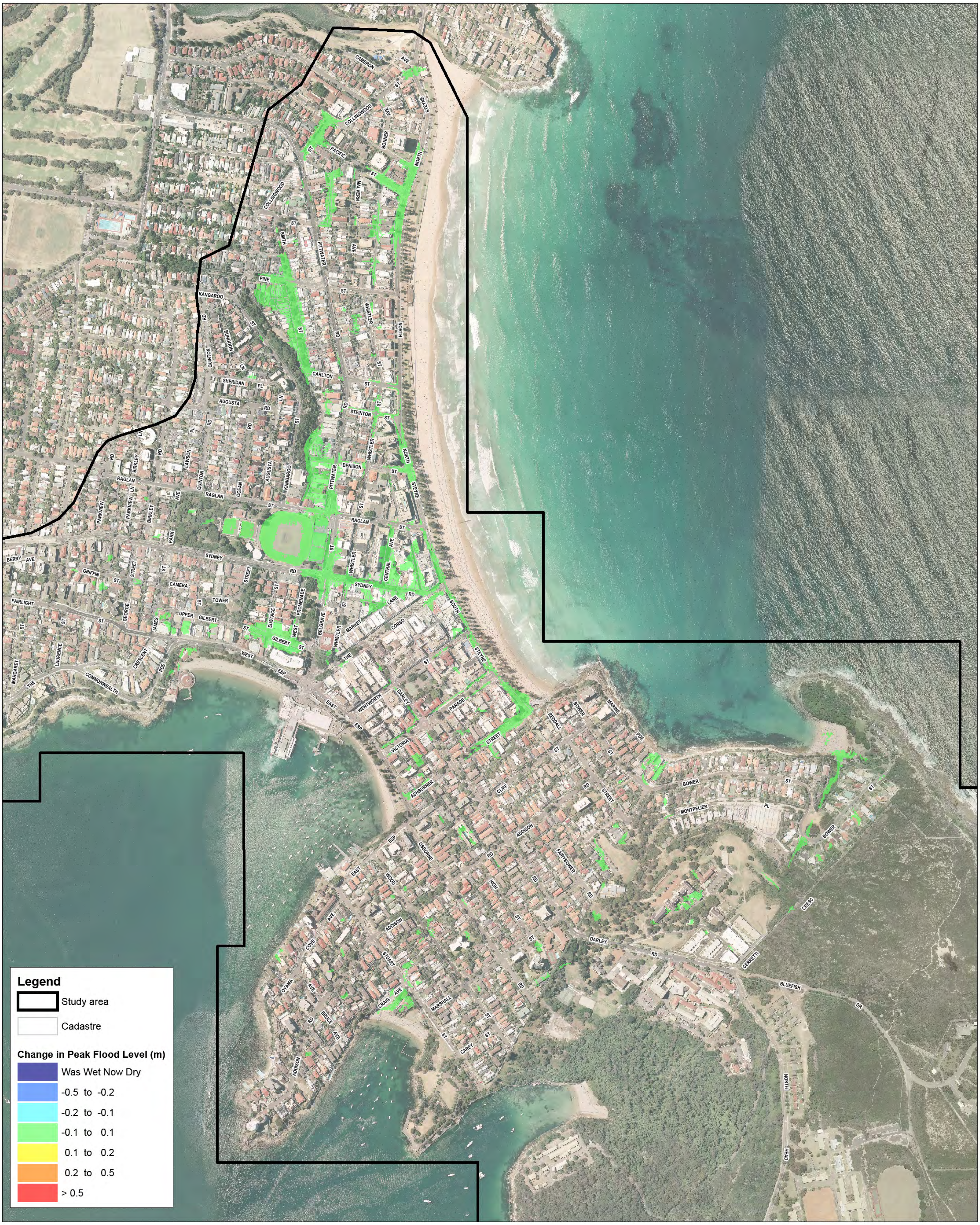
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Level
20% Decreased Roughness
Map 2/3

Figure 74

Cardno



N

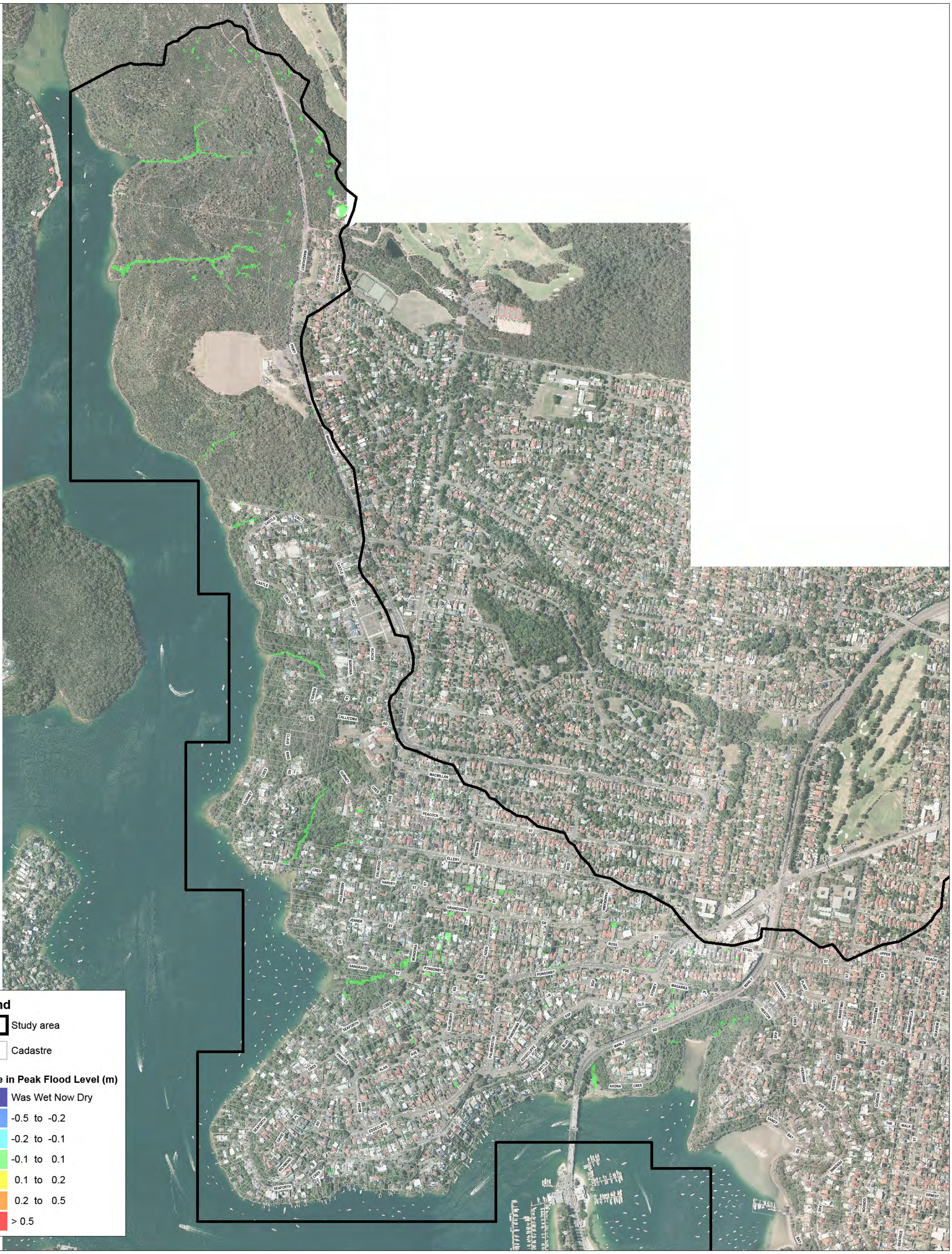
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Level
20% Decreased Roughness
Map 3/3

Figure 75

Cardno



N

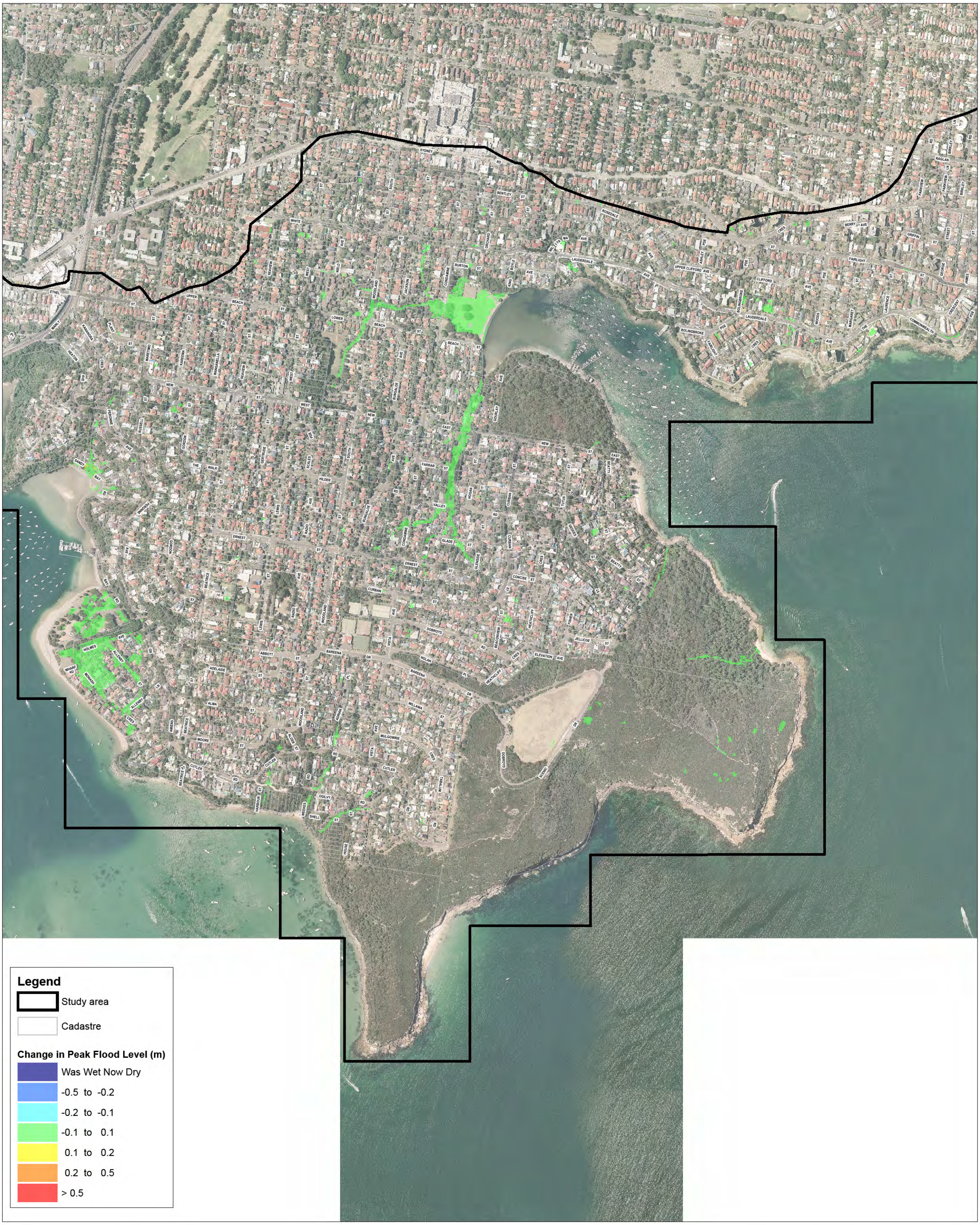
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Level
20% Increased Roughness
Map 1/3

Figure 76

Cardno



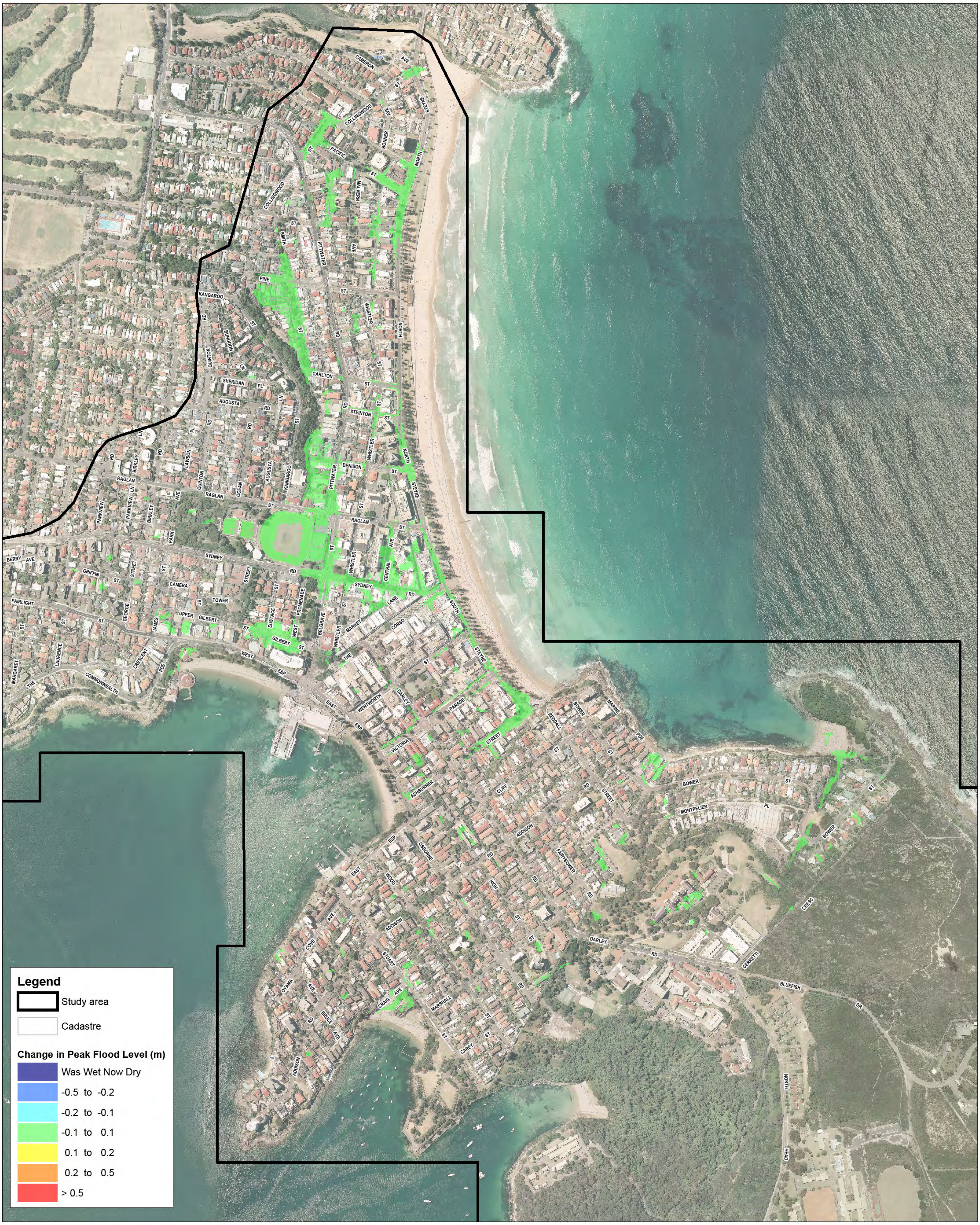
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Level
20% Increased Roughness
Map 2/3

Figure 77

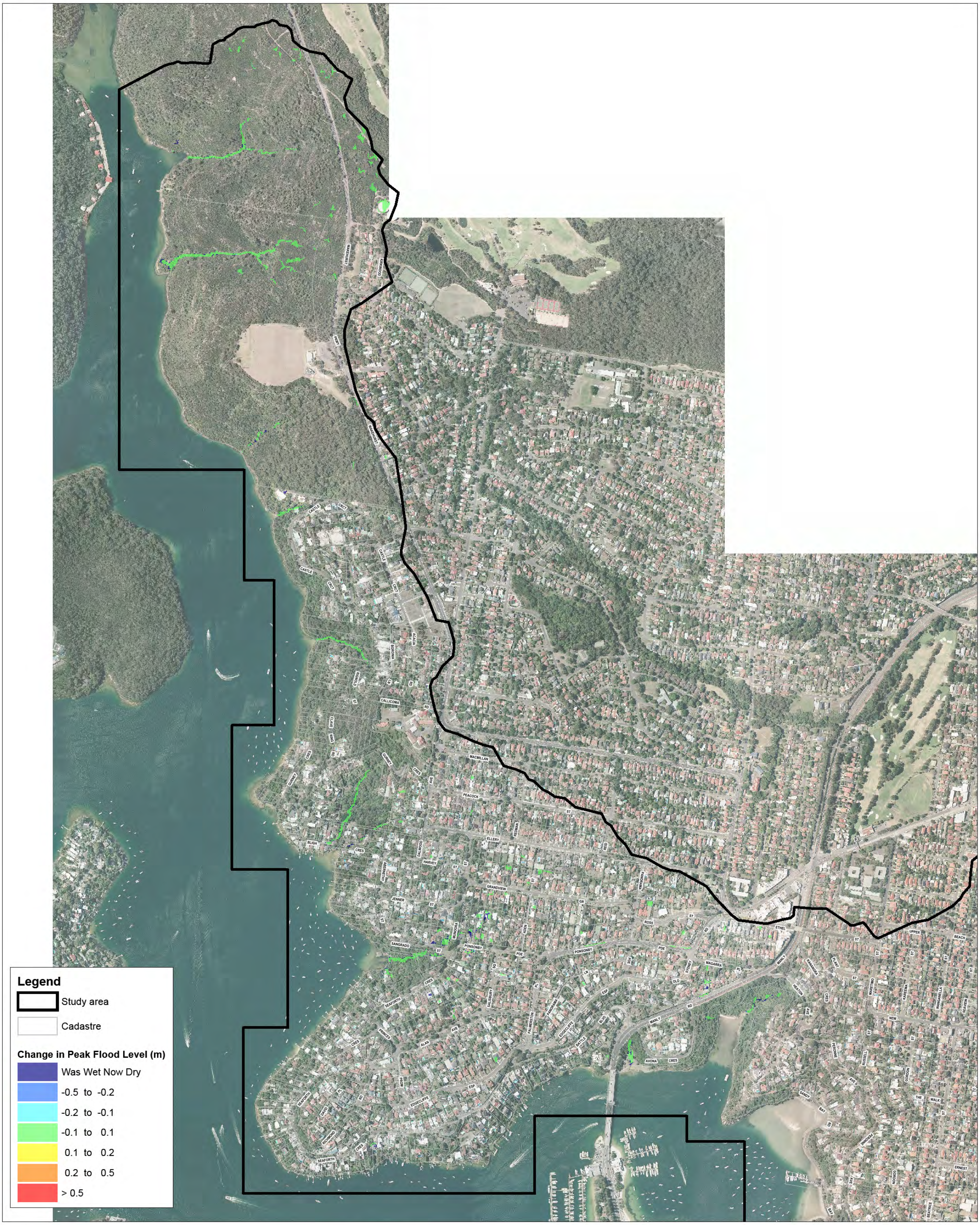
Cardno



Manly to Seaforth Flood Study
Change in Peak Flood Level
20% Increased Roughness
Map 3/3

Figure 78

Cardno



N

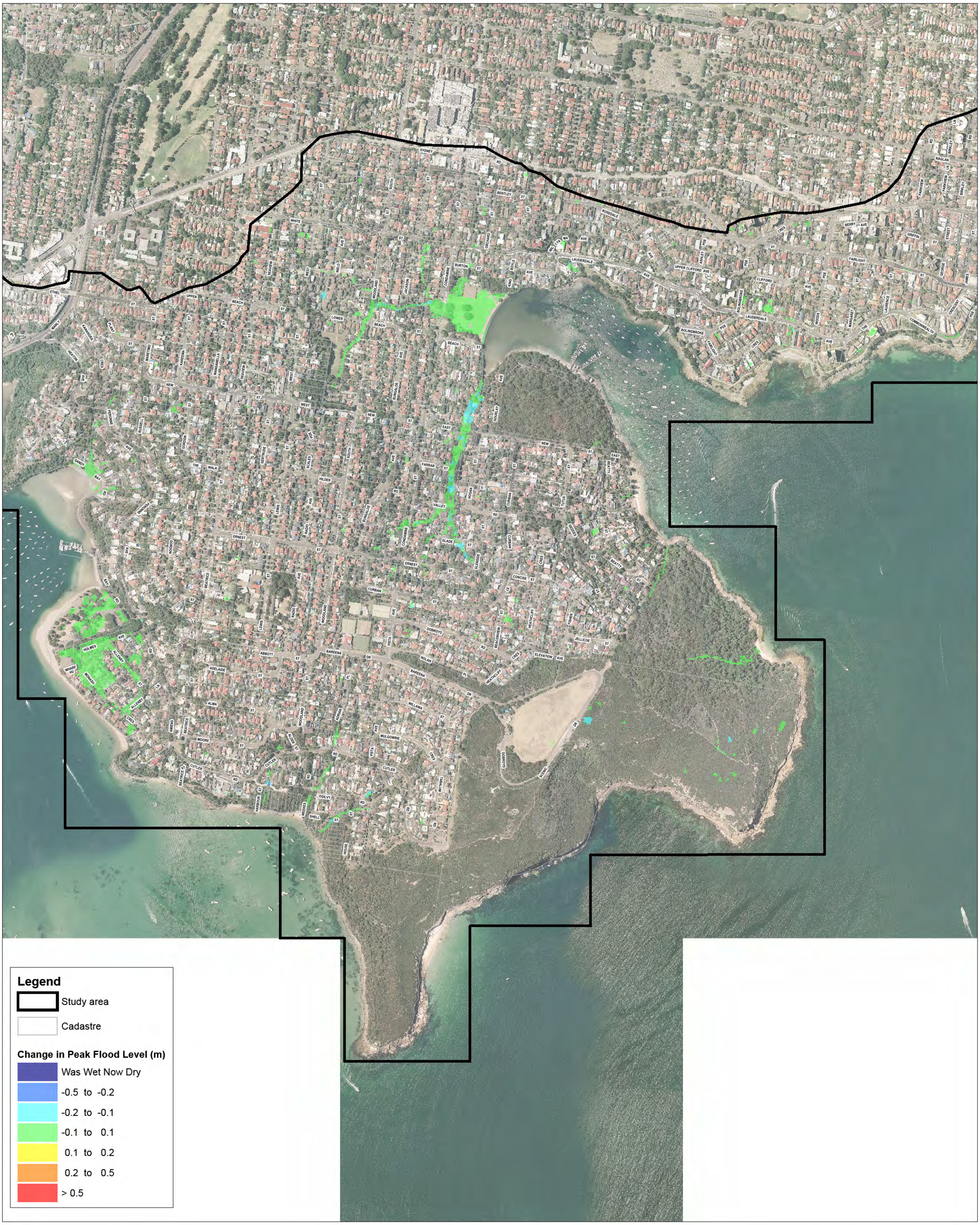
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Level
20% Decreased Rainfall Intensity
Map 1/3

Figure 79

Cardno



Legend

Study area

Cadastre

Change in Peak Flood Level (m)

Was Wet Now Dry

-0.5 to -0.2

-0.2 to -0.1

-0.1 to 0.1

0.1 to 0.2

0.2 to 0.5

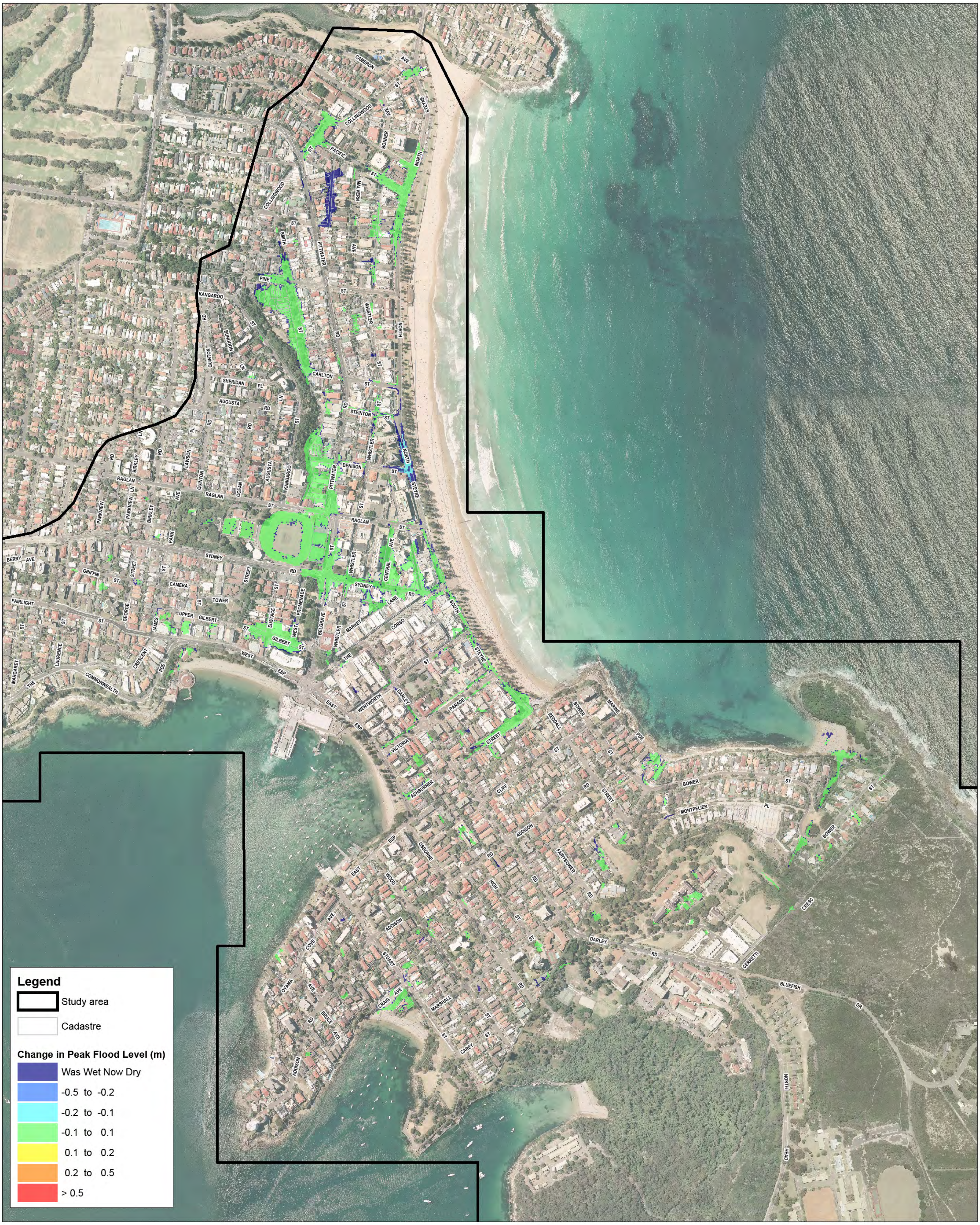
> 0.5

0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Level
20% Decreased Rainfall Intensity
Map 2/3

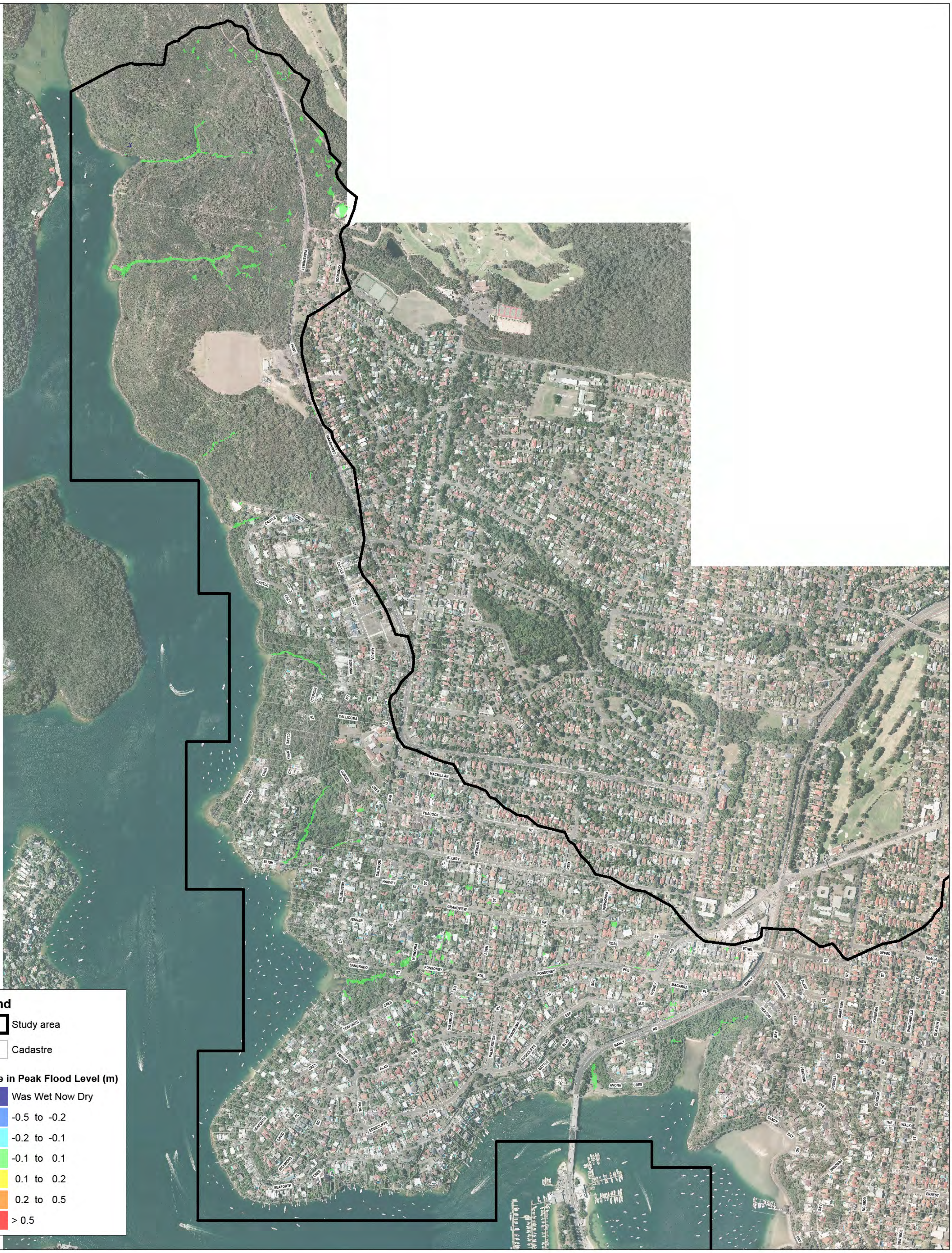
Figure 80



Manly to Seaforth Flood Study
Change in Peak Flood Level
20% Decreased Rainfall Intensity
Map 3/3

Figure 81

Cardno



N

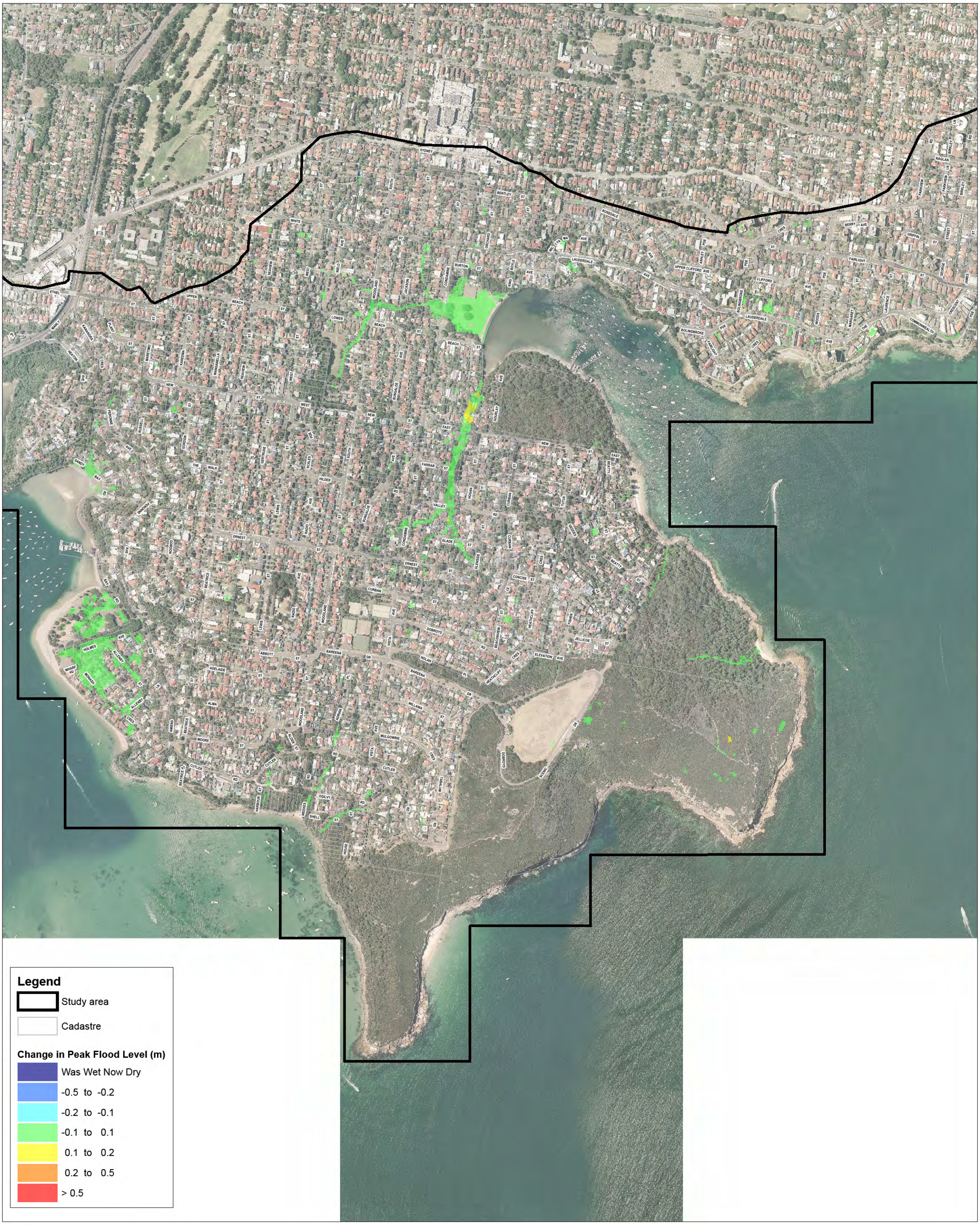
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Level
20% Increased Rainfall Intensity
Map 1/3

Figure 82

Cardno



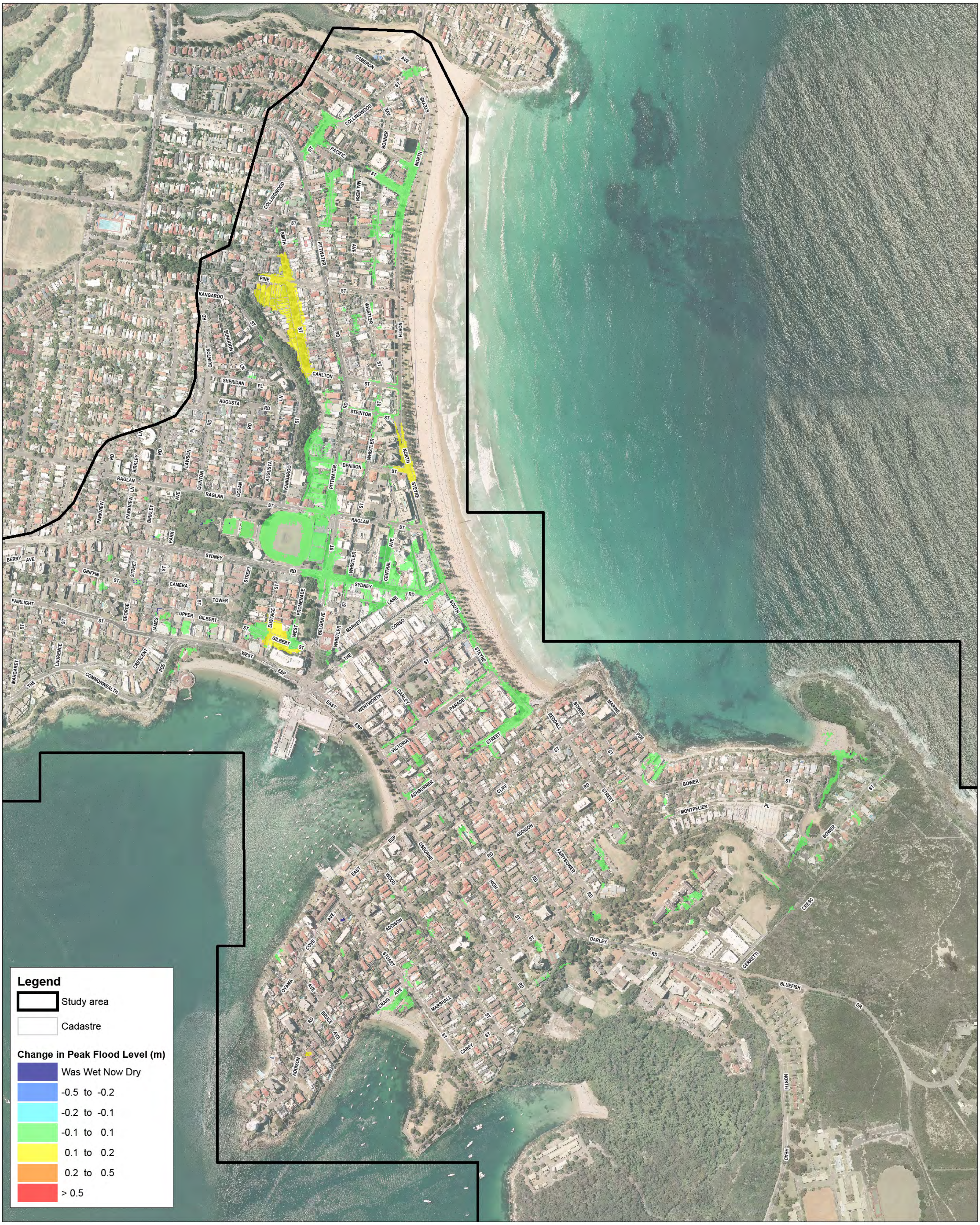
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Level
20% Increased Rainfall Intensity
Map 2/3

Figure 83

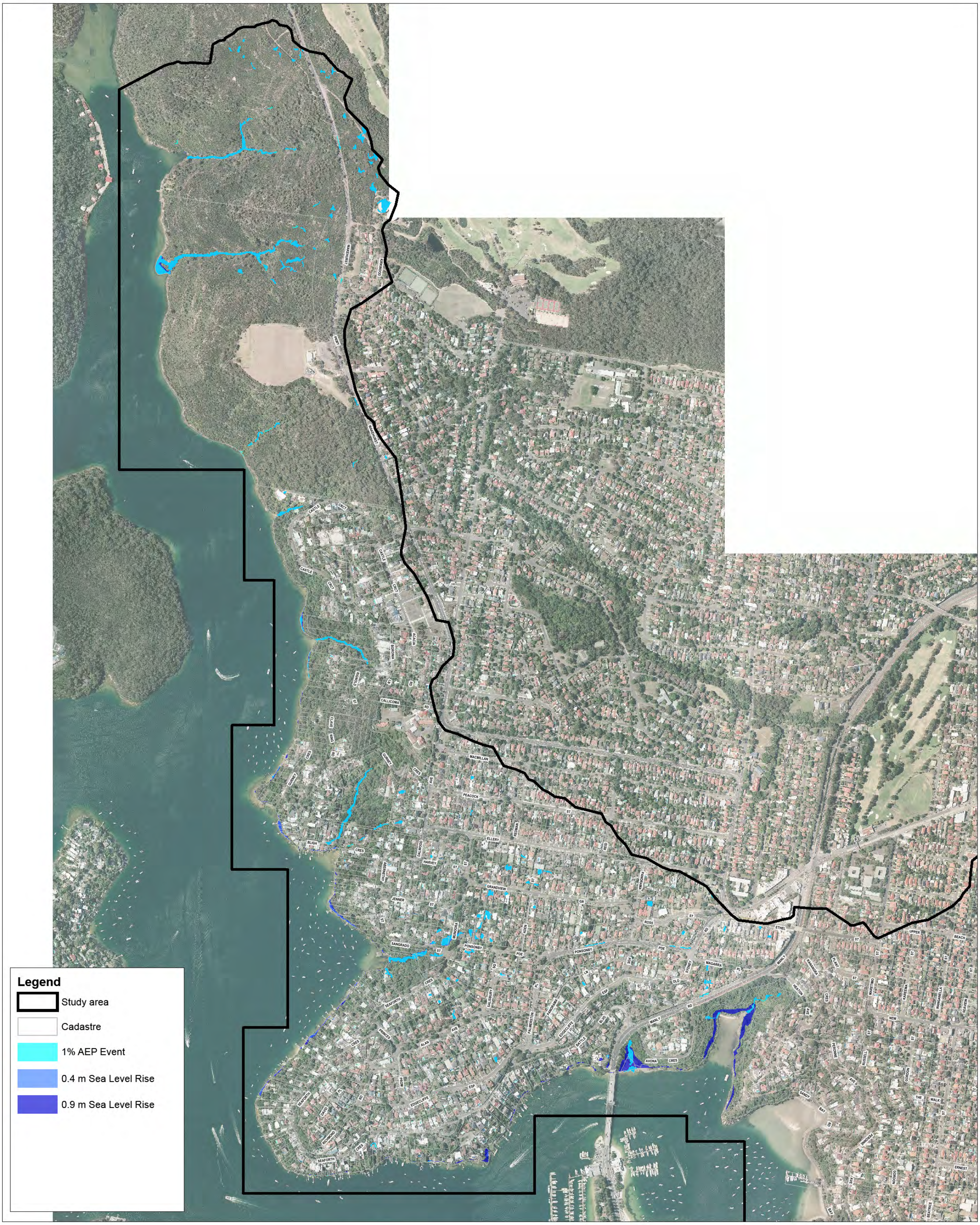
Cardno



Manly to Seaforth Flood Study
Change in Peak Flood Level
20% Increased Rainfall Intensity
Map 3/3

Figure 84

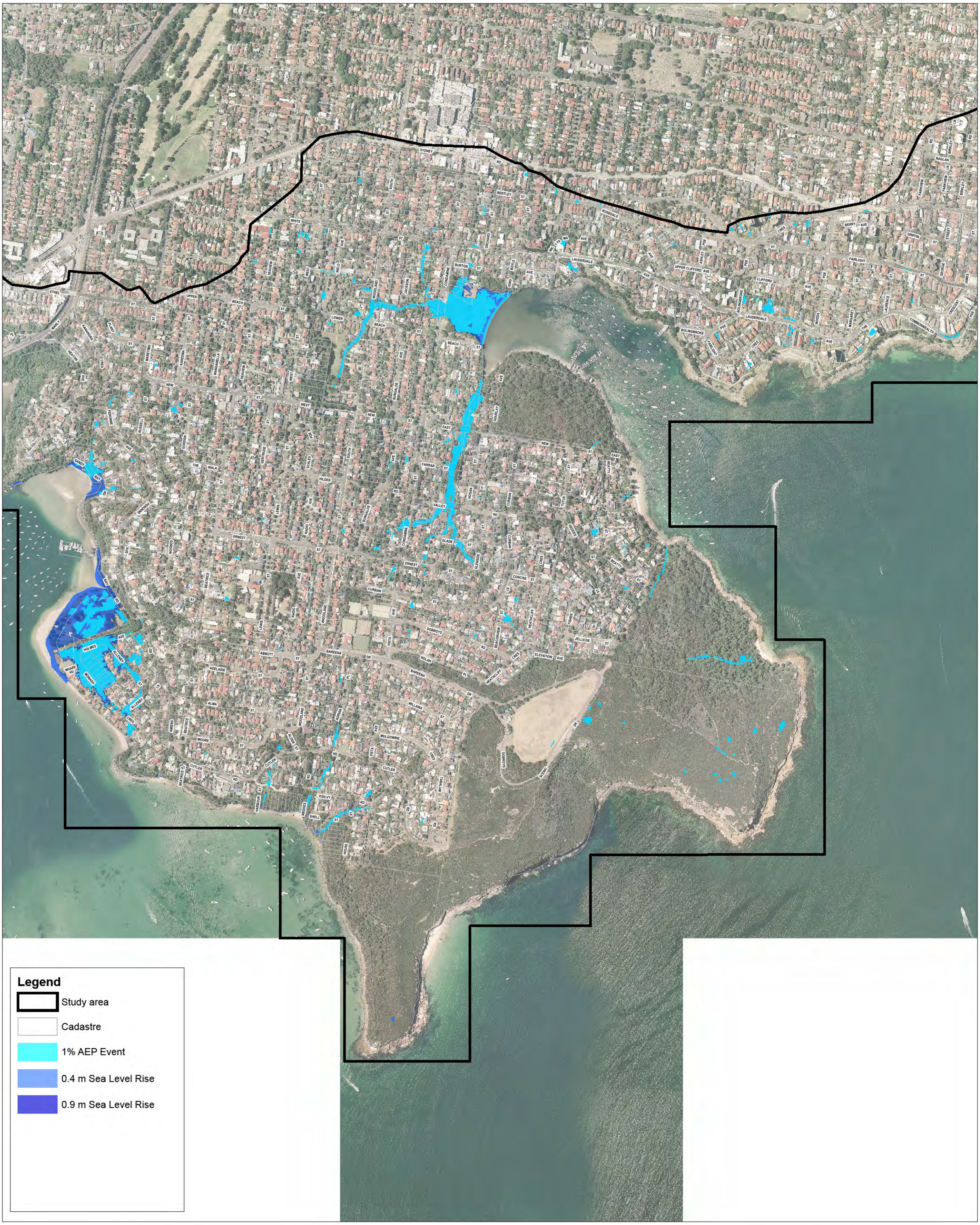
Cardno



Manly to Seaforth Flood Study
Change in Peak Flood Inundation Extent
Increased Tailwater Levels
Map 1/3

Figure 85

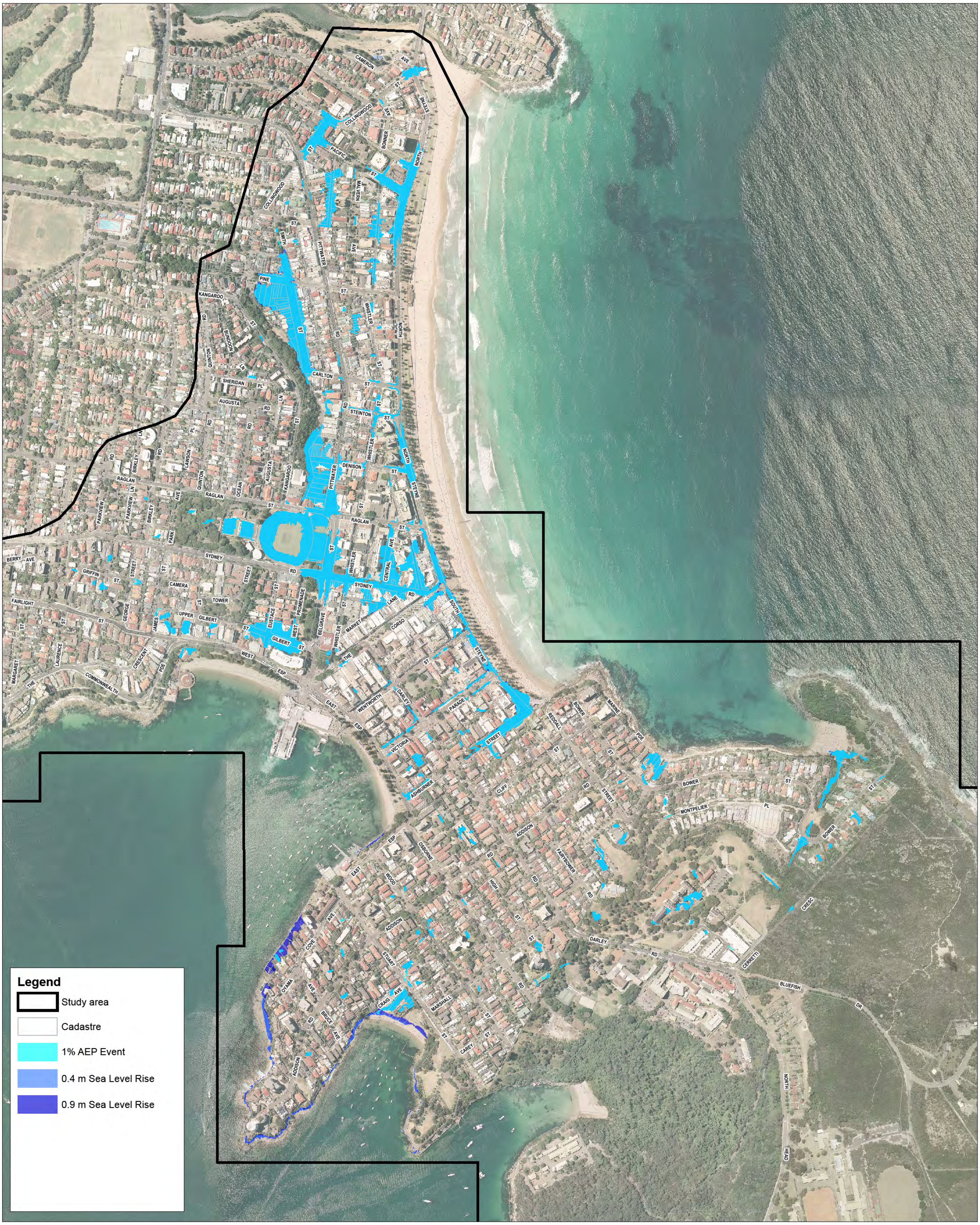
Cardno



Manly to Seaforth Flood Study
Change in Peak Flood Inundation Extent
Increased Tailwater Levels
Map 2/3

Figure 86

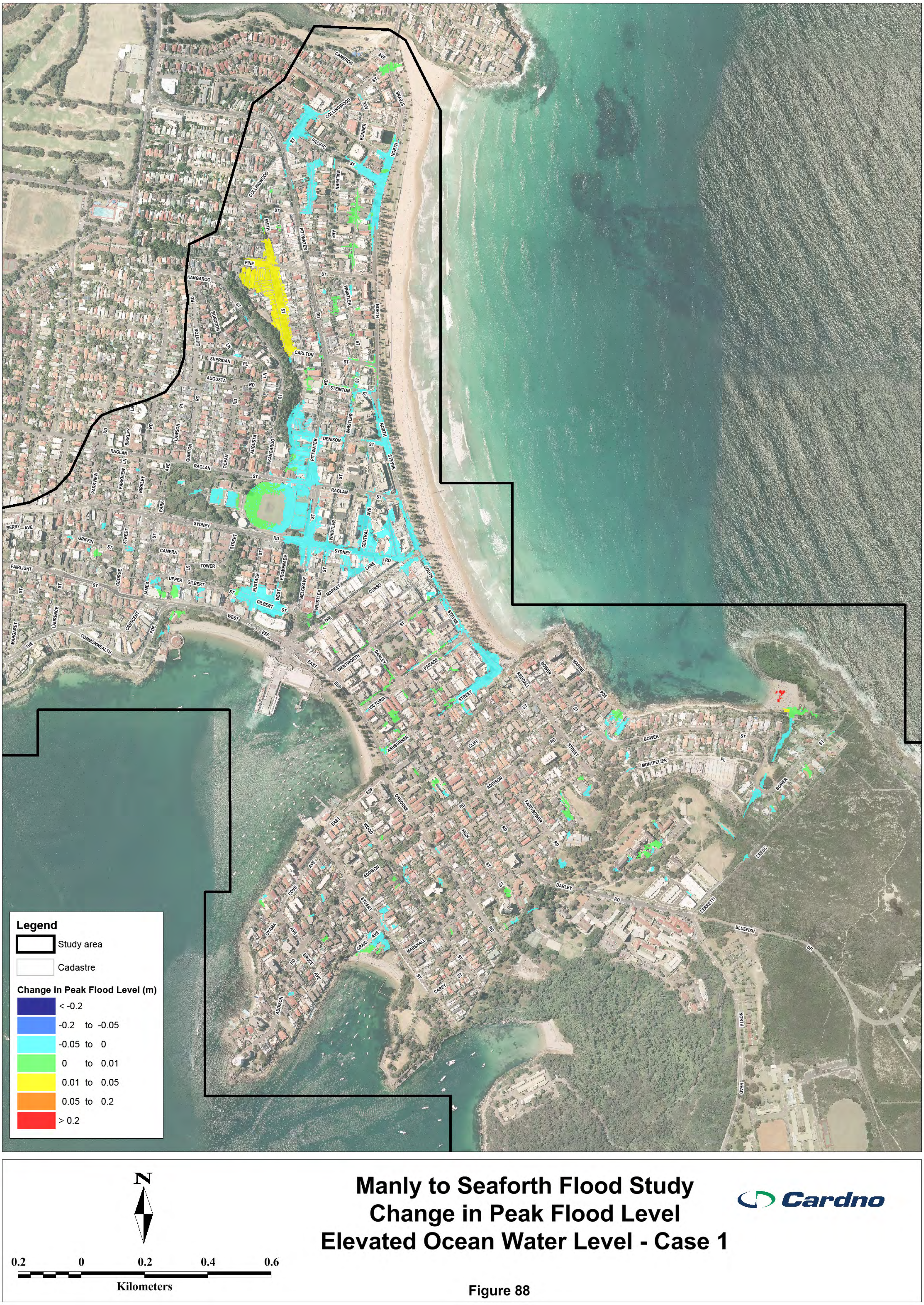
Cardno



Manly to Seaforth Flood Study
Change in Peak Flood Inundation Extent
Increased Tailwater Levels
Map 3/3

Figure 87

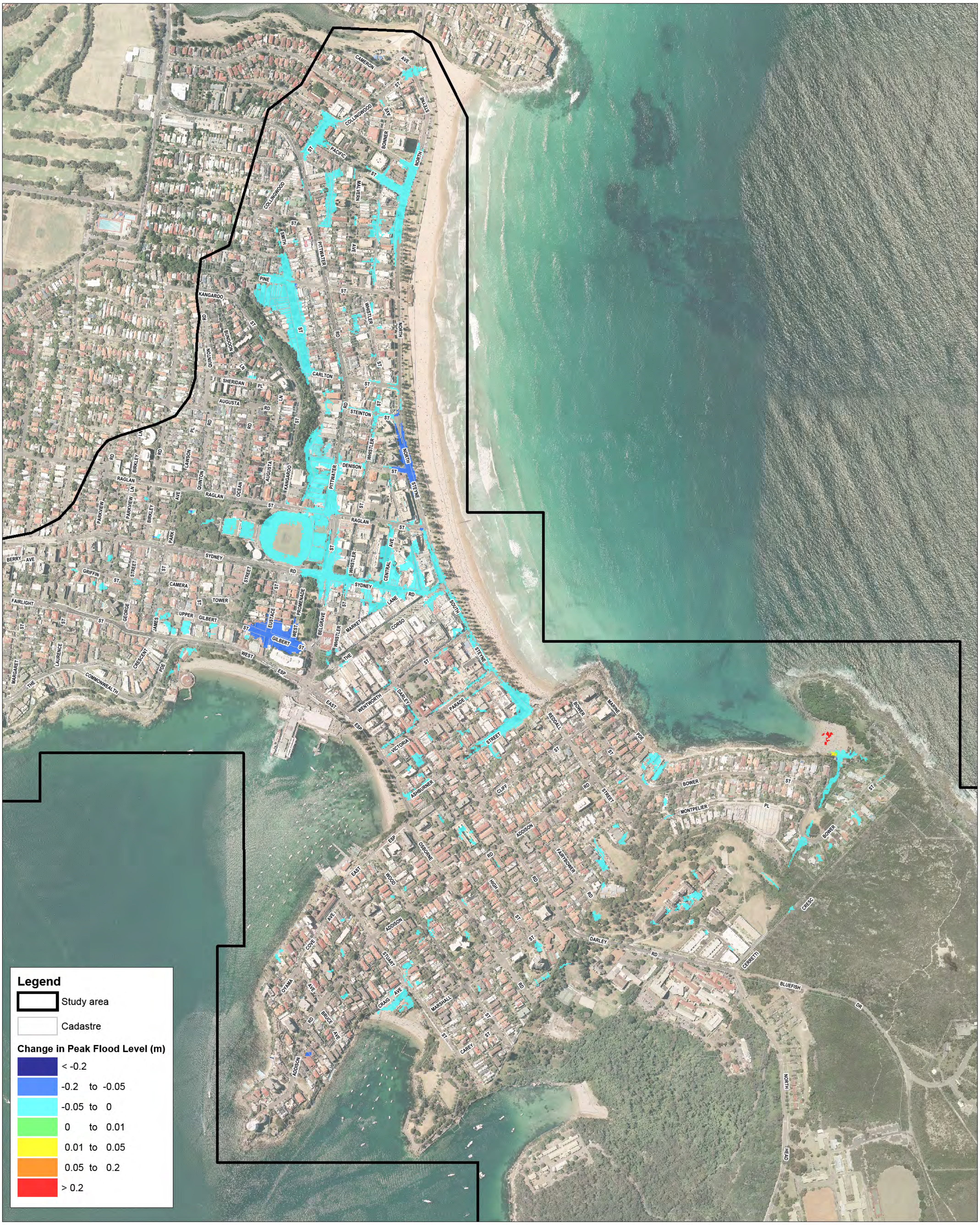
Cardno



Manly to Seaforth Flood Study
Change in Peak Flood Level
Elevated Ocean Water Level - Case 1

Cardno

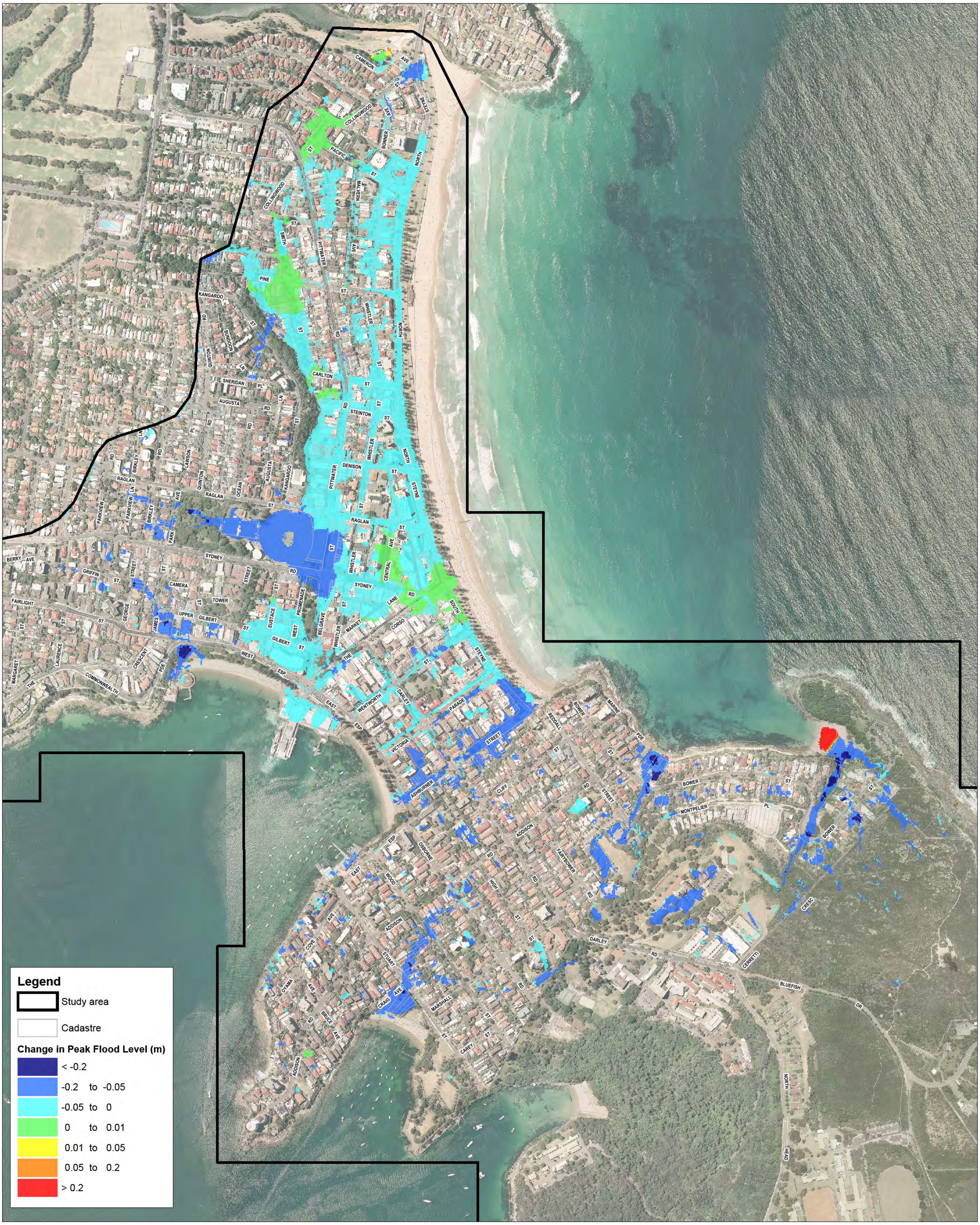
Figure 88



Manly to Seaforth Flood Study
Change in Peak Flood Level
Elevated Ocean Water Level - Case 2

Cardno

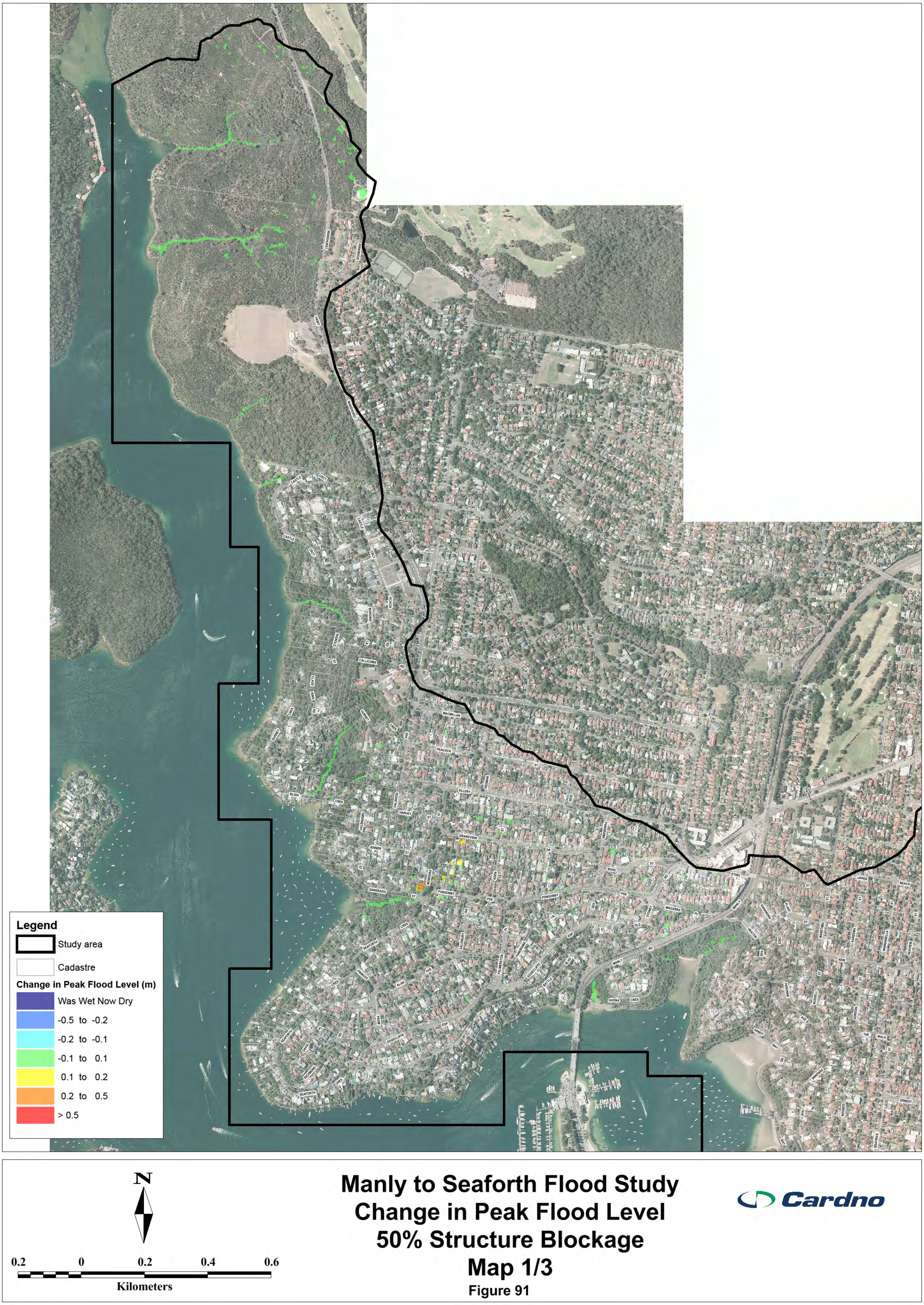
Figure 89



Manly to Seaforth Flood Study
Change in Peak Flood Level
Elevated Ocean Water Level - Case 3

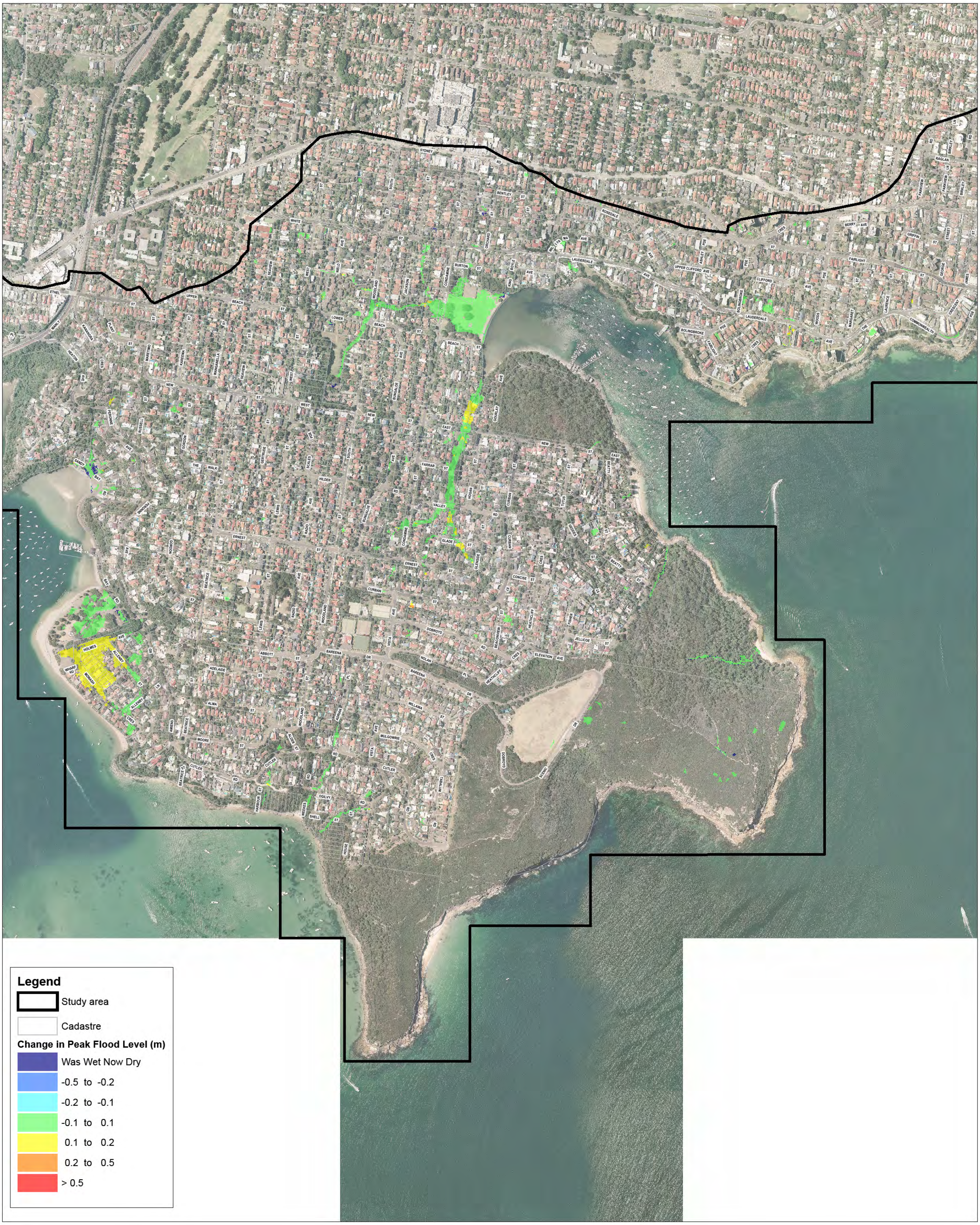
Cardno

Figure 90



Manly to Seaforth Flood Study
Change in Peak Flood Level
50% Structure Blockage
Map 1/3

Figure 91



Legend

Study area

Cadastre

Change in Peak Flood Level (m)

Was Wet Now Dry

-0.5 to -0.2

-0.2 to -0.1

-0.1 to 0.1

0.1 to 0.2

0.2 to 0.5

> 0.5

N

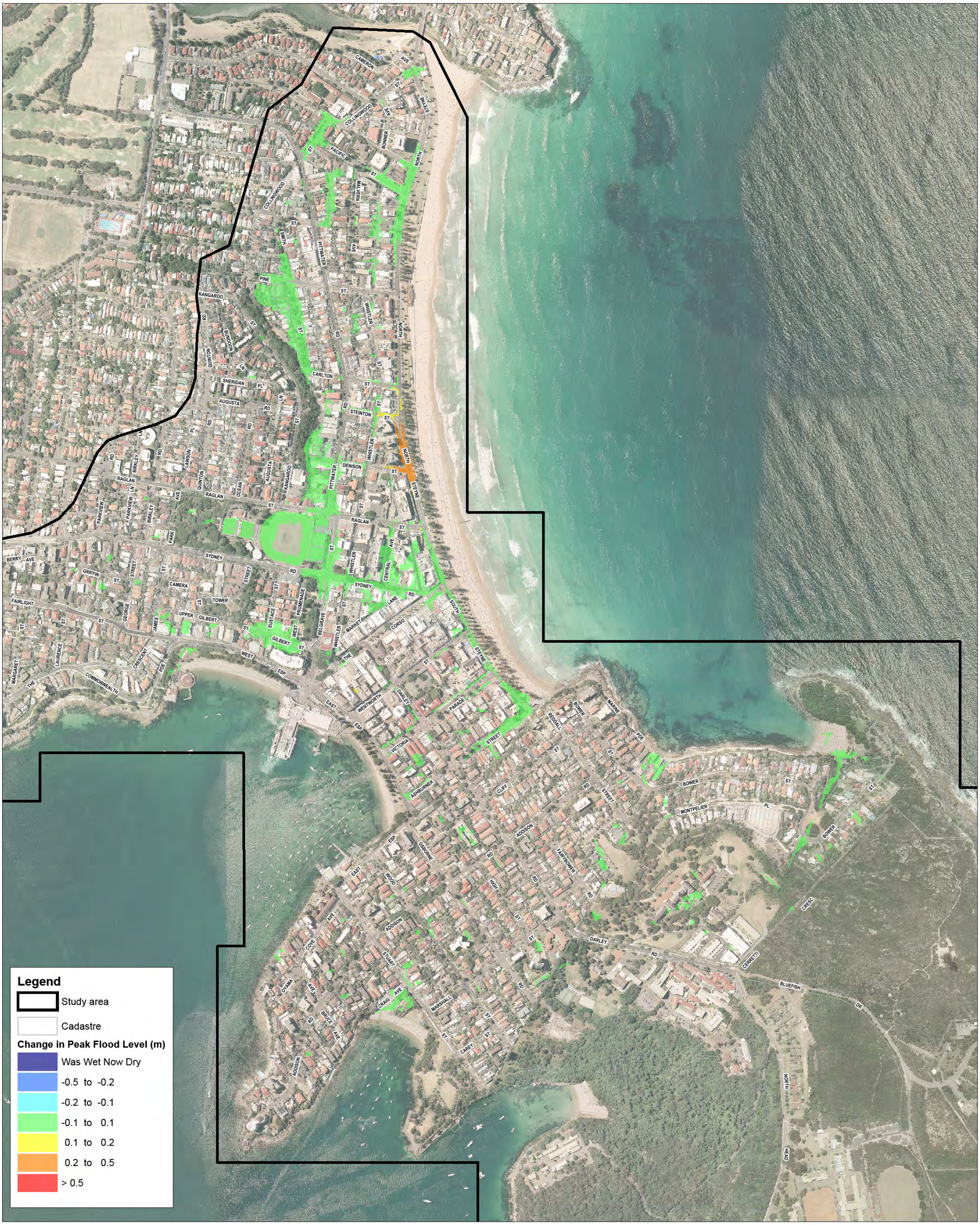
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Level
50% Structure Blockage
Map 2/3

Figure 92

Cardno



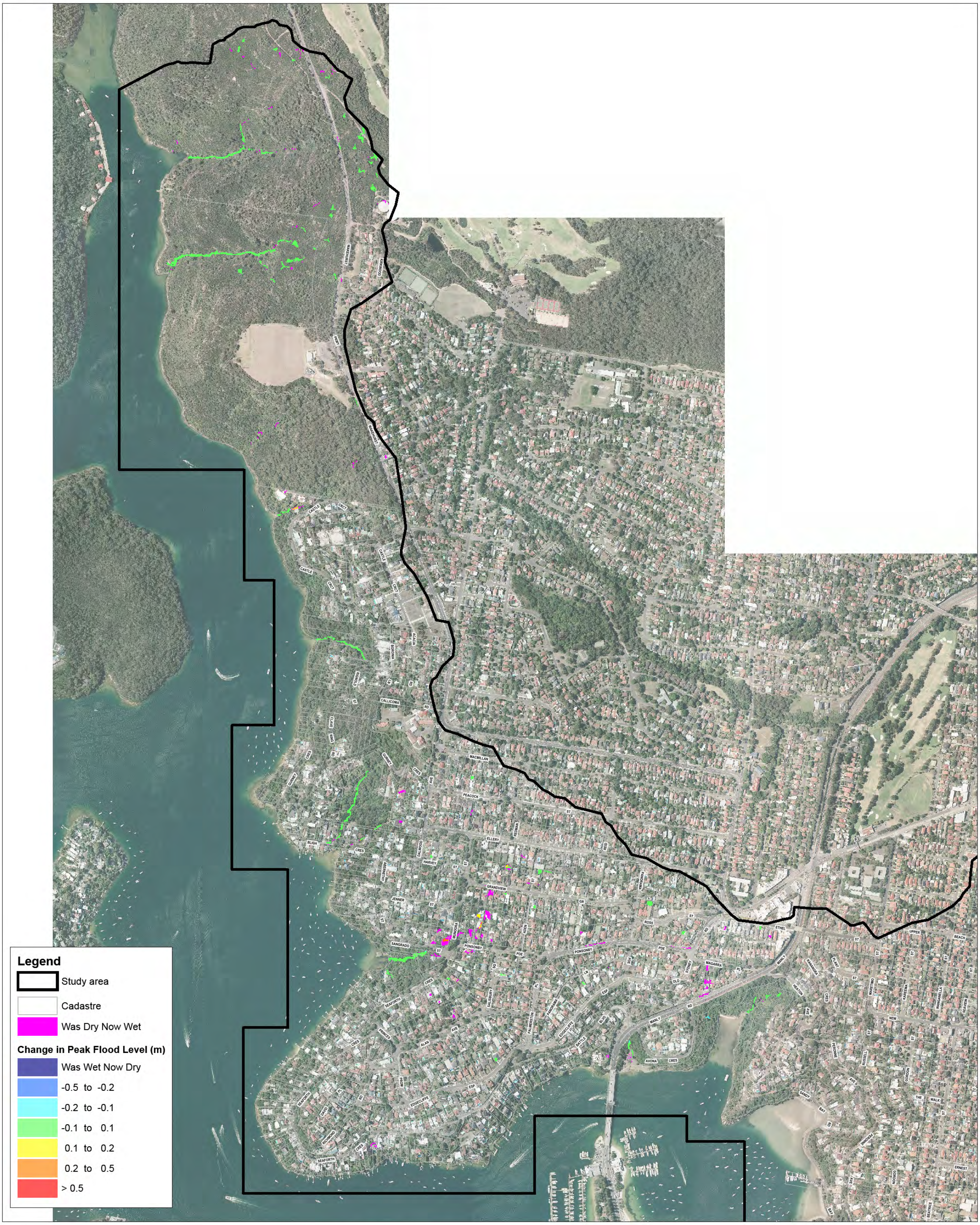
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Level
50% Structure Blockage
Map 3/3

Figure 93

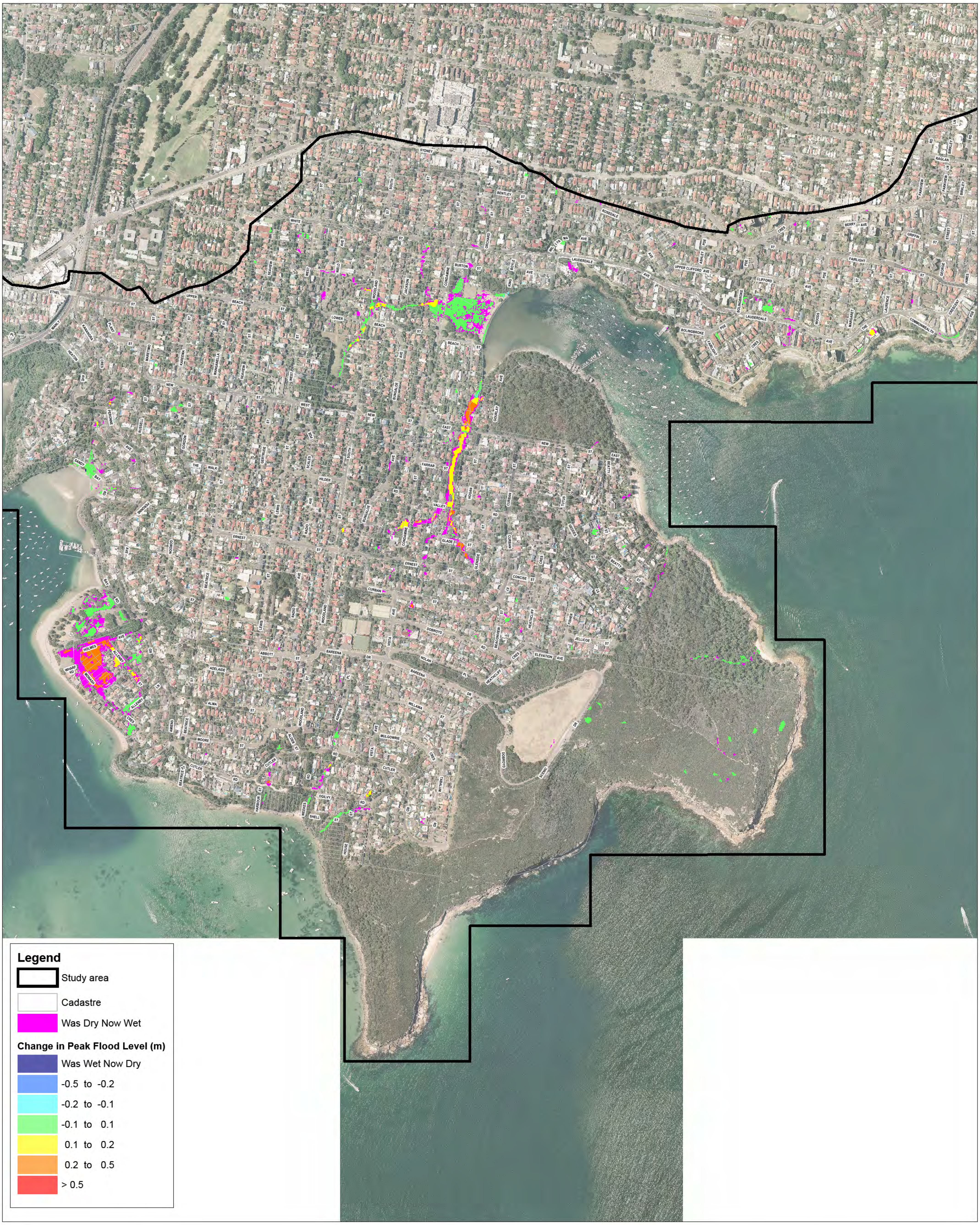
Cardno



Manly to Seaforth Flood Study
Change in Peak Flood Level
100% Structure Blockage
Map 1/3

Figure 94

Cardno



Legend

Study area

Cadastre

Was Dry Now Wet

Change in Peak Flood Level (m)

Was Wet Now Dry

-0.5 to -0.2

-0.2 to -0.1

-0.1 to 0.1

0.1 to 0.2

0.2 to 0.5

> 0.5

N

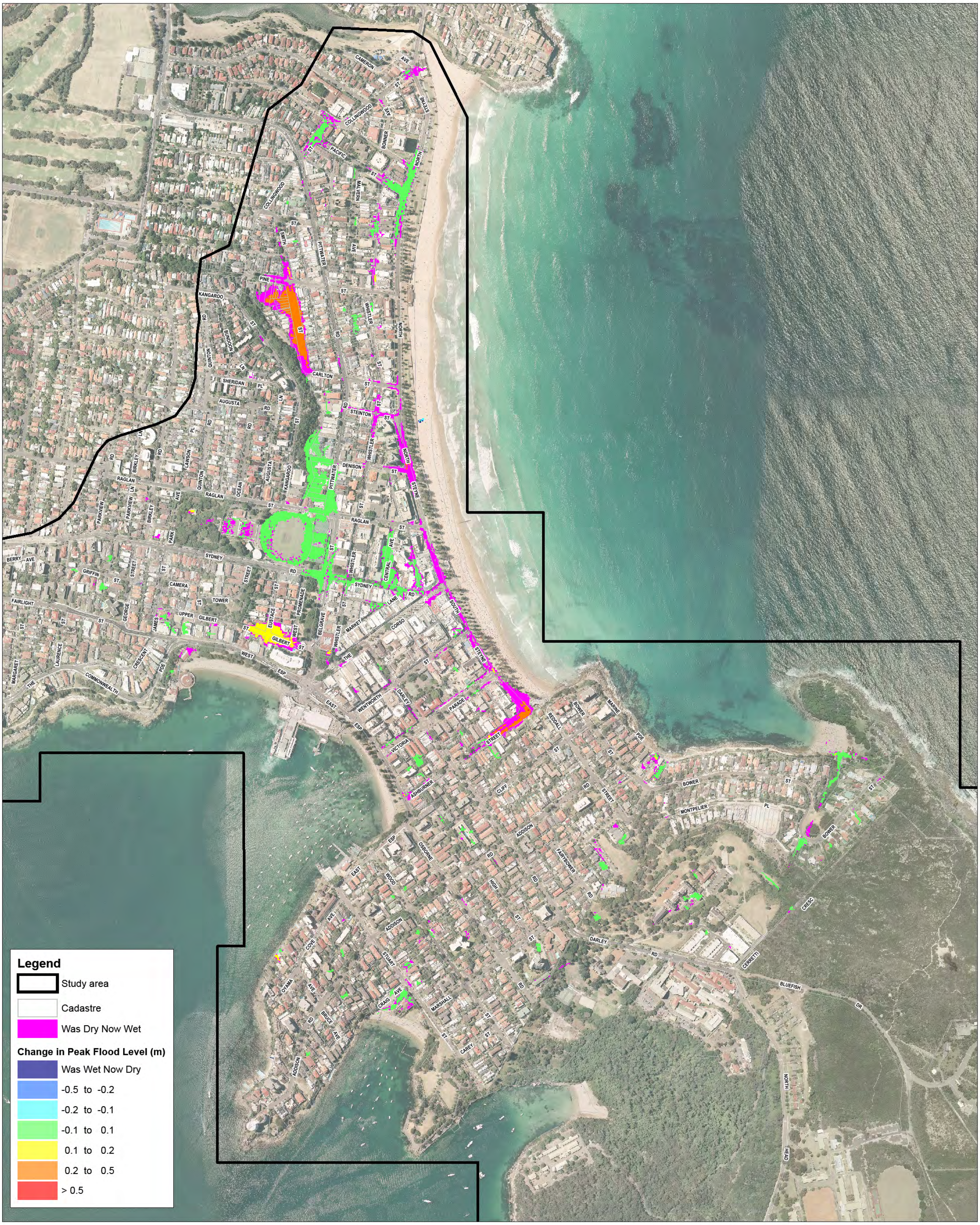
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Level
100% Structure Blockage
Map 2/3

Figure 95

Cardno



N

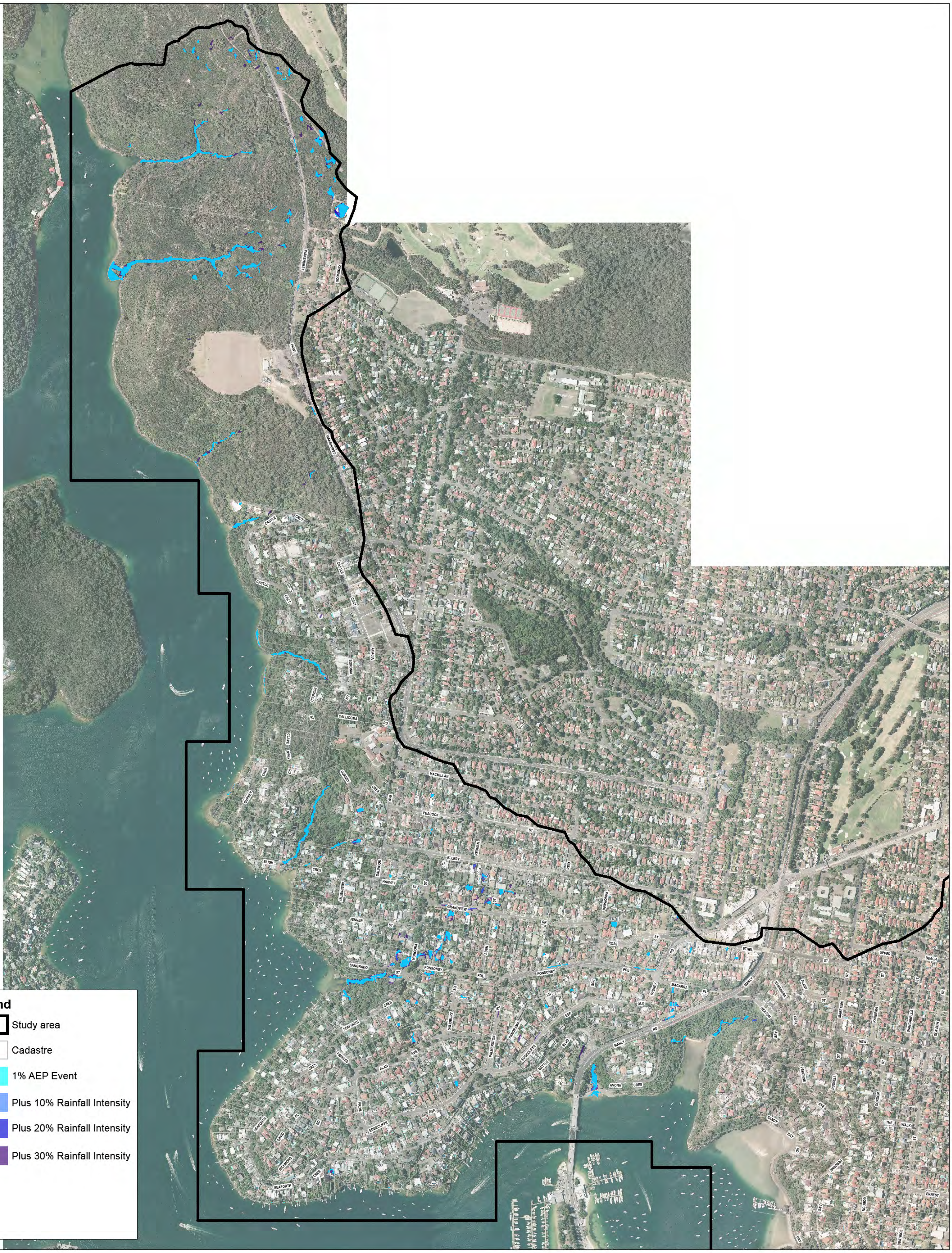
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Level
100% Structure Blockage
Map 3/3

Figure 96

Cardno



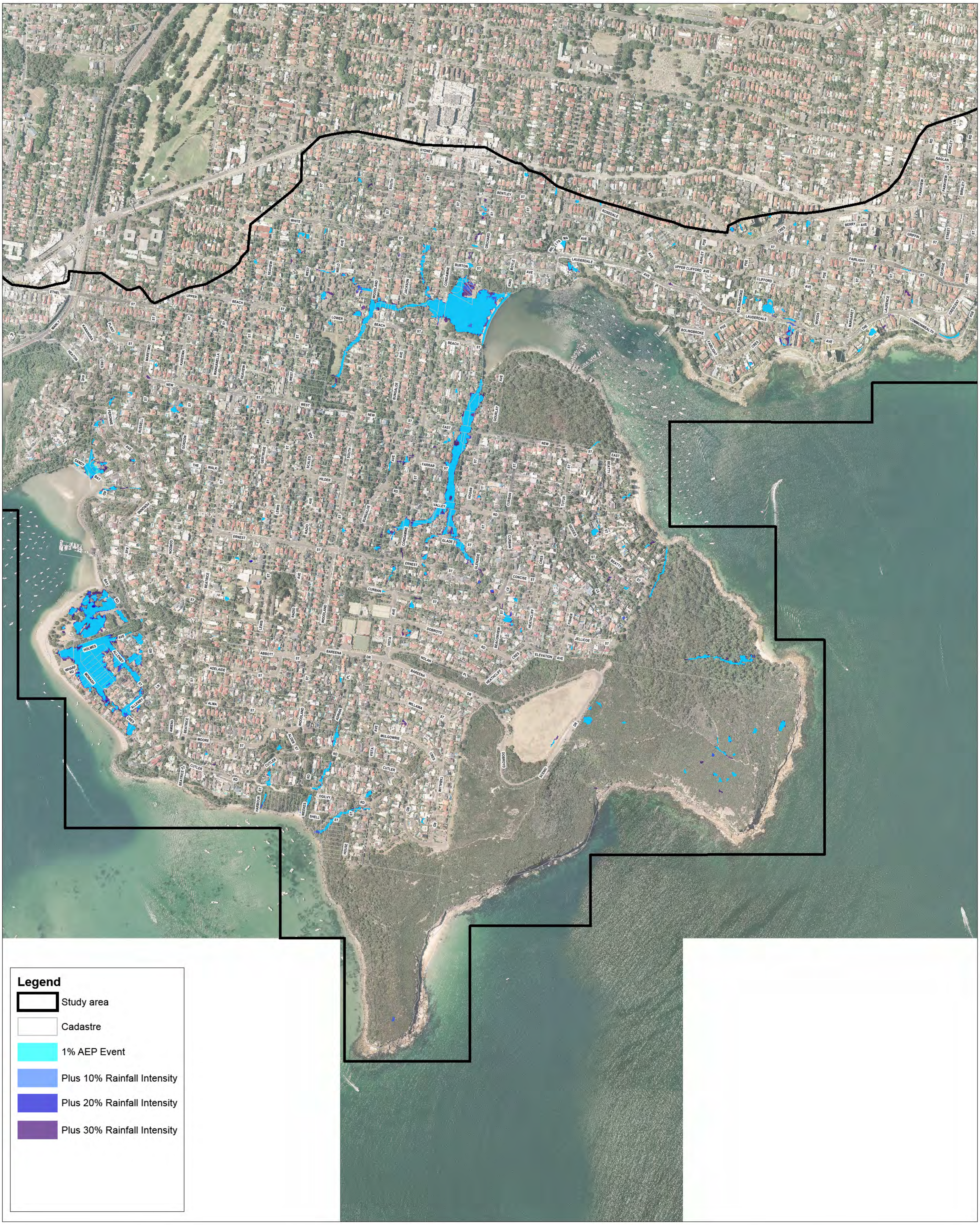
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Inundation Extent
Increased Rainfall Intensities
Map 1/3

Figure 97

Cardno



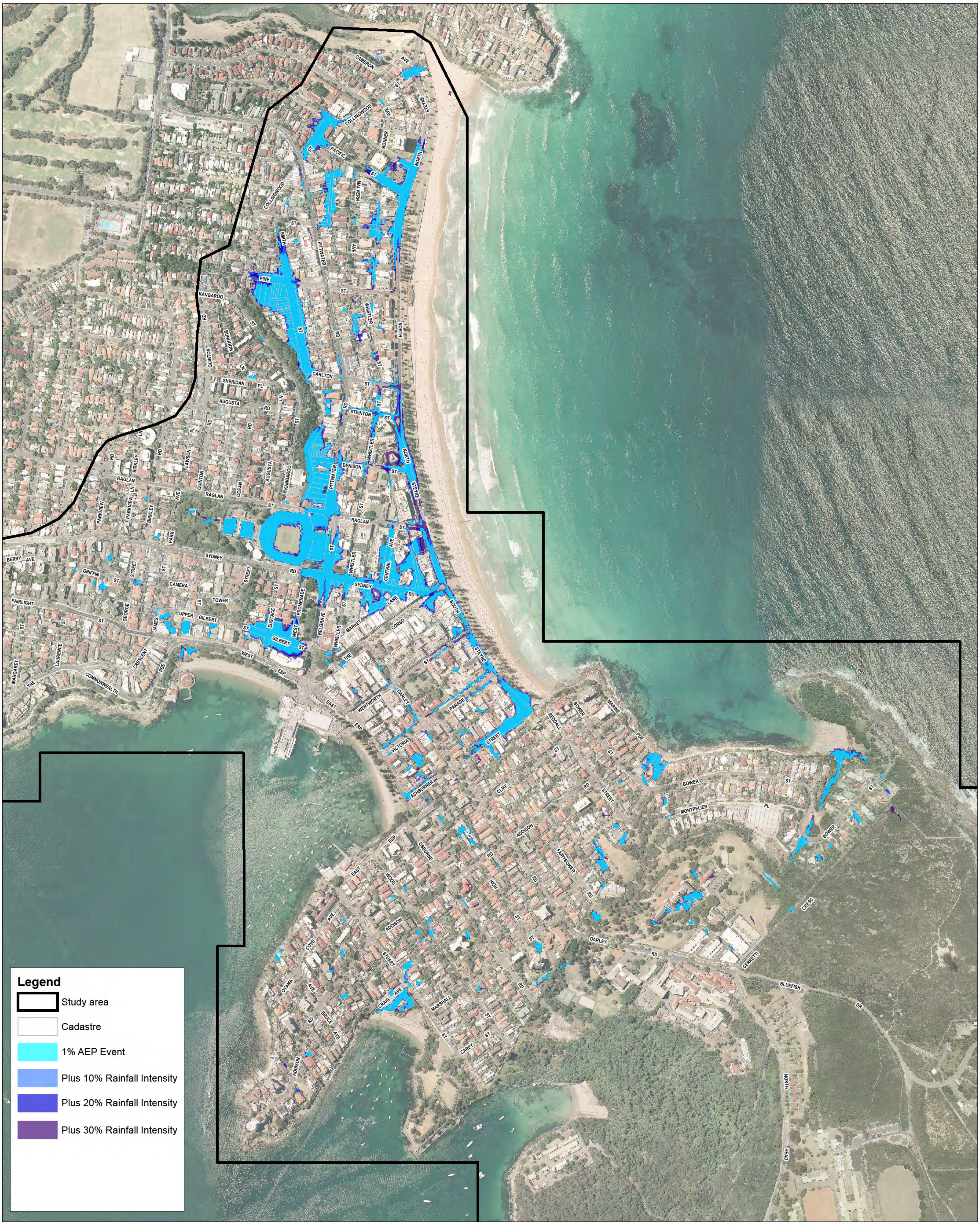
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Inundation Extent
Increased Rainfall Intensities
Map 2/3

Figure 98

Cardno



N

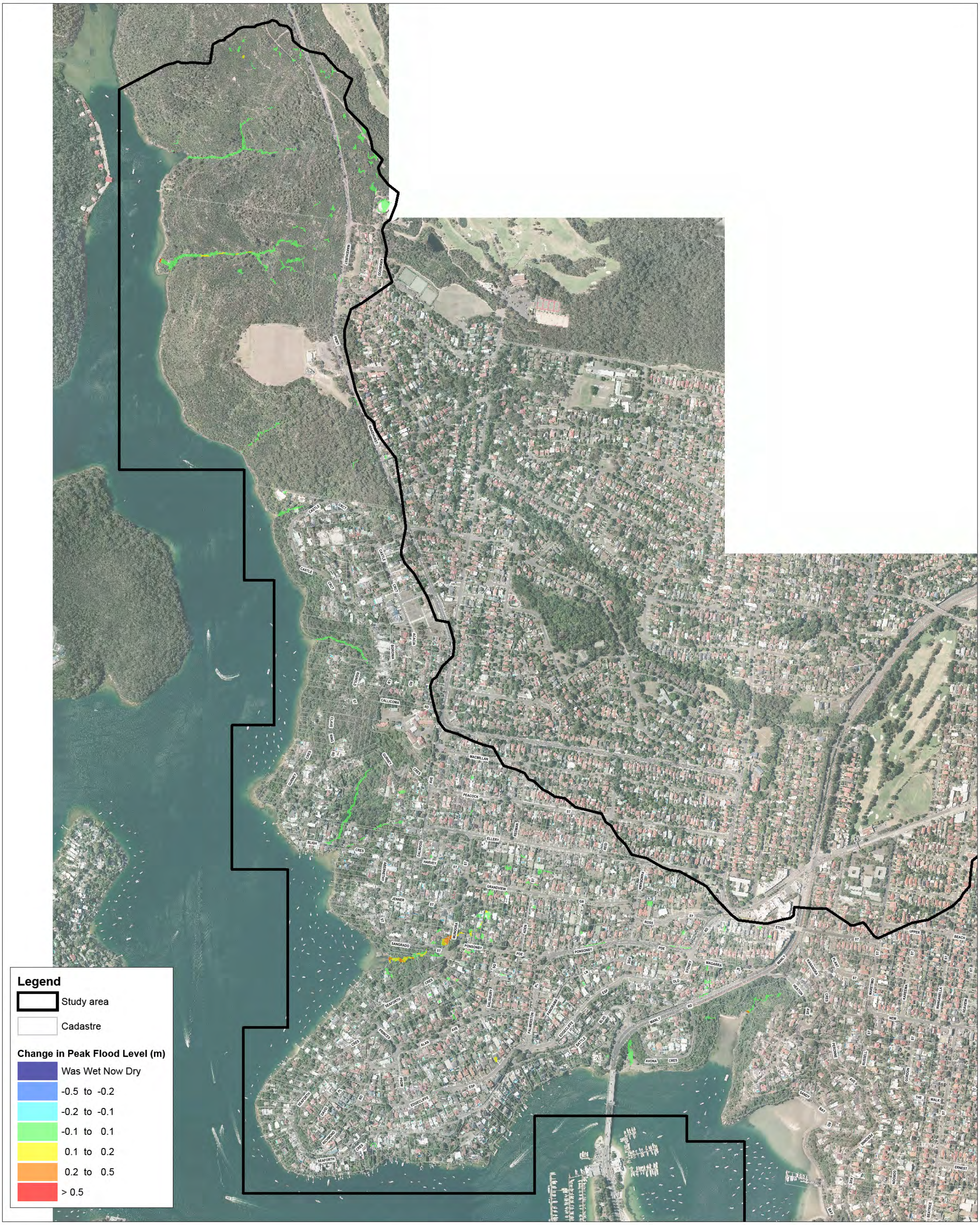
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Inundation Extent
Increased Rainfall Intensities
Map 3/3

Figure 99

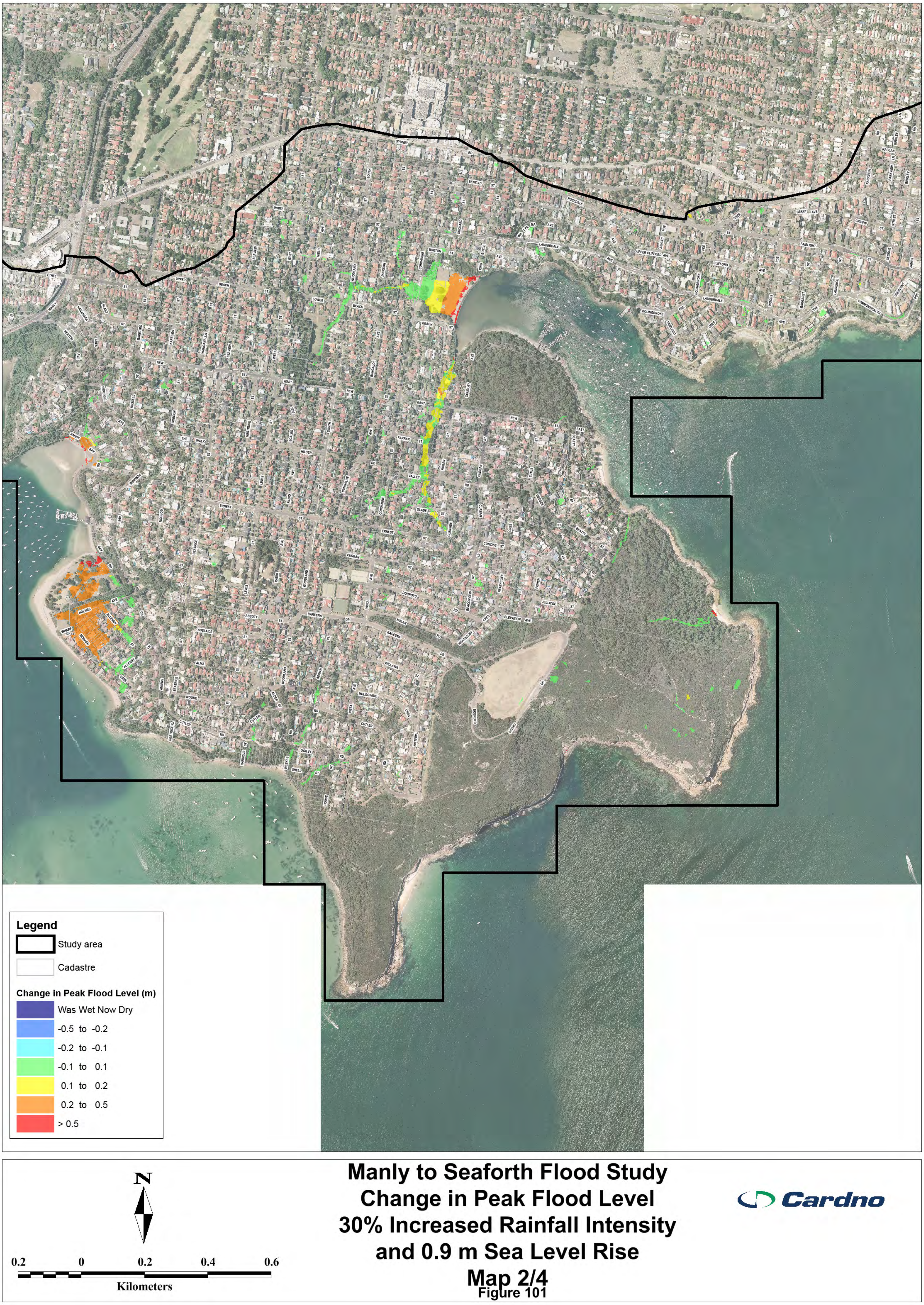
Cardno



Manly to Seaforth Flood Study
Change in Peak Flood Level
30% Increased Rainfall Intensity
and 0.9 m Sea Level Rise
Map 1/4

Cardno

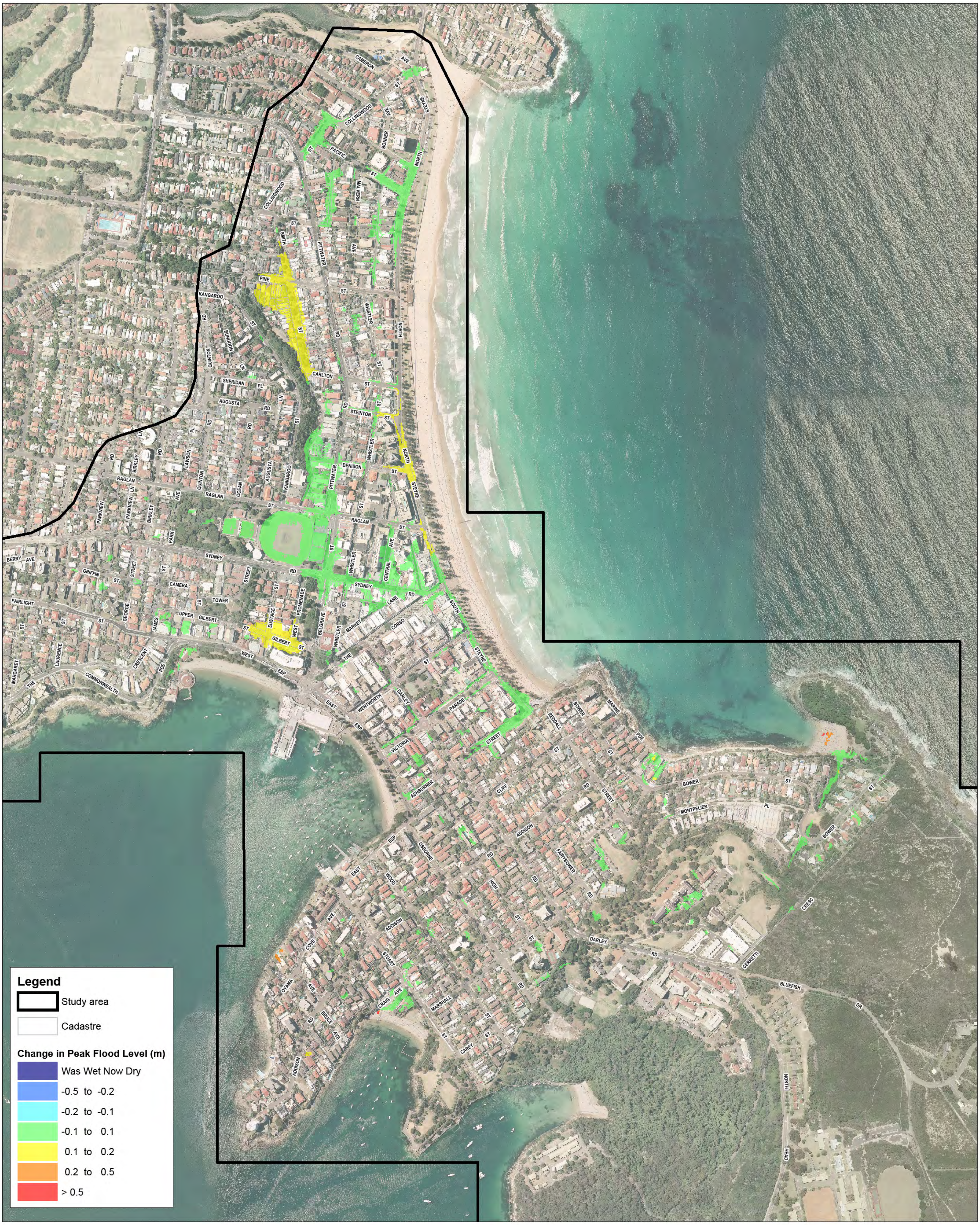
Figure 100



Manly to Seaforth Flood Study
Change in Peak Flood Level
30% Increased Rainfall Intensity
and 0.9 m Sea Level Rise
Map 2/4

Figure 101

Cardno



N

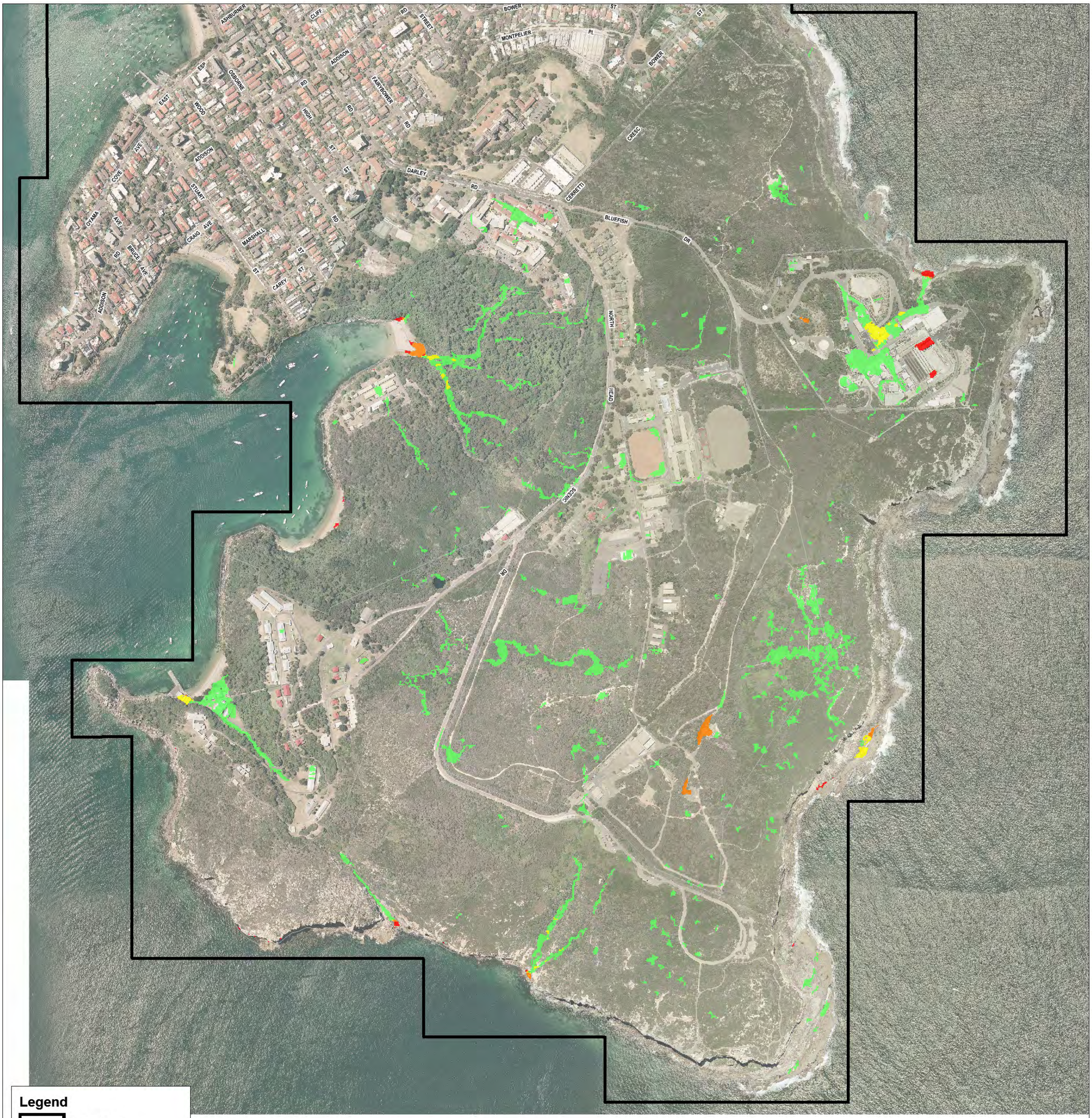
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Level
30% Increased Rainfall Intensity
and 0.9 m Sea Level Rise
Map 3/4

Figure 102

Cardno



Legend

Study area

Cadastre

Change in Peak Flood Level (m)

Was Wet Now Dry

-0.5 to -0.2

-0.2 to -0.1

-0.1 to 0.1

0.1 to 0.2

0.2 to 0.5

> 0.5

N

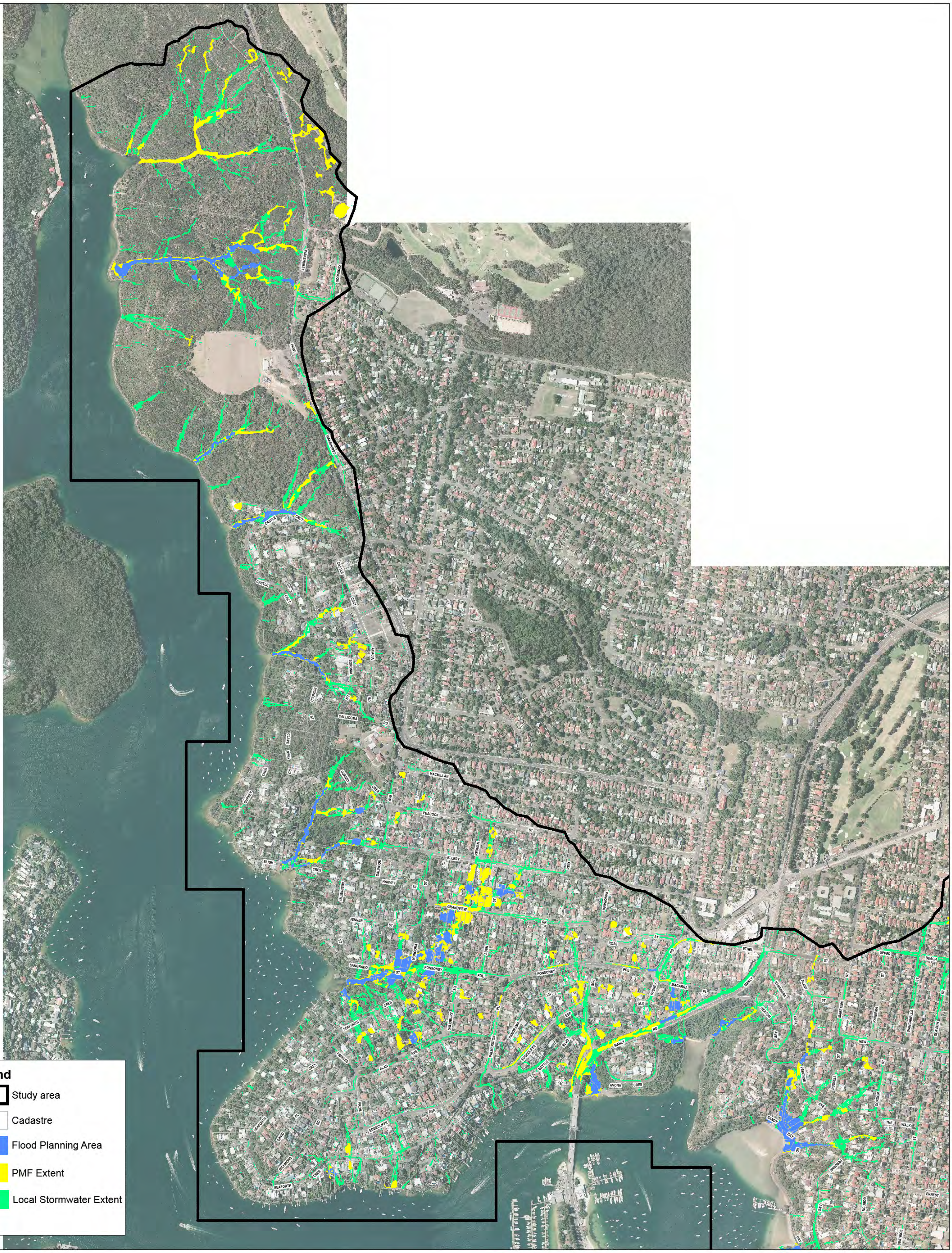
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
Change in Peak Flood Level
30% Increased Rainfall Intensity
and 0.9 m Sea Level Rise
Map 4/4

Figure 103

Cardno



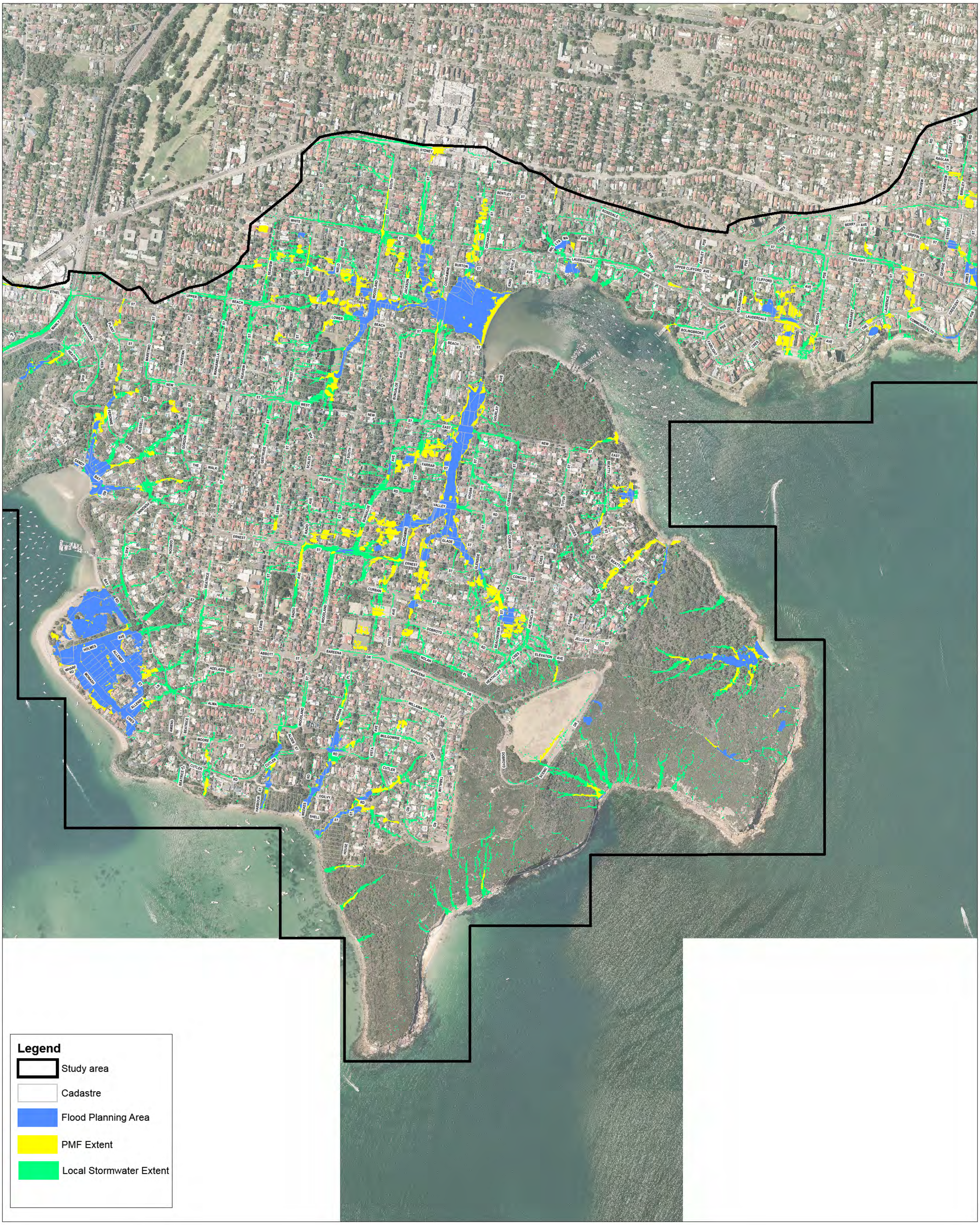
N

0.2 0 0.2 0.4 0.6
Kilometers

Manly to Seaforth Flood Study
Flood Planning Area
Map 1/4

Cardno

Figure 104



N

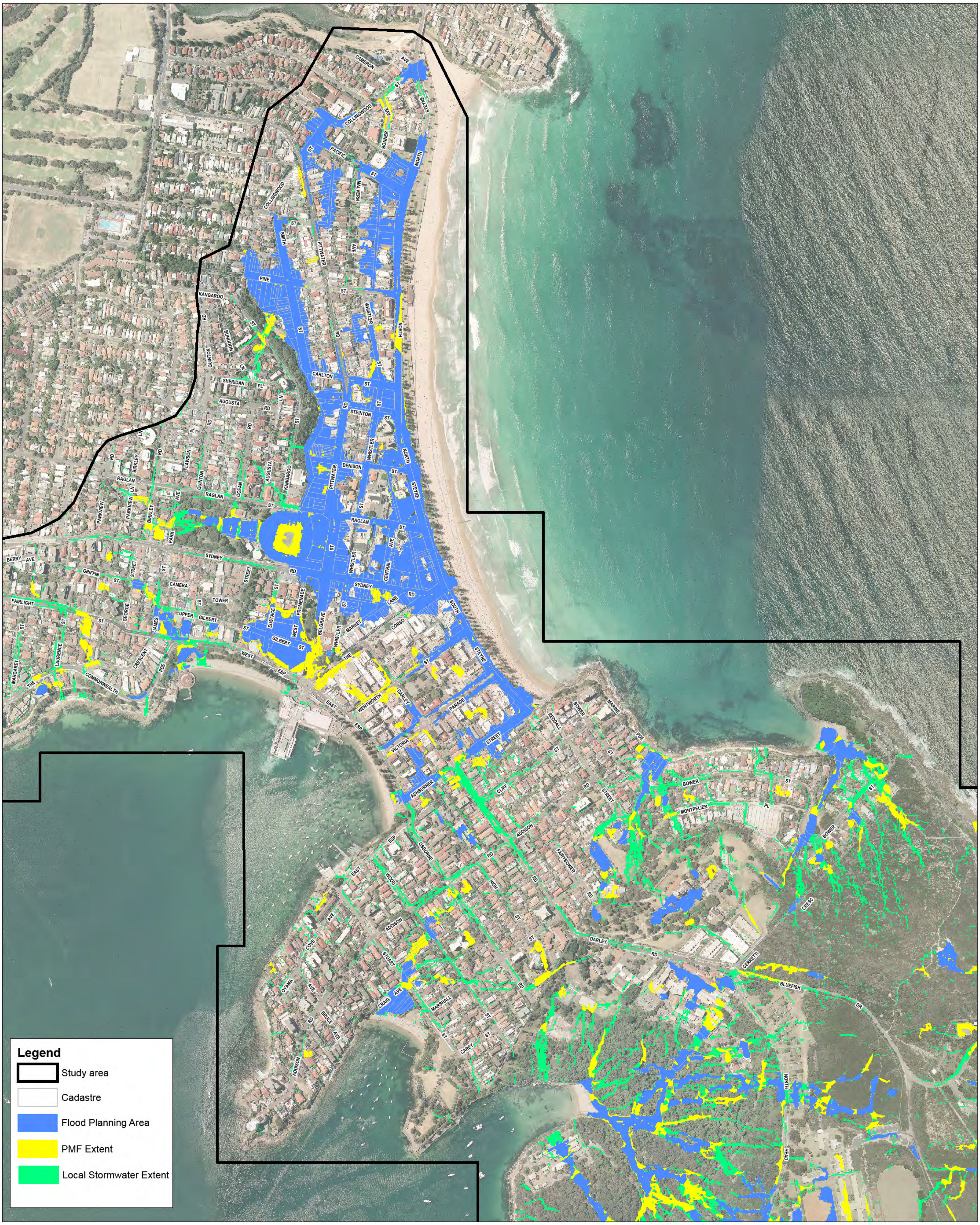
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
Flood Planning Area
Map 2/4

Cardno

Figure 105



N

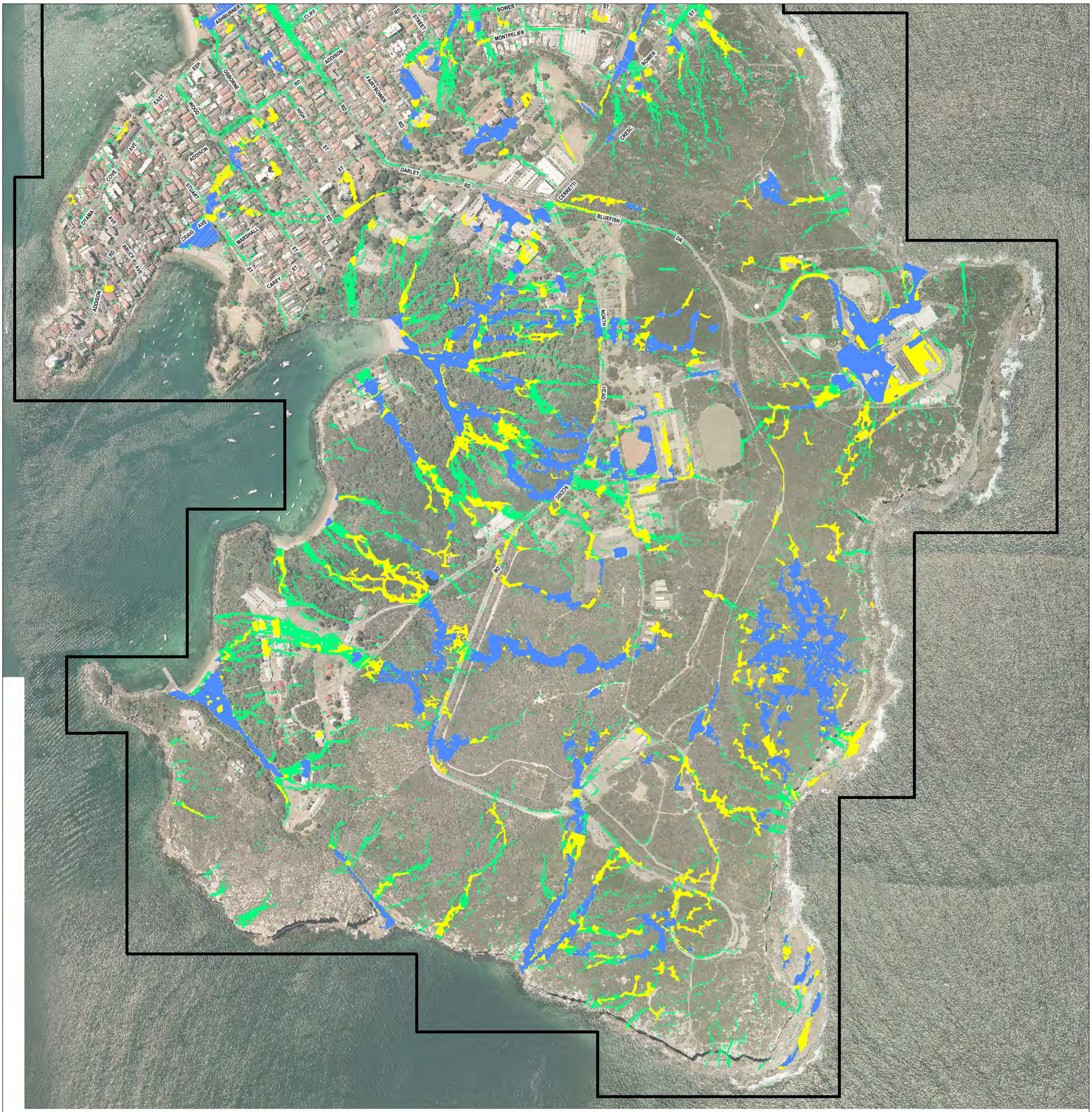
0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
Flood Planning Area
Map 3/4

Cardno

Figure 106



Legend

- Study area
- Cadastre
- Flood Planning Area
- PMF Extent
- Local Stormwater Extent

N

0.2 0 0.2 0.4 0.6

Kilometers

Manly to Seaforth Flood Study
Flood Planning Area
Map 4/4

Cardno

Figure 107

APPENDIX

D

COMMUNITY CONSULTATION

FLOOD STUDY

MANLY LOCAL GOVERNMENT AREA FLOOD STUDY RESIDENT SURVEY

MARCH 2014

Manly Council is undertaking a Flood Study of the Manly Local Government Area (LGA) Catchment to gain a detailed understanding of flood behaviour and flood risks to the community. The study area encompasses several suburbs including all of Clontarf and Balgowlah Heights, the majority of Manly and Seaforth, and parts of Balgowlah and Fairlight (see Figure 1). The study area makes up the remaining area of the Manly LGA that was not part of the Manly Lagoon Catchment Flood Study Area. Cardno has been engaged by Council to undertake the study.

Community input to the Flood Study is important in understanding historic flood behaviour. As a local resident, landowner or business owner, you may have experienced flooding in the past, and your observations of flood levels, duration of flooding, and drainage patterns can assist the study team in identifying problem areas.

Please find below a series of questions about flooding and drainage in the survey below. We would like to invite you to complete the online survey at https://surveymonkey.com/s/ManlyLGAFS. Alternatively, please return the completed hard copy survey to Council in the enclosed reply paid envelope (no stamp required). We would appreciate your feedback by 30 May 2014. All information provided will remain confidential and is used only for the purposes of this study.

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Question 1: Could you please provide us with the following details? We may contact you to discuss the information you provide.

Name:____

Address:____

Phone or email:____

Question 2: What is the property type?

- ☐ Residential
- ☐ Industrial
- ☐ Commercial
- ☐ Other (Please Specify)______________________________

Question 3: How long have you lived or worked at this property?

__________years__________months

Question 4: What is the status of the property?

- ☐ Owner-occupied residence or owner-operated business
- ☐ Leased to tenants
- ☐ Other (Please Specify)______________________________

Question 5: What is your level of awareness of flooding having occurred in the study area?

- ☐ Aware / personal knowledge
- ☐ Some awareness
- ☐ No prior knowledge

Question 6: Have you ever experienced flooding at the address you specified above from streets, channels or creeks? Do you have any evidence of past flood events in the study area (e.g. photos, video footage, watermarks on walls or posts)? Yes / No

If you answered yes to this question, please provide details of the date(s) the flooding occurred and which parts of your property were affected.

Example response, back yard only: 12 February 2012 at 10:30pm. Back yard flooded from direction of adjacent creek for a period of 15-30 minutes. Floodwaters continued along the fence line and into adjacent properties.

- ☐ Front or back yard
- ☐ Shed or garage
- ☐ Residential - below floor level
- ☐ Residential - above floor level
- ☐ Commercial (e.g. shop) - below floor level
- ☐ Commercial - above floor level
- ☐ Industrial (e.g. factory)
- ☐ Other

Please specify:

Question 7: If you have experienced flooding elsewhere in the study area, what other areas have you seen flooded? Please provide details below.

- ☐ Residential or commercial areas______________________________
- ☐ Roads or footpaths______________________________
- ☐ Parks______________________________
- ☐ Other______________________________

Please specify:

Question 8: Have you ever been inconvenienced by a flood event? Please provide details with respect to the date, time and nature of the issue.

- ☐ My/our daily routine was affected (e.g. it was difficult to get to work)____________________
- ☐ My/our safety was threatened______________________________
- ☐ Access to our property was affected (e.g. driveway or roads flooded)____________________
- ☐ My/our property and/or its contents were damaged______________________________
- ☐ My/our business was unable to operate during or after the flood____________________
- ☐ Other ______________________________

Please specify:

Question 9: Have you noticed any stormwater drains, creeks, channels, bridges and/or culverts blocked during a flood event?

- ☐ Yes
- ☐ No

If Yes, please provide details including the location and extent of blockage (e.g. would you say it was 20%, 50% or 80% blocked?). What was causing the blockage (leaves, branches, rubbish, other)?

Question 10: If you have any other information you would like to provide to inform the Manly LGA Flood Study, please provide details below.

Would you like to be kept informed on the progress of the Flood Study, including future consultation activities?

- [ ] Yes
- [ ] No

Thank you for providing this information. Please remember to place all pages in the reply paid envelope and return it to Council by 30 May 2014. A representative from Council or their consultants, Cardno, may contact you in the near future to discuss your response.

This project is supported by the NSW Government's Floodplain Management Program