

ATTACHMENTS UNDER SEPARATE
COVER

ORDINARY COUNCIL MEETING
28 APRIL 2026



PORT STEPHENS
C O U N C I L

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FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.

PORT STEPHENS COUNCIL



ANNA BAY AND TILLIGERRY CREEK
FLOODPLAIN RISK MANAGEMENT
STUDY AND PLAN

DRAFT FOR PUBLIC EXHIBITION



MARCH 2026

ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.



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ANNA BAY AND TILLIGERRY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

DRAFT FOR PUBLIC EXHIBITION
MARCH 2026

Project Anna Bay and Tilligerry Creek Floodplain Risk Management Study and Plan	Project Number 120008
Client Port Stephens Council	Client's Representative Samuel Tyter
Project Manager Erin Askew	

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ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.

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**ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.**

**ANNA BAY AND TILLIGERRY CREEK FLOODPLAIN RISK MANAGEMENT STUDY
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LIST OF ACRONYMS

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ALS	Airborne Laser Scanning
ARR	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DECC	Department of Environment and Climate Change (now DCCEEW)
DNR	Department of Natural Resources (now DCCEEW)
DPE	Department of Planning and Environment (now DCCEEW and DPHI)
DPHI	Department of Planning, Housing and Infrastructure
DRM	Direct Rainfall Method
DTM	Digital Terrain Model
GIS	Geographic Information System
GPS	Global Positioning System
IFD	Intensity, Frequency and Duration (Rainfall)
LiDAR	Light Detection and Ranging
LFC	Layered Flow Constriction
mAHD	meters above Australian Height Datum
OEH	Office of Environment and Heritage (now DCCEEW)
PMF	Probable Maximum Flood
SRMT	Shuttle Radar Mission Topography
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydraulic model)
WBNM	Watershed Bounded Network Model (hydrologic model)

ADOPTED TERMINOLOGY

Australian Rainfall and Runoff (ARR, ed Ball et al, 2016) recommends terminology that is not misleading to the public and stakeholders. Therefore the use of terms such as “recurrence interval” and “return period” are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. However, rare events may occur in clusters. For example there are several instances of an event with a 1% chance of occurring within a short period, for example the 1949 and 1950 events at Kempsey. Historically the term Average Recurrence Interval (ARI) has been used.

ARR 2016 recommends the use of Annual Exceedance Probability (AEP). Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP. The table below describes how they are subtly different.

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For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance Probability is not meaningful and misleading particularly in areas with strong seasonality. Therefore, the term Exceedances per Year (EY) is recommended. 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.

The Probable Maximum Flood is the largest flood that could possibly occur on a catchment. It is related to the Probable Maximum Precipitation (PMP). The PMP has an approximate probability. Due to the conservativeness applied to other factors influencing flooding a PMP does not translate to a PMF of the same AEP. Therefore, an AEP is not assigned to the PMF.

This report has adopted the approach recommended by ARR and uses % AEP for all events rarer than the 50 % AEP and EY for all events more frequent than this.

Frequency Descriptor	EY	AEP (%)	AEP	ARI
			(1 in x)	
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
Frequent	1	63.21	1.58	1
	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
Rare	0.11	10	10	9.49
	0.05	5	20	19.5
	0.02	2	50	49.5
Very Rare	0.01	1	100	99.5
	0.005	0.5	200	199.5
	0.002	0.2	500	499.5
	0.001	0.1	1000	999.5
Extreme	0.0005	0.05	2000	1999.5
	0.0002	0.02	5000	4999.5
			↓	
		PMP/ PMP Flood		

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FOREWORD

The NSW State Government's Flood Prone Land Policy provides a framework to ensure the sustainable use of floodplain environments. The primary objective of the NSW Government's Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods using ecologically sustainable methods, where possible. At the same time, the Policy recognises the benefits flowing from the use, occupation, and development of flood prone land. The Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

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

The Policy provides for technical and financial support by the Government through five sequential stages:

1. **Data Collection**
Compilation of existing data and collection of additional data.
2. **Flood Study**
Determine the nature and extent of the flood problem.
3. **Floodplain Risk Management Study**
Determines and evaluates flood risk management options in consideration of social, ecological and economic factors relating to flood risk.
4. **Floodplain Risk Management Plan**
Plan of management for the floodplain including preferred options is publicly exhibited, and public and stakeholder feedback is considered in the finalisation of the Plan. Formally adopted by Council after public exhibition and any necessary revisions.
5. **Implementation of the Plan**
Implementation of flood mitigation works and measures to protect existing development, use of planning policies and controls to ensure new development is compatible with the flood risk and the incorporation of study outputs to improve flood preparedness and response.

This study represents the third and fourth stages of this process.

The Anna Bay and Tilligerry Floodplain Advisory Panel assists Council through the floodplain risk management process, acting as both a focus group and forum.

Port Stephens Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Department of Climate Change, Energy, the Environment and Water.

**ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.****EXECUTIVE SUMMARY**

The Floodplain Risk Management Study and Plan for Anna Bay and Tilligerry Creek (FRMS&P), which follows on from the Anna Bay and Tilligerry Creek Flood Study (Reference 1), has been undertaken in accordance with the NSW Government's Flood Prone Land Policy. This study provides recommendations for reducing flood risk within the study area (Figure 1). The flood behaviour was first defined in Reference 1 which developed a hydrological and hydraulic model. These models have been thoroughly reviewed and updated due to significant development within the study area, recent storm events and updated industry guidelines. Details about the model update have been provided in Section 5.

In this study, a full assessment of the existing flood risk in the study area has been carried out, including hydraulic hazard across the study area, over floor flooding of residential, commercial, and industrial properties, identification of known flooding issues and hotspots, and emergency response during a flood event. This assessment supersedes the outcomes of the Anna Bay and Tilligerry Creek Flood Study (Reference 1). Various measures aimed at managing this flood risk were assessed for their efficacy across a range of criteria. The options were rated according to a detailed matrix of possible impacts. Those rated highest have been recommended in the Floodplain Risk Management Plan and prioritised based upon how readily the management measures can be implemented, their capital cost, what constraints exist and how effective the measures are. Measures with little cost that can readily be implemented, and which are effective in reducing damage or personal danger would have high priority.

Flood Prone Land Policy Framework

The NSW Government Flood Prone Land Policy supported by the Flood Risk Management Manual provides a framework for the assessment and management of flood risk across the state. Specifically, the Flood Risk Management Manual and its supporting guidelines guides Councils in the development and implementation of detailed local floodplain risk management plans in order to plan for and manage flood risk. The Flood Risk Management Manual outlines the process and the roles and responsibilities of the various stakeholders involved in the process.

Council (both elected members and Council staff) are primarily responsible for managing flood prone land through the implementation of floodplain risk management strategies. The Floodplain Advisory Panel assists Council in the development and implementation of these strategies by providing a forum for discussion of the differing viewpoints within the study area, identifying management options and considering and making recommendations to Council on appropriate measures and controls with the primary objective of achieving a beneficial but equitable result for the study area. The Panel is the driving force behind the study and may be required to vote to determine the majority opinion if consensus cannot be reached.

State Government agencies provide funding and technical support to assist Council and the committee in developing a robust Floodplain Risk Management Plan. In most cases a specialist consultant is engaged by Council to undertake the required technical investigations and assessment. The committee directs the consultant through this investigation and receives this information from the consultants to assist with their deliberations.

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WMAwater has undertaken the investigation and assessment for this Anna Bay and Tilligerry Creek Floodplain Risk Management Study under the guidance and direction of the Floodplain Advisory Panel and developed the Anna Bay and Tilligerry Creek Floodplain Risk Management Plan.

Study Area

The study area (Figure 1) for the Anna Bay and Tilligerry Creek studies comprise of the localities of Anna Bay, Boat Harbour, One Mile, Fishermans Bay, Bobs Farm, Taylors Beach, Salt Ash, Tanilba Bay, Mallabula and Lemon Tree Passage. The study area covers an area of approximately 160 km², with land use in the area predominantly composed of rural landscape, nature reserves, waterways and primary production lots for farming use.

The study area is characterised by large areas of low-lying terrain, particularly in the areas adjoining Tilligerry Creek. The ground level increases when moving to the southern shoreline with steep sand dunes seen at Stockton Beach in the Worimi Conservation Lands. There are numerous drainage channels located within the study area which drain the floodplain of Tilligerry Creek including Main Drain, Back Drain, and Fern Tree Drain in Anna Bay and Moors Drain in Salt Ash. These drainage channels formalise the natural watercourse and Main Drain has been fitted with a floodgate.

There are numerous drainage channels located within the study area which drain the floodplain of Tilligerry Creek including Main Drain, Back Drain, and Fern Tree Drain in Anna Bay and Moors Drain in Salt Ash. These drainage channels formalise the natural watercourse and have been fitted with floodgates.

Existing Flood Behaviour

Flood behaviour in the study area is influenced by catchment runoff, ocean conditions as well as riverine flooding (from the Hunter River). The terrain of the study area is flat and low-lying with significant portion of land being lower than 2 m AHD. Flooding in these low-lying areas (such as Marsh Road, foreshore areas of Lemon Tree Passage, and Bobs Farm) is influenced by ocean conditions. In the upstream areas, where the terrain is generally steeper (Salt Ash, Tanilba Bay, Mallabula, and Anna Bay), overland flooding dominates. However, due to high tailwater levels (driven by ocean conditions) drainage of these overland flow paths may be hindered as well.

Salt Ash and Marsh Road is influenced by ocean conditions and are inundated by deep flood waters in high tide events. Lemon Tree Passage Road becomes inundated at Salt Ash.

At Tanilba Bay, Mallabula, and Lemon Tree Passage, local catchment runoff and flood levels in elevated areas are generally low. Lemon Tree Passage Road near these suburbs is mostly unaffected by flooding, however, local roads intersecting with Lemon Tree Passage Road such as President Wilson Walk and Meredith Ave may be inaccessible. Foreshore areas low-lying and highly sensitive to ocean conditions. With elevated tidal conditions, overland flow paths are unable to drain to their outlets.

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Urbanised areas of Anna Bay, Fishermans Bay and Boat Harbour, which are generally elevated have lower flood depths. However, this area has a few trapped low points such as McKinley Swamp, Clark St low point, the intersection of Gan Gan Rd and Morna Point Rd, which have deep flooding and may hinder evacuation in the area.

Economic Impact of Flooding

A flood damages assessment was carried out for the inundation of residential and commercial properties in the study area. The internal damages assessment was based on estimated floor levels. The assessment identified 1981 properties impacted by flooding over floor and 3299 properties impacted externally across the Study Area. The annual average damages for residential and commercial/industrial properties were found to be \$23,123,739. This represents the average cost of flooding each year.

Floodplain Risk Management Measures

This Floodplain Risk Management Study process under the direction of the Floodplain Advisory Panel has identified and assessed a range of risk management measures that would help mitigate flooding to reduce existing and future flood damages. The options were assessed using a multicriteria analysis, which considered not only flood impacts, but also construction feasibility, economic merits and the alleviation or exacerbation of property damages, risk to life and pressure on the NSW SES.

These measures have been grouped into the following general categories:

Flood modification measures modify the flood's physical behaviour (depth, velocity) by undertaking structural works in particular areas of the floodplain. Among the flood modification options considered are upgrades to the stormwaters lines and retarding or detention basins.

Property modification measures modify the existing land use or buildings as well as development controls for future development. These measures primarily involve updating policies and regulations which relate to development on the floodplain. Property modification measures including Voluntary Purchase and Voluntary House Raising were assessed, as well as a broad range of planning measures that aim to reduce flood risk to life, to proposed development and to the wider floodplain.

Response modification measures are aimed at changing and enhancing the community's response to the potential hazards of flooding. This is achieved by educating the property owners and the wider community about flooding, its behaviour and potential damages, so that they can make better informed decisions. The response modification measures considered in this FRMS are generally to 'continue and improve' on current flood emergency management systems and practices including improvements to driver safety.

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Recommended Options

The outcomes of the analysis undertaken in this Floodplain Risk Management Study are presented in this report and from that information the Floodplain Advisory Panel has made recommendations which include property modification (for example, planning controls), flood modification (for example, drainage upgrades) and response modification (for example, community education, flood emergency management planning), and are detailed in Table 1 overleaf. The Final Draft Floodplain Risk Management Study and Plan will be placed on public exhibition to allow the broader community and stakeholders to provide feedback on the recommendations. The Floodplain Advisory Panel will consider the submissions received and any appropriate changes made before finalisation and adoption of the Floodplain Risk Management Plan by Council.

DRAFT FOR PUBLIC EXHIBITION

ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.



Table 1: Draft Floodplain Management Plan

FLOODPLAIN RISK MANAGEMENT MEASURES									
Option ID	Type	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	Priority
FM01	Flood Modification	Flood Barrier at Blake Pde Park	Construction of a 1m high flood barrier at existing storage basin. Initially, a more detailed analysis in the form of a feasibility investigation would be undertaken to refine and develop the concept before implementation is recommended.	May reduce flood affectation at two properties in frequent events only	Moderate capital costs and limited benefit to flood damages. Visual aesthetics of Blake Pde Park may be impacted. Further upgrade to stormwater pipes along Morna Point Rd are required to reduce flood levels in larger flood events.	Council	May be eligible for NSW Government funding assistance	Low (Feasibility) Moderate (Implementation)	High ⁽¹⁾ (Feasibility) Low (Implementation)
FM02	Flood Modification	Flood Barrier Along Hutcheson Road	Installation of flood barrier in the form of permanent low-level impervious fencing and driveway raising of 3 private properties along Hutcheson Rd. Initially, a more detailed analysis in the form of a feasibility investigation would be undertaken to refine and develop the concept before implementation is recommended.	Removes above flood flooding in 2 properties in the current 1% AEP event. Low capital costs Council has experience implementing similar works	Minor flood level increase within Hutcheson Rd corridor (+30mm in current 1% AEP). Works may impact existing drainage and this requires consideration in concept development. Works within private property and will require community consultation.	Council	May be eligible for NSW Government funding assistance	Low (Feasibility) Low (Implementation)	High ⁽¹⁾ (Feasibility) Medium (Implementation)
FM04	Flood Modification	Diversion Drain Near Purcell Avenue, Lemon Tree Passage	Construction of drain up to 1.5 m depth drain from spillway of existing basin. Initially, a more detailed analysis in the form of a feasibility investigation would be undertaken to refine and develop the concept before implementation is recommended.	Reduces peak flood levels by up to 120 mm	Removal of vegetation for drain Access to drain site for construction	Council	May be eligible for NSW Government funding assistance	Low (Feasibility) Low (Implementation)	High ⁽¹⁾ (Feasibility) Low (Implementation)
FM06	Flood Modification	Drainage of Davidson St Low Point	Additional pipe connecting Davidson St low point to the existing stormwater network. Initially, a more detailed analysis in the form of a feasibility investigation would be undertaken to refine and develop the concept before implementation is recommended.	Reduces flood extent such that above floor flooding reduces from four properties to one.	New pipe network passes under existing private property. New pipe network passes under Campbell Ave and may require a deep trench excavation. Current 1% AEP event only impacts four residential properties. Annual average damages are unlikely to be significantly reduced.	Council	May be eligible for NSW Government funding assistance	Low (Feasibility) High (Implementation)	Medium ⁽¹⁾ (Feasibility) Low (Implementation)
FM09	Flood Modification	Channel and Drainage Upgrade at Anna Bay near Gan Gan Road	Upgrade of Fern Tree Drain and additional stormwater network upgrades at Anna Bay near Gan Gan Rd. Initially, a more detailed analysis in the form of a feasibility investigation would be undertaken to refine and develop the concept before implementation is recommended.	Reduction in peak flood levels and above floor flooding in rare events	High capital cost and complex implementation	Council	May be eligible for NSW Government funding assistance	Low (Feasibility) High (Implementation)	Medium ⁽¹⁾ (Feasibility) Low (Implementation)
FM10	Flood Modification	Drainage of Clark Street Low point	Additional stormwater infrastructure in accordance with condition of consent.	Reduction in local peak levels and duration of inundation.	High capital costs. Complex construction methodology.	Private developer ⁽²⁾	Private developer	High	Medium (Feasibility) High at time of Development (Implementation)
FM11	Flood Modification	Upgrade Drainage at Lemon Tree Passage Road at Tanilba Bay and Mallabula	Drainage upgrade at Lemon Tree Passage Road at Tanilba Bay and Mallabula Initially, a more detailed analysis in the form of a feasibility investigation would be undertaken to refine and develop the concept before implementation is recommended.	Reduces flood affectation to properties along the northern side of Lemon Tree Passage Road	Further works are required to ensure properties downstream of Lemon Tree Passage Road will not be affected.	Council	May be eligible for NSW Government funding assistance	Low (Feasibility) High (Implementation)	High ⁽¹⁾ (Investigation) Medium (Implementation)



FLOODPLAIN RISK MANAGEMENT MEASURES									
Option ID	Type	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	Priority
FM12	Flood Modification	Upgrade Drainage at Lemon Tree Passage Road at Salt Ash – Detailed Investigation	Upgrade of cross drainage at Lemon Tree Passage Rd at Salt Ash Initially, a more detailed analysis in the form of a feasibility investigation would be undertaken to refine and develop the concept before implementation is recommended.	Reduces road overtopping in frequent events	High capital costs. Cross drainage requires maintenance to be effective	Council	May be eligible for NSW Government funding assistance	Low (Feasibility) High (Implementation)	High ⁽¹⁾ (Investigation) Medium (Implementation)
PM13	Property Modification	Voluntary House Purchase	Undertake further investigation of the identified properties in a VP scheme, including consultation with the identified properties, prioritisation and if appropriate, prepare the documentation for funding applications.	Voluntary Purchase (VP) schemes are a long-term option to remove residential properties from areas of high flood hazard reducing risks to life of residents and potential rescuers.	Community appetite for or acceptance of VP may be a challenge. VP schemes are long term options, have high costs and may take approximately a decade to implement.	Council	May be eligible for NSW Government funding assistance	Low (Investigation) High (Implementation)	High ⁽¹⁾ (Investigation) Low (Implementation)
PM14	Property Modification	Flood Planning Levels	Council to continue to use the following Flood Planning Levels: The level of the 1% AEP (annual exceedance probability) flood event in the year 2100 plus 0.5 metre freeboard, except for overland flooding areas where a freeboard of 0.3 metre is applied. The area of land below the Flood Planning Level (i.e. the Flood Planning Area) is subject to flood-related development controls.	FPLs are effective tools to limit property damage to new development and redevelopment. FPLs may pertain to minimum floor levels or flood proofing levels depending on the type of development.	May be considered more onerous for developers.	Council	Council	In house	High
PM15	Property Modification	Flood Planning Policy	Implement a range of minor recommendations to improve Council's Flood Planning Policy as applied through Council's Development Control Plan	Ensure developments are designed, constructed and managed in such a way as to minimise flood risk to the structure and (if relevant) its occupants, in addition to minimising the impacts of flooding.	There may be resistance from developers who consider new controls to be onerous or likely to reduce the development yield.	Council	Council	In house	High
PM16	Property Modification	Voluntary House Raising	Undertake a feasibility investigation for the identified properties (including to confirm structural compatibility of the identified buildings, owner interest and a more accurate cost estimate of raising to at least the DFE + 0.5 m flood level), and if found viable, prepare the documentation for funding applications.	Seeks to reduce the frequency of exposure to flood damage of the house and its contents by raising the house above the Flood Planning Level (FPL), resulting in a reduction in the frequency of household disruption and associated trauma and anxiety.	External flood risk remains, and evacuation is required before inundation in cases where the property becomes isolated. Community appetite may be a challenge. VHR schemes are long term options and may take approximately a decade to implement.	Council/ Landholder	May be eligible for NSW Government funding assistance	Low (Investigation) High (Implementation)	High ⁽¹⁾ (Investigation) Low (Implementation)
PM17	Property Modification	Flood Proofing	Include options for the use of flood proofing to the FPL for non-residential land uses within Council's DCP	This will enable new and existing buildings to be developed with due consideration given to their flood risk and minimisation of internal flood damages.	More vulnerable uses may use building in the future, and this would need to be managed.	Council	Council	In house	High
RM18	Response Measure	Flood Awareness and Preparedness	Establish and implement ongoing and collaborative education to improve flood awareness.	Flood awareness significantly improves preparedness for and recovery from flood events, building a more flood resilient community.	Ongoing efforts to ensure information is not forgotten. Potential for residents to become bored or complacent with messaging.	Council in collaboration with other response agencies and community organisations.	Council	Annual Budget to be determined and allocated.	High
RM19	Response Measure	Evacuation Planning	Update of the Port Stephens Flood Emergency Sub Plan to include the information provided as part of this floodplain risk management study, including updates to the flood behaviour, flood emergency response classification, and within the study area.	Detailed information will allow for better management and recovery of flood risk and will increase understanding of the different levels and types of risk present in the study area.	Modelled results should be used as a guide only, as real flood behaviour may vary from modelled design results	NSW SES	NSW SES	In house	High

(1) Progression of Feasibility Investigations are reliant on funding availability.

(2) This option will be delivered by a private developer in association with an approved consent condition. Should consent not be pursued, Council may assume responsibility of the option subject to funding availability.

**ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.****1. INTRODUCTION**

This document details the Anna Bay and Tilligerry Floodplain Risk Management Study (FRMS) and the Anna Bay and Tilligerry Floodplain Risk Management Plan (FRMP and abbreviated together as FRMS&P) and follows on from the Anna Bay and Tilligerry Flood Study (Reference 1) which provided an indication of the nature and extent of the flood problem within the study area under existing conditions and in accordance with industry guidelines that were current at the time. Flood behaviour has been defined across a range of event sizes based on industry guidelines current when FRMS&P commenced and this understanding of flood behaviour supersedes that in the Anna Bay and Tilligerry Flood Study (Reference 1). The assessment also included those events which have been recorded in the past, as well as larger events which may occur in the future. This Floodplain Risk Management Study seeks to investigate methods by which to manage existing, future and continuing flood risk and hazard in the study area and ultimately develop a Floodplain Risk Management Plan in accordance with best practice, which can be implemented by Council.

Effective flood plain management requires a strong understanding of current flood behaviour and risks. The Flood Study was undertaken in accordance with the methodologies outlined Australian Rainfall and Runoff 1987, which was considered best practice at the time. In 2019, a significant update of the Australian Rainfall and Runoff guidelines were released, and the current study considers these revised guidelines. A range of other policies and guidelines such as the NSW Government's Flood Prone Land Policy, Floodplain Development Manual (Reference 2) and the Flood Risk Management Manual (Reference 3) provide overarching guidance to the study. The primary objective of FRMS&P is to reduce the impact of flooding on individual owners and occupiers of flood prone land, and to reduce private and public losses caused by flooding.

The region has experienced a recent flood event in March 2021, for which anecdotal reports and photographs of flood impacts are available. This presents an opportunity to improve the model performance by considering it in the calibration process. This is incorporated in the FRMS&P and further strengthens understanding of current flood behaviour and risks.

This FRMS improves our understanding of the potential impacts of floods on the local community and will form a basis for the ongoing management of flood risk in the Anna Bay Tilligerry catchment. It allows the testing and investigation of practical, feasible and economic management measures to manage existing, future, and residual flood risk. Aiming to reduce flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard. Additional information from the study will support emergency management functions as well as resilience and preparedness strategies. The FRMS will provide a basis for informing the development of a FRMP.

Tilligerry Creek is located within the Port Stephens Council Local Government Area (LGA). The study area for the Anna Bay and Tilligerry Creek Floodplain Risk Management Study and Plan (FRMS&P) includes 164 km² and encompasses the estuarine section of Tilligerry Creek and its floodplain (Diagram 1). The study area includes areas discharging towards Tilligerry Creek and the Tomaree and Tilligerry Peninsulas.

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The eastern end of the Tomaree and Tilligerry Peninsulas are urbanised (Tanilba Bay, Anna Bay Mallabula, Boat Harbour, One Mile, and Lemon Tree Passage) and more densely populated. These townships are connected to the mainland (Newcastle and Williamtown) via Lemon Tree Passage Road in the Tilligerry Peninsula and Nelson Bay Road in the Tomaree Peninsula. Along these major roads are several townships including Salt Ash, Bobs Farm, and Taylors Beach. In frequent flood events, Lemon Tree Passage Road becomes overtopped and access to the townships in the Tilligerry Peninsula is cut off. Nelson Bay Road becomes overtopped in rarer events, losing access to the Tomaree Peninsula.

There are numerous drainage channels located within the study area which drain the floodplain of Tilligerry Creek including Main Drain, Back Drain, and Fern Tree Drain in Anna Bay and Moors Drain in Salt Ash. These drainage channels formalise the natural watercourse and have been fitted with floodgates.

Flood behaviour in the study area is influenced by catchment runoff, ocean conditions as well as riverine flooding (from the Hunter River). The terrain of the study area is flat and low-lying with significant portion of land being lower than 2 m AHD. Flooding in these low-lying areas (such as Marsh Road, foreshore areas of Lemon Tree Passage, and Bobs Farm) is influenced by ocean conditions. In the upstream areas, where the terrain is generally steeper (Salt Ash, Tanilba Bay, Mallabula, and Anna Bay), overland flooding dominates. However, due to high tailwater levels (driven by ocean conditions) drainage of these overland flow paths may be hindered as well.

Diagram 1: Study Area Overview



**ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.****2. BACKGROUND****2.1. Study Area**

The study area (Figure 1) for the Anna Bay and Tilligerry Creek studies comprise of the localities of Anna Bay, Boat Harbour, One Mile, Fishermans Bay, Bobs Farm, Taylors Beach, Salt Ash, Tanilba Bay, Mallabula and Lemon Tree Passage. Located in the Hunter-Central Rivers district of NSW, Tilligerry Creek flows into Port Stephens Bay near Bull's Island. Oyster farming and production is a popular aquaculture activity in the Tilligerry Creek.

The study area covers an area of approximately 160 km², with land use in the area predominantly composed of rural landscape, nature reserves, waterways and primary production lots for farming use. Anna Bay comprises the highest population in the study area with approximately 4,200 (ABS, 2021). Land use in Anna Bay is predominantly low-density resident residential on the south along Gan Gan Road, predominantly surrounded by rural landscape. Some commercial development is located along Gan Gan Road in Anna Bay. Other urban centres in the study area include Boat Harbour, Tanilba Bay, and Lemon Tree Passage. These urban centres are primarily residential with small pockets of commercial seen along Cook Parade and Meredith Avenue in Lemon Tree Passage, and along Lemon Tree Passage Road and Pershing Place in Tanilba Bay. Some industrial development is located along Industrial Crescent in Lemon Tree Passage. Taylors Beach has the largest hub of commercial and industrial development in the area and is located along Port Stephens Drive.

The main road network in the floodplain includes Gan Gan Road, Nelson Bay Road, Marsh Road, Lemon Tree Passage Road and Port Stephen Drive. Nelson Bay Road runs generally from east to west throughout the study area and is the main arterial road connecting Newcastle to Williamtown and the Tomaree Peninsula. Lemon Tree Passage Road runs east west connecting the Tilligerry Peninsula to Williamtown and Newcastle.

The study area is characterised by are large areas of low-lying terrain, particularly in the areas adjoining Tilligerry Creek. The ground level increases when moving to the southern shoreline with steep sand dunes seen at Stockton Beach in the Worimi Conservation Lands. These sand dunes are considered the largest moving coastal dunes in the southern hemisphere and are a significant tourist destination.

2.2. Social Characteristics

Information is available from the 2021 census (<http://www.abs.gov.au/>) (Reference 4) for each of the localities in the study area. This is used to help define social characteristics of this study area. Understanding the social characteristics of the area can be used to inform the risk assessment process through providing metrics for some of the aspects which influence the vulnerability of a community. Census data regarding house tenure and age distribution can also provide an indication of the community's lived experience with recent flood events, and hence an indication of their flood awareness.

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FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.**

According to The Flood Preparedness Manual (Reference 5), it is also possible, using population census data and other information held by councils and state agencies, to identify the potential number and location of people in an area (or the proportion of the community's population) with special needs or requiring additional support during floods.

The Flood Preparedness Manual identifies that, in general, people who belong to the following groups may be considered especially susceptible to the hazard posed by flooding:

These include:

- **The elderly**, especially those living alone and/or frail, who are often unable to respond quickly or without assistance;
- **Those with low incomes**, including the unemployed and others on pensions, who may lack resources which would give them independence of decision making and action;
- **Single-parent families, large families or families with very young children**: these may be characterised by low adult / child ratios making evacuation difficult;
- **Those lacking access to a motor vehicle** may need additional assistance to evacuate;
- **Newcomers** (i.e. those residents in their communities for only short periods or visitors and tourists), who are unlikely to appreciate the flood threat and may have difficulty understanding advice about flooding. They may need special attention in terms of threat education and communication of warnings and other information;
- **Members of Culturally and Linguistically Diverse communities**, who need special consideration with respect to the development of preparedness strategies as well as warnings and communications during flood events. Special attention may also be needed if actions which become necessary during floods offend cultural sensitivities;
- **The ill or infirm** who need special consideration with respect to mobility, special needs, medications, support and 'management' to ensure they continue to receive appropriate care and information; and
- **Those whose homes are isolated by floods**, requiring early evacuation, or if evacuation orders are ignored, may need medical evacuation resupply of essential items, or emergency rescue.

A review of the social characteristics can also provide an indication of the existing flood awareness in a community considering statistics of years of residence, home ownership or having access to the internet at home.

Table 2 below shows the 2021 census statistical for the available State Suburbs (SSCs) compared to the NSW average.



Table 2: 2021 Census Data

	NSW	Anna Bay	Boat Harbour	One Mile	Fishermans Bay	Bobs Farm	Taylors Beach	Salt Ash	Tanilba Bay	Mallabula	Lemon Tree Passage
Population demographics:											
Median age	39	52	47	54	59	57	51	46	48	49	52
0 – 14 years	19.0%	15.4%	17.2%	12.0%	9.1%	9.1%	18.6%	16.1%	16.9%	15.9%	14.8%
15 - 64 years	64.4%	54.9%	60.2%	53.3%	75.0%	51.6%	61.4%	62.7%	55.7%	59.2%	55.4%
> 65 years	16.7%	29.7%	22.5%	34.7%	15.9%	39.3%	20.0%	21.2%	27.4%	24.9%	29.8%
Households											
Average people per household	2.6	2.3	2.6	2.6	2.2	2.3	2.3	2.7	2.4	2.4	2.3
Average children per family	1.8	1.8	1.8	2	1.4	1.6	1.7	1.8	1.9	1.8	1.8
Dwellings											
Own/mortgage property	64.0%	78.7%	79.7%	89.3%	100.0%	84.0%	63.6%	84.0%	70.8%	72.9%	71.1%
Rent property	32.6%	18.4%	18.9%	0.0%	10.7%	9.4%	21.8%	12.0%	26.4%	25.1%	25.9%
Moved into area:											
- within last year	14.8%	13.1%	15.0%	8.0%	19.7%	24.0%	9.3%	6.4%	13.5%	12.9%	14.8%
- within last five years	39.9%	41.8%	42.1%	36.9%	59.7%	46.3%	37.7%	24.1%	38.3%	34.0%	37.7%
Vehicles											
No vehicles at dwelling	9.0%	2.7%	0.8%	4.1%	0.0%	2.0%	0.0%	1.3%	3.7%	3.4%	2.8%
Ave vehicles per dwelling	1.8	1.9	2.2	2.4	2	2.1	1.9	2.6	1.9	2.2	1.8
Cultural Diversity											
Speak only English at home	67.6%	91.6%	93.9%	87.8%	88.2%	90.2%	93.8%	90.5%	92.9%	94.1%	89.9%
Households where non-English is spoken	29.5%	4.5%	4.7%	4.7%		2.7%	0.0%	6.1%	4.3%	2.8%	5.5%
Other languages spoken		Italian (0.5%) German (0.3%) Nepali (0.2%) Spanish (0.2%) Thai (0.2%)	French (0.6%) Japanese (0.5%) Polish (0.4%) Spanish (0.3%) Mandarin (0.3%)	Dutch (1.8%) Italian (1.2%)		Thai (0.9%) Vietnamese (0.6%) German (0.5%)		Thai (0.5%) Spanish (0.5%) Polish (0.5%) Sinhalese (0.4%) Mandarin (0.4%)	German (0.5%) Spanish (0.3%) Macedonian (0.3%) Thai (0.2%) Dutch (0.2%)	German (0.4%) Malay (0.4%) French (0.4%)	German (0.6%) Italian (0.3%) Spanish (0.3%) Croatian (0.3%) Mandarin (0.3%)
Income											
Median weekly household income	\$1,829	\$1,189	\$1,741	\$1,542	\$1,875	\$1,211	\$1,625	\$1,461	\$1,131	\$1,170	\$1,071
< \$650 gross per week	15.30%	21.79%	10.83%	24.26%	10.71%	22.66%	5.45%	16.22%	21.42%	20.16%	24.32%

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2.3. Environmental Features

Tilligerry Creek is characterised by a long narrow channel with muddy tidal flats at the foreshore. The majority of the land bordering Tilligerry Creek has been zoned as Environmental Conservation in the Port Stephens Local Environmental Plan 2013. The State Environmental Planning Policy (SEPP, 2021) has classed large areas of the study area as both coastal wetlands (Resilience and Hazards) or koala habitat. Chapter 3 within the SEPP (Biodiversity and Conservation) 2021 applies to all rural zoned lands (RU1, RU2, and RU3) within Port Stephens LGA. The construction of drains and embankments in the study area have modified the foreshore area. Erosion and structure protection are key issues in the lower parts of the Tilligerry Creek.

A number of state conservation areas are situated in the study area including the Tilligerry State Conservation Area, Worimi National Park and Tomaree National Park. Stockton Beach is located in the Worimi Conservation Lands within the study area and begins at Anna Bay stretching 32 km in a south-east direction towards Newcastle. As describe above in Section 2.1, Stockton Beach is home to the largest moving coastal dunes in the southern hemisphere. Due to large ocean swells, high tides and heavy rainfall, Stockton Beach has experienced extensive beach erosion. Numerous studies have been conducted to understand the sediment transport processes at Stockton Beach and determine potential mitigation options available. Stockton Beach is of environmental importance and significant to the local community.

Port Stephens Council developed the Foreshore Management Plan (2009) and identified large areas of high value koala habitat. These areas are primarily located along the northern shore of Tilligerry Creek and smaller areas can be found along the shoreline of Tanilba Bay and Lemon Tree Passage. There are a number of threatened flora and fauna within the study area and Reference 6 reports that the foreshore environment has seen extensive clearing and land use modification. Endangered ecological communities within the study area include:

- Swamp Oak Floodplain Forest: primarily along northern side of Tilligerry Creek, Taylors Beach, south-east of Anna Bay and One Mile.
- Saltmarsh Communities: areas around Bobs Farm Creek.
- Swamp Sclerophyll: scattered around One Mile, Bobs Farm and Salt Ash.

2.4. Land Use

Land use zoning is defined by the Port Stephens Local Environmental Plan 2013 and is reproduced on Figure 2. The study area is predominantly zoned as *RU1 - Rural Landscape* and *C1 - National Parks and Nature Reserves*. The majority of the urban development is zoned *R2 - Low Density Residential*. The Anna Bay Strategy & Town Plan (2008), Local Housing Strategy (2024) and the Housing Supply Plan (2024) also provide proposed land uses.

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FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.****3. AVAILABLE DATA**

The following sections describes available data, and where available the accuracy and limitations with the data.

3.1. Land Use

Land use information was provided for the entire study area and is described further in Section 2.1. The cadastre provided for the Port Stephens local government area covers the full extent of the study area. This cadastre was developed in 2015 and will be used for mapping and analysis for this FRMS&P.

3.2. Locations of Rezoning Applications

Locations of potential rezoning applications near Anna Bay were provided. These potential applications included areas north of Gan Gan Road and Clark St, areas north of Old Main Road, and along Nelson Bay Rd near Latitude Dr.

The Port Stephens Local Housing Strategy (summarised in Section 7.3.3) outlines a number of areas within the study area which have been identified for potential future development.

3.3. Digital Elevation Model

There are two Digital Elevation Models (DEMs) provided, one for the Anna Bay and Tilligerry study area and another for the Nelson Bay Road upgrade.

The main study area DEM was developed by Jacobs and comprises information from LiDAR data captured by the NSW Land and Property Information captured in 2012 and 2013 for Port Stephens and Raymond Terrace respectively. The LiDAR has a reported vertical accuracy of ± 0.15 m and Jacobs notes that the DEM has limitations in accuracy where there is dense vegetation or waterbodies.

The DEM for Nelson Bay Road Upgrade was developed in 2015. The raw LiDAR was not provided, this data will be downloaded to enable extraction of building footprints.

3.4. Bathymetric Survey

Bathymetric survey in Tilligerry Creek was conducted in 2016 and used in the Williamtown-Salt Ash TUFLOW model. This survey was extracted from the Williamtown-Salt Ash TUFLOW model and used in the Jacobs TUFLOW models.

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3.5. Hydraulic Structures

Hydraulic structures included in the provided TUFLOW model are shown in Figure 4 to Figure 6. Structures included in the modelling include relevant pit and pipe information provide by Port Stephens Council, details of floodgates along Tilligerry Creek (NSW Department of Primary Industries (DPI)), Nelson Bay Road upgrade cross drainage (RMS), Lemon Tree Passage Road upgrade design (Council) and Anna Bay drainage channels cross sections (DPI).

The raw survey information for these structures have also been provided as part of the SES Flood Study handover pack.

3.6. Peer Review

This study has been independently peer reviewed by Grantly Smith from Restore Blue. The outcomes of the peer review have been considered in finalisation of this report. A copy of the peer review is provided in Appendix E.

3.7. Previous Studies

The following section provides a summary of previous studies undertaken within the study area.

3.7.1. Anna Bay Catchment Drainage / Flood Study Masterplan (SKM, 1995)

The primary objective of the Anna Bay Catchment Drainage / Flood Study Masterplan (Reference 7) was to develop a framework for future network planning, flood mitigation and water quality in the study area. The study focused on understanding the capacity of the current drainage system and plan future development in the study area. The study developed a RAFTS-XP hydrologic model and a 1D Mike-11 hydraulic model to assess flooding and network capacity in the area. The program AQUALM-XP was used to model water quality.

The study outlined the constraints to development in parts of the catchment, including: *“extensive oyster leases in the downstream receiving waters, acid sulphate soils, low lying areas subjected to flooding, poor existing drainage network, wildlife areas and corridors, flat grades on land in some areas, existing flood problems”*. The study developed a plan to manage the existing flood problem to enable future development.

Recommended works include upgrading the drains along Gan Gan Road, installation of three drains through the sand hills north of Gan Gan Road, increasing capacity of drains through the swamp area, increasing culvert capacity under Gan Gan Road, Nelson Bay Road and Port Stephens Drive, and a gross pollutant trap and water quality control pond. The report provided a preliminary cost of works to allow the ultimate potential development within the catchment, with a final estimation of roughly \$3.6 million.

ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.**3.7.2. Port Stephens Flood Study, Stage 3 – Foreshore Flooding (Manly Hydraulics Laboratory, 1998).**

The Port Stephens Flood Study (Reference 8) focuses on foreshore flooding the tidal estuary of Port Stephens. The study area does not directly correspond to the Anna Bay and Tilligerry study area, however does interact with flood behaviour in the area.

This study has been undertaken in three parts. Stage 1 investigated previous reports and historical data to estimate the preliminary 1% AEP water levels. Stage 2 determined design water levels, wind and wave conditions and ocean wave conditions. Stage 3 produced the 5% AEP and 1% AEP flood levels for Port Stephens. Design water levels are a combination of ocean levels, local wind setup, catchment runoff and local runoff.

3.7.3. Port Stephens Foreshore (Floodplain) Management Study and Plan (Webb, McKeown & Associates, 2002)

The Port Stephens Foreshore Floodplain Management Study and Plan (Reference 9) follows on from the Port Stephens Foreshore Flood Study. Similar to the Port Stephens Flood Study, the study area does not directly overlap with the Anna Bay and Tilligerry study however, flooding does interact.

The FRMS&P assesses the flood hazard and identifies potential management options for managing existing and future flood risk in Port Stephens. The average annual tangible flood damages (AAD) for Port Stephens were calculated to be approximately \$840,000. Flood modification measures deemed suitable, included foreshore levees, walls and artificial dunes, offshore breakwaters and configuration dredging. Additionally, vegetation barriers were considered to protect from wave runup and for the environmental benefits, however foreshore residents water views would be affected. Property modifications measures have been considered and are likely required to be combined as house raising is only suitable for a small number of buildings, flood proofing permanent or temporary is only suitable for non-residential properties and voluntary purchase has a high cost per property. Larger scale property modification procedures including updating planning regulations to control future developments have been suggested. Suitable response modification factors included developing a Flood Warning System, improvements to the evacuation plan and update to the awareness and preparedness program.

3.7.4. Tilligerry Creek Flood Study (Lawson and Treloar, 1998)

Lawson and Treloar were engaged by Port Stephens Council to deliver the Tilligerry Creek Flood Study in 1998 (Reference 10). This study was undertaken to analyse the flood behaviour and magnitude for the Tilligerry Creek floodplain between Fullerton Cove and Port Stephens. The study has adopted the model from the Lower Hunter River Flood Study (LHRFS) and extended it to include the relevant areas.

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Flooding in Tilligerry Creek is caused by local runoff and overtopping of the Hunter River levee system. The study area is characterised by high sandhills behind Stockton Beach and low lying swampy floodplains to the North West. Williamstown RAAF Base, Nelsons Bay Road and Cabbage Tree Road are elevated impact flood behaviour in the study area.

The model was calibrated to the local catchment runoff event of February 1990. Flood Behaviour was determined for 1%, 2%, 5%, 10% and 20% AEP and the PMF extent. Results were presented using longitudinal profiles and 2-D contour maps. Relevant findings were that the Fullerton Cove Ring Levee protects the Tilligerry Creek floodplain from Hunter River flood flows up to the 2% AEP flood event. The Flood Study determined that the 1% AEP flood event would induce widespread inundation in Tilligerry creek floodplain with low flow velocities however Nelsons Bay Road between Fullerton Cove and Cabbage Tree Road is not overtopped. The model has the capacity to be the basis for a Floodplain Management Study.

**3.7.5. Drainage Investigation Report Anna Bay North Structure Plan
(Parsons Brinckerhoff, 2004)**

This study (Reference 11) comprises a structure plan for Anna Bay North, which includes a drainage investigation for the purpose of understanding the existing network capacity and develop a plan to mitigate potential future impacts from development. Study area includes a large area of the Anna Bay Township and the area of development along Gan Gan Road east-west of Anna Bay.

The study provides a detailed description of current drainage infrastructure of the catchment. XP-SWIMM was used to develop both the hydrologic and hydraulic models. Models were run for a number of development scenarios including the existing development and two potential future development scenarios.

The study recommends seven mitigation options including; rainwater tanks on all new allotments, infiltration trenches on all new allotments, a constructed drainage system linking catchment 4 (the undeveloped land north-south of Gan Gan Road) to the Anna Bay Main Drain, detention storage infrastructure within catchment 4, pit and pipe network in future developed areas, vegetated swales and unlined channels and an engineered floodway north of Anna Bay to convey a 1% AEP event.

**3.7.6. Port Stephens Design Flood Levels Climate Change Review
(WMA Water, 2010)**

Similar to the studies discussed in Section 3.7.2 and Section 3.7.3, the study area considered in this report only somewhat overlaps with the Anna Bay and Tilligerry Creek study area. However, ocean water levels within Port Stephens do impact flooding in the Anna Bay and Tilligerry Creek study area.

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This study (Reference 12) carried out a climate change review for the purpose of understanding the impact a future climate may have on design flood levels in the Port Stephens estuary. The primary outcomes are that a climate change induced ocean level will directly raise the design flood levels and wave runup levels by the amount of assumed ocean level rise. Additionally a climate change induced rainfall increase of 30% would raise flood levels in Port Stephens estuary by less than 0.1m. The current freeboard of 0.5m should be applied to the flood planning level with climate change induced ocean level increase. The induced region wide flood planning level is 3.4 m AHD however if a non-uniform level was assumed regions could have a lower flood planning level as their current freeboard is significantly higher than 0.5m.

3.7.7. Williamtown Salt Ash Floodplain Risk Management Study and Plan (BMT WBM, 2015)

BMT completed the Williamtown Salt Ash Floodplain Risk Management Study and Plan (Reference 13) for Port Stephens Council. This study and plan follow on from the delivery of the Williamtown Salt Ash Flood Study and Flood Study Review (BMT, 2005 and 2012). The primary objectives of this study and plan were to identify and assess measures to manage the existing flood risk, determine planning and development controls to reduce future flood risks and prepare a recommended floodplain management plan.

As part of the study, modelling was updated to include updated LiDAR, a revised flood frequency analysis and additional climate change scenario modelling. The study identified the low-lying coastal areas of Fullerton Cover and Tilligerry Creek were at high risk to climate change. Mitigation measures were recommended to focus on climate change adaptation.

The report highly prioritised mitigation measures such as the Hunter River Levee Scheme review, planning and development controls, and options that modify flood response such as improving community flood awareness, update of Local Flood Plans and improving flood warning system.

Medium prioritised options include flood proofing for individual buildings, voluntary house raising, update of the Regional Floodplain Development Strategy to incorporate a cumulative development assessment, and undertake long-term strategic planning and climate change adaptation planning. Low priority options include the Nelson Road upgrades and Salt Ash flood gate.

3.7.8. Nelson Bay Road, Flooding and Cross Drainage – Upgrade Stage 3 (Lyll & Associates, 2012)

The report (Reference 14) investigates the potential flood impacts of the proposed upgrades to Nelson Bay Road. The proposal is to upgrade Nelson Bay Road between Bobs Farm and Anna Bay to a four lanes. The upgrade was to be completed in three stages, the first two of which had been completed. Stage 3 included constructing 3.9 km of a new 2 lane carriageway at the end of Stage 2 works.

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This report investigates the potential flood impacts and provides recommendations for managing these impacts. Existing flood environment is dominated by overland flows from the local catchment at the southern side of the road, which flow through cross drainage pipes and drain to Tilligerry Creek and Bobs Farm Creek.

Existing and post road upgrade conditions were evaluated for the 10% AEP and 1% AEP flood events. Under existing conditions, the road is overtopped in the 10% AEP flood event. The proposed cross drainage increases the road immunity to the 1% AEP flood event. The proposed cross drainage does not increase flood levels in developed areas however it does induce minor increases in the existing easements and watercourse north of the cross drain. Increases in hydraulic capacity due to waterway dimensions isn't required however existing pipelines on the northern side of the road downstream of the cross drains should be upgraded to carry 1 % AEP flows.

3.7.9. Anna Bay and Tilligerry Creek Flood Study (Jacobs, 2017)

Jacobs completed the Anna Bay and Tilligerry Creek Flood Study in 2017 (Reference 1). The study was jointly funded by Port Stephens Council and Department of Planning, Industry and Environment (formerly known as Office of Environment and Heritage). The Flood Study aims to investigate the existing and future flood behaviour for the localities of Anna Bay, Boat Harbour, One Mile, Fishermans Bay, Bobs Farm, Taylors Beach, Salt Ash, Tanilba Bay, Mallabula and Lemon Tree Passage.

This study provides the technical basis on which this FRMS&P can be developed. The primary objective of this Flood Study was to define the flood behaviour in the study area including local Tilligerry Creek catchment flooding and complex interaction between the Hunter River and Fullerton Cove, and tidal inundation. Flood behaviour was defined for the 20%, 10%, 5% and 1% AEP and the Probable Maximum Flood event. The study provided information on flood levels and depths, velocities, provisional flood hazard and hydraulic categories. It also identified the impacts future flood behaviour for the 5% and 1% AEP events for a range of difference scenarios of increasing sea level and rainfall intensity.

A XP-RAFTS hydrologic model was used to determine the hydrologic inflows for input into the 1D/2D hydraulic TUFLOW model. ARR1987 design methodology has been used for the study. 2013 LiDAR survey obtained from the NSW Land and Property Information was used as inputs into the TUFLOW model to define topography. Three separate TUFLOW models were developed for the study area including, a 20m regional model and two finer-scale urban model at a 2m grid resolution. The finer-scale urban models take precedence over the regional model. Calibration and verification of model results were undertaken against available records and local resident's observations for the April 2015 and January 2016 flood events.

The Flood Study undertook an initial investigation into possible structural mitigation options, these will be explored further as part of this FRMS&P.

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FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.****4. COMMUNITY CONSULTATION**

One of the central objectives of the FRMS&P process is to actively liaise with the community throughout the process, to keep them informed about the current study, identify community concerns and gather information from the community on potential management options for the floodplain. The consultation programme consists of:

- The Floodplain Advisory Panel,
- The Council website, and
- Public meetings.

A community questionnaire was made available on the Council's website from 21st February, 2024. This questionnaire sought suggestions from the community on mitigation options during flooding events. Additionally, a community consultation session was conducted on 28th February, 2024 at Salt Ash Community Hall. Issues raised during the community consultation and in the questionnaire were:

- Drainage issues at Salt Ash due to blocked or discontinuous drains throughout the area.
- Inundation of Lemon Tree Passage Road during flood events.
- Flooding issues in Anna Bay at Gan Gan Rd, Old Main Rd, and Morna Pt Rd.
- Flooding issues at Bobs Farm and along Marsh Rd

4.1. Floodplain Advisory Panel

The Floodplain Advisory Panel oversees and assists with the floodplain risk management process being carried out within the Council LGA. The committee is comprised of representatives from various stakeholder groups and includes:

- Planners,
- Port Stephens Council,
- Department of Climate Change, Energy, Environment, and Water (DCCEEW)
- Hunter Water Corporation,
- SES,
- Elected local residents, and
- Catchment specific representatives.

A number of mitigation options were workshopped with the committee, which formed the basis for the options assessment and draft management study.

4.2. Public Exhibition

Following approval by the Committee, this Floodplain Risk Management Study and draft Plan will be placed on public exhibition. This is the opportunity for the community to examine the report and the study outcomes and make any comments or suggestions.

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5. HYDROLOGICAL AND HYDRAULIC ANALYSIS

5.1. Hydrologic Modelling Update

The hydrologic model for the study area extends from west to east from Medowie to One Mile covering the entire Tilligerry Creek and Tomaree and Tilligerry Peninsulas. The sub-catchments used in the hydrologic model are presented in Figure 1. Flooding in the study area is complex and may be a result of local catchment flooding within the study area (i.e. rainfall runoff from sub-catchments in Figure 3), high ocean tidal levels, and riverine flooding from the Hunter River. The hydrologic model (Figure 3) developed as part of this study does not include riverine flooding from the Hunter River. Hydrologic modelling for the Hunter River had been completed in the previous 2017 Flood Study (Reference 1) through flood frequency analysis.

The hydrologic modelling used as part of this study has been based on the hydrologic modelling in the 2017 Flood Study (Reference 1) with several key updates:

- Hydrologic modelling software updated from XP-RAFTS to WBNM
- Hydrologic modelling parameters updated from ARR 1987 to ARR 2019

The outcomes of this FRMS&P now supersede that from the Anna Bay and Tilligerry Flood Study (Reference 1).

5.1.1. Watershed Bounded Network Model (WBNM)

Firstly, the hydrologic model was converted from XP-RAFTS to Watershed Bounded Network Model (WBNM) software. This was necessary as XP-RAFTS software as a standalone product is being decommissioned and no longer supported by its developer. WBNM is widely used throughout Australia and particularly NSW. WBNM simulates a catchment and its tributaries as a series of sub-catchment areas linked together to replicate the rainfall and runoff process through the natural stream network. Input data includes the definition of physical catchment characteristics including surface area of sub-catchments, proportion of impervious surfaces, stream length adjustments, initial and continuing losses, temporal and spatial patterns over the catchment.

Key parameters for WBNM represent the physical characteristics of each sub-catchment including total area and percentage of pervious areas. Other typical model parameters include;

- Rainfall Losses: two values, initial and continuing loss, modify the amount of rainfall excess to be routed through the model sub-catchments;
- Lag Parameter: this affects the timing of the runoff response to the rainfall and is subject to catchment size, shape and slope; and
- Non Linearity Exponent: adjustment of the non-linearity of catchment response.

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Hydrologic modelling parameters was conducted based on ARR2019 (Reference 15), whereas the 2017 Flood Study (Reference 1) was conducted based on ARR1987.

In 2016, the 4th Edition of Australian Rainfall and Runoff (ARR 2016) was released (Reference 16). A minor update mainly to Book 9 Runoff in Urban Areas was released in 2019. While ARR 1987 (Reference 17) has been considered industry best practice for many years, there have been developments in knowledge of hydrologic and hydraulic mechanisms and computational processing capabilities since its release. This drove the need for the industry guideline to be updated to the ARR 2016 version. The release of the updated version of ARR in 2019 (Reference 15) incorporated new design inputs including: rainfalls, losses, areal reduction factors (ARF), temporal patterns, pre-burst rainfalls and spatial patterns.

The current study updated design inputs (losses, pre-burst ratios, and temporal patterns) for the study area using the ARR 2019 methodology. The design input data were accessed through the ARR Data Hub (Reference 15). The pre-burst ratios from the ARR Data Hub were multiplied by the revised IFD rainfall burst to achieve pre-burst depth. The ARR Data Hub website allows sampling of the inputs by either a region shape file or as coordinates in the latitude and longitude projection.

5.2. TUFLOW Model Review and Update

The hydraulic TUFLOW models cover the entire study area and aim to provide design flooding parameters such water levels and depths across the area. While anecdotal evidence from the study area indicates that sandy soils cause some groundwater interaction in flood events, the effects of groundwater have not been assessed in this FRMS. The effects of high infiltration rates in sandy soils have been incorporated in the model, however in the groundwater surcharge or interflow has not been assessed.

Hydraulic modelling in the Anna Bay and Tilligerry Creek study area is covered by three TUFLOW models, referred to as the Regional model, Tilligerry urban model, and Anna Bay urban model. A review of these three models was conducted to identify improvements to the hydraulic models utilised in Reference 1. The following improvements have been made:

- Update to the TUFLOW version 2020-10-AC-iSP-w64 with HPC solution
- Hydraulic model extent and grid resolution refinement
- Review of hydraulic roughness according to aerial photography
- Update to 1D hydraulic structures
- Update to Boundary Conditions

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The three TUFLOW models have been updated to the TUFLOW version, 2020-10-AC-iSP-w64. This version uses an HPC solution that reduces run times by 90% compared to original classic TUFLOW version.

With the version update, minor differences (up to 0.1m) occurred in the regional west of the study area on the Lower Hunter floodplain. Most of the differences occurred due to the introduction of a different and current industry best practice turbulence model between the two versions. Further iterations were run with a different Manning's depth approach and layered flow constriction calculation, but they did not produce any significant differences in modelled results.

The urban models are mostly unaffected by the change of version with some minor changes of up to +0.03 m and -0.02 m. As the study area was not impacted and differences were minor and within +/- 0.1 m, the differences were considered acceptable.

The model was run in single precision mode and the model was reviewed by ensuring volume errors, timesteps, and control numbers were within acceptable limits.

5.2.2. Hydraulic Model Extent and Resolution

The Regional model has a grid resolution of 20 m and did not include any stormwater or hydraulic features across the urban area. The lack of hydraulic detail resulted in overland flow paths being ill-defined and water being trapped in low points in urban areas. Therefore, the Regional hydraulic model extent was reduced to exclude the urban areas already modelled within the urban TUFLOW models.

The local inflows covering the urban areas were removed from the Regional model and new inflows were added downstream of those urban areas. The removal of those urban areas from the Regional model was preferred to the addition of stormwater and hydraulic details.

The Tilligerry urban model was extended to the very north shore of Tanilba Bay covering an additional 2.5 km², such that the model now extends from the Gir-um-bit State Conservation Area to Henderson Park. The use of the HPC TUFLOW software as well as an improvement of the computational capability allowed the urban model to be updated to a 1 m grid resolution. This improvement in resolution significantly improves the definition of overland flow paths resulting in greater flows between buildings. Figure 4 to Figure 6 show the study area with the model extents and the digital elevation data.

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5.2.3. Hydraulic Roughness and Infiltration

The LEP (Figure 2) was used to define the roughness of the TUFLOW models in Reference 1. However, some of the land defined as urban in the LEP are vegetated or roads. For all three models the roughness layers were reviewed against the aerial photography to certify that the correct hydraulic roughness was applied. The Manning's n values from Reference 1 are still used for this study and shown in Figure 7 to Figure 9. Table 3 show the model roughness values.

Table 3: TUFLOW Model Hydraulic Roughness Values from Reference 1

Land Use/Land Cover	Manning's 'n'	Comment
Default Floodplain	0.035	Typically, rural areas and grassed areas
Dense forest and mangroves	0.150	
Tilligerry Creek channel	0.020	
Urbanised areas	0.060	Higher value accounts for fences, landscaping etc.
Road and paved areas	0.020	Urban area models only

Local experience of flooding in the study area indicates that the sandy soil in the region means that flooding is affected by groundwater and infiltration. Infiltration rates of 118 mm/hr have been applied to Woromi National Park and the entirety of Anna Bay as discussed in Section 5.3.1.

5.2.4. Hydraulic Structures

Open channels and drains are modelled as 1D elements, where surveyed cross sections were used to determine the channel dimensions. The 1D elements model the channel's conveyance whilst the 2D domain account for most of the temporary floodplain storage and conveyance. The connection of the channels to the floodplain was revised such that a continuous set of 2D cells connect the 1D channels to the floodplain. Two approaches were used for removing the 2D cells storage at the channel locations:

- The 2D domain was nulled out at the location of the channels; and
- The 2D domain was left as it is with a storage reduction factor set at 0.99.

The first approach is the preferred approach in modelling. However, in the east and south part of the study area, some roads induce the backwatering of floodwater into a complex system of open channels. This backwatering effect results in instabilities in the 1D channels and the second approach was used at the locations.

Secondary drains and creeks were modelled as 2D break lines. The use of break lines is justified by the lack of surveyed cross section and hydraulic details. Additional break lines were digitised over the Regional model (Bob's farm), Tilligerry Creek urban model (Tanilba Bay model extension), and the Anna Bay urban model (north-western corner of the model towards Nelson Bay Road). The width of the 2D break lines was revised across the model to ensure that a continuous set of cells were lowered.

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The 1m x 1m grid resolution allows for the modelling of stormwater flows in the two urban models. The stormwater network is modelled as 1D elements with pipes modelled as lines which convey the flow between pits which are modelled as points. The following modifications were made:

- Several pipes were added to the model, specifically in the Tilligerry Creek urban model at the Avenue of the Allies and in the eastern part of the Regional model as well as Bob's Farm.
- The number of cells for culverts and stormwater pipe were modified to match the PSC database.
- The inverts of the stormwater pits were determined using the LIDAR elevation minus a constant value. However, where a pipe had an upstream invert lower than downstream the pit inverts were modified to ensure that the upstream side was higher than downstream.
- The location of headwall and pits were modified to match their locations on the aerial photography and the LiDAR.

Buildings act as major blockages in the floodplain and their inclusion is necessary to make sure that the TUFLOW model accurately replicates flow paths. Buildings were modelled by nulling out the 2D domain. No major update was made to the existing building database as there has been minimal development. However, the building database was extended to cover the extension of the Tilligerry Creek urban model. The building footprints were downloaded from the BING online database, following their review against the aerial imagery.

The blockages of the culverts and stormwater networks in the study area from the 2017 Flood Study (Reference 1) have been adopted for this FRMS. These blockages were based on calibrations events undertaken as part of the 2017 Flood Study (Reference 1) and blockage sensitivity analyses were undertaken in the 2017 Flood Study as well (Reference 1).

5.2.5. Boundary Conditions

The Regional model area is directly connected to the ocean via the port of Newcastle and the Tilligerry Creek entrance and the Reference 1 outflow condition was adopted. The Port Stephens downstream boundary condition was not updated using the approach in Reference 18 as the Reference 1 boundary condition was created specific to the area and is more locally representative.

The two urban model downstream boundary conditions were modified to better reflect the behaviour of the Regional model. The north-west boundary condition of the Anna Bay urban model was updated to mirror the results of the Regional model as well as the boundary condition at the open channel located south of the Tilligerry Creek urban model. A stage hydrograph was extracted at those locations from the Regional model and set as the downstream boundary condition for the urban models.

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The TUFLOW inflows over the study area were updated to use the new WBNM hydrologic model. The inflows located west of Williamtown are still using the XP-RAFTS inflows as the original model was not available for conversion. The Hunter River and Williams River inflows were unchanged for the range of design events in Reference 1 (Table 4). For flood events between the current 0.5% AEP event and the PMF event the river inflows were interpolated.

Table 4 : Inflows from Williams River and Hunter River

Design Events (Current day)	Peak Flow m ³ /s	
	Williams River	Hunter River
10% AEP	750	2200
5% AEP	900	3600
2% AEP	1300	5600
1% AEP	2900	7500
0.5% AEP	3500	8800
0.2% AEP	3991	9604
1 in 1000 AEP	4467	10445
PMF	13659	24000

Following the calibration phase the infiltration was updated from 300 mm/hr in the Regional model and 50 mm/hr in the Anna Bay Urban model to 118 mm/hr. The infiltration extends all over the Anna Bay urban model. The Anna Bay Urban model uses the imperviousness in Table 5 to modulate the infiltration value to take in account the influence of the catchment urbanisation on infiltration. The Tilligerry Creek model does not include infiltration.

Table 5: Imperviousness Value to Modulate Infiltration

Soil Type	Imperviousness %
Default floodplain	0
Dense forest mangroves and rocky shoreline	0
River channel	100
Urbanised areas	60
Roads	95

5.3. Historical Flooding

The study area has experienced a number of flood events including major flooding in 1955 and 1990. Other flood events include the April 2015, January 2016 and March 2021 flood events.

The 1955 flood event was the largest known flood event experienced in the study area. The Fullerton Cove Levee was overtopped and Williamtown was inundated by Hunter River floodwaters. Floodwaters continued downstream to Salt Ash before eventually draining to Port Stephens. Anecdotal records indicate flood depths were knee deep at Williamtown and Salt Ash. Limited recorded and anecdotal information is available for the 1990 flood event. However, rainfall totals were the highest of known record with 450mm in 48 hours and 480mm in 3 days at Williamtown.

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The hydraulic model was calibrated using the March 2021 event and validated using the April 2015 and January 2016 events. It should be noted that observed flood levels were used for the March 2021 whilst observed flood behaviour and flood depths were used for the April 2015 and January 2016 events.

5.3.1. Calibration to March 2021

In March 2021, high rainfalls occurred over the eastern coast of New South Wales from Sydney to Clarence River to the North. The rainfall event within the study area began on 18th of March. Initially a set of temporal patterns was used to establish the sensitivity of the flood levels to the rainfall temporal patterns from the available pluviometers. The influence of various local parameters was also investigated in the hydraulic model setup such as, floodgates in the regional model and infiltration over Anna Bay.

Table 6 compares the observed flood levels and the flood levels out of the Regional model for the March 2021 event. Those observed flood levels occurred between the 25th and 26th, although the peak storm event was on the 19th. To account for this the water level was extracted from the hydraulic model on days 8 and 9 of simulation and compared to the observed flood levels.

Table 6: Regional Model Calibration to 2021 Historical event

ID	Location	Observed flood levels (mAHD)	Temporal Patterns used												
			Belmore Bridge		Bulahdelah		Williamown RAAF		Gostwyck		Hexham Bridge		Seaham		
			Floodgate blockage												
			99%	50%	99%	50%	99%	50%	99%	50%	99%	50%	99%	50%	
TGAB_1	Nelson Bay Road	4.1	0.16	0.16	0.11	0.11	0.16	0.17	0.16	0.16	0.17	0.17	0.12	0.12	
TGAB_2		4.1	0.16	0.16	0.11	0.11	0.16	0.17	0.16	0.16	0.17	0.17	0.12	0.12	
TGAB_3		4.1	0.16	0.16	0.11	0.11	0.16	0.17	0.16	0.16	0.17	0.17	0.12	0.12	
TGAB_4		4.0	0.19	0.19	0.09	0.09	0.20	0.20	0.19	0.19	0.22	0.22	0.08	0.08	
TGAB_5		4.1	0.15	0.15	0.10	0.10	0.15	0.16	0.15	0.15	0.16	0.16	0.11	0.11	
TGAB_6		3.9	0.37	0.37	0.32	0.32	0.37	0.38	0.37	0.37	0.38	0.38	0.33	0.33	
TGAB_7		4.1	0.13	0.13	0.08	0.08	0.13	0.14	0.13	0.13	0.14	0.14	0.09	0.09	
TGAB_8		4.2	-0.01	-0.01	-0.13	-0.13	-0.01	0.00	-0.01	-0.01	0.02	0.02	-0.14	-0.14	
TGAB_10		3.9	0.16	0.16	0.08	0.08	0.17	0.17	0.16	0.16	0.18	0.18	0.06	0.06	
TGAB_11		3.9	0.22	0.22	0.12	0.12	0.22	0.22	0.21	0.21	0.24	0.24	0.10	0.10	
TGAB_12		4.0	0.31	0.31	0.26	0.26	0.31	0.32	0.31	0.31	0.32	0.32	0.27	0.27	
TGAB_13		4.1	0.21	0.21	0.16	0.16	0.21	0.22	0.21	0.21	0.22	0.22	0.17	0.17	
TGAB_15		4.0	0.26	0.26	0.21	0.21	0.27	0.27	0.26	0.26	0.27	0.27	0.22	0.22	
TGAB_16		4.1	0.19	0.19	0.14	0.14	0.19	0.20	0.19	0.19	0.20	0.20	0.15	0.15	
TGAB_17		4.2	0.07	0.07	0.03	0.03	0.08	0.08	0.07	0.07	0.08	0.08	0.04	0.04	
TGAB_18		4.1	0.06	0.06	-0.06	-0.06	0.06	0.07	0.06	0.06	0.09	0.09	-0.07	-0.07	
TGAB_19		4.2	0.14	0.14	-0.12	-0.12	0.14	0.14	0.13	0.13	0.15	0.15	0.07	0.07	
TGAB_71		Lemon	1.8	0.08	0.15	-	0.12	0.15	0.19	0.06	0.14	0.09	0.16	0.01	0.13
TGAB_72			1.8	0.08	0.15	-	0.12	0.15	0.19	0.06	0.14	0.09	0.16	0.01	0.13
TGAB_73	1.8		0.12	0.19	-	0.15	0.19	0.23	0.10	0.18	0.13	0.20	0.05	0.16	

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ID	Location	Observed flood levels (mAHD)	Temporal Patterns used											
			Belmore Bridge		Bulahdelah		Williamown RAAF		Gostwyck		Hexham Bridge		Seaham	
			Floodgate blockage											
			99%	50%	99%	50%	99%	50%	99%	50%	99%	50%	99%	50%
TGAB_74		1.8	-	-	-	-	0.19	0.21	-	-	-	-	-	-
TGAB_75		1.5	0.38	0.45	-	0.40	0.46	0.48	0.37	0.43	0.40	0.45	0.31	0.41
TGAB_76		1.8	0.10	0.17	-0.12	0.12	0.18	0.20	0.09	0.15	0.12	0.17	0.03	0.13
TGAB_77		1.8	0.06	0.12	-0.15	0.07	0.13	0.15	0.04	0.10	0.07	0.12	-0.01	0.09
TGAB_78		1.8	-0.01	0.06	-	0.01	0.07	0.10	-0.03	0.05	0.01	0.07	-0.08	0.03
TGAB_79		1.5	0.28	0.35	-	0.30	0.36	0.39	0.26	0.34	0.30	0.36	0.21	0.32
TGAB_80		1.7	0.15	0.22	-0.07	0.17	0.23	0.25	0.14	0.20	0.17	0.22	0.08	0.18
TGAB_81		1.7	0.17	0.23	-0.04	0.19	0.24	0.26	0.15	0.21	0.18	0.23	0.10	0.20
TGAB_82		1.8	0.09	0.16	-	0.13	0.16	0.19	0.07	0.15	0.10	0.16	0.02	0.14
TGAB_83		1.8	0.12	0.19	-	0.15	0.20	0.23	0.11	0.18	0.14	0.20	0.05	0.17
Average error			0.16	0.19	0.13	0.14	0.19	0.20	0.15	0.18	0.17	0.20	0.11	0.15

The sensitivity analysis shows that the various temporal patterns used in the hydrologic model produce very similar flood levels. Nelson Bay Road as well as most of the study area is not impacted by the floodgate assumptions. At Lemon Tree Passage the hydraulic model provided a better match when the floodgates were 99% blocked with most of the area not flooded with a 50% blockage.

Three scenarios were run for investigating the sensitivity of the Anna Bay model to infiltration:

- Scenario A assumes an infiltration limited to the Clark Street low point of 50 mm/hr with the Reference 1 Flood Study losses.
- Scenario B assumes an infiltration extended all over Anna Bay of 300 mm/hr (sand dunes rate) with the Reference 1 Flood Study losses.
- Scenario C assumes a standard value of 118 mm/hr over Anna Bay and the East coast dune area using the current Datahub losses.

Scenario A using the same losses as Reference 1, produced higher flood levels by 0.5 m on average. The flood levels are 0.7 m higher in the Birudi sand reserve, 0.5 m higher in the Essington Way Basin and 0.2 m higher in the Gan Gan Road low point.

Reference 1 modelled infiltration only for the Gan Gan Road low point and not over the rest of the suburb and the current results suggests that some form of infiltration is required elsewhere.

Scenario B used the Reference 1 infiltration values of the “sand dunes” in all of the Anna Bay urban model. Although the hydraulic model results are much closer to the floodmarks, the average difference is 0.1 m, 0.2 m and 0.2 m respectively in the Birudi Sand Reserve, the Essington Way Basin and Gan Gan Road. Some areas of Anna Bay were shown as not flooded in the model results but were inundated on the event photos provided, indicating that this level of infiltration may be too extreme.

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Significant groundwater interaction has been observed in the study area, particularly the Clark Street low point. Anecdotal evidence suggests that during the March 2021 event, delayed ponding of groundwater occurred several days after the event as floodwaters infiltrated and moved through the highly conductive sandy soils. This interaction is likely the cause of the observed ponding in this area that is not represented in the surface flow model results. There are significant challenges to including this mechanism in the current modelling tools, including insufficient data, it is important to acknowledge that ponding may occur at this location due to the groundwater mechanism that is not represented in the current modelling tools.

The Scenario C modelling uses the Reference 1 value for sand infiltration. The average error for the Anna Bay model is 0.2 m with only 3 floodmarks not shown as inundated and an average error in the Birudi Sand Reserve, the Essington Way Basin and Gan Gan Road respectively of 0.3 m, 0.2 m and 0.2 m. While these results do not match the flood marks as well as Scenario B, the extent of inundation (observed by inundation at a higher number of flood marks) is considered to be a better representation of the event.

Although the Gan Gan Road low point flood levels show little sensitivity to the infiltration values, the 118 mm/hr infiltration value is supported by the Reference 1 and is preferable to the 50 mm/hr value due to the better match to the inundation extent.

The 300 mm/hr infiltration value generally provides a better fit to the floodmarks but there are still some parts of the suburbs not inundated whereas the photos suggest they were inundated.

Whilst the Scenario C model overestimates the flood levels by an average of 0.2 m it should be noted that many of the floodmarks for Anna Bay were not taken at the peak.

For the above reasons, the infiltration has been updated across the Anna Bay urban model and Regional model (coastal dune area) using a consistent value of 118 mm/hr (i.e Scenario C). Table 6 compares the observed flood levels and the flood levels from the Anna Bay urban model for the March 2021 event using the Bulahdelah temporal pattern. It should be noted that these values are suitable for the study area wide calibration and should not be used for localised stormwater design assessments. For these assessments loss values should be adopted from Council's Development Control Plan. The Bulahdelah temporal pattern provided the best calibration results and was the closest observed top the study area.

For the design events and the validation events, the floodgates were assumed 99% blocked and the infiltration rate adopted as Scenario C.

5.3.2. Validation to April 2015 and January 2016 Events

The April 2015 and January 2016 events were modelled in WBNM using the two temporal patterns available. The daily rainfall gauges were used to derive a grid of rainfall depth for the events.

Both temporal patterns produce very similar flood levels in the hydraulic model. The model slightly overestimates the observed flood depth by an average of 0.2 m.

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5.3.3. Outcomes from Calibration and Verification

The hydraulic models with the adopted parameters overall produces a reasonably good match with the observed flood level/depth with an average error of 0.1 to 0.2 m across all three storms. For the 2021 event the model replicated the flood level within an average of 0.3 m, the uncertainty of the floodmarks could be the main cause of the discrepancies. This calibration and verification process indicates that while the hydraulic model provide a reasonable match with the observed values, the model also tend to overestimate flood levels. This is considered acceptable as it provides a more conservative approach.

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**ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.****6. EXISTING FLOOD BEHAVIOUR****6.1. Description of Flood Behaviour**

The study area is vulnerable to flooding from three separate sources namely, local creek flooding from Tilligerry Creek, overtopping of Fullerton Cove from the Hunter River, and impacts from tidal inundation. The model boundary has been extended in the northern areas of Tanilba Bay. Diagram 2 presents a graphic representation of the conceptual flood model for the study area. Peak flood levels in each event have been reported for selected locations in Table 7. The locations of these reporting points are shown in Figure 1.

Port Stephens and Tilligerry Creek are impacted by high tidal levels. There are large areas of existing development vulnerable to flooding during coastal inundation from high tides or storm surge. These areas are particularly sensitive to increases in ocean levels due to a changing climate.

Fullerton Cove Levee is overtopped for levels in Fullerton Cove exceeding 1.085 m AHD between Fourteen Foot Drain and Ten Foot Drain. A 10% AEP Hunter River flood event in the current conditions, there are minor overflows at isolated low points along the Fullerton Cove Levee system. However, Nelson Bay Road forms an embankment running north to south and constrains flows from Hunter River to what drains through the cross-drainage. Subsequently, the Hunter River does not largely impact the study area to the east of Nelson Bay Road. The road is overtopped at 2.2 mAHD and is not overtopped in the current 1% AEP.

The dominant flooding mechanism in the Anna Bay and Tilligerry Creek study area is from local catchment flooding and Tilligerry Creek flooding. There are three major drainage channels draining the low-lying rural areas of Anna Bay to Tilligerry Creek at Taylors Beach namely, Main Drain, Back Drain and Fern Tree Drain. The Main Drain is fitted with flood gates 800 m downstream of Port Stephens Drive and prevents inundation from normal high tide levels. Generally, these low lying areas in Anna Bay are inundated from local catchment flooding, however high tailwaters can prevent floodwaters from draining. The floodgate installed in Main Drain is overtopped from elevated ocean levels and higher than normal tide levels.

The Boron Drain exists north of the Main Drain and joins just downstream of Port Stephens Drive. Residential and industrial properties adjacent to Boron Drive are inundated by local catchment flooding and elevated Port Stephens water levels.

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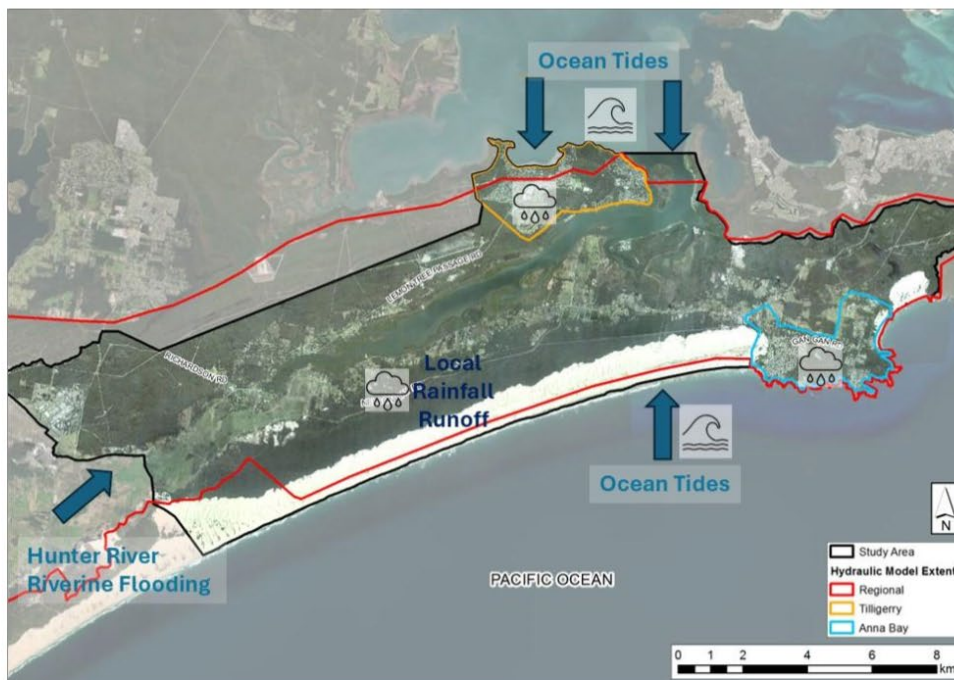


Diagram 2: Conceptual Flood Model

Table 7: Peak Flood Level at Key Reporting Locations in Current Climate Conditions

ID	Location	Peak Flood Level (m AHD)							
		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
1	Tilligerry Creek Near Salt Ash	1.5	1.53	1.82	1.88	1.93	1.93	1.93	3.94
2	Marsh Road near Nelson Bay Road	1.42	1.51	1.81	1.87	1.92	1.92	1.92	3.24
3	Nelson Bay Road at Bobs Farm	1.68	1.7	1.79	1.95	2.02	2.06	2.08	2.17
4	Main Drain Flood Gate	1.11	1.31	1.64	1.72	1.79	1.79	1.79	1.81
5	Tilligerry Creek near Lemon Tree Passage	1.48	1.51	1.7	1.75	1.81	1.81	1.81	1.84
6	Tanilba Bay at President Wilson Walk	7.72	7.79	7.86	8.07	8.13	8.18	8.23	8.34
7	Lemon Tree Passage at Meredith Ave	2.19	2.22	2.24	2.27	2.28	2.29	2.3	2.34
8	Boat Harbour Low Point	2.37	2.69	2.86	3.01	3.18	3.37	3.63	5.61
9	McKinley Swamp	2.66	2.87	3	3.13	3.25	3.41	3.61	4.33
10	Clark St Low Point	5.18	5.54	5.66	5.71	5.8	5.88	5.98	6.68
11	Main Drain at One Mile	0.92	1.07	1.15	1.31	1.39	1.46	1.24	1.24
12	Fern Tree Drain at Anna Bay	1.09	1.26	1.3	1.36	1.4	1.46	1.55	1.67

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The Anna Bay and Fishermans Bay urban areas have several trapped low points including McKinley Swamp, Gan Gan Road and Morna Point Road intersection and Anna Bay Public School. There is a low point at Clark Street, which is drained by a submersible pump, pumping stormwater west along Gan Gan Road to join the stormwater system. The pump system has a low capacity and is at capacity in frequent flood events.

Properties are impacted as frequent as the current 20% AEP flood event at the low points along Gan Gan Road and Morna Point Road intersection and Clark Street.

6.1.2. Boat Harbour

The Boat Harbour urban area is predominantly impacted by local overland flooding. The main overland flow paths are adjacent to Blanch Street and Boat Harbour Road draining to Boat Harbour Beach. In the north main flow paths are along the roads of Blanch Street and Hawkes Way draining towards the trapped low point near Gan Gan Road. In the current 1% AEP flood event, properties are inundated by up to 0.5 m.

The trapped low point near Gan Gan Road and Blanch Street is vegetated. In rarer events, this trapped low point extends to the low point along Gan Gan Road.

6.1.3. One Mile

One Mile is largely impacted by tidal flooding. The stormwater network in the area drains to the Main Drain and due to the flood gates being overtopped in larger ocean events, the area is vulnerable to tidal waters backing up Main Drain. This can also prevent local catchment runoff from draining.

Dwellings in the area are generally flood free, with yards only impacted in the PMF flood event. Some yards are impacted in events as frequent as the current 20% AEP. The One Mile Beach Holiday Park is inundated in some areas by local catchment flooding. There are large areas of swampy undeveloped land that are inundated.

6.1.4. Bobs Farm

Bobs Farm is impacted by tidal inundation, local catchment flooding, and flooding from the Hunter River depending on location and size of the event. North of Nelson Bay Road (along Marsh Road), the area is predominantly impacted by tidal inundation from Tilligerry Creek. Elevated levels overtop Marsh Road and while there are floodgates installed on culverts in this area, this prevents local catchment runoff from draining. Large areas of high hazard flooding can be seen in the vicinity of Marsh Road. Properties along Marsh Road can be impacted in flood events as frequent as the current 20% AEP flood event with some properties flooded by up to 1 m – 2 m in the current 1% AEP flood event. Hunter River flooding is the dominant flood mechanism in the PMF event.

South of Nelsons Bay Road, local catchment flooding is the dominant flood mechanism. Similar to the above, elevated tidal levels can prevent local catchment runoff from discharging.

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Salt Ash can be impacted from all three flood mechanisms. Marsh Road and properties to the south of Marsh Road are predominantly impacted from elevated tidal levels. There are areas of high hazard flooding along Marsh Road. South of Nelson Bay Road, the area is largely dominated by local catchment flooding. However, Nelson Bay Road is overtopped in the current 1% AEP event and then the area is also influenced by elevated tidal levels.

Areas adjacent to Tilligerry Creek and south of Nelson Bay Road are mainly impacted by the Hunter River in the PMF event. South of Lemon Tree Passage Road and west of Brownes Road elevated tidal levels dominates and some properties in this area are impacted. North of Lemon Tree Passage Road, flooding is due to local catchment runoff. Flooding starts near the swampy areas north of the rural properties and flows south-east towards Lemon Tree Passage Road. The stormwater network that drains the area is at a low capacity and floodgates installed are not operating correctly due to vegetation blockages. Properties north of Lemon Tree Passage Road are inundated in the current 20% AEP flood event.

6.1.6. Tanilba Bay and Mallabula

Tanilba Bay and Mallabula are inundated by local catchment runoff. The runoffs drains and ponds in trapped low points along road sags, swales or to detention basins. Properties adjacent to Lloyd George Grove at President Wilson Walk can be inundated from local catchment runoff. Floodwaters drain via a stormwater network, open channels and through culverts underneath Lemon Tree Passage Road. The network discharges to an open channel in Tanilba Bay Golf Club and eventually discharges to Tilligerry Creek. East of President Wilson Walk, the area drains via the detention basins, east to the open channels and then to the culverts south of Lemon Tree Passage.

6.1.7. Lemon Tree Passage

Lemon Tree Passage is primarily impacted by local catchment runoff and overland flooding. Some roads and properties along the foreshore of Tilligerry Creek are low lying and inundated by elevated tidal levels. Properties along Paroa Avenue are most impacted, as floodwaters drain to and pond here. Properties along Meredith Avenue, Mackie Street and Cook Parade are inundated by high tide levels. High hazards in the area are largely contained to the foreshore area, drainage channels and swales.

6.2. Hydraulic and Hazard Classification**6.2.1. Hazard Classification**

Hazard classification plays an important role in informing floodplain risk management in an area as it reflects the likely impact of flooding on development and people, providing a measure of potential risk to life and property damage, from a flood event.

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The NSW Floodplain Development manual, *Managing the floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR, 2017) and the *NSW Flood Risk Management Manual* (NSW Government, 2023) provide procedures for determining the hazard based on the flood velocity and depth. The Floodplain Development Manual (NSW Government, 2005) hazard classifications are essentially binary – either Low or High Hazard as described in Figure L2 of that document. This method has been selected in the 2017 Anna Bay and Tilligerry Flood Study (Reference 1) for presenting hazard classification.

AIDR (2017) and the NSW Flood Risk Management Manual (Reference 3) provide revised hazard classifications that add clarity to the hazard categories and what they mean in practice. The classification is divided into six categories which indicate the restrictions on people, buildings and vehicles (Reference 19)

Hydraulic hazard categories have been determined for the study area in accordance with the NSW Flood Risk Management Manual and its accompanying guideline FB03 – Flood Hazard. FB03 provides a best practice approach for understanding of the potential vulnerabilities as a result of hydraulic hazard of flood water. A summary of this categorisation is provided in Diagram 3.

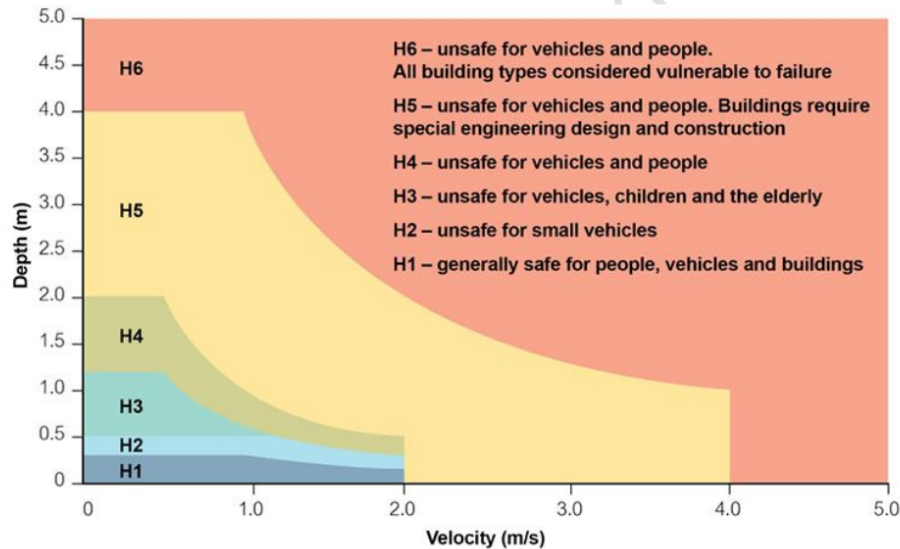


Diagram 3: General flood hazard vulnerability curves (Source: Reference 3)

In the current 1% AEP event, most areas within the flood extent at Bobs Farm are classified as H4 and above. Marsh Road is classified as H4 and most properties along this road are classified as H5. Near the intersection with Marsh Road at Salt Ash, Nelson Bay Road is classified as H3. Properties north of Lemon Tree Passage Road are mostly classified as H1 or H2. As Lemon Tree Passage Road approaches Nelson Bay Road, it becomes classified as H3.

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At Anna Bay and Boat Harbour, most residential properties are classified as H1 or H2. Low points with deep inundation such as McKinley Swamp and the corner of Gan Gan Road and Blanch Street are classified as H3 or H4. Gan Gan Road near Anna Bay Public School is classified as H3. Fern Tree Drain is classified as H5 and its surrounds are typically H3 and above. Most of One Mile is classified as H3 and above. As the buildings at One Mile are typically raised, the immediate surrounds of the properties are typically H1 and the local roads are H2.

Most residential properties at Tanilba Bay and Mallabula are classified as H1. The basins, storage areas and drains along Lemon Tree Passage Road are classified as H3. The intersection of President Willson Walk and Lemon Tree Passage Road is classified as H3 as there is a low point in the road.

At Lemon Tree Passage, Meredith Avenue and Cooks Parade is classified as H3. Most properties along the foreshore area are classified as H3.

The *Floodplain Development Manual* (NSW Government, 2005) requires that other factors be considered in determining the 'true' hazard including: size of flood, effective warning time, flood readiness, rate of rise of floodwaters, depth and velocity of floodwaters, duration of flooding, evacuation problems, effective flood access, type of development within the floodplain, complexity of the stream network and the inter-relationship between flows. However, to assess the full flood hazard, all adverse effects of flooding have to be considered. As well as considering the provisional (hydraulic) hazard, threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production should be incorporated into the assessment.

The conversion from 'provisional' hazard to 'true' hazard requires subjective decisions on how these aspects interact with the population at risk. To overcome this problem, practice has evolved to map provisional hazard and to separately identify evacuation risk over the full range of flood events. Evacuation response requirements have been assessed and are discussed in Section 9.1. For this reason, a true hazard conversion has not been carried out.

6.2.2. Hydraulic Categorisation

For the purposes of floodplain risk management in NSW floodplains are divided into one of three Hydraulic categories (floodway, flood storage and flood fringe).

Hydraulic categories describe the flood behaviour by categorising areas depending on their function during the flood event, specifically, whether they transmit large quantities of water (floodway), store a significant volume of water (flood storage) or do not play a significant role in either storing or conveying water (flood fringe). As with categories of hazard, hydraulic categories play an important role in informing floodplain risk management in an area. Although the three categories of hydraulic function are described in the Flood Risk Management Manual (Reference 3), their definitions are largely qualitative, and the manual does not prescribe a method to determine each area.

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The Manual (Reference 3) describes three techniques to identify flood function, which are indicator, encroachment, and conveyance techniques. Indicator techniques rely on physical and hydraulic properties to determine flood function and the most common indicator technique is Howells et. al. (2003) which uses velocity, depth, and depth velocity product as indicators. While indicator techniques are able to provide a basis for understanding flood function in the area, it may also miss floodways that are below the selected threshold. Manual assessments and refinement of the floodway is required to ensure floodways are continuous. Conveyance techniques are robust for identifying floodways, however they cannot be used for determining flood storage. This technique involves delineating centreline of watercourses and determining the area required to convey a certain percentage of the peak flow. Lastly, encroachment technique involves a trial and error approach and incremental narrowing or widening of the floodways and flood storage until acceptable impacts are achieved.

Neither conveyance techniques nor encroachment techniques were suitable for categorising the floodplain due to its flood behaviour. While conveyance techniques are objective and robust for determining floodways, its implementation is difficult when flow paths are complex (such as multiple watercourses discharging to one main water course and meandering flow paths). Encroachment techniques are not suitable as the process is highly iterative and the flood behaviour is such that modifications in floodway and flood storage boundaries may produce unacceptable impacts in other locations. This causes a highly subjective and irreproducible representation of flood function.

The provisional hydraulic categories completed as part of this FRMS were determined using the following procedure:

1. Preliminary hydraulic categories defined using the Howells et. al. (2003) indicator technique. The key indicators and their thresholds are presented in Table 8 for the regional model and in Table 9 for the urban models.
2. Refine floodway by
 - a. Converting small, isolated floodways (less than 3200 m² i.e. 8 model grid cells in regional model and less than 100 m² in urban models) to flood storage.
 - b. Converting isolated floodways, which were disconnected any major watercourse to flood storage.
3. Digitise existing channels or minor watercourses by assuming 20 m width and categorise these as floodways.
4. Manually digitise connections for discontinuous floodways.

Table 8: Hydraulic Categorisation Indicator Technique Thresholds for Regional Model

Category	Threshold
Floodway	(Depth Velocity Product (i.e. $d \times V$) $> 0.5 \text{ m}^2/\text{s}$ AND Velocity $> 0.2 \text{ m/s}$) OR (Velocity $> 0.6 \text{ m/s}$ AND Depth $> 0.3 \text{ m}$)
Flood Storage	Remaining flood extent with Depth $> 0.5 \text{ m}$
Flood Fringe	Remaining flood extent with Depth $< 0.5 \text{ m}$

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Table 9: Hydraulic Categorisation Indicator Technique Thresholds for Urban Models

Category	Threshold
Floodway	(Depth Velocity Product (i.e. $d \times V$) $> 0.3 \text{ m}^2/\text{s}$ AND Velocity $> 0.2 \text{ m/s}$) OR (Velocity $> 1 \text{ m/s}$ AND Depth $> 0.2 \text{ m}$)
Flood Storage	Remaining flood extent with Depth $> 0.3 \text{ m}$
Flood Fringe	Remaining flood extent with Depth $< 0.3 \text{ m}$

The provisional hydraulic categorisation for the study area for the Year 2100 5% AEP, Year 2100 1% AEP, and Year 2100 1 in 500 AEP using the procedure above has been presented in Figure 55 to Figure 60. The process of identifying flood function is generally requires judgement by experienced practitioners and involves consideration of the scale and intent of the study, the morphology and flood behaviour as well as its impacts on community and consequences. There is no one prescribed method which can be used to determine the hydraulic categorisation across all areas and types of flood behaviour.

The produced hydraulic categorisation is considered fit for purpose and has been checked by two methods. Firstly, the high hydraulic hazard areas of frequent events (Year 2100 20% AEP) have been checked against the floodway. This is to ensure that all participating watercourses have been considered in the flood function. Secondly, a preliminary run of the conveyance technique based on the 90% conveyance has been compared against the floodway. This is to ensure that the floodway for the main watercourse had sufficient width to convey most of the flow.

In the Year 2100 1% AEP event, Tilligerry Creek and parts of Marsh Road at Bobs Farm is a floodway. The remaining areas of Bobs Farm is flood storage. At Salt Ash, the intersection of Tilligerry Creek and Nelson Bay Road is a floodway. Properties north of Lemon Tree Passage Road are mostly flood fringe. However, towards the east some of these properties are within the flood storage. Main Drain and most areas between Lemon Tree Passage Road and Tilligerry Creek is flood storage.

In the Year 2100 1% AEP event, at Anna Bay and Boat Harbour, most residential properties are in the flood fringe. Low points with deep inundation such as McKinley Swamp and the corner of Gan Gan Road and Blanch Street are considered to be flood storage. Fern Tree Drain a floodway and its surrounds forms the flood storage. In the PMF event, Gan Gan Road becomes a floodway.

Most of One Mile is flood storage. As the buildings at One Mile are typically raised, the immediate surrounds of the properties and the local roads are typically flood fringe. The drains at One Mile are floodways.

Most residential properties at Tanilba Bay and Mallabula in the flood fringe. The basins and storage areas along Lemon Tree Passage Road form the flood storage. Drains along Lemon Tree Passage Road and through the Tanilba Bay Golf Course are floodways. At Lemon Tree Passage, Meredith Avenue and Cooks Parade are floodways. Most properties along the foreshore area are in flood storage. Properties in the more elevated parts of Lemon Tree Passage are mostly flood fringe.

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Port Stephens Council (Council) is responsible for local planning and land management in the Port Stephens LGA, including the management of the floodplain and drainage systems. The planning policies held and used by Council in their management of the floodplain are underpinned and bound by national and State planning legislation. It is important to understand the national and state context prior to making recommendations for Council to amend its own local planning policies to ensure that any changes are consistent with the requirements of State and national legislation.

An overview of the national and State planning instruments that influence planning in relation to flood risk at the local government level is provided below to provide this background.

7.1. Federal Planning Provisions**7.1.1. Building Code of Australia**

The Building Code of Australia (BCA) is a national code that outlines building regulations for the design and construction of buildings and other structures throughout Australia. The aim of these regulations is to ensure the protection of people and the environment. The BCA is part of the wider National Construction Code (NCC) that comprises the BCA and the Plumbing Code of Australia (PCA). The NCC was developed by the Australian Building Codes Board (ABCB) which is made up of representatives from the local, state and federal level.

The National Construction Code (NCC) is called up by the Building Act 1975 and with it, gives effect to the Building Code of Australia (BCA). The Building Act is given legal effect in New South Wales under the EP&A Act. Any provision of the BCA may be overridden by, or subject to, State or Territory legislation. The BCA must, therefore, be read in conjunction with that legislation.

The BCA contains requirements to ensure new buildings and structures and, subject to State and Territory legislation, alterations and additions to existing buildings located in flood hazard areas do not collapse during a flood when subjected to flood actions resulting from the defined flood event.

The BCA provides additional requirements for buildings in flood hazard areas consistent with the objectives of the BCA which primarily aim to protect the lives of occupants of those buildings in events up to and including the defined flood event.

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Surface water must be diverted away from Class 1 buildings as follows:

- (a) Slab-on-ground — finished ground level adjacent to buildings:
the external finished surface surrounding the slab must be drained to move surface water away from the building and graded to give a slope of not less than (see Figure 3.1.2.2):
- (i) 25 mm over the first 1 m from the building in low rainfall intensity areas for surfaces that are reasonably impermeable (such as concrete or clay paving); or
 - (ii) 50 mm over the first 1 m from the building in any other case.
- (b) Slab-on-ground — finished slab heights:
the height of the slab-on-ground above external finished surfaces must be not less than (see Figure 3.1.2.2):
- (i) 100 mm above the finished ground level in low rainfall intensity areas or sandy, well-drained areas; or
 - (ii) 50 mm above impermeable (paved or concreted areas) that slope away from the building in accordance with (a); or
 - (iii) 150 mm in any other case.

7.2. State Planning Provisions**7.2.1. NSW Environmental Planning and Assessment Act 1979**

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) provides the framework for regulating and protecting the environment and controlling the impact of development. Pursuant to Section 9.1(2) of the EP&A Act, the Minister has directed that councils have the responsibility to facilitate the implementation of the NSW Government's Flood Prone Land Policy. The policies and guidelines described in this Section fall under the EP&A Act. The objects of the Act are set out below.

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The objects of this Act are as follows:

- (a) to promote the social and economic welfare of the community and a better environment by the proper management, development and conservation of the State's natural and other resources,*
- (b) to facilitate ecologically sustainable development by integrating relevant economic, environmental and social considerations in decision-making about environmental planning and assessment,*
- (c) to promote the orderly and economic use and development of land,*
- (d) to promote the delivery and maintenance of affordable housing,*
- (e) to protect the environment, including the conservation of threatened and other species of native animals and plants, ecological communities and their habitats,*
- (f) to promote the sustainable management of built and cultural heritage (including Aboriginal cultural heritage),*
- (g) to promote good design and amenity of the built environment,*
- (h) to promote the proper construction and maintenance of buildings, including the protection of the health and safety of their occupants,*
- (i) to promote the sharing of the responsibility for environmental planning and assessment between the different levels of government in the State,*
- (j) to provide increased opportunity for community participation in environmental planning and assessment.*

7.2.2. NSW Flood Prone Land Policy

The primary objectives of the NSW Government's Flood Prone Land Policy are:

- to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone land, and*
- to reduce public and private losses resulting from floods whilst utilising ecologically positive methods wherever possible.*

The Flood Risk Management Manual 2023 (Reference 3) is consistent with and supports the delivery of the NSW Flood Prone Land Policy. The Flood Risk Management Manual (Reference 3) supersedes the previous NSW Floodplain Development Manual 2005 (Reference 2). This FRMS was in progress prior to the release of the Flood Risk Management Manual 2023 (Reference 3). Due to this timing, this FRMS is consistent with the previous NSW Floodplain Development Manual 2005 (Reference 2) and has been updated to be consistent with the Flood Risk Management Manual 2023 (Reference 3) where possible.

The Flood Risk Management Manual 2023 (Reference 3) relates to the development of flood prone land for the purposes of Section 733 of the Local Government Act 1993. Section 733 of the Local Government Act 1993 provides councils with statutory indemnity for decisions made and information provided in good faith from the outcomes of the management process (undertaken in accordance with the Manual).

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The Manual outlines a merits approach based on floodplain management and recognises differences between urban and rural floodplain issues. At the strategic level, this allows for the consideration of social, economic, cultural, ecological and flooding issues to determine strategies for the management of flood risk. This approach recognises that there can be benefit to development on flood liable land and seeks to ensure development is consistent with its exposure to flooding but also avoid the unnecessary sterilisation of flood prone land.

7.2.3. Flood Prone Land Package

On the 14th July 2021, the then Department of Planning and Environment (DPE) implemented updates to the Flood Prone Land Package. The purpose of the package is to increase flood resilience in New South Wales, reduce loss of life and property damage. The package provides councils additional land use planning tools to manage flood risk beyond the 1% AEP flood event and strengthen evacuation consideration in land use planning.

The changes include:

- A revised Ministerial Direction 4.1 regarding flooding issued under Section 9.1 of the Environmental Planning and Assessment Act 1979,
- a revised planning circular on flooding
- a new guideline: Considering Flooding in Land Use Planning
- Revised Local Environmental Plan flood clauses,
- Amendments to Schedule 2, Clause 9 of the Environmental Planning and Assessment Regulation 2021,
- State Environmental Planning Policy Amendment (Flood Planning) 2021.

The key changes and implications are outlined below:

- Amendments to Schedule 4 of EP&A Regulation (2000) including changes to Clause 7A(1), Clause 7A(2) (now Schedule 2, Clause 9 of the EP&A Regulation (2021)). These amendments now require councils to note on Section 10.7 certificates if any flood related development controls apply to the land relating to either the Flood Planning Area, hazardous materials / industry, sensitive, vulnerable or critical uses.
- The Ministerial Direction 4.3 (now Direction 4.1) has been amended to remove the requirement for councils to seek exceptional circumstances to apply residential development controls to land outside the 1% AEP flood event (previously included in Clause 7 of Direction 4.3).
- Two proposed LEP clauses relating to the Flood Planning Area, and Special Flood Consideration.
 - The Flood Planning Area clause allows council to extend the FPA to include more extreme flood events where the flood risk requires land use planning tools.
 - The clause relating to Special Flood Consideration provides councils the mechanism to apply development controls to land outside the FPA but within the PMF. This clause is specific to land with a significant risk to life, sensitive, vulnerable or critical uses, or land with hazardous materials or industry.

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7.2.4. Ministerial Direction 4.1

Direction 4.1 was issued on 1st March 2022 to replace the previous Direction 4.3. Directions are issued by the Minister for Planning to relevant planning authorities under Section 9.1(2) of the *Environmental Planning and Assessment Act 1979*.

Direction 4 pertains to "Resilience and Hazards", with Direction 4.1 relating specifically to Flood Prone Land, the clause is shown below.

Objectives

The objectives of this direction are to:

- (a) ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005,
- (b) ensure that the provisions of an LEP that apply to flood prone land are commensurate with flood behaviour and includes consideration of the potential flood impacts on and off the subject land.

Application

This direction applies to all relevant planning authorities that are responsible for flood prone land when preparing a planning proposal that creates, removes or alters a zone or a provision that affects flood prone land.

Clauses (1)-(5) of Direction 4.1 state:

(1) A planning proposal must include provisions that give effect to and are consistent with:

- (a) The NSW Flood Prone Land Policy, and
- (b) The principles of the Floodplain Development Manual 2005,
- (c) The Considering flooding land use planning guideline 2021, and
- (d) any adopted flood study and/or floodplain risk management plan prepared in accordance with the principles of the Floodplain Development Manual 2005 and adopted by the relevant council.

(2) A planning proposal must not rezone land within the Flood Planning Area from Recreation, Rural, Special purpose or Conservation Zones to a Residential, Employment, Mixed Use, W4 Working Waterfront, or Special Purpose Zones.

(3) A planning proposal must not contain provisions that apply to the Flood Planning Area which:

- (a) permit development in a floodway,
- (b) permit development that will result in significant flood impacts to other properties,
- (c) permit development for the purposes of residential accommodation in high hazard areas,
- (d) permit a significant increase in the development and/or dwelling density of that land,
- (e) permit development for the purpose of centre-based child care facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate,
- (f) permit development to be carried out without development consent except for the purposes of exempt development or agriculture. Dams, drainage canals, levees, still require development consent,
- (g) are likely to result in a significantly increased requirement for government spending on emergency management services, flood mitigation and emergency response measures, which can include but not limited to the provision of road infrastructure, flood mitigation infrastructure and utilities or
- (h) permit hazardous industries or hazardous storage establishments where hazardous materials cannot be effectively contained during the occurrence of a flood event.

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(4) A planning proposal must not contain provisions that apply to areas between the Flood Planning Area and probable maximum flood to which Special Flood Considerations apply which:

- (a) permit development in floodway areas,
- (b) permit development that will result in significant flood impacts to other properties,
- (c) permit a significant increase in the dwelling density of that land,
- (d) permit the development of centre-based childcare facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate,
- (e) are likely to affect the safe occupation of and efficient evacuation of the lot, or
- (f) are likely to result in a significantly increased requirement for government spending on emergency management services, and flood mitigation and emergency response measures, which can include but not limited to road infrastructure, flood mitigation infrastructure and utilities.

(5) For the purposes of preparing a planning proposal, the flood planning area must be consistent with the principles of the Floodplain Development Manual 2005 or as otherwise determined by a Floodplain Risk Management Study or Plan adopted by the relevant council.

A planning proposal may be inconsistent with this direction only if the planning proposal authority can satisfy the Planning Secretary (or their nominee) that:

- (a) the planning proposal is in accordance with a floodplain risk management study or plan adopted by the relevant council in accordance with the principles and guidelines of the Floodplain Development Manual 2005, or
- (b) where there is no council adopted floodplain risk management study or plan, the planning proposal is consistent with the flood study adopted by the council prepared in accordance with the principles of the Floodplain Development Manual 2005 or
- (c) the planning proposal is supported by a flood and risk impact assessment accepted by the relevant planning authority and is prepared in accordance with the principles of the Floodplain Development Manual 2005 and consistent with the relevant planning authorities' requirements, or
- (d) the provisions of the planning proposal that are inconsistent are of minor significance as determined by the relevant planning authority.

Note: In this direction:

- (a) "flood prone land" "flood storage" "floodway" and "high hazard" have the same meaning as in the Floodplain Development Manual 2005.
- (b) "flood planning level" "flood behaviour" and "flood planning area" has the same meaning as in the Considering flooding in land use planning guideline 2021.
- (c) Special flood considerations are outlined in the Considering flooding in land use planning guideline 2021 and an optional clause in the Standard Instrument (Local Environmental Plans) Order 2006.
- (d) Under the floodplain risk management process outlined in the NSW Government's Floodplain Development Manual 2005, councils may produce a flood study followed by a floodplain risk management study and floodplain risk management plan.

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A planning circular '*Considering flooding in land use planning: guidance and statutory requirements*' PS 21-006 was released with the recent changes to the Flood Prone Land Package on 14th July 2021. The revised circular provides advice on a package of changes regarding how land use planning considers flooding and flood-related constraints, including Section 10.7 Planning Certificates, local planning direction 4.1, LEP clauses and associated guidelines.

In Planning Circular PS21-006 it is noted that: "*Section 733 of the Local Government Act 1993 (the LG Act) protects councils from liability if they have followed the principles of the Manual*".

7.2.6. Considering flooding in land use planning guideline

The guideline aims to provide councils with mechanisms to manage flood risk for the full range of flooding up to the Probable Maximum Flood (PMF) and give further consideration to evacuation constraints. Within the proposed Flood Prone Land package, there are two main categories council can use to address flooding impacts namely, flood planning areas or special considerations.

The Flood Prone Land Package aims to provide councils the ability to apply development controls to areas where the flood risk requires it. The FDM identifies either the 1% AEP flood event or an equivalent historic event as an appropriate starting point when selecting the Defined Flood Event (DFE). However, it recommends considering selecting a more extreme flood event where there are significant economic, social, environmental or cultural risks associated with a larger event.

The Special Flood Considerations category provides council the ability to apply controls to land outside FPA but within the PMF flood event where there is a significant risk to life or risk of hazardous material impacting the community or environment.

7.2.7. Section 10.7 Planning Certificates

Formerly known as Section 149 Planning Certificates, Section 10.7 Planning Certificates describe how a property may be used and the development controls applicable to that property. The Planning Certificate is issued under Section 10.7 of the Environmental Planning and Assessment Act 1979.

When land is bought or sold, the Conveyancing Act 1919 and Conveyancing (Sale of Land) Regulation 2022 requires that a Section 10.7 Planning Certificate be attached to the contract of sale for the land.

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Section 10.7 of the EP&A Act states:

- (1) A person may, on payment of the prescribed fee, apply to a council for a certificate under this section (a planning certificate) with respect to any land within the area of the council.
- (2) On application made to it under subsection (1), the council shall, as soon as practicable, issue a planning certificate specifying such matters relating to the land to which the certificate relates as may be prescribed (whether arising under or connected with this or any other Act or otherwise).
- (3) (Repealed)
- (4) The regulations may provide that information to be furnished in a planning certificate shall be set out in the prescribed form and manner.
- (5) A council may, in a planning certificate, include advice on such other relevant matters affecting the land of which it may be aware.
- (6) A council shall not incur any liability in respect of any advice provided in good faith pursuant to subsection (5). However, this subsection does not apply to advice provided in relation to contaminated land (including the likelihood of land being contaminated land) or to the nature or extent of contamination of land within the meaning of Schedule 6.
- (7) For the purpose of any proceedings for an offence against this Act or the regulations which may be taken against a person who has obtained a planning certificate or who might reasonably be expected to rely on that certificate, that certificate shall, in favour of that person, be conclusively presumed to be true and correct.

The Environmental Planning and Assessment Regulation 2021, Schedule 2 specifies the information to be disclosed on a Section 10.7 (2) Planning Certificate. In particular, Schedule 2, Clause 9 refers to flood related development control information and requires councils to provide the following information:

- (1) If the land or part of the land is within the flood planning area and subject to flood related development controls.
- (2) If the land or part of the land is between the flood planning area and the probable maximum flood and subject to flood related development controls.
- (3) In this clause—

flood planning area has the same meaning as in the Flood Risk Management Manual.

Flood Risk Management Manual means the *Flood Risk Management Manual*, ISBN 978-1-923076-17-4, published by the NSW Government in June 2023.

probable maximum flood has the same meaning as in the Flood Risk Management Manual.

Section 10.7 (2) and (5) certificates contain the information prescribed in Schedule 2 described above and additional information relating to the property. In a flooding context, additional information may include notations on flood hazard, percentage of the lot affected by flooding, or peak flood depths and levels on the property, or “*advice on other such relevant matters affecting the land of which it may be aware*” (EP&A Act, 10.7 (5)).

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7.2.8. State Environmental Planning Policy (Exempt and Complying Development Codes) 2008

The aims of the State Environmental Planning Policy (Exempt and Complying Development Codes) (SEPP) 2008 are presented below.

This Policy aims to provide streamlined assessment processes for development that complies with specified development standards by:

- (a) providing exempt and complying development codes that have State-wide application, and*
- (b) identifying, in the exempt development codes, types of development that are of minimal environmental impact that may be carried out without the need for development consent, and*
- (c) identifying, in the complying development codes, types of complying development that may be carried out in accordance with a complying development certificate as defined in the Act, and*
- (d) enabling the progressive extension of the types of development in this Policy, and*
- (e) providing transitional arrangements for the introduction of the State-wide codes, including the amendment of other environmental planning instruments.*

Part 3 of the SEPP contains standards relating to development in flood control lots. This is described below.

7.2.9. State Environmental Planning Policy (Exempt and Complying Development Codes) Amendment (Housing Code) 2017

Part 3 of the SEPP relates to the "Housing Code". This section replaces the former "General Housing Code", which was repealed in June 2017. Part 3 is divided into 5 "Divisions", with Division 2 containing General standards relating to land type. Part 3.5 specifically relates to Complying Development on flood control lots and is reproduced below.

3.5 Complying development on flood control lots

- 1) *Development under this code must not be carried out on any part of a flood control lot, other than a part of the lot that the council or a professional engineer who specialises in hydraulic engineering has certified, for the purposes of the issue of the relevant complying development certificate, as not being any of the following:*
 - a) a flood storage area,*
 - b) a floodway area,*
 - c) a flow path,*
 - d) a high hazard area,*
 - e) a high risk area.*
- 2) *If complying development under this code is carried out on any part of a flood control lot, the following development standards also apply in addition to any other development standards:*
 - a) if there is a minimum floor level adopted in a development control plan by the relevant council for the lot, the development must not cause any habitable room in the dwelling house to have a floor level lower than that floor level,*

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- b) *any part of the dwelling house or any attached development or detached development that is erected at or below the flood planning level is constructed of flood compatible material,*
 - c) *any part of the dwelling house and any attached development or detached development that is erected is able to withstand the forces exerted during a flood by water, debris and buoyancy up to the flood planning level (or if an on-site refuge is provided on the lot, the probable maximum flood level),*
 - d) *the development must not result in increased flooding elsewhere in the floodplain,*
 - e) *the lot must have pedestrian and vehicular access to a readily accessible refuge at a level equal to or higher than the lowest habitable floor level of the dwelling house,*
 - f) *vehicular access to the dwelling house will not be inundated by water to a level of more than 0.3m during a 1:100 ARI (average recurrent interval) flood event,*
 - g) *the lot must not have any open car parking spaces or carports lower than the level of a 1:20 ARI (average recurrent interval) flood event.*
- 3) *The requirements under subclause (2) (c) and (d) are satisfied if a joint report by a professional engineer specialising in hydraulic engineering and a professional engineer specialising in civil engineering states that the requirements are satisfied.*
 - 4) *A word or expression used in this clause has the same meaning as it has in the Flood Risk Management Manual, unless it is otherwise defined in this Policy.*
 - 5) *(Repealed)*

7.3. Local Planning Provisions

Updated and relevant planning controls are important in flood risk management. Appropriate planning restrictions, ensuring that development is compatible with flood risk, can significantly reduce flood damages. Planning instruments can be used as tools to guide new development away from high flood risk locations and ensure that new development does not increase flood risk elsewhere. They can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population. Councils use Local Environmental Plans (LEPs) and Development Control Plans (DCPs) to govern control on development with regards to flooding.

Environmental Planning Instruments such as LEPs guide land use and development by zoning all land, identifying appropriate land uses that are allowed in each zone, and controlling development through other planning standards and DCPs. LEPs are made under the EP&A Act 1979 which contains mandatory provisions on what they must contain and the steps a Council must go through to prepare them. In 2006 the NSW Government initiated the Standard Instrument LEP program and produced a new standard format which all LEPs should conform to. LEPs are used as tools to guide new development away from high flood risk locations and ensure that new development does not adversely affect flood behaviour. LEPs can also be used to develop appropriate evacuation and disaster management plans to better reduce flood risks to the existing population.

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7.3.1. Port Stephens Local Environment Plan

The study area is covered by the Port Stephens Local Environment Plan 2013 (Reference 20) and was prepared under the Standard Instrument LEP program and is discussed below.

Clauses relating to flood planning were previously contained in Part 7.3, however has since been repealed and replaced with Clause 5.21 in 2021. Clause 5.21 has been updated in 2023 to supersede the Floodplain Development Manual 2005 (Reference 2) with the Floodplain Risk Management Manual 2023 (Reference 3). Clause 5.21 of the Port Stephens Local Environment Plan relates to flood planning and states:

5.21 Flood planning

(1) The objectives of this clause are as follows:

- (a) to minimise the flood risk to life and property associated with the use of land,**
- (b) to allow development on land that is compatible with the flood function and behaviour on the land, taking into account projected changes as a result of climate change,**
- (c) to avoid adverse or cumulative impacts on flood behaviour and the environment,**
- (d) to enable the safe occupation and efficient evacuation of people in the event of a flood.**

(2) Development consent must not be granted to development on land the consent authority considers to be within the flood planning area unless the consent authority is satisfied the development—

- (a) is compatible with the flood function and behaviour on the land, and**
- (b) will not adversely affect flood behaviour in a way that results in detrimental increases in the potential flood affectation of other development or properties, and**
- (c) will not adversely affect the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood, and**
- (d) incorporates appropriate measures to manage risk to life in the event of a flood, and**
- (e) will not adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.**

(3) In deciding whether to grant development consent on land to which this clause applies, the consent authority must consider the following matters—

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(a) the impact of the development on projected changes to flood behaviour as a result of climate change,
(b) the intended design and scale of buildings resulting from the development,

(c) whether the development incorporates measures to minimise the risk to life and ensure the safe evacuation of people in the event of a flood,

(d) the potential to modify, relocate or remove buildings resulting from development if the surrounding area is impacted by flooding or coastal erosion.

(4) A word or expression used in this clause has the same meaning as it has in the Considering Flooding in Land Use Planning Guideline unless it is otherwise defined in this clause.

(5) In this clause—

Considering Flooding in Land Use Planning Guideline means the Considering Flooding in Land Use Planning Guideline published on the Department's website on 14 July 2021.

flood planning area has the same meaning as it has in the Flood Risk Management Manual.

Flood Risk Management Manual means the Flood Risk Management Manual, ISBN 978-1-923076-17-4, published by the NSW Government in June 2023.

Clause 5.22 relating to Special Flood Consideration provides councils the mechanism to apply development controls to land outside the FPA but within the PMF. This clause is specific to land with a significant risk to life, sensitive, vulnerable or critical uses, or land with hazardous materials or industry.

5.22 Special flood considerations

(1) The objectives of this clause are as follows—

(a) to enable the safe occupation and evacuation of people subject to flooding,

(b) to ensure development on land is compatible with the land's flood behaviour in the event of a flood,

(c) to avoid adverse or cumulative impacts on flood behaviour,

(d) to protect the operational capacity of emergency response facilities and critical infrastructure during flood events,

(e) to avoid adverse effects of hazardous development on the environment during flood events.

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(2) This clause applies to—

- (a) for sensitive and hazardous development—land between the flood planning area and the probable maximum flood, and**
- (b) for development that is not sensitive and hazardous development—land the consent authority considers to be land that, in the event of a flood, may—**
 - (i) cause a particular risk to life, and**
 - (ii) require the evacuation of people or other safety considerations.**

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority has considered whether the development—

- (a) will affect the safe occupation and efficient evacuation of people in the event of a flood, and**
- (b) incorporates appropriate measures to manage risk to life in the event of a flood, and**
- (c) will adversely affect the environment in the event of a flood.**

(4) A word or expression used in this clause has the same meaning as it has in the Considering Flooding in Land Use Planning Guideline unless it is otherwise defined in this clause.

(5) In this clause—

Considering Flooding in Land Use Planning Guideline—see clause 5.21(5).

flood planning area—see clause 5.21(5).

Flood Risk Management Manual—see clause 5.21(5).

probable maximum flood has the same meaning as in the Flood Risk Management Manual.

sensitive and hazardous development means development for the following purposes—

- (a) boarding houses,**
- (b) caravan parks,**
- (c) correctional centres,**
- (d) early education and care facilities,**
- (e) eco-tourist facilities,**
- (f) educational establishments,**
- (g) emergency services facilities,**
- (h) group homes,**
- (i) hazardous industries,**
- (j) hazardous storage establishments,**
- (k) hospitals,**

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- (l) hostels,*
- (m) information and education facilities,*
- (n) respite day care centres,*
- (o) seniors housing,*
- (p) sewerage systems,*
- (q) tourist and visitor accommodation,*
- (r) water supply systems.*

7.3.2. Port Stephens Development Control Plan

The Anna Bay and Tilligerry Creek study area is covered by the Port Stephens DCP (2024) (Reference 21). Chapter B5 of the Port Stephens DCP applies to all development on flood prone land. The Chapter seeks to achieve five objectives namely:

The controls are varied based on a combination of development type, hazard classification, and flood function (low/high hazard, floodway, flood storage and flood fringe). The DCP places controls such as the suitability of development, minimum finished floor level, the requirement of a floor impact and risk assessment, and flood compatible designs.

The Draft Lower Hunter River Floodplain Cumulative Development Impact Study and Plan (Reference 34) has been prepared and contains recommendations for controls relating to cumulative development thresholds and requirements. It is understood that at the time of writing, this study and its recommendations, were awaiting adoption by Council, following which they will be incorporated into the DCP.

7.3.3. Port Stephens Local Housing Strategy 2024 and Housing Supply Plan 2024

The Port Stephens Local Housing Strategy sets out Council's vision for the future of land use and housing development in Port Stephens and provides the framework for where housing can be delivered. The strategy focuses on expected future growth and promoting diverse housing solutions.

Anna Bay and the Tilligerry Peninsula provide opportunities for growing local centres through small scale developments like townhouses and shop top housing, as well as infill housing.

The Port Stephens Housing Supply Plan takes the strategic framework provided in the Local Housing Strategy and demonstrates how and where the housing needs can be met over the next 20 years. Flooding, as well as ecological aspects have been identified as major constraints to further development of the Anna Bay area.

The Housing Supply Plan concludes that development should focus in and around the existing town centres of Anna Bay and Tanilba Bay, evolving to more active urban centres with low and mid-rise housing. In addition to expansion of existing lifestyle communities, such as Latitude One and Sunrise with further development of small lot detached housing and identified new housing precincts at Tanilba Bay Golf Course.

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November 1995)**

Volume 1 of the Port Stephens Flood Emergency Sub Plan (Reference 24) was updated and endorsed by Port Stephens Council in December 2022. This document sets out the multi-agency arrangements for the emergency management of flooding in the Port Stephens Council LGA. Volume 1 outlines the strategies and associated actions for the prevention/mitigation of flood impacts, preparation and response for a flood emergency and recovery operations. Volume 2 (Reference 25) and Volume 3 (Reference 26) of the Port Stephens Local Flood Plan were last updated in November 1995. These volumes presented the hazard and risk of flooding as well as the SES response arrangements for Port Stephens.

7.3.5. Port Stephens Floodplain Risk Management Policy (2017)

The Port Stephens Floodplain Risk Management Policy (Reference 27) was first adopted in December 2017 and has been last updated in May 2022. The purpose of the policy is to commit to an integrated risk management approach. The policy defines flood planning level: The level of the 1% AEP (annual exceedance probability) flood event in the year 2100 plus 0.5 metre freeboard, except for overland flooding areas where a freeboard of 0.3 metre is applied. The area of land below the Flood Planning Level (i.e. the Flood Planning Area) is subject to flood-related development controls.

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8. CONSEQUENCES OF FLOODING ON THE COMMUNITY

8.1. Impacts of Flooding on Public Infrastructure

Public sector (non-building) damages include; recreational/tourist facilities; water and sewerage supply; telephone and electricity supply including transmission poles/lines, sub-stations and underground cables; roads and bridges including traffic lights/signs; and costs to employ the emergency services and assist in post-flood clean up. Public sector damages can contribute a significant proportion to total flood costs but are difficult to accurately calculate or predict.

Costs to Councils from flooding typically comprise;

- Clean-up costs;
- Erosion and siltation;
- Removing fallen trees;
- Inundation of Council buildings;
- Direct damage to roads, bridges and culverts, water and sewer infrastructure;
- Removing vehicles washed away;
- Assistance to ratepayers;
- Increases in insurance premiums;
- Closures of streets;
- Loss of working life of road pavements; and
- Operational costs in the lead up to and during flood events.

8.2. Economic Impact of Flooding

The impact of flooding can be quantified through the calculation of flood damages. Flood damage calculations do not include all impacts associated with flooding. They do, however, provide a basis for assessing the economic loss of flooding and also provide a non-subjective means of assessing the merit of flood mitigation works such as retarding basins, levees, drainage enhancement etc. The quantification of flood damages is an important part of the floodplain risk management process. By quantifying flood damage for a range of design events, appropriate cost effective management measures can be analysed in terms of their benefits (reduction in damages) versus the cost of implementation. The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including:

- The magnitude (depth, velocity and duration) of the flood,
- Land use and susceptibility to damages,
- Awareness of the community to flooding,
- Effective warning time,
- The availability of an evacuation plan or damage minimisation program,
- Physical factors such as failure of services (sewerage), flood borne debris, sedimentation, and
- The types of assets and infrastructure affected.

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Anna Bay and Tilligerry Creek Floodplain Risk Management Study and Plan

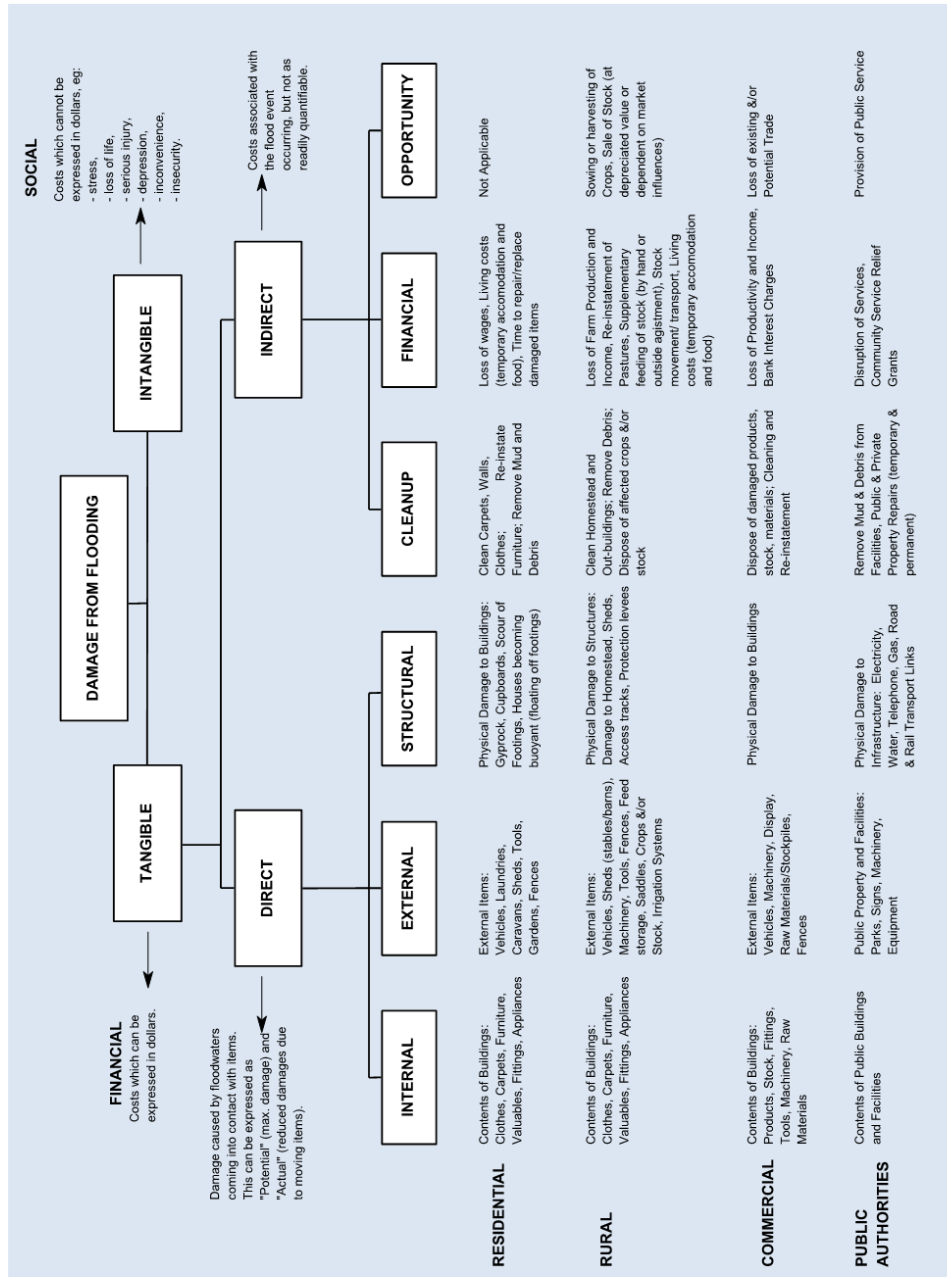
The estimation of flood damages tends to focus on the physical impact of damages on the human environment, but there is also a need to consider the ecological cost and benefits associated with flooding. Flood damages can be defined as being tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned, while intangible damages are those to which a monetary value cannot easily be attributed. Types of flood damages are shown in Table 10.

The assessment of flood damages not only quantifies potential costs due to flooding but also identifies when properties are likely to become flood affected by either flooding on the property or by over floor flooding, as shown in Appendix B.

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Table 10: Flood Damages Categories (including damage and losses from permanent inundation)



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Tangible flood damages are comprised of two basic categories; direct and indirect damages (refer Table 10). Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or in a reduction to their value. Direct damages are further classified as either internal (damage to the contents of a building including carpets, furniture), structural (referring to the structural fabric of a building such as foundations, walls, floors, windows) or external (damage to all items outside the building such as cars, garages). Indirect damages are the additional financial losses caused by the flood for example the cost of temporary accommodation, loss of wages by employees etc.

Given the variability of flooding, property and content values, the total likely damages figure in any given flood event is useful to get a feel for the magnitude of the flood problem, however it is of little value for absolute economic evaluation. Flood damages estimates are also useful when studying the economic effectiveness of proposed mitigation options. Understanding the total damages prevented over the life of the option in relation to current damages, or to an alternative option, can assist in the decision-making process.

The standard way of expressing flood damages is in terms of average annual damages (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. This means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods.

In order to quantify the damages caused by inundation for existing development, a floor level survey was undertaken. This was used in conjunction with modelled flood level information to calculate damages. Due to the number of properties, number of isolated properties and cost, it was not possible to survey all houses within the PMF extent for the study area.

A flood damages assessment was undertaken for existing development in accordance with current DPE guidelines and the Floodplain Development Manual 2023 (Reference 3). The damages were calculated using a number of height-damage curves which relate the depth of water above the floor with tangible damages. Each component of tangible damages is allocated a maximum value and a maximum depth at which this value occurs. Any flood depths greater than this allocated value do not incur additional damages as it is assumed that, by this level, all potential damages have already occurred.

8.2.1.1. Direct Internal Damages

Internal damages were assumed follow the default damages of \$550 per square metre adopted in the Floodplain Development Manual (DPE, 2023) for residential properties. In floods larger than the current 1% AEP event there is the possibility that some buildings may collapse or have to be destroyed. The cost of these damages have not been included in the analysis.

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Structural damages were assumed to follow the default damages relationships to the dwelling size and number of storeys adopted in the Floodplain Development Manual (DPE, 2023). In floods larger than the current 1% AEP event there is the possibility that some buildings may collapse or have to be destroyed. The cost of these damages have not been included in the analysis.

8.2.1.3. Direct External Damages

External damages were assumed to follow the default damages of \$17,000 (with depth threshold greater than 0.3 m) adopted in the Floodplain Development Manual (DPE, 2023).

8.2.1.4. Indirect Damages

Indirect damages were assumed to follow the default damage relationship in the Floodplain Risk Management Manual (Reference 3). That is, for residential clean-up costs of 4,500 and relocations costs of \$430 per week will apply if over floor inundation exists. Non-residential indirect costs, which cover clean-up costs and loss of trading are 30% of the direct damages.

8.2.1. Intangible Damages

Intangible damages were assumed to follow the default damage relationship in the Floodplain Risk Management Manual (Reference 3). These intangible damages cover social and wellbeing impacts of flooding to the community and the Floodplain Risk Management Manual (Reference 3) indicates that these damages should only incorporated in the assessment if agreed by DPE. These intangible damages have been incorporated in this assessment and were found to contribute only a small portion of the total flood damages (<5%).

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8.2.2. Summary of Damages

The number of properties flooded in each event is summarised in Table 12 for both flooding above ground level and above floor level. It should be noted that this summary does not take into account flooding to any basements or cellars. Where properties have basements, damages can be underestimated. This analysis was completed in 2023 and has used inflation rates from then. A total of 644 properties within the study area are flooded above floor level in a current 1% AEP event and approximately 2055 properties are flooded above floor level in the PMF event. A total of 317 properties have been identified in the study area, that are flooded above floor level in events of current 10% AEP or more frequent. When considering the distribution of flooded properties across events, as shown in Table 12, the number of affected properties increase steadily up to the current 0.2% AEP and in the PMF event, the number of affect properties increase significantly. This is because in rare to extreme events, riverine flooding from the Hunter River dominates flooding in the study area Nelson Bay Road overtops at Fullerton Cove.

The total flood damages which incorporate tangible and intangible damages are summarised in Table 11. Similar to the number of flooded properties, the total flood damages increase steadily up to the current 0.2% AEP and rapidly increase in the PMF event. A further breakdown of the total flood damages and average annual damages per damage type is presented in Table 11. Structural damages contribute the largest portion (60%) of the total damages and is followed by internal damages (26%), external damages (10%) and intangible damages (4%).

Table 11: Flood Damages per Damage Category

Event (Current)	Structural	Internal	External	Intangibles
20% AEP	\$31,421,000	\$13,743,000	\$5,296,000	\$1,252,000
10% AEP	\$35,750,000	\$15,431,646	\$6,224,000	\$1,400,400
5% AEP	\$50,755,000	\$22,353,000	\$8,717,000	\$2,057,000
2% AEP	\$66,512,000	\$28,879,000	\$11,095,000	\$2,633,000
1% AEP	\$76,865,000	\$33,314,000	\$12,680,000	\$3,027,000
0.5% AEP	\$87,111,000	\$37,881,000	\$14,361,000	\$3,429,000
0.2% AEP	\$101,680,000	\$43,948,000	\$16,410,000	\$3,977,000
PMF	\$358,585,000	\$181,723,000	\$36,144,000	\$17,730,000
AAD	\$13,861,000	\$6,070,000	\$2,326,000	\$867,000

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Table 12: Summary of Flood Damages

Flood Event (Current)	No. Lots Affected	No. Dwellings Flooded Above Floor Level	Total Damages for Event	Average Damage Per Flood Affected Property	% of AAD	
Residential	20% AEP	941	234	\$46,179,000	\$540,000	34%
	10% AEP	1024	274	\$52,347,000	\$528,000	24%
	5% AEP	1243	386	\$73,826,000	\$512,000	16%
	2% AEP	1542	494	\$96,125,000	\$522,000	13%
	1% AEP	1694	567	\$110,532,000	\$519,000	5%
	0.5% AEP	1840	644	\$125,108,000	\$519,000	3%
	0.2% AEP	2052	736	\$143,935,000	\$525,000	2%
	PMF	3024	1814	\$492,922,000	\$650,000	3%
	Average Annual Damages			\$20,217,000	\$6,690	
Total	20% AEP	1002	242	\$51,711,000	\$585,000	34%
	10% AEP	1090	282	\$58,805,000	\$573,000	24%
	5% AEP	1339	403	\$83,882,000	\$557,000	16%
	2% AEP	1665	519	\$109,118,000	\$560,000	13%
	1% AEP	1837	597	\$125,886,000	\$557,000	5%
	0.5% AEP	1988	678	\$142,783,000	\$558,000	3%
	0.2% AEP	2233	790	\$166,015,000	\$562,000	2%
	PMF	3299	1981	\$594,183,000	\$718,000	3%
	Average Annual Damages			\$23,124,000	\$7,010	

Annual Average Damage (AAD) the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. That is, the AAD is equivalent to the total damage caused by all floods over a long period of time divided by the number of years in that period. Note that it is assumed that the development situation is constant over the analysis period. This means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods. The AAD and the contribution to the AAD for each event is presented in Table 12. The AAD per property in the study area is \$7,009. The current 20% AEP and current 10% AEP event together contribute to more than half of the AAD.

8.3. Climate Change

There is strong evidence that increases in global temperatures will lead to an increase in the intensity of rare rainfall, and that extreme flooding globally has increased over the 20th century (Reference 28). Global warming has been observed for several decades and has been linked to changes in key parts of the hydrologic cycle including changes in rainfall behaviour, rainfall intensity, soil moisture and runoff (Reference 29). Climate change can alter flood behaviour in the catchment by changing:

- Probability of long duration rainfall intensities;
- Storm type and frequency;
- Rainfall spatial and temporal patterns; and
- Antecedent conditions.

The interaction of these characteristics makes predicting the impact of climate change on flood behaviour complex.

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The interaction of a warming climate and rainfall is complex. A warmer climate leads to an increase in the potential moisture-holding capacity of the atmosphere which is one of the key factors in the depth of precipitation in rarer rainfall events, however on large catchments like the Hunter River long duration rainfall events are also dependant on sources and transport of moist air. Statistically significant increases in rainfall intensity have been detected in Australia for short duration rainfall events and are likely to become more evident towards the end of the 21st century (Reference 30).

Changes in long duration events are expected to be smaller and harder to detect, but projections analysed by Reference 31 showed that an increase in daily precipitation intensity is likely under climate change. It is worth noting that a warming climate can lead to decreases in annual rainfall along with increases in flood producing rainfall.

8.3.2. Spatial and Temporal Rainfall Behaviour

The influence of warmer climate on the spatial and temporal aspects of rainfall is not as well understood as the likely changes in rainfall intensity. Work by Abs et al. (Reference 32) suggests that increases will be more pronounced in areas with strong orographic enhancement which could lead to larger increases in upper reaches of the catchment. Work by Wasco and Sharma (Reference 33) analysing historical storms found that, regardless of the climate region or season, temperature increases are associated with rainfall patterns becoming less uniform, with the larger fractions increasing in rainfall intensity and the lower fractions decreasing.

8.3.3. Antecedent Conditions

Changes to rainfall and evaporation as a result of climate change will impact on the antecedent conditions prior to an event. It is likely that evaporation will increase (Reference 29) by 2030 and 2070 by approximately 2%. Increased evaporation in combination with decreased rainfall could result in decreases in annual runoff, and hence drier antecedent conditions. The impact on flood events is likely to be less consistent.

8.3.4. Assessment of Climate Change Impacts

The 2005 Floodplain Development Manual (Reference 2) and the 2023 Flood Risk Management Manual (Reference 3) requires that Flood Studies and Floodplain Risk Management Studies consider the impacts of climate change (sea level rise and rainfall increase) on flood behaviour. A range of climate change scenarios have already been considered in the Flood Study (Reference 1), which were combinations of 0.4 m and 0.9 m sea level rise and 10% and 20% of rainfall increase. At the time of the assessment, ARR2019 (Reference 15) recommended usage of the scenarios RCP4.5 and RCP8.5 for rainfall increase. This corresponds to 9.5% (RCP4.5) and 19.7% (RCP8.5) for the year 2090. These interim factors assumed a 5% increase in rainfall per 1°C increase in mean temperature based on the IPCC 5th Assessment Report (AR5) (2014). The following climate change scenarios (rainfall by the year 2100) were considered in this climate change assessment:

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- **Increase in peak rainfall and storm volume:**
 - low level rainfall increase = 9.5%,
 - high level rainfall increase = 19.7%
- **Sea level rise:**
 - a 0.4m increase in level by year 2050
 - a 0.9m increase in level by year 2100

ARR2019 Version 4.1 (Reference 15) recommends implementation of rainfall increase by factoring the rainfall depth (or intensities) of an event. This was implemented in the study area by adjusting the rainfall depth in the hydrologic model. However, implementation of rainfall increases in the areas which were within the hydraulic model but beyond the study area were difficult as the hydrologic models for these areas were unavailable.

In areas (the Hunter River), where hydrologic models were not available, inflows were factored instead of rainfall depths. This was considered acceptable as in the 1% AEP event, there is minor interaction between the Hunter River and the study area.

Figure 64 to Figure 66 presents the 1% AEP flood level impacts due to climate change (2090 sea level rise and 19.7% rainfall increase) as well as decrease in catchment roughness due to future developments.

Tilligerry Creek is highly sensitive to sea level rise with flood level increases up to 0.9 m along most of the Creek in the 1% AEP event. At Salt Ash, 1% AEP flood levels in areas north of Lemon Tree Passage Road increase by up to 0.55 m as parts of the road are overtopped, and culverts are affected by backwater from Tilligerry Creek. Most of Marsh Road has flood levels increases in the 1% AEP by up to 0.7 m as the road is low-lying and has similar flood behaviour as Tilligerry Creek. At Bobs Farm, in the current climate conditions, Nelsons Bay Road has minor overtopping (<0.1 m) in the 1% AEP event with waters flowing over the road from the south to the north. In future climate conditions with sea level rise, Nelson Bay Road is overtopped by high tides and areas south of Nelson Bay Road is affected by waters from Tilligerry Creek. Flood levels in the 1% AEP event increase by up to 0.9 m along most of Main Drain. Port Stephens Drive is overtopped by back water from high tides in current climate conditions and remains overtopped in future climate conditions with sea level rise. Nelson Bay Road at Anna Bay is not overtopped in the current climate conditions in the 1% AEP event but becomes overtopped in future climate conditions with sea level rise.

At Tanilba Bay, flood level increases are minor (<0.1 m) in the main town centre near Lemon Tree Passage Road. In the foreshore areas, flood levels increase up to 0.9 m due to sea level rise in the 1% AEP event. At Lemon Tree Passage, flood level increases in the 1% AEP event are up to 0.9 m in the foreshore areas. Elevated areas in Lemon Tree Passage had minor flood level increases (<0.1 m) in the future climate conditions in the 1% AEP event.

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In Fern Tree Drain, 1% AEP flood levels increase by up to 0.95 m as due to a combination of sea level rise and rainfall increase. McKinley Swamp has flood level increases by 0.27 m in the 1% AEP event. Low points in Anna Bay such as Gan Gan Road at Morna Point Rd and the basin at Morna Point Rd have flood level increases of 0.15 m to 0.2 m in future climate conditions. The low point at Clark St increases in flood levels by up to 0.15 m and is affected by rainfall increase only. One Mile in affected by Main Drain, which is heavily influenced by tide levels, and has flood level increases up to 0.8 m across most of the area.

Recently ARR2019 has been updated to Version 4.2 and includes a range of updates related to current research on the impacts and assessment of climate change. This includes the release of revised relative increases in rainfall per 1°C increase in mean temperature based on the IPCC 6th Assessment Report (AR6) (2023). In February 2026, ARR2019 v4.2 provided the basis for the release of the Draft Climate Change and Natural Hazards SEPP, which provides guidance to consent authorities, allowing informed, balanced and merit based decisions in light of climate changed induced flood risk. Given the timing of the release of ARR2019 v4.2 and the Draft SEPP, they have not been applied to this study, however a comparison is provided below.

For the study catchment, the critical durations vary from 180 min to 36 hours which correspond to increases in rainfall in the range of 8% to 11.8% per 1°C increase in mean temperature. The interim factors applied to rainfall in accordance with ARR 2019 Version 4.1 are lower than those in ARR 2019 Version 4.2. For example, ARR 2019 Version 4.1 predicts 9.5% increase in rainfall by 2090 based on RCP 4.5, while ARR 2019 Version 4.2 predicts 14% increase in rainfall by 2030 for a 180 min duration under the Shared Socioeconomic Pathway (SSP) 2-4.5 scenario. SSP2-4.5 has the developed world continuing on the current trajectory, a middle of the road scenario. Moreover, ARR 2019 Version 4.2 projects a 31% increase in rainfall by 2090 under the SSP2-4.5 scenario for a 180 minute duration storm; greater than that assessed for RCP 8.5 under ARR 2019 Version 4.1 and discussed above.

ARR 2019 Version 4.2 also provides revised initial and continuing loss parameters as a result of evidence of drying antecedent moisture conditions, which will generally increase losses. This reduces the impact of increases in rainfall intensities, particularly for frequent floods or those systems where peak flood behaviour is volume driven. For example, ARR 2019 Version 4.2 predicts a 5% increase in initial loss and 9% increase in continuing loss by 2090 under the SSP2-4.5 scenario.

In order to attempt to quantify how climate change under ARR 2019 Version 4.2 will affect the study area the Climate Change Calculator (ccc.wmawater.com.au) was used. The tool provides an understanding of the change in risk due to a current understanding of climate change. Calculations were undertaken for a central location in the study area. Diagram 4 shows how the 180 minute 1% AEP catchment average rainfall will change under various climate pathways.

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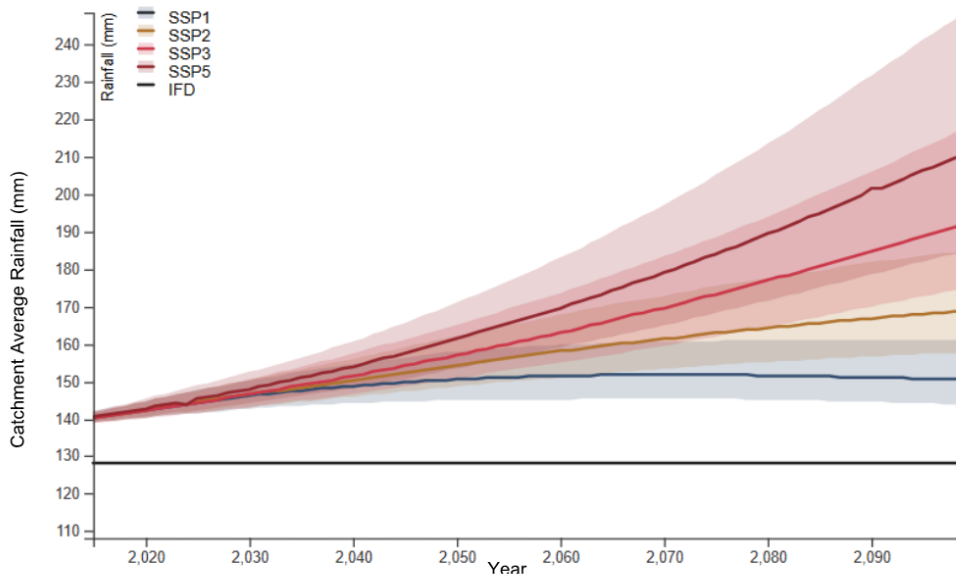


Diagram 4: Change in Catchment Average Rainfall under Climate Change – 1% AEP

Table 13 shows the probability of a 1% (1 in 100) AEP event based on past climate under current and various future dates for each emissions scenario. Under SSP3-7.0 which has the developed world making limited additional movement to a low carbon economy, the current 1% AEP flood in 2090 will be more than 5 times more likely to occur with a probability of 1 in 17.1 AEP. In contrast Table 14 shows the historical design standard needed to be adopted to achieve the 1% AEP (1 in 100 AEP) in the future. To achieve 1% AEP design standard in 2090 under SSP3-7.0 a historic design standard of 1 in 801 AEP would need to be adopted. Warming to date means that the historical 1% AEP event is nearly twice as likely with an AEP of 1 in 52.2.

Table 13: A historical 1 in 100 AEP event (BOM 2016 IFD) is equivalent to a 1 in X AEP event in the future

	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
2025	52.4	52.2	52.5	50.7
2030	49.3	48.7	48.5	46.2
2060	42.7	37.9	35.0	30.8
2090	41.9	26.6	17.1	11.9
Mean over 70 year period	43.1	34.3	27.7	22.1

Table 14: A future 1 in 100 AEP event is equivalent to a 1 in X AEP historical event (BOM 2016 IFD):

	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
2024	191	192	191	199
2030	204	207	208	219
2060	239	274	302	355
2090	245	433	802	1368
Mean over 70 year period	219	263	317	392

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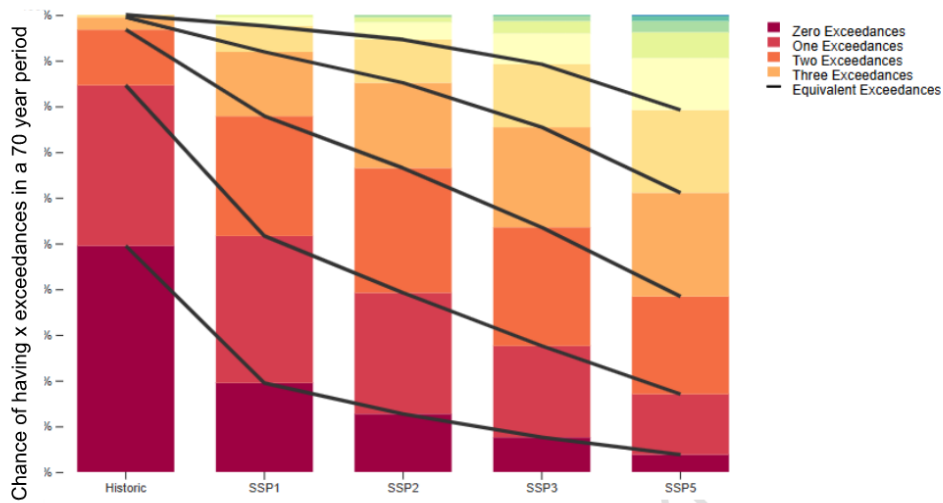


Diagram 5: Expected Exceedances over 70 year period

Diagram 5 shows the number of exceedances over a 70 year period from 2025 to 2094 of the historical 1% AEP design level under various scenarios. One of the reasons the 1% AEP design standard has been used throughout most of the western world is that under a fixed climate and a 70 year life span there is approximately a 50% chance of not experiencing a 1% AEP flood. The 50% chance of experiencing one or more floods is made up of a 33% chance of experiencing one and 13% chance of experiencing two and a 4% chance of experiencing three or more. This is shown in the first column. With climate change there is a significant increase in the number of events people will experience. Under SSP3-7.0 a chance of no 1% AEP flood over a 70 year period is less than 10%.

Future flooding related assessments for the study area and across the wider Local Government Area should assess future climate scenarios in accordance with ARR 2019 Version 4.2 (or future updates). At the time of writing there is no adopted guidance on which Shared Socioeconomic Pathways are appropriate for assessment, however Draft Climate Change and Natural Hazards SEPP indicates that it is reasonable to assess a likely current scenario (SSP 2 – 4.5), in addition to an upper conservative scenario (SSP 3 – 7.0) to understand the sensitivity and potential consequences of changing flood behaviour. Specific adopted guidance from relevant authorities would override this suggestion.

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AND MANAGING FLOOD RISK****9.1. Information for Emergency Management Planning****9.1.1. Road Inundation**

The overtopping depths in current conditions for key access roads in the study area are summarised in Table 15 **Error! Reference source not found.**. These depths are based on the flood level and elevation of the road at the location of the road overtopping. The event which the access to the road is lost is bolded in red. Roads were considered inaccessible when flood hazards were H2 or greater. Locations of the key access and their first cut event are shown in Diagram 6. These locations are also shown in more detail in Figure 64 to Figure 66 for each of the hydraulic model areas.

Time to closure of roads assuming lost access are presented in Table 15 **Error! Reference source not found.**. A range of time to closures are shown and are based on all the modelled events where the road access was lost. In general, frequent event had longer time to closures and rarer events had shorter time to closures. The time to closure for the 1% AEP event is shown in brackets.

Note that the time to closure were measured from the start of the main burst, whereas most real storm events would have pre-burst. The time of closure presented is indicative only as it was assessed based on the selected design events, which does not include all rainfall durations. Therefore, under different storm durations the time to closure will vary. Additionally, locations ID 1 is inundated by Tilligerry Creek and is tidally influenced. In the hydraulic model, the design rainfalls have been simulated to coincide with the peak of the tide. Therefore, ID 1 was closed prior to the start of the main burst.

Depths at these locations cannot be linked to a reference gauge as there is no suitable gauge within the study area which captures the flood behaviour impacting these locations.

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Table 15: Road Inundation Depth (m) at Key Access Roads in the current climate conditions

ID	Location	Road Level (m AHD)	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF	Time to closure from start of rainfall (h) [#]
1	Lemon Tree Passage Rd near Michael Dr	1.03	0.62	0.7	0.78	0.91	0.93	0.95	0.97	3.06	-26 - -14 (-14.7)
2	Nelson Bay Rd near Marsh Rd	1.33	-	0.02	0.22	0.29	0.34	0.34	0.37	2.57	2 - 14 (2.2)
3	Nelson Bay Rd	4.93	0.35	0.44	0.55	0.62	0.7	0.84	1.05	1.53	0 - 9 (0.9)
4	Nelson Bay Rd near Frost Rd	4.05	-	-	0.16	0.26	0.31	0.4	0.52	0.53	7 - 23 (11)
5	Gan Gan Rd near Anna Bay Boreline	8.41	-	0.26	0.49	0.69	0.77	0.85	0.93	1.11	1 - 10 (2.4)
6	Tilligerry Trk	7.19	0.42	0.48	0.55	0.65	0.68	0.7	0.73	0.79	1 - 3 (1.7)
7	President Wilson Walk near Lemon Tree Passage Rd	7.52	0.2	0.27	0.34	0.55	0.61	0.66	0.71	0.82	3 - 5 (3.5)
8	Mallabula Rd near Tanilba Rd	3.77	0.36	0.36	0.38	0.44	0.47	0.5	0.54	0.58	1 - 2 (1.7)
9	Meredith Ave at Mackie St	1.79	0.07	0.13	0.21	0.34	0.37	0.4	0.43	0.5	3 - 8 (7)
10	Gan Gan Rd near McKinley Swamp	2.93	0.12	0.09	0.11	0.2	0.32	0.48	0.68	1.39	0 - 1 (0.9)
11	Gan Gan Rd near Morna Point Rd	3.07	0.07	0.11	0.22	0.33	0.49	0.61	0.74	1.42	0 - 2 (1.3)
12	Gan Gan Rd near Essington Way Basin	4.09	0.21	0.34	0.46	0.48	0.54	0.59	0.65	0.88	0 - 5 (1.1)
13	Old Main Rd	4.68	-	0.07	0.14	0.2	0.27	0.7	1.24	1.96	0 - 2 (-)
14	Gan Gan Rd near Clark St	5.43	0.11	0.17	0.23	0.28	0.37	0.45	0.55	1.25	0 - 2 (1.4)

Time to closure range across selected events from 20% AEP to PMF event. Time to closure for a selected 1% AEP event shown in brackets.

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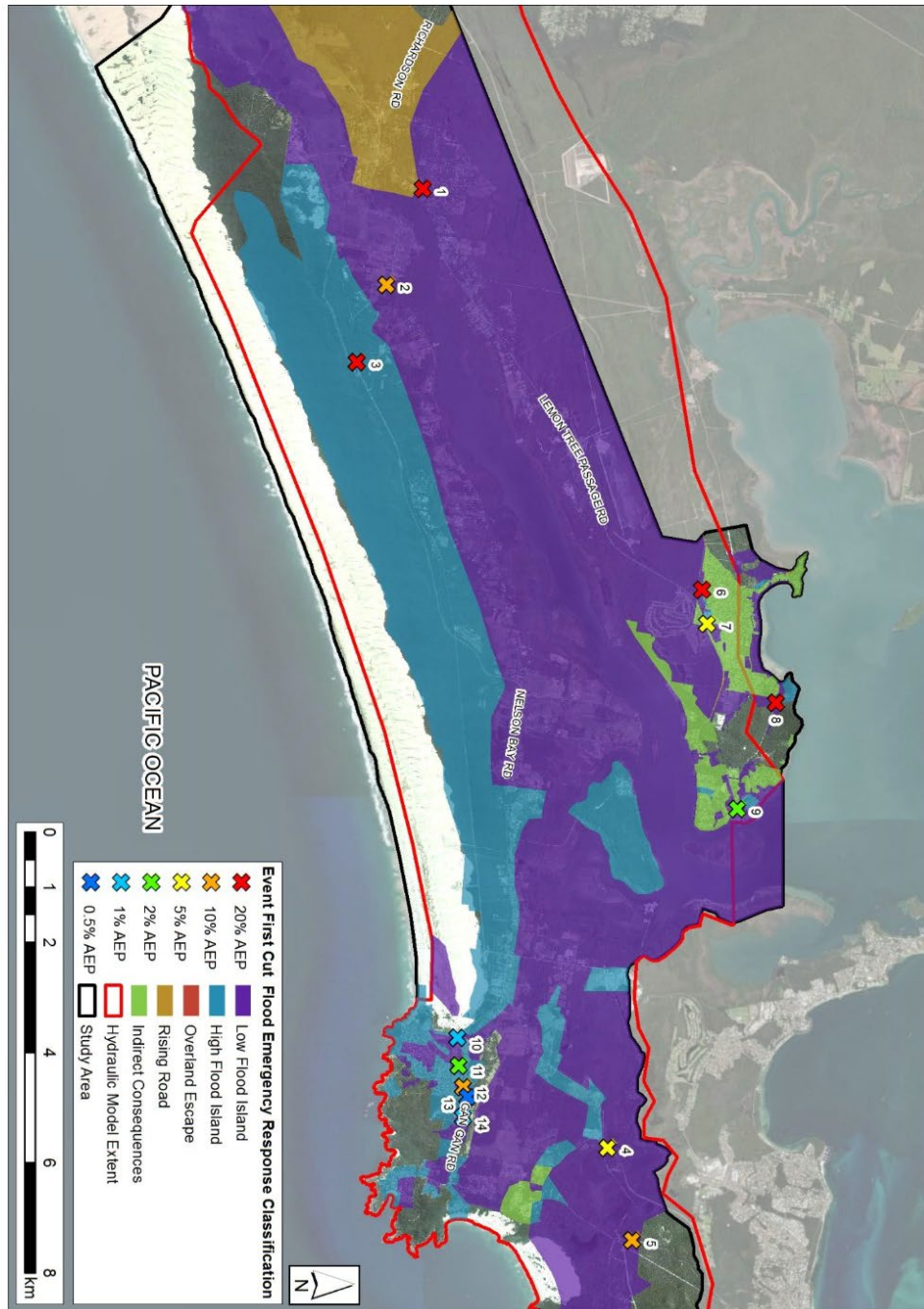


Diagram 6: Road Inundation Locations and Flood Emergency Response Classifications

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9.1.2. Flood Emergency Response Classification

Managing the floodplain: a guide to best practice in flood risk management in Australia (Reference 19) provides guidance on how to categorise emergency response requirements on the Floodplain. Flood studies are required to address the management of continuing flood risk to both existing and future development areas. As continuing flood risk varies across the floodplain, so does the type and scale of the emergency response problem and therefore the information necessary for effective Emergency Response Planning (ERP). Classification provides an indication of the vulnerability of the community in flood emergency response and identifies the type and scale of information needed by the State Emergency Services (SES) to assist in emergency response planning (ERP).

Criteria for determining flood ERP classifications and an indication of the emergency response required for these classifications are provided in the Floodplain Risk Management Guideline (Reference 3), (Flood Emergency Response Planning: Classification of Communities). Table 16 summarises the response required for areas of different classification. However, these may vary depending on local flood characteristics and resultant flood behaviour, i.e. in flash flooding or overland flood areas.

Table 16: Response Required for Different Flood ERP Classifications

Classification	Response Required		
	Resupply	Rescue/Medivac	Evacuation
High Flood Island	Yes	Possibly	Possibly
Low Flood Island	No	Yes	Yes
Rising Road	No	Possibly	Yes
Overland Escape	No	Possibly	Yes
Indirect Consequence	Possibly	Possibly	Possibly

The classifications used are described below, taken directly from the Floodplain Risk Management Guideline (Reference 3):

- High Flood Island (HFI). The flood island has land higher than the limit of flooding for the event being considered. During a flood these high islands are isolated from other areas of the community by floodwater, terrain, development, or infrastructure. However, there is an opportunity for people to retreat to higher ground within the island, and therefore, the direct risk to life is reduced. The area may require resupply by boat or air if not evacuated before the road is cut. If it is not possible to provide adequate support (such as community and medical facilities) during the period of isolation, evacuation will have to take place before isolation occurs. Isolation without these services is more likely to result in fatal decisions to cross floodwaters.
- Low Flood Island (LFI). The flood island is lower than the limit of flooding for the event being considered. During a flood event the area initially becomes isolated by floodwater, terrain, development or infrastructure. If floodwater continues to rise after it is isolated, the land on the island will eventually be completely inundated by floodwaters. Evacuation of the community will be required prior to evacuation routes being closed as people left stranded on the island may drown.

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- Areas that are flooded with Rising Road Access (FER) are those areas where access roads rise steadily uphill and away from the rising floodwaters. The community will not be completely isolated before inundation reaches its maximum extent, even in the PMF. Evacuation can take place by vehicle or on foot along the road as floodwater advances. People should not be trapped unless they delay their evacuation from their homes, for example, people living in 2-storey homes may initially decide to stay but reconsider after water surrounds them. These communities contain low-lying areas from which people will be progressively evacuated to higher ground as the level of inundation increases. This inundation could be caused either by direct flooding from the river system or by localised flooding from creeks.
- Areas that are Flooded with an Overland Escape Route (FEO) are those areas where escape from rising floodwater is possible by traversing overland to higher ground. The area may also have access roads to flood-free land that cross lower-lying flood prone land. Evacuation can take place by road only until access roads are closed by floodwater. Escape from rising floodwater after roads are cut is possible but involves traversing overland to higher ground. Anyone not able to walk out before access roads are cut must be reached by using boats and aircraft. If people cannot get out before inundation, rescue will most likely be from rooftops.
- Not Flooded, with Indirect Consequences (NIC). These are areas that are outside the limit of flooding and therefore will not be inundated nor will they lose road access, however, they may be indirectly affected as a result of flood damaged infrastructure or due to the loss of transport links, electricity supply, water supply, sewage or telecommunications services. These areas may therefore require resupply or, in the worst case, evacuation.

The study area has been classified according to the Floodplain Risk Management Guidelines (Reference 3) and are shown in Figure 64 to Figure 66. Emergency response in the study area is complex as most populated areas can only be accessed via Lemon Tree Passage Road (overtopped in the current 10% AEP) or Nelson Bay Road (overtopped in the current 1% AEP), whereas properties within populated areas such as Tanilba Bay and Mallabula have higher ground levels and are generally flood free. For the purposes of assessing emergency response, neither of these roads were assumed to be accessible during flood events.

Emergency response classifications for the broader area are provided in Figure 64. Most areas in Salt Ash which relies on Lemon Tree Passage Road for access to the wider Port Stephens region were determined to be a Low Flood Island. Dwellings along in this area typically have sufficiently high floor levels to be unaffected by the current 1% AEP event, however in rarer events above floor flooding is common. Given that there is no access and no refuge area available it is considered to be a Low Flood Island. Areas along Marsh Rd and at Taylors Beach are considered Low Flood Island as the terrain is flat and low-lying. Areas in Salt Ash and Williamstown which do not rely on Lemon Tree Passage Rd for evacuation were considered to have rising route access (FER). Areas along Nelson Bay Road were considered High Flood Islands (HFI) as although access is cut off, ground levels are higher and generally flood free.

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Figure 65 presents the emergency response classifications at the eastern end of the Tilligerry Peninsula. Most populated areas were classified as not flooded with indirect consequences (NIC). This is because flooding in these areas is generally contained within the road corridor and above floor flooding is not experienced, however access off the peninsula is cut as Lemon Tree Passage Road is overtopped. Occupants in these areas can be safe within their dwellings, however access to services may be affected. Areas where flood depths are greater and inundate dwellings above floor level (such as at Lemon Tree Passage Rd near President Wilson Walk and foreshore areas) were classified as Low Flood Island (LFI).

Figure 66 presents the emergency response classifications at Anna Bay, Boat Harbour and One Mile. Locations in Anna Bay were classified as Low Flood Island (LFI) as there are multiple low points throughout the area. In rarer events, dwellings are flooded above floor level in these areas and there is no access to the wider regions as Gan Gan Road and Nelson Bay Rd is overtopped. Areas which had higher ground levels such that dwellings were not flooded above floor level are classified as High Flood Island (HFI) as occupants can take refuge in their own dwellings however access to them is cut.

9.1.3. Review of Port Stephens Flood Emergency Sub Plan

Volume 1 of the Port Stephens Flood Emergency Sub Plan (Reference 24) was endorsed by Council since December 2022. This Sub Plan outlines the roles and responsibilities of each agency for the emergency management of flooding within the Port Stephens LGA.

Volume 1 of the Sub Plan was updated and in general in accordance with the most up to date information and practice. Volume 1 should be updated to reference the Flood Risk Management Manual (Reference 3), which supersedes the Floodplain Development Manual (Reference 2).

Volume 2 (Reference 25) and Volume 3 (Reference 26) of the Port Stephen Local Flood Plan outlines the hazards and risk as well as the SES response arrangement in Port Stephens. Both these documents were last updated in November 1995. Both volumes of the local flood plan have LGA wide applications with few specific mentions of locations within the study area.

Volume 2 (Reference 25) describes the general hazards and risk within the LGA and identifies that the flooding from storm surge and wave action may affect Tanilba Bay, Boat Harbour, Bobs Farm, Mallabula, and Anna Bay.

Significantly more flood information has been made available as part of this floodplain risk management study as well as the previous flood study (Reference 1) since the last update of Volume 2 (November 1995). Volume 2 should be updated to incorporate this new information. In particular, the flood behaviour of urbanised areas on Tilligerry and Tomaree Peninsulas, which are typically of lower flood risk (indirect consequences or high flood islands) but constrained by road closure of Lemon Tree Passage Road and Nelson Bay Road. Effects on the community should be presented in Volume 2 for each risk area. This should include an overview of the community, flood behaviour and flood response emergency classification, and key hydraulic structures, as well as any at risk facilities.

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Volume 3 (Reference 26) details the SES response arrangements during a flood event. In Volume 3, the study area does not fall within any operational areas which have specific response arrangements, therefore only the general arrangements apply. Volume 3 provides guides to, evacuation warning messages, disseminating flooding information, and assessing resource requirements for evacuation operations. These assessments include assumptions on the time required for door knock preparation, transportation, and household evacuation. The information provided within Volume 3 is generally useful for the LGA, however, given the lack of warning time available for the study area, guidance from Volume 3 is of limited use.

Volume 3 was last updated in November 1995 and is of limited use for the study area due to the lack of warning time. The study area is large and requires different response arrangements for each area. Information developed as part of this study should be incorporated into Volume 3. Volume 3 should be updated for each area with information relating to:

- Risks - Flood response emergency classification and at risk population and number of properties, key risk and consequences.
- Strategy – Agency controlling response, general strategy, information, action for property protection
- Response – Evacuation centres, routes and closure, evacuation method and assembly area, rescue and resupply

Detailed recommendations for the update of the Flood Emergency Sub Plan is provided as part of Option RM19 in Section 10.5.2.

9.2. Flood Planning Area

The flood planning level (FPL) is used to define land subject to flood related development controls and is generally adopted as the minimum level to which floor levels in the flood affected areas must be built. The FPL includes a freeboard above the design flood level. It is common practice to set minimum floor levels for residential buildings, garages, driveways and even commercial floors as this reduces the frequency and extent of flood damages. Freeboards provide reasonable certainty that the reduced level of risk exposure selected (by deciding upon a particular event to provide flood protection for) is actually provided.

In the Anna Bay Flood Study (Reference 1), the adopted flood planning level was defined as the 1% AEP flood level in the climate change scenario of the year 2100 (+0.9 m sea level rise) and 20% rainfall increase plus freeboard. A freeboard of 0.5 m was adopted for all mainstream flooding and a freeboard of 0.3 m was adopted for all overland flooding.

The FPL is shown in Figure 67 to Figure 69. The FPL adopted in this study is defined as the 1% AEP flood level in the climate change scenario of the year 2100 (+0.9 m sea level rise) and rainfall increase of the 2090 according to the RCP8.5 scenario (i.e. 19.7% rainfall increase) plus a freeboard. A freeboard of 0.5 m was adopted for all mainstream flooding, and a freeboard of 0.3 m was adopted for all overland flooding.

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9.3. Flood Planning Constraint Classifications

AIDR National Handbook (Reference 19) provides guidance on the how to classify land within the floodplain based on its flood risk to better inform land use planning activities. These categories condense the wealth of flood information produced in a flood study and classify the floodplain into areas with similar degrees of constraint. These FPCCs can be used in high level assessments of land use planning to inform and support decisions for strategic planning.

For detailed land use planning activities, it is recommended that the flood behaviour across the range of flood events be considered, depending on the level of constraint.

The Australian Disaster Resilience Handbook Collection recommends the use of four constraint categories. It is recommended that isolation potential also be considered for the high constraint category. This could include areas classified as Low Flood Island or High Flood Island (Refer Section 9.1.2).

There are four flood planning constraint categories. The intent of these categories is to collapse all the flood study mapping outputs into areas of consistent constraints. The FPCCs categorise the floodplain into areas ranging from the most constrained (and therefore least suitable for intensification of land use or development—FPCC1), to the least constrained (and therefore more suitable for intensification of land use or development—FPCC4).

The constraints defined by Reference 19 have been adapted to suit the study area and are outlined in Table 17. The Design Flood Event (DFE) was taken as the Year 2100 1% AEP event and the Year 2100 0.2% AEP event was used as the greater than DFE event. The associated FPCC map can be found on in Figure 70 to Figure 72.

Table 17: Flood Planning Constraint Categories for the Study Area

	Constraints	Implications	Considerations
FPCC 1	Floodway and flood storage areas in the DFE event.	Any development is likely to affect flood behaviour in the Year 2100 1% AEP event and cause impacts elsewhere.	Majority of developments and uses have adverse impacts on flood behaviour or are vulnerable. Consider limiting uses and developments to those that are compatible with flood function and hazard.
	H6 hazard in the DFE event	Hazardous conditions considered unsafe for vehicles and people, all types of buildings considered vulnerable to structural failure.	
FPCC 2	Floodway in the Year 2100 0.2% AEP event	People and buildings in these areas may be affected by dangerous floodwaters in rarer events.	Many uses and developments will be more vulnerable in these areas. Consider limiting new uses to those compatible with flood function and hazard (including rarer flood flows) or consider treatments to reduce the hazard (such as filling).
	H5 flood hazard in the Year 2100 1% AEP event	Hazardous conditions considered unsafe for vehicles and people, and all buildings vulnerable to structural damage.	

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	Constraints	Implications	Considerations
	H6 flood hazard in the Year 2100 0.2% AEP event	Hazardous conditions develop in rare events which may have implications for the development and its occupants.	Consider the need for additional development control conditions to reduce the effect of flooding on the development and its occupants.
FPCC 3	Within the FPA	Hazardous conditions may exist creating issues for vehicles and people. Structural damage to buildings is unlikely.	Standard land use and development controls aimed at reducing damage and the exposure of the development to flooding are likely to be suitable. Consider additional conditions for critical utilities, vulnerable facilities and key community infrastructure.
FPCC 4	Within the PMF extent	Emergency response may rely on key community facilities such as emergency hospitals, emergency management headquarters and evacuation centres operating during an event. Recovery may rely on key utility services being able to be readily re-established after an event.	Consider the need for conditions for emergency response facilities, key community infrastructure and land uses with vulnerable users.

9.4. Potential Rezoning Applications

Several locations have been flagged for potential rezoning from RU2 Rural Landscape to R2 Low Density Residential, E1 Local Centre, C3 Environmental Management, and RE1 Public Recreation. Locations which are potentially rezoned to residential or local centres include:

- Areas north of Old Main Road on both the southern and northern sides of eastern arm of Fern Tree Drain
- Areas north of Gan Gan Rd near Clark St
- Areas west of One Mile along Back Drain and Main Drain
- Area east of the intersection of Nelson Bay Rd and Latitude Dr

Figure 73 and Figure 74 presents the changes in peak flood level due to conceptual rezoning of the land. This potential rezoning was implemented in the hydraulic model by raising the ground terrain to the Year 2100 1% AEP level. As shown in Figure 73 in the regional model, filling of the rezoned land results in flood level increases of 25 mm in the floodplain at Main Drain. As shown in Figure 74 in the urban Anna Bay model, filling of the potential rezoned land results in flood level increases of up to 100 mm in Fern Tree Drain. In the Clark St low point, flood levels increase by up to 0.25 m.

While filling of potential land rezoning in the floodplain of Main Drain and Back Drain resulted in only 25 mm of flood level increase (in Year 2100 1% AEP), it remains constrained by emergency response options and evacuation access. This area is categorised primarily as flood storage with flood depths greater than 1 m in the Year 2100 1% AEP.

Duration of inundation and lost access should be considered during emergency planning and in particular any shelter-in-place developments. Substantial fill will be required if ground levels are to be raised to the FPL.

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Most of the locations flagged for potential rezoning are on Flood Prone Land (within the PMF), with exception of some locations on higher ground (north of Fern Tree Drain and east of Clark St low point). Areas which may become residential zones and have developments with habitable rooms need to comply with state and local legislation and policy, including the Port Stephens Local Environmental Plan Clause 5.21 and 5.22 and Local Planning Direction 4.1. This includes but is not limited to ensuring developments have appropriate floor levels, hydraulic function is maintained, hazard is not increased, groundwater interaction on inundation and emergency egress requirements are met. The controls outlined in the Port Stephens Development Control Plan should also be considered.

Potential areas flagged in the Clark St Low Point are categorised as flood storage with flood depths are greater than 1 m in the Year 2100 1% AEP. Peak flood levels increase by up to 0.25 m in the Year 2100 1% AEP. It is understood that this area comprises predominantly sand dunes, with high hydraulic conductivity. The TUFLOW model as part of this FRMS is unable to accurately capture the effects of this infiltration. According to the hydraulic modelling as part of this FRMS, these flood level increases exceed acceptable thresholds and therefore, filling of this area is not recommended. However, with additional information and modelling which accounts for the soils in this region, flood level increases may be reduced. The effect of infiltration, however, likely has less impacts to flood levels for short duration and rare events as infiltration is typically a slower process.

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10. OPTIONS ASSESSMENT

10.1. Overview

The 2023 NSW Government Flood Risk Management Manual (Reference 3) separates risk management measures into three broad categories:

Flood modification measures modify the physical behaviour of a flood (depth, velocity and redirection of flow paths) and include flood mitigation dams, retarding basins and levees.

Property modification measures modify land use and development controls. This is generally accomplished through means such as flood proofing (house raising or sealing entrances), strategic planning (such as land use zoning), building regulations (such as flood-related development controls), or voluntary purchase.

Response modification measures modify the community's response to flood hazard by educating flood affected property owners about the nature of flooding so that they can make informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

10.2. Relative Merits of Management Measures

A number of methods are available for assessing the relative merits of competing measures. The benefit/cost approach has long been used to quantify the economic worth of each option, enabling ranking against similar projects in other areas. It is a standard method for using the time value of money to appraise long-term projects in terms of the reduction in flood damages (benefit) compared to the cost of the works. Generally, the ratio expresses only the reduction in tangible damages as it is difficult to accurately include intangibles (such as anxiety, risk to life, ill health and other social and environmental effects).

The potential environmental or social impacts of any proposed flood mitigation measure must be considered in the assessment of any management measure and these cannot be evaluated using the classical benefit/cost approach.

10.3. Flood Modification Measures

Flood modification measures aim to modify the behaviour of a flood itself by reducing flood levels or velocities or by excluding water from areas under threat. These measures usually involve structural works (often permanent, though temporary structures can also be assessed) which are generally installed to modify flood behaviour on a wider scale; and typically include works such as levee banks, retarding basins and drainage networks. Depending on the type of flood behaviour, spatial constraints and catchment conditions, different flood modification measures will be better suited to reducing flood risk than others. A key consideration when assessing flood modification options is ensuring that, in pursuit of reducing flood risk in one area, the option does not adversely affect other areas.

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10.3.1. Options Not Considered Further

A range of other options were identified in the initial assessment and found to not be viable in reducing flood risk or presented significant constraints across other assessed areas, these were discounted with no further assessment undertaken. The following table provides an overview of these options not considered further. The general location of these options have been shown in Figure C1 to Figure C3.

Table 18 Options Not Considered Further

ID	Description	Assessment
M03	Upgrade of Morna Point Rd and Argyle Ave (Anna Bay) stormwater pipes	Works have negligible impact on flood behaviour and property damage but likely has substantial costs.
M08	Detention Basin in the park at Meredith Ave and Mackie St (Lemon Tree Passage)	The park is relatively low lying and is affected by the high ocean tide levels. Therefore, adding storage in this location provided no benefits in terms of property damage and has high associated costs.
M11	Drain at Eucalyptus Drive (One Mile)	Current condition of the drain should be ascertained. Formalisation of the drain was tested and shown to have negligible impacts on flood behaviour and property damage.
M13	New stormwater pipe along Meredith Ave (Lemon Tree Passage) which discharges directly to the ocean	Works have negligible impact on property damage but likely has substantial costs. Raising of the Shearman Ave to allow for evacuation access is not recommended as Shearman Ave acts as a floodway during events. Therefore, road raising would increase flood damage on properties in the area.
M15	Upgrade of stormwater pipes at Essendene Gardens and Hartford St (Mallabula)	Works have negligible impact on trafficability of these roads and property damage. These roads are not considered high priority for evacuation purposes and existing floodwaters in the properties are shallow.
M16	Widening of drain parallel to Wychewood Ave (Mallabula)	Works have negligible impact on property damage as floodwaters in Mallabula are mostly contained within road corridor.
M18	Tilligerry Track stormwater network upgrade	Works have negligible impact on property damages but likely has substantial costs. Greater improvements to flooding in this area are likely achieved by reviewing impacts from Lemon Tree Passage Road.
M22	Upgrade of Gan Gan Rd at Anna Bay Public School	Works have negligible impact on evacuation access as Old Main Road can be used as an alternative access.

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M29	Detention Basin at Hutcheson Rd	Works improve flood affectation downstream of the basin, however worsen flood affectation upstream of the basin.
M34	Pump from One Mile residential area to One Mile Beach	Works are likely to incur high costs with negligible benefits to properties. The works have implementation constraints as the One Mile residential area and One Mile Beach are separated by a sand dune, such that overland flow from the residential area naturally flows towards Main Drain.

10.3.2. Flood Barriers and Levees

Levees are built as means of eliminating the inundation of floors and yards during a flood event (up to the design height of the levee together with a freeboard allowance of typically 0.5 m). Levees can be successfully employed on large river systems where they protect a large number of properties. They often comprise earthen embankments but can also be constructed as concrete walls or other similar structures.

Unless designed for the PMF, levees will be overtopped. Under overtopping conditions, the rapid inundation may produce a situation of greater hazard than exists today. This may be further exacerbated if the community is under the false sense of security that a levee has “solved” the flood problem (as happened with Nyngan in 1990 and Hurricane Katrina in New Orleans, USA).

In the event of levee failure, properties impacted are likely to experience relatively short to no warning time of the failure, resulting in high velocities and high inundation depths in a relatively short period of time and therefore a high provisional hazard. It should be noted that overtopping of a levee is not considered failure of the levee, as the levee may have been designed to overtop in some events. A large number of houses are not built to withstand the hydrostatic pressure that would be present following failure of the levee and ponding of floodwater.

10.3.2.1. Flood Barrier at Blake Pde Park (FM01)

Description	Flood barrier at Blake Pde Basin
Benefits	<ul style="list-style-type: none"> Reduces flood affectation in two properties in frequent events only
Constraints	<ul style="list-style-type: none"> Moderate capital costs and limited benefit to flood damages Visual aesthetics of Blake Pde Park may be impacted. Further upgrade to stormwater pipes along Morna Point Rd are required to reduce flood levels in larger flood events.
Overall Evaluation	Progress to FRMP, including a further detailed feasibility investigation.

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Location and existing flood behaviour

The park located on the northern side Blake Parade, Anna Bay currently acts as a basin during flood events. This basin stores runoff from Dunmore Ave, Morna Point Rd and Blake Parade. At the western side of the basin, the backyards of downstream properties have low ground levels and are inundated with waters from the basin. Estimation of the floor level at the downstream properties indicates that the dwelling may be inundated in current events 5% AEP or rarer.

Proposed option

This option involves construction of a 1 m high flood barrier (for protection up to the current 1% AEP event) at the rear of the downstream properties to prevent water from the basin from entering the lot. The implementation of this option is shown in Diagram 7 as well as in Figure C4.



Diagram 7: Proposed option FM01

Modelled impacts

The changes in the peak flood levels due to the option in the current 10% AEP event is shown in Figure C5. With the options constructed, peak flood level impacts show that the flood barrier does not reduce flood levels in the current 1% AEP event. This is because overland runoff from Morna Point Rd flows into the lot. However, in the current 10% AEP event, it is shown that with the flood barrier the flood extent is reduced in both properties.

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Construction a flood barrier will likely have low environmental impacts as there are no significant changes to flood behaviour. Removal of vegetation and trees may be required to install the flood barrier.

This option does not worsen flood affectation in neighbouring properties therefore is unlikely to have negative social impacts. However, construction of the flood barrier may impact the overall aesthetics of the basin area.

Costs and economic assessment

This option has moderate capital costs. However, it also has minimal impact on reducing flood damages as only two properties may benefit from this option. Given the minimal benefit, this option is unlikely to be economically viable.

Feasibility

Implementation of this option is likely to be constrained by available area and is subject to negotiation with the residents if the flood barrier were to be constructed within their property. Additionally, flap gates are required to ensure that the flood barrier does not prevent runoff from Morna Point Rd from entering the basin.

Evaluation

This option is recommended for progression as a floodplain risk management option, further investigation in the form of a feasibility study would be undertaken to refine and develop the concept before implementation is progressed. The feasibility study has been assigned a high priority while the works implementation is assigned a low priority. This option has moderate costs and may only improve flood affectation for two properties in frequent events only. Furthermore, the floor levels of these properties are estimated based on available LiDAR data. Survey of the existing floor levels of these properties should be undertaken as part of detailed assessments if this option was to progress.

Further testing of constructing a flood barrier as well as improving stormwater pipes along Morna Point Rd showed that for the flood barrier to be effective in the rare events, upgrade to the stormwater pipes would be required.

Anecdotally (from residents in the area), this basin has not been operating properly as waters from surrounding roads are not discharged into the basin. Based on the available 2012 LiDAR, no significant blockages are preventing runoff from discharging to the basin. It is recommended Council investigates the ground levels in the vicinity to ensure that there are no blockages which prevent the basin from capturing runoff efficiently.

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10.3.2.2. Flood Barrier Along Hutcheson Rd (FM02)

Description	Installation of flood barrier in the form of permanent low-level impervious fencing and driveway raising of 3 private properties along Hutcheson Rd.
Benefits	<ul style="list-style-type: none"> Removes above floor flooding in 2 properties in the current 1% AEP event Low capital costs Council has experience implementing similar works
Constraints	<ul style="list-style-type: none"> Minor flood level increase within Hutcheson Rd corridor (+30mm in current 1% AEP). Works may impact existing drainage, and this requires consideration in concept development. Works within private property and will require community consultation.
Overall Evaluation	Progress to FRMP, including a further detailed feasibility investigation.

Location and existing flood behaviour

Along Hutcheson Road and between Dean Parade and Russell St, the ground terrain is such that overland flows from Hutcheson Road flows through properties (in particular, 3 and 5 Hutcheson Road and 9, 11, and 13 Russell Street). The most affected property is 11 Russell St as it is located at the low point.

Proposed option

This option involves constructing a flood barrier along the front of the properties along Hutcheson Road, such that overland flows no longer flow through their properties and flow down Hutcheson Road instead. The required height of this flood barrier is low (0.35 m high), therefore it can be achieved by low level impermeable walls along the property boundary and raising driveways. The implementation of this option is shown in Diagram 8 as well as in Figure C6.

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Diagram 8: Proposed option FM02

Modelled impacts

The changes in the peak flood levels due to the option in the current 10% AEP, 1% AEP, and 1 in 500 AEP event are shown in Figure C7 to Figure C9. As a result of this option, 3 and 5 Hutcheson Road are no longer flooded and 9, 11, and 13 Russell Street have flood levels reduced by up to 0.37 m. There is minor flood level increase (+30 mm) within the road corridor of Hutcheson Road. Changes in peak flood level due to the option in the Year 2100 1% AEP climate change event is shown in Figure C10. While there is less reduction in peak flood levels in Year 2100 in comparison to the current conditions, this option remains effective in reducing peak flood levels.

Social and environmental impacts

This option reduces flood affectation in several properties and without increasing flood levels in neighbouring properties. Flood levels are increased on Hutcheson Road by 30 mm, however this is minor and unlikely to affect road access. There are minimal environmental impacts associated with this option as it involves construction in currently developed land.

Costs and economic assessment

This option has low capital costs and improves flood damages to several properties.

Feasibility

This option features installing low-level impervious fencing and driveway raising of private properties. The proposed works may impact on the function of the existing drainage system; this should be considered as the concept is refined. Consultation and working with the community will be required for these proposed works. Council has experience in implementing similar works at Shoal Bay.

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Evaluation

This option has low costs and relatively simple implementation whilst improving flood affectation at several properties. Therefore, this option is recommended for progression as a floodplain risk management option. Further investigation in the form of a feasibility study would be undertaken to refine and develop the concept before implementation is progressed. The feasibility study has been assigned a high priority while the works implementation is assigned a medium priority.

10.3.3. Flood Mitigation Dams and Retarding Basin

DESCRIPTION

Dams have been used in rural areas of NSW to reduce peak flows downstream. However, typically their main purpose is for water supply. Dams are rarely used as a flood mitigation measure on account of the:

- high cost of construction,
- high environmental damage caused by the construction,
- possible sterilisation of land within the dam area,
- high cost of land purchase,
- risk of failure of the dam wall,
- likely low benefit cost ratio, and
- lack of suitable sites, as a considerable volume of water needs to be impounded by the dam in order to significantly reduce flood levels downstream.

Based on an assessment of the catchment and taking into account the above factors, flood mitigation dams were not considered further.

Retarding basins are small-scale flood mitigation dams commonly used in urban catchments for the same reasons. A retarding basin provides temporary storage for floodwaters, and works by capturing floodwaters during an event, to be released at a lower flow rate once the peak of the flood has passed. Retarding basins can be an effective means of reducing peak flood levels, however depending on the outlet design and operation, may increase the duration of flooding by prolonging the release of stored floodwaters.

DISCUSSION

There are a number of challenges and inherent disadvantages associated with retarding basins, that need to be carefully evaluated. These include:

- Availability of land and appropriate topography – a significant area is needed to achieve the necessary storage capacity,
- Public safety during and following a flood event, particularly for basins of significant area and/or depth,
- Risk of overtopping or failure if the basin is already full when additional rainfall occurs (e.g. long duration floods or multi-burst storms),
- Ongoing maintenance to ensure structural integrity of the basin wall/embankment, and to prevent outlet pipes and gates from silting up or being damaged.

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10.3.3.1. Detention Basin at Meredith Ave and Kenneth Pde (FM03)

Description	Detention Basin at Meredith Ave and Kenneth Pde
Benefits	<ul style="list-style-type: none"> Flood levels reduced along evacuation route (Meredith Ave) in rare events Flood levels reduced over a large area however only by up to 60 mm No existing buildings or developments within the proposed basin
Constraints	<ul style="list-style-type: none"> Land acquisition required. High capital costs and BC ratio <1.
Overall Evaluation	Not progressed to FRMP

Location and existing flood behaviour

Meredith Ave at Lemon Tree Passage is affected by overland flow which is unable to discharge due to high ocean tide levels. The area is currently greenspace and receives overland flows from the south and west (from Meredith Ave). The area is in the upstream areas of the catchment.

Proposed option

This option involves constructing a detention basin at the southwestern corner of the intersection of Meredith Ave and Kenneth Pde. The crest level of the basin embankment is required to be 1.2 m high (inclusive of a 0.5 m freeboard) to sufficiently store a current 1% AEP event. As the basin is located in the upstream areas of the catchment, areas downstream of the basin will remain subject to overland flow from local rainfall. The implementation of this option is shown in Diagram 9 as well as in Figure C11.



Diagram 9: Proposed option FM03

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Modelled impacts

The changes in the peak flood levels due to the option in the current 20% AEP to PMF events are shown in Figure C12 to Figure C19. In the current 1% AEP event, flood levels are reduced by up to 60 mm downstream of the basin, 3 properties become no longer flooded above floor level and 14 properties have reduced flooding above floor level by up to 50 mm. Within the basin, peak flood levels increase, however no existing properties are affected by this. Changes in peak flood level due to the option in the Year 2100 1% AEP climate change event is shown in Figure C20. In the Year 2100 climate change conditions, the option lowers peak flood levels by up to 50 mm in areas downstream of the basin.

Social and environmental impacts

This option features moderate environmental impacts as the basin footprint is within greenspace and tree removal will be required. This option does not reduce flood extent significantly and does not improve evacuation access as Meredith Ave remains inundated.

Costs and economic assessment

This option features high costs as it involves construction of a basin as well as restructuring of underground stormwater structures. Table 19 presents the reduction in flood damages if the option were to be implemented. A reduction in average annual damages of \$28,900 is estimated. For this option to be economically viable, the costs of this option would need to be less than \$500,000.

Table 19: Reduction in average annual damages – Detention Basin at Meredith Ave and Kenneth Pde

Event (Current)	Reduction in Property Flooding	Reduction in Above Floor Flooding	Reduction in Damages
20% AEP	-9	1	\$61,000
10% AEP	-1	-2	-\$46,000
5% AEP	0	0	\$175,000
2% AEP	3	1	\$269,000
1% AEP	2	3	\$322,000
0.5% AEP	3	6	\$587,000
0.2% AEP	1	3	\$755,000
PMF	0	4	\$587,000
Average Annual Damages Reduction			\$29,000

Feasibility

This option features a detention basin at a greenfield site with a relatively low embankment.

Evaluation

This option has high costs and whilst improving flood affectation only at several properties. Therefore, this option is not recommended for progression as a floodplain risk management option.

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Channel works include any measure that increases the hydraulic efficiency of the main channel or immediate overbank areas. In this way, flood levels are reduced by either increasing the waterway area or increasing the velocity of flow. Channel modifications can help to reduce peak upstream flood levels by improving conveyance, although such measures may also increase flood levels in adjacent or downstream locations. Changes to velocity are also likely to occur because of changing the channel shape or size. In general, for channel modifications to be effective in reducing flood levels, significant excavation is required which can have a range of environmental impacts, including removal of riparian vegetation, and as a result, loss of native habitat and in some cases, bank stability. Measures include:

- vegetation or other forms of clearing,
- channel widening,
- dredging,
- concrete lining,
- creek shortening,
- removal, raising or upgrading of hydraulic structures (bridges, roads).

All the above measures have been employed at various times on different river systems in NSW. However, they may introduce additional problems such as bank erosion, sedimentation, issues with land ownership and permission, increases in flood levels downstream, and these measures require an on-going maintenance regime.

Local drainage systems typically reach capacity in an event equivalent to a 0.2EY, and excess runoff flows overland, potentially posing a threat to pedestrians, motorists, and if of sufficient depth, properties. The options assessed in the following section are intended to decrease the flood risk associated with overland flow. It is noted that these options are unlikely to have significant benefits in terms of reducing property damages, however the reduction in severity or frequency of nuisance inundation, particularly along roads, could be beneficial to the community.

Flood gates or rubber flap valves allow local runoff to be drained from an area (say an area protected by a levee) when the external level is low, but when the river is elevated, the gates prevent floodwaters from the river entering the area.

Pumps are generally also associated with levee designs. They are installed to remove local runoff behind levees when flood gates are closed or if there are no flood gates.

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10.3.4.1. Diversion Drain Near Purcell Ave, Lemon Tree Passage (FM04)

Description	Construction of drain up to 1.5 m depth drain from spillway of existing basin
Benefits	<ul style="list-style-type: none"> Reduces peak flood levels by up to 120 mm
Constraints	<ul style="list-style-type: none"> Removal of vegetation for drain Access to drain site for construction
Overall Evaluation	Progress to FRMP, including a further detailed feasibility investigation.

Location and existing flood behaviour

There is an existing farm dam west of Purcell Ave at Lemon Tree Passage. The spillway of this dam flows with the natural terrain and east to inundate properties along Purcell Ave.

Proposed option

This option involves constructing a drain which runs southeast such that it diverts the water from the spillway to the greenspace downstream without passing through existing properties. The implementation of this option is shown in Diagram 10 as well as in Figure C21.



Diagram 10: Proposed option FM04

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Modelled impacts

The changes in the peak flood levels due to the option in the current 10% AEP, 1% AEP and PMF events are shown in Figure C22 to Figure C24. In the current 1% AEP event, peak flood levels are reduced by up to 120 mm and one dwelling has above floor flooding reduced by to 47 mm. Properties along Purcell Ave remain inundated above floor as they are also affected by overland flow from the local catchment. Figure C25 presents the changes in peak flood levels in the Year 2100 1% AEP event due to the option. The Year 2100 1% AEP changes in peak flood levels follow a similar pattern to the current condition changes.

Social and environmental impacts

This option has low environmental impacts and only requires vegetation removal along the proposed channel.

Costs and economic assessment

This option features low costs however it also has limited benefits to flood damages as it only reduces flood affectation to one property.

Feasibility

The option features simple implementation. However, access to the site of the proposed drain may be a constraint as it is surrounded by dense vegetation.

Evaluation

This option is recommended to be progressed to the FRMP as it provides some improvement to flood affectation and has low capital costs. Further investigation in the form of a feasibility study would be undertaken to refine and develop the concept before implementation is progressed. The feasibility study has been assigned a high priority while the works implementation is assigned a low priority.

10.3.4.2. Drain at Hawkes Way, Boat Harbour (FM05)

Description	Construction 1 m wide 1.5 m depth drain along the Castaway Place Asset Protection Zone.
Benefits	<ul style="list-style-type: none"> Removes above floor flooding in 3 properties in events up to the current 1% AEP Low capital costs
Constraints	<ul style="list-style-type: none"> Requires approval from external agencies (NPWS)
Overall Evaluation	Not progressed to FRMP

Location and existing flood behaviour

Several properties along Hawkes Way have shallow inundation (<0.1 m depth in 1% AEP) due to overland flows from the catchments to the west. There is an existing pit and pipe which captures some flow from the rear of the properties to the stormwater network along Hawkes Way. However, there is still some flow which is not captured by the pit and inundates the properties.

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Proposed option

This option involves constructing a channel which drains towards the north and discharges to the low point north of Castaway Cl. This proposed channel would intercept flows from the west and direct them away from the properties along Hawkes Way and towards the existing low point north of Castaway Cl. Alignment of this proposed drain is shown in Diagram 11 as well as in Figure C26.

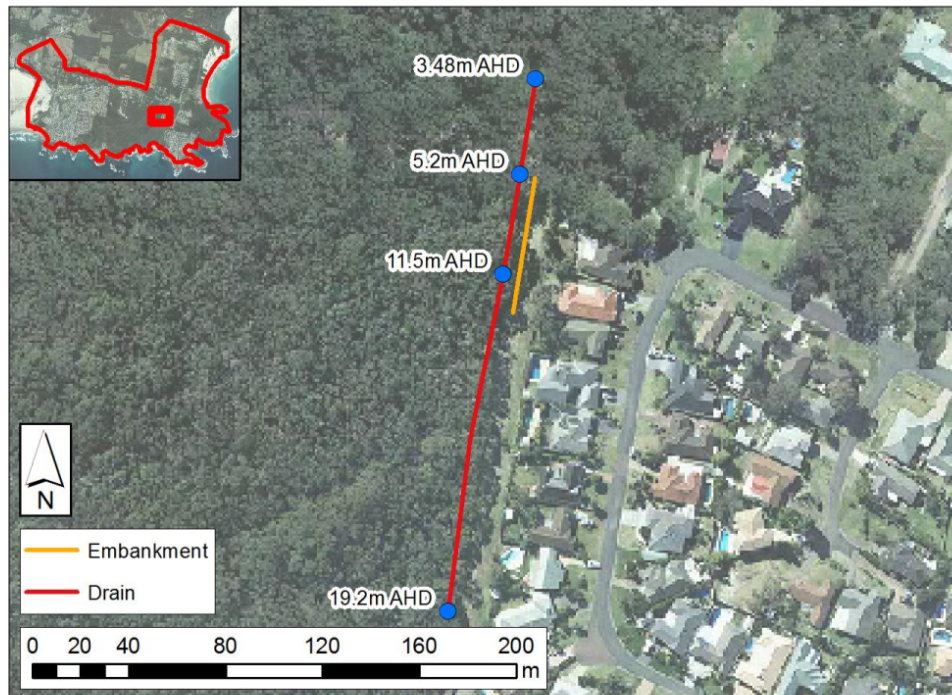


Diagram 11: Proposed option FM05

Modelled impacts

Impacts on the current 10% AEP, 1% AEP, and 1 in 500 AEP peak flood level are shown in Figure C27 to Figure C29. This option reduces the current 1% AEP flood extent such that properties along Hawkes Way are no longer affected. Figure C30 presents the peak flood level impacts for the 1% AEP event in the year 2100 and shows that this option will likely remain effective.

Social and environmental impacts

This option allows several properties along Hawkes Way to be flood free without increasing flood affectation to neighbouring properties. As the option is along an existing APZ, its environmental impacts are minimal.

Costs and economic assessment

This option features low capital costs. However, there are minor property benefits as the existing flood depths in this area are shallow.

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Feasibility

The alignment of the proposed channel does not run through any private properties, therefore, no land acquisition or access to private property is required. This option has been suggested internally by PSC; however, it was rejected by external agencies (National Parks and Wildlife Services) as they did not support the conversion of the existing Asset Protection Zone (APZ) to a multi-purpose APZ.

Evaluation

Given the constraints, this option is not recommended for progression as a floodplain risk management option.

10.3.4.3. Drainage of Davidson St Low Point (FM06)

Description	Additional pipe connecting Davidson St low point to the existing stormwater network.
Benefits	<ul style="list-style-type: none"> Reduces flood extent such that above floor flooding reduces from four properties to one.
Constraints	<ul style="list-style-type: none"> New pipe network passes under existing private property. New pipe network passes under Campbell Ave and may require a deep trench excavation. Current 1% AEP event only impacts four residential properties. Annual average damages are unlikely to be significantly reduced.
Overall Evaluation	Progress to FRMP, including a further detailed feasibility investigation.

Location and existing flood behaviour

A trapped low point is located that the rear of the properties bounded by Davidson St, Margaret St, Campbell Ave, and Pacific Ave. In a current 1% AEP event, four properties are inundated above floor. As the low point captures runoff from the properties along these roads only, other options such as stormwater pits, which capture runoff prior to inflow to the low point, were not considered.

Proposed option

This option involves installation of a stormwater pit and pipe (1 x 0.45 m diameter) which connects to the existing stormwater network at Campbell Ave and discharges to McKinley Swamp. The implementation of this option is shown in Diagram 12 as well as in Figure C31.

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Diagram 12: Proposed option FM06

Modelled impacts

Impacts on the current 10% AEP, 1% AEP, and 1 in 500 AEP peak flood level are shown in Figure C32 to Figure C34. With the proposed additional drainage, in the current 1% AEP event, peak flood level reduces by 140 mm within the low point. The number of properties flooded above floor reduce from 4 to 1 in the current 1% AEP event and 7 to 5 in the current 1 in 500 AEP event. Figure C35 presents the changes in peak flood levels in the Year 2100 1% AEP event due to the option. The Year 2100 1% AEP changes in peak flood levels follow a similar pattern to the current condition changes, however the benefits are to a lesser extent.

Social and environmental impacts

This option features low environmental impacts as it involves construction in areas which are currently urbanised.

Costs and economic assessment

This option features high capital costs as it involves installation of underground structures within an existing property. This option only benefits several properties are likely to have a benefit cost ratio less than 1.

Feasibility

Construction of the proposed additional drainage constrains this option as its footprint extends into an existing property and full or partial acquisition of this property may be required. Community consultation and liaison with the owner of this property will be required.

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Evaluation

This option is recommended to be progressed to the FRMP as it provides some improvement to flood affectation but has high capital costs. Further investigation in the form of a feasibility study would be undertaken to refine and develop the concept before implementation is progressed. The feasibility study has been assigned a medium priority while the works implementation is assigned a low priority.

10.3.4.4. Reinststate Floodgates Along Main Drain (FM07)

Description	Reinststate existing floodgates along Main Drain
Benefits	<ul style="list-style-type: none"> • Reduce in inundation time in Main Drain floodplain
Constraints	<ul style="list-style-type: none"> • Does not improve flood affectation above floor in any properties. • High capital costs
Overall Evaluation	Not progressed to FRMP

Location and existing flood behaviour

Along Main Drain 800m west of Port Stephens Dr, there are existing floodgates (3 gates of 1.8 m width by 1.55 m height), which prevents backwater from high tidal levels. Currently, the floodgates are non-operational. These floodgates operated by the Anna Bay Drainage Union. In a current 1% AEP event, Main Drain is affected by tidal inundation with deep floodwaters (>1 m) and low flood velocities (<0.5 m/s).

Proposed option

This option involves reinstating the existing floodgates. The implementation of this option is shown in Diagram 13 as well as in Figure C36.

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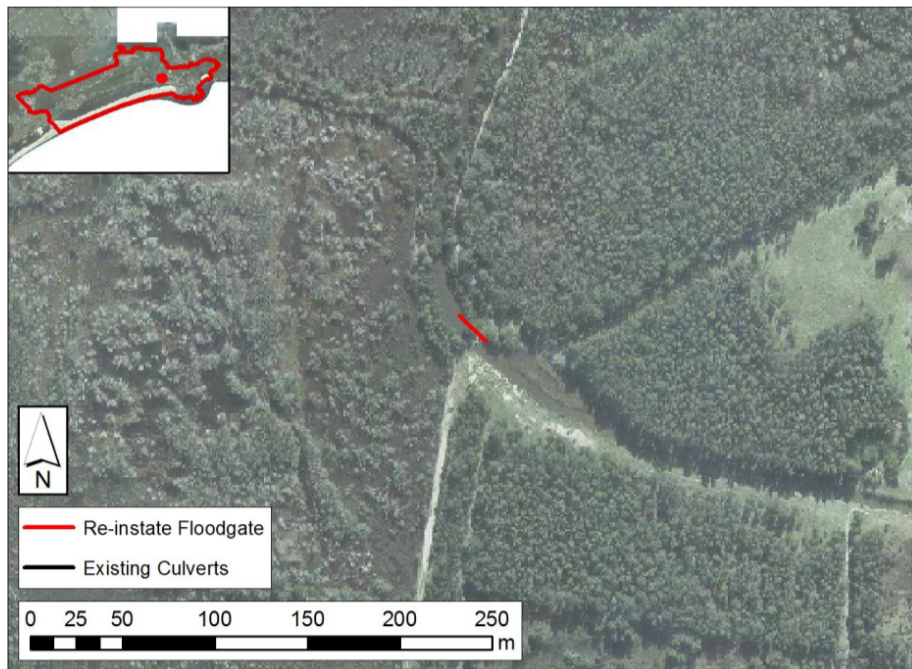


Diagram 13: Proposed option FM07

Modelled impacts

Figure C37 presents the changes in peak flood level due the option. In the current 1% AEP event, this option has negligible impact on peak flood levels.

Social and environmental impacts

In the current 1% AEP event, there is no change to the number of properties flooded above floor and evacuation access does not significantly improve.

Costs and economic assessment

This option features moderate capital costs and negligible reduction in flood damages as flood affectation in properties have not been reduced. Therefore, this option is not economically viable.

Feasibility

Reinstatement of these floodgates is simple to implement. However, these floodgates are operated and maintained by the Anna Bay Drainage Union and negotiation with Anna Bay Drainage Union will be required.

Evaluation

This option is not recommended to be progressed to the FRMP as it provides negligible improvement to flood affectation in rare events and the operation/maintenance of the floodgates are undertaken by Anna Bay Drainage Union.

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10.3.4.5. Stormwater Drainage at Intersection of Tanilba Ave and Lloyd George Grove (FM08)

Description	Installation of a stormwater pipeline which drains the sag at Lloyd George Grove and discharges west of Tanilba Ave.
Benefits	<ul style="list-style-type: none"> • Reduces peak flood hazard in the current 10% AEP event from H3 (unsafe for vehicles, children and elderly) to H1 (generally safe). • Reduces flood extent in two private properties in the current 1% AEP event • Does not require land acquisition or private property access • Minimal environmental impacts
Constraints	<ul style="list-style-type: none"> • High capital costs • Requires deep trench excavation (approximately 2 m) • Requires shutdown of Lloyd George Grove and Tanilba Ave during construction
Overall Evaluation	Not progressed to FRMP

Location and existing flood behaviour

East of its intersection with Tanilba Ave, Lloyd George Grove sags such that in the current 10% AEP the flood depths are greater than 0.5 m and the peak flood hazard is H3 (unsafe for all vehicles, children, and the elderly). In the current 1% AEP event, two properties on the south side of Lloyd George Grove are affected on their front yards (no above floor flooding).

Proposed option

This option involves installation of a new stormwater pipeline (of 0.6 m diameter and 200 m length) which runs west underneath Tanilba Ave. The implementation of this option is shown in Diagram 14 as well as in Figure C38.

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Diagram 14: Proposed option FM08

Modelled impacts

Impacts of this option on the current 1% AEP peak flood level is shown in Figure C39. With the option, the current 1% AEP flood extent is contained within the road corridor and no longer affects the properties along Lloyd George Grove. Modelling of the current 10% AEP design event also revealed that peak flood hazards are reduced to H1 (generally safe). Flood levels are increased by up to 60 mm downstream of the outlet of the proposed pipeline.

Social and environmental impacts

With the option Lloyd George Grove becomes trafficable in the current 10% AEP, however it is considered low priority for evacuation purposes and alternative routes are available. Properties along Lloyd George Grove are no longer flooded in this area and increases in flood levels downstream of the pipeline outlet does not affect any existing properties.

This option has relatively low environmental impacts as its footprint is within an existing road corridor.

Costs and economic assessment

This option likely features moderate to high capital costs as it requires both excavation of a deep trench and installation of a pipe. As the option only has minor property benefits, the reduction in AAD is minimal it is expected that the benefit to cost ratio is very small ($\ll 1$).

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Feasibility

This option involves installation of a 0.6 m pipeline through an existing road corridor. Although land acquisition is not required, installation of the pipeline will require shutdown of both Tanilba Ave and Lloyd George Grove.

Due to the high point along Tanilba Ave which the pipeline will need to negotiate, installation of this pipeline will require excavation of a deep trench (approximately 2 m).

Evaluation

This option has notable benefits to Lloyd George Grove and two properties along it. However, as Lloyd George Grove is not considered a priority evacuation route, benefits are only seen in a minimum number of properties, and high capital costs, this option is not recommended.

10.3.4.6. Channel and Drainage Upgrade at Anna Bay near Gan Gan Road (FM09)

Description	Upgrade of Fern Tree Drain and additional stormwater network upgrades at Anna Bay near Gan Gan Rd
Benefits	<ul style="list-style-type: none"> Reduction in peak flood levels and above floor flooding in rare events
Constraints	<ul style="list-style-type: none"> High capital costs Complex implementation
Overall Evaluation	Progress to FRMP, including a further detailed feasibility investigation.

Location and existing flood behaviour

Along Gan Gan Rd at Anna Bay there are several low points near McKinley Swamp, Morna Point Rd, and the Essington Way basin. Of these low points, the intersection with Morna Point Rd is most densely populated and in the current 1% AEP event, 8 properties are inundated above floor level. Around McKinley Swamp three properties inundated above floor level, whereas no properties are inundated above floor from Essington Way Basin.

In the current 10% AEP event, Old Main Rd is considered generally safe to be travelled on, whereas Gan Gan Rd is inundated near the Essington Way basin. In the current 1% AEP event, Old Main Rd is generally safe except on the eastern end, whereas Gan Gan Rd is mostly inundated.

As there were no properties inundated above floor level around Essington Way and Old Main Rd could be used for evacuation access, no mitigation options have been proposed for the upgrade of Gan Gan Rd at Essington Way.

Proposed option

This option comprises several features:

- Additional drainage pit and pipe (3 pipes of 1.2 m diameter) which captures water from the Morna Point Rd and Gan Gan Rd intersection and directs flows to the eastern arm of Fern Tree Drain

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- Installation of a 15m floodway which runs from McKinley Swamp to the western arm of Fern Tree Drain
- Construction of a culvert under Old Main Rd to ensure connectivity of the installed 15 m floodway
- Re-directing Gan Gan Rd stormwater pipes to the western arm of Fern Tree Drain
- Widening Fern Tree Drain by 3 m to ensure there is enough capacity to receive the additional flows from the other flood modification features above.

The implementation of this option is shown in Diagram 15 as well as in Figure C40.

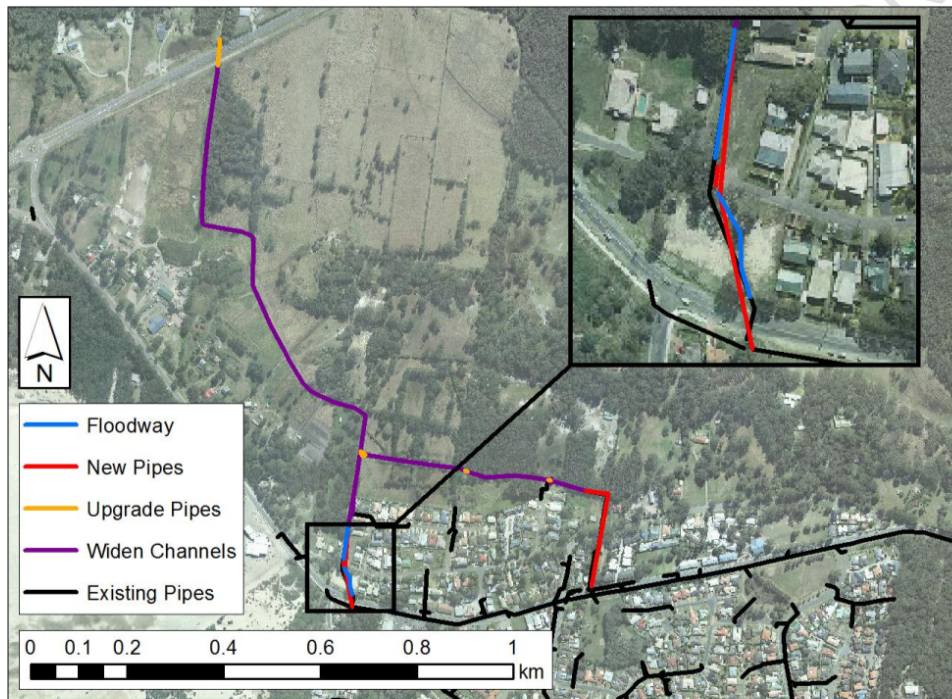


Diagram 15: Proposed option FM09

Modelled impacts

Figure C41 to Figure C48 presents the peak flood level impacts with the option for a range of events from current 20% AEP to the PMF. As shown in Figure C45, in the current 1% AEP event, flood levels are reduced at the intersection of Morna Point Rd and Gan Gan Rd by up to 0.27 m and within McKinley Swamp by up to 0.31 m. Flood extent along Gan Gan Rd near Morna Point Rd also reduced. Peak flood levels increase within Fern Tree Drain by up to 50 mm, however there are no existing buildings or roads affected by this.

Peak flood hazards along Gan Gan Rd and Campbell Ave have reduced from H3 to H1. A total of 9 properties are no longer flooded above floor level.

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Figure C49 presents the peak flood level impact with the option in the 1% AEP event in year 2100. In the year 2100, the option produces similar patterns in peak level impacts as it does in the current climate. Peak flood levels are reduced by up to 0.31 m at Morna Point Rd and Gan Gan Rd and up to 0.4 m in McKinley Swamp.

Social and environmental impacts

This option produces minimal environmental impacts as its footprint are within currently urbanised areas.

This option reduces above floor flooding in a number of properties and reduces flood hazards along Gan Gan Rd. However, this option also increases flood levels within Fern Tree Drain and may increase flood affectation on the land neighbouring Fern Tree Drain.

Costs and economic assessment

This option features high costs as it involves construction of multiple elements. Table 20 presents the reduction in flood damages if the option were to be implemented. A reduction in average annual damages of \$56,800 is estimated. For this option to be economically viable, the costs of this option would need to be less than \$990,000.

Table 20: Reduction in average annual damages – Channel and drainage upgrade at Anna Bay

Event (Current)	Reduction in Property Flooding	Reduction in Above Floor Flooding	Reduction in Damages
20% AEP	1	0	\$5,000
10% AEP	-1	0	-\$2,000
5% AEP	5	0	\$17,000
2% AEP	9	1	\$156,000
1% AEP	22	9	\$1,254,000
0.5% AEP	28	22	\$3,122,000
0.2% AEP	29	28	\$5,459,000
PMF	43	57	\$15,879,000
Average Annual Damages Reduction			\$57,000

Feasibility

Implementation of this option is highly complex at it involves construction of multiple elements. Construction of the additional pipes from McKinley Swamp to the Fern Tree Drain, the additional pipe network from the Morna Point Rd and Gan Gan Rd intersection, and the floodway is likely to required land acquisition or implementation of easements on existing properties. Construction of the culvert (as part continuing the floodway) underneath Old Main Rd will require shutdown of Old Main Rd.

Evaluation

This option has complex implementation and high capital costs however as it significantly reduces flood damages it is recommended that this option is progressed. Further investigation in the form of a feasibility study would be undertaken to refine and develop the concept before implementation is progressed. The feasibility study has been assigned a medium priority while the works implementation is assigned a low priority.

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10.3.4.7. Clark St Low Point (FM10)

The Clark Street catchment has been included in the Anna Bay town planning strategy (Reference 23) as a location flagged for further development. This area is a trapped low point and has existing pumps which pump water from this area to the stormwater network along Gan Gan Road. The existing pump is a Grundfos AP100.100.45. Upgrade to the existing pumps have been discussed in the 2018 Flood Study (Reference 1) and it was found that the pumping rate (44 L/s) is insignificant in comparison to the catchment inflow rates (2 m³/s). The substratum of the area is predominantly sand with high infiltration. Unfortunately, the effect of this infiltration and the interaction with groundwater cannot be modelled accurately within the existing hydraulic model.

A variety of options to mitigate/reduce the impact of flooding have previously been considered for the Clark St low point. In recent times, the catchment has been investigated in detail by engineering consultants to support a proposed development in the area. Hydraulic modelling has been undertaken with particular focus on the local groundwater and infiltration interaction. The investigation has developed a proposed mitigation solution for the catchment. Further information should be sought from Council regarding this mitigation solution and the associated modelling. The proposed drainage mitigation option developed is consistent with a mitigation option proposed in the adopted 2018 Flood Study (Reference 1).

Should funding be available, it is considered appropriate to pursue the proposed mitigation option from an engineering perspective given the resulting reduction of flood risk on the local floodplain. Please note that further feasibility studies may be required by Council to confirm the viability of the option including the resultant social, environmental and economic impacts.

10.3.4.8. Upgrade Drainage at Lemon Tree Passage Road at Tanilba Bay and Mallabula (FM11)

Description	Drainage upgrade at Lemon Tree Passage Road at Tanilba Bay and Mallabula
Benefits	<ul style="list-style-type: none"> Reduces flood affectation to properties along the northern side of Lemon Tree Passage Road
Constraints	<ul style="list-style-type: none"> Further works are required to ensure properties downstream of Lemon Tree Passage Road will not be affected.
Overall Evaluation	Progress to FRMP, including a further detailed feasibility investigation.

Location and existing flood behaviour

Lemon Tree Passage Road (LTP Rd) passes to the south of Tanilba Bay and is the main regional road connecting Tanilba Bay, Mallubula, and Lemon Tree Passage to the wider Newcastle Area. Lemon Tree Passage Road is not overtopped in the current 1% AEP event at Tanilba Bay, however it is overtopped east of Mallubula by less than 100 mm. In the current 1% AEP event, there are several locations where overland flow from the local catchment at Tanilba Bay ponds against the road. These locations featured high flood depths along the north side of the road and large flood level differences between the northern (upstream) side and southern (downstream) side of the road.

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Some notable locations along Lemon Tree Passage Road where ponding occurs are:

- Channel downstream of Tilligerry Trk and President Poincare Parade – Two existing channels join just upstream of LTP Rd and passes under it via a culvert featuring 2 pipes of 0.9 m diameter. The culverts discharge into a channel downstream within Tanilba Bay Golf Course. In the current 1% AEP event, within the channel, peak flood depths are up to 1.55 m. The channel overtops its banks and flows west, ponding against the north side of LTP Rd. LTP Rd is set ~180 m (at the channel) from residential properties. Therefore, improvements to the culvert under LTP Rd alone is unlikely to significantly improve flooding at residential properties. However, it will allow upstream drainage upgrades to be more effective.
- Intersection of Ave of the Allies and LTP Rd – The existing stormwater network captures water from Tilligerry Trk, Pollus Pde, and Ave of the Allies to a channel which flows west and joins with the channel downstream of Tilligerry Trk and President Poincare Pde. There is one existing culvert however it is only a 0.375 m pipe. In the current 1% AEP event, Ave of Allies have flood depths up to 0.5 m and flood levels of 7.6 m AHD. Whereas, south of LTP Rd flood levels are 7.2 m AHD.
- Intersection of President Wilson Walk and Lloyd George Grove – The existing stormwater network captures water from Presidential Wilson Walk and Lloyd George Grove and runs through LTP Rd via a 1.05 m pipe. The stormwater pipeline continues south and discharges to a channel within Tanilba Bay Golf Course. In the current 1% AEP event, the intersection has peak flood depths up to 0.71 m. Along President Wilson Walk peak flood levels are flat (indicating ponding) at 8.13 m AHD and several commercial properties are inundated.
- Area south of Strathmore Road and Mallabulla Sporting Complex – An existing channel runs east along the north side of LTP Road until it reaches a culvert east of Mallubula and passes under LTP Rd. Residential properties along the south side of Strathmore Rd are set back from LTP Rd by at least 50 m and therefore are lower flood affectation. In the current 1% AEP event, flood depths near the residential properties are up to 0.3 m. Peak flood levels are flat and only vary from 8.28 m AHD near the residential properties to 8.27 m AHD near Mallabulla Sporting Complex. Peak flood levels only drop 7.91 m AHD as it reaches the culvert crossing LTP Rd. LiDAR of the terrain in this area show that there is a natural slope from the north to south side of LTP Rd, indicating that without LTP Rd waters would have naturally flowed south.

Proposed option

Drainage at LTP Rd is complex and solutions to the flood affectation in this area requires in depth investigation to ensure appropriate a suitable solution is attained. Therefore, this option involves a recommendation that council undergoes a detailed assessment of LTP Rd drainage at Tanilba Bay.

To demonstrate the potential benefits of this option, pipes upgrades have been implemented in the TUFLOW. This is shown in Diagram 16 as well as in Figure C50.

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Diagram 16: Proposed option FM11

Modelled impacts

Several preliminary options have been modelled in TUFLOW including:

- Upgrade of the cross drainage culvert west of the intersection of Pollus Pde and LTP Rd from 2 x 0.9 m Pipe to 2 x 1.2 m (width) x 0.9 m (height) box culverts.
- Widening of the channel downstream of the above cross drainage culvert.
- Upgrade to the culvert connecting channels near the rear of 37 Tilligerry Trk from 1 x 0.9 m Pipe to 2 x 0.9 m Pipe.
- Upgrade of the cross drainage culvert and its downstream pipes at President Wilson Walk by installing an additional barrel (of the same size) to its existing pipeline.
- Installation of a new cross drainage culvert (2 x 1.2 m diameter pipe) along LTP Rd south of Strathmore Rd.

The changes in peak flood level due to these changes in the current 1% AEP event are shown in Figure C51.

Social and environmental impacts

Improvement to LTP Rd drainage will improve flood affectation particularly at properties near President Wilson Walk, Lloyd George Grove, Ave of Allies, Pollus Pde, and Tilligerry Trk. However, reduction in flood levels north of LTP Rd will likely increase flood levels in Tanilba Bay Golf Course. Options to mitigate these adverse impacts will need to be investigated.

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Improvement to LTP Rd drainage will alter the flood behaviour from the existing. However, LiDAR of ground levels show that in general the north slopes towards the south such that water should naturally flow from north to south if LTP Rd was not present.

Costs and economic assessment

Upgrade of drainage to the LTP Rd will likely incur high capital costs, however it may improve flood damages over a large area. No cost benefit analysis has been conducted as part of this FRMS.

Feasibility

The construction phase of the drainage upgrade of LTP Rd will require shutdown of the road and may cause significant disruption to the community.

Evaluation

Preliminary options for drainage upgrade have been modelled, and they show improvements to flood affectation. It is recommended that a further detailed assessment of the drainage along Lemon Tree Passage Road is undertaken before implementation is progressed. The detailed investigation has been assigned a high priority while the works implementation is assigned a medium priority.

10.3.5. Flood Access

DESCRIPTION

One of the main ways of improving evacuation is to ensure that there are adequate evacuation routes available and appropriate warnings as to when the routes will become impassable.

DISCUSSION

Maintaining appropriate access to or from affected areas during times of flooding is important to ensure that:

- people have the chance to evacuate themselves and valuables/belongings before becoming inundated or trapped by rising floodwaters,
- emergency services (NSW SES, ambulance, police, etc.) are not restricted or exposed to unnecessary hazards in carrying out their duties, and
- areas are not isolated for extended periods of time, preventing people from going about their normal routines or business or restricting access to essential services.

There are a number of issues to be considered in raising roads including:

- the relatively high cost,
- the level they should be raised to,
- how much benefit is provided,
- whether the raising of the road causes an unacceptable hydraulic impact, and
- the entire evacuation route needs to be raised to a minimum serviceability level from the affected area to high ground.

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10.3.5.1. Upgrade Drainage at Lemon Tree Passage Road at Salt Ash (FM12)

Description	Upgrade of cross drainage at Lemon Tree Passage Rd at Salt Ash
Benefits	<ul style="list-style-type: none"> Reduces road overtopping in frequent events
Constraints	<ul style="list-style-type: none"> High capital costs Cross drainage requires maintenance to be effective
Overall Evaluation	Progress to FRMP, including a further detailed feasibility investigation.

Location and existing flood behaviour

Lemon Tree Passage Rd runs east west connecting suburbs (such as Tanilba Bay, Mallabula and Lemon Tree Passage) in the Tilligerry Peninsula to the mainland areas of Port Stephens and the Hunter Region via Nelson Bay Road.

There are 15 existing sets of cross drainage culverts along Lemon Tree Passage Rd (from Michael Dr to the eastern end of Rookes Rd). Most of these culverts connect drains from the northern side of the Lemon Tree Passage Rd to drains downstream which eventually discharge to Tilligerry Creek.

Community consultation has indicated that these culverts frequently become blocked by debris. There are no existing culverts along Lemon Tree Passage Rd from Rookes Rd to Tanilba Bay, despite several locations of overtopping.

Lemon Tree Passage Rd is a regional road which is subject to overtopping during frequent events (current 20% AEP). The road overtops at several locations including at its intersection with Michael Dr and Rookes Rd and near 160 Lemon Tree Passage Rd.

Lemon Tree Passage Rd and areas north of it are dominated by local catchment rainfall events. Runoff from local catchments from the north overtops the road at several locations. However, these areas are affected by tide levels as high tailwater levels reduce the flow through the culverts. Lemon Tree Passage Rd is overtopped by local catchment flows rather than backwater from Tilligerry Creek in the current 1% AEP ocean level. However, as sea level rises with climate change, the forecasted 0.9 m sea level rise backwaters Lemon Tree Passage Rd.

Proposed option

This option involves upgrading of the cross drainage culverts along Lemon Tree Passage Rd to achieve flood immunity in the current 10% AEP event. This involves increasing cross drainage capacity by one additional barrel (with the same size as the existing) to each set of culverts.

The additional barrel was chosen to be the same size as the existing to ensure that the culvert had enough ground cover without raising the road. The implementation of the option in the TUFLOW model is shown in Diagram 17 as well as Figure C52. Additional works involving expanding the upstream and downstream drains in the immediate surrounds of the inlet and outlet may be required to ensure efficient capture and discharge of flow.

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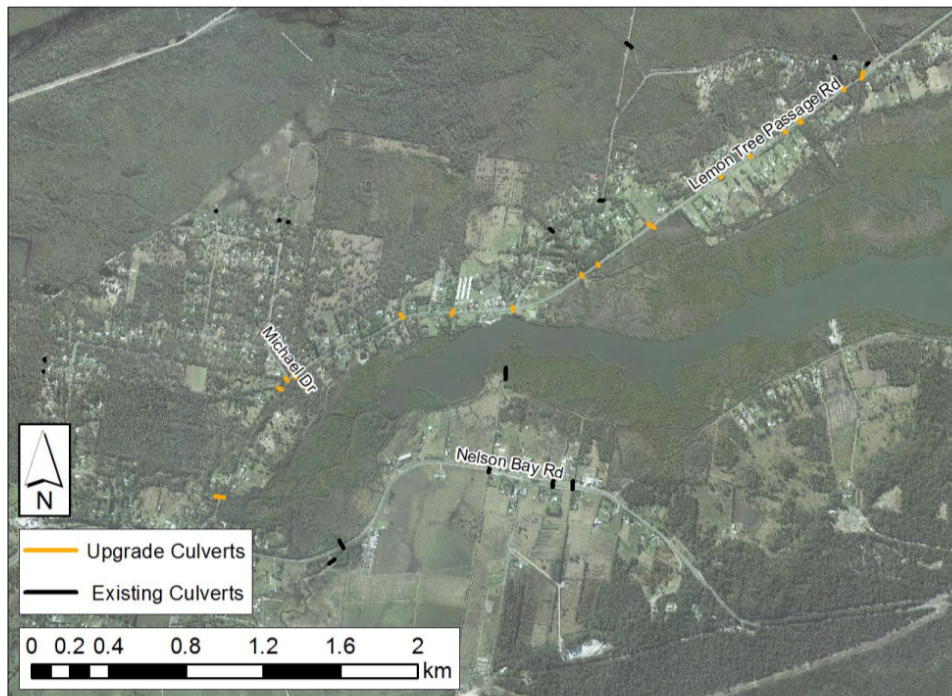


Diagram 17: Proposed option FM12

Modelled impacts

Figure C53 presents the changes in peak flood level in the current 10% AEP event when the option is in place. With the option, Lemon Tree Passage Rd is no longer overtopped in the current 10% AEP event and peak flood levels in the area are reduced by up to 0.7 m (near the eastern intersection of Lemon Tree Passage Rd and Rookes Rd).

In the current 1% AEP event, Lemon Tree Passage Rd remains overtopped, and the number of properties inundated above floor level is not reduced. However, on local roads which feed onto Lemon Tree Passage Rd such as President Wilson Walk and Lloyd George Grove, flood hydraulic hazards reduce from H3 (unsafe for all vehicles, children, and the elderly) to H2 (unsafe for small vehicles) in the current 1% AEP event.

Priority of which culvert crossing to upgrade can be assessed by inspecting the peak flood level impacts. Locations where culvert upgrade resulted in a large change in flood level (such as at the eastern intersection of Rookes Rd and at Michael Dr) should be prioritised.

Social and environmental impacts

This option improves road access to the wider community within the Tilligerry Peninsula during frequent to intermediate flood events. It also reduces flood affectation to the residents in the Salt Ash area in frequent events. However, during construction of this option, closure of Lemon Tree Passage Rd is expected.

This option features low environmental impacts as flood behaviour has not been significantly altered.

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Costs and economic assessment

This option provides significant benefits in evacuation access and flood damage reduction in frequent events. However, it also features high capital costs. Further detailed assessments should be undertaken to determine which culverts are more critical to upgrade to reduce costs.

Feasibility

The proposed works are significant and would require a comprehensive construction and design process. There are limited constraints which would impact on the feasibility of this option.

Evaluation

This option is recommended to be progress to the FRMP as it provides significant benefits to route access and reduces flood damages in frequent flood events. It is recommended that a further detailed assessment is undertaken to:

- Prioritise culverts to upgrade
- Assess options to install new culverts where there are no existing culverts between Salt Ash and Tanilba Bay (i.e. near Oyster Cove Rd).
- Assess a combination of road raising and culvert upgrade if flood immunity greater than the current 10% AEP should be required.

The detailed investigation has been assigned a high priority.

10.4. Property Modification Measures

10.4.1. Voluntary Purchase (PM13)

Description	Voluntary House Purchase
Benefits	<ul style="list-style-type: none"> • Removes community from high flood hazard areas and reduces risks to life of residents and potential rescuers
Constraints	<ul style="list-style-type: none"> • High capital costs • Social concerns
Overall Evaluation	Progress to FRMP, including a further detailed feasibility investigation.

Background

Voluntary purchase (VP) involves the acquisition of flood affected residential properties (particularly those frequently inundated in high hazard areas) and demolition of the residence to remove it from the floodplain. Generally, the land is returned to open space. The following eligibility criteria must be met to allow funding under the VP Scheme:

1. *Only councils are eligible to apply for funding - it is not open to home owners directly. Requests from home owners for properties to be purchased for hardship reasons are not eligible for funding.*
2. *The following local government areas are not eligible for funding and should apply under the Resilient Homes Program:*
 - a. *Ballina*

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- b. Byron
 - c. Clarence Valley
 - d. Kyogle
 - e. Lismore
 - f. Richmond Valley
 - g. Tweed.
3. Voluntary purchase will only be considered if there are no other feasible flood risk management options available to address the risk to life at the property.
 4. Funding is only available for residential properties and not commercial or industrial properties.
 5. Funding is only available for properties with buildings that were approved and constructed prior to 1986.
 6. Funding is only available for properties identified in a VPS through the FRMP process and where a scoping study has been completed (if necessary).
 7. The properties in a VPS should be identified in an adopted FRMP developed in accordance with the Flood risk management manual (2023). In limited circumstances, funding can be considered for a VP prior to completion of a FRMP. However, proper investigations and assessments need to be completed, and clear and compelling evidence needs to be provided as the basis for expediting consideration ahead of a completed FRMP. This would generally include determining the scope of the VPS.
 8. Properties must be located:
 - within high hazard areas where there is a significant risk to life for occupants and those who may have to evacuate or rescue them – however, a house in a location that is classed as high hazard on the basis of depth or provisional hazard alone would not be automatically eligible for VP. Hazard categorisation should be based on the true hazard assessment and consider a range of other factors that influence flood hazard as detailed in the Flood risk management manual (2023)
 - within a floodway where the removal of the house may be part of a floodway clearance program. A floodway clearance program is aimed to reduce the impact of development on flood behaviour elsewhere in the floodplain and enable the floodway to more effectively perform its flow conveyance function
 - within the footprint of a proposed flood mitigation measure or where a flood mitigation measure may result in a significant increase in flood risk to a house that cannot be protected – eligibility will be considered as part of the detailed investigation and design for the works project. Funding the purchase of the property would be considered as part of the total works package, which could include pre-construction activities.
 9. Properties that are tenanted and have a fixed term lease with more than 6 months remaining on the fixed term, are not eligible for funding.
 10. Unless the property is being purchased to facilitate mitigation work, vacant land is not eligible for funding as it does not achieve the main aim of VP (except under the circumstances outlined at point 11). Development controls should be used to limit the development of vacant land for flood mitigation and flood risk purposes.

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11. *Vacant land may be eligible for purchase where redevelopment is not considered appropriate due to the flood risk and where a flood or fire event has resulted in partial or full demolition of a previous house. These properties are generally identified for VP in a FRMP, but if a property is not identified for VP in a FRMP then strong justification for VP needs to be provided.*
12. *Multistorey properties may be eligible for funding despite the upper floors not being directly affected by over-floor flooding. Residents retreating to the upper floors and their potential rescuers may still face significant risk to life, and the building may not be designed to cope with flood conditions. An additional hazard assessment needs to be undertaken to confirm eligibility of multistorey properties.*

Proposed Option

Voluntary purchase is mainly implemented over a long period for residential areas in high hazard areas. Voluntary purchase is a means of removing isolated or remaining buildings, thus freeing both residents and potential rescuers from the danger and cost of future floods. It also helps to restore the hydraulic capacity of the floodplain (storage volume and waterway area).

Voluntary purchase has no environmental impacts although the economic cost and social impacts can be high. Many residents do not accept voluntary purchase because it would have significant impact on their community and way of life. Among these concerns are:

- it can be difficult to establish a market value that is acceptable to both the State Valuation Office and the resident,
- in many cases residents may not wish to move for a reasonable purchase price,
- progressive removal of properties may impose stress on the social fabric of an area,
- it may be difficult to find alternative equivalent priced housing in the nearby area with similar aesthetic values or features.

It is not uncommon for the uptake of voluntary purchase properties to slow down once most of the owner-occupied housing stock has been purchased. This can create fragmented neighbourhoods where it is common for the remaining housing to be dominated by rental properties and visually unappealing businesses.

Land swap schemes can also help accelerate the clearance of the floodway, such as that undertaken in Grantham, Lockyer Valley, Queensland following the January 2011 floods. Through such a scheme, people who own land within the floodway would be offered deeds for another parcel of land outside of the floodway in return for their current property, which is returned to Council for demolition and clearance.

Voluntary purchase should be considered for properties in high to extreme hazard (H5 and H6) areas in a rare event (current 1% AEP). Properties in hazard category H4 may be considered where the peak flood depths are large enough to make house raising unrealistic or where they are in a particularly dangerous location.

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Approximately 5 dwellings have been identified for consideration for voluntary purchase based on the flood behaviour only. Dwellings have been included if they are in hazard categories of H5 or H6 in the current 1% AEP event AND there is above floor flooding in the current 20% AEP event.

A further 24 properties fall within the H4 hazard area, however, are inundated with flood depths greater than 1m in the current 1% AEP event and greater than 0.5m in the current 10% AEP event.

Furthermore, these properties have no evacuation route as access is frequently overtopped and tidal influenced such that no warning time is available. The frequency of inundation, lack of warning time and evacuation access in this area increases the flood risk to both the residents and the potential rescuers. Therefore, priority to voluntary purchase may also be considered in this area.

Voluntary Purchase Scheme eligibility should be verified in a feasibility study. Additionally, dwellings summarised above included dwellings within residential land zoning only (low density residential or rural landscape). There may be commercial properties within these residential land zones that have been included in the properties summarised above. Conversely, there may be residential dwellings within commercial land zonings which have not been identified. Detailed assessment of whether each property is eligible for voluntary purchase according to the VP scheme should be undertaken.

Evaluation

Approximately 5 properties within the study area have been identified based on flood behaviour only, this list can be extended to 29 properties when other factors are considered. This list of properties can be used as a basis for a scoping study which investigates whether properties are eligible under the VP scheme.

10.4.2. Flood Planning Levels (PM14)**DESCRIPTION**

Flood Planning Levels (FPLs) are an important development control in floodplain risk management. Through planning controls Council has requirements for all new development to set finished floor levels above a given flood level. The Flood Risk Management Manual (Reference 3) provides a comprehensive guide to the purpose and determination of FPLs. The FPL is a useful mitigation measure for future flood risk and is derived from a combination of flood level results from a flood event of specific probability, usually the 1% AEP, and freeboard of usually 0.5m. FPLs do not apply to existing development, but through development controls which are enforced on generally all new development.

DISCUSSION

Stipulating FPLs for all new development is one of the most effective measures in reducing flood damages to new properties without preventing development in a flood prone area entirely. Defining the appropriate FPL involves trading off the social and economic benefits of a reduction in the frequency, inconvenience, damage and risk to life caused by flooding against the social, economic and environmental costs of restricting land use and development in flood prone areas and of implementing management measures.

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Developments more vulnerable to flooding such as hospitals, electricity sub stations, and housing for the elderly or less physically mobile, should consider rarer events than the 1% AEP when determining their FPL. However, the FPL does not address the full range of issues when considering flood and permanent inundation risk such as access and failure of essential services. According to the Flood Risk Management Manual (Reference 3), the purpose of freeboard is to give reasonable certainty that the reduced flood risk exposure implied by selection of a particular flood as the basis of a FPL is actually provided, given the following factors:

- uncertainties in estimates of flood levels,
- differences in water level because of local factors,
- increases due to wave action, and
- future scenarios not considered in

FPLs are generally required to be defined or applied for the following broad land uses:

- community services (schools, halls),
- critical services (hospitals, police stations, Council offices),
- residential (single and multi-unit),
- rural areas,
- commercial/industrial,
- recreational facilities,
- caravan parks,
- additions/extensions to existing structures, and
- public utilities (electricity, sewer, water, phone, etc).

The current Port Stephens Floodplain Risk Management Policy (Reference 27) defines the FPL as:

“The level of the 1% AEP (annual exceedance probability) flood event in the year 2100 plus 0.5 metre freeboard, except for overland flooding areas where a freeboard of 0.3 metre is applied. The area of land below the Flood Planning Level (i.e. the Flood Planning Area) is subject to flood-related development controls.”

The study area has a flat terrain as well as flat peak flood levels, such that in many areas application of 0.5 m freeboard to the 1% AEP year 2100 event would result in levels greater than the PMF. This in turn means that there may be some areas within the Flood Planning Area (areas below the FPL) which are not considered Flood Prone Land (PMF flood extent). A lesser freeboard of 0.3 m has been selected for overland flow areas due to this. No formal definition of overland flooding areas has been specified in the Floodplain Risk Management Policy. The previous flood study (Reference 1) had suggested that overland flooding areas in the study area could be defined as locations with ground levels greater than 3.2 m AHD. The elevation of 3.2 m AHD was determined from applying the current 1% AEP ocean tide level (1.8 m AHD) with 2100 sea level rise (+0.9 m) and freeboard (0.5 m).

Council should continue to use the FPL to set flood proofing requirements for non-residential buildings. Council should consider making the FPA and other flood information and extents available on its website.

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This study has amended the 1% AEP event flood level throughout the hydraulic model extent from those levels used to define the FPL in the current DCP. Therefore, it is recommended that the DCP be updated to reflect this.

SUMMARY

It is recommended that Council update its flood planning area and flood planning levels based on the current modelling. Council should consider making the FPA and other flood information and extents available on its website.

RECOMMENDATIONS

Revise FPL and FPA as per the outcomes of this Study. Council should consider making the FPA and other flood information and extents available on its website.

10.4.3. Flood Planning Policy (PM15)

DESCRIPTION

Appropriate planning instruments ensure that development can be undertaken considering compatibility with the flood risk. Effective planning instruments can reduce residual flood risk over time as redevelopment occurs. Planning instruments can be used as tools to:

- Reduce risk to life,
- Reduce damage to the proposed development itself, and
- Reduce damage to the broader floodplain and existing development.

They can also be used to develop appropriate evacuation and disaster management plans to reduce flood risks to the existing population. The types of controls (this list is not exhaustive) that achieve each of the objectives listed above are shown in Table 21.

Table 21: Planning Instrument Objectives – Control Type

Objective	Type of Control
Reduce Risk to Life	Evacuation considerations, vulnerable land use and occupant considerations, flood awareness and education (Section 10.7 certificates), prevention of ingress of water to car parks.
Flood Damage to New Development	FPLs, location considerations including, hydraulic hazard and category considerations, structural requirements.
Flood Damage to Existing Development	Flood impact consideration, design considerations, location considerations including, hydraulic hazard and category considerations.

The primary planning instruments used by local Councils are the LEP and DCP. The LEP is a legal planning instrument that guides planning decisions for Council through zoning and development controls. They provide a framework for the way land can be developed and used. The DCP support the objectives of the LEP and are used by Council to define and articulate the specific standards needed for different types of developments. Flood related development controls are a key aspect for development that occurs on flood prone land.

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DISCUSSION

The primary objective of the NSW Government’s Flood Policy is “to reduce the impact of flooding and flood liability on individual owners and occupiers, and to reduce private and public losses resulting from flooding, utilising ecologically positive methods wherever possible”.

Appropriate development controls involve consideration of the social, economic, environmental and risk to life of consequences associated with the occurrence and management of floods.

This involves trading off various benefits of reducing the impacts of flooding on development, against the costs of restricting land use in flood prone areas and of implementing appropriate management measures.

The outcomes of this study should feed into an updated Development Control Plan (DCP) in respect to flood related development controls or, alternatively, the existing documents can simply refer to this study and plan. Section 7.3.1 and Section 7.3.2 provides a summary of the current LEP and DCP for Port Stephens Council. A review of these documents are detailed below. Development controls are typically based on the 1% AEP event. Flood maps of a range of events are produced by the study such that Council can be aware of the full range of flood risk within the study area.

The Section B5 of Port Stephens Council Development Control Plan (Reference 21) outlines the development controls applied on the LGA. The DCP applies to all development on flood prone land (i.e. within the PMF extent). The FPL is defined by the Port Stephens Floodplain Risk Management Policy (Reference 27) as the 1% AEP with climate change in the year 2100 plus a 0.5 m freeboard (except in overland flow areas where freeboard is 0.3 m). Key considerations and whether they are included in the documents are provided in Table 22.

Table 22: Flood-related Development Control Considerations

Aspect/Control	Contained in LEP/DCP	Comment
Terminology	Yes	Uses consistent terminology in line with the Flood Risk Management Manual 2023 and ARR 2019. Flood risk category definition recommended to be updated in utilising H1-H6 hazard categories to differentiate between high and medium flood risk.
Clarity and Ease of Application	Partial	The DCP overall is clear and concise. However, further clarity should be provided for applicability of the development controls in Section B5.A. Figure B1 indicates that developments on minimal risk flood prone land (with exception of sensitive uses) has no

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Aspect/Control	Contained in LEP/DCP	Comment
		<p>applicable development controls, however, there are controls for fencing on all flood prone land.</p> <p>Clause B5.17 written ambiguously such that it is unclear whether fill is or is not supported.</p>
Flood Planning Level	Yes	Discussed in Section 10.4.2.
Flood Planning Area	Yes	Flood planning area is the land inside the extent of the flood planning level. Ensure map is available on Council's website if separate from the DCP, since changes to the NSW Government planning framework in relation to flooding has removed the FPA overlay from the LEP.
Consideration of flood affectation and land use	Yes	<p>Development controls consider the land use, although this primarily extends only to minimum floor levels and FIRA. Consideration could be given to implementing a matrix approach, with differing requirements specified depending on the flood risk and type of development.</p> <p>While the flood extent is categorised by both flood hazard and flood function in the DCP (Figure BG), there are only controls which depend on hydraulic categories and there are no controls dependent on hydraulic hazard.</p>
Minimum Floor Level	Partial	<p>Minimum floor levels are specified based on development type.</p> <p>Further clarification should be provided definitions of habitable rooms as the current definition is not applicable to developments other than residential development.</p>
Minimum Carpark Level	Yes	Current 1% AEP flood level
Driveway and Access	Yes	Finished access levels are a minimum or the current 1% AEP floor level or level of the flood immunity of the connecting public road.
Flood Proofing	Yes	Consideration of flood compatible building materials and structural soundness for developments within the flood planning area or sensitive use developments within the flood prone area. are included in the DCP.
Flood Impacts	Partial	<p>The DCP requires all fill on land identified as floodway or as flood storage to have a floor impact and risk assessment (FIRA). Otherwise, FIRA are only required where the proposed development could result in flood impacts or as Council deems necessary.</p> <p>A draft of the Lower Hunter River Floodplain Cumulative Development Impact Study and Plan (Reference 34) has been provided to WMA. This study contains a draft DCP section for controls relating to cumulative development thresholds and requirements for local siting performance criteria. It is recommended that this study is incorporated into the DCP.</p>

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Aspect/Control	Contained in LEP/DCP	Comment
Development in Floodways	Partial	<p>Additional clauses listed in Section B5.C of the DCP apply to developments on land identified as floodway. It is stated in this section that one of the objectives are to 'ensure development on land identified as floodway is restricted to low risk development'. Note that while this is mostly applicable, the purpose of hydraulic categorisation is to delineate areas which are necessary for conveying and storing water. Therefore, development controls dependent on hydraulic hazards should be prescribed to reduce the impact of the development on the floodplain.</p> <p>Conversely, the flood affectation to development and any at risk property or people due to flooding is dependent on the flood hazard. It is recommended that the DCP objective is updated to consider this.</p> <p>According to Figure BI, fill is supported in the floodway subject to development controls. A FIRA is required for fill on land identified as floodway. While requirements of the FIRA are noted in the DCP, there are no thresholds provided for acceptable impacts. It is recommended that thresholds provided in Reference 34 are incorporated.</p> <p>Council should consider a review of the definition of flood function across all catchments within the Local Government Area, while it is not appropriate to apply consistent indicator method parameters due to varying flood behaviour, it would be appropriate to maintain some level of consistency in the overarching approach that is applied.</p>
Evacuation	Partial	<p>Evacuation requirements in the DCP are indirectly addressed by controls relating to driveways and access as well as emergency onsite refuge requirements.</p> <p>Requirements for shelter in place (SIP) are provided in the DCP based on the access to a public road. Given the extended inundation times in some locations of the study area, an additional clause could be included in the DCP to allow for investigation on inundation duration when investigating shelter in place. It is recommended evacuation requirements in the DCP should be updated to require consideration of a formalised Emergency Response Flood Plan and specify requirements for evacuation or shelter in place. The requirements should refer to the NSW Government's Shelter-in-Place Guidelines and the Flood Risk Management Manual Supporting Guideline – Support for Emergency Management Planning EM01.</p>
Fencing	Yes	<p>The DCP requires fencing on flood prone land to be stable in events up to the current 1% AEP event and not obstruct the flow of floodwater.</p>
Future Climate	Yes	<p>The DCP current adopts the FPL as the year 2100 1% AEP event, which incorporates climate change in the planning controls. In addition to this the FIRAs are required to assess a range of events in the current climate, 2050, and 2100. Flood-related development</p>

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Aspect/Control	Contained in LEP/DCP	Comment
		controls considering best available climate change data to combat future sea level rise and increased rainfall intensity. It is recommended that Council establishes a climate change policy which outlines the scientific basis for climate change, adopts a planning horizon (or different planning horizons for different applications) and specify rainfall increase and sea level rise parameters (ideally in accordance with ARR 2019 (Version 4.2 or future updates), and outline its application to Council's operations, planning instruments, policies and floodplain management strategy.

The flood constraint category mapping aims to consolidate all the mapping outputs to assist planners. Council may wish to use this to determine areas where development should be constrained and areas where less restrictions are required. The AIDR guide provides example planning constraints for the various FPCC categories. For example, FPCC1 – Development is discretionary provided it does not adversely affect flood function. Intensification of existing and new key community, utility and vulnerable, residential and commercial uses may be prohibited.

SUMMARY

As part of the Floodplain Management Study, Council's Local Environment Plans and various related Development Control Plans have been reviewed. Council and the community should consider minor changes to its DCP as discussed.

RECOMMENDATION

- Update flood risk category definition to the H1 to H6 hazard categories in accordance with the Flood Risk Management Manual 2023 (Reference 3)
- Review the DCP for overall clarity, in particular Section B5.A and Clause 5.17.
- Provide the FPA map on Council's website separate from the DCP.
- Implement a matrix approach which specifies development controls based on development type and flood risk.
- Update definition of habitable room such that it can be applied to commercial and industrial developments and include definition of onsite waste water level.
- Refine controls as necessary to incorporate the effect of flood hazard (as opposed to controls dependent only on flood function). Noting that flood hazard is related to how flooding affects the development, whereas flood function is related to how the development affects the floodplain.
- Define threshold for acceptable impacts in the DCP when undertaking a flood risk impact assessment. Both thresholds for impacts due to the developments itself as well as due to cumulative fill across the catchment should be included. These thresholds have been defined in the Reference 34. It is recommended that the outcomes of Reference 34 are incorporated into the DCP.
- Develop a climate change policy which outlines the scientific basis for climate change, adopts a planning horizon (or different planning horizons for different applications) and specify rainfall increase and sea level rise parameters, and outline its application to Council's operations, planning instruments, policies and floodplain management strategy.

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10.4.4. Voluntary House Raising (PM16)

Description	Voluntary House Raising
Benefits	<ul style="list-style-type: none"> Reduces the frequency of exposure to flood damages for residential properties, also reduces disruption, associated trauma and anxiety.
Constraints	<ul style="list-style-type: none"> External flood risk remains Isolation risks High capital costs Social concerns
Overall Evaluation	Progress to FRMP, including a further detailed feasibility investigation.

DESCRIPTION

House raising has been widely used throughout NSW to eliminate inundation from habitable floors. This approach provides more flexibility in planning, funding and implementation than voluntary purchase. However, its application is limited as it is not suitable for all building types and only becomes economically viable when above floor inundation occurs frequently (say in a 10% AEP event or less).

1. Only councils are eligible to apply for funding – it is not open to homeowners directly. Requests from homeowners to raise houses for hardship reasons are not eligible for funding.
2. The following local government areas are not eligible for funding and should apply under the Resilient Homes Program:
 - a. Ballina
 - b. Byron
 - c. Clarence Valley
 - d. Kyogle
 - e. Lismore
 - f. Richmond Valley
 - g. Tweed.
3. Funding is only available for residential properties, not commercial or industrial properties.
4. Funding is only available for properties with buildings that were approved and constructed prior to 1986.
5. Funding is only available for properties identified in a VHR scheme through the FRMP process and where a Scoping Study has been completed (if required).
6. The properties in a VHR scheme must be identified³ in an adopted FRMP developed in accordance with the Flood risk management manual (2023). In limited circumstances, funding can be considered for a VHR prior to completion of an FRMP. However, proper investigations and assessments need to be completed and clear and compelling evidence needs to be provided as the basis for expediting consideration ahead of a completed FRMP. This would generally include determining the scope of the VHR scheme.
7. Properties that are benefiting substantially from other floodplain mitigation measures – such as houses already protected by a levee or those that will be – will not be funded for VHR.
8. VHR should generally return a positive net benefit in damage reduction relative to its cost (benefit–cost ratio⁴ greater than 1). Consideration may be given to lower benefit–cost ratios where there are substantial social and community benefits, or VHR is compensatory work for the adverse impacts of other mitigation works.
9. VHR should involve raising residential properties above a minimum design level and must comply with the council’s relevant development control plan.

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DISCUSSION

House raising is suitable for most non-brick single storey buildings on piers and is particularly relevant to those situated in low hazard areas on the floodplain. A number of techniques may be used. The benefit of house raising is that it eliminates inundation to the height of the floor and consequently reduces the flood damages. However, it does not reduce the external hazard, evacuation issues or yard/garage damages.

The Floodplain Management Program Grant Funding of this measure generally only cover the basic costs of raising the structure. The subsidy is usually offered on a relative basis depending on the severity of the problem and potential damages. Residents will most likely have to contribute their own funds to make up any difference and to facilitate the associated works or modifications.



Photo 1: Examples of House Raising

Most low-lying properties along Tilligerry Creek are subject to frequent flooding. A total of 239 properties are inundated above floor level in the current 20% AEP and 281 in the current 10% AEP. Of these properties inundated above floor level in the current 10% AEP, 279 properties have hazard categories ranging from H1 to H4. House raising is not suitable for properties with greater hazards than H4 as due to structural integrity of the buildings. Properties are generally raised to be above the flood planning level therefore, if above floor flooding is deep currently in the current 1% AEP event, house raising is not feasible. Excluding dwellings which have inundation too deep (>1 m) for house raising leaves a total of 263 potential properties which can be further investigated for voluntary house raising.

Properties identified to be suitable for voluntary house raising are located:

- Along Marsh Road
- At Salt Ash north of Lemon Tree Passage Rd
- At the low point at Clark St, Anna Bay

The cost of basic house raising is typically in the order of \$80-120,000 per house. The event when a property is first flooded above floor level is shown on Figure D7 to Figure D9. It is recommended that Council develop a prioritised list of houses for raising.

An indication of the property's eligibility for house raising could be recorded on the Section 10.7 Certificate to ensure future potential purchasers are made aware of their options.

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A total of 281 properties were identified as being flooded above floor in frequent events (current 10% AEP). An estimated 263 residential properties have been identified based on flood behaviour only. These properties can be used as a basis for a scoping study which identifies eligible properties and prioritises them for VHR.

10.4.5. Flood Proofing (Option PM17)**DESCRIPTION**

Flood proofing or flood resilient building is a strategy applied to reduce the damage and recovery costs and time following flood events. It is often divided into two categories; wet proofing and dry proofing. Wet proofing assumes that water will enter a building and aims to minimise damages and/or reduce recovery times through use of water-resistant materials, locating electricals above the FPL, storage of possessions at higher levels, tie down of items that may float, and facilitation of drainage and ventilation after flooding. Dry proofing aims to totally prevent flood waters from entering a building and is typically best incorporated into a structure at the construction phase, though can also be retrofitted to existing buildings. Dry proofing measures are typically installed at doorways or garage entry points, however other openings (such as for ventilation) should also be considered. Dry proofing measure are often only effective if sufficient warning time is available for their placement at the onset of a flood event.

DISCUSSION

Retrofitting some aspects of permanent flood proofing measures can be difficult and costly, and therefore permanent flood proofing is best implemented during construction and allowed under development controls. Elements such as flooring and lower wall protection is more easily retrofitted. As such, flood proofing can be stipulated within Council DCPs as an option for structures below the FPL, as a minimum.

Access to community facilities, shops, healthcare services, sporting facilities and pubs are key to a community's recovery from a flood event and contribute significantly to community resilience and emotional recovery. While such premises would still not be operational during a flood nor immediately afterwards (pending safe access, reconnection of utilities etc.), flood proofing would significantly decrease the duration of business closures after the event.

It is noted however that flood proofing individual buildings would not reduce external flood damages (e.g. to carparks, garages, sheds, fences or stock yards or to the external structure of buildings) nor does it reduce potential risk to life. Furthermore, if buildings are wet-proofed there would still be clean-up costs incurred, as well as days of business lost during the flood itself and the immediate recovery period.

Flood proofing can also be an option for sensitive and hazardous land uses, where controls would require, aspects to the essential operation, such as generators to be located at a higher level.

A range of existing guidance materials are available including the Blue Book – Reducing Vulnerability of Buildings to Flood Damage – Guidance on building in flood prone areas (2006), Queensland Reconstruction Authority – Flood Resilient building Guidance for Queensland Homes (2019) and NSW SES Business Flash Flood Tool Kit.

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Flood proofing is currently not eligible for funding assistance through the NSW Government's Floodplain Management Program, however other funding sources may be available to landholders.

SUMMARY

Flood proofing is a good solution for reducing flood risk to commercial and industrial properties. Flood proofing for residential dwellings is considered less appropriate as there can still be risk to life if people remain in the building; raising floor levels above flood levels is considered to be safer. However, as existing houses cannot be raised, flood proofing is useful for existing properties.

Grant funding is not usually available for flood proofing. This option is generally less expensive than house raising. Although Council cannot be responsible for flood proofing existing properties, they can enforce flood proofing for any new development within flood prone areas through planning controls. Furthermore, Council can, through a flood awareness campaign targeted at both commercial and residential property owners, make available information on flood proofing existing buildings such as temporary flood barriers.

RECOMMENDATION

Promote flood proofing for properties below the habitable floor level.

10.5. Response Modification Measures

10.5.1. Flood Awareness and Preparedness (Option RM18)

DESCRIPTION

The success of any flood warning system and the evacuation process depends on:

- *Flood Awareness*: How aware is the community to the threat of flooding? Have they been adequately informed and educated?
- *Flood Preparedness*: How prepared is the community to react to the threat? Do they (or the NSW SES) have damage minimisation strategies (such as sand bags, raising of possessions) which can be implemented?
- *Flood Evacuation*: How prepared are the authorities and the evacuees to evacuate households to minimise damages and the potential risk to life? How will the evacuation be implemented, where will the evacuees be moved to?

DISCUSSION

A community with high flood awareness will suffer less damage and disruption during and after a flood because people are aware of the potential of the situation. On river systems which regularly flood, there is often a large, local, unofficial warning network which has developed over the years and residents know how to effectively respond to warnings by raising goods, moving cars, lifting carpets, etc. Photographs and other non-replaceable items are generally put in safe places. Often residents have developed storage facilities, buildings, etc., which are flood compatible. The level of trauma or anxiety may be reduced as people have survived previous floods and know how to handle both the immediate emergency and the post flood rehabilitation phase in a calm and efficient manner.

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The level of flood awareness within a community is difficult to evaluate. It will vary over time and depends on a number of factors including:

- *Frequency and impact of previous floods.*
- *History of residence.*
- *Whether an effective public awareness program has been implemented.*

Residents of the study area generally have a moderate level of flood awareness, particularly with the flood affectation caused in the recent years 2015, 2016, and 2021. However, this awareness is usually of the smaller more frequent events in the order of 10% AEP (2021). Continued education of residents of the chance of this occurring again is recommended.

While the residents in the study area are very familiar with nuisance flooding (the study area is low-lying and affected by frequent tidal events), this however does not always translate to awareness of significant floods such as the 1% AEP event.

For risk management to be effective it must become the responsibility of the whole community. It is difficult to accurately assess the benefits of an awareness program but it is generally considered that the benefits far outweigh the costs. The perceived value of the information and level of awareness, diminishes as the time since the last flood increases.

A major hurdle is often convincing residents that major floods will occur in the future. Many residents hold the false view that once they have experienced a large flood then another will not occur for a long time thereafter. This viewpoint is incorrect as a 1% AEP event (or sometimes termed a 100 year ARI) has the same chance of occurring next year, regardless of the magnitude of the event that may have recently occurred (a 1 in 20 chance each year).

Regular awareness campaigns are recommended to ensure that the level of flood awareness in the study area stays high.

SUMMARY

Based on feedback received from the community, it would appear that the majority of residents in the study area have a moderate level of flood awareness and preparedness.

As time passes since the last significant flood, the direct experience of the community with historical floods will diminish. It is important that a high level of awareness is maintained through implementation of a suitable Flood Awareness Program that would include Floodsafe brochures, additional flood markers, flood history reminders on significant anniversaries of major events, as well as advice provided on the Council's and SES's websites. These need to be updated on a regular basis.

Table 23 provides examples of various flood awareness methods that can be used.

Table 23: Flood Awareness Methods

Method	Comment
Letter/Pamphlet from Council	These may be sent (annually or bi-annually) with the rate notice or separately. A Council database of flood liable properties/addresses makes this a relatively inexpensive and effective measure. The pamphlet can inform residents of subsidies, changes to flood planning levels or any other relevant information. These should also be handed out as part of rental property information.

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Method	Comment
School Project or Local Historical Society	This provides an excellent means of informing the younger generation about flooding. It may involve talks from various authorities and can be combined with water quality, estuary management, etc.
Displays at Council Offices, Library, Schools, Local Fairs	This is an inexpensive way of informing the community and may be combined with related displays. Include photographs, newspaper articles and information on development controls and standards, flood evacuation and readiness procedures.
Historical Flood Markers or Depth Indicators on Roads	Signs or marks can be prominently displayed in parks, on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators on roads advise drivers of the potential hazards. Particularly appropriate near local waterways and low points which become flow paths during large events.
Articles in Local Newspapers	Ongoing articles in the newspapers will ensure that the problem is not forgotten. Historical features and remembrance of the anniversary of past events make good copy.
Collection of Data from Floods	Collection of data from floods that occur in the future will assist in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible.
Notification of Section 149 Planning Certificate Details	Floodplain property owners were indirectly informed that they were potentially flood affected as part of the public consultation program and floor level survey. Future residential property owners are advised during the property searches at the time of purchase by details provided on the Section 149 certificate.
Web-based tools	Online presentations, activities, gauge data, GIS information on Council website.
Updates on Council website	Council already provide regular updates on the current flood situation on the home page of their website. The website also provides information on flood preparedness, response and recovery.
NSW SES flood awareness programs	The NSW SES are undertaking a flood awareness program in the Lower Bellinger and Kalang Rivers including, leaflets and flyers, and stalls at local events.

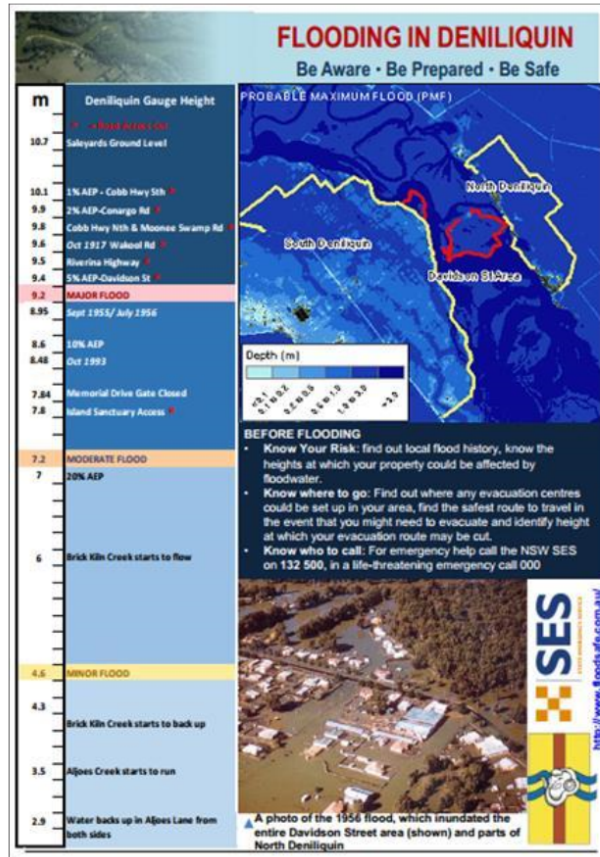
The specific flood awareness measures that are implemented will need to be developed by Council taking into account the views of the local community, funding considerations and other awareness programs within the LGA. The details of the exact measures would need to be developed in consultation with affected communities. It is important that the system be web/GIS based and publicly available.

Below is an example of a fridge magnet produced to educate residents on what a specific gauge height means.

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RECOMMENDATION

Develop a flood awareness program.

10.5.2. Evacuation Planning (Option RM19)

DESCRIPTION

It may be necessary for some residents to evacuate their homes in a major flood. This would be undertaken under the direction of the SES who are the lead agency under the Displan. Some residents may choose to leave on their own accord based on flood information from the radio or other warnings, and may be assisted by local residents.

DISCUSSION

The main problems with all flood evacuations are:

- They must be carried out quickly and efficiently,
- They are hazardous for both the rescuers and the evacuees,
- Residents are generally reluctant to leave their homes, causing delays and placing more stress on the rescuers and increasing the risk to the rescuers,
- The number of people to be evacuated,

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- The mobility or special requirements to evacuate residents, and
- Evacuation routes may be cut some distance from the residential areas and people do not appreciate the danger.

A number of residents will be required to be evacuated in a flood event. The NSW SES has the skills and experience to undertake the necessary evacuations. Any flood awareness programs should target the need for evacuation.

Access to properties can be cut for some time and residents will try to drive through floodwaters to return home or undertake regular tasks. The NSW SES advice is never to drive through floodwaters but recent past events in Queensland, NSW and Victoria in 2011 demonstrated that many people do not adhere to this advice. Cars can float in as little as 0.3 m depth of water and consequently a number of lives have been lost and the lives of rescuers put at risk in rescuing stranded motorists. Warning signs advising motorists of the risk of driving through floodwaters could be provided at low cost.

Most locations in the study area are flat and low-lying including the arterial roads such as Lemon Tree Passage Rd and Nelson Bay Rd which provide access from the study area to Newcastle. Flooding of these roads are tidal influenced and/or local catchment influenced both which generally have short warning times. Therefore, flood warning systems will not be effective in these areas.

Appendix B contains information on when properties are first flooded that can be used by the SES for evacuation planning.

A review of the Port Stephens Flood Emergency Sub Plan is presented in Section 9.1.3. Volume 2 of the Port Stephens Local Flood Plan should be updated to include the information provided as part of this floodplain risk management study, including updates to the flood behaviour, flood emergency response classification, and within the study area.

SUMMARY AND RECOMMENDATIONS

- The Volume 2 and Volume 3 of Port Stephens Local Flood Plan was prepared in November 1995. This should be updated to include the flood information produced as part of this study.
- Any major future events within this time should be incorporated into flood intelligence and evacuation planning.
- Signs advising of the risk of driving through floodwaters should be placed on inundated roads to reduce the number of people driving through flood waters.
- Update to Flood Risk Management Manual (Reference 3)

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FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.****11. MULTI CRITERIA ASSESSMENT MATRIX****11.1. Introduction**

The Flood Risk Management Manual (Reference 3) recommends the use of multi-criteria assessment when assessing flood risk mitigation measures. A multi-criteria assessment (MCA) provides a method by which options can be assessed against a range of criteria and offers a greater breadth of assessment than is available by considering only the reduction in flood risk or economic damages, for example. Such additional criteria may include social, political and environmental considerations and intangible flood impacts that cannot be quantified or included in a Cost-Benefit Analysis. It should be noted that the assessment of the suitability of floodplain mitigation options is a complex matter, and an MCA will not give a definitive 'right' answer but will provide a tool to debate the relative merits of each option. A draft score has been allocated to "Community and Stakeholder Support" and will be confirmed following Public Exhibition.

11.2. Scoring System

A scoring system has been devised to allow stakeholders to assess the various options across a consistent basis to allow for direct comparison. The scoring system is divided into four key criterion: Flood Behaviour, Economic, Social and Environmental. Scores for each criteria are to be assigned to each option then summed to determine the overall score. Options with higher scores indicate benefits across a range of criteria and should be prioritised over those with lower positive scores, which may be more neutral or have a combination of pros and cons. Conversely, options with the lowest negative scores indicate the option would cause adverse outcomes in a number of criteria and should not be considered further. The scoring system is provided in Table 24.

Traditionally, a cost-benefit analysis (CBA) style assessment of the options was undertaken to assess the capital and ongoing costs versus the economic benefit of the reduction in average annual flood damages. Due to the nature of the options for the study areas, this detailed economic assessment was not completed. The majority of options are road upgrades to improve access. The improved reliability of access does not have a direct tangible benefit that can be economically quantified and hence a CBA has not been undertaken, but rather a qualitative comparison of capital costs has been included in the MCA.



Table 24: Multicriteria Assessment Scoring System

Criteria	Metric	-3	-2	-1	Score 0	1	2	3	
Economic	Economic Merits	Comparison of the economic benefits against the capital and ongoing costs	BC < 0.1	BC: 0.1- 0.5	BC: 0.5-0.9	BC = 1 (Or NA)	BC: 1.0 - 1.4	BC: 1.4 - 1.7	BC >1.7
	Implementation Complexity	Potential design, implementation and operational challenges and constraints. Risk can increase with implementation timeframe	Major constraints and uncertainties which may render the option unfeasible	Constraints or uncertainties which may significantly increase costs or timeframes	Constraints or uncertainties which may increase costs or timeframes moderately	NA	Constraints that can be overcome with moderate investment of time and resources	Constraints that can be overcome easily	No constraints or uncertainties
	Staging of Works	Ability to stage proposed works	Works cannot be staged			NA	Some minor components of the works may be staged	Some major components of the works may be staged	
Social	Impact on Emergency Services	Change in demand on emergency services (SES, Police, Ambulance, Fire, RFS etc).	Major disbenefit	Moderate Disbenefit	Minor Disbenefit	Neutral	Minor Benefit	Moderate Benefit	Major Benefit
	Emergency Access	Flood depths and duration changes for critical transport routes	Key access roads become flooded that were previously flood free	Significant increase in main road flooding	Moderate increase in local or main road flooding	No Change	Moderate decrease in local or main road flooding	Significant decrease in main road flooding	Local and main roads previously flooded now flood free
	Impact on critical and/or vulnerable facilities ¹	Disruption to critical facilities	Inoperational for several days	Inoperational for one day	Inoperational for several hours	No Change	Period of inoperation reduced by 0-4 hours	Period of inoperation reduced by > 4 hours	Prevents disruption of critical facility altogether
	Impact on Properties	No. of properties flooded over floor. Across all events	>5 adversely affected	2-5 adversely affected	<2 adversely affected	None	<2 benefitted	2 to 5 benefitted	>5 benefitted
	Impact on flood hazard	Change in hazard classification	Significantly increased in highly populated area (Increasing to H5/H6)	Moderately increased in populated area (Increasing by 2 or more categories)	Slightly increased (Increase by 1 category)	No Change	Slightly reduced (Decrease by 1 category)	Moderately reduced in populated area (Decrease by 2 or more categories)	Significantly reduced in highly populated area (Decrease from H5/H6)
	Community Flood Awareness	Change in community flood awareness, preparedness and response	Significantly reduced	Moderately reduced	Slightly reduced	No Change	Slightly improved	Moderately improved	Significantly improved
	Social disruption	Closure of or restricted access to community facilities (including recreation)	Normal access significantly reduced or facilities disrupted for > 5 days	Normal access routes moderately reduced or facilities disrupted for 2-4 days	No Change to access but facilities disrupted for up to 12 hours	No Change	Reduces duration of access disruption or facility disruption by up to 12 hours	Reduces duration of access disruption or facility disruption by 2-4 days	Prevents disruption of access or facility altogether
Environmental	Community and stakeholder support ²	Level of agreement (expressed via formal submissions and informal discussions)	Strong opposition by numerous submissions	Moderate opposition in several submissions	Individual submissions with opposition	Neutral	Individual submissions with support	Moderate support in several submissions	Strong support by numerous submissions
	Impacts on Flora & Fauna (inc. street trees)	Impacts or benefits to flora/fauna	Likely broad-scale vegetation/habitat impacts	Likely isolated vegetation/habitat impacts	Removal of isolated trees, minor landscapng.	Neutral	Planting of isolated trees, minor landscapng.	Likely isolated vegetation/habitat benefits	Likely broad-scale vegetation/habitat benefits
	Heritage Conservation Areas and Heritage Items	Impacts to heritage items	Likely impact on State, National or Aboriginal Heritage Item	Likely impact on local heritage item	Likely impact on contributory item within a heritage conservation area	No impact	Reduced impact on contributory item within a heritage conservation area	Reduced impact on local heritage item	Reduced impact on State, National or Aboriginal Heritage item
Other Aspects	Financial Feasibility and Funding Availability	Capital and ongoing costs and funding sources available	Significant capital and ongoing costs, or no external funding or assistance available	Moderate capital and ongoing costs, no funding available	High capital and ongoing costs, partial funding available	NA	Moderate capital and ongoing costs, partial funding available; or low capital and ongoing costs, no funding available	Low to moderate capital and ongoing costs, partial funding available	Full external funding and management available
	Compatibility with existing Council plans, policies or projects	Level of compatibility	Conflicts directly with objectives of several plans, policies or projects	Conflicts with several objectives or direct conflict with one or few objectives	Minor conflicts with some objectives, with scope to overcome conflict	Not relevant	Minor support for one or few objectives	Some support for several objectives, or achieving one objective	Achieving objectives of several plans, policies or projects

¹ Critical facilities are those properties that, if flooded, would result in severe consequences to public health and safety. These may include fire, ambulance and police stations, hospitals, water and electricity supply, buses/train stations and chemical plants. Vulnerable facilities refer to those properties with vulnerable occupants, such as nursing homes or schools.

² Community and stakeholder support scores will be completed following Public Exhibition

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Table 25: Multi Criteria Assessment Results

Category	ID	Option	Economic Merits	Implementation Complexity	Staging of Works	Impact on Emergency Services	Road Access	Impact on critical and/or vulnerable facilities ¹	Impact on Properties	Impact on flood hazard	Community Flood Awareness	Social disruption	Community and Stakeholder Support ²	Impacts on Flora & Fauna (inc. street trees)	Heritage Conservation Areas and Heritage Items	Financial Feasibility and Funding Availability	Compatibility with existing Council plans, policies or projects	Total Score	Overall Rank
Flood Modification	FM01	Flood Barrier at Blake Pde Park	0	-1	0	0	0	0	1	0	0	-1	0	-1	0	1	1	0	15
	FM02	Flood Barrier Along Hutcheson Rd	0	2	0	0	0	0	2	1	0	0	0	0	0	1	1	7	11
	FM03	Detention Basin at Meredith Ave	-2	-1	0	0	0	0	2	0	0	0	0	-1	0	-1	1	-2	17
	FM04	Drain near Purcell Ave	0	1	0	0	0	0	1	1	0	0	0	-1	0	1	1	4	13
	FM05	Drain at Hawkes Way	0	1	0	0	0	0	2	3	0	0	0	-1	0	1	1	7	11
	FM06	Drainage of Davidson St Low Point	0	-2	0	0	0	0	2	0	0	0	0	0	0	-3	1	-2	17
	FM07	Reinstate Flood Gates Along Main Drain	-3	0	0	0	0	0	0	0	0	0	0	0	0	-2	1	-4	19
	FM08	Stormwater Drainage at Lloyd George Grove	0	-1	0	1	1	0	1	2	0	0	0	0	0	-2	1	3	14
	FM09	Anna Bay near Gan Gan Rd	-2	1	2	3	2	0	3	2	0	1	0	-1	0	-1	2	12	4
	FM10	Clark St Low Point	-3	-3	2	2	1	0	2	1	0	0	0	-2	0	-3	2	-1	16
	FM11	Drainage Upgrade at Lemon Tree Passage at Tanilba Bay	0	1	2	2	1	0	3	1	0	0	0	0	0	0	1	11	6
	FM12	Drainage Upgrade at Lemon Tree Passage at Salt Ash	0	1	2	3	2	1	1	0	0	0	0	0	0	1	1	12	4
Property Modification	PM13	Voluntary Purchase	0	-1	0	2	0	0	3	0	1	0	2	0	0	1	1	9	9
	PM14	Flood Planning Levels	1	1	0	1	0	1	3	1	1	0	1	0	0	2	3	15	2
	PM15	Flood Planning Policy	1	1	2	2	0	2	3	1	1	0	2	0	0	1	3	19	1
	PM16	Voluntary House Raising	2	-1	0	1	0	0	3	0	1	0	0	0	0	1	1	8	10
	PM17	Flood Proofing Measures	0	2	1	0	0	0	2	2	0	1	1	0	0	0	1	10	8
Response Modification	RM18	Flood Awareness and Preparedness	0	2	2	3	0	0	0	0	3	0	0	0	0	1	3	14	3
	RM19	Evacuation Planning	0	1	2	3	0	0	0	0	1	1	0	0	0	2	1	11	6

(1) Critical facilities are those properties that, if flooded, would result in severe consequences to public health and safety. These may include fire, ambulance and police stations, hospitals, water and electricity supply, buses/train stations and chemical plants. Vulnerable facilities refer to those properties with vulnerable occupants, such as nursing homes or schools.
 (2) Community and stakeholder support scores will be confirmed following Public Exhibition

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The multi-criteria matrix assessment results, presented in Table 25, can be used to both understand the benefits and disadvantages of individual options, but to also see trends across the full suite of options assessed in the FRMS&P. The following results and trends are noted:

- Flood Planning Policy (PM15) received the highest score, as it delivers strong widescale benefits across a range of criteria including economics, reduction in flood risk, property affectation, as well as playing a role in community flood awareness;
- Flood Planning Level (PM14), and Flood Awareness and Preparedness (RM18) are cost effective and have additional benefits relating to improvements to community flood awareness. These options are the next highest scoring options.
- Response Modification Measures and Property Modification Measures tend to score more highly than Flood Modification measures, as they can be implemented for a relatively low cost, lead to the reduction of property damage and improvement in community resilience in the long term, and do not incur negative environmental impacts.
- The majority of flood modification measures, that is, structural options, do not score well in terms of economic merits. Reasons for this include:
 - “Tangible Benefits” included in the Cost Benefit Analysis are determined from the reduction in property damages (Annual Average Damages (AAD)). The benefits from the majority of these options come from improved road access which is not included in the AAD calculation.
- The lowest scoring options with negative score include FM07, FM03 and FM06, which involve major structure upgrades with feasibility challenges. A negative score indicates that the option has more constraints than benefits.

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The Floodplain Risk Management Plan summarises the recommended measures that have been investigated as part of the Floodplain Risk Management Study. Measures have been assessed for effectiveness against a range of criteria. The assessment criteria included how the option affected property damages, community flood awareness, impact on the NSW SES, and economic merits, and a range of other factors.

Many of the recommended options, particularly the flood modification options, require a further feasibility investigation to refine and develop the concept options developed as part of this study.

Recommended options are prioritised based upon how readily the management measures can be implemented, their capital cost, what constraints exist and how effective the measures are. Measures with little cost that can readily be implemented, and which are effective in reducing damage or personal danger would have high priority. Priorities have also been assigned to the further feasibility investigations, as these can more readily be progressed (subject to funding) in contrast to implementation. Prioritisation of feasibility investigations are based on the risk-benefit ratio, including the number of properties benefitted, as well as the likely complexity and cost of the feasibility investigation.

Table 26 lists the mitigation measures that have been recommended by the Floodplain Risk Management Study for implementation and describes the purpose of the measure, as well as its priority, cost, timeframe and the party responsible for its implementation. Detailed description of each recommendation is provided in Section 10 of the Study.

The Floodplain Risk Management Plan has been prepared in accordance with the NSW Floodplain Development Manual, and the NSW Flood Risk Management Manual.

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Table 26: Draft Floodplain Management Plan

FLOODPLAIN RISK MANAGEMENT MEASURES									
Option ID	Type	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	Priority
FM01	Flood Modification	Flood Barrier at Blake Pde Park	Construction of a 1m high flood barrier at existing storage basin. Initially, a more detailed analysis in the form of a feasibility investigation would be undertaken to refine and develop the concept before implementation is recommended.	May reduce flood affectation at two properties in frequent events only	Moderate capital costs and limited benefit to flood damages. Visual aesthetics of Blake Pde Park may be impacted. Further upgrade to stormwater pipes along Morna Point Rd are required to reduce flood levels in larger flood events.	Council	May be eligible for NSW Government funding assistance	Low (Feasibility) Moderate (Implementation)	High ⁽¹⁾ (Feasibility) Low (Implementation)
FM02	Flood Modification	Flood Barrier Along Hutcheson Road	Installation of flood barrier in the form of permanent low-level impervious fencing and driveway raising of 3 private properties along Hutcheson Rd. Initially, a more detailed analysis in the form of a feasibility investigation would be undertaken to refine and develop the concept before implementation is recommended.	Removes above flood flooding in 2 properties in the current 1% AEP event. Low capital costs Council has experience implementing similar works	Minor flood level increase within Hutcheson Rd corridor (+30mm in current 1% AEP). Works may impact existing drainage and this requires consideration in concept development. Works within private property and will require community consultation.	Council	May be eligible for NSW Government funding assistance	Low (Feasibility) Low (Implementation)	High ⁽¹⁾ (Feasibility) Medium (Implementation)
FM04	Flood Modification	Diversion Drain Near Purcell Avenue, Lemon Tree Passage	Construction of drain up to 1.5 m depth drain from spillway of existing basin. Initially, a more detailed analysis in the form of a feasibility investigation would be undertaken to refine and develop the concept before implementation is recommended.	Reduces peak flood levels by up to 120 mm	Removal of vegetation for drain Access to drain site for construction	Council	May be eligible for NSW Government funding assistance	Low (Feasibility) Low (Implementation)	High ⁽¹⁾ (Feasibility) Low (Implementation)
FM06	Flood Modification	Drainage of Davidson St Low Point	Additional pipe connecting Davidson St low point to the existing stormwater network. Initially, a more detailed analysis in the form of a feasibility investigation would be undertaken to refine and develop the concept before implementation is recommended.	Reduces flood extent such that above floor flooding reduces from four properties to one.	New pipe network passes under existing private property. New pipe network passes under Campbell Ave and may require a deep trench excavation. Current 1% AEP event only impacts four residential properties. Annual average damages are unlikely to be significantly reduced.	Council	May be eligible for NSW Government funding assistance	Low (Feasibility) High (Implementation)	Medium ⁽¹⁾ (Feasibility) Low (Implementation)
FM09	Flood Modification	Channel and Drainage Upgrade at Anna Bay near Gan Gan Road	Upgrade of Fern Tree Drain and additional stormwater network upgrades at Anna Bay near Gan Gan Rd. Initially, a more detailed analysis in the form of a feasibility investigation would be undertaken to refine and develop the concept before implementation is recommended.	Reduction in peak flood levels and above floor flooding in rare events	High capital cost and complex implementation	Council	May be eligible for NSW Government funding assistance	Low (Feasibility) High (Implementation)	Medium ⁽¹⁾ (Feasibility) Low (Implementation)
FM10	Flood Modification	Drainage of Clark Street Low point	Additional stormwater infrastructure in accordance with condition of consent.	Reduction in local peak levels and duration of inundation.	High capital costs. Complex construction methodology.	Private developer ⁽²⁾	Private developer	High	Medium (Feasibility) High at time of Development (Implementation)
FM11	Flood Modification	Upgrade Drainage at Lemon Tree Passage Road at Taniiba Bay and Mallabula	Drainage upgrade at Lemon Tree Passage Road at Taniiba Bay and Mallabula Initially, a more detailed analysis in the form of a feasibility investigation would be undertaken to refine and develop the concept before implementation is recommended.	Reduces flood affectation to properties along the northern side of Lemon Tree Passage Road	Further works are required to ensure properties downstream of Lemon Tree Passage Road will not be affected.	Council	May be eligible for NSW Government funding assistance	Low (Feasibility) High (Implementation)	High ⁽¹⁾ (Investigation) Medium (Implementation)



FLOODPLAIN RISK MANAGEMENT MEASURES									
Option ID	Type	Option	Description	Benefits	Concerns	Responsibility	Funding	Cost	Priority
FM12	Flood Modification	Upgrade Drainage at Lemon Tree Passage Road at Salt Ash – Detailed Investigation	Upgrade of cross drainage at Lemon Tree Passage Rd at Salt Ash Initially, a more detailed analysis in the form of a feasibility investigation would be undertaken to refine and develop the concept before implementation is recommended.	Reduces road overtopping in frequent events	High capital costs. Cross drainage requires maintenance to be effective	Council	May be eligible for NSW Government funding assistance	Low (Feasibility) High (Implementation)	High ⁽¹⁾ (Investigation) Medium (Implementation)
PM13	Property Modification	Voluntary House Purchase	Undertake further investigation of the identified properties in a VP scheme, including consultation with the identified properties, prioritisation and if appropriate, prepare the documentation for funding applications.	Voluntary Purchase (VP) schemes are a long-term option to remove residential properties from areas of high flood hazard reducing risks to life of residents and potential rescuers.	Community appetite for or acceptance of VP may be a challenge. VP schemes are long term options, have high costs and may take approximately a decade to implement.	Council	May be eligible for NSW Government funding assistance	Low (Investigation) High (Implementation)	High ⁽¹⁾ (Investigation) Low (Implementation)
PM14	Property Modification	Flood Planning Levels	Council to continue to use the following Flood Planning Levels: The level of the 1% AEP (annual exceedance probability) flood event in the year 2100 plus 0.5 metre freeboard, except for overland flooding areas where a freeboard of 0.3 metre is applied. The area of land below the Flood Planning Level (i.e. the Flood Planning Area) is subject to flood-related development controls.	FPLs are effective tools to limit property damage to new development and redevelopment. FPLs may pertain to minimum floor levels or flood proofing levels depending on the type of development.	May be considered more onerous for developers.	Council	Council	In house	High
PM15	Property Modification	Flood Planning Policy	Implement a range of minor recommendations to improve Council's Flood Planning Policy as applied through Council's Development Control Plan	Ensure developments are designed, constructed and managed in such a way as to minimise flood risk to the structure and (if relevant) its occupants, in addition to minimising the impacts of flooding.	There may be resistance from developers who consider new controls to be onerous or likely to reduce the development yield.	Council	Council	In house	High
PM16	Property Modification	Voluntary House Raising	Undertake a feasibility investigation for the identified properties (including to confirm structural compatibility of the identified buildings, owner interest and a more accurate cost estimate of raising to at least the DFE + 0.5 m flood level), and if found viable, prepare the documentation for funding applications.	Seeks to reduce the frequency of exposure to flood damage of the house and its contents by raising the house above the Flood Planning Level (FPL), resulting in a reduction in the frequency of household disruption and associated trauma and anxiety.	External flood risk remains, and evacuation is required before inundation in cases where the property becomes isolated. Community appetite may be a challenge. VHR schemes are long term options and may take approximately a decade to implement.	Council/ Landholder	May be eligible for NSW Government funding assistance	Low (Investigation) High (Implementation)	High ⁽¹⁾ (Investigation) Low (Implementation)
PM17	Property Modification	Flood Proofing	Include options for the use of flood proofing to the FPL for non-residential land uses within Council's DCP	This will enable new and existing buildings to be developed with due consideration given to their flood risk and minimisation of internal flood damages.	More vulnerable uses may use building in the future, and this would need to be managed.	Council	Council	In house	High
RM18	Response Measure	Flood Awareness and Preparedness	Establish and implement ongoing and collaborative education to improve flood awareness.	Flood awareness significantly improves preparedness for and recovery from flood events, building a more flood resilient community.	Ongoing efforts to ensure information is not forgotten. Potential for residents to become bored or complacent with messaging.	Council in collaboration with other response agencies and community organisations.	Council	Annual Budget to be determined and allocated.	High
RM19	Response Measure	Evacuation Planning	Update of the Port Stephens Flood Emergency Sub Plan to include the information provided as part of this floodplain risk management study, including updates to the flood behaviour, flood emergency response classification, and within the study area.	Detailed information will allow for better management and recovery of flood risk and will increase understanding of the different levels and types of risk present in the study area.	Modelled results should be used as a guide only, as real flood behaviour may vary from modelled design results	NSW SES	NSW SES	In house	High

(1) Progression of Feasibility Investigations are reliant on funding availability.

(2) This option will be delivered by a private developer in association with an approved consent condition. Should consent not be pursued, Council may assume responsibility of the option subject to funding availability.

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FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.****13. REFERENCES**

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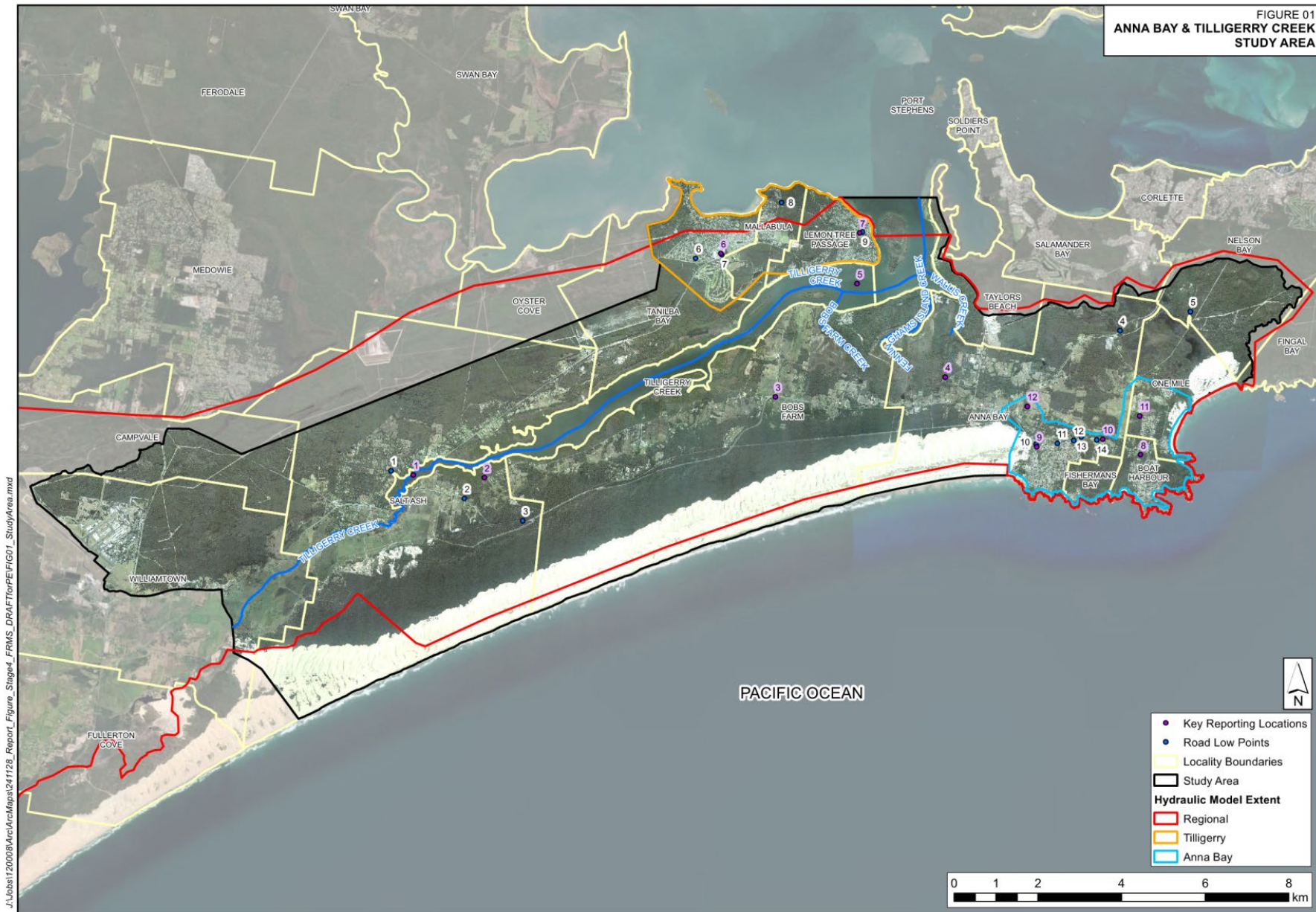
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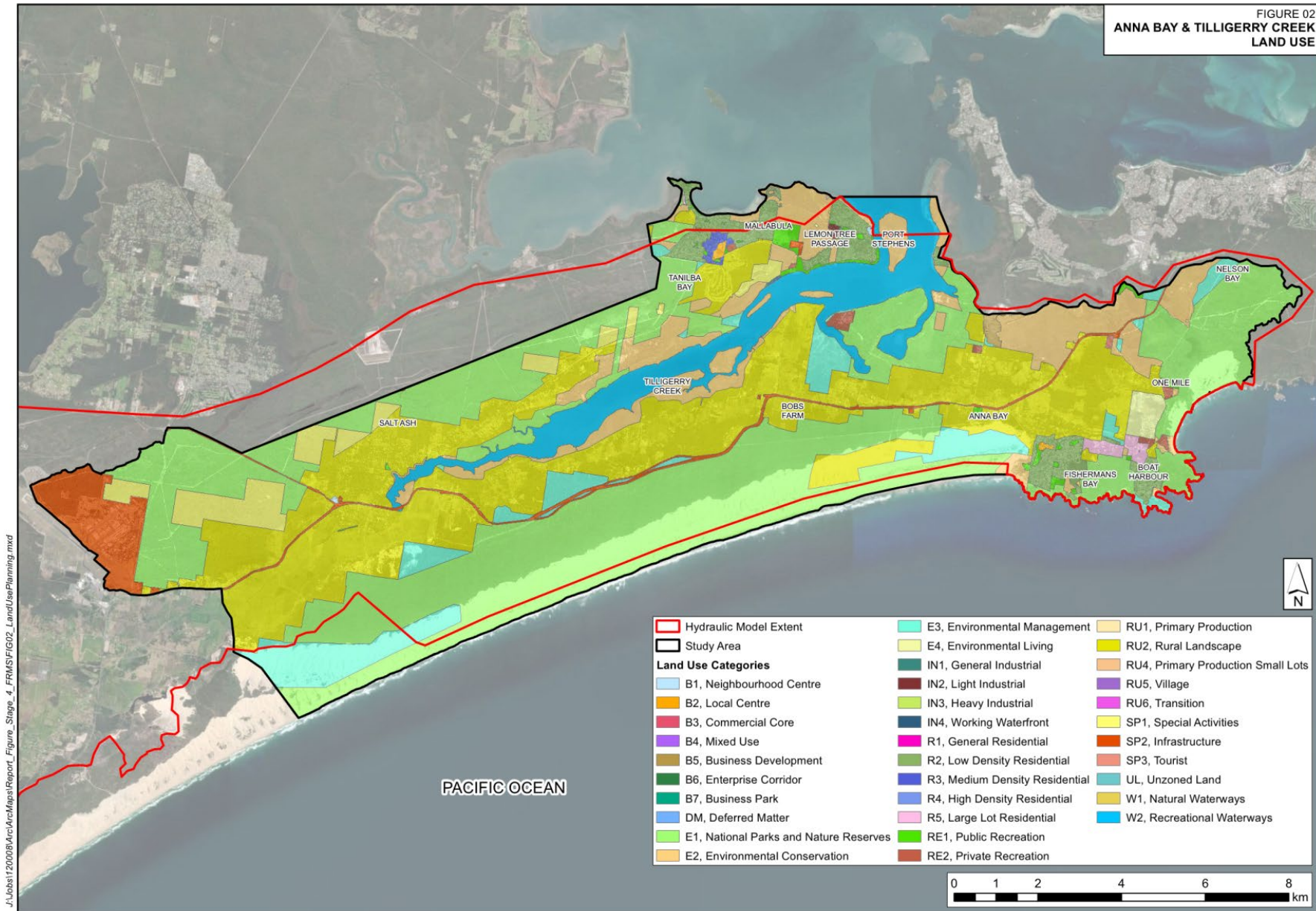


Figures

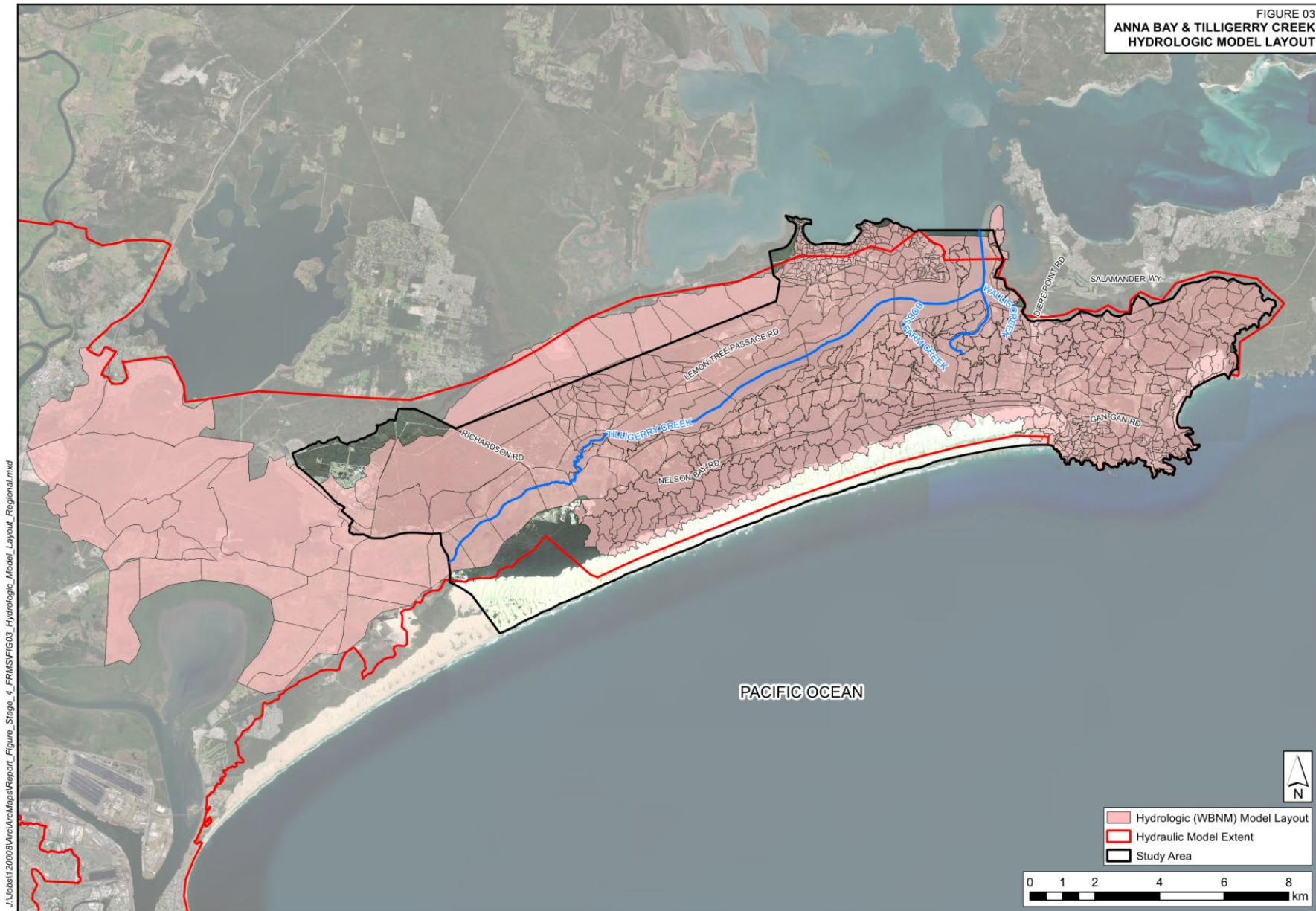
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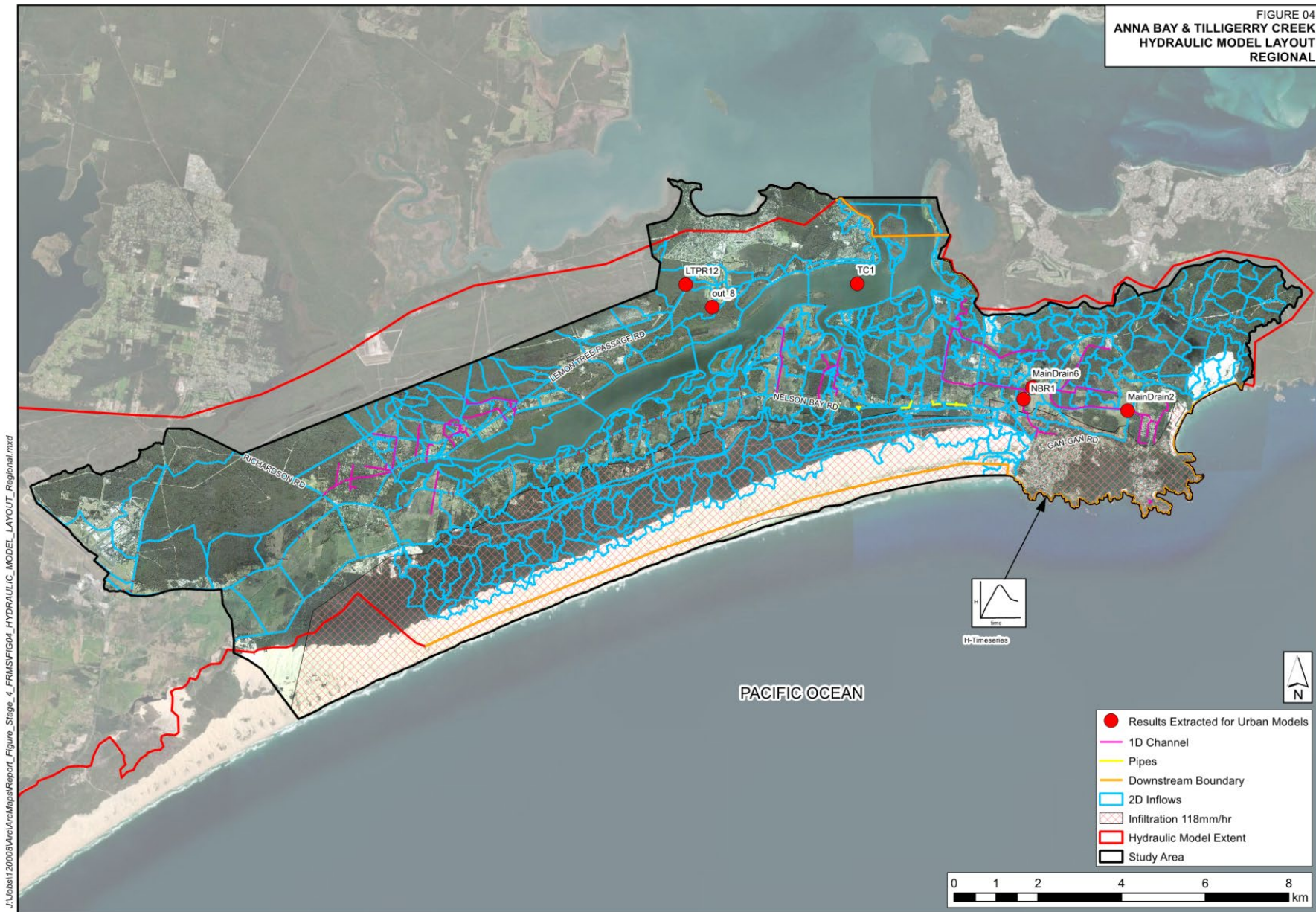
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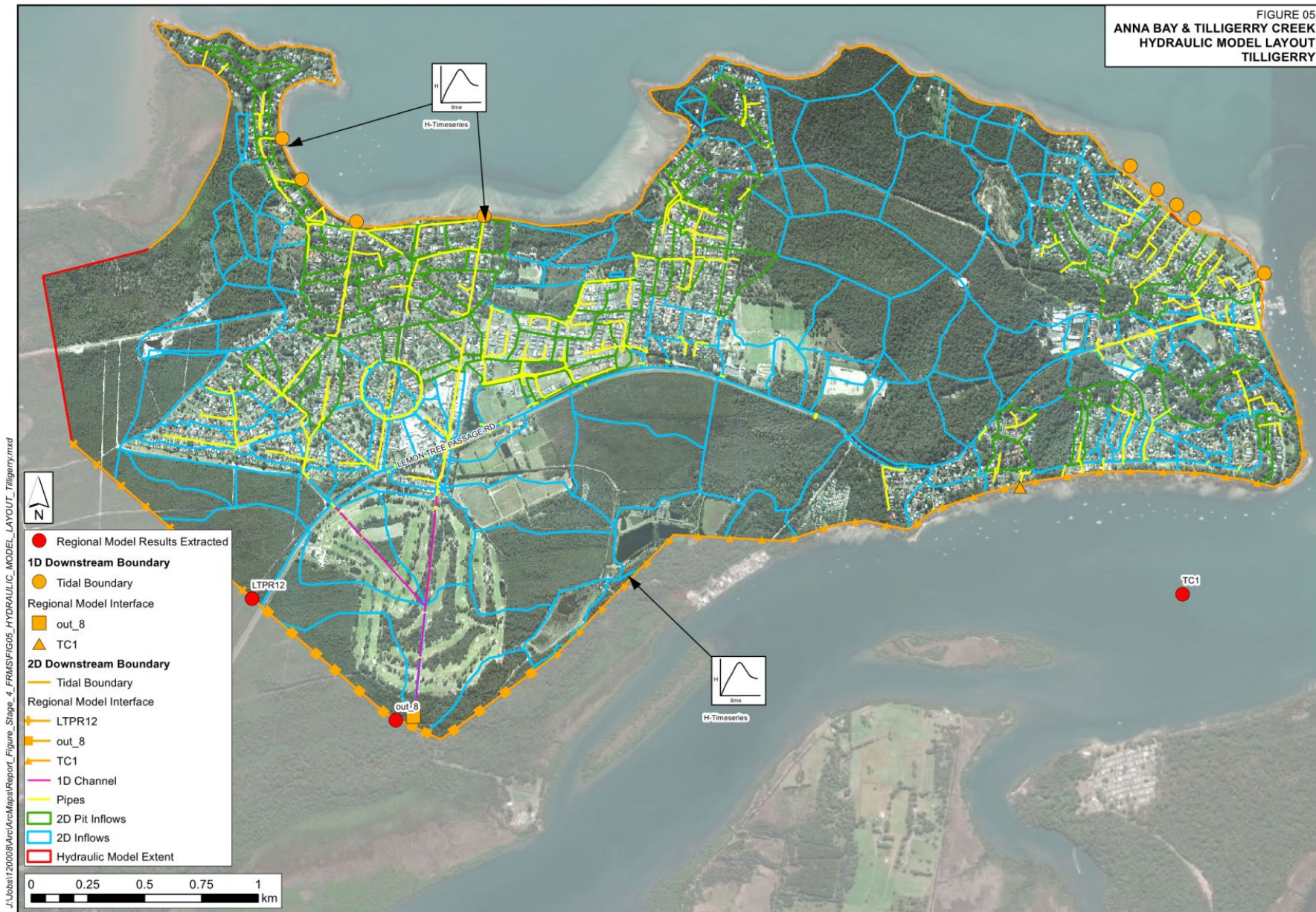
ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.

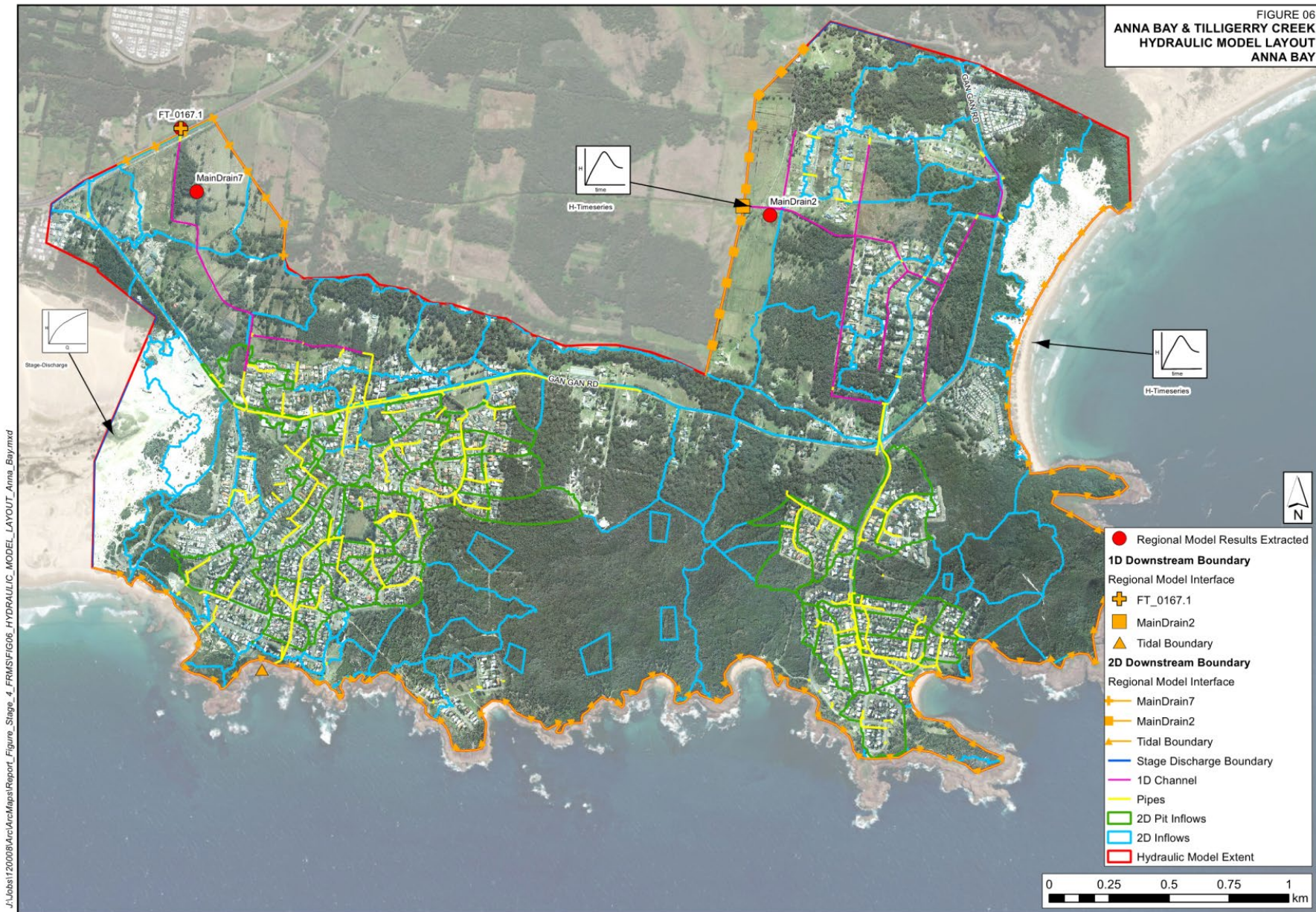


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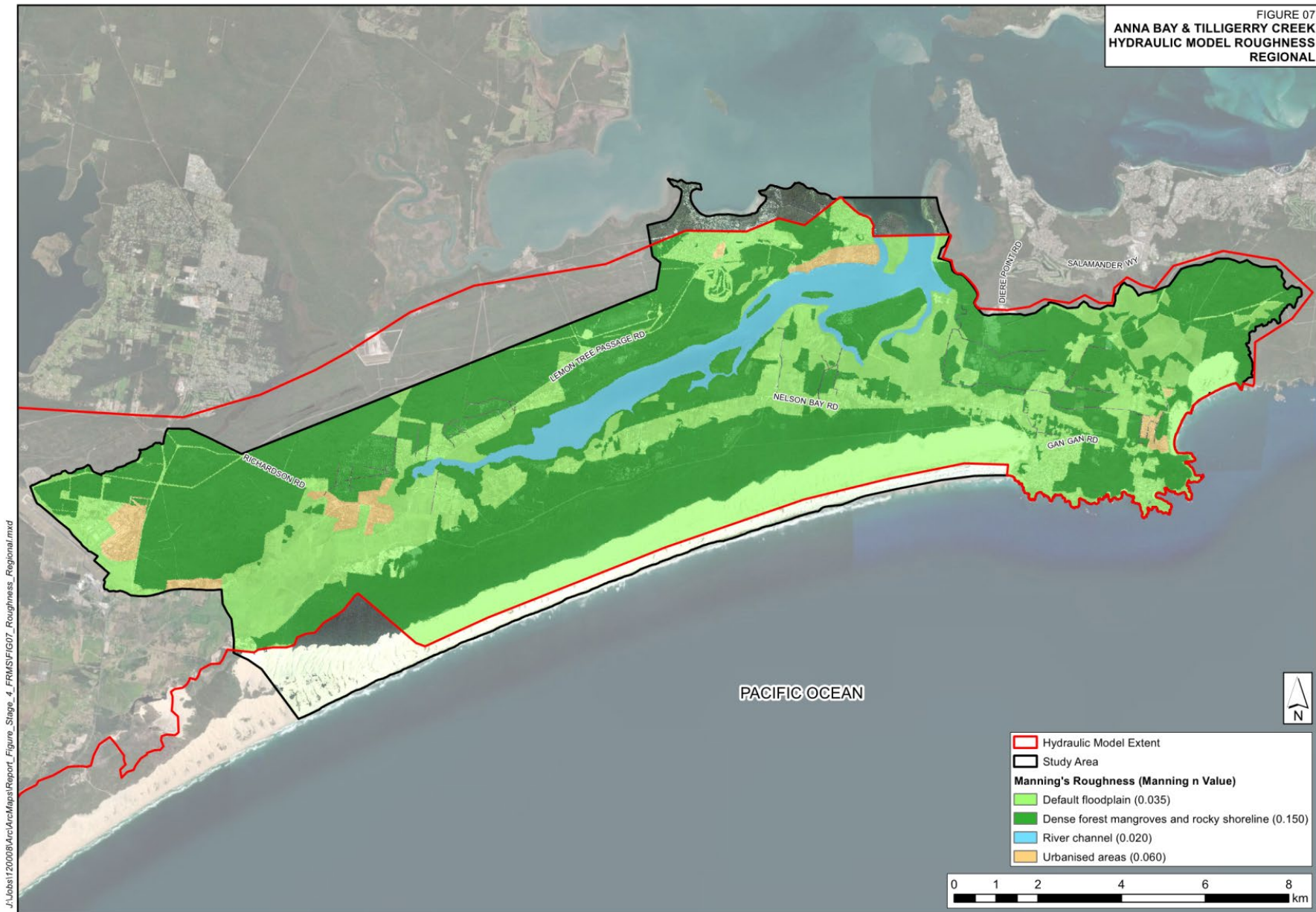


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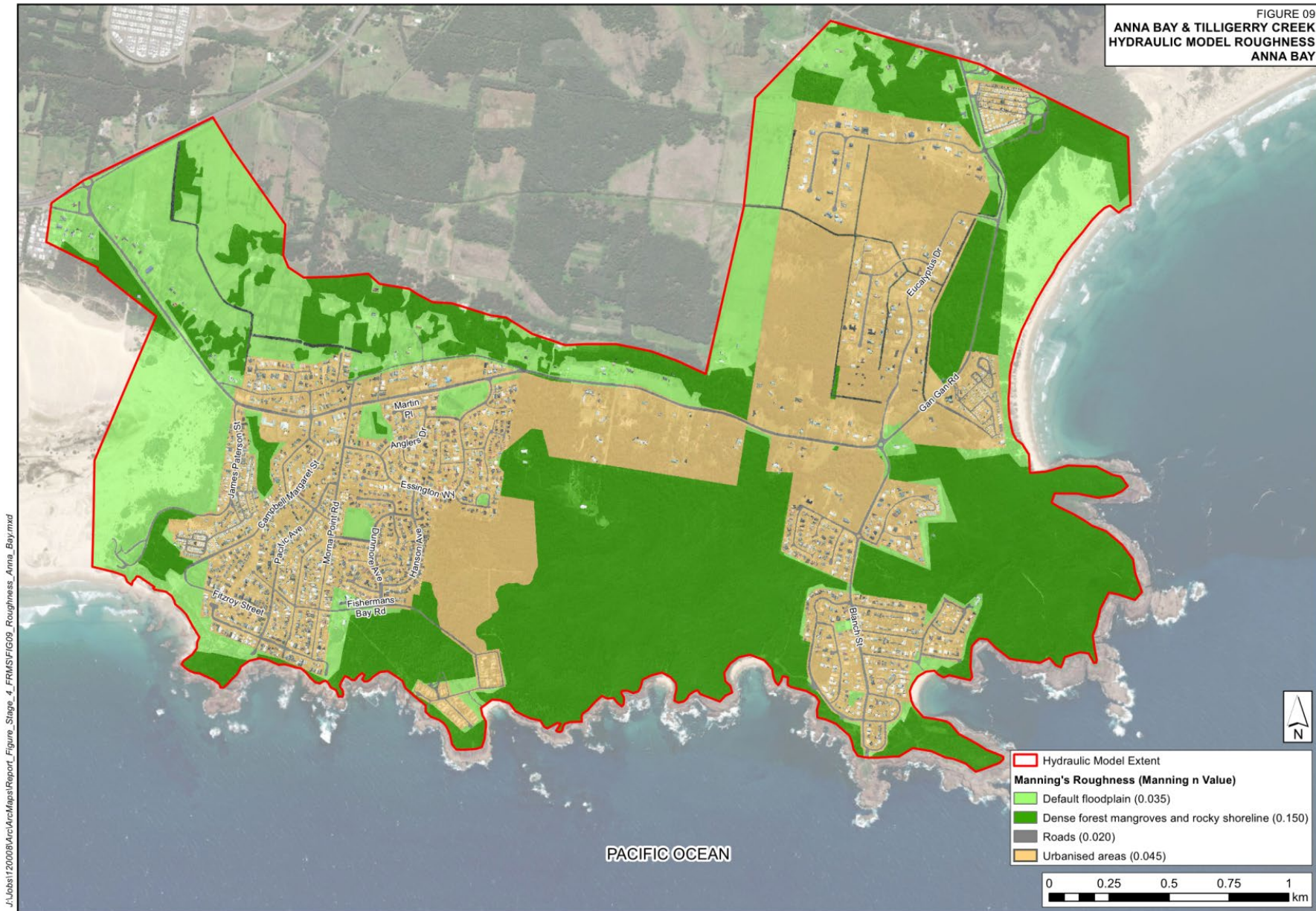


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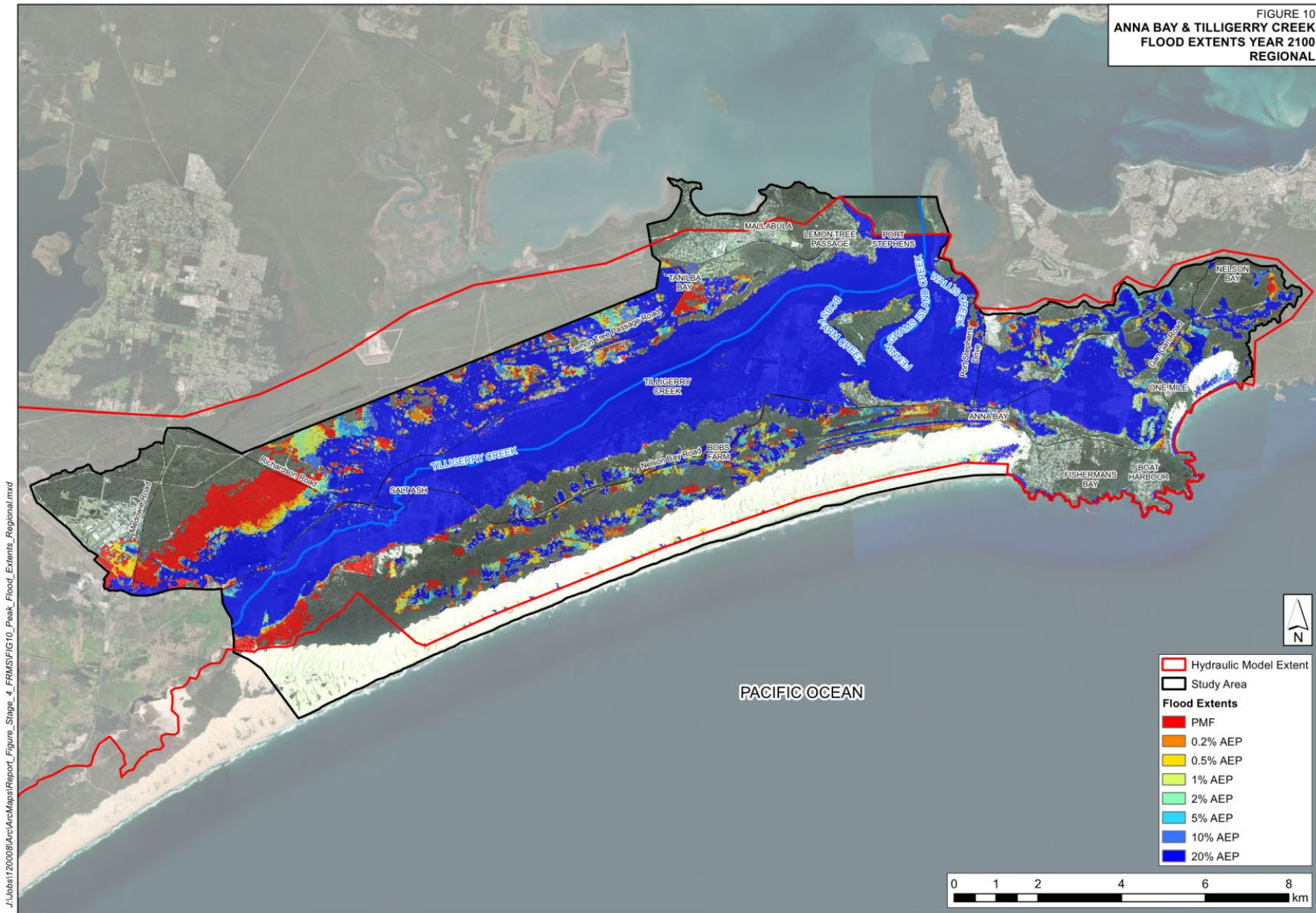


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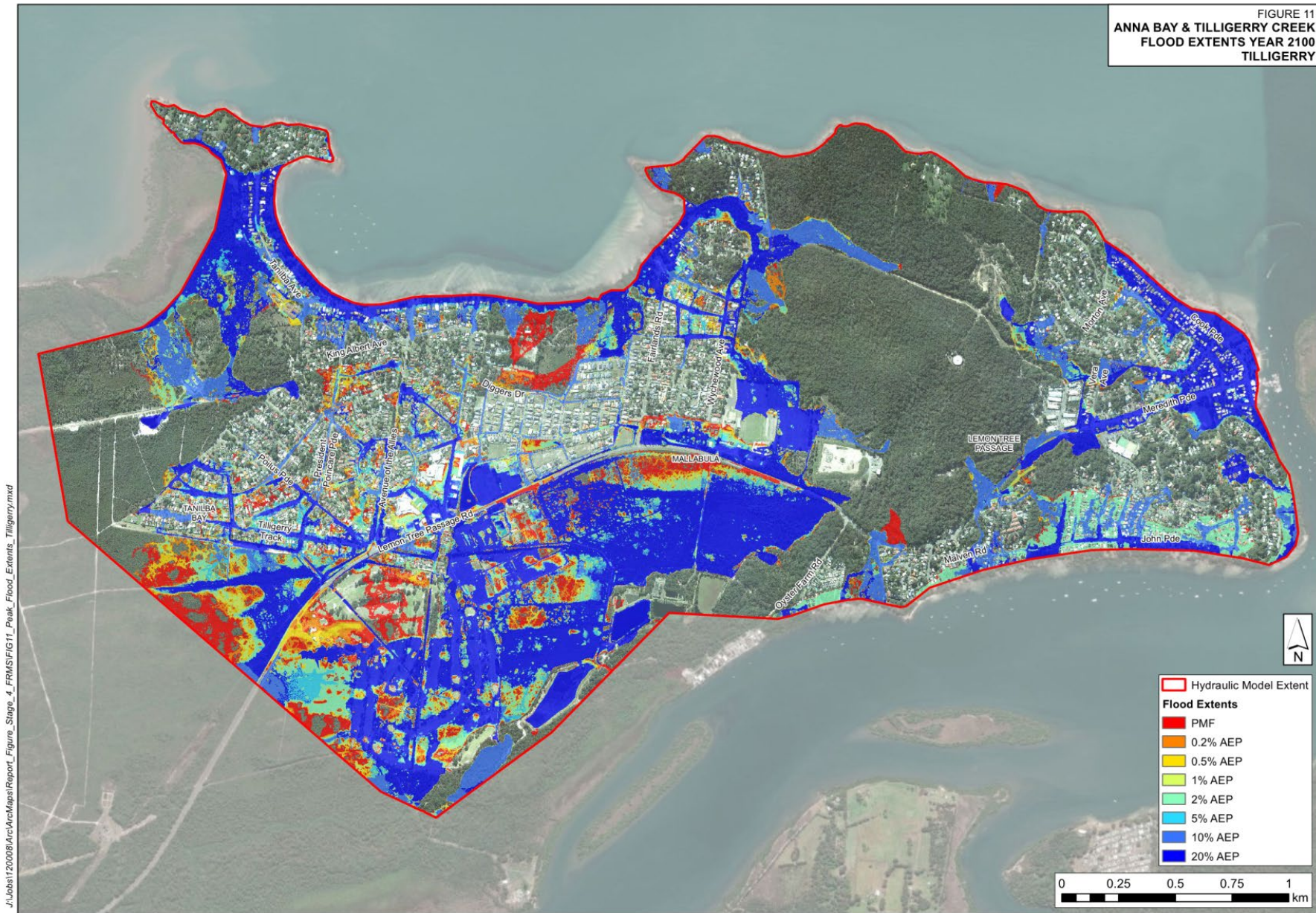


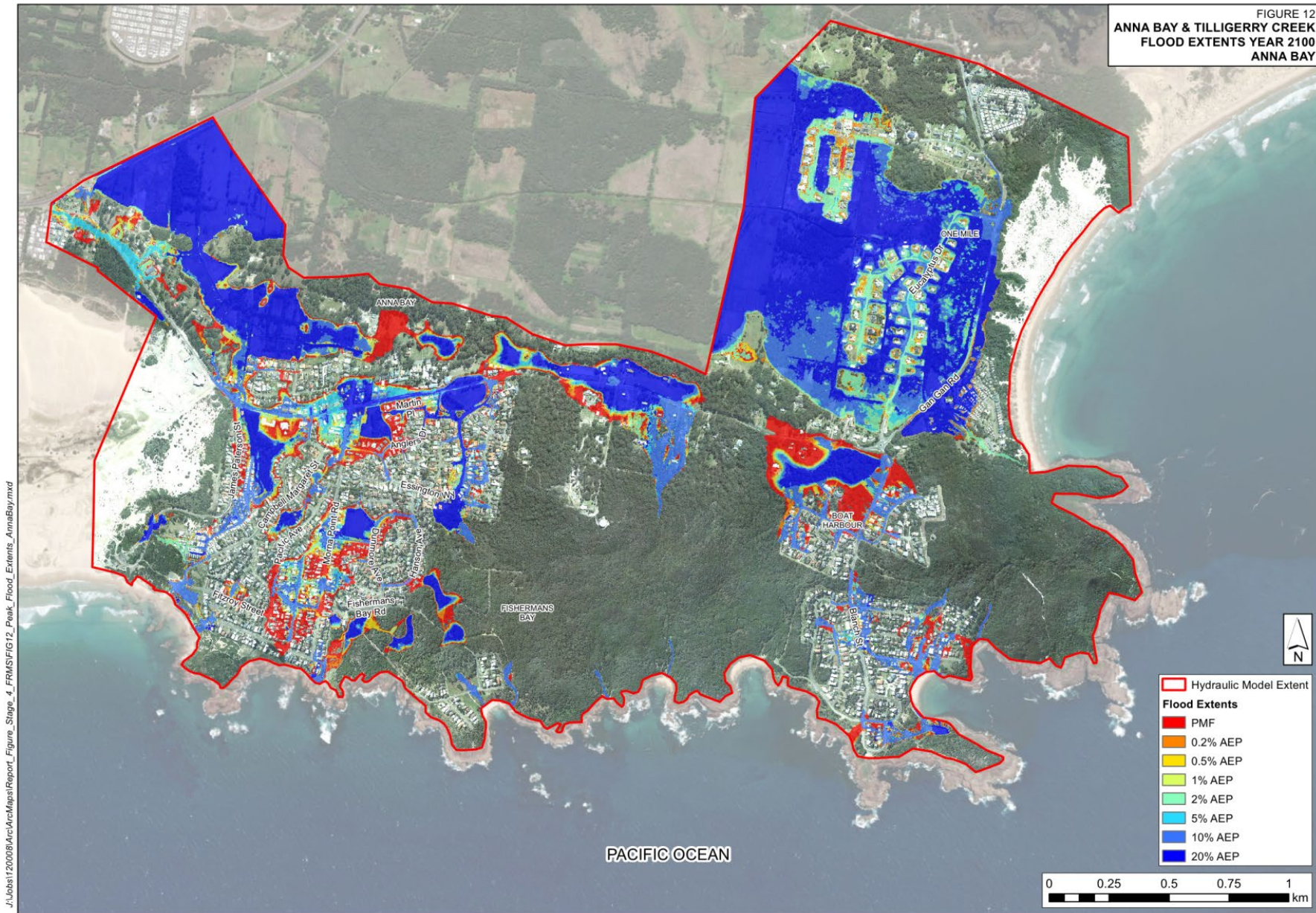


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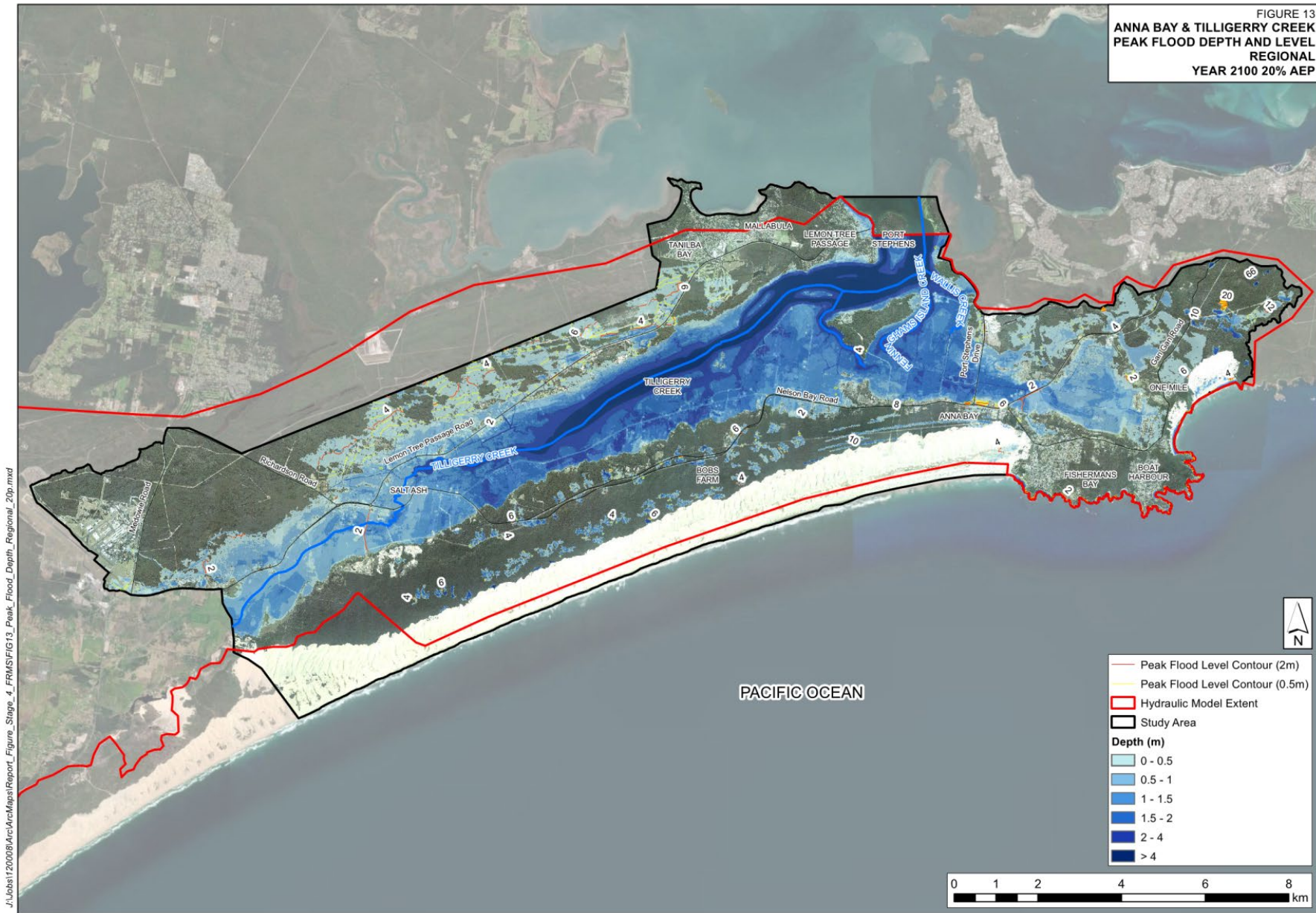
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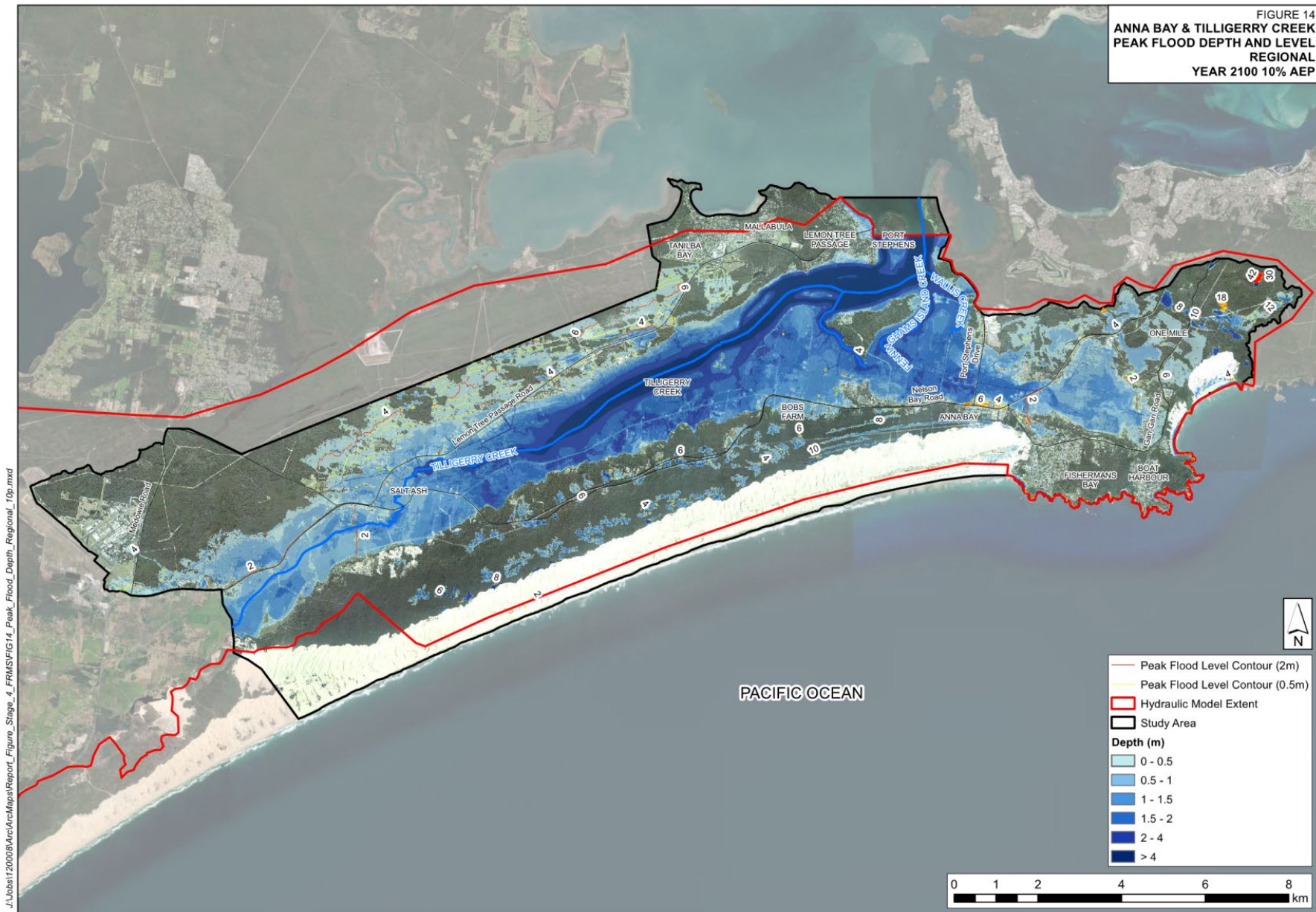


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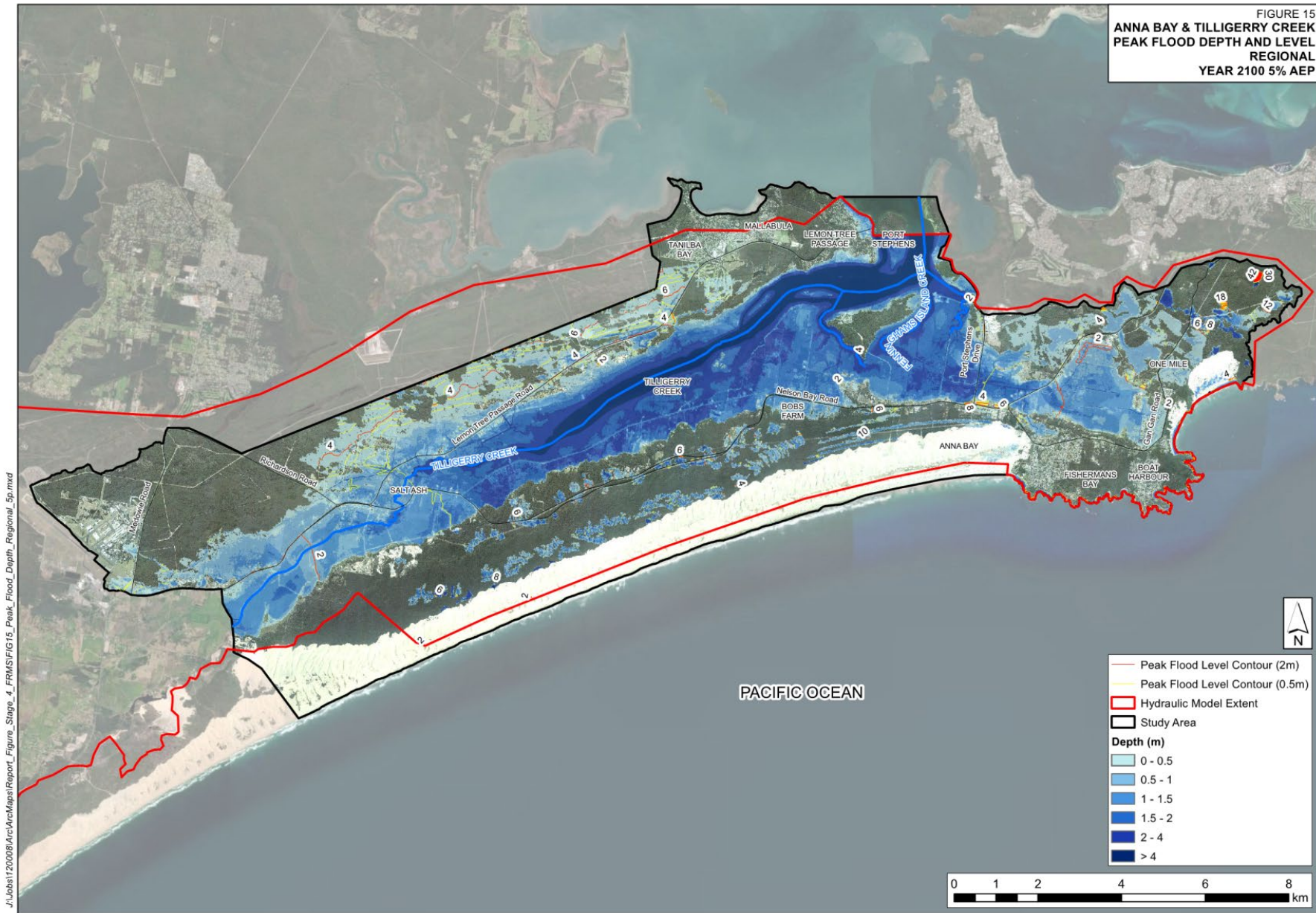
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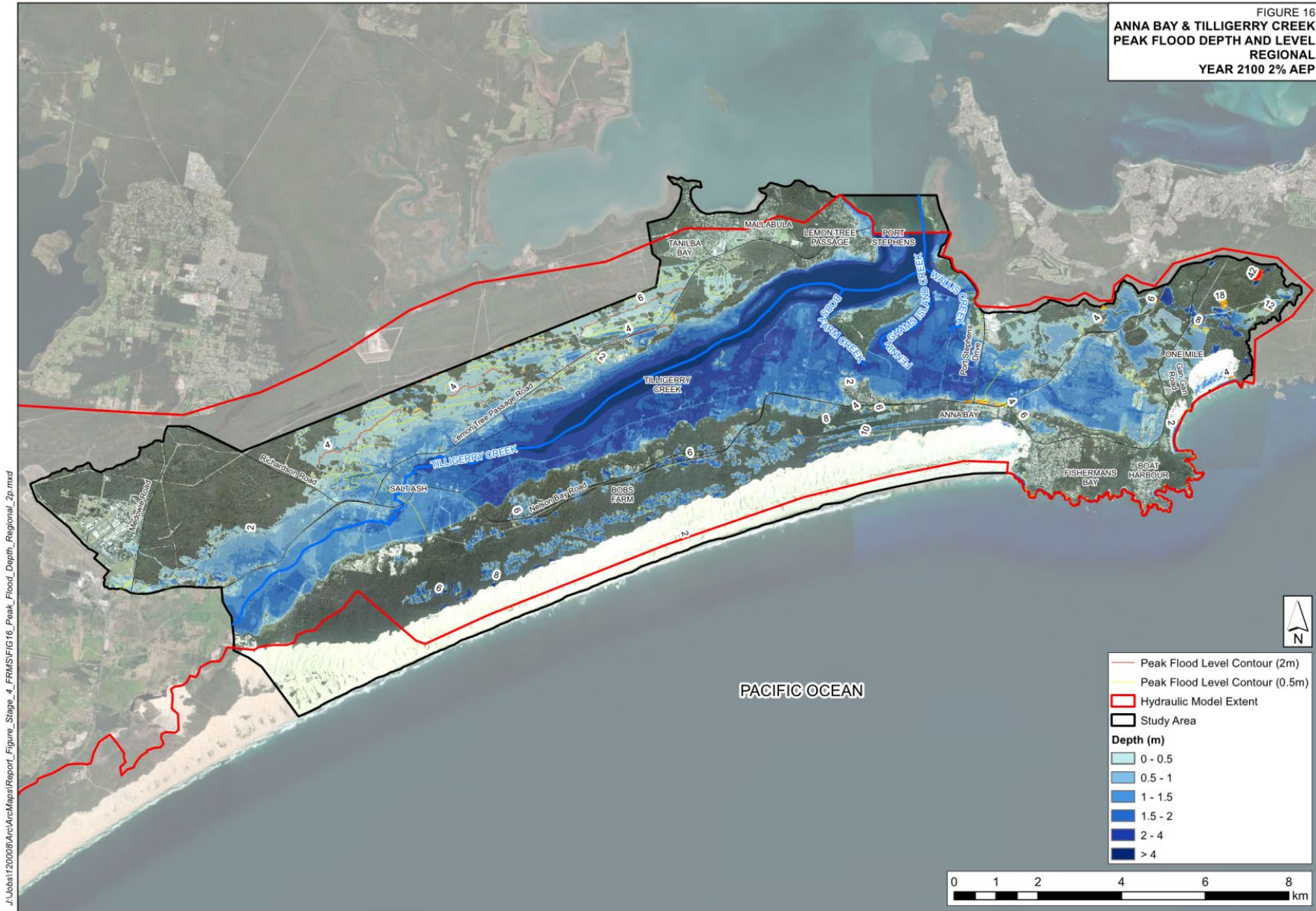
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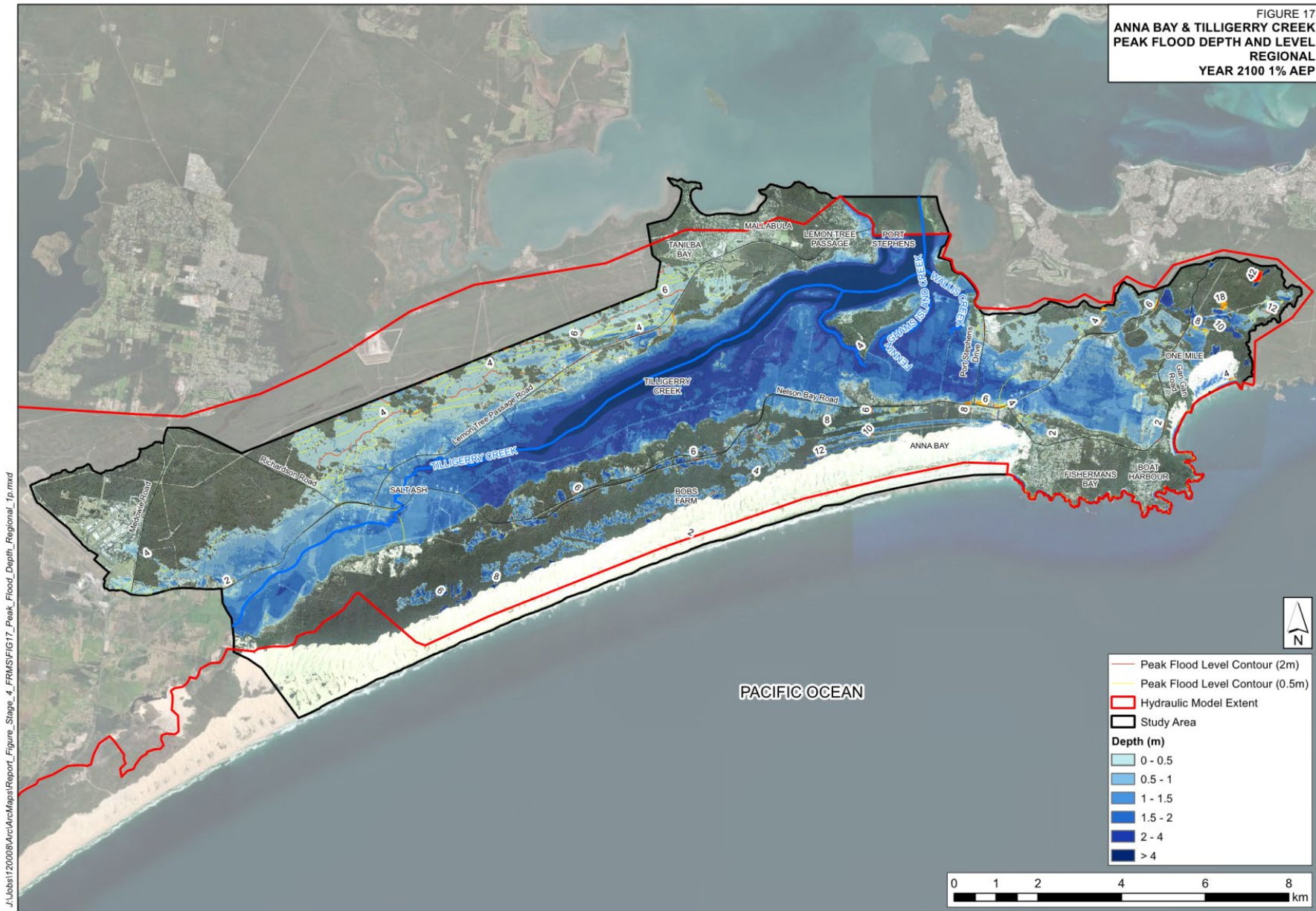


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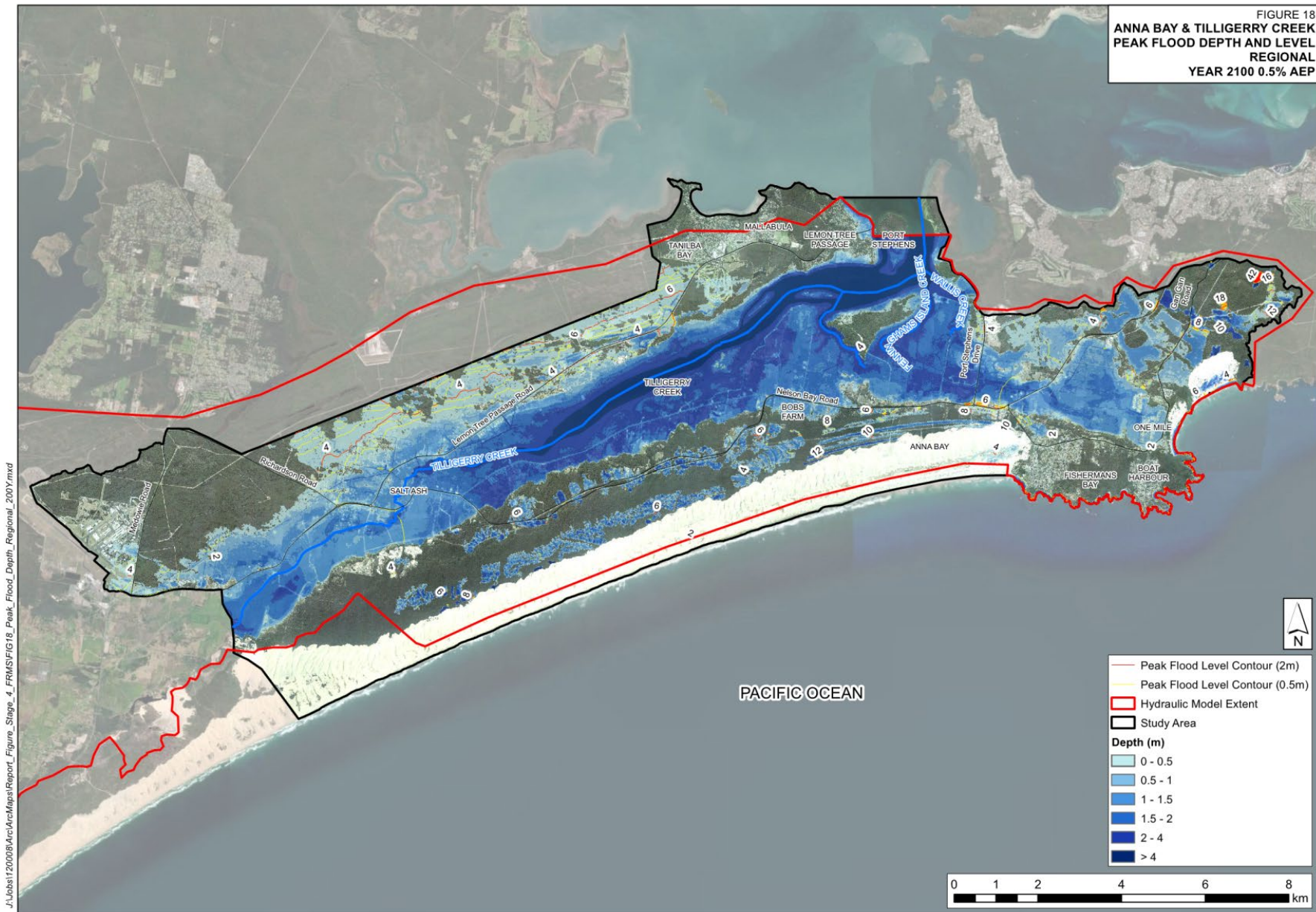


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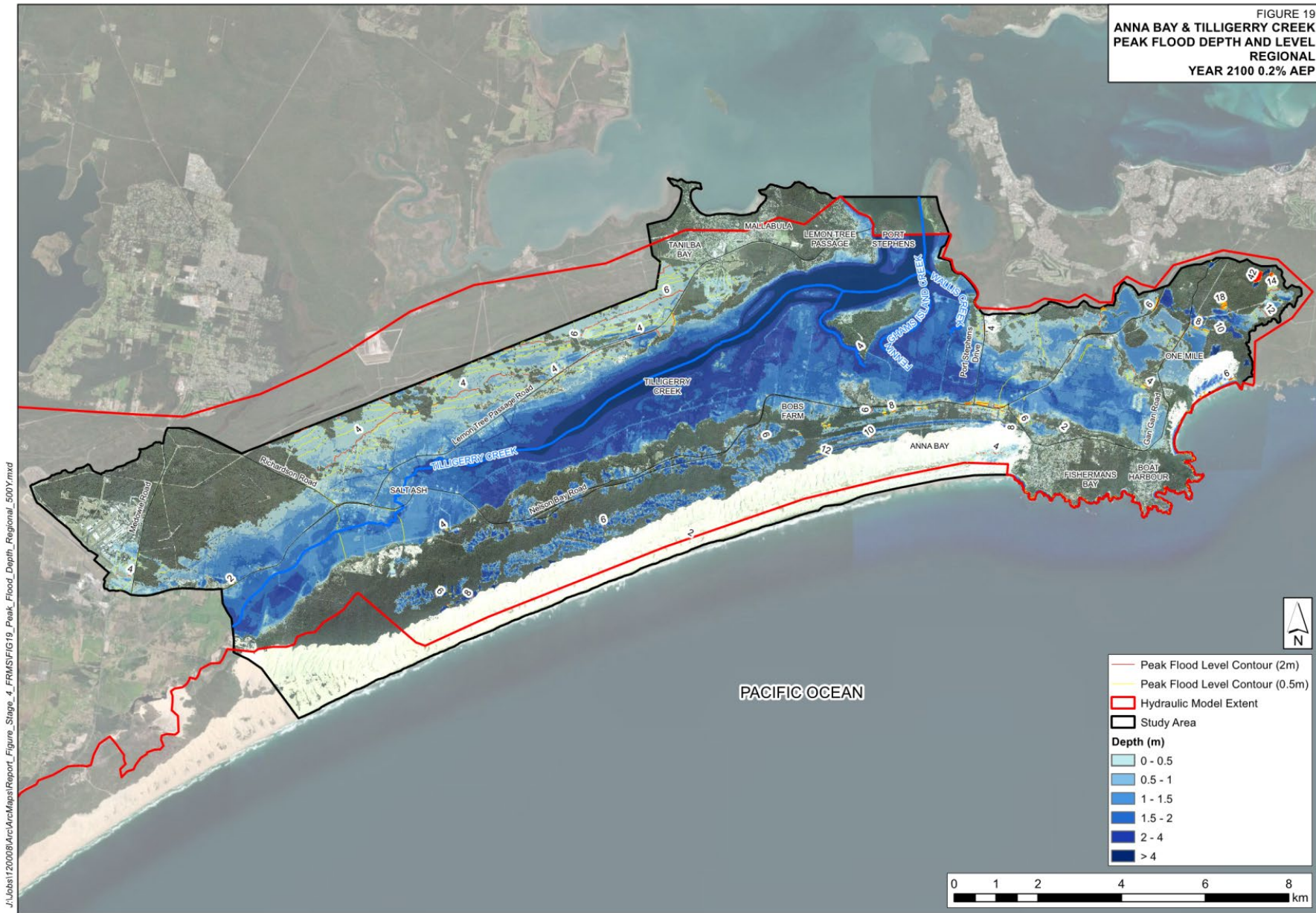
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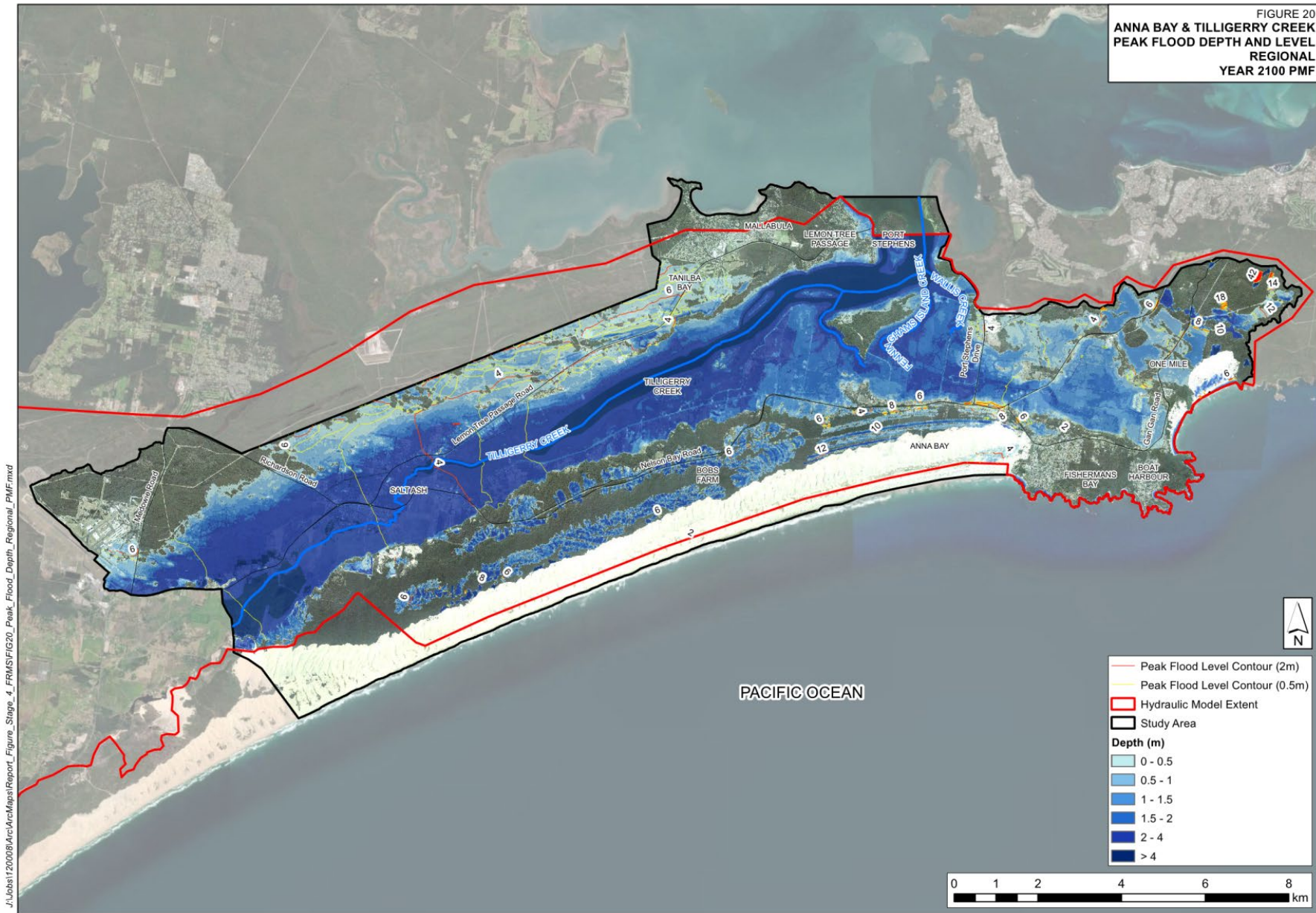
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ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.



ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.



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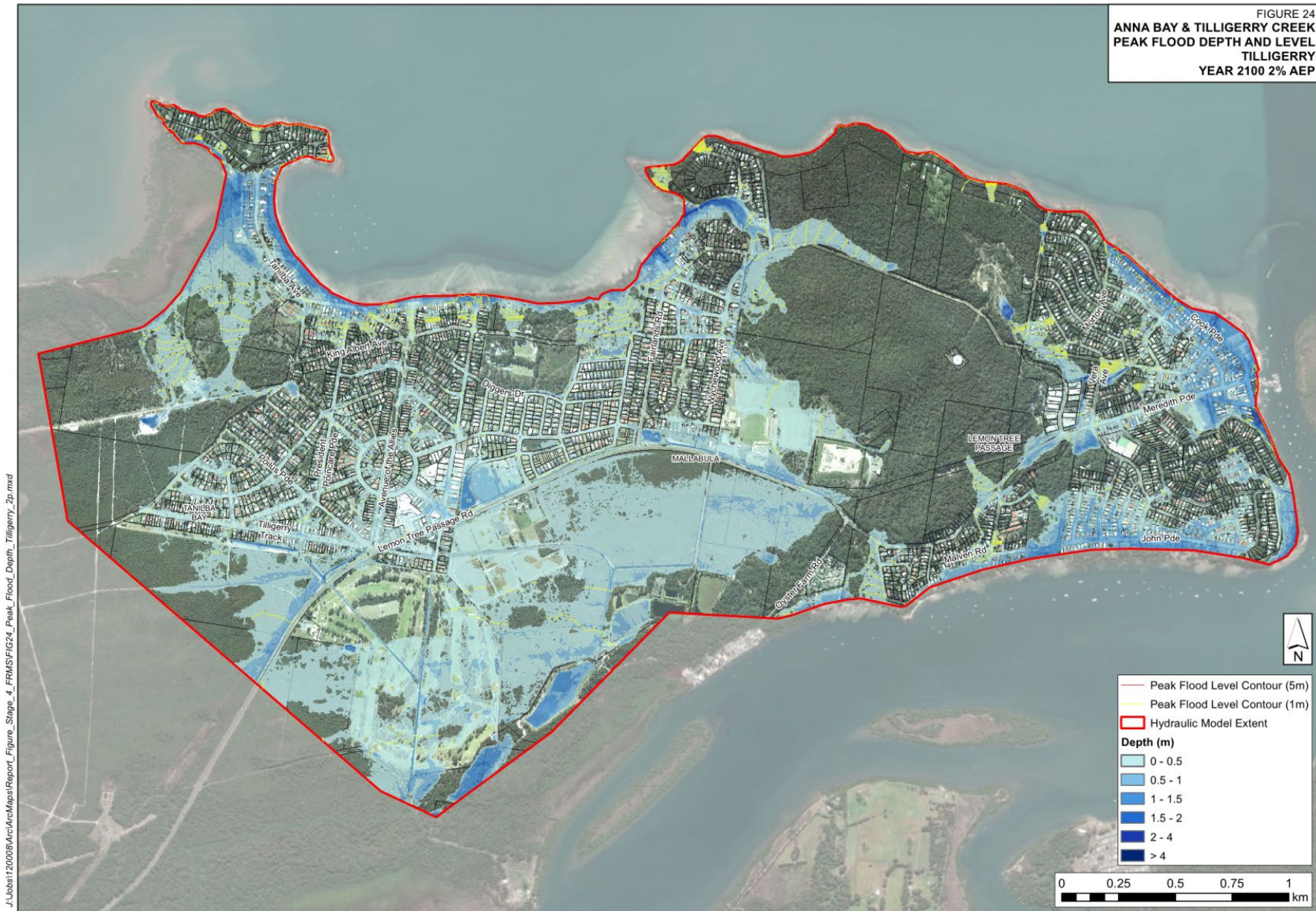
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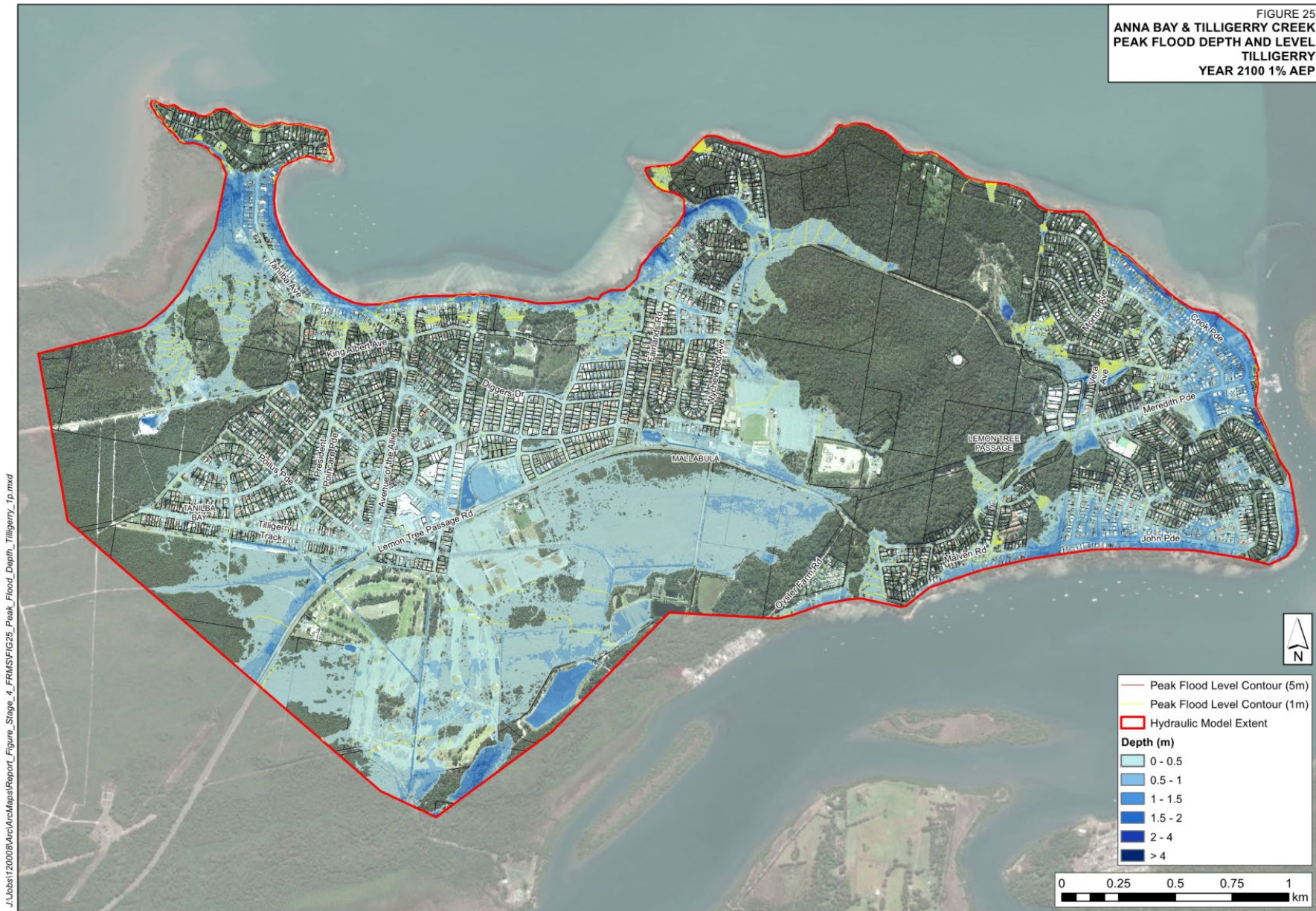
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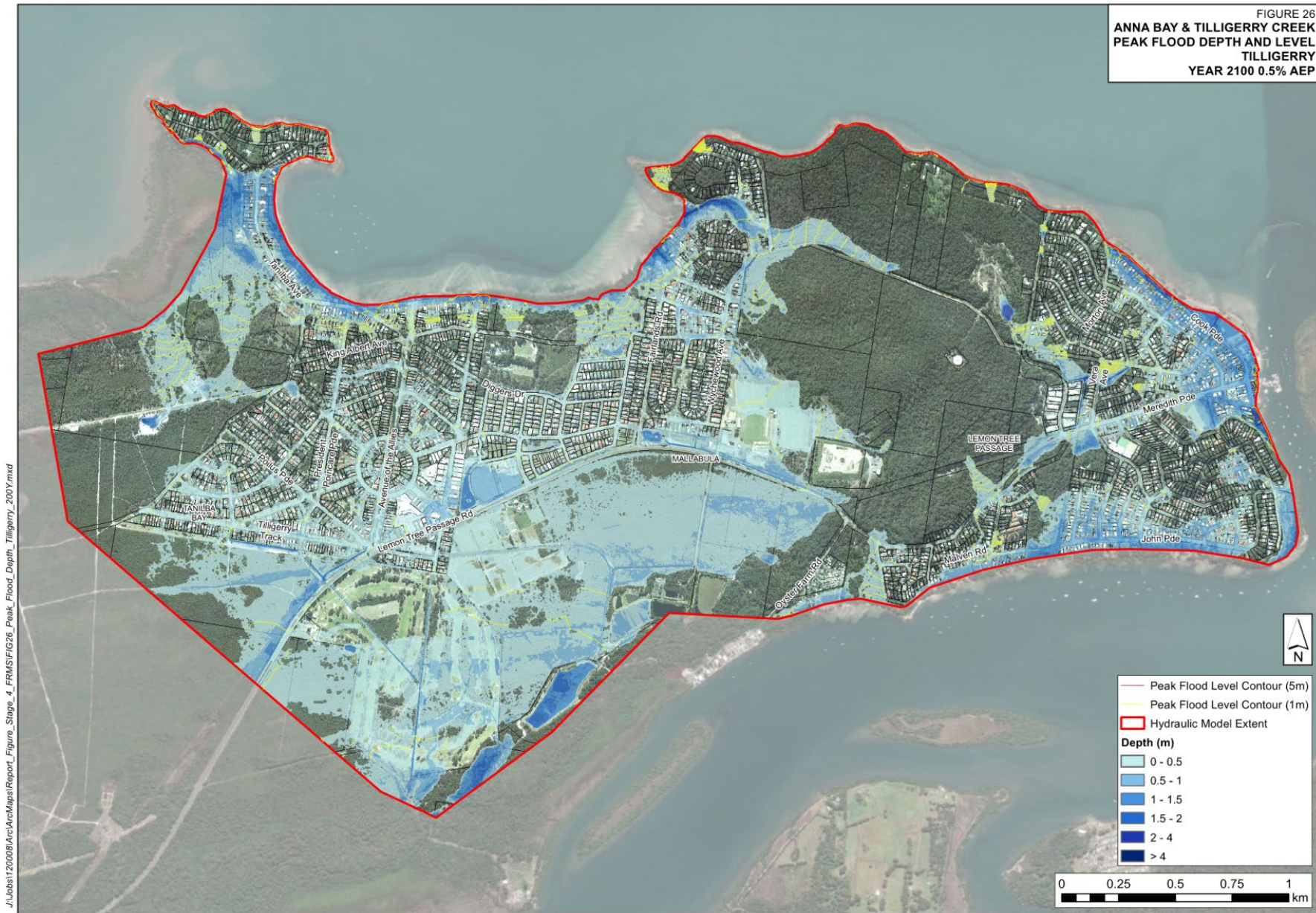
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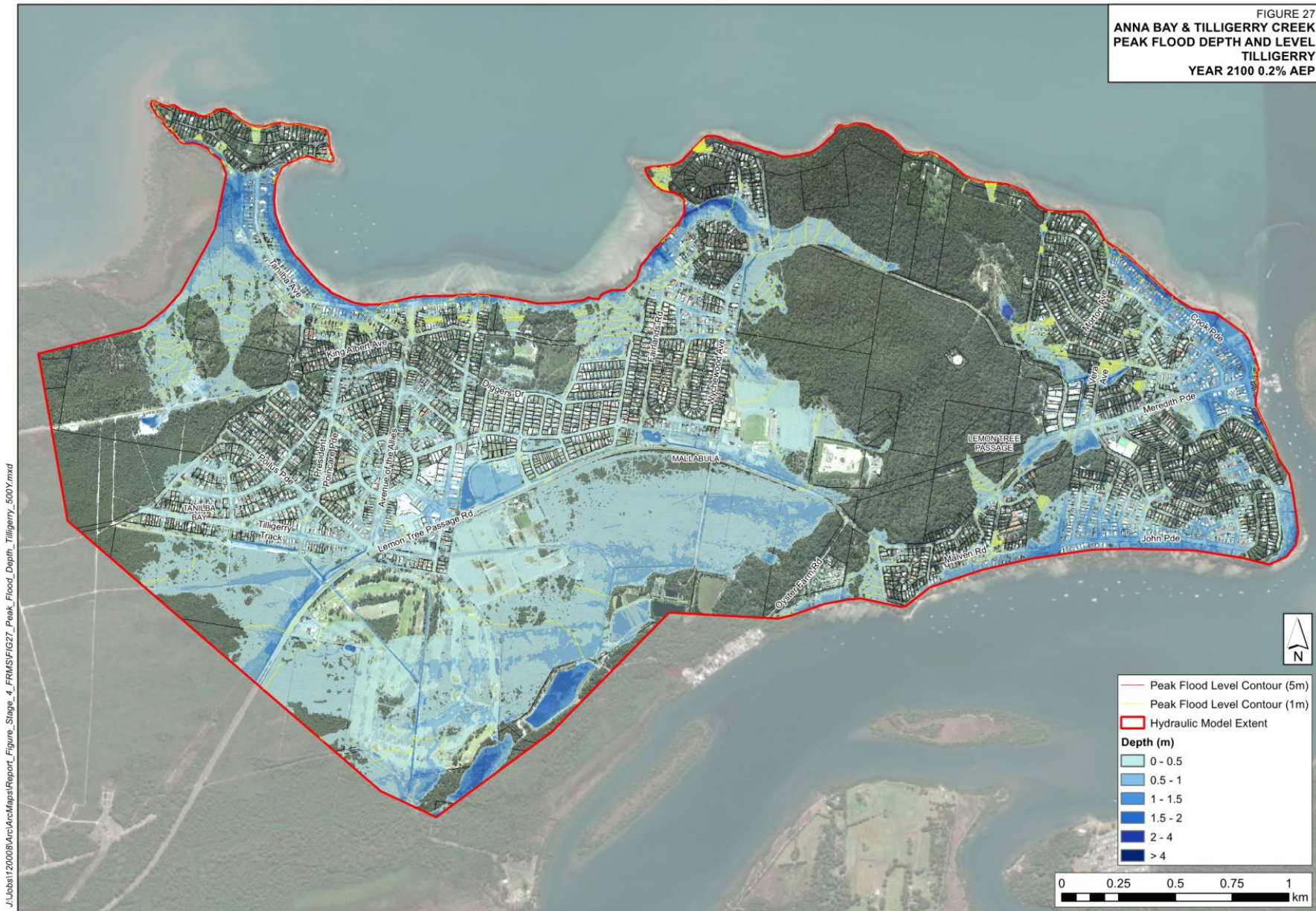
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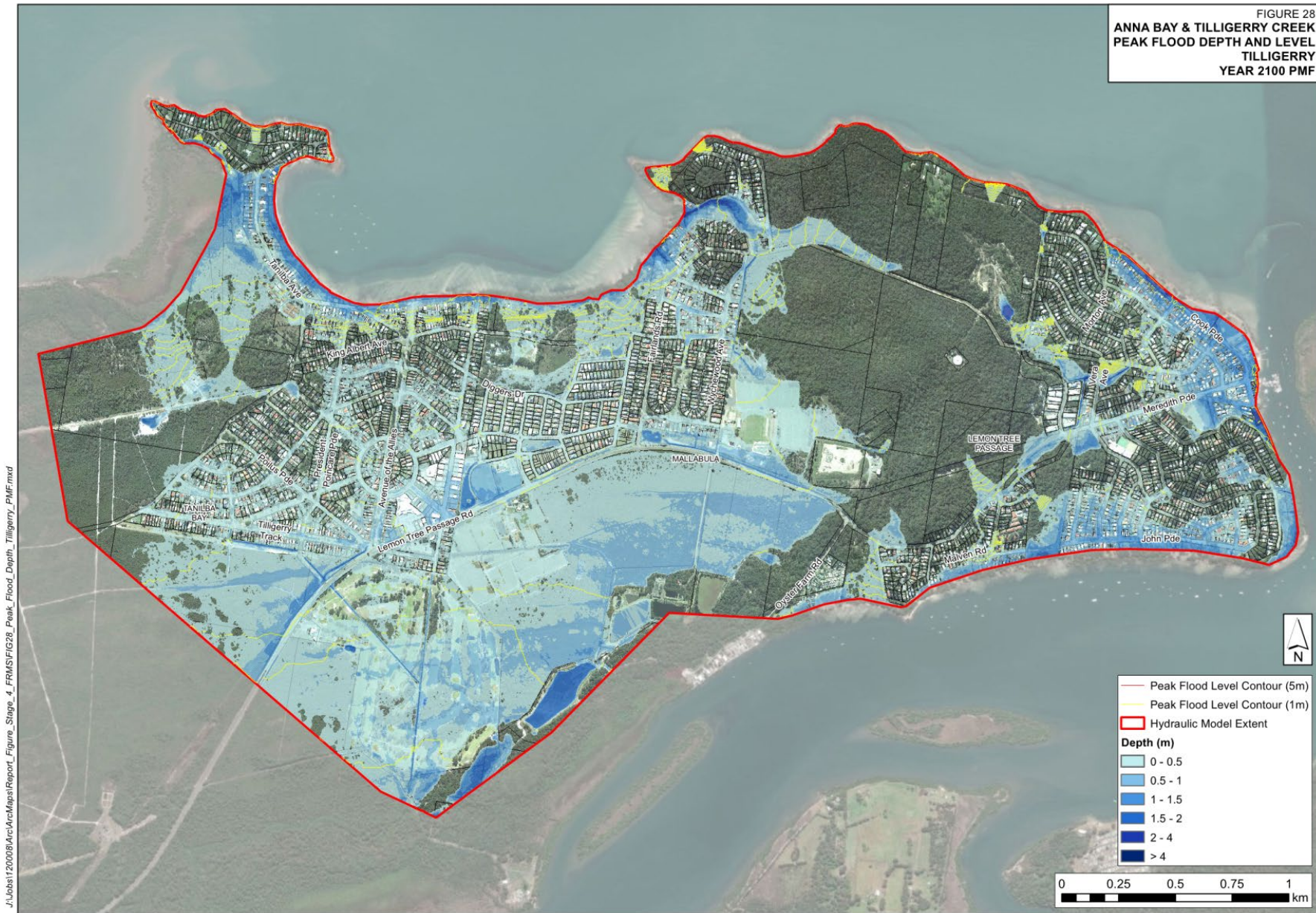
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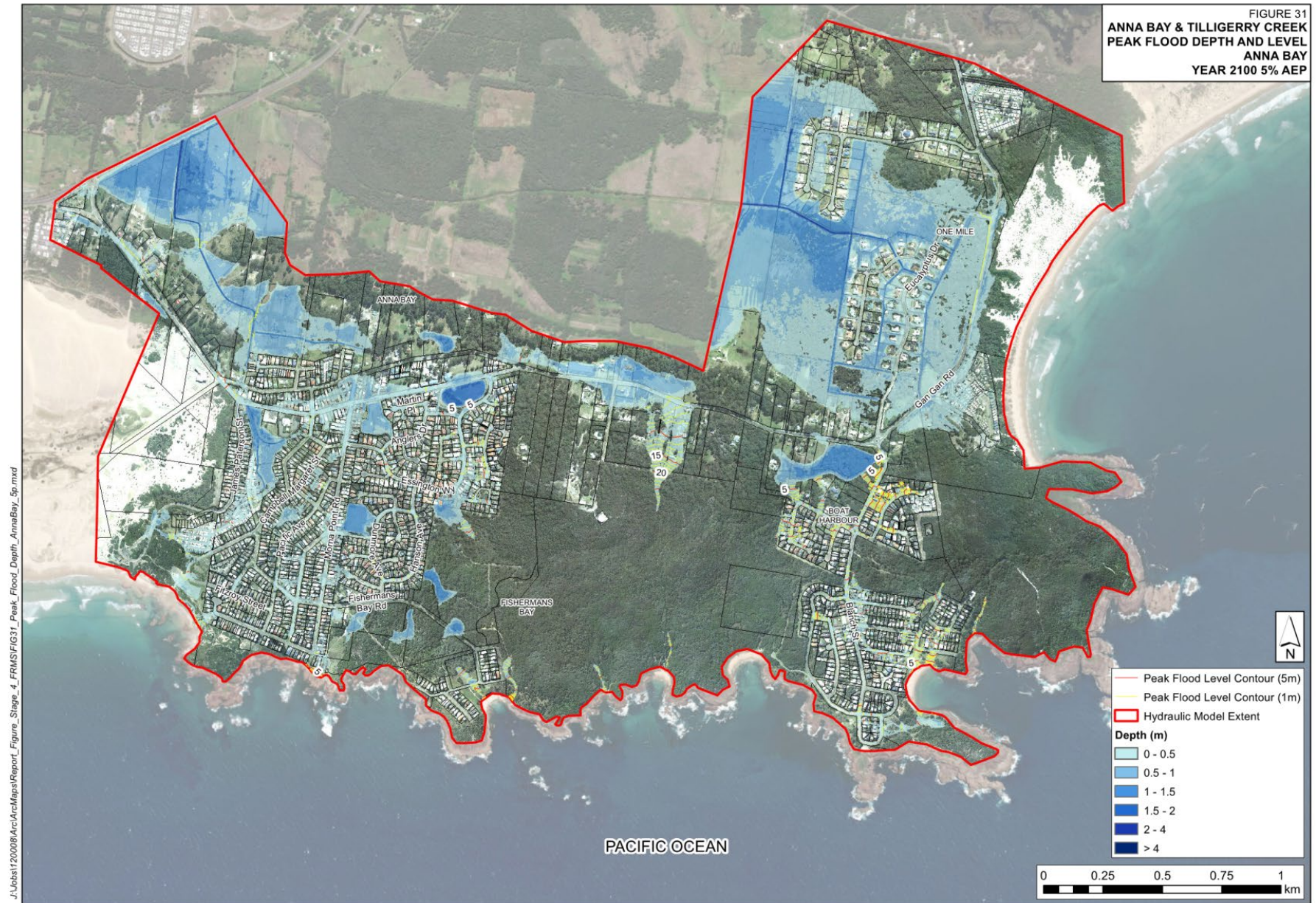
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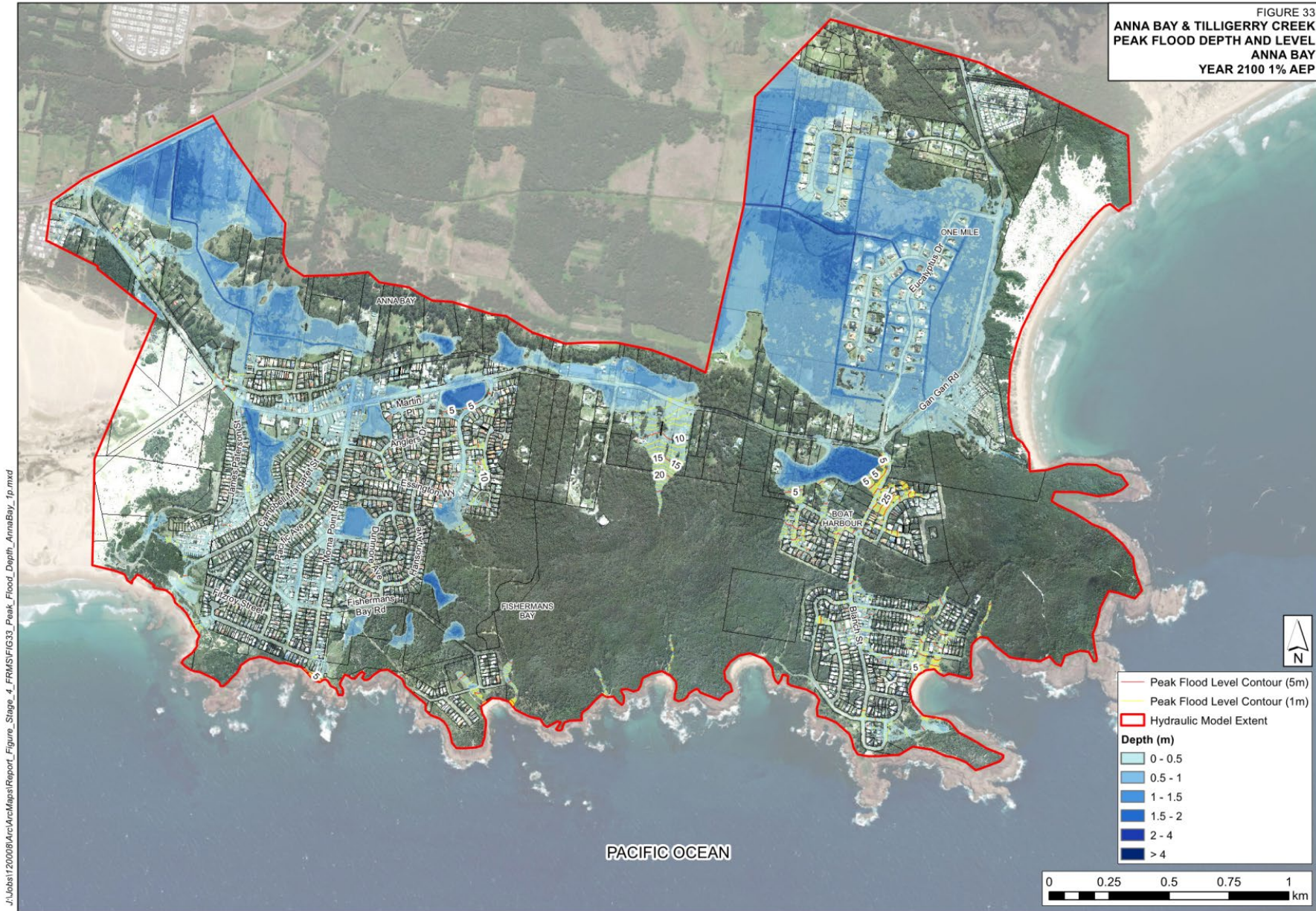
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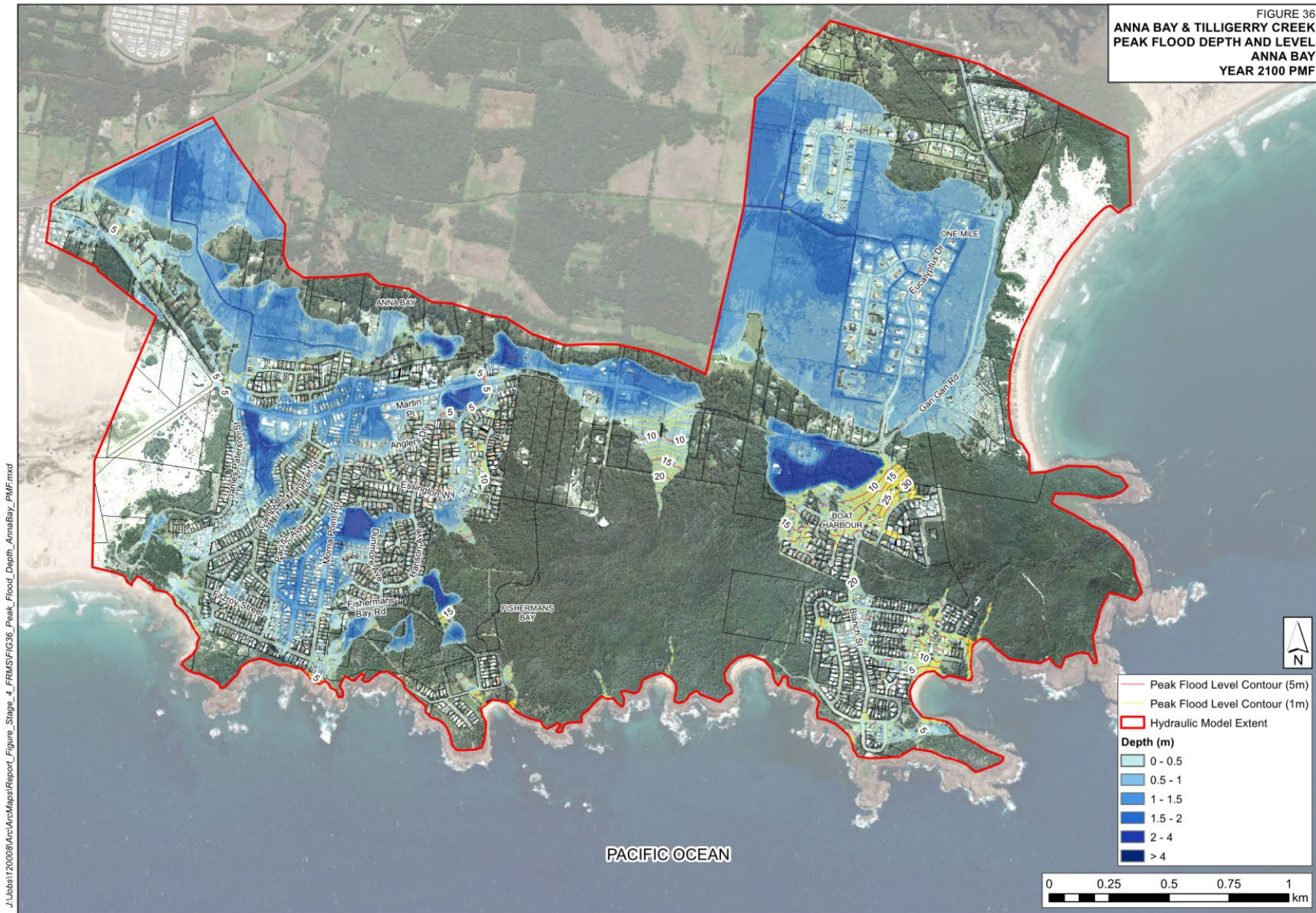


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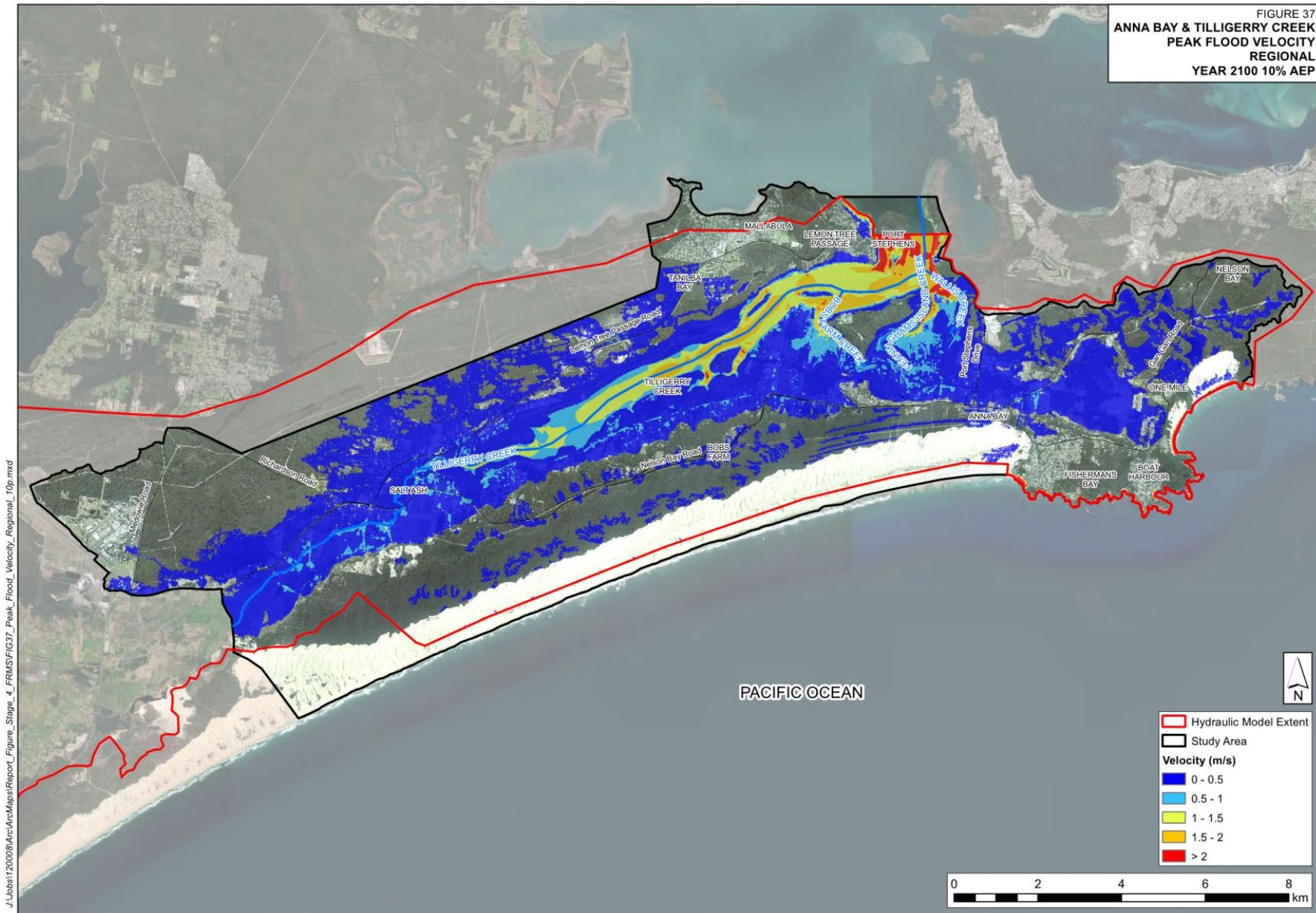
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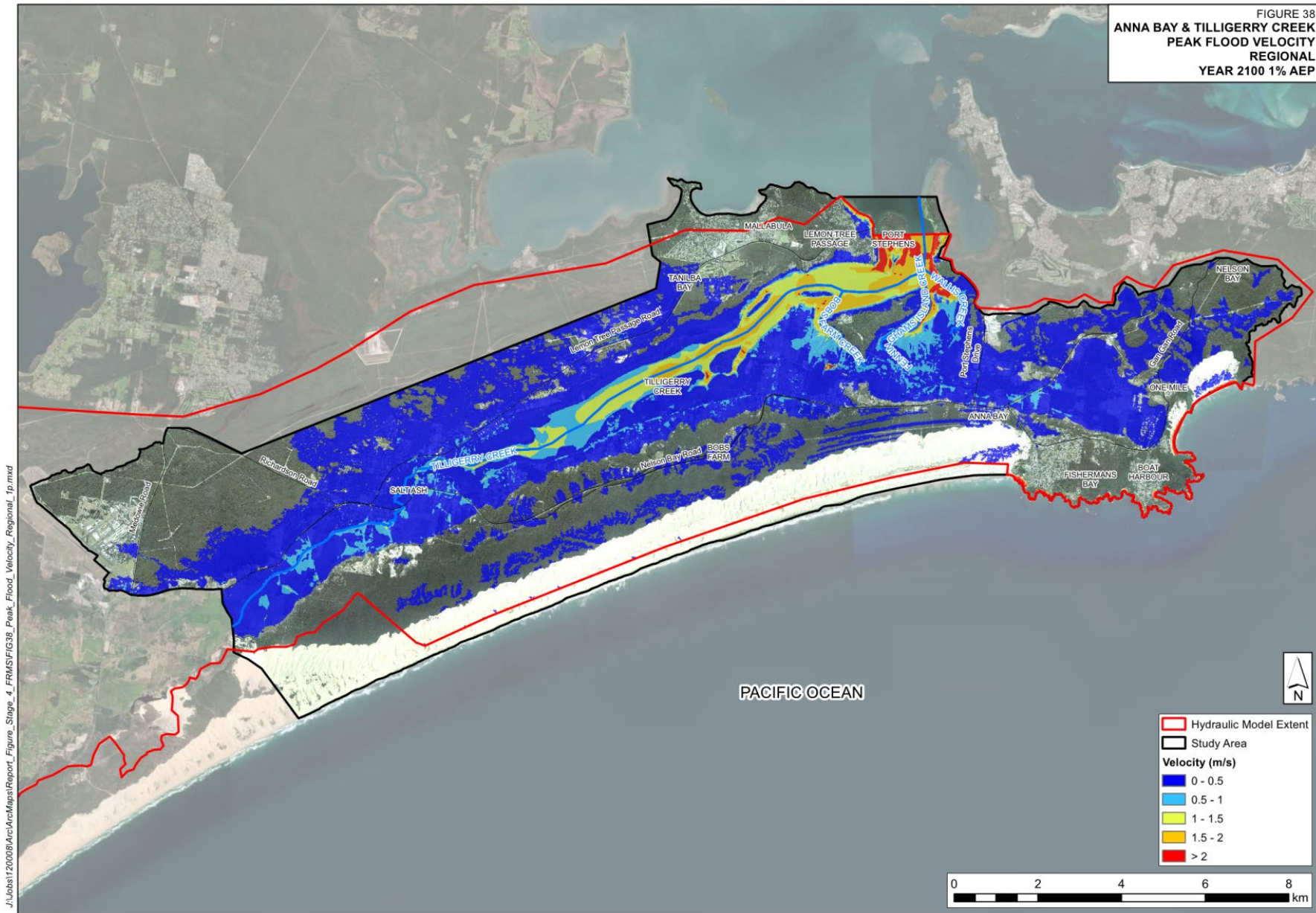


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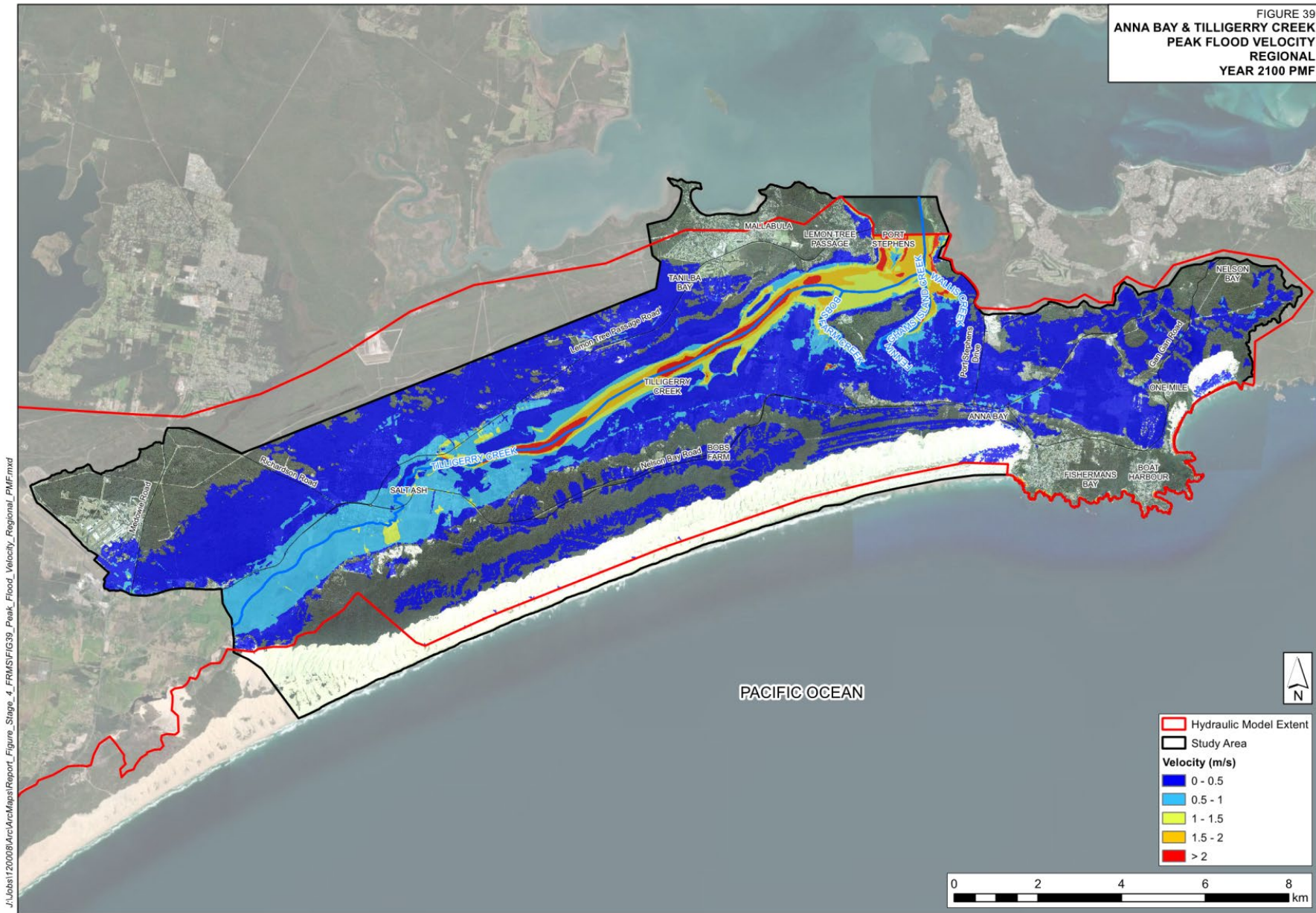
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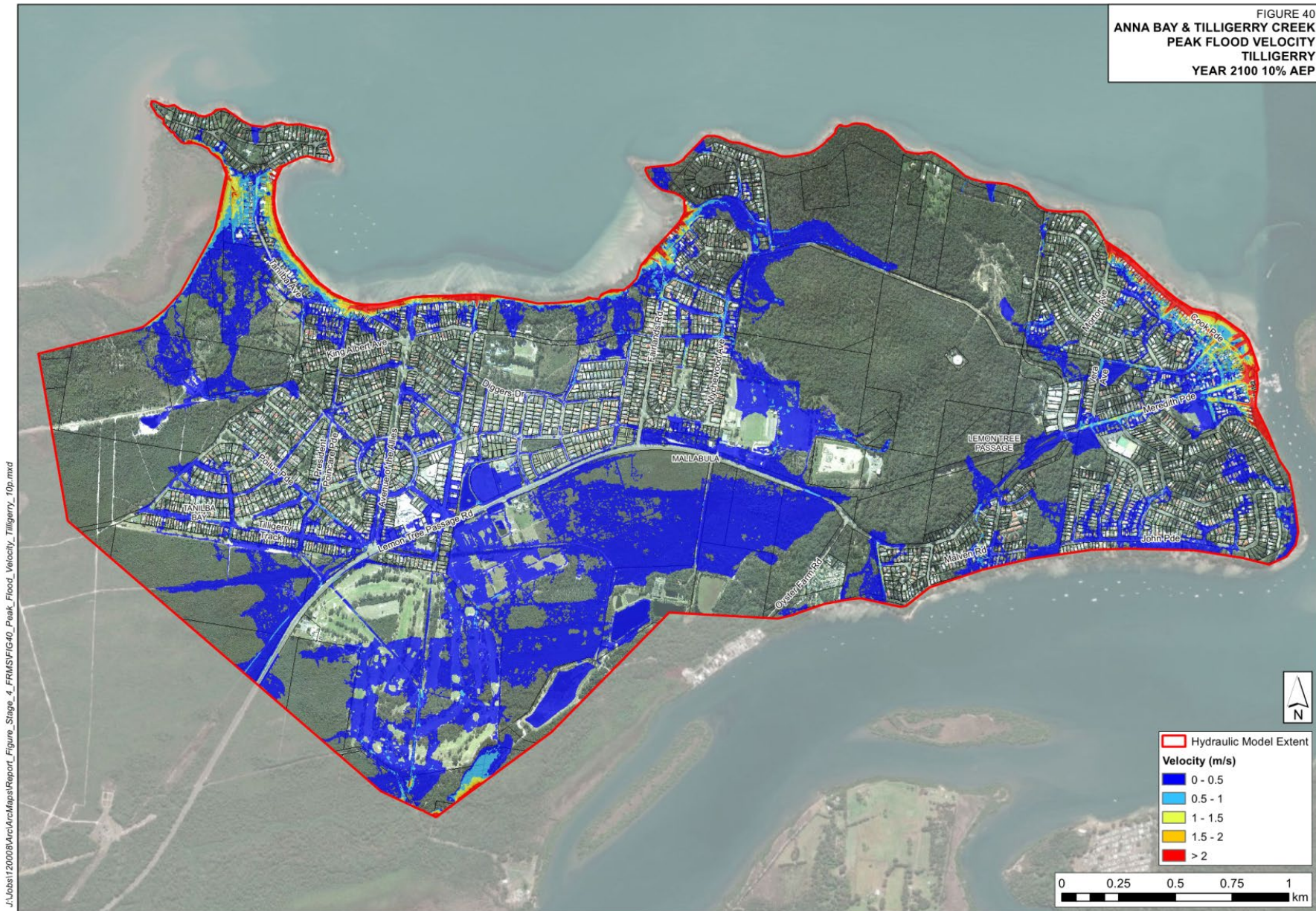
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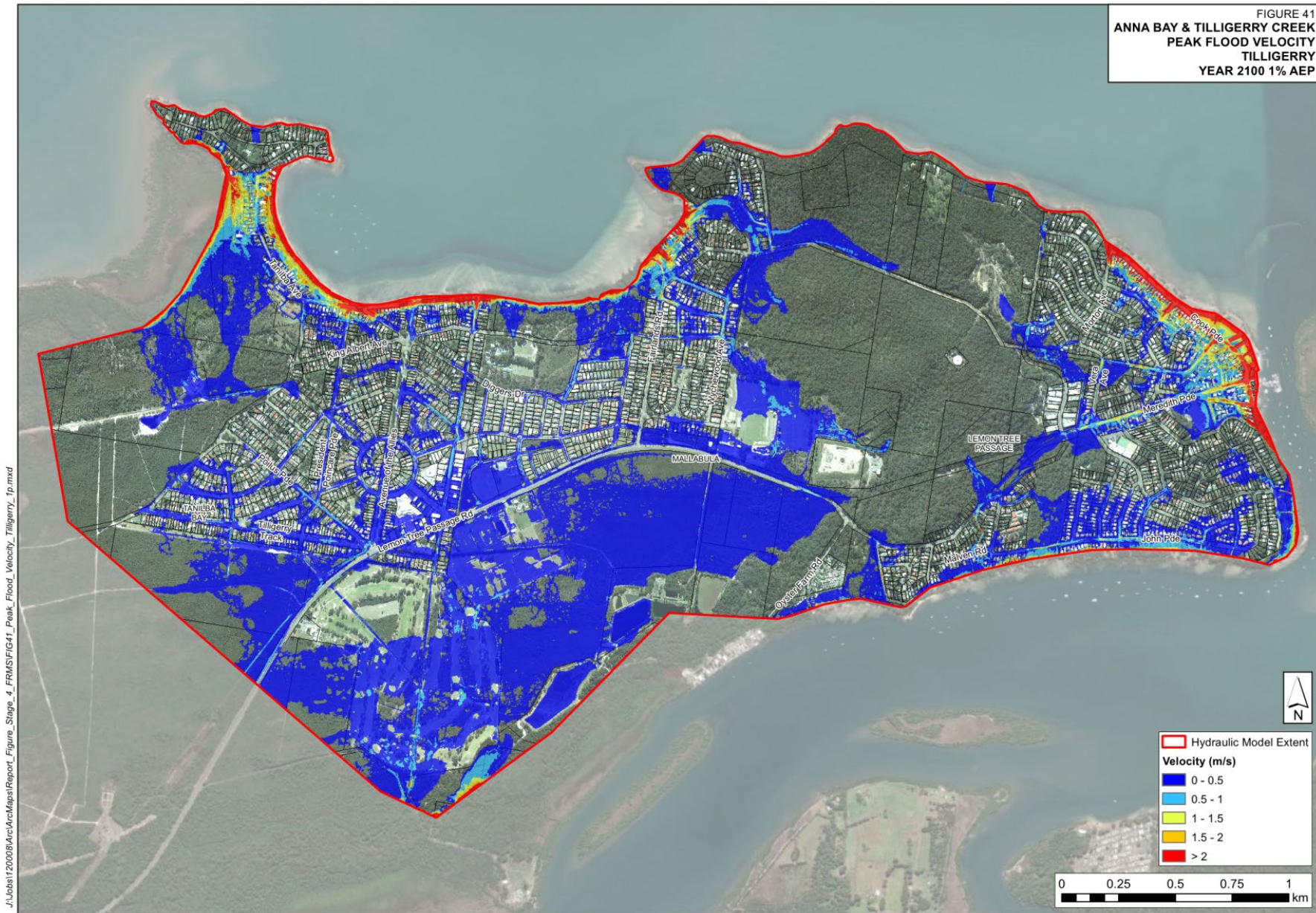
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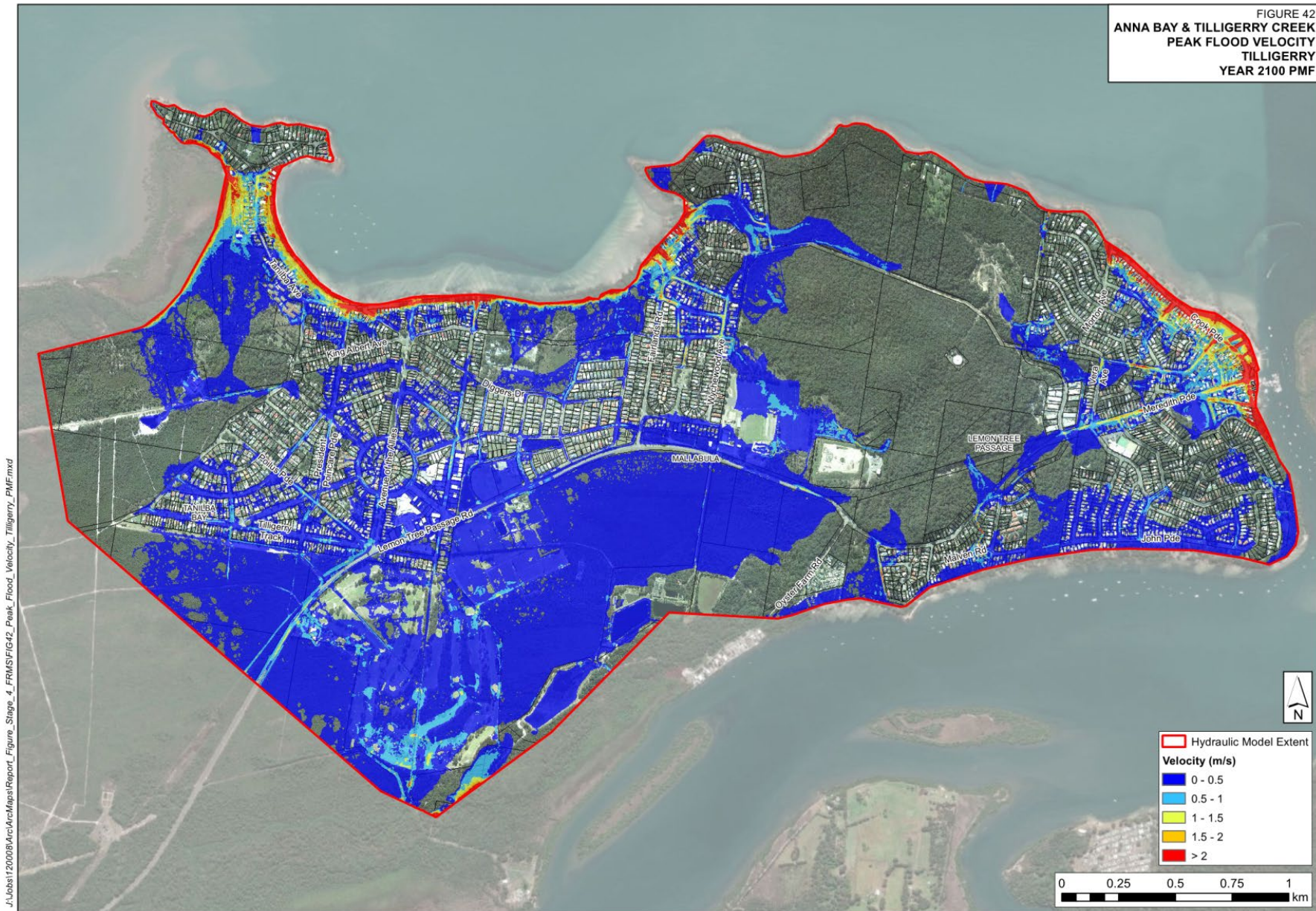
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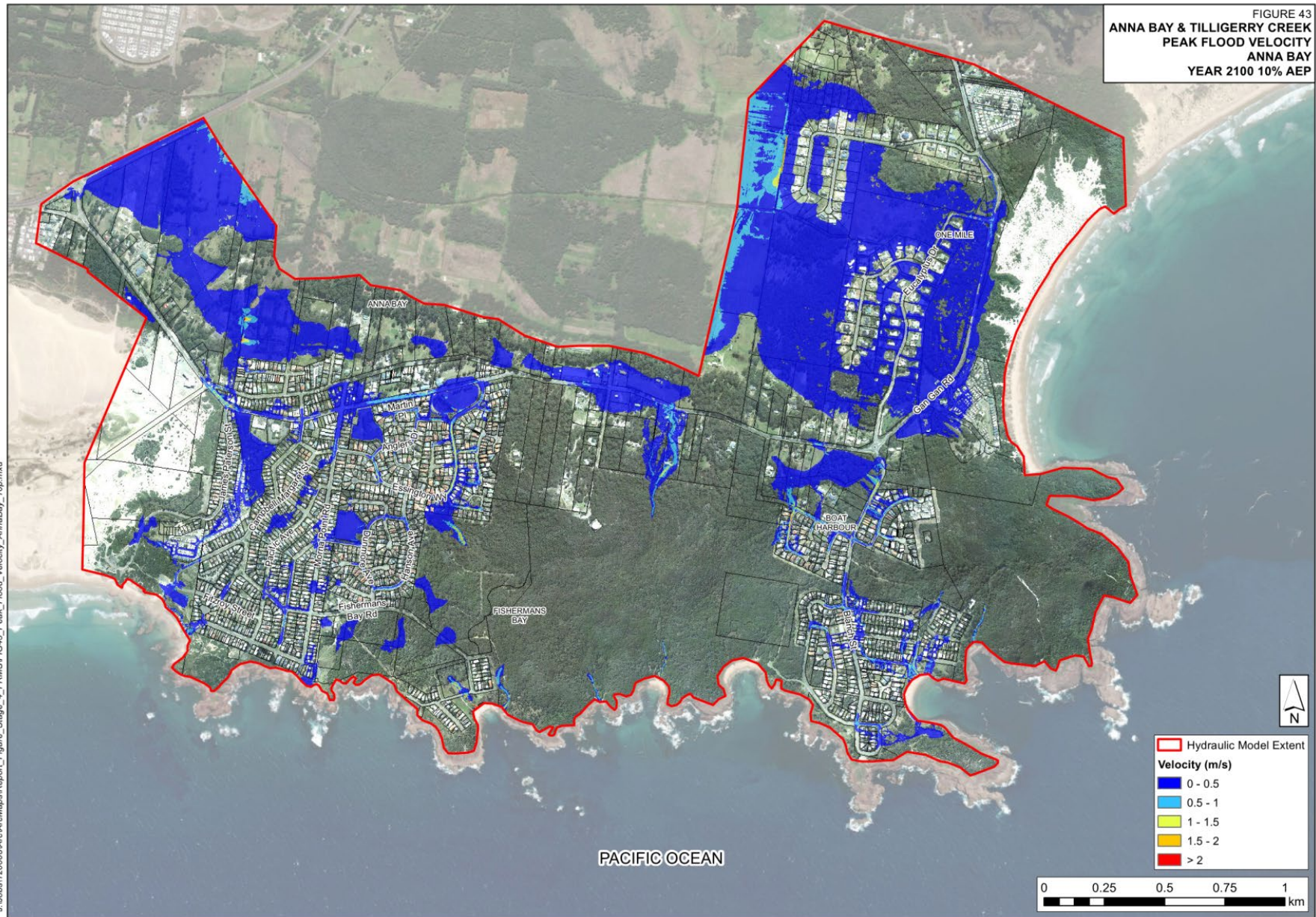
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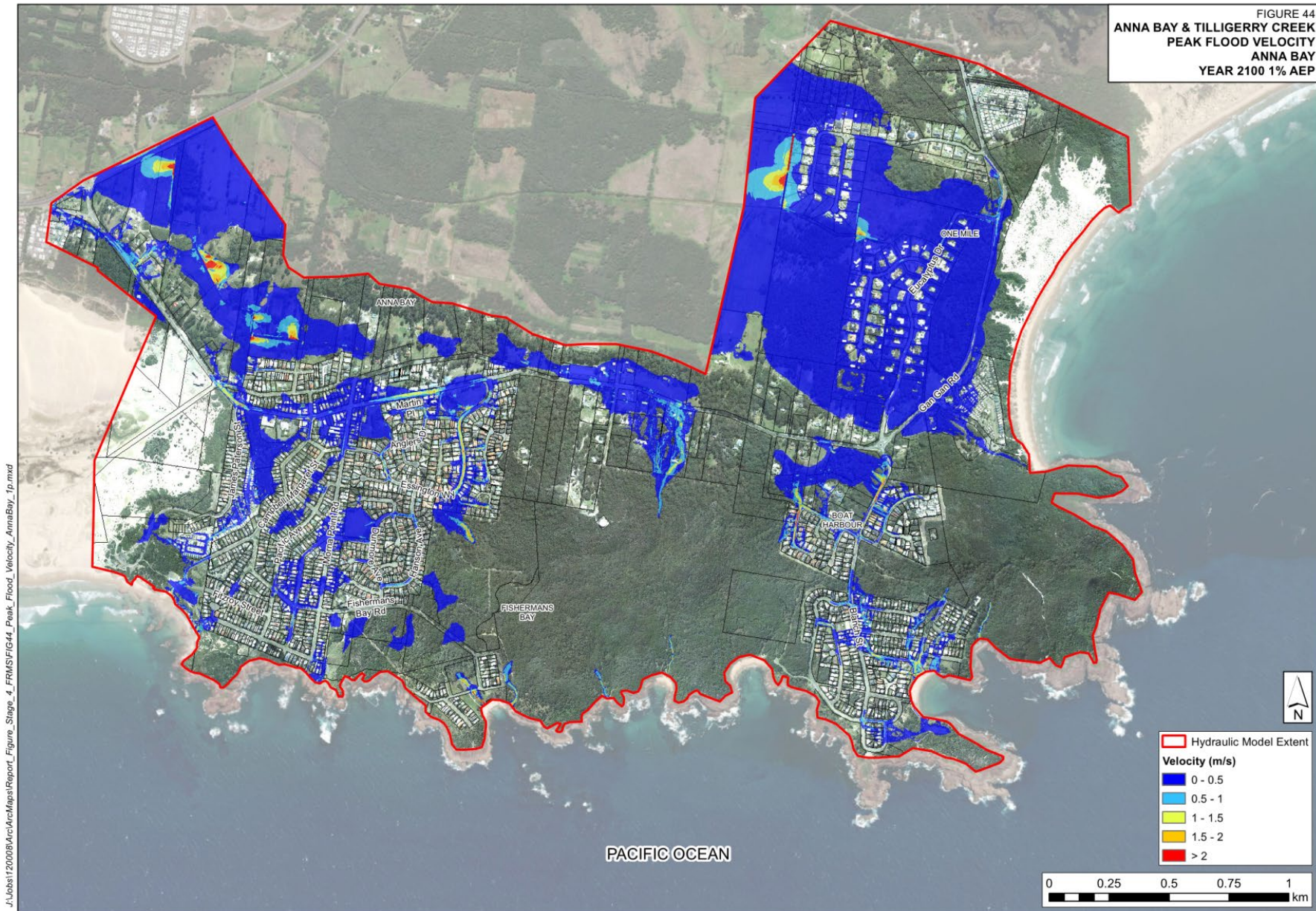
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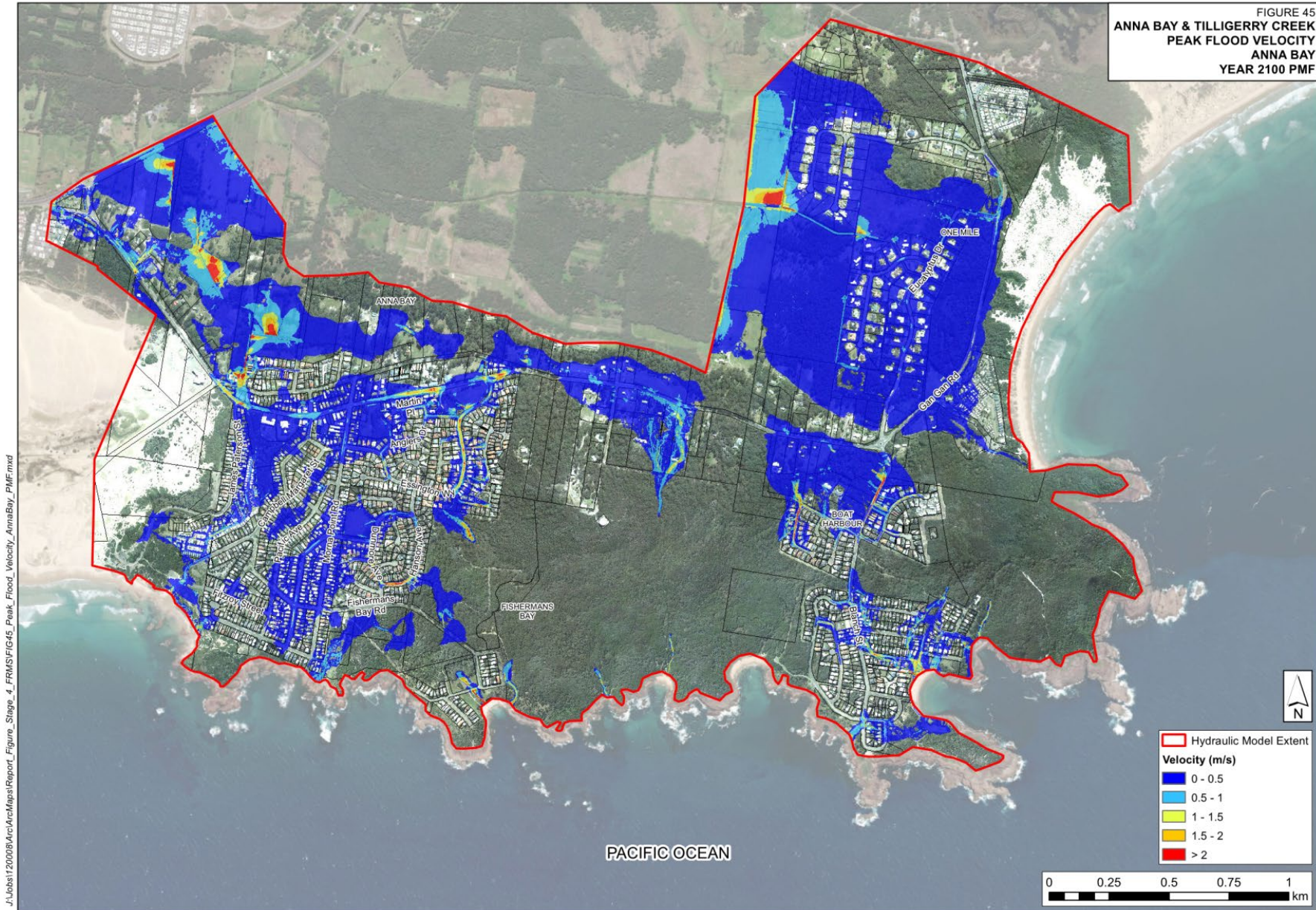


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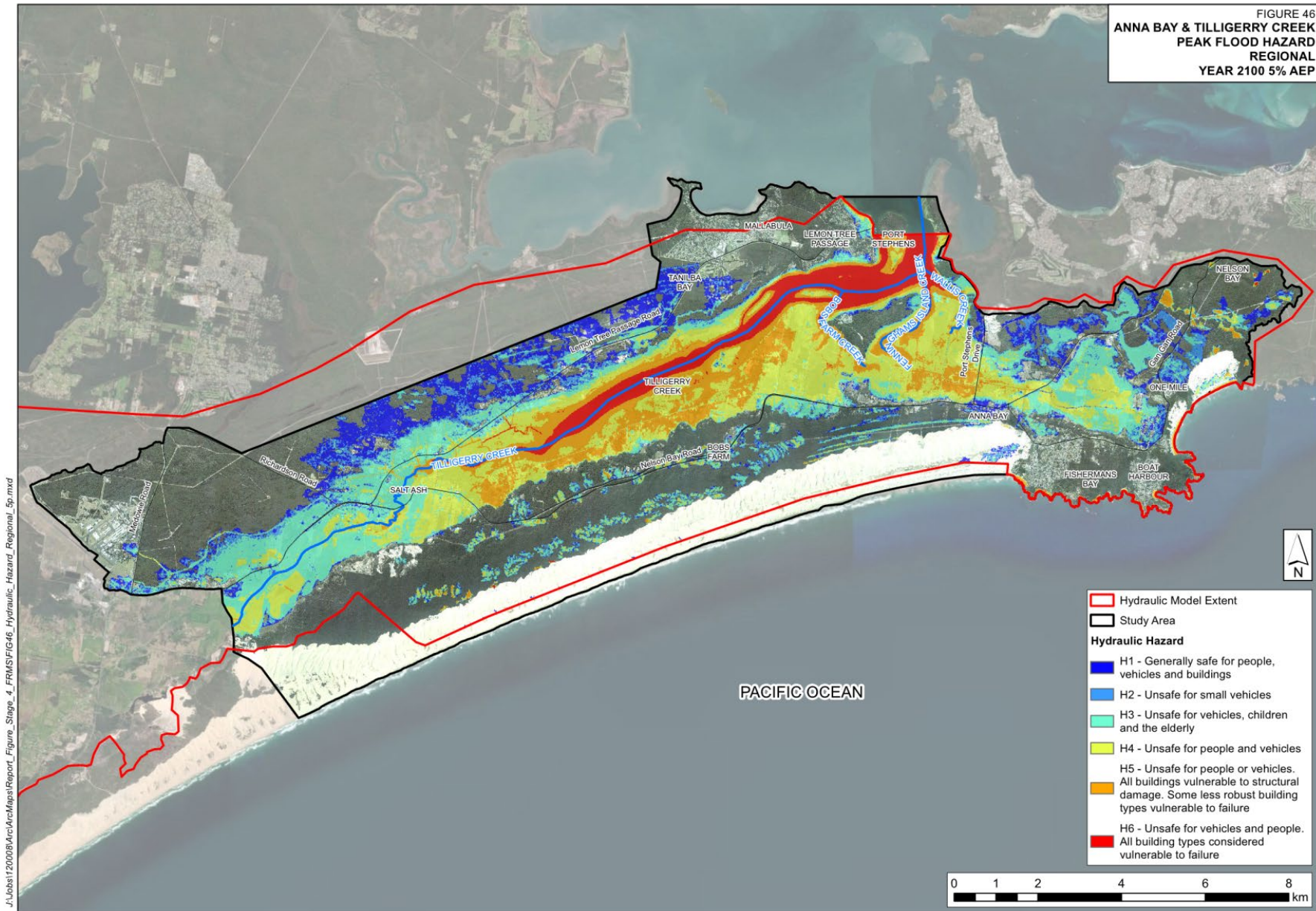


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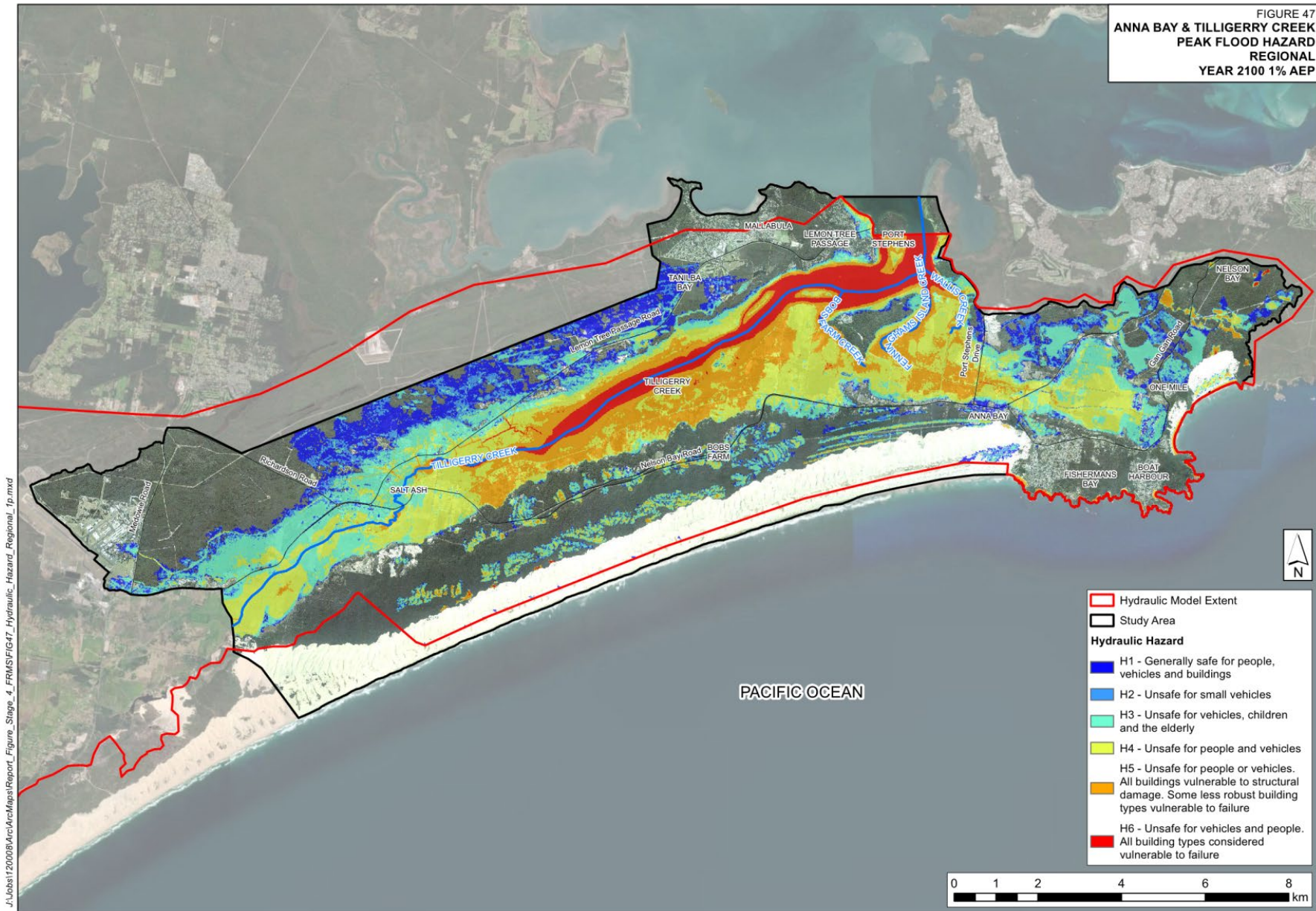




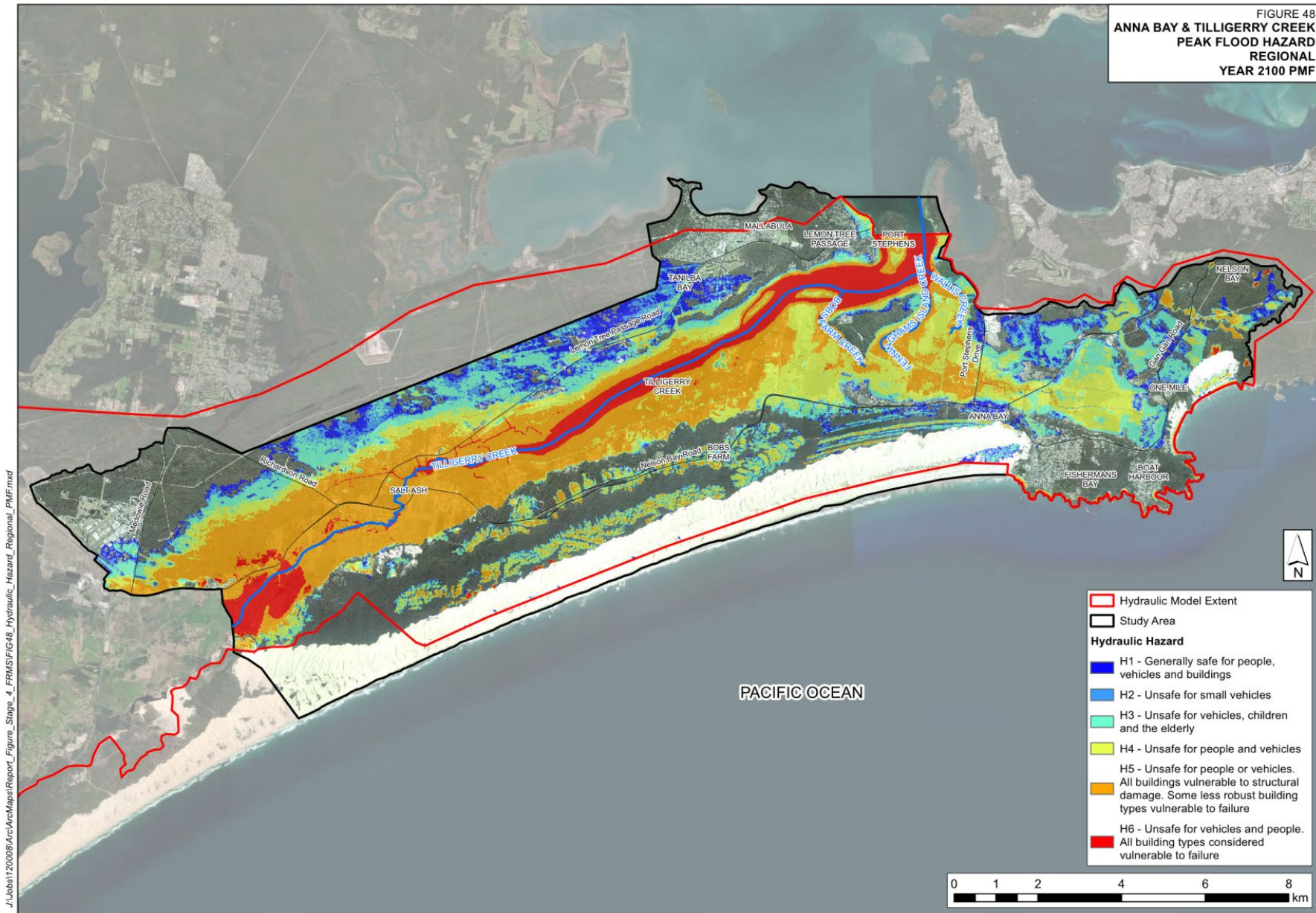
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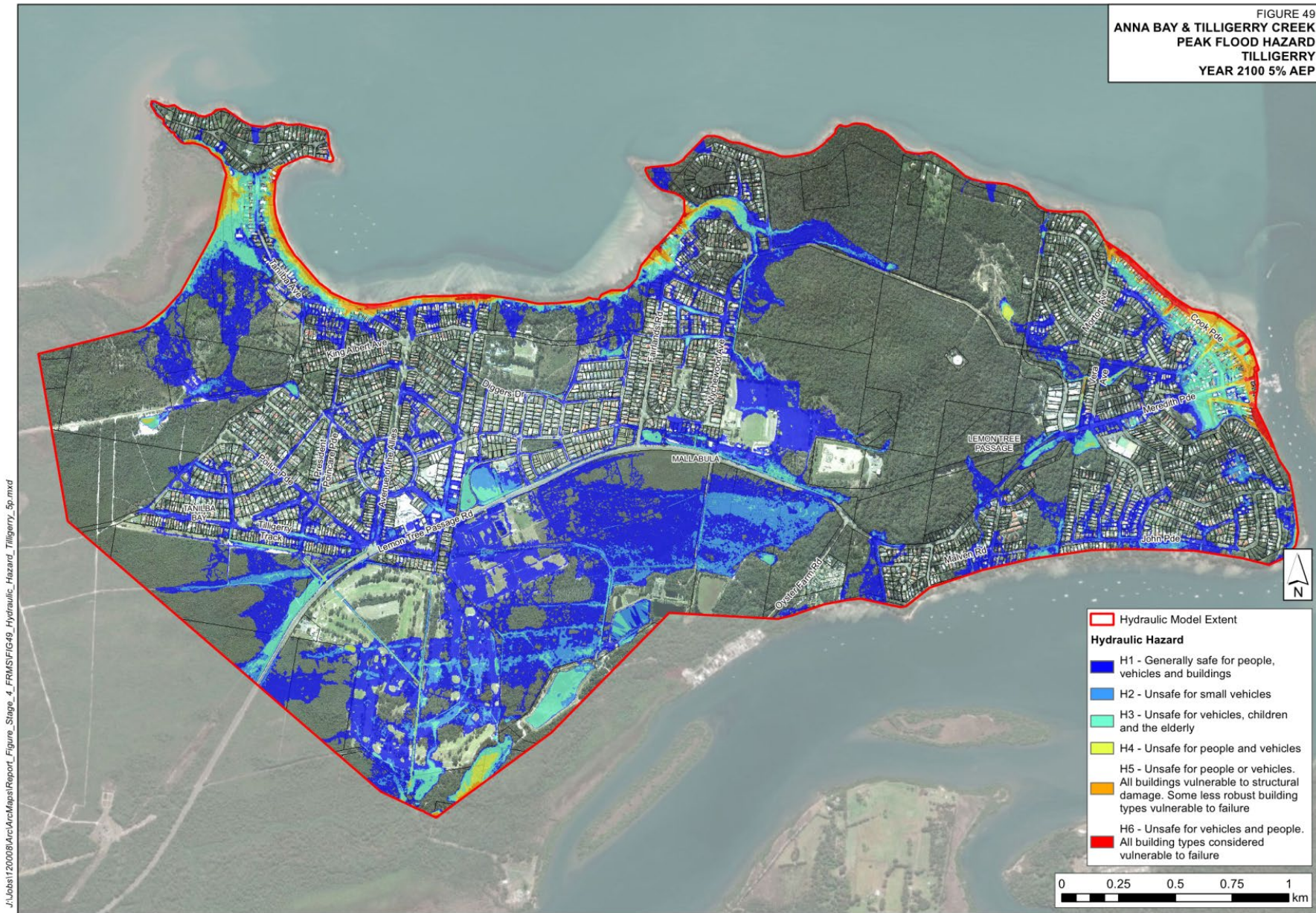
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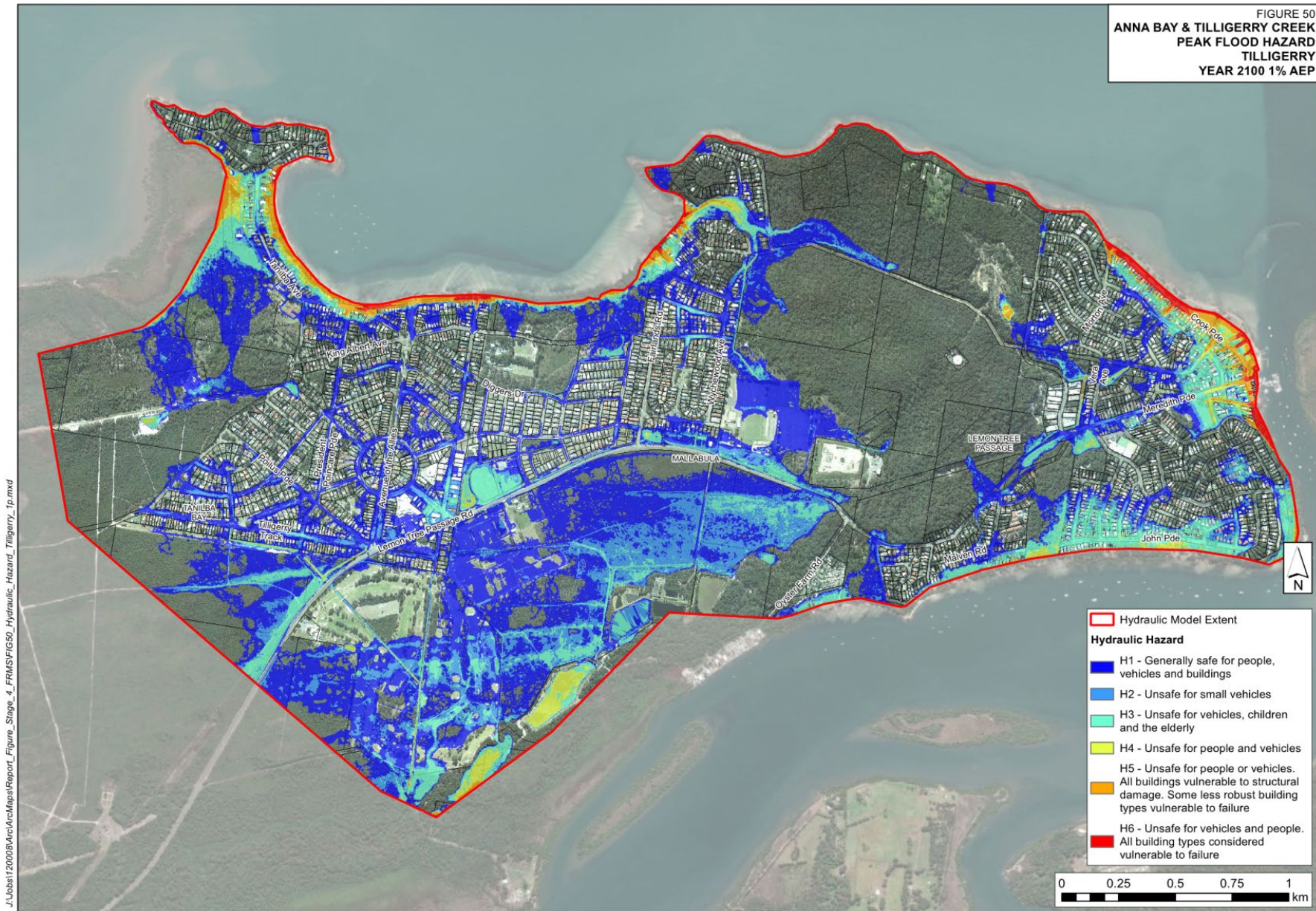
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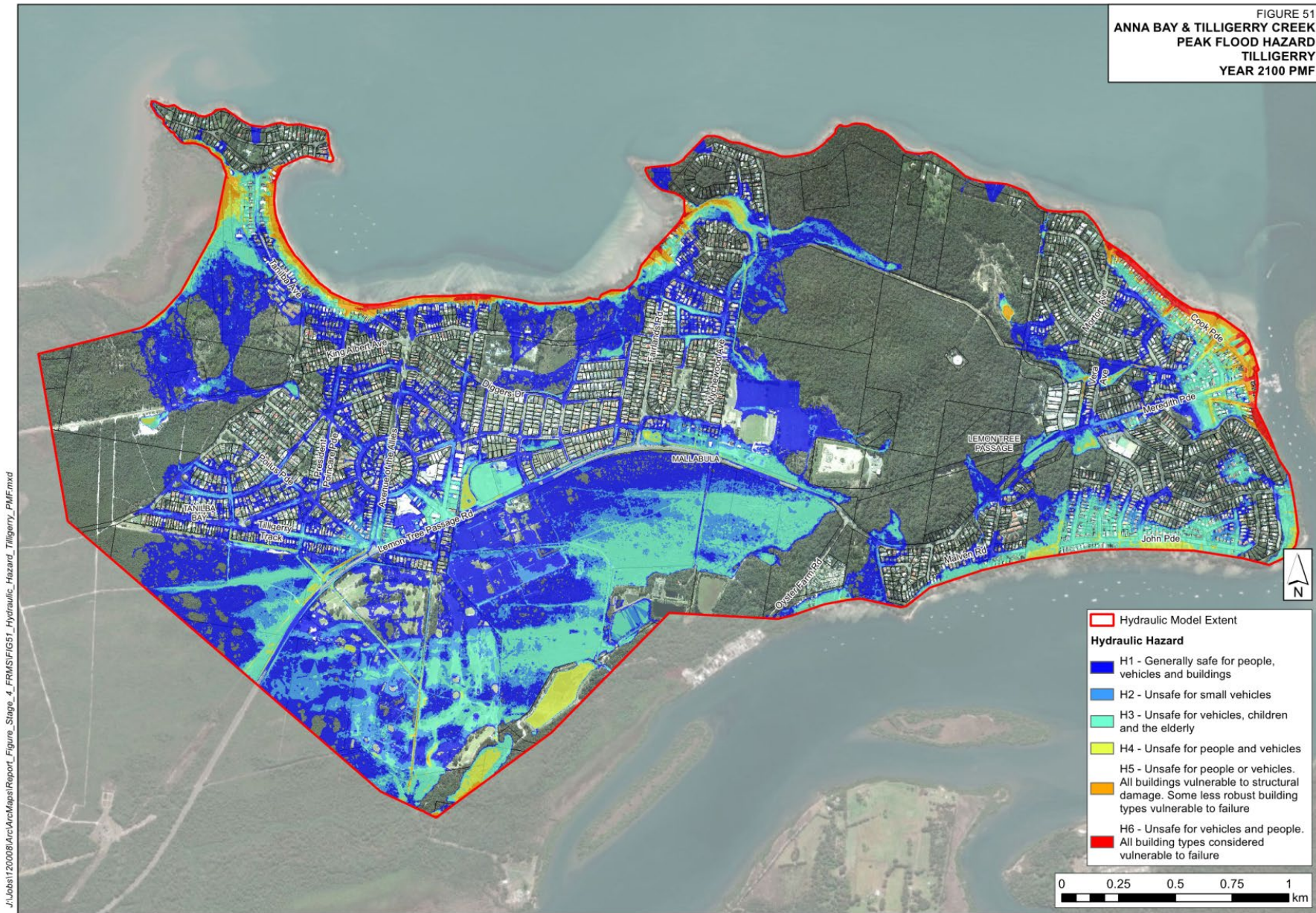
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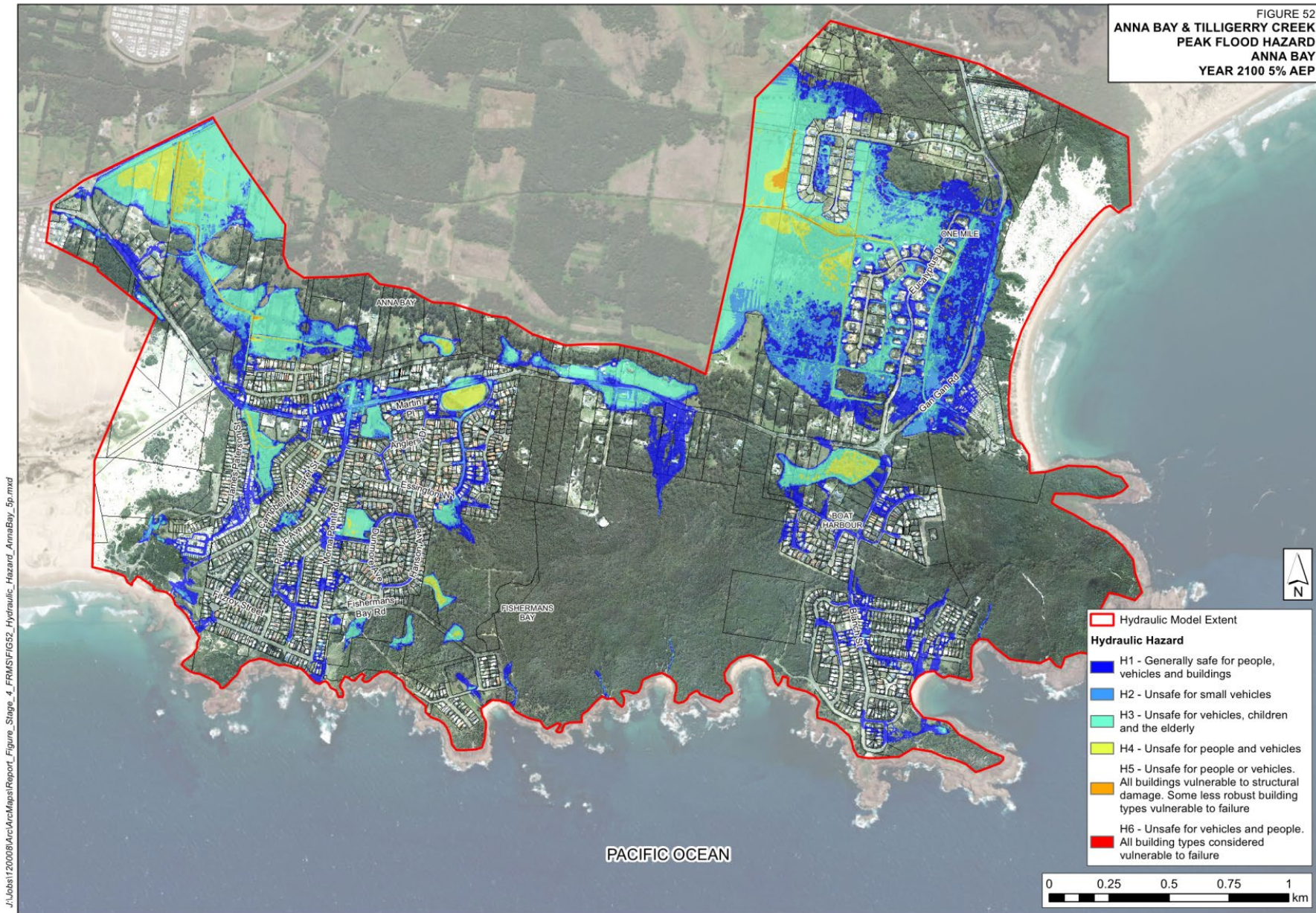
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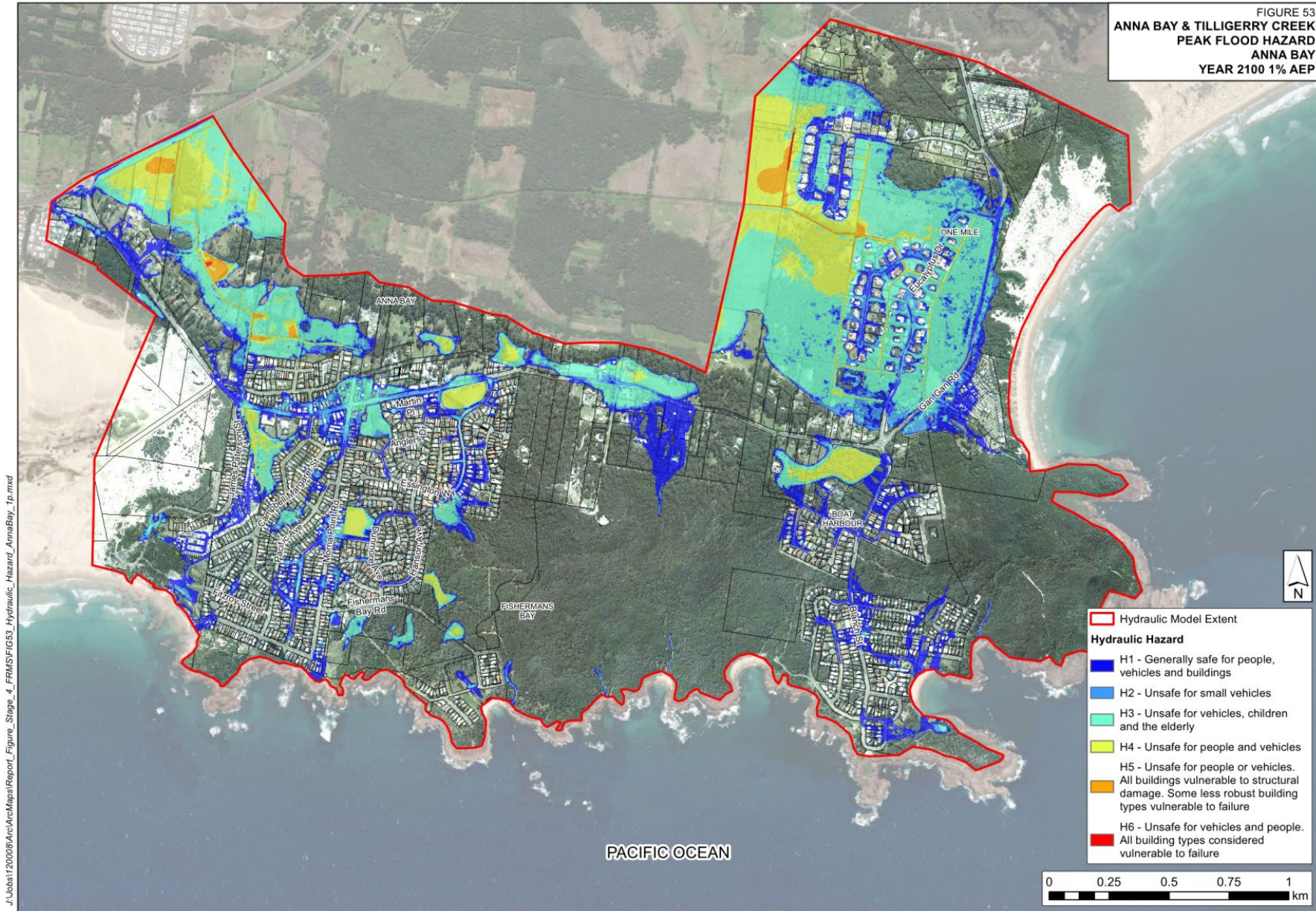
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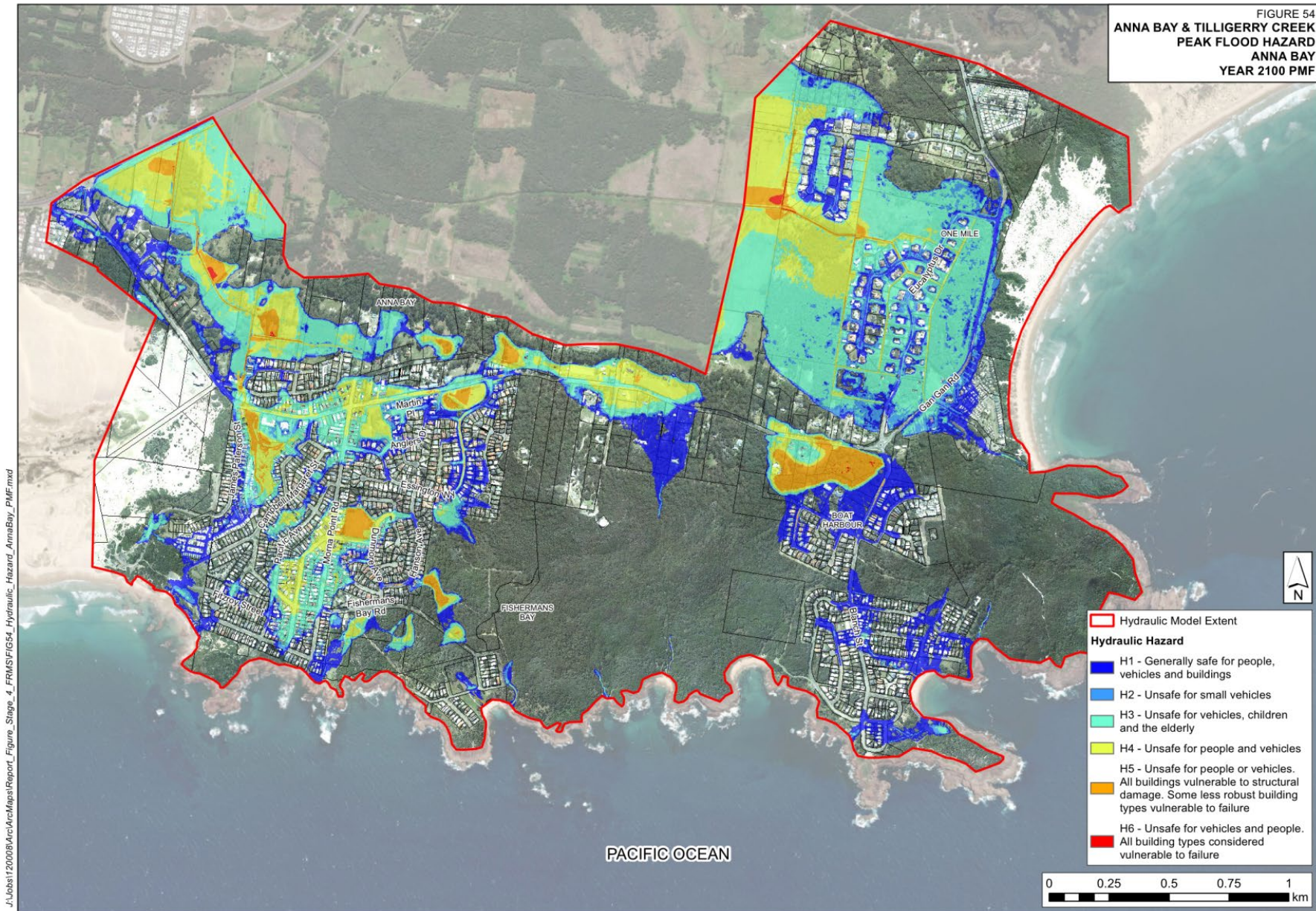
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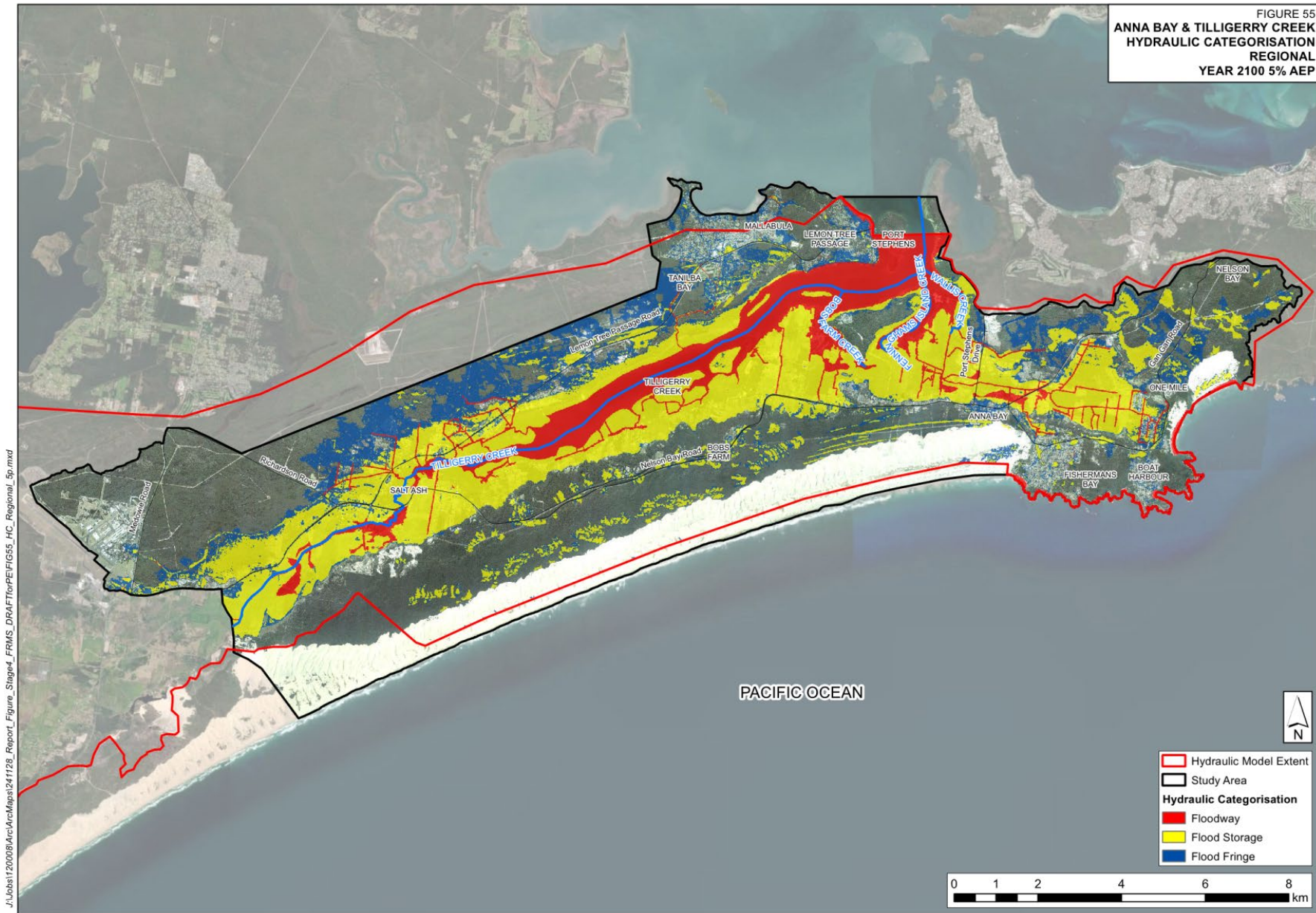
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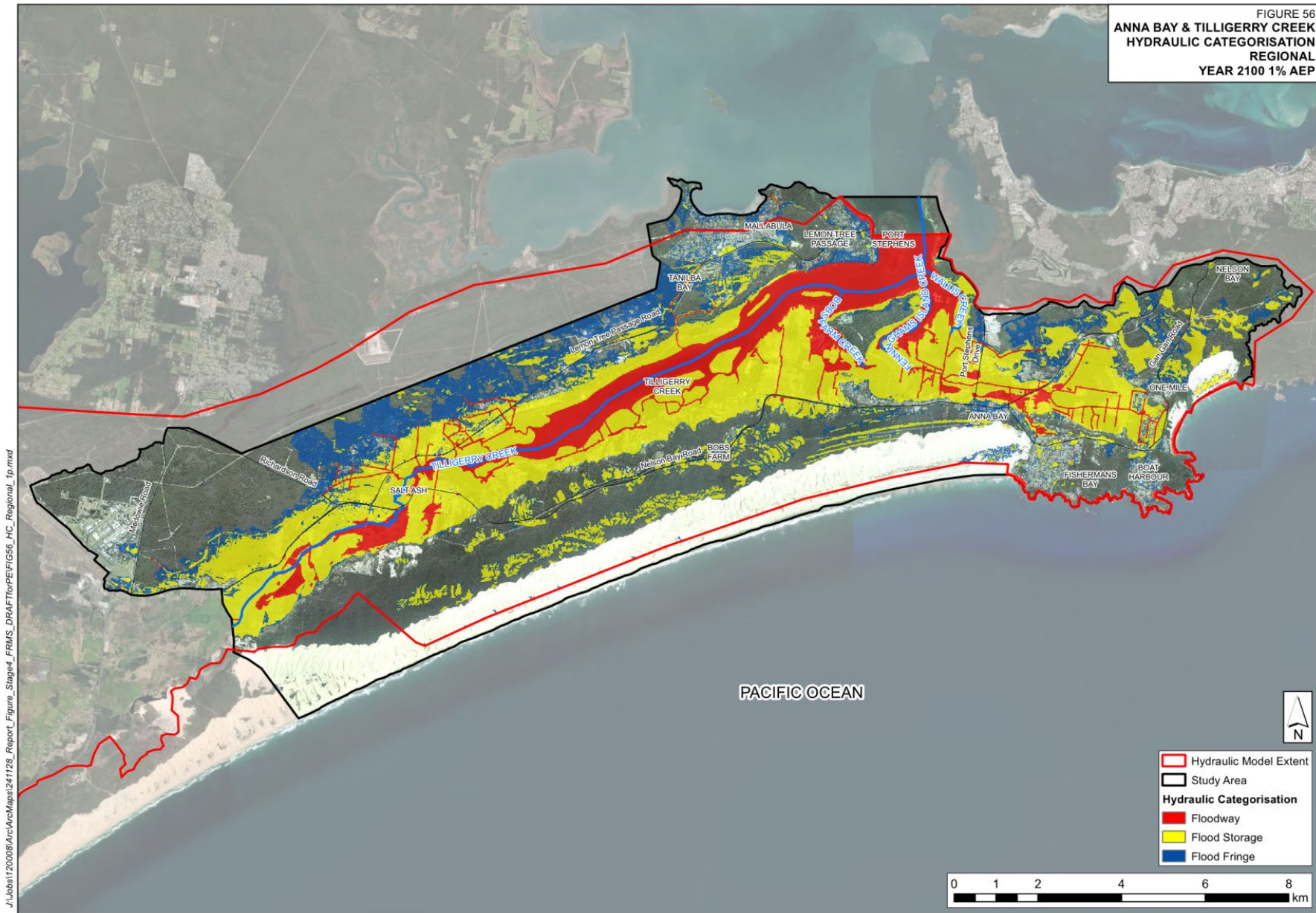
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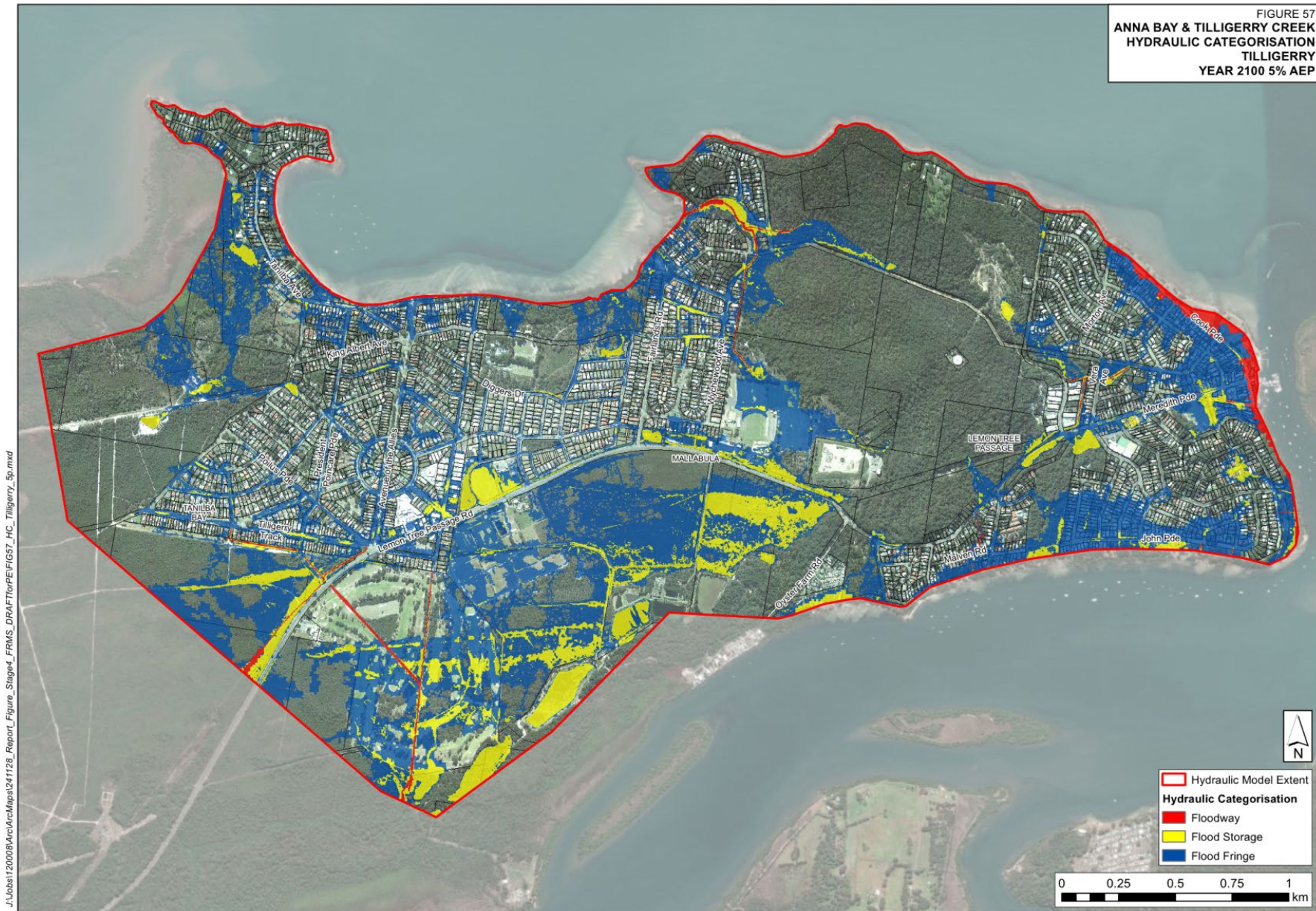


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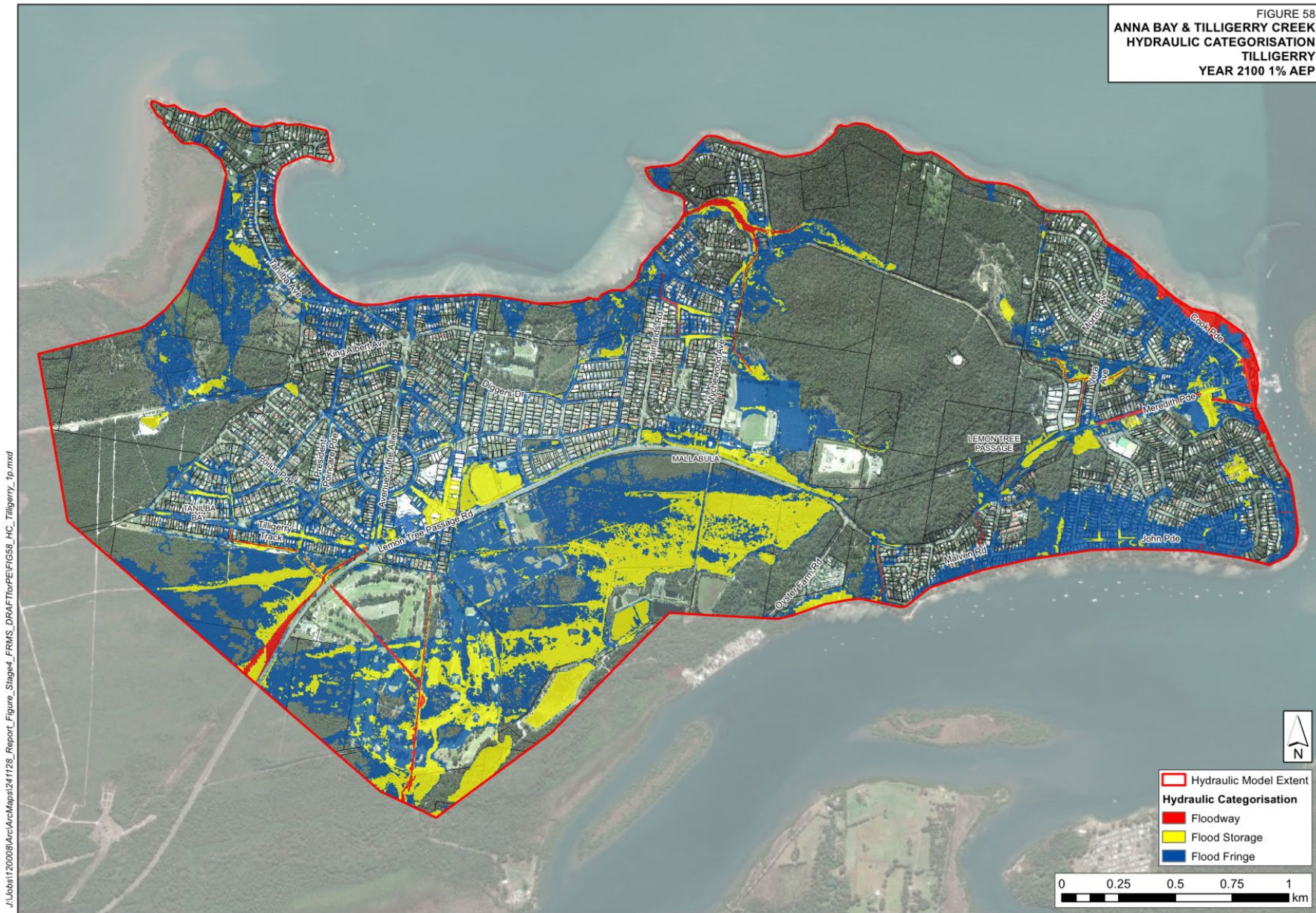


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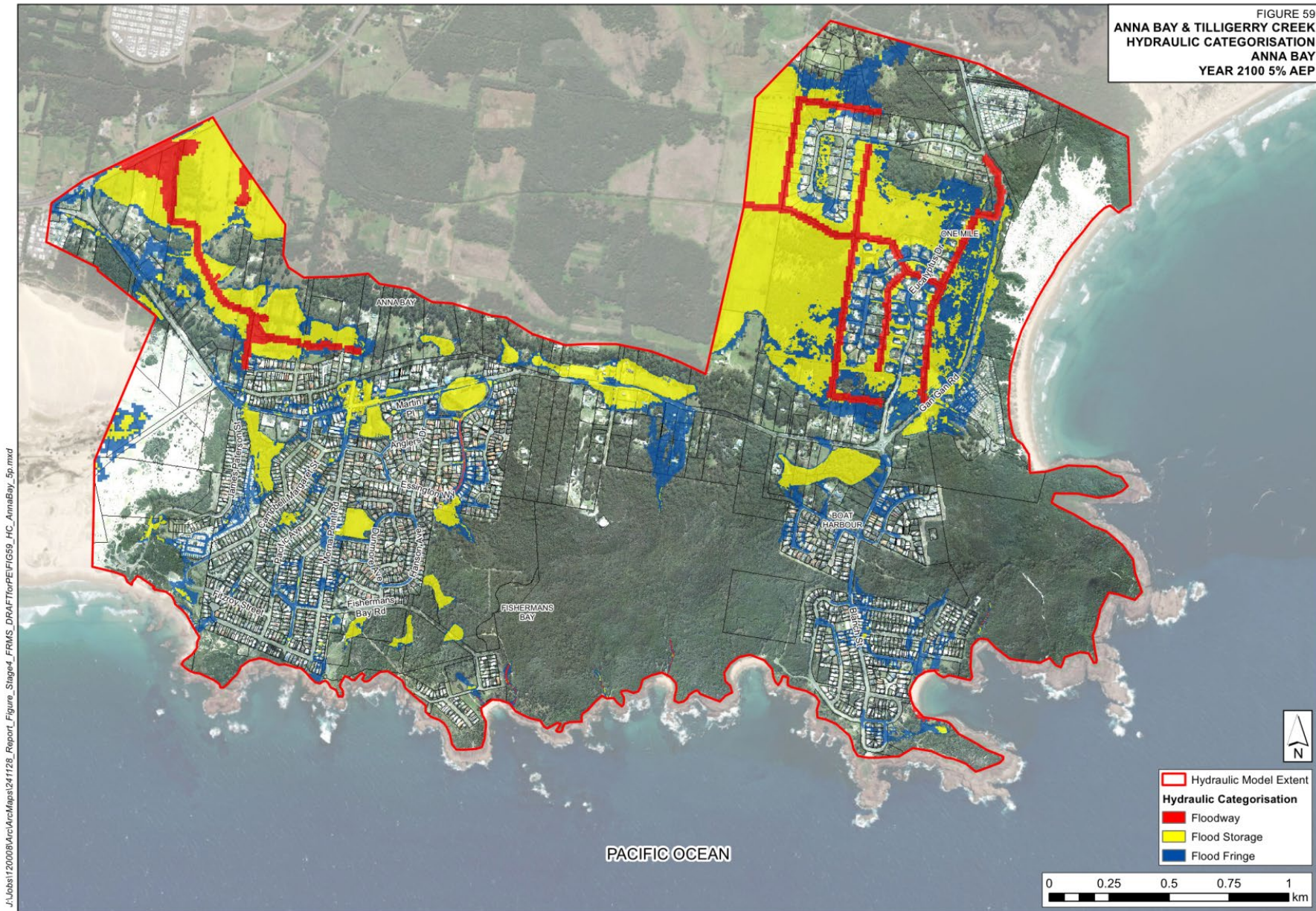
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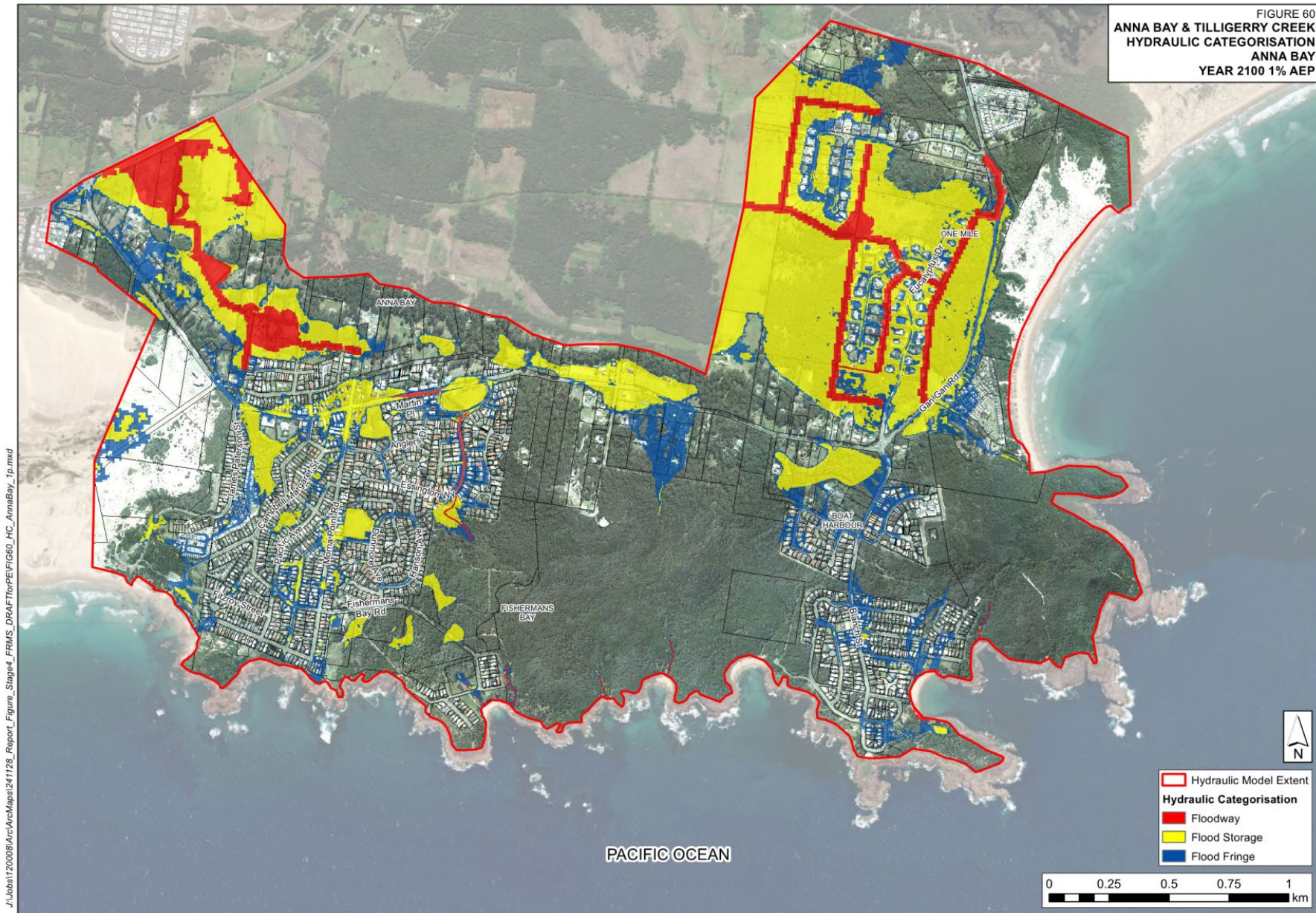


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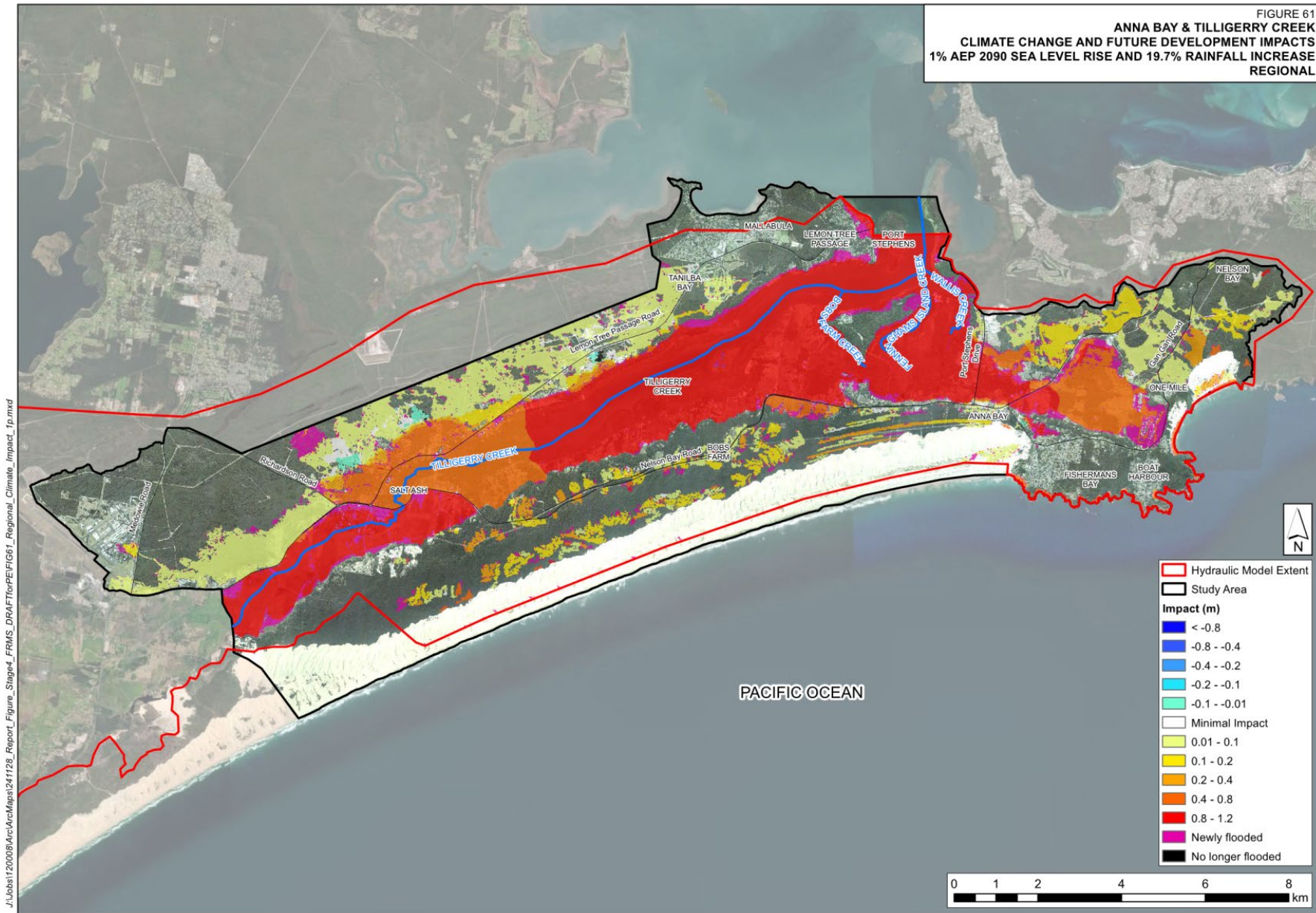


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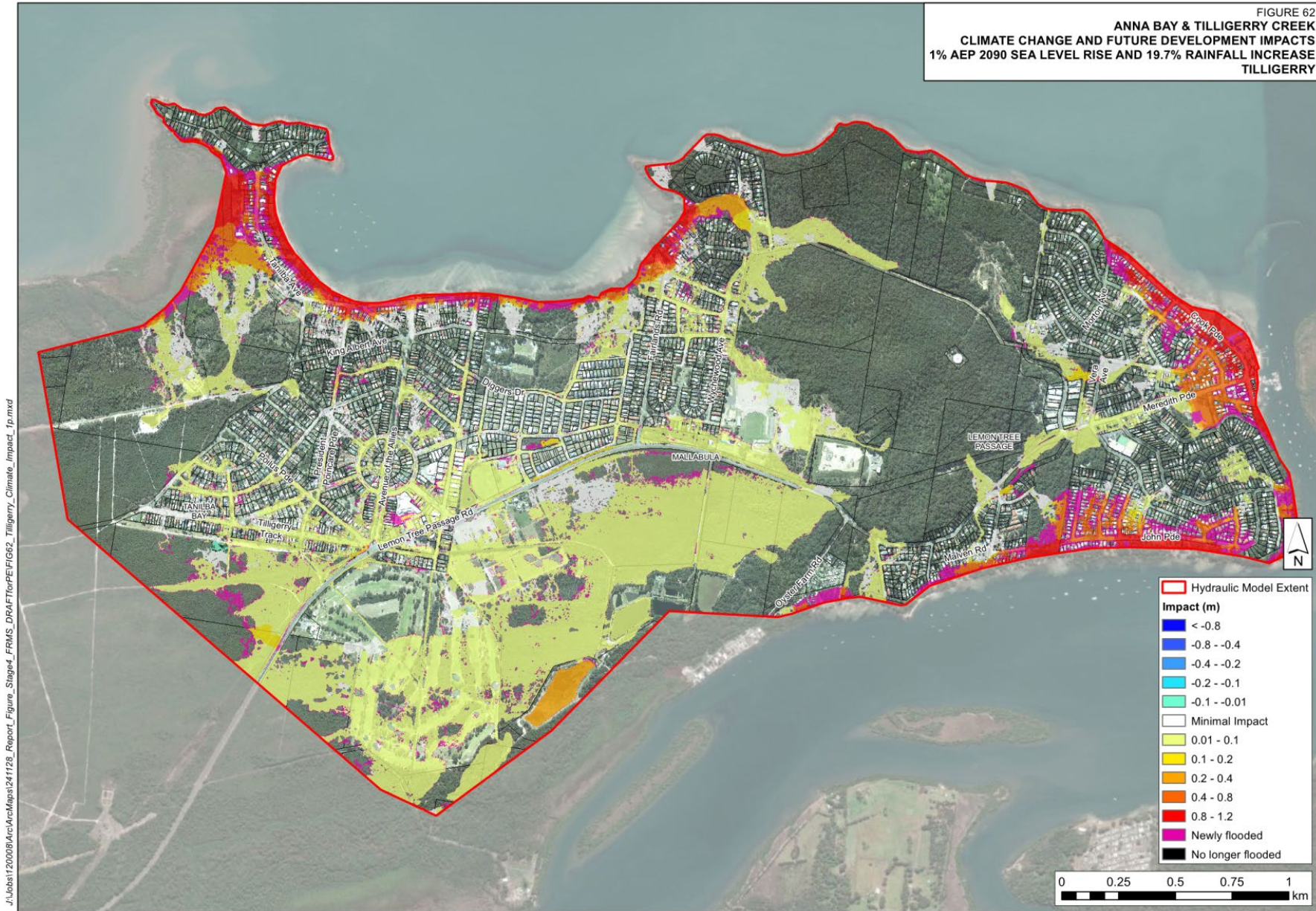


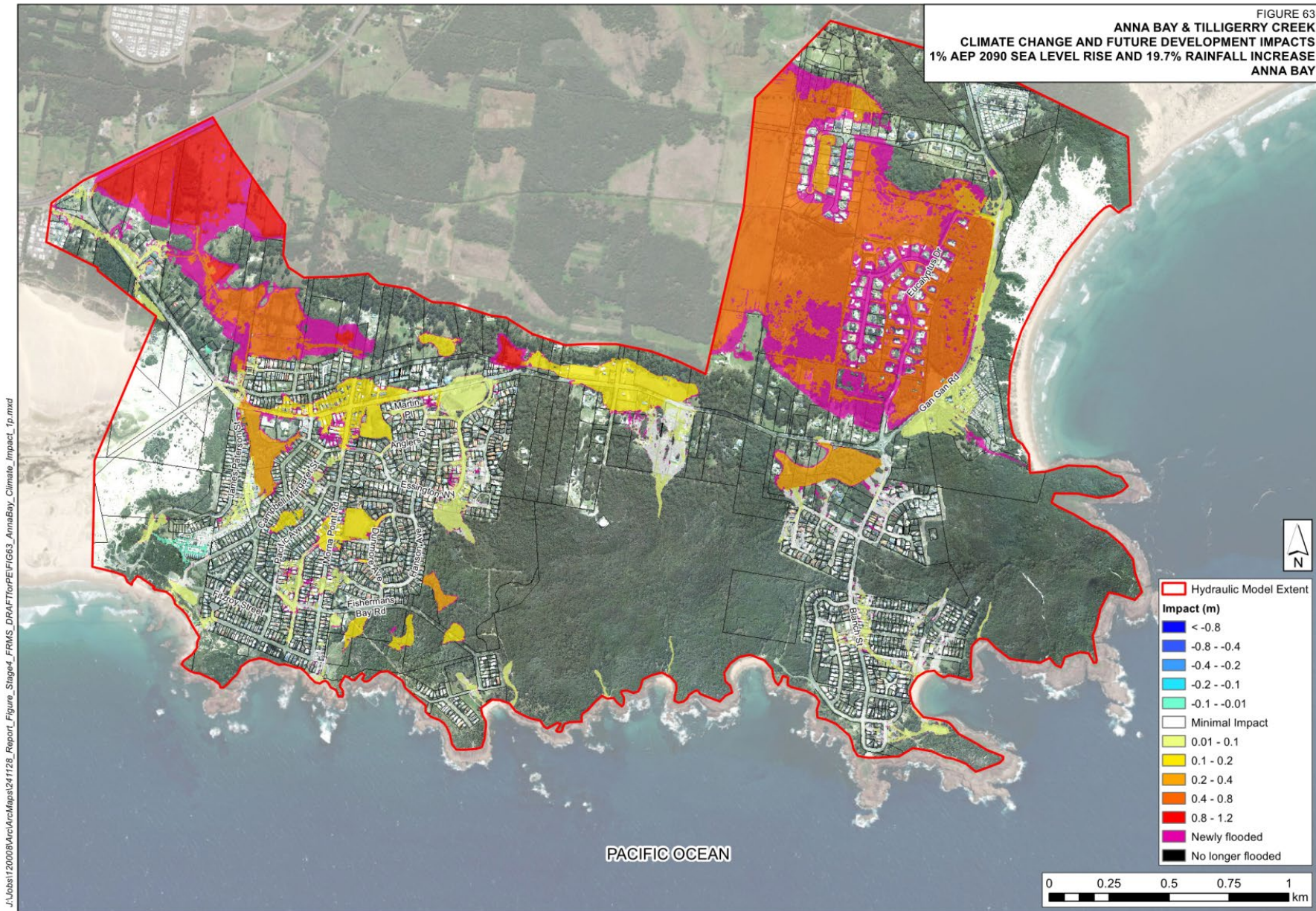


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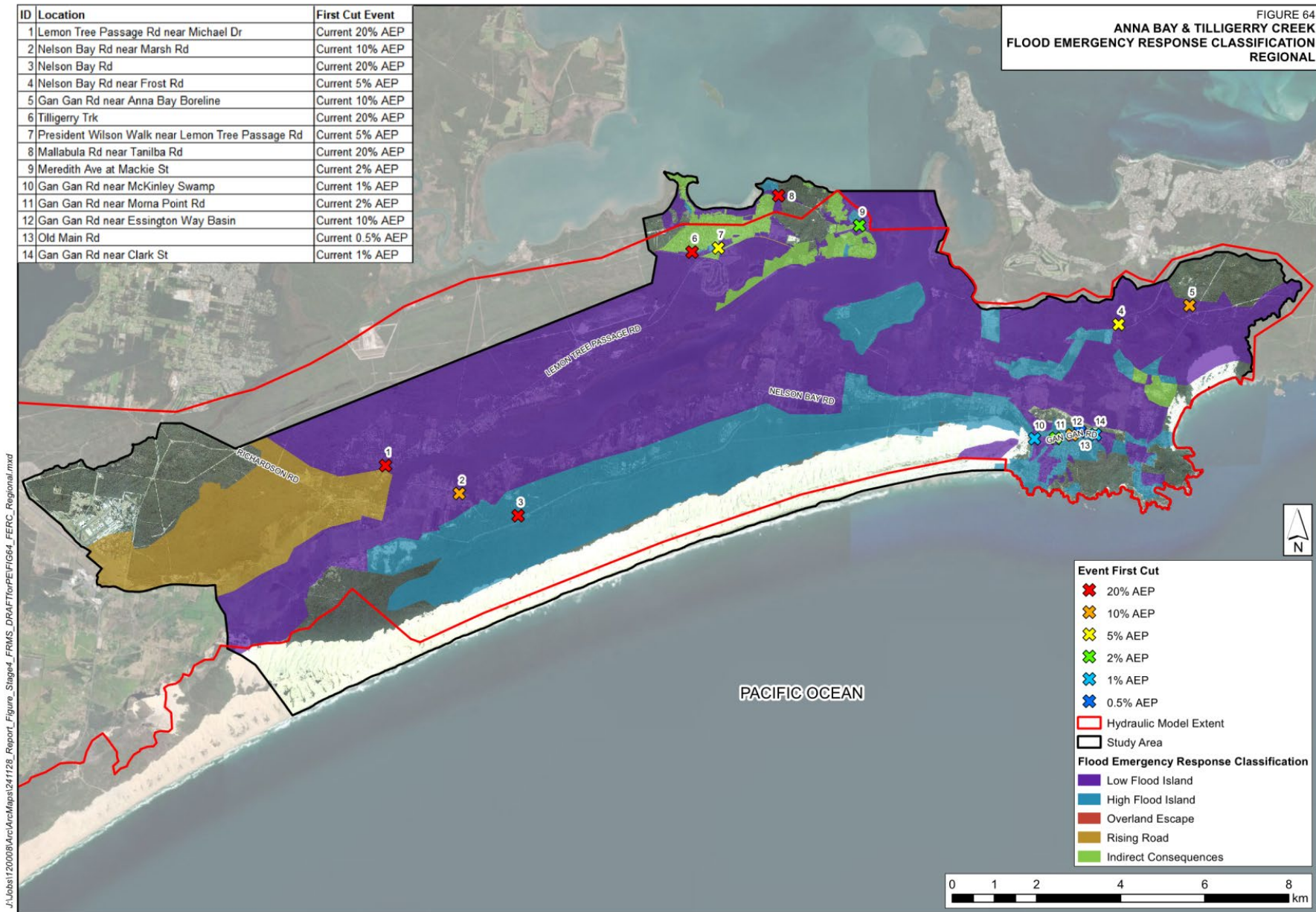


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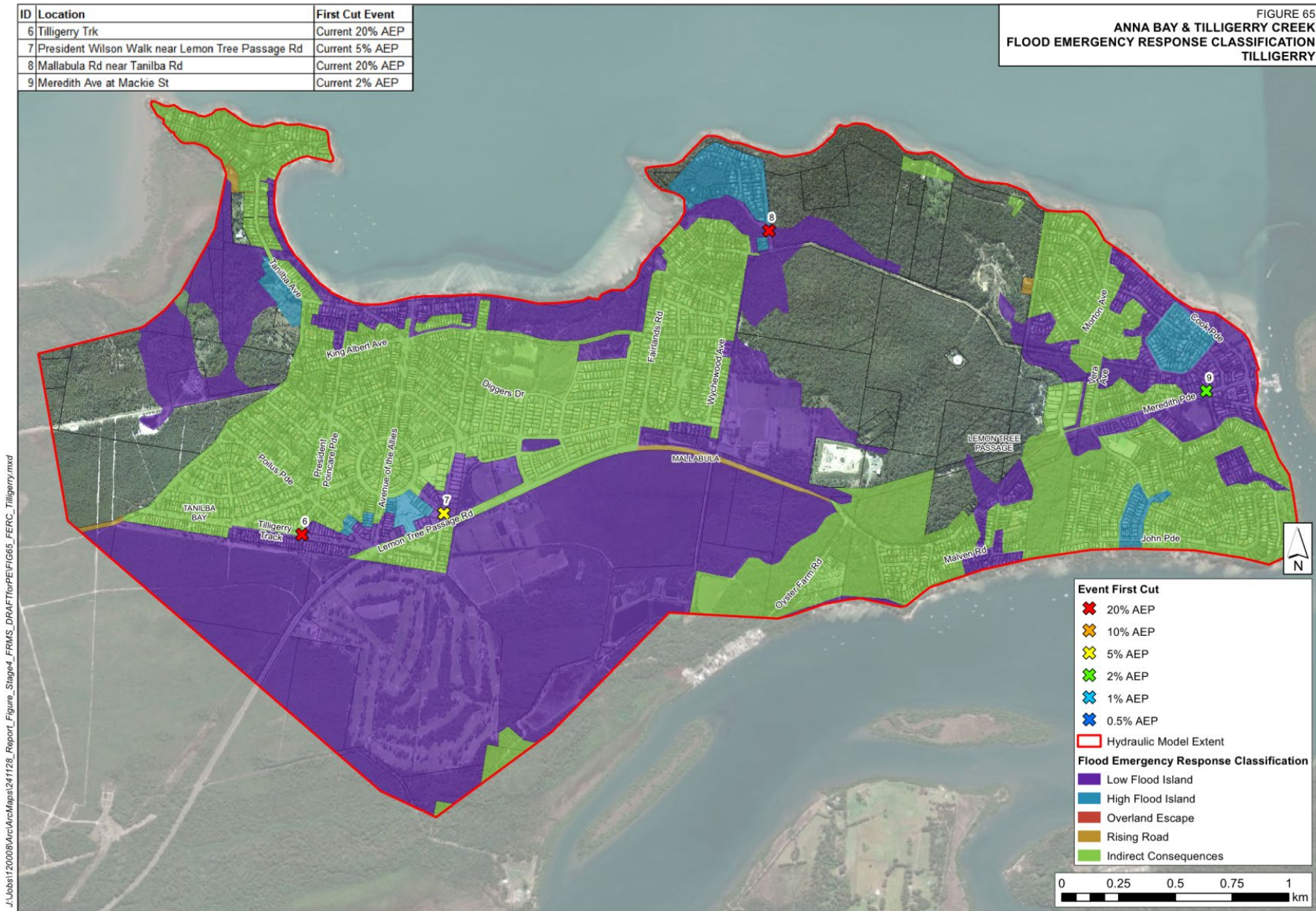




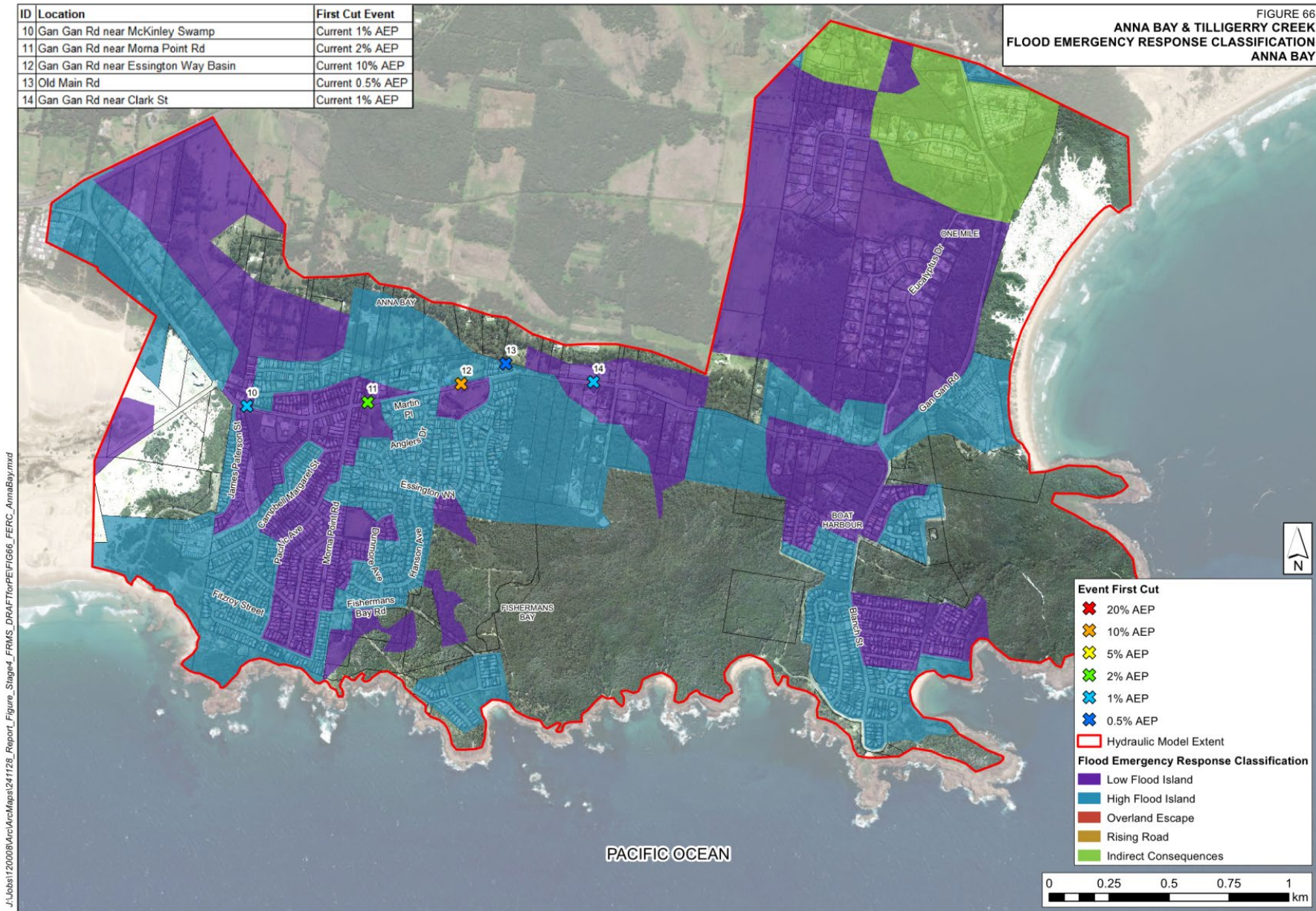
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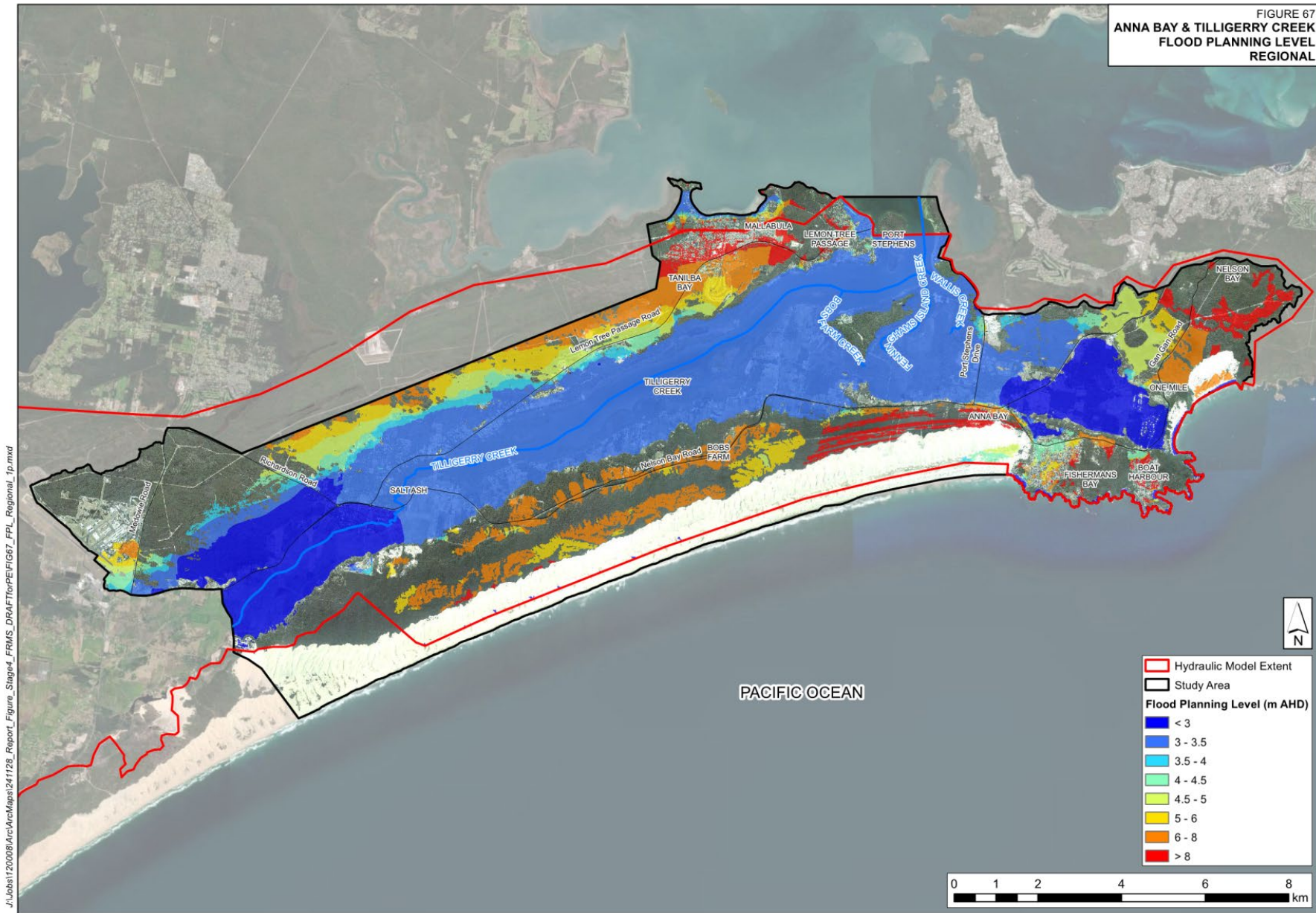
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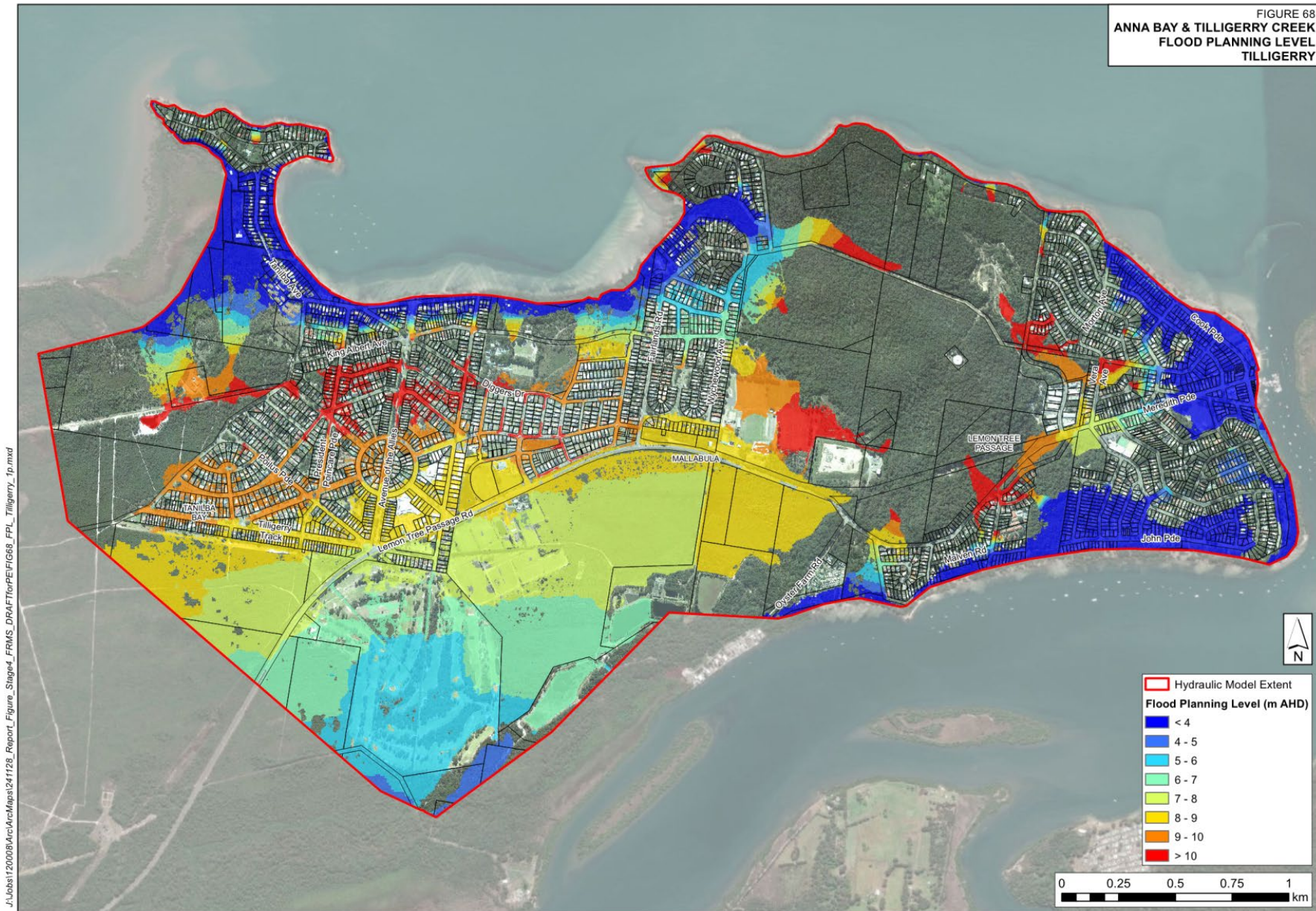
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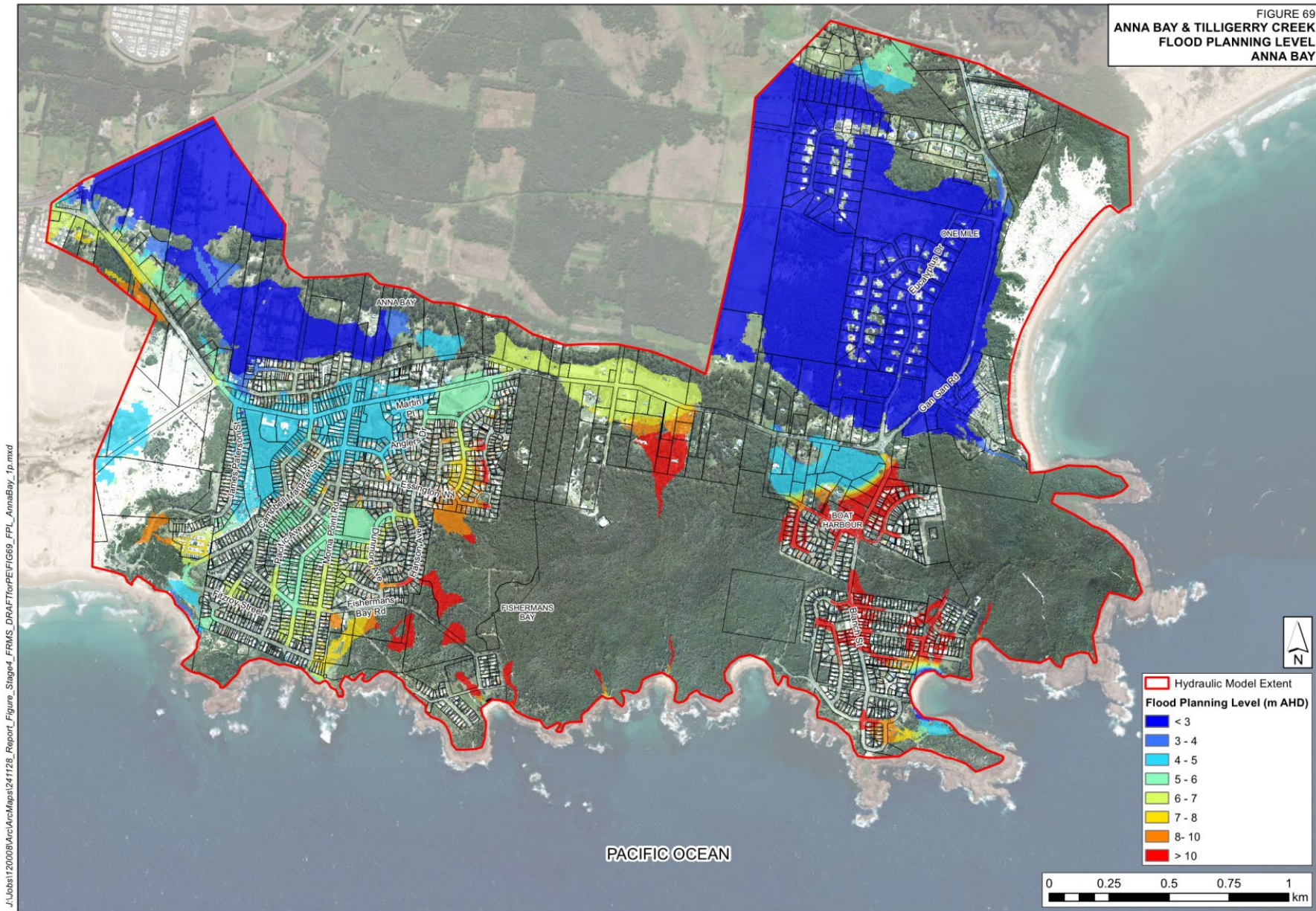


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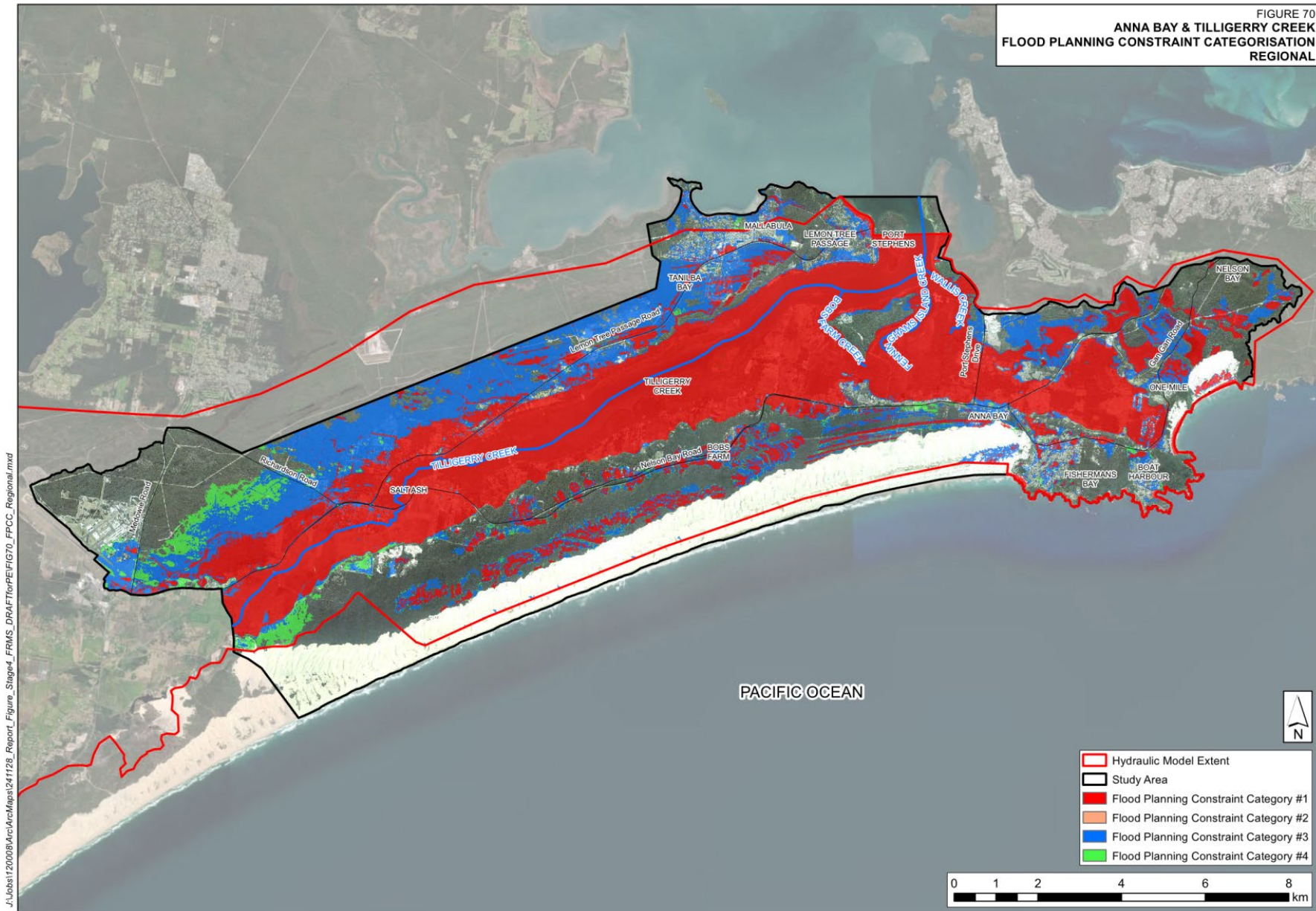


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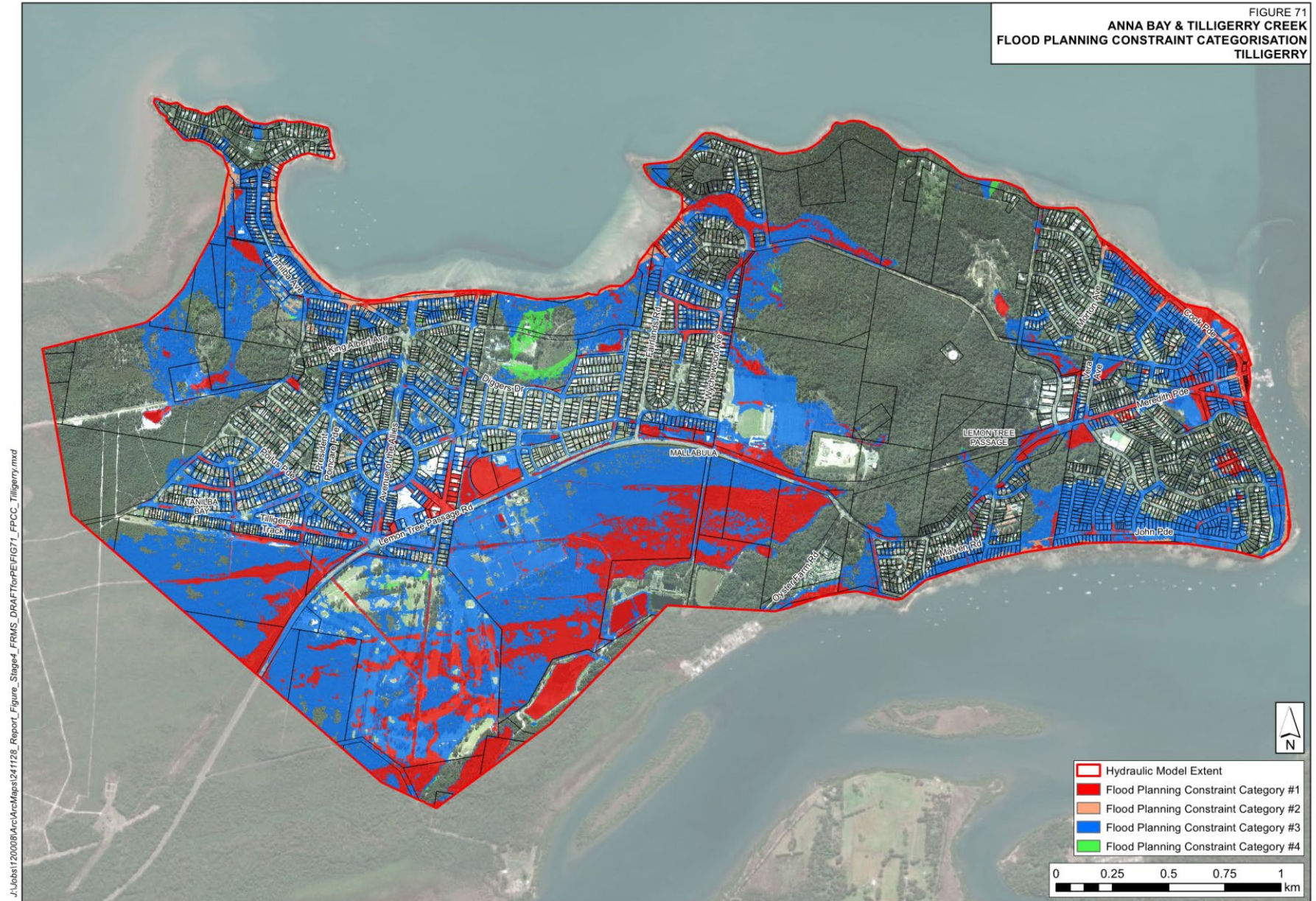




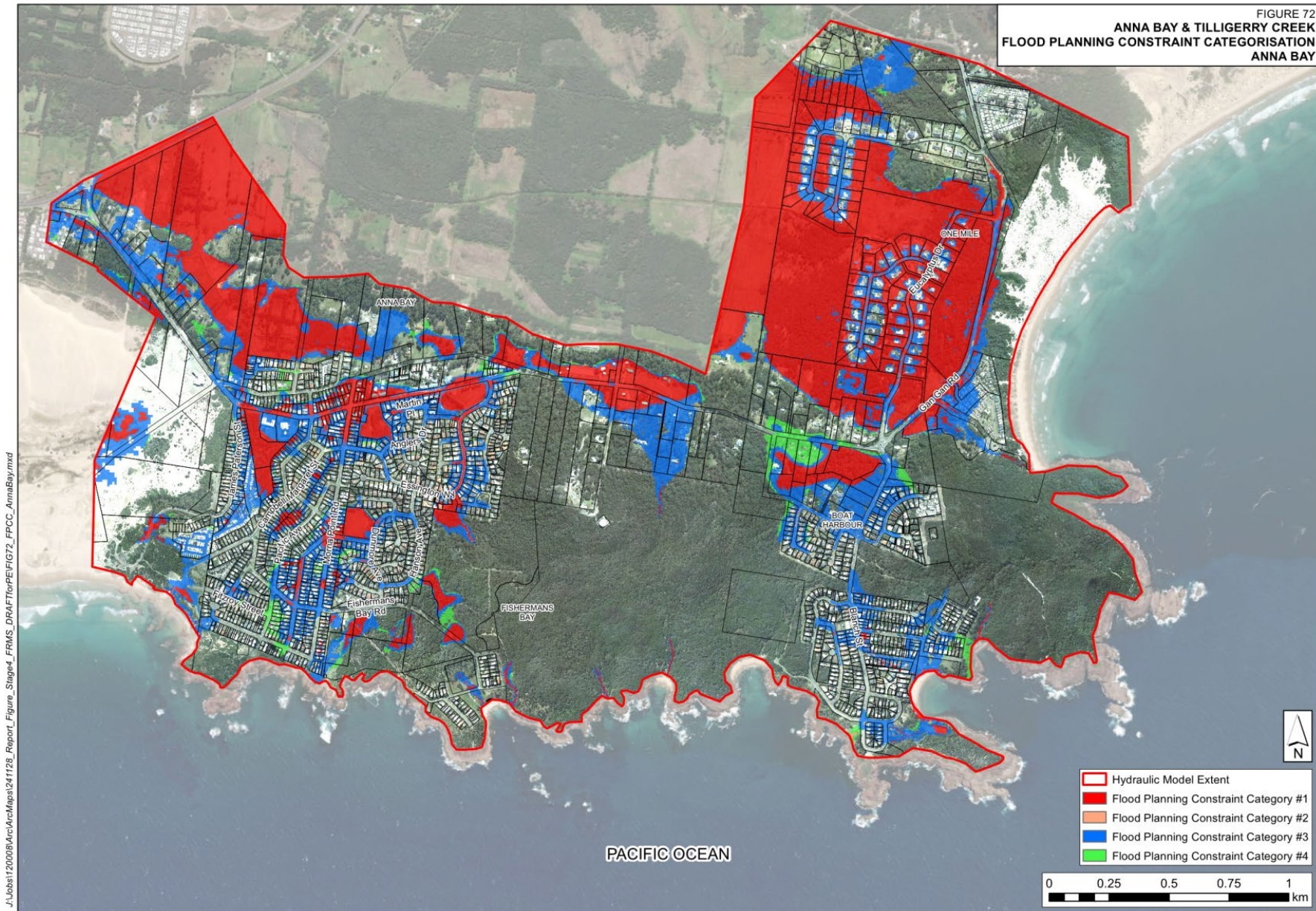
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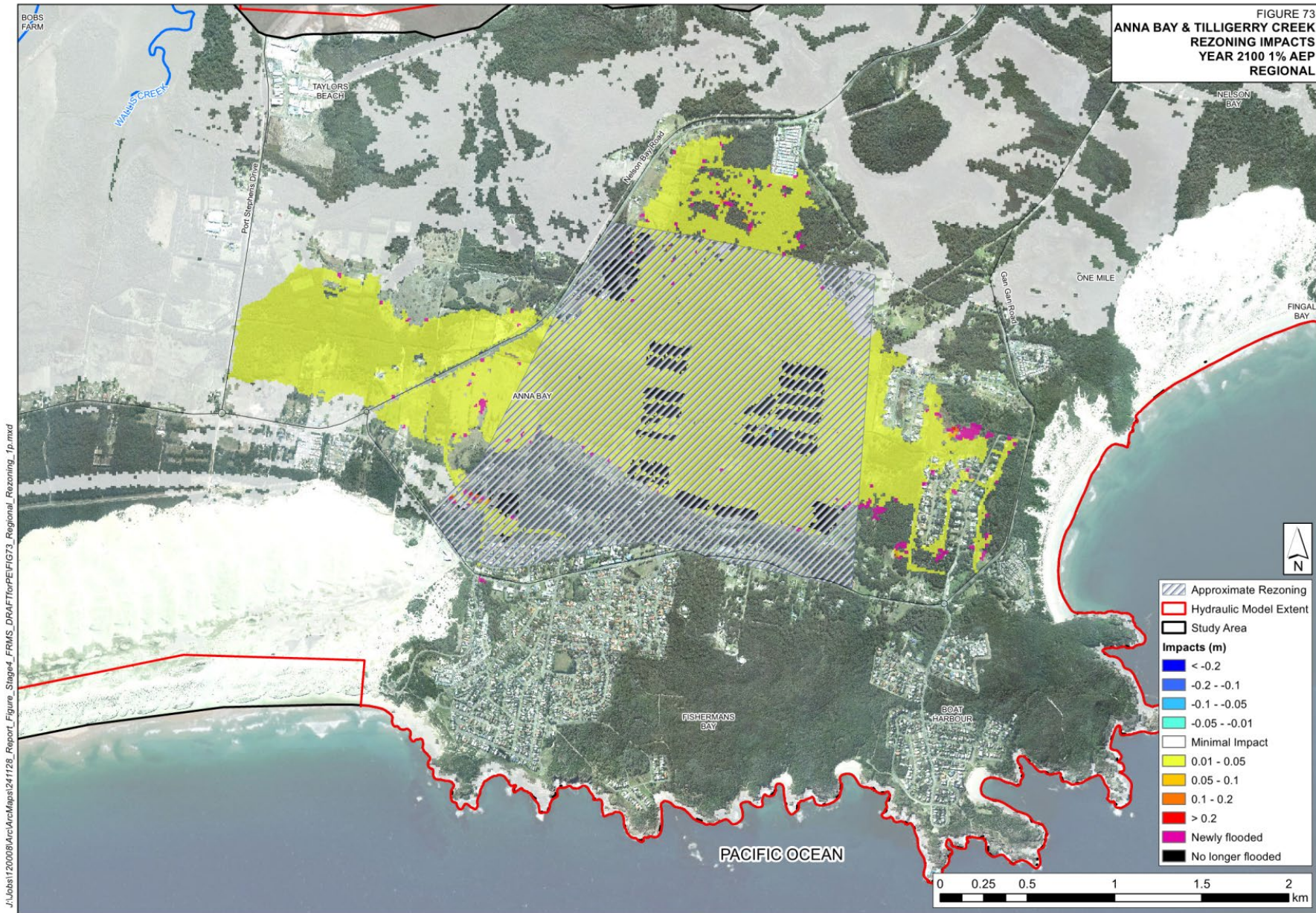


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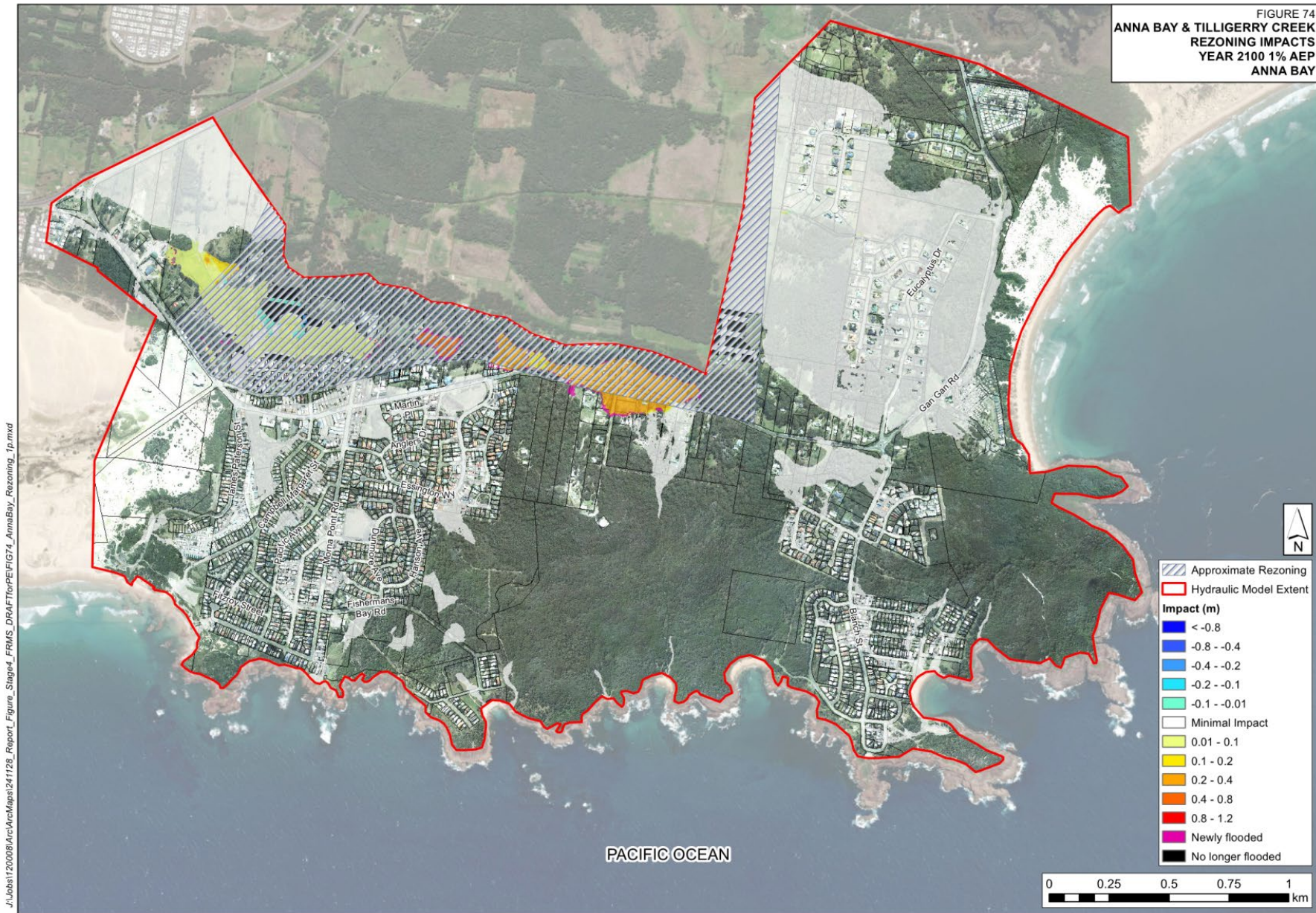


ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.





ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.



ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.

DRAFT FOR PUBLIC EXHIBITION



Appendix A

ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.



APPENDIX A. 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.

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	<p>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.</p>
disaster plan (DISPLAN)	<p>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.</p>
discharge	<p>The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m³/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).</p>
ecologically sustainable development (ESD)	<p>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.</p>
effective warning time	<p>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.</p>
emergency management	<p>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.</p>
flash flooding	<p>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.</p>
flood	<p>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.</p>
flood awareness	<p>Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.</p>
flood education	<p>Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.</p>
flood fringe areas	<p>The remaining area of flood prone land after floodway and flood storage areas have been defined.</p>
flood liable land	<p>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).</p>

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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.

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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	<p>in a residential situation: a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom.</p> <p>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.</p>
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	<p>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:</p> <ul style="list-style-type: none"> - 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

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	<ul style="list-style-type: none"> - 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	<p>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.</p> <p>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.</p>
minor, moderate and major flooding	<p>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:</p> <p>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.</p> <p>moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.</p> <p>major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.</p>
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.

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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.

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Appendix B

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APPENDIX B. COMMUNITY CONSULTATION

The responses of a community survey conducted in late February 2024 in the Anna Bay and Tilligerry Creek Region are represented in this section. The community survey was targeted to examine the community’s opinion regarding different potential flood mitigation options as well as they opinions on the existing solutions.

A total of 30 responses were collected as part of the survey. 46% of respondents (12 poeple) are residents of Tilligerry Creek, 31% of respondents (8 people) are residents of Anna Bay, and the remaining 23% of respondents (6 people) live in other towns in the region. 46% (14 people) of these respondents have been living in the area for 20+ years, with 86% (26 people) of the respondent’s properties being residences. Of the 30 respondents, 76% (23 people) live in a flood affected area, and 70% live near a creek, river or drain channel.

Diagram B 1 to Diagram B3 summarises the respondent’s opinions on existing flood mitigation in the Anna Bay and Tilligerry Creek region. As in diagram 1, 90% of respondents (23 people) believe flooding could be improved in their area. Of these respondents, the locations within the area that they believe could be improved includes Gan Gan Rd in Anna Bay near Robinson Sand and Soil, Rookes Rd, Morna Point Rd, Old Main Rd, Nelson Bay Rd Valerie Rd, David Drive. Oakfield Road, Rookes Road, Michael Drive, Lemon Tree Passage Road, Hideaway Drive, Clarke Street, Robinson Reserve and Marsh Rd. Of these areas, most respondents believe that the ground is low lying, so the water has nowhere to go, as shown in Diagram B 2. As in Diagram B 3, majority of these respondents believe that better maintenance of the drains in the specified areas would improve flooding.

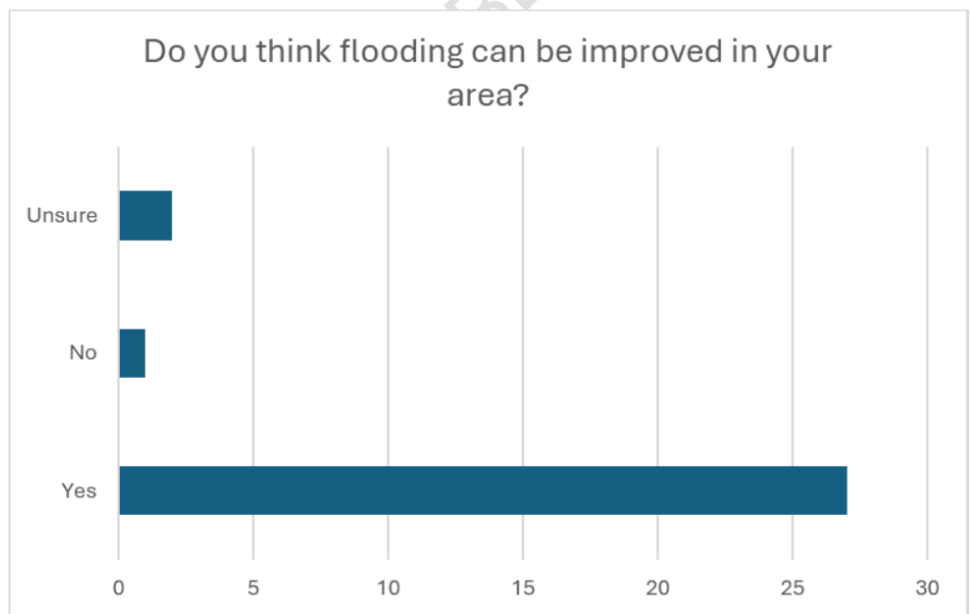


Diagram B 1

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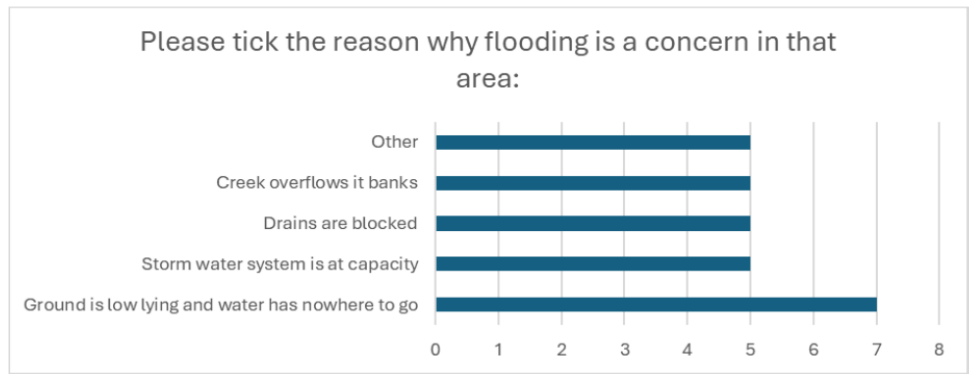


Diagram B 2

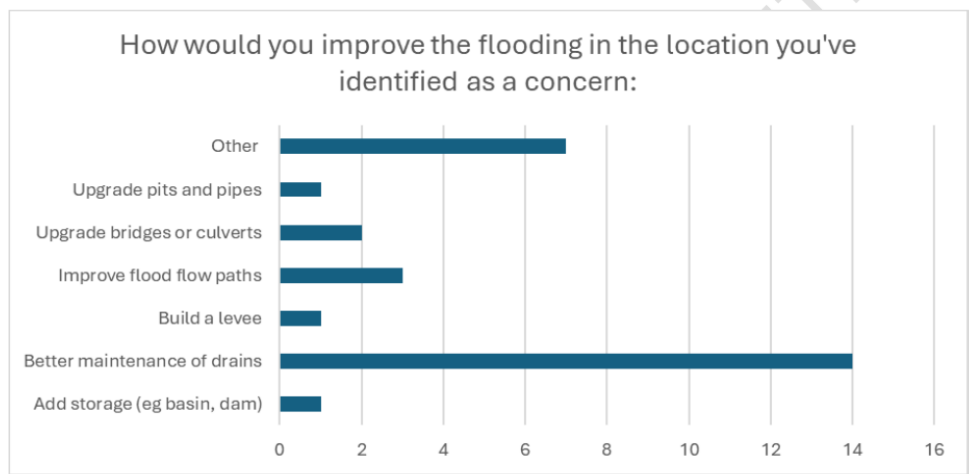


Diagram B 3

Diagram B 4 depicts what the community believes to be the most important measure for managing flood risk, with capital works to expand the capacity of the storm water system the most preferential option across the responses.

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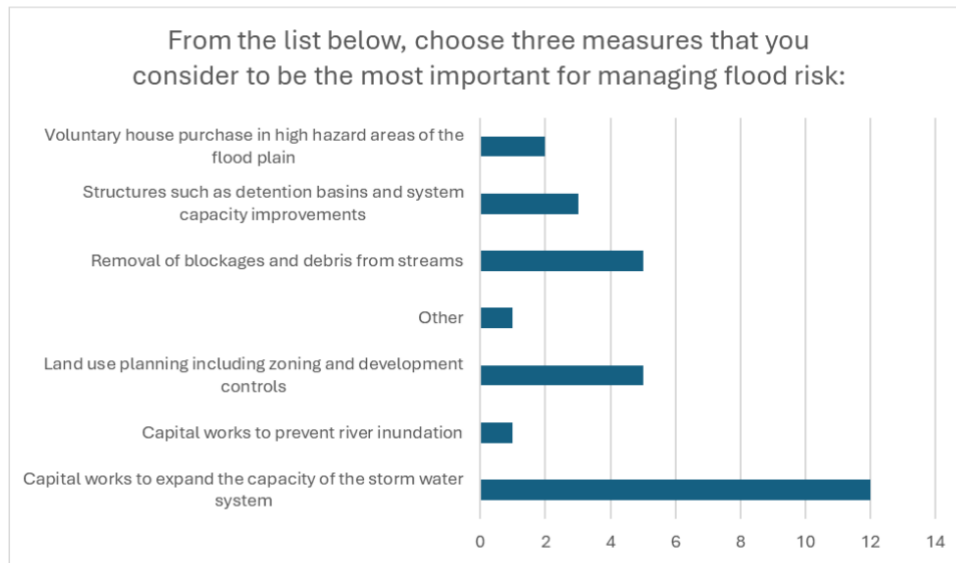


Diagram B 4

Diagram B 5 shows that 60% of the surveyed community are affected directly by flooding. Of these 60%, to protect themselves and their property from floods, 4 said they use sandbags, 5 said they used water pumps and 7 said they move what they can to higher ground. Additionally, 5 respondents said that if they had to evacuate due to flood events they would have no route to escape due to road inundation, while 14 respondents know of higher ground and have an escape route.

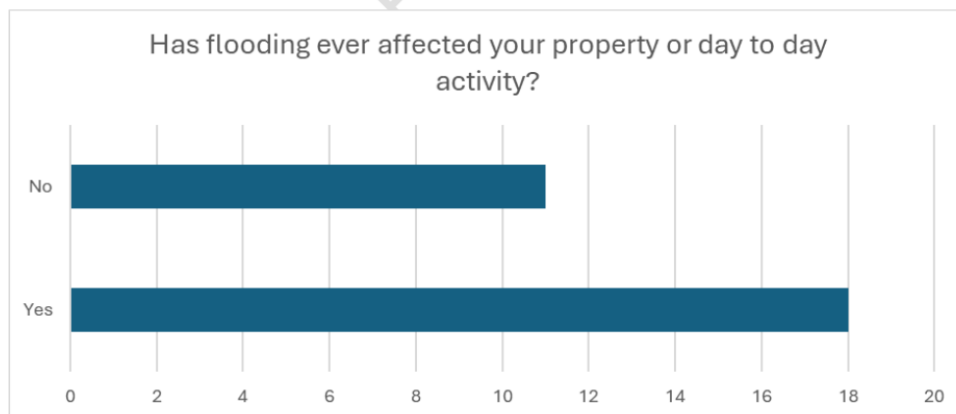


Diagram B 5

Diagram B 6 to Diagram B 8 summarise the communities preferred ways of receiving flood information and updates. 40% of respondents trust SES to provide accurate information during flood events. 80% of respondents would prefer to receive flood warnings through emergency SMS.

Diagram B 8 shows that most respondents need road closure information and expected impacted areas during

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or after a flood event.

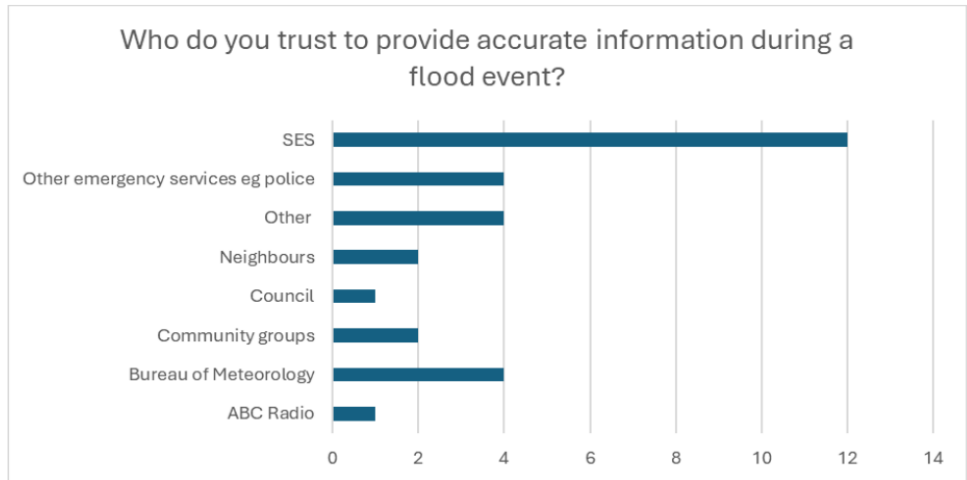


Diagram B 6

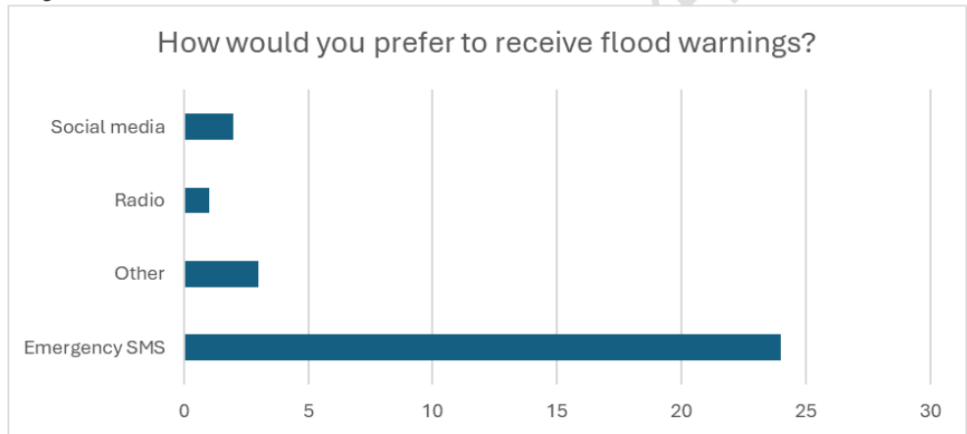


Diagram B 7

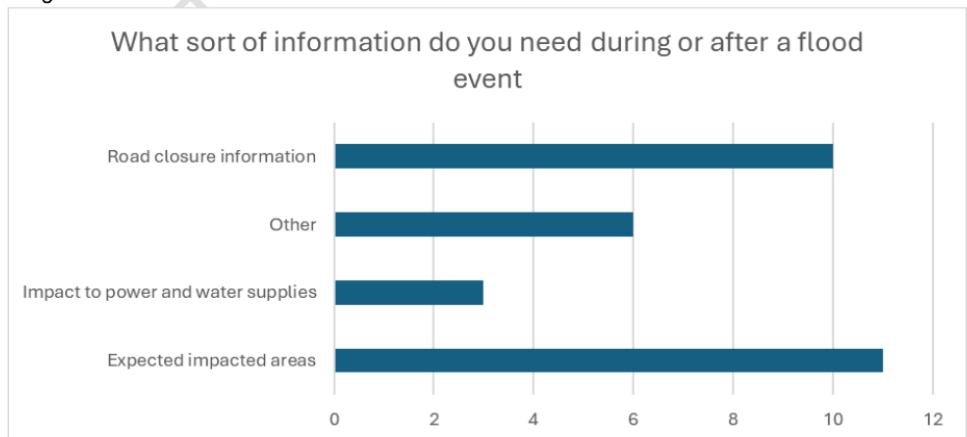


Diagram B 8

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Appendix C

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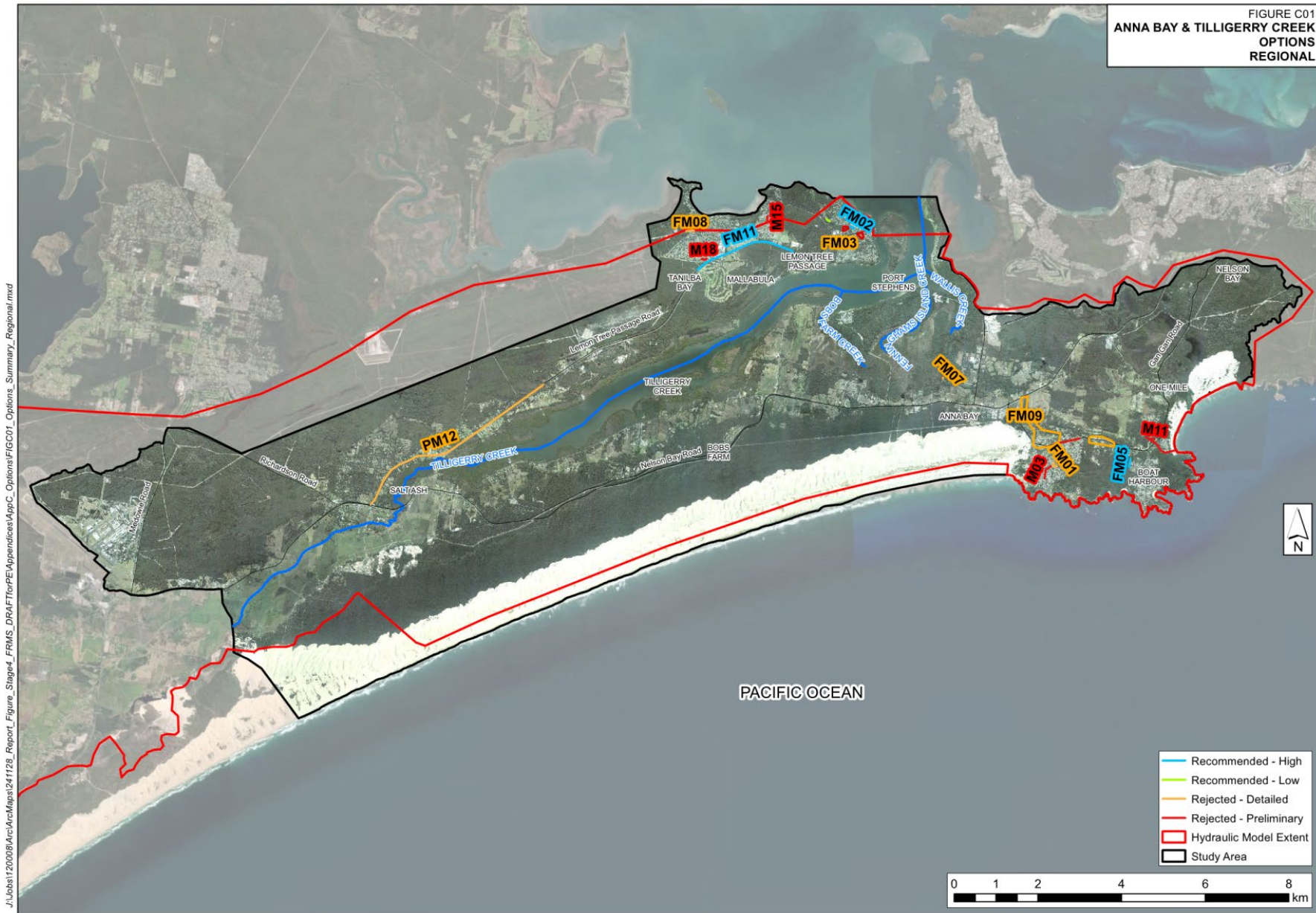


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APPENDIX C. MITIGATION OPTION

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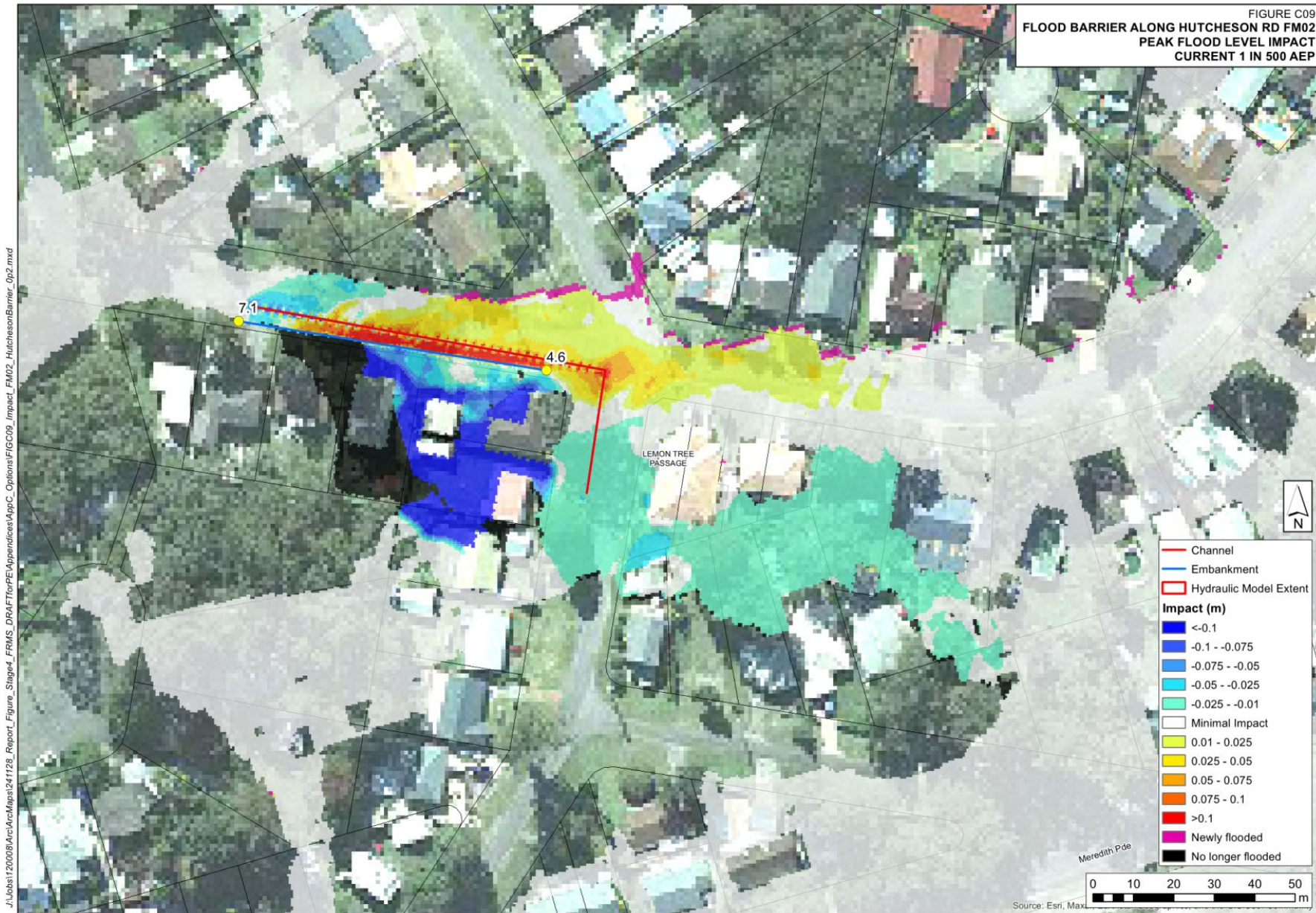




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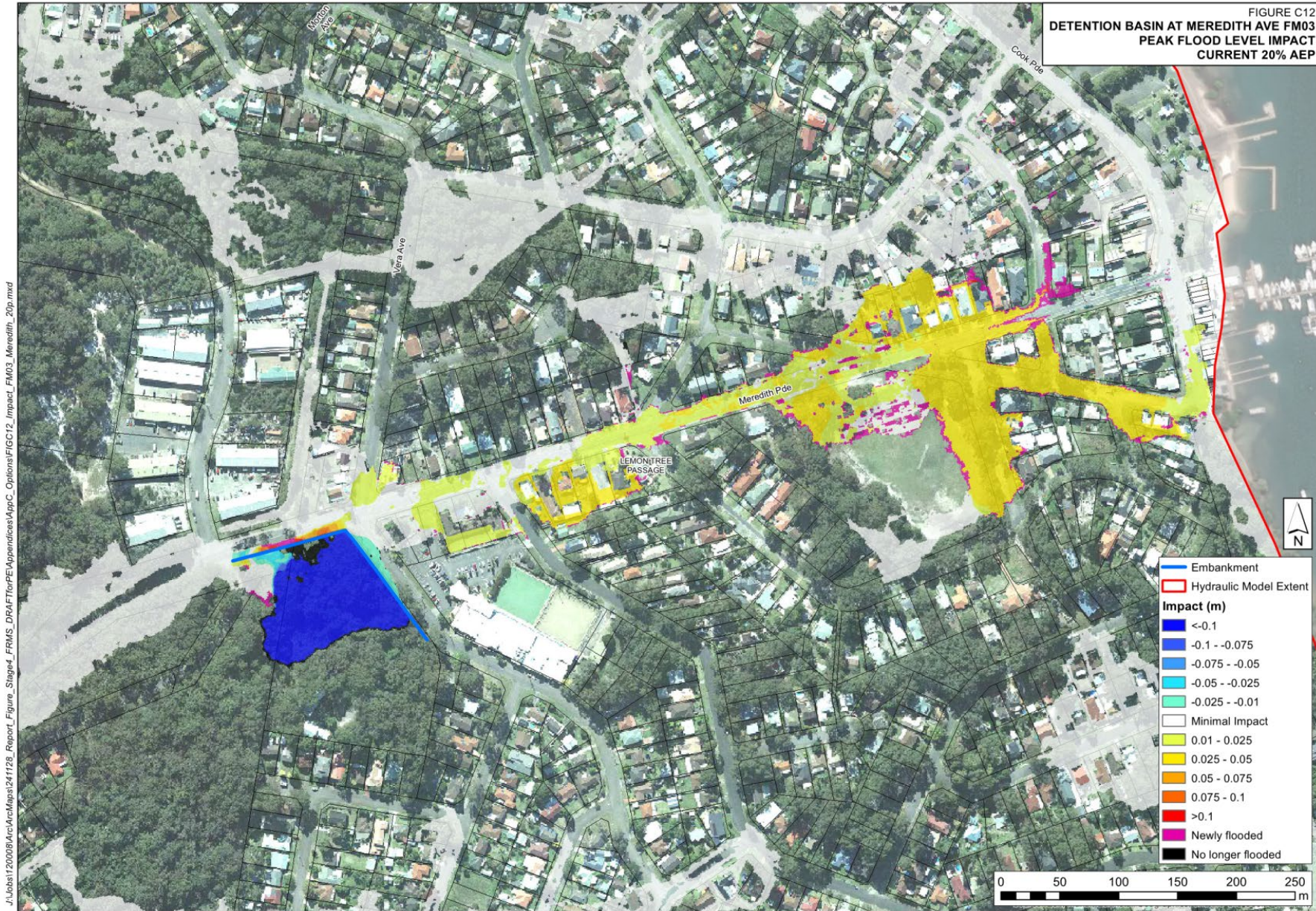




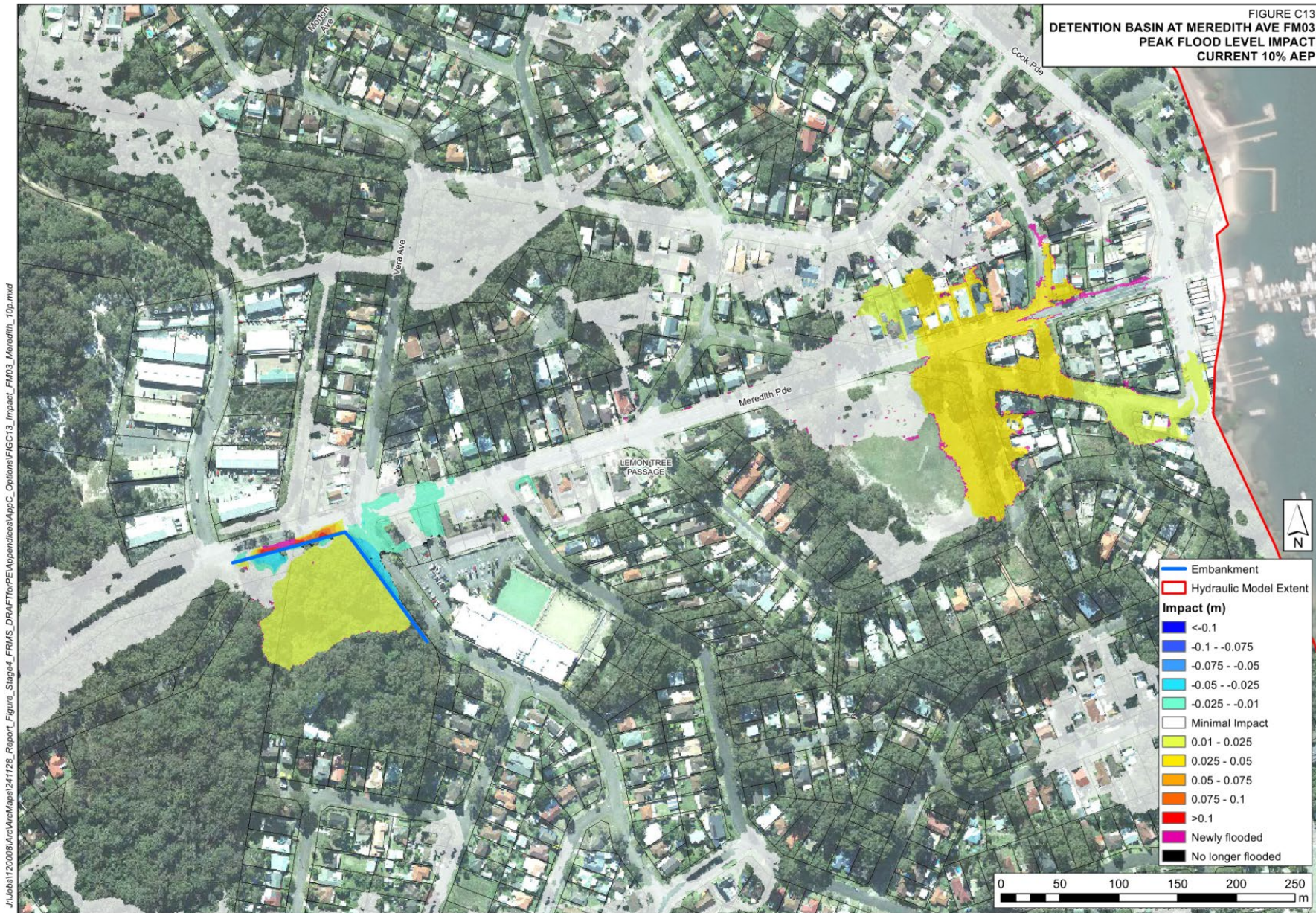


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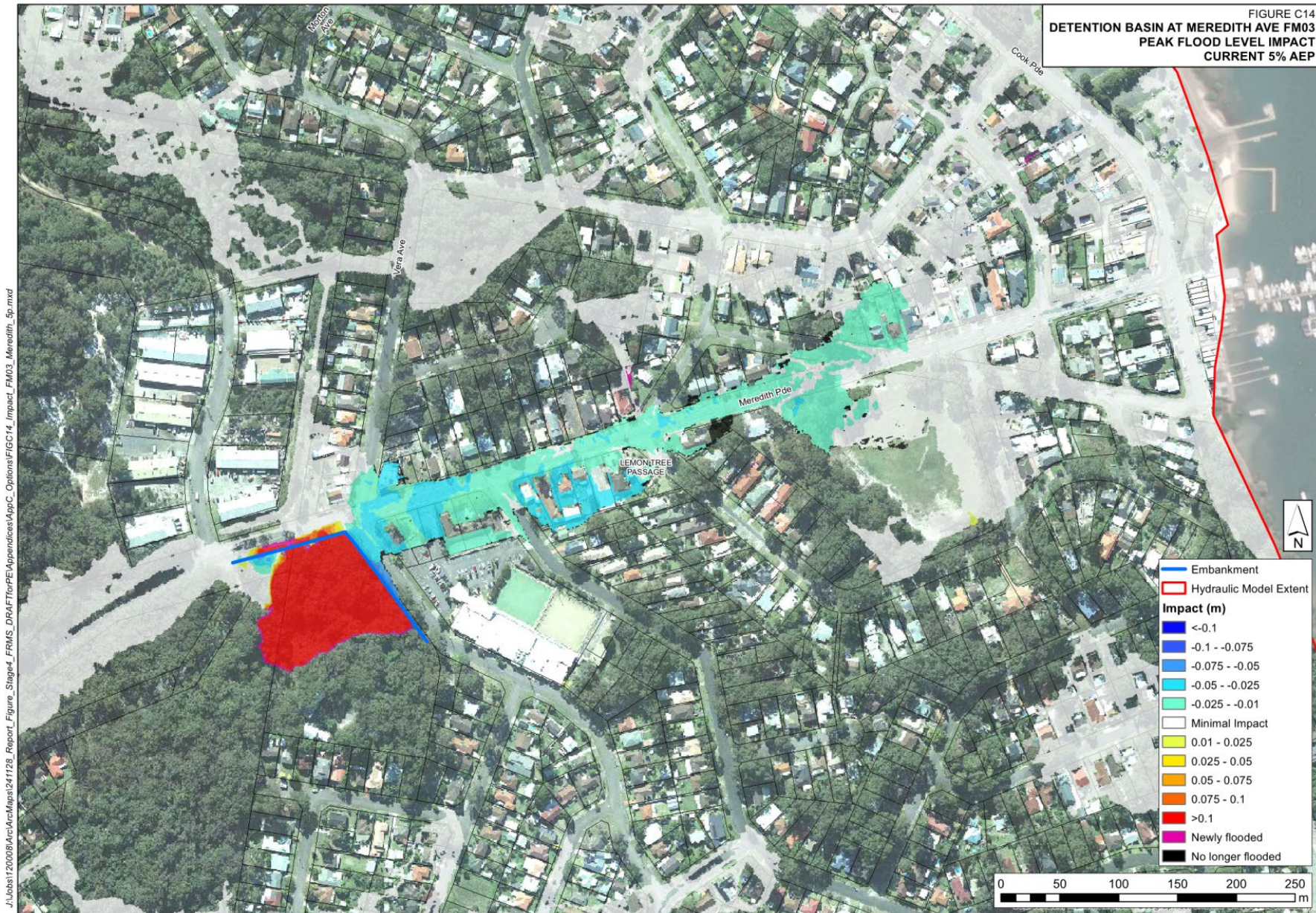




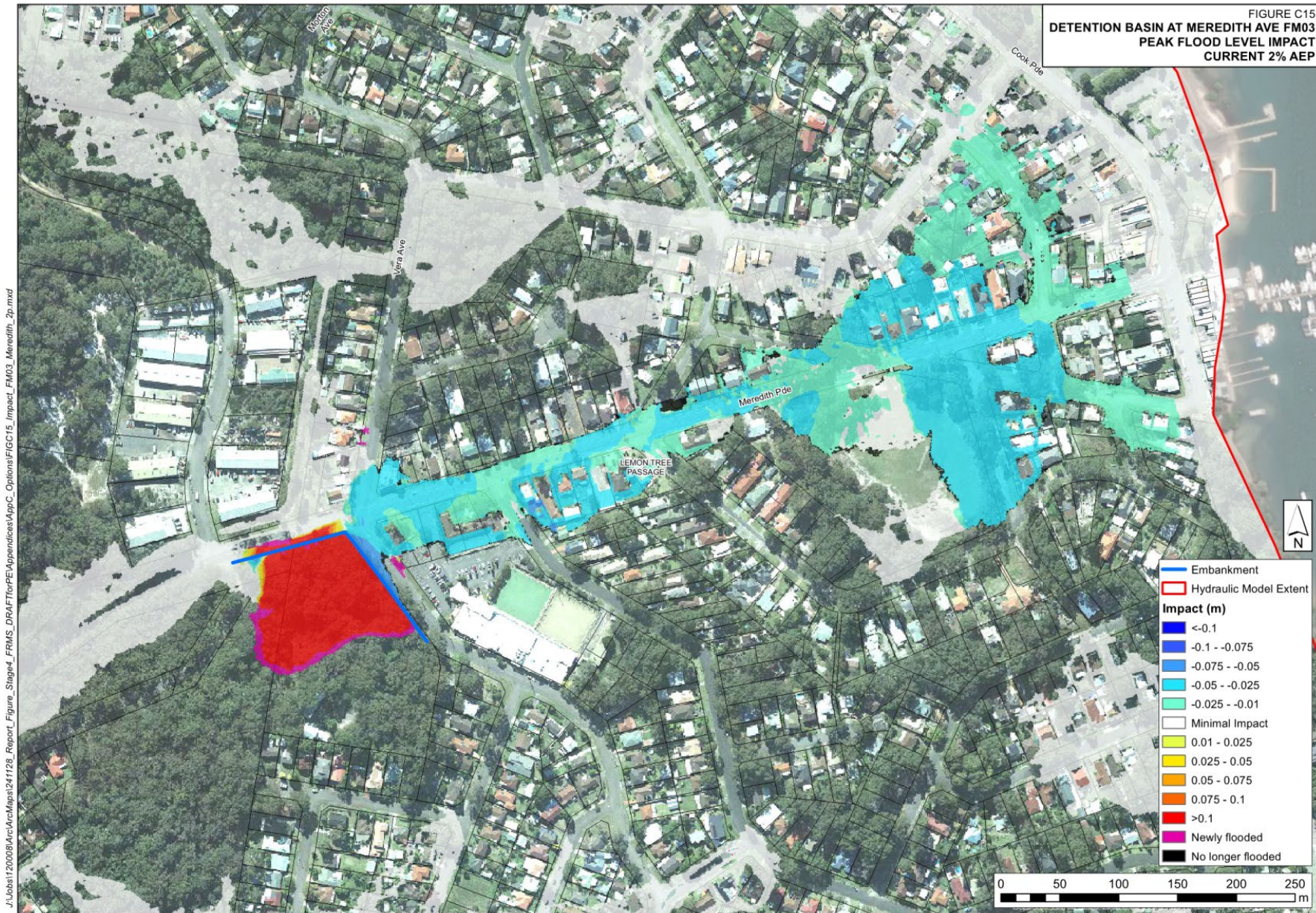
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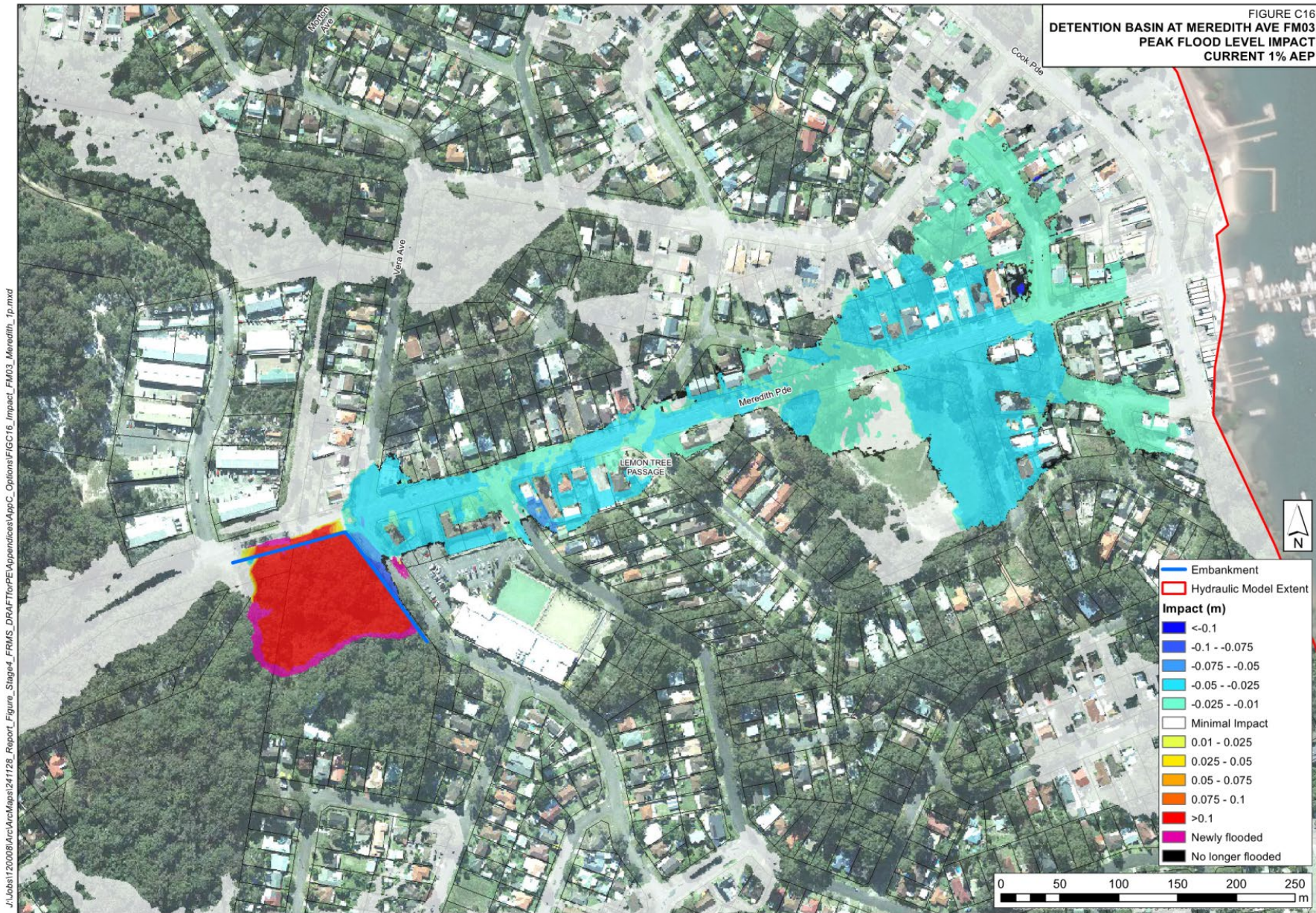
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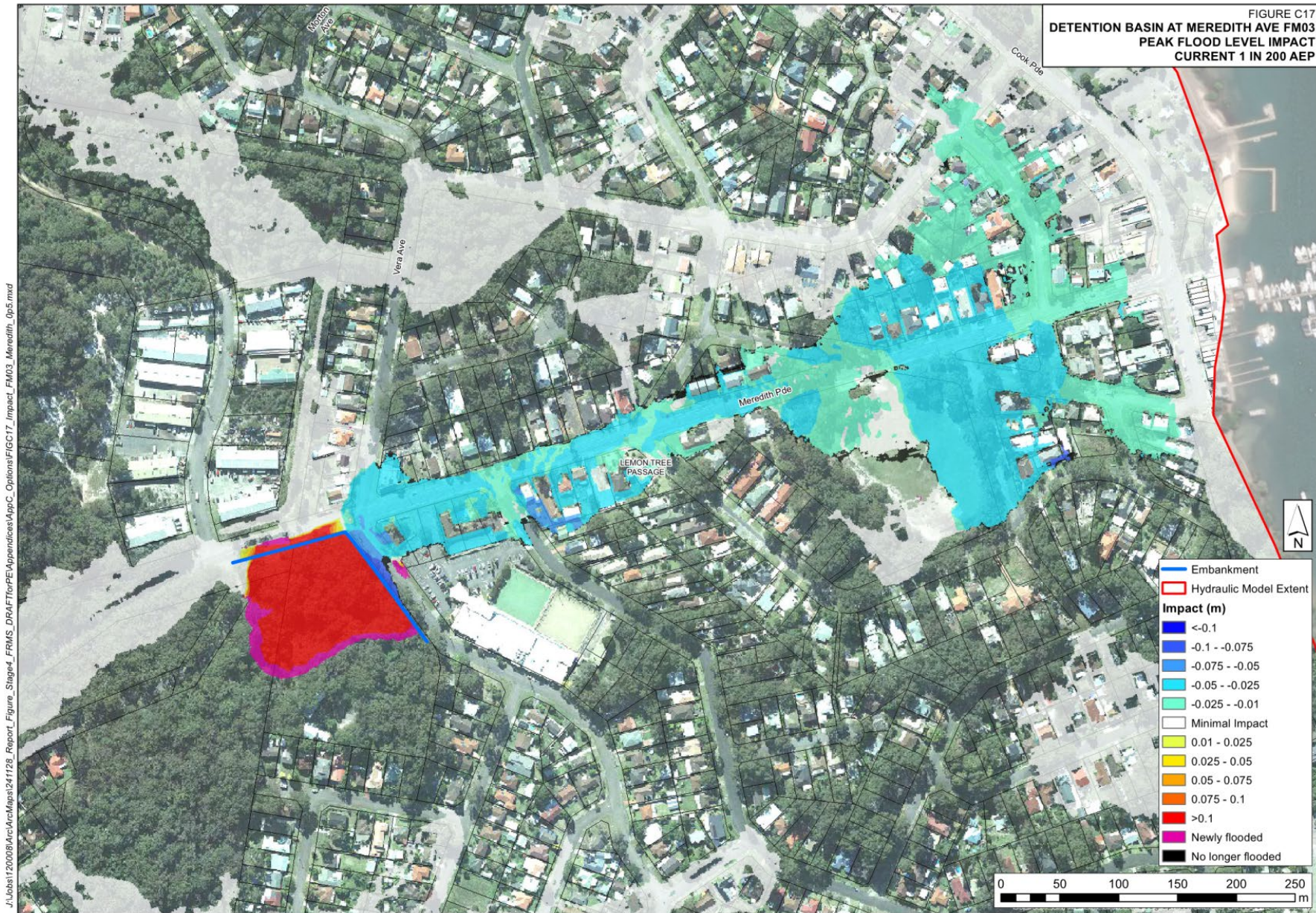
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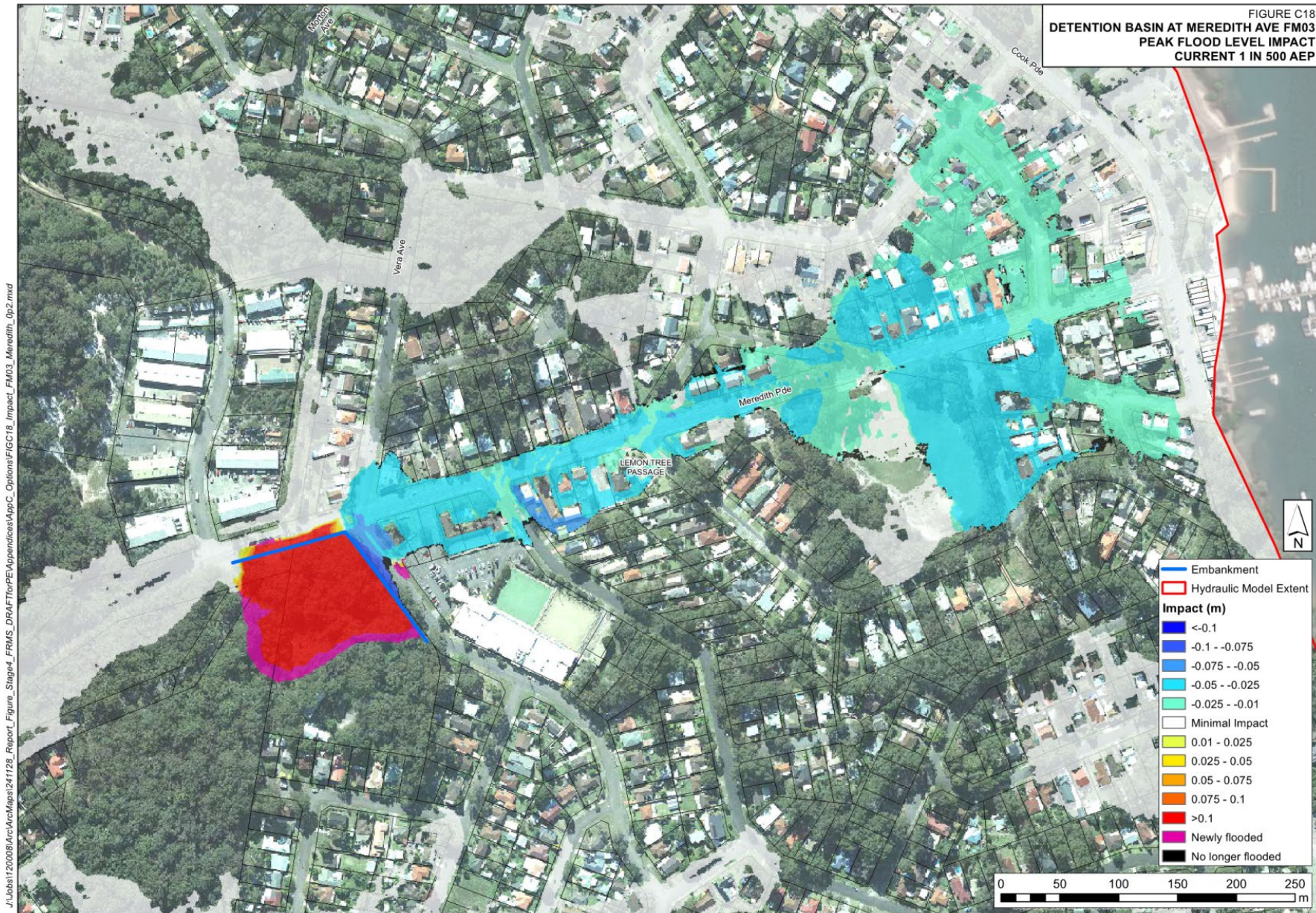
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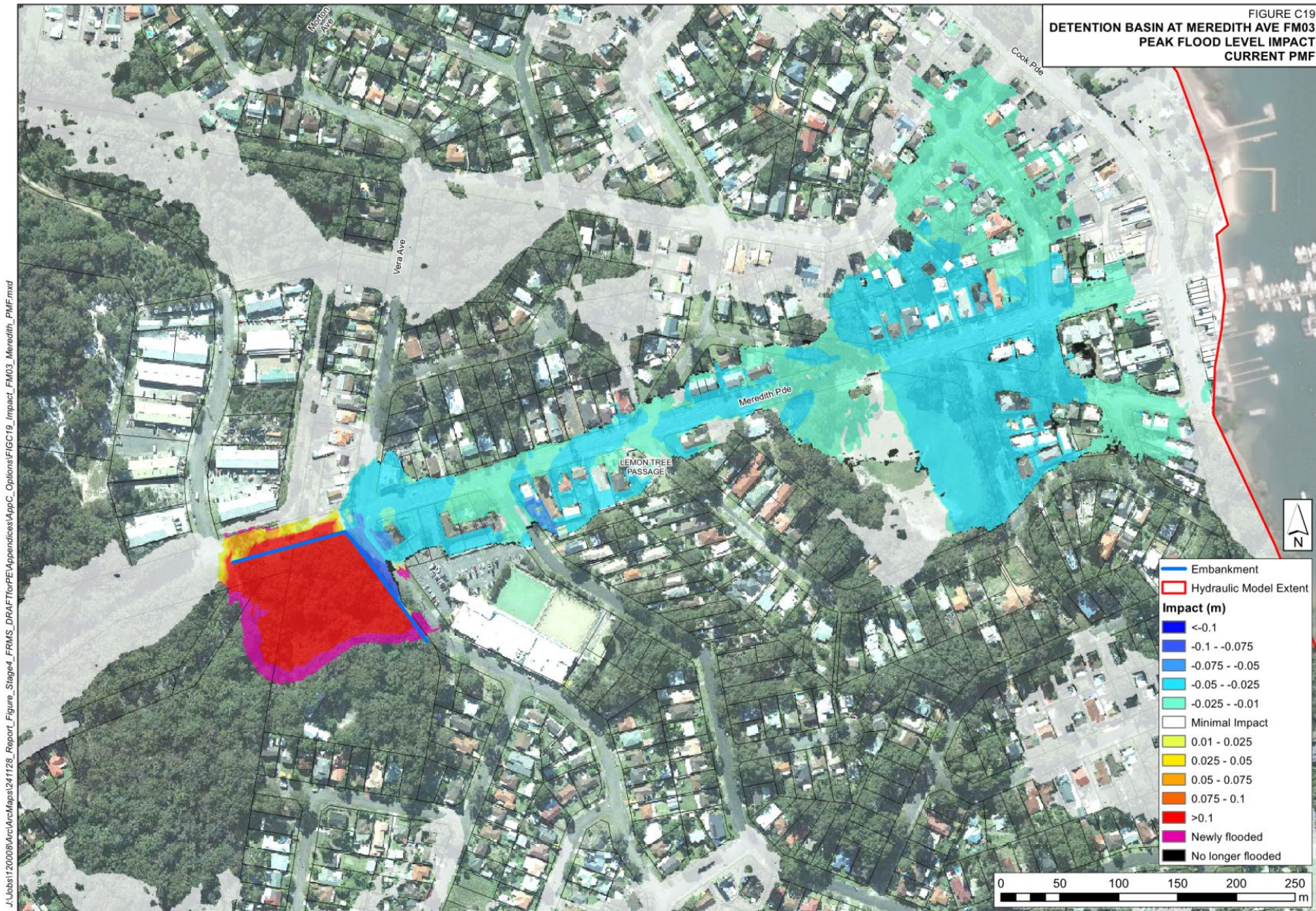
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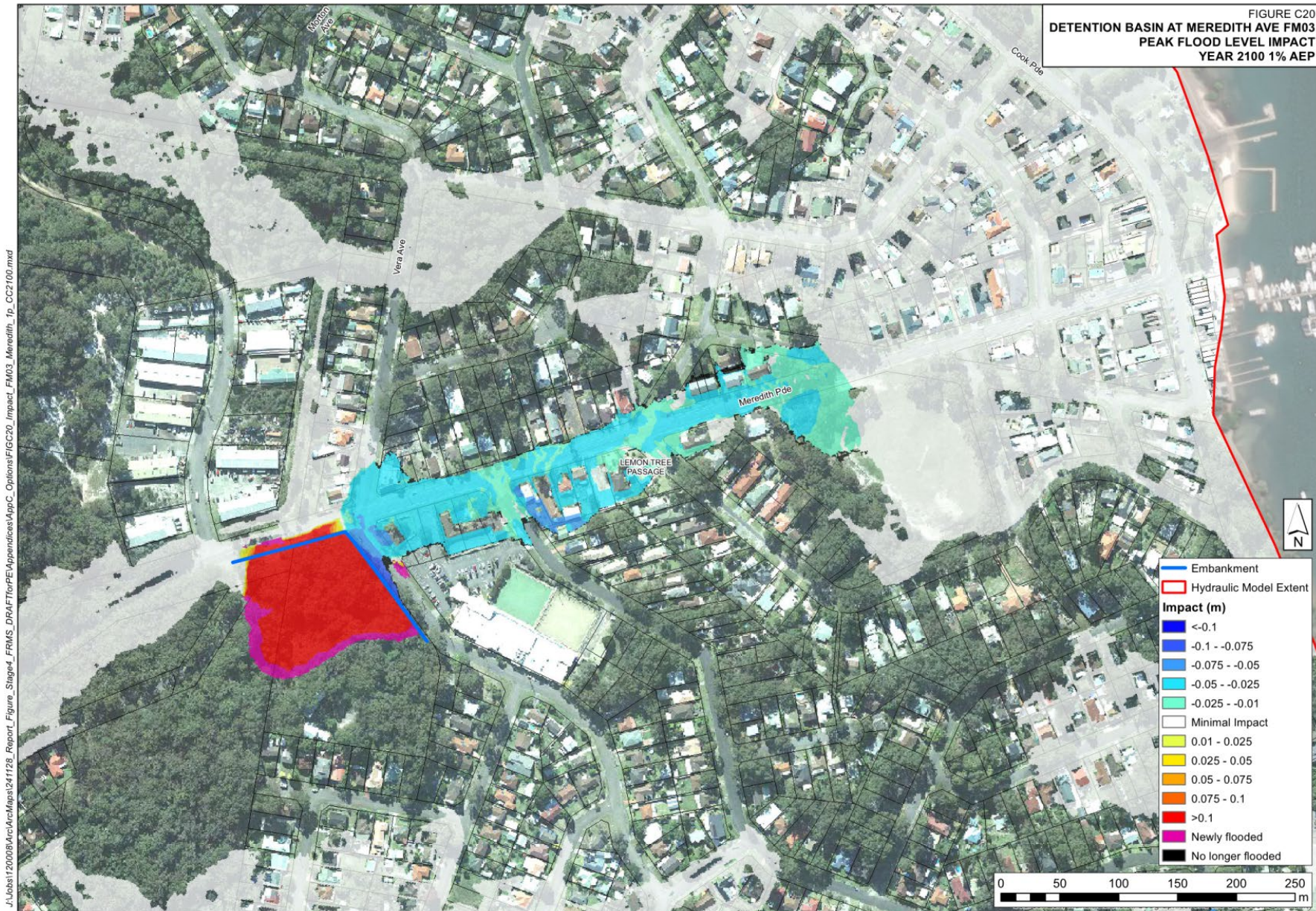
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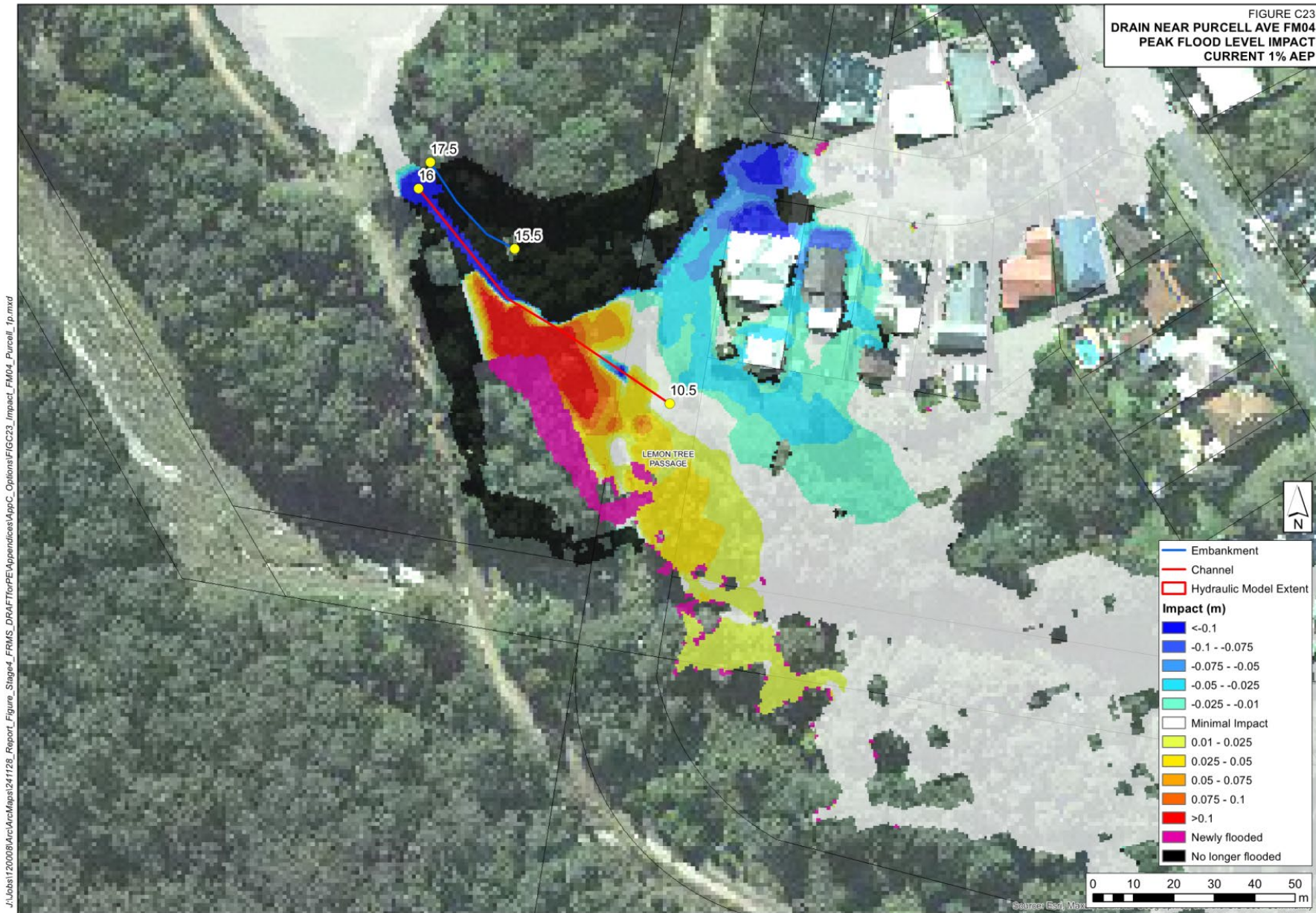
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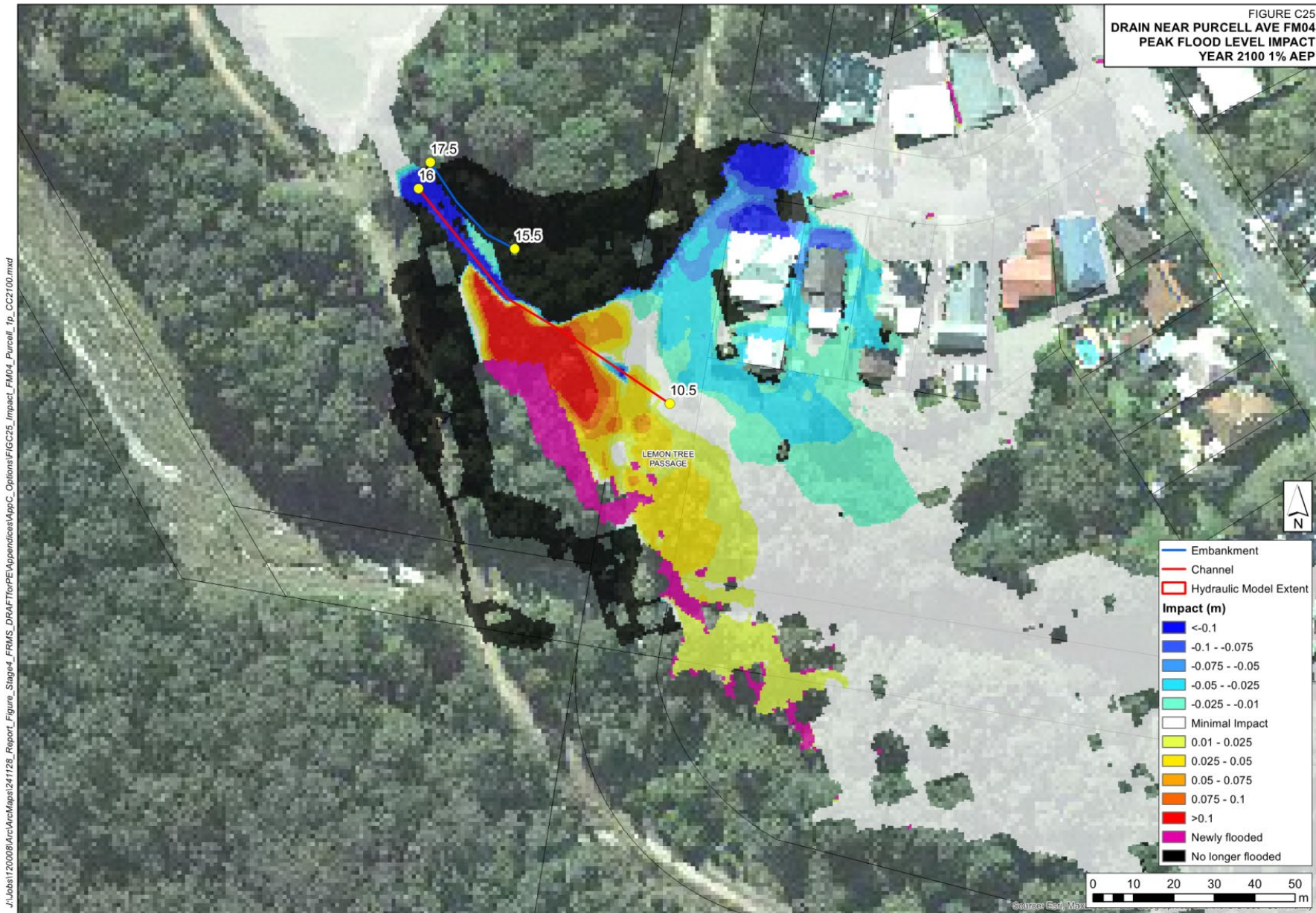
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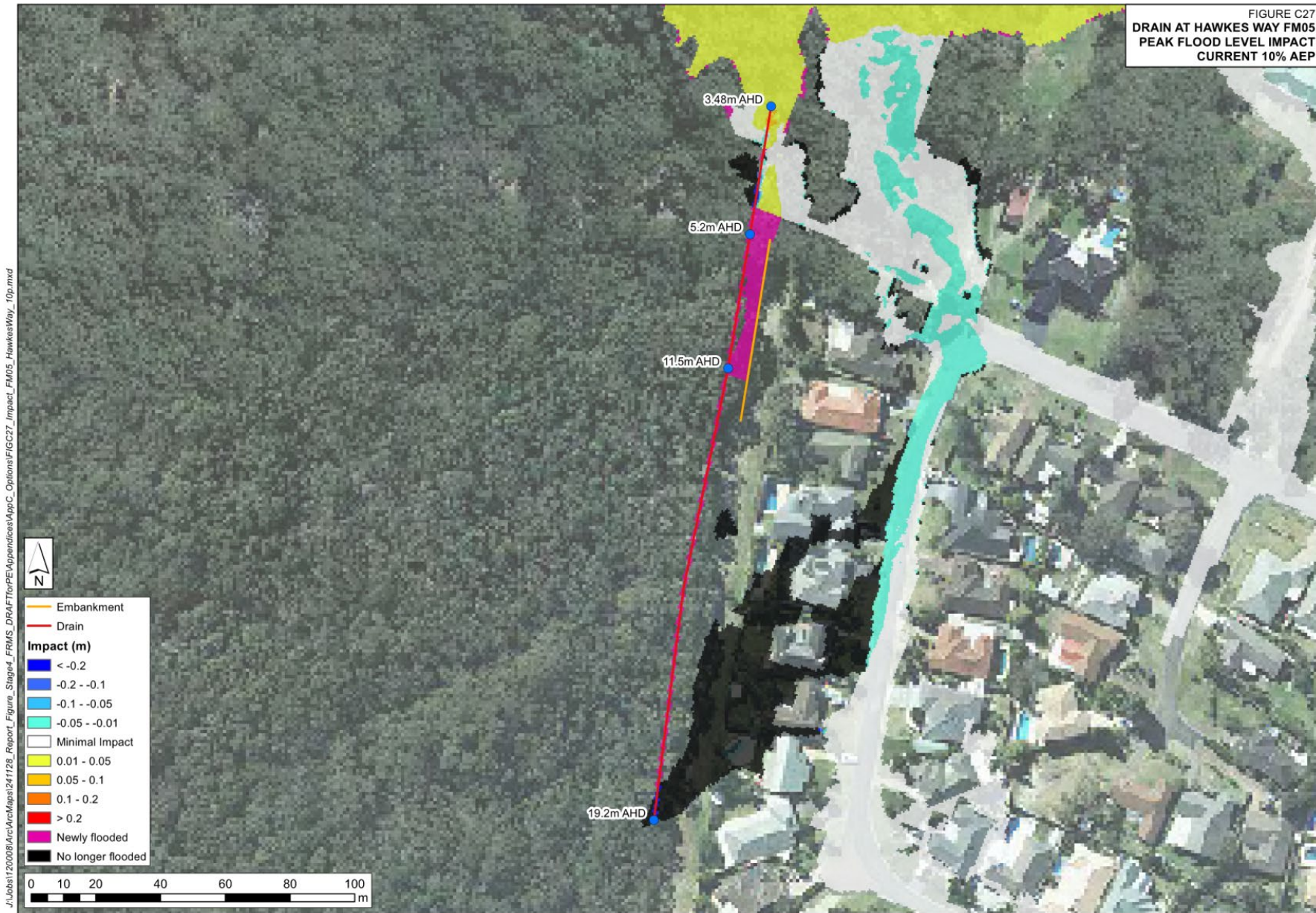


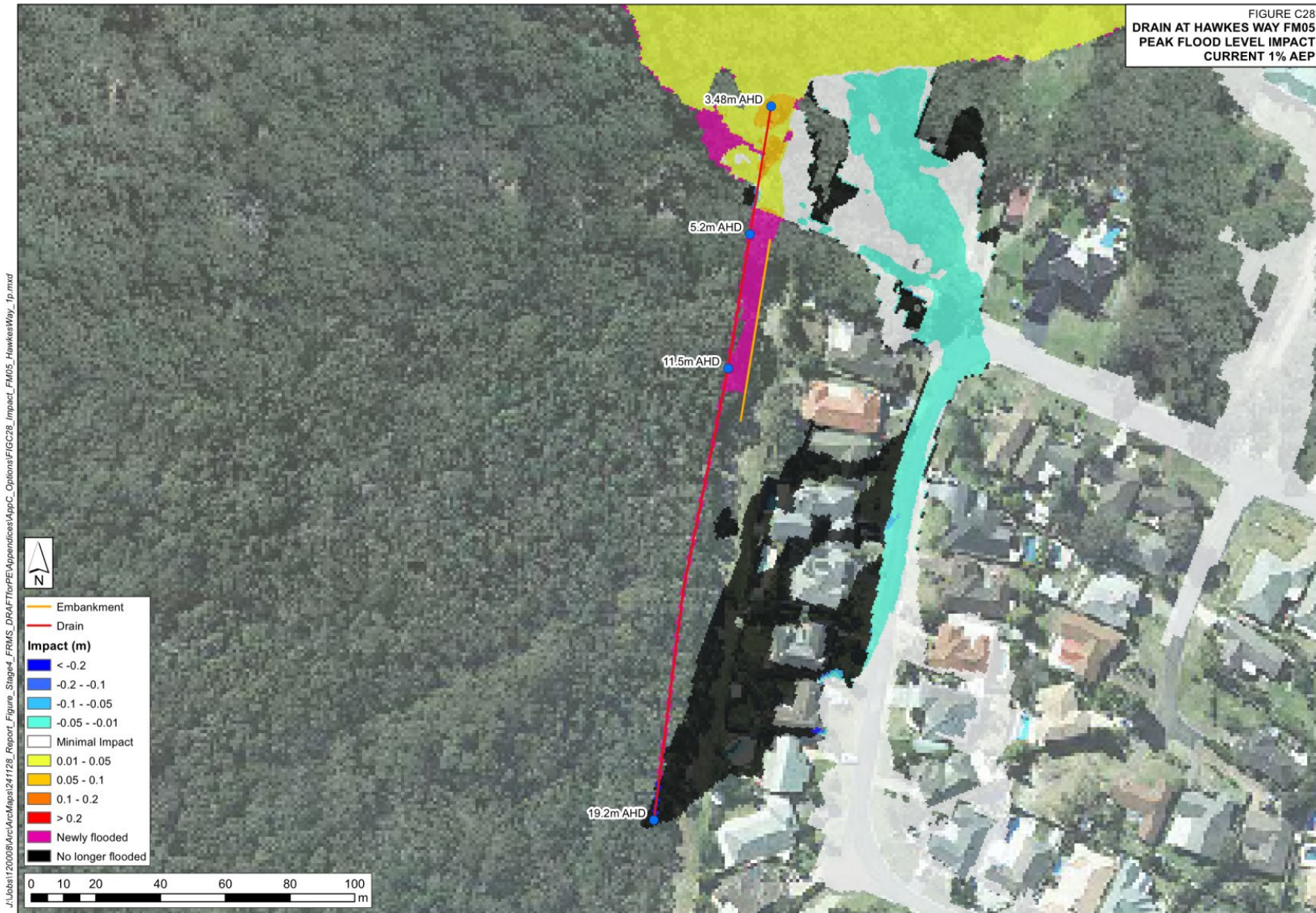


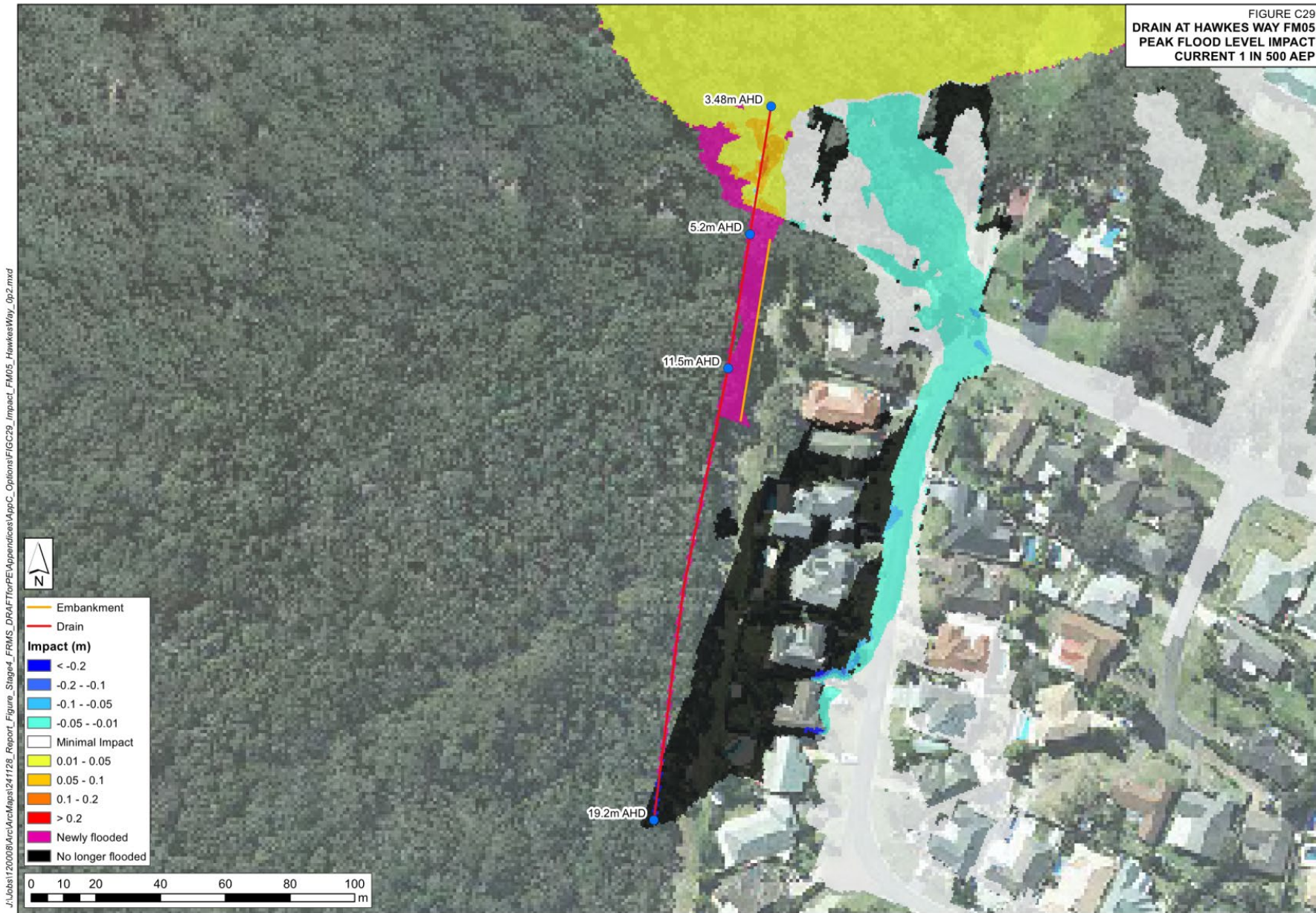


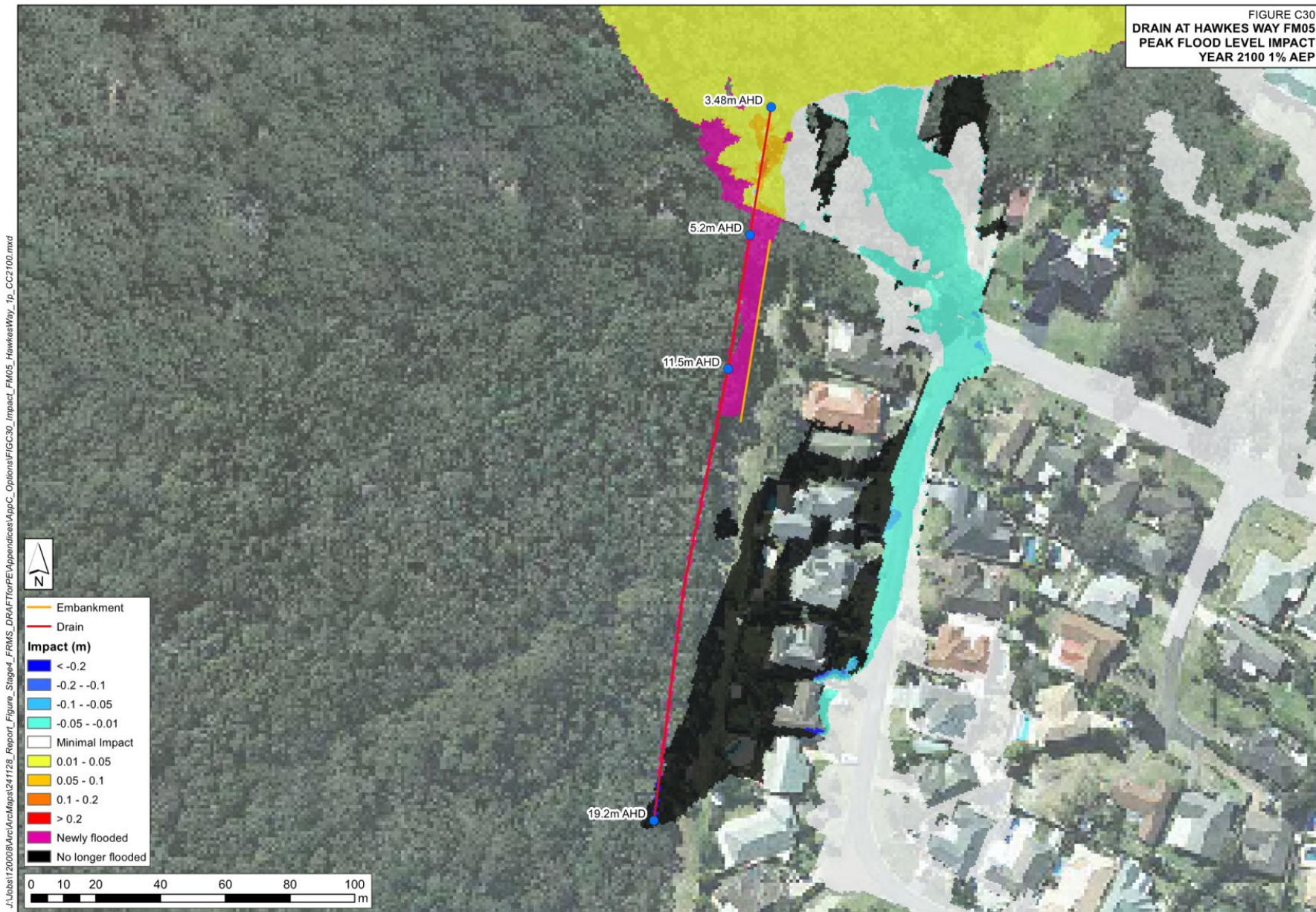
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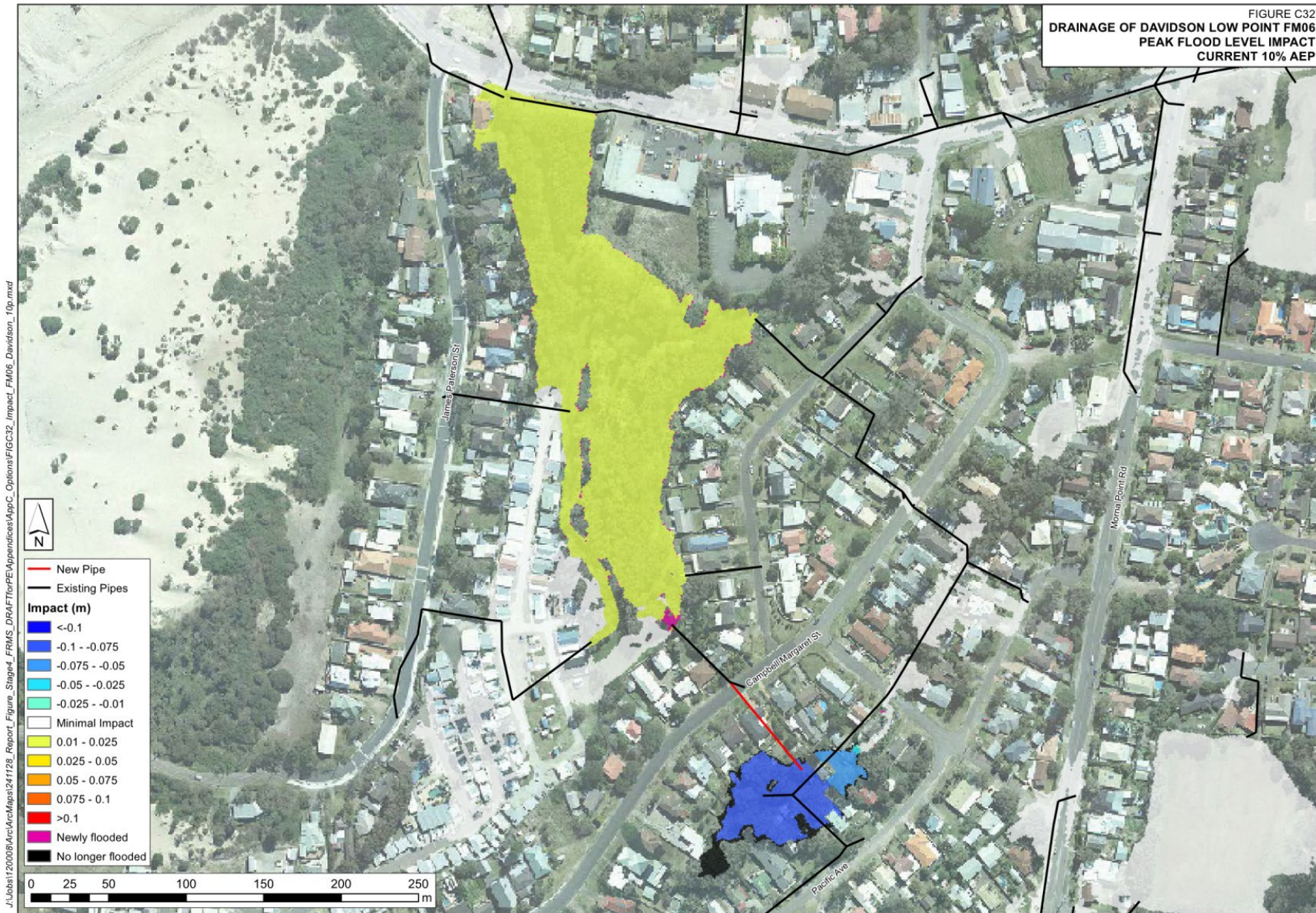




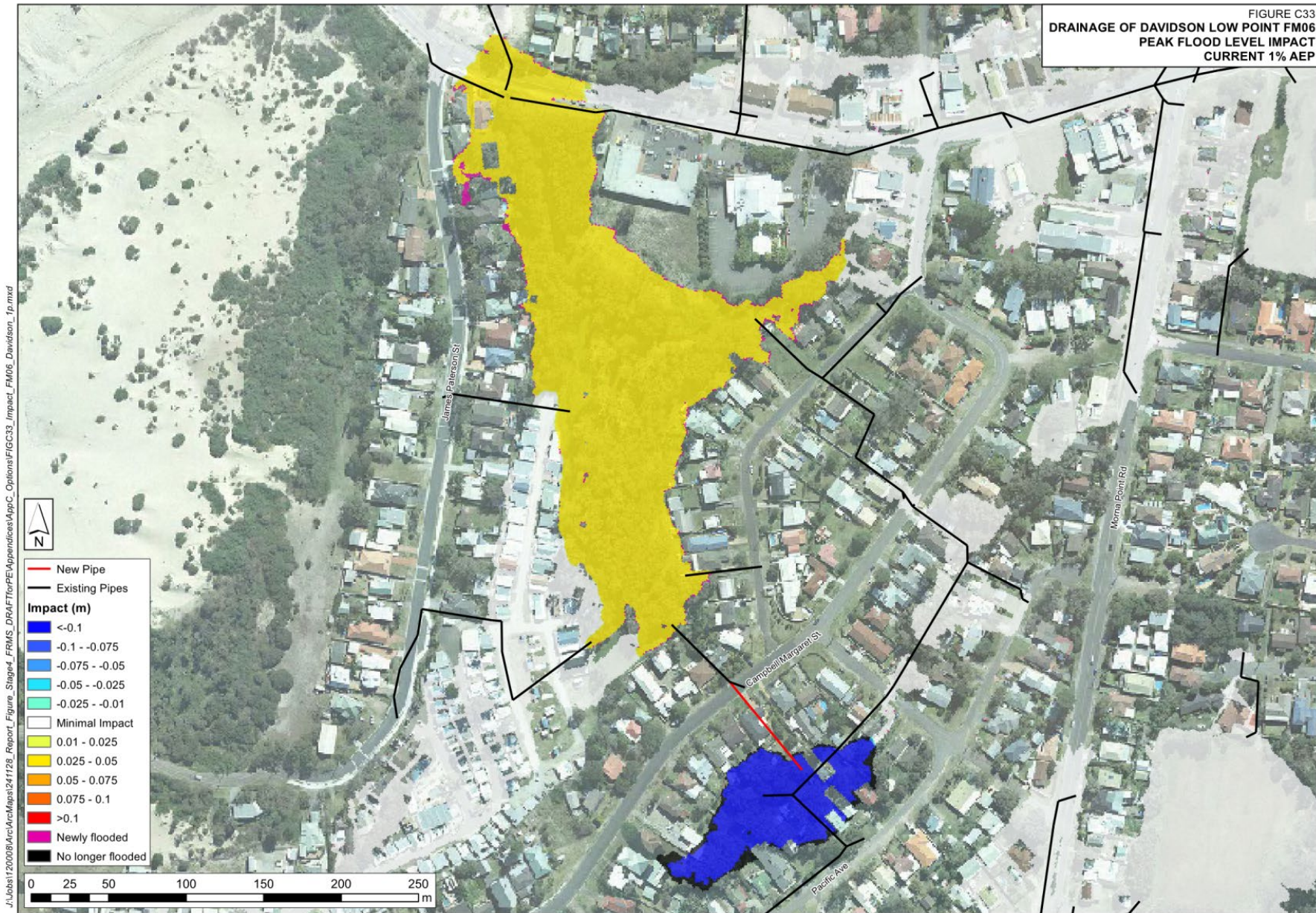




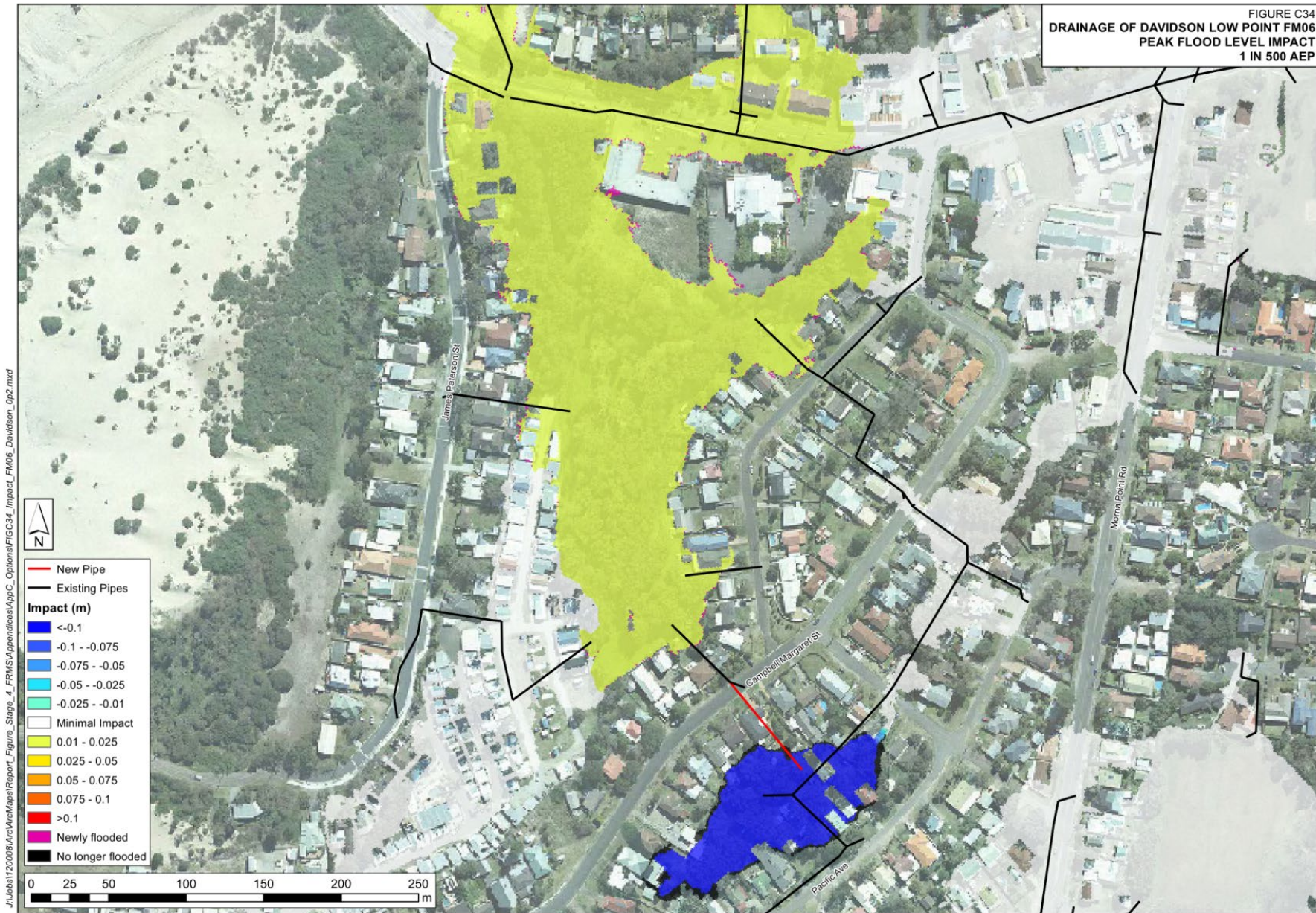
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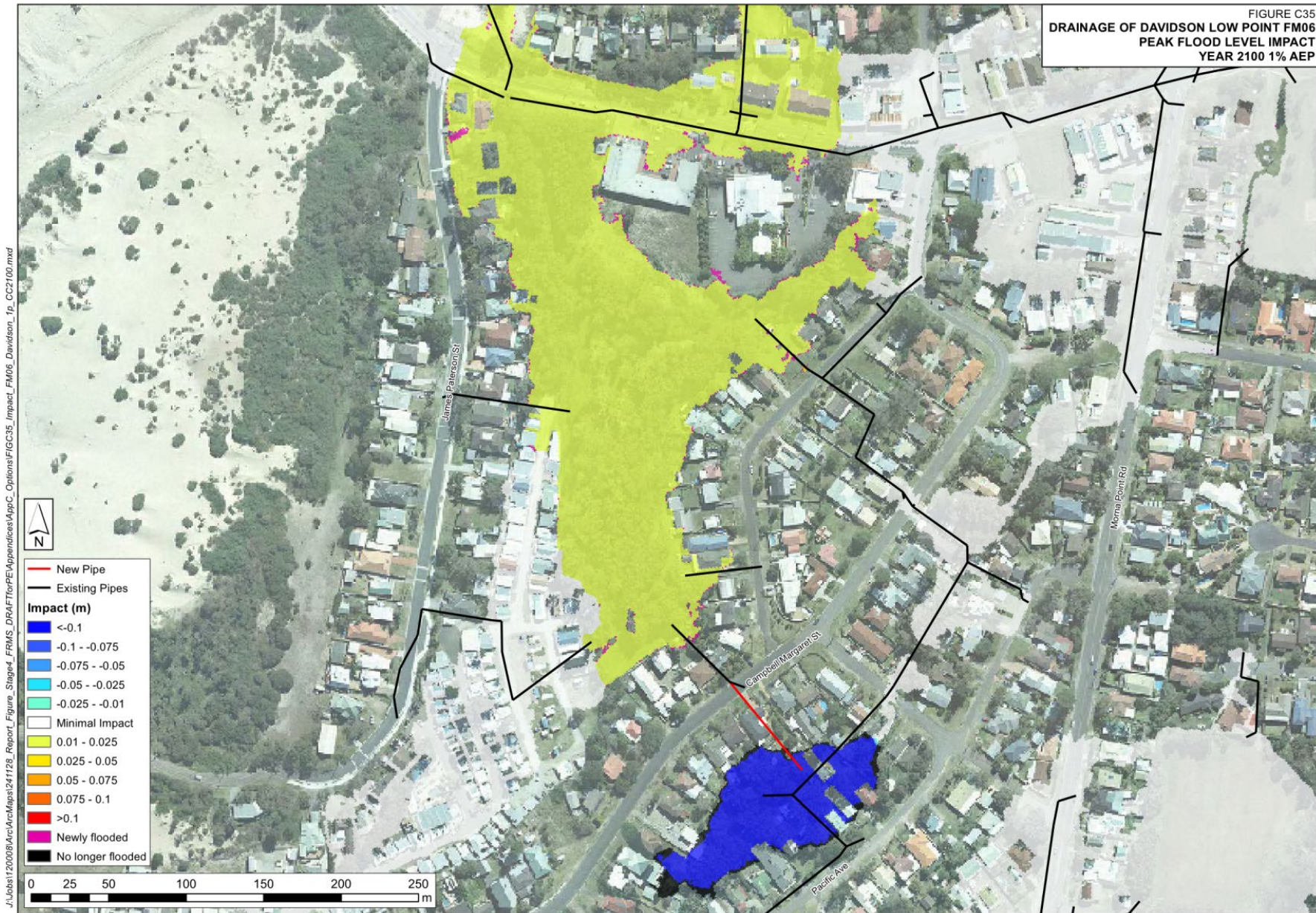
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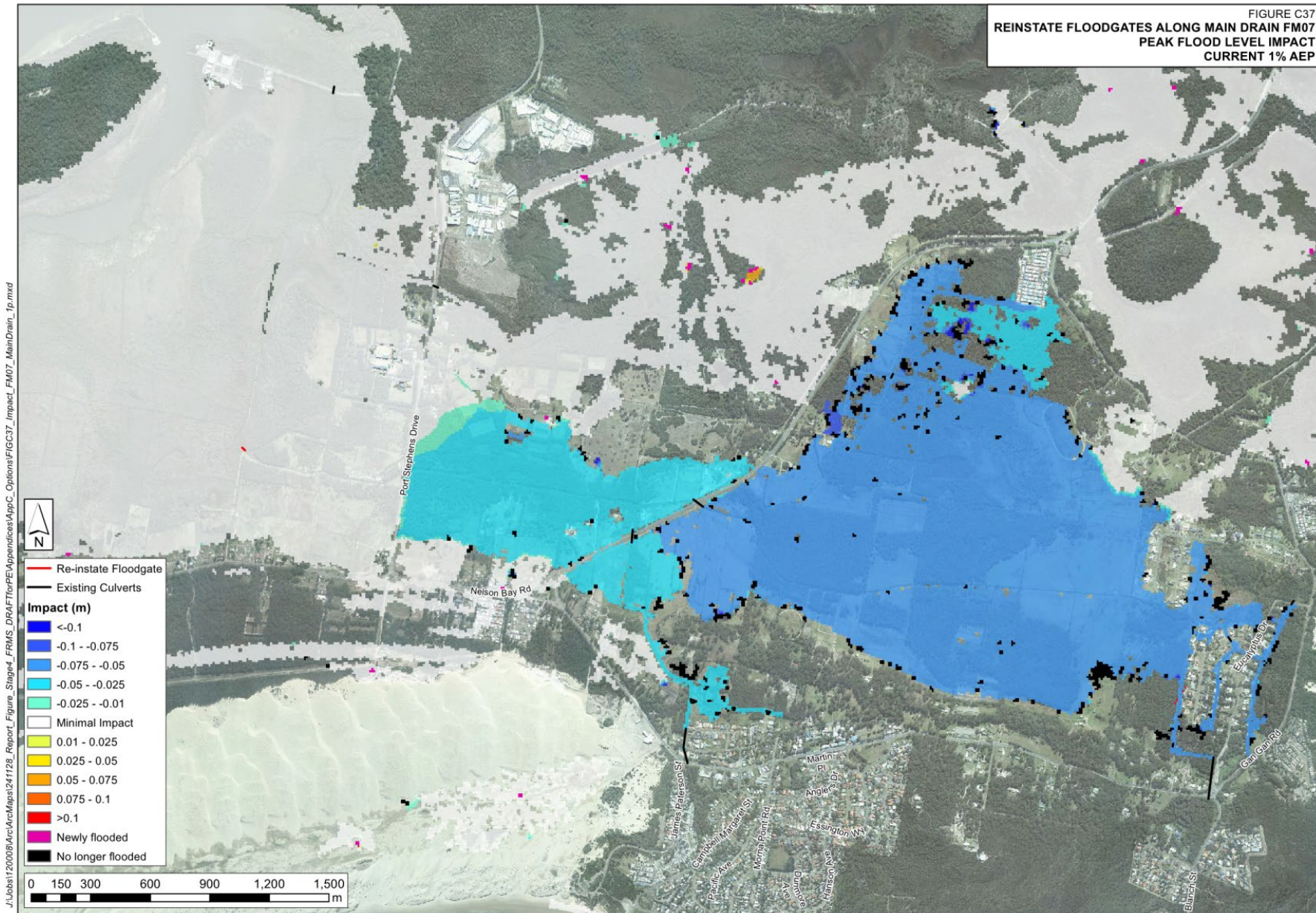


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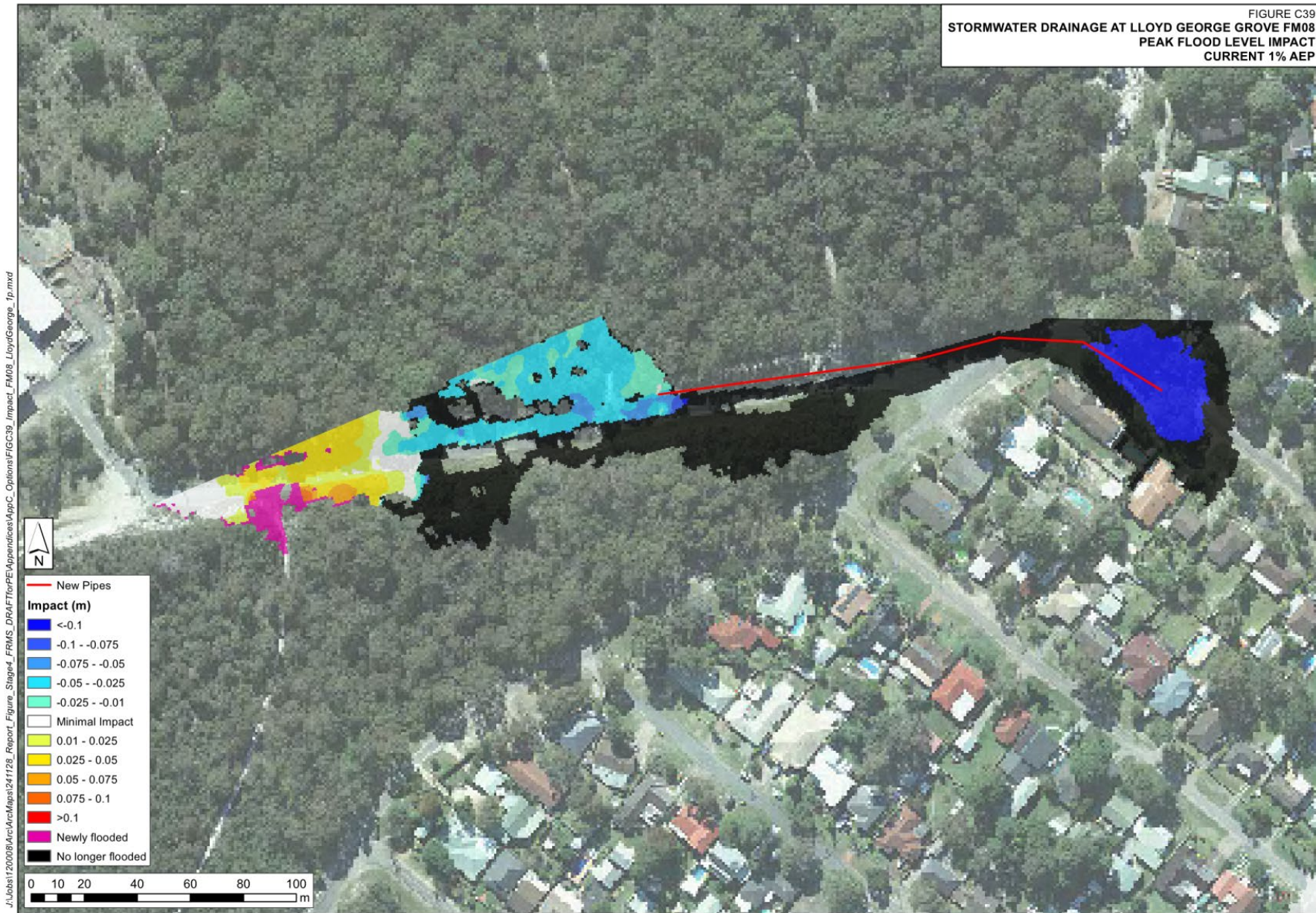


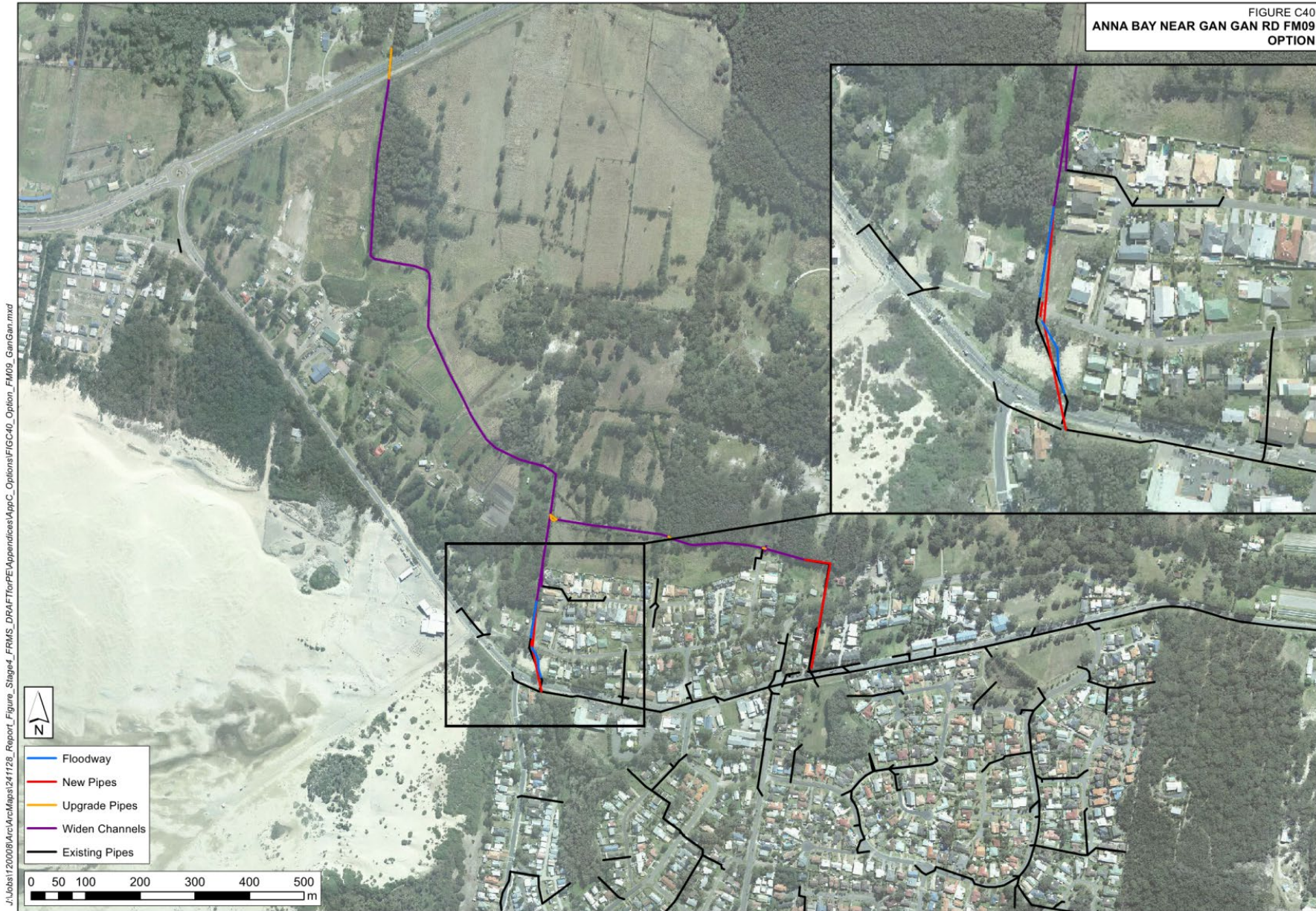


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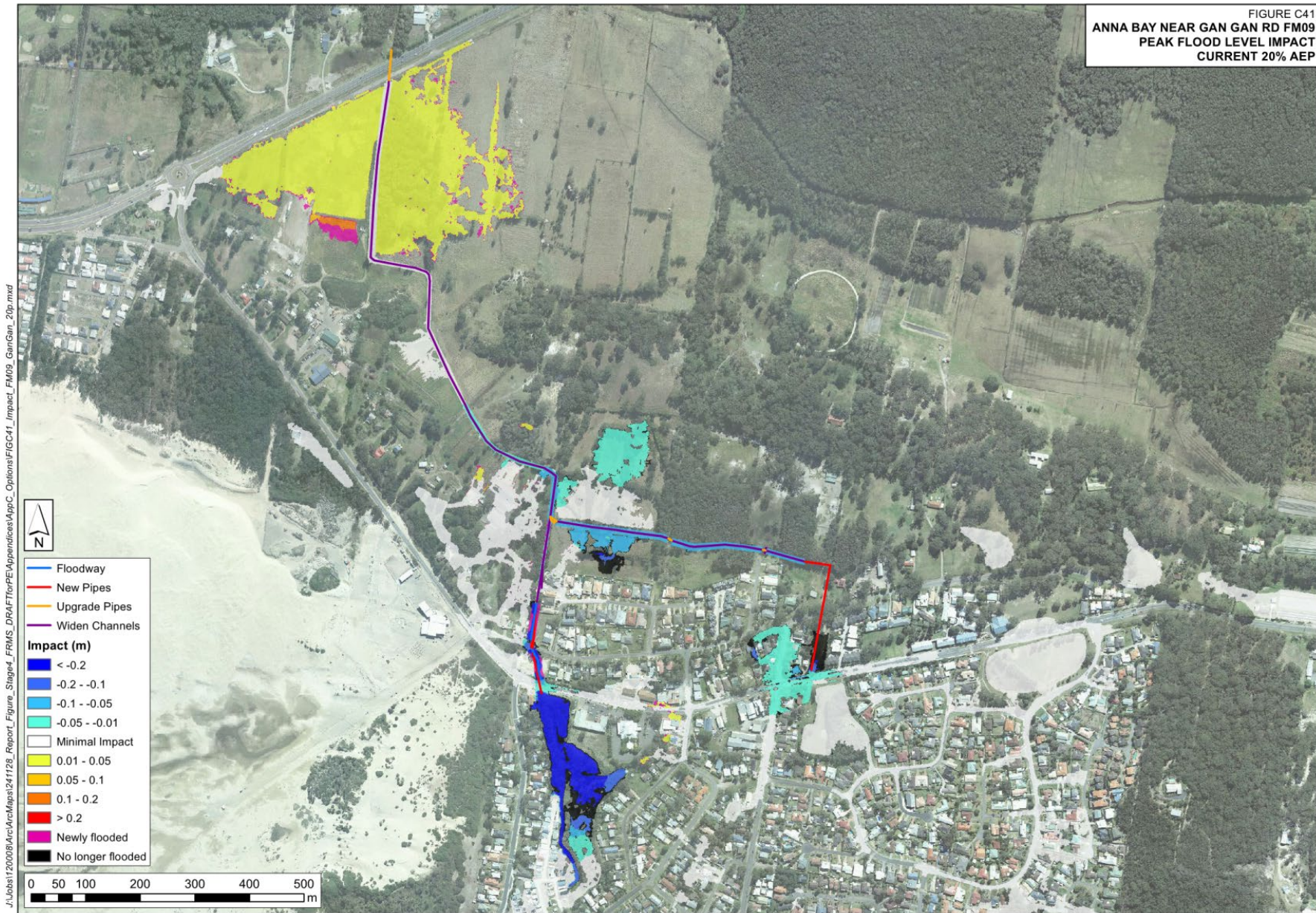




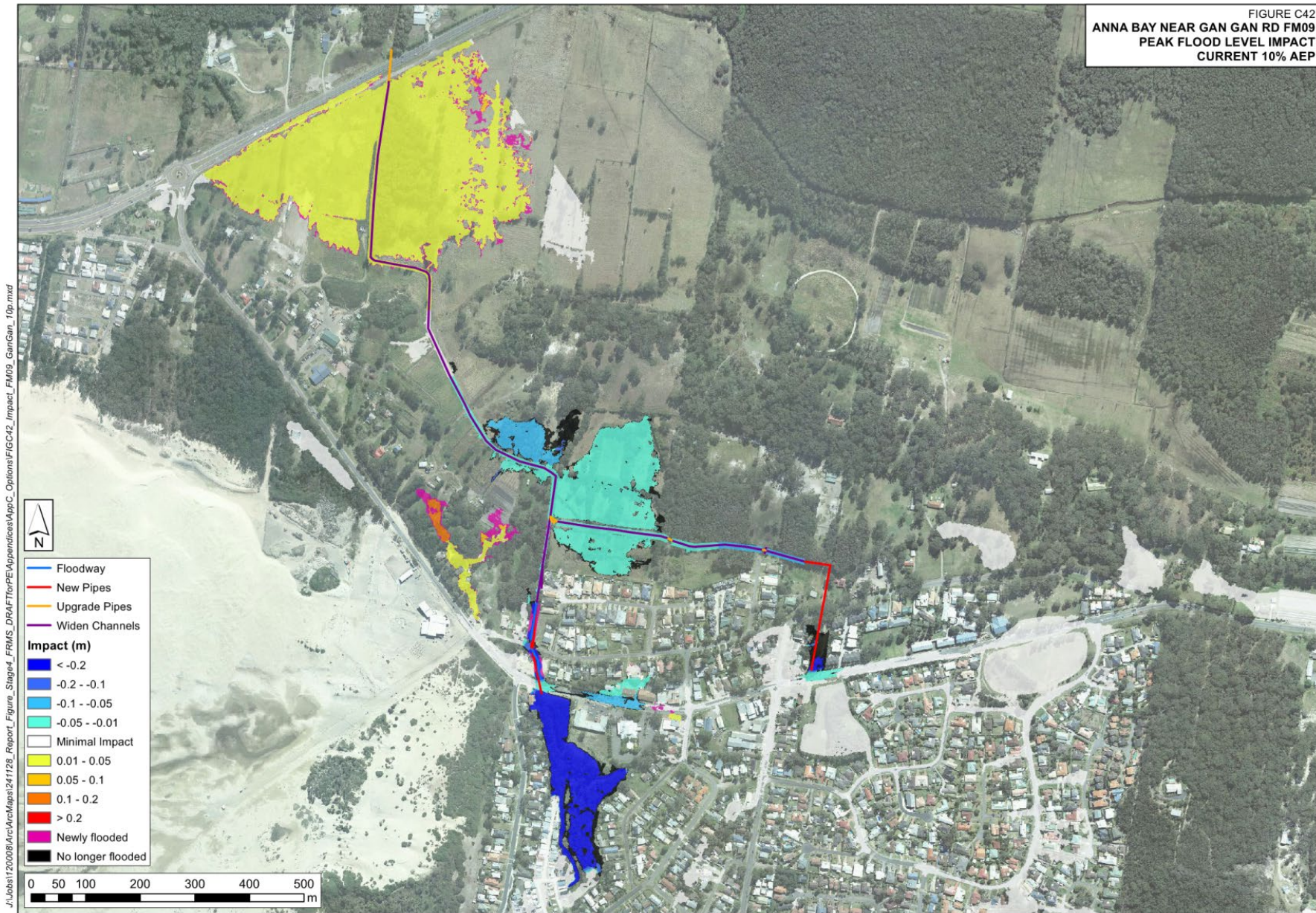




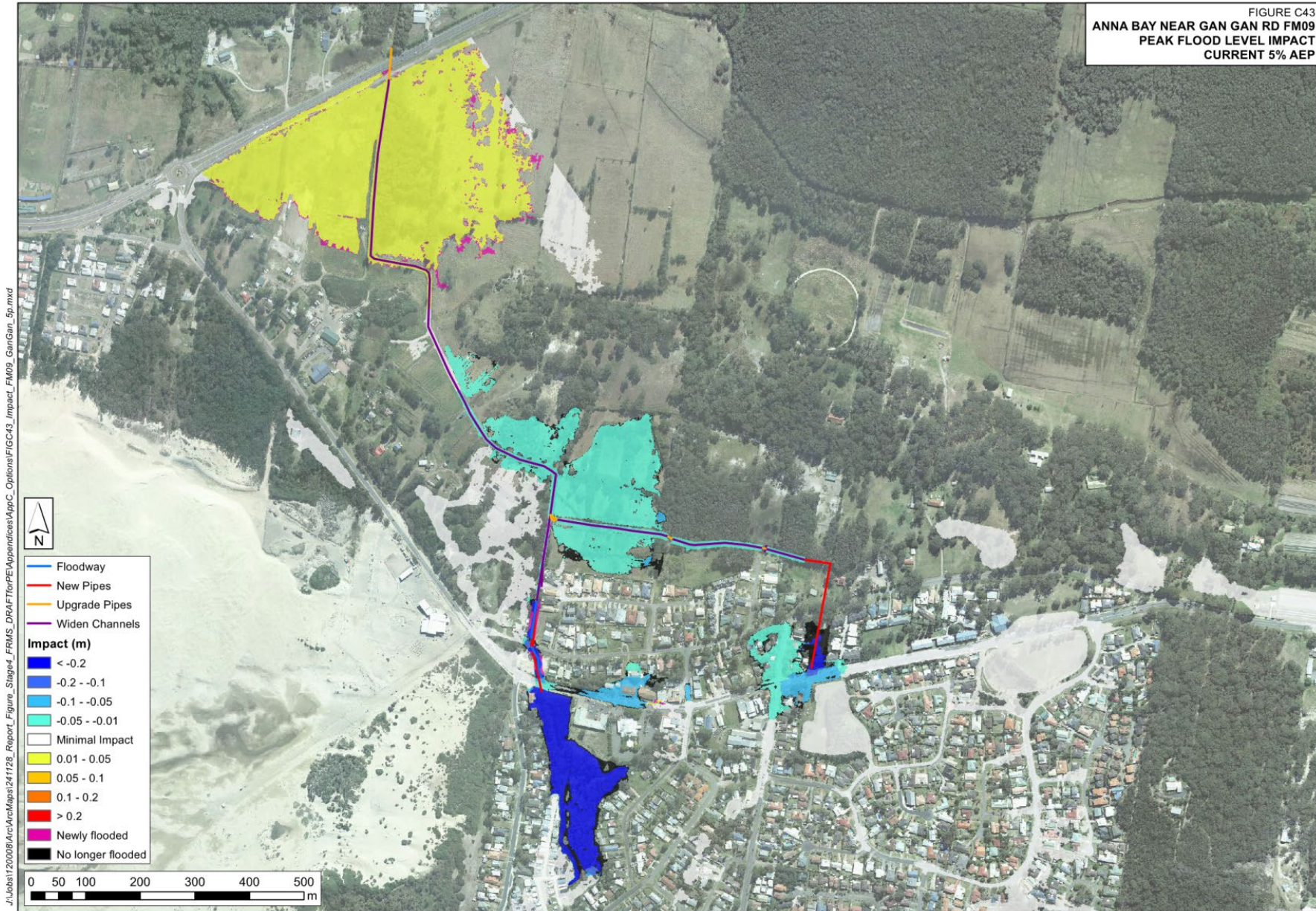
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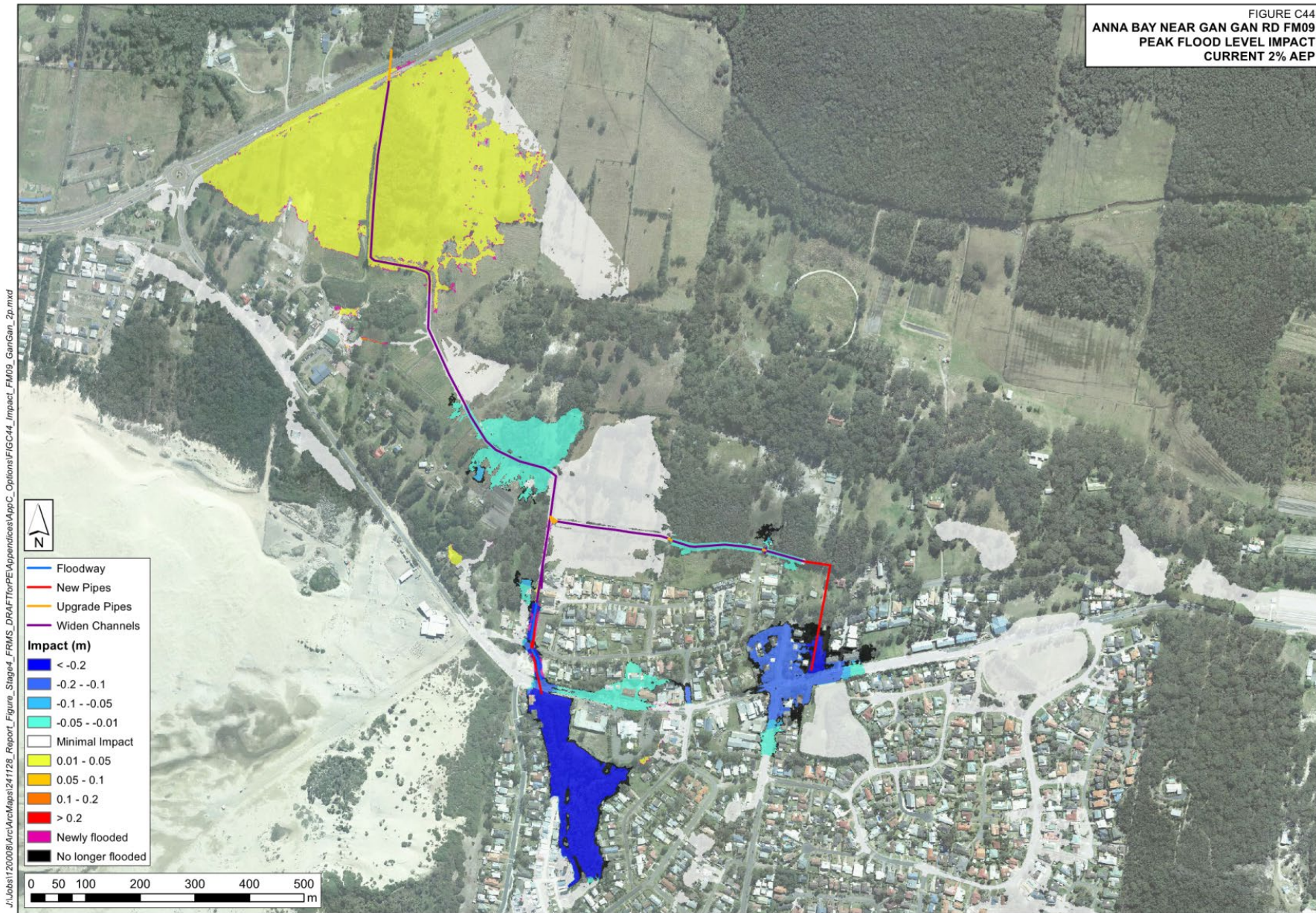
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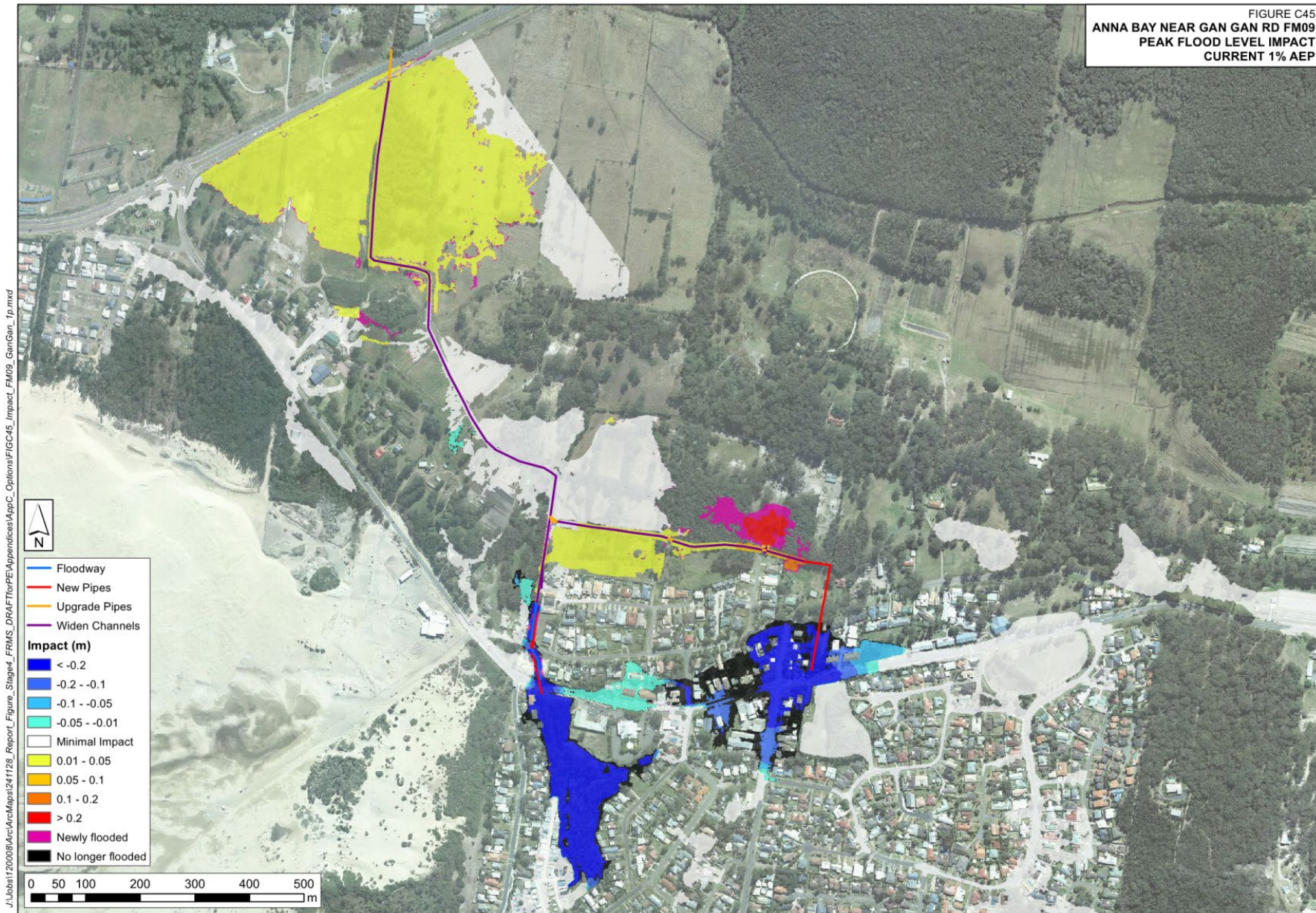
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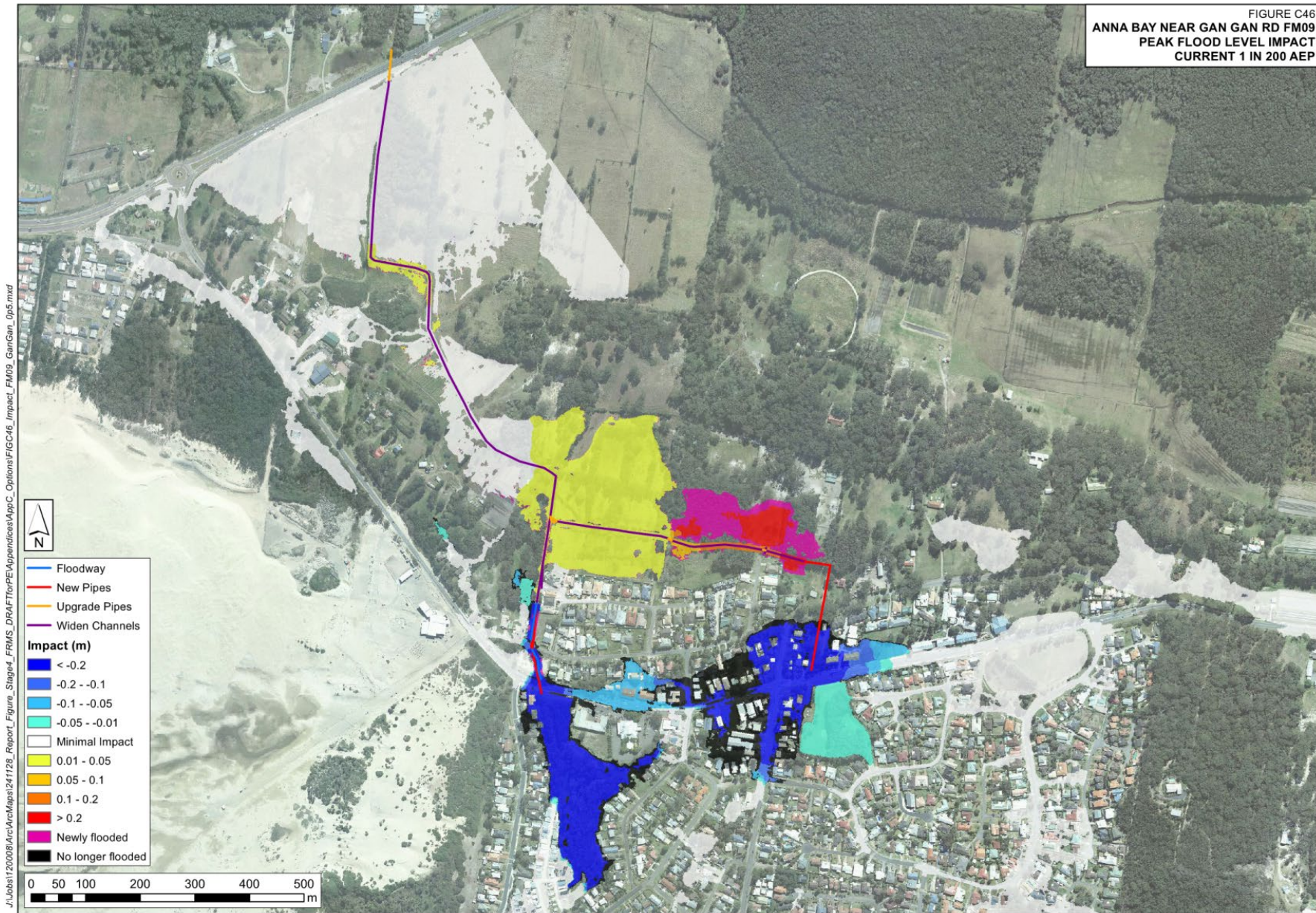
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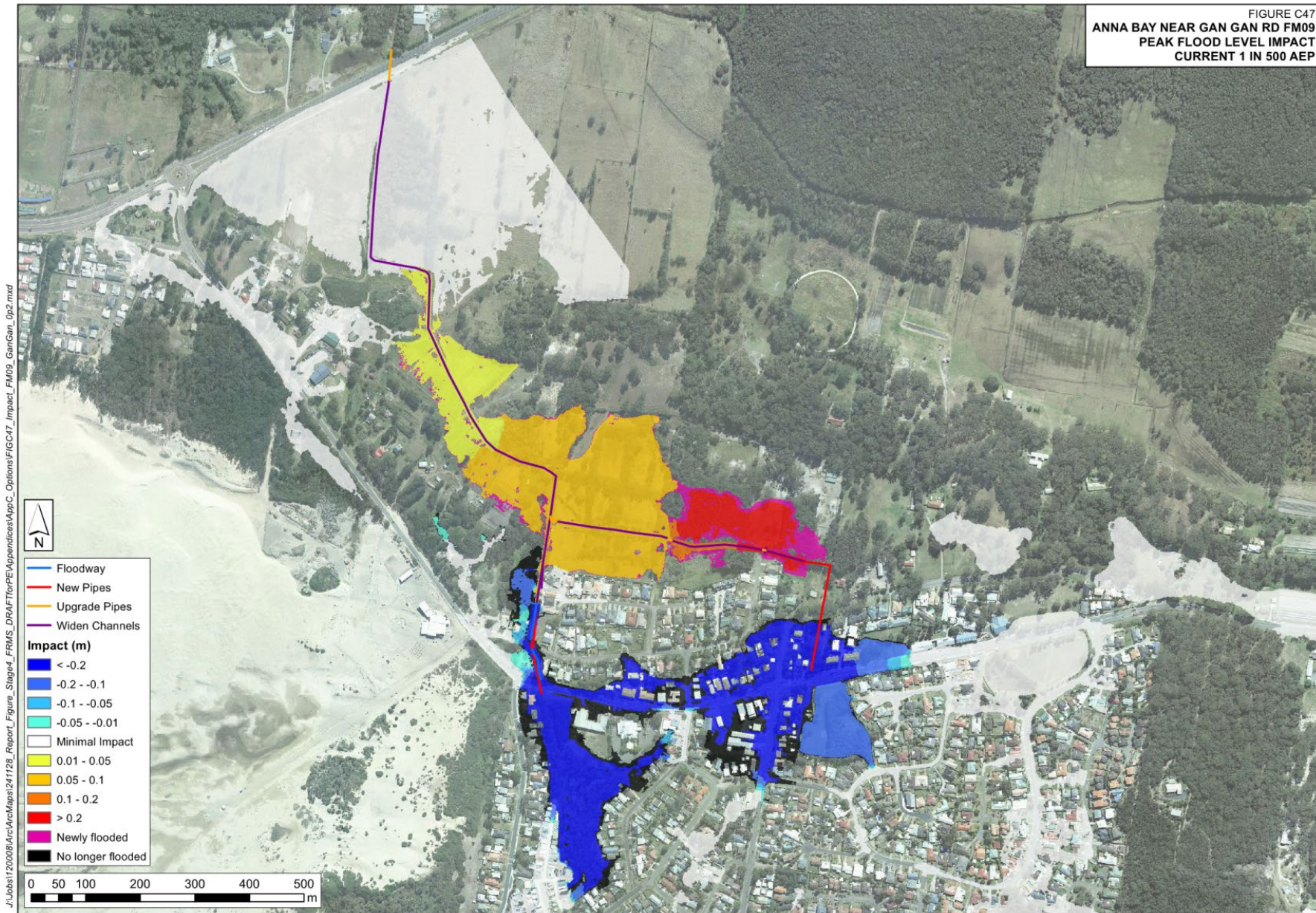
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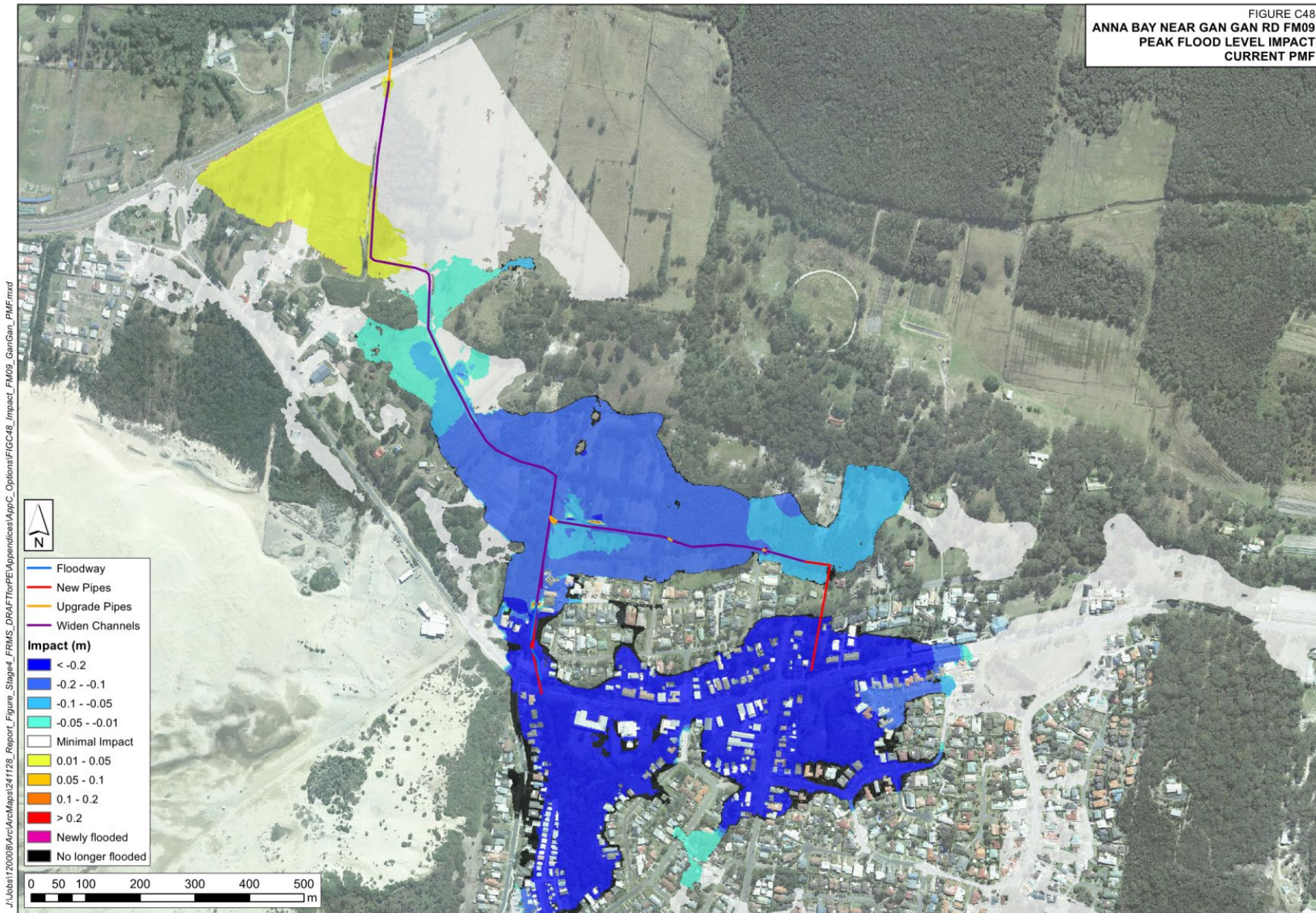
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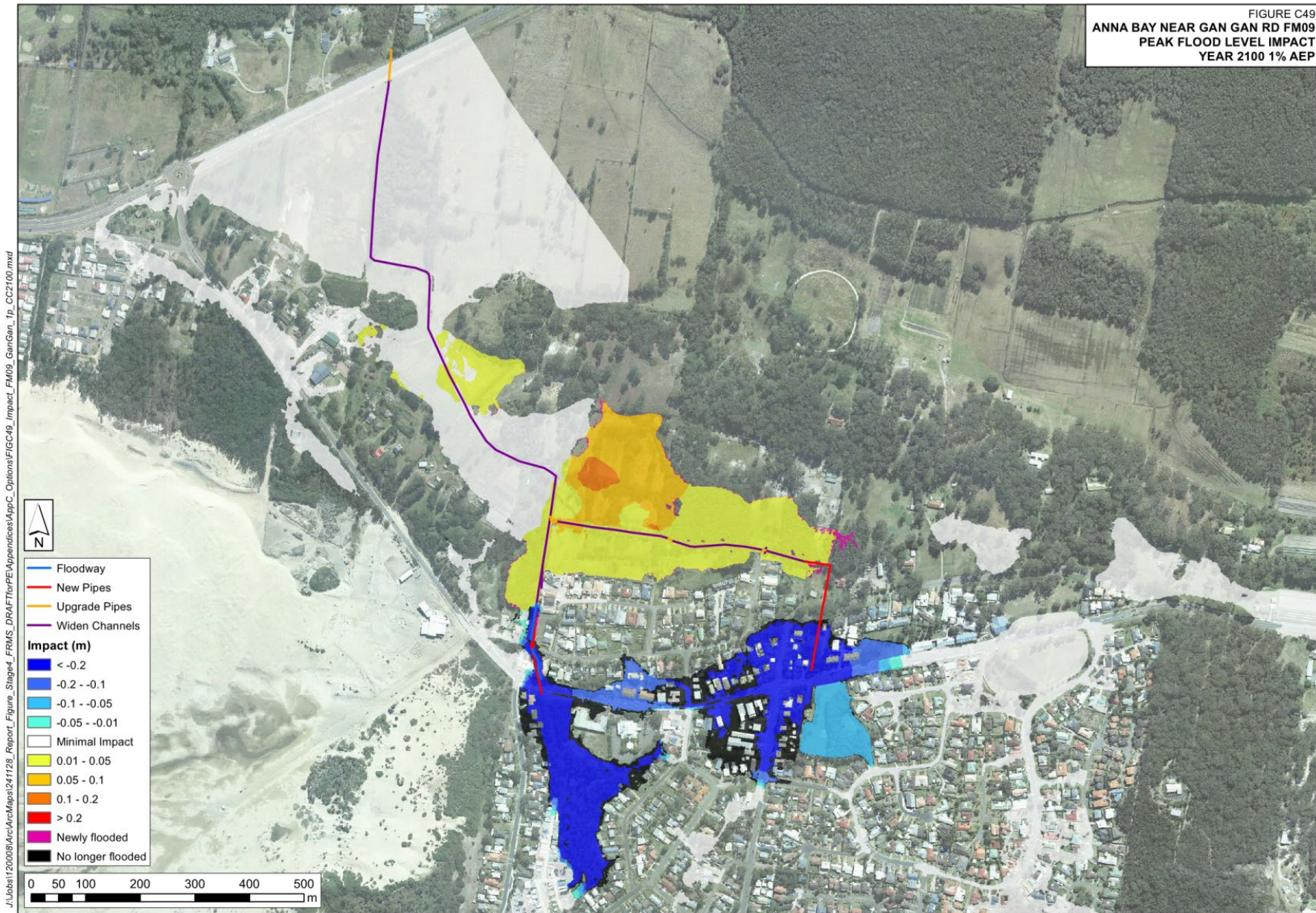
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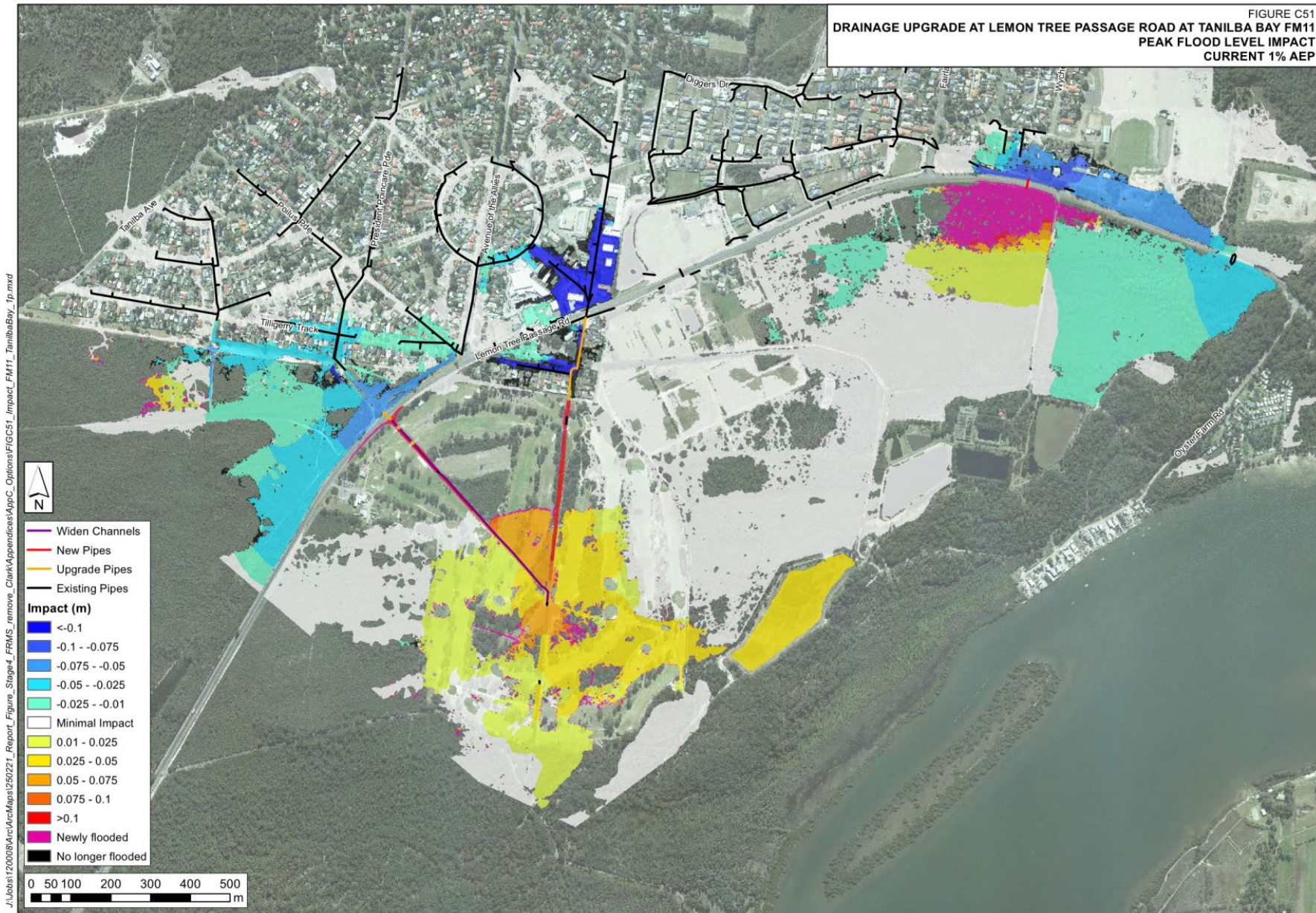


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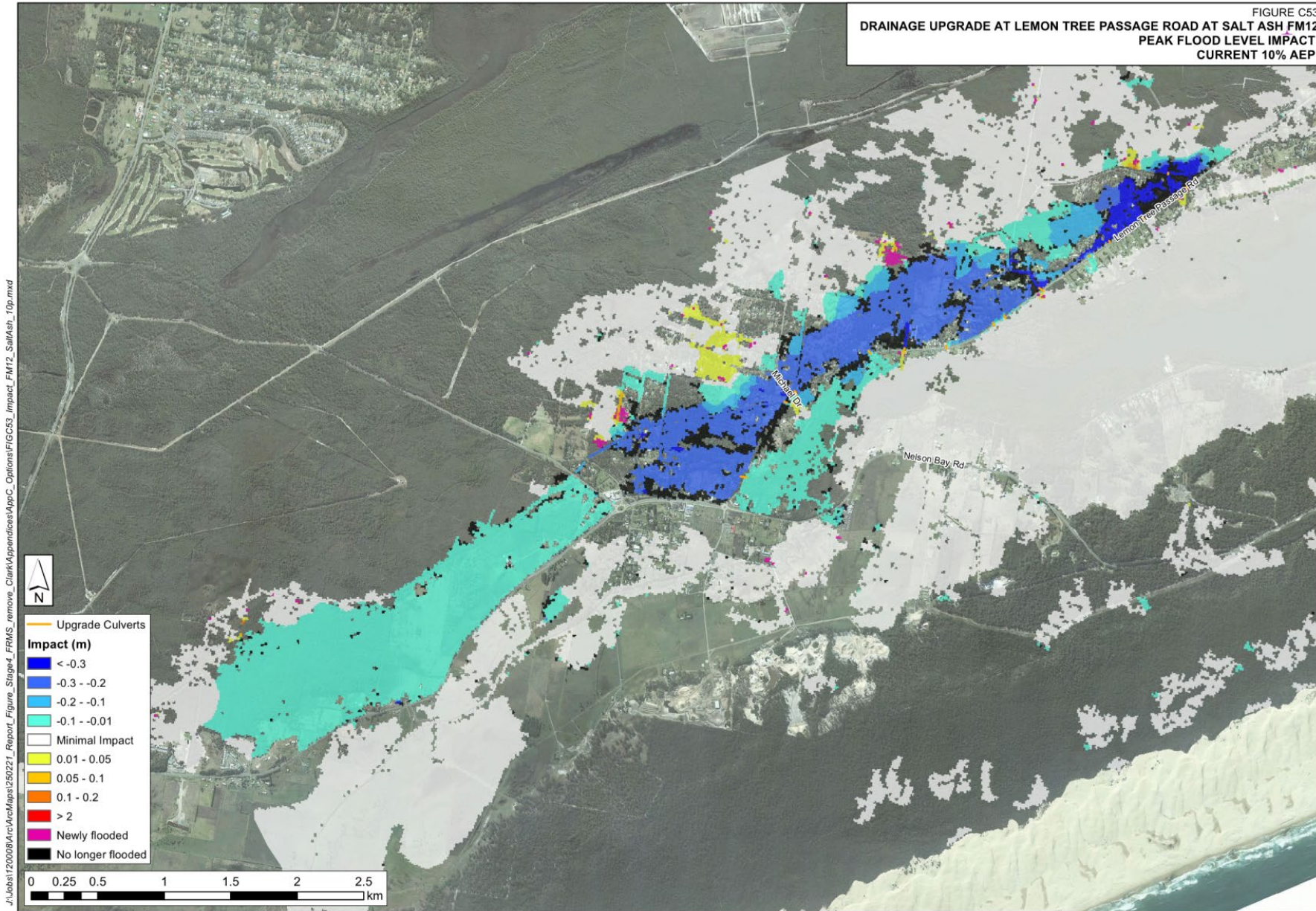


ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.





ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.



ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.

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Appendix D

**ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.**



Anna Bay and Tilligerry Creek Floodplain Risk Management Study and Plan

**APPENDIX D. FLOOR LEVEL SURVEY AND PROPERTY
INUNDATION**

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ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.

Memorandum



DATE: 22 June 2022
SUBJECT: Floor Level Survey – Methodology Overview
PROJECT NUMBER: 120008

1. OVERVIEW

Port Stephens Council (PSC) have engaged WMAwater to conduct a floor level survey as part of a larger scope of completing the Anna Bay and Tilligerry Creek Floodplain Risk Management Study and Plan. This memorandum serves as documentation to accompany the data produced as a result of the floor level survey.

Floor level data is used in the development of floodplain risk management studies in a number of ways, including:

- Understanding existing properties and communities at risk of flooding,
- Undertaking flood damage assessments which are in turn used to quantify the existing economic impacts from floods, and the potential benefits arising from considered management options,
- Support analysis and recommendations made with regards to emergency management, including evacuation route planning.

ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.

2. FLOOR LEVEL SURVEY CAPTURE METHOD

A number of methods are available for obtaining floor level estimates. The algorithmic extraction combined with constant floor rise assumption methods were utilised as selected by PSC.

Algorithmic capture implemented a combination of both python and GIS based algorithms. Cleaning of available LiDAR was conducted such that scatter of points was removed to provide accurate building roof profiles. The algorithm then used the eave level and ground level from available LiDAR and DEMs to assign an assumed building type (e.g. slab on ground, lowset) based on the difference. For each building type, an assumed floor rise was adopted to estimate the floor level. Algorithmic extraction requires LiDAR and building footprints. It's estimated accuracy is ± 0.5 m, however, provides an economic solution compared to other methodology such as traditional survey.

The assumption of floor level based on building type used for this assessment has been summarised in Table 1.

Table 1: Floor level assumption based on building type

Building Type	Floor level assumption (m)
One storey – high set	1.5
One storey – low set	0.8
One storey – slab	0.3
Two storey	0.3
Multi storey	0.3

The algorithmic capture method involves a number of assumptions which comes with limitations that require acknowledgement. This method does not provide visual verification of the floor type or floor rise. It also assumes a standard floor rise based on the building/floor type. However, it is less expensive, as well as less time consuming in the analyses involved.

Research undertaken by WMAwater for the Queensland Reconstruction Authority investigated the influence of floor level accuracy on flood damage estimations. A key finding from the work was that the higher accuracy survey methods, such as traditional capture, did not substantially improve economic assessments and the algorithmic method still provided floor level estimates that are fit for purpose.

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3. DATA USED

The data required to perform the floor level survey via algorithmic extraction has been summarised in Table 2.

Table 2: Input data for floor level survey

Data Used	Source	Comments
LiDAR	<ul style="list-style-type: none"> Marine LiDAR classified point cloud data (LAS), 2019, State Government of NSW and Department of Planning, Industry and Environment. Port Stephens 2012 Point Cloud, 2012, State Government of NSW and Department of Finance, Services and Innovation. 	Point cloud data published in 2019 (Anna Bay area flown in 2018) was preferred over 2012 data where available.
Building footprints	<ul style="list-style-type: none"> Extracted from LiDAR. Australia Building Footprints, 2022, Microsoft. 	LiDAR extracted footprints were preferred where available.
Survey extents	<ul style="list-style-type: none"> Probable maximum flood (PMF) extent from The Anna Bay and Tilligerry Creek Flood Study (Jacobs, 2017). 1% AEP with 2100 climate change (CC) flood extent from The Anna Bay and Tilligerry Creek Flood Study (Jacobs, 2017). 	Combined extents of the PMF and 1% AEP with 2100 climate change was used. 1% AEP + 2100 CC had greater extents in the coastal zones.
Cadastre data	<ul style="list-style-type: none"> Spatial Services – NSW Cadastre, 2018, State Government of SNW and Department of Customer Service. 	Land use information was extracted for the survey.
Digital Elevation Model	<ul style="list-style-type: none"> Digital Elevation Model (DEM) from the Anna Bay and Tilligerry Creek Flood Study (Jacobs, 2017). 	Digital Elevation Model for property ground levels.

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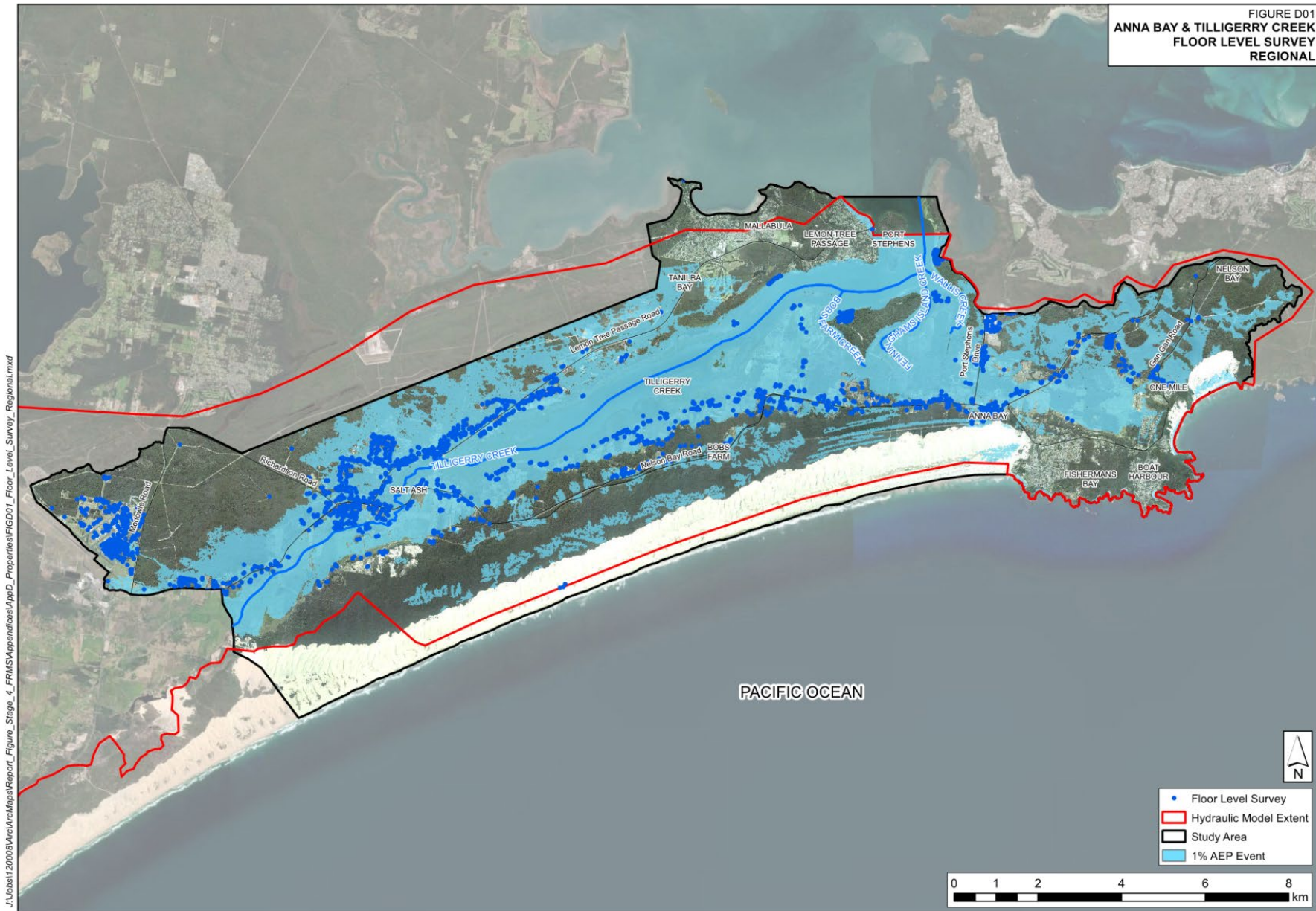
4. SUMMARY OF RESULTS

The algorithm capture found 10,476 building footprints within the survey extents. For each of these buildings, a number of floor level attributes were assigned. The output of the floor level survey is a shapefile containing the building footprint polygons with attributes. A summary and description of the attributes produced has been presented in Table 3. It is noted that not all of the 10,476 buildings are necessarily impacted by significant flood depths. The number of flood impacted buildings will be assessed in the upcoming Floodplain Risk Management Study.

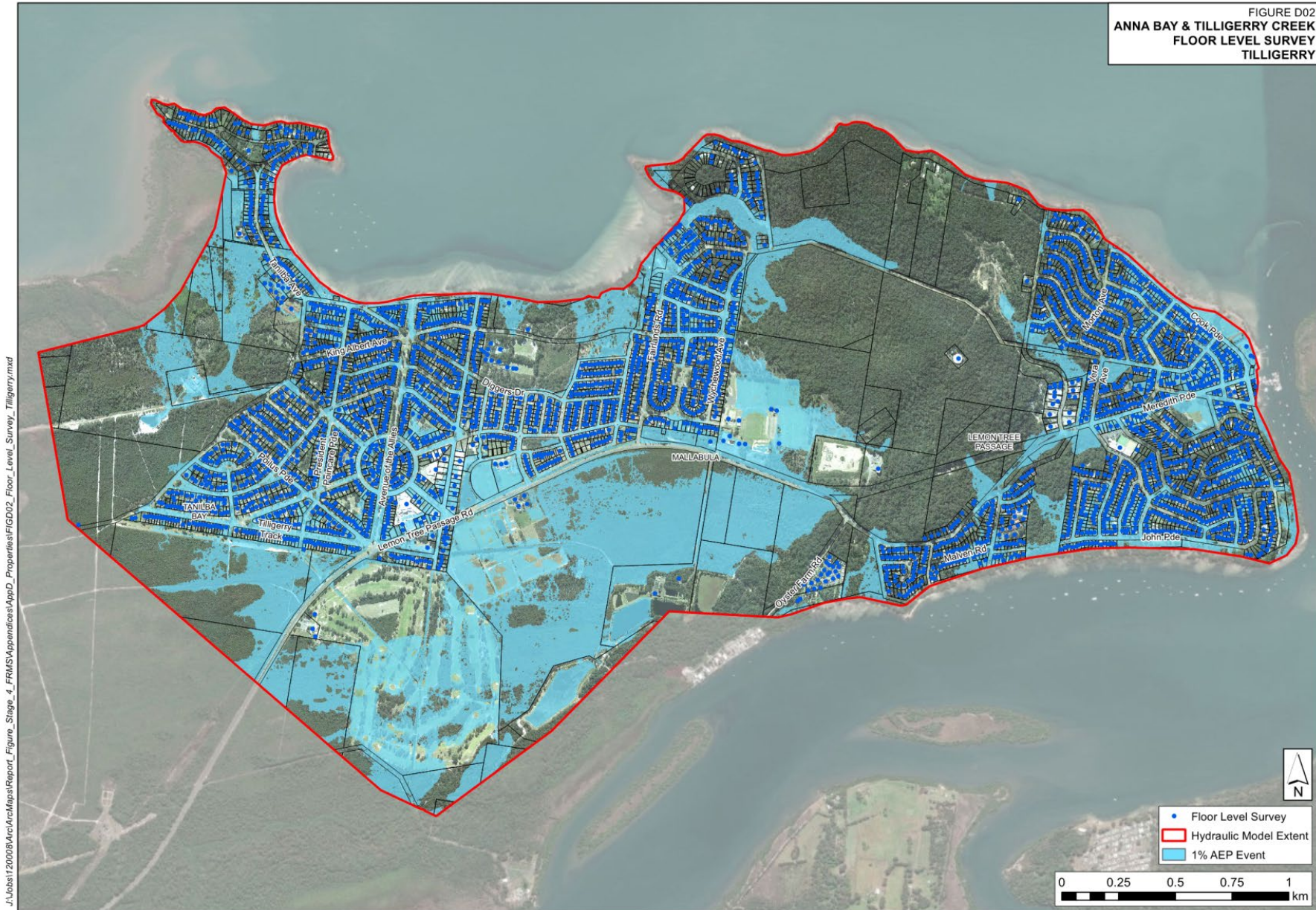
Table 3: Floor level survey attributes

Attribute	Description
Area	Building footprint area (m ²)
LIDAR_MAX	Maximum roof height within building footprint, derived from building classified LiDAR points
Z_CENT	Ground height of building centroid
CLASS_1ST	Initial building classification
CLASS_FIN	Final building classification after checks
FLOOR_REL	Building floor height relative to ground
FLOOR_ABS	Absolute floor height (FLOOR_REL + Z_CENT)
EDGE_AVG	Average height of DEM along building footprint outline, derived from building classified LiDAR points
LIDAR_MIN	Minimum roof height within building footprint, derived from building classified LiDAR points
LAY_CLASS	Land USE
suburbname	Suburb
postcode	Postcode
lotnumber	Lot Number
sectionnum	Section Number
plannumber	Plan Number
planlabel	Plan Label
controllin	Land Ownership
footprint	Source of building footprints (2018 LIDAR, 2012 LIDAR, Bing Building Footprints) (in prioritisation order >)

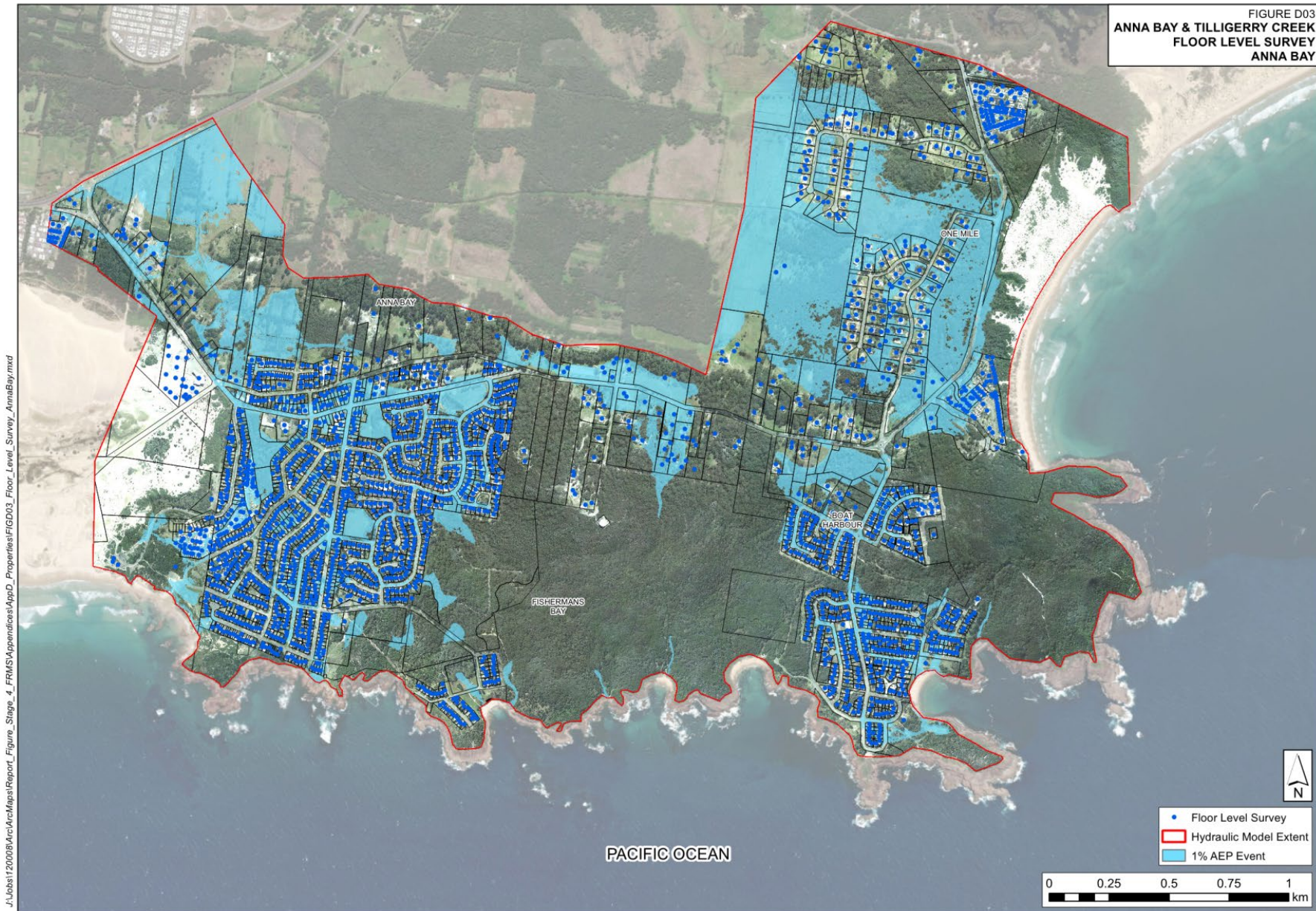
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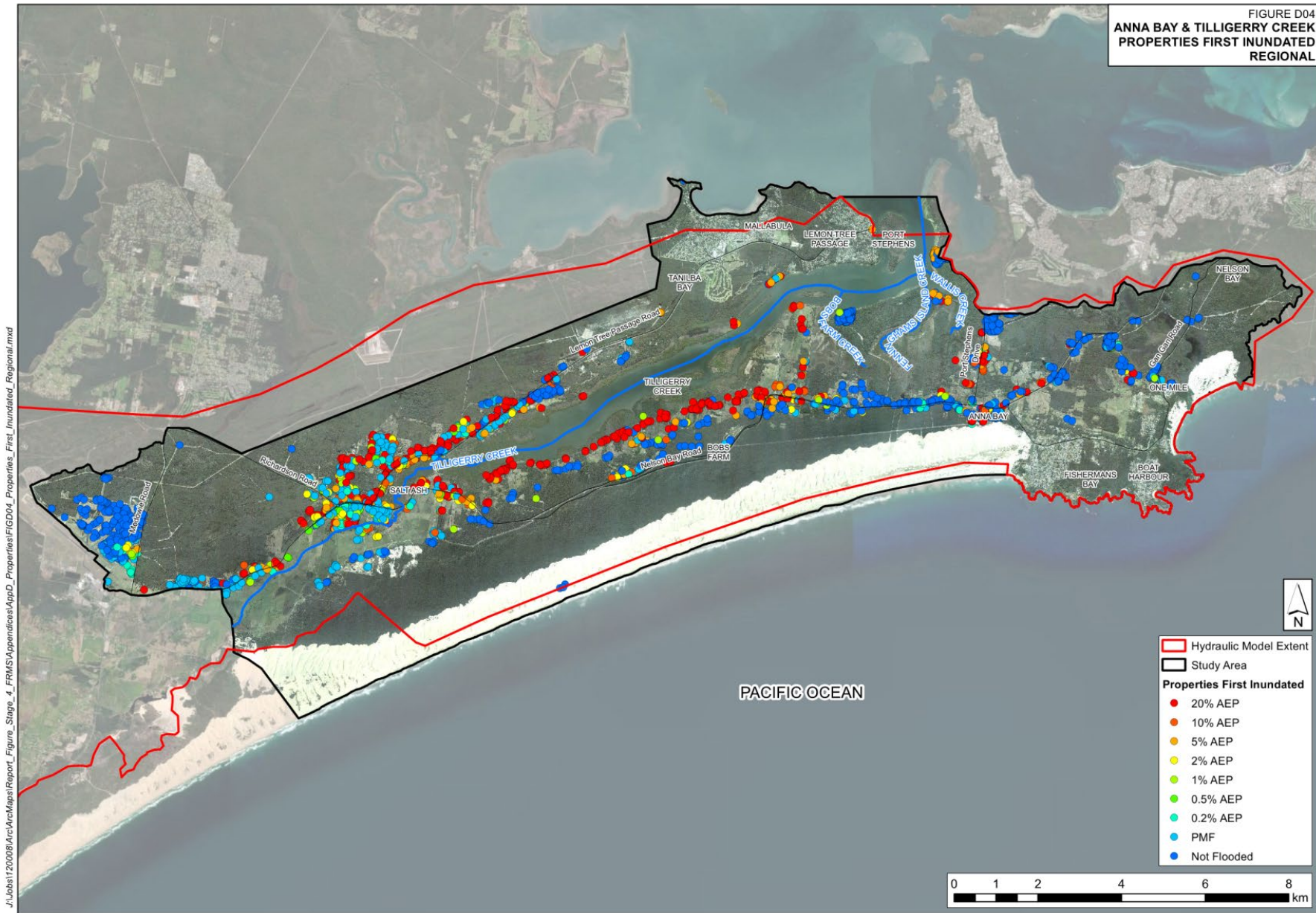
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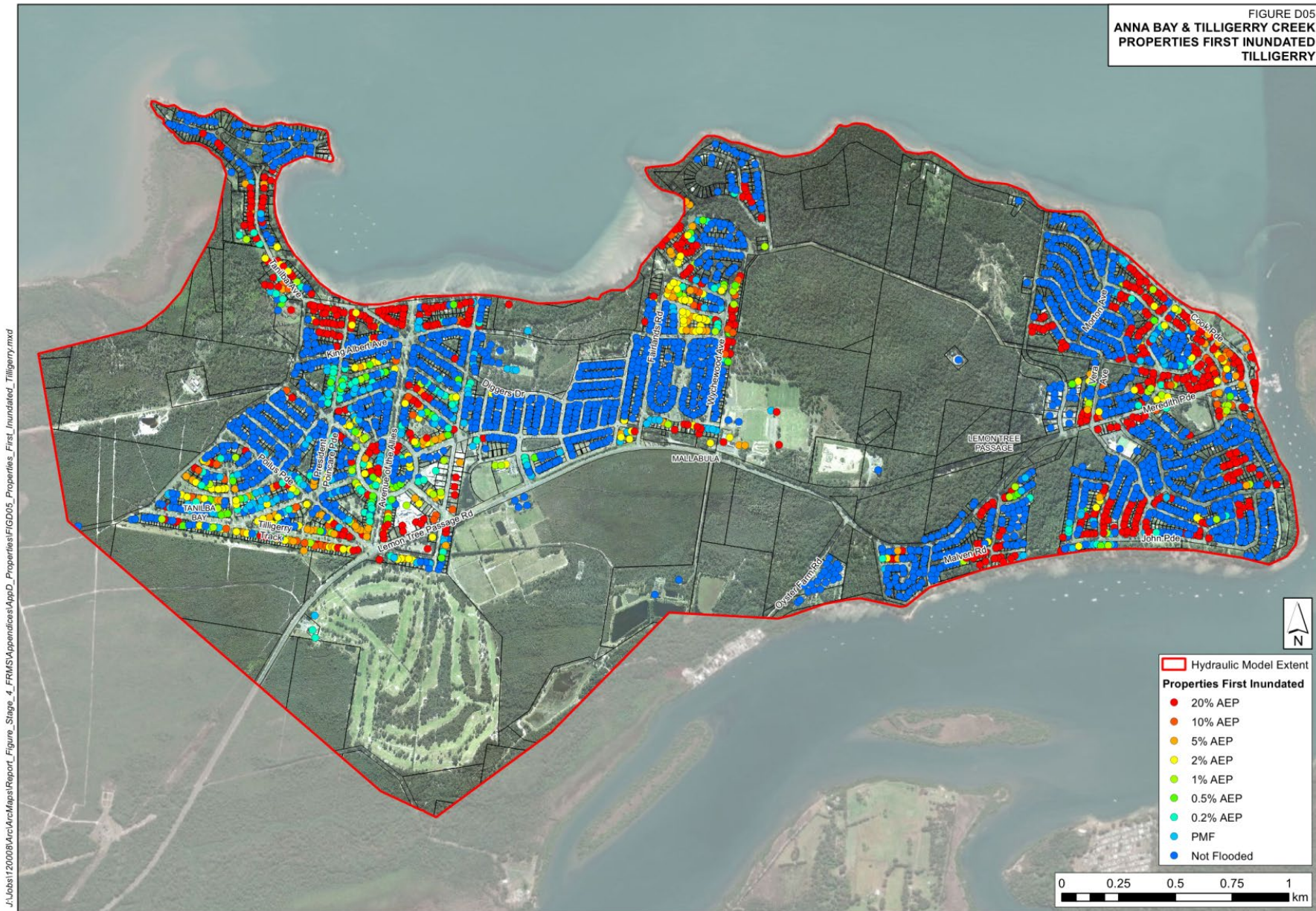
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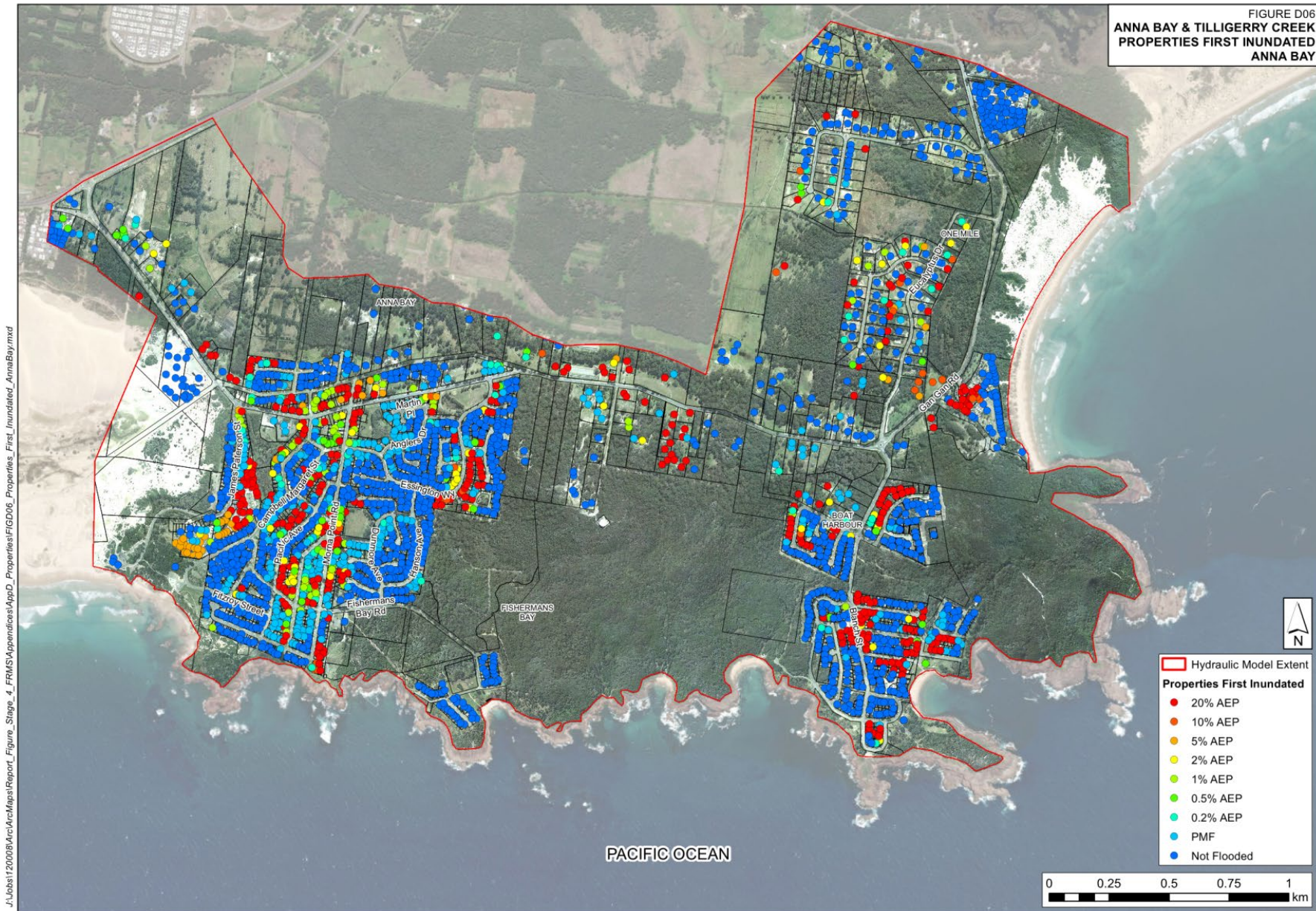
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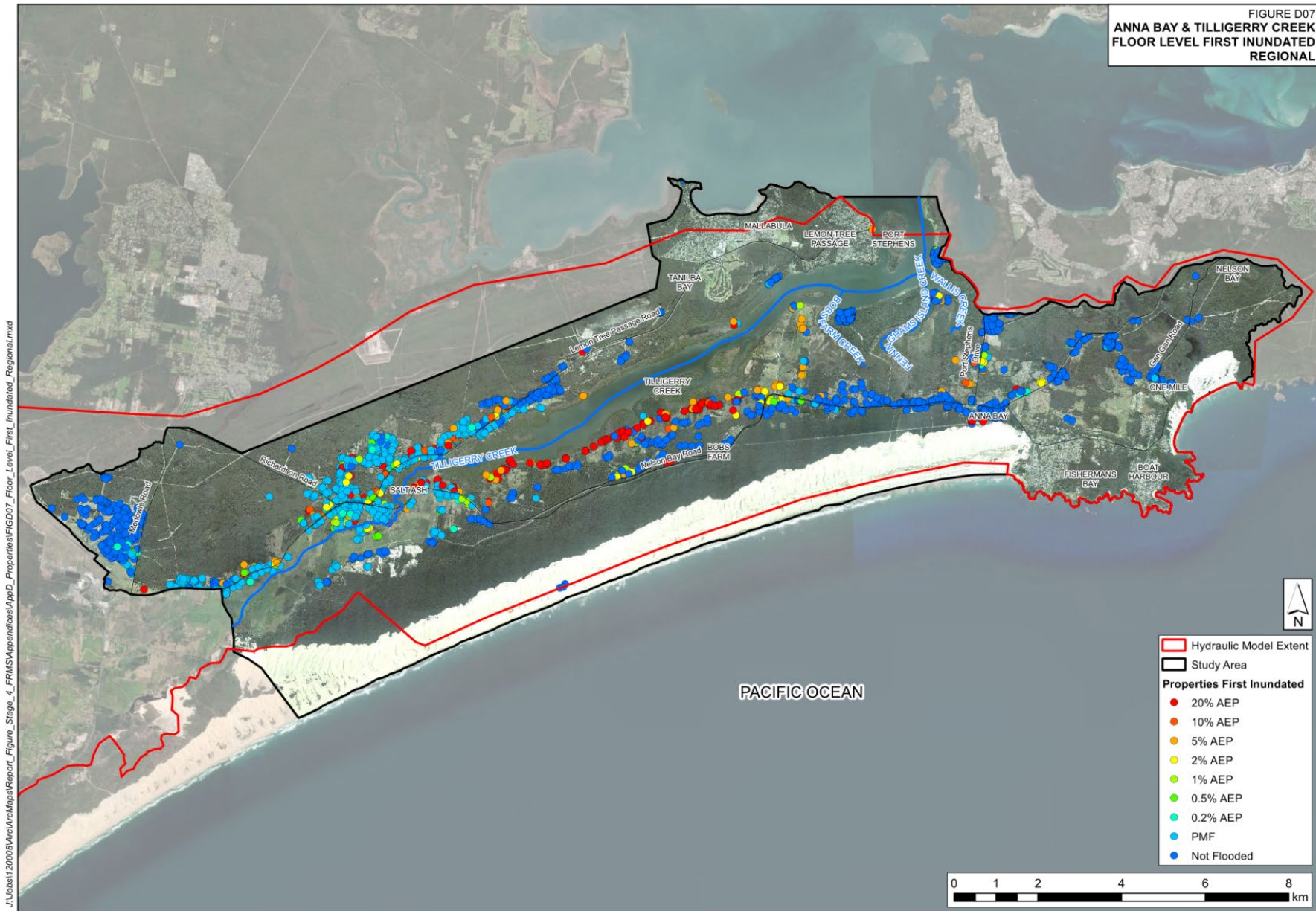
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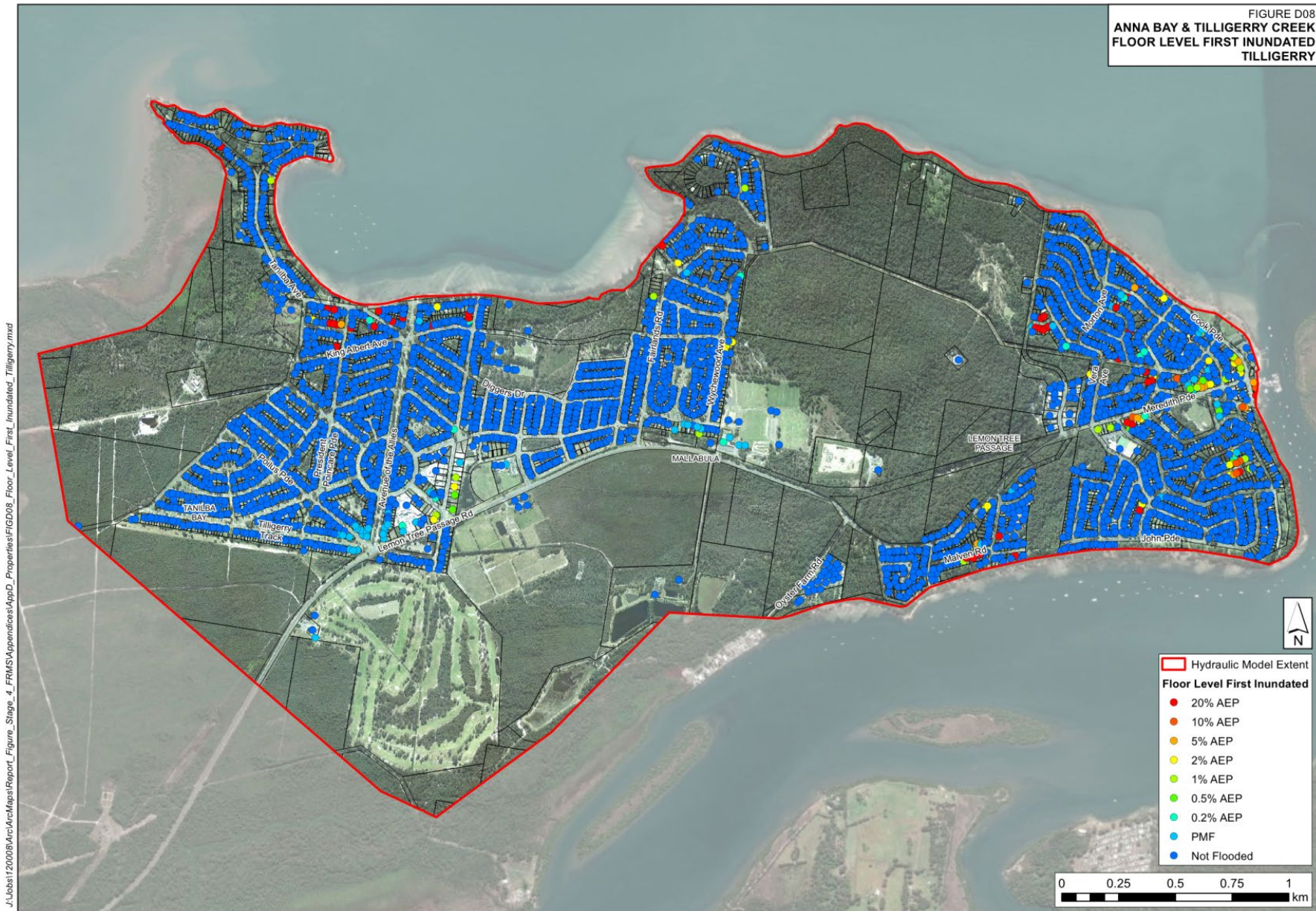
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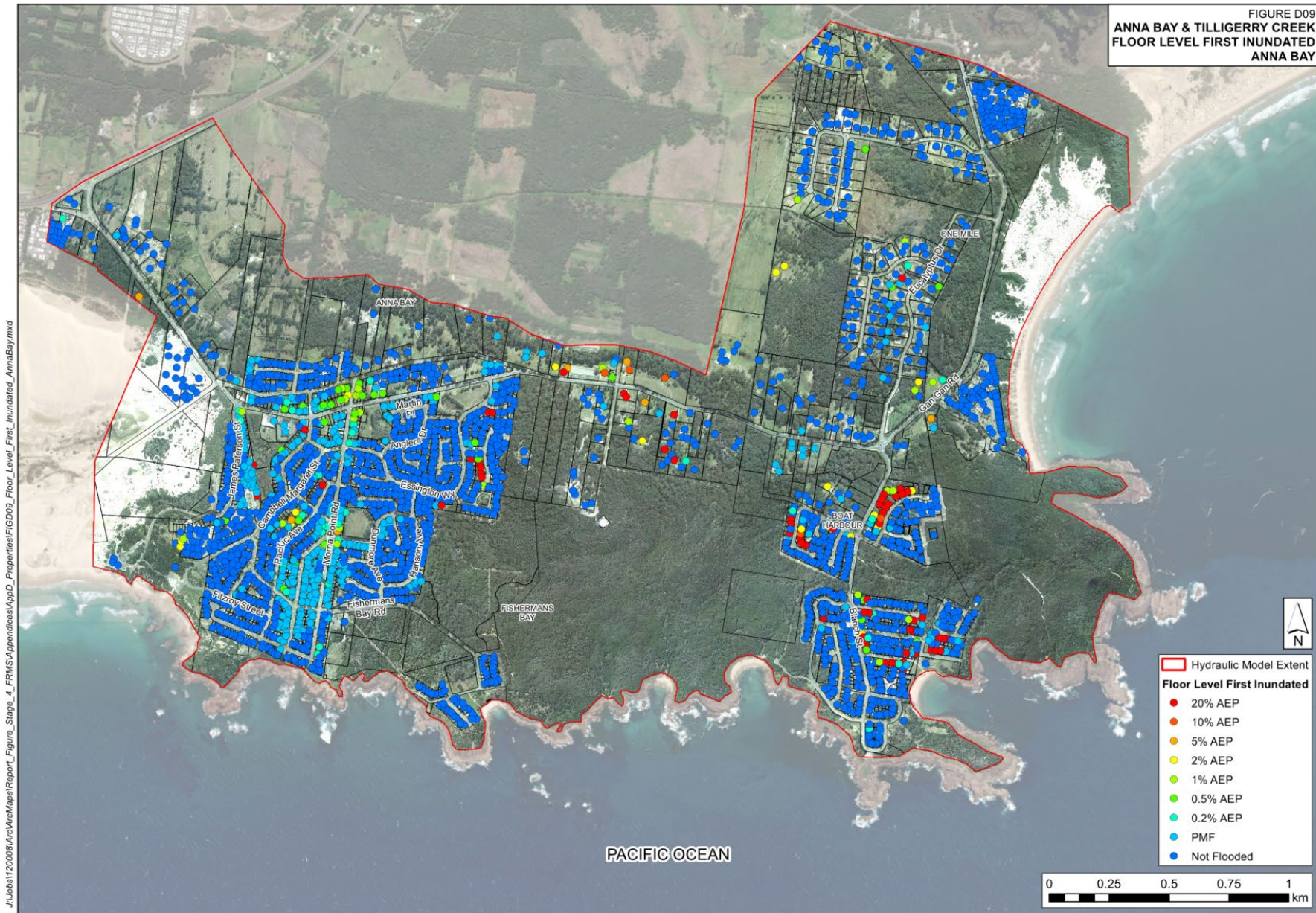
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ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.



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Appendix E

ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.



APPENDIX E. PEER REVIEW

Peer Review Recommendation	Consultant Response
<p>1: Provide a figure illustrating the location and interfacing of the three model domains</p>	<p>Figure 4 to Figure 6 which show the hydraulic model layout for each model has been updated to show how the regional models were applied to the urban models.</p>
<p>2: Provide reporting (suitable commentary and supporting figures) describing a conceptual model of flooding in the catchment and floodplain. Where necessary provide more detailed conceptual models describing the urban catchment study areas. The description of the conceptual model should be written in plain English to a standard suitable for an educated non-technical reader. This reporting should assist Council's floodplain managers and planners to more readily interpret the technical model outputs.</p>	<p>A diagram of the conceptual flood model has been added to Section 6.1.</p>
<p>3: Key model parameters adopted for design flood modelling should be clearly documented and justified in the report.</p>	<p>This information is presented in Section 5. Section 5.2 has been updated to confirm that groundwater effects have not been assessed.</p>
<p>4: Provide a tabulated summary of peak flood levels and flow velocities at key locations in the study area for the modelled design flood events.</p>	<p>Table has been added to report showing peak flood levels at key locations. Locations of reporting points shown is in Figure 1.</p>
<p>5: Clearly articulate the potential impact of culvert blockage on design flood levels and document the recommended approach to dealing with culvert blockage when setting floodplain development controls.</p>	<p>Design blockages from the 2017 Flood Study were applied for the design flood modelling in this FRMS. The flood study indicates that the design blockage was based on blockage for calibration events. Blockage sensitivity was assessed in the flood study. The Report has been updated with an additional paragraph in Section 5.2.4 to explain the above.</p>
<p>6: The model authors should investigate whether these higher velocities are 'real' or the manifestation of model instabilities. If the model is unstable at the boundaries the instability should be rectified. If the model instability cannot be reasonably controlled then the effect of the instability on model results should be investigated to determine whether the instability is affecting the model results in areas of the floodplain where the model results are being relied upon to set planning controls.</p>	<p>The velocities at the model boundaries have been reviewed and found that the initial water level was too low for the climate change scenarios. This caused high velocities at the beginning of the simulation as water rushed into the model. This has been rectified and the locations of high velocity did not impact on levels set for planning controls.</p>

ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.



Peer Review Recommendation	Consultant Response
7: An overview figure(s) indexing the location of zoomed in figures should be provided.	Overview inset has been add to options figures which are zoomed in. Road labels in the figures and figure titles aid the reader in locating where zoomed in figure is.
2.1: Include a response in the FRMS&P report demonstrating how each of the recommendations in my review of 28 March 2024 has been addressed.	Table of responses has been included in Appendix E (this table).
2.2: ES Section “Existing Flood Environment” should be updated and expanded to include a more detailed explanation of flood behaviour in the areas where most property is affected. The description provided in Section 1 Introduction is more appropriate.	Additional details have been added to the executive summary under the Study Area heading.
2.3: Consider rounding off the flood damage estimate e.g. to the nearest \$100,000. While the flood damage estimates have been made based on recently updated references from DPE RBA2024006 L20241126 GPS 3 published in 2023, a clear note should be provided as to whether the flood damage estimates have been adjusted to 2024 values. (see also Section 8.2 of the main report).	Values have been rounded to the nearest \$1,000 (As per Rec. 9). Added in note that the damages were calculated based on 2023 inflation.
2.4: In the ES Section “Recommended Options”, considered stratifying the options in Table 1 in order of priority (e.g. high, medium and low priority) so that the reader is directed to higher priority options first.	Table is grouped by option type and report order.
2.5: Add a note in the report identifying whether the model was run in single or double precision mode, and how the model results were checked to ensure issues with mass balance and floodplain drainage time were checked.	A sentence has been added in Section 5.2.1 noting single precision and that checking of model for volume errors, timesteps, and control numbers indicated results within acceptable limits.
2.6: Include a figure clearly identifying the locations listed in Table 6.	This information was previously shown in internal Model Update Report
2.7: Provide an explicit statement on the performance of the model confirming that the model is reproducing observed flood behaviour. An explicit statement on the performance of the model when predicting design flood behaviour should also be provided i.e. are the model design flood model predictions considered to be conservative or not?	Added in a sentence saying that they are matching well but in general overestimated historical behaviour.

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Anna Bay and Tilligerry Creek Floodplain Risk Management Study and Plan

Peer Review Recommendation	Consultant Response
2.8: Re-write Section 6 (and the remainder of the report) carefully referencing relevant figures in the relevant sections of the report.	Additional information has been added.
2.9: Review Table 11 and delete any redundant data. Consider rounding the values in Table 10 and Table 11 to the nearest thousand dollars.	Updated damages to the nearest \$1,000.
2.10: As per the Executive Summary, considered stratifying the options in Table 23 in order of priority (e.g. high, medium and low priority) so that the reader is directed to higher priority options first.	Table is grouped by option type and report order.
2.11: Carefully check the figure number on each figure at the end of the report. Carefully update cross references to figures in the report text.	This has been completed
2.12: The report requires a comprehensive editorial review prior to being publicly exhibited.	This has been completed

ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.

28 March 2024

Our Ref: RBA2024006 L20240328 GPS



Erin Askew
Director
WMAwater
Level 2, 160 Clarence St
Sydney NSW 2000

By email:

Dear Erin,

Peer review: Anna Bay and Tilligerry Creek – hydrologic and hydraulic model update

1. Introduction

Restore Blue Advisory Services Pty Ltd (Restore Blue) was engaged by WMAwater to undertake an expert peer review of the report *Anna Bay and Tilligerry Creek – Hydrologic and Hydraulic Model Update* noted as Draft Stage 2 and dated November 2023. Further background to the project, the need for a model update, and the scope and tasks proposed for the model update are provided in the supporting memorandum titled *Anna Bay and Tilligerry Creek FRMS – Flood Study Model Review* and dated 22 February 2021. Please note that I have reviewed the listed reports only and have not interrogated model files or model result files directly.

This review has been completed by me, Grantley Smith. I have more than thirty years of direct experience delivering hydrology and water resources projects both locally in NSW, nationally and internationally in a range of technical and management roles. My industry peers consider me to be an expert in catchment and floodplain hydrology and modelling. I have provided similar peer review of flood studies and floodplain management studies in my former role as Director of Industry Research at the UNSW Water Research Laboratory. My CV is attached (Addendum A). The review comments provided in this report are my professional opinion based on my accumulated knowledge. I am not aware of any perceived or actual conflict of interest in providing this review.

2. Review comments

2.1 Overview of the report

The report is technical in nature and describes the modelling approach in detail. In its current form, the report documents the intended purpose of the study scope outlined in the WMAwater memo from February 2021 of updating the hydrologic model to meet the requirements of Australian Rainfall and Runoff 2019 and updating the noted shortcomings of the hydrodynamic model configuration.

The report while being suitable for the technical reader, requires a level of interpretation which might be beyond the expertise of others who seeking to understand flooding issues in the study area more generally. While the figures in the report generally support the report commentary, interpreting the spatial location of the figures is sometimes difficult where the figures provide a zoomed in view of the floodplain.

RBA2024006 L20240328 GPS

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FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.**

Suggested improvements to the reporting are provided below.

2.2 Modelling approach

Overall, I consider that the modelling approach as documented follows best practice in respect of Australian Rainfall and Runoff and the NSW Flood Risk Management Manual.

The choice of modelling systems, available datasets applied in the hydrologic (WBNM) and hydrodynamic (TUFLOW) model development, model calibration/validation process and adopted model calibration parameters are documented to an adequate level of detail.

The adopted modelling approach has applied three separate, but linked models:

- i) A regional model of the Tilligerry Creek floodplain from the Hunter River floodplain through to Port Stephens. This model uses regional scale hydrology and represents the lower elevations of the floodplain at a 20m model resolution.
- ii) Two local models:
 - a. Anna Bay Urban Model; and
 - b. Tilligerry Creek Urban Model.

These two models, configured on a 1m grid, represent two higher, urbanised parts of the catchment and floodplain on the periphery of the regional floodplain in more detail.

While the report describes how the models interface, the location and orientation of the three hydrodynamic model domains is not illustrated in any of the figures.

Recommendation 1: Provide a figure illustrating the location and interfacing of the three model domains

The models are simulated separately with the two urban area models interfacing with the regional model at their respective downstream boundaries. Downstream boundary time series for the two urban models have been extracted from the regional floodplain model. While this modelling approach is acceptable, there can be issues with compatibility of the model results in areas nearby the boundaries. Where such compatibility issues are noted to manifest, a clear protocol for prioritising model results should be adopted and reported.

2.3 Overview of flooding behaviour

While historical flood data records are described in report *Section 4.5 Historical Flood Levels and Observed Behaviour* and flood behaviour is described for calibration events in *Section 4.6 Hydraulic Model Calibration and Validation* and design flood events in *Section 5.1 Existing Flood Behaviour*, the report currently lacks a holistic description of flooding mechanisms in the study area.

Recommendation 2: Provide reporting (suitable commentary and supporting figures) describing a conceptual model of flooding in the catchment and floodplain. Where necessary, provide more detailed conceptual models describing the urban catchment study areas. The description of the conceptual model should be written in plain English to a standard suitable for an educated, non-technical reader. This reporting should assist Council's floodplain managers and planners to more readily interpret the technical model outputs.

**ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.**

The report notes that the degree of surface water and groundwater interaction is an issue for model calibration for the regional flood model (report Section 4.6.1) with a range of groundwater infiltration rates tested. While adopting a constant infiltration rate meets the general modelling requirements typically adopted in similar flood studies, it is a gross simplification of a highly variable and non-linear process.

During flood conditions, especially during more extreme floods in the range used to set flood planning controls, the limit of groundwater storage could reasonably be expected to be reached with groundwater expressing to the surface and/or the ground being saturated (i.e. the limit of infiltration being reached). The infiltration parameters adopted for design flood events should be carefully considered and reasoning behind the adopted rates carefully documented.

More generally, it is noted that the historical events adopted for model calibration are significantly smaller than the design flood events applied when setting floodplain development controls. There is a reliance, then, on the model to extrapolate to the larger design flood events with model results likely to be sensitive to adopted design model parameters.

Recommendation 3: Key model parameters adopted for design flood modelling should be clearly documented and justified in the report.

While mapping of the design flood conditions has been provided, reader understanding of the variability of flooding across the range of design floods would benefit from a tabulated summary of peak flood levels and flow velocities at a range of key locations on the floodplain.

Recommendation 4: Provide a tabulated summary of peak flood levels and flow velocities at key locations in the study area for the modelled design flood events.

2.4 Culvert blockage

Model calibration notes that the degree of culvert blockage is an issue for historical flood events. Culvert blockage would therefore need to be carefully considered for design flood event modelling so that floodplain development controls can be set accordingly.

Recommendation 5: Clearly articulate the potential impact of culvert blockage on design flood levels and document the recommended approach to dealing with culvert blockage when setting floodplain development controls.

2.5 Modelled flood behaviour

On viewing the presented model results for design flood conditions, it appears that there may be an issue with model stability at the downstream model boundaries. Higher localised flow velocities adjacent to the downstream model boundary location as illustrated in report Figure D29 for the regional model and report Figure D45 for the Tilligerry Urban model hint at model instabilities possibly manifesting as artificial flow circulations on the model boundaries.

Recommendation 6: The model authors should investigate whether these higher velocities are 'real' or the manifestation of model instabilities. If the model is unstable at the boundaries the instability should be rectified. If the model instability cannot be reasonably controlled, then the effect of the instability on model results should be investigated to determine whether the instability is affecting the model results in areas of the floodplain where the model results are being relied upon to set planning controls.

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FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.**

2.6 Report figures

The report figures in their current configuration are somewhat difficult to interpret, particularly from the point of view of spatial location and orientation when a zoomed in view is provided.

Recommendation 7: An overview figure(s) indexing the location of zoomed in figures should be provided.

3. Summary

Thank you for the opportunity to provide this review. Please contact me on p: 0410309243 should you wish to discuss the details raised in this letter further.

Yours sincerely,

Grantley Smith
Director

Addendum A: CV Grantley Smith

ITEM 1 - ATTACHMENT 1 ANNA BAY AND TILLIGERRY CREEK
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN.

26 November 2024

Our Ref: RBA2024006 L20241126 GPS



Erin Askew
Director
WMAwater
Level 2, 160 Clarence St
Sydney NSW 2000

By email:

Dear Erin,

Peer review: Anna Bay and Tilligerry Creek – Floodplain Risk Management Study and Plan

1. Introduction

Restore Blue Advisory Services Pty Ltd (Restore Blue) was engaged by WMAwater to undertake an expert peer review of the report *Anna Bay and Tilligerry Creek Floodplain Risk Management Study and Plan* (FRMS&P) (WMAWater, 2024) Revision 1.1 noted as Draft for Public Exhibition Stage 2 and dated October 2024.

The FRMS&P builds on and addresses foundational floodplain risk and hazard datasets developed using an updated suite of floodplain models as described in the report *Anna Bay and Tilligerry Creek – Hydrologic and Hydraulic Model Update* (WMAWater, 2023).

Please note that I have reviewed the listed reports only and have not interrogated model files or model result files directly.

This review has been completed by me, Grantley Smith. I have more than thirty years of direct experience delivering hydrology and water resources projects both locally in NSW, nationally and internationally in a range of technical and management roles. My industry peers consider me to be an expert in catchment and floodplain hydrology and modelling. I have provided similar peer review of flood studies and floodplain management studies in my former role as Director of Industry Research at the UNSW Water Research Laboratory. My CV is attached (Addendum A). The review comments are my professional opinion based on my accumulated knowledge. I am not aware of any perceived or actual conflict of interest in providing this review.

2. Review comments

2.1 Response to my review of 28 March 2024

My previous review letter of 28 March 2024 is referred to in report Section 3.6 "Peer Review" and the letter itself included as an appendix to the FRMS&P report. The review letter provides a series of observations regarding the flood study model (as reported in *Anna Bay and Tilligerry Creek – Hydrologic and Hydraulic Model Update, November 2023*) and a list of recommendations to consider, which might improve the model and the report. I understand from our discussion on 15 November 2024 that these recommendations have since been addressed. Since the review letter is included in the report, I'd

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recommend that the FPRMS&P report documents a direct response to the recommendations so that the reader can see how the recommendations have been addressed. Note also that my name is misspelt in Section 3.6.

Recommendation 1: *Include a response in the FRMS&P report demonstrating how each of the recommendations in my review of 28 March 2024 has been addressed.*

2.2 Overview of the FRMS&P report

The NSW State Government's Flood Prone Land Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy provides for technical and financial support from the NSW State Government through five stages. Stages three and four of the floodplain management process refer to the Floodplain Risk Management Study and Floodplain Risk Management Plan. The report as tabled for review is comprehensive, and the applied approach and content provided generally meet the requirements of the Policy. The report has quantified floodplain risk over a range of design flood events from the 20% Annual Exceedance Probability (AEP) event to the PMF and investigated a range of management options in consideration of local social, economic and ecological factors under the supervision of a local flood management committee.

The floodplain management options have been evaluated and compared using a multi-criteria assessment approach, which has been used to prioritise the options as high, medium or low priority.

The prioritised options have been combined into a draft Floodplain Management Plan for public exhibition.

The report provided to me for review, while generally sound, has a range of errors and omissions that need to be addressed prior to being publicly exhibited for comment.

2.3 Executive Summary

In my opinion, the Executive Summary (ES) should be able to be read as a 'stand-alone' document that highlights the key elements of the main report. In this regard, the ES would benefit from the inclusion of a copy of Figure 1 and Figures 10, 11 and 12 (as a suggested minimum) from the report being reproduced in the ES itself.

While the majority of the study area is the low lying area of floodplain between Fullerton Cove and Port Stephens, my understanding is that the majority of flood affected residents and property are situated in smaller, concentrated areas of development in Anna Bay, Fishermans Bay, Boat Harbour, Tanilba, Mallabulla and Lemon Tree Passage.

Recommendation 2: *ES Section "Existing Flood Environment" should be updated and expanded to include a more detailed explanation of flood behaviour in the areas where most property is affected. The description provided in Section 1 Introduction is more appropriate.*

In the ES Section "Economic Impact of Flooding", the annual average damages is stated to be \$23,123,739. In my opinion, stating this number to eight (8) significant figures is an overstatement of the accuracy of the flood damage estimation analysis.

Recommendation 3: *Consider rounding off the flood damage estimate e.g. to the nearest \$100,000. While the flood damage estimates have been made based on recently updated references from DPE*

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published in 2023, a clear note should be provided as to whether the flood damage estimates have been adjusted to 2024 values. (see also Section 8.2 of the main report).

Recommendation 4: *In the ES Section "Recommended Options", considered stratifying the options in Table 1 in order of priority (e.g. high, medium and low priority) so that the reader is directed to higher priority options first.*

2.4 Flood modelling

Overall, I consider that the modelling approach as documented follows best practice in respect of Australian Rainfall and Runoff and the NSW Flood Risk Management Manual.

Section 5.2 provides a description of the WMAwater TUFLOW model review. I note that recent similar TUFLOW flood models depicting broad, flat floodplains have had issues simulating the flood inundation duration correctly when TUFLOW is run in single precision mode.

Recommendation 5: *Add a note in the report identifying whether the model was run in single or double precision mode, and how the model results were checked to ensure issues with mass balance and floodplain drainage time were checked.*

Section 5.3 provides a summary of the re-calibration and validation of the model including Table 6 which provides a comparison of historical and modelled flood levels for the March 2021 flood. This discussion would be assisted by including a flood inundation figure(s) depicting the locations listed in Table 6.

Recommendation 6: *Include a figure clearly identifying the locations listed in Table 6.*

Section 5.3.3 describes the outcomes of the calibration and verification of the model. My view is that, beyond the current information on the calibration accuracy, the reader would benefit from an explicit statement in this section on how the model calibration supports the design flood analysis and the management options assessment going forwards.

Recommendation 7: *Provide an explicit statement on the performance of the model confirming that the model is reproducing observed flood behaviour. An explicit statement on the performance of the model when predicting design flood behaviour should also be provided i.e. are the model design flood model predictions considered to be conservative or not?*

Section 6 describes the existing design flood behaviour. While the written descriptions are reasonable, the reader would benefit by being directed to the relevant figure(s) in the report as particular flood features are described in the text. Currently the report refers to figures up to Figure 9 in Section 5.2.3 page 11 and the next reference to any figure is to Figure 55 in Section 6.2.2 page 22.

Recommendation 8: *Re-write Section 6 (and the remainder of the report) carefully referencing relevant figures in the relevant sections of the report.*

Section 8.2.2 "Summary of Damages". Table 11 seems to have double the number of expected values across design events. The damage estimates in Table 10 and Table 11 are to the nearest dollar which may lead the reader to the conclusion that these numbers have high accuracy. In my opinion, stating these numbers to the nearest dollar overstate of the accuracy of the flood damage analysis.

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***Recommendation 9:** Review Table 11 and delete any redundant data. Consider rounding the values in Table 10 and Table 11 to the nearest thousand dollars.*

Section 8.3.2 "Spatial and temporal rainfall behaviour". Note that Conrad Wasko's name is mis-spelt.

2.5 Floodplain Management Options Assessment, multi-criteria assessment and ranking of options

I note that the floodplain management options assessment has been conducted under the guidance and direction of Council's Flood Advisory Panel. I have reviewed the assessment and consider that it has been conducted in accordance with the Flood Prone Land Policy Framework.

***Recommendation 10:** As per the Executive Summary, considered stratifying the options in Table 23 in order of priority (e.g. high, medium and low priority) so that the reader is directed to higher priority options first.*

2.6 Report figures

The report figures have generally been produced to a high standard and improved in line with my recommendations provided in my first review of 28 March 2024.

Note there is a problem with the figure numbering. There are multiple figures with the same figure number e.g. Figures 67, 68, 69, 70, 71, 72, etc.

***Recommendation 11:** Carefully check the figure number on each figure at the end of the report. Carefully update cross references to figures in the report text.*

2.7 Editorial

There are numerous spelling, grammatical and typographical errors in the document. I have highlighted some of these (non-exhaustive) in the accompanying marked up copy of the report. Note also that there is an issue with the page numbering.

***Recommendation 12:** The report requires a comprehensive editorial review prior to being publicly exhibited.*

3. Summary

Thank you for the opportunity to provide this review. Please contact me on p: 0410 309 243 should you wish to discuss the details raised in this letter further.

Yours sincerely,

Grantley Smith
Director

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References:

WMAwater (2023) Anna Bay and Tilligerry Creek – Hydrologic and Hydraulic Model Update

WMAwater (2024) Anna Bay and Tilligerry Creek Floodplain Risk Management Study and Plan

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Grantley Smith

In his 30+ years as a professional engineer, Grantley has developed his skills on a broad range of projects providing assessment and solutions for water engineering and water resources investigations. He is a team leader with a proven track record for leading multi-disciplinary teams delivering practical solutions to environmental investigations. He has particular expertise in the selection and application of appropriate physical or numerical models to support design solutions, planning, management and forecasting across the water spectrum.

Grantley has specialist expertise in water resources management through a hands-on career investigating catchment processes. He is acknowledged by his peers as an expert in modelling catchments and floodplains and was instrumental in the pioneering use of 2D hydrodynamic models for floodplain flow prediction and inundation mapping. His experience gained through direct participation in the evolution of floodplain modelling has provided him with an outstanding knowledge of the application and interpretation of appropriate models to support environmental planning, management and forecasting for floodplains. Grantley is a lead author and key contributor to reports supporting the revision of Australian Rainfall and Runoff, most recently contributing to guidelines for appropriate use of numerical models and flood safety. He is also the lead author of the guideline on flood hazard assessment supporting the national best practice manual Managing the floodplain - a guide to best practice in flood risk management in Australia (AEMI Handbook 7). His skills include the simplification of technical data and modelling outputs in to forms readily communicated to non-technical stakeholders.

Qualifications and affiliations

BE Hons (Civil Engineering), UQ
MEngSc (Water Engineering), UNSW
CPEng, FIEA (Chartered Professional Engineer, Fellow Engineers Australia)
NPER, RPEQ (National Professional Engineers Register, Registered Professional Engineer Queensland)
Past Chair: Engineers Australia Sydney Water Panel

Professional history

2022 - Co-Founder and CEO Restore Blue
2020-2022: Director – Industry Research, UNSW WRL
2012-2020: Principal Engineer & Manager, UNSW WRL
2009-2011: Senior Project Engineer, UNSW WRL
1999-2009: Principal Engineer NSW State Manager, DHI Water and Environment, Australia
1990-1999: Engineer/Senior Engineer, Lawson and Treloar, NSW

Expertise

- Project management
- Hydrological processes and modelling
- Water resources management
- Surface water/groundwater interactions
- Flow forecasting
- Blue Carbon Wetlands
- Hydrodynamic and water quality modelling
- Wetland hydrology
- Environmental flow delivery
- Estuarine processes
- Hydraulic structures

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Summary of relevant experience

Wetland restoration

Tomago Wetlands, NSW
Yarrahappini Wetlands, NSW
Chowilla floodplain baseline, SA
Chowilla floodplain options, SA
Koondrook Forest, NSW
Gunbower Forest, VIC
Macquarie Marshes, NSW

Rivers and flooding

Hydraulic and cost benefit assessment of the impact of climate change on the Hunter Valley Flood Mitigation Scheme, NSW
Newcastle city-wide floodplain risk management plan, NSW
Lower Hunter River floodplain, NSW
Ironbark Creek floodplain, NSW
Middle Creek flood and sediments, NSW
Woy Woy flooding, NSW
Darling River, Bourke - Louth, NSW
Dark Creek flooding, NSW
River Murray environmental flow easements, NSW
Haslam Creek hydraulic investigation, NSW
Frenchs Creek FPMS, NSW
Warrah Creek flooding, NSW
Blackman's Swamp Creek FS, NSW
Mawson Lakes channel, SA
Flood damage assessment, Czech Republic
Bohle River flood study, QLD
Onion Creek, Texas, USA
Tenterfield flood study, NSW
Brickfield Creek flood study, NSW

Flood hazard

Flood fatalities estimation
National Flood Hazard Guideline – AEM Handbook 7
Flood hazard – analysis methods

Hydrology and forecasting

Wollondilly/Wingecarribee, NSW
Shoalhaven (Tallowa Dam), NSW
SCA real-time forecasting system framework, NSW
Vistula River, Poland

Dams and structures

Somerset Dam, QLD
Lake Macdonald, QLD
Hume Dam gate operations, NSW
Copeton Dam fuse plug EIA, NSW
Tumut 3 turbine upgrade, NSW
Chaffey Dam break, NSW
Bethungra Dam break, NSW
Potts Hill reservoir, NSW
Cordeaux Dam break, NSW
Avon Dam break, NSW
Nepean Dam break, NSW

Water and wastewater

Sydney Water sewer sediment blockage analysis, NSW
Maldon odour control, VIC
Sydney Water two-phase, dynamic H2S model scoping, NSW
Industrial waste impacts, Sydney Water, SWOOS, NSW
Balickera pump station upgrade, NSW
Sydney Water SCAMPS, NSW
Northside storage tunnel, NSW
Shelly Beach H2S assessment, NSW

Coasts, estuaries and outfalls

Hunter River water quality model, NSW
Sydney desalination plant outfall, NSW
Newcastle Harbour extreme ocean water levels, NSW
Port Jackson model, NSW
SWC SOLP receiving waters, NSW
Illawarra outfall design and commissioning, NSW
Danish Olympic Sailing Team – Sydney Olympics, NSW
Cooks River dispersion study, NSW
Lake Illawarra entrance, NSW
Kikori River pipeline stability, PNG

Panels and review

Sydney Water – Review of SWOOS upgrade at Mill Stream
NSW Department of Planning – Warragamba Dam Wall raising expert review
TfNSW – Warragamba Dam Wall Raising evacuation model
VIC DELWP flood program - peer review
QLD CSG surface water review
Ord River irrigation scheme expansion
Lower Lakes acid sulphate review
NSW Rivers environmental restoration program, hydraulic modelling

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