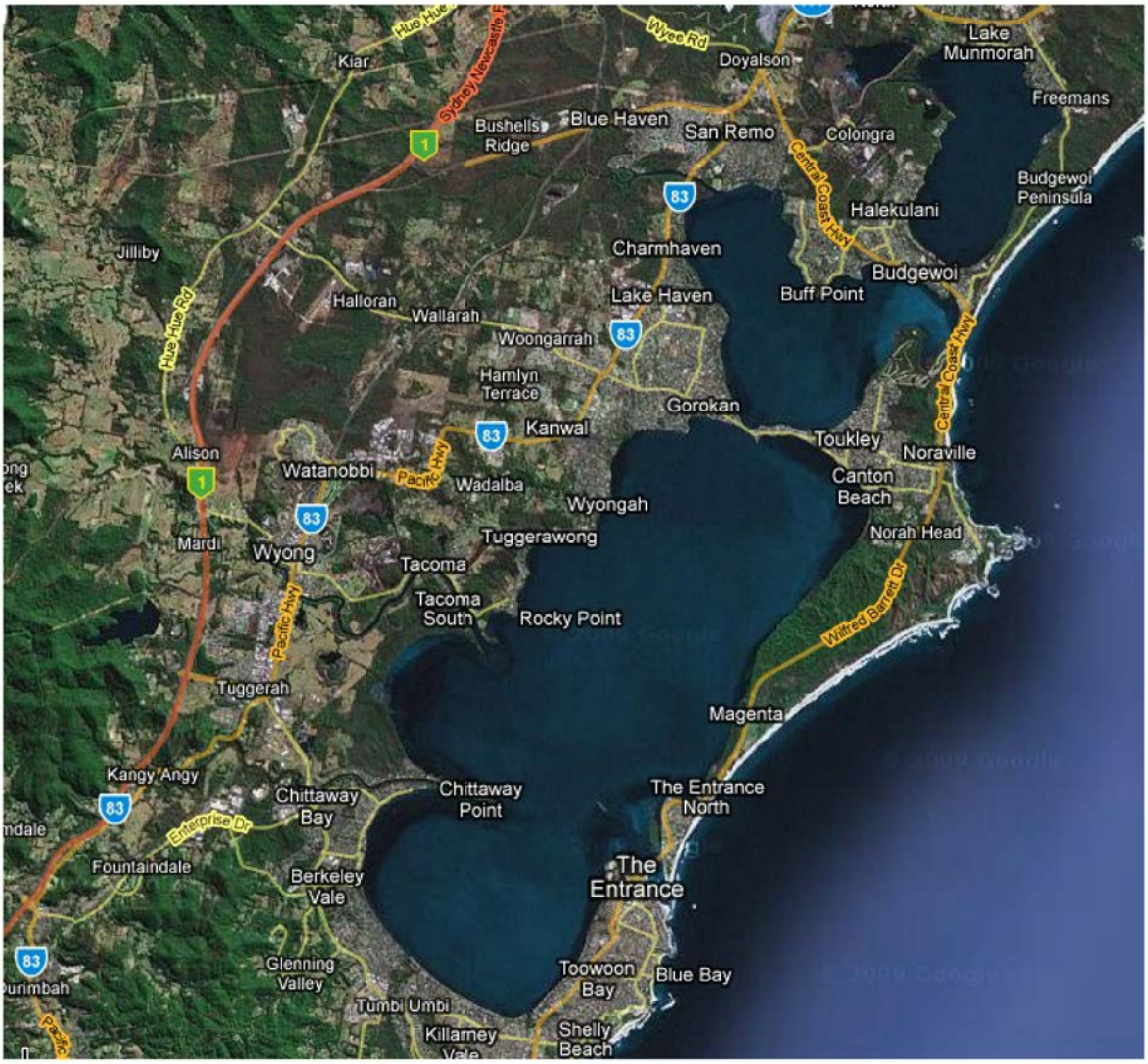
WYONG SHIRE COUNCIL

TUGGERAH LAKES

FLOODPLAIN RISK MANAGEMENT

STUDY and PLAN

FINAL REPORT



wma water

November 2014

Level 2, 160 Clarence Street
Sydney, NSW, 2000

Tel: 9299 2855
Fax: 9262 6208
Email: wma@wmawater.com.au
Web: www.wmawater.com.au

TUGGERAH LAKES FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

FINAL REPORT
NOVEMBER, 2014

Project Tuggerah Lakes Floodplain Risk Management Study and Plan	**Project Number** **29001**
Client **Wyong Shire Council**	**Client's Representative** Peter Sheath
Authors **Richard Dewar**	**Prepared by**
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TUGGERAH LAKES FLOODPLAIN RISK MANAGEMENT STUDY

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1. FOREWORD

The State Government's Flood Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood 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 the following four sequential stages:

1. *Flood Study*
   - determine the nature and extent of the flood problem.

2. *Floodplain Risk Management Study*
   - evaluates management options for the floodplain in respect of both existing and proposed development.

3. *Floodplain Risk Management Plan*
   - involves formal adoption by Council of a plan of management for the floodplain.

4. *Implementation of the Plan*
   - construction of flood mitigation works to protect existing development,
   - use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

The Tuggerah Lakes Floodplain Risk Management Study and Plan constitutes the second and third stages of the management process for the floodplain surrounding Tuggerah Lakes. It has been developed for Wyong Shire Council and prepared by WMAwater (formerly Webb, McKeown & Associates) for the future management of flood liable lands surrounding the foreshore of Tuggerah Lakes.

Wyong Shire 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 Office of Environment and Heritage.

2. TUGGERAH LAKES FLOODPLAIN RISK MANAGEMENT PLAN

2.1. Introduction

The Tuggerah Lakes Floodplain Risk Management Plan has been prepared in accordance with the NSW Floodplain Development Manual (April 2005) (Reference 1) and:

- *is based on a comprehensive and detailed evaluation of all factors that affect and are affected by the use of flood prone land;*
- *represents the considered opinion of the local community on how to best manage its flood risk and its flood prone land;*
- *provides a long-term path for the future development of the community.*

The Tuggerah Lakes system comprises Tuggerah Lake, Budgewoi Lake and Lake Munmorah and the immediate floodplain (Figures 1 and 2). The lakes occupy an area of approximately 80 km^2 (11% of the total catchment area of 750 km^2) and are surrounded by residential developments, areas of open space and rural lands. The major rivers which drain into the lakes are the Wyong River (447 km^2) and Ourimbah Creek (160 km^2).

The lakes system is one of the most highly regarded residential and tourist features of the area and is enjoyed by many. Its relatively shallow depth (1.9 m) means that it cannot be used by large recreational sailing or motorised vessels. The Tuggerah Lakes system is termed an ICOLL (Intermittent Open and Closed Lake or Lagoon) with a sandy beach berm at the entrance that is intermittently open and closed. Flooding occurs as a result of intense rainfall over the catchment which causes overtopping of the beach berm and increased water levels in the three lakes and inundation of the surrounding floodplain. The extent of flooding is influenced by the level of the beach berm at the entrance and whether elevated ocean levels in the Pacific Ocean can overtop the berm and enter Tuggerah Lake or restrict the outflow of floodwaters.

A Flood Study for Tuggerah Lakes (Reference 2) was completed in September 1994 where a Mike-11 hydraulic model was established, calibrated to historical flood data and used to determine design flood levels. The study showed that in a major flood the peak water level is the same in all three inter-connected lakes.

The development on the foreshore largely consists of residential houses/flats/villas with some commercial premises and infrastructure (sewer pumping stations, roads etc.). The lake water levels are normally in the range 0.2 to 0.4 mAHD and tidal fluctuations are effectively nil (less than ±0.05 m around the entrance channel only). The lakes rise in response to runoff from the contributing catchments, with the peak level determined by the amount of runoff and the channel capacity at the entrance.

Significant flooding in the catchment has occurred on numerous occasions in the past and most recently in February 1990 and June 2007. The largest recorded flood was in June 1949. In the June 2007 flood (and a similar number in February 1990) over 160 building floors were inundated causing considerable property damage and some infrastructure damage.

Up to 1300 buildings would be inundated above floor in a 1% AEP flood event (1 in 100 year) resulting in over $40 million dollars in tangible damages. Up to 1600 buildings would be inundated above floor level in a 0.5% AEP event (1 in 200 year). The estimated long-term average annual damage for the foreshore properties around the Tuggerah Lakes system is $2.2 million.

Wyong Shire Council sought to examine a range of floodplain management measures to reduce the impact of flooding in the Tuggerah Lakes Floodplain Risk Management Study which determined the nature of the flood problem (extent and magnitude of flood damages) and investigated possible floodplain management measures.

2.2. Floodplain Risk Management Measures Considered

A matrix of all possible management measures was prepared and evaluated in the Floodplain Risk Management Study taking into account a range of parameters.

This process eliminated a number of measures (refer Section 6.2) including: flood mitigation dams and retarding basins, channel modification works (straightening, concrete lining, removal of vegetation), flood proofing of buildings, and voluntary purchase of affected buildings.

The most effective means of managing flood risk in the Tuggerah Lakes floodplain were found to be:

- Land use planning,
- Infrastructure planning,
- Adaptation planning,
- Emergency management planning and evacuation,
- Flood awareness education.

The evaluation process for assessing each measure involved interaction with the Floodplain Management Committee, the Technical Sub-committee of the Floodplain Management Committee itself and the general public through the public consultation process. Thus the proposed measures represent the considered opinion of both technical experts and local residents.

It is recommended that a working group is formed for the implementation of the Tuggerah Lakes Floodplain Risk Management Plan. This working group would consist of members of the various sections of Council, including (but not limited to) Floodplain Management, Land Use Planning, Roads and Stormwater, Water and Sewer and Development Assessment staff.

2.3. Proposed Floodplain Risk Management Measures

The proposed measures are described below (in no particular order within each priority group).

HIGH Priority

1. **Adaption Planning for foreshore suburbs**
    - **Cost:** moderate
    - **Responsibility:** Wyong Shire Council
    - **Timeframe:** within 3 years of adoption of this Plan

There are over 5,500 properties within the foreshore floodplain of Tuggerah Lakes. Careful consideration is required with the long-term planning for these areas, which will necessitate discussions with land owners and infrastructure providers, such as the road authority, water supply, sewerage, electricity, gas, and other public utilities.

The floodplain surrounding Tuggerah Lakes cannot feasibly be protected from future sea level rise by structural measures, due to the expansive areas of low lying land. The priority suburbs where Wyong Shire Council needs to begin detailed investigations into the long-term land use planning, which will need to be incorporated into future revisions of the LEP are:

- Chittaway – North and South,
- South Tacoma,
- North Entrance,
- Berkeley Vale,
- Tuggerawong.

The remaining foreshore and flood prone suburbs should then be completed. This could be broken down into two steps, the second phase following the outcomes of the first phase. The initial pilot project would encompass one of the high priority areas and commence in the immediate short term, with the outcomes then applied to the other high priority areas to ensure they are applicable. The remaining foreshore flood prone areas would be completed sequentially after that based on the outcomes and recommendations of the high priority area studies.

Many of these areas have high hydraulic hazard in the current flood planning event and during floods there are significant concerns about property damage and the safety of residents. These low-lying areas currently do not have satisfactory access during a large flood event, a situation which will only be exacerbated by potential sea level rise. The level of existing flood risk and vulnerability of infrastructure to flooding risks to these areas is currently considered inadequate for residential purposes. However, the rise in water level in Tuggerah Lakes is relatively slow (24 to 48 hours) and if given adequate warning and made flood aware and prepared, and if inclined many residents should be able to evacuate safely. Thus further development in these key areas is only supported on a floodplain management basis that Wyong Shire Council, in conjunction with the SES, immediately start work on precinct or community based emergency management and evacuation planning and on-going flood management education for each of the floodprone areas. These undertakings are listed separately below as “Flood Emergency Management Planning” and “Raising Flood Awareness”.

2. Flood Emergency Management Planning

- **Cost:** moderate
- **Responsibility:** State Emergency Services and Wyong Shire Council
- **Timeframe:** Establish within 1 year of adoption of this Plan and on going

Provision of safe evacuation is a short term solution for many of the existing properties located within the flood affected areas of Tuggerah Lakes. It is however recognised that evacuation can be difficult to enforce when people are actually directed to evacuate. This has become obvious during the recent flood events throughout QLD, Victoria and NSW in the past couple of years, with the media reporting many stories of “people staying behind”. These attitudes need to be addressed through the flood awareness program work, which has been listed as a separate recommended mitigation option.

Public health issues are the biggest issue facing floodplain management in the Tuggerah Lakes catchment. This is due to the vulnerability of the sewer assets in numerous locations, which has lead to sewer overflows in residential areas during previous flooding events.

Early evacuation may also enable earlier shut-down of some of the vulnerable assets, such as sewer mains and/or sewer pump stations.

The SES is the combat agency responsible for managing people during floods and is responsible for the preparation and planning of local flood plans. Council is the consent authority for planning and development in the Tuggerah Lakes floodplain, and is also responsible for implementation of the State Governments Policy on sea level rise. This floodplain risk management study and plan has defined the flood planning areas and development controls on the basis that flood emergency planning will be undertaken for the existing developed areas of the catchment.

Flood Emergency Planning is dependent upon the SES and their resources and capacity to complete such planning. Therefore the SES needs to confirm that any future evacuation can be realistically achieved and will not endanger lives. Council can assist the SES with completing this planning through their floodplain management program as well as the Local Emergency Management Committee.

3. Public Education and Raising Flood Awareness

- **Cost:** moderate
- **Responsibility:** Wyong Shire Council and State Emergency Services
- **Timeframe:** establish within 1 year of adoption of this Plan and on going

A program should be initiated by the SES in conjunction with Wyong Shire Council to educate and raise public awareness of flooding. This education and awareness must be an on-going program, and cannot simply be a one off event. A variety of methods are provided in the risk management study and examples from other Councils (Rockdale, Pittwater, Maitland) will assist.

The SES promotes community flood education through its "Floodsafe" program, which can be tailored to suit the local flooding conditions. Council has a social responsibility to begin and continue with flood education for the residents of these areas, on a regular basis as it continues to facilitate development in these areas. Council has a significant network of community education opportunities through which flood awareness could be incorporated into the existing programs. There are also a significant number of community groups that could also be used as a forum for raising flood awareness. The SES has a dedicated Community Education Officer for the Sydney Northern Region who can work in conjunction with Council staff to develop and implement the on-going Flood Awareness program.

The flood education strategy should be developed in conjunction with the community.

4. Development of management plan for Vulnerable Water and Sewer Assets

- **Cost:** minor
- **Responsibility:** Wyong Shire Council and Water Authority
- **Timeframe:** to be undertaken over the next 2 years

Waste water that goes down sinks, toilets and showers ends up in the sewer. The sewerage system has overflow points, called gullies that act as safety valves. A gully is an open pipe which is covered by a grate and found outside the house. They are designed to protect public health by preventing sewage backing up into people's homes. There are a significant number of private residential sewer gullies which are at or near ground level around the foreshore of Tuggerah Lakes. If flood levels overtop the top of the gully then flood water will flow into the sewer and exceed the capacity of the system. For this reason the parts of the sewerage network are often turned off during floods, as has occurred in the February 1990 and June 2007 events. Some sewer pumping stations were also turned off during minor flood events in as well as minor flooding events in 2010, 2011 and 2013.

The initial stage of this project would be to determine the extent of the problem via visual inspections of the public and private manholes and sewer outlets. The next stage of the process would require formulation of a risk management plan to manage these risks – that is, a plan that looks at managing the vulnerable water and sewer assets in the floodprone areas of Tuggerah Lakes.

This information could then be passed on to the SES for inclusion in the Local Flood Plan. The vulnerability of the sewer assets plays a role in determining flood emergency response planning in the Tuggerah Lakes catchment, and so updates to the sewer asset management should be passed on to the SES as they occur.

5. Formalise an Entrance Management Strategy to Manage Flooding

- **Cost:** moderate
- **Responsibility:** Wyong Shire Council and Office of Environment and Heritage
- **Timeframe:** to be undertaken over the next 4 years

This strategy is to clearly differentiate from the existing informal entrance opening policy arrangements currently in place and the current dredging practice. The prime objective is to include consideration of emergency entrance opening for the management of flooding.

The strategy is to consider potential sea level rise and the impacts it may have on the geomorphic and environmental characteristics of the area, particularly for the more frequent flood events.

The Office of Environment and Heritage has funded a Hydrodynamic and Morphodynamic study of the entrance channel which will help to inform Council of appropriate management options for the opening to the ocean. The study is not specifically considering management of the opening during flood times, and so Wyong Shire Council will need to look at this issue in further detail. Council needs to clearly promote/educate the community on the difference between the management of the entrance for flooding purposes and the management for other reasons, such as for tourism or ecological benefits.

6. Develop Asset Management Procedures for the Wilfred Barrett Drive Levee

- **Cost:** minor
- **Responsibility:** Wyong Shire Council
- **Timeframe:** Plan to be completed and implemented within 1 year of adoption of this Plan

Develop specific asset management maintenance procedures for the existing levee and associated infrastructure (stormwater outlets and rubber backflow valves) of Wilfred Barrett Drive at north entrance. The rubber valves were installed in October 2013, which replaced the previous flap gates.

7. Update Section 149(2) Planning Certificates

- **Cost:** minor
- **Responsibility:** Wyong Shire Council
- **Timeframe:** to be completed within 1 year of adoption of this Plan

Upon adoption of the development controls recommended in this Plan, land subject to flood related development controls should be identified appropriately on Section 149(2) Certificates as required under the Environmental Planning and Assessment Act.

8. Address and Manage Local Frequent Flooding Issues

- **Cost:** minor
- **Responsibility:** Wyong Shire Council
- **Timeframe:** ongoing

Frequent local flooding issues should be identified and recorded in a database. This database could include information from the SES, complaints from residents to Council and observations from Council and SES staff.

Investigation of management measures to address the issues should be undertaken following each significant event when these issues arise.

9. Maintenance of Water Level and Rainfall Gauges

- **Cost:** minor
- **Responsibility:** Wyong Shire Council
- **Timeframe** ongoing

Council currently owns several water level and rainfall gauges in the catchment. The SES and BoM use these for flood forecasting and warnings. An asset management procedure should be developed for this infrastructure to ensure they are in working order at all times. A Memorandum of Understanding, or something similar, could be developed between Council. SES and BoM.

10. Undertake Transfer of all Relevant Flood Related Information to the Community, Insurance Council of Australia and NSW State Emergency Service

- **Cost:** minor
- **Responsibility:** Wyong Shire Council
- **Timeframe:** ongoing

Flood mapping to be included on Council's on-line mapping portal.

Flood mapping should also be provided to the Insurance Council of Australia, for the sake of properly understanding flood risk to price insurance premiums fairly.

The SES should be advised of all available flood related information and provided with digital copies if required. Council staff could also assist in the update to the Local Flood Plan.

MEDIUM Priority

11. Review Tuggerah Lakes Flood Study and Floodplain Risk Management Plan

- **Cost:** moderate
- **Responsibility:** Wyong Shire Council and Office of Environment and Heritage
- **Timeframe:** within 5 years of adoption of this Plan

This would include assessment of wind wave run-up in conjunction with sea level rise in Tuggerah Lakes during flood and non-flood times, and assessment of any new entrance management measures that Council is proposing to implement. Review could include a detailed floor level survey of all properties located within the floodplain of Tuggerah Lakes. Outputs of the study could inform or update appropriate development controls.

LOW Priority

12. Assess and Manage the Risk of Electrocution during Floods

- **Cost:** minor
- **Responsibility:** Wyong Shire Council
- **Timeframe:** within 2 years of adoption of this Plan

There may be a high risk of electrocution during floods and for this reason (and others) the electricity supply was cut during the February 1990 and June 2007 floods (this also means loss of sewage pumping stations). This issue should be addressed and managed by both the asset owner and the electrical provider.

13. Investigate Opportunities for House Raising

- **Cost:** minor
- **Responsibility:** Wyong Shire Council
- **Timeframe:** within 2 years of adoption of this Plan

There are a number of vulnerable properties within the floodplain of Tuggerah Lake that may be able to be elevated above the flood planning level. This could be done after the strategic planning of the floodprone areas has been updated. Such a scheme would need the support of the community and government agencies for funding.

14. Develop Specific Flood Related Controls for Existing and Future Tourist Parks

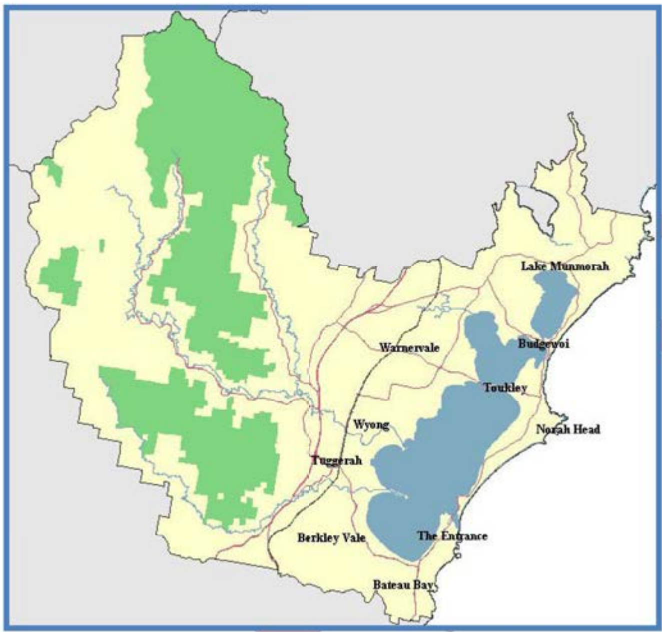
- **Cost:** minor
- **Responsibility:** Wyong Shire Council and Tourist Park operators
- **Timeframe:** within 2 years of adoption of this Plan

Tourist parks represent a significant risk to the safety of occupants and damage to structures during floods. Specific flood related controls need to be developed to address and manage this risk for existing and future (or extensions) parks.

3. INTRODUCTION

3.1. Background

The Tuggerah Lakes system is located on the New South Wales Central Coast approximately 80 km north of Sydney (Figure 1 and below) and comprises the three inter connected lakes of Tuggerah, Budgewoi and Munmorah.



Tuggerah Lakes Catchment Area

The main features of the lakes are shown in Table 1.

Table 1: Tuggerah Lakes Main Features

Total Catchment Area to the Ocean	750 km^2	
Area of Lakes	Tuggerah Lake Budgewoi Lake Lake Munmorah	55 km^2 14 km^2 8 km^2
Length of Tuggerah Lake	13 km in a north-south direction	
Maximum Width of Tuggerah Lake	6 km in an east-west direction	
Perimeter Length of Lakes	110 km	
Average Water Depth	1.9 m	
Major Contributing Catchments	Wyong River Ourimbah Creek Wallarah Creek	447 km^2 160 km^2 32 km^2

Tuggerah Lake is connected to the Pacific Ocean by a tidal channel at The Entrance. The size of the opening at The Entrance has fluctuated and on occasions has been closed for several months. It has closed completely approximately ten times since 1900. Since mid 1993 Wyong Shire Council has initiated a policy of maintaining a permanently open entrance (by dredging) to allow tidal interchange. There are no entrance training works which are typically found on many estuaries (and lake entrances such as Lake Macquarie) along the NSW coast.

The water level in the lakes is typically at 0.3 mAHD in all three lakes but can vary depending on the state of the entrance and amount of runoff (Australian Height Datum - AHD is the common national plane approximating mean sea level). Under normal circumstances the ocean tide has little impact (less than ±0.05 m) on the water level in the lakes. The average depth of water in the lakes (at 0.3 mAHD) is 1.9 m with the deepest area being in Lake Munmorah (up to 3.7 m deep at 0.3 mAHD). There is no difference in water level between the lakes in normal or flood times due to the large connecting channels at Gorokan and Budgewoi.

The study area comprises the floodplain areas surrounding the three lakes and properties at Wyong and Tuggerah with ground levels below approximately 3 mAHD. For the purposes of this investigation the study area was subdivided into ten floodplain management areas shown on Table 2 and on Figure 2. It should be noted that only properties with building floors below approximately 2.7 mAHD were included in the database provided by Wyong Shire Council.

Table 2: Floodplain Management Areas

Area	Suburbs Included (refer Figure 2)	Building Floors Surveyed(3)
TUGGERAH LAKE		
TL1	The Entrance North	242
TL2	The Entrance, Long Jetty	250
TL3	Killarney Vale, Tumbi Umbi	208
TL4	Berkeley Vale	399
TL5	Chittaway Bay, Chittaway Point	292
TL6	Rocky Point, Tacoma, Tacoma Sth, Wyongah, Tuggerawong	283
TL7(1)	Noraville, Gorokan, Toukley	184
	BUDGEWOI LAKE	
BL1	Lake Haven, San Remo, Blue Haven, Buff Point, Charmhaven	301
	LAKE MUNMORAH	
LM1(2)	Budgewoi, Lake Munmorah	261
	SUBURBS NOT SURROUNDING THE LAKES	
EX1	Wyong, Tuggerah	107
2527		

NOTES:
1. Gorokan and Toukley surround both Tuggerah Lake and Budgewoi Lake
2. Budgewoi surrounds both Budgewoi Lake and Lake Munmorah
3. Some properties contain multiple buildings (flats, villas or caravans)

Wyong Shire Council engaged WMAwater (formerly Webb, McKeown & Associates) to prepare a Floodplain Risk Management Study and Plan for Tuggerah Lakes. The objectives of the Study are to identify and compare various management options, including an assessment of their social, economic and environmental impacts, together with opportunities to enhance the foreshore and floodplain environments. The primary aim of the Plan is to reduce the 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 and risk.

A glossary of flood related terminology is provided in Appendix A.

3.2. Floodplain Risk Management Process

As described in the Floodplain Development Manual (Reference 1), the Floodplain Risk Management Process entails four sequential stages:

Stage 1: *Flood Study*
Stage 2: *Floodplain Risk Management Study*
Stage 3: *Floodplain Risk Management Plan*
Stage 4: *Implementation of the Plan*

The Tuggerah Lakes Floodplain Risk Management Study and Plan constitutes the second and third stages in the process. The Flood Study stage was completed in September 1994 with publication of the Tuggerah Lakes Flood Study (Reference 2) and the Compendium of Data (Reference 3). In this study a one-dimensional (1D) hydraulic computer model was used to determine design flood levels for the foreshore areas of Tuggerah Lakes across the full range of design events.

3.3. History of Flooding

Historical records (started in 1927) show that periodically the level of the lake has rose in response to heavy rainfall over the catchment. This has resulted in inundation of land and occasionally of buildings (Figures 3 and 4). Accurate recordings of lake levels have only been available since installation of the Toukley and Killarney Vale gauges in 1985. Historical records show that the highest known level was 2.1 mAHD in 1949 with the most recent major events occurring in February 1990 (1.6 mAHD) and in June 2007 (1.65 mAHD). Accurate water levels records are available from water level recorders for these two events and these are shown on Figure 5. The dates and approximate peak lake levels of all known significant floods are shown in Table 3. Figure 6 provides ground contours (up to 6 mAHD) which indicates the extent of inundation for the historical events.

Table 3: Flood Events (in order of severity)

Date	Approximate Peak Lake Level (mAHD)
18 June 1949	2.1
Easter 1946	1.9
2 May 1964	1.9
1927	1.8
1931	1.8
10 June 2007	1.65
4 February 1990	1.6
4 March 1977	1.6
1963	1.5
1953	1.5
1941	1.5

NOTES:
1. Data obtained from the Flood Study (References 2 and 3).
2. Levels are an average of several recorded heights.
3. It is likely that several floods prior to 1970 may not have been recorded.

3.4. Tuggerah Lakes Flood Study, September 1994 (Reference 2)

The Flood Study was undertaken to determine flood behaviour for the 1%, 5%, 20% and 50% AEP floods and the PMF. The results, based on frequency analysis and hydrologic/hydraulic computer modelling of the lake system, are shown on Table 4.

Table 4: Design Flood Levels

Event	Flood Level (m AHD)
PMF	2.70
1% AEP	2.23
5% AEP	1.80
20% AEP	1.36
50% AEP	0.91

Inundation of land surrounding the lakes due to flooding results from a combination of factors, as shown in Table 5.

Table 5: Factors Affecting the Peak Lake Level

Major Factors	Comments
Volume of Rainfall	Generally rainfall over a period of 2 to 5 days is required to produce an elevated lake level.
Size of the Outlet at The Entrance	The size (width and depth) of the outlet controls how much water is released from the lakes. During the flood the outlet becomes deeper and wider as the runoff carries the sand blocking the outlet into the ocean.
Volume of Temporary Floodplain Storage (including the area of the lakes)	At the peak of the 1% AEP flood (2.3 mAHD) over 160 000 ML (80 km^2 and 2 m deep) of runoff is temporarily stored in the lakes. This represents approximately 65% of the total runoff volume in the 1% AEP (48 hour duration) event. Changing the volume of temporary storage (e.g. filling the floodplain) will impact upon the peak level. Dredging of the lakes will have no impact as this would occur below the normal water level of 0.3 mAHD and would therefore contain water prior to the event. Lowering the normal water level would provide more temporary floodplain storage and thus reduce the peak level.
Initial Water Level	The water level can fluctuate from say 0.1 mAHD to over 0.5 mAHD which produces a significant change in the available temporary floodplain storage capacity.
Minor Factors	**Comments**
Intensity of Rainfall	It is the volume of rainfall rather than the peak intensity of rainfall which is more important.
Antecedent Catchment Moisture Conditions	The "wetness" of the catchment prior to the rainfall event determines the volume of runoff. Generally if the catchment is "very dry" prior to the event it will "soak" up a lot of the rainfall and produce less runoff than from a "wet" catchment.
Level of Catchment Development	Sealing of pervious areas (houses, roads, factories, etc.) will increase the volume of runoff. However it is considered that the present extent of development has had only a minor impact, as it represents only a small percentage of the total catchment area.
Catchment Deforestation or Other Agricultural Changes	These activities will tend to increase the volume of runoff. It is considered that these changes have had only a minor impact upon runoff volumes during a flood.
Evapo_transpiration	Any change in the amount of evapo-transpiration will produce only a

	minor change in the total runoff volume.
Wind or Wave Activity within the Lakes	Strong winds may elevate the water level from one side of Tuggerah Lake to the other by a maximum of ±0.2 m. The Flood Study concluded that in normal circumstances it is much less and this factor has been ignored in the design flood analysis.

3.4.1. Frequency Analysis

The frequency analysis was based on data collected in the period 1927 to 1992. The data available prior to 1961 are very limited (only six events), however these were included in the analysis as the period contains four out of the five highest recorded levels. A summary of the available data is shown in Table 6 (includes June 2007).

Table 6: Summary of Historical Flood Data (mAHD)

Number of events above 2.0 m (2% AEP)	1 - June 1949 (2.1 m)
Number of events above 1.8 m (5% AEP)	5
Number of levels above 1.6 m (10% AEP)	7
Highest events in recent times	4th February 1990 (1.6 m) and 10th June 2007 (1.65 m)
Third highest event in recent times	February 1977 (1.59 m)
Average rainfall period to produce a flood	5 days
Amount of rainfall to produce a flood	>300 mm

The study concluded that the quality of the historical height data is poor and greater reliance should be placed on the hydrologic/hydraulic modelling. It should be noted that the June 2007 event was unusual in that the flood peak occurred approximately 36 hours after the start of the rain (Figure 5). This rapid rise in the flood peak (from 0.3 m to 1.4 mAHD in 24 hours) was also experienced at Lake Macquarie.

3.4.2. Hydrologic/Hydraulic Modelling

A WBNM hydrologic computer model was set up to cover the entire catchment area (750 km^2) to the outlet at The Entrance. This model calculates flows based on the rainfall over the catchment. The flows are input to a Mike-11 hydraulic computer model which determines the water level in the lakes. Both models were calibrated to historical data (February 1992, August 1990, February 1990 and May 1974). As this study was completed in 1994 it did not include the June 2007 event.

Design rainfalls from Australian Rainfall and Runoff were input to the hydrologic model. The hydraulic model determined that the 48 hour storm produced the highest lake level and this was adopted as the critical storm duration. The rate of rise of the water level in the 1% AEP event is approximately 0.1 m per hour and the water level peaks approximately 40 hours after the start of the rainfall (Figure 5).

The peak lake level is dependent upon the dimensions of the outlet channel at the Entrance. If there is no opening to the ocean water levels will rise to the crest of the foreshore dune before overtopping and subsequent erosion of the dune occurs. For design analysis the dimensions were obtained from the results of an entrance breach model that was calibrated for the historical floods. Sensitivity analysis showed that the 1% AEP level could be reduced by up to 0.1 m by assuming other breach parameters. It was concluded that the hydraulic modelling could be improved by undertaking a long term data collection programme to better define the breach processes.

Joint probability analysis was used to investigate the relationship between ocean levels and catchment runoff. It was concluded that, based on the available data, the storms which produce severe rainfall over the catchment do not necessarily result in significant elevated ocean levels. The ocean conditions adopted for design are shown in Table 7.

Table 7: Adopted Design Ocean Conditions

AEP	Elevated Ocean Level (mAHD)	Wave Conditions Used for Set Up
1% AEP	1.32	4.5 Hs
20% AEP	0.6	4.5 Hs
50% AEP	0.6	none

Note: Hs is the average of the highest one_third of waves observed in a wave record.

Sensitivity results showed that the 1% AEP level was reduced by 0.2 m if a 0.6 mAHD ocean level and no wave set up was assumed (as used for the 50% AEP event).

3.4.3. Results and Recommendations

The results showed that a uniform peak water level was applicable to all three lakes and the accuracy of the 1% AEP level was considered to be ±0.15 m. Design flood extents and hydraulic hazard are shown on Figures 7 and 8. The provisional hydraulic hazard was assumed as HIGH if the water depth is greater than 0.8m and LOW if less than 0.8m in the design event.

The report recommended that long term data be collected at the entrance to the Pacific Ocean and streamflow gauging at the upstream river gauging stations be improved.

3.4.4. Conclusions

The Flood Study has been rigorously carried out based on the technology and approach available at the time and provides accurate estimates of the design flood levels. The Mike-11 hydraulic model has been successfully calibrated and tested, potentially providing a suitable tool for use in this Floodplain Risk Management Study for assessing floodplain management measures. Unfortunately the entrance breach mechanism adopted in the Mike-11 model for the Flood Study has been superseded and cannot now be re-run. A completely new breach mechanism would have to be applied which would then involve a re-calibration and re-doing the design flood level analysis.

Two Dimensional (2D) hydraulic models are now widely available and provide more accurate estimation of local velocities and flow direction across the floodplain. However such a model would not provide a significant advantage over the Mike-11 model as the key factor is simulation of the entrance breaching process and 2D models are no better than Mike-11 in this regard.

Data collected from future floods should be used to re-assess the model calibration of the entrance breaching process where appropriate as the entrance breach modelling is the critical factor in determining design flood levels. As data on the entrance hydraulics becomes available these should be used to refine the entrance breach model.

Unfortunately for the reasons given above the Mike-11 model cannot be re-run for the June 2007 event and it would appear that no data on the entrance hydraulics during the June 2007 event are available.

3.4.5. Tuggerah Lakes Flood Study, Compendium of Data, 1993 (Reference 3)

This study provides a comprehensive description of:

- previous flood studies undertaken within the area, including the tributary creeks,
- historical flood events since 1867,
- water level and rainfall recorders,
- survey and mapping information,
- references regarding flooding.

3.4.6. Tuggerah Lakes Flood Study, Flood Forecasting System, September 1995 (Reference 4)

As part of the Flood Study (Reference 2) a Flood Forecasting System (FFS) was established based on the Mike-11 Flood Forecasting model. The FFS was commissioned in 1993 and utilised data from seven rain gauges and four river height gauges. The data are captured using the ALERT system. The reliability of the flood forecasting system will increase as more flood data become available and the system is recalibrated. To date the system has not been tested in a real time situation as it would appear it was not in operation for the June 2007 event.

3.5. Mine Subsidence

The Mine Subsidence Board is a service organisation operating for the community in coal mining areas of NSW and is responsible for administering the Mine Subsidence Compensation Act. The Act provides for compensation or repair services where improvements are damaged by mine subsidence resulting from the extraction of coal. The Act also makes the Board responsible for reducing the risk of mine subsidence damage to properties by assessing and controlling the types of buildings and improvements which can be erected in Mine Subsidence Districts.

Mine subsidence may result from current or future mining and the approval to mine is controlled by the Department of Mineral Resources through a comprehensive application process, which includes consideration of existing surface development. The amount of subsidence will influence the extent of damage that may occur and commonly this is hairline cracks to walls and cornices, and fine cracks to brickwork.

In NSW, if a home or other improvement is damaged as a result of subsidence following the extraction of coal, the owner's rights are protected by the Mine Subsidence Compensation Act. Buildings built outside of and prior to the proclamation of a Mine Subsidence District are automatically covered for compensation. However, homes and other structures built in contravention of, or without, the Board's approval in a Mine Subsidence District, are not eligible for compensation in the event of damage due to mine subsidence. Claims can be made for damage to improvements and for damage to household and other effects.

Development applications in mines subsidence areas must obtain approval from Wyong Council as well as the Mines Subsidence Board. The Mines Subsidence Board generally applies an additional freeboard. A “generic” freeboard amount is difficult to obtain as individual collieries are contacted for every development application.

The Mines Subsidence Board has indicated that the northern part of Tuggerah Lakes (north of the Wyong River in the west and Norah Head in the east) is within a mine subsidence area. The magnitude of subsidence could be between 0.1m and 0.6m. The magnitude of the subsidence means that existing buildings could become flood liable if subsidence occurs. At present the amount of subsidence is not included in the Minimum Floor Level Policy, however this should be re-considered by Council (if appropriate information is provided by the Mines Subsidence Board), particularly in light of potential similar magnitude climate change increases in flood level.

4. STUDY AREA

4.1. Land Use

The land within the floodplain surrounding the lakes is presently classified under a number of different zonings. The predominant zonings are:

- Rural 1(c) - Rural holdings
- Residential 2(a) - Single dwelling
- Residential 2(b) - Multiple dwellings
- Business 3(a) - General business
- Business 3(c) - Neighbourhood business
- Special Use 5(a) - Special use
- Open Space 6(a) - Open space and recreation
- Open Space 6(b) - Regional open space
- Environmental Protection 7(a) Conservation
- Environmental Protection 7(b) Scenic protection

The Tuggerah Lakes system is an attractive feature of the local area. Residents enjoy views across the water and use the lakes for recreation (swimming, fishing, boating). The lakes are the major tourist feature of Wyong Shire and a significant tourist industry has developed along the foreshores and at the entrance. The lakes are not used for commercial purposes other than for providing cooling waters for the Lake Munmorah power station and fishing.

The main features of the lake foreshore are:

- The majority of the residential developments fronting the lakes (southern and northern shores of Tuggerah Lake, western, northern and southern shores of Budgewoi Lake, and the southern and northern shores of Lake Munmorah) are located on high ground which slopes gradually down to the water. The majority of these are not affected by elevated lagoon levels. However, the gradual slopes, particularly in Killarney Vale, Tumbi Umbi and Berkeley Vale means that the floodplain extends several hundred metres into the developments.
- There are extensive areas of open space surrounding the water (Tuggerah, North Entrance Peninsular Nature Reserve, Crown Land at Toukley, land adjoining Lake Munmorah power station and on the eastern shore of Lake Munmorah).
- The main residential developments affected by flooding are on the southern shore of Tuggerah Lake and along the mouths of the Wyong River and Ourimbah Creek.
- During a large flood the floodplains of Ourimbah Creek, Wyong River and Tuggerah Lakes combine to inundate over 10 km^2 of land east of the main northern railway line.
- There are few vacant residential, commercial or industrial lots surrounding the lake foreshore. The majority of future activities will be the re-development or extension of existing land use activities. In recent years there has been a limited amount of subdivision for residential dual occupancies and other higher density usage.
- There are few non-residential usages around the foreshore apart for tourist related

developments, particularly at the Entrance.

- There are a number of tourist facilities on the foreshore including over 10 caravan or other holiday tourist parks (Figure 2), motels, private and public jetties and parks.

4.2. The Entrance Channel

Water levels in the lake are primarily controlled by the entrance channel which connects Tuggerah Lake to the ocean. The channel is approximately one kilometre long and is characterised by numerous shoals. At the bridge it is approximately 350 m wide (between the abutments). As the volume of the lake is so large less than one percent is exchanged in each tidal cycle. The entrance channel has been modified by human activities notably by construction of the bridge and more recently by dredging of the entrance channel.

The channel has responded to natural and man-made effects through changes in the pattern of erosion and sedimentation. These are natural phenomena which will always occur regardless of what man-made works are implemented. During a flood it is likely that the entrance channel will be scoured out initiating a new regime of erosion and sedimentation. Waves have washed over the narrow strip of land in the north east corner of Budgewoi Lake (see photograph below).

Some experts are of the view that the entrances to coastal lakes such as Tuggerah Lakes or Lake Macquarie should not be controlled as this disrupts the natural estuarine processes and consequently the ecology of the lake. Solving one problem with man-made works tends to impact upon other areas. Management of the estuary and lake environs must therefore consider the broad implications of any works and the inter-relationships.

Many residents are concerned about sedimentation in the entrance channel restricting the outflow of floodwaters whilst others are concerned about the water quality and recreational attributes of the area affecting tourist activities.

The following photographs provide a brief description of the nature of the entrance channel.

Outflow in June 2007 flood

Entrance channel in June 2007 flood

Entrance channel - February 1990 flood

Entrance channel – June 2007 flood

Entrance in 1995

Entrance in 1996 showing dredge operating

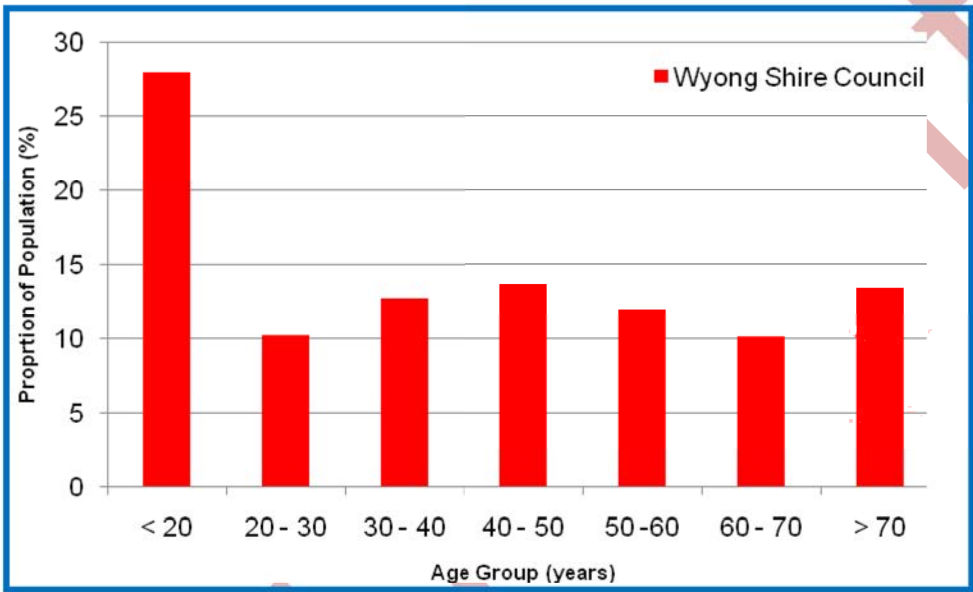
Entrance in 2010

Dredge operating at entrance

North east corner of Budgewoi Lake where waves have washed across

4.3. Community Demographics

An age-based breakdown of the Wyong Shire Council LGA community is provided in the chart below. As is evident in this data, the Tuggerah Lakes region is home to a large population of young families (school-age children with 30-50 year old parents), and a substantial elderly community. 90% of the Wyong Shire population resides in separate houses, 6% in semi-detached dwellings, 3% in flats, units, or apartments, and the remaining 1% in other dwelling types such as caravans, cabins and houseboats.



In 1998 Wyong Shire Council commissioned a demographer to compile a report projecting the population growth in the Wyong LGA based on 1996 census data. According to this report – *Wyong Shire Population Projections, 1996 to 2021*, the local population is set to expand by 40% to 196,000 people by 2020.

In terms of the built environment, the shores of the Tuggerah Lakes are primarily dominated by residential and commercial zones with only two major tracts of undeveloped land: one of these stretching from Rocky Point to the north, to Chittaway Point to the south along the western foreshore of Tuggerah Lake; and the other incorporating Wyrrabalong National Park, starting in the north at Norah Head and continuing south to Magenta on the Budgewoi peninsular, separating Tuggerah Lake and the Pacific Ocean.

4.4. Environmental Summary

The following section was taken from the Summary of the June 2005 Tuggerah Lakes Estuary Management Study.

The Tuggerah Lakes estuary was formed some 6,500 years ago when sea level rose after the last ice age. Most of the geomorphic features of the estuary are no longer active, except for the river deltas of Wyong and Ourimbah Creeks and the tidal delta at The Entrance. Sedimentary *processes within the estuary are slow, with no evidence for general depth changes since comprehensive bathymetry studies in the 1970's. There are however, small-scale changes with some places becoming shallower around inflows (e.g. Tumbi Creek) whereas other places have become deeper, some due to the effects of mine subsidence. The Tuggerah estuary is one of the slowest infilling estuaries on the NSW coast, and at current rates, would take over 1000 years to fill completely. Tidal flushing contributes very little to circulation and mixing patterns. The bottom sediments within the estuary are relatively "healthy" apart from small-scale problems in some areas. Investigations on pollutants within the sediments indicated very small amounts of pesticides whilst heavy metals were below those found to cause adverse ecological effects. The sediments within the estuary have significant concentrations of nutrients which are available for plant growth. Nutrient concentrations within the water column are above the water quality guidelines and the estuary can be classified as having a medium nutrient status.*

The entrance is now kept open to the sea by a sand dredge, which allows some limited flushing and mixing to occur, however, the overall effects of flushing are small when the size of estuary is taken into account. As there are no new sources of marine sands entering the estuary, the eastern shorelines have become siltier and in areas where there is continued organic enrichment, "organic oozes" can still be found.

Management of the wider catchment has improved with greater controls on development and farming. The completion of the sewerage scheme has also helped to reduce the amount of nutrient entering the estuary via septic systems and overflows. During heavy rain, nutrients and sediment still enter the estuary from stormwater and from the major tributaries. Symptoms of eutrophication still occur, especially around some of the developed foreshores, as small-scale blooms of drift macro-algae. The processes that drive these blooms are still being examined however their ability to damage the underlying benthic community is without question as is the role the benthic animals play in nutrient cycling.

The turbidity in the estuary has decreased since the 1980's and whether this was due to reduced patterns of rainfall and/or reduced concentrations of suspended material in the water column is unknown. The extent of seagrass habitat within the estuary has not increased since its decline during the 1980's. Anecdotal evidence suggests that there has been some re-colonisation of seagrasses into shallow areas around the estuary, which may have been lost. The salt marshes of the estuary have continued to decline as a result of disturbance and establishing their role in nutrient cycling proves and wrack assimilation is very important.

The process study found that Tuggerah Lakes estuary was "healthier" than it was during its eutrophic stage in the 1980's and 1990's. The question is whether this level can be sustained with increased future development or whether the system would be pushed over some threshold, returning it to the previous eutrophic state of the 1980's.

4.5. Community Consultation

4.5.1. Approach

Council was responsible for all of community consultation procedures and several measures were employed by Council as part of the initial community consultation phase of this floodplain risk management study, including:

- A survey was posted to all of the residential and commercial properties located in the 1% AEP flood extent,
- The survey was also available on Council's website for download or completion and submission electronically,
- Presentations were undertaken at all of the Precinct and/or Progress Associations located around the Tuggerah Lakes foreshores,
- There was ongoing advertising in the local papers regarding all of the above means of communications.

4.5.2. Community Survey

The community consultation survey newsletter/questionnaire is included in Appendix B. The aim of the survey was to gain an understanding of the existing flood knowledge of the community, the community's experience with previous flood events in Tuggerah Lakes, and what management measures the community thought should be used to manage the flood risk. Respondents were also requested to list any additional information or comments.

Approximately 6,500 surveys were posted out at the end of January 2010, and by the end of March 2010, the closing date for responses, Council had received 1,285 responses. 10 of these were completed and submitted online via Council's website, 12 were hand delivered to Council, and the remainder of the surveys were received by post. Additional surveys were received by Council after the March 31st 2010 closing date but these were not included in the survey results. Council officers undertook some 12 visits to private residences to discuss the survey, as some residents were not comfortable putting their comments in writing.

The survey results indicated that over 90% of respondents were owner/occupiers of their property, with an average age of ownership of almost 30 years. Only 33% of respondents had not experienced flooding at their property. Of the remaining, 18% had experienced floodwaters in the house or work, and 58% had experienced floodwaters entering into their backyard.

The majority of the respondents were living or working in the area during the June 2007 flood event and a number of respondents were living in the area when the February 1990 flood event occurred.

Table 8 summarises the surveys responses regarding floodplain risk management measures suitable for use in the Tuggerah Lakes catchment. Different management measures were listed and respondents were asked to rank these options in order of their preference. Number 5 indicated the most preferred method and number 1 the least preferred method.

Table 8: Summary of Community Views on Management Measures

	Most preferred		Least preferred	
	Rank	%	Rank	%
Recognition of natural flowpath	5	59%	2,4	7%
Vegetation control	5	45%	2,4	5%
Building development controls	5	42%	2,4	5%
Educating the community	5	42%	2,4	6%
Flood forecasting, flood warning, evacuation planning and emergency response	5	34%	2,4	8%
Floodgates or levee banks	5	23%	2,4	9%
Opening or dredging the entrance channel	5	68%	2,4	3%
Voluntary house purchase	1	24%	2,4	9%
House raising	3	24%	2,4	11%

The survey highlighted the fact that 36% of the respondents had not looked for any information in relation to the flood or flood risk of their property. This result was surprising a the survey was sent out only to those properties located within the 1% AEP flood extent, and more than 74% of respondents had experienced some form of flooding in either the June 2007 or February 1990 flood events.

4.5.3. Presentations at Precinct / Progress Associations

Council staff made presentations at the following community groups between February and May 2010:

- Bateau Bay / Killarney Vale Precinct Committee,
- The Entrance Community Precinct Committee,
- The Entrance North Progress Association,
- Lake Munmorah /Chain Valley Bay Community Precinct Committee,
- Lake Munmorah / Chain Valley Bay Precinct Committee,
- Budgewoi / Buff Point Precinct Committee,
- North Wallarah Precinct Committee.

The key views from these presentations were:

- the apparent lack of flood knowledge of the residents and commercial operators who live or work around the Tuggerah Lakes area,
- the community appeared to have little understanding of the flooding characteristics of the Tuggerah Lakes and considered that the June 2007 and February 1990 events were equivalent to a 1% AEP flood event (in reality less than a 5% AEP event),
- the community's impression is that a permanent opening of the entrance channel would have a significant impact on reducing flood levels in Tuggerah Lakes,
- the community has little understanding of emergency management procedures and that the SES are the agency responsible for emergency management (not Wyong Council) and help during flood emergencies,
- in summary there was a lot of interest from the community to further their knowledge and to contribute to Council's floodplain management plan for Tuggerah Lakes.

The key views on floodplain management measures were:

- the majority of the community would like a permanent opening at the Entrance Channel (some raised concern over the possible ecological impacts) and/or a breakwall at the Entrance – sandbags or permanent structure (with possibility of a marina),
- concerns were raised regarding adequate drainage / blocking of drains / Council maintenance of drains (or lack of),
- a second outlet to the ocean at Budgewoi Lake was suggested,
- siltation of the lakes is occurring and this requires regular dredging required,
- traffic during flooding causes further damage – strategies are required to manage traffic during floods,
- over development of flood prone land has occurred exacerbating flooding and increasing runoff,
- there is the potential to capture stormwater runoff,
- community education – how people can reduce the impacts of flooding e.g. capture by rain water tanks, and how to react in a flood situation / where to go / warnings / assistance especially for elderly,
- flooding affects insurance premiums and house values,
- there was some general acceptance of flooding as a natural phenomena,
- acceptance of Council's minimum floor level policy,
- there should be some notification to potential buyers / tenants of the flooding potential,
- the community was interested in climate change issues.

5. EXISTING FLOOD ENVIRONMENT

5.1. Flood Behaviour

Flooding of the foreshore area of the lakes can result from a combination of the following:

- significant rainfall in the catchment. The lake level rises as the inflow from the catchment and direct rainfall over the lakes exceeds the outflow to the ocean,
- elevated ocean levels resulting from the astronomical tide, barometric and wind setup and wave setup force water into Tuggerah Lake,
- wind waves across the lake breaking on the foreshore and "running up" the foreshore. The extent and magnitude of this effect depends on the wind speed, wind direction and nature of the foreshore topography (land slope, presence of vegetation or man made structures that may restrict the wave impacts),
- rainfall over the local catchment being unable to drain away quickly and ponding in low spots. This is usually termed local flooding and causes inconvenience but generally no above floor inundation. It is exacerbated by elevated lake levels.

Flooding which occurs primarily as a result of intense rainfall over the catchment is termed ***rainfall dominated or induced*** flooding, whilst if flooding occurs primarily from tidal and oceanic influences it is termed ***oceanic or wave dominated/induced*** flooding. The influence of the two mechanisms will vary between events.

5.2. Hydraulic Classification

The Floodplain Development Manual (Reference 1) defines three hydraulic categories which can be applied to areas of the floodplain; floodway, flood storage and flood fringe.

Floodways are "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 flow, or a significant increase in flood levels". At Tuggerah Lakes the floodway areas are considered to be any land below approximately 1 mAHD that front onto the lakes (refer Figure 6). There are several areas below 1 mAHD that do not front the lakes (particularly in the Wyong River floodplain), these are not classified as floodway.

Flood storage are 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."

Flood fringe is "the remaining area of flood prone land after floodway and flood storage areas have been defined".

There is no precise definition of flood storage and flood fringe or accepted approach to differentiate between the two areas. For this study it was assumed that all the land on the perimeter of the lakes outside the floodway areas and not within the floodplain of the Wyong River, Ourimbah Creek or Wallarah Creek is flood fringe. Land beyond the perimeter of the lakes and within the floodplain of the Wyong River, Ourimbah Creek or Wallarah Creek is flood storage. A precise line distinguishing flood fringe from flood storage has not been determined as part of this study as it would require detailed investigation.

5.3. Flood Hazard Classification

The Floodplain Development Manual (Reference 1) determines the *provisional flood hazard* categorisation of an area based on the combination of the depth and velocity of floodwaters on the land. As the flood fringe and flood storage areas surrounding the lake have effectively nil velocity the provisional hazard categories were derived based solely upon the depth of inundation. If the depth is > 0.8m then the provisional hazard is HIGH, if the depth is < 0.8m then the provisional hazard is LOW. This is shown on Figure 8 for the 1% AEP event.

Flood hazard is a measure of the overall adverse effects of flooding. As well as considering the provisional (hydraulic) hazard it also incorporates threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production. As with provisional (hydraulic) hazard, land is classified as either *low* or *high* hazard for a range of flood events. The classification is a qualitative assessment based on a number of factors as listed in Table 9.

Table 9: Hazard Classification

Criteria	Weight [(1)]	Comment
Size of the Flood	High	Up to a (say) 20% AEP event the damages are confined to isolated properties. In larger floods the damages are increased significantly inundating large parts of Berkeley Vale, Tumbi Umbi and Killarney Vale.
Flood Awareness of the Community	High	Whilst residents are aware that the lake level rises during a flood the magnitude of the rise in (say) a 1% AEP event will be much greater than what is expected by the majority of the community.
Depth and Velocity of Floodwaters	Low	Shallow depths (generally less than 0.5 m) and very low velocity.
Effective Warning and Evacuation Times	Medium	Probably only 6 hours. There is only a very small likelihood that residents would be caught completely unaware, but they are unlikely to have the foresight to react appropriately to the situation.
Evacuation Difficulties	Medium to High	For the majority evacuation should be relatively easy as there is nearby high ground for vehicles and the majority of goods can be saved by raising them (say) 1 m off the ground within the building. However the number of buildings/people requiring assistance will severely extend the services of the rescue services (SES, Police, etc.) with the main areas on the southern shore of Tuggerah Lake. At Tacoma and Chittaway Point the hazard is significantly increased due to the distance (> kilometre) to high ground.
Rate of Rise of Floodwaters	Low	The rate of rise of floodwaters in lake systems is slow compared to river systems. The average rate was approximately 50 mm/h in February 1990 while the average rate for the 1% AEP design event is approximately 100 mm/h. However peak rates of up to 300 mm/h were recorded in June 2007. Whilst the rate of rise is slow this must be considered within the context that only a small rise is needed to inundate a large number of buildings.
Duration of Flooding	High	The duration of inundation is much longer than on a river system. The lake may be near its peak for (say) 24 hours (Figure 5). However, this extended duration is unlikely to add significantly to the damages but will

		increase the risk to life (more crossings) and will add considerably to the level of inconvenience and the recovery time.
Effective Flood Access	Low to Medium	The vehicular and pedestrian access routes are all along sealed roads and present no unexpected hazards if the roads have been adequately maintained. Boats can effectively be used to ferry residents to high ground. In events up to the 1% AEP flood four wheel drive access is possible. In larger events with greater depths (above 0.5 m) other forms of transport will be required. The main problem will be congestion due to the number of vehicles.
Additional Concerns such as Bank Erosion, Debris, Wind Wave Action	Low	The impact of this factor will vary between events and even within a flood event as the wind direction changes. It will have its greatest impact within (say) 50 m of the shoreline. The impact of debris is unlikely to be a factor except in the most extreme cases where major floating objects (boats broken from their moorings, timber and debris picked up from upstream floodplains) come into contact with buildings or residents. Erosion or sedimentation during a flood event is also unlikely to be a significant factor except in areas of high wind/wave activity, along the entrance channel (high velocities). Wind set up may raise water levels by up to 0.2 m. The Flood Study did not consider the effect of wave runup.
Provision of Services	High	In both the February 1990 and June 2007 floods the sewerage system was turned off at several pump stations. For June 2007 this information is summarised on Figure 8. The reasons why the various parts of the system was shut down is varied but it would appear that the loss of power was the main reason. In parts the system was off for up to 4 days. This meant that all properties (inundated by floodwaters or not) were without a sewerage system and once the holding tanks were full raw sewage was discharged into Tuggerah Lakes presenting a significant health risk to residents. Apart from power failure it is understood that water supply was maintained in both February 1990 and June 2007.

Note: (1) Relative weighting in assessing the hazard.

Based on the above assessment, the hazard at Tuggerah Lakes would be increased to HIGH for the majority of inundated properties. None of the factors in Table 9 produce a decrease in the flood hazard. It is not possible to accurately map the properties that have a LOW provisional hazard that then become HIGH hazard with consideration of the factors shown in Table 9.

The general hazard classification will increase in isolated areas where the general depth of above ground inundation exceeds 1 m and/or there is a risk of isolation and difficulties for evacuation. These include:

- Chittaway Point,
- Tacoma South,
- Tacoma.

In floods greater than the 1% AEP (Figure 8) the hazard will increase as the depth increases. For the majority of areas the increase will be gradual and residents will be able to escape to high ground. In a PMF event the main areas of High Hazard are the same as for the 1% AEP event, with the addition of The Entrance North. In the 1% AEP and greater events the road (Wilfred Barrett Drive) protecting The Entrance North will be overtopped and the area will require evacuation. Once the levee is overtopped the rapid influx of floodwaters will significantly increase the flood hazard.

As an outcome of this present study the flood hazard will consider the impacts of climate change on flood levels. The effect of mine subsidence is generally less than 100mm and has to date been included within the freeboard allowance.

Flood hazard mapping taking into account sea level rise is discussed in Section 8.

5.4. Flood Risk and the Social Impacts of Flooding

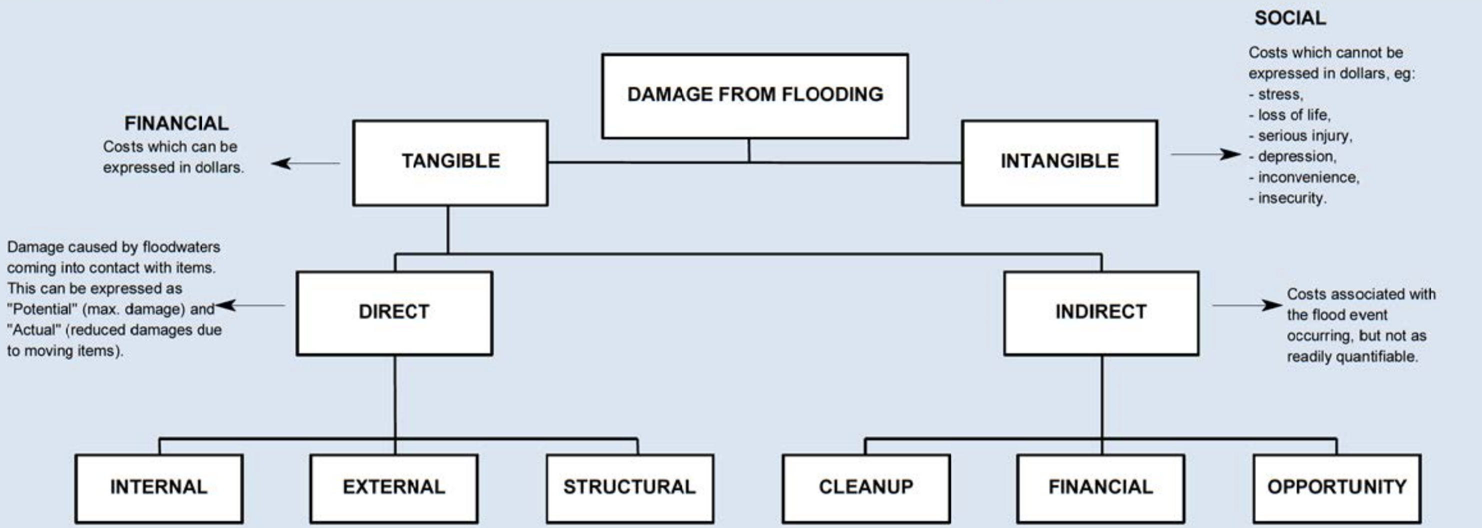
The costs of flood damages and the extent of the disruption to the community depend upon many factors including:

- the magnitude (depth, velocity and duration) of the flood,
- land usage 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 erosion of the lake foreshore, failure of services (sewerage – refer Figure 9), flood borne debris, sedimentation and wind/wave runup.

In order to quantify the effect of inundation on the existing development along the foreshore a floor level database was provided by Wyong Shire Council for use in this study. This database was originally prepared in the early 1990's by field survey but was updated in 2009 by Wyong Shire Council as part of the present study. The number of buildings with floors near to or above the PMF (2.7 mAHD) is unreliable as the cost to undertake a full re-survey could not be justified (approximately $80 per building and possibly > 1000 buildings). The database also included some 70 non residential properties (out of over 2500) including, shops, service stations, motels, caravan parks, child care centres, senior citizen centres and some foreshore developments (boat hire, sailing clubs). Unfortunately the database did not identify which feature of the property was identified by the floor level assigned to the property (whether a small shed or a substantial building). As the focus of this floodplain management study is on residential properties, given the relatively small number of non-residential properties identified and the fact that many are on the foreshore as part of their function (boat hire) a full re-survey of these properties was not justified and existing information considered appropriate for this study.

Flood damages can be defined as being "tangible" or intangible". Tangible damages are those for which a monetary value can be assigned, in contrast to intangible damages, which cannot easily be attributed a monetary value. A summary of the types of damages is provided in Table 10.

Table 10: Flood Damages Categories



	INTERNAL	EXTERNAL	STRUCTURAL	CLEANUP	FINANCIAL	OPPORTUNITY
RESIDENTIAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Laundries, Caravans, Sheds, Tools, Gardens, Fences	Physical Damage to Buildings: Gyprock, Cupboards, Scour of Footings, Houses becoming buoyant (floating off footings)	Clean Carpets, Walls, Clothes; Re-instate Furniture; Remove Mud and Debris	Loss of wages, Living costs (temporary accomodation and food), Time to repair/replace damaged items	Not Applicable
RURAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Sheds (stables/barns), Machinery, Tools, Fences, Feed storage, Saddles, Crops &/or Stock, Irrigation Systems	Physical Damage to Structures: Damage to Homestead, Sheds, Access tracks, Protection levees	Clean Homestead and Out-buildings; Remove Debris; Dispose of affected crops &/or stock	Loss of Farm Production and Income, Re-instatement of Pastures, Supplementary feeding of stock (by hand or outside agistment), Stock movement/ transport, Living costs (temporary accomodation and food)	Sowing or harvesting of Crops, Sale of Stock (at depreciated value or dependent on market influences)
COMMERCIAL	Contents of Buildings: Products, Stock, Fittings, Tools, Machinery, Raw Materials	External Items: Vehicles, Machinery, Display, Raw Materials/Stockpiles, Fences	Physical Damage to Buildings	Dispose of damaged products, stock, materials; Cleaning and Re-instatement	Loss of Productivity and Income, Bank Interest Charges	Loss of existing &/or Potential Trade
PUBLIC AUTHORITIES	Contents of Public Buildings and Facilities	Public Property and Facilities: Parks, Signs, Machinery, Equipment	Physical Damage to Infrastructure: Electricity, Water, Telephone, Gas, Road & Rail Transport Links	Remove Mud & Debris from Facilities, Public & Private Property Repairs (temporary & permanent)	Disruption of Services, Community Service Relief Grants	Provision of Public Service

5.4.1. Tangible Flood Damages

Tangible flood damages are comprised of two basic categories, direct and indirect damages. Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or a reduction in 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 including the cost of temporary accommodation, loss of wages by employees etc.

While the total likely damages in a given flood are useful to get a “feel” for the magnitude of the flood problem, it is of little value for absolute economic evaluation. When considering the economic effectiveness of a proposed mitigation option, the key question is what are the total damages prevented over the life of the option? This is a function not only of the high damages which occur in large floods but also of the lesser but more frequent damages which occur in small floods.

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. By this means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods. For the calculation of AAD at Tuggerah Lakes it was assumed that there are no flood damages in the one year event.

A flood damages assessment was undertaken for existing development in the Tuggerah Lakes community and is summarised in Figure 10 and Tables 11 and 12. It should be noted that a significant contribution to the average annual damages is the houses inundated in the 20% AEP and smaller events.

Table 11: Summary of Building Floors Inundated

Floodplain Management Area (Table 2)	AEP								PMF
	50%	20%	10%	5%	2%	1%	0.5%	0.2%	
BL1	0	10	37	66	132	171	199	221	287
EX1	0	3	8	16	42	52	62	69	101
LM1	0	5	20	41	87	122	154	186	249
TL1	0	1	11	36	84	129	159	194	238
TL2	0	1	5	12	61	111	149	178	241
TL3	0	1	2	12	31	65	96	123	204
TL4	0	5	24	68	160	224	275	299	390
TL5	0	9	26	56	137	184	198	214	244
TL6	0	6	21	40	119	176	206	236	279
TL7	0	3	13	24	53	78	98	119	183
Total	0	44	167	371	906	1312	1596	1839	2416

A graph of the building floors for each floodplain management area is provided below.

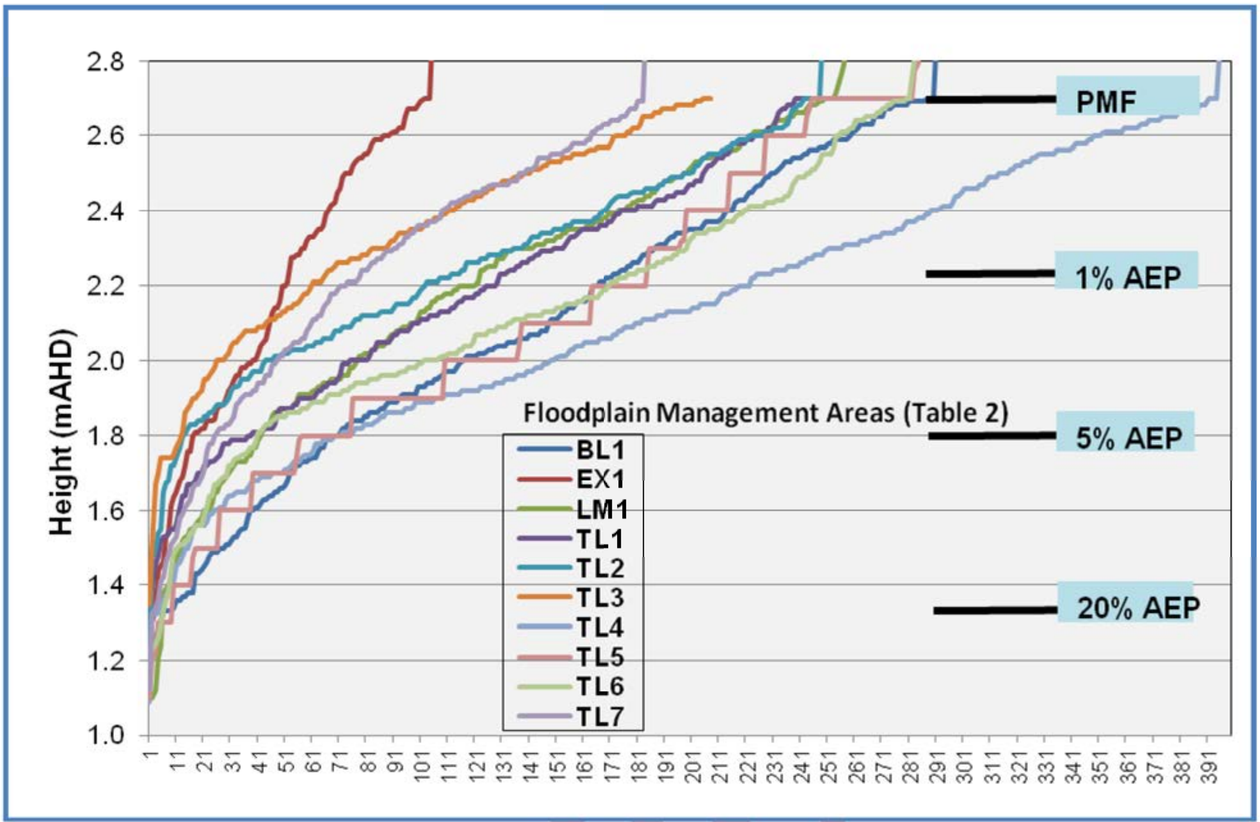


Table 12: Summary of Flood Damages

Area	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
BL1	$6,000	$137,000	$819,000	$1,865,000	$4,100,000	$6,302,000	$7,906,000	$9,352,000	$13,220,000
EX1	$0	$37,000	$180,000	$429,000	$1,163,000	$1,848,000	$2,353,000	$2,827,000	$4,258,000
LM1	$0	$127,000	$454,000	$1,079,000	$2,540,000	$4,099,000	$5,405,000	$6,748,000	$10,497,000
TL1	$1,000	$40,000	$223,000	$718,000	$2,281,000	$4,035,000	$5,466,000	$6,879,000	$10,572,000
TL2	$0	$25,000	$134,000	$352,000	$1,301,000	$2,837,000	$4,246,000	$5,643,000	$9,691,000
TL3	$0	$15,000	$67,000	$219,000	$767,000	$1,686,000	$2,609,000	$3,600,000	$6,967,000
TL4	$0	$75,000	$483,000	$1,511,000	$4,405,000	$7,436,000	$9,825,000	$11,897,000	$17,523,000
TL5	$0	$158,000	$703,000	$1,653,000	$4,012,000	$6,328,000	$7,934,000	$9,294,000	$12,608,000
TL6	$0	$93,000	$458,000	$1,086,000	$3,025,000	$5,381,000	$7,219,000	$8,878,000	$12,940,000
TL7	$6,000	$81,000	$312,000	$697,000	$1,607,000	$2,594,000	$3,440,000	$4,288,000	$7,166,000
Total	$13,000	$788,000	$3,833,000	$9,609,000	$25,201,000	$42,546,000	$56,403,000	$69,406,000	$105,442,000

* Tangible damages includes external damages which may occur with or without house floor inundation

The damages were calculated with use of a number of stage damage curves (that is, curves which relate flood depths with tangible damages) which were developed based on guidelines provided by DECCW.

Each component of tangible damages is allocated a maximum value and a maximum stage 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 damage has already occurred.

For the Tuggerah Lakes assessment internal damages were allocated a maximum value of $60,000 occurring at a depth of 2 m above the building floor level (and linearly proportioned between the depths of 0 - 2 m). Structural and indirect damages were grouped together and given a maximum value of $20,000 assumed to occur at 1.5 m depth above building floor level and linearly proportioned for the depths below this. External damages were allocated a maximum of $4,000 occurring at 0.5 m above the property ground level and linearly proportioned for depths below this.

Based on the above the average annual damages for the foreshore areas are $2.2 million.

5.4.2. Intangible Flood Damages

The intangible damages associated with flooding are inherently more difficult to estimate. In addition to the direct and indirect damages discussed above additional costs/damages are incurred by residents affected by flooding, such as stress, risk/loss to life, injury etc. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to several hundred times greater than the tangible damages) and depend on a range of factors including the size of flood, the individuals affected, community preparedness, etc. However, it is important that the consideration of intangible damages is included when considering the impacts of flooding on a community. An overview of the types of intangible damages likely to occur at Tuggerah Lakes is discussed below.

Isolation

Isolation will become a significant factor for local residents in areas such as Tacoma and Chittaway Point. There is also a high level of community support and spirit, which can to some extent negate the effects of isolation and can certainly assist in a flood (as happened in June 2007). However, isolation is of significant concern if a medical emergency arises during a flood.

Population Demographics

There are no particular features of the population demographics of the community on the foreshores of Tuggerah Lakes that would contribute to additional intangible damages (aged or particularly young population) except for a high proportion of visitors in tourist parks along the foreshore (Figure 2).

Stress

In addition to the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up etc.,) many residents who have experienced a major flood are fearful of the occurrence of another flood event and its associated damage. The extent of the stress depends on the individual. To some extent this does not appear to be a significant issue at Tuggerah Lakes as a number of residents experienced both the February 1990 and June 2007 events and did not indicate this as a problem in their responses to the community survey (Appendix B).

Risk to Life and Injury

During any flood event there is the potential for injury as well as loss of life. At Tuggerah Lakes the absence of high velocities as well as high flood depths (< 1m) means that the risk is smaller than in other flood liable communities. However the risk is increased due to the duration of inundation, the length of some evacuation routes and particularly the presence of polluted floodwaters due to overflows from shutting down the sewerage system.

5.5. Flood Awareness and Flood Warning

The flood awareness of the community and the available flood warning time are important factors in reducing the likely flood damages. Based on experience in other areas and discussions with local residents and others it is likely that the flood awareness of the community is medium to low. A contributing factor is that a percentage of the population will be temporary (holiday makers or possibly weekenders). However the available flood warning time is high for the following reasons:

- the lakes rise relatively slowly (say on average less than 100 mm per hour),
- Council operates a newly installed flood warning system based upon rainfall and river gauges (Reference 5),
- the residents will be aware of the water actually rising across their yards (unless at night),
- residents are generally aware that as the lakes rise they will inundate the surrounding foreshore areas. Residents who have been in the area for a few years will have experienced minor rises in the water level (and possibly the February 1990 and June 2007 events) and will be aware that larger events may occur causing more severe inundation.

Public sector (non-building) damages include:

- recreational/tourist facilities,
- water and sewerage supply,
- gas supply,
- telephone supply,
- electricity supply including transmission poles/lines, sub-stations and underground cables,
- roads and bridges including traffic lights/signs,
- costs to employ the emergency services and assist in cleaning up.

Damages to the public sector can contribute a significant proportion of the total flood costs. There are no accurate estimates of the amount of damages to the public sector in previous floods but there are limited records from the February 1990 flood (none available for June 2007) and these are listed in Table 13. It should be noted that these are for the whole of the Wyong Shire Council area. Individual items have been specified where data are available.

Table 13: February 1990 Flood – Estimate of Public Property Damages

Flood and Storm Damage to Roads (very little as a result of elevated lake levels)	$350,000
FLOOD DAMAGE TO WYONG SHIRE COUNCIL ASSETS	
Emergency Works	
• **minor damage to boat ramps and other facilities around the lake,**	$10,000
• **Jean Avenue boat ramp,**	$11,000
• **Colongra Bay boat ramp,**	$12,000
• **removal of flood debris,**	$14,000
• **desiltation of drainage pipes in Wyong Shire,**	$14,000
• **lightning damage.**	$11,000
Sub-Total	**$72,000**
Permanent Restoration Works	
• **Budgewoi Circle retaining wall,**	$15,000
• **Canton Beach koppers log wall,**	$30,000
• **Alister Avenue retaining wall,**	$13,300
• **Dianne Avenue retaining wall,**	$32,700
• **Willow Creek, Long Jetty stabilisation of watercourse,**	$75,000
• **Memorial Park, The Entrance scouring of material,**	$100,000
• **Pipe Clay Point retaining wall,**	$30,000
• **other damage (mainly to areas away from the lakes).**	$147,000
Sub-Total	**$443,000**
WYONG SHIRE COUNCIL TOTAL	**$865,000**

Note: $'s rounded in $1990

5.6. Environmental Impacts of Flooding

Flooding is a natural phenomenon that has been a critical element in the formation of the present topography. Thus erosion, sedimentation and other results from flooding should be viewed as part of the natural ecosystem. It is only when these effects impact on man-made elements that they are of concern, and similarly, when development impacts or exacerbates these processes.

5.7. Flood Emergency Response Classification

To assist in the planning and implementation of response strategies, the SES in conjunction with DECCW has developed guidelines to classify communities according to the impact that flooding has upon them. Flood affected communities are considered to be those in which the normal functioning of services is altered, either directly or indirectly, because a flood results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue.

Based on the guidelines, communities are classified as either Flood Islands, Road Access Areas, Overland Access Areas, Trapped Perimeter Areas or Indirectly Affected Areas (refer Table 14). From this classification an indication of the emergency response required can be determined.

Table 14: Emergency Response Classification of Communities

Classification	Response Required		
	Resupply	Rescue/Medivac	Evacuation
High Flood Island	Yes	Possibly	Possibly
Low Flood Island	No	Yes	Yes
Area with Rising Road Access	No	Possibly	Yes
Areas with Overland Escape Routes	No	Possibly	Yes
Low Trapped Perimeter	No	Yes	Yes
High Trapped Perimeter	Yes	Possibly	Possibly
Indirectly Affected Areas	Possibly	Possibly	Possibly

The guideline was applied for the community and for all communities on the foreshore of Tuggerah Lakes the community was classified as Low Flood Island based on the following criteria:

- There are homes and access roads below the PMF,
- Vehicle evacuation routes are cut before homes are inundated,
- There are no habitable areas for refuge (except the homes themselves),
- The homes are first surrounded by floodwaters and then inundated,
- Thus vehicle evacuation must be completed before the route is closed.

Summary

A local flood action plan should be prepared and provided to the community. Due to the extensive area and number requiring the services of the SES the main focus for many will be on self-help during the flood.

5.8. Potential Future Changes

5.8.1. Implications of Climate Change and Sea Level Rise

Climate change has the potential to cause an increase in the sea level as well as a possible increase in design rainfall intensities. The likely impacts of a rise in sea level include:

- an increase in the intensity and frequency of storm surges;
- increased foreshore erosion and inundation of low lying coastal lands;
- further loss of important coastal wetland ecosystems; and
- damage to and destruction of human assets and settlements.

In developed areas such as Tuggerah Lakes, changes in average climate together with a rise in sea level are likely to affect building design, standards and performance as well as energy and water demand and in particular coastal/estuary planning.

Given that Tuggerah Lakes has a long foreshore, future development and redevelopment of foreshore areas will need to factor how future sea-level rise will impact on the developments.

This is particularly pertinent to the construction and reconstruction of foreshore structures, such as seawalls, fixed jetties and boat ramps, and the issue of maintaining public foreshore access in the future. Mitigation and adaptation options to address the potential impacts of climate change, particularly for coastal communities, will become increasingly more expensive and problematic in the longer term.

The effect of climate change (sea level rise and rainfall increase) has been investigated further in Section 7.

5.8.2. Implications of Future Development

Due to the limited availability and relatively small scale of residential zoned land in the contributing catchments, the hydrologic impacts (increased runoff) of increased building construction will have no significant impact on the flood regime. Future filling of the floodplain (for roads or building pads) will reduce the available temporary floodplain storage capacity. However given the magnitude of the existing floodplain, the area of the lakes and the likely scale of the filling it is considered that future filling of the floodplain will have no significant impact on flood levels. All filling proposals must still be considered in terms of their potential impact on local drainage and overland flow paths.

6. FLOODPLAIN RISK MANAGEMENT MEASURES

6.1. General

The NSW Government's Floodplain Development Manual (2005) (Reference 1) separates floodplain management measures into three broad categories:

Flood modification measures modify the flood's physical behaviour (depth, velocity and redirection of flow paths) and include flood mitigation dams, retarding basins and levees. At Tuggerah Lakes this would also include any works that modify the entrance of to the Pacific Ocean.

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

A number of methods are available for judging the relative merits of competing measures. The benefit/cost (B/C) approach has long been used to quantify the economic worth of each option enabling the ranking against similar projects in other areas. The benefit/cost ratio is the ratio of the net present worth (the total present value of a time series of cash flows). It is a standard method for using the time value of money to appraise long-term projects 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 B/C approach. For this reason a matrix type assessment has been used which enables a value (including non-economic worth) to be assigned to each measure.

6.1.1. Criteria for Assessment of Measure in Matrix

The following criteria have been assigned a value in the management matrix:

- impact on flood behaviour (reduction in flood level, hazard or hydraulic categorisation) over the range of flood events,
- number of properties benefited by measure,
- technical feasibility (design considerations, construction constraints, long-term performance),

- community acceptance and social impacts,
- economic merits (capital and recurring costs versus reduction in flood damages),
- financial feasibility to fund the measure,
- environmental and ecological benefits,
- impacts on the State Emergency Services,
- political and/or administrative issues,
- long-term performance given the likely impacts of climate change and sea level rises
- risk to life.

Details of the scoring system for the above criteria are provided in Table 15 and largely relate to the impacts in a 1% AEP event.

Table 15: Matrix Scoring System

	-3	-2	-1	0	1	2	3
Impact on Flood Behaviour	>100mm increase	50 to 100mm increase	<50mm increase	no change	<50mm decrease	50 to 100mm decrease	>100mm decrease
Number of Properties Benefited	>5 adversely affected	2-5 adversely affected	<2 adversely affected	none	<2	2 to 5	>5
Technical Feasibility	major issues	moderate issues	minor issues	neutral	moderately straightforward	straightforward	no issues
Community Acceptance	majority against	most against	some against	neutral	minor	most	majority
Economic Merits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Financial Feasibility	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Environmental and Ecological Benefits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Impacts on SES	major disbenefit	moderate disbenefit	minor disbenefit	neutral	minor benefit	moderate benefit	major benefit
Political/administrative Issues	major negative	moderate negative	minor negative	neutral	few	very few	none
Long Term Performance	major disbenefit	moderate disbenefit	minor disbenefit	neutral	positive	good	excellent
Risk to Life	major increase	moderate increase	minor increase	neutral	minor benefit	moderate benefit	major benefit

It should be noted that in some communities any increase in flood level is unacceptable, however for flood mitigation works that provide a major benefit to one part of the community, whilst having a minor impact to another part a less rigid approach may be considered.

6.2. Measures Not Considered Further

Early in the study it was apparent that after a preliminary matrix assessment that a number of floodplain management measures were not worthy of further consideration. These are summarised in Table 16.

Table 16: Floodplain Management Measures Not Considered Further

Measure	Impact				
	Reduction in Flood Level	**Social Effect**	**Environ-mental Impact**	**Cost to Implement**	**Benefit/ Cost Ratio**
FLOOD MODIFICATION MEASURES:					
Flood Mitigation Dams, etc.	Yes	Nil	Very High	Very High	Low
Floodways	Yes	Very High	Medium	Very High	Low
Catchment Treatment	Minimal	Nil	Low	Low	Nil
PROPERTY MODIFICATION MEASURES:					
Voluntary Purchase of all Buildings Inundated in the PMF	Nil	High	Nil	High per building	Probably Low
Rezoning of all land inundated in the PMF.	Nil	Very High	Some	High	Unknown
RESPONSE MODIFICATION MEASURES:					
Flood Insurance	Nil	Some	Nil	Now available for most homes	

6.2.1. Flood Mitigation Dams, Retarding Basins, On-Site Detention

Large flood mitigation dams within the catchment are not viable on economic, social and environmental grounds. Construction of retarding basins (say up to 50 000 m^3) and the use of on-site stormwater detention or retention systems are increasingly being used in developing catchments. These measures are appropriate for use in controlling flooding in small catchments (say up to 5 km^2) or to mitigate the effects of increased runoff caused by development. However, these structures would have negligible impact upon lake levels.

6.2.2. Floodways

Floodways are lower overbank areas which can carry significant flow during floods. Possible locations of floodways are anywhere on the east side of the lakes which could take flow to the ocean. Suggestions have been made to construct another opening on Budgewoi Lake (700 m south of Budgewoi road bridge) or on Tuggerah Lakes north of The Entrance North. Whilst this measure would reduce flood levels by letting the water out faster (the amount depends on the size of the opening), the high social (loss of land), environmental (loss of flora and fauna, impact on lagoon ecosystem, impact on coastal processes at the existing and new outlets) and economic costs (excavation and bridging costs) make this measure impractical.

6.2.3. Catchment Treatment

Catchment treatment modifies the runoff characteristics of the catchment to reduce inflows to the lake. For an urban catchment, this involves planning to maximise the amount of pervious area, maintaining natural channels where practical and the use of on-site detention (now called

Water Sensitive Urban Design or WSUD). For a rural catchment, this involves limiting deforestation or contour ploughing of hill slopes. This measure can be effective on small catchments but has a negligible impact on large catchments such as Tuggerah Lakes.

As a general concept, catchment treatment techniques and WSUD should be encouraged (e.g. on-site detention, limit on-site imperviousness for developments, controls on rural land use) along with water quality and other environmental controls as these approaches provide significant non flooding benefits. However as a floodplain management to reduce flood levels in Tuggerah Lakes they are ineffectual and not supported for this purpose.

6.2.4. Voluntary Purchase of all Buildings

Voluntary purchase of all the buildings inundated above floor level in the 1% AEP flood (over 1300 at say $500 000 per building) cannot be economically or socially justified. Generally, Government funding is only available for voluntary purchase of buildings that are frequently flooded in a high hazard area. Even purchasing the 160 houses inundated above floor level in the February 1990 and June 2007 events would cost approximately $80 million. Voluntary purchase may also introduce a number of social problems (residents are unwilling to sell or find alternative accommodation with similar attributes) which can be difficult to resolve. Results from the public consultation program indicated little support for this measure.

6.2.5. Rezoning

Rezoning of flood liable land for higher density development could encourage people to purchase and demolish existing flood liable property and redevelop the area in accordance with Council's design floor level policy. This strategy is difficult to implement, as generally the surrounding residents, who are not flood affected, consider that the quality of the area would be adversely affected by the increased building density. Furthermore the high cost to purchase the existing land and building is unlikely to make this measure financially attractive to developers. Additional concerns are the cost to provide and maintain on going services (particularly with sea level rise) as well as the likely lack of adequate flood access.

6.2.6. Flood Insurance

Flood insurance does not reduce flood damages but transforms the random sequence of losses into a regular series of payments. It is only in the last five years or so that flood insurance has become readily available for houses, although it was always available for some very large commercial and industrial properties. There are many issues with the premium for this type of insurance and how insurance companies evaluate the risk (is it based on the house floor being inundated or the ground within the property?). These issues are outside the scope of this present study and are currently being investigated by the Federal Government following the recent Victorian and Queensland floods.

6.3. Flood Modification Measures

Flood modification involves changing the behaviour of the flood itself, by reducing flood levels or velocities, or excluding floodwaters from areas under threat. This includes:

- dams (not considered further),
- retarding basins (not considered further),
- management of the entrance,
- levees, flood gates, pumps,
- local drainage issues,
- enlarging the entrance channel,
- emergency opening of the entrance,
- wave runup vulnerability assessment.

Discussion on each of these measures is provided in the following sections.

6.3.1. Management of the Entrance

DESCRIPTION

If the entrance to Tuggerah Lakes becomes blocked by sand build up (formation of a berm) then floodwaters will pond to the height of the berm before any outflow occurs. Thus potentially, a long duration but low intensity rainfall event could cause significant flooding. This situation is typical of all Intermittently Open and Closed Lake and Lagoons (ICOLL) along the NSW coast. Councils adopt different management approaches depending on the nature of the ICOLL and the local constraints. For example, Gosford City Council has different approaches for each of its four lagoons (Wamberal, Terrigal, Avoca and Cochrone Lagoons). The management approach needs to be developed taking into account the hydraulic, social, economic and environmental factors. Generally the approaches adopted today involve less human interference and a more "natural" opening regime. Ad hoc or informal opening or clearing of the entrance is not recommended.

DISCUSSION

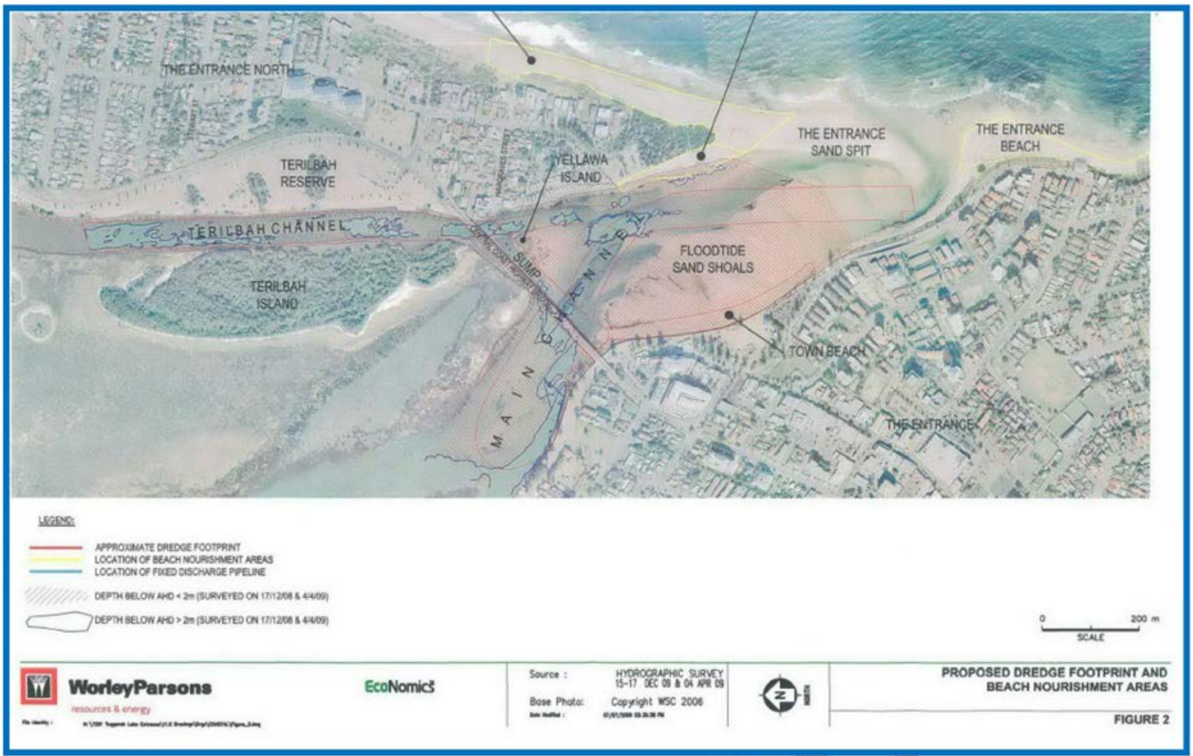
From a flooding perspective, an entrance that is as wide and as deep as possible ensures flood levels are as low as possible for a rainfall-induced event (i.e flooding from rainfall is the dominant mechanism). The opposite is true for an ocean/estuary-induced event (flooding due to high ocean/estuary levels rather than due to high rainfalls). At some of the smaller ICOLLs (Terrigal, Wamberal, Smiths Lake) Councils "control" the height of the entrance (by opening the entrance by mechanical means) to minimise flooding. However, this can only be achieved through regular maintenance and a quick response to the weather conditions. This procedure is an additional expense for Council, but more importantly, alters the natural lakes ecosystem.

The current best-practice for managing ICOLLs is for the opening/closing regime to be self-maintaining, as far as possible, with human intervention only when there is likely to be a significant adverse social impact.

Dredging of the entrance has been undertaken intermittently since 1993. Reference 5 provides a review of environmental factors to support the continued dredging and indicates that maintenance dredging is required to "maintain tidal flows and reduce flood risks to life and property in low lying areas of the estuary". The proposal involves dredging up to 100,000 m^3 per annum (though may be only 30,000 m^3) with the dredged sands deposited on the depleted ocean beaches to the north of the entrance mouth. Whilst the report mentions a reduction in flood risk several times there is no quantitative assessment of the benefit and it does state that "it is not likely to significantly impact peak flood levels in the lake". The report also justifies dredging as it would prevent more frequent closure of the mouth. The annual cost to Wyong Shire Council for dredging at the entrance to Tuggerah Lakes is in the order of $0.5 million.

The following comments are made regarding the flooding issues referred to in Reference 5.

- Neither Reference 5 nor the quoted references provide any quantitative assessment of the benefits to flooding of dredging and to the best of our knowledge no hydraulic study has been undertaken which quantifies the benefits to flooding of dredging the entrance to Tuggerah Lakes.
- Reference 5 is unclear on how dredging will benefit flooding. Is the benefit of dredging only to reduce the duration of flooding and there will be no reduction in peak flood levels and/or will dredging prevent closure of the entrance and so reduce flood levels?
- It is unclear how dredging will reduce the duration of flooding. Whilst in theory any removal of sand from upstream of the berm at the beach will provide some reduction as it will "facilitate scour", the link between dredging and reduction in duration is not defined. Whilst any reduction in the duration of flooding is of benefit this needs to be quantified in terms of a reduction in tangible and intangible damages (is a 1 hour reduction in duration when your property is inundated for 2 days of significance?).
- Reference 5 proposes a large extent of dredging (see plan below). Whilst dredging near the beach berm may have a benefit in "facilitating scour" it is unclear how dredging upstream of the bridge or adjacent to the Town Beach will provide much benefit.



- Generally a "closed" entrance will increase flood levels compared to an "open" entrance as the floodwaters must overtop the "closed" entrance before floodwaters can escape. Reference 5 indicates that dredging will prevent more frequent closure of the entrance but it does not describe the link between dredging and prevention of closure of the entrance. It is agreed that dredging near the beach berm or actually within the beach berm will assist (by how much is not known) but how will dredging upstream of the bridge assist? Also the dredge only operates for 3 months a year. Thus outside this period what certainty is there that the entrance will not close when the dredge is elsewhere?

OUTCOMES

Dredging will not adversely affect flooding. The only exception to this is possibly in an elevated ocean event with large waves which may "enter" the entrance more than in a non- dredged scenario causing "pumping up" of the lake or wave damage downstream of the bridge. However the benefit to the community in terms of reduced tangible or intangible flood damages due to dredging has never been quantified.

It is difficult to obtain a quantitative estimate of the benefits of dredging, namely: a reduction in flood level, a reduced duration of inundation or a reduced likelihood of entrance closure and presumably this is why this has not been undertaken. Unfortunately even today's sophisticated Two Dimensional hydraulic models cannot accurately simulate the scouring of an entrance during a flood.

Even if it is shown that dredging provides a significant positive benefit in reducing flood levels this benefit will diminish in the period following dredging. Thus if a flood occurs immediately prior to the start of the next dredging period it is possible that there will be no reduction in flood level or duration of inundation as infilling has occurred (that is why further dredging is required). On this basis dredging cannot be used as a means of lowering the design flood levels adopted for flood related development control purposes.

The June 2007 event occurred with the current dredging regime in operation. It is unclear if the dredging activities prior to the event had any benefit but certainly they did not prevent the lake from reaching approximately the 10% AEP flood level (slightly higher than February 1990) resulting in considerable tangible and intangible damages to the community.

Possibly the dredging regime since 1993 has prevented minor flooding, if so this has not been documented. By comparison it is noted that Lake Macquarie (permanently open entrance) in the adjoining catchment also has only experienced two large floods since 1990 (June 2007 and February 1990) with June 2007 slightly higher than February 1990.

In the absence of any technical study it is considered that the dredging regime will have no negative impacts on flooding but only minor positive benefits (an indicative assessment is less than a 30mm reduction in peak level and maybe 6 hours reduction in duration of inundation). Whilst any reduction in flood level or duration of inundation is beneficial this must be balanced against the economic, social and environmental cost of dredging and whether the funds could achieve a greater benefit if spent on other floodplain risk management measures.

Dredging will result in a small reduction in the risk of closure of the entrance but cannot eliminate the likelihood of closure. Obviously after a period of drought and conducive ocean activity the entrance may close with or without dredging, if the dredge is present it can open the entrance but if no dredging regime is undertaken and the entrance closes then a bulldozer can be brought in to undertake the same action (as happens at Terrigal Lagoon or Shoalhaven Heads).

The minor positive benefit from dredging will only accrue to those works undertaken near the beach berm and dredging further upstream of the bridge will be of extremely limited value for flooding purposes.

An overall summary of the effects of dredging (not specifically for the dredging that is currently undertaken at the entrance by Council) is provided in Table 17.

In conclusion there is very limited justification for dredging of the entrance to Tuggerah Lakes in terms of reducing flood damages and other measures may provide a greater benefit cost ratio in reducing flood damages.

There are no quantitative records describing how the entrance berm (length, width, timeframe) is breached in a flood. A simple procedure to obtain such information would be to install a digital still or video camera at the entrance.

Table 17: Overall Summary of Effects of Dredging of the Entrance Channel

ISSUE	COMMENT
ADVANTAGES:	
Provides some reduction in flood levels. The magnitude will depend on the extent of dredging at the time of the flood.	Even a small reduction in flood level for each event equates to a significant reduction in damages: • a 0.01 m reduction decreases the AAD by 3%, • a 0.1 m reduction decreases the AAD by 30%.
Provides benefit over the full range of floods.	Many flood mitigation measures are only beneficial in a small range of events.
May provide additional non-flooding water benefits.	The improvement in water quality and / or tidal circulation will be minimal.
May increase tourist potential	It is generally acknowledged that tidal flushing and the relatively safe water environment resulting from dredging will attract tourist to the area (swimming, boating, fishing).
Dredged material may be used elsewhere.	Beach nourishment or sale of material.
DISADVANTAGES:	
High initial cost.	Over $1 million dollars to purchase a dredge. Difficult to obtain government funding for works of this magnitude.
Likely high maintenance cost.	Ongoing maintenance will be required to ensure that infilling does not subsequently occur (approximately $0.5 million per annum). The cost to maintain the dredge is over $150,000 per annum.
Disposal of material.	A suitable site is required.
Possible environmental impacts.	These would have to be rigorously examined in an Environmental Impact Statement (EIS) and include: • water quality, • flora/fauna, • erosional/sedimentation regime, • lake flushing, • impact on tidal regime, • increased ocean wave penetration.
Possible adverse social impacts.	These may include: • the noise of the dredge, • visual pollution, • increased tidal range (more frequent exposure of mud flats), • affectation on the local tourist industry, • loss of fish spawning and prawning areas, • destruction of aquatic flora and fauna.
Likely hydraulic benefit (reduction in flood level).	A significant amount of dredging would be required to achieve (say) a 0.01 m reduction in flood level. Will the community support a large expenditure to achieve such a small reduction in flood level?
Increase in ocean affectation	It is possible that a wider and deeper entrance will allow ocean waves to enter the entrance channel more freely that at present, possibly during elevated ocean events damage to foreshore structures may occur.

6.3.2. Levees, Flood Gates and Pumps

DESCRIPTION

Levees are built to exclude previously inundated areas of the floodplain from the river up to a certain design event and are commonly used on large river systems (e.g. Hunter and Macleay Rivers) but can also be found on small creeks in urban areas.

Flood gates 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 or lake is elevated, the gates prevent floodwaters from the river entering the area (they are commonly installed on drainage systems within a leveed 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.

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 the levee has "solved" the flood problem (as happened with Hurricane Katrina in New Orleans, USA).

DISCUSSION

There is one levee with associated flood gates at The Entrance North with Wilfred Barrett Drive acting as the levee bank. Photographs from the February 1990 and June 2007 floods (refer Figures 3 and 4) indicate that in both events there was considerable inundation within the leveed area. It is unclear whether this was due to the local catchment runoff being unable to drain away successfully or inflow from malfunctioning flap gates. Certainly Wilfred Barrett Drive was not overtopped (approximate crest level of 2.5 mAHD and thus above the 1% AEP flood level with no freeboard).

Some of the key issues regarding levees are summarised in Table 18.

Table 11 indicates that approximately 50% of the buildings surveyed (242) at The Entrance North would not be inundated above floor level in a 1% AEP event if the Wilfred Barrett Drive levee operated successfully (i.e no internal drainage issues). Unfortunately the results from the February 1990 and June 2007 events suggest that there are failures resulting in significant inundation of roads and possibly building floors (up to 11 building floors in February 1990).

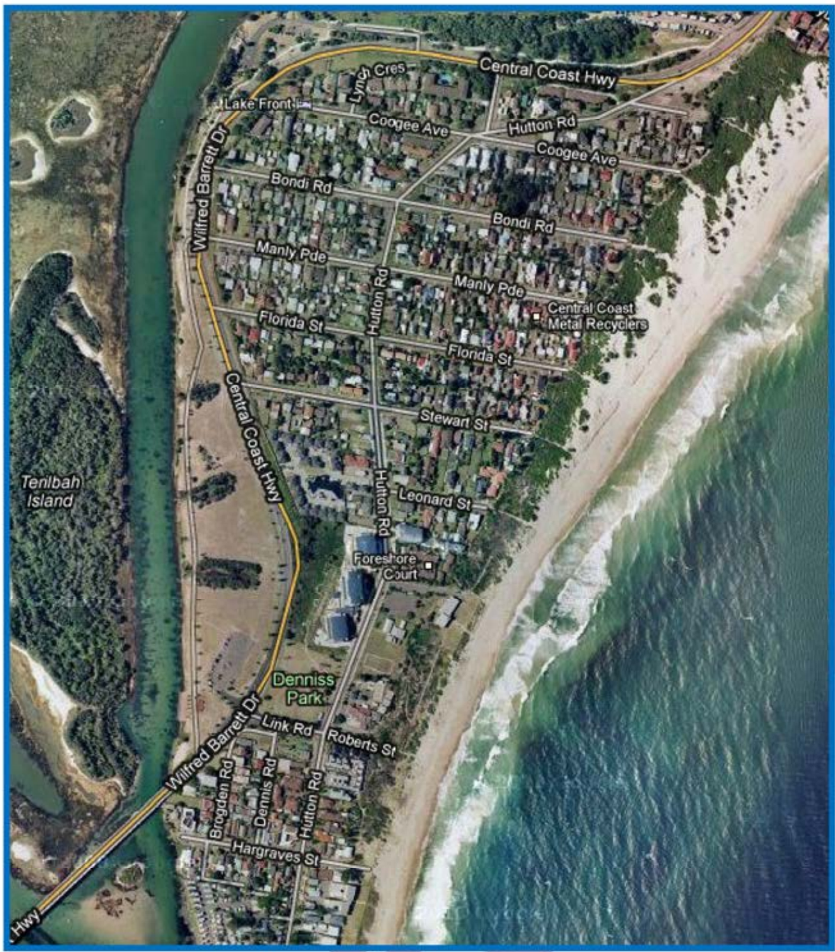
Levees have been considered for other areas around the foreshore however there are no obvious areas (inability to tie into high ground, significant upstream catchment, not cost effective due to the length of structure required) where a levee similar to The Entrance North could be constructed.

Table 18: Key Features of Levee Systems

ISSUE	COMMENT
ADVANTAGES:	
"Environmentally Sensitive Measure"	A vegetated earthen embankment which blends into the foreshore environment will generally have little impact upon the environmental quality of the area.
Protects a large number of buildings.	A levee system could protect a large number of buildings from being inundated up to the 1% AEP or even larger flood event. At Tuggerah Lakes it is possible to protect to the PMF as this event is only 0.5 m greater than the 1% AEP.
Low maintenance cost.	A levee system needs to be inspected annually for erosion or failure. The annual cost of maintenance will be (say) less than $10 000 per annum.
DISADVANTAGES:	
Visually obtrusive to residents.	Residents enjoy living in the area because of the visual attraction of the water and a (say) 1.5 m high embankment will significantly affect their vista. Anything which reduces the vista is unlikely to be accepted by the majority of residents. A freeboard of usually 0.5m should be added to the design flood level
High cost	No detailed costings have been undertaken at this stage. It is likely that the levees will cost several million dollars depending upon their size and location.
Low benefit cost ratio	Whilst the levee system may protect a large number of buildings from being inundated in a (say) 1% AEP event it is likely to have a low benefit cost ratio as there are few buildings inundated (and so being able to be protected) in the more frequent floods (less than a 10% AEP event).
Local runoff from within the "protected area" or upstream may cause inundation.	The ponding of local runoff from within the "protected area" may produce levels similar to that from the lake itself. At present local runoff already causes problems in several areas. Constructing a levee will compound this problem. It can be addressed by the installation of pumps or flap valves on pipes but these add to the cost and the risk of failure (as occurs at The Entrance North).
May create a false sense of security.	Unless the levee system is constructed to above the PMF level (say 2.7 mAHD) it will be overtopped. When this occurs the damages are likely to be higher as the population will be much less flood aware (as happened in New Orleans, USA).
Relaxation of flood related planning controls.	Most residents consider that following construction of a levee the existing flood related planning controls (minimum floor level, structural integrity certificate) should be relaxed. However, many experts consider that this should not be the case unless the levee is built to the PMF level and the risk of failure is nil. The general opinion is that a levee should reduce flood damages to existing development but should not be used as a means of protecting new buildings through a reduction in existing standards.
Restricted access to the water.	Access to the water for boating and other activities requiring easy access will be restricted. This can be addressed by (expensive) re-design of entry points.

Review of The Entrance North Levee System

The Entrance North is predominantly a residential suburb located immediately north of the road bridge at The Entrance. It is separated into two areas by a small ridge near Link Road. This investigation deals with the area north of the Link Road/Roberts Street which has a catchment area of approximately 50 hectares (see diagram below).



The Entrance North Levee System (photo courtesy of Google)

The details of the properties in the floor level database are provided in Table 19. It should be noted that some buildings are not in the database as their floor levels are above the PMF (2.7 mAHD).

Table 19: Key Details: The Entrance North to the north of Link Road/Roberts Street

Number of Buildings in Floor Level Database	**209**
Number of identified non-residential buildings	3
Lowest habitable floor level	1.2 mAHD
Lowest ground level	<1.0 mAHD
Buildings with floor levels < 1.3 mAHD	1
Buildings with floor levels < 1.5 mAHD	2
Buildings with floor levels < 1.7 mAHD	15
Buildings with floor levels <1% AEP lake level (2.23 mAHD)	110 (53%)
Percentage of land area <1.2 mAHD	3%
Percentage of land area <1.5 mAHD	16%
Percentage of land area <2.0 mAHD	47%
Percentage of land area <2.5 mAHD	65%

The area is protected from inundation from the Pacific Ocean by the coastal dune system (up to 13 mAHD). Wilfred Barrett Drive (constructed in approximately 1965) forms a levee (road level at approximately 2.5 mAHD based on the ALS) preventing inundation from an elevated lake level. In the south, between the northern approaches to the bridge and the sand dunes, there is no defined levee bank but ground levels are generally above 2.5 mAHD.

There are 14 culverts (8 * 450 mm, 3 * 600 mm, 3 * 525 mm) under Wilfred Barrett Drive. The upstream inverts are at approximately 0.5 mAHD and the lengths of the culverts vary from 15 m to 120 m (average length of approximately 50 m at a slope of 0.3%). In 1995 (following the February 1990 event) the outlets of the culverts were fitted with hinged flap gates to prevent water entering from Tuggerah Lakes.

During the February 1990 flood (prior to installation of the flap gates) the area was inundated in two ways. Firstly from local runoff ponding on the land side of Wilfred Barrett Drive and secondly from the subsequent elevated lake levels entering through the culverts (peak lake level of 1.6 mAHD). Up to 11 buildings in the area may have been inundated above floor. Local residents indicate that both mechanisms produced similar peak levels although at different times. No other historical flood data are available within this area. In the February 1992 flood the lake reached 1.1 mAHD and would have caused inundation in low lying parts but would not have affected building floors. No accurate details are available of how many floors were inundated in the June 2007 event.

Inundation from elevated lake levels (to the level of Wilfred Barrett Drive and ground levels near Link Road) is prevented by the flap gates as long as they operate as designed. There is a risk flap gates may fail and be stuck open or shut for a number of reasons including:

- human interference (children),
- Council has advised that there are vandalism and maintenance issues with the flap gates,
- vegetation or other debris (wood, weed growth at the outlet),
- rust or corrosion.

The only practical way to ensure that the gates operate as designed is by a rigorous inspection and awareness program. This may include:

- a regular inspection (say every 6 months) by Council staff,
- the local community and/or the Neighbourhood Watch being informed of the significance of the flap gates and advised to inform Council if they observe a problem. This approach can be linked into a flood awareness program for Tuggerah Lakes and will foster ownership of the scheme,
- inclusion of a procedure within the Flood Warning System to ensure that once notification of a flood is obtained, an inspection of the flap gates is undertaken immediately. This may be carried out by Council staff or the SES and would ensure that the gates close when Tuggerah Lake rises. Emergency measures (e.g. sandbags) should be available in case a flap gate is missing or prevented from closing. It is envisaged that there would be adequate warning time to carry out this task,
- replacement of the hinged flap gates with rubber “duck bill” valves may reduce the problem. The cost to replace each flap gate would be approximately $10,000.

It is unclear if the gates failed during the June 2007 event. Inundation from local runoff ponding behind the levee will always occur. The depth of inundation largely depends upon:

- the volume of runoff,
- the capacity of the culverts,
- the storage volume in the area,
- the lake level.

Pumps have been suggested as a means of addressing the problem but are not widely used in levee type situations in NSW. Some of the drawbacks of employing pumps are:

- high capital cost (say) $50,000 per pump, plus $20,000 for a control panel, plus $10,000 for a pump well, plus $10,000 for an outlet structure. In many instances two sets of pumps are installed in case one set is being repaired or maintained when the flood occurs,
- high maintenance cost. The pumps have to be regularly maintained and tested by trained personnel,
- relatively high risk of failure. Experience in other areas has shown that as the pumps are used only infrequently there is a relatively high risk of failure due to:
  - inadequate maintenance of the pumps causing seals or valves to deteriorate,
  - power cuts caused by the storm,
  - failure of the device which activates the pumps.

The pumps are only required to operate for a short time (several hours) possibly once or twice a year. If they fail to start or fail during the event there is practically no likelihood that service personnel will be able to restart them prior to the peak level being reached. An alternative to pumps is to install additional flap gated culverts under Wilfred Barrett Drive, however there is a significant capital cost to place pipes under the roadway.

A longitudinal survey of Wilfred Barrett Drive was carried out by Council in 1997. As a result approximately a 50 m length of road was raised (by up to 0.2 m) to the 1% AEP level. Survey near Link Road was undertaken by Council in 1997 and showed that the height of the natural barrier is at approximately 2.3 mAHD (approximately the 1% AEP flood level).

There is little (if any) freeboard between the crest of Wilfred Barrett Drive and the 1% AEP lake level. During such an event it is possible that wind/wave action may cause overtopping of the road in places. A long term goal may be to raise Wilfred Barrett Drive to the PMF Level (2.7 mAHD).

OUTCOMES

A preliminary review of the flood liable areas surrounding Tuggerah Lakes indicates that there are no other areas where a levee system, similar to that at The Entrance North could be constructed to protect existing buildings. The levee system at The Entrance North would appear to not have worked successfully in the June 2007 event due to issues with internal drainage. It is recommended that further investigation be undertaken to improve the performance of the system.

6.3.3. Local Drainage Issues

DESCRIPTION

Local flooding is probably the flooding mechanism which is most widely identified by the community as being of concern, the only exception being where the residents actually experienced the February 1990 or the June 2007 floods. This problem occurs in nearly all suburbs due to the relatively flat grades. Many residents consider that local flooding is a significant issue (possibly many view this as a greater issue than the more infrequent flooding of Tuggerah Lakes) and report this to Council.

DISCUSSION

Local flooding results from rainfall over the local catchment being unable to quickly drain away. Generally it only occurs after over 24 hours of rain and will not cause above floor inundation. In the past there has been extensive ponding but this has been significantly reduced with installation of kerb and guttering in the streets adjoining the lakes. Ponding in yards still occurs and may take several days to drain away. It is likely to be associated with high water table conditions and is exacerbated when a slight rise in the lake level occurs simultaneously or if the sub-surface drainage system is restricted by debris or silt.

Upgrading the sub-surface system to improve yard to road drainage would improve the situation but is unlikely to solve the problem and would not be cost effective (on the basis of a reduction in tangible damages).

Debris (litter, vegetation) in the piped system is not considered to be a major contributing factor according to Council officers. Installation of agricultural drains in the yards would assist in reducing the incidence of local flooding. As the benefits of the works are largely intangible (reduction in inconvenience) it is difficult to justify these works on economic grounds.

There is an already existing problem with maintenance of channels and culverts due to excessive vegetation growth.

OUTCOMES

Local flooding is a significant issue for many residents but preliminary investigation indicates that there is no viable economic solution. One approach would be to more closely identify the worst affected areas and provide a newsletter suggesting how residents could install (at their expense) agricultural drains to reduce the problem (if successful with high water table conditions). This could be combined with assistance from landcare groups to control exotic vegetation in the watercourses. A community based approach (say by the local progress association) with input from Council, is likely to be the most successful. At a minimum the problem should be more closely monitored and identified by Council. This should be accompanied by a public education program to explain the difference between local and lakes flooding and how the public can be involved in reducing the local flooding problem.

6.3.4. Enlarging the Entrance Channel

DESCRIPTION

During a flood the rate of outflow from Tuggerah Lake to the Pacific Ocean is smaller than the rate of inflow to the lakes system. Consequently the water level in the lakes rises until the outflow equals the inflow. Enlarging the outlet (widening and/or deepening) will increase the rate of outflow and therefore reduce the peak lake level. However it is not just the size of the outlet at the start of a flood which is critical. During a flood the outlet is eroded by the floodwaters becoming deeper and wider. The rate of erosion of the outlet is largely dependent upon the quantity of sand which has to be removed from the entrance channel and beach berm area during the event.

For a number of years Council has been examining the possibility of creating a permanent tidal opening so as to:

- reduce nuisance flooding,
- improve tidal flushing and water quality,
- maximise productivity of the fishery,
- enhance the quality of the area and so attract tourists,
- reduce the need for artificial opening of the waterway when it closes (it has closed approximately ten times since 1900).

The following recent studies have been undertaken:

October 1987 - Jet Pumping Systems for Maintaining Tidal Entrances (Reference 6): this study concluded that jet pumps will not maintain the location of an untrained tidal inlet channel per se. The jet pumps could be outflanked and rendered ineffective by channel migration. To overcome this, some form of restraining wall or walls would be required to fix the channel location above the jet pumps. The cost of the pumps was $820 000 with an annual maintenance cost of $54 000 (in $1987).

Subsequently in October 1988 (Reference 7) the feasibility of constructing an entrance restraining wall was investigated. The work was terminated due to the relatively high cost of the structure and concern at the adequacy of the scour protection system. An indicative cost was $580 000 (in 1988).

In 1990/1991 studies (Reference 8) were carried out (including a trial dredge) on a mobile dredge system. It was proposed that the system operate upstream of the entrance channel with a submersible pump downstream of the entrance channel. Since mid 1993 Council has employed a mobile dredge to maintain a permanent open entrance (Reference 5).

In 2013, Cardno Pty Ltd (Reference 20) completed a NSW Office of Environment and Heritage funded study to develop a numerical model of the lake system to independently assess the potential effectiveness of entrance training walls in addressing water quality issues. A detailed model was prepared using the Delft3D package.

DISCUSSION

The inlet to Tuggerah Lake is a delta extending approximately two kilometres from the beach to the lake. The 800 m reach from the beach to the road bridge is the entrance area, consisting of rapidly moving sand shoals with one or more tidal channels. Upstream of the bridge there is a sandy delta which is largely stabilised by weed growth and two islands have developed.

A considerable amount of detailed survey work has been undertaken as part of the previous investigations of the outlet. This indicates that the maximum waterway width is 350 m but under normal circumstances the outlet is restricted to (say) a 20 m to 50 m wide channel with bed levels at a maximum of -1.5 m to -2.0 mAHD.

During a flood the sand in the entrance channel is swept out to sea. A rock shelf (at -1 mAHD to +0.5 mAHD) at the southern most point limits the size of the opening. Following a flood, tidal flows together with wind and wave action cause the partial (or complete) closure of the opening. Photographs taken near the peak of the February 1990 flood indicate that the outlet to the ocean was probably only 100 m to 150 m wide (refer Figure 3 – Photo 11).

Previous studies (References 6, 7, 8) have indicated that a permanently open channel, of sufficient dimensions to pass a large flood event, with minimal hydraulic restriction, is not economically viable. A hydraulic assessment to increase the capacity of the entrance channel was undertaken in the late 1990's (this work cannot now be replicated – refer Section 3.4.1). Two design scenarios were investigated for the 1% AEP event (results in Table 20), namely:

- Case A: a 250 m wide (to -1 mAHD) channel from the road bridge to the ocean.
- Case B: as above plus removal of the beach berm at the entrance.

Table 20: Impact of Maintaining a 250 m wide Entrance Channel

Event (AEP)	Design Flood Levels (mAHD) and Change (m)				
	Existing Entrance Condition	A: Fully Dredged Entrance Condition		B: Fully Dredged Entrance Condition and Beach Berm Removed	
	Level (mAHD)	Level (mAHD)	Change (m)	Level (mAHD)	Change (m)
1%	2.23	1.92	-0.31	1.78	-0.45
5%	1.82	1.58	-0.24	1.47	-0.35
20%	1.35	1.31	-0.04	0.96	-0.37
50%	0.94	0.91	-0.03	0.67	-0.27

The results show that Case A produces little benefit (maximum reduction of 0.04 m) in the 20% AEP and smaller events. For the 1% and 5% AEP events the reduction is 0.31 m and 0.24 m respectively.

Case B, which includes removal of the beach berm provides a further reduction in flood level. The total reduction ranges from 0.27 m (50% AEP) to 0.45 m (1% AEP). Removal of the berm provides the most additional benefit in the 50% and 20% AEP events.

A fully open channel (250 m wide to -1 mAHD) will provide a significant reduction in flood levels (a 1% AEP event becomes a 5% AEP event) and would reduce the 1% AEP damages by approximately 80%. However, there are many factors which must be considered including:

- the cost of undertaking and maintaining a fully open channel. The studies to date have indicated that it is not economically feasible,
- the possible environmental consequences to the Tuggerah Lakes ecosystem,
- the possible effect on the local tourist and recreational fishing industry,
- will an open entrance cause adverse ocean wave impacts in the entrance channel?
- will an open entrance affect the local coastal environment?
- design flood levels were estimated assuming a given design scenario (rainfall, ocean level, offshore wave climate and partially open entrance). If a different entrance scenario is adopted (i.e. fully open) the effects of other design scenarios must be analysed. For example a 1% AEP ocean level (say 2.0 mAHD if including wave setup) plus nominal runoff from the catchment may produce higher levels and therefore become the 1% AEP design scenario.

Anecdotal information suggests that the 1949 flood (peak level of 2.1 mAHD) was as a result of a severely choked entrance. Under Council's present entrance dredging policy a repeat of that situation would probably not occur. This factor was taken into account in the determination of the design flood levels in the Flood Study.

The 2013 Cardno Entrance Morphodynamic Modelling study produced the following conclusions regarding the effects of the following entrance scenarios:

- Existing case (no training wall);
- A single training wall 150 metres north of the existing southern rock wall; and
- Dual training walls at 100, 150 and 200 metres apart.

Firstly, the effect of training walls on flooding was tested by simulating the passage of a 1% AEP flood. The model assessed the scour of sand from the entrance, taking account of the underlying bed rock. It was found that the single training wall and dual training wall cases with 150 and 200 metre wide openings had no significant effect on peak flood levels around the lakes.

However, the reduced entrance area simulated by the 100 metre wide opening case caused an increase in peak flood levels of about 8 centimetres. More significantly perhaps, water levels for this scenario were assessed to remain elevated for several days longer than the other scenarios. With in-excess of 1300 properties around the lakes expected to experience over floor flooding in such an event, any worsening of flood impact was considered unacceptable. Accordingly, the 100 metre spacing scenario was excluded from further modelling work.

Following the simulation of flood passage, the model was run to examine the behaviour of the entrance channels and offshore post-flood shoals for a six weeks post flood period. For all scenarios, the model indicated that the entrance would not self-scour and shoaling would commence once the flood subsided. Therefore, if Council retains its current objectives related to flooding, lower entrance water quality and recreational amenity, it is expected that maintenance dredging of the type already undertaken would need to continue because the training walls do not materially improve the scouring and transport of sediment in the entrance area – in the short to medium term.

There would, however, be a gradual accumulation of sand on North Entrance and South Entrance beaches in the immediate vicinity of the training walls, and the 'return' associated with the northern training wall would limit the extent of the erosion of Karagi Point during a flood.

OUTCOMES

Construction and maintenance of a larger opening at The Entrance might provide greater hydraulic benefit and reduction in flood damages. The benefits of a reduction in flood level must be weighed against the initial and maintenance costs, the impact upon the lakes ecosystem, the impact upon the local tourist industry and the possible effect upon coastal and estuarine processes.

6.3.5. Emergency Opening of the Entrance

DESCRIPTION

Having an "open" entrance at the time of a flood will ensure that floodwaters can readily exit to the ocean. This situation is typical of all ICOLLs and has been addressed in different ways by various Councils. At Smiths Lake Great Lakes Council has a policy of opening the lake using a backhoe once the lake rises to 2.1 mAHD (the lake empties in approximately 8 hours). At Terrigal Lagoon and at Shoalhaven Heads the respective Councils have an entrance management policy which ensures that a nominated berm level is maintained through excavation by bulldozer.

For small ICOLLs the relatively short catchment response time (< 12 hours) means that there is little time from the onset of the rain to the lake rising to enable a bulldozer to be employed to lower the berm and let the floodwaters escape. At Tuggerah Lakes this is a possibility due to the longer response time (24 hours) and has been investigated.

DISCUSSION

The feasibility of employing earthmoving equipment to excavate the entrance channel during a flood event depends upon a number of factors including:

- adequacy of warning time: In order to provide the greatest benefit the equipment must be employed for as long as possible prior to the peak. It may take several hours to site the machinery,
- removal of excavated material: Where will the excavated material be placed? For maximum benefit it needs to be removed from the channel area,
- rate of rise of Tuggerah Lake: Above (say) 1.0 mAHD the equipment would become bogged. In the June 2007 flood the lake rose from 0.3 mAHD to 1 mAHD in approximately 16 hours,
- safety considerations: The equipment and labour are working in a harsh environment (rain, wind, ocean waves, rising water level, possibly darkness). There is a high risk to life and loss of equipment,
- ocean activity: A hostile ocean environment (high wave activity, storm tides) may severely limit the effectiveness. Ocean activity may cause the sand in the entrance to build up at a faster rate than it can be removed. Experience at Terrigal Lagoon (Gosford City Council) has shown that it is not always possible to open the entrance,
- availability of machinery and labour: It is likely that the equipment and labour will only be required (say) every five (or maybe longer) years. This makes it difficult for Council to guarantee that it will be readily available at short notice when required,

- cost: The cost to undertake the works depends upon the type of equipment and for how long it is used (say $20,000). However if it reduces the flood peak by even a small amount this will still produce a high benefit cost ratio due to the number of house floors inundated,
- benefit of the work: The reduction in peak level attributable to the work will vary for each flood and cannot be predicted. It is unlikely that the work will result in a higher lake level, unless in exceptional circumstances (elevated ocean level penetration).

OUTCOMES

This measure is likely to produce some reduction in the peak lake level, albeit a small reduction (say less than 0.1 m). Apart from the tangible benefit there is a large intangible benefit as the residents will appreciate that Council is committed to reducing the impact of flooding. This measure should be investigated further.

6.3.6. Wave Vulnerability Assessment

DESCRIPTION

Flooding in Tuggerah Lakes is associated with major storm events that usually last several days. As a result, there is a high likelihood that flood waters and wind generated lake waves will coincide. Under flood conditions, these waves would have the potential to cause additional damage to inundated properties as a result of wave impacts and/or to damage properties above flood levels as a result of wave runup inundation.

Properties on the lake foreshore margins with an exposed lake reach are the most likely to be subject to wave impacts. The waves could potentially cause structural damage as a result of repeated alternating horizontal hydraulic and vertical uplift forces, which could cause walls to collapse and windows to break. Flows generated by the waves could also dislodge loose furniture / equipment and cause localised scour.

Wave runup would be confined to those areas were waves could penetrate to a sloping foreshore. The waves would then break on the foreshore and runup, potentially causing inundation of properties and/or foreshore erosion.

Wave impact and runup effects would vary during the storm and at different locations as a result of changing foreshore exposure, lake reach length and direction, lake depth, foreshore vegetation, foreshore structures, bed profile etc. There are no accurate historical records (height of waves, damage, frequency of occurrence etc.) of significant wave impact and runup activity in Tuggerah Lakes. However, the following table identifies those areas with the most potential or otherwise for wave impact or runup damage.

The nominated fetch length was based on the length and direction of open water likely to produce the largest wind wave during a 1% AEP storm event. The wind data use was the long term BOM record from Sydney Airport. The (Shore Protection Manual, 1984) simplified wave prediction model was then used to estimate the significant wave height and period at 24 locations around the foreshore of the lakes.

Wave vulnerability was assessed (Table 21) based on four general conditions for each of the 24 foreshore locations including consideration of:

- relative significant wave height and period,
- foreshore levels and slopes,
- foreshore development exposure, level and extent,
- foreshore vegetation density.

The generalised conditions used were:

- None - no significant vulnerability,
- Minor - only a small number of properties vulnerable,
- Moderate - a significant level of vulnerability to a number of properties,
- Major - a substantial level of vulnerability to a large number of properties.

Table 21: Wave Vulnerability Assessment

Location	Fetch		Significant Wave		Wave Vulnerability	
	Direction	Dist. (km)	Height (m)	Period (sec)	Impact	Runup
The Entrance	W	4.1	1.25	3.4	Minor	Minor
Long Jetty	NW	4.3	1.20	3.4	Major	None
Killarney Vale	NW	4.0	1.10	3.3	Major	None
Tumbi Umbi	NE	3.5	0.95	3.0	Major	Minor
Berkeley Vale	E	4.0	0.96	3.1	Major	Minor
Chittaway Bay	SE	4.3	1.25	3.4	Major	Minor
Chittaway Pt (N)	NE	9.1	1.35	3.9	Major	None
Rocky Point	NE	6.2	1.20	3.6	Moderate	Minor
Tuggerawong	S	4.9	1.30	3.6	Major	None
Wyongah	SE	3.7	1.20	3.3	None	None
Kanwal	SE	3.7	1.20	3.3	None	None
Gorokan (S)	SW	7.7	1.20	3.9	Minor	Minor
Toukley (S)	SW	8.5	1.5	4.0	Minor	Minor
Canton Beach	SW	9.2	1.6	4.2	Moderate	Moderate
Gorokan (N)	NE	3.7	0.91	3.0	Minor	Minor
Lake Haven	E	3.9	0.92	3.1	Minor	Minor
Charmhaven	SE	4.4	1.25	3.4	Minor	None
San Remo	S	4.4	1.25	3.4	None	None
Buff Point	S	2.5	0.95	2.9	None	None
Budgewoi	SW	3.6	1.20	3.2	Minor	Minor
Toukley (N)	NW	4.6	1.15	3.4	Minor	Minor
Budgewoi (N)	NW	3.5	1.20	3.2	Moderate	Minor
Halekulani	NW	2.6	0.91	2.8	None	None
Lake Munmorah	S	4.0	1.20	3.3	Minor	Minor

DISCUSSION

Wind waves during a severe storm can have a significant height up to 1.5m and a period of 4 seconds. Such waves when impacting on exposed inundated properties fronting the foreshore could substantially increase structure damages and when breaking on inclined foreshores could runup and inundate properties higher than the lake water level. Wave impact and runup could also cause foreshore erosion and extensive property and infrastructure/services damage. In general, no allowance is made for the structural impacts of these waves. The damages resulting from wave impacts and runup are difficult to accurately quantify as there is little data available.

Mitigation measures for wave impacts and runup are possible and at some ocean beaches concrete barriers (or similar) are used to deflect the waves and rock protection has been employed near Speers Point at Lake Macquarie. At other places vegetation re growth can be used to "dampen" the waves. Both these approaches are unlikely to be acceptable to the local community (access and aesthetic impacts) and for this reason development controls to include wave runup are the preferred approach rather than mitigation measures.

OUTCOMES
The effects of wave impacts and runup on the houses fronting on to the foreshore needs to be considered further. It is recommended that further studies are undertaken so as to quantify the impacts on houses and other structures and to formulate appropriate development controls.

6.4. Response Modification Measures

6.4.1. Flood Warning

DESCRIPTION
It may be necessary for a number of residents to evacuate their homes during or following a major flood such as the February 1990 and June 2007 events, though it is understood that many residents stayed in their homes (possibly moved to an upper floor). Apart from the risk to life and "inconvenience" issues the main reason for evacuating residents is because of failure of the sewerage system. This occurred in both these events (refer to Figure 8 for failure in the June 2007 flood).

The amount of time for evacuation depends on the available warning time. Providing sufficient warning time has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services.

Flood warning and the implementation of evacuation procedures by the State Emergency Services (SES) are widely used throughout NSW to reduce flood damages and protect lives. Adequate warning gives residents time to move goods above the reach of floodwaters and to evacuate from the immediate area to high ground. The effectiveness of a flood warning scheme depends on:

- the maximum potential warning time before the onset of flooding,
- the actual warning time provided before the onset of flooding. This depends on the adequacy of the information gathering network and the skill and knowledge of the operators,
- the flood awareness of the community responding to a warning.

For smaller catchments a Severe Weather Warning (SWW) is provided by the BOM but this is not specific to a particular catchment.

DISCUSSION

The Bureau of Meteorology (BOM) is responsible for flood warnings on major river systems such as Tuggerah Lakes. Flood warning systems are based on stations which automatically record rainfall or river levels at upstream locations and telemeter the information to a central location (Reference 4). This information is then provided to the SES who undertake evacuation.

Studies have shown that flood warning systems generally have high benefit/cost ratios if sufficient warning time is provided. In this regard all residents should be made aware of the types of warnings issued by the BOM (refer flood awareness in Section 6.4.3).

Flooding on Tuggerah Lakes differs from flooding on the tributary creeks or on major river systems. Firstly, the rate of rise of the lake is relatively slow providing more warning time. Secondly, the magnitude of the rise is also relatively small (only 1.9 m in a 1% AEP event) with the level responding more to the volume of runoff rather than the magnitude of the peak inflows. Finally, the entrance conditions are more dominant than in most river systems. If a large rainfall event occurs when the entrance is fully open the peak level will be much less than if it occurred when the entrance was closed and heavily silted.

As the lake rises relatively slowly (refer Figure 5) residents are unlikely to be "caught completely unaware" and should have some time to prevent damages to easily moved items such as televisions, rugs, clothing and cars as long as they are in the building at the time or nearby. As the depth of inundation is shallow (generally less than 1.0 m) it is also easy to raise goods above the floodwaters. Intangible damages such as the loss of memorabilia, important papers and pets should also be much reduced.

The Flood Study (Reference 2) examined a range of rainfall durations (24h to 72h) to determine the design storm duration which produces the highest lake level and concluded that the 48h duration was critical, although the 36h and 72h duration were only 0.04 m lower. However, it is misleading to consider that the duration of the design rainfall event is necessarily related to the available warning time. A much shorter duration storm (36h) may produce a peak very similar (but slightly smaller) than the adopted design duration. The peak level in the 48h 1% AEP event occurs 38h after the start of the storm. For the first 6h there is little runoff from the catchments and the lakes barely rise. Thereafter the lakes rise at a relatively constant rate of 90 mm per hour.

The lakes are at their peak for approximately 10h before falling at a similar rate to their rise in the 1% AEP event however Figure 5 indicates that both February 1990 and June 2007 produced a greater duration of inundation.

The Flood Study indicated that the peak level was relatively insensitive to the adopted ocean level and also showed little change as a result of varying the entrance breach model parameters by ±10%.

OUTCOMES

Wyong Council already has a flood warning system (Reference 4) but it would appear that it did not operate successfully in June 2007 and no warning was provided to the SES. A thorough review of the system should be undertaken to ensure that it will work successfully in all future events.

The state of the entrance is the single largest factor controlling the peak level and must be adequately taken into account in any forecasting system. Whilst it takes a relatively long duration rainfall event to produce an elevated lake level, the critical rise which produces the peak can occur within the order of 12 hours (1.5 mAHD to 2.2 mAHD). This is a short time in terms of the need to protect people and minimise damages, particularly given the number of residents requiring assistance.

A more rigorous entrance breach modelling procedure should be implemented in the flood forecasting system to predict the time and magnitude of the peak lake level. This would enable the SES to effectively manage their response to provide the maximum benefit. The linking of the floor level database used in this study to the flood warning system would ensure that the warning can be “tailored” to residents who would be affected rather than a blanket warning to all residents. The flood warning system should also be used to indicate where and when roads are inundated.

The greatest improvement in the accuracy of any flood warning predictions generally only occurs following major flood events. It is imperative therefore that a post flood assessment report be prepared following each future flood event with particular emphasis on the adequacy and accuracy of the flood warning system. It is unclear whether this has been adequately undertaken for the June 2007 event.

Improving the flood warning system is relatively inexpensive and is likely to have a high benefit/cost ratio. It has no apparent environmental or social dis-benefits.

6.4.2. Flood Emergency Management

DESCRIPTION

As mentioned above, it may be necessary for some residents to evacuate their homes in a major flood. This would be undertaken unde the direction of the SES though some residents may leave on their own accord or upon advice from the radio or other warning and may be assisted by local residents. The main problems with all flood evacuations are:

- they must be carried out quickly and efficiently,
- they are hazardous for both rescuers and the evacuees,
- residents are generally reluctant to leave their homes, causing delays and placing more stress on the rescuers,
- people do not appreciate the dangers of crossing floodwaters.

For this reason, the preparation of a Community Flood Emergency Response Plan (CFERP) helps to minimise the risk associated with evacuations by providing information regarding evacuation routes, refuge areas, what to do/not to do during floods etc. It is the role of the SES to develop a CFERP.

DISCUSSION
The SES have the skills and experience to undertake the necessary evacuations.

OUTCOMES
The SES should ensure that the Local Flood Plan for all settlements surrounding Tuggerah Lakes is up to date and includes feedback from the June 2007 event. This might include floor level and ground level details provided in this report and the Flood Study. In addition input from the local community (e.g Council, RFS, SES and community representatives) through a Community Flood Emergency Response Plan (CFERP)) is required to ensure that workable actions for the community are incorporated. Priority should be given to the implementation of this Plan once completed, which will involve ongoing community education and awareness.

6.4.3. Public Information and Raising Flood Awareness

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? Has it been adequately informed and educated?

Flood Preparedness: How prepared is the community to react to the threat? Do they (or the SES) have damage minimisation strategies (such as sand bags, raising possessions) which can be implemented?

Flood Evacuation: How prepared are the authorities and the residents to evacuate households to minimise damages and the potential risk to life? How will the evacuation be done, 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. To some extent many of the above issues are valid for Tuggerah Lakes as a result of the June 2007 and February 1990 floods.

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.* A major flood causing a high degree of flood damage in relatively recent times will increase flood awareness. If no floods have occurred, or there have been a number of small floods which cause little damage or inconvenience, then the level of flood awareness may be low. As a result of the June 2007 flood, which caused significant damage the community generally has a medium level of awareness at this time (it will decline as the time since the last flood increases).
- *History of residence.* Families who have owned properties for a long time will have established a considerable depth of knowledge regarding flooding and a high level of flood awareness. A community which consists predominantly of short lease rental homes will have a low level of flood awareness. It would appear that the majority of the residents have lived in the area for several years and are familiar with flooding.
- *Whether an effective public awareness program has been implemented.* It is understood that no large scale awareness program has been implemented.

For floodplain 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 (larger than June 2007) will occur in the future.

Some NSW Councils (Rockdale, Pittwater, Maitland) have initiated catchment wide flood awareness strategies (for residential and commercial). For Tuggerah Lakes only a residential strategy is required as there are no significant commercial areas. Wyong Shire Council's and the SES website also provide excellent information on flood awareness and other flood related information.

OUTCOMES

Based on feedback it would appear that the majority of residents around the foreshores of Tuggerah Lakes have a medium level of flood awareness and preparedness. However this would not be the case for the "holiday" visitors in caravan/holiday parks.

As the time since the last significant flood increases, 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 a Floodsafe brochure as well as advice provided on the Councils and SES's web sites. These need to be updated on regular basis to ensure that they are current.

This study also supports the recently implemented Community Working Group framework as a means of implementing flood awareness strategies. Table 22 provide examples of various methods that can be used.

Table 22: Flood Awareness Methods

Method	Comment
Letter/Pamphlet from Council	These may be sent (annually or biannually) 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 ongoing implementation of the Floodplain risk Management Plan, changes to flood levels or any other relevant information.
Council Web Site	Council should develop a web site that provides both technical information on flood levels as well as qualitative information on how residents can make themselves flood aware. This site would provide an excellent source of knowledge on flooding on the foreshores of Tuggerah Lakes (and elsewhere in the LGA) as well as on issues such as climate change. It is recommended that Council's web site be updated as and when required.
Community Working Group	Council should initiate a Community Working Group framework which will provide a valuable two way conduit between the local residents and Council.
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 topics relating to water quality, estuary management, etc.
Displays at The Entrance or at caravan parks	This is an inexpensive way of informing the community and may be combined with related displays.
Historical Flood Markers	Signs or marks can be prominently displayed on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators advise of potential hazards. These are inexpensive and effective.
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 are interesting for local residents
Collection of Data from Future Floods	Collection of data (rate of outflow at the entrance or photographs) assists in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible.
Types of Information Available	A recurring problem is that new owners consider they were not adequately advised that their property was flood affected on the 149 Certificate during the purchase process. Council may wish to advise interested parties, when they inquire during the property purchase process, regarding flood information currently available, how it can be obtained and the cost. This information also needs to be provided to all visitors who may rent for a period.
Establishment of a Flood Affectation Database and Post Flood Data Collection Program	A database would provide information on (say) which houses require evacuation, which public structures will be affected (e.g. telephone or power cuts). This database should be reviewed after each flood event. It is already being developed as part of this present study. This database should be updated following each flood with input from the Community Working Group.
Flood Preparedness Program	Providing information to the community regarding flooding helps to inform it of the problem and associated implications. However, it does not necessarily adequately prepare people to react effectively to the problem. A Flood Preparedness Program would ensure that the community is adequately prepared. The SES would take a lead role in this.
Develop Approaches to Foster Community Ownership of the Problem	Flood damages in future events can be minimised if the community is aware of the problem and takes steps to find solutions. The development of approaches that promote community ownership should therefore be encouraged. For example residents should be advised that they have a responsibility to advise Council if they see a problem such as potential blockage of flap gated pipes or such like. This process can be linked to water quality or other water related issues including estuary management. The specific approach can only be developed in consultation with the community.

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 by the Community Working Group.

6.5. Property Modification Measures

6.5.1. Strategic Planning Issues

DESCRIPTION

The division of flood prone land into appropriate land use zones can be an effective and long term means of limiting danger to personal safety and flood damage to future developments. Zoning of flood prone land should be based on an objective assessment of land suitability and capability, flood risk, environmental and other factors. In many cases, it is possible to develop flood prone lands without resulting in undue risk to life and property.

The strategic assessment of flood risk (as part of the present study) can prevent new development occurring in areas with a high hazard and/or with the potential to have significant impacts upon flood behaviour in other areas. It can also reduce the potential damage to new developments likely to be affected by flooding to acceptable levels. Development control planning includes both zoning and development controls.

DISCUSSION

Flood hazard mapping has been undertaken as part of this study (Figure 8), based on the best available information (airborne laser scanning and accurate to ±0.2m) and should be used by Council to identify properties subject to flood related development controls.

The possible implications of increases in flood level due to climate change are discussed in Section 7.

OUTCOMES

Strategic planning is the main approach for reducing flood damages to future developments. The issue of climate change and implications for Flood Planning Levels are discussed in Section 7.

6.5.2. House Raising

DESCRIPTION

House raising has been widely used throughout NSW to eliminate or significantly reduce inundation from habitable floors. However it has limited application as it is not suitable for all building types. Also, it is more common in areas where there is a greater depth of inundation than at Tuggerah Lakes and raising the houses allows creation of an underfloor garage or non-habitable area (though it is essential that this underfloor area and its contents will not incur flood damages, if it is infilled this may negate the benefits of house raising).

DISCUSSION

House raising is suitable for most non-brick single storey houses on piers and is particularly relevant to those situated in low hazard areas on the floodplain. The benefit of house raising is that it eliminates inundation to the height of the floor and consequently reduces the flood damages. It should be noted that larger floods than the design flood (used to establish the minimum floor level) will inundate the house floor. It also provides a "safe refuge" during a flood, assuming that the building is suitably designed for the water and debris loading. However the potential risk to life is still present if residents choose to enter floodwaters or larger floods than the design flood occurs.

Funding is available for house raising in NSW and has been widely undertaken in rural areas (Macleay River floodplain) and urban areas (Fairfield and Liverpool). An indicative cost to raise a house is $60,000 though this can vary considerably depending on the specific details of the house. Home raising was the traditional method of eliminating tangible flood damages but is less prevalent today in NSW as:

- the majority of suitable buildings have already been raised,
- the houses that can be raised are nearing the end of their useful life,
- house styles and requirements (ensuites, cabling, air conditioning) means that the timber, piered homes are less attractive than in the past,
- most households indicate that they would prefer to use the funding to construct a new house,
- re-building rather than renovations are becoming more cost effective. In many suburbs in Sydney 30 year old brick homes are being demolished as the cost per m^2 to renovate is up to twice the per m^2 cost of re-building. Thus if 50% of the house is to be renovated it is cheaper to re-build.

The house raising potential at Tuggerah Lakes cannot be accurately assessed due to the lack of detail in the floor level database.

An alternative to house raising for buildings that are not compatible, is flood proofing or sealing off the entry points to the building. This measure has the advantage that it is generally less expensive than house raising and causes less social disruption. However this measure is really only suitable for commercial and industrial buildings where there are only limited entry points and aesthetic considerations are less of an issue. Also there are issues of compliance and maintenance. Based upon our experience we do not consider flood proofing a viable measure for existing houses in Tuggerah Lakes. However flood compatible building or renovating techniques should be employed for extensions or renovations where appropriate. Guidelines are provided in a booklet *"Reducing Vulnerability to Flood Damage"* prepared for the Hawkesbury Nepean Floodplain Management Steering Committee (June 2006).

A house raising/re-building subsidy scheme has been considered whereby the home owner can put the payment towards the cost of a replacement house constructed in a flood-compatible way rather than raising the existing building. Such a scheme has been promoted in other flood prone communities in NSW where there are large numbers of houses that could be raised but many owners wish to re build and/or consider it more cost effective. This scheme would provide a financial incentive to undertake house raising or re-building works and would be available to all house owners whose house is flood liable. However such a scheme is not expected to receive funding from the Federal or State government's flood mitigation program and thus the costs may have to be borne entirely by Council.

Slab-on-ground construction is probably the most common method of housing construction. A significant issue with this mode of construction is that the building floor is generally not much higher than the ground level, thus there is a risk with overland flow or shallow depths of flooding some inundation will occur. Also there is no realistic possibility that this type of house can be raised.

Subsidies for house raising implies that Council and the State Government will be maintaining the existing services for the life of the building and including sea level rise. This situation needs to be reviewed before approval is given to ensure that these services can actually be provided in the future.

OUTCOMES

For the majority of flood affected buildings around Tuggerah Lakes house raising and flood proofing are not viable means of flood protection. However if advertised and favourable responses are obtained from the owners a house raising subsidy scheme could be further investigated (subject to ensuring that Council and the State Government will be maintaining the existing services for the life of the building and including sea level rise).

In addition a house re-building subsidy scheme should be initiated in order to provide an incentive to all house owners whose house is flood liable.

Council should consider whether slab-on-ground construction is an appropriate form of house construction in areas that will be subject to a climate change induced increase inundation levels.

6.5.3. Reduce Failure of Sewerage System

DESCRIPTION

As noted previously and shown on Figure 8 for the June 2007 event, the sewerage system has failed during floods in the past. This failure represents a significant health risk to residents who wade through floodwaters. Failure predominantly occurs due to power outages (fallen power lines) but in large events the pumping stations may be turned off due to the influx of flood waters into the sewerage system.

Failure of the sewerage system can mean that properties that are not inundated by floodwaters but are connected to a non working pump station are also affected. Thus a significant number of properties are living with a non-working sewerage system (some for up to 4 days) which discharges raw sewerage into Tuggerah Lakes. Whilst the volume of discharge is minimal compared to the volume of floodwaters it becomes a significant hazard as the floodwaters are relatively static with little mixing along the foreshores.

DISCUSSION

The failure of the sewerage system during floods should be addressed. Initially this would involve a preliminary investigation and review of the June 2007 failures. This would then lead to a means to reduce the failures (more secure power supply or raise vents in yards). Properties with floor levels below the flood planning level will require careful consideration to see how this can be achieved.

OUTCOMES

The failure of the sewerage system around Tuggerah Lakes during floods is considered one of the most significant floodplain management issues affecting the community and must be addressed.

6.5.4. Risk of Electrocution

DESCRIPTION

As noted previously the sewerage system has failed during floods. It is unclear exactly the reasons why each system was turned off but certainly one key reason was the failure of electricity supply and this is discussed in Section 6.5.3. However it is also understood that one of the reasons why the electricity was not turned on as soon as it was repaired was the possible risk of electrocution.

DISCUSSION

There is always the risk of electrocution in times of flood and whilst this has occurred elsewhere there is no record of loss of life due to electrocution at Tuggerah Lakes in the February 1990 or the June 2007 events. In order to determine the magnitude of this problem a survey of the low lying properties and/or a flood education program should be undertaken.

OUTCOMES

There is a risk of electrocution in times of flood at Tuggerah Lakes which needs to be addressed. Possible approaches are to undertake a survey of low lying properties by a qualified electrician and/or require building owners to submit a certification from an electrician. At a minimum the flood education program should encompass this issue.

6.6. Other Management Measures

6.6.1. Modification to the s149 Certificates

DESCRIPTION

Councils issue planning certificates to potential purchasers under Section 149 of the Environmental Planning and Assessment Act of 1979. The function of these certificates is to inform purchasers of planning controls and policies that apply to the subject land. Planning certificates are an important source of information for prospective purchasers on whether there are flood related development controls on the land. They need to rely upon the information under both Section 149(2) and 149(5) in order to make an informed decision about the property. It should be noted that only Part 2 is compulsory when a house is purchased and thus detail in Part 5 may not be made known to the purchaser unless it is specifically requested. Under Part 2

Council is required to advise if it is aware of the flood risk as it is of any other known risk (bush fire).

The current wording shown on Section 149(2) and 149(5) certificates provides only limited details of the extent of flood affectation.

DISCUSSION

Because of the wide range of different flood conditions across the State, there is no standard way of conveying information. As such, Councils are encouraged to determine the most appropriate way to convey information for their areas of responsibility. This will depend on the type of flooding, whether from major rivers or local overland flooding, and the extent of flooding (whether widespread or relatively confined).

It should be noted that the Section 149 certificate only relates to the subject land and not any building on the property. This can be confusing or misleading to some.

The information provided under Part 2 of the certificate is determined by the legislation and unless specifically included by the Council provides no indication of the extent of inundation. Under Part 5 there is scope for providing this additional type of information. Residents in many areas have suggested that insurance companies, lending authorities or other organisations may disadvantage flood liable properties that have only a very small part of their property inundated. Some Councils have addressed this concern by adding information onto Part 5 to show the percentage of the property inundated as well as floor levels and other flood related information.

In addition the hazard category (Figure 8) could be provided and also advice regarding climate change increases in flood level.

OUTCOMES

It is recommended that Council consider adding additional flood related information to the Section 149 Certificate.

6.6.2. Planning Regulations for Tourist/Caravan Parks

DESCRIPTION

There are 11 tourist/caravan parks on the foreshores of Tuggerah Lakes (Table 23). The number of cabins/sites in the floodplain is unknown.

Table 23: Tourist Parks on the Foreshore of Tuggerah Lakes

Park	Suburb
Budgewoi Holiday Park	Budgewoi
Lakeview Tourist Park	Long Jetty
A Paradise Park Cabins	Long Jetty
Duncan's Lakefront Park	Long Jetty
El Lago Waters Tourist Park	The Entrance
Dunleith Caravan Park Kiosk	The Entrance North
Two Shores Holiday Village	The Entrance North
Canton Beach Holiday Park	Toukley
Canton Beach Waterfront Tourist Park	Toukley
Lakedge Caravan Park	Toukley
Tuggerah Shore Caravan Park	Tuggerawong

These parks within the floodplain present their own unique problems, namely:

- there is generally poor access with a single entrance/exit which may be controlled by gates,
- a poor (or no) site map is generally available to show the internal road system or the types of vans,
- fixed annexes on caravans or cabins which may contain high cost equipment such as freezers or stoves,
- there may be poor internal lighting which may fail during a flood,
- there is probably no flood emergency plan or it has not been tested recently,
- there may be a problem in communicating to the residents due to the lack of or failure of the public address system or telephone network,
- short term residents will have little flood awareness of the flood risk or damage minimisation measures,
- a number of cabins or vans may be vacant thus increasing the workload and possible risk to life of the “rescuers” in removing vans or raising goods in cabins,
- there is the risk that vans may float and crash into each other or obstruct exit routes,
- caravans and many cabins have little structural integrity and thus can easily be damaged by floodwaters,
- the internal fittings (cupboards, fridges, beds) are usually non-removable and quickly damaged by floodwaters.

DISCUSSION

In theory caravans can be easily moved to high ground in a flood. However, in practice experience has shown that this is unlikely to occur for the above reasons.

Tuggerah Lakes has a much slower rate of rise than a river system and for a large number of parks there is nearby high ground where caravans and residents can be easily moved. Also, as the cabins and caravans are all (say) 0.5 m above the natural surface they are unlikely to be inundated above floor in events smaller than a 2% AEP event (assuming the ground level is 1.5 mAHD or above). An aerial photograph of the Two Shores Caravan Park in the June 2007 event is shown below.

Two Shores Caravan Park in the June 2007 flood

Shoalhaven City Council has special provisions for caravan parks on the floodplain which include:

- rapid knock down annexes,
- quick release ties on the vans to prevent them floating away,
- an effective evacuation strategy documented in a Flood Action Plan,
- restrictions on the type of vans, e.g. un-towable vans not permitted in certain areas, no rigid annexes,
- specific inclusion of caravan parks in the SES Local Flood Plan.

OUTCOMES

Cabins and caravan parks on the floodplain can represent a significant hazard during a flood. On the foreshore of Tuggerah Lakes the hazard is low because there is usually a long warning time, nearby high ground and the frequency of inundation is low.

This issue should be investigated further by a field inspection to accurately assess the hazard of each park. Following this, consideration should be given to implementing adequate safety provisions. At a minimum any "at risk" parks should be clearly identified in the SES Flood Plan.

7. CLIMATE CHANGE: IMPLICATIONS & ADAPTIVE STRATEGIES

7.1. State Government Policy

The *2005 Floodplain Development Manual* (Reference 1) requires that Flood Studies and Floodplain Risk Management Studies consider the impacts of climate change on flood behaviour.

Since completion of the Tuggerah Lakes Flood Study (Reference 2) in September 1984, current best practice for considering the impacts of climate change (sea level rise and rainfall increase) have been evolving rapidly. Key developments in the last three years have included:

- release of the Fourth Assessment Report by the Inter-governmental Panel on Climate Change (IPCC) in February 2007 (Reference 9), which updated the Third IPCC Assessment Report of 2001 (Reference 10);
- preparation of *Climate Change Adaptation Actions for Local Government* by SMEC Australia for the Australian Greenhouse Office in mid 2007 (Reference 11);
- preparation of *Climate Change in Australia* by CSIRO in late 2007 (Reference 12), which provides an Australian focus on Reference 9;
- release of the Floodplain Risk Management Guideline *Practical Consideration of Climate Change* by the NSW Department of Environment and Climate Change in October 2007 (Reference 13 - referred to as the DECC Guideline 2007);
- Hunter, Central and Lower North Coast Regional Climate Change Project — Report 3: Climate Change Impact for the Hunter, Lower North Coast and Central Coast Region of NSW (Hunter and Central Coast Regional Environmental Strategy, 2009, Reference 14);
- In October 2009 the NSW Government issued its Policy Statement on Sea Level Rise (Reference 15) which states: *"Over the period 1870–2001, global sea levels rose by 20 cm, with a current global average rate of increase approximately twice the historical average. Sea levels are expected to continue rising throughout the twenty-first century and there is no scientific evidence to suggest that sea levels will stop rising beyond 2100 or that the current trends will be reversed.*

  Sea level rise is an incremental process and will have medium- to long-term impacts. The best national and international projections of sea level rise along the NSW coast are for a rise relative to 1990 mean sea levels of 40 cm by 2050 and 90 cm by 2100[1]*. However, the Intergovernmental Panel on Climate Change (IPCC) in 2007 also acknowledged that higher rates of sea level rise are possible"*;
- In August 2010 the NSW State Government Department of Environment, Climate Change and Water issued the following:
  - *Flood Risk Management Guide (Reference 16): Incorporating sea level rise benchmarks in flood risk assessments*,
  - *Coastal Risk Management Guide (Reference 17): Incorporating sea level rise benchmarks in coastal risk assessments*,

  In addition an accompanying document *Derivation of the NSW Government's sea level rise planning benchmarks* (Reference 18) provided technical details on how the sea level rise assessment was undertaken.

- In August 2010 The Department of Planning also exhibited:
  - *NSW Coastal Planning Guideline: Adapting to Sea Level Rise* (Reference 19).
- The most current NSW Government advice is that in October 2012 the 2009 Sea Level Rise Policy is no longer NSW Government policy and advised Councils to adopt their own sea level rise projections based on competent and credible scientific advice.

7.2. Wyong Council's Sea Level Rise Policy

On 10th October 2012 Council acknowledged that the 2009 NSW Sea Level Rise Policy Statement (Reference 15) is no longer NSW Government Policy and resolved "*that its sea level rise interim policy consist of compliance with the 1% AEP flood level and 500mm freeboard allowance*".

On 24th July 2013 Council considered a staff report entitled "*Consideration of Freeboard and Sea Level Rise Planning Levels*". Council chose not to accept the report's recommendation to amend the sea level rise policy to provide a sea level rise allowance of 0.4m for planning purposes. Council resolved to reaffirm its current sea level rise policy consisting of compliance with the 1% AEP flood level and 500mm freeboard allowance and to review the draft WLEP2013 and DCP in line with this policy.

7.3. Climate Change Sensitivity Parameters

As a result of the information provided in the above and other documents, and to keep up-to-date with current best practice, this study incorporates an assessment of climate change. It should be noted that the estimated rise in sea level along the NSW varies between the above reports and at this time there is no absolute value that has been adopted by all experts. Wyong Shire Council has resolved not to adopt any further planning allowance for sea level rise at this time. This assessment in this report therefore uses the previous NSW sea level rise benchmarks for the sake of sensitivity analysis.

7.3.1. Rainfall Intensity Parameters

The sea level climate change scenarios specified in the DECC Guideline 2007 have now been superseded. However the increase in rainfall intensities are still the best that are available and advise that sensitivity analysis should be undertaken for:

- **increase in peak rainfall and storm volume:**
  - low level rainfall increase = 10%,
  - medium level rainfall increase = 20%,
  - high level rainfall increase = 30%.

A high level rainfall increase of up to 30% is recommended for consideration due to the uncertainties associated with this aspect of climate change and to apply the "precautionary principle". It is generally acknowledged that a 30% rainfall increase is probably overly conservative and that a timeframe for the provision of definitive predictions of the actual increase is unknown. The DECC Guideline 2007 is currently the only reference providing benchmarks for rainfall increases.

7.3.2. Sea Level Rise Parameters

The most recent guidelines (Reference 19) supersedes those sea level rise benchmarks provided in the DECC Guideline 2007 but provides no advice on rainfall increases. Reference 19 indicates:

- a 0.4 m sea level rise by the year 2050
- a 0.9 m sea level rise by the year 2100

However it should be noted that climate change (man made or due to natural processes) will still occur beyond 2100.

Table 24 provides a tabulation of the number of properties in Low and High hazard areas under existing and 0.4m and 0.9m sea level rise scenarios.

Table 24: Hazard in the 1% AEP event with Sea Level Rise

		Sea Level Rise	
Classification of Property	**Existing**	**0.4m**	**0.9m**
Low Hazard	3108	2583	2352
High Hazard	2392	4062	5787
Total	5500	6645	8139
% Increase		21%	48%
How Property Changes with Sea Level Rise Compared to Existing			
	Remains Low	1438	0
	Remains High	2392	2392
	Not Previously Inundated Becomes Low	1145	2352
	Low Becomes High	1670	3108
	Not Previously Inundated Becomes High		287

7.4. How Could Climate Change Affect Water Levels in Tuggerah Lakes?

Climate change has the potential to alter the water level in both non flood and flood times.

7.4.1. During Non Flood Times

The main impacts in non flood times will be:

- The "normal" water level in Tuggerah Lakes will rise from the current 0.2m/0.3 mAHD average water level. An indicative increase is the same as the expected sea level rise (by 0.4m in 2050 and 0.9m in 2100),
- It is possible that the tidal range and seasonal variation in water level may change in

response to rainfall or temperature changes but the extent is unknown at this time.

The increase in the "normal" water level in Tuggerah Lakes in "non flood" times may result in increased maintenance costs and/or modifications costs for existing developments and infrastructure due to more frequent inundation in non flood times. For example, low lying roads will be more frequently inundated during elevated water levels. Inflows of water from Tuggerah Lakes to sewer surcharge vents in backyards may also occur more frequently. The increased cost for residents and Wyong Shire Council to maintain the existing developments and infrastructure is unknown. A separate study is required to quantify the effect in non flood times but it is likely that at some time in the future the existing services will (say a road) become unable to be maintained and it will have to be relocated or re-built. This may mean that the existing developments will need to be relocated or exist without the current standard of services.

Any change in the "normal" water level regime may also impact on the ecology of the Tuggerah Lakes. The implications of this are outside the scope of this Floodplain Risk Management Study.

7.4.2. During Flood Times

There are several broad ways in which climate change will affect water levels in Tuggerah Lakes during floods, namely:

1. *The increase in ocean level* will raise the "normal" water level in Tuggerah Lakes as well as the assumed ocean level adopted for design flood analysis in the Tuggerah Lakes Flood Study (Reference 2). A peak ocean level of 1.32 mAHD was adopted in Reference 2 together with a wave setup condition which resulted in approximately an additional 0.1 m sea level rise. Whether the full ocean level increase will be transmitted into a similar increase in the design flood level in Tuggerah Lakes is not accurately known as it will depend on many factors including the state of the entrance (open, closed or dredged) and the rate of scour during a flood (unknown). For this study it has been conservatively assumed that any increase in ocean level will result in a similar increase in design flood level in Tuggerah Lakes.
2. *The increase in peak rainfall intensity and storm volume* will increase design flood levels in Tuggerah Lakes. No hydraulic modelling has been undertaken to accurately determine the increase in lake level but based on results from the Tuggerah Lakes Flood Study (Reference 2) a 10% increase in rainfall intensity approximately equals a 0.1m rise in design flood level in Tuggerah Lakes.
3. *The height of the sand berm at the Entrance* may be affected by an increase in ocean level, this in turn will affect the outflow characteristics of the entrance during a flood and the resulting design flood levels. It is also possible that increased rainfall intensities may cause the entrance to open more often and so the entrance berm might be assumed to be lower at the start of the design storm. At this time the impact on the entrance berm is unknown.
4. *A change in wind activity* may affect wind wave activity on the lakes and so change the "wave runup" flood level on the lakes. At this time the impact of this effect is

unknown.

According to the best available advice from the IPCC and NSW Government experts (summarised in Reference 19) it is likely that design flood levels will increase by of the order of 0.4m by the year 2050 and 0.9m by the year 2100 due to sea level rise alone. This may increase by a further 0.1m+ if the increase in rainfall intensity and volume occurs concurrently.

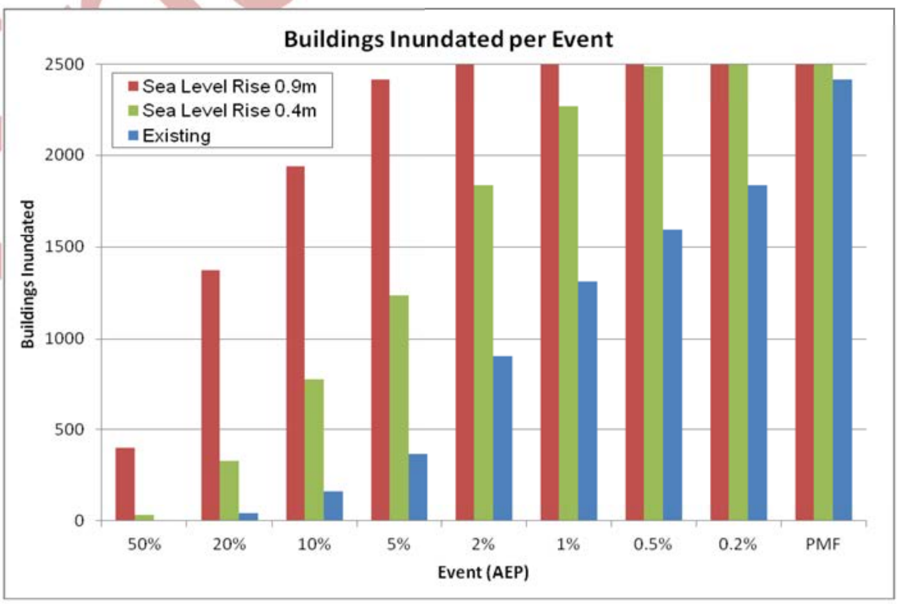
The increase in the number of flood liable buildings due to a 0.4m and 0.9m increase in flood level is indicated in Table 25. Figures 11 to 14 indicate the following impacts on flooding:

- Figure 11 - buildings inundated above floor level with a 0.9m sea level rise.
- Figure 12 - PMF flood extents for existing conditions and with 0.4m and 0.9m sea level rise.
- Figures 13 and 14 - the change in flood hazard for the 1% AEP event with a 0.4m and 0.9m sea level rise.

Table 25: Effect of Climate Change Induced Sea Level Rise

	Existing	Sea Level Rise 0.4m			Sea Level Rise 0.9m		
Event AEP	Buildings Inundated	Buildings Inundated	Increase	Increase (%)	Buildings Inundated	Increase	Increase (%)
50%	0	30	30	-	405	405	-
20%	44	335	291	661%	1374	1330	3023%
10%	167	778	611	366%	1942	1775	1063%
5%	371	1233	862	232%	2416	2045	551%
2%	906	1839	933	103%	2506		
1%	1312	2267	955	73%	2518		
0.5%	1596	2487	891	56%	2523		
0.2%	1839	2497	658	36%	2523		
PMF	2416	2517			2524		

Above 2500 the number inundated is not accurate



Flood Damages for 0.4m Sea Level Rise									
Area	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
BL1	$75,000	$1,634,000	$3,557,000	$5,921,000	$9,352,000	$12,055,000	$14,023,000	$15,480,000	$18,466,000
EX1	$21,000	$367,000	$981,000	$1,723,000	$2,827,000	$3,816,000	$4,582,000	$5,152,000	$6,337,000
LM1	$102,000	$930,000	$2,174,000	$3,801,000	$6,748,000	$9,376,000	$11,284,000	$12,723,000	$15,672,000
TL1	$30,000	$570,000	$1,896,000	$3,716,000	$6,879,000	$9,548,000	$11,285,000	$12,557,000	$15,090,000
TL2	$15,000	$298,000	$998,000	$2,535,000	$5,643,000	$8,548,000	$10,513,000	$11,976,000	$14,881,000
TL3	$9,000	$166,000	$609,000	$1,507,000	$3,600,000	$5,917,000	$7,709,000	$9,054,000	$11,778,000
TL4	$38,000	$1,250,000	$3,715,000	$6,904,000	$11,897,000	$15,852,000	$18,648,000	$20,688,000	$24,819,000
TL5	$104,000	$1,459,000	$3,365,000	$5,850,000	$9,294,000	$11,710,000	$13,510,000	$14,937,000	$17,853,000
TL6	$58,000	$928,000	$2,482,000	$4,953,000	$8,878,000	$11,781,000	$13,726,000	$15,161,000	$17,932,000
TL7	$58,000	$606,000	$1,383,000	$2,398,000	$4,288,000	$6,290,000	$7,745,000	$8,806,000	$10,964,000
Total	$510,000	$8,208,000	$21,160,000	$39,308,000	$69,406,000	$94,893,000	$113,025,000	$126,534,000	$153,792,000

Flood Damages for 0.9m Sea Level Rise									
Area	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
BL1	$1,942,000	$6,695,000	$10,068,000	$13,220,000	$16,783,000	$18,766,000	$19,918,000	$21,244,000	$24,309,000
EX1	$447,000	$1,959,000	$3,064,000	$4,258,000	$5,668,000	$6,457,000	$6,961,000	$7,395,000	$8,265,000
LM1	$1,119,000	$4,394,000	$7,440,000	$10,497,000	$14,007,000	$16,146,000	$17,311,000	$18,037,000	$20,284,000
TL1	$761,000	$4,375,000	$7,615,000	$10,572,000	$13,674,000	$15,335,000	$16,277,000	$16,885,000	$18,610,000
TL2	$373,000	$3,146,000	$6,424,000	$9,691,000	$13,267,000	$15,161,000	$16,175,000	$16,946,000	$18,520,000
TL3	$231,000	$1,871,000	$4,162,000	$6,967,000	$10,252,000	$12,046,000	$13,009,000	$13,669,000	$15,013,000
TL4	$1,586,000	$8,021,000	$12,947,000	$17,523,000	$22,470,000	$25,220,000	$26,666,000	$27,923,000	$30,956,000
TL5	$1,787,000	$6,720,000	$9,931,000	$12,608,000	$16,180,000	$18,202,000	$19,411,000	$20,554,000	$23,073,000
TL6	$1,122,000	$5,840,000	$9,694,000	$12,940,000	$16,395,000	$18,198,000	$19,341,000	$20,212,000	$22,405,000
TL7	$722,000	$2,787,000	$4,809,000	$7,166,000	$9,756,000	$11,237,000	$11,996,000	$12,644,000	$14,191,000
Total	$10,090,000	$45,808,000	$76,154,000	$105,442,000	$138,452,000	$156,768,000	$167,065,000	$175,509,000	$195,626,000

7.4.3. Are the Implications of Climate Change Significant?

At some localities in NSW an increase in flood level or the "normal water level" will have little impact on the existing or development potential of the area. For the floodplain surrounding Tuggerah Lakes this is not the case and both a rise in the "normal" water level and the design flood levels will have significant implications for the area and needs to be addressed.

7.5. Mitigation/Adaptation Measures to Protect Existing Developments

7.5.1. Flood Warning and Awareness

Flood warning and flood awareness are measures that are currently employed within Wyong LGA to lessen the impacts of flooding. It is unlikely that significant advances can be made in these measures to negate the adverse impacts of climate change. However the present flood awareness program by the SES and Wyong Shire Council should be updated to include potential climate change impacts.

7.5.2. Flood Modification Measures

Flood modification measures such as dredging the existing entrance channel, forming a 2nd entrance or constructing entrance training walls to maintain a permanent entrance should be further examined. Currently these measures are cost prohibitive and would introduce many environmental issues that would need to be addressed. In other areas measures considered are a "Thames" style barrage to prevent elevated ocean levels from entering. Unfortunately such a barrier is unlikely to be successful for all events as the same meteorological event that produces elevated ocean levels (storm surge) also produces intense rainfall causing flooding. Thus a barrier would provide little benefit in such a scenario at Tuggerah Lakes.

7.5.3. Levees

Levees are one such measure that could be used to protect existing development. Whilst at first glance levees may appear a viable means of protection there are a number of concerns with their application, including:

- high cost,
- landtake cost and can the land be obtained?
- flooding from rainfall within the leveed area can itself be a major problem. pumps or gravity systems to remove this runoff are not always successful,
- levees restrict access (boating, fishing etc) and views of the water – the main reason why residents live in such areas,
- to be 100% secure they need to be constructed to the PMF level,
- vehicle access to the leveed area and services relocation will generally require extensive additional works,
- levees require on going maintenance and a failure in any part during a flood (bank collapse, flap gated culvert fails) renders the structure of little value.

An example is at The Entrance North where Wilfred Barrett Drive acts as a levee and the stormwater pipes within the levee are flap-gated to allow drainage from the leveed area but no inflow from Tuggerah Lakes. There have been issues with vandalism or the flap-gates being blocked by debris as well as difficulties providing adequate outflow with a high water level in Tuggerah Lakes (as occurred in June 2007).

In conclusion levees can provide a mitigation measure but for the reasons given above it is likely that for many areas (Chittaway Point) this will not be a viable measure.

7.5.4. House Raising

House raising has been used at many places in NSW (Maitland, Lismore, Kempsey, Fairfield) as a viable means of flood protection. It is likely that some of the existing flood liable buildings could be raised but not all buildings are viable for raising for the following reasons:

- it is more cost effective to construct a new house,
- generally only single storey houses can be raised,

- generally only timber, fibro and other non masonry construction can be raised,
- generally only pier and non slab on ground construction can be raised,
- there can be many additional construction difficulties (brick fire place, brick garage attached to house, awnings or similar attached to house).

In conclusion it will not be possible to raise all the flood liable buildings and other measures need to be employed. However for existing houses raising is a viable solution if the area remains serviceable (adequate sewer and roads).

7.5.5. Upgrade Sewerage System

One of the main factors affecting existing residences around Tuggerah Lakes (both those inundated and those not inundated) during a flood is the failure of the sewerage system. This occurred during the June 2007 and February 1990 floods and service was lost for up to 4 days. This loss of service affects both flood liable and non flood liable properties if they are connected to a pump station that fails. Failure occurs for many reasons and it is not entirely clear what was the key factor in the past flood events. Failure can occur due to:

- loss of electricity supply (power outage or damage to power lines caused by storm damage),
- failure at the pumping station,
- the pumps are turned off as the water level rises above toilets or sewer vents and the pumping stations are "pumping Tuggerah Lakes".

The loss of supply of a sewerage system represents a potential life threatening hazard to human life as raw sewage will enter the flood waters which residents will be wading around in. In addition residents who do not have a functioning sewage system should be evacuated from their homes, this would also include those houses that are not inundated but experience a failure of the sewerage system for several days. This will place considerable additional burden on the SES.

This issue requires urgent attention and a study should be undertaken to investigate the means to reduce this problem.

7.5.6. Areas that Cannot be Protected by Adaptation Measures

It may be that some areas cannot be protected by the above adaptation measures. For these areas Council will need to establish a retreat policy.

7.6. Mitigation/Adaptation Measures to Protect Future Developments

7.6.1. Flood Related Development Controls

Flood related development controls (largely stipulation of a minimum floor level at say the 1% AEP plus a freeboard of 0.5m – termed the Flood Planning Level or FPL) is the most constructive measure for reducing flood damages to new residential developments. More vulnerable developments to flooding (hospitals, electricity sub stations, "seniors" housing) must consider rarer events greater than the 1% AEP when determining their FPL. Flood warning and awareness measures are employed to provide damages minimisation in larger events (such as the June 2007 flood at Newcastle) than the design standard (generally the 1% AEP). Thus the simplest and most effective measure to protect future development is to raise the FPL to account for climate change. However this measure does not address the associated range of issues when considering flood risk such as access and failure of essential services.

The 0.5m freeboard should still be included in the FPL and it should not be assumed that the freeboard can take account of climate change. According to the 2005 Floodplain Development Manual (Reference 1) the *purpose of the freeboard is to provide reasonable certainty that the reduced flood risk exposure provided 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,
- the cumulative effect of subsequent infill development on existing zoned land,
- climate change.

In a real flood some of these factors may reduce the flood level (local factors) or not apply at all (no wave action). Whilst climate change is included as one of the above factors there is no advice as to what the contribution for each factor should be. The Flood Risk Management Guide (Reference 16) states "*Freeboard should not be used to allow for sea level rise impacts, instead these should be quantified and applied separately*..". The 0.5m freeboard allowance allows for uncertainties, thus if the best advice is that ocean levels will rise by 0.9m by the year 2100 then the FPL should be raised by 0.9m to account for this increase. The climate change component in the 0.5m freeboard allowance accounts for any uncertainty in estimation of the 0.9m ocean levels rise (in reality the true rise may be less or more).

Whilst raising the floor levels will ensure that the floors are not inundated in the design event (with sea level rise) there is still the issue of whether adequate services (sewer, roads) can be provided and that the private land will be suitable for habitation (i.e not regularly inundated so as to make the land unsuitable).

7.6.2. The Same Mitigation/Adaptation Measures Suggested to Protect Existing Developments

The flood modification, levees and house raising measures suggested to protect existing developments can also be employed to protect future development. These measures may become viable as the only means of providing protection if they are considered appropriate by the community.

Generally levees are viewed as a means of protecting existing developments and not for providing protection for new developments. However a future sub division could be constructed such that a future levee would be able to be constructed if required. The success of this measure will depend on how the residents at the time accept the adverse consequences of levee construction, such as loss of view or loss of access.

House raising is a means by which a new house can be built at the existing FPL but is constructed in such a manner that it can be raised in the future as climate change impacts occur. This type of modular/adaptive housing construction is not common in NSW but is employed in the USA where the habitable floor may be several metres above the ground. A concern with this approach is that the surrounding ground in the property may remain saturated due to rising water tables and will also become more frequently inundated. Also of concern is the increase in maintenance required to ensure the condition of the roads remains acceptable and evacuation routes are maintained. These issues will need to be addressed if this type of housing construction is permitted.

7.6.3. Filling of the Floodplain

The filling of the floodplain is generally not considered an acceptable means of permitting future development as it "destroys" the ecology of the floodplain and also raises flood levels by eliminating temporary floodplain storage (and in some cases reduces the hydraulic conveyance). At Tuggerah Lakes the effect on flood levels will be negligible given the size of the existing floodplain and the likely quantity of fill. If the ecological issues can be overcome this will provide a means of permitting future development.

This approach could also be adopted for infill development as long as care is taken to ensure local drainage issues are not exacerbated and services (roads, sewer, water) can be accommodated. Possibly a staged approach can be undertaken where the new buildings and garages are constructed on elevated pads and in time the remainder of the property and the roads are raised. This piece-meal approach can lead to dis-harmony within the community when there are some filled and some non filled properties.

7.6.4. Planned Retreat

As the predicted sea level rise occurs some developed parts of the floodplain surrounding Tuggerah Lakes may have to be resumed as park land or similar. However there is no certainty regarding the predicted sea level rise or the exact timeframe. Thus it may be possible to permit new development in these areas with the proviso that if sea level rise eventuates then the development must retreat according to a planned retreat strategy. This strategy could be based on a suite of conditions, or thresholds including groundwater levels, inundation in non flood times or availability of access allowing residents to stay until site conditions are considered unsuitable. This approach is more suited to commercial developments (tourist parks) than residential developments but should be considered.

7.6.5. Limit the Extent of Development

Future residential development in low lying areas could be restricted to the "lowest residential" zoning. Thus any development that will increase the present residential density would not be permitted. Thus dual occupancy, sub division or increasing the % site coverage (increasing the size of the building) would not be permitted. These controls could be further refined through a site specific DCP.

7.7. Related Issues that may Threaten the Long Term Viability of Areas

7.7.1. Evacuation Requirements

For many of the existing flood liable areas (Chittaway Point and Tacoma), even if house raising or construction of a levee was undertaken and the sewerage issues resolved there is still no safe access to high ground in flood. Whilst in a medical emergency a helicopter or flood boat could access the area many residents will attempt to cross the floodwaters (collect children, leave house, obtain food). This represents a burden on the SES to "rescue" residents and a risk to life to the residents who cross floodwaters unprepared.

At present many locations do not have adequate flood access and this will be exacerbated with climate change. The lack of adequate access may mean that some areas should not be further developed.

7.7.2. Frequency of Inundation of Land in Non Flood Times

A lot of residential properties have land at or below 1 mAHD and during non flood times this land is never inundated as the "normal" water level is around 0.3 mAHD with a maximum water level of around 0.7 mAHD in non flood times (but after constant heavy rain). However during flood times such as the June 2007 event, where the water level reached 1.6 mAHD, floodwaters can remain above 0.8 mAHD for 4 days and above 0.5 mAHD for 8 days.

With sea level rise then the "normal" water level in Tuggerah Lakes will rise by a similar amount to the sea level rise. This will mean that low lying land will be more frequently inundated and with a 0.9m sea level rise all land below 1 mAHD (approximately the existing 3 year ARI flood level)) will be permanently inundated. Consideration needs to be given to when the land becomes unsuitable for habitation due to frequent inundation.

7.7.3. Mine Subsidence

The Mines Subsidence Board has indicated that the northern part of Tuggerah Lakes (north of the Wyong River in the west and Norah Head in the east) is within a mine subsidence area. The magnitude of subsidence could be between 0.1m and 0.6m. Further detail is required to define the likely extent and magnitude of mine subsidence and an appropriate allowance, over and above the 0.5m freeboard, should be included in the FPL.

7.7.4. Maintenance of Services

A rise in the "normal" water level in Tuggerah Lakes and more frequent inundation during floods, as a consequence of a sea level rise, will impact on the maintenance of services (mainly roads but presumable many other services as well, such as sewer, gas and electricity). This will add to the maintenance budget of Wyong Shire Council or the supply authority and may mean that, for example, the road standard will be reduced to a lesser standard in order to maintain a level of service. This reduction in service supply may have ongoing ramifications for public safety or such like.

Wyong Shire Council has advised that over $12 million is required for upgrading/maintenance of the sewerage system within inundated areas over the next 20 years to accommodate the current demand and excluding any associated costs for a climate induced sea level rise. When the predicted sea level rise benchmarks are considered with regard to the existing service levels, such as sewer outlets and manhole levels, significant works and costs are required to maintain the service at working condition.

8. FLOOD RELATED DEVELOPMENT CONTROL PRECINCTS

8.1. Background

Wyong Council has revised the Floodplain Management Chapter of the Development Control Plan and this will be exhibited in 2014. The intent of the DCP revision is to:

- Refer to on-line flood planning maps on Council's website, rather than maps embedded within the LEP;
- Simplify the development control matrix;
- Achieve compliance with Council's interim Sea Level Rise policy;
- Interact effectively with the Exempt and Complying Development Codes State Environment Planning Policy (SEPP).

Under the Codes SEPP proposed development on a "flood control lot" can still potentially proceed without the matter coming to Council's attention. Development in flood fringe areas can potentially be approved under a Complying Development Certificate (CDC), unless the land is considered by the Council to be *Flood Storage Area, Flow Path, High Hazard, High Risk or Floodway*.

It is proposed to map the four Precinct Areas in the DCP for the sake of CDCs and Council's own development controls and this mapping would be consistent with the LEP mapping.

Precinct 1: Above FPL to PMF
Precinct 2: Up to FPL
Precinct 3: Flood Storage and Flow Paths
Precinct 4: High Hazard

Note that a CDC could potentially be approved in either Precinct 1 or Precinct 2 without the DA coming to Council. It is therefore important that Council's on-line mapping and DCP clearly distinguish the different precincts.

8.2. Precincts that would apply for Tuggerah Lakes Foreshore Areas

Precinct 1: Above FPL to PMF

- Zero area. Does not apply given that FPL = PMF

Precinct 2: Up to FPL

- RL 2.7mAHD. Area below FPL (2.2 + 0.5 = 2.7)

Precinct 3: Flood Storage and Flow Paths

- RL 1.8mAHD. Within this area the depth of flooding in a 1% AEP flood would be at least 0.4m and this level would also match the 5% AEP flood level trigger level for non-habitable floors, car parking and driveways in the codes SEPP.

Precinct 4: High Hazard

- RL 1.2mAHD, within this area the depth of flooding in a 1% AEP flood would be at least 1.0m, which is defined by the provisional hydraulic hazard categorization as high hazard.

Refer to Wyong Shire Council's Development Control Plan 2013, Chapter 3.3: Floodplain Management to view the Development Control Matrix.

9. ACKNOWLEDGMENTS

This study was carried out by WMAwater and funded by Wyong Shire Council and the Office of Environment and Heritage. The assistance of the following in providing data and guidance to the study is gratefully acknowledged:

- Wyong Shire Council;
- Office of Environment and Heritage;
- Floodplain Management Committee;
- Residents surrounding the foreshores of Tuggerah Lakes.

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Cardno Pty Ltd, November 2013

Figures

FIGURE 1

CATCHMENT MAP

MAP WITH COMPLIMENTS OF AUSLIG

LEGEND

CATCHMENT BOUNDARY

2.5 0 2.5 5 7.5 10 12.5km

SCALE

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FIGURE 2
FLOODPLAIN MANAGEMENT AREAS

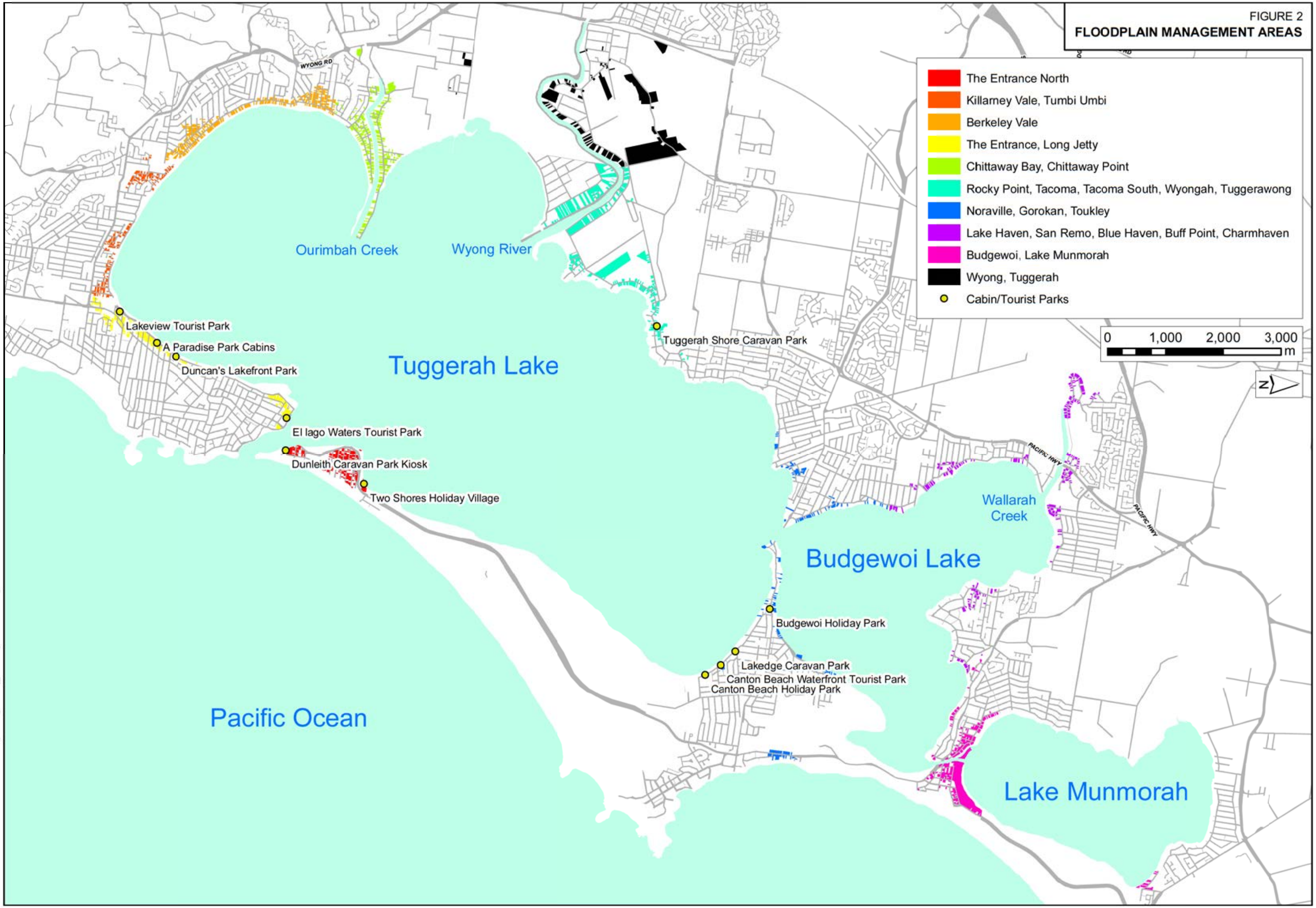

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FIGURE 3
TUGGERAH LAKES
4th/5Th FEBRUARY 1990


Photo 1: Tuggerawong, Monday & March St


Photo 2: Rocky Point


Photo 3: South Tacoma


Photo 4: Chittaway, Geoffrey Rd & Kalau Dr downstream of Oberon Rd


Photo 5: Chittaway Point, Geoffrey Rd


Photo 6: Berkeley Vale, Platypus Rd & Blenheim Ave


Photo 7: Berkeley Vale: Wombat, Black Swan St & Albatross, Platypus Rd


Photo 8: Tumbi Umbi, Hinemoa Ave


Photo 9: Killarney Vale, Shops & Nursing Home


Photo 10: Long Jetty


Photo 11: The Entrance


Photo 12: The Entrance North, Mini St

FIGURE 4
TUGEGERAH LAKES
9th/10th JUNE 2007


Photo 1: The Entrance North


Photo 2: The Entrance North


Photo 3: Long Jetty Foreshore Reserve


Photo 4: Killarney Vale


Photo 5: Berkeley Vale


Photo 6: Aloha Dr, Chittaway Bay


Photo 7: Chittaway Bay


Photo 8: Chittaway Point


Photo 9: Henry St, Chittaway Point. Looking east

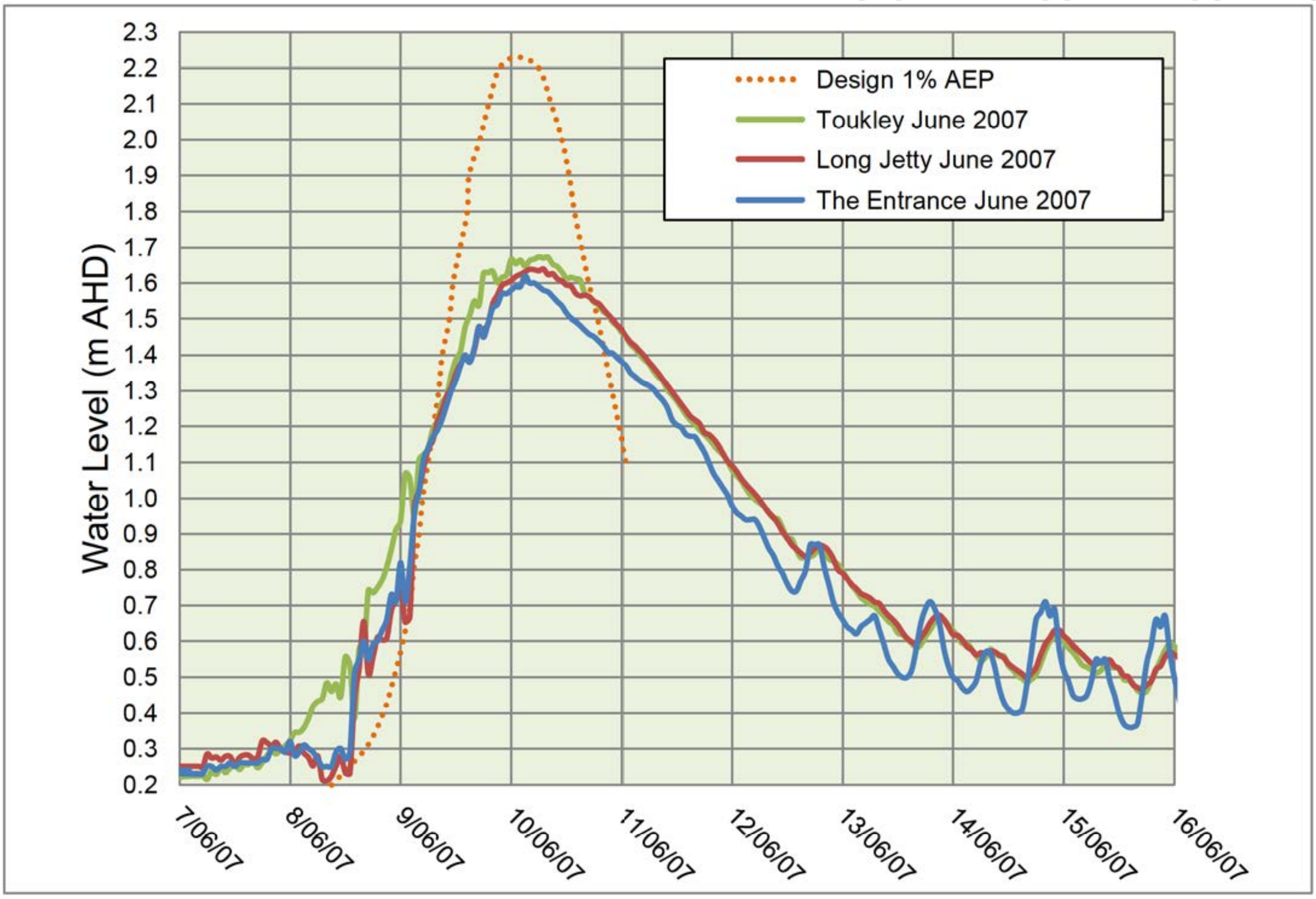

Photo 10: Henry St and Hyles St, Chittaway Point

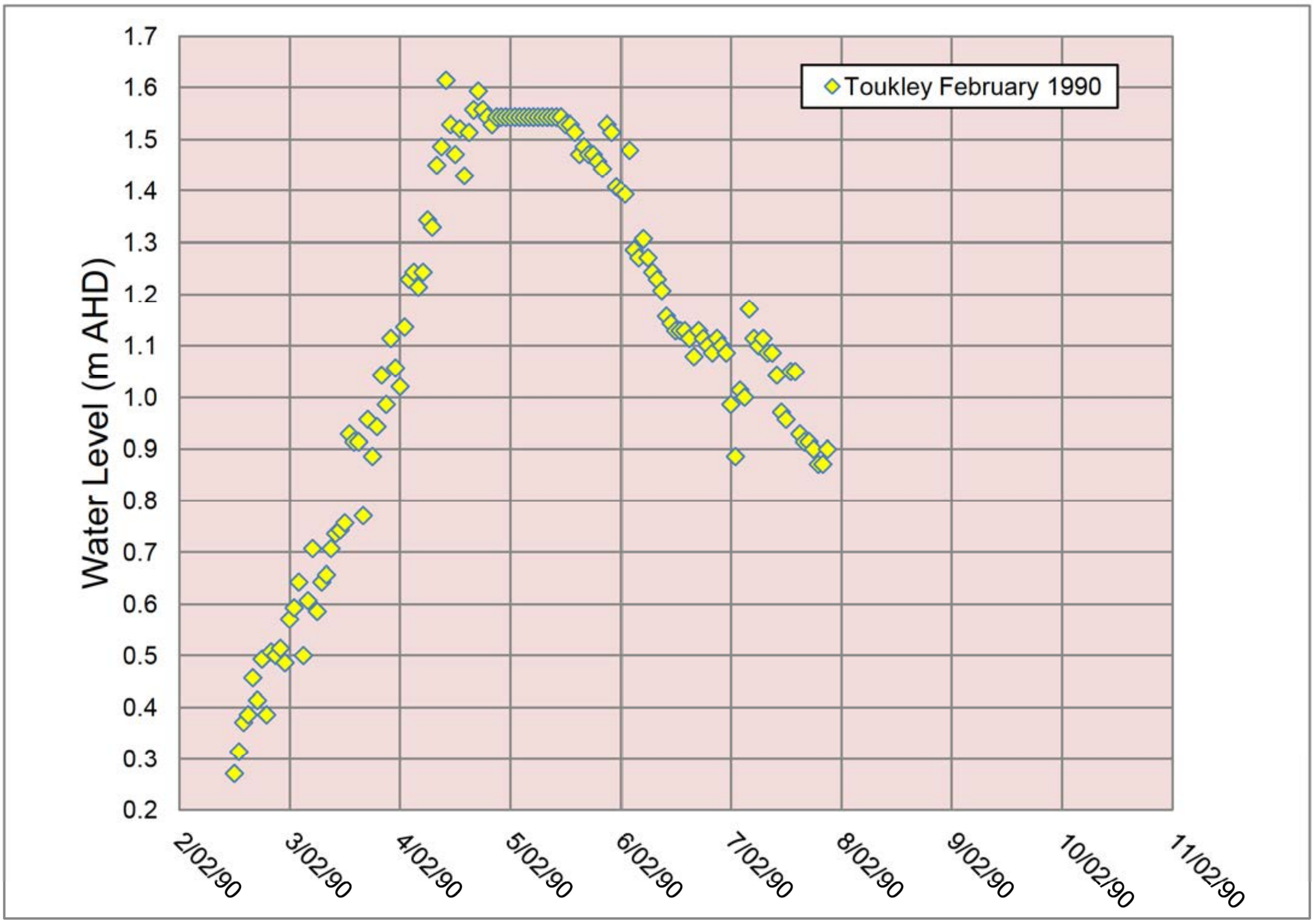

Photo 11: Aloha Dr/Kalua Dr, Chittaway Point


Photo 12: Geoffrey Rd, Chittaway Point

FIGURE 5

HISTORICAL FLOOD HYDROGRAPHS





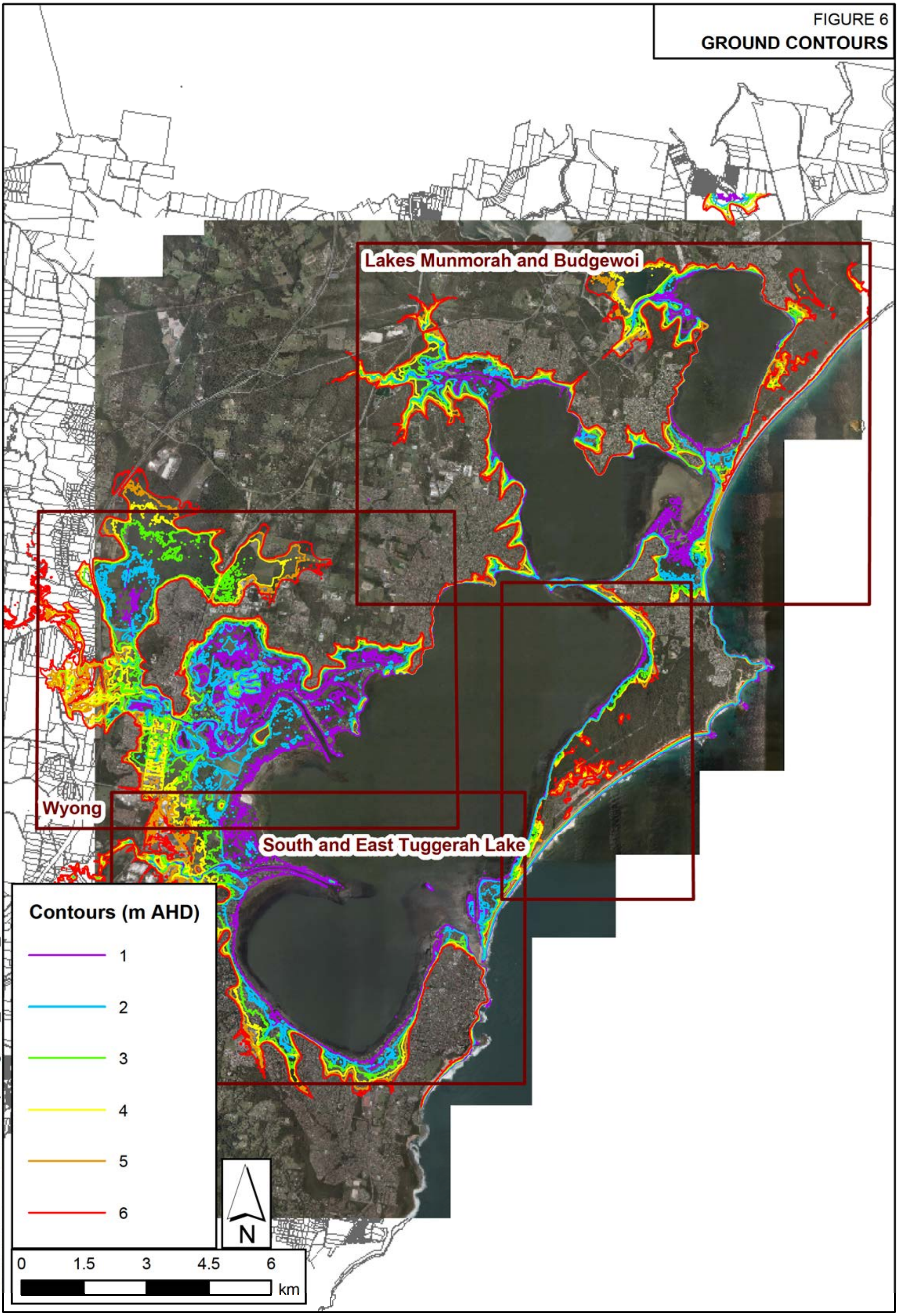


FIGURE 6
GROUND CONTOURS
Lakes Munmorah and Budgewoi
Wyong
South and East Tuggerah Lake
Contours (m AHD)
1
2
3
4
5
6
N
0
1.5
3
4.5
6
km
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FIGURE 6A

GROUND CONTOURS
SOUTH AND EAST OF TUGGERAH LAKE

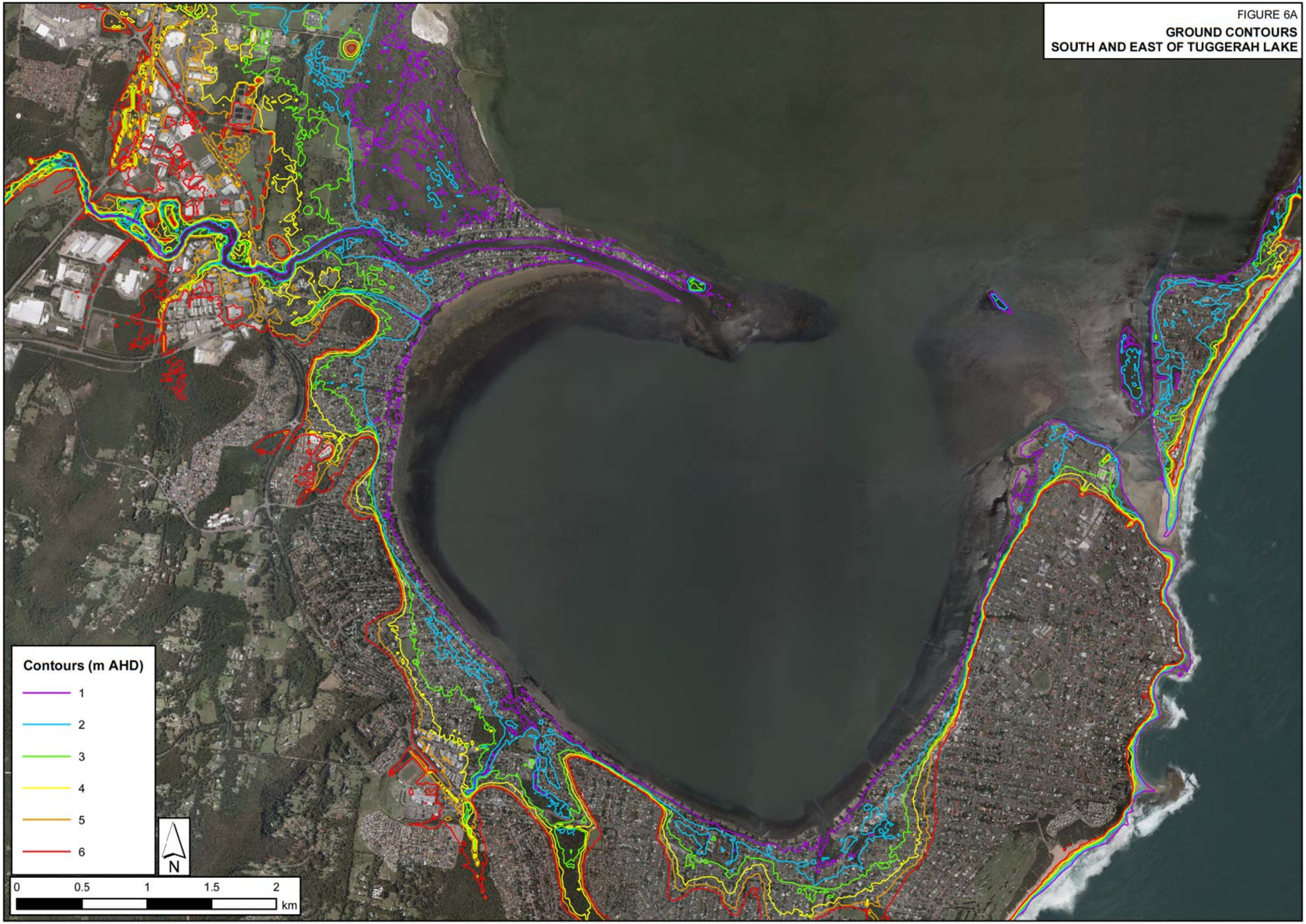

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FIGURE 6B
GROUND CONTOURS WYONG

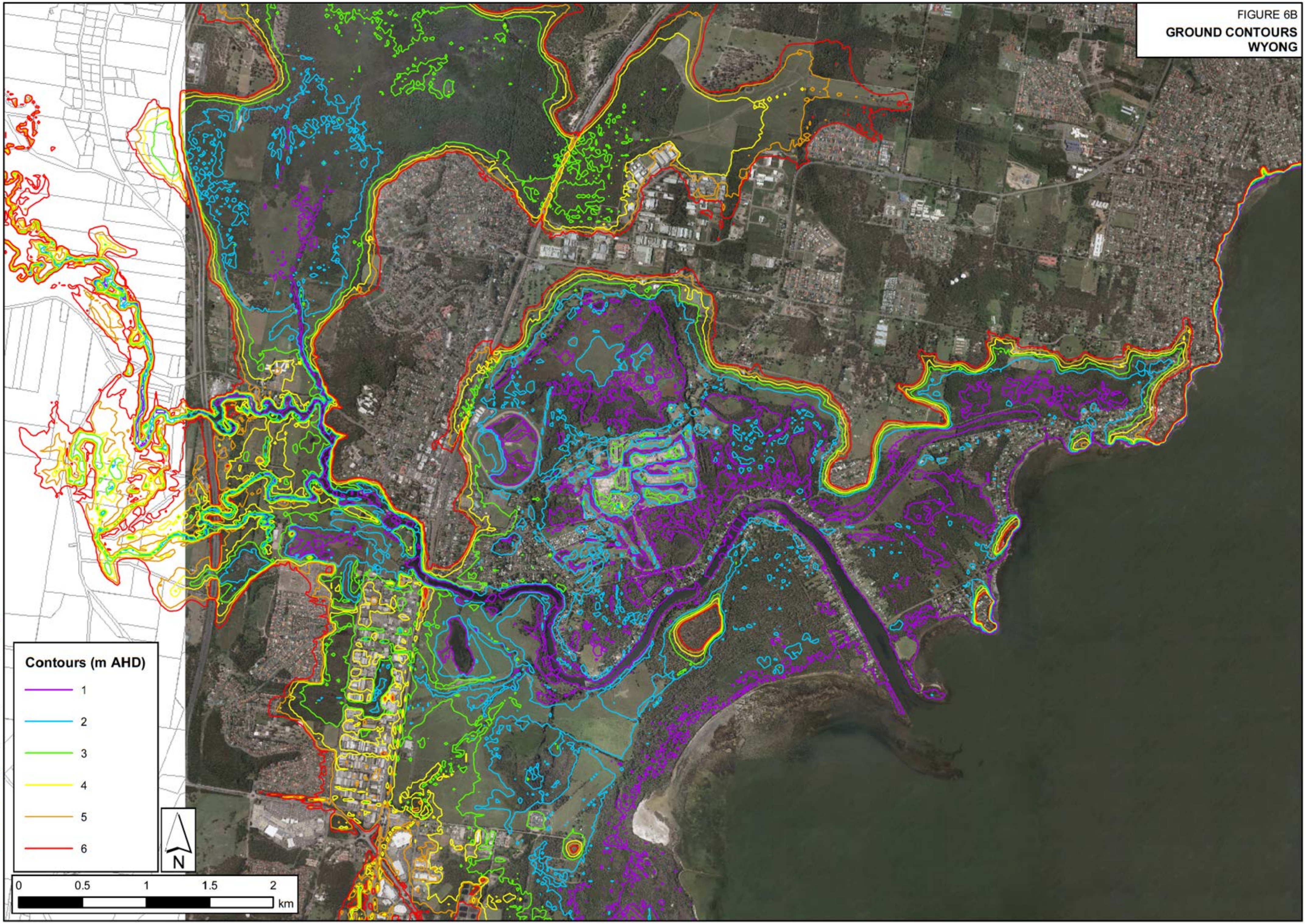

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FIGURE 7

EXTENT OF INUNDATION TUGGERAH LAKES

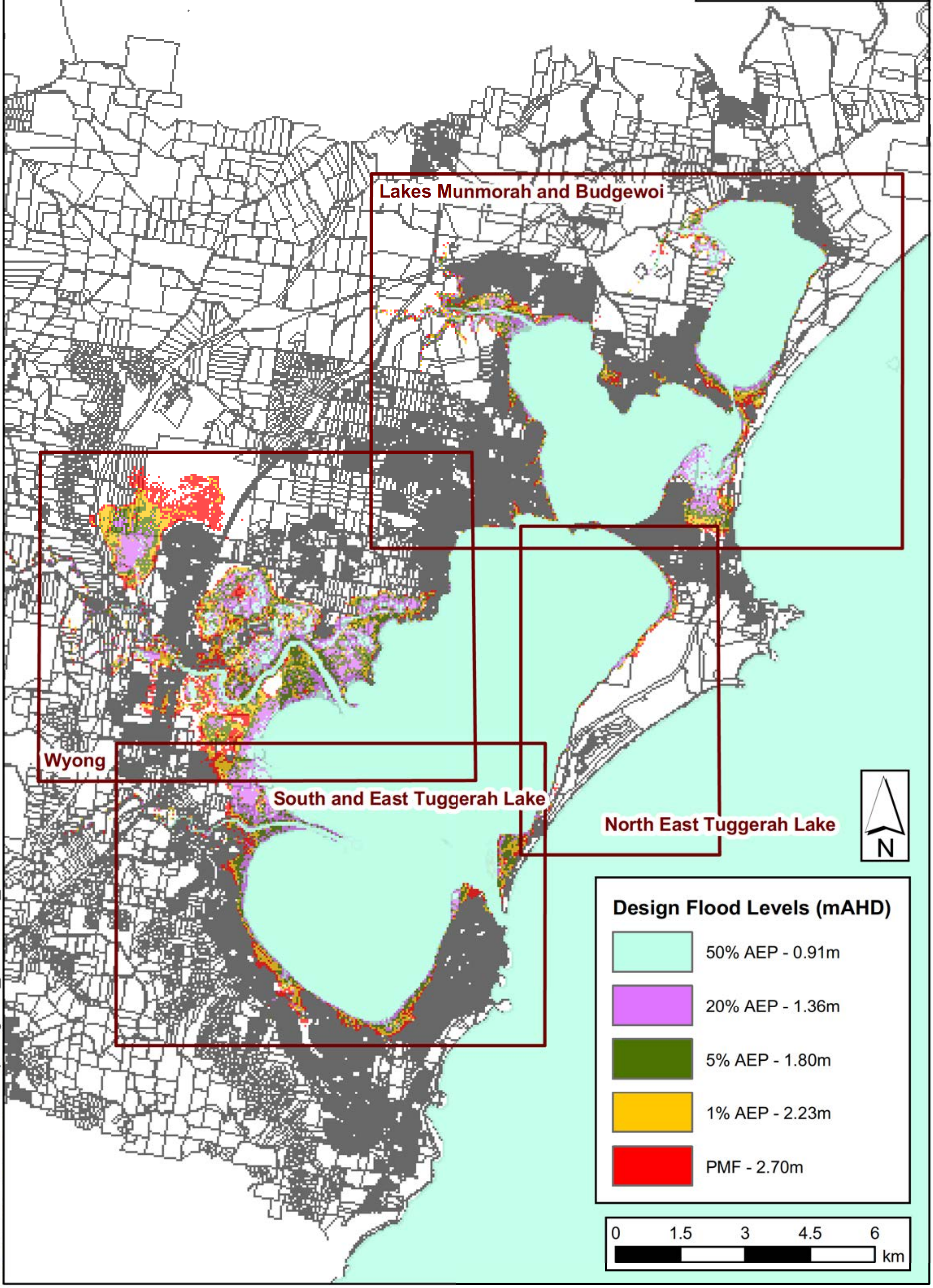

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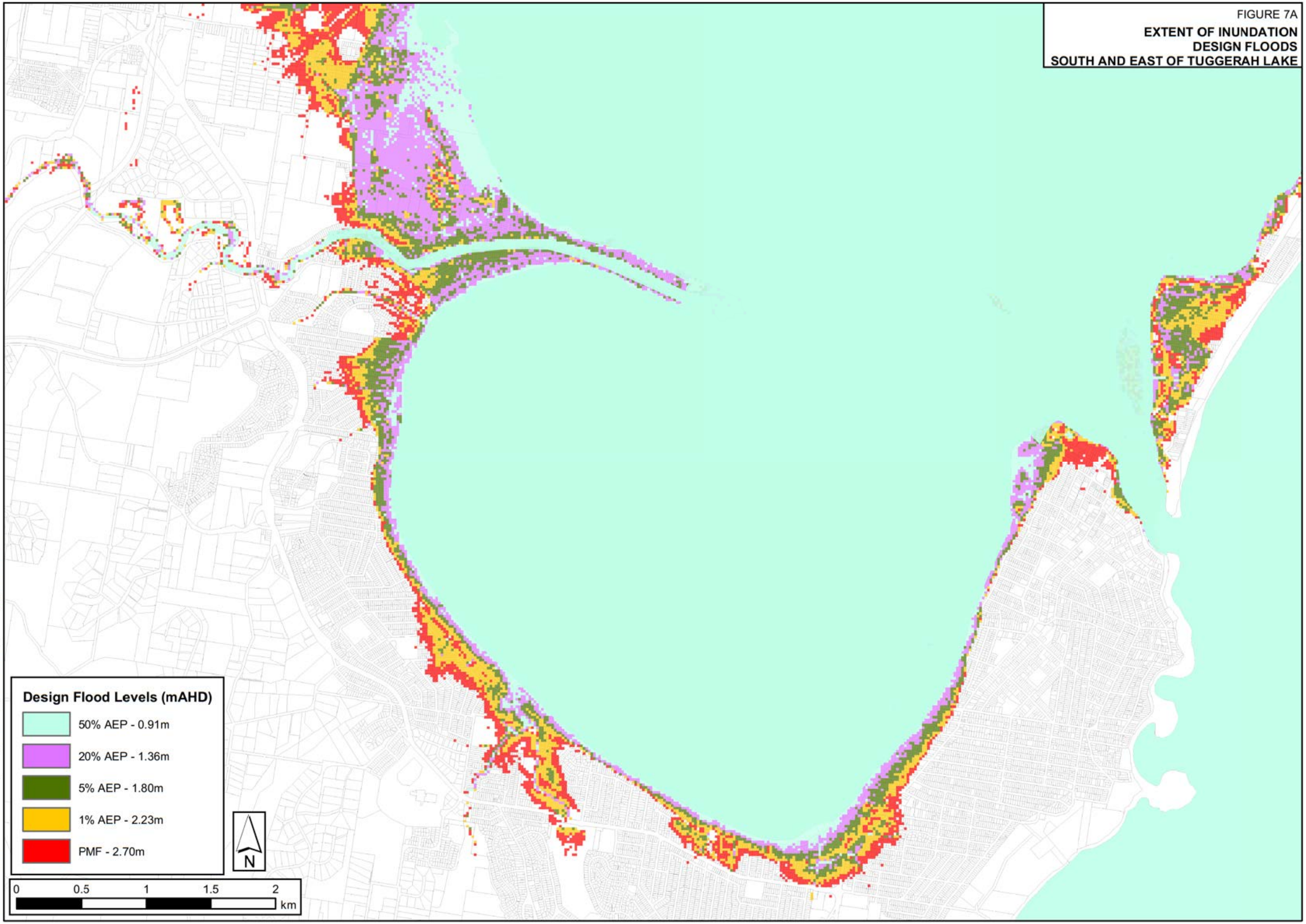
FIGURE 7A
EXTENT OF INUNDATION
DESIGN FLOODS
SOUTH AND EAST OF TUGGERAH LAKE



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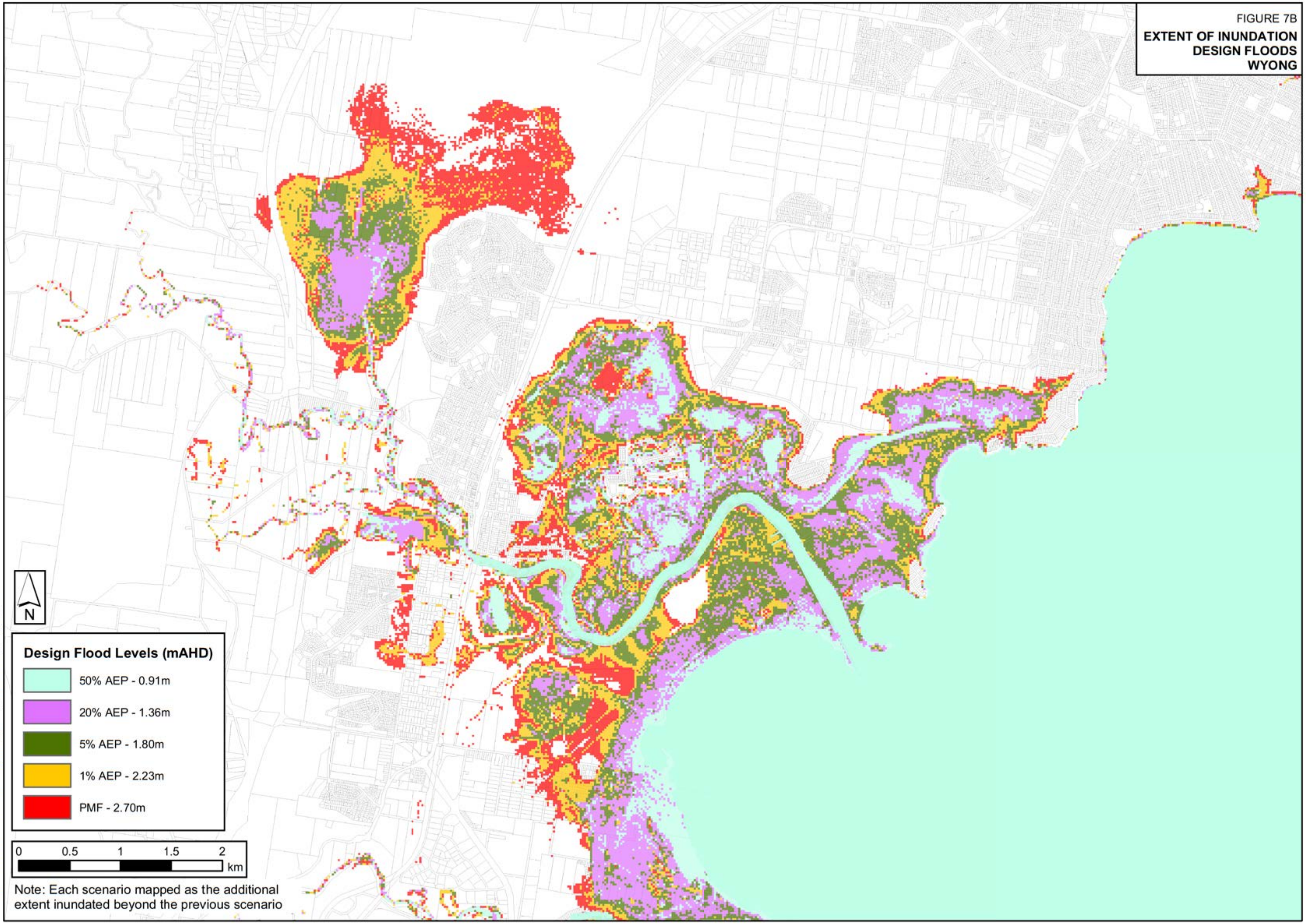

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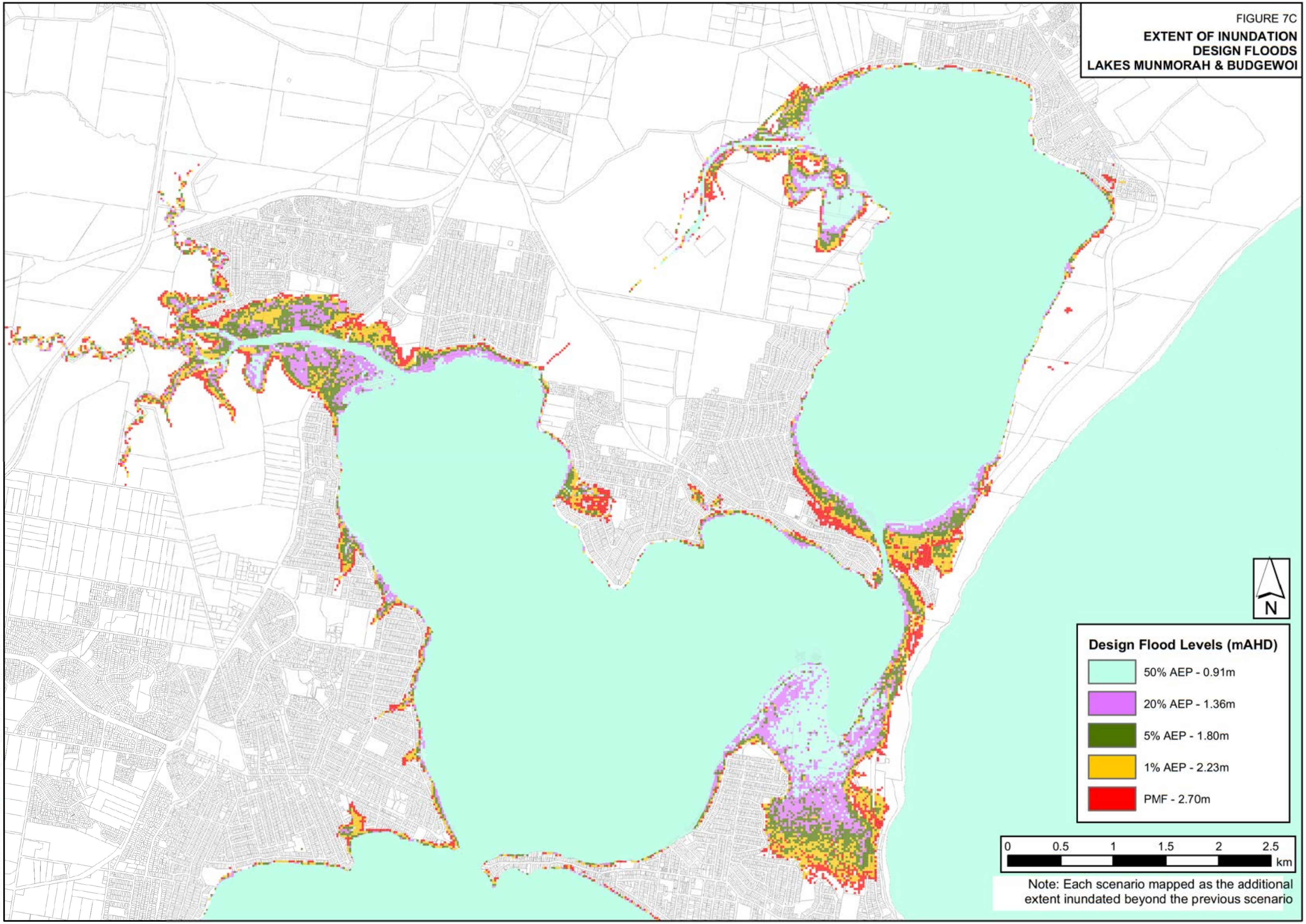

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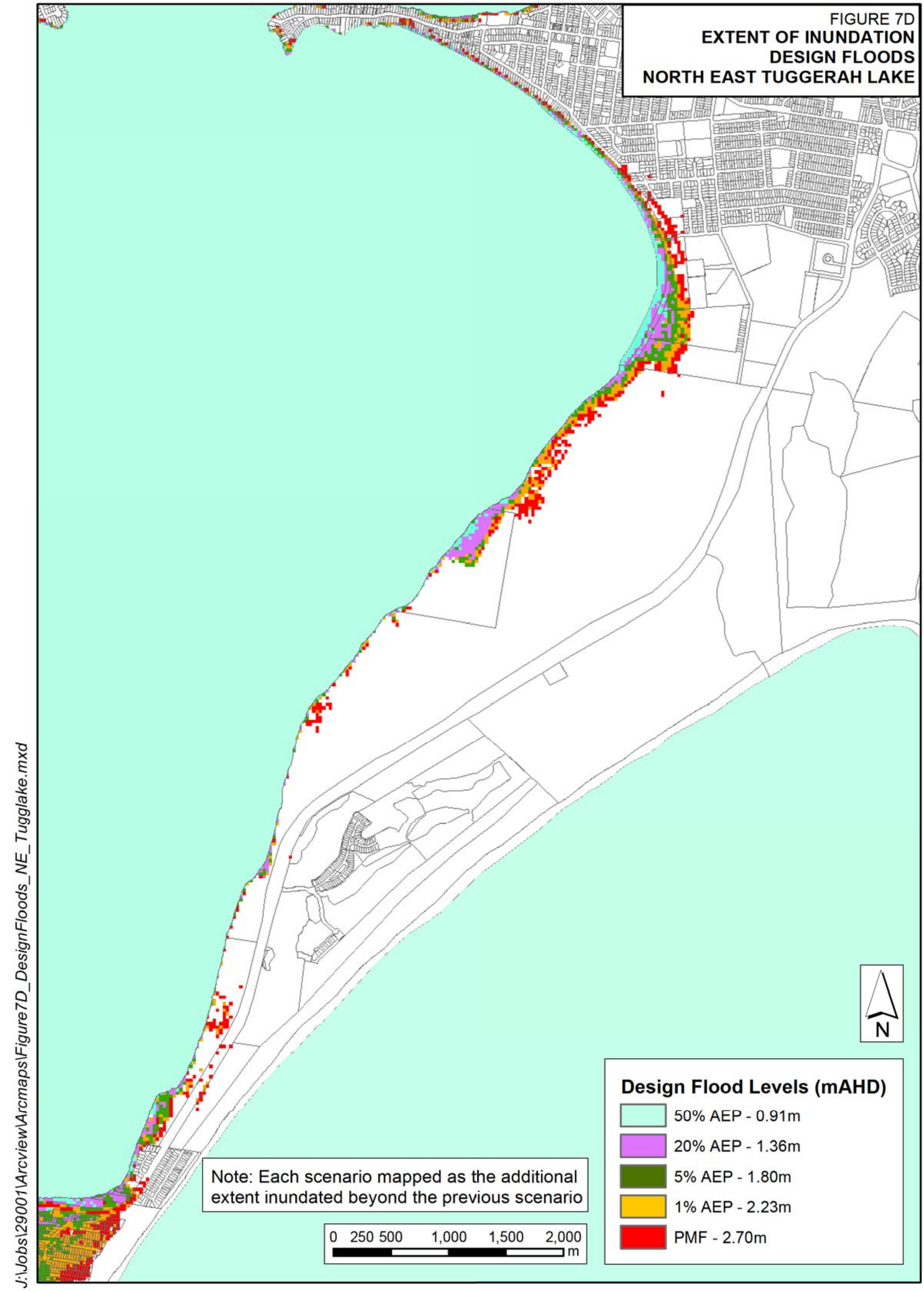

FIGURE 7D
EXTENT OF INUNDATION
DESIGN FLOODS
NORTH EAST TUGGERAH LAKE
Design Flood Levels (mAHD)
50% AEP - 0.91m
20% AEP - 1.36m
5% AEP - 1.80m
1% AEP - 2.23m
PMF - 2.70m
Note: Each scenario mapped as the additional extent inundated beyond the previous scenario
0 250 500 1,000 1,500 2,000 m
N
J:\Jobs\29001\Arcview\Arcmaps\Figure7D_DesignFloods_NE_Tugglake.mxd

FIGURE 8
EXISTING 1% AEP HYDRAULIC HAZARD AND SEWERAGE SYSTEM IMPACT

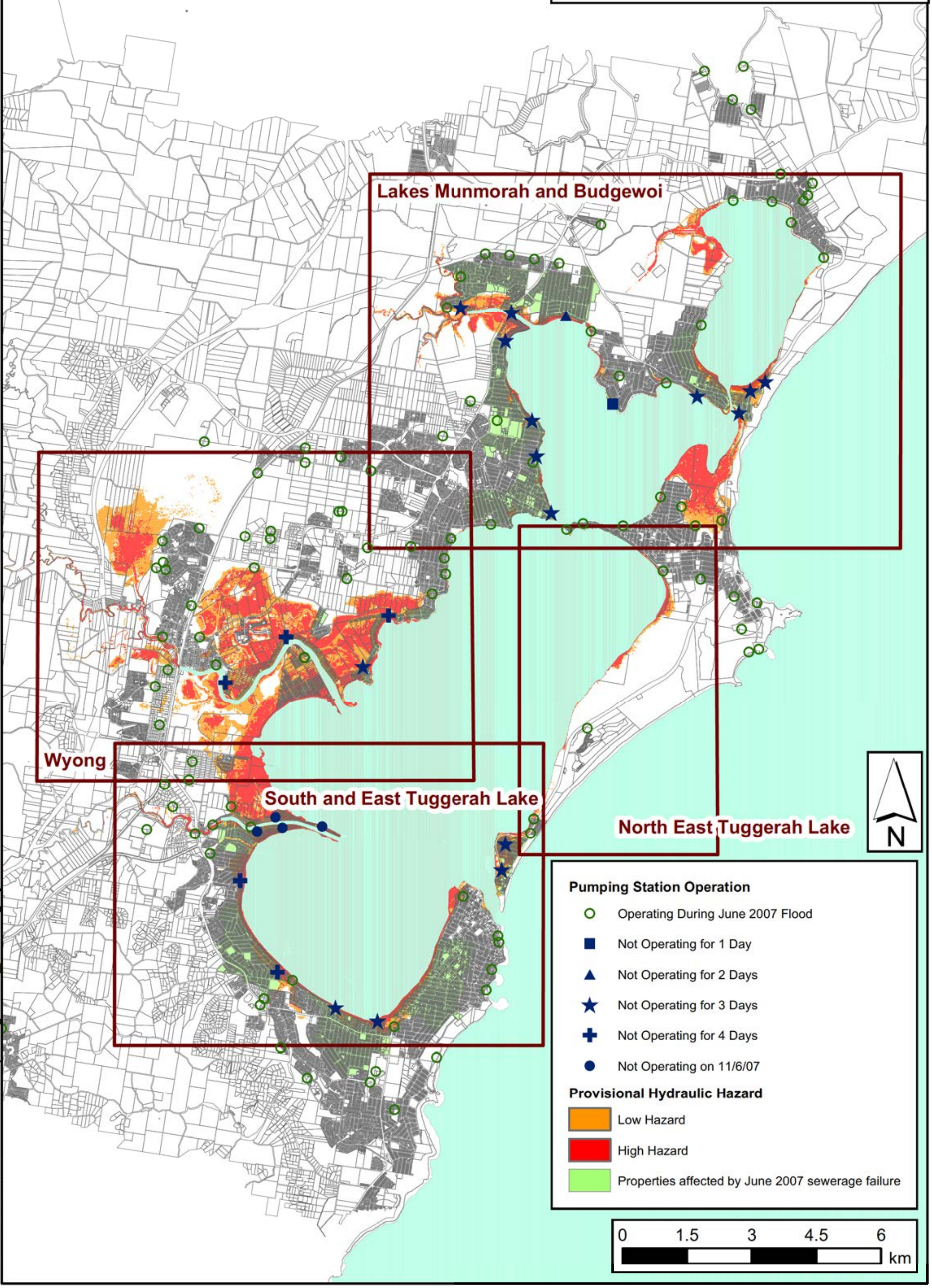

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FIGURE 8A

EXISTING 1% AEP HYDRAULIC HAZARD AND SEWERAGE SYSTEM IMPACT SOUTH AND EAST OF TUGGERAH LAKE

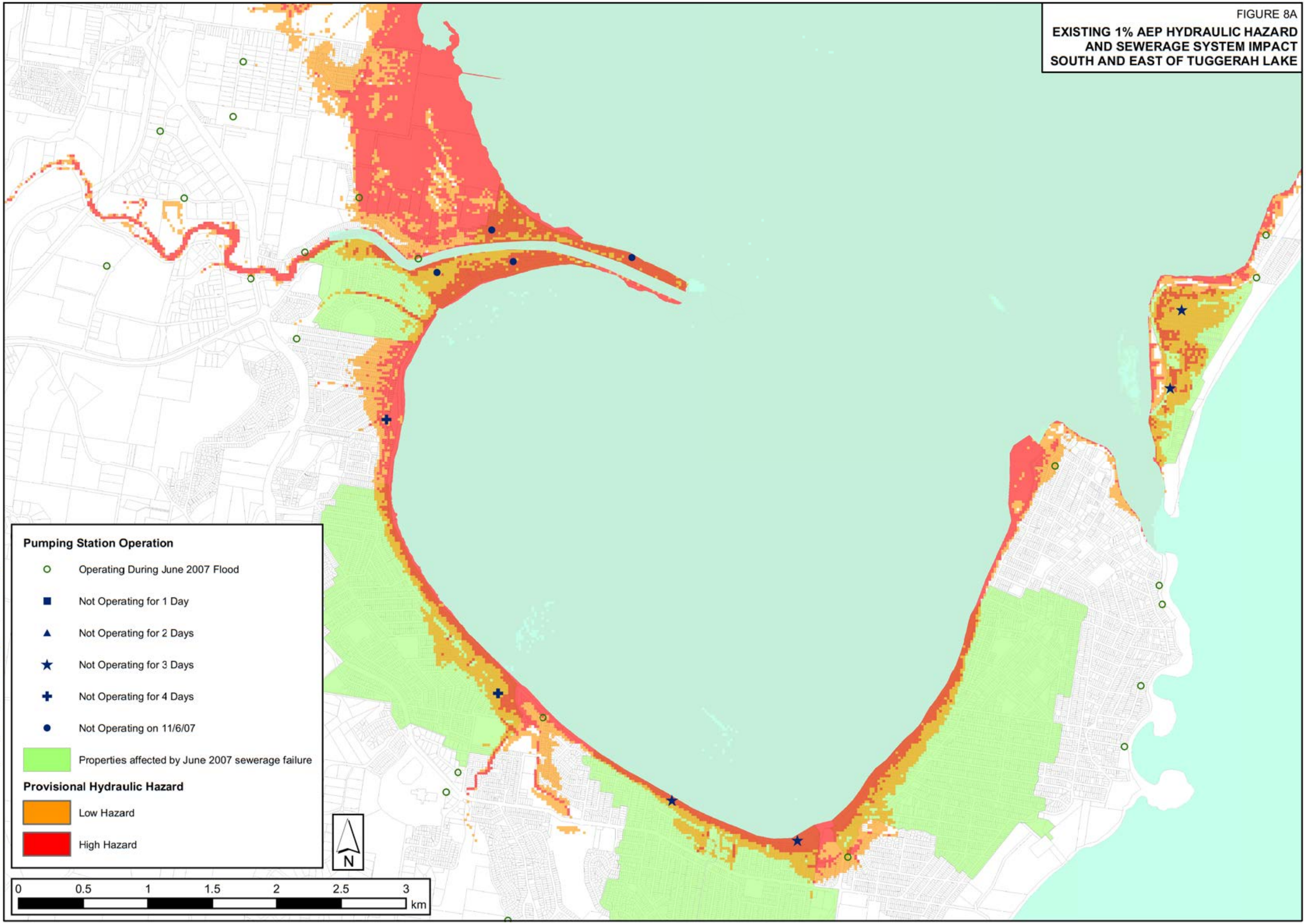

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FIGURE 8B

EXISTING 1% AEP HYDRAULIC HAZARD AND SEWERAGE SYSTEM IMPACT WYONG

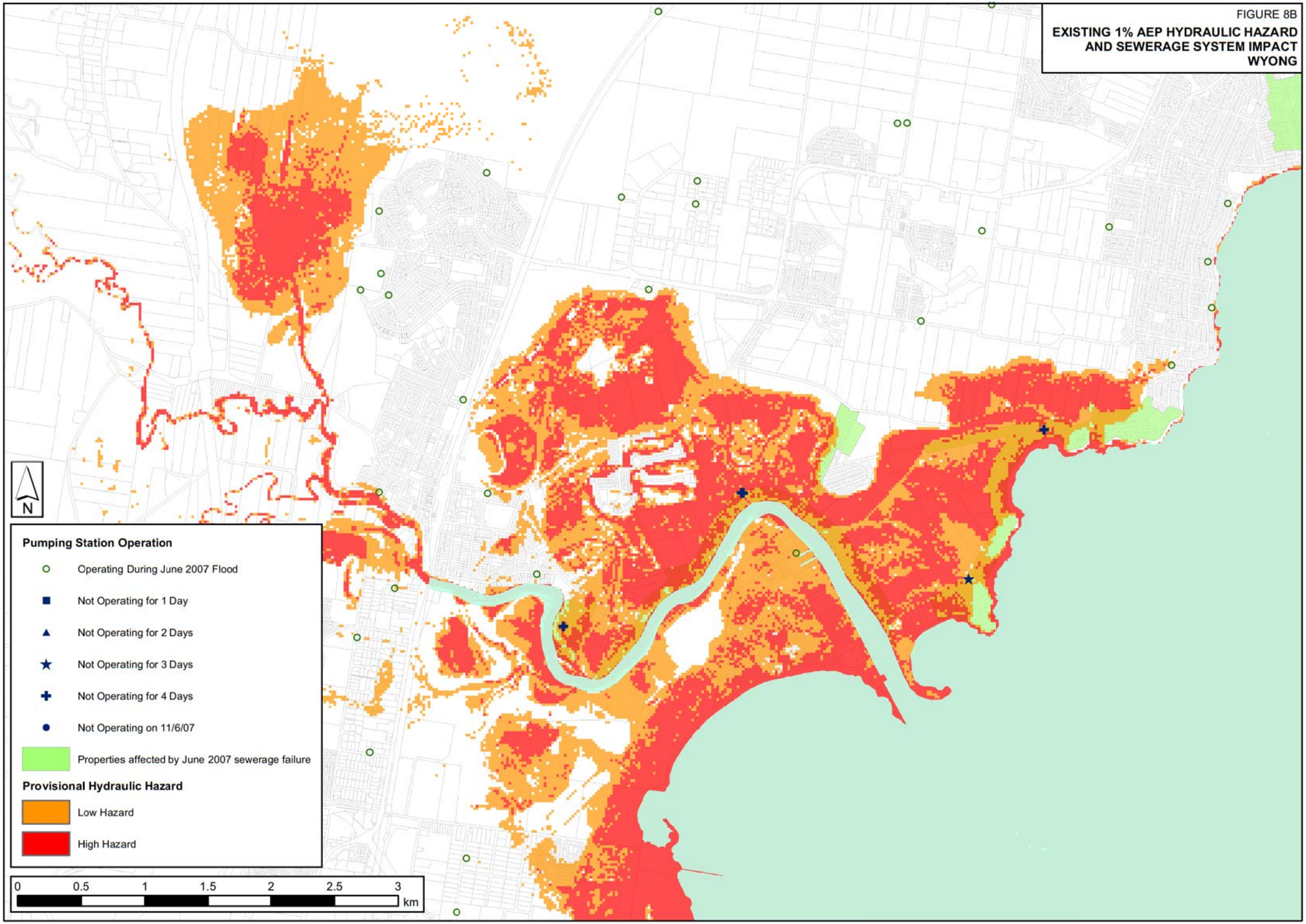

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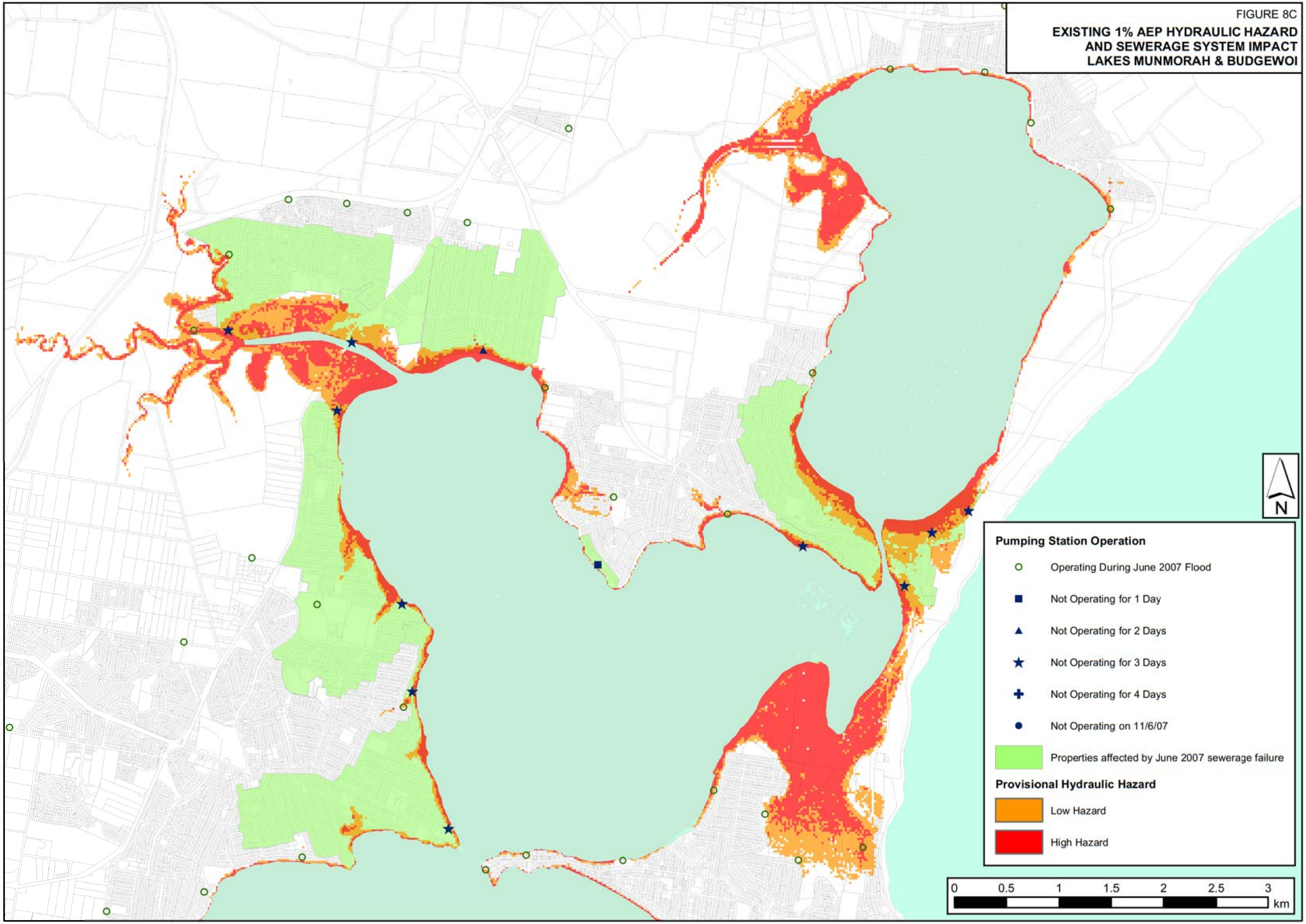
FIGURE 8C

EXISTING 1% AEP HYDRAULIC HAZARD AND SEWERAGE SYSTEM IMPACT LAKES MUNMORAH & BUDGEWOI



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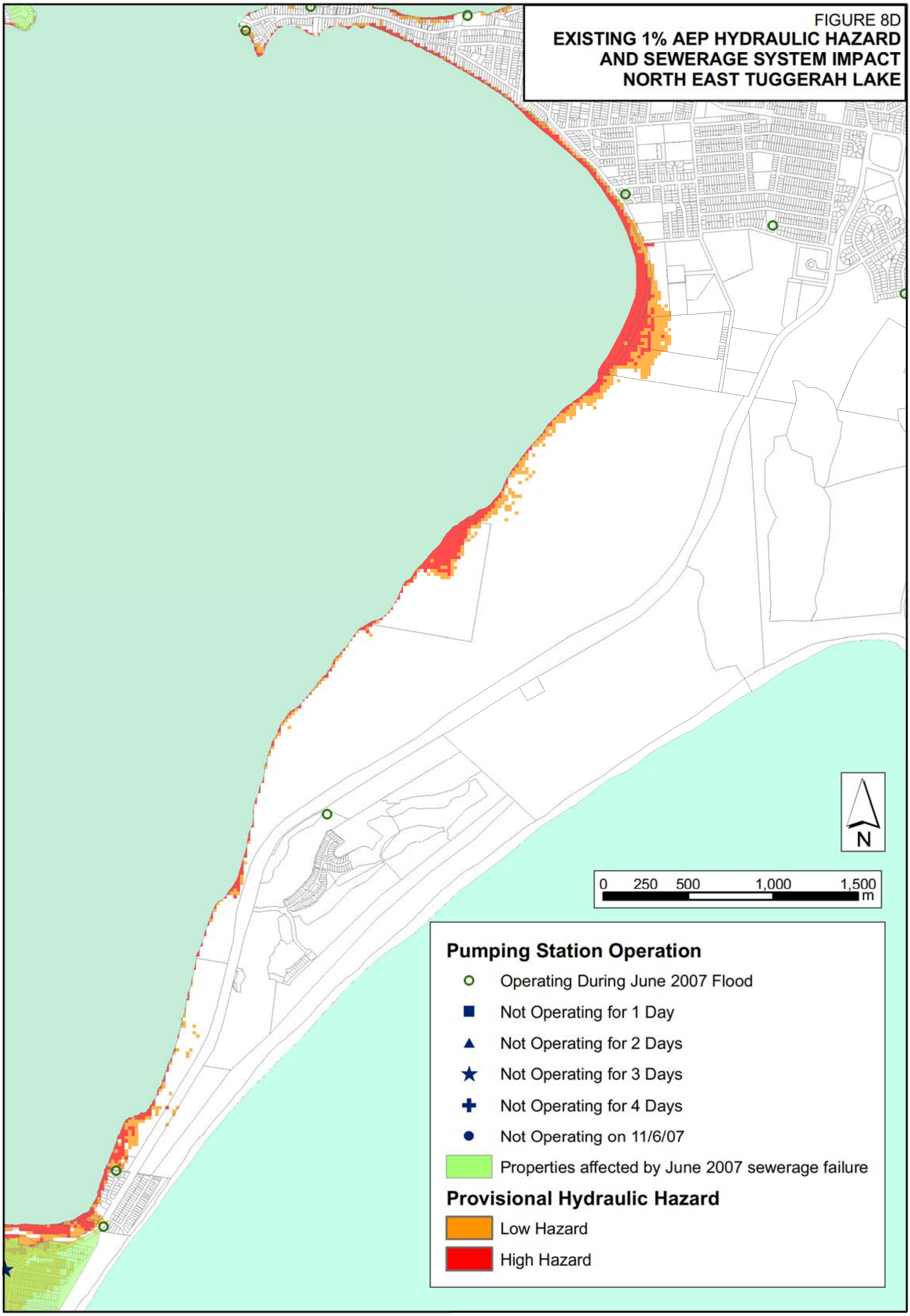

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FIGURE 9A

SEWERAGE AREAS
SOUTH AND EAST OF TUGGERAH LAKE

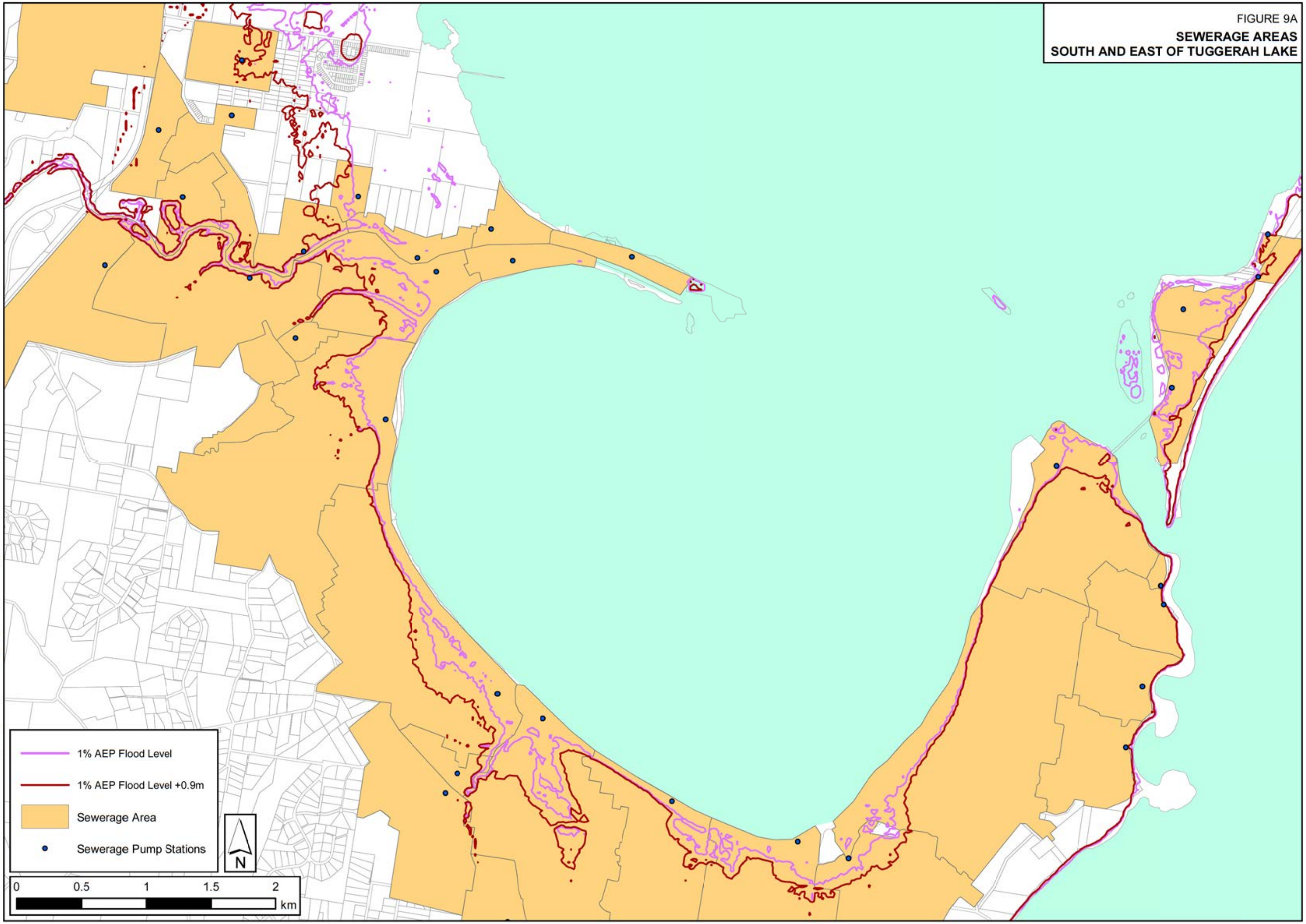

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FIGURE 9B

SEWERAGE AREAS WYONG

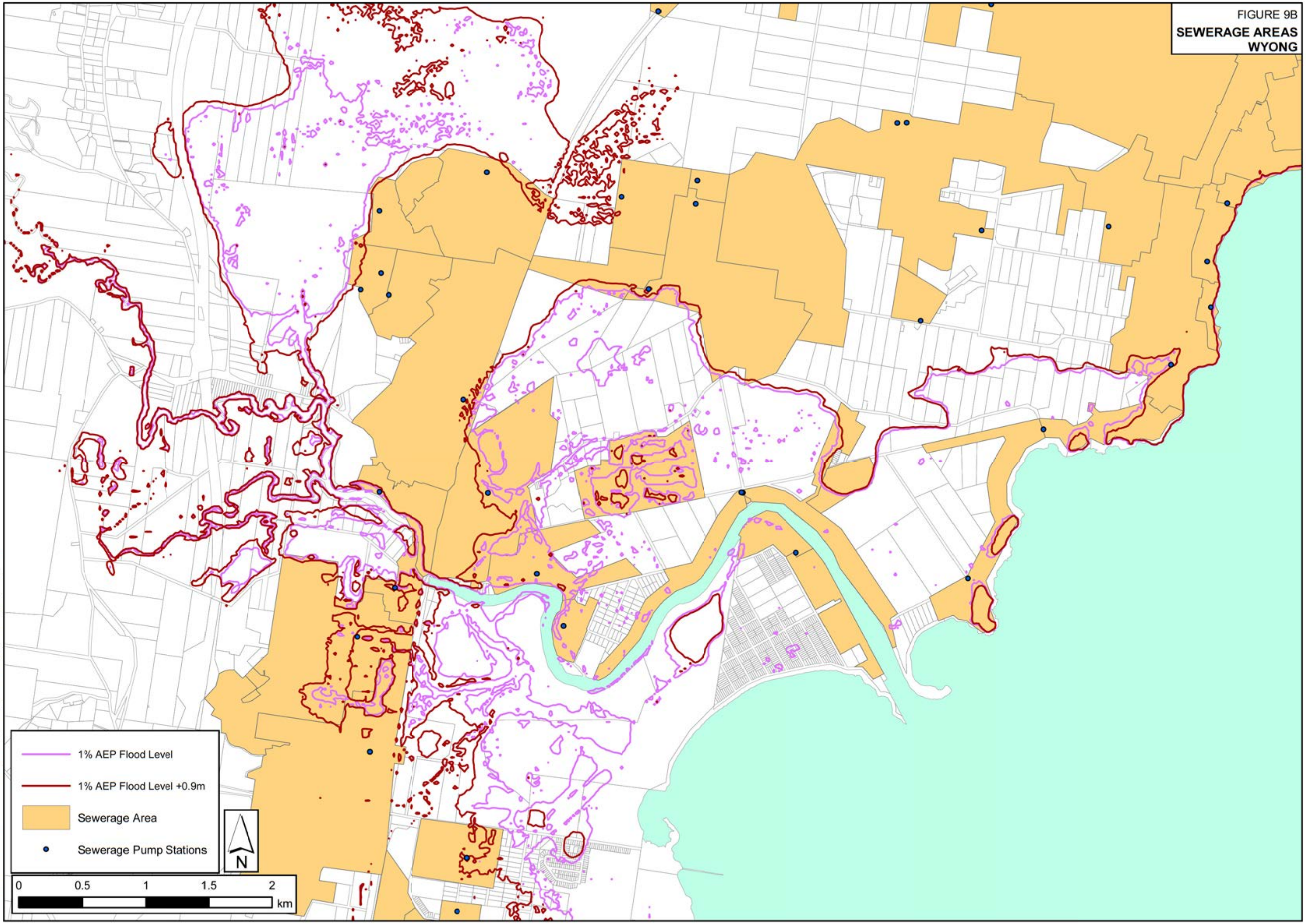

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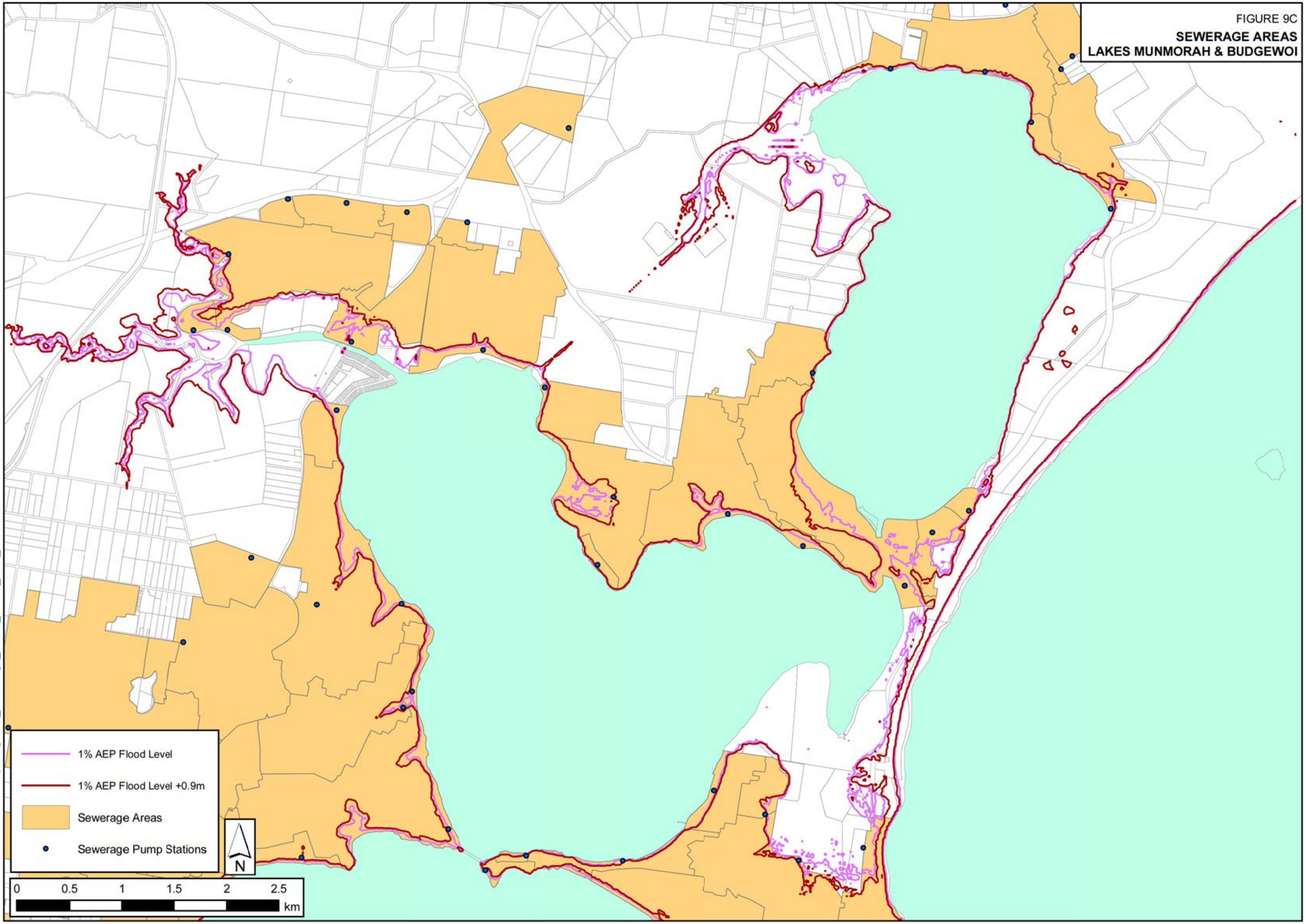
FIGURE 9C
SEWERAGE AREAS
LAKES MUNMORAH & BUDGEWOI



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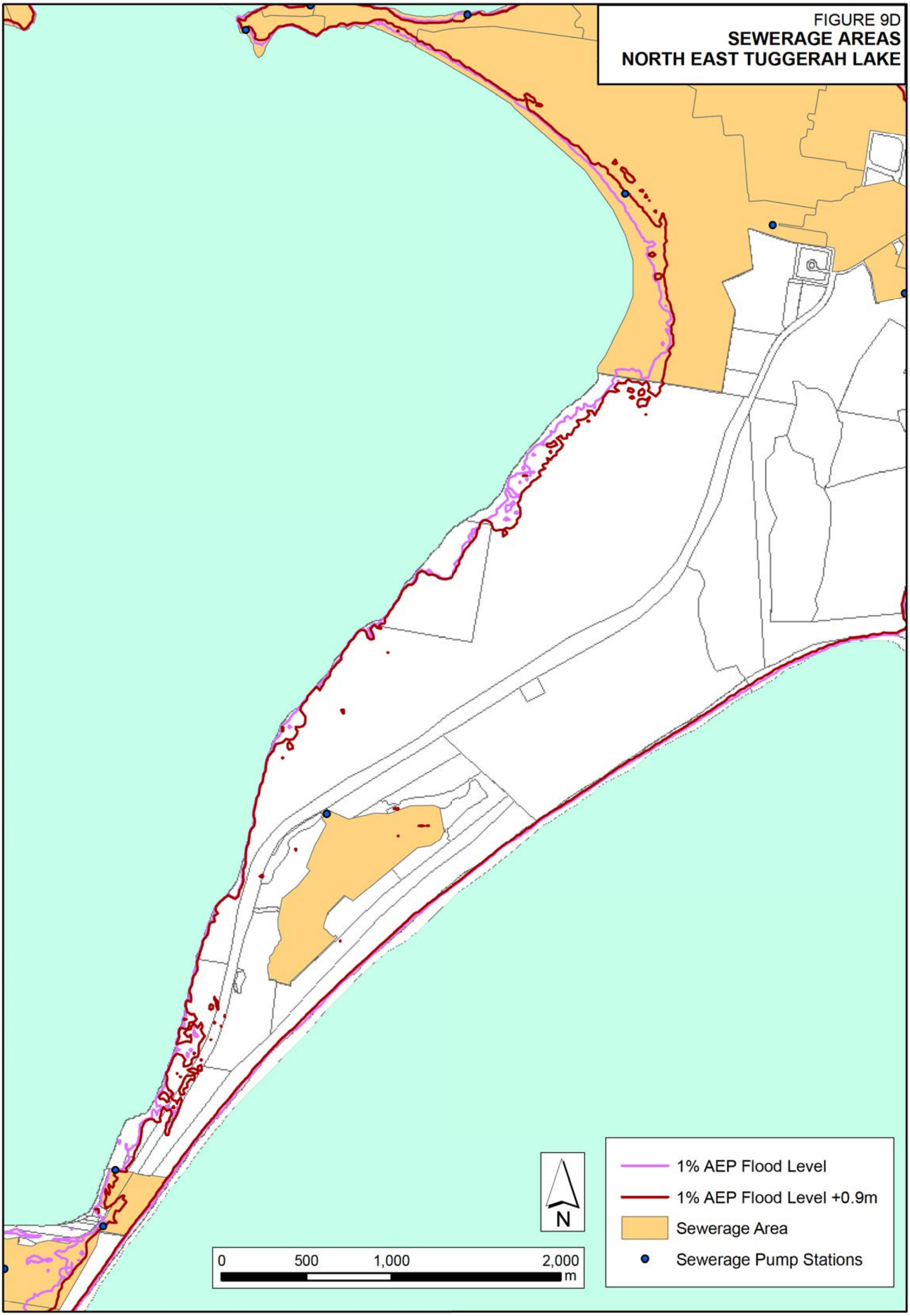

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FIGURE 10A

FLOOD LIABLE BUILDINGS
EXISTING
SOUTH AND EAST OF TUGGERAH LAKE

This plan indicates the frequency of flood which first inundates the floor level of the building on the property. This information has been obtained by comparing the building floor level (obtained through Council survey) and the design flood levels for Tuggerah Lakes.

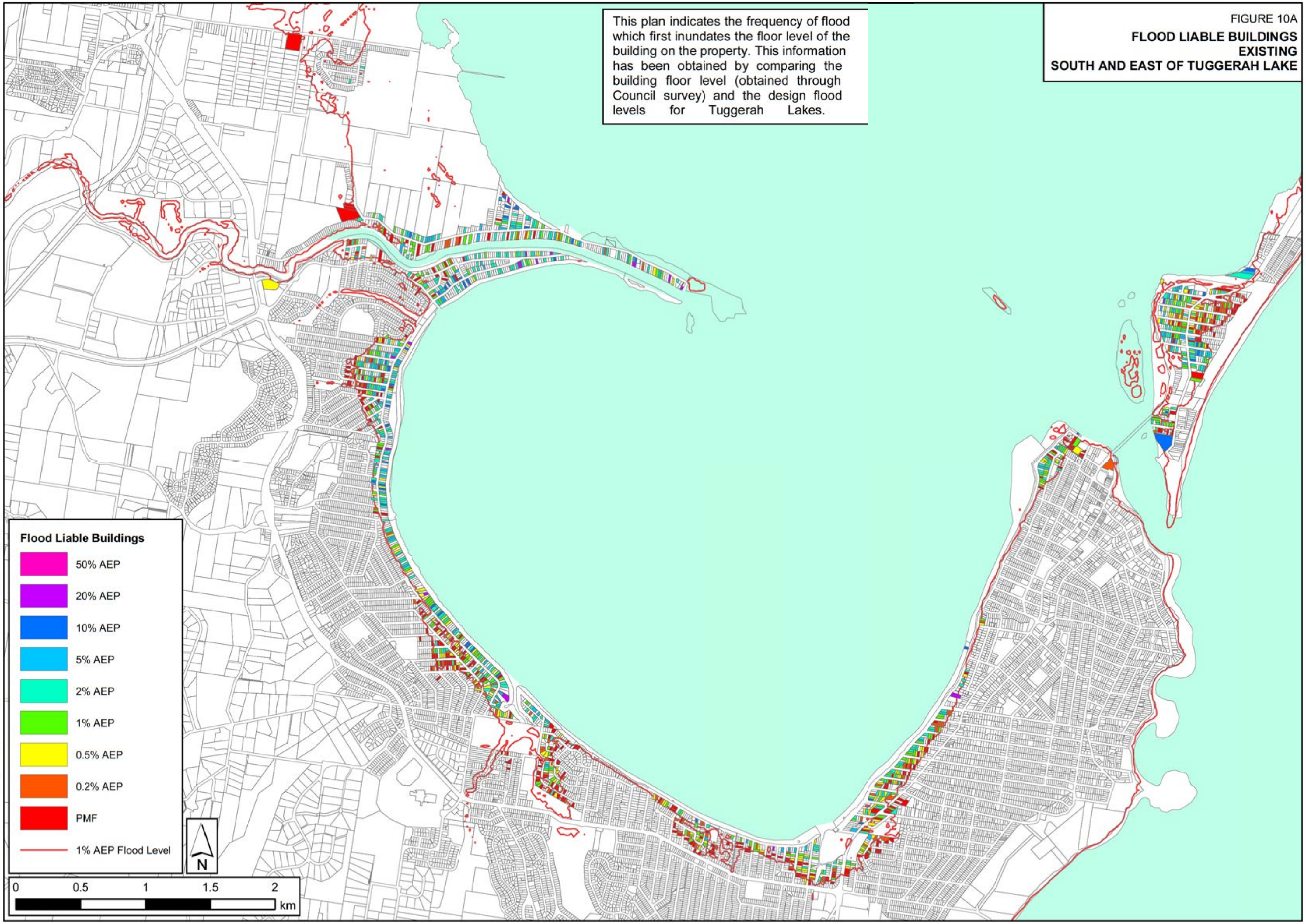

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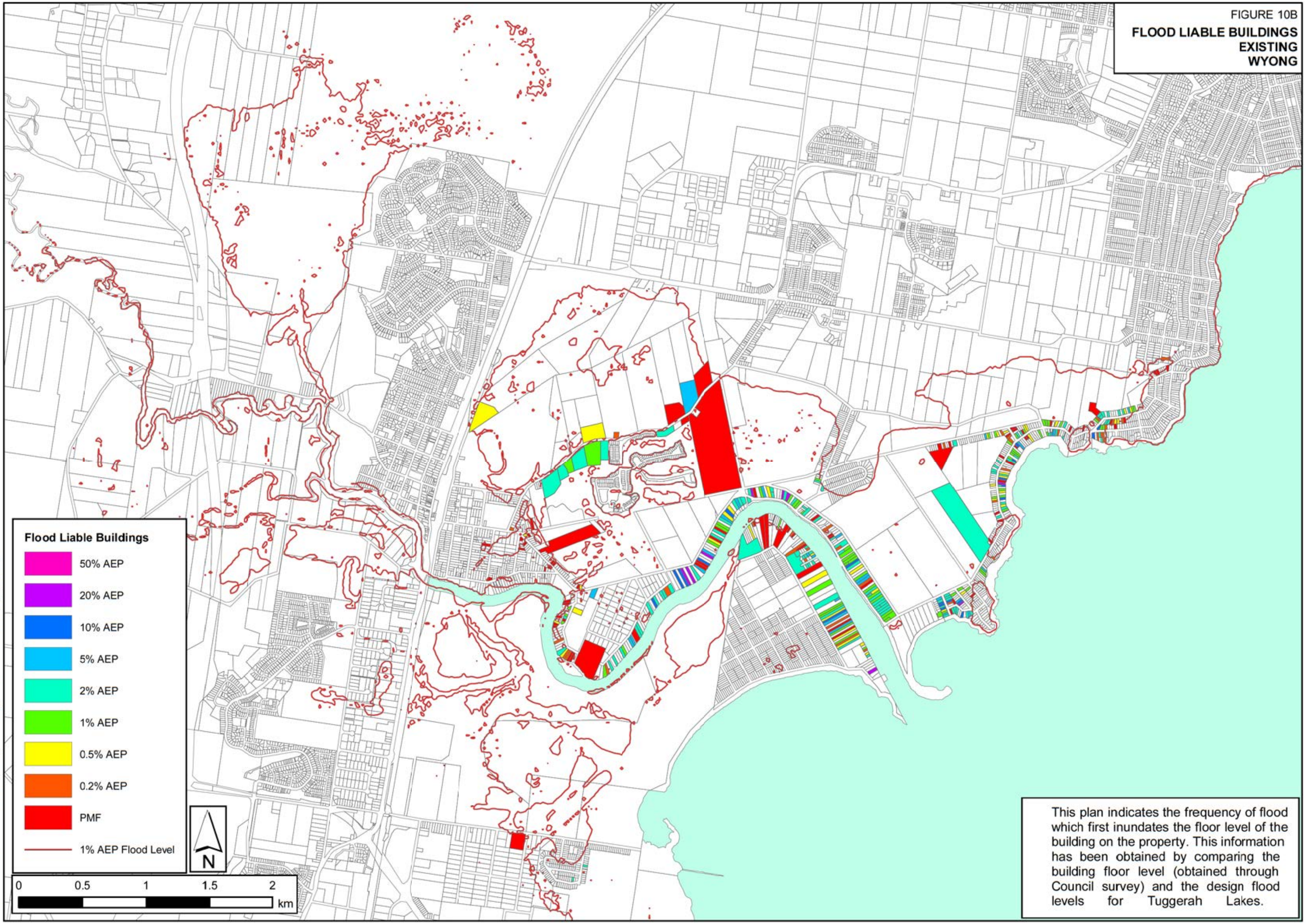
FIGURE 10B

FLOOD LIABLE BUILDINGS EXISTING WYONG



This plan indicates the frequency of flood which first inundates the floor level of the building on the property. This information has been obtained by comparing the building floor level (obtained through Council survey) and the design flood levels for Tuggerah Lakes.

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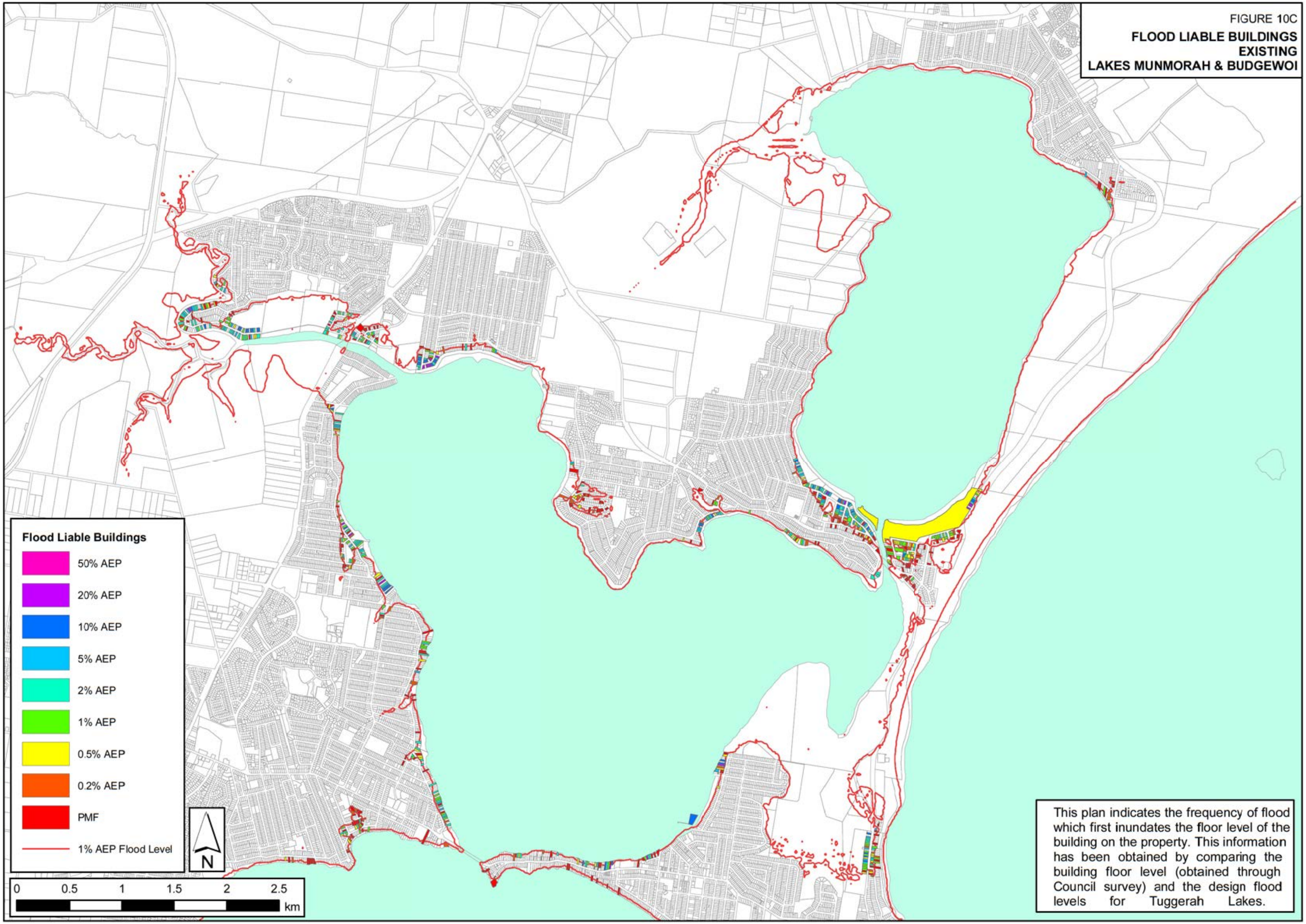
FIGURE 10C

FLOOD LIABLE BUILDINGS
EXISTING
LAKES MUNMORAH & BUDGEWOI



This plan indicates the frequency of flood which first inundates the floor level of the building on the property. This information has been obtained by comparing the building floor level (obtained through Council survey) and the design flood levels for Tuggerah Lakes.

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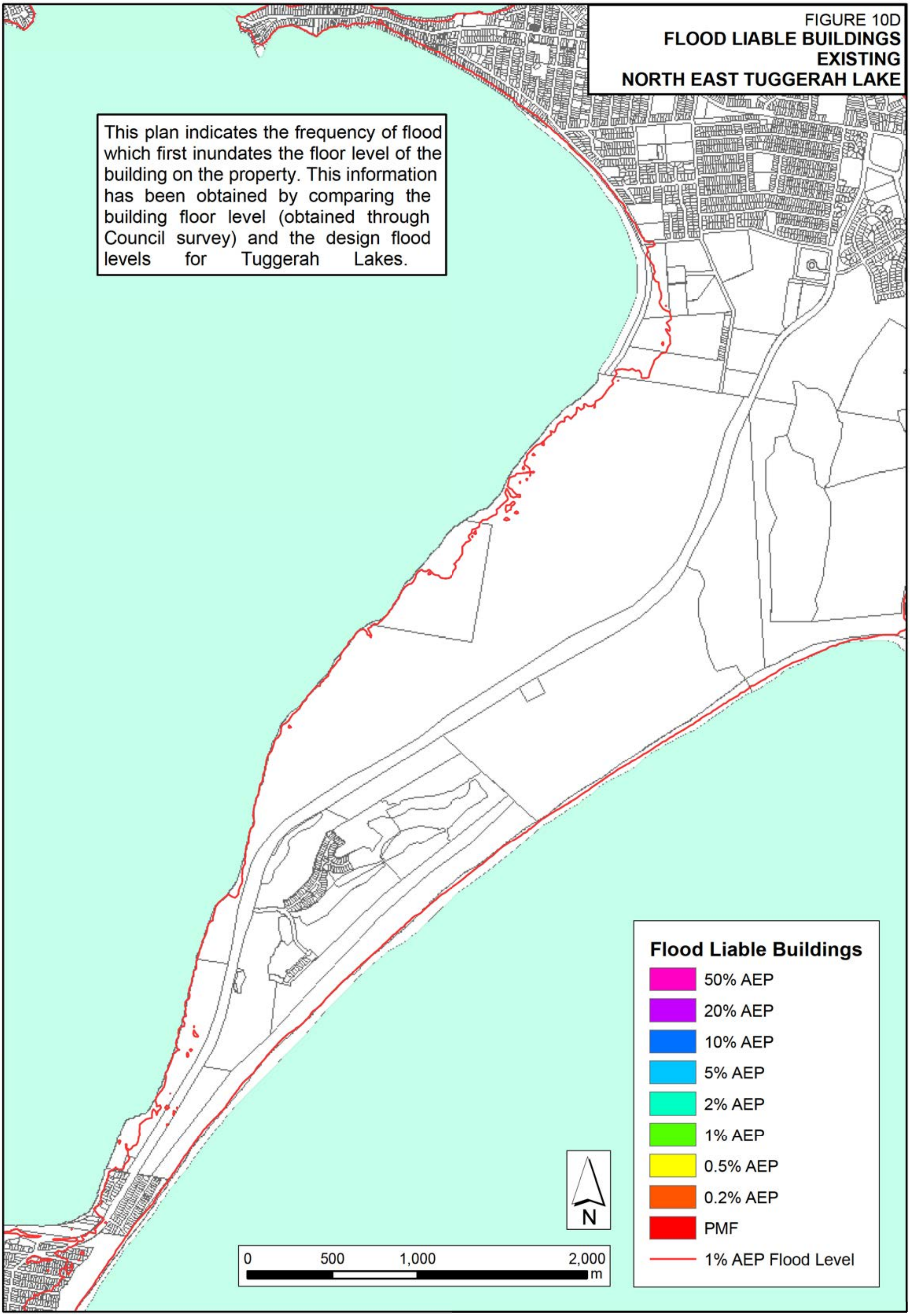

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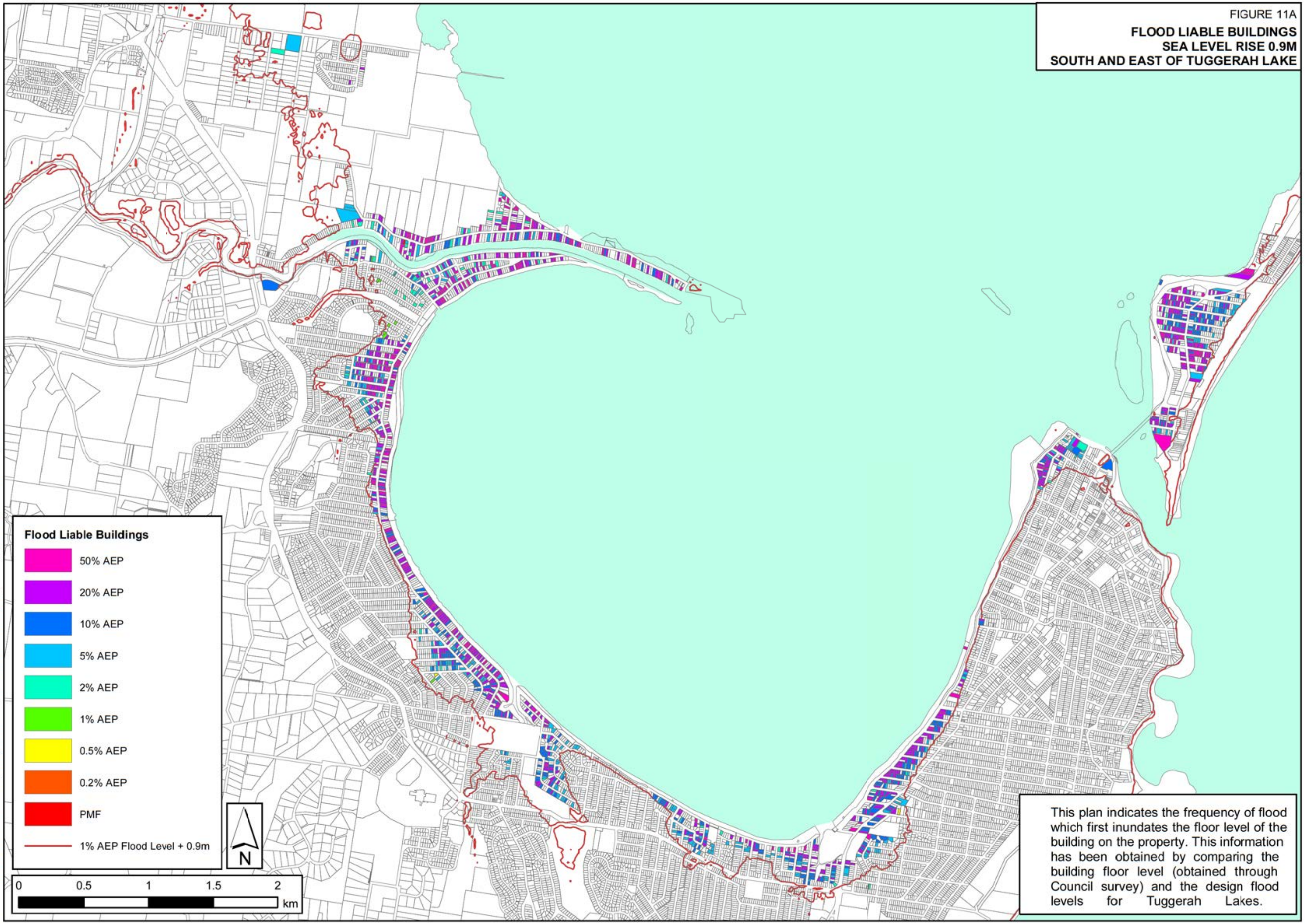
FIGURE 11A

FLOOD LIABLE BUILDINGS
SEA LEVEL RISE 0.9M
SOUTH AND EAST OF TUGGERAH LAKE



This plan indicates the frequency of flood which first inundates the floor level of the building on the property. This information has been obtained by comparing the building floor level (obtained through Council survey) and the design flood levels for Tuggerah Lakes.

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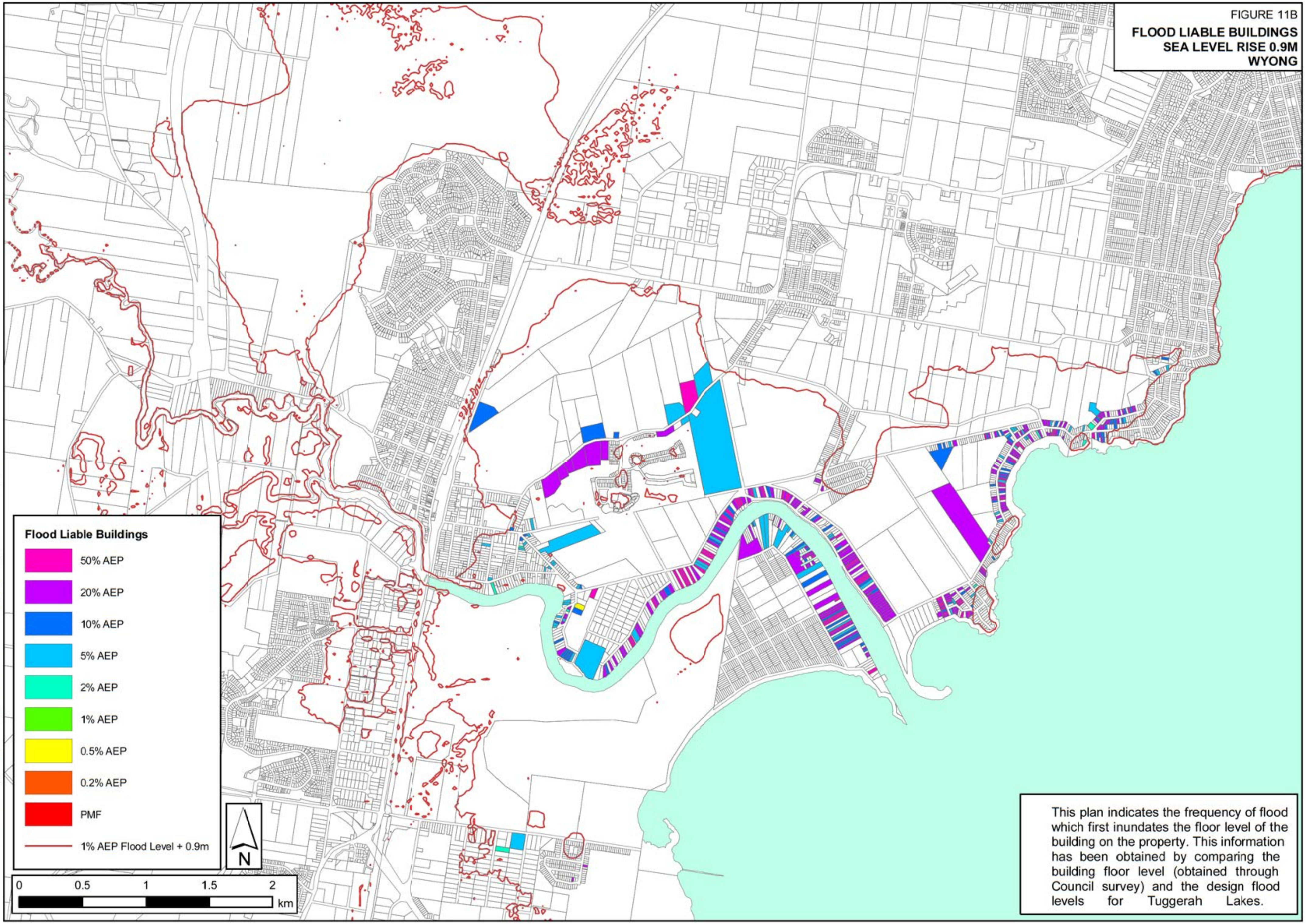
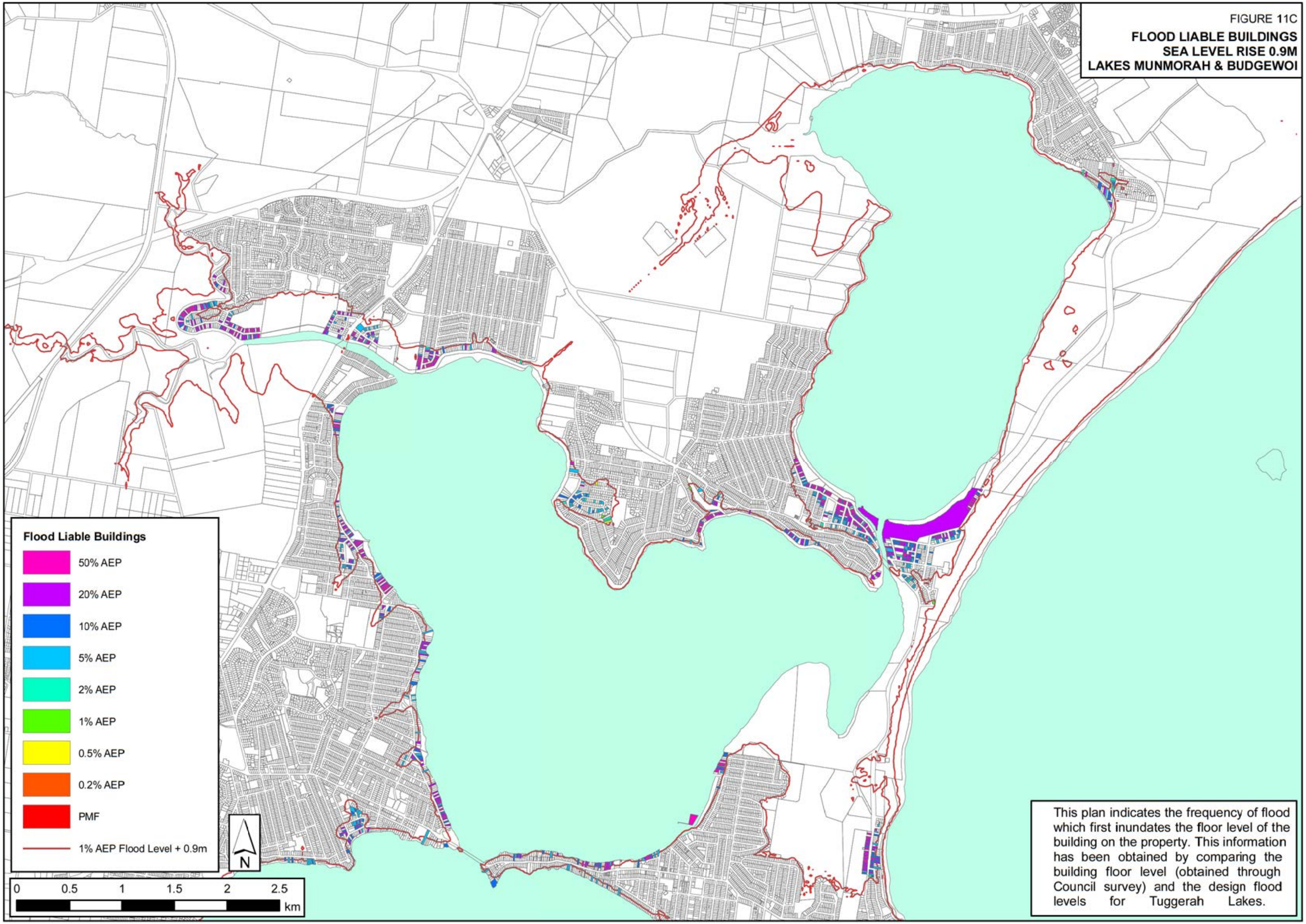


J:\Jobs\29001\Arcview\Arcmaps\Figure11B_FloodLiableBuildings_Wyong_ClimateChange.mxd

FIGURE 11C

FLOOD LIABLE BUILDINGS
SEA LEVEL RISE 0.9M
LAKES MUNMORAH & BUDGEWOI



This plan indicates the frequency of flood which first inundates the floor level of the building on the property. This information has been obtained by comparing the building floor level (obtained through Council survey) and the design flood levels for Tuggerah Lakes.

J:\Jobs\29001\Arcview\Arcmaps\Figure11C_FloodLiableBuildings_Lakes_Mun_Bud_climatechange

FIGURE 11D

FLOOD LIABLE BUILDINGS SEA LEVEL RISE 0.9M NORTH EAST TUGGERAH LAKE

This plan indicates the frequency of flood which first inundates the floor level of the building on the property. This information has been obtained by comparing the building floor level (obtained through Council survey) and the design flood levels for Tuggerah Lakes.

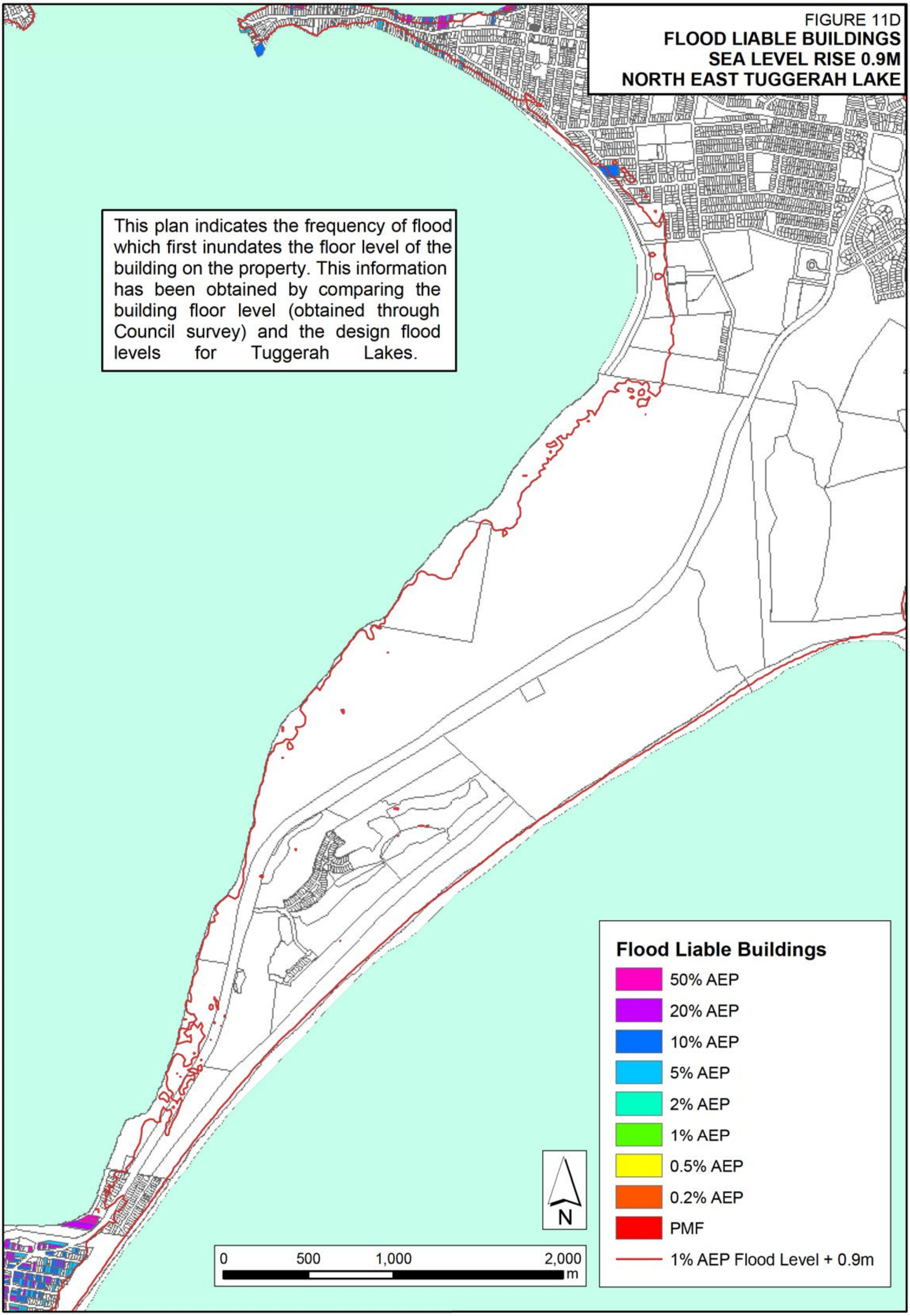


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FIGURE 12A

PMF CONTOURS
SOUTH AND EAST OF TUGGERAH LAKE

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FIGURE 12B
PMF CONTOURS
WYONG

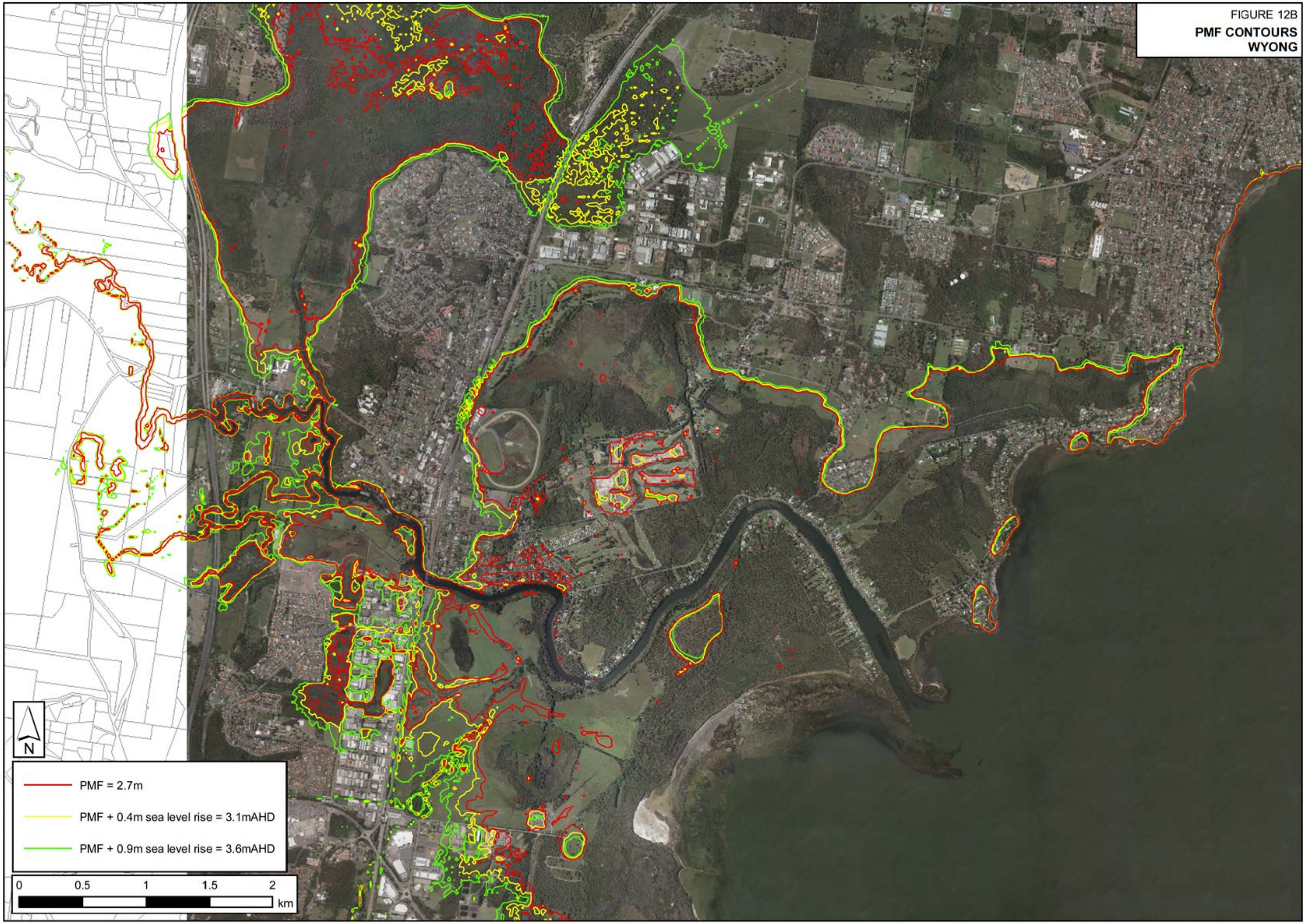

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FIGURE 12C

PMF CONTOURS
LAKES MUNMORAH & BUDGEWOI

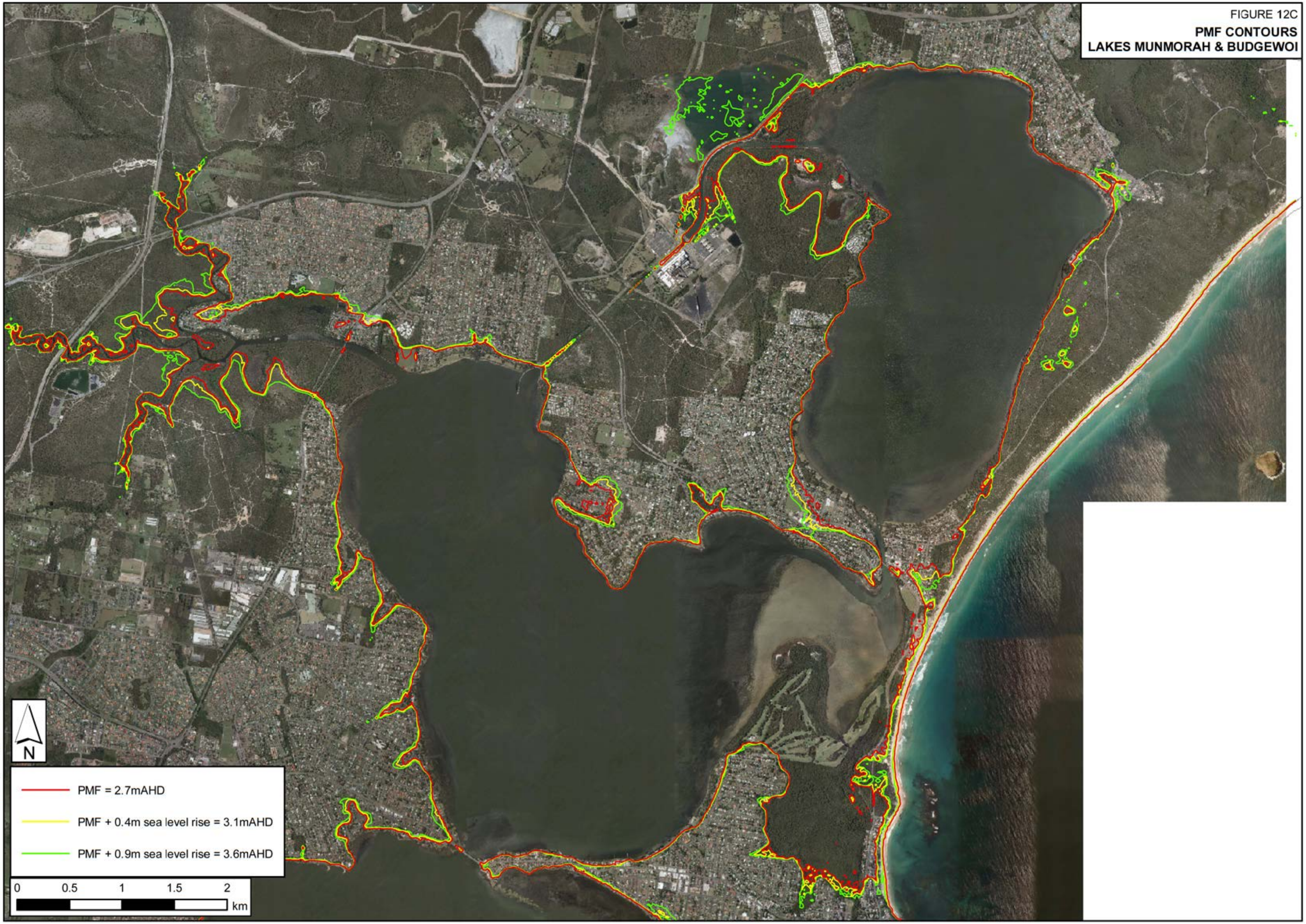

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FIGURE 12D
PMF CONTOURS
NORTH EAST TUGGERAH LAKE

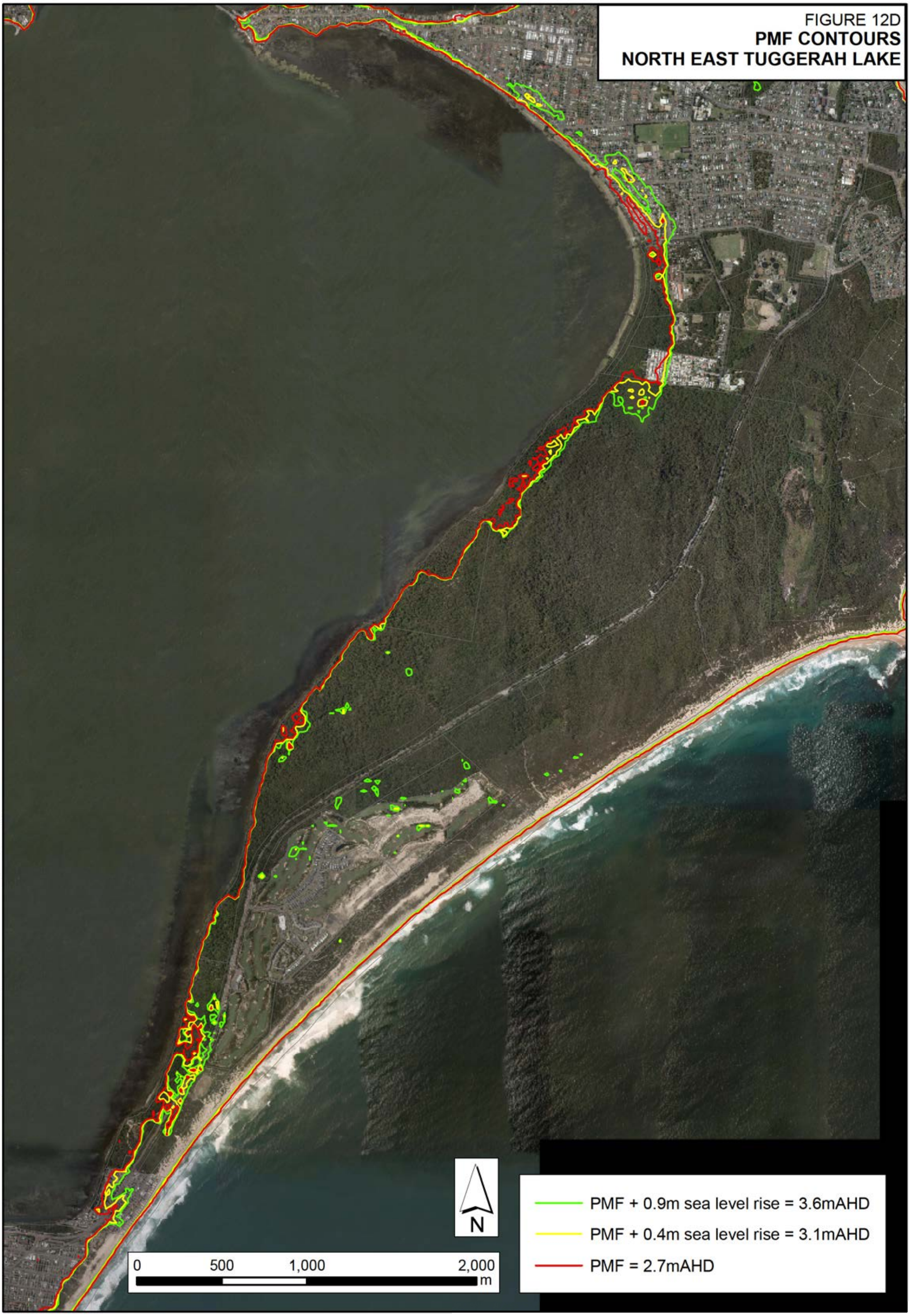

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FIGURE 13
1% AEP HYDRAULIC HAZARD WITH 0.4M SEA LEVEL RISE AND SEWERAGE SYSTEM IMPACT

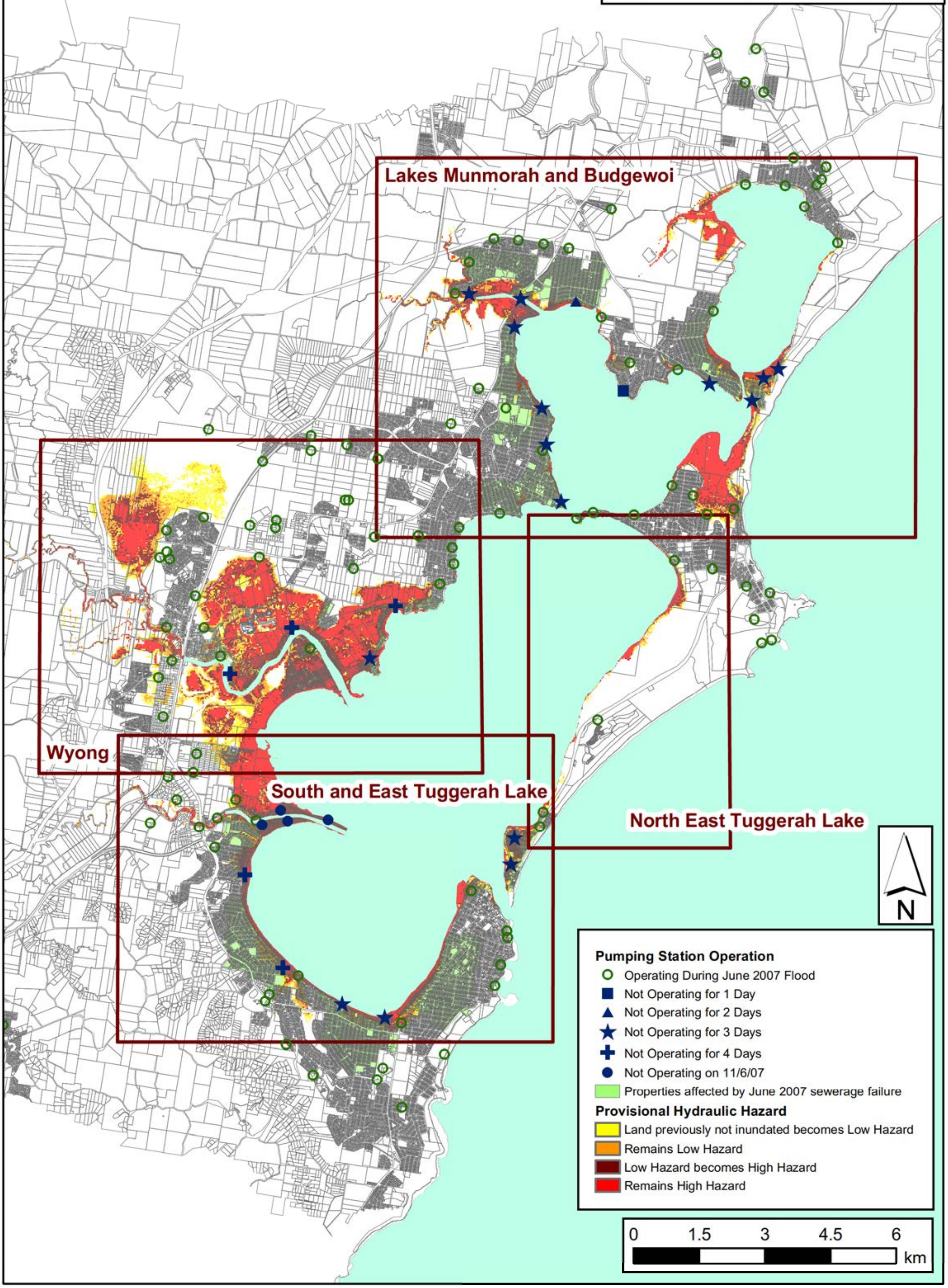

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FIGURE 13A
1% AEP HYDRAULIC HAZARD WITH 0.4M SEA LEVEL RISE AND SEWERAGE SYSTEM IMPACT SOUTH AND EAST OF TUGGERAH LAKE

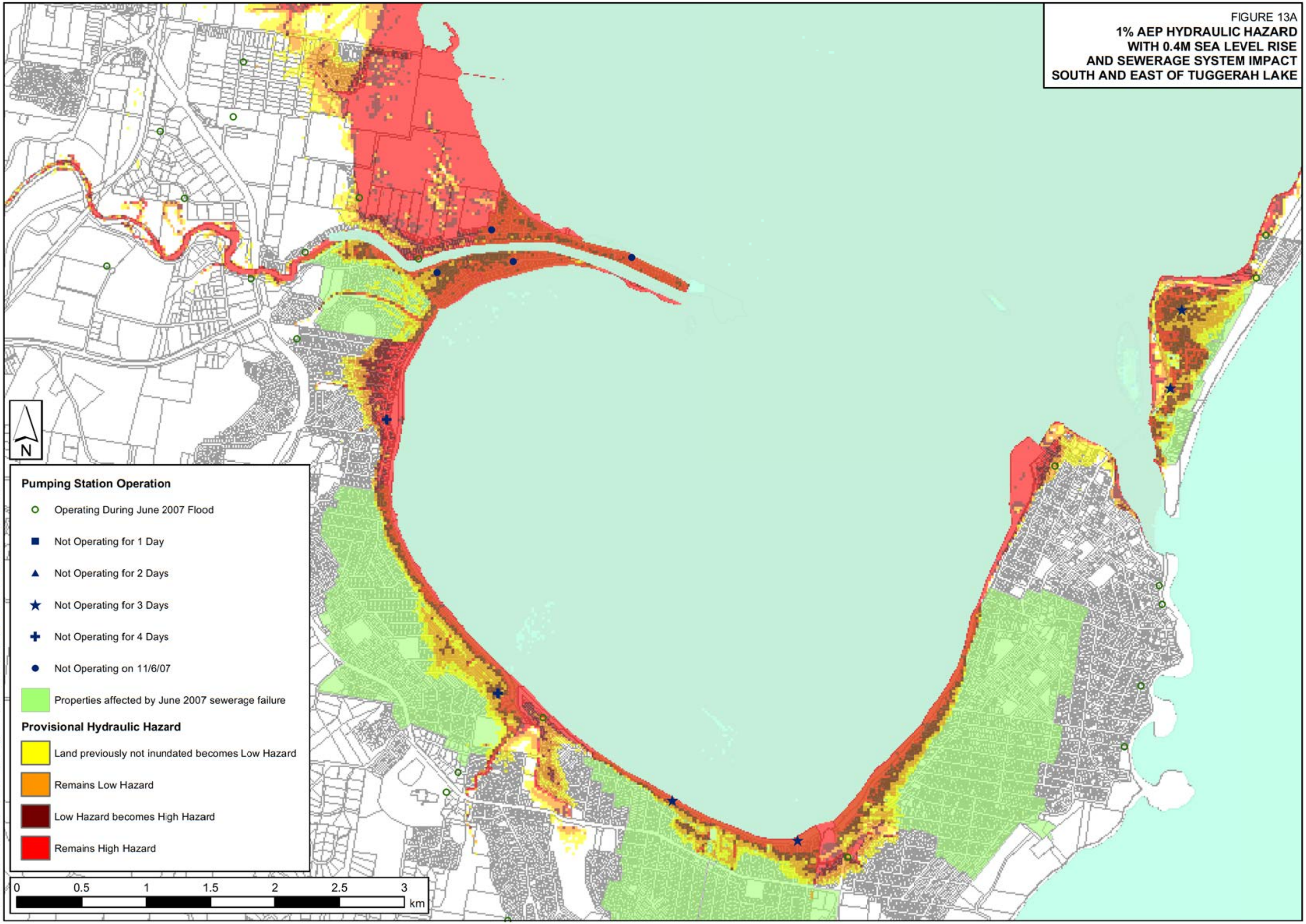

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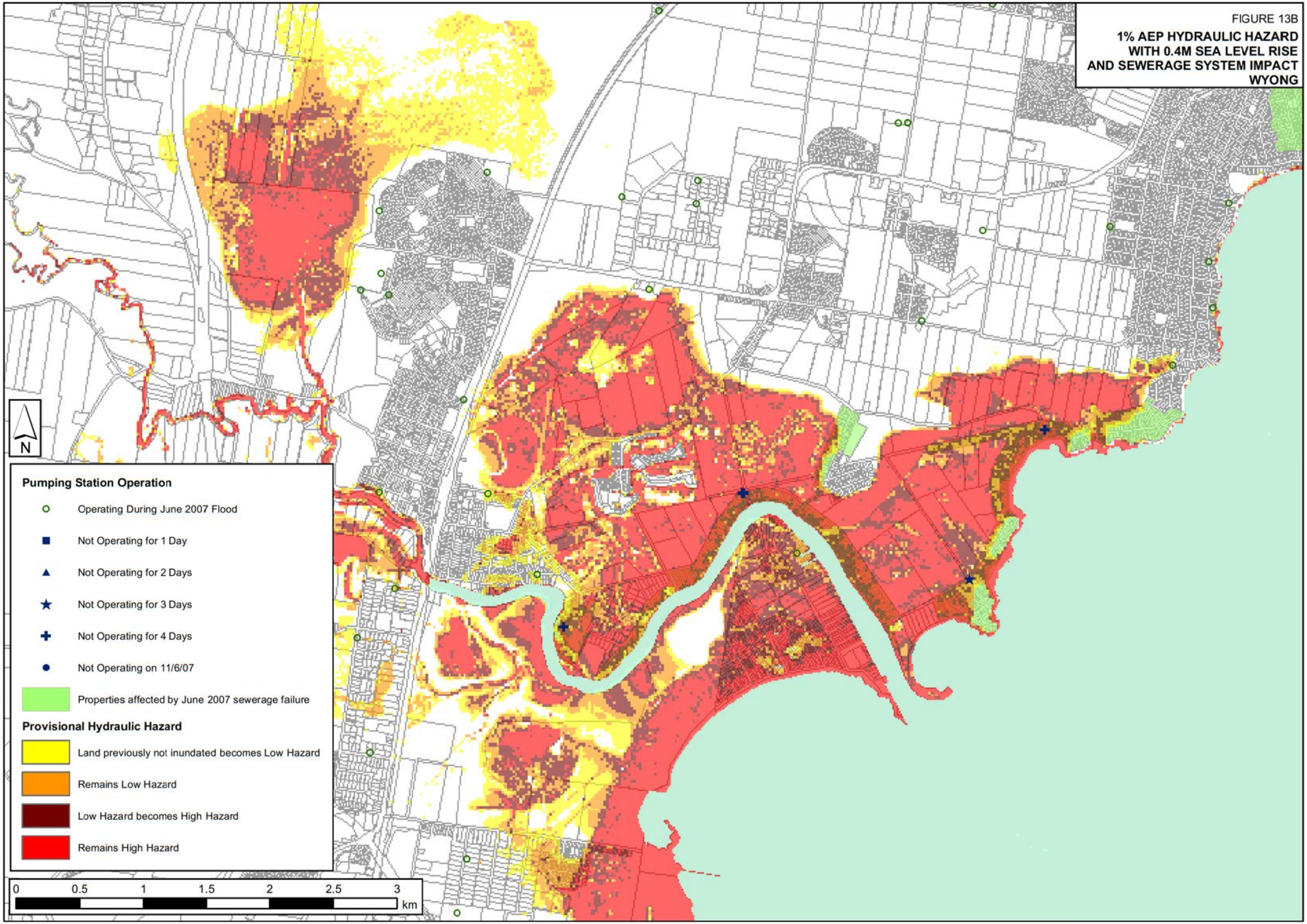
FIGURE 13B

1% AEP HYDRAULIC HAZARD WITH 0.4M SEA LEVEL RISE AND SEWERAGE SYSTEM IMPACT WYONG



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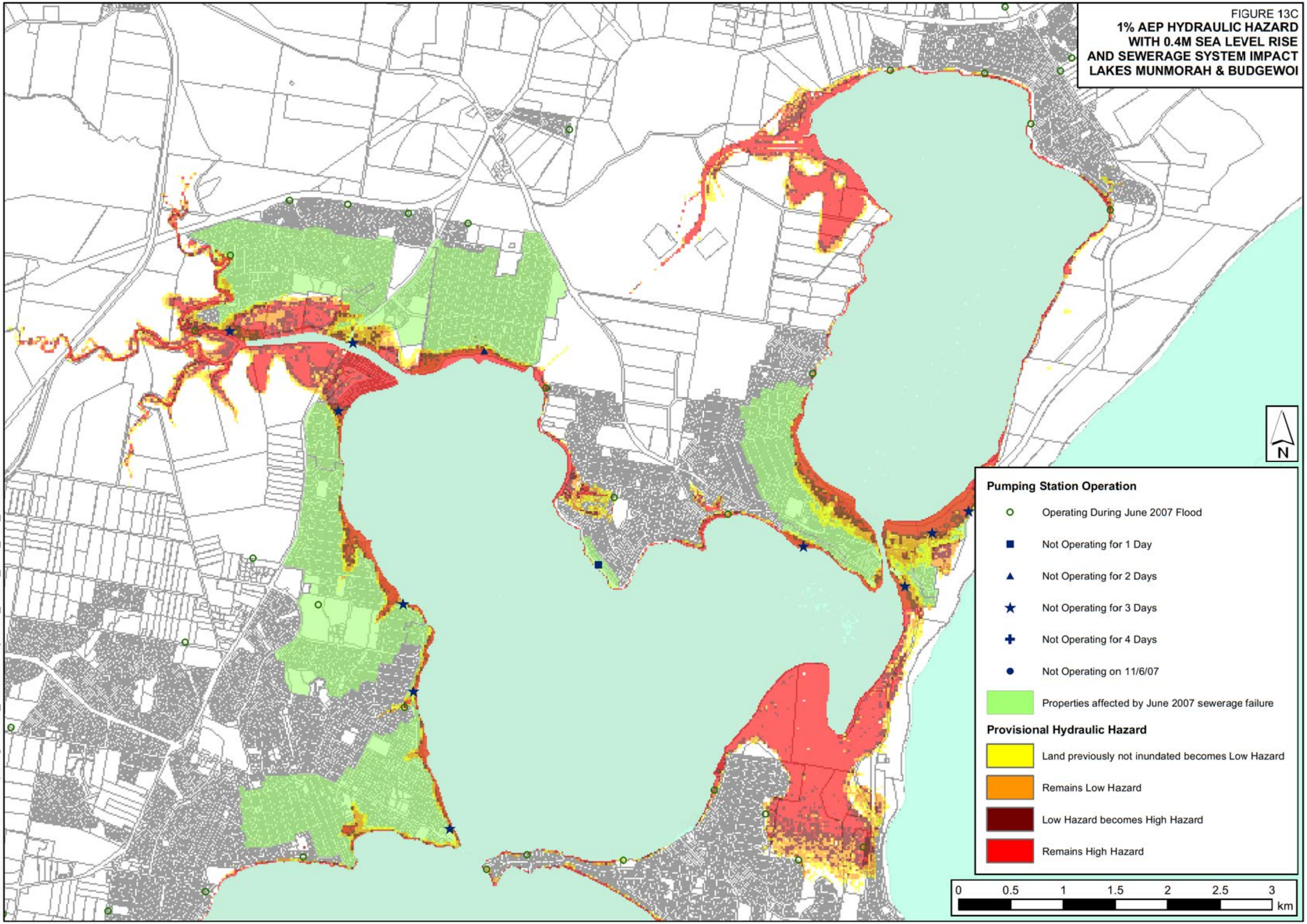

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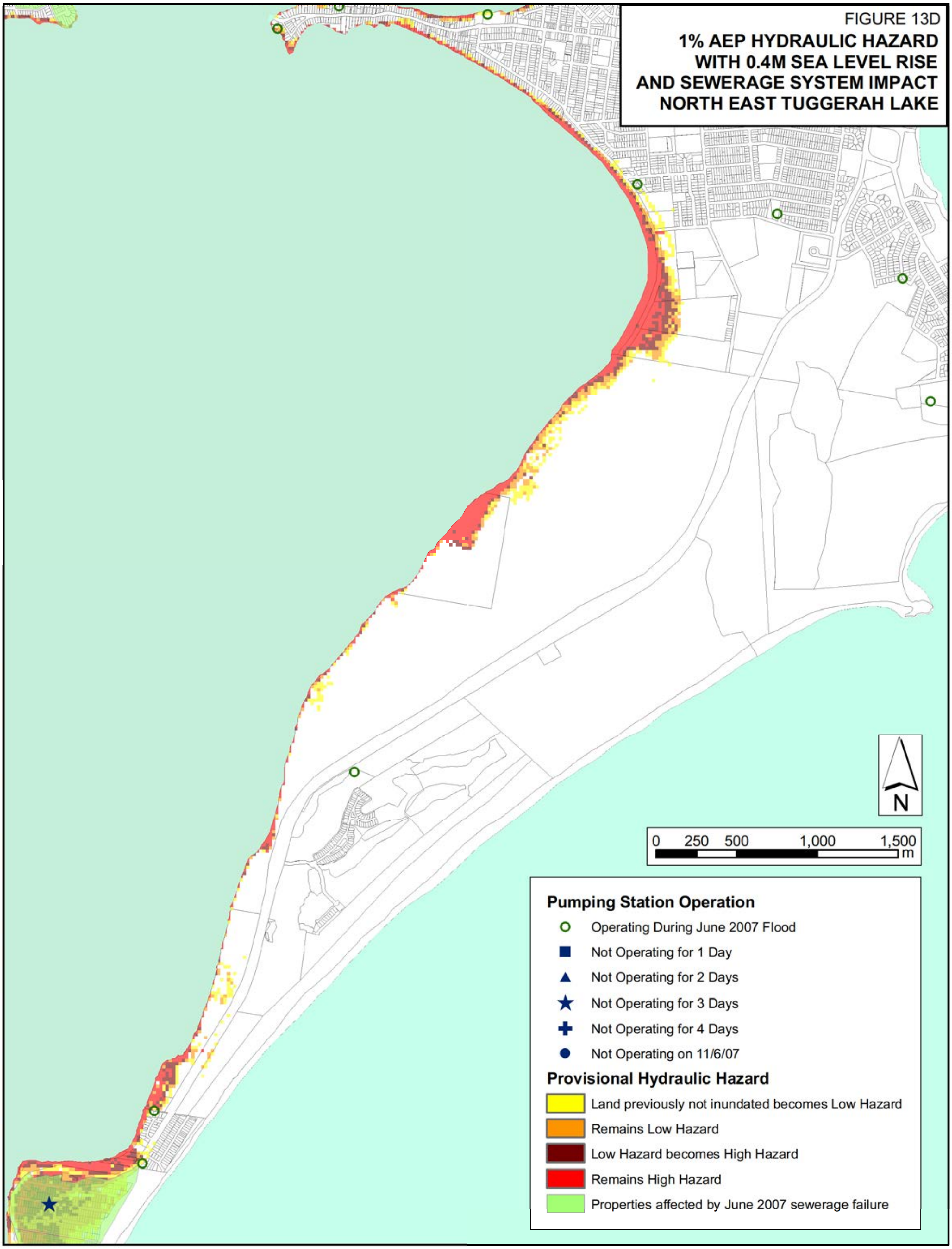

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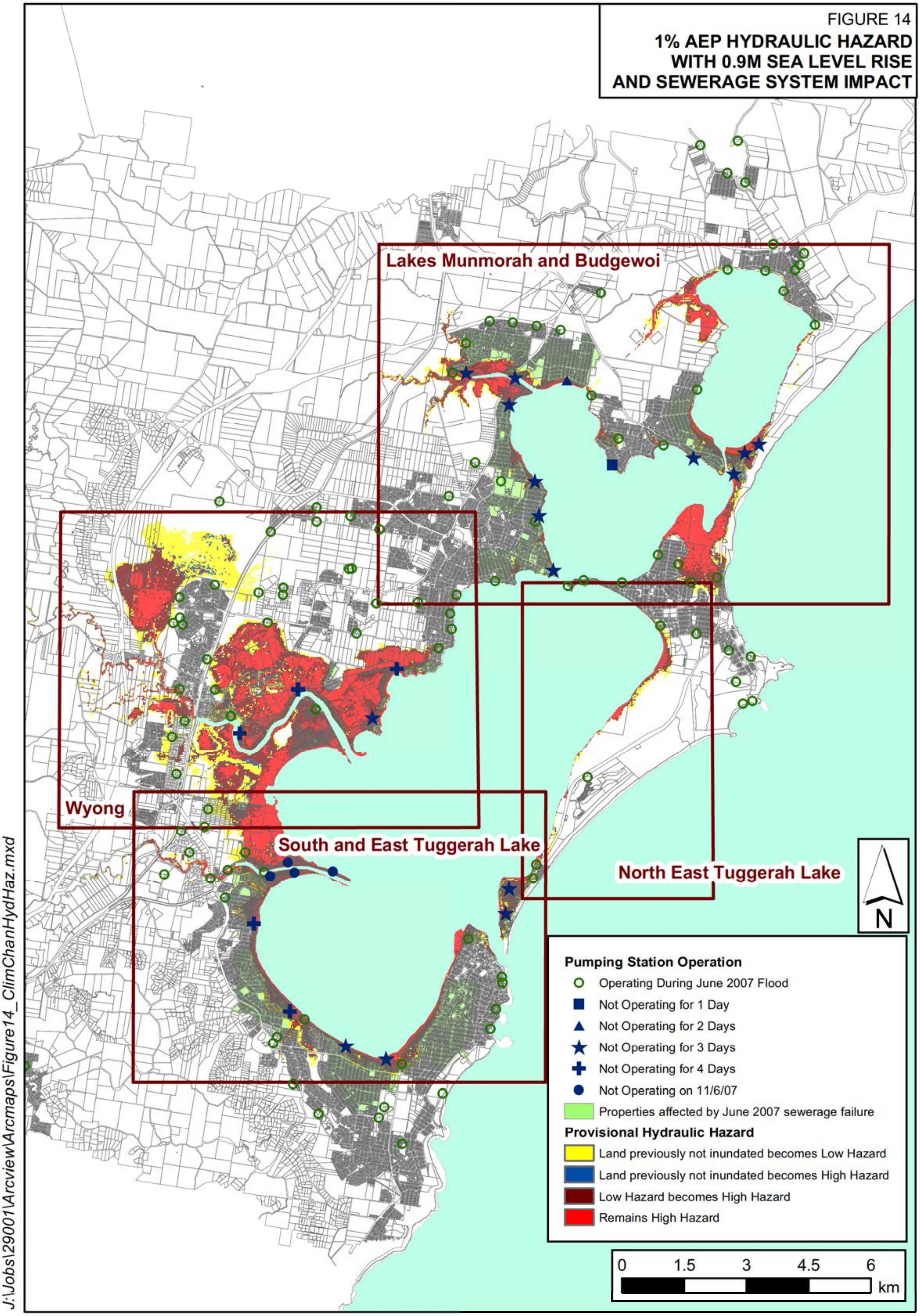
FIGURE 14
1% AEP HYDRAULIC HAZARD
WITH 0.9M SEA LEVEL RISE
AND SEWERAGE SYSTEM IMPACT
Lakes Munmorah and Budgewoi
Wyong
South and East Tuggerah Lake
North East Tuggerah Lake
N
Pumping Station Operation
Operating During June 2007 Flood
Not Operating for 1 Day
Not Operating for 2 Days
Not Operating for 3 Days
Not Operating for 4 Days
Not Operating on 11/6/07
Properties affected by June 2007 sewerage failure
Provisional Hydraulic Hazard
Land previously not inundated becomes Low Hazard
Land previously not inundated becomes High Hazard
Low Hazard becomes High Hazard
Remains High Hazard
0
1.5
3
4.5
6
km
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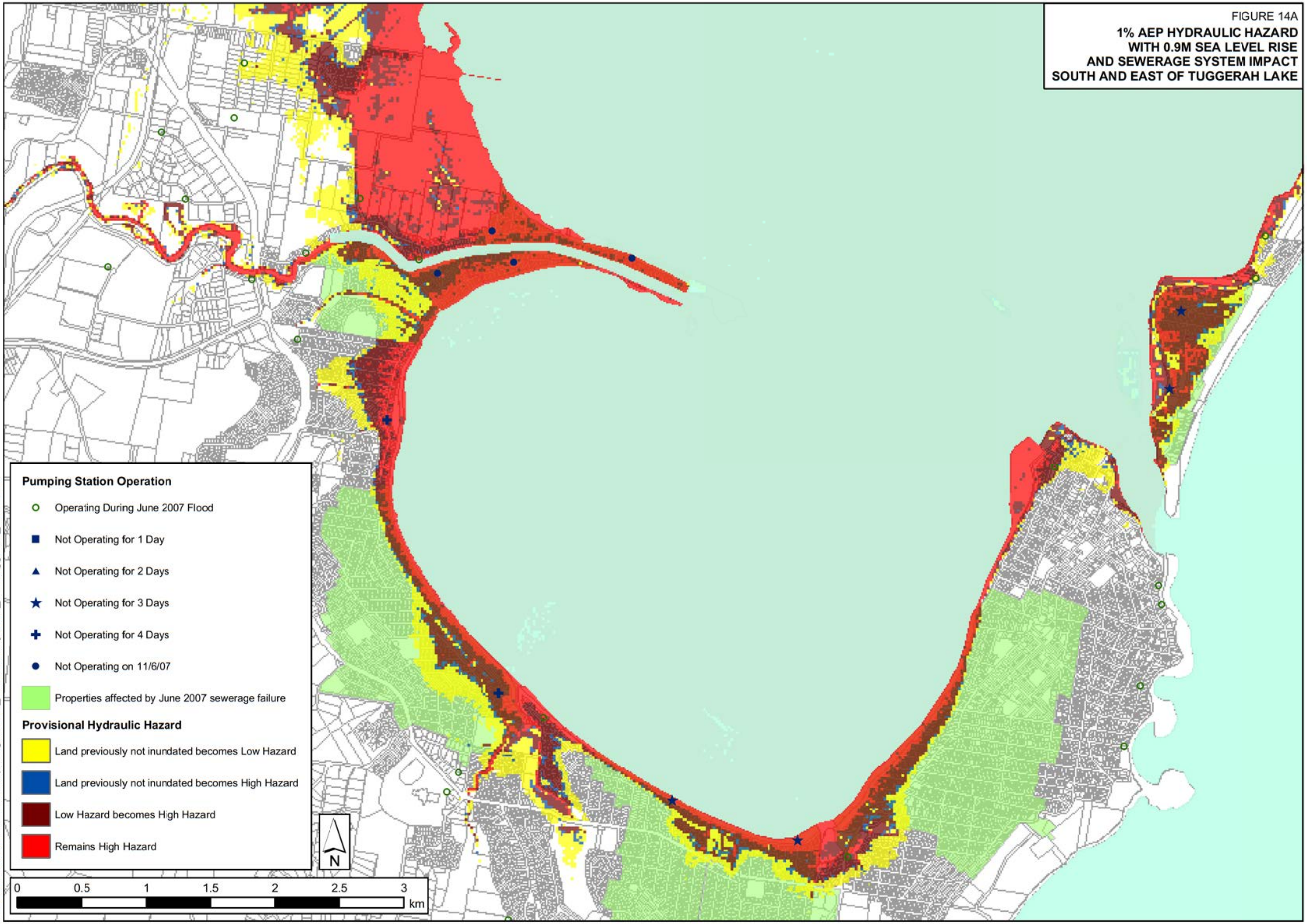
FIGURE 14A
1% AEP HYDRAULIC HAZARD
WITH 0.9M SEA LEVEL RISE
AND SEWERAGE SYSTEM IMPACT
SOUTH AND EAST OF TUGGERAH LAKE
Pumping Station Operation
Operating During June 2007 Flood
Not Operating for 1 Day
Not Operating for 2 Days
Not Operating for 3 Days
Not Operating for 4 Days
Not Operating on 11/6/07
Properties affected by June 2007 sewerage failure
Provisional Hydraulic Hazard
Land previously not inundated becomes Low Hazard
Land previously not inundated becomes High Hazard
Low Hazard becomes High Hazard
Remains High Hazard
N
0
0.5
1
1.5
2
2.5
3
km
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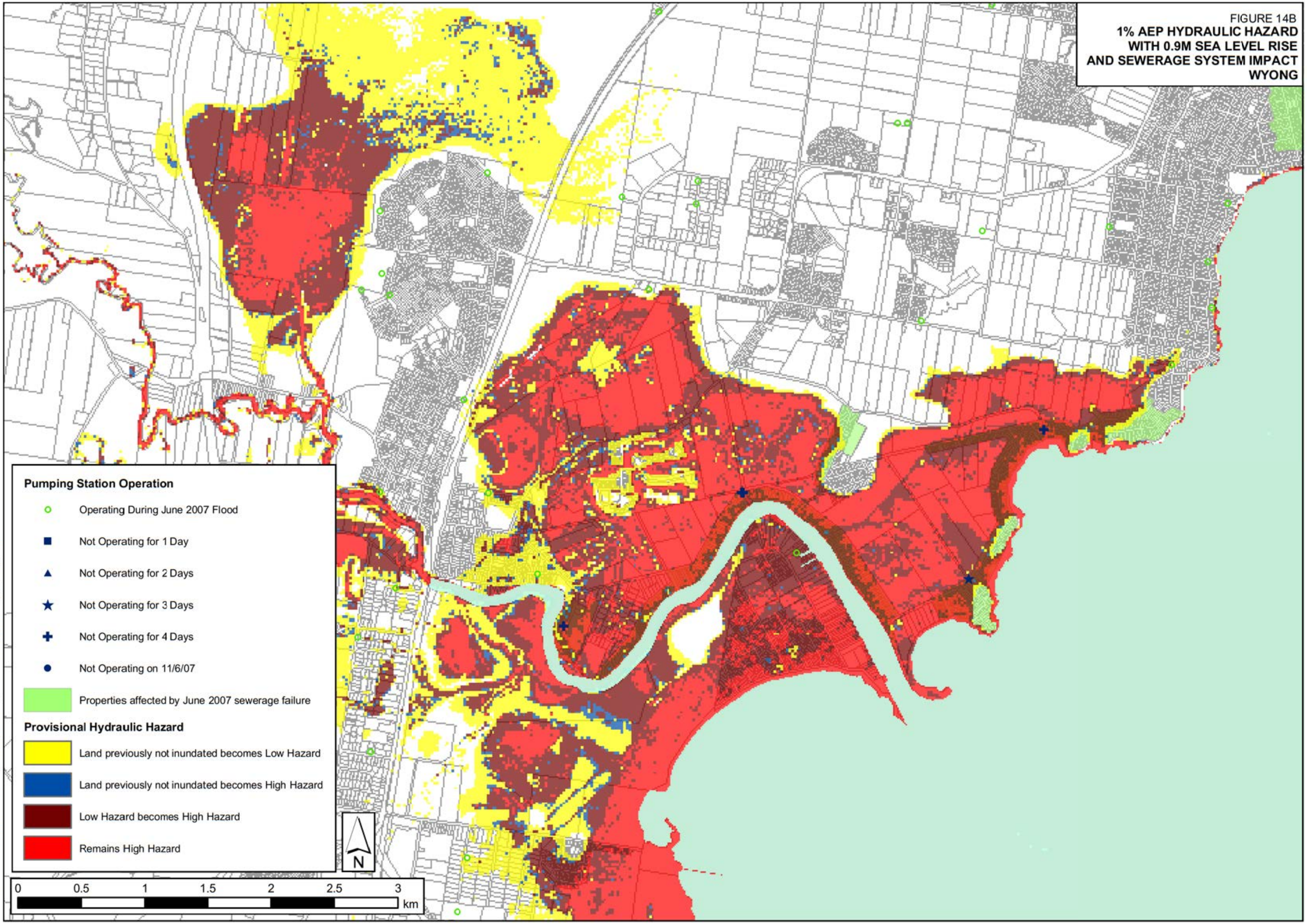


FIGURE 14B
1% AEP HYDRAULIC HAZARD
WITH 0.9M SEA LEVEL RISE
AND SEWERAGE SYSTEM IMPACT
WYONG
Pumping Station Operation
Operating During June 2007 Flood
Not Operating for 1 Day
Not Operating for 2 Days
Not Operating for 3 Days
Not Operating for 4 Days
Not Operating on 11/6/07
Properties affected by June 2007 sewerage failure
Provisional Hydraulic Hazard
Land previously not inundated becomes Low Hazard
Land previously not inundated becomes High Hazard
Low Hazard becomes High Hazard
Remains High Hazard
N
0
0.5
1
1.5
2
2.5
3
km
J:\Jobs\29001\Arcview\Arcmaps\Figure14B_ClimChanHydHaz_Wyong_0.9m.mxd

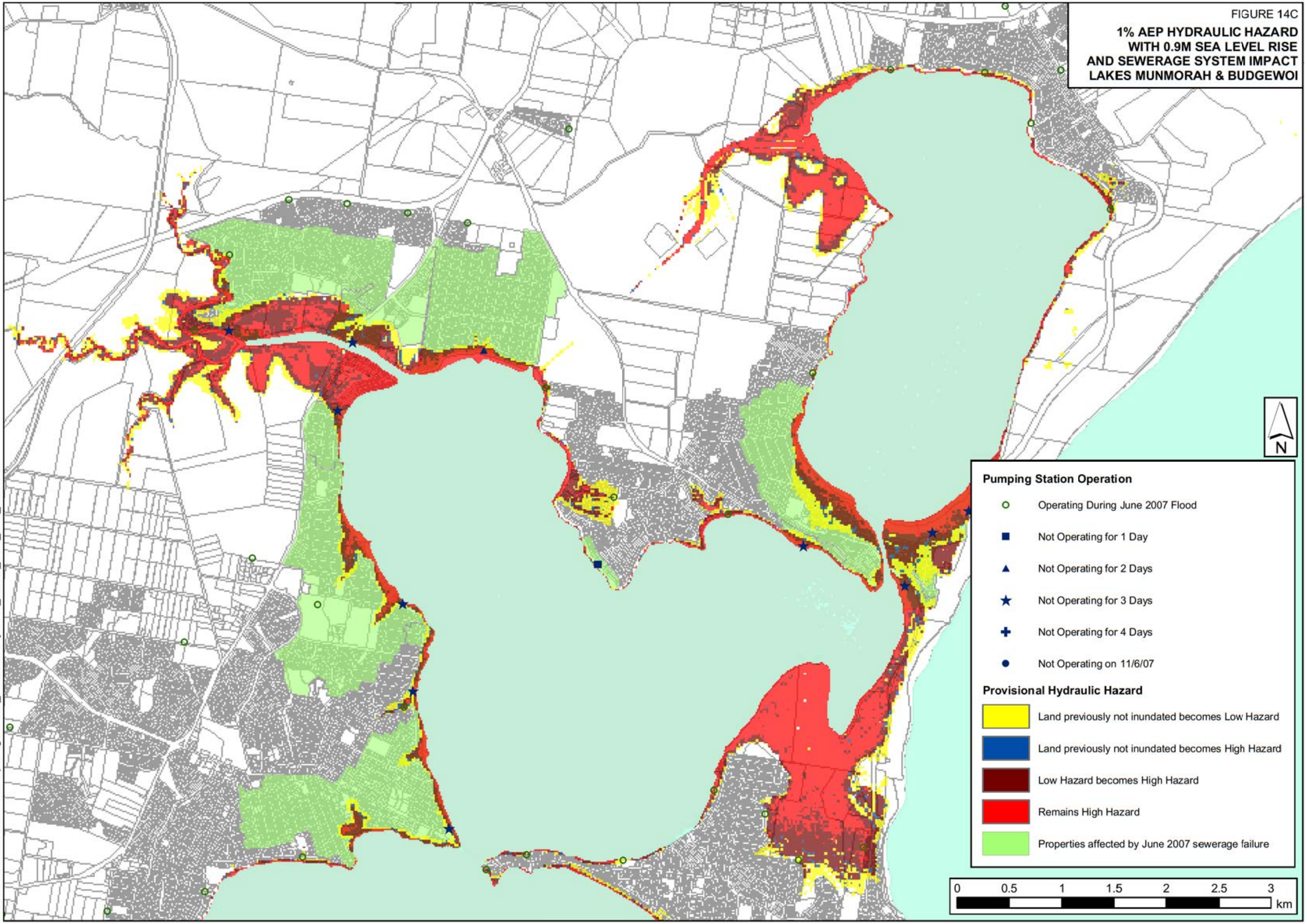
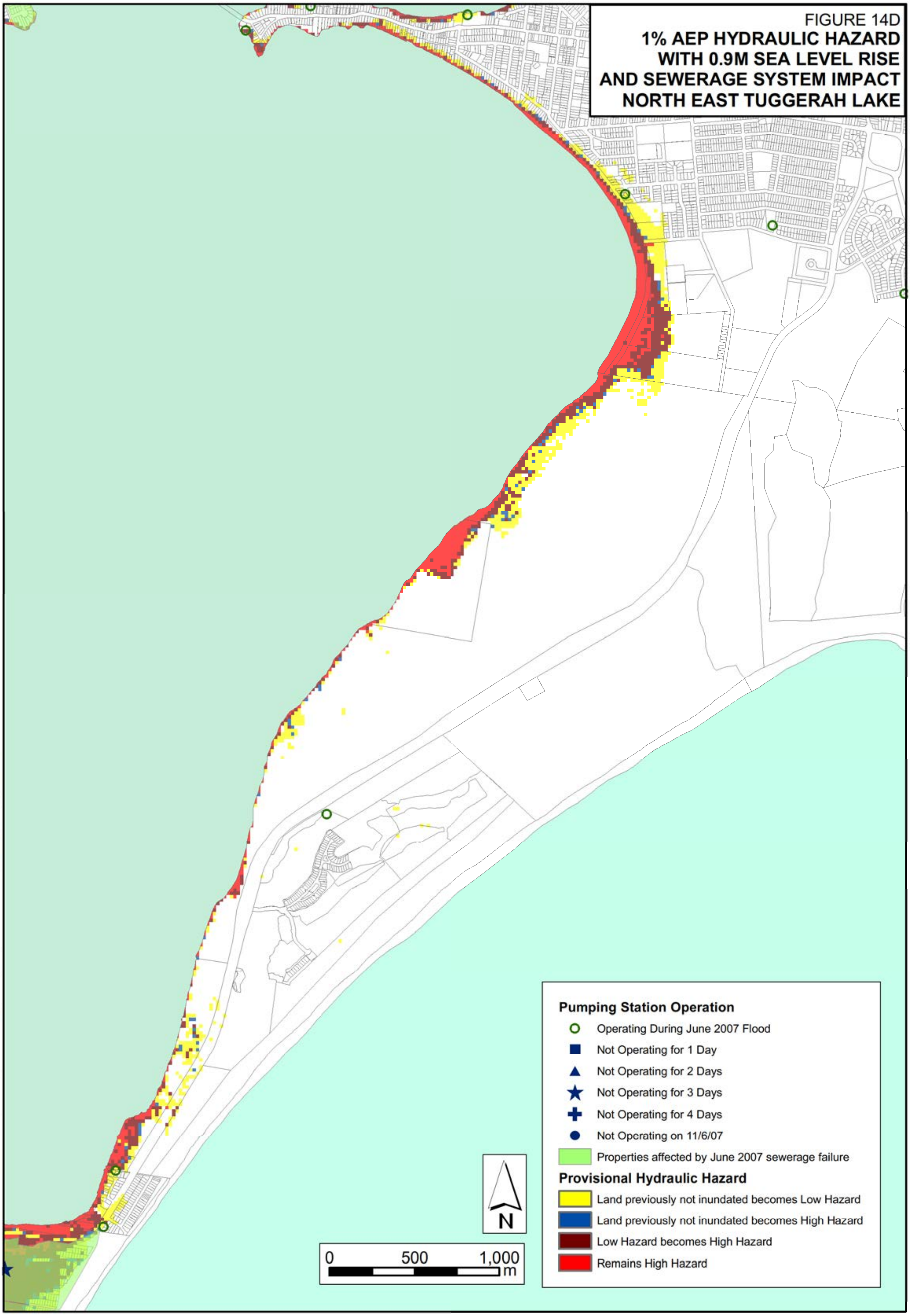


FIGURE 14C
1% AEP HYDRAULIC HAZARD
WITH 0.9M SEA LEVEL RISE
AND SEWERAGE SYSTEM IMPACT
LAKES MUNMORAH & BUDGEWOI
N
Pumping Station Operation
Operating During June 2007 Flood
Not Operating for 1 Day
Not Operating for 2 Days
Not Operating for 3 Days
Not Operating for 4 Days
Not Operating on 11/6/07
Provisional Hydraulic Hazard
Land previously not inundated becomes Low Hazard
Land previously not inundated becomes High Hazard
Low Hazard becomes High Hazard
Remains High Hazard
Properties affected by June 2007 sewerage failure
0
0.5
1
1.5
2
2.5
3
km
J:\Jobs\29001\Arcview\Arcmaps\Figure14C_ClimChanHydHaz_Lakes_Mun_Bud_0.9m.mxd



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Final Report

Appendix A

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. redevelopment: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major

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

	probable maximum flood event, that is, flood prone land.
floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic 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)	FPLs are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the standard flood event in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are

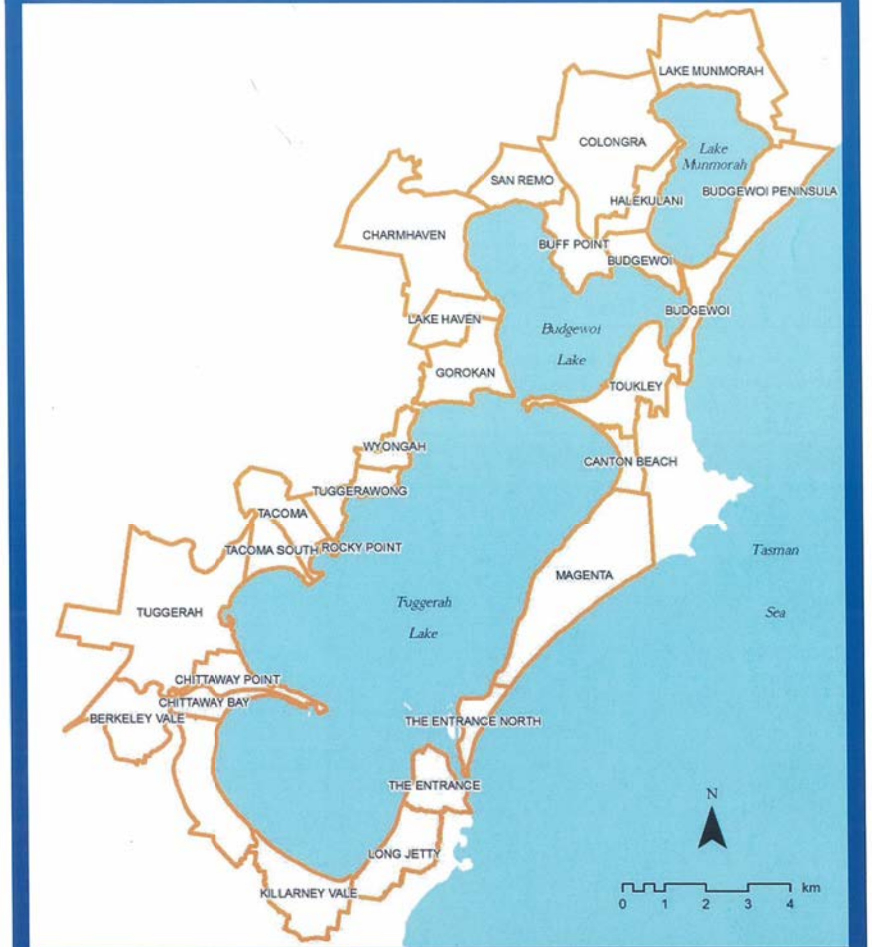
	areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	in a residential situation: a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. in an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: • the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or • water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or • major overland flow paths through developed areas outside of defined drainage reserves; and/or • the potential to affect a number of buildings along the major flow path.
mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage,

	hazard and behaviour implications, and environmental protection and well being of the States rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.
peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to water level. Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time

	during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

If you have any further comments that relate to the Tuggerah Lakes Floodplain Risk Management Study and Plan, please provide them in the space below (or attach additional pages if needed):



Tuggerah Lakes and Surrounding Suburbs

For more information please contact:

Lara Critchley
Senior Planning Engineer (Hydrology)
Lara.critchley@wyong.nsw.gov.au

Shah Alam
Engineer Hydrology
Shah.alam@wyong.nsw.gov.au

Does flooding in the Tuggerah Lakes area affect you?

BE IN THE DRAW TO WIN A $50 GIFT VOUCHER

Pacific Highway, Charmhaven I June 2007

Local Resident Survey

Tuggerah Lakes Floodplain Risk Management Study and Plan I 2010

Flooding is a natural event that can risk human lives, services, goods and properties. There have been large floods in Wyong Shire in 2007, 2004, 1990, 1964 and 1949. Having a good understanding of floods and planning for them can help reduce the risks.

In June 2007 flooding resulted in about:

- 2000 flooded homes
- 10 000 flooded properties
- 500 people needing rescue
- Three days of high flood waters in Wyong Shire.

Wyong Shire Council is preparing a Tuggerah Lakes Floodplain Risk Management Study and Plan. The aim of the plan is to help ensure that Council can plan for and manage the impacts of flooding, and minimise the risks to the community before, during and after flood events.

Do you live, work or play in the Tuggerah Lakes area? Your experience of floods can provide important information to Council. Your ideas of what Council can do to manage flood prone land will help us prepare the plan.

Council would like you to participate in this survey and ask that you fill in and return using the reply paid envelope provided by 31 March 2010.

For more information on flooding go to Wyong Shire Council's website at: http://www.wyong.nsw.gov.au/environment/flooding

All returned surveys will be put in a draw to win a $50 gift voucher.

Q1. Please provide us with the following details (optional): We may wish to contact you to discuss some of the information you have provided us.

Name: ______________________

Address: ______________________

Daytime Phone: ______________________

Email: ______________________

Q2. Is your property:

Owner occupied	Occupied by a tenant	A business	School/Aged Care
☐	☐	☐	☐

Q3. How long have you lived, worked and/or owned your property?

__________ Months __________ Years

Q4. Have you ever experienced flooding since living / working / owning your property?

- ☐ Floodwaters entered my house / work / school / aged care building (date________ / location________________)
- ☐ Floodwaters entered my backyard (date________ / location________________)
- ☐ No, I haven't experienced a flood (go to Q.6)

Q5. If you have experienced a flood, how did the flooding affect you and your family / business?

- ☐ Parts of my house / work / school / aged care building were damaged
- ☐ The contents of my house / work / school / aged care were damaged
- ☐ My backyard was damaged
- ☐ My car was damaged
- ☐ Other property was damaged (please specify________________)
- ☐ I couldn't leave my house / work / school / aged care
- ☐ Family members couldn't return to the house / work
- ☐ My family had to evacuate the house / work
- ☐ The flood disrupted my daily routine
- ☐ The sewer stopped working (for how long?)________________)
- ☐ The flood affected me in other ways (please specify________________________)
- ☐ No, the flood didn't affect me

Q6. Do you think your property could be flooded sometime in the future?

- ☐ No
- ☐ Yes, but only a small part of my yard
- ☐ Yes, most of my yard
- ☐ Yes, my house could flood over the floor

Q7. Where have you looked for information about flooding on your property?

- ☐ Council's customer service centre
- ☐ Other information from Council (please specify ________________________)
- ☐ Viewed a Property Planning (Section 149) Certificate
- ☐ Information from a real estate agent
- ☐ Information from relatives, friends, neighbours, or previous owner
- ☐ Other information (please specify ________________________)
- ☐ No information has been looked for
- ☐ I do not believe my property is affected by flooding

Q8. What do you think are the best ways for Council to get feedback from, and to talk about flooding with the local community?

- ☐ Council's website
- ☐ Emails from Council
- ☐ Council's Floodplain Management Committee
- ☐ Formal Council meetings
- ☐ Council's information page in the local paper
- ☐ Other articles in the local paper
- ☐ Information days in the local area
- ☐ Community meetings
- ☐ Mail outs to all residents / business owners in the study area

Q9. As a local resident, you may have your own ideas on how to reduce flood risks. Which of the following options would you prefer for Tuggerah Lakes? Please also provide comments as to the location where you think the option might be suitable. 1= least preferred 5= most preferred (please circle a number)

Option	Example	Preference	Other Comments?
Recognition of natural flow path	Council may leave a floodway as parkland instead of developing the area	1 2 3 4 5	
Vegetation control	Removing weeds & stabilisation of a river bank by planting trees	1 2 3 4 5	
Building development controls	Council may set a particular floor level height for new buildings and extensions which is above the flood level	1 2 3 4 5	
Education of community	Community learn how to prepare for flooding and what to do during a flood	1 2 3 4 5	
Flood forecasting, flood warning, evacuation planning and emergency response	Flood warnings on the Council website	1 2 3 4 5	
Floodgates or levee banks	A wall or gate built to keep water from overflowing from a river or lake etc.	1 2 3 4 5	
Opening or dredging The Entrance Channel	Council could perform major works to open the channel	1 2 3 4 5	
Voluntary house purchase	Council may offer to buy back flood affected properties from owners	1 2 3 4 5	
House raising	Some houses could be raised above flood planning level	1 2 3 4 5	
Other (please attach a page if needed)	Any other ideas you may have for Council to manage flooding	1 2 3 4 5	

Local Resident Survey – Results

Tuggerah Lakes Floodplain Risk Management Study and Plan | 2010

Q 1.	Please provide us with the following details (optional)? We may wish to contact you to discuss some of the information you have provided us.	Name: Address: Daytime Phone: Email:		
Q 2.	Is your property (please click in check boxes).	Owner occupied 92.8%	Occupied by a tenant 6.3%	A business 0.8% / School/Aged Care 0.4%
Q 3.	How long have you lived, worked and/or owned your property?	Months	Average 30.8	Years

Q 4.	Have you ever experienced flooding since living / working / owning your property?	☐ Floodwaters entered my house / work / school / aged care building (date / location)	18.4%
		☐ Floodwaters entered my backyard (date / location	58.2%
		☐ No, I haven't experienced a flood (go to Q.6)	33.3%
Q 5.	If you have experienced a flood, how did the flooding affect you and your family / business?	☐ Parts of my house / work / school / aged care building were damaged	15.6%
		☐ The contents of my house / work / school / aged care were damaged	14.5%
		☐ My backyard was damaged	34.3%
		☐ My car was damaged	7.7%
		☐ Other property was damaged (please specify)	15.3%
		☐ I couldn't leave my house / work / school / aged care	22.8%
		☐ Family members couldn't return to the house / work	13.8%
		☐ My family had to evacuate the house / work	10.8%
		☐ The flood disrupted my daily routine	37.5%
		☐ The sewer stopped working (for how long?)	24%
		☐ The flood affected me in other ways	23.5%
		☐ No, the flood didn't affect me	12.4%
Q 6.	Do you think your property could be flooded sometime in the future?	☐ No	11.5%
		☐ Yes, but only a small part of my yard	6%
		☐ Yes, most of my yard	7.2%
		☐ Yes, my house could flood over the floor	12.6%
Q 7.	Where have you looked for information about flooding on your property?	☐ Council's customer service centre	11.5%
		☐ Viewed a Property Planning (Section 149) Certificate	6.%
		☐ Information from a real estate agent	7.2%
		☐ Information from relatives, friends, neighbours, or	12.6%
		previous owner	29.1%
		☐ Other information (please specify)	8.9%
		☐ No information has been looked for	36.4%
		☐ I do not believe my property is affected by flooding	12.5%
Q 8.	What do you think are the best ways for Council to get feedback from, and to talk about flooding with the local community?	☐ Council's website	18.5%
		☐ Emails from Council	14.2%
		☐ Council's Floodplain Management Committee	10.6%
		☐ Formal Council meetings	5.3%
		☐ Council's information page in the local paper	47.5%
		☐ Other articles in the local paper	31.2%
		☐ Information days in the local area	24.4%
		☐ Community meetings	21.3%
		☐ Mail outs to all residents/business owners in the study area	65.6%

Q 9. As a local resident, you may have your own ideas on how to reduce flood risks. Which of the following options would you prefer for Tuggerah Lakes? Please also provide comments as to the location where you think the option might be suitable.
1= least preferred 5= most preferred (please choose a number from the drop down list)

Option	Example	Preference	Percentage
Recognition of natural flow path	Council may leave a floodway as parkland instead of developing the area	1	7.0%
		2	3.2%
		3	6.6%
		4	3.2%
		5	59.2%
Vegetation control	Removing weeds & stabilisation of a river bank by planting trees	1	11%
		2	4.5%
		3	11.6%
		4	4.5%
		5	45.2%
Building development controls	Council may set a particular floor level height for new buildings and extensions which is above the flood level	1	10%
		2	4.8%
		3	16.3%
		4	4.8%
		5	42.1%
Education of community	Community learn how to prepare for flooding and what to do during a flood	1	7.7%
		2	5.7%
		3	16.7%
		4	5.7%
		5	41.8%
Flood forecasting, flood warning, evacuation planning and emergency response	Flood warnings on the Council website	1	13.1%
		2	8.2%
		3	16.9%
		4	8.2%
		5	33.9%
Floodgates or levee banks	A wall or gate built to keep water from overflowing from a river or lake etc.	1	21.7%
		2	8.8%
		3	13.4%
		4	8.8%
		5	28.3%
Opening or dredging The Entrance Channel	Council could perform major works to open the channel	1	8.5%
		2	2.8%
		3	6.6%
		4	2.8%
		5	67.8%
Voluntary house purchase	Council may offer to buy back flood affected properties from owners	1	23.5%
		2	8.8%
		3	19.6%
		4	8.8%
		5	21%
House raising	Some houses could be raised above the flood planning level	1	18.5%
		2	10.9%
		3	23.8%
		4	10.9%
		5	17.9%