Appendix A

APPENDIX A TERMINOLOGY AND GLOSSARY

A1 Probability Terminology

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

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

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

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

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

A copy of the draft terminology is available at: http://www.arr.org.au/arr-guideline/draft-chapters/

A2 Glossary

Taken from the Floodplain Development Manual (April 2005 edition)

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

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

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

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

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

Appendix B

APPENDIX B: FLOOD STUDY AND MODEL CONVERSION TO TUFLOW

B.1 Hydraulic Model Conversion to TUFLOW

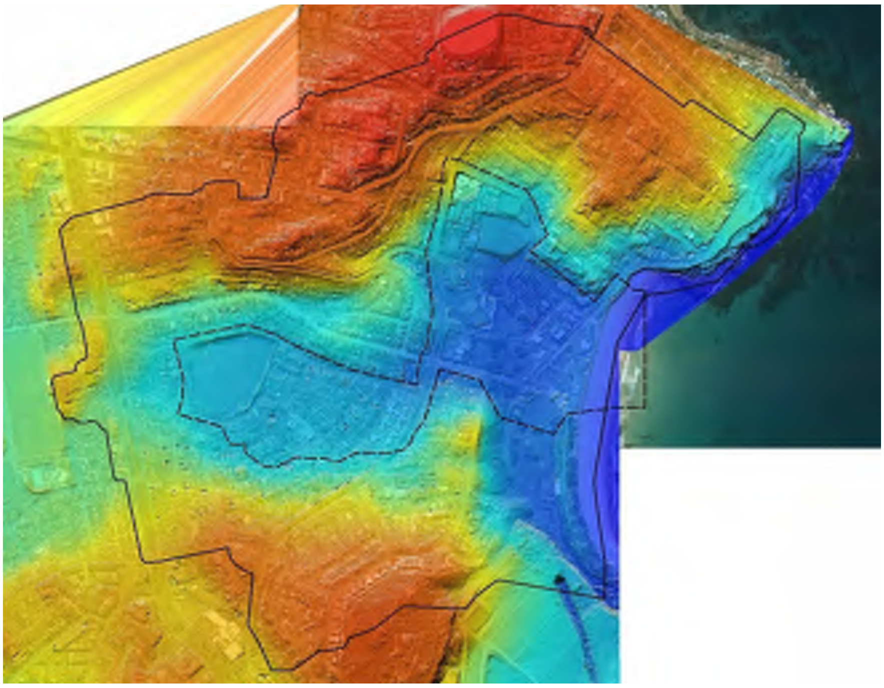
Hydraulic modelling undertaken as part of the Flood Study is typically used to inform the FRMS&P. This hydraulic modelling defines the base case scenario; the potential flood behaviour for a range of design events under current conditions. A number of mitigation options are then assessed against the base case to establish impact of potential measures. Model results are also used to inform the damages assessment and benefit/cost ratio potential measures.

As part of this FRMS&P the modelling approach undertaken in the 2011 Flood Study (Reference 3) was revised. The main change was to undertake the modelling in TUFLOW rather than SOBEK. Whilst both are 2D models and suitable for the task TUFLOW has become the dominant 2D modelling approach in NSW and principally for this reason Council requested that it be changed. The main tasks that were undertaken are described in the following sections.

B1.1 Task 1: Prepare DTM for TUFLOW Hydraulic Model

LIDAR or ALS survey data was adopted as the base DTM for the 2011 Flood Study SOBEK model. However the 2D hydraulic modelling approach was only undertaken for the lower regions of the catchment (bounded by the black dotted line in Photo B1) to better represent the complexity of the overland flow behaviour in this area. For the current TUFLOW model, the same DTM was adopted with the 2D model extents extended to cover the whole Maroubra Bay catchment (bounded by the black continuous line in Photo B1). Within the 2D model domain, the topography was defined using a regular grid of 2 m x 2 m cells.

Photo B1: DTM for TUFLOW model



B1.2 Task 2: Convert and Refine 1D Pits and Pipes Network from SOBEK to TUFLOW

All SOBEK elements including pits and pipes were extracted and interpreted as TUFLOW elements. Photo B2 shows the pits/pipes drainage network for the TUFLOW model. The drainage system for the catchment defined in the TUFLOW model comprises:

- 1,039 pits and nodes, including surface inlets, junctions, headwall inlets and outlets; and
- 1,038 links/reaches representing sub-surface drainage lines (e.g. circular pipes or box culverts).

Photo B2: Pits/pipes Drainage Network

Overland flow paths previously represented in 1D in the SOBEK model for the upper regions of the catchment are now defined by the DTM within the 2D TUFLOW model domain. The definition of these flow paths was previously based on the locations of pits and the layout of roads, drainage reserves and other potential flow paths identified from site inspections, topographic information and available survey data. To ensure the correct overtopping level was represented in the TUFLOW model, break-lines were created for features such as road crowns and kerbs.

B1.3 Task 3: Prepare Inflow Boundary Conditions from MIKE-Storm

The catchment hydrology was extracted from MIKE-Storm for a number of design rainfall events including the 1% AEP event. The 1% AEP event was primarily used in the testing of the robustness of the model conversion process. The hydrology for historical events (i.e. 1959 and 1999) has also been extracted and utilised in the model calibration and validation process. The hydrological parameters (i.e. fraction impervious, rainfall losses) adopted for this study remain unchanged from the 2011 Flood Study.

The inflow boundary conditions were applied within the TUFLOW 2D model domain as shown in Photo B3.

Photo B3: Application of Inflow Boundary Conditions (yellow circles)

B1.4 Task 4: Manning's Roughness and Effective Flow Paths

The hydraulic efficiency of flow paths within both the SOBEK and TUFLOW models was represented in part by the hydraulic roughness or friction factor formulated as Manning's 'n'. This factor describes the net influence of bed roughness and incorporates the effects of vegetation and other features that may affect the hydraulic efficiency of the particular flow path. The values for each grid cell were estimated based on established references and engineering experience. These values, as provided in Table B1, were applied to the 2D overland area based on land use in both models but with slight differences as the TUFLOW model 2D extent covered the whole catchment. The inclusion of areas such as the Arthur Byrne Reserve means that an additional category has to be defined to account for medium vegetation areas.

Table B1: Adopted Manning's 'n' values in TUFLOW

Land Use	Manning's 'n'
Car park and open space	0.03
Roads and pavements	0.015
Light vegetation, parks, grassed area	0.03
Medium vegetation, trees	0.06

All pipes and culverts (modelled in 1D) were allocated a Manning's 'n' roughness of 0.015.

The blockage effect presented by buildings on the floodplains was accounted for by "nulling" the corresponding grid cells based on the digitised building outlines (refer Photo B4) which constrict the available flow path. Hence there is no need to use higher Manning's 'n' values for those areas. The loss of temporary floodplain storage by nulling the building outlines and assuming the buildings are impermeable is a slightly conservative assumption as in reality some floodwaters may enter these buildings under some flooding scenarios. Nevertheless this approach was adopted as it was considered that the impact of such an assumption would be negligible relative to the overall flood runoff volume.

Photo B4: "Nulling" of Grid Cells based on Building Outlines

B1.5 Task 5: Model Testing and Comparison of Results

Testing of the interpreted model elements was carried out using the 1% AEP event design flows to mainly ascertain the impact on the modelling results of the different approaches used in the two hydraulic models (i.e. SOBEK vs. TUFLOW) including the definition of pit inlet capacity and pipe losses.

In the SOBEK model, a weir system was defined to transfer water from the surface to the 1D sub-surface pipe network. The TUFLOW model utilised a slightly different approach whereby a short channel called the pit channel was inserted at the pit node to transfer water between the 2D domain on the surface and the 1D sub-surface pipe network.

The SOBEK model does not implicitly calculate energy losses at pits in the pipe drainage network. Typically these types of losses result from changes in flow direction, changes in elevation and losses associated with the expansion and contraction of flow as it passes through the pit. It was therefore necessary to modify the SOBEK model configuration to account for these losses by incorporating an orifice at each exit from a pit with representative orifice coefficients.

The TUFLOW model, on the other hand, calculates losses based on the Engelhund Manhole Loss Approach for manholes automatically inserted at all pipe/culvert junctions/nodes.

The potential for pit blockages within the drainage system was accounted for by adopting a 20% blockage factor for on-grade pits and a 50% blockage factor for pits located at sag points. As a result of post flood experiences at North Wollongong – 1998 and Newcastle – 2007, it is also considered best practice to implement some level of blockage for trunk drainage. A consensus was reached with Council that a blockage factor should be incorporated in modelling the drainage pipes and hence a 25% blockage factor was adopted for the sub-surface drainage system.

Referring to Figure B1 which compares the pipe flow hydrographs for the 1% AEP event generated by the TUFLOW and SOBEK models, the TUFLOW 0% pipe blockage results seem to match the SOBEK results better. For most locations, the TUFLOW model predicted lower peak flows (for both blockage scenarios) which is to be expected since pipe flow in the SOBEK model is more efficient. In comparing the 1% AEP peak flood levels at various locations within the catchment (refer Figure B2), the TUFLOW 25% pipe blockage results are generally closer to the SOBEK results. For both pipe blockage scenarios, a reduction of the peak flood levels was generally predicted by the TUFLOW model which can be explained by the better representation of floodplain storage in the TUFLOW model compared to the SOBEK model. This has major implication on the predicted flood extents which in turn determine the number of properties tagged as flood affected.

Calibration of the TUFLOW hydraulic model to historical events provided results that are not dissimilar to those of the previous study, with the level of ponding over-estimated in the lower reaches of the catchment (refer Figure B3, Table B2 and Table B3). The hydrological parameters (i.e. fraction impervious, rainfall losses) adopted for this study remain unchanged from the 2011 Flood Study.

Table B2: Model Calibration Results – January 1999 Event

Location	**Observed Water Level (mAHD)**	**Modelled Water Level - SOBEK (mAHD)**	**Modelled Water Level - TUFLOW (mAHD)**
Fenton Ave & Chapman Ave	5.45-5.8	5.98	5.97
Marine Pde & McKeon St	5.63-5.8	5.97	5.96

Table B3: Model Validation Results – October 1959 Event

Location	Observed Water Level (mAHD)	Modelled Water Level - SOBEK (mAHD)	Modelled Water Level - TUFLOW (mAHD)
Fenton Ave & Chapman Ave	5.6-5.7	5.98	5.98
Marine Pde & McKeon St	n/a	5.98	5.97

A field trip was also undertaken to confirm assumptions regarding overland flow through private properties as well as the model's performance at several key locations in the catchment.

Overall, the TUFLOW model produced results that are fairly similar to those from the SOBEK model (difference in peak flood levels largely within ±300mm) despite the various revisions introduced herein and this provides a certain degree of confidence for the model results to be adopted for use in the FRMS&P.

B1.6 Task 6: Further Model Refinement and Design Runs

After the successful calibration and validation of the revised TUFLOW hydraulic model against historical flood events, the model was further refined to take into account minor changes in the catchment that have taken place subsequent to the 2011 Flood Study. These changes include:

- Revised outlet structure for the Coral Sea Park flood retarding basin; and
- Modification to the pit inlet configuration for the Haig Street trapped low point between Flower Street and Maroubra Road.

The resulting TUFLOW model and associated Manning's "n" layers are shown on Figure B4 and Figure B5 respectively.

The design events were modelled (refer Tables B4 and B5) with these revisions incorporated into the model for the 1 EY, 0.5 EY, 0.2 EY, 5% AEP, 1% AEP and PMF events. The critical duration storm in terms of peak outflows and levels for the lower parts of the catchment was found to be 120 minutes which is the same as that of the 2011 Flood Study for the 1% AEP event. However, for the PMF event, the critical duration storm was taken as 60 minutes rather than 90 minutes as previously adopted. Flood mapping is provided as Appendix C.

Table B4: Peak Flows (m^3/s) for Design Events

ID	Location - Refer Figure 1	1 EY	0.5 EY	0.2 EY	5% AEP	1% AEP	PMF
1D Pipe Flows							
P1	Main Stormwater Outlet	2.5	6.1	9.3	10.9	11.8	14.1
P2	Downstream of Byrne Crescent	0.5	1.5	2.6	2.8	2.8	3.0
P3	Coral Sea Park Outlet	0.7	2.0	2.9	3.5	3.9	4.1
P4	Downstream of Haig St	0.2	0.4	0.8	0.8	0.9	1.0
P5	Downstream of Fitzgerald Ave/Maroubra Rd Intersection	1.6	3.9	5.7	6.4	6.9	6.8
P6	Downstream of Duncan St/McKeon St Intersection	0.4	1.1	1.8	2.1	2.1	2.1
P7	Maroubra Rd Outlet	0.1	0.3	0.5	0.5	0.6	0.6
P8	Torrington Rd Outlet	0.2	0.4	0.5	0.6	0.6	0.9

ID	Location - Refer Figure 1	1 EY	0.5 EY	0.2 EY	5% AEP	1% AEP	PMF
	2D Overland Flows						
OF1	Beach Overflow	NF	NF	NF	NF	<0.1	158.8
OF2	CSP Basin Overflow	NF	NF	NF	NF	NF	36.4
OF3	Yorktown Pde	<0.1	0.2	0.9	2.2	3.9	16.0
OF4	Astoria Circuit	<0.1	<0.1	0.3	1.3	2.9	13.4
OF5	Byrne Cres	NF	NF	<0.1	0.6	1.1	4.8
OF6	South Maroubra Village Green	<0.1	<0.1	<0.1	<0.1	0.4	7.4
OF7	Malabar Rd	<0.1	0.1	0.5	2.8	6.4	82.8
OF8	Fitzgerald Ave	<0.1	0.1	0.2	0.3	0.7	6.9
OF9	Maroubra Bay Public School	NF	NF	1.3	4.6	7.8	33.8
OF10	Broome St	0.5	2.0	4.0	9.8	17.9	144.4

Table B5: Peak Flood Levels (mAHD) for Design Events

ID	Location - Refer Figure 1	1 EY	0.5 EY	0.2 EY	5% AEP	1% AEP	PMF
H1	Marine Pde N of Maroubra Beach	8.6	8.7	8.8	8.8	8.9	9.1
H2	Tyrwhitt St	19.8	20.0	20.1	20.2	20.2	20.5
H3	Haig St	46.5	46.6	46.7	47.0	47.3	48.0
H4	Maroubra Rd & Flower St Intersection	NF	49.4	49.4	49.4	49.4	49.4
H5	Fitzgerald Ave & Chester Ave Intersection	20.7	20.7	20.8	20.9	20.9	21.2
H6	U/S of Retirement Village, Curtin Cr	24.0	24.1	24.1	24.4	24.6	25.0
H7	White Ave	38.9	39.0	39.1	39.3	39.3	39.5
H8	Near Corner of ANZAC Pde & Fitzgerald Ave	19.8	19.9	20.0	20.3	20.3	20.6
H9	Astoria Circuit	NF	NF	17.9	18.0	18.0	18.4
H10	Coral Sea Park	13.9	13.9	14.1	14.4	14.7	15.4
H11	Fenton Ave	NF	5.1	5.6	5.9	6.2	7.4
H12	Marine Pde & McKeon St Intersection	5.0	5.0	5.2	5.9	6.2	7.3
H13	Bottom of Byrne Crescent	NF	NF	17.4	17.4	17.5	17.7
H14	Beatty Lane	30.6	30.6	30.6	30.6	30.6	30.6
H15	French St	NF	38.6	38.6	38.6	38.7	38.8
H16	Malabar Rd U/S of Fitzgerald Ave	9.3	9.3	9.3	9.3	9.3	9.3
H17	Midway Dr D/S End of Coral Sea Park	NF	NF	NF	NF	14.8	15.0
H18	Yorketown Pde U/S of New Orleans Cr	12.9	12.9	13.0	13.0	13.1	14.0
H19	Fitzgerald Ave (St Mary & St Josephs School)	7.4	7.5	7.5	7.6	7.6	8.9
H20	D/S End of Bowling Club	NF	6.4	6.5	6.5	6.5	7.4
H21	Fenton Ave & Chapman Ave Intersection	NF	5.1	5.6	5.9	6.2	7.4

B1.7 Task 7: Sensitivity Analyses

A range of sensitivity analyses were undertaken to quantify the potential variation in the model results due to different assumptions in the key modelling parameters adopted. A comparison was carried out using peak flood levels and flows for the 1% AEP design event. The following scenarios were considered (similar to the 2011 Flood Study):

- Increasing the impervious fraction for the established residential areas of the catchment by 20%, 40% and 60%;
- ±20% change in Manning's 'n' value for overland flow paths and sub-surface drainage; and
- 0% and 50% pipe blockage.

A summary of the results obtained are shown in Tables B6 and B7. From the results, it can be observed that:

- The model is very sensitive to changes in impervious area above the calibrated 10%, with some overland flows increased by more than 100% when 60% impervious area is used. This is due to the adopted high loss ratio for pervious areas which means the majority of the runoff is from the impervious areas;
- Increasing the Manning's 'n' value for overland flow paths caused a greater attenuation of flows and generally results in a reduction in peak flows up to about 10%. However, there were locations where the peak flows were increased. This could be attributed to the relative timing of overland flows from contributing sub-catchments. The converse of these observations holds true for the effect of decreasing the Manning's 'n' value by a similar amount;
- Pipe flows are relatively sensitive to the blockage assumptions as expected (±40%). The reduced pipe flows generally translate to an increase in the overland flows as well as peak flood levels throughout the catchment;
- In terms of peak flood level estimates, the greatest changes were found to result from variations in estimated runoff due to changes in the assumed impervious fraction for the catchment. For example, an impervious fraction of 60% was found to increase flood levels by up to 0.3 m, depending upon the location within the catchment; and
- By contrast, the peak flood level estimates were much less sensitive to variations in the hydraulic model parameters such as the Manning's 'n' value. For ±20% variations in Manning's 'n' the corresponding variations in flood levels was found to be generally within ±0.05 m, with the flow variations typically within ±10% for the pipe flows.

Table B6: Sensitivity Analyses – Change in Peak Flows (%) for the 1% AEP Design Event

ID	Location - Refer Figure 1	Base (m^3/s)	Impervious Fraction +20%	Impervious Fraction +40%	Impervious Fraction +60%	Manning's 'n' -20%	Manning's 'n' +20%	0% Pipe Blockage	50% Pipe Blockage
1D Pipe Flows									
P1	Main Stormwater Outlet	11.8	1%	3%	4%	4%	-7%	33%	-36%
P2	Downstream of Byrne Crescent	2.8	0%	1%	1%	2%	-4%	33%	-35%
P3	Coral Sea Park Outlet	3.9	1%	4%	7%	5%	-6%	26%	-33%
P4	Downstream of Haig St	0.9	1%	3%	6%	2%	-2%	32%	-33%
P5	Downstream of Fitzgerald Ave/Maroubra Rd Intersection	6.9	1%	0%	1%	4%	-8%	34%	-37%
P6	Downstream of Duncan St/McKeon St Intersection	2.1	0%	1%	1%	4%	-6%	28%	-36%
P7	Maroubra Rd Outlet	0.6	0%	1%	3%	0%	0%	32%	-33%
P8	Torrington Rd Outlet	0.6	2%	4%	22%	5%	-2%	28%	-32%
2D Overland Flows									
OF3	Yorktown Pde	3.9	9%	25%	38%	-2%	-2%	-11%	11%
OF4	Astoria Circuit	2.9	12%	33%	55%	0%	3%	-12%	17%
OF5	Byrne Cres	1.1	4%	16%	25%	11%	-2%	-4%	10%
OF6	South Maroubra Village Green	0.4	30%	99%	187%	31%	-11%	-74%	94%
OF7	Malabar Rd	6.4	14%	39%	64%	9%	-2%	-14%	17%
OF8	Fitzgerald Ave	0.7	21%	73%	128%	7%	-3%	-2%	7%
OF9	Maroubra Bay Public School	7.8	10%	16%	34%	24%	-10%	-14%	5%
OF10	Broome St	17.9	7%	27%	44%	5%	-4%	-6%	5%

Table B7: Sensitivity Analyses – Change in Peak Flood Levels (m) for the 1% AEP Design Event

ID	Location - Refer Figure 1	Base (mAHD)	Impervious Fraction +20%	Impervious Fraction +40%	Impervious Fraction +60%	Manning's 'n' -20%	Manning's 'n' +20%	0% Pipe Blockage	50% Pipe Blockage
H1	Marine Pde N of Maroubra Beach	8.87	0.01	0.03	0.04	0.01	-	-	0.01
H2	Tyrwhitt St	20.17	-	0.01	0.02	-0.01	0.01	-	-
H3	Haig St	47.29	0.06	0.16	0.26	-	-	-0.11	0.15
H4	Maroubra Rd & Flower St Intersection	49.43	-	-	-	0.04	-	-	-
H5	Fitzgerald Ave & Chester Ave Intersection	20.95	0.01	0.04	0.07	-0.01	0.01	-0.01	0.02
H6	U/S of Retirement Village, Curtin Cr	24.62	0.02	0.07	0.11	0.01	-	-0.09	0.07
H7	White Ave	39.35	0.01	0.02	0.03	-0.01	0.01	-0.03	0.02
H8	Near Corner of ANZAC Pde & Fitzgerald Ave	20.34	0.01	0.04	0.06	-	0.01	-0.01	0.02
H9	Astoria Circuit	18.04	0.01	0.02	0.04	-0.01	0.01	-	-
H10	Coral Sea Park	14.67	0.05	0.15	0.24	-0.01	0.02	-0.09	0.12
H11	Fenton Ave	6.22	0.06	0.16	0.25	-0.01	0.02	-0.12	0.14
H12	Marine Pde & McKeon St Intersection	6.22	0.06	0.16	0.25	-0.02	0.02	-0.13	0.14
H13	Bottom of Byrne Crescent	17.51	-0.02	-0.02	-0.01	0.01	-0.04	-0.01	-0.04
H14	Beatty Lane	30.56	-	-	-	-	-	-	-
H15	French St	38.67	0.01	0.01	0.02	-	-0.01	-	-
H16	Malabar Rd U/S of Fitzgerald Ave	9.29	-	-	-	-	-	-	-
H17	Midway Dr D/S End of Coral Sea Park	14.83	-	0.01	0.03	-	0.01	-	0.01
H18	Yorketown Pde U/S of New Orleans Cr	13.08	0.02	0.07	0.12	-0.01	0.02	-0.04	0.05
H19	Fitzgerald Ave (St Mary & St Josephs School)	7.64	0.08	0.11	0.13	0.07	0.06	-0.03	0.08
H20	D/S End of Bowling Club	6.50	-	0.01	0.02	-0.01	-	-	-0.01
H21	Fenton Ave & Chapman Ave Intersection	6.22	0.06	0.16	0.25	-0.01	0.02	-0.12	0.14
		Average	*+0.02*	*+0.06*	*+0.09*	*0*	*+0.01*	*-0.04*	*+0.04*

B1.8 Task 8: Climate Change Scenarios

The sensitivity of the model results to various climate change scenarios was also assessed in accordance with the 2007 DECC guidelines:

- 10%, 20% and 30% increase in design rainfall intensity; and
- 0.4 m and 0.9 m rise in tailwater level in Maroubra Bay corresponding to the 2050 and 2100 sea level rise scenarios.

A summary of the results obtained are shown in Tables B8 and B9. The table shows the differences between the results for each climate change run and the 1% AEP design flood event (base case).

Table B8: Climate Change Scenarios – Change in Peak Flows (%) for the 1% AEP Design Event

ID	Location- Refer Figure 1	Base (m^3/s)	Rainfall Increase +10%	Rainfall Increase +20%	Rainfall Increase +30%	Sea Level Rise 2050 Scenario (+0.4m)	Sea Level Rise 2100 Scenario (+0.9m)
1D Pipe Flows							
P1	Main Stormwater Outlet	11.8	2%	4%	6%	0%	0%
P2	Downstream of Byrne Crescent	2.8	1%	1%	2%	0%	0%
P3	Coral Sea Park Outlet	3.9	3%	7%	7%	0%	0%
P4	Downstream of Haig St	0.9	2%	5%	8%	0%	0%
P5	Downstream of Fitzgerald Ave/Maroubra Rd Intersection	6.9	-1%	0%	4%	-1%	-2%
P6	Downstream of Duncan St/McKeon St Intersection	2.1	1%	1%	2%	0%	0%
P7	Maroubra Rd Outlet	0.6	1%	3%	3%	0%	0%
P8	Torrington Rd Outlet	0.6	3%	6%	24%	0%	0%
2D Overland Flows							
OF3	Yorktown Pde	3.9	18%	38%	53%	0%	0%
OF4	Astoria Circuit	2.9	25%	48%	70%	0%	0%
OF5	Byrne Cres	1.1	18%	37%	67%	0%	0%
OF6	South Maroubra Village Green	0.4	99%	200%	368%	0%	0%
OF7	Malabar Rd	6.4	28%	56%	89%	1%	2%
OF8	Fitzgerald Ave	0.7	41%	94%	150%	-1%	0%
OF9	Maroubra Bay Public School	7.8	17%	39%	74%	0%	1%
OF10	Broome St	17.9	22%	45%	72%	1%	0%

Table B9: Climate Change Scenarios – Change in Peak Flood Levels (m) for the 1% AEP Design Event

ID	Location - Refer Figure 1	Base (mAHD)	Rainfall Increase +10%	Rainfall Increase +20%	Rainfall Increase +30%	Sea Level Rise 2050 Scenario (+0.4m)	Sea Level Rise 2100 Scenario (+0.9m)
H1	Marine Pde N of Maroubra Beach	8.87	0.02	0.04	0.06	-	-
H2	Tyrwhitt St	20.17	0.01	0.03	0.06	-	-
H3	Haig St	47.29	0.13	0.25	0.34	-	-
H4	Maroubra Rd & Flower St Intersection	49.43	0.01	-	-	-	-
H5	Fitzgerald Ave & Chester Ave Intersection	20.95	0.03	0.06	0.09	-	-
H6	U/S of Retirement Village, Curtin Cr	24.62	0.07	0.12	0.17	-	-
H7	White Ave	39.35	0.02	0.04	0.05	-	-
H8	Near Corner of ANZAC Pde & Fitzgerald Ave	20.34	0.03	0.05	0.08	-	-
H9	Astoria Circuit	18.04	0.01	0.03	0.05	-	-
H10	Coral Sea Park	14.67	0.12	0.24	0.34	-	-
H11	Fenton Ave	6.22	0.13	0.24	0.33	-	-
H12	Marine Pde & McKeon St Intersection	6.22	0.13	0.24	0.33	-	-
H13	Bottom of Byrne Crescent	17.51	-0.01	-0.03	0.04	-	-
H14	Beatty Lane	30.56	-	-	0.01	-	-
H15	French St	38.67	0.01	0.02	0.03	-	-
H16	Malabar Rd U/S of Fitzgerald Ave	9.29	-	-	-	-	-
H17	Midway Dr D/S End of Coral Sea Park	14.83	0.02	0.03	0.04	-	-
H18	Yorketown Pde U/S of New Orleans Cr	13.08	0.06	0.09	0.13	-	-
H19	Fitzgerald Ave (St Mary & St Josephs School)	7.64	0.10	0.13	0.17	-	-
H20	D/S End of Bowling Club	6.50	0.01	0.02	0.05	-	-
H21	Fenton Ave & Chapman Ave Intersection	6.22	0.13	0.24	0.33	-	-
		Average	*+0.05*	*+0.09*	*+0.13*	*0*	*0*

From the results, it can be observed that:

- Rainfall increase generally produces a substantial change in peak overland flows, much more than the pipe flows;
- Increases of up to 0.9m in the downstream ocean tailwater produced almost no changes in flows or flood levels, indicating the insensitivity of the model results to tailwater assumptions;
- In terms of peak flood level estimates, significant changes were found to result from variations in estimated runoff due to increased rainfall. For example, an increase of 30%

in rainfall was found to increase flood levels by up to 0.35 m, depending upon the location within the catchment; and

- The outcomes indicate that the estimated 1% AEP flood levels behind the main dune are not adversely impacted by changes in sea level rise (up to an increase of 0.9 m). A review of model results for the various sea level scenarios suggests that this outcome reflects the significant hydraulic gradient in the main trunk system between the Marine Parade low point (where the invert of the trunk system is at 3.0 mAHD) and the main system outlet (where the invert of the 3.06 m W x 1.68 m H outlet is at 0.41 mAHD). Under the high sea level rise scenario, the peak velocities within the main outlet on the beach was found to be in the order of 3 m/s (for the 1% AEP event). It is considered unlikely that blockage of the outlet by sand would be sustained during a flood as the system discharges.

B.2 Additional Design Event Modelling

Council required additional design event modelling for the 0.5 EY and 0.2 EY events as part of this FRMS&P. Mapping of the additional design events peak flood levels and depths is presented in Appendix C.

Note that when interpreting the model results to derive flood level estimates, care should be taken to review both the estimated level and depth results together with detail survey to confirm an appropriate flood level, particularly where the estimated depths are reasonably shallow (e.g. less than 0.3 m for the 1% AEP event). In these instances, the depths approach the limit of accuracy of the underlying survey data.

B.2.1 GIS Flood Database

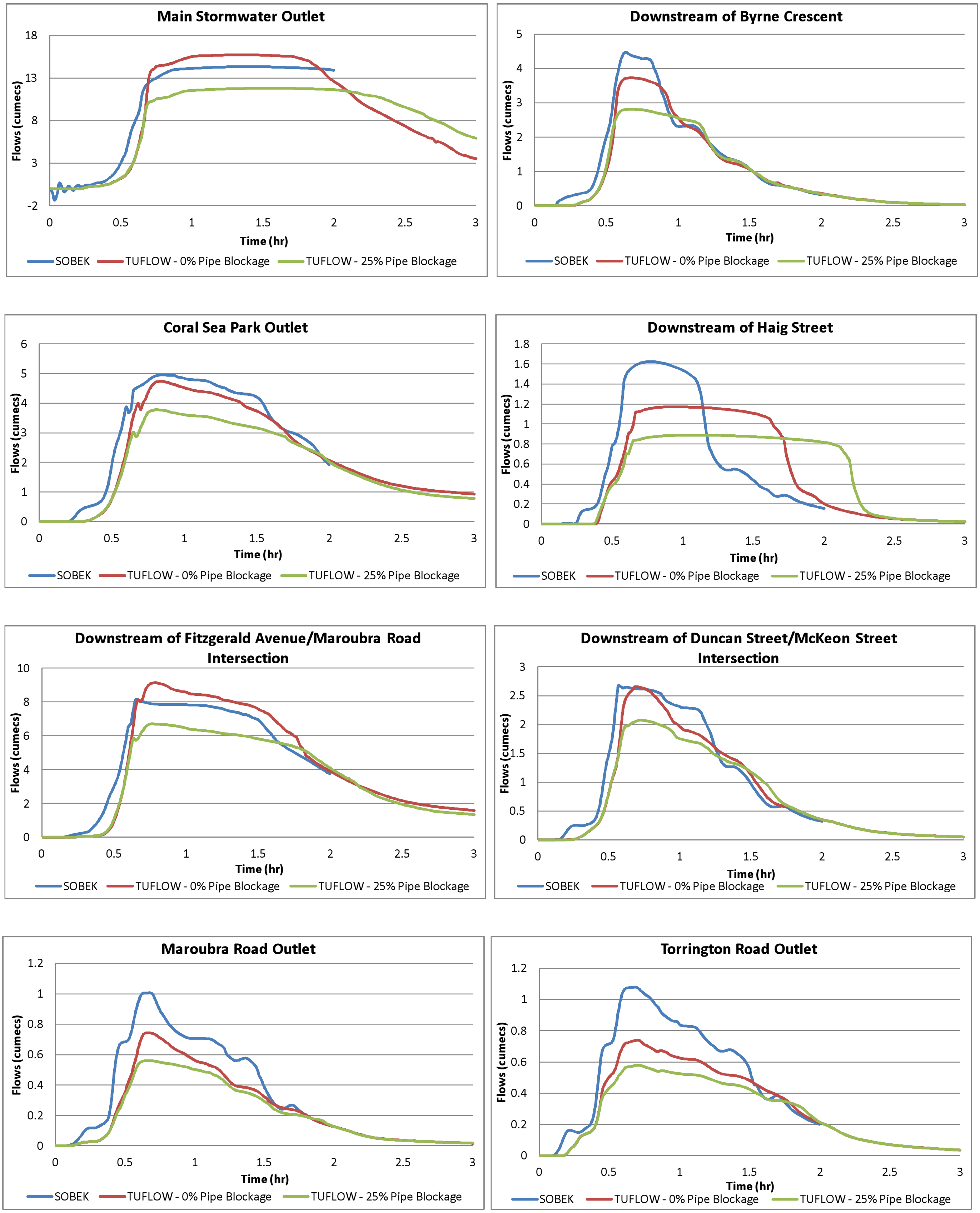
Council has an existing flood level database (GIS format) which identifies flood levels at properties, their flood affectation and their FPA tagged status on the s149 certificate. Flood level data for the Maroubra Bay area has been updated as part of this study with an updated database provided to Council including;

- Physical property information;
- Lowest habitable floor level (from Sydney Surveyors survey); and
- Development category (from current LEP land uses);
- Design event flood information;
- Peak flood levels;
- Peak flood velocity;
- Hydraulic classification; and
- Flood hazard category;
- First design event resulting in property inundation over floor;
- Cost of damages from damages survey; and
- Flood tagging for FPA and s149 certificates.

B.3 Flood Management Options Modelling

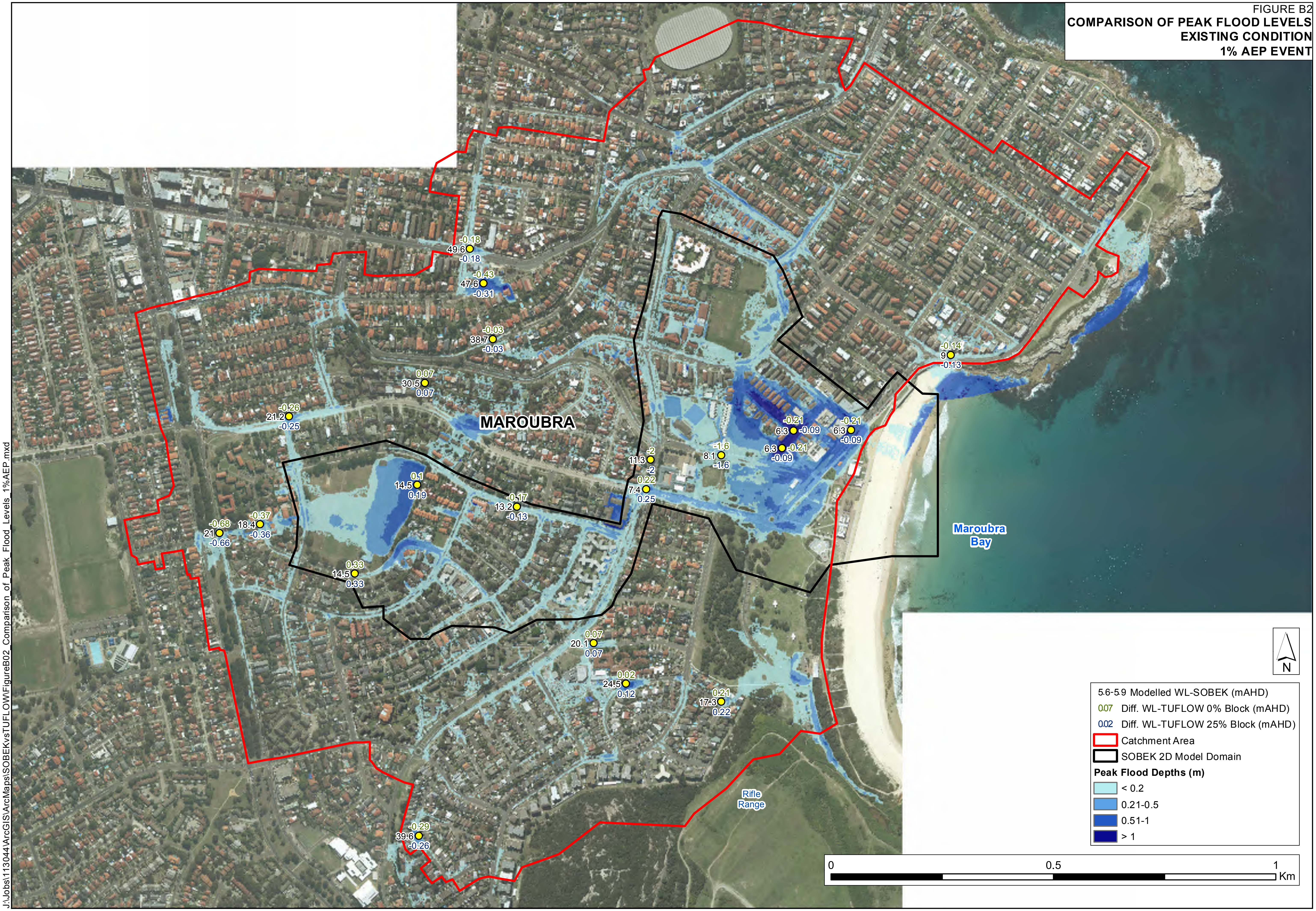
The hydraulic modelling was used to assess the impacts on flood behaviour of a number of flood modification measures. Model geometry was amended to reflect the options, such as changing culvert sizes or adding new culverts, amending ground levels, or other relevant changes. Mapping of flood modification measure impacts is included in Appendix D.

FIGURE B1
COMPARISON OF HYDROGRAPHS
EXISTING CONDITIONS
1% AEP EVENT

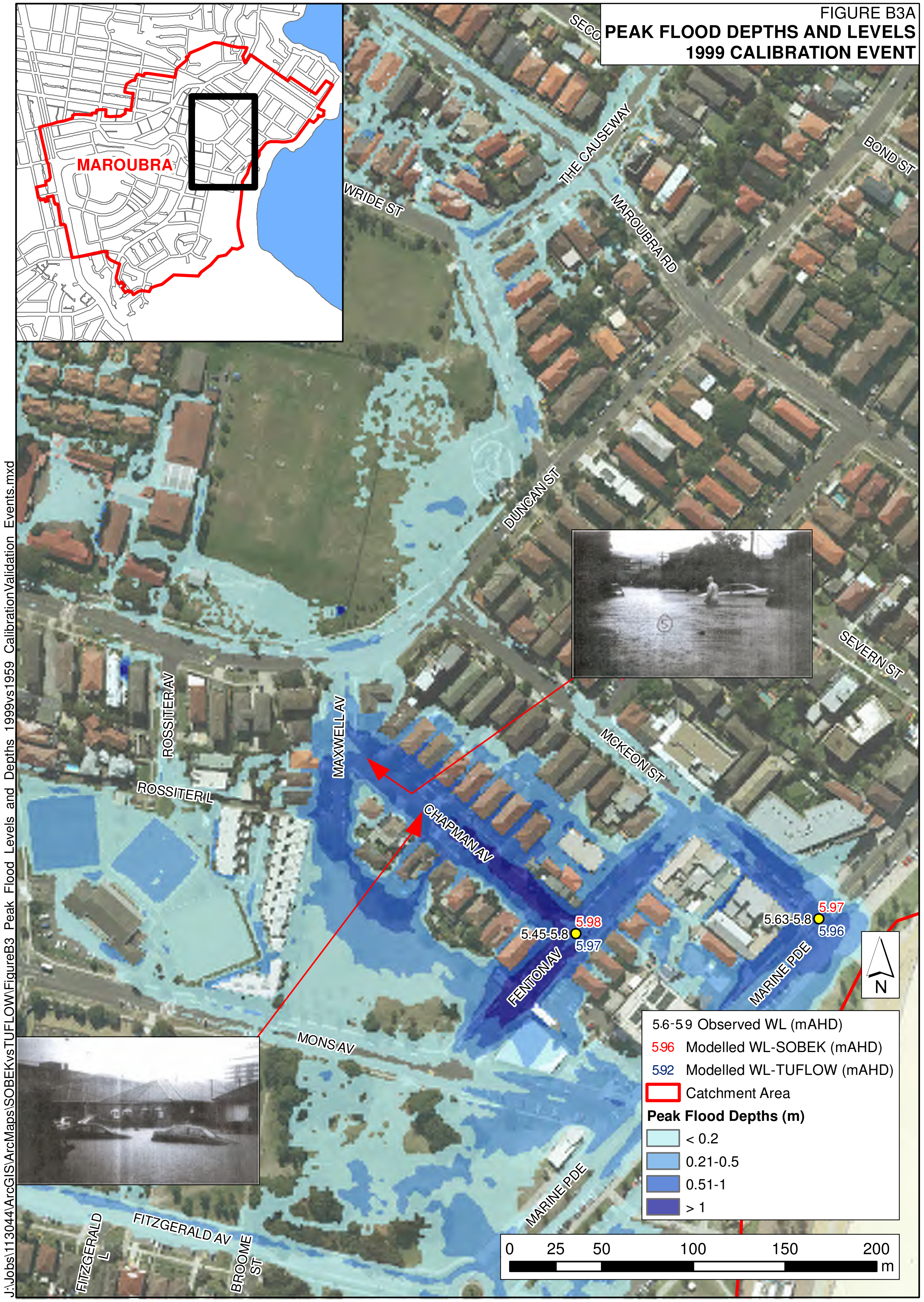


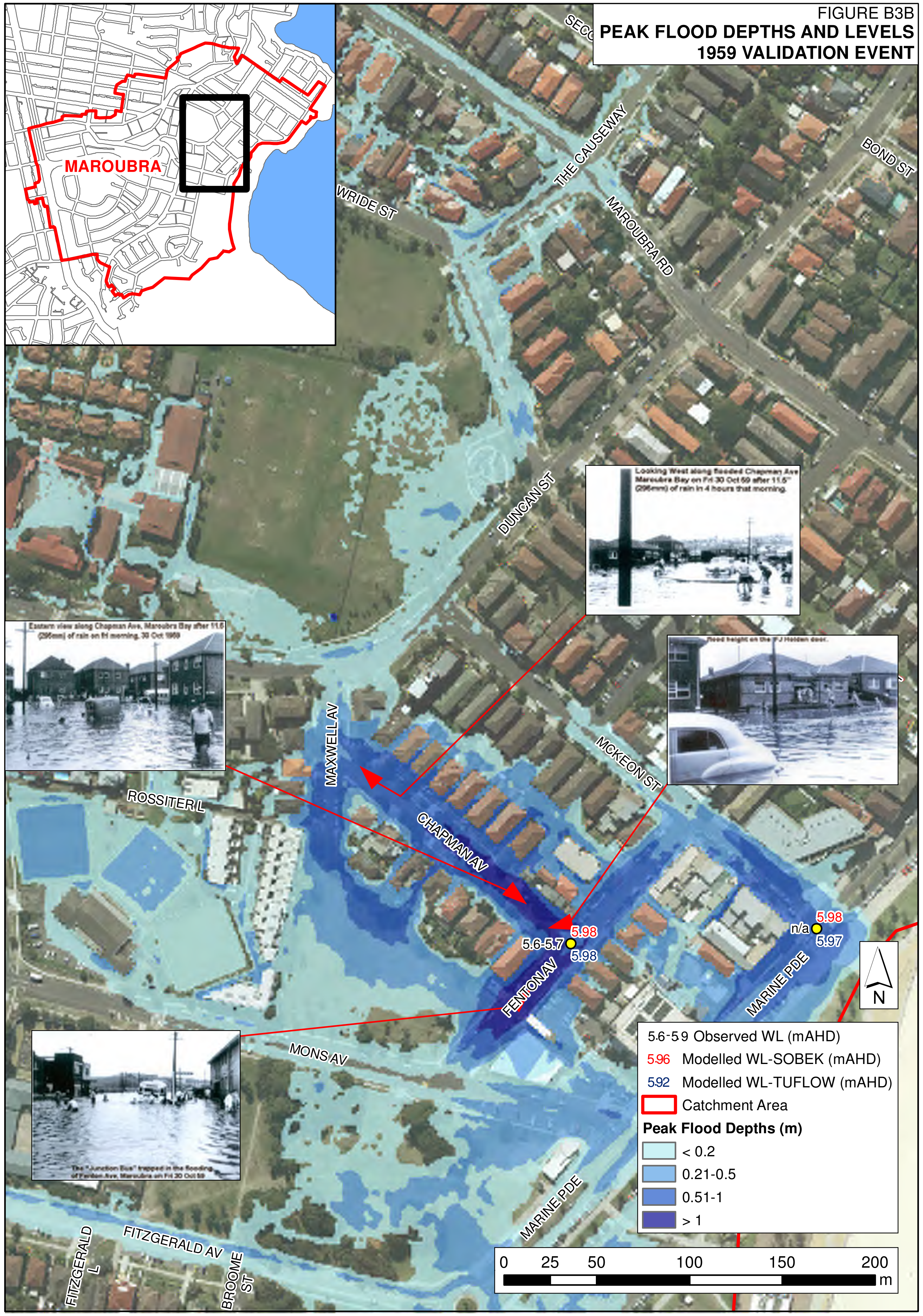
J:\Jobs\113044\Working\SOBEKvsTUFLOW\Stormwater_Outlet_Q.xlsx

FIGURE B2
COMPARISON OF PEAK FLOOD LEVELS
EXISTING CONDITION
1% AEP EVENT



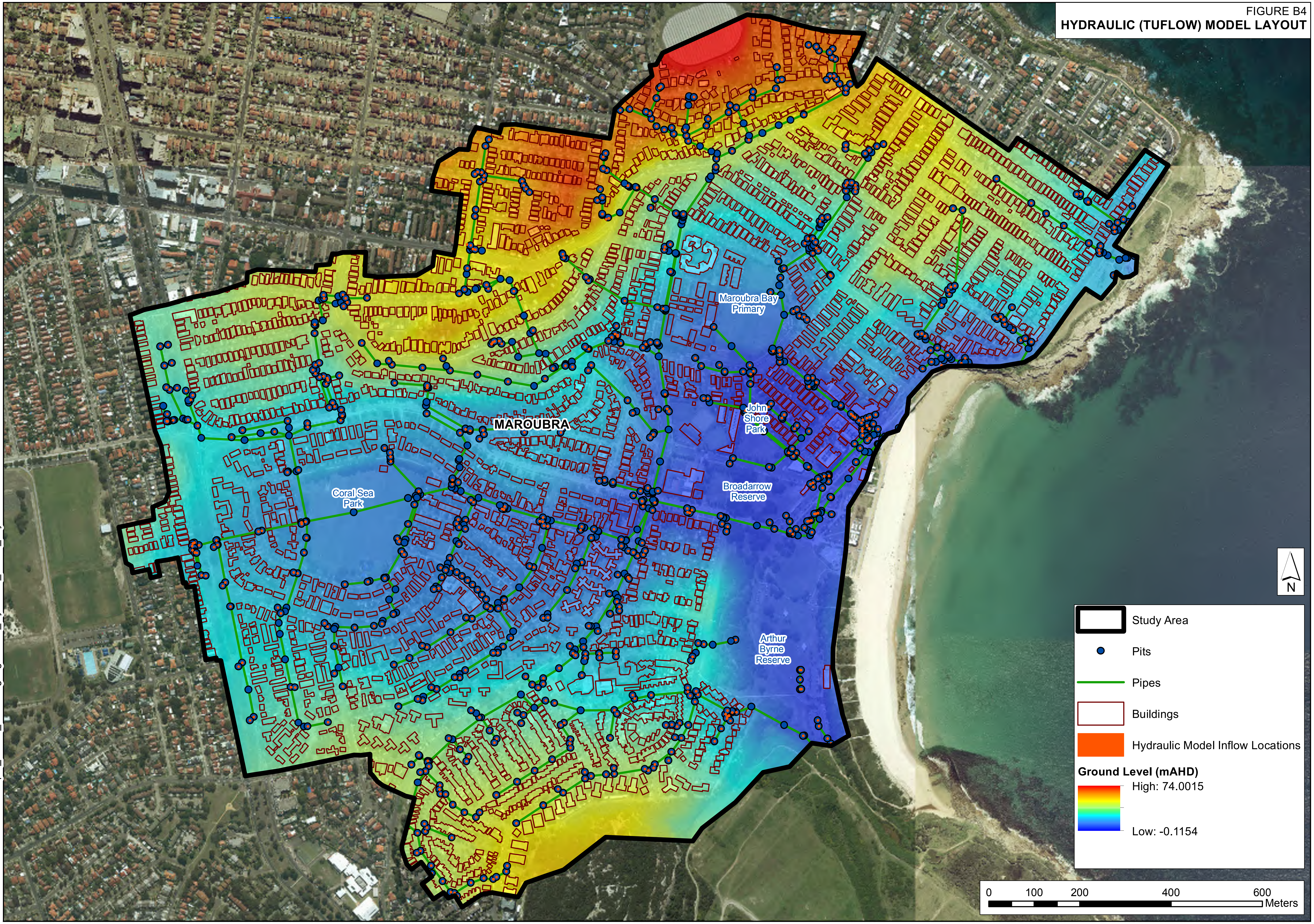
J:\Jobs\113044\ArcGIS\ArcMaps\SOBEKvsTUFLOW\FigureB02_Comparison_of_Peak_Flood_Levels_1%AEP.mxd



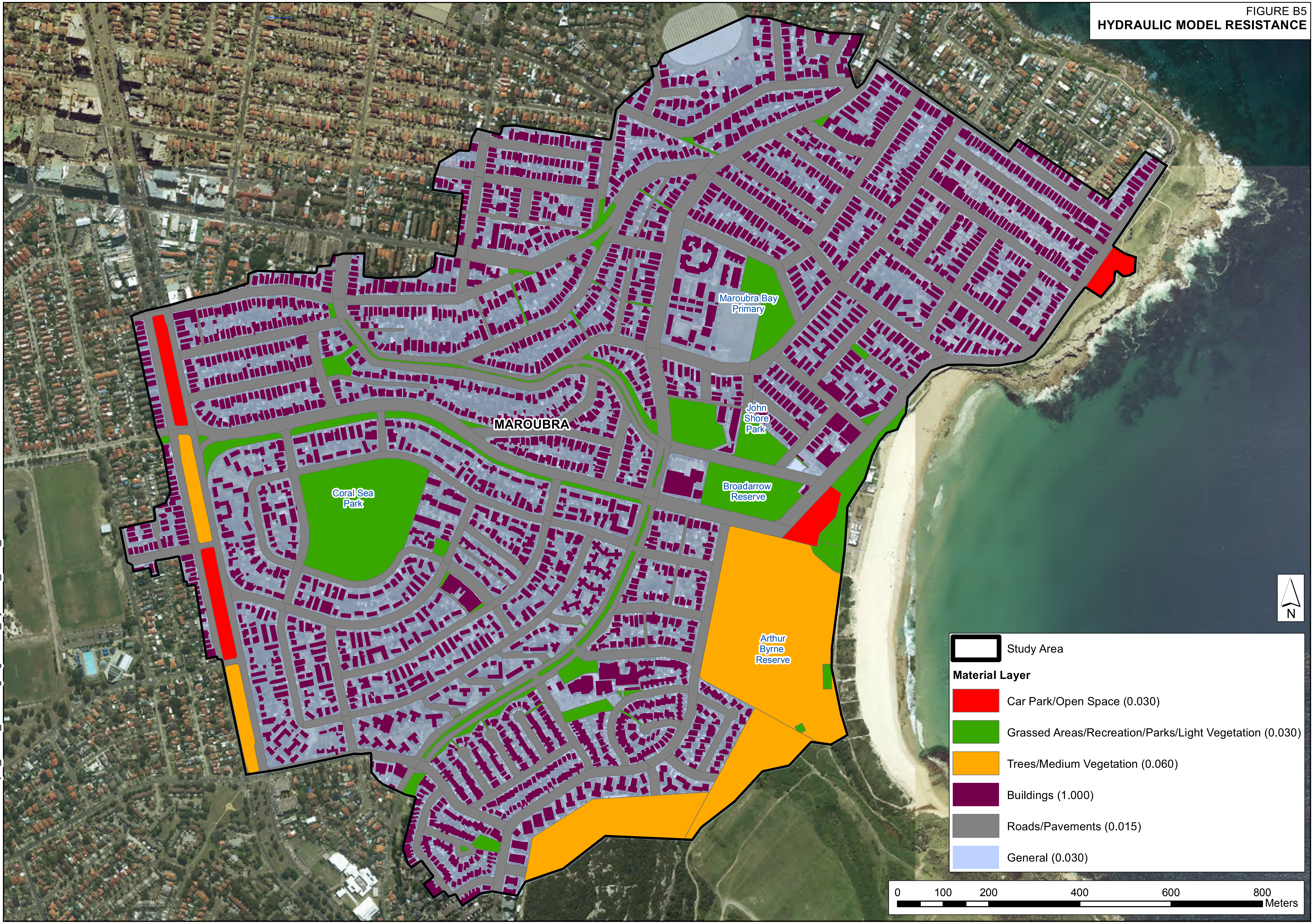


J:\Jobs\113044\ArcGIS\ArcMaps\SOBEKvsTUFLOW\FigureB3 Peak Flood Levels and Depths 1999vs1959 CalibrationValidation Events.mxd

FIGURE B4
HYDRAULIC (TUFLOW) MODEL LAYOUT



J:\Jobs\113044\ArcGIS\ArcMaps_FRMS_Modelling\FigureB04_Hydraulic_Model_Layout.mxd



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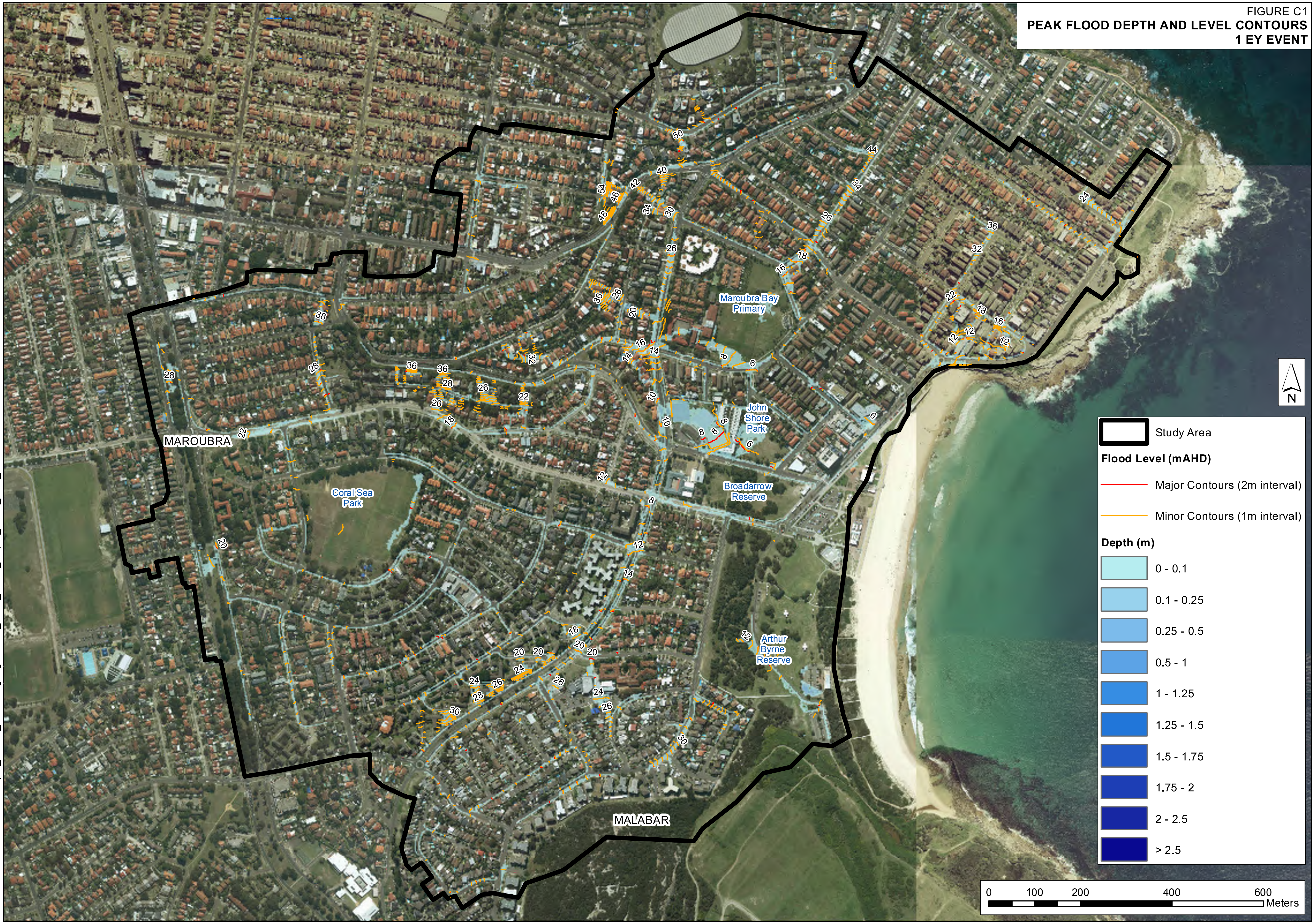
Appendix C

APPENDIX C: FLOOD MAPPING - EXISTING CONDITIONS

FIGURES

FIGURE C1
PEAK FLOOD DEPTH AND LEVEL CONTOURS 1 EY EVENT



J:\Jobs\113044\ArcGIS\ArcMaps_FRMS_Modelling\FigureC01_Peak_Flood_Depth_Level_1EY_Event.mxd

FIGURE C2
PEAK FLOOD DEPTH AND LEVEL CONTOURS
0.5 EY EVENT

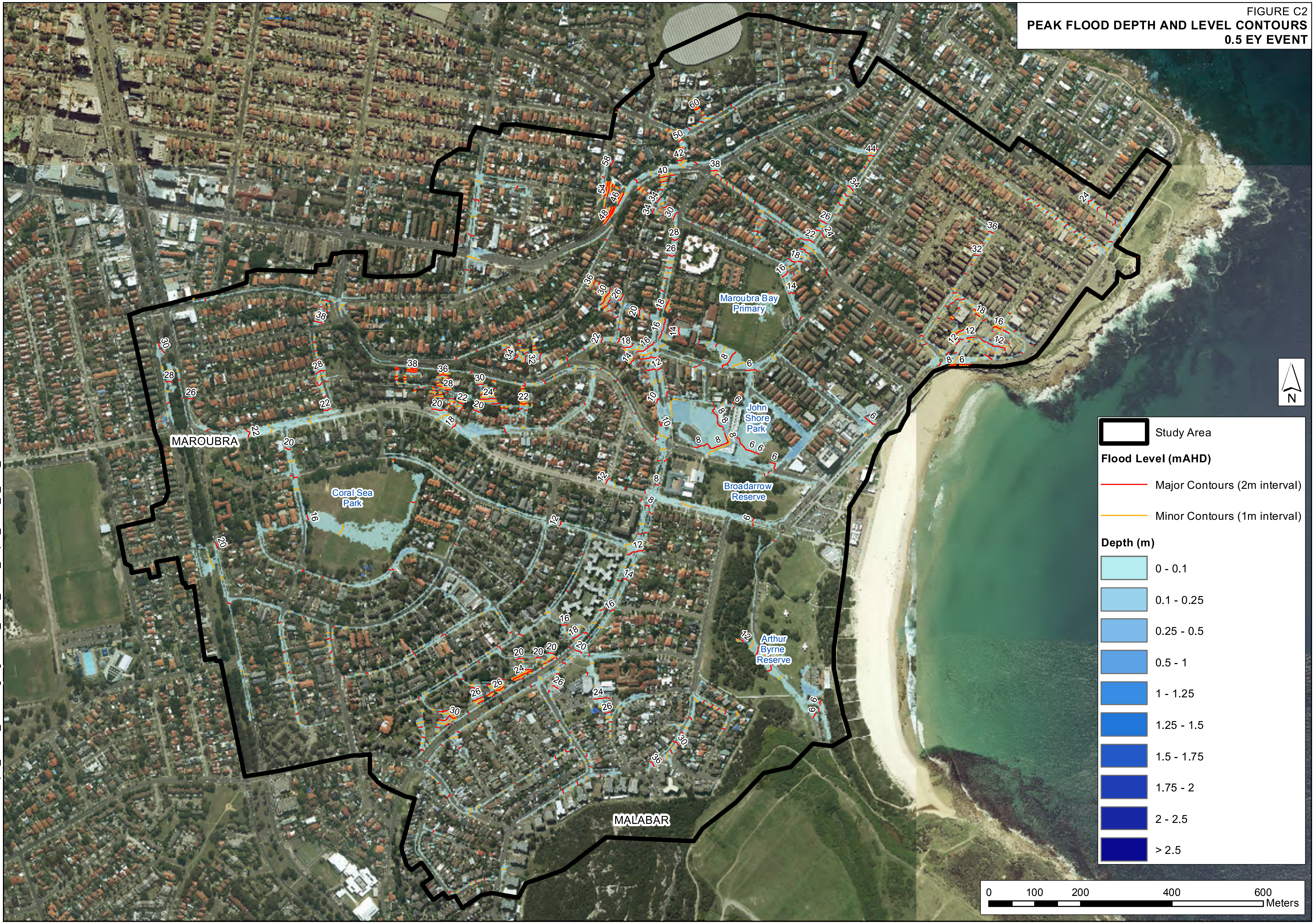


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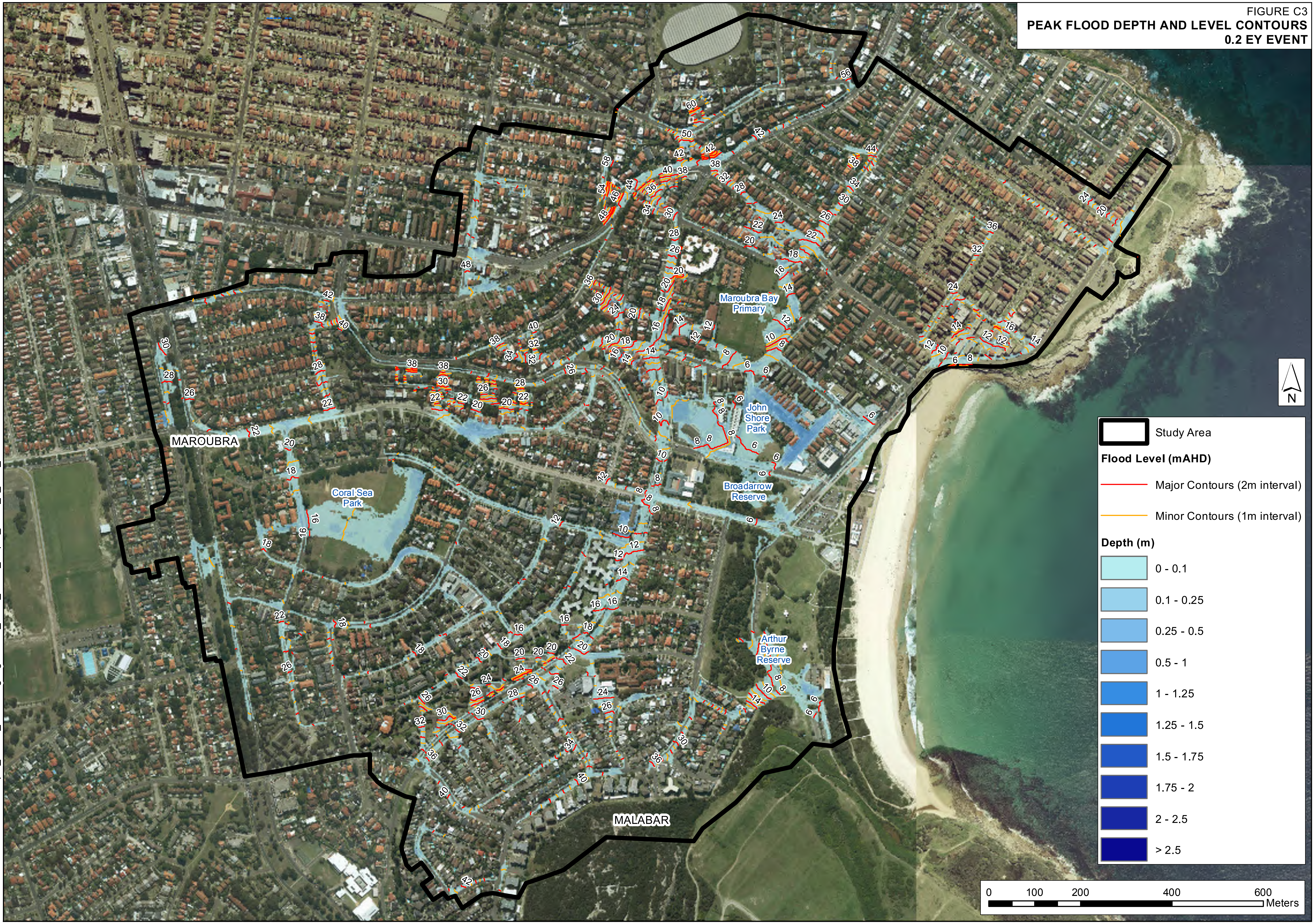
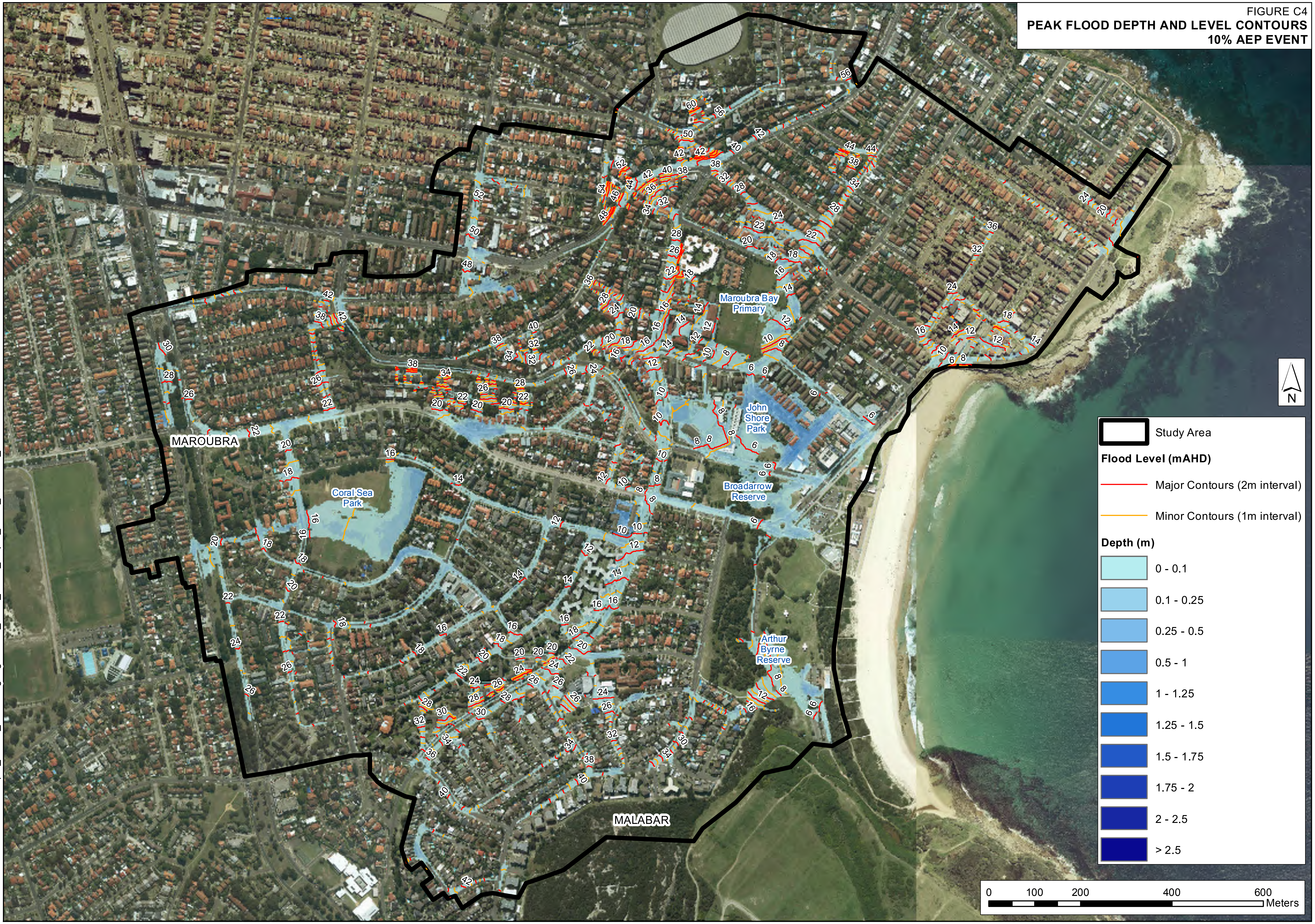
FIGURE C3
PEAK FLOOD DEPTH AND LEVEL CONTOURS
0.2 EY EVENT



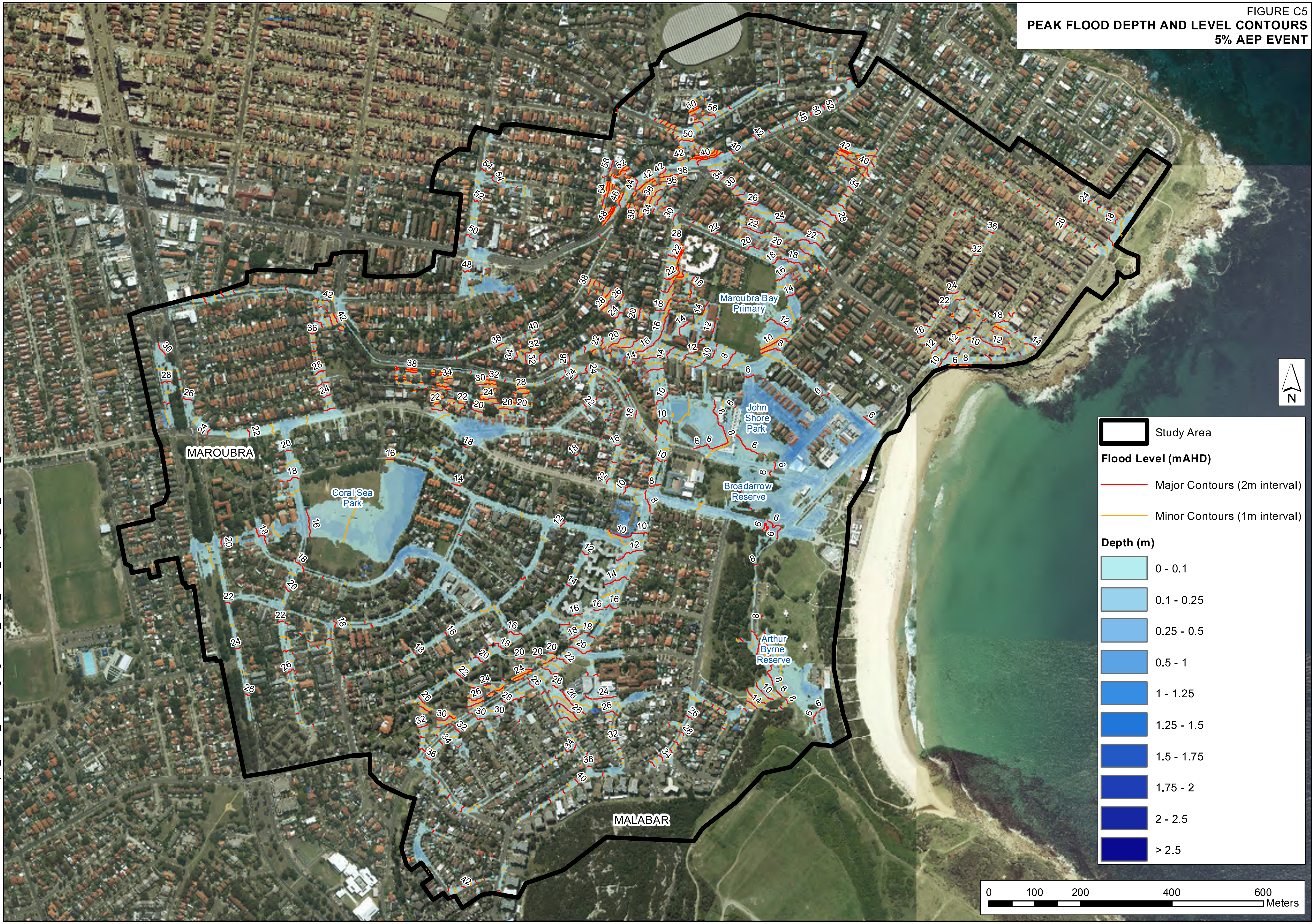
J:\Jobs\113044\ArcGIS\ArcMaps_FRMS_Modelling\FigureC03_Peak_Flood_Depth_Level_0_2EY_Event.mxd

FIGURE C4
PEAK FLOOD DEPTH AND LEVEL CONTOURS
10% AEP EVENT



J:\Jobs\113044\ArcGIS\ArcMaps_FRMS_Modelling\FigureC04_Peak_Flood_Depth_Level_10%AEP_Event.mxd

FIGURE C5
**PEAK FLOOD DEPTH AND LEVEL CONTOURS
5% AEP EVENT**



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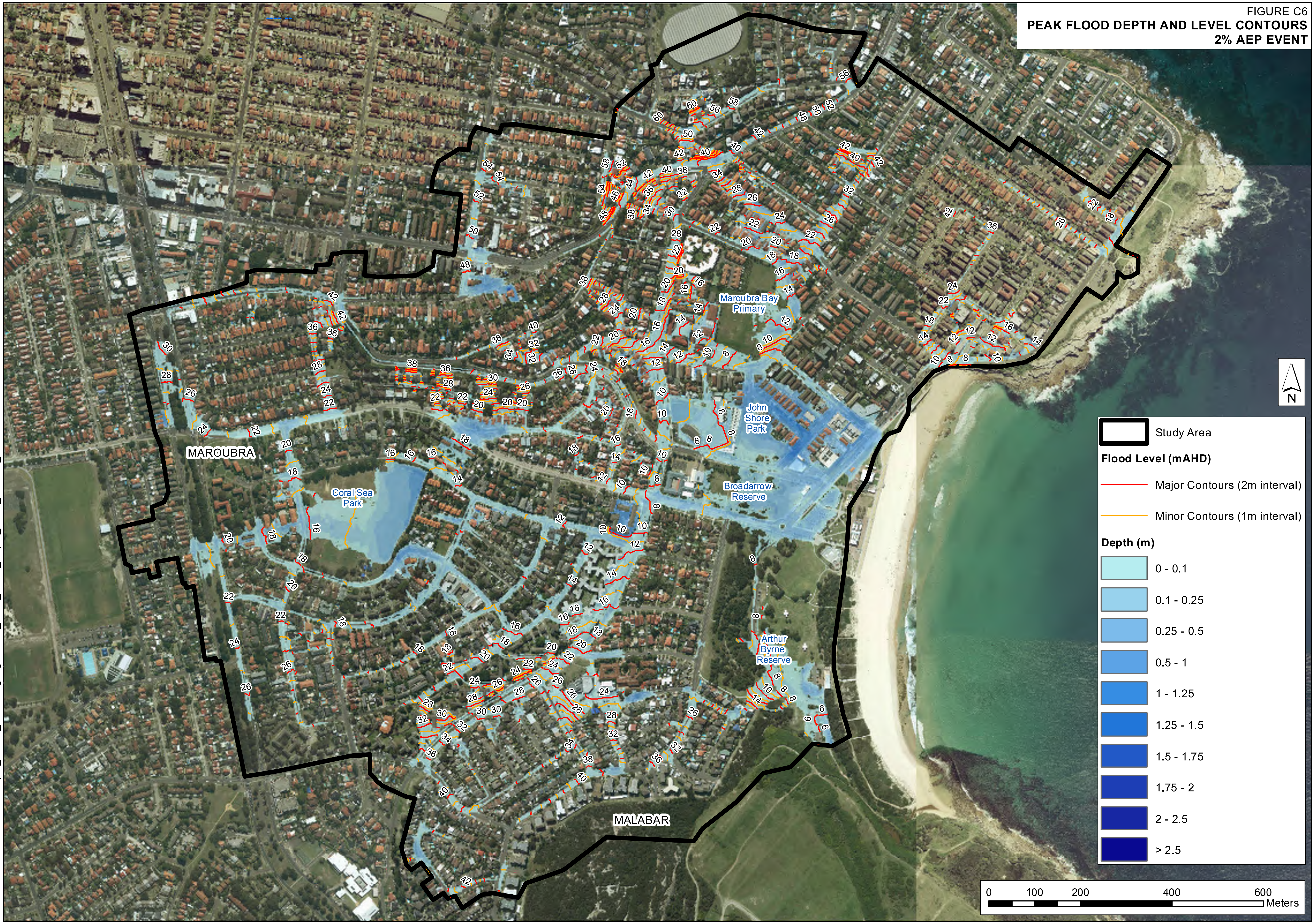
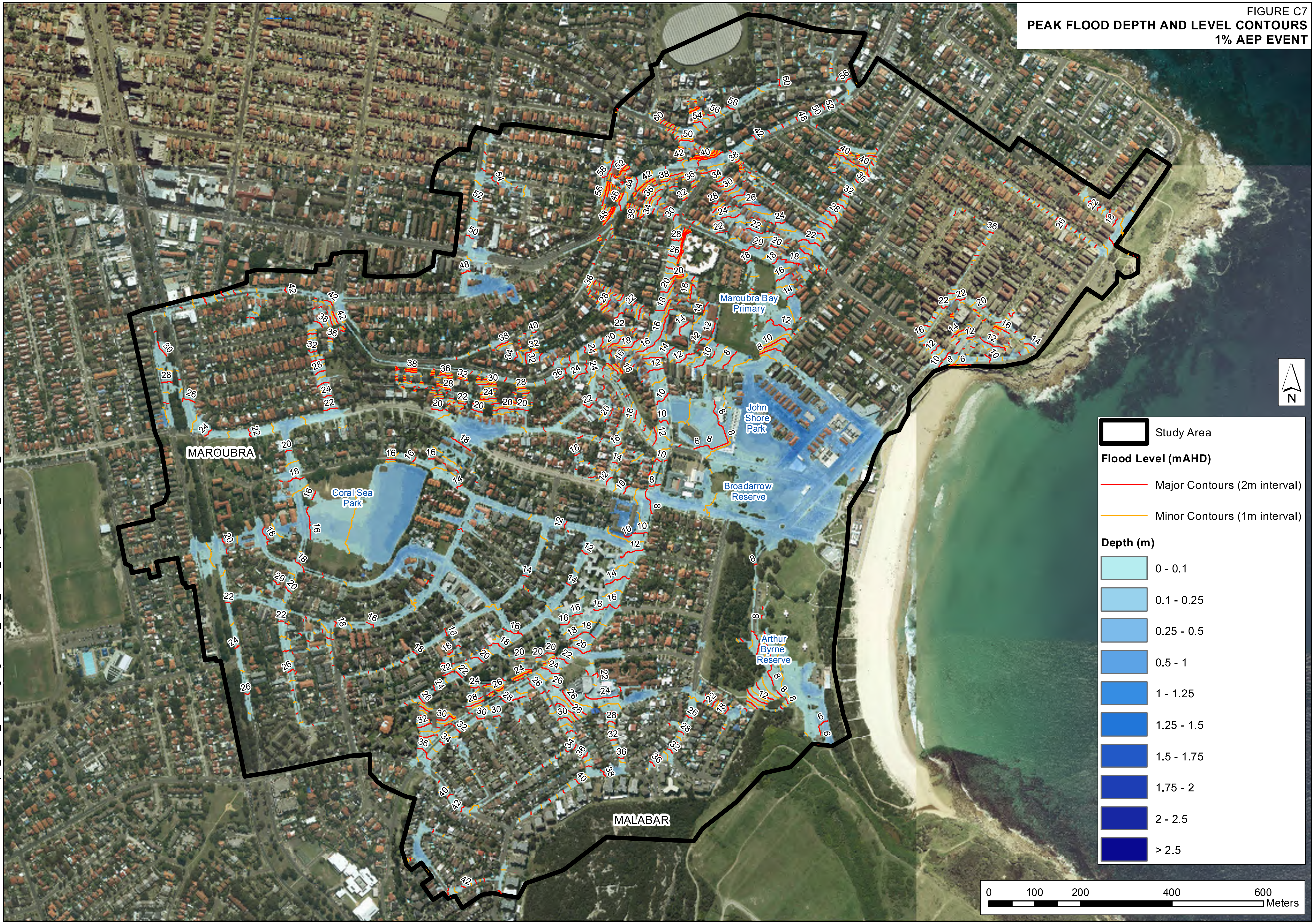


FIGURE C6
PEAK FLOOD DEPTH AND LEVEL CONTOURS
2% AEP EVENT

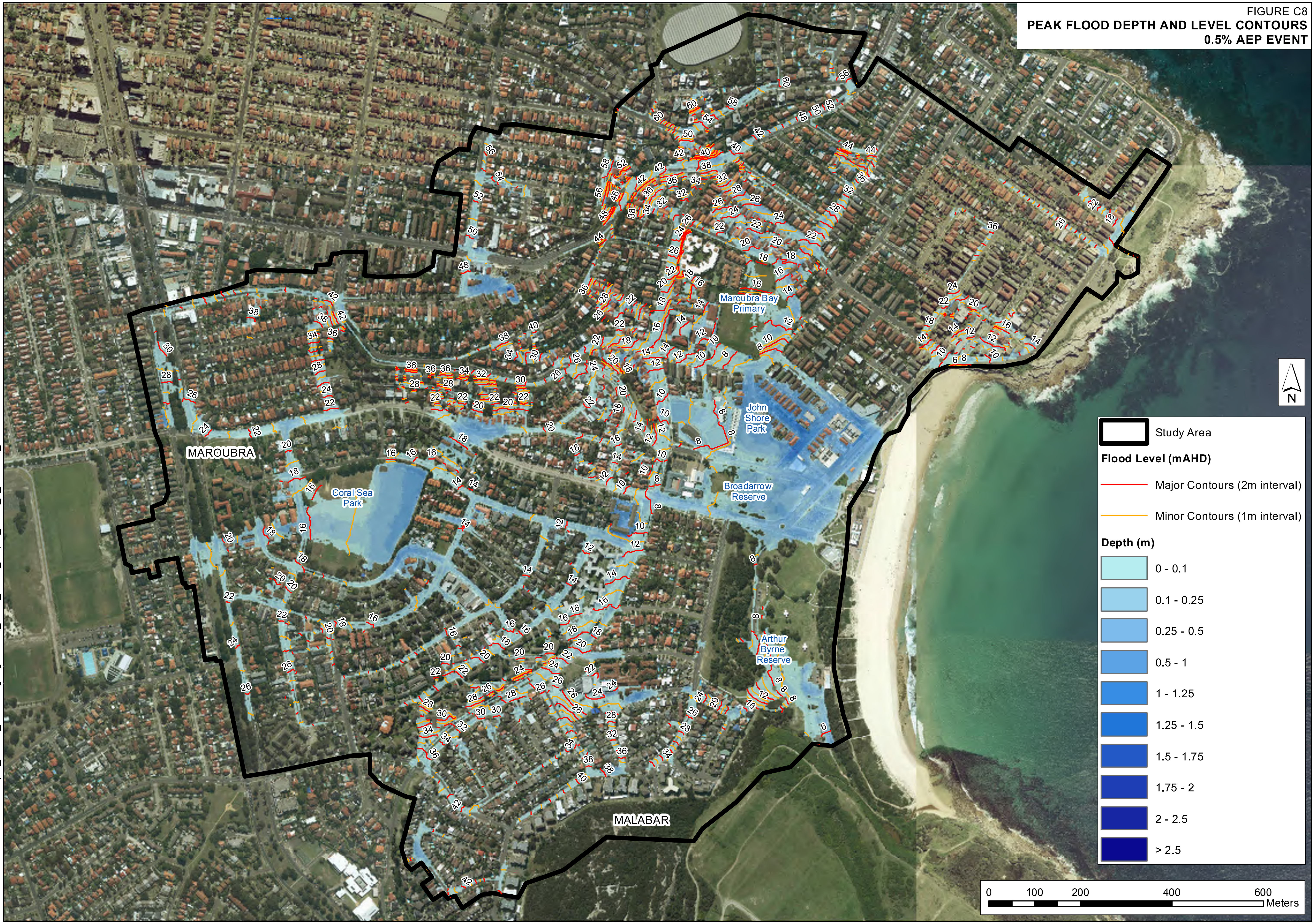
J:\Jobs\113044\ArcGIS\ArcMaps_FRMS_Modelling\FigureC06_Peak_Flood_Depth_Level_2%AEP_Event.mxd

FIGURE C7
PEAK FLOOD DEPTH AND LEVEL CONTOURS 1% AEP EVENT



J:\Jobs\113044\ArcGIS\ArcMaps_FRMS_Modelling\FigureC07_Peak_Flood_Depth_Level_1%AEP_Event.mxd

FIGURE C8
PEAK FLOOD DEPTH AND LEVEL CONTOURS
0.5% AEP EVENT



J:\Jobs\113044\ArcGIS\ArcMaps_FRMS_Modelling\FigureC08_Peak_Flood_Depth_Level_0_5%AEP_Event.mxd

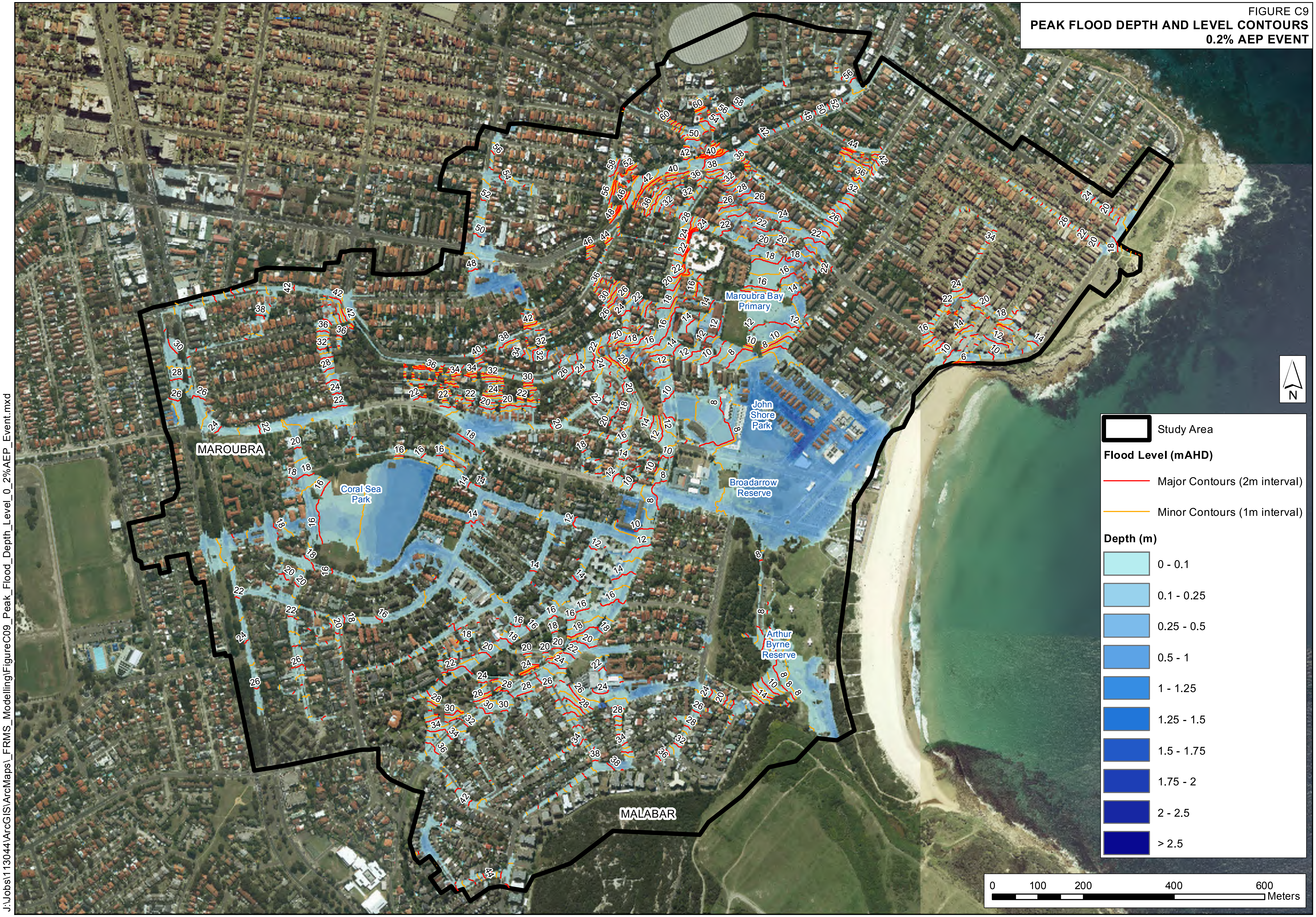


FIGURE C9
PEAK FLOOD DEPTH AND LEVEL CONTOURS
0.2% AEP EVENT
Maroubra Bay Primary
John Shore Park
Broadarrow Reserve
Coral Sea Park
MAROUBRA
Arthur Byrne Reserve
MALABAR
N
Study Area
Flood Level (mAHD)
Major Contours (2m interval)
Minor Contours (1m interval)
Depth (m)
0 - 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 1
1 - 1.25
1.25 - 1.5
1.5 - 1.75
1.75 - 2
2 - 2.5
> 2.5
0 100 200 400 600
Meters
J:\Jobs\113044\ArcGIS\ArcMaps_FRMS_Modelling\FigureC09_Peak_Flood_Depth_Level_0_2%AEP_Event.mxd

FIGURE C10
PEAK FLOOD DEPTH AND LEVEL CONTOURS
PMF EVENT

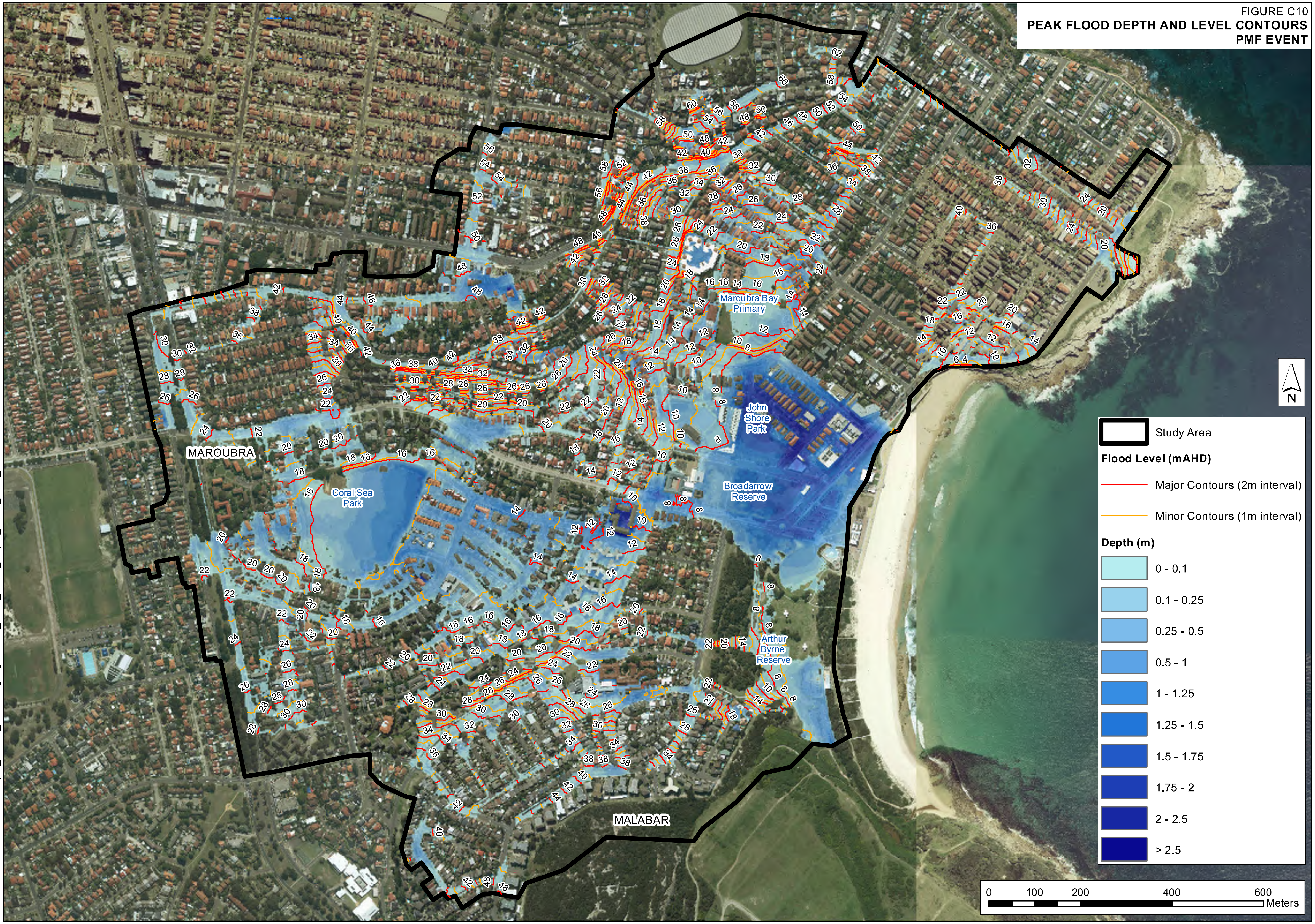


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FIGURE C11
PEAK FLOOD VELOCITY
1 EY EVENT

Study Area

Velocity (m/s)

- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- 2 - 2.5
- > 2.5

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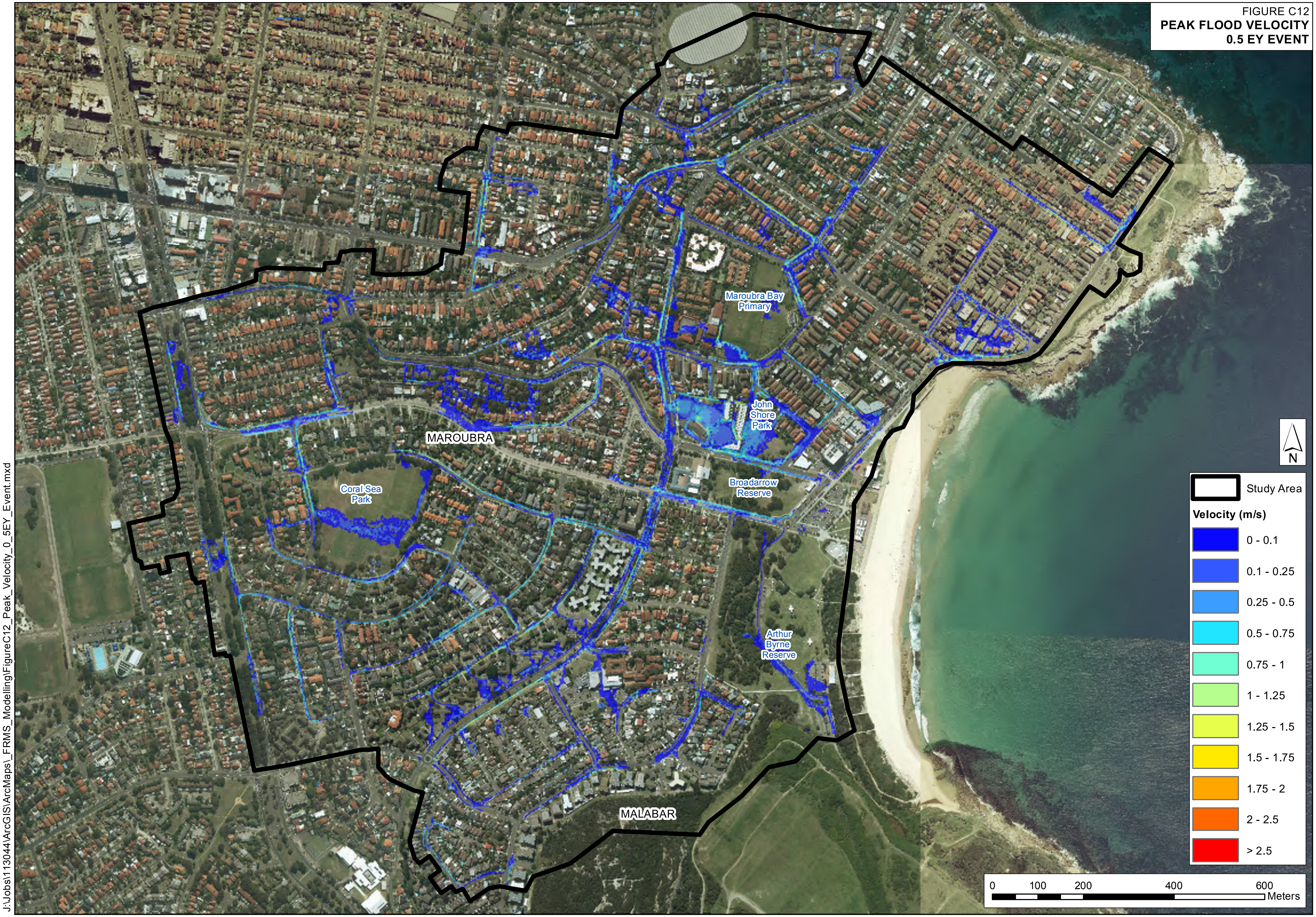
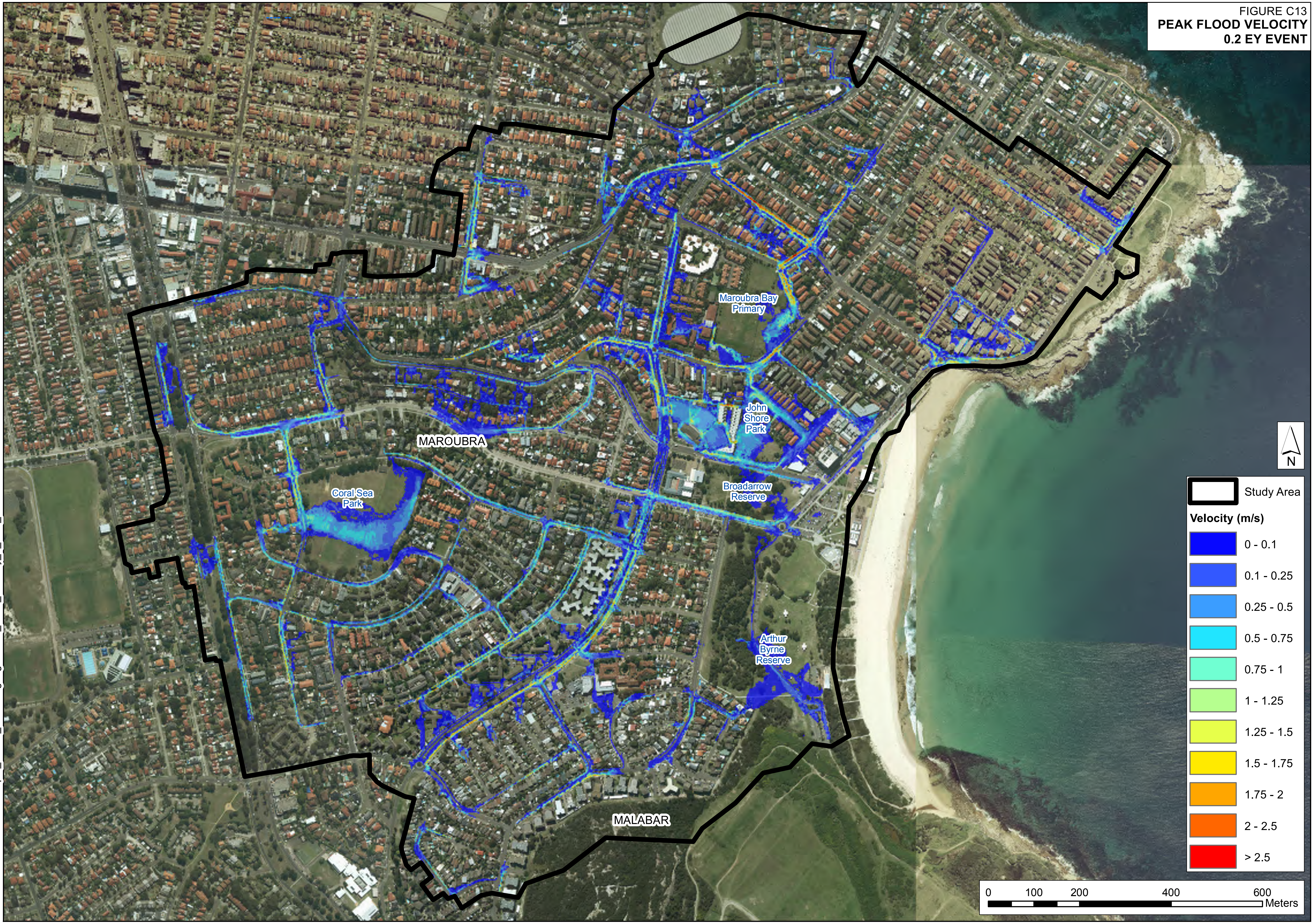


FIGURE C12
PEAK FLOOD VELOCITY
0.5 EY EVENT
Maroubra Bay Primary
John Shore Park
MAROUBRA
Coral Sea Park
Broadarrow Reserve
Arthur Byrne Reserve
MALABAR
N
Study Area
Velocity (m/s)
0 - 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 1.25
1.25 - 1.5
1.5 - 1.75
1.75 - 2
2 - 2.5
> 2.5
0 100 200 400 600 Meters
J:\Jobs\113044\ArcGIS\ArcMaps_FRMS_Modelling\FigureC12_Peak_Velocity_0_5EY_Event.mxd

FIGURE C13
PEAK FLOOD VELOCITY
0.2 EY EVENT



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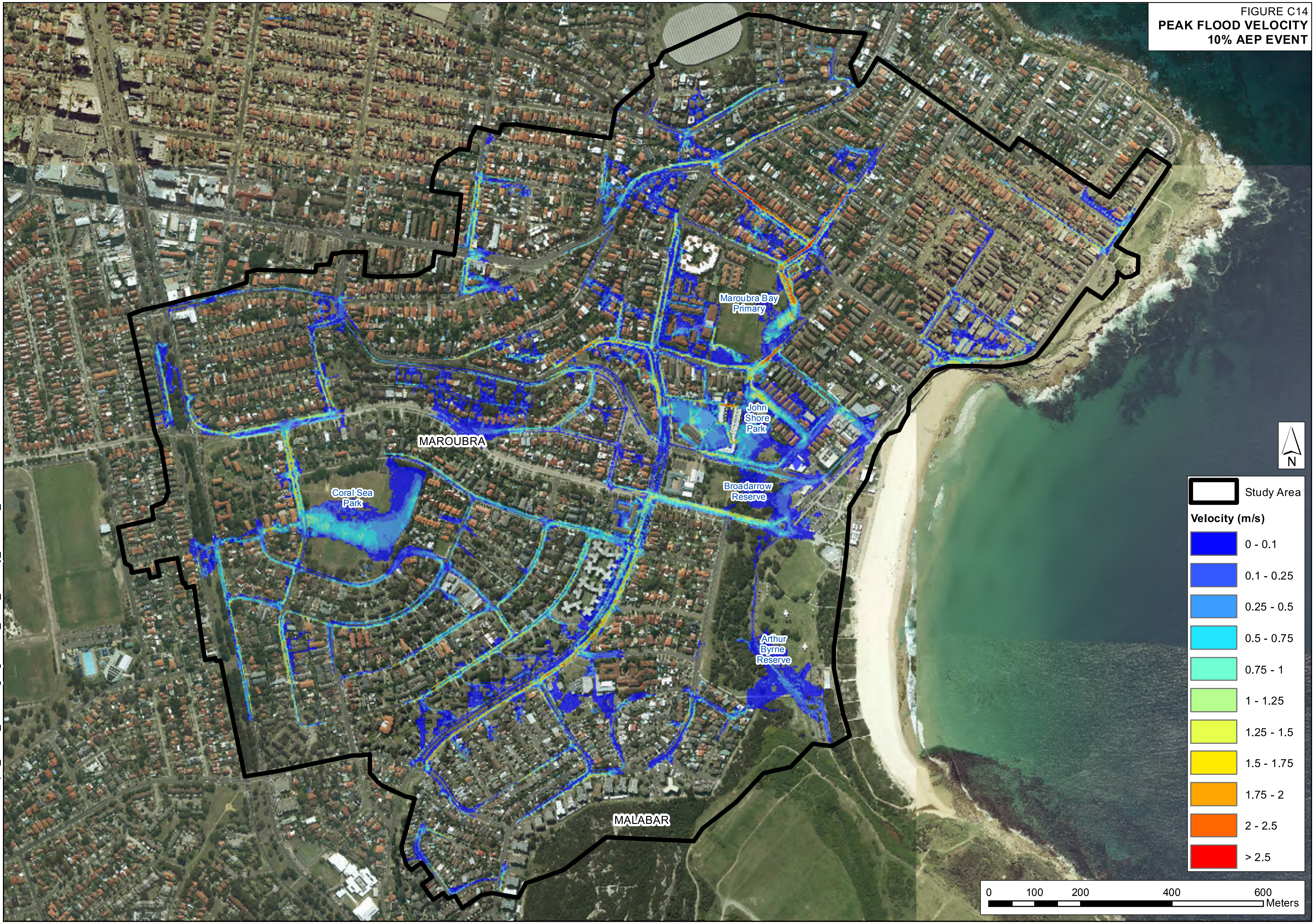

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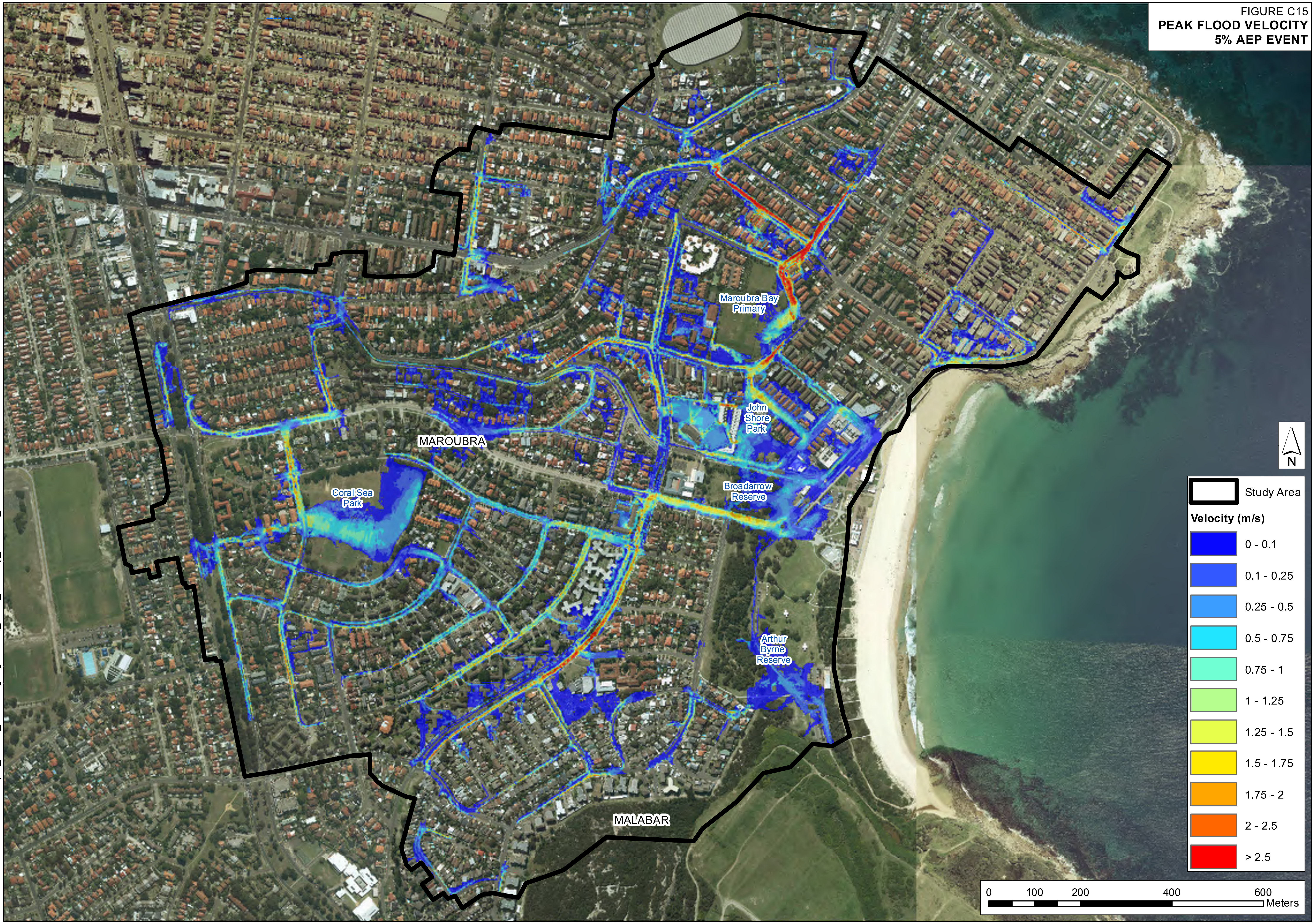

FIGURE C15
PEAK FLOOD VELOCITY
5% AEP EVENT

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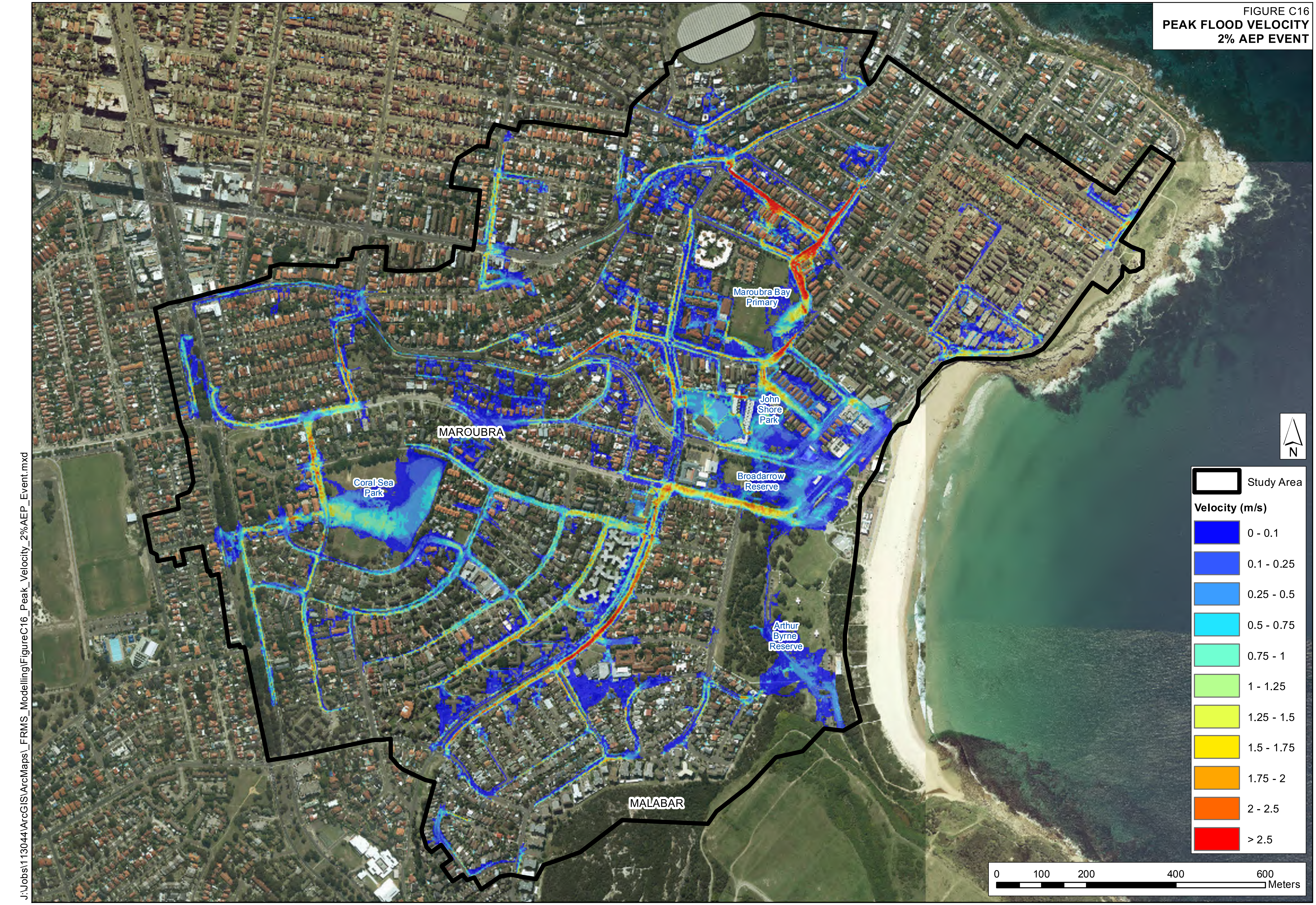
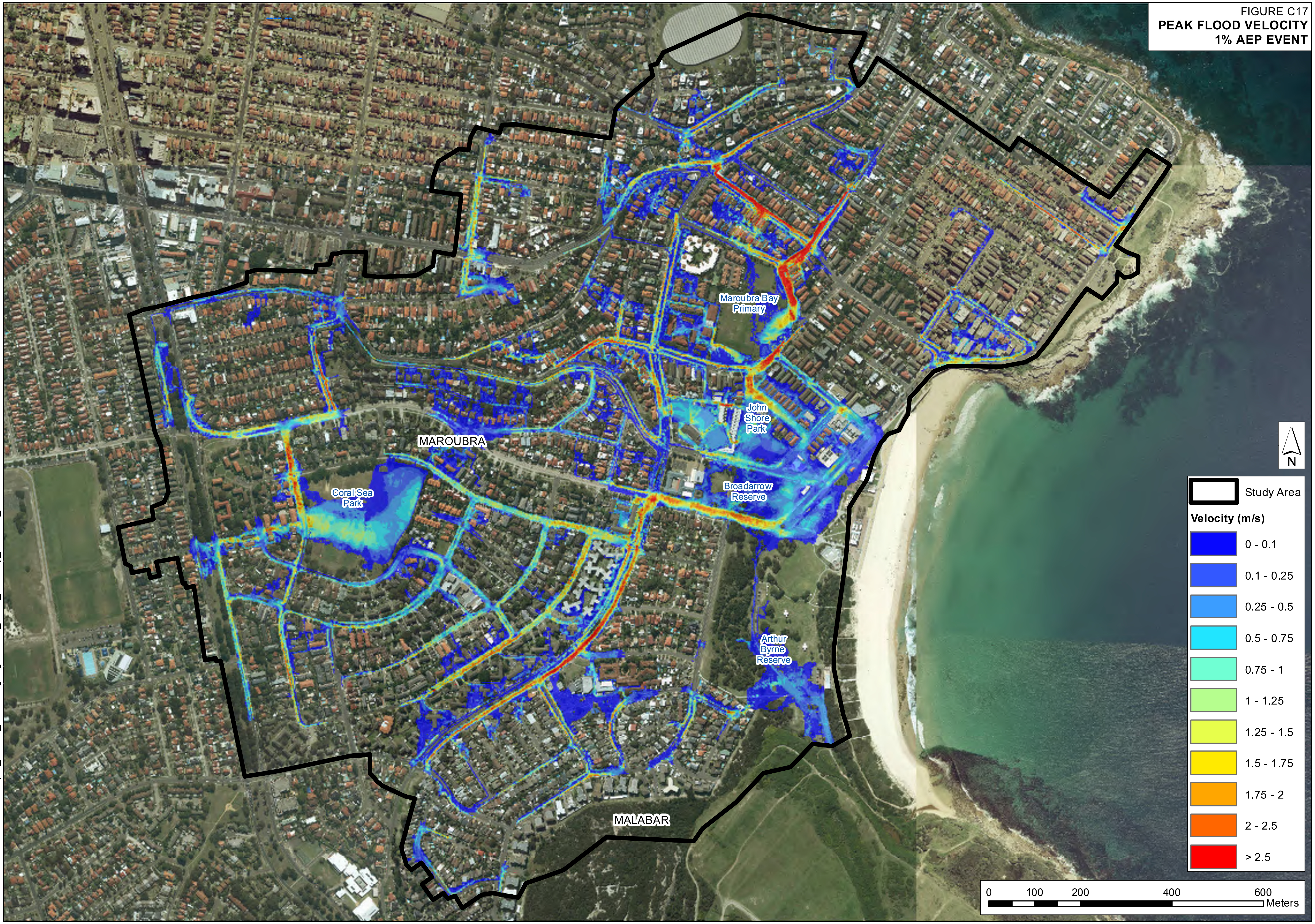


FIGURE C16
PEAK FLOOD VELOCITY
2% AEP EVENT
MAROUBRA
MALABAR
Coral Sea Park
Maroubra Bay Primary
John Shore Park
Broadarrow Reserve
Arthur Byrne Reserve
N
Study Area
Velocity (m/s)
0 - 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 1.25
1.25 - 1.5
1.5 - 1.75
1.75 - 2
2 - 2.5
> 2.5
0 100 200 400 600
Meters
J:\Jobs\113044\ArcGIS\ArcMaps_FRMS_Modelling\FigureC16_Peak_Velocity_2%AEP_Event.mxd



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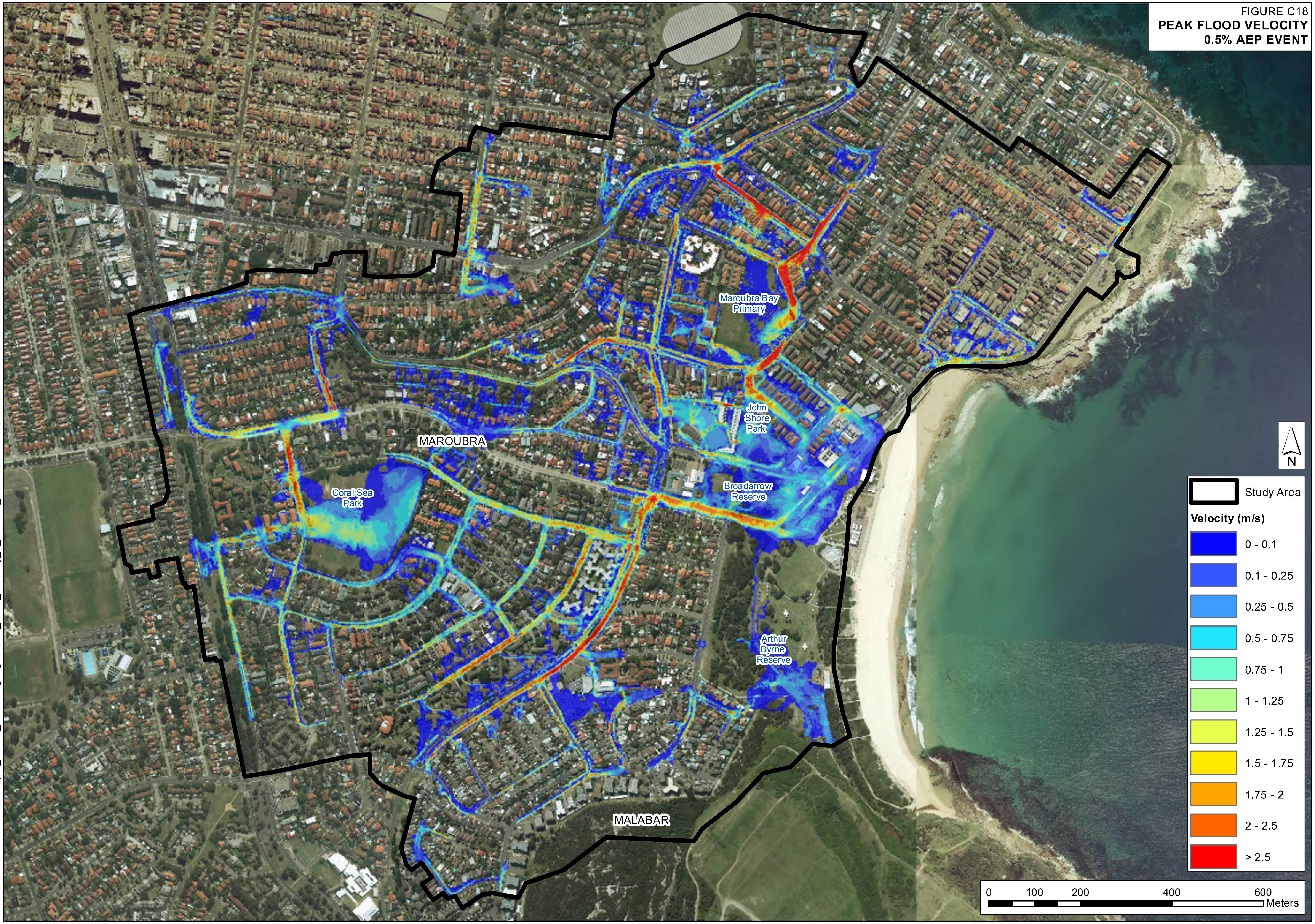

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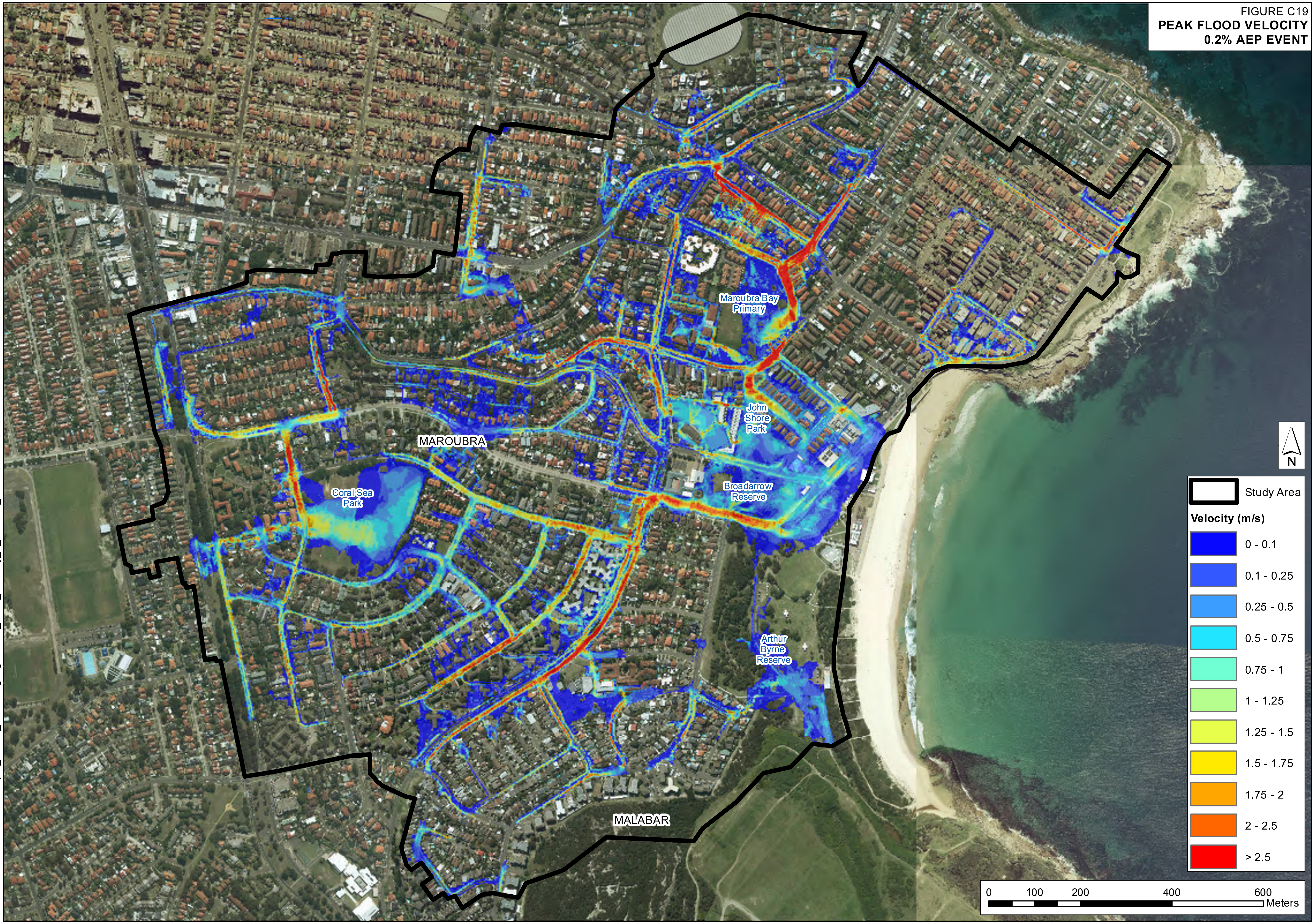


J:\Jobs\113044\ArcGIS\ArcMaps_FRMS_Modelling\FigureC19_Peak_Velocity_0_2%AEP_Event.mxd

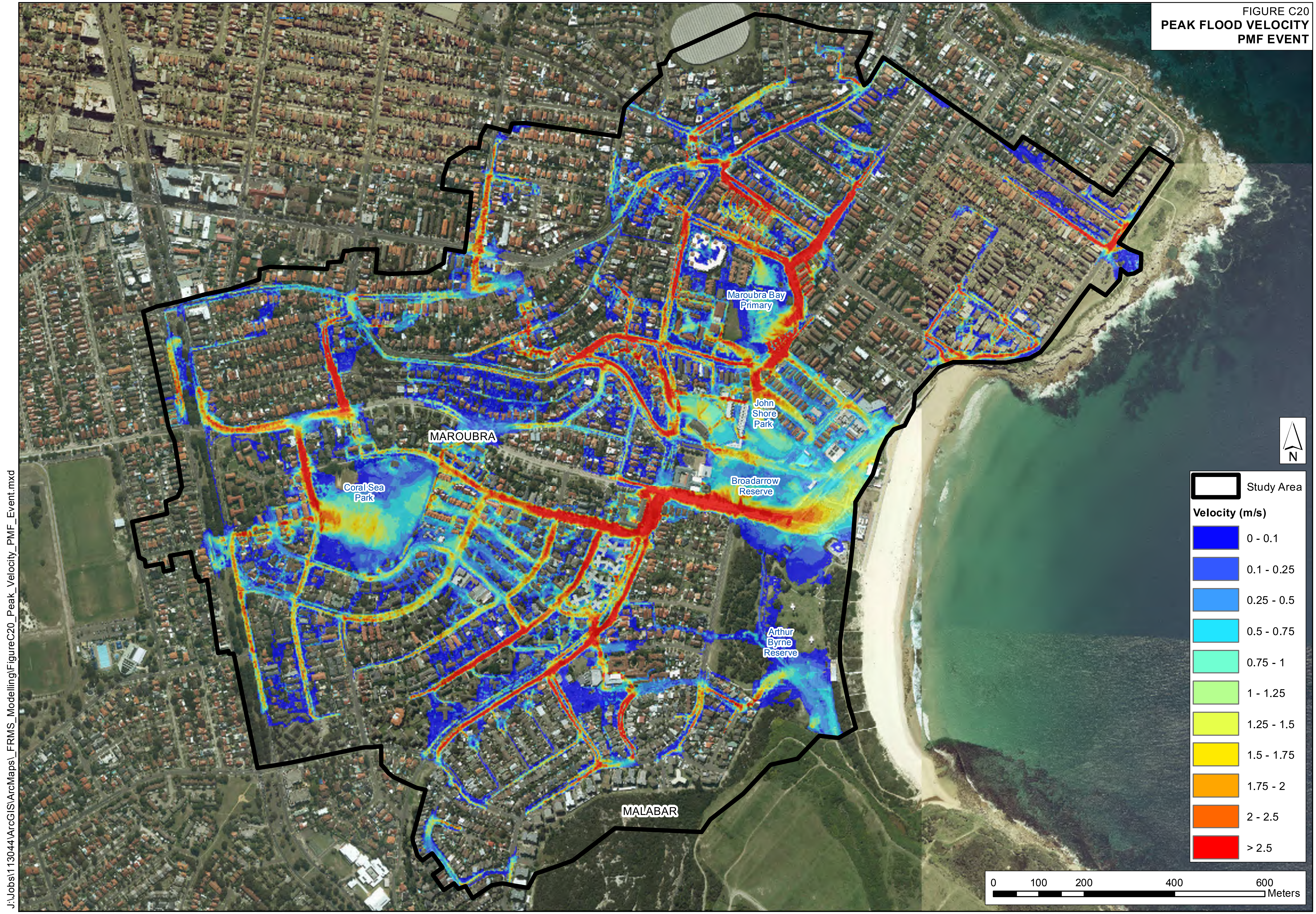
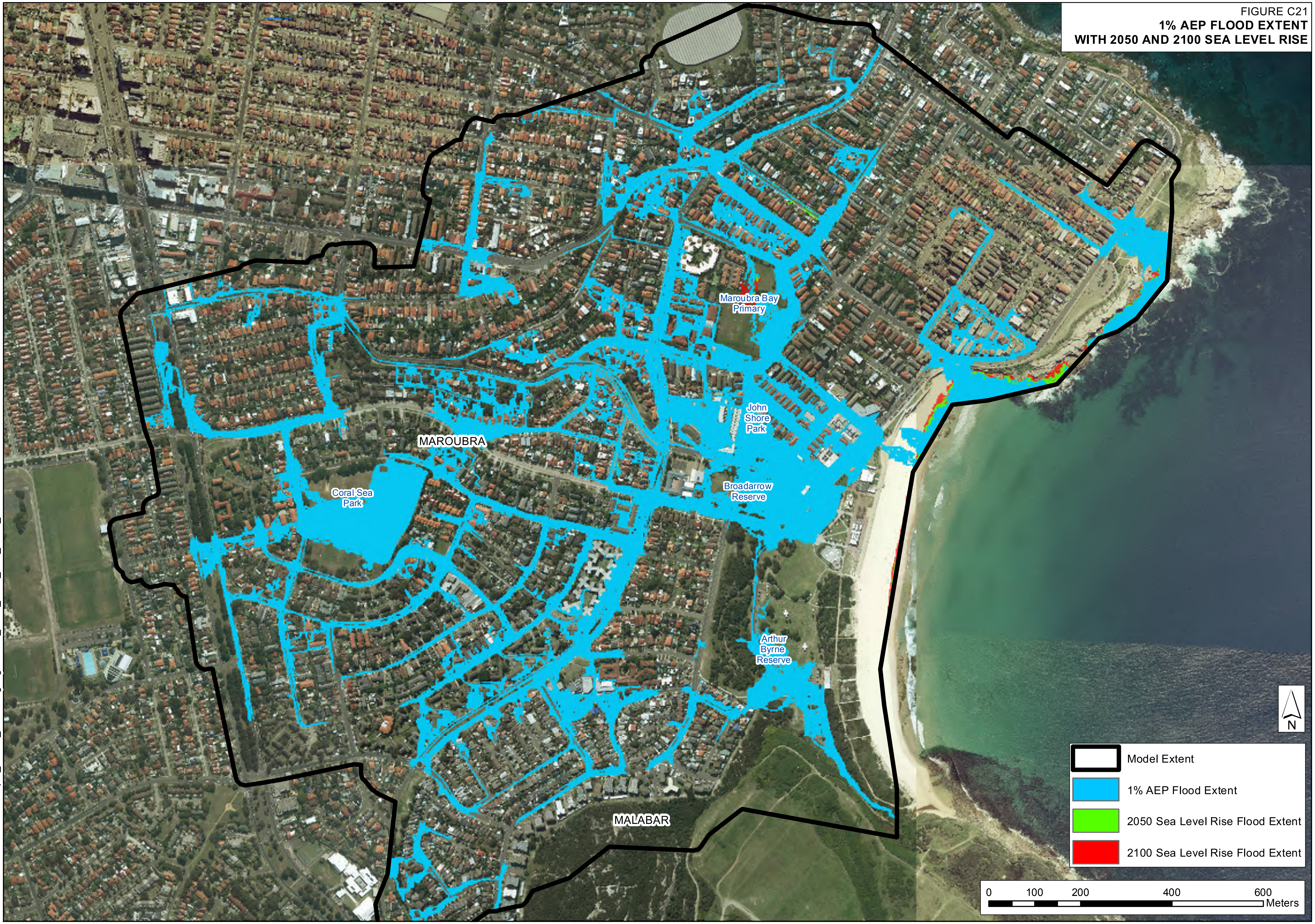


FIGURE C20
PEAK FLOOD VELOCITY
PMF EVENT
Maroubra Bay Primary
John Shore Park
MAROUBRA
Coral Sea Park
Broadarrow Reserve
Arthur Byrne Reserve
MALABAR
N
Study Area
Velocity (m/s)
0 - 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1
1 - 1.25
1.25 - 1.5
1.5 - 1.75
1.75 - 2
2 - 2.5
> 2.5
0 100 200 400 600
Meters
J:\Jobs\113044\ArcGIS\ArcMaps_FRMS_Modelling\FigureC20_Peak_Velocity_PMF_Event.mxd

FIGURE C21
1% AEP FLOOD EXTENT WITH 2050 AND 2100 SEA LEVEL RISE



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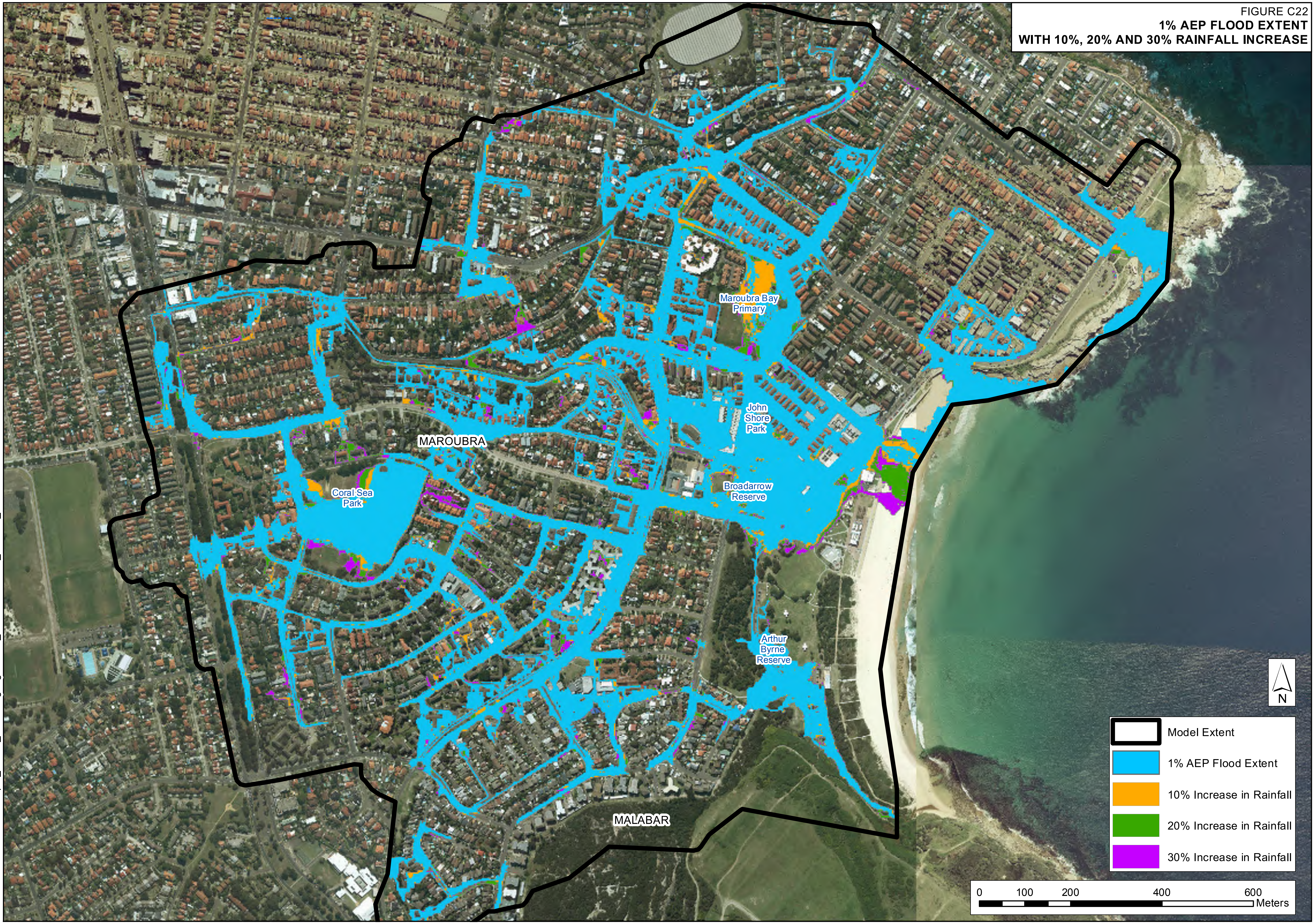

J:\Jobs\113044\ArcGIS\ArcMaps_FRMS_Modelling\FigureC22_RainfallIncrease_1%AEP_Event.mxd