Brisbane Water Foreshore

Floodplain Risk Management Study

FINAL

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Prepared for Gosford City Council

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Cover photograph shows a view of Empire Bay from Cockle Channel (taken 30 June, 2008).

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Preamble

This *Floodplain Risk Management Study* (FRMS) for the Brisbane Water foreshore floodplain has been prepared by Cardno (NSW/ACT) Pty Ltd (Cardno) for Gosford City Council (GCC). This document has been prepared in accordance with the *New South Wales* (NSW) *Flood Prone Land Policy* and the principles of the *Floodplain Development Manual* (NSW Government, 2005) and examines options for the management of flooding of the foreshores of the Brisbane Water estuary.

Strategic Context

This FRMS has a strategic context not only at a local government level but also at a regional, state, national and international level. This document has been prepared with regard to recent international scientific research collated and conducted by the Intergovernmental Panel on Climate Change (IPCC) and at a national level (CSIRO). This document also inter-relates to plans of management for floodplains and foreshore areas on a more regional level (i.e. the Hunter region and the Hawkesbury Nepean River catchment).

Floodplain Risk Management Process

The *Floodplain Development Manual* (NSW Government, 2005) provides guidelines to facilitate the formulation of *Floodplain Risk Management Plans* through the floodplain risk management process. *The Manual* describes the floodplain risk management process as:

1. Establish a Floodplain Risk Management Committee (now called Catchments and Coast Committee);
2. Data Collection;
3. Flood Study;
4. **Floodplain Risk Management Study;**
5. Floodplain Risk Management Plan;
6. Plan Implementation; and
7. Review of Plan.

This *Floodplain Risk Management Study* (FRMS) document represents the fourth stage in the above process, following the completion of the *Brisbane Water Foreshore Flood Study* in 2009 (Cardno, 2013). Unlike many other floodplain risk management studies which have been prepared for Gosford City Council (GCC), this study primarily considers those risks associated with *coastal flooding* of the foreshore of Brisbane Water. This type of flooding occurs when sea water rises due to tides and ocean storms, and is distinct from *catchment flooding* which occurs when creek water rises due to heavy and/or prolonged rain in the catchment. For the Brisbane Water foreshores, catchment flooding is associated with lower flood levels compared to coastal flooding due to storm surge. This document focuses on the impacts associated with coastal flooding. Assessments of catchment flooding can be found in the FRMS & Plans for various creeks, e.g. Narara Creek FRMS, Erina Creek FRMS, Kincumber Creek FRMS, etc.

The floodplain risk management process allows for continual updating and review so that resulting documents may keep pace with any new information as it becomes available. This FRMS is not a static document. Rather, it is a dynamic document that is actively reviewed approximately every five years. This FRMS document aims to be consistent with the objectives of other Floodplain Risk Management Studies and Plans for sub-catchments within the Brisbane Water Catchment.

Study Objectives

The objectives of this *Floodplain Risk Management Study* are to:

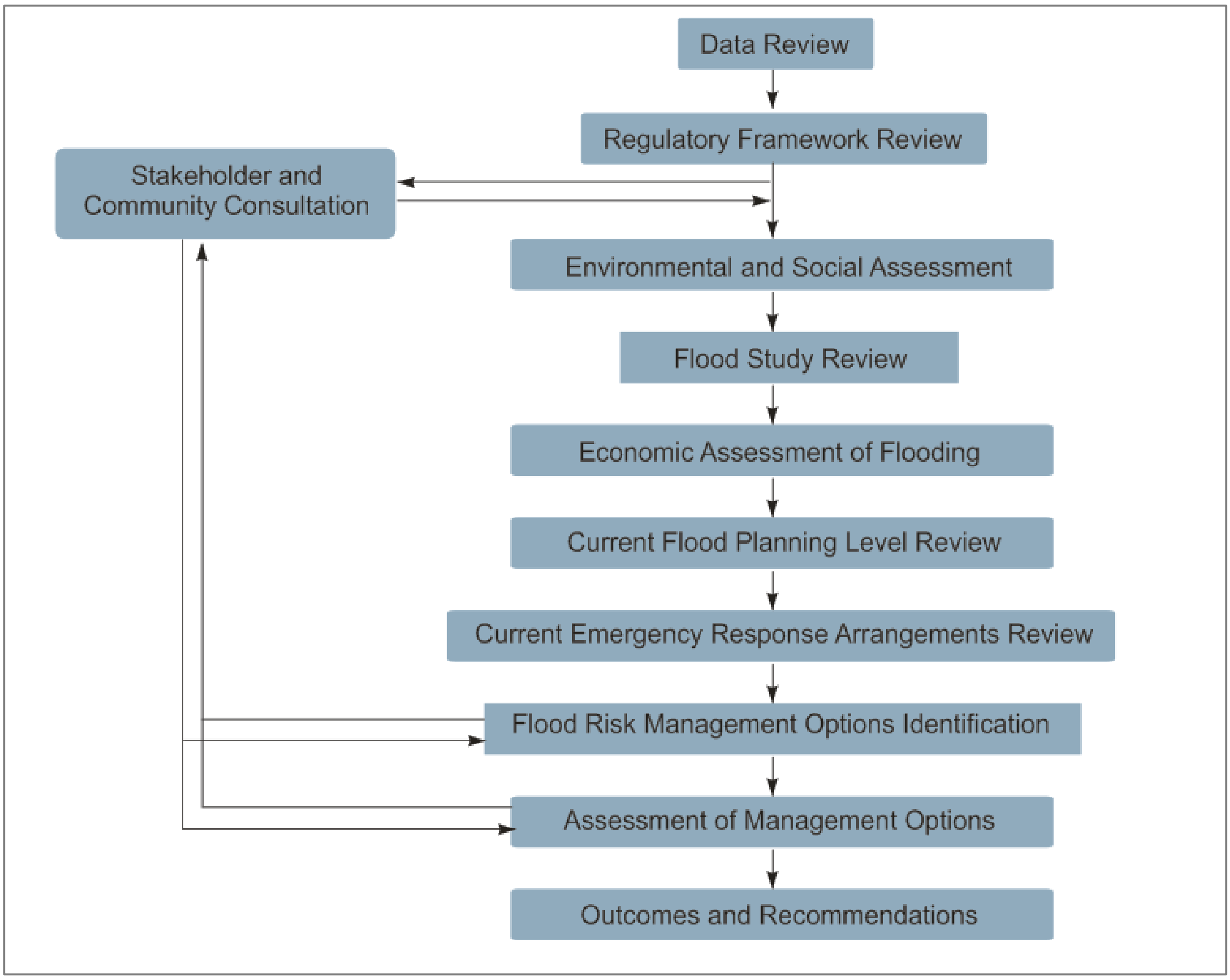
- Derive an appropriate mix of management measures and strategies to effectively manage the full range of flood risk in accordance with Appendix G of the *Floodplain Development Manual* (NSW Government, 2005); and
- Utilise an effective public participation and community consultation program.

A range of measures/strategies to meet these objectives have been investigated to address risks to:

- Residential areas fronting Brisbane Water;
- Residential areas within the floodplain (i.e. PMF extent);
- Drainage reserves/wetlands/marshes; and
- Properties affected by projected sea level rise.

Study Methodology

The format of this document follows the study methodology, which is described in **Section 1.4**. A summary of the study methodology is provided diagrammatically below.



Regulatory and Management Context

The management of coastal flood risks is closely linked with a large range of legislative and planning processes, as described in **Section 3** of this document.

Gosford City Council is planning to prepare a series of *Climate Change Adaptation Plans* (CCAPs) as separate documents (as distinct from the Floodplain Risk Management process) and would seek to establish a framework for the management of projected climate change, subject to funding resources available to Council. A management option proposed in this FRMS (management option PM9, refer **Appendix I**) would form part of these CCAPs and is more specific to tidal inundation and projected sea level rise, which forms one of the many aspects to be considered in the CCAPs. The CCAPs would assist in providing appropriate sea level rise "trigger" levels or events that may be utilised to initiate a particular response or a particular management option. The results of the CCAPs would flow into a review of the Brisbane Water FRMS and subsequent review of Gosford City Council policy, Local Environmental Plans and Development Control Plan documents.

Executive Summary

Overview

This *Floodplain Risk Management Study* (FRMS) for the Brisbane Water foreshore floodplain has been prepared by Cardno (NSW/ACT) Pty Ltd (Cardno) for Gosford City Council (GCC). This document was prepared in accordance with the principles of the *Floodplain Development Manual* (including the *New South Wales Flood Prone Land Policy*) (NSW Government, 2005) and examines options for the management of flooding of the foreshore areas of the Brisbane Water estuary. This study considers the flooding that results from *coastal processes*, such as significant coastal wave events and surges associated with large ocean storms (e.g. those experienced in May 1974 and more recently in June 2007 when the *Pasha Bulker* ran aground in Newcastle).

This FRMS is to be utilised in conjunction with the *Floodplain Risk Management Plan* (FRMP) which will be prepared by Cardno for GCC as a separate document.

Historical Context

Following a history of flooding over a period of 50 years, the NSW Government in 1977 introduced the NSW Flood Prone Lands Policy which promoted the removal of urban development from flood prone areas where this was practical and appropriate. Floodplain management moved from engineering-based solutions to a planning based concept. While this policy has evolved over time it does provide a starting point for the management of development in and around the Brisbane Water foreshore.

A brief historical context is provided below:

- May 1974 – Residences of the Brisbane Water Foreshore experienced the highest recorded flood of 1.99m AHD at the northern most point of the Broadwater (PWD 1991) caused predominantly by high tides, local wave (0.46m) and a large (8.0m) ocean wave setup from the south-east. Local flooding was also experience due to surcharge of stormwater networks.
- Planning Circulars were issued by the Department of Environment and Planning in 1977, 1978 and 1982 directing NSW Municipal and Shire Councils that, where in the absence of flood mapping Councils shall consult the Water Resources Commission or the Department of Public Works before granting consent.
- July 1980 – Council resolved to adopt *Guidelines for Development of Properties* relating to development of identified properties requiring Minimum Floor Levels or properties identified within a floodway, its aim was to identify subdividable land that which was free of flooding or where a subdivision existed required special measures that may be used without aggravating existing flood conditions.
- October 1981 – In a matter relating to a proposed subdivision being developed on the Brisbane Foreshore Floodplain, Council requested and received advice from the Department of Public Works stating that “the department recommends a minimum habitable floor level requirement of 0.5m above the 1 in 100 year flood level for residential development, that is, RL 102.5m G.S.D.” (GCC records, DPW 1981). The level stated is related to the Gosford Sewage Datum (GSD) which is the equivalent of 2.45m AHD (Australian Height Datum). In recommending the minimum habitable floor level, the Department of Public Works considered “that a reasonable design flood level for land fronting Brisbane Water, including the above site is 1: 100 year. RL 102.0m G.S.D”. This is the equivalent of 1.95m AHD.
- February 1982 – Council resolved to adopt a Flood Management Policy.

The 1.95m AHD level was based upon levels recorded in a significant ocean storm in 1974 and good engineering judgement. Records provide a historical insight into use of the current flood planning level of 2.45m AHD as the minimum floor level for properties at or below the adopted flood standard of 1.95m AHD. A recommendation of this study is to maintain the 2.45m AHD as an interim flood planning benchmark while recognising the complexity and variability of the topography of the Brisbane Water Estuary and where necessary and appropriate adjust for development controls, and to prepare for implementation of a revised flood planning level in the future.

Council has a strong tradition in planning for hazards by developing policy through the preparation of Floodplain Risk Management Plans. This Floodplain Risk Management Study explores a range of management options that can be debated by the community, and from which the Council can make decisions around current, future and residual risks.

Flooding Processes

This investigation of Brisbane Water relates primarily to potential floodwaters that rise up from the ocean (and into the estuary) and overtop seawalls and the foreshore. This type of flooding is referred to as *coastal flooding* and is often the result of severe coastal events such as storm surge. This FRMS considers the management of risks associated with coastal flooding because it is the major type of flooding that affects the foreshores of Brisbane Water (Cardno, 2013).

This FRMS does not relate to floodwaters that originate from heavy or prolonged rain causing stormwater to travel downslope towards the estuary. This type of flooding is referred to as *catchment flooding,* which is associated with increased creek flows. This flooding mechanism is not dominant in the study area and so has not been considered as a primary mechanism of flooding in this investigation. It is instead covered in separate *Floodplain Risk Management Plans* for affected tributaries of Brisbane Water. The impacts of proposed management measures on catchment flooding have been considered in the assessment of floodplain management options as part of this study.

Existing and Future Flood Risks

This Floodplain Risk Management Study considers the flooding that results from coastal processes, such as significant coastal wave events and storm surge associated with low pressure systems off the East Coast of Australia. In accordance with the Floodplain Development Manual (NSW Government, 2005), the potential flood risks posed on the Brisbane Water foreshore floodplain were assessed in the *Brisbane Water Foreshore Flood Study* (Cardno, 2013). A calibrated hydrodynamic model was developed for the study and was coupled with a whole of Brisbane Water SWAN wave model to allow the simultaneous simulation and interaction of hydrodynamic (tide and wind forcing) and wave processes (Cardno, 2010). The model was calibrated using recorded water level data, including levels recorded on the night of 25 & 26 May 1974.

The potential flood risks posed by coastal flooding on the Brisbane Water foreshore floodplain were assessed in the *Flood Study* (Cardno, 2013). On the basis of the simulated results, the Flood Study determined that the 1974 event was higher than a 100 year ARI event but less than a 200 year ARI event. Given the complexity of the study and the relatively small difference between these events, (less than 0.1m at Gosford) the modelled “system” shows good agreement with observed levels in 1974.

Additional assessments have been undertaken as part of this FRMS to assess the flood risk for additional flood events and further consider the impacts of projected sea level rise (SLR) on coastal flooding. The existing flood risk has been assessed for the 5, 20, 100 and 200 year ARI and Probable Maximum Flood (PMF) events. The 100 year ARI and PMF extents are shown in **Figure ES1**. The future flood risk associated with 0.4m and 0.9m of SLR has been assessed for the 2, 5, 20, 100, 200 and 500 year ARI and PMF events (refer to **Appendix F**).

The potential impacts of more regular (but much less severe) *tidal inundation* associated with SLR that may be experienced on a day-to-day basis (aligned with the tides) has been assessed in **Appendix G**, but potential management options for this mechanism have not been assessed since it does not form part of the Floodplain Risk Management process. Potential impacts of SLR on tidal inundation would instead be investigated in the proposed *Brisbane Water Foreshore Climate Change Adaptation Plans* (CCAPs). These CCAPs are planned to be prepared as separate documents (distinct from the Floodplain Risk Management process) and would seek to establish a framework for the management of projected climate change effects, including sea level rise.

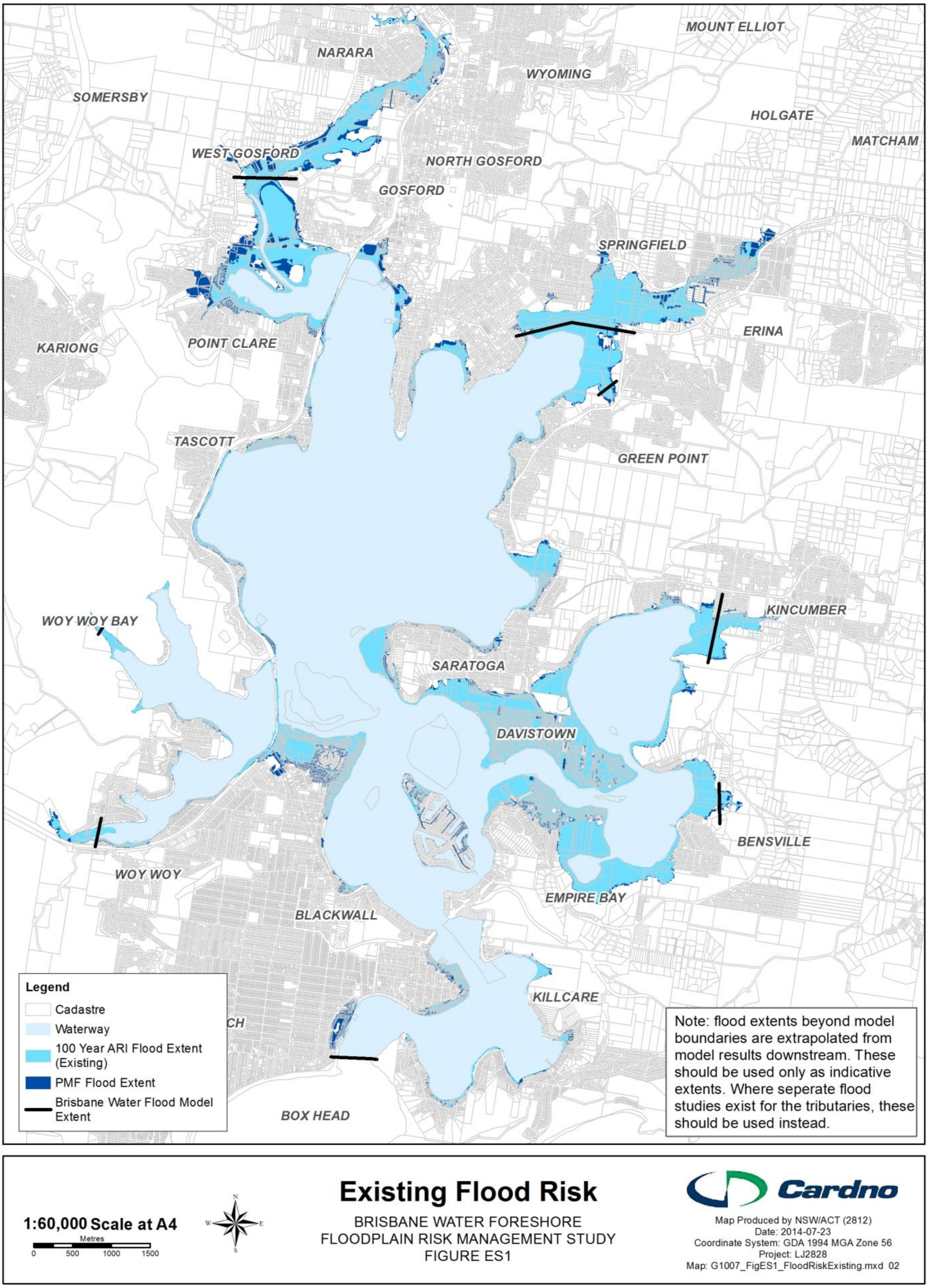


Figure ES1: Existing Flood Risk – 100 year ARI and PMF Coastal Flood Extents

Impact of Flooding

Major historical coastal flood events for the Brisbane Water foreshore floodplain include the severe ocean storm of 1974 and the more recent, but less severe, event in 2007. Past flooding of the Brisbane Water foreshore floodplain has caused property damage, impeded emergency access and inconvenienced residents. For the present day scenario, coastal flood risks are moderate, with around 856 properties likely to experience structural damage in the present day 100 year ARI event. Around half of these properties (473) would actually experience over-floor flooding due to floor levels being below the 100 year ARI flood level. Houses that are subject to over-floor flood risks in the 100 year ARI event are generally more than 34 years old (i.e. established prior to the introduction of the current flood planning level (2.45m AHD) by Council). If the current planning level (2.45m AHD) was applied to all flood-affected properties, the majority of these properties would not experience any flooding inside dwellings for any flood event. As such, the flood risk associated with these properties may decrease in the future as these properties are replaced with newly built homes. In many locations, since flood depths and velocities would not cause high hazard conditions, the current potential impacts of flooding are likely to be managed with relative ease, providing adequate mitigation measures are implemented.

While the *Brisbane Water Foreshore Flood Study* (Cardno, 2013) identified the hazards associated with the flood risk, this FRMS identifies the associated economic consequences should a recurrence of the events such as the 1974 ocean storm again affect the properties in and around the Brisbane Water foreshores.

Average Annual Damage (AAD) provides an estimate of the economic cost of flooding for a particular floodplain in any given year. It is a probability approach based on the flood damages calculated for each design flood event. An estimate of AAD has been calculated as part of this FRMS (**Section 7**). This analysis was based on the results of a detailed property survey for all affected properties on the Brisbane Water foreshores within the existing PMF extent, which was commissioned by Council in 2014. The current estimate of AAD for flooding on the Brisbane Water Foreshore Floodplain is $5,448,989. An assessment of AAD for the projected 0.9m SLR scenario was also undertaken, based on the results of a rapid property survey for properties outside the limit of the detailed property survey.

Council's commitment to considering future risks associated with Sea Level Rise (SLR) is contained within Council’s Climate Change Policy D2.11 (May 2010). Council has considered and accepted competent scientific opinion at the Ordinary Meeting in August 2013 with the endorsement of Climate Change Scenarios for SLR recommended by the *Hunter and Central Coast Regional Environment Strategy* (HCCREMS, 2010) *Potential Impacts of Climate Change on the Hunter, Central and Lower North Coast of NSW*. Council endorsed a range of 0.4 to 0.9 metres rise in sea level relative to 1990 that is widely accepted by competent scientific opinion. Council also resolved to review these climate change scenarios following the release of the 5th Intergovernmental Panel for Climate Change (IPPC).

Council has primary responsibility for the regulation of planning and development in the coastal zone and in response to flood risk. Council recognises the coastal planning principles that should be applied in the decision making process. These principles are identified in the *NSW Coastal Planning Guideline – Adapting to Sea Level Rise* (August 2010). In recognising these principles Council reviewed the current and future hazards that may impact the built and natural environment posed by ocean-generated storm surge in and around the Brisbane Water Foreshore.

Projected sea level rise has been assessed for the floodplain, but results are unlikely to accurately represent future AAD given the high number of variables between now and when sea levels rise to 0.9m. Results should only be used as an approximate guide. However, the results do indicate that the number of properties affected and the damages incurred by flooding would increase substantially under projected sea level rise conditions (if adaptation does not take place).

In addition to property and dwellings, infrastructure and assets (including underground utilities) may be impacted by coastal flooding. Nearby roads may be affected and ingress and egress to and from flood-affected areas may be limited in some locations. Attempted contact with private asset managers as part of this FRMS (for assets such as electricity, gas and telecommunications services) proved unsuccessful; however, future consultation is anticipated as part of the CCAPs and will be necessary to ascertain impacts and identify management strategies, particularly with projected sea level rise.

Planning Levels

The decision of Council to apply a design flood level of 1.95m AHD as a development control measure some 34 years ago has provided a “benchmark” from which to consider the effects of ocean storms in the short, medium and longer term. The challenge now is to determine the longer-term trends of Climate Change and incorporate those measures that are practical and appropriate for future generations.

The 1974 storm event resulted in an observed flood level of approximately 1.95m AHD in Brisbane Water. Since that time, this level has been used as the basis for flood planning levels in the area. The current flood planning level of 2.45m AHD incorporates the observed 1974 levels (which differ depending on location, e.g. 2.01m AHD at Gosford and 1.59m AHD at Davistown) with an additional 0.5m to account for uncertainty (e.g. additional flood impacts resulting from wave and wind set-up, wave run-up and potential climate change).

Due to the uncertainty associated with applying the risk of sea level rise into planning considerations, it is recommended that a short term approach to considering sea level rise be adopted as part of an interim FPL until the outcomes of the CCAPs are known.

The adoption of the 2050 sea level rise prediction would account for the predicted increases in flood levels over the next 35 years. Whilst this does not fully account for the typical lifespan of a residential building (50 years), it does afford some protection against sea level rise until the outcomes of CCAPs are known. The sea level rise component of the FPL should be reviewed at that stage, or before if relevant information becomes available.

Therefore the recommended interim FPL for the Brisbane Water foreshore floodplain is:

FPL = 100 year ARI DSWL + SLR (as defined in Council’s policy) + 0.5m Freeboard

Further, it is recommended that vulnerable or longer term development types such as critical infrastructure consider the application of the 2100 projected sea level rise as part of the FPL.

Following the completion of the CCAPs, it is the intent that Council will have a more detailed recommendation for the inclusion of the impacts of climate change on planning considerations. This will assist Council with defining an appropriate component of SLR into the FPL for Brisbane Water floodplain. It is recommended that the FPL for Brisbane Water be reviewed at that time.

Specific recommendations for design levels for all development types are provided in the Draft Development Control Matrix provided in **Appendix H**. The impacts of waves should be considered for development within 20m of the foreshore for the majority of Brisbane Water and within 40m of the foreshore near the entrance to the ocean where ocean swell waves need to be considered. The management of wave run-up is addressed through development controls rather than the FPL.

Management Issues and Options

In floodplain risk management the three types of risk are generally considered (existing, future and continuing risk). In the case of Brisbane Water (and likely for any coastal location) primarily related to the potential impact of sea level rise. The key flooding processes that were identified as causing flood risk management issues in the floodplain are:

- Present day <u>coastal flood</u> inundation risk (infrequent likelihood, high water levels occurring under existing conditions, moderate consequences)
- Future <u>coastal flood</u> inundation risk (infrequent likelihood, high water levels occurring under future, sea level rise conditions, high consequences); and
- Future <u>tidal inundation</u> risk (more frequent likelihood, but with lower water levels than for coastal flood inundation occurring under future, sea level rise conditions, moderate consequences).

During the process of identifying flooding issues in Brisbane Water, it became apparent that the above flood processes were intertwined and somewhat difficult to separate out for the purposes of identifying and implementing appropriately prioritised flood risk management techniques. For example, options that provide protection against present day coastal inundation risk (no sea level rise) may also inherently provide protection against future tidal inundation risk (with sea level rise). This is simply because the water levels for future everyday tidal inundation may be lower than for existing infrequent flood events.

It was concluded that the present day flood risk to the area (i.e. 100 year ARI, no SLR) remains the primary concern, and that sea level rise, although still a very important issue, is not immediately endangering life or property and therefore has a lower priority in terms of risk management.

To seek to manage the flood risks and associated economic consequences identified above, a series of coastal flood risk issues and management options were identified for the Brisbane Water foreshore floodplain and are discussed in this FRMS. Management issues and options were identified in accordance with the findings of the *Foreshore Flood Study* (Cardno, 2013) and in consultation with government agencies, the Catchments and Coast Committee and the community.

Measures available for the management of flood risk can be categorised according to the way in which the risk is managed. There are three broad categories of management:

- **Flood Modification (FM) measures** – Flood modification measures are options aimed at preventing / avoiding or reducing the likelihood of flood risks. These options reduce the risk through modification of the flood behaviour in the catchment.
- **Property Modification (PM) measures** – Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks. Rather than necessarily modify the flood behaviour, these options aim to modify properties (both existing and future) so that there is a reduction in flood risk.
- **Emergency Response Modification (EM) measures** – Emergency response modification measures aim to reduce the consequences of flood risks. These measures generally aim to modify the behaviour of people during a flood event.

Due to the nature of flooding in the floodplain (i.e. dominated by coastal processes) and the sensitivity of flood levels and the foreshore to projected sea level rise, the development of flood management options for the Brisbane Water foreshore floodplain has considered a holistic approach to managing current flood behaviour and flood behaviour as a result of projected sea level rise. The following summarises the range of options considered for the existing scenario and projected sea level rise scenario:

- *Options that address the current flood risks only* – These options aim to address the risk of coastal flooding that is currently experienced in the floodplain. It is anticipated that some of these options will form the basis of the FRMP.
- *Options that address the current flood risks but also benefit conditions under projected sea level rise* – These options aim to address the existing risk of coastal flooding but also have some incidental benefit under projected sea level rise conditions.
- *Options that relate to projected sea level rise only* – These options aim to consider the potential impacts of coastal flooding under projected sea level rise conditions in areas currently not impacted by flooding. It is anticipated that these options will not generally be recommended for inclusion in the FRMP though these options will be further considered in the CCAPs.

It is noted that flood mitigation options presented in this Study have primarily been identified in consideration of residential land uses since the majority of assets within the floodplain are residential properties. The risks to sensitive uses (such as aged care and schools) have been considered in the development of emergency response options and appropriate planning controls for these uses. Other asset types, including commercial, industrial and utilities have also been considered where relevant information was available.

A summary of all management options identified for the floodplain is provided in **Tables ES1-ES3**. A more detailed description of each identified management option is provided in **Appendix I**.

Assessment of Management Options

A lengthy assessment process using a multi-criteria matrix assessment (MCA) was undertaken for this study by experienced engineers for the comparative assessment of all options identified for the floodplain (using a similar approach to that recommended in the *Floodplain Development Manual,* NSW Government, 2005). The MCA was undertaken to adequately analyse the costs and benefits of each identified management option using a subjective but transparent approach. It was based on a quadruple bottom line assessment, incorporating:

- Economic considerations;
- Social considerations;
- Environmental considerations; and
- Planning and governance considerations.

Indicative capital and recurrent (annual) costs are provided for each option in **Tables ES1-ES3**

These cost estimates are indicative only and provide an approximation of the <u>relative costs</u> involved in implementing the option. Costs are to be used as a <u>guide only</u>.

Table ES1: Summary of Considered Flood Modification (FM) Management Options

Options	Management Location – Impact	Management Location – Option ID	Indicative Maximum Capital Cost Across all Management Areas	Indicative Recurrent Cost	Notes	Flood Mitigation Outcomes
Refer to Appendix I for Options Information						
Roads raised above the 100 ARI (+0.9m SLR) flood level	Specific Locations	FM1a	$232,800,000	$4,631,000	Seeks to address 100 year ARI +0.9m SLR (staged). May worsen catchment flooding on upstream side of road.	The impacts of flood events on access and evacuation would be reduced.
			Includes demolition of existing roads, disposal costs, and subsoil drainage. Residential roads $2180/m, main roads at $5115/m and highways $6200/m.			
"Major", "critical" and "only" access roads raised above the 100yr ARI (+0.9m SLR) flood level.	Specific Locations	FM1b	$117,800,000	$2,350,000	Seeks to address 100 year ARI +0.9m SLR (staged). May worsen catchment flooding on upstream side of road.	The impacts of flood events on access and evacuation would be reduced for major, critical and only access roads.
			Includes demolition of existing roads, disposal costs, and subsoil drainage. Residential roads $2180/m, main roads at $5115/m and highways $6200/m. Refer to Appendix I for selected roads.			
Storm surge barrier at Half Tide Rocks	Floodplain-wide	FM2a	$2,400,000,000	$1,400,000	Substantive economic costs and environmental issues.	Propagation of elevated ocean water levels up the estuary would be reduced in 100% of locations.
			Costs are highly dependent on the design and a range of site factors.			
Storm surge barrier at the Rip Bridge	Floodplain-wide	FM2b	$1,800,000,000	$1,100,000	Substantive economic costs and environmental issues.	Propagation of elevated ocean water levels up the estuary would be reduced in 93% of locations.
			Costs are highly dependent on the design and a range of site factors.			
Wave energy dissipating foreshore structures	Specific Locations	FM3	$14,800,000	$441,200	Only protection from wave inundation above flood events is provided.	Individual properties protected from wave run-up to the 100 year ARI (with 0.9m SLR).
			Construction of dissipation structure calculated at $1200 per linear metre. Assumes rockfill extends 4m from the shoreline at average 1m depth.			
Stormwater flood gates/flap valves	Floodplain-wide	FM4	$100,000	$35,000	Addresses existing coastal flooding of low-lying areas where stormwater surcharge occurs. Low cost-option.	Protection for locations affected by surcharge of the stormwater system (up to 100 year ARI without SLR).
			Includes the installation and maintenance of six flap valves.			
Seawall maintenance	Specific Locations	FM5	$14,464,000	$144,640	Existing seawalls only. More detailed sea wall inspections necessary. Could be integrated into public infrastructure upgrades.	Maintains existing flood protection and provides some protection from wave run-up.
			Calculated at average of $415 per linear metre. Highly dependent on the current condition of the wall.			
Levees above PMF (+0.9m SLR)	Specific Locations	FM6a	$200,000,000	$3,971,000	Approximately 56km of levees, protection for private and public property. Considers projected sea level rise. Could be integrated into public infrastructure upgrades	Regulates flooding up to the PMF event (with SLR) and increases evacuation time.
			Calculated at an average of $3500 per lin.metre. Includes clearing vegetation, excavation, and drainage pit. Does not include any road or pavement works. Assumes average 1.5 m height, 1m crest width, 1 in 5 batters.			
Levees above 5 year ARI +0.9m SLR (approximately equivalent to existing PMF)	Specific Locations	FM6b	$97,100,000	$1,927,000	Approximately 56km of levees, protection for private and public property. Considers projected sea level rise. Could be integrated into public infrastructure upgrades	Regulates flooding up to the 5 year ARI event (with SLR) and increases evacuation time for larger events.
			Calculated at average of $1700 per linear metre. Includes clearing vegetation, excavation, and drainage pit. Does not include any road or pavement works. Assume average 0.5 height, 1m crest width, 1 in 5 batters.			
Increase the size of the Northern Railway Bridge opening	Specific Locations	FM7a	$10,000,000	$500,000	Likely increased conveyance of storm surge.	Improves conveyance of catchment flows to the estuary from the areas surrounding Fagans Bay.
			Highly dependent on the design and construction methodology, so 50% contingency assumed. Assumes double the length of existing structure.			
Flood gates at the Northern Railway Bridge	Specific Locations	FM7b	$19,000,000	$560,000	Construction could be incorporated into redevelopment. May increase catchment flooding in 100 year ARI event.	Improves protection from storm surge events.
			Floodgates cost based on information provided by a floodgate manufacturer for potentially suitable gate structures (for a gate covering 60 m x 3 m).			
Flood gates at the Woy Woy Railway Bridge	Specific Locations	FM8	$19,000,000	$560,000	May increase catchment flooding in the 100 year ARI event.	Improves protection from storm surge events.
			Floodgates cost based on information provided by a floodgate manufacturer for potentially suitable gate structures (for a gate covering 60 m x 3 m).			
Regional filling of floodplain	Specific Locations	FM9	$1,925,700,000	$0	Broad scale filling is unlikely and instead it is likely to be undertaken on an ad hoc basis.	Provides protection of properties up to the PMF with 0.9m SLR.
			Assumes 1m raise. Includes clearing, demolition of pavements, reconstruction of pavements, clean sand filling, compaction and drainage, engineering judgement cost for relocating utilities. An allowance of $300,000 per property has been included for master planning consultation and other aspects of the land raising process.			
Raise railway infrastructure	Floodplain-wide	FM10	$25,000,000	$500,000	State government expenditure.	Protection of state railway infrastructure above the 100 year ARI (with 0.9m SLR).
			Assumes 15km of rail is affected. Costs include clearing, fill, compaction, laying, footbridges and culverts. Does not include bridge upgrades. Highly dependent on design and construction method.			

Costs represent the TOTAL esimated cost of implementating the option across ALL management areas. However, costs marked in grey may be lower depending on which (and how many) management areas are recommended for implementation of the option.

Table ES2: Summary of Considered Property Modification (PM) Management Options

Options	Management Location		Indicative Maximum Capital Cost Across all Management Areas	Indicative Recurrent Cost	Notes	Flood Mitigation Outcomes
Refer to Appendix I for Options Information	Impact	Option ID				
Voluntary House Purchase Program (identified properties only) (VHPP)	Floodplain-wide	PM1	$9,800,000	$0	**Criteria:** Affected by events >=20yrARI or 100yrARI with depths >0.1m. Must comprise residential dwelling not suitable for raising.	Eliminates flood risk for selected properties (11 properties identified).
			Assumes an average price of $515,000 per property for 19 properties.			
Voluntary House Raising Program (identified properties only)	Floodplain-wide	PM2	$630,000	$0	**Criteria:** Affected by events >=20yrARI or 100yrARI with depths >0.1m. Must comprise residential dwelling suitable for raising.	Reduces flood risk for selected properties (21 properties identified).
			Assumes market price of house raising $30,000 per house for 21 properties			
Investigate Land Swap Program	Floodplain-wide	PM3	$380,000	$0	Criteria for VHPP used to identify residential properties. Investigation relates to potentially swappable Council-owned land.	Depending on investigation results, flood risk could be removed for selected properties.
			Costs relate to land swap for 19 properties.			
Property flood risk education program	Floodplain-wide	PM4	$20,000	$4,000	Could include main program of education, distribution of brochures, periodic re-education programs. Program to be developed.	Educates the wider community on the impacts of flood events.
			Difficult to determine costs and would be dependent upon program adopted.			
Continue to monitor sea level rise	Floodplain-wide	PM5	$15,000	$4,500	Responsibility and costs could be transferred to State. "King tide" events each year could be a good way to engage community monitoring.	Monitoring data can be used to establish trigger levels for use in land use planning options.
			Includes maintenance of gauges as required. Reporting of results and periodic distribution to community via Council's website.			
Relocate critical infrastructure and facilities out of the floodplain	Specific Locations	PM6	$14,700,000	$0	State Government.	Elimination of flood risk for critical infrastructure and enhancement of emergency services to operate in emergencies.
			Includes relocation and new property costs for three properties (one police station, one ambulance station and one NSW SES facility).			
Review planning instruments and development controls	Floodplain-wide	PM7	$50,000	$10,000	Implications for utilities will need careful consideration.	Properties progressively protected to 100 year ARI (with 0.9m SLR). Results from PM5 used to establish trigger levels.
			One review and one update of document. Future updates as required. Included in annual budget			
Develop development controls and planning measures	Floodplain-wide	PM8	$100,000	$15,000	Interim development controls may be in place while more detailed investigations proceed.	Planning outcomes should progressively minimise the impacts of flooding for future generations.
			Assumes investigation and review of planning documents. Future amendments as required, especially as new sea level rise data becomes available. Difficult to determine costs and would be dependent upon level of detail required.			
Develop sea level rise management strategies	Floodplain-wide	PM9	$480,000	$72,000	Could include an update to Council's sea level rise policy position.	Detailed assessment of impacts associated with SLR e.g. infrastructure, fauna, flora and heritage.
			Assumes that future amendments to strategies and policies as required, especially as new sea level rise data becomes available. Difficult to determine costs and would be dependent upon level of detail adopted.			
Evaluate utilities infrastructure	Floodplain-wide	PM10	$150,000	$7,500	Consultation with private utilities managers would be required.	Assessment of impacts associated with SLR with regard to utilities. Appropriate planning for future services to areas.
			Assumes investigation and review of utilities infrastructure in line with climate change.			
Detailed assessment of overland flow impacts of major structural options	Specific Locations	PM11a	$1,100,000	$0	Costs are higher than for Option PM11b, since no existing studies have been undertaken.	Detailed assessment - new study.
			Cost are based on the undertaking of an investigation for each management area.			
Review/update of assessment of overland flow impacts of major structural options	Specific Locations	PM11b	$420,000	$0	Costs are lower than for Option PM11a, since studies have already been done, although an update will still be required.	Review/update of existing study.
			Cost are based on the undertaking of an investigation for each management area.			
Implement managed retreat	Floodplain-wide	PM12	$1,300,000,000	$0	Substantial further investigation is necessary.	Provides protection of properties up to the PMF with 0.9m SLR.
			Assumes 33% of floodplain relocates/ retreats. Cost of new properties, equivalent to average price of $515,000 per property with 2527 properties. Does not include offset in cost if original properties were sold.			

Costs represent the TOTAL esimated cost of implementating the option across ALL management areas. However, costs marked in grey may be lower depending on which (and how many) management areas are recommended for implementation of the option.

Table ES3: Summary of Considered Emergency Response Modification (EM) Management Options

Options	Management Location		Indicative Maximum Capital Cost Across all Management Areas	Indicative Recurrent Cost	Notes	Flood Mitigation Outcomes
Refer to Appendix I for Options Information	Impact	Option ID				
Emergency response education program	Floodplain-wide	EM1	$250,000	$25,000	This strategy would need to be reviewed annually and reinforced with community knowledge.	Educates the wider community about the impacts of flood events on access and evacuation.
			Assumes a program of education undertaken by a part-time staff-member. Dependent upon program adopted.			
Install "Road Floods" Signage	Specific Locations	EM2	$6,000	$900	Could be implemented with Option EM2 and Option EM4 to combine technologies. Distance of signage to residences is noteworthy due to perception of reduced property values.	Assists in notifying residents that road is subject to flooding.
			Installation and maintenance of signage. Estimated $1,050 per sign.			
Review of Gosford City Flood Plan	Floodplain-wide	EM3	$20,000	$0	NSW SES responsibility. Projected sea level rise should be incorporated into the revision.	Emergency services (including volunteers) better prepared to assist the community during flood events with access and evacuation.
			Includes one review and update of document.			
Review flood warning systems	Floodplain-wide	EM4	$35,000	$7,000	Further investigations required to assess gaps in systems.	Assists in optimising flood warning and evacuation processes.
			Includes initial review and implementation of updates. Further reviews as necessary. Dependent upon program adopted.			
Install pumping station at known sag points	Specific Locations	EM5	$120,000	$12,000	Unlikely to provide substantial benefit due to the localised nature of the areas and shallow depth of ponding.	Assists in removing ponded floodwaters that may otherwise remain for long periods.
			Assumes small pumping station only. Costs would be highly dependent on design.			
Road upgrades to faciltate efficient evacuation	Floodplain-wide	EM6	$52,000,000	$520,000	Extent of upgrade would need much further investigation.	Facilitates more effective evacuation from, and emergency services access to sensitive areas such as residences.
			Main road reconstruction calculated at $5,115 per linear metre. Costs would be highly dependent on design and construction methods.			
Review evacuation centres	Floodplain-wide	EM7	$50,000	$2,500	Some evacuation centres are located within the floodplain.	Assists in optimising evacuation.
			Costs relate to review of centres. Review may lead to an upgrade of key evacuation centres which would involve significant costs.			
Develop alternative road evacuation plan	Floodplain-wide	EM8	$40,000	$2,000	Some roads are located within the floodplain.	Assists in optimising evacuation.
			Enhance road evacuation through the development of an alternative route plan for implementation during flood events.			

Costs represent the TOTAL esimated cost of implementating the option across ALL management areas. However, costs marked in grey may be lower depending on which (and how many) management areas are recommended for implementation of the option.

Recommended Management Options

The options assessment process allowed a number of the most suitable options to be recommended for implementation. This approach does not provide a definitive answer as to what should be included in the FRMP and what should be omitted. Rather, it provides a method by which stakeholders can consider options and, if necessary, debate the rankings assigned to inform the process of selecting options to ultimately become part of the FRMP.

Table ES4 provides a summary of recommended management options in ranked order.

Overall, the majority of the recommended options relate to the existing flood scenario, since this presents the greatest risk at the current time. Although some management options relate to projected sea level rise, these generally do not rank very highly in the options assessment because they do not address the objectives of this FRMS. However, many options have been identified to have potential to be updated / upgraded or modified to account for projected sea level rise in the future.

The types of options that are likely to be viable in the short term are those that can be implemented immediately to address existing flood risks. A DCP Matrix was prepared as a key option as part of this FRMS to assist Council in the assessment of development applications within the floodplain (**Appendix H**). **Section 8** provides a summary of the history of flood planning levels for the study area. For flood risks over the medium and long term, those options that require further investigation may be implemented (including those relating to projected sea level rise). In the intervening time, interim development controls may be appropriate, which will be investigated further in the CCAPs. Planning controls would be subject to change according to any relevant new flood-related data or information (including updated information on the impacts of projected sea level rise on the floodplain).

It is important to note that whilst the DCP matrix is in preparation, a DCP is only a guide to the controls that can be imposed on a development (EP&A Act, Section 74BA and Section 74C). Unless an LEP specifically makes reference to controls on a specific location, even site-specific controls in a DCP are a guide only.

The following summarises how well options scored according to existing and sea level rise scenarios:

- *Options that address the existing case flood risk only* – These options ranked higher overall compared to options relating only to sea level rise.
- *Options that address the existing case flood risk but also benefit conditions under sea level rise* – These options ranked highly, mostly because of their benefit in managing existing scenario flood risks, with additional benefits under sea level rise conditions.
- *Options that relate to sea level rise only* – These options were not generally recommended: however some of these options did score well. Although not a high priority at present, it is anticipated that sea level-related options that scored well in the MCA would be investigated further in the CCAPs or future FRMSs, as more information on sea level rise is acquired.

The outcome of the assessment sets the direction for the FRMP, suggesting that the most effective approach to the management of the floodplain should include:

- An emphasis on updating existing planning and development controls;
- Provision for alternative emergency access routes and “Road Floods” signage;
- Small structural options such as tidal flaps (flood gates) to prevent stormwater surcharge;

- Voluntary acquisition, house-raising or land swap for severely affected properties;
- Maintenance or enhancement of existing seawall structures (environmentally-friendly seawalls are preferred);
- Education programs;
- Relocation of key facilities out of the floodplain where possible (e.g. SES Headquarters and Woy Woy Police Station);
- Further investigation of the potential impacts of sea level rise (e.g. lobby the State Government to provide additional information, conduct further investigations and undertake the CCAPs to assist in considering management options for projected sea level rise
- Support the need for overland flow investigations where structural floodplain risk management options are proposed; and
- Consultation with private utilities managers to ensure services can be maintained to properties in the floodplain (e.g. water, sewerage, electricity, gas and telecommunications).

There are a range of complex issues involved in floodplain risk management at Brisbane Water. Under existing conditions, flood depths and to some degree flood velocities can cause hazardous conditions within the floodplain. However, the majority of the floodplain is more likely to experience low-hazard flood conditions, with relatively good flood warning times and fairly short flood durations for many locations. As such, existing coastal flood risks are likely to be managed with relative ease, providing adequate mitigation measures are implemented (particularly for specified locations where flood risks are higher). To address existing and residual risks, this FRMS provides a series of recommendations for short-term flood risk management. For future flood risks (associated with projected sea level rise), long-term management recommendations and tools have been provided for use in further investigations and studies.

Implementation

A plan for the implementation of recommended management options will be discussed in the FRMP. Generally, two timeframes are proposed for the implementation of management options:

- **Immediate** – options that could be implemented in the short term. Feasibility of the option is generally high and additional investigations or further development of the management strategy would be minimal;
- **Staged** – options that could be implemented in the short to medium term. However, additional investigations, feasibility studies or further development of the management strategy are likely to be required. Where appropriate, interim policy and planning measures could be employed in the intervening time.

In addition, there are several options in this Floodplain Risk Management Study with timeframes identified as “Trigger”. Although these options have not been identified for inclusion in the FRMP, these options are recommended for further investigation as part of the CCAPs:

- **Trigger** – options that could be implemented over the long term, generally relating to projected sea level rise. Further investigations are required and the implementation of the option would be based on a predefined sea level rise “trigger level” to indicate when implementation of the option would be viable. Where appropriate, interim policy and planning measures could be employed until the specified trigger level was reached.

The above action timelines provide an indication of those options which may be implemented more quickly. For example, Option PM10 (Evaluate utilities infrastructure relative to flood risk) ranked higher than Option 1_EM2 (Install flood signs). However, Option 1_EM2 has an immediate action timeframe (whereas Option PM10 has a staged action timeframe). This means that although Option

1_EM2 ranked slightly lower, it can be implemented immediately, whilst Option PM10 requires implementation over a longer time-frame due to other constraints.

For those options in **Table ES4** identified as having an action timeline of “staged”, the option could be undertaken to address existing risk in the first instance, but over the medium to long term (as more information becomes available) could be modified to incorporate sea level rise. This concept particularly relates to large structural options. For example, development controls or council policies could be updated in the short term as a result of the recommendations in the Plan with additional reviews to be undertaken as additional information becomes available or updated (e.g. sea level rise predictions).

Table ES4: Brisbane Water Foreshore Floodplain Preferred Management Options (Ranked Order)

Option ID	Management Strategy	Action Timeline	Rank (Overall)*
EM7	Review evacuation centre locations with a view to upgrading key evacuation centres that lie outside the floodplain.	Immediate	1
EM8	Enhance road evacuation through the development of an alternative route plan for implementation during flood events.	Immediate	2
EM3	Review the Gosford Local Flood Emergency Sub-Plan (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results.	Immediate	3
EM4	Review flood warning systems on a periodic basis and update as necessary.	Immediate	4
PM7	Review and amend planning instruments and development controls across the floodplain to ensure consistency with coastal flooding. Review every five years.	Immediate	5
PM5	Continue to monitor sea levels and perform periodic analyses to ascertain the rate of sea level rise within Brisbane Water. Periodically communicate results to the community.	Immediate	6
PM10	Evaluate utilities infrastructure relative to flood risk and projected sea level rise benchmarks. Partner with private utilities managers to better understand the risks to assets and formulate a plan of management over the long term for integration into Council's planning objectives.	Staged	7
1_EM2	Install and maintain "Road Floods" signs at the Central Coast Highway, and Yallambee Avenue, West Gosford	Immediate	11
14_EM2	Install and maintain "Road Floods" signs at Blackwall Road, Brick Wharf Road and North Burge Road, Woy Woy.	Immediate	11
13_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Booker Bay.	Immediate	14
3_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Point Frederick, East Gosford and Green Point.	Immediate	14
9_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows on St Huberts Island.	Immediate	14
PM8	Develop development controls and planning measures for all management areas via two stages - 1. Interim Developent Control Measures to be implemented until further investigations are completed; and 2. Review interim measures following completion of Climate Adaptation Plans.	Staged	18
3_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Koolewong and Tascott.	Immediate	19
7_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Kincumber, Kincumber South and Bensville.	Immediate	19
PM4	Conduct a program of strategic, balanced and socially sensitive education to advise the local community and prospective property purchasers about the risk and effects of coastal flooding.	Staged	19
EM1	Conduct targeted flood education programs for flood-affected residents.	Staged	24
4_PM6	Relocate NSW SES (Gosford) headquarters out of the floodplain.	Staged	25
PM9	Develop management strategies (as part of Climate Change Adaptation Plans for each management area) to adapt to the impacts of projected sea level rise on tidal inundation.	Staged	26
14_PM6	Relocate Woy Woy Police Station out of the floodplain.	Staged	29
PM3	Investigate a land swap program for properties that meet specified criteria with land that Council owns in non flood-prone areas.	Staged	30
PM2	Implement a voluntary house raising program for identified dwellings that meet specified criteria.	Staged	31
FM4	Install flood gates on stormwater pipe outlets as required.	Staged	43
11_FM3	Modify the existing foreshore at Pretty Beach and Wagstaffe in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	45
7_FM5	Undertake a program of seawall maintenance and raising along the foreshore.	Staged	46
3_FM3	Modify the existing foreshore at Point Frederick, East Gosford, Green Point, Koolewong, Tascott and Point Clare in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	47
13_FM3	Modify the existing foreshore at Booker Bay in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	48
9_FM3	Modify the existing foreshore at St Huberts Island in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	48

*Those options where mutual exclusivity was found to apply have been removed from this list, hence rankings may jump.

The estimated total capital cost of implementing the options listed in Table ES4 would be approximately $20M, noting that this is primarily comprised of State infrastructure costs such as relocation of Gosford SES headquarters. It is essential to note that this stated cost is preliminary only. Some management options require further investigation and this is likely to lead to a change in the stated implementation cost.

The implementation of any of the management options will be dependent on funding availability, and funding for several options is likely to be sourced from both the State and Federal Government. Where a recommended option applies to State infrastructure, partnerships should be developed with the State and Federal Governments if the arrangement is mutually beneficial. This would assist in achieving objectives of the Federal, State and Local Governments simultaneously and would be likely to allow cost-sharing and an overall reduction in implementation costs to both parties. For other options, such as those to be implemented by a State authority (e.g. NSW State Emergency Service), substantial funding from the State would also be anticipated.

Figure ES2 shows the distribution of costs according to the implementation timeframe (action timeline). This demonstrates that a relatively small portion of the implementation costs would be incurred immediately.

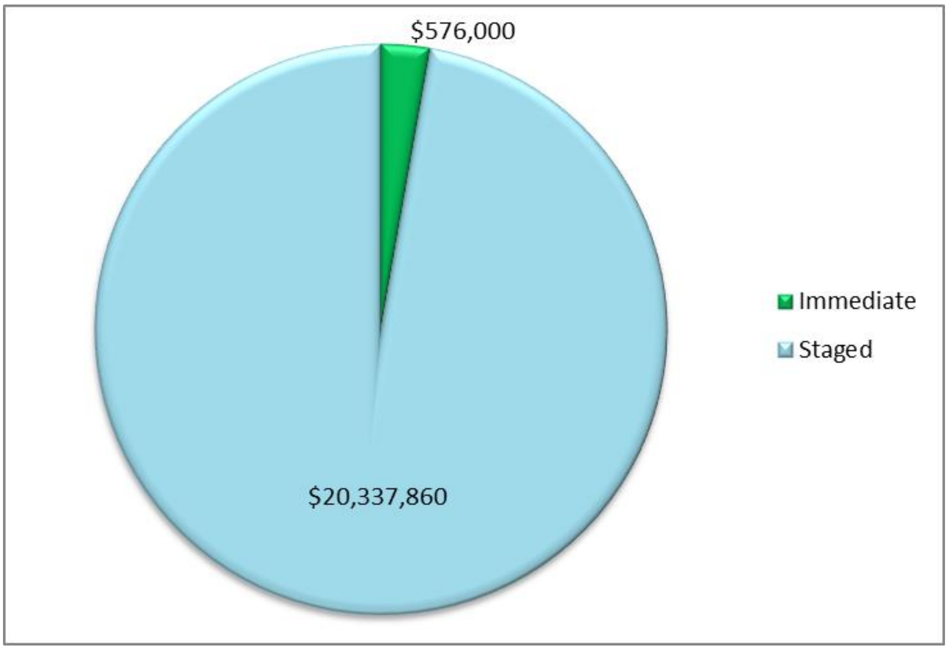


Figure ES2: Distribution of Total Capital Costs Associated with Recommended Options – Action Timeline

Next Steps

Following consultation with the community, the recommended options may be amended and the amended list of actions will then be incorporated into the draft *Brisbane Water Floodplain Risk Management Plan* as proposed management actions. This document, once prepared, will recommend a cost-effective plan to manage flood risk and will outline the process of implementation for recommended management actions within the floodplain.

Public consultation is to be undertaken during the exhibition of this *Floodplain Risk Management Study* and the subsequent *Floodplain Risk Management Plan*. This consultation and review will lead to the final recommended floodplain risk management actions for implementation as part of the Management Plan.

In addressing the key flooding processes on the foreshores of Brisbane Water, this FRMS recommends a two-phased approach as described below.

<u>Phase One</u>

Implement practical, feasible and cost-effective management options that will address present day coastal flooding inundation. Key recommendations are:

- Review and amend planning instruments and development controls with respect to the current identified hazards, while recognising the need to address climate change. This could be achieved by maintaining the current Flood Planning Level of 2.45 m AHD as the "benchmark" for interim development controls until such time as Phase 2 has been implemented (noting that Council may need to seek an exemption for the use of this flood planning level from the NSW Government);
- When renewing capital infrastructure, consideration of proposed management options identified in this FRMS should be included in any economic evaluation of the project;
- Review existing critical infrastructure that would not function affectively during times of emergency;
- Review *Gosford Local Flood Emergency Sub-Plan 2013*;
- Seek funding to prepare Climate Change Adaption Plans (CCAPs) for the management areas identified in the FRMS that will be affected by projected SLR; and
- Strengthen the community's capacity to understand and assess risks so that they can reduce their exposure to a hazard as it approaches.

<u>Phase Two</u>

Provide decision makers with an effective, proportional and compliant roadmap that is socially, environmentally, economically and politically acceptable within a timeframe to allow for effective adaption planning that is commensurate with identified future hazards associated with tidal and coastal inundation. Key recommendations are:

- Review floodplain risk management options identified in the FRMS to reflect individual characteristics of the management areas;
- Prepare Climate Change Adaption Plans (CCAPs) using decision-making principles identified in the HCCREMS (2013) *Decision Support for Coastal Adaptation: A Handbook*;
- Build a planning system that is flexible enough to deal with multiple hazards; and
- Embed climate change adaptation into day-to-day local government operations.

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Glossary

ABC	Australian Broadcasting Corporation
Amenity	Those features of an area that foster its use for various purposes.
Annual Exceedance Probability (AEP)	The probability, expressed as a percentage, that a given event will occur in any one year. For example, a 1 in 20 year event is described as having a 5% AEP.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	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, 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.
BoM	Australian Bureau of Meteorology
Brisbane Water foreshore floodplain	The area of land adjacent to the Brisbane Water estuary that is subject to coastal flooding.
Cadastre	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Catchment Flooding	The overtopping of creek banks causing flooding, usually associated with heavy or prolonged rainfall events in the catchment.
CCAP	*Climate Change Adaptation Plan*
CCC	Catchments and Coast Committee
CMA	Catchment Management Authority
Coastal flood / flooding	Flooding along the coastal foreshores due to an increase in ocean or estuarine water levels and associated with storm surge.
CP Act	NSW *Coastal Protection Act, 1979*
Creek rehabilitation	Rehabilitating the natural 'biophysical' (i.e. geomorphic and ecological) functions of the creek.
DCP	Development Control Plan
DECC	Department of Environment and Climate Change (now OEH).
DECCW	Department of Environment, Climate Change and Water (now OEH)

Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. e.g. some roads may be designed to be overtopped in the 1 Year ARI flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
DII	Department of Industry and Investment (formerly DPI and now DPI). Incorporates NSW Fisheries.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
DoL	Department of Lands (now part of DPI)
DoP	Department of Planning (Now DoPI)
DoPI	Department of Planning and Infrastructure
DPI	Department of Primary Industries
DWE	Department of Water and Energy (now part of DPI and OEH)
East Coast Low	East Coast Lows (ECL) are intense low-pressure systems which occur on average several times each year off the eastern coast of Australia, in particular southern Queensland, NSW and eastern Victoria. Although they can occur at any time of the year, they are more common during Autumn and Winter with a maximum frequency in June. East Coast Lows will often intensify rapidly overnight making them one of the more dangerous weather systems to affect the NSW coast.
EP&A Act	NSW *Environmental Planning and Assessment Act, 1979*
EPBC Act	Commonwealth *Environmental Protection and Biodiversity Conservation Act, 1999.*
Fauna	Any mammal, bird, reptile, amphibian or fish.
Flood / flooding	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal flooding resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.

Flood planning levels (FPL)	Flood levels (plus an appropriate freeboard) selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storage	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodplain	Area of land which is subject to flooding up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood Planning Area	Area below the Flood Planning Level.
FPL	Flood Planning Level
Freeboard	A factor of safety that is usually expressed as the difference in height between the level of floodwaters (in this case 100 year ARI) and the adopted flood planning level. Provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain such as wave action and localised hydraulic behaviour.
FRMS	Floodplain Risk Management Study
FRMP	Floodplain Risk Management Plan
Flood-prone land	Land susceptible to flooding by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events (such as the 100 year ARI).
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined waterways. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur.
Flora	Species of the plant kingdom.
GCC	Gosford City Council
Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.

Highest Astronomical Tide (HAT)	The highest high tide predicted to occur under average meteorological conditions and any combination of astronomical conditions. This generally occurs when the sun and the moon are closest to the Earth. This level may not be reached every year. This is not the most extreme level that can be reached as storm surges may cause significantly higher levels to occur.
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Highest High Water – Spring Solstice (HHWSS)	Solstice tides (often referred to as King Tides) occur in June and December of each year, when the sun is directly over the Tropic of Cancer and Capricorn respectively.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Joint Occurrence	The occurrence of two or more processes at any given point in time. With respect to coastal processes, joint occurrence could include the simultaneous occurrence of high astronomical tides, storm surges and wind-waves which would lead to highly elevated water levels.
Inundation	See *Flood / flooding*.
King tide	Non-scientific term to describe high tides well above average levels. Solstice tides (occurring in June and December each year) are often referred to as King Tides.
LiDAR	Light Detection and Ranging. A method of remote sensing used to measure distance by illuminating a surface with a calibrated laser and measuring the time taken for the laser to be reflected back to its source. This technology is frequently used to gather topographic/ground elevation data for large areas.
IPCC	Intergovernmental Panel on Climate Change
LALC	Local Aboriginal Land Council
LEP	Local Environment Plan
LG Act	*Local Government Act, 1993*
LGA	Local Government Area
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
LPMA	Land and Property Management Authority (now part of DPI)

Management Area	An area of Brisbane Water foreshore floodplain that has been delineated for the purposes of this *Floodplain Risk Management Study*. There are 15 areas in total, each of which represent areas of similar flooding conditions within the estuary and foreshores.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow and estuary inundation.
MA	Management Area
MCA	Multi-criteria Analysis
Mean High Water Neap (MHWN)	The long term mean of the heights of two successive high waters when the range of the tide is the least at the time of the first and last quarter of the moon.
Mean High Water Spring (MHWS)	The long term mean of the heights of two successive high waters during those periods of 24 hours when the range of tide is greatest, during full and new moons.
Mean Low Water Neap (MLWN)	The long-term mean of the heights of two successive low waters when the range of the tide is the least at the time of the first and last quarter of the moon.
Mean Low Water Spring (MLWS)	The long term mean of the heights of two successive low waters during those periods of 24 hours when the range of tide is greatest, during full and new moons.
MPA	Mapping Area
MSL	Mean Sea Level
NPWS	National Parks and Wildlife Services; part of OEH
NPW Act	NSW *National Parks and Wildlife Act , 1974*
NSW SES	New South Wales State Emergency Service
OEH	Office of Environment and Heritage (formerly DECCW)
Ocean inundation	See *Coastal Flooding*
PoEO Act	NSW *Protection of Environment Operations Act, 1997*
Probability	A statistical measure of the expected frequency or occurrence of flooding.

Probable maximum flood	The flood calculated to be the maximum that is likely to occur.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
RMS	Roads and Maritime Services (formerly the RTA).
RTA	NSW Roads and Traffic Authority (now Roads and Maritime Services).
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Sea wall	Wall built parallel to the shoreline to assist in protecting the shoreline from erosion.
SEPP	State Environmental Planning Policy
SREP	State Regional Environment Plan
Stormwater flooding	Flooding by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Storm surge	The increase in coastal water level caused by the effects of storms. Storm surge consists of two components: the increase in water level caused by the reduction in barometric pressure (barometric setup) and the increase in water level caused by the action of wind blowing over the sea surface (wind setup).
Topography	A surface which defines the ground level of a chosen area.
Tides	The regular rise and fall of the sea level in response to the gravitational attraction between the sun, moon and Earth.
Tidal inundation	Inundation of coastal areas in alignment with the tidal cycle. Currently, this type of inundation occurs once or twice a year, during spring or king tides. This inundation mechanism is likely to increase in severity with projected sea level rise.
TSC Act	NSW *Threatened Species Conservation Act, 1995*
Wave run-up	The vertical distance above mean water level reached by the uprush of water from waves across a beach or up a structure.
Wave set-up	The increase in water level within the surf zone above mean still water level caused by the breaking action of waves.
Wind set-up	The increase in mean sea level caused by the "piling up" of water on the coastline by wind.

1 Introduction

This *Floodplain Risk Management Study* (FRMS) for the Brisbane Water foreshore floodplain has been prepared by Cardno for Gosford City Council. This document has been prepared in accordance with the *New South Wales* (NSW) *Flood Prone Land Policy* and the principles of the *Floodplain Development Manual* (NSW Government, 2005) and examines options for the management of flooding of the foreshores of the Brisbane Water estuary.

This FRMS is to be utilised in conjunction with the *Floodplain Risk Management Plan* (FRMP) which will be prepared as a separate document after the public exhibition of this draft FRMS. The FRMP will outline the floodplain management measures to be adopted for implementation along with the implementation strategy associated with these measures.

1.1 Study Context

The Brisbane Water estuary is a wave dominated barrier estuary and tidal tributary of the Lower Hawkesbury River system. It is located approximately 50km north of Sydney within the City of Gosford Local Government Area (LGA).

The study area encompasses the foreshores of Brisbane Water and is defined as the land that is affected by coastal flooding. This area was based on the results of the *Brisbane Water Foreshore Flood Study* (Cardno, 2013). While the focus of this study is the flood risk posed by the existing flooding scenario, the flood risk associated with projected sea level rise has also been considered. In the initial stages of this project, investigations were undertaken in accordance with the *NSW Sea Level Rise Policy Statement* (DECCW, 2009b). In late 2012, the State Government repealed this policy and associated sea level rise benchmarks as part of Stage One of its coastal management reforms. It was announced that councils would now determine their own sea level rise projections to suit their local conditions.

Council's commitment to considering future risks associated with Sea Level Rise (SLR) is contained within Council’s Climate Change Policy D2.11 (May 2010). Council has considered and accepted competent scientific opinion at the Ordinary Meeting in August 2013 with the endorsement of Climate Change Scenarios for SLR recommended by HCCREMS (2010) *Potential Impacts of Climate Change on the Hunter, Central and Lower North Coast of NSW*. Council endorsed a range of 0.4 to 0.9 metres rise in sea level relative to 1990 that is widely accepted by competent scientific opinion. Council also resolved to review these climate change scenarios following the release of the 5th Intergovernmental Panel for Climate Change (IPPC).

The study area for this investigation includes *up to the PMF extent with 0.9m sea level rise*, however, as mentioned, the emphasis of the study is on those areas within the **existing PMF** extent. The study area is shown in **Figure 1.1** (the PMF with 0.9m SLR). Further details on flood behaviour and flood extent mapping are provided in **Section 6**.

This study is limited to the impacts of *coastal flooding* from the main estuary body (also referred to as ocean inundation or storm surge flooding) and does not incorporate *catchment flooding* from the tributaries of Brisbane Water (such as Narara and Erina Creeks). These tributary floodplains have been addressed in separate floodplain risk management documents held by Council.

1.2 Floodplain Management Process

The *NSW Flood Prone Land Policy* (NSW Government, 2001) guides and directs the management of flood-prone land throughout NSW. It is directed at providing solutions to existing flooding problems in developed areas and ensuring that new developments are compatible with the flood hazard and do not create additional flooding problems in other areas.

The risk to human life and damage to property caused by flooding should be managed so as to ensure the future well-being of the community. Where possible, these risks should be reduced through controlling development on land affected by potential floods and applying a “merit-based approach” to all development decisions which take account of social, economic and ecological considerations, and also their effect on infrastructure and services.

In accordance with the *NSW Flood Prone Land Policy*, as outlined in the *Floodplain Development Manual* (NSW Government, 2005), Gosford City Council (GCC) is responsible for local planning and land management in the Brisbane Water foreshore floodplain, with the State Government subsidising flood mitigation works and measures as appropriate. This *Floodplain Risk Management Study* has therefore been prepared to fulfil the requirements of the *NSW Flood Prone Land Policy*.

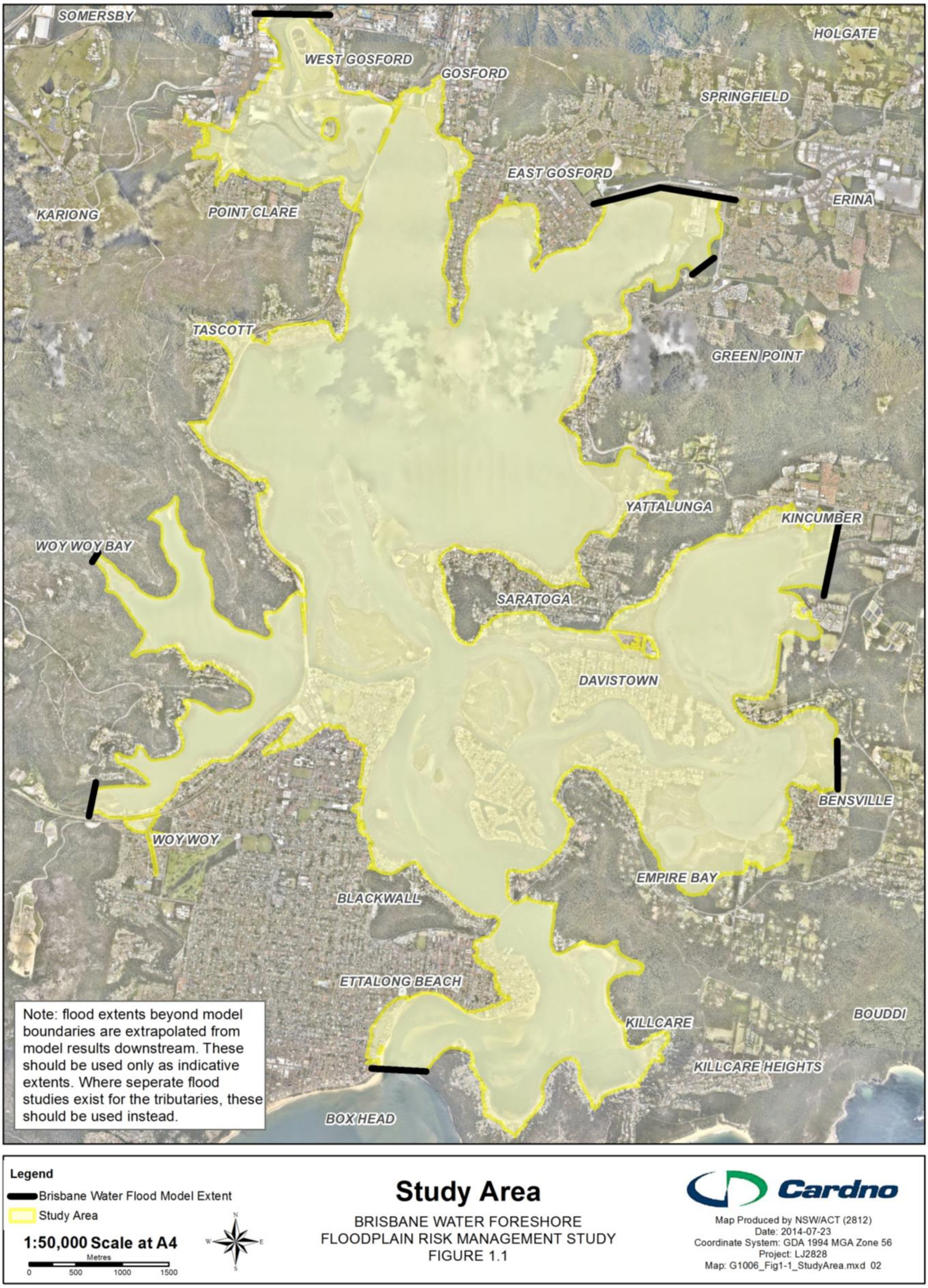

Figure 1.1: Study Area (Probable Maximum Flood Extent with 0.9m Sea Level Rise)

The *Floodplain Development Manual* (NSW Government, 2005) lays out guidelines to facilitate the formulation of management plans through the Floodplain Risk Management Process. *The Manual* describes the Floodplain Risk Management process as:

1. Establish a Floodplain Risk Management Committee (now called Catchments and Coast Committee);
2. Data Collection;
3. Flood Study;
4. **Floodplain Risk Management Study;**
5. Floodplain Risk Management Plan;
6. Plan Implementation; and
7. Review of Plan.

This document follows the previously prepared *Brisbane Water Foreshore Flood Study* (Cardno, 2013) and represents the fourth stage in the above process. The fifth stage, the *Floodplain Risk Management Plan* (FRMP) will follow immediately after the completion of the FRMS.

1.3 Study Objectives

The objectives of this *Floodplain Risk Management Study* are to:

- Derive an appropriate mix of management measures and strategies to effectively manage the full range of flood risk in accordance with Appendix G of the *Floodplain Development Manual* (NSW Government, 2005); and
- Utilise an effective public participation and community consultation program.

A range of measures/strategies to meet these objectives have been investigated to address risks to:

- Residential areas fronting Brisbane Water;
- Residential areas above the 100 year ARI level;
- Drainage reserves/wetlands/marshes; and
- Properties affected by projected sea level rise.

1.4 Study Methodology

The format of this document follows the study methodology, which involved the following:

- A review of available data and study inputs (**Section 2**);
- An assessment of the regulatory and management framework for the study area (**Section 3**);
- Consultation with the community and stakeholders (**Section 4**);
- An assessment of the environmental and social features of the floodplain (**Section 5**);
- A review of the *Foreshore Flood Study* (Cardno, 2013) defining the existing flood risks and an assessment of projected sea level rise to define future flood risks (**Section 6**);
- An assessment of the economic impact of flooding (**Section 7**);
- A review of the an appropriate flood planning level applied for the study area (**Section 8**);
- A review of current emergency response arrangements within the region (**Section 9**);
- Identification of management options to address flood risk (**Section 10**);
- Multi-criteria matrix assessment of identified management options and an economic assessment of hydraulically-modelled options (**Section 11**);
- Outcomes and recommendations for the *Management Plan* (**Section 12**); and
- A summary of conclusions and the next steps of the floodplain risk management process (**Section 13**).

2 Data Collection and Inputs to the Study

2.1 Flood Study Report

The *Brisbane Water Foreshore Flood Study* (Cardno, 2013) forms the basis for the *Floodplain Risk Management Study* (FRMS, this document). The following summarises some key elements and outcomes of the *Brisbane Water Foreshore Flood Study* (Cardno, 2013):

- **Public participation:** An information leaflet and questionnaire were prepared and delivered to residents, whose properties were considered to be lower than 2.5m AHD and potentially at risk of flooding.
- **Brisbane Water design foreshore flood levels:** Design still water levels and flood extents for a full range of flood events for existing catchment conditions were determined. All contributing physical processes of wind, rain, waves and tide were considered. Local wave conditions were also assessed at discrete locations around the foreshore.
- **Provisional hazard and hydraulic categorisation:** To achieve effective and responsible floodplain risk management, the Brisbane Water floodplain was divided into areas that reflect the different hydraulic impacts of development activity on flood behaviour and the hazard impact of flooding on development and people. This was undertaken for the 20 year ARI, 100 year ARI and PMF events.

The investigations were based on extensive data analysis and calibrated modelling systems, with the outcomes of each showing considerable consistency. Some key conclusions of the study were:

- The two major mechanisms for broad-scale flooding of Brisbane Water foreshore floodplain are:
  - Coastal flooding; and
  - Catchment flooding (in one location only).
- Coastal flooding is dominant for the majority of the foreshore areas – severe ocean storms cause the highest water levels rather than catchment floods of the same average recurrence interval (ARI) or Annual Exceedance Probability (AEP). The exception is within Fagans Bay, which is affected by Narara Creek and the northern railway causeway.

2.2 Planning Documents

In the preparation of this FRMS, a review of Council's planning documents relevant to floodplain risk management for the Brisbane Water foreshore floodplain was also conducted. This included a review of the following key documents:

- *Gosford Local Environment Plan* (2014); and
- *Gosford Development Control Plan* (2013).

Further information regarding planning documents and policies is provided in **Section 3.2**.

In addition, this FRMS aims to be consistent with the outcomes of other Floodplain Risk Management Studies within the catchment.

2.3 Available Data

Data used for this FRMS included:

- Results of the *Brisbane Water Foreshore Flood Study* (Cardno, 2013);
- Site inspection observations;
- Floor level survey data;
- Data in GIS format including cadastre, catchment contours and flood extents for waterways other than Brisbane Water;
- Airborne Laser Scanning (ALS) data;
- Aerial photography;
- Catchment/tributary Floodplain Risk Management Study documents; and
- Relevant emergency response documents such as the Gosford Local Flood Plan, evacuation locations etc.

2.4 Brisbane Water Estuary Management Study and Plan

This *Floodplain Risk Management Study* was prepared alongside the *Brisbane Water Estuary Management Study* (Cardno, 2011a) and the *Brisbane Water Estuary Management Plan* (Cardno, 2011b) which are administered under the separate Estuary Management Process (also overseen by OEH and GCC). Although the *Brisbane Water Estuary Management Study and Plan* (EMS&P) and the FRMS documents are separate, these documents have been reviewed in the context of one another to ensure a level of consistency between the investigations and recommendations. Compatibility between the two studies is integral in forward planning of the estuary in terms of both human use and estuarine processes. The estuary management options recommended in the EMS&P have been reviewed in the context of the flood risk management options (**Section 10**) to ensure that the two plans provide a consistent approach to management of the estuary and its floodplain.

3 Regulatory and Management Context

3.1 Overview

The objective of this chapter is to establish the context for the *Floodplain Risk Management Study* in terms of legislative requirements, policy directions and related management plans and actions. **Figure 3.1** outlines the context in diagrammatic form.

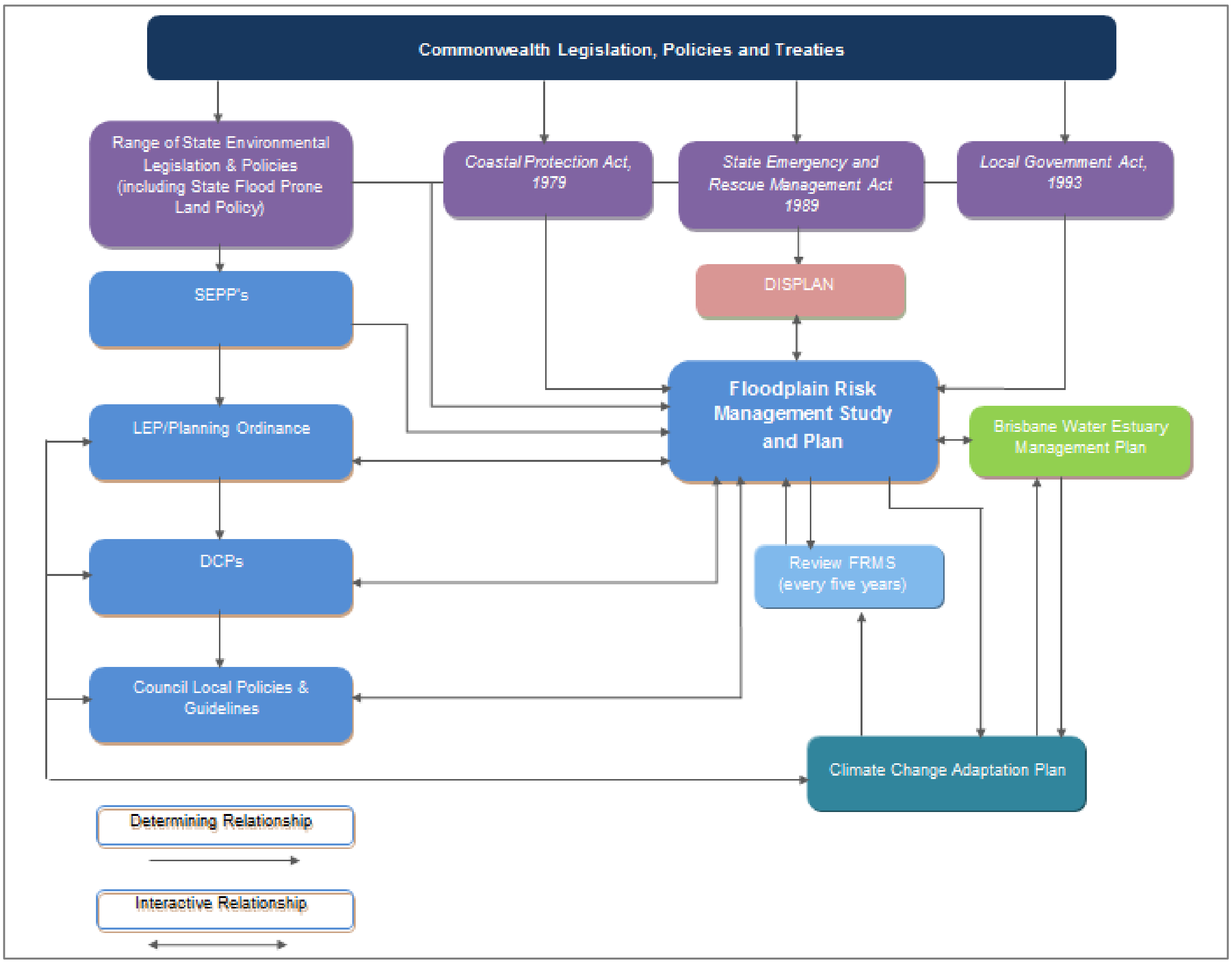

Figure 3.1: Key Elements of the Regulatory and Management Context

3.2 Relevant Environmental Legislation

In addition to setting the context for the Study, it is important to note the following legislation would need to be considered with respect to any future development proposed as a management action or otherwise.

3.2.1 Local Planning Legislation

The following planning documents and development controls are administered by Gosford City Council.

Gosford Local Environment Plan (GCC, 2014a)

The Gosford LEP (LEP) (GCC, 2014a) was gazetted in February 2014 and replaces the previous planning instrument (*Gosford Planning Scheme Ordinance*, GPSO). The Gosford LEP 2014 provides guidance as to land use zoning within the LGA and the types of development that are permitted within each zone. Previous zoning numbers (GPSO) and their new equivalent in the LEP are shown in **Table 3.1**.

Table 3.1: Changes to Land Use Zones

LEP 2014 Zones	Previous GPSO Zones
RU Rural	"1" rural zones such as 1(a) Agriculture
R Residential	"2" zones such as 2(a) Residential
B Business	3 zones such as 3(a) Business General
IN Industrial	4 zones such as 4(a) Industrial General, 4(a1) Somersby Industrial Park
SP Special Purpose Note: DoPI Practice Note requires that this only be used in special circumstances, and generally sites will be included in the adjoining zone	5 zones for special uses such as post offices, churches, waste disposal facilities etc.
RE Recreation	6 open space zones such as 6(a) Recreation
E Environment Protection	7 zones such as 7(a) Conservation, 7(c2) Rural Small Holdings and "8" Zone (National Parks)
W Waterways	Unzoned waterways, e.g. Brisbane Water, coastal lagoons

Those inclusions in the LEP having relevance to the management of the Brisbane Water foreshore floodplain include:

- Flood prone land local clauses (7.2 and 7.3);
- Development within the coastal zone (under the NSW *Coastal Protection Act 1979* the "coastal zone" covers the whole of the Brisbane Water estuary and foreshores);
- Development below the mean high water mark;
- Development of lands affected by acid sulfate soils (ASS);
- Foreshore building lines; and
- Heritage conservation.

Gosford Development Control Plan 2013 (GCC 2013a)

In accordance with State Government requirements, a range of DCP documents have been amalgamated into one document under the *Gosford Development Control Plan* (DCP) *2013* (GCC 2013a).

The purpose of the *DCP 2013* is to:

- Meet legislative requirements that only one DCP apply to any site;
- Contain controls which support and provide further detail to those contained within LEP 2014;
- Ensure DCP controls are consistent with LEP 2014 in regard to new definitions, zones, terminologies, LEP clauses etc;
- Introduce new controls where required as a result of the State government's Standard Template;
- Update existing controls to ensure consistency with other government legislation;

- Introduce/add to controls which address character, best practice urban and environmental design and residential amenity; and
- Include character statements for the Mountains precinct.

Chapter 6.7 - Water Cycle Management in *DCP 2013* (a section within Part 6 – Environmental Controls) is of particular relevance to this FRMS. This chapter applies to all development in the City of Gosford that requires consent, and relates to the application of WSUD and flood mitigation principles in the LGA. Specific objectives of the chapter that relate to flooding include:

- To reduce private and public losses resulting from floods;
- To enable safe access or evacuation of people to the existing public road network during flooding;
- To maintain the existing flood regime and flow conveyance capacity;
- To avoid significant adverse effects on the floodplain environment that would cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of any river bank or watercourse; and
- To limit land uses to those compatible with flow conveyance function and flood hazard.

This chapter sets out flood control provisions such that:

- Flood-related development controls may apply for any development on flood prone land (up to the PMF) for the purposes of: subdivision of land, earthworks, the erection of a building, the carrying out of a work, or flood mitigation works; and
- Flood-related development controls will not apply for development for the purposes of residential accommodation (other than group homes and seniors housing) on land that is flood prone but is not in the flood planning area. (i.e. land that is above 100 Year ARI flood level + freeboard but below the PMF).

A range of matters are also addressed regarding:

- Floor levels (habitable and non-habitable);
- Floodplain Risk Management Plans;
- Flood impacts;
- Building components;
- Local overland flooding;
- Filling;
- Projected sea level rise;
- Subdivisions;
- Access and parking (100 year ARI Flood Event and PMF Event); and
- Fencing.

Gosford Waterfront Development Control Plan (GCC, 2014b)

The Gosford Waterfront site was declared a potential State Significant Site in June, 2010. The Gosford Waterfront Development Control Plan (Gosford Waterfront DCP) establishes new land use zones, height limits and floor space ration controls along 9.9 ha of the Gosford Waterfront. Gosford Waterfront's land use zones allow for:

- Mixed uses including commercial, retail, hotel and conference facilities and residential;
- New regional community facilities including a proposed regional performing arts centre and conservatorium;
- Public spaces and recreational areas; and
- New waterside restaurants and retail facilities on an expanded breakwater.

Gosford Planning Scheme Ordinance (GCC, 2013b)

The *Gosford Planning Scheme Ordinance* (GPSO) was the previous planning instrument for Gosford. The *Gosford Local Environment Plan* (GCC, 2014a) has replaced the GPSO.

3.2.2 Local Policies

The following local policies are administered by Gosford City Council.

D2.08 Flood Management

This policy aims to control development of properties in flood prone areas. The policy provides for mapping of flood-prone areas, building regulations, public education and mitigation works.

D2.09 Flood Management – NSW Government Policy

The primary objective of the policy is to reduce the impact of flooding liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible.

D2.10 Catchments and Coast Committee Policy

The principal objective of the Catchments and Coast Committee is to assist Council in the development and implementation of a *Floodplain Risk Management Plan* for the area under its jurisdiction. The policy sets out the membership of the committee and how the committee should operate.

D2.11 Climate Change Policy

Council's commitment to considering future risks associated with Sea Level Rise (SLR) is contained within Council's Climate Change Policy D2.11 (May 2010). Council has considered and accepted competent scientific opinion at the Ordinary Meeting in August 2013 with the endorsement of Climate Change Scenarios for SLR recommended by HCCREMS (2010); *Potential Impacts of Climate Change on the Hunter, Central and Lower North Coast of NSW*.

Council endorsed a range of 0.4 to 0.9 metres rise in sea level relative to 1990 that is widely accepted by competent scientific opinion. Council also resolved to review these climate change scenarios following the release of the 5th Intergovernmental Panel for Climate Change (IPPC).

3.2.3 Local Strategies and Plans

Local strategies and plans relate specifically to the Gosford region but are administered by various bodies (often in collaboration) such as Gosford City Council and the NSW Government.

Gosford City Disaster Plan (DISPLAN) (Gosford LEMC, 2009)

This document was prepared by the Gosford Local Emergency Management Committee (LEMC). A detailed review of the DISPLAN is provided in **Section 9.2**. This plan will be replaced by the EMPLAN (in preparation).

Gosford City Flood Plan (Gosford LEMC, 2009a)

This document was prepared by the Gosford Local Emergency Management Committee (LEMC) as a sub-plan to the Local DISPLAN. It deals specifically with flood emergencies and provides similar information as the Local DISPLAN. A detailed review of the Local Flood Plan is provided in **Section 9.2.2**. This plan will be replaced by the Local Flood Sub Plan of the EMPLAN (in preparation).

Gosford Vision 2025 – Community Strategic Plan (GCC, 2011)

Gosford Vision 2025 (GCC, 2011) provides an overview of the Council's strategic direction for the whole of the Gosford LGA into the future. A number of key focus areas are outlined, for which a series of objectives have been defined. It is understood that the maintenance of open space foreshore areas is particularly important, in terms of both public access and amenity, but working within the context of environmental management. Monitoring and maintenance of ecosystem functioning is considered important for both environmental protection purposes and public health and safety. It is noted that there is a particular emphasis on water resources and catchment management.

Central Coast Regional Plan 2011-2015 (RDA, 2011)

The *Central Coast Regional Plan* is essentially a regional version of Gosford City and Wyong Shire Councils' Community Strategic Plans. It describes the region, its attributes and challenges, suggests a vision to aspire to, and discusses objectives and actions with respect to economic, environmental and social aspects of the region.

Central Coast Regional Strategy (DoP, 2008)

The *Central Coast Regional Strategy* covers the Gosford City and Wyong Shire LGAs and has been developed by the NSW Government as a long-term land use plan for the region. The regional strategy contains policies and actions designed to cater for the region's projected housing and employment growth over the period to 2031 and outlines how and where future development should occur to appropriately accommodate growth and to provide sufficient capacity to cater for more than 45,000 new jobs, reducing the need for local residents to commute outside of the region for work (DoP, 2008).

The strategy contains provisions for the protection of the coastal environment, improvement of recreational facilities where appropriate, the minimisation of development pressure of tourist activities and the protection of cultural heritage values (DoP, 2008).

Gosford City Centre Masterplan (GCC and LPMA, 2010)

The *Gosford City Centre Masterplan* is the framework that will lead the development and revitalisation of Gosford City Centre into the future. It describes the potential future of Gosford, giving reasonable certainty and predictability for potential investors, developers and landowners, and attracting future residents and tourists. The Masterplan primarily gives a clear direction for positive change, indicating what kind of development and creation of public realm is appropriate and necessary to revitalise the city. The Masterplan will serve as a document for the community to understand the proposed changes and how those changes will help to grow Gosford as the Regional City of the Central Coast.

The Masterplan makes reference to flooding within the context of projected sea level rise. It states that available options to mitigate against projected sea level rise include:

- The development of the waterfront at a higher level to create a barrier to sea level rise. This system introduces significant issues with regard to the re-engineering of the stormwater system. Building high development around the entire waterfront will create a trapped low point for the stormwater behind the development which is expensive and difficult to remove.
- The filling of all areas impacted by sea level rise, which provides better opportunity for dealing with the stormwater system.

These suggested options align with the flood risk management options presented in this FRMS (**Section 11**).

Gosford Waterfront (Gosford Challenge) (GCC and DoL, 2009)

This began collaborative effort of the Department of Lands (now part of DPI), Gosford City Council and strategic design partner Cox Architects, with the primary purpose being to create a better place for the people of the Central Coast of New South Wales through urban renewal of the Gosford City Centre. This resulted in a rezoning of the 9.9ha Gosford Waterfront site on 11 February 2014, establishing new land use zones, height limits and floor space ratio controls for the site. The Gosford Waterfront Development Control Plan (GCC, 2014b) is described in **Section 3.2.1**.

3.2.4 Regional Strategies and Plans

Hunter-Central Rivers Catchment Action Plan 2013-2023 (Hunter-Central Rivers CMA, 2013)

The Catchment Action Plan (Action Plan) provides a whole of government and whole of community strategic plan which aims to capture the full range of issues, roles and responsibilities of all the key organisations involved in natural resource management and decision making. The Action Plan considers the region as a complex social and ecological system and recognises that effective natural resource management must acknowledge and respond to the needs of communities, industries and individuals, as well as the natural resources of the region. Detailed spatial information is included in the Action plan through a series of maps showing where some catchment management actions and initiatives may need to occur to address threats and get the best possible outcomes.

Key issues identified for the region include:

- Reduced abundance and distribution of native species;
- Planning framework;
- Land management;
- Population growth;
- Community values, health and well-being;
- Waste;
- Natural disasters
- Climate change;
- Governance and decision-making; and
- Water quality and quantity.

Central Coast Catchment Blueprint (DLWC, 2003)

This document was developed through consultation between the community and the government. It sets overarching natural resource management priorities for rural, coastal and urban catchments in the Central Coast region.
Management targets were established for Aquatic Ecosystem Health in relation to both estuaries (including Brisbane Water) and river and creek systems. Targets were also set for Land Capability, Terrestrial Biodiversity and Native Vegetation. An Action Plan table lists priorities, actions, timeframe for implementation, responsible agencies/organisations and the desired investment level.

3.2.5 Plans of Management

The plans of management relevant to floodplain management relate specifically to the Gosford region but are administered by various bodies (often in collaboration) such as Gosford City Council and the NSW Government. These plans relate primarily to natural resource management but are important to consider in the context of flooding, particularly in the case of feasible flood risk management options.

Brisbane Water Plan of Management (GCC, 2000)

In response to increasing development pressure in the early 1990's, Council prepared the *Brisbane Water Plan of Management*. A committee was established for the development and implementation of the Plan, with assistance provided by relevant technical specialists and organisations. The Plan covers:

- The context in which the Plan operates;
- Estuarine Habitat Management;
- Water Quality;
- Heritage within Brisbane Water;
- Water Use and Occupations within Brisbane Water;
- Water Depth and Sedimentation;
- Channel and Foreshore Protection;
- Residential Structures within Brisbane Water;
- Tourism and Transportation;
- Public Water Access Facilities;
- Commercial and Club Waterfront Development;
- Planning Provisions for Brisbane Water; and
- Implementation and Future Actions.

Since the *Plan of Management* (GCC, 2000) was developed, a considerable amount of additional information about the estuary processes and function of Brisbane Water estuary has become available, primarily through the *Brisbane Water Estuary Processes Study* (Cardno, 2008). Some changes in the nature, magnitude and/or extent of the management issues affecting the estuary have occurred since this time these are reflected in the *Brisbane Water Estuary Management Study* (Cardno, 2011a).

The *Brisbane Water Plan of Management* (GCC, 2000) is superseded by the *Brisbane Water Estuary Management Plan* (Cardno, 2011b).

Gosford City Council Plans of Management

Gosford City Council Plans of Management that are relevant to this *Floodplain Risk Management Study* include:

- *Coastal Open Space System (COSS) Action Strategy* (August 1992)
- *Caroline Bay Plan of Management* (February 1998)
- *Ettalong Beach Reserve Plan of Management* (2003) which also includes:
  - *Ettalong Beach Dune Management Plan – Ettalong Foreshore* (June 2007); and
  - *Ettalong Beach Masterplan;*
- *Plan of Management – Foreshore Parks* (1996);
- *Plan of Management – Gosford Foreshore* (2004);
- *Saratoga Recreation Area and Wetland – Final Plan of Management* (2004);
- *Yattalunga Foreshore Reserve – Plan of Management* (2003);
- *Gosford District Stormwater Management Plan* (1999); and
- *Brisbane Water Estuary Management Plan* (2011).

It should be noted that the storm water management plan and the estuary management plan are not official Plans of Management as prescribed under the Local Government Act or the Crown Lands Act but have been prepared under other mechanisms (Stormwater Management Plan was prepared under a Section 21 direction under the Protection of the Environment Operations Act and the Estuary Management Plan was prepared under the Coastal Protection Act, 1979).

National Park Plans of Management

Plans of Management exist for the National Parks that exist in the Brisbane Water estuary area, namely:

- *Bouddi National Park Draft Plan of Management* (NPWS, 1999), and
- *Brisbane Water National Park Plan of Management* (NPWS, 1992).

These Plans are not as likely to be relevant for this study but have been included for completeness, particularly since the Brisbane Water National Park lies adjacent to Brisbane Water on the western side of the estuary.

3.2.6 Regional Environmental Planning Policies

Planning reforms undertaken by the NSW State Government meant that from 1 July, 2009 regional environmental plans were no longer part of the hierarchy of environmental planning instruments in NSW and all REPs took on the status of SEPPs.

3.2.7 State Legislation

A summary of selected acts and regulations that apply to the Gosford region and details of how they apply to this FRMS is presented in **Table 3.2**. These legislative instruments are administered by the NSW Government.

Table 3.2 Relevant State Legislation

Act/Regulation	Details
Local Government Act, 1993	The *Local Government Act 1993* is primarily administered by the Department of Premier and Cabinet (Division of Local Government) and gives local councils the power to control and regulate the drainage of land in their locality.
Environmental Planning and Assessment Act 1979	The NSW environmental planning system operates under *the Environmental Planning and Assessment Act, 1979* (EP&A Act). It aims to encourage proper management, development and conservation of natural and artificial resources to ultimately promote the environment and the economic and social welfare of the community, and also seeks to promote the sharing of responsibility between state and local government and facilitate public involvement in the planning and assessment process. The EP&A Act is the primary legislation controlling development activity in the State of NSW and is administered by the Department of Planning and Infrastructure Council and other consent or determining authorities. Under the Act, appropriate authorities must assess environmental impacts of new developments before development commences.
Protection of the Environment Operations Act 1997	The *Protection of the Environment Operations Act 1997* is administered by the Environmental Protection Authority and ultimately aims to protect, enhance and restore the quality of the environment in New South Wales, to reduce risk to human health and promote mechanisms that minimise environmental degradation through a strong set of provisions and offences. A licence is required from OEH if any of the activities associated with the proposed works are determined to be a "scheduled activity" under Schedule 1 of the Act.
Threatened Species Conservation Act 1995	The provisions of this Act must be complied with for any future development proposals in or around Brisbane Water that are likely to affect or have the potential to affect threatened species. The National Parks and Wildlife Service administer this Act.
State Emergency and Rescue Act 1989	This Act defines an emergency due to an actual or imminent occurrence (such as fire, flood, storm, earthquake, explosion, accident, epidemic or warlike action) which: ▪ Endangers, or threatens to endanger, the safety or health of persons or animals in the State, or ▪ Destroys or damages, or threatens to destroy or damage, property in the State, being an emergency which requires a significant and coordinated response. The legislation sets out the ways to manage such emergencies at a state, district and local level.
Noxious Weeds Management Act 1993	Any proposed vegetation rehabilitation for the Brisbane Water estuary and foreshores must be in accordance with the Noxious Weeds Management Act 1993.
Water Management Act, 2000	The *Water Management Act 2000* controls the extraction of water, the use of water, the construction of works such as dams and weirs and the carrying out of activities in or near water sources in New South Wales. The Act creates mechanisms for protecting and restoring water sources and their dependent ecosystems, improved access rights to water, and partnership arrangements between the community and the government for water management.

Act/Regulation	Details
Fisheries Management Act 1994	The *Fisheries Management Act 1994* requires approval to be obtained from the Department of Primary Industries for any works taking place within 50 metres of aquatic habitats. Any future development proposals in or around the Brisbane Water estuary must comply with the provisions of this Act.
Native Vegetation Act 2003	This Act aims to provide for, encourage and promote the management of native vegetation on a regional basis in keeping with the social, economic and environmental interests of NSW. Any future works which may affect native vegetation must be in accordance with the provisions of this Act. Exemptions of the Act include land that is critical habitat (under the TSC Act or FM Act), national parks, and land within a zone designated 'residential' (but not rural residential), 'village', 'township', 'industrial' or 'business' under the relevant environmental planning instrument.
Native Vegetation Regulation 2013	The *Native Vegetation Regulation 2013* provides regulations for the protection of Native Vegetation, including the use of Property Vegetation Plans (PVPs). This regulation relates mainly to rural agricultural land, and so given the nature of the land use zoning along the Brisbane Water foreshore floodplain the regulation is unlikely to apply.
Coastal Protection Act 1979	This Act aims to provide for the protection of the coastal environment of the State for the benefit of both present and future generations. The Brisbane Water estuary is located in the declared NSW Coastal Zone to which this Act applies.
Coastal Protection Regulation 2011	The primary objective of the *Coastal Protection Regulation 2011* which commenced on 3 March 2011 is to support the amendments to the Coastal Protection Act (described below).
Coastal Protection Amendment Act 2012	Formed part of two-stage coastal reform process initiated by the State Government. The main elements of the Stage 1 coastal reforms were: ▪ Amendment of the Coastal Protection Act 1979 by the Coastal Protection Amendment Act 2012 to make it easier for landowners to place large sandbags on beaches as temporary coastal protection works, to reduce erosion impacts during minor storms. Landowners are still be able to lodge a development application for larger works; ▪ Clarifying what information councils should put in section 149 certificates relating to projected sea level rise impacts - new guidelines will be prepared for councils by the Department of Planning and Infrastructure; and ▪ Giving councils the flexibility to consider coastal hazards in the context of their local circumstances – the State Government no longer recommends state-wide sea level rise benchmarks for councils. The main elements of the Stage 2 (current stage) coastal reforms are: ▪ Establishing a simpler and more integrated legal and policy framework for coastal management; ▪ Providing improved guidance and technical advice to councils, while enabling and supporting local decision making; ▪ Identifying potential funding options, particularly to implement coastal asset management strategies.

Act/Regulation	Details
Heritage Act 1977	The *Heritage Act 1977* provides protection for natural and cultural heritage by providing for the listing of heritage items or places on the State Heritage Register and providing for the making of interim heritage orders for the protection of heritage items or places. Under the *Heritage Act 1977*, it is an offence to harm relics protected by Interim Heritage Orders, the State Heritage Register or environmental planning instruments. If a heritage item or place is damaged (e.g. in the course of flood emergency response), OEH must be notified as soon as is practicable subsequent to a flood event.
Crown Lands Act 1989	Crown lands are dealt with in the best interests of the State: S.10 of the CL Act 1989 requires Crown land to be managed to the "benefit of the people of NSW". In particular, management must have regard to the principles of Crown land management, namely: ▪ That environmental protection principles be observed in relation to the management and administration of Crown land; ▪ That the natural resources of Crown land (including water, soil, flora, fauna and scenic quality) be conserved wherever possible; ▪ That public use and enjoyment of Crown land be encouraged; ▪ That, where appropriate, multiple use of Crown land be encouraged; ▪ That, where appropriate, Crown land be used and managed in such a way that both the land and its resources are sustained in perpetuity; and ▪ That Crown land be occupied, used, sold, leased, licensed or otherwise dealt with in the best interests of the State consistent with the above principles.
National Parks and Wildlife Act 1974	The *National Parks and Wildlife Act 1974* (NPW Act), administered by OEH, is the primary legislation for the management of national parks and the protection of Aboriginal cultural heritage in NSW (Part 6 of the Act provides specific protection for Aboriginal objects and places). The objects of the Act are: ▪ The conservation of nature, including the conservation of habitat, ecosystems and ecosystem processes, biological diversity, landforms of significance, landscapes and natural features of significance; ▪ The conservation of objects, places or features of cultural value within the landscape, including places, objects and features of significance to Aboriginal people, places of social value to the people of New South Wales and places of historic, architectural or scientific significance; ▪ Fostering public appreciation, understanding and enjoyment of nature and cultural heritage and their conservation; and ▪ Providing for the management of land reserved under this Act in accordance with the management principles applicable for each type of reservation.

3.2.8 State Policies and Guidelines

A summary of policies and guidelines administered by the NSW Government is shown in **Table 3.3**.

Table 3.3: Relevant State Policies

Policy	Details
Flood Prone Land Policy (2001) and Floodplain Development Manual (2005)	The *Floodplain Development Manual 2005* incorporates the *NSW Flood Prone Land Policy 2001.* The Manual provides a framework for implementing the policy. The *NSW Flood Prone Land Policy* promotes the use of a merit approach, which balances social, economic, environmental and flood risk parameters to determine whether particular development or use of the floodplain is appropriate and sustainable. The Policy aims to reduce the impacts of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods. The policy also recognises the benefits of use, occupation and development of flood prone land.
Floodplain Risk Management Guidelines:	
Temporary/Relocatable Flood Barriers (2007)	This guideline provides advice on the limits of the use of temporary/relocatable flood barriers and the investigation of their use in floodplain risk management studies
Rainwater Tanks – Limitations as FRM Devices (2007)	This guideline provides advice on the limitation of rainwater tanks and their effectiveness in managing flood risk,
Drainage Behind and Through Levees (2007)	This guideline addresses the funding eligibility for the components drainage systems behind and through levees under the State Government's Floodplain Management Program.
Flood Emergency Response Planning Classification of Communities (2007)	This guideline was developed in conjunction with the State Emergency Service (SES) to provide a basis for the flood emergency response categorisation of floodplain communities (both existing and future). Classification provides an indication of the relative vulnerability of the community in flood emergency response and when used with FRM Guideline SES Information Requirements from the FRM Process it identifies the type and scale of information needed by the SES to assist with emergency response planning (ERP).
SES Requirements from the FRM Process (2007)	This guideline outlines the outputs from the FRM process required to assist the State Emergency Service (SES) in effective emergency response planning (ERP). The outputs and the associated work required depend upon the type and scale of emergency response problems for the location as discussed in the FRM Guideline – Flood Emergency Response Classification for Communities.
Modelling Reports and Supporting Information (including Model Files) for Review (2007)	This guideline outlines the requirements for modelling and supporting information including model files to facilitate effective peer review as part of flood studies and FRM studies.
Floodway Definition (2007)	This guideline addresses the identification of floodways in the FRM Process as outlined in the *NSW Floodplain Development Manual 2005.*
NSW Coastal Policy (1997)	The *NSW Coastal Policy* provides a framework for the balanced and coordinated management of the coastal zone in accordance with the principals of ecologically sustainable development. This policy applies to the Brisbane Water estuary and foreshores due to its proximity to the coast.
Flood Risk Management Guide - Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments (2010)	This guide provides direction for incorporating sea level rise planning benchmarks in floodplain risk management planning and flood risk assessments for new development. Although this guideline relates more specifically to future development, its principles can also be applied to existing development.

Policy	Details
Coastal Design Guidelines for NSW (2003)	The *Coastal Design Guidelines for NSW* have been prepared with reference to the *NSW Government's Coastal Policy 1997* and provide a framework for discussion and decision making involving coastal planning, design and development proposals between all stakeholders. The guidelines are based on the principles of ecologically sustainable development.
Various applicable *State Environmental Planning Policies* (SEPPs) including: 4, 14, 19, 33, 50, 71	Specific sections of this report make reference to SEPPs as required.
NSW Coastal Planning Guideline: Adapting to Sea Level Rise (2010)	This guideline provides direction on how projected sea level rise is to be considered in land use planning and development assessment in coastal NSW. This Guideline applies to all coastal areas of NSW, namely all land fronting tidal waters including the coastline, beaches, coastal lakes, bays and estuaries and tidal sections of coastal rivers.
Floodplain Risk Management Guideline: Practical Consideration of Climate Change (2007)	This guideline sets out a framework for examining and managing the impact of climate change in projects undertaken under the State Floodplain Management Program and in accordance with the *Floodplain Development Manual* (NSW Government, 2005).
NSW Sea Level Rise Policy Statement (2009) ***(now repealed)***	This policy was repealed in late 2012. Previously, it acknowledged that increased sea levels will have significant medium to long-term social, economic and environmental impacts. The policy previously provided a framework to support coastal communities in adapting to long-term rising sea levels in a manner that minimised the resulting social disruption, economic costs and environmental impacts.

3.2.9 Commonwealth Legislation

Environmental Protection and Biodiversity Conservation Act 1999

This Act establishes the obligation to preserve native species and ecological communities that are listed as endangered or vulnerable. The Act provides for the protection and conservation of aspects of the environment that are matters of national environmental significance, such as threatened species and places of world and national heritage.

4 Consultation

Consultation is an important element in the undertaking of a *Floodplain Risk Management Study*. The program of consultation undertaken as part of this study not only canvassed the community and stakeholders for information and opinions, it also sought to improve awareness and understanding of flooding risks within the local community, and to initiate commitments from the relevant stakeholders with respect to the subsequent stages of the process, being the implementation of the Plan.

The program of consultation described below consisted of actions throughout the duration of the study. A variety of methods were used in order to maximise the potential for consultation and participation in developing the Management Study.

4.1 Consultation with the Committee

The Catchments and Coast Committee (CCC) was established by Gosford City Council to oversee the FRMS. The CCC includes community members, NSW State Emergency Service (NSW SES) representatives and OEH representatives. The CCC has direct involvement and assisted in guiding the direction of the FRMS. Cardno attended the following meetings of the CCC in the preparation of this study:

- 17 December 2009: *Information Session* – Cardno presented a summary of the previous *Foreshore Flood Study* (Cardno, 2013) results, and a forward direction for the FRMS.
- 26 August 2010: *Management Options Workshop* – Cardno presented the preliminary list of management options to the Committee and requested feedback on these options.
- 7 September 2011: *Management Options Workshop 2* – Cardno presented a refined list of management options in response to Council and Committee comments and requested feedback on these options.
- 14 August 2013: *Presentation at Committee Meeting* – Cardno presented the Management Study to the Committee with emphasis on the existing flooding scenario, updated options and development control matrix. The Committee were able to express their views and ask questions of Cardno and Council.
- 1 October 2014: *Public Exhibition Period – Sub-committee Planning Workshop*: Cardno presented additional information to the Committee regarding the planning recommendations in the FRMS. Committee members provided input regarding planning matters to be used in the development of the FRMP.
- 3 February 2015: *Sub-committee Workshop* – Cardno presented a status update on the FRMS, with an emphasis on planning controls and the proposed flood planning level options for discussion and comment.

Further consultation with the Catchments and Coast Committee is being undertaken by Council.

4.2 Stakeholder Consultation

4.2.1 Letter Distribution and Follow-Up

Agency stakeholder consultation was undertaken in August 2009. A letter was distributed to the organisations listed below, seeking their input to the *Floodplain Risk Management Study*, particularly with respect to identification of flood-related management issues:

- Darkinjung Local Aboriginal Land Council*;
- Department of Environment, Climate Change and Water (now OEH)*;

- Department of Industry and Investment (now DPI);
- Department of Planning (now DoPI)*;
- Department of Planning (Heritage Branch) (now OEH);
- Energy Australia* (now AusGrid);
- Gosford City Council Water and Sewer Department;
- Hunter-Central Rivers Catchment Management Authority* (now Local Land Board);
- Jemena Gas*;
- Land and Property Management Authority (now part of DPI)*;
- NSW Maritime* (now RMS);
- Optus*;
- Railcorp* (now Transport for NSW);
- Roads and Traffic Authority (now RMS);
- Royal Volunteer Coastal Patrol*;
- State Emergency Service*; and
- Telstra*.

Organisations marked with an * did not submit a response after follow up. A copy of the form letter distributed to these stakeholders is provided in **Appendix A**. These stakeholders and any additional stakeholders will be given an opportunity to provide input to the study during the public exhibition period.

4.2.2 Stakeholder Responses

Copies of responses received from stakeholders (those received in official letter format only) are provided in **Appendix A**. The stakeholder responses received are summarised in **Table 4.1**.

Table 4.1: Received Stakeholder Responses

Agency/Organisation	Response
Department of Industry and Investment (now Department of Primary Industries) (letter)	The following summarises the response from DII (now DPI): The main issue concerning flood management in Brisbane Water is the impact of proposed flood mitigation options on aquatic habitats (mangroves, seagrasses and saltmarsh), water quality and water flow. The Department recommends that where such impacts cannot be avoided, that management options are discussed with the Department's Aquatic Habitat Protection Unit, particularly if it is proposed to harm aquatic habitat. The following study and policy/guidelines may be useful in finalising management options: ▪ *Mapping the Habitats of NSW Estuaries* (Creese *et al*., 2009); and ▪ *Policy and Guidelines: Aquatic Habitat Management and Fish Conservation* (DPI, 1999).

Agency/Organisation	Response
Department of Planning – Heritage Branch (now Office of Environment and Heritage) (letter)	The following summarises the response from DoP – Heritage Branch (now OEH): The Brisbane Water study area includes many remnant historic shipbuilding and river transport structures. It is recommended that the following be considered in preparation of the Study: ▪ A field survey of historic infrastructure should be undertaken and results translated into practical guidelines within the Plan; ▪ Equipment used by emergency services during a flood event (e.g. plant machinery and equipment on foreshore edge) can have a detrimental effect on historic infrastructure. Guidelines and mitigation measures to prevent or minimise these impacts should be included in the Plan; ▪ Guidelines and recommendations for managing incidence of damage or destabilisation of remnant historic structures following a flood event (e.g. contacting DoP) should be included in the Plan; ▪ A stability and structural integrity assessment should be undertaken prior to any decision to completely demolish such structures being made; ▪ Requirements and obligations under the NSW *Heritage Act 1977* should be included in the FRMS; ▪ Guidelines for Aboriginal and non-Aboriginal heritage items that could be affected by future flood events should also be included in the Plan. The following resources may be of use, including: ▪ *NSW Maritime Heritage Online Database* (2010); and ▪ *The Shipbuilders of Brisbane Water NSW* (Dundon, 1997).
Gosford City Council Water and Sewer Department (email)	A spreadsheet was forwarded to Cardno describing the effect of flooding on water and sewer infrastructure for both the 100 year ARI flood event and the average tide for present conditions and three sea level rise scenarios. A summary of the data for the existing and high level rise (0.9m) is presented in **Table 4.2**.
Roads and Traffic Authority (now Roads and Maritime Services) (email)	The following summarises the response from the RTA (now RMS): The following roads lie within the study area: ▪ *Brisbane Water Drive, West Gosford (HW30/MR349)*; and ▪ *Racecourse Road, West Gosford.* A Review of Environmental Factors has recently been prepared for an intersection upgrade at Brisbane Water Drive and Manns Road (RMS 2010 and RMS, 2013) and should be considered with respect to flooding.

4.2.3 Asset Managers

The contacted private asset managers (Energy Australia, Telstra, Optus and Jemena Gas) did not respond to the consultation letter despite follow-up telephone calls and emails.

With regard to water and sewer infrastructure, **Table 4.2** summarises the data submitted to Cardno by Gosford City Council in regard to the impact of projected sea level rise on Council assets.

Table 4.2: Summary of Affected Water/Sewer Assets for the 100 Year ARI Flood Event (Existing Scenario and Medium and High Sea Level Rise Scenarios – Gosford City Council)

Asset Type*	100 Year ARI Flood Event	Assets Affected		Percent Affected of Total (%)
		Length (km)	Number	
Gravity Mains	**Existing**	**72.1**	**-**	**6.3**
	0.45m SLR	100.3	-	8.8
	0.91m SLR	114.3	-	10.0
Pressure Mains	**Existing**	**78.6**	**-**	**51.3**
	0.45m SLR	84.4	-	55.0
	0.91m SLR	84.9	-	55.3
Water Mains	**Existing**	**58.7**	**-**	**5.7**
	0.45m SLR	77.0	-	7.5
	0.91m SLR	86.9	-	8.5
Maintenance Hole	**Existing**	**-**	**1514**	**4.3**
	0.45m SLR	-	2527	7.2
	0.91m SLR	-	2890	8.2

*Information on other utilities in the floodplain was not available.

The data in **Table 4.2** suggests that affectation of Council's water and sewer assets is a current issue for the floodplain. Projected sea level rise has the potential to exacerbate this issue. Unsealed underground services may be affected by the potential long term changes in groundwater levels adjacent to the estuary associated with climate change and this issue should be into consideration when developing the CCAPs.

4.3 Community Consultation

Council adopted a Community Engagement Strategic Framework in May 2014. The goals of this framework are to inform, consult, involve, collaborate and empower the community. Consultation with the community included (and will include) the following components:

- Resident Survey;
- Consultation with the CCC; and
- Public Exhibition of the Draft FRMS document.

These are described in more detail below, and copies of community consultation materials can be found in **Appendix A**.

4.3.1 Resident Brochure and Survey

Overview

A resident survey was carried out to obtain community opinions on possible options to manage flood risks. The survey included a questionnaire regarding the residents' opinions on generic options for managing flooding in a non-technical format. A map and an information brochure were included to outline the purpose and background of the study. The information presented to the residents emphasised the importance of their involvement in the study.

A press release was prepared for publishing in the local newspaper to inform the residents of the FRMS and the resident survey. Information about the study was also published on Council's website. Letters were mailed to residents within the study area and a reply paid system was used, with the opportunity to respond via email also provided.

Responses from this survey have been collated and results are summarised below.

Results

The findings of the Resident Survey issued to local residents of the Brisbane Water foreshore floodplain in September 2009 (closing date 16 October 2009) are presented below. These final results have been gathered from 1,068 completed surveys which represent 16.4% of the total number of surveys issued (6,500) which is considered to be an excellent response rate.

In general terms, the survey returned a range of opinions and a number of key suggestions by the community. Key results from the resident survey are outlined below beginning at Question 2 (noting that Question 1 was personal contact details). For Questions 4 to 8, a graphical representation of the results is presented (**Figure 4.1 to 4.5**) in addition to the percentages for each response. For each question, the response with the highest proportion of respondents who preferred this response is presented in **bold** text.

Question 2 – Property Type

For this question it was found that respondents were often adding their own property type rather than selecting one of the three types specified in the question (owner occupied, occupied by a tenant, or a business). The additional entries have been included in **Table 4.3**.

.

Table 4.3: Results from Question 2

Property Type	Number of Respondents
A business	11
Holiday House	1
Investment Property	1
Occupied by a tenant	68
Occupied by a Tenant/A business	1
Owner Occupied	930
Owner Occupied/A Business	6
Owner Occupied/Occupied by Tenant	9
Unknown	4
Vacant	1
Total	**1032**

Question 3 – How long have you lived in, worked and/or owned your property?

There were a variety of responses for this question ranging from just one month to nearly 100 years. On average, length of occupancy/tenancy was found to be 18 years.

Question 4 – Have you ever experienced flooding since living/working/owning your property?

1. 3% have had floodwaters entering house/business
2. 17% have had floodwaters entering yard/ surrounding property
3. 7% couldn't drive their car because the road was flooded
4. 4% saw the creek banks break
5. 14% of respondents' neighbourhoods were flooded
6. **55% have not experienced a flood**

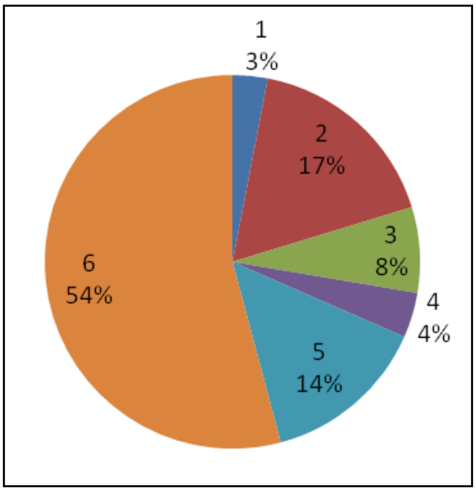

Figure 4.1: Results from Question 4

Question 5 – If you have experienced a flood, how did the flooding affect you and your family/business?

1. 5% reported parts of their house/business building damaged
2. 4% reported contents in their house/business damaged
3. 24% have had their garden or yard damaged
4. 2% of respondents' cars were damaged
5. 6% stated that other property was damaged (e.g. garage, jetty, pool)
6. 6% said that they could not leave their house
7. 3% reported that family/workmates couldn't return home/work
8. 2% of people had to evacuate their house/business
9. 14% said the flood disrupted their daily routine
10. 8% said the flood affected them in other ways (e.g. emotional, stress, damaged roads)
11. **26% said the flood didn't affect them**

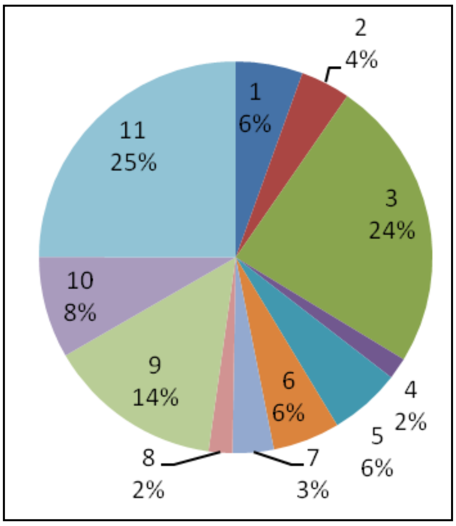

Figure 4.2: Results from Question 5

Question 6 – Do you think your property will be flooded sometime in the future?

1. **61% did not think their property will be flooded**
2. 22% thought only a small part of their yard may be flooded
3. 11% thought most of their yard/outdoor areas could be flooded
4. 6% thought that their house/business could flood over the floor

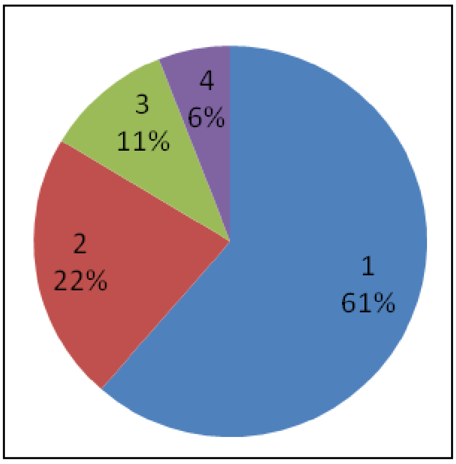

Figure 4.3: Results from Question 6

Question 7 – Have you looked for information about flooding on your property?

1. 6% have used Council's customer service centre
2. 4% have sought other information from council (e.g. flood maps, DA)
3. 5% have viewed a Property Planning Certificate
4. 3% have received information from a real estate agent
5. 11% have received information from friends/relatives/neighbours etc.
6. 4% have sought other information (e.g. library, history)
7. 33% have not sought any information
8. **34% did not believe their property is affected by flooding**

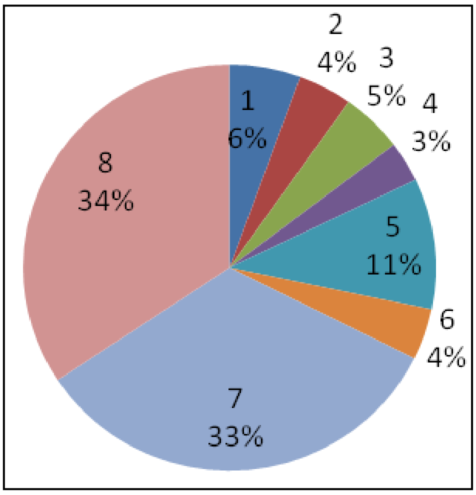

Figure 4.4: Results from Question 7

Question 8 – What do you think are the best ways to get input and feedback from the local community about the options being considered to manage flooding and the results of this project?

1. 8% prefer Council's website
2. 6% prefer emails from Council
3. 6% prefer Council's Catchments and Coast Committee
4. 1% prefers formal Council meetings
5. 19% prefer Council's information page in the local paper
6. 13% prefer other articles in the local paper
7. 9% would like information days in the local area
8. 10% prefer community meetings
9. **28% prefer mail outs to residents & business owners**

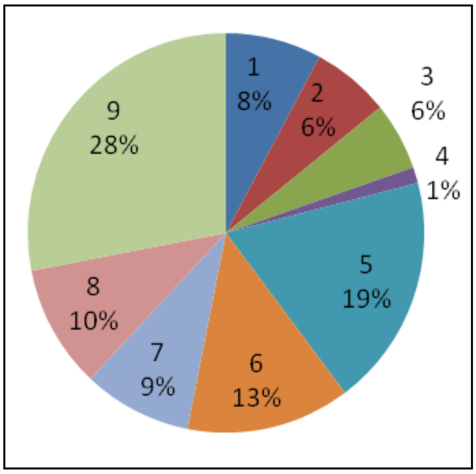

Figure 4.5: Results from Question 8

Question 9 – Preferred Options

The results for this question are presented in **Table 4.4**. For each proposed option, respondents were requested to assign a score (1-5, with 1 being least preferred and 5 being most preferred). For each management option, the score that was assigned most frequently by respondents (i.e. the largest percentage of respondents for that option) is presented in **bold** text.

Table 4.4: Results from Question 9

Question Number	Proposed Option	Percentage (%) of Respondents for each Preference					Total Number of Respondents
		1	2	3	4	5	
9.1	Retarding or detention basins; these temporarily hold water and reduce peak flood flows	23.1	12.1	21.2	15.1	**28.6**	637
9.2	Stormwater harvesting, such as rainwater tanks	11.5	6.8	10.0	11.5	**59.8**	745
9.3	Improved flood flow paths	7.5	3.9	15.0	21.5	**51.9**	705
9.4	Culvert/ bridge/pipe enlarging	11.1	8.8	17.5	17.7	**44.8**	701
9.5	Levee banks	**26.6**	15.9	21.5	11.7	24.1	664
9.6	Environmental channel improvements, including removal of weeds & bank stabilisation	10.3	6.2	12.6	16.5	**54.3**	753
9.7	Planning and flood-related development controls	8.6	7.7	19.5	21.8	**42.4**	694
9.8	Education of community, providing greater awareness of potential hazards	12.2	11.0	23.5	21.3	**32.0**	682
9.9	Flood forecasting, flood warning, evacuation planning and emergency response	10.4	9.6	20.3	20.0	**39.6**	694
9.10	Other	9.2	0.8	0.8	7.6	**81.7**	131

Question 10 – Additional Options

Question 10 requested respondents to outline any additional options they thought were appropriate for flood risk management in the Brisbane Water foreshore floodplain. The following outlines some examples of additional options that were suggested by the community:

- Ongoing maintenance of stormwater infrastructure is required (e.g. regular cleaning);
- Installation of kerbs and guttering is required on many streets;
- Stormwater runoff catchment drains should be installed;
- Stormwater harvesting should be undertaken (for use on playing fields, ovals and reserves);
- Rainwater tanks should be installed in households;
- Seawalls require installation and/or maintenance;
- Protection and retention of existing mangroves areas is required;
- Maintenance and reduction of mangroves is required;
- Dredging is required in a number of areas (Brisbane Water Entrance, Kincumber Creek, Erina Creek, Narara Creek, Hardys Bay, a number of channels etc.); and
- A flood tide control mechanism combined (potentially including a tide flow power generation station) could be installed at the Rip Bridge or Half Tide Rocks.

Many of these proposed management options relate to catchment flooding rather that coastal flooding and should therefore be considered in more detail in respective catchment floodplain risk management documents. The management options assessment for foreshore flooding as a result of coastal flooding is discussed in **Section 11**.

4.3.2 Consultation with Community Representatives

The Catchments and Coast Committee has a number of community representatives. Consultation with the CCC is described in **Section 4.1**.

4.3.3 Public Exhibition and Community Engagement Strategy

Public Exhibition

The draft version of this *Floodplain Risk Management Study* was made available for comment via a period of public exhibition. The draft study was placed on public exhibition from 27 August to 12 November 2014. Due to the nature and significance of the study, the exhibition period allowed for a longer period of time than the 4 weeks that is usually allowed for. Responses received from the community during the public exhibition period have been considered and addressed in this final document.

Community Engagement

A community engagement strategy was undertaken by Council at the public exhibition stage. Council developed the strategy with the Committee and adopted the Community Engagement Strategic Framework in May 2014. The purpose of the strategy was to engage with the community as part of the development of the FRMS. The adopted Community Engagement Strategic Framework is provided in **Figure 4.6**.

Project Name	Draft Brisbane Water Foreshore Floodplain Risk Management Study	Revision Date	18-February-2014

What Success looks like	The Project Team	The Council	The Community & Other Stakeholders
	The document has delivered an appropriate range of management options for the public to consider.	To provide information to communicate the effects of coastal flooding implications and to present suitable solutions.	Understand the issues relating to flood hazards and the management options and strategies proposed.

INFORM	CONSULT	INVOLVE	COLLABORATE	EMPOWER
Public Participation Goal	**Public Participation Goal**	**Public Participation Goal**	**Public Participation Goal**	**Public Participation Goal**
To provide the public with balanced and objective information to assist them in understanding the problems, alternatives and/or solutions.	To obtain public feedback on analysis, alternatives and/or decisions.	To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered.	To partner with the public in each aspect of the decision, including the development of alternatives and the identification of the preferred solution.	To place final decision-making in the hands of the public.
Promise	**Promise**	**Promise**	**Promise**	**Promise**
We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and provide feedback on how public input influenced the decision.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how public input influenced the decision.	We will look to you for direct advice and innovation in formulation solutions and incorporate your advice and recommendations into the decisions to the maximum extent possible.	We will implement what you decide.
Stakeholders	**Stakeholders**	**Stakeholders**	**Stakeholders**	**Stakeholders**
Other Utilities	Commercial Groups	Community Interest Groups Affected Residence Wider Community MP's - Local Members	Gosford Council Business Units State Agencies Emergency Services	Councillors Catchments & Coast Committee
Engagement Tools	**Engagement Tools**	**Engagement Tools**	**Engagement Tools**	**Engagement Tools**
• Briefings • Displays & Exhibits • Interactive Videos • Information Repository • Media Releases • Printed Information •Technical Papers	• Citizens Committee • Electronic Diplomacy • Open House • Public Meetings • Questionnaires and Response • Submissions • Briefings Internal	• Expert Panel • Simulations • Technical Assistance	• Workshops/Key Stakeholder Interviews • Field Trips • Websites	• Catchments & Coast Committee • Council Stratpol Workshops • Council Meetings

Figure 4.6: Community Engagement Strategic Framework

To enable and encourage greater community engagement from the community, a variety of methods were used throughout the exhibition period. **Table 4.5** shows the range of engagement tools used against the engagement type with respect to the adopted Community Engagement Strategic Framework

Table 4.5: Engagement Tools

Engagement Tool	Date (2014)	Inform	Consult	Involve	Collaborate	Empower
Media Release	18 August	■	■			
GCC Website 'On Exhibition ' launch	18 August	■	■			
Gosford Have Your Say website launch	18 August	■	■	■		
Public Notice Gosford Connect	20 August	■				
Media Release NBN News	20 August	■				
Scheduled Facebook/Twitter post	22 August	■	■			
Scheduled Facebook/Twitter post	25 August	■	■			
Media Release Gosford Connect	27 August	■	■			
Information Session 1 – Erina Centre (afternoon) Feedback loops, Interactive Mapping, Information Packs, Presentation	27 August	■	■	■		
Scheduled Facebook/Twitter post	29 August	■	■			
Drop-in Session – Davistown	3 September	■	■	■		

Engagement Tool	Date (2014)	Inform	Consult	Involve	Collaborate	Empower
(afternoon) One on One Session, Information Packs						
Radio interview and project overview (ABC radio)	3 September	■				
Information Session 2 – Erina Centre (evening) Feedback loops, Interactive Mapping, Information Packs, Presentation	4 September	■	■	■		
Progress Associations newsletter update	9 September	■	■			
Information Session 3 – Erina Centre (midday) Feedback loops, Interactive Mapping, Information Packs, Presentation	10 September	■	■	■		
Community Forum invite letterbox drop	17-24 September	■				
Catchments and Coast Committee	7 May 17 September	■	■	■		
Information Session 4 – Woy Woy (afternoon) Feedback loops, Interactive Mapping, Information Packs, Presentation	18 September	■	■	■		
Letter to Utilities	25 September	■				
Catchments and Coast Technical Subcommittee Workshop	18 December 2013 27 November 2013 13 February 17 July 1 October	■	■	■	■	
Community Forum – Erina (evening)	8 October	■	■	■	■	
Progress Association meetings	24 September 7 October 23 October	■	■	■		
Report to Council Strategy & Policy	20 May 2014	■	■	■		
Report to Council for Adoption	TBA 2015	■	■	■	■	■
Newsletters (6) sent to all participants who registered interest as the exhibition progressed	27 August - 12 November	■				

The main methods of engagement included the Information Sessions with the Community Forum and the online web presence. These were the most utilised and successful methods of engagement with the community.

Community Information Sessions

Five community information sessions were held between 27 August and 18 September 2014. These sessions were held at:

- The Erina Centre;
- Davistown Progress Hall; and
- Peninsula Community Centre.

Residents were informed about the community information sessions through: emails, advertising in newspapers, media release, council's website and social media. According to council's attendance registers 79 people attended the four information sessions. The majority of these (82%) indicated that they first heard about the community information sessions via the newspaper.

Each information session followed a similar format which included; a period of time for residents to review information on display and ask questions of council staff followed by a short presentation and question time. Communication tools and activities used at the community information sessions included; information stands, posters, electronic displays, iPads, brochures, power point presentation, question session and ask questions and written feedback forms.

Community Forum

A community forum was held on 8 October 2014. The communication aim of the forum was to ensure all participants had easy access to information and were provided with an opportunity to have their say in a supportive environment. Residents were informed about the community forum through: letterbox drops, emails, advertising in newspapers, media release, council's website and social media.

According to Council's attendance register 85 people attended the community forum. The majority of participants first heard about the community forum through the newspaper (37%) and the letterbox drop (37%). The format of the forum was based on feedback and lessons learnt from the earlier community information sessions. The format included a period of time for residents to review information on display and ask questions of council staff, presentations from a panel of experts (including Phil Watson from Office of Environment & Heritage, Emma Maratea from Cardno and Laurie Ratz from Insurance Council of Australia), short question session after each speaker, followed by an open forum where participants could make statements and ask questions. The forum followed a set agenda which was developed prior to the event.

Feedback on Community Engagement

To ensure lessons could be learnt from each community information session and the forum, a brief two page feedback form was provided to all participants. Council received approximately 47 completed feedback forms from participants. Based on data contained in these forms the participant feedback was as follows:

- *Communication mediums* – Letterbox drops, emails and local newspapers were the most effective way to communicate with local residents. Social media proved largely ineffective as did council's online forum which attracted only 19 participants;
- *Attendance levels* – Attendance levels increased as the consultation process progressed. This is most likely attributed to publicity generated in the media after the first information session and the decision to conduct a letterbox drop of relevant areas;

- *Written material* – A majority of participants rated the written material provided by Council as being very helpful in giving them an understanding of the Floodplain Risk Management Study, although they also stated there was too much information. The way the information was laid out rated well and this most likely helped people to understand what many viewed as too much or complex information;
- *Presentations* – Most participants rated the presentations during the community information sessions as being very helpful in giving them an understanding of the Floodplain Risk Management Study, although they also indicated the presentations were a bit too long;
- *Community forum* – Most participants rated the community forum as being very helpful in giving them an understanding of the Floodplain Risk Management Study and believed the format enabled them to have their say. Participants viewed the presentations by the guest speakers and answers given by them during the question sessions and forum as informative, although there were some negative comments about the lack of detail in the presentation given by the speaker from the Insurance Council of Australia; and
- *Council staff* – All participants rated council as helpful and friendly both during the community information sessions and community forum.

5 Environmental and Social Characteristics

A summary of the environmental and social characteristics of the Brisbane Water estuary and foreshores is provided in the sections below. These sections draw heavily on the findings of previous studies conducted by Cardno for the Brisbane Water estuary, namely the *Brisbane Water Estuary Processes Study* (Cardno, 2008) and the *Brisbane Water Estuary Management Study* (Cardno, 2011a). Reference should be made to these documents for more detailed information and figures.

5.1 Catchment Area and Topography

The Brisbane Water estuary has a relatively small catchment (164.5km^2) compared to the size of the main estuary waterbody (27.6km^2). The Brisbane Water catchment has undergone extensive rural, residential and industrial development, however natural forest still covers about 50% of the total catchment area.

The principal aspects of the catchment that affect Brisbane Water are the variations, temporal and spatial, in runoff and material loads (e.g. nutrient/sediment) delivered to the waterway. Brisbane Water has sandy and silty shorelines, such as those found at Ettalong, Booker Bay, and Fagan’s Bay. Some of the catchment areas are steep, such as Killcare, and others are flat, such as Davistown.

The climate, soil types, terrain and development condition of the catchment all affect the volume and rate of stormwater runoff, as well as the uplifted sediment load and type and mass of contaminants delivered to the estuary. This can result in localised impacts within the estuary (e.g. enclosed areas such as Fagan’s Bay and the mouth of Narara Creek), however as outlined above, relative to the surface area and volume of the waterway, the catchment is quite small and catchment flows themselves have very little impact on water levels in the larger estuary (Cardno, 2013).

5.2 Catchment Land Use

Much of the western part of the Brisbane Water catchment consists of Brisbane Water National Park, with Bouddi National Park covering part of the south-western corner of the catchment. There are also a number of other Reserves within the catchment. The catchment is partly urbanised with major concentrations of development centred on Gosford in the north and the region of Umina Beach, Ettalong Beach and Woy Woy in the southwest. Other smaller residential centres, including Green Point, Kincumber, Saratoga, Davistown, St Hubert’s Island, Killcare and Pretty Beach, are scattered along the eastern parts of the catchment. Increasing urbanisation in the catchment has been reported to be placing further pressure on the environment (GCC, 2003).

Cardno (2008) categorised land use in the catchment on the basis of aerial photography from 1954, 1986 and 2005. A large proportion of the catchment is comprised of forested or rural/open space. The current dominant land use types include:

- Forest – 50%;
- Rural – 20%; and
- Urban residential – 25%.

In general, land use has changed since European settlement from bushland to urban residential land uses in many parts of the catchment, particularly around Gosford and Ettalong/Woy Woy, with smaller residential areas located around the foreshores. Parts of the western and northern catchment have remained in a significantly more natural state and the National Park areas have been retained substantially in an undeveloped state. However, the population of Gosford has grown significantly in recent years and this trend is expected to continue in the future. Foreshore planning will become increasingly important as the development pressure increases.

5.3 Geology and Soils

Brisbane Water was formed as the result of the drowning of an ancient river valley in relatively recent geological time. The catchment topography rises to 300m above sea level on the high escarpment forming the western catchment boundary. The western to north-western parts of the catchment have generally higher elevations than elsewhere in the catchment. A high proportion of these elevated areas are forested.

The *1:100,000 scale Geological Series Sheet for Sydney* (Chapman and Murphy, 1989) and the *Soil Landscapes Map for Gosford* (Murphy and Tille, 1993) indicate that the catchment is underlain by Hawkesbury Sandstone and the Narrabeen Group Terrigal Formation. Quaternary Alluvium is shown over most of the Woy Woy–Umina Peninsula and around the south-eastern foreshores of the estuary.

The predominant soil types in the Brisbane Water catchment are Erina and Watagan, being classed as Erosional and Colluvial soil types respectively. Erina soils are prone to very high soil erosion hazard, low wet-strength subsoil, localised run-on and seasonal waterlogging of foot-slopes. Watagan soils have mass movement hazard, steep slopes, severe soil erosion hazard and occasional rock outcrops.

5.4 Water Quality

5.4.1 Catchment Inputs

Cardno (2008) found that poor water quality is an issue in some portions of the Brisbane Water estuary, particularly with respect to nutrient and sediment inputs. This has the potential to lead to a range of environmental impacts, such as eutrophication, algal blooms and a decline in seagrasses, and may alter the community dynamics in a range of estuarine habitats. Similarly, poor water quality can impact on recreational usage in some parts the waterway. Whilst available data suggests that water quality is currently of a standard generally suitable for recreational purposes, it is important that monitoring continues to ensure public health and safety. The Gosford District Stormwater Management Plan (1999) provides further detail of the stormwater quality entering Brisbane Water and the Coastal Lagoons noting that a community water quality monitoring program was implemented by Council and community representatives in 1998 (GCC, 1999).

5.4.2 Oceanic Influence

Oceanic processes to some extent governs water quality processes within the estuary. Flushing times are much longer in the upper-estuary due to the attenuation of tidal flows and distance from Broken Bay. This is evident in the salinity data presented in the *Estuary Processes Study* (Cardno, 2008), with salinity generally lower and showing a higher variability for stations located adjacent to creek mouths. In addition, the locations for which flushing occurs over a longer time period are also generally coincident with the major population and commercial/industrial centres. For these reasons, the upper-estuary, particularly The Broadwater, is subject to generally poorer water quality and longer recovery times after a rainfall event. Nonetheless, it appears that there has been a general trend towards water quality improvement in more recent years, although whether this is due to the implementation of catchment-based controls or changes in rainfall patterns (i.e. drought periods) is unclear.

5.5 Flora and Fauna

Estuaries are dynamic ecosystems that are under the influence of complex physical, chemical and biological processes. The Brisbane Water foreshore floodplain represents the interface between a range of different environments, i.e. marine and freshwater, terrestrial and aquatic. Within these broad categories are a number of different habitats ranging from terrestrial habitats (bushland), to intertidal habitats (wetlands / saltmarsh, Casuarina forest, mangroves, mudflats and rock platforms), and aquatic habitats (seagrass beds, submerged rock platforms and sandy or muddy estuarine beds).

Although Brisbane Water has been largely modified by urban encroachment, it remains an area of considerable biodiversity. A comprehensive sampling program was undertaken throughout the Brisbane Water estuary, focusing on the biodiversity of macroinvertebrates (Gladstone, 2007). Five habitats were sampled throughout the estuary (*Zostera capricorni* seagrass meadows, subtidal unvegetated sediment, intertidal mud flats, intertidal hard substrates (natural and anthropogenic) and mangroves) and a total of 324 species (72,524 individuals) were recorded, representing 16 phyla.

5.5.1 Flora

The foreshore of Brisbane Water is the interface between the terrestrial and aquatic environments and includes the estuarine beaches, saltmarshes and wetlands. The Brisbane Water estuary has had significant modifications to its natural foreshores since European colonisation. Prior to the large-scale development of the Brisbane Water estuary, the foreshores and shallow intertidal areas were dominated by Casuarina forests, saltmarsh and mangrove habitat. These wetland environments are important in providing shelter, food, breeding grounds, nursery areas and migratory corridors for marine life, as well as functioning in water storage, buffering water quality and resisting storm-related erosion (OzEstuaries, 2009).

Saltmarsh

Saltmarsh communities occur along the major creeks and are generally fringed by Estuarine Swamp Forest dominated by *Casuarina glauca* (Swamp Oak) with an understorey of sedges and rushes. Further back, on areas with impeded drainage, Swamp Mahogany-Paperbark forests occur characterised by *Eucalyptus robusta* (Swamp Mahogany) and a range of paperbark species such as *Melaleuca biconvexa, Melaleuca linariifolia* (Snow in Summer), *Melaleuca styphelioides* (Prickly-leaved Paperbark) and *Melaleuca quinquenervia* (Broad-leaved Paperbark).

Saltmarsh environments consist of high-intertidal to supra-tidal halophytic (salt-tolerant) vegetation such as salt tolerant grasses, reeds, sedges and small shrubs (OzEstuaries, 2009). Saltmarshes and associated vegetation provide habitat for a wide range of invertebrates, as well as low-tide and high-tide visitors, such as birds and fish (OzEstuaries, 2009). Typically the sediment found in saltmarshes consists of poorly-sorted, anoxic sandy silts and clays with high concentrations of iron sulfides associated with acid sulphate soils (ASS). Carbon concentrations are low and concentrations of organic matter in the soil material are generally high.

Saltmarshes are important for (OzEstuaries, 2009):

- Primary productivity and a support resource for estuarine food webs, particularly for juvenile fish and crustaceans;
- Mediating a balance of nutrients and organic matter between saltmarsh and other interacting, estuarine ecosystems;
- Coastal protection from storm erosion and extreme tides;
- Trapping and binding sediments in the process of land progradation; and
- Maintenance of general estuarine ecosystem function.

This was confirmed for Brisbane Water estuary by Freewater *et al.* (2007), who found that crab zoeae released form saltmarshes within the estuary were a major food source for fish, including a number of recreational fish species.

Mangroves

Mangrove plants grow along sheltered intertidal shores and are subject to large environmental fluctuations in salinity, water temperature, nutrients and oxygen (OzEstuaries, 2009). Mangroves are important habitats for fish, crabs, birds and other animals.

Mangrove trees provide large amounts of organic matter, which is consumed by many small aquatic animals that are eaten by larger carnivorous fish and other animals (DPI, 2007a). The main important functions that mangroves perform are (OzEstuaries, 2009):

- Providing shoreline protection from storms and waves;
- Sediment accretion / trapping;
- Nutrient cycling;
- Buffering of water quality;
- Acting as a major source of primary productivity in coastal environments;
- Providing important nursery habitat for many marine species, including commercially important fish and prawn species;
- Acting as a sink for atmospheric carbon (and thereby mitigating climate change); and
- Acting as an indicator for monitoring change in coastal environments.

Seagrass / Macroalgae

Seagrasses are aquatic flowering plants that form meadows in soft sediments in near-shore estuarine or coastal waters in temperate and tropical regions (OzEstuaries, 2009). Estuarine seagrass habitats are subject to episodic inflows of terrestrial runoff with pulses of nutrients, turbidity and reduced salinity.

Larkum *et al.* (1989; cited Boyland, 2006) identified six important ecological functions of seagrasses:

- Influences on the immediate physical environment (e.g. waves/circulation);
- Stabilisation of sediments;
- Nutrient cycling;
- High levels of primary productivity;
- Provision of food and shelter; and
- Acting as a nursery ground for numerous estuarine and marine species.

Seagrasses also contribute organic matter to the food chain and remove nutrients and sediments from the water, which can improve water quality (DPI, 2007a). Many invertebrate species are associated with seagrass beds, which provide a range of microhabitats due to their structural complexity. As such, seagrass beds provide habitat for many other estuarine and coastal organisms, including commercially and recreationally important fish, mollusc and crustacean species, which use seagrass beds as feeding grounds, nurseries or refugia (DPI, 2007a).

Phytoplankton.

Phytoplankton are microscopic, photosynthetic, plants that are suspended in the euphotic zone of the water column (depth of water subject to light penetration). Phytoplankton forms the basis of the marine food web and so there is a strong correlation between plankton abundance and fish production (DPI, 2007a).

Aquatic Weeds

Caulerpa taxifolia is an exotic fast-growing marine seaweed that, although normally found in warm tropical waters, has become established in several areas that do not form part of its normal range of distribution (DPI, 2007b). *C. taxifolia* can alter marine habitats and affect biodiversity (e.g. by out-competing native flora). *C. taxifolia* has been detected in the Brisbane Water estuary however the origin of the NSW population is not known (DPI, 2007b).

5.5.2 Fauna

The Brisbane Water estuary has high levels of species biodiversity.

Macrobenthic Invertebrates

Benthic invertebrates are organisms that live on the bottom of a water body (or in the sediment) and have no backbone (OzEstuaries, 2009). Such organisms include worms and crabs. These invertebrates maintain environmental health through the performance of a range of ecosystem functions, such as that they:

- Play an important role in cycling nutrients;
- Are essential in the breakdown of detritus and other organic matter;
- Form the basis of many food chains (particularly benthic invertebrates);
- Provide habitat for some species;
- Regulate populations of other organisms through predation, parasitism and herbivory; and
- Help maintain water quality by filtering large amounts of water during feeding.

Fish and Prawns

The Brisbane Water estuary is habitat for diverse fish and prawn assemblages. Some recreationally important species include *Hyporhampus australis* (Eastern Garfish), *Acanthopagrus australis* (Yellow-finned Bream), *Rhabdosagrus sarba* (Tarwhine) and *Girella tricuspidata* (Luderick).

Oysters

Oysters are bivalve molluscs which feed by filtering phytoplankton, bacteria and nutrients from the surrounding water. The oyster industry is an important part of the local economy. In terms of Sydney Rock Oyster production, in 2007/2008 a total of ~250,000 dozen oysters were produced in the Brisbane Water estuary, with a total value of $1.3 million representing approximately 3.6% of the NSW industry total for that year (Wiseman, 2009). In comparison, in 2004/2005, the production was more than double at ~520,000 dozen oysters and the current production is a result of the system recovering after a QX outbreak.

Oyster leases can function to provide valuable habitat for a range of species, including fish (particularly juvenile fish) which shelter amongst the leases (DPI, 2007a). Oysters and the habitats associated with oyster leases are likely to be important resources for other species, such as birds.

Avifauna

The Brisbane Water estuary provides a diverse array of habitat suitable for birds, and houses a variety of shorebirds, waterbirds and forest birds. The estuary is on the route of the East Asian-Australasian Flyway which is used by shorebirds to move between Australia / New Zealand, East Asia and the Arctic region of the northern hemisphere. An avifauna assessment by Robinson (2006) indicated that there are at least 110 species (including 4 exotic species) from 23 Orders, 34 Families (including 1 exotic family) and 79 Genera (including 3 exotic Genera) documented from the estuary.

5.6 Recreational Use

Recreational use of the Brisbane Water estuary and foreshores includes a range of activities such as swimming, bushwalking, boating, and bird watching.

People living in close proximity to the estuary are able to access the estuary and foreshores on a regular basis. The areas in which the public can best gain access to the foreshore occur between Ettalong Beach and Woy Woy, within Woy Woy Bay, between Koolewong and Tascott, between Point Clare and West Gosford, and at Yattalunga, Saratoga and Killcare (Cardno, 2008).

The estuary and foreshores are important for local recreation clubs such as Gosford, Saratoga and Woy Woy Sailing Clubs, Gosford Water Ski Club and Woy Woy Sea Scouts, which hold activities on a regular basis, particularly on weekends and during the summer.

There are two National Parks that exist within close proximity to the Brisbane Water estuary, namely Brisbane Water National Park, which covers an area of 11,473ha between Gosford city and the Hawkesbury River, and Bouddi National Park which stretches from Macmasters Beach to Box Head and Wagstaffe Point. These national parks have significant recreation value, both locally and regionally, and include facilities for bushwalking, picnicking, camping, fishing and swimming.

5.7 Aboriginal and Non-Aboriginal Cultural Heritage

5.7.1 Aboriginal Heritage

The greater Gosford area has traditionally been inhabited by the Kuringai and Darkinjung and it was not until 1788 that Europeans actually visited Brisbane Water (Vinnicombe, 1980; cited HLA Envirosciences, 2005). The natural resources found in the estuary and catchment made the Brisbane Water estuary an attractive place for Aboriginal groups to camp and there are a large number of places and artefacts associated with the area.

The results of an Aboriginal Heritage Information Management System (AHIMS) search were discussed by Cardno (2008). The AHIMS search revealed the following:

- 274 known sites have been identified in Brisbane Water and the surrounding catchments; and
- 74 of these sites are on or adjacent to Brisbane Water, with the remainder being near the shoreline or on related tributaries.

The vast majority of these sites were found to be rock engravings, middens or shelters with middens, indicating the dominant activities of the Aboriginal people in the area in the past. The areas of Pretty Beach and Daleys Point were found to have the highest concentration of known sites, and Kariong, Woy Woy and Cockle Broadwater also have high numbers of sites. Additionally, the high number and variability of sites recorded within the catchment indicates that there is high potential for more sites to be discovered. It is noted that there is potential for significant finds in foreshore areas. It is likely that some of these culturally important items may be affected by existing and future flooding.

5.7.2 Non-Aboriginal Heritage

Early explorations by European settlers occurred in the Brisbane Water area after 1788 and by 1840, the shores were being intensively settled by Europeans. As such, the Brisbane Water estuary contains a number of non-Aboriginal heritage items and places. A total of some 190 non-Aboriginal heritage sites are listed in the Gosford LEP (2014). Heritage items are summarised by HLA Envirosciences (2005) and include 11 terrestrial heritage items located on the estuary foreshores, five terrestrial heritage places, 10 marine heritage items and two heritage items listed on the Register of the National Estate.

Some of these heritage items are likely to be affected by existing and future flooding, including Empire House, Empire Bay and two historic hotel buildings in Woy Woy.

5.7.3 Damage to Heritage Items and Places

Information was provided by NSW Heritage Branch (now OEH) regarding the potential damage to both Aboriginal and non-Aboriginal heritage items or places, particularly those along the Brisbane Water foreshore. Damage to heritage could originate from:

- The impacts of flooding itself, including the projected impacts of sea level rise (i.e. inundation or erosion of heritage items/places);
- Development/installation of flood modification options (structural works) in the vicinity of heritage items or places; and
- Use of heavy vehicles and/or equipment by emergency services in the vicinity of heritage items or places during or after a flood event.

5.8 Visual Amenity

The Brisbane Water estuary and foreshores have particularly high scenic value and include areas of pristine vegetation and extensive views of the water from many locations. Beaches, inlets and bays can be distinguished in the foreground with inherent juxtaposition of bushland-covered hills in the distance. From a recreational perspective, access to existing key vantage points allows for the public to experience the landscape character of the Brisbane Water estuary and its surrounds.

Increased waterway and foreshore development can correspond to a decrease in visual amenity. In the case of Brisbane Water, impacts on the visual character of the area are associated with uncontrolled, cluttered and inappropriate waterfront and foreshore development. The visual character of the Brisbane Water foreshore floodplain may be impacted by flood modification options (e.g. due to the construction of a levee). Such impacts require mitigation and would be assessed under the standard state environmental impact assessment process.

5.9 Utilities and Services

Within the Brisbane Water foreshore floodplain are a range of above-ground and underground infrastructure assets including electricity, water, sewer, natural gas and telecommunications infrastructure. These assets are predominately managed by private companies, with the exception of stormwater, water and sewer assets which are managed by Gosford City Council's Water and Sewer department.

Many of these assets are designed to withstand intermittent flooding. However, the impact of projected sea level rise on utilities and services is potentially a major issue within the floodplain.

5.10 Demographic Characteristics

The demographic characteristics of a catchment are an important consideration when developing a *Floodplain Risk Management Plan*. It is important to understand the current and past demographic trends such that flood management can be implemented appropriately (i.e. the net benefit of investing significant resources for the management of flood risks into a floodplain where the population is steadily decreasing may not outweigh the costs).

Population size and past population increase or decline is important when considering the existing and future flood risk in a floodplain. It is also important to consider demographic characteristics when preparing emergency response or evacuation procedures (e.g. information may need to be presented in a range of languages and special arrangements may need to be made for less mobile members of the community).

A search was undertaken on the Australian Bureau of Statistics website to obtain Census data for suburbs adjacent to the Brisbane Water waterway. A reasonable estimate has been obtained for the catchment. Four postal code areas can be found in the catchment area, however one of them (2250) also encompasses a much larger area than the catchment of Brisbane Water. This postcode was hence split into suburbs. The remaining three post code areas (2251, 2256 and 2257) were searched, in addition to 7 suburbs within the 2250 postcode area (Tascott, Point Clare, West Gosford, Gosford, Point Frederick, East Gosford and Erina). The results were compiled and analysed, and are presented in **Table 5.1**. The foreshore area does not encompass any of these postcode areas or suburbs entirely, but is comprised of sections of each.

Table 5.1: Demographic and Population Characteristics of the Brisbane Water Catchment (ABS, 2011)

Population Characteristics	Statistics
Total population (includes overseas visitors) Males Females	95,073 45,340 49,733
Indigenous population (Aboriginal and Torres Strait Islander)	2,223
Age Distribution	
0 to 14 years	16,372
15 to 24 years	10,557
25 to 64 years	46,261
65 years and over	21,878
Households	
Average household size (persons)	2.2
Dwellings (total)	46,344
Fully owned	14,015
Being purchased	11,422
Renting	10,513
Other or not specified	10,394

General trends for the whole Gosford LGA (as distinct from the data in **Table 5.1** which is for the Brisbane Water Catchment area) are provided below. ABS (2011) recorded the following:

- A population of 162,439 people as at the 2011 Census (9 August 2011), the 12th largest LGA in NSW. It was equal to 2.4% of the NSW population of 6,917,656.
- An increase in 4,282 people over the five years from the 2006 Census to the 2011 Census, the 32nd largest population growth in an LGA in NSW. It was equal to 1.2% of the 365,679 increase in the population in NSW.
- A growth rate of 0.5% per year over the five years to August 2011, the 85th fastest growth in population of an LGA in NSW.

This information has been taken into account in the consideration of emergency response arrangements (**Section 9**) and in the assessment of options (**Sections 10-13**).

6 Flood Behaviour

6.1 Overview

This investigation of Brisbane Water relates primarily to potential floodwaters that rise up from the ocean (and into the estuary) and overtop seawalls and the foreshore. This type of flooding is referred to as *coastal flooding* and is often the result of severe coastal events such as storm surge. This FRMS considers the management of risks associated with coastal flooding because it is the major type of flooding that affects the foreshores of Brisbane Water (Cardno, 2013).

This FRMS does not relate to floodwaters that originate from heavy or prolonged rain causing stormwater to travel downslope towards the estuary. This type of flooding is referred to as *catchment flooding* which is associated with increased creek flows. This flooding mechanism is not dominant in the study area and so has not been considered as a primary mechanism of flooding in this investigation. It is instead covered in separate *Flood Risk Management Plans* for affected tributaries of Brisbane Water. The impacts of proposed management measures on catchment flooding have been considered in the assessment of floodplain management options as part of this study.

The Brisbane Water Flood Study (Cardno, 2013) undertook some limited modelling of catchment events. A comparison of this modelling with the floor level data collected for this study (see **Section 7**) show that very few properties on the foreshore of Brisbane Water are likely to experience over floor flooding as a result of catchment flooding alone. However, some inundation of property outdoor areas along the immediate foreshore could be expected in a 100

Existing flooding conditions within the Brisbane Water foreshore floodplain were considered in the *Foreshore Flood Study* (Cardno, 2013). Existing flood risks form the key part of this FRMS because they are the risks that can be currently experienced. Flood risks associated with projected sea level rise have been considered in this investigation, however it is considered more appropriate to address projected sea level rise risks in future FRMSs and the proposed CCAPs (refer to proposed management option PM9 in **Appendix I**). The above information is summarised in Table 6.1.

Table 6.1: Summary of Flood Behaviour

Existing Scenario (Without Sea Level Rise)		Future Scenario (With Sea Level Rise)	
Issue	***Description***	***Issue***	***Description***
Coastal flooding	Dominant. Infrequent occurrence, high water levels, moderate consequences.	Coastal flooding	Dominant. Infrequent occurrence, higher water levels, high consequences. Projected to increase by 0.4m by 2050 and 0.9m by 2100.
Overland/ Catchment flooding	Not dominant in estuary. Dealt with in sub-catchment or tributary FRMS&Ps (e.g. Erina Creek, Empire Bay/Davistown etc.).	Overland/ Catchment flooding	Not dominant in estuary. Dealt with in sub-catchment or tributary FRMS&Ps (e.g. Erina Creek, Empire Bay/Davistown etc.).
		Tidal inundation	More frequent likelihood, lower water levels, moderate consequences. Projected to start occurring with SLR as a shift in the tidal prism occurs.

The following outlines key sections within this document that relate to the nature of flooding within the Brisbane Water estuary:

- **Existing flooding behaviour:**
  - Flood behaviour description (**Section 6.2**);
  - Flood extent mapping (**Section 6.2** and **Appendix C**);
  - Provisional flood hazard mapping and hydraulic categorisation (**Section 6.2** and **Appendix D**);
  - Hydraulic categorisation (**Section 6.2** and **Appendix E**);
  - Assessment of the effects of hydraulic controls (e.g. bridges) on catchment flows and coastal flooding (**Section 6.3**)
  - Flood damages assessment (**Section 7**); and
  - Flood planning level review (**Section 8**).
- **Projected sea level rise:**
  - Flood behaviour description (**Section 6.4**);
  - Flood extent mapping (**Section 6.4 and Appendix F**); and
  - Flood damages assessment (**Section 7**).

This information is based upon on the results of the *Flood Study* (Cardno, 2013).

6.2 Existing Flood Behaviour

6.2.1 Key Flood Study Findings

There are three types of flooding affecting foreshore properties, coastal flooding (the dominant form of flooding in terms of risk and damage), mainstream flooding (where a creek discharges into Brisbane Water) or overland flow (being flows from relatively small catchments around the whole perimeter of Brisbane Water draining to Brisbane Water via stormwater drains).

The *Brisbane Water Foreshore Flood Study* (Cardno, 2013) concluded that coastal flooding is dominant for the majority of the foreshore areas, i.e. severe ocean storms cause the highest water levels rather than catchment floods of the same ARI. The exception was found to be within Fagans Bay, which can be dominated by catchment flooding in less frequent events (i.e. events greater than 200 Year ARI). This is due to large catchment flows from Narara Creek and the local hydraulic control (the northern railway bridge) which reduces the rate of discharge of catchment flows into the estuary. The recently completed *Review of the Narara Creek Flood Study* (Golder Associates, 2012) provides more detailed analysis of the impact of catchment flooding of Fagans Bay foreshore.

Based on existing conditions, the *Foreshore Flood Study* (Cardno, 2013) incorporated:

- Flood extent and provisional flood hazard mapping based on the velocity-depth criteria defined in the *Floodplain Development Manual NSW Government* (2005). Extent mapping was prepared for three peak design flood events, namely the 20 year ARI, 100 year ARI and PMF; and
- Definition of the hydraulic categories (namely flood fringe, flood storage and floodway areas). The model results and relevant post-processing using available guidelines and methods (such as reported in Howells *et al*, 2003). Hydraulic categories were presented for the 100 year ARI event.

Flood extents for existing conditions were developed using the results of the hydraulic (oceanic) modelling based on a detailed digital elevation model (DEM) (2007) of the Brisbane Water estuary foreshore and catchment areas (provided by Council) and available survey of low-lying areas.

Full details of the flood modelling for existing conditions can be sourced from the *Brisbane Water Foreshore Flood Study* (Cardno, 2013).

6.2.2 Flood Behaviour by Locality (Existing Scenario)

A summary of the existing flooding issues and the number of properties affected on a location-by-location basis is provided in **Table 6.2** (the number of properties affected under the 0.4m and 0.9m projected sea level rise scenarios has also been included for comparison).

The floodplain has been broken down into 15 management areas which were established because flood behaviour varies across the floodplain. Each management area identified below is subject to similar flood characteristics:

1. West Gosford and Point Clare;
2. Gosford;
3. Point Frederick, East Gosford, Green Point, Koolewong and Tascott;
4. Erina;
5. Yattalunga and Saratoga;
6. Davistown;
7. Kincumber, Kincumber South and Bensville;
8. Empire Bay;
9. St Huberts Island;
10. Daleys Point, Killcare and Hardys Bay;
11. Pretty Beach and Wagstaffe;
12. Ettalong;
13. Booker Bay;
14. Woy Woy and Blackwall;
15. Horsfield Bay, Phegans Bay and Woy Woy Bay.

These 15 management areas have been used to assist in the development of management approaches and are further discussed in **Section 10** of this FRMS (and mapped in **Figure 10.1**).

Table 6.2: Flood Behaviour, Issues and Properties Affected by Flooding for each Location

Location	Description of Flooding Issues	Dominated By	Predominantly Affected Land Uses	Number of Properties Affected#		
				100yr ARI (Existing)	100yr ARI (0.4m SLR)	100yr ARI (0.9m SLR)
1	➢ Fagans Bay is dominated by catchment flooding in events greater than the 100 year ARI event. This is due to large catchment flows from Narara Creek and the local hydraulic control (the northern railway bridge). ➢ These reduce the rate of discharge of catchment flows into the estuary. ➢ The recently completed *Review of the Narara Creek Flood Study* (Golder Associates, 2012) provides more detailed analysis of catchment flooding in this location.	➢ Catchment flows in lower probability events. ➢ Coastal flooding in higher probability events.	➢ Open Space ➢ Residential ➢ Special Uses / Infrastructure	162	257	310
2	➢ The foreshore of this location is likely to experience some flooding in less frequent events. ➢ Coastal flooding would affect mainly commercial properties, but only in less frequent events such as the 100 year ARI, 200 year ARI and PMF. ➢ Wave overtopping over the sea wall has occurred in past storm events. ➢ Existing high tides in the Gosford area may result in foreshore inundation, especially with joint occurrence of storm conditions.	➢ Coastal flooding in all events.	➢ Commercial ➢ Special Uses / Infrastructure ➢ Open Space	47	82	103

Location	Description of Flooding Issues	Dominated By	Predominantly Affected Land Uses	Number of Properties Affected#		
				100yr ARI (Existing)	100yr ARI (0.4m SLR)	100yr ARI (0.9m SLR)
3	➢ Some localised areas of flooding in more frequent ARIs likely to occur, mainly overground flooding for residential properties. ➢ Some areas of Tascott are also affected by catchment flows from Tascott Creek. Existing high tides in this area can cause foreshore inundation, especially high tides with joint occurrence of storm conditions.	➢ Coastal flooding in all events.	➢ Residential ➢ Open Space	540	683	797
4	➢ High tides and higher probability ARI events may cause foreshore inundation in this area. ➢ Some areas are affected by catchment flows from Erina Creek.	➢ Coastal flooding in all events.	➢ Open Space. ➢ Special Uses / Infrastructure. ➢ Industrial	13	14	15
5	➢ Residential properties affected by coastal flooding. ➢ Existing high tides in these areas can cause foreshore inundation, especially with joint occurrence of storm conditions.	➢ Coastal flooding in all events.	➢ Residential ➢ Open Space	253	332	376
6	➢ A large number of residential properties are affected, even in more frequent flood events. ➢ Inland penetration of flood waters is larger due to very flat terrain. ➢ Existing high tides in this area can cause foreshore inundation, especially with joint occurrence of storm conditions.	➢ Coastal flooding in all events.	➢ Residential ➢ Open Space	1099	1133	1149

Location	Description of Flooding Issues	Dominated By	Predominantly Affected Land Uses	Number of Properties Affected#		
				100yr ARI (Existing)	100yr ARI (0.4m SLR)	100yr ARI (0.9m SLR)
7	➢ Relatively small areas of residential properties in these suburbs are affected, and mostly in less frequent events. ➢ Existing high tides in this area can cause foreshore inundation, especially high tides with joint occurrence of storm conditions.	➢ Coastal flooding in all events.	➢ Open Space. ➢ Residential ➢ Special Uses / Infrastructure	116	175	242
8	➢ Residential properties are affected even in higher probability ARIs. ➢ Existing high tides in this area can cause foreshore inundation, especially with joint occurrence of storm conditions.	➢ Coastal flooding in all events.	➢ Residential ➢ Open Space	435	514	554
9	➢ Flooding is generally limited by fill levels on the island having been set to above the 100 year ARI event, an only a very small portion of waterfront properties is generally affected. ➢ High tide events in conjunction with storms can cause surcharge of the stormwater system which affects local roads. ➢ Over-floor flooding is unlikely to occur for most residential properties, however over-ground flooding may be experienced. ➢ Storm surge events greater than 100 year ARI have the potential to inundate this area.	➢ Coastal flooding in all events.	➢ Residential	432*	529	552

Location	Description of Flooding Issues	Dominated By	Predominantly Affected Land Uses	Number of Properties Affected#		
				100yr ARI (Existing)	100yr ARI (0.4m SLR)	100yr ARI (0.9m SLR)
10	➢ Flooding is limited by fairly steep terrain at Killcare and Hardys Bay and very steep terrain at Daleys Point. ➢ Over-floor flooding is unlikely to occur for most residential properties, however over-ground flooding may be experienced.	➢ Coastal flooding in all events.	➢ Open Space ➢ Residential	79	142	214
11	➢ Existing high tides in this area can cause foreshore inundation, especially high tides with joint occurrence of storm conditions.	➢ Coastal flooding in all events.	➢ Residential	105	125	146
12	➢ Residential properties are generally not affected by flooding in more frequent events. ➢ In the existing 100 year ARI event, the foredune protects properties from direct inundation, however properties are inundated instead due to surcharge of the stormwater system whereby elevated waters in Brisbane Water "back up" the stormwater system. ➢ High tides do not generally result in foreshore inundation within Ettalong.	➢ Coastal flooding in all events.	➢ Open Space ➢ Residential	10^	112	119
13	➢ Some water-front residential properties in this location are likely to be subject to over-ground flooding in more frequent events such as the 5 and 20 year ARI. ➢ Existing high tides in this area can cause foreshore inundation, especially high tides with joint occurrence of storm conditions. In these instances, roads and some residential properties are affected.	➢ Coastal flooding in all events.	➢ Residential	207	275	353

Location	Description of Flooding Issues	Dominated By	Predominantly Affected Land Uses	Number of Properties Affected#		
				100yr ARI (Existing)	100yr ARI (0.4m SLR)	100yr ARI (0.9m SLR)
14	➢ Residential and commercial properties are affected by flooding even in more frequent flood events such as the 5 year ARI and 20 year ARI. ➢ Existing high tides in this area can cause inundation, especially with joint occurrence of storm conditions.	➢ Coastal flooding in all events.	➢ Residential ➢ Commercial ➢ Special Uses / Infrastructure ➢ Open Space	704	884	1034
15	➢ Coastal flooding is confined to small areas within these three bays and is limited in its extent by steep terrain. ➢ Some overground flooding may be experienced but over-flood flooding is unlikely due to floor levels.	➢ Coastal flooding in all events.	➢ Open Space ➢ Residential	102	124	147

These numbers indicate all properties that intersect with the flood extent for each respective event, even when flooding occurs only on a very small portion of the foreshore land of the property, with no over-floor flooding. Numbers include all properties (residential, commercial, industrial, open space etc.).

* St Huberts Island is not substantially affected by flooding in the existing 100 year ARI event (see # note above). However, a large number of properties was picked up because most properties have a very small waterfront potion that is affected by flooding. A more realistic number of affected properties for the existing 100 year ARI event (i.e. where a substantial portion of the property is affected) is 10.

^ A substantial increase in affected properties occurs if indirect flooding (via surcharge of the stormwater system) is considered (86 properties instead of 10).

6.2.3 Flood Levels (Existing Scenario)

A summary of existing maximum water levels in the estuary for each management area is provided in **Table 6.3**. It is noted that levels in this table do not incorporate wave run-up.

The complete maximum water level dataset can be found in the Appendices of the *Foreshore Flood Study* (Cardno, 2013). The original dataset has been summarised with regards to the 15 management areas described above.

The results of the hydraulic modelling simulations (as summarised in **Table 6.3**) show that extreme water levels caused by ocean storm events are the predominant driver of extreme water levels within the estuary. A direct comparison of equivalent catchment storm and ocean storm ARI events showed that ocean storm levels exceed those of the catchment storms. This is consistent with historical data and the responses provided in resident surveys. Furthermore, at the peak of a 100 year ARI ocean storm event, the volume of water within the estuary is approximately 128,000,000m^3, while the total run-off during a 100 year ARI, 6 hour catchment storm event is in the order 23,500,000m^3. The effect of this catchment event would therefore not be expected to be of the same significance as ocean events.

Table 6.3: Existing Case Peak Water Levels for Catchment and Ocean Floods (Cardno, 2013)

Management Area	Catchment Flood Peak Water Level (m AHD)					Ocean Storm Peak Water Level (m AHD)				
	PMF	200yr	100yr	20yr	5yr	PMF	200yr	100yr	20yr	5yr
1	2.47	1.65	1.44	1.17	0.99	2.23	1.83	1.74	1.55	1.39
2	1.43	1.23	1.13	1.01	0.93	2.23	1.83	1.75	1.55	1.39
3	1.33	1.19	1.10	1.00	0.92	2.10	1.76	1.68	1.50	1.35
4	1.36	1.21	1.12	1.01	0.93	2.08	1.75	1.67	1.50	1.35
5	1.34	1.19	1.11	1.00	0.92	2.02	1.71	1.64	1.47	1.33
6	1.24	1.15	1.06	0.94	0.87	1.75	1.55	1.49	1.36	1.24
7	1.25	1.17	1.08	0.96	0.88	1.64	1.49	1.44	1.32	1.22
8	1.24	1.16	1.06	0.94	0.86	1.65	1.49	1.44	1.32	1.21
9	1.20	1.12	1.04	0.94	0.87	1.84	1.60	1.54	1.40	1.27
10	1.11	1.10	1.03	0.95	0.92	1.77	1.62	1.55	1.45	1.36
11	1.08	1.07	1.01	0.95	0.92	1.85	1.70	1.59	1.49	1.38
12	1.05	1.05	1.01	0.98	0.97	2.08	1.85	1.78	1.63	1.51
13	1.11	1.11	1.02	0.94	0.90	1.87	1.65	1.58	1.45	1.35
14	1.22	1.14	1.05	0.95	0.89	1.92	1.65	1.58	1.43	1.29
15	1.32	1.20	1.11	1.00	0.92	2.07	1.74	1.66	1.49	1.35

6.2.4 Flood Extents (Existing Scenario)

The existing 100 Year ARI and PMF extents are shown on **Figure 6.1** and **Figure 6.2** respectively. Flood extents for all events are provided in **Appendix C**.

The flood extents within the hydraulic model boundary were mapped using the results of the Flood Study (Cardno, 2013) and LIDAR (2007) data. The water level results at the model boundaries have been extrapolated upstream into the tributaries at a later stage and as such, were mapped using 2013 LIDAR data.

A series of representative cross-sections were prepared to visually demonstrate the flooding issues that are typical of each management area. A cross-section for each management area showing flood levels is provided in **Appendix B**.

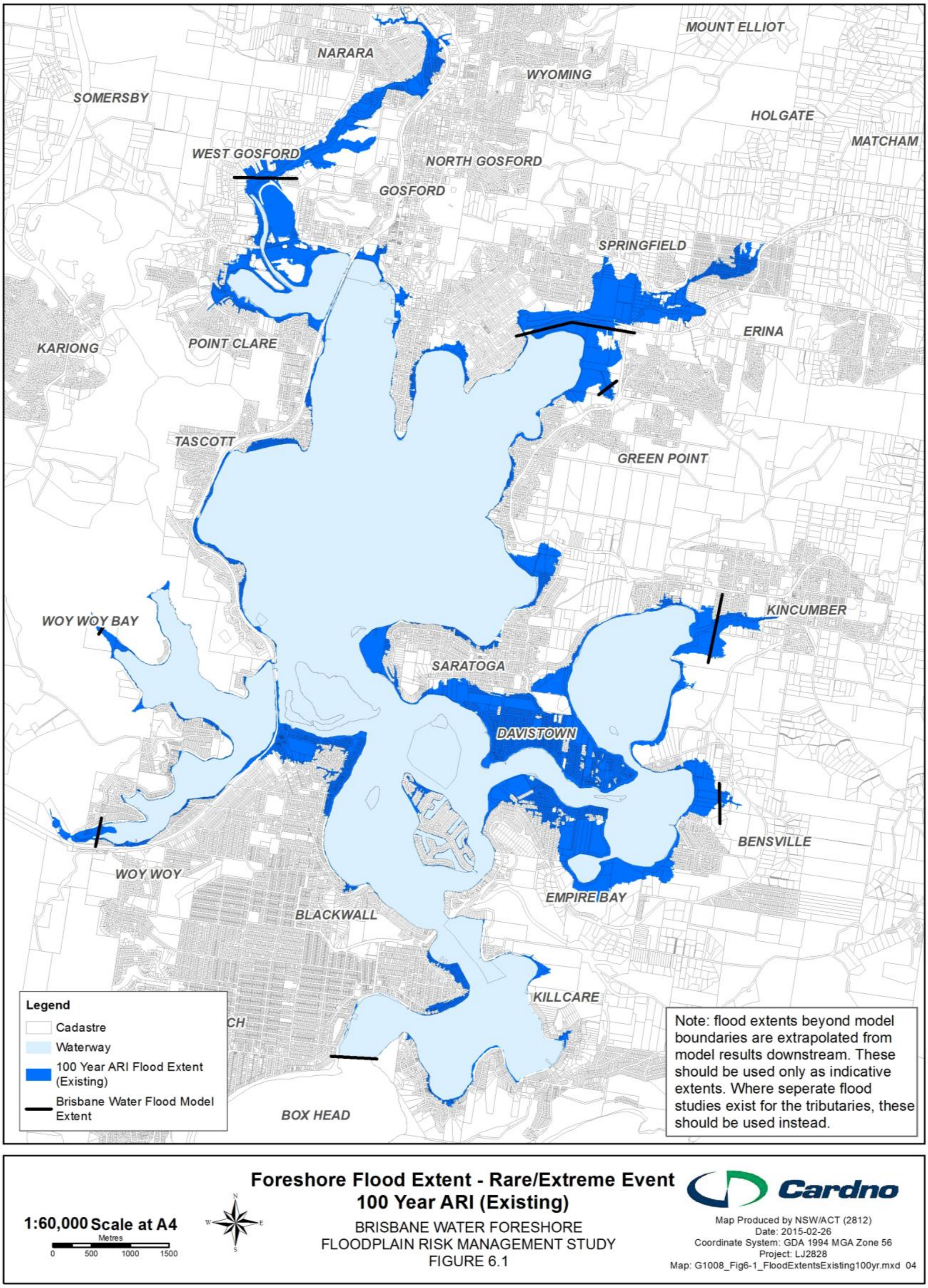

Figure 6.1: Foreshore Flood Extent – Existing 100 year ARI

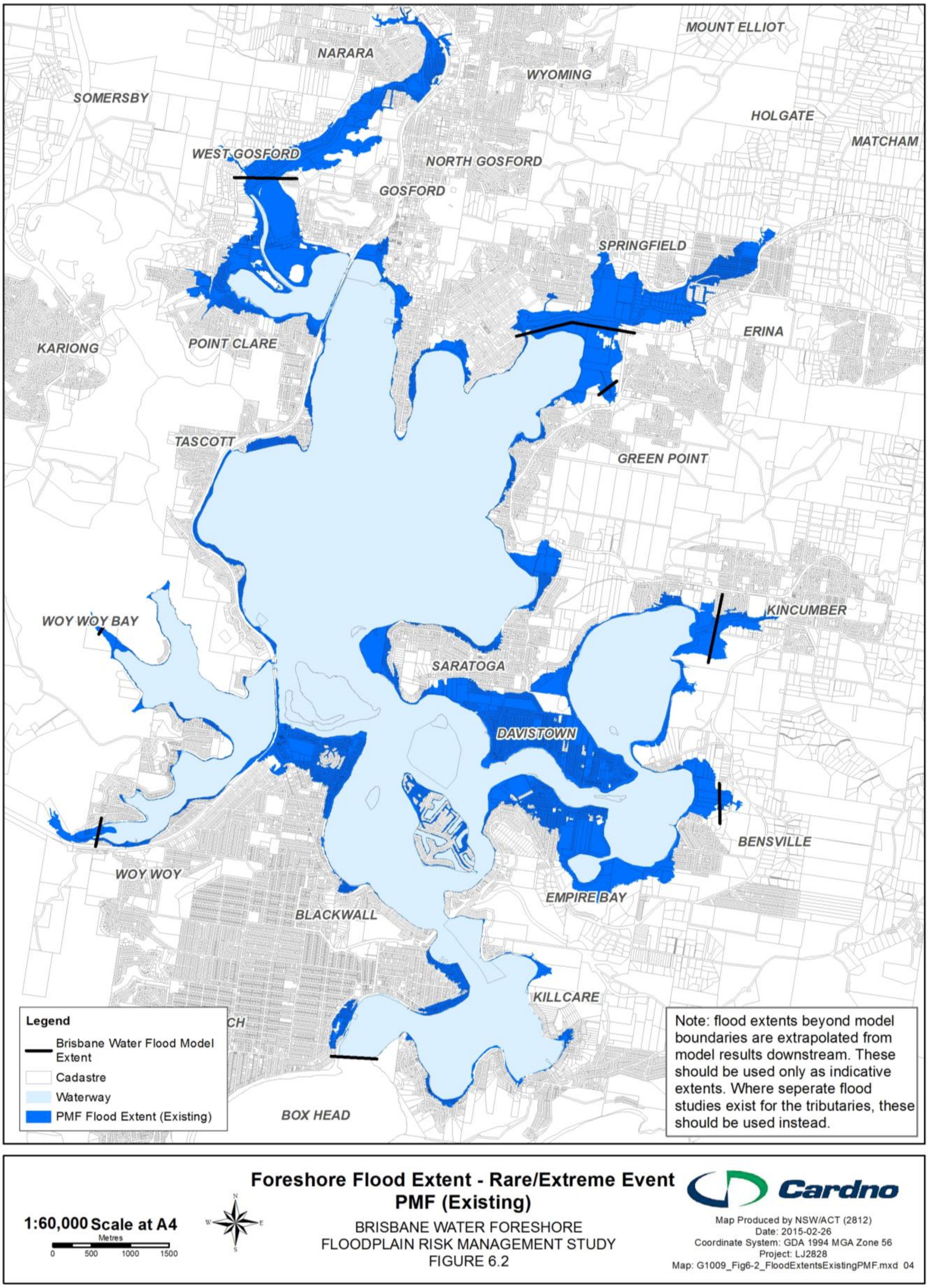

Figure 6.2: Foreshore Flood Extent - Existing PMF

6.2.5 Flood Hazard (Existing Scenario)

Flood hazard can be defined a threat to life and limb and damage caused by a flood. The hazard caused by a flood varies both in time and place across the floodplain.

6.2.5.1 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters (Figure L2, NSW Government, 2005). The Floodplain Development Manual (2005) defines two categories for provisional hazard - High and Low.

The provisional flood hazard was defined as part of the Flood Study (Cardno, 2013) for the 20 and 100 Year ARI and PMF events using an in-house developed program, which utilises the model results of flood depths and velocity. Provisional flood hazard, based on the design still water level and wave setup (but not wave run-up) for the 5, 20, 100 and 200 Year ARI and PMF events has been mapped as part of this FRMS and is provided in **Appendix D**.

It is noted that with projected sea level rise, areas currently mapped as low hazard are likely to transition over time to high hazard, which has implications for planning and development.

6.2.5.2 True Hazard (Existing Scenario)

Provisional flood hazard categorisation is based around initial hydraulic evaluations and does not consider the range of other factors that influence the “true” flood hazard. Provisional hazard has therefore has been assessed in conjunction the following factors to determine true hazard:

- Size of flood;
- Effective warning time;
- Flood readiness;
- Rate of rise of floodwaters;
- Depth and velocity of floodwaters;
- Duration of flooding;
- Evacuation problems;
- Effective flood access; and
- Type of development.

Over time, provisional and true hazard categories may change with projected sea level rise transitioning from low to high hazard.

Size of Flood

The size of a flood and the damage it causes varies from one event to another. For the purposes of this FRMS, provisional flood hazard has been assessed for the 5, 20, 100 and 200 year ARI and the PMF event to provide an indication of the flood hazard that applies to the floodplain for a range of events.

The 100 year ARI hazard mapping forms the basis of the draft development controls (**Appendix H**). The hazard extents for the other events provide a useful indication of areas where large water level depths are experienced, and this may be useful information for the NSW SES in emergency response.

Effective Warning Time

The effective warning time can be described as the time it takes for people to undertake appropriate actions prior to a flood occurring (such as transporting belongings and/or evacuating). The amount of effective warning time is less than the total warning time available to emergency agencies because additional time is needed to alert people that flooding is imminent and for people to begin effective property protection and/or evacuation procedures.

The Brisbane Water estuary has a catchment of approximately 17,000 hectares. The large catchment size and predominately flat, low lying characteristics of the lower catchment in comparison to other floodplains in the region result in a critical duration flood event of 9 hours for the 100 year ARI flood event. This represents a moderate to long amount of time before the peak of a flood event and effective warning time is therefore likely to be relatively long. In addition, forecasts for storm surge and coastal flooding are generally available further in advance than for catchment flooding due to the nature of meteorological predictions. Warning time for the floodplain can be up to a few days in advance if the flooding is related to an event such as an east-coast low but may be shorter depending on the accuracy of predictions.

The effective warning time available to the floodplain is not considered of such a significant duration that it would enable areas of high hazard to be reduced to low hazard. However, the effective warning time has been considered when developing appropriate development controls related to emergency management (e.g. while the priority has been given to evacuation in accordance with NSW SES objectives, the ability to ”shelter in place” has been considered within the controls).

Flood Readiness

Flood readiness can greatly influence the time taken by flood-affected residents and visitors to respond in an effective fashion to flood warnings. In communities with a high degree of flood readiness, the response to flood warnings is generally prompt, efficient and effective. Flood readiness is generally influenced by the time elapsed since the area last experienced severe flooding and the regularly and effectiveness of flood education campaigns.

The last major flood event for the Brisbane Water floodplain was in 1974 (approximately a 150 - 200 year ARI flood event in some cases around the foreshore), with a more recent but less severe event in 2007.

Community education may often increase flood-readiness, however, it difficult to say that a community is truly “flood ready” due to a range of variables, (e.g. presence of current residences at last flood, human behaviour under pressure etc.). The responses from the resident survey (**Section 4.3.1**) found that around 55% of respondents have not experienced flooding in the Brisbane Water foreshore floodplain.

The outcome of the community consultation combined with the substantial amount of time elapsed since the 1974 flood event and limited nature of the 2007 event, would suggest that it is not appropriate to assume that the community is “flood ready”. As such, the flood hazard definition has not been altered to reflect a high level of flood readiness.

Rate of Rise of Floodwaters

The rate of rise of floodwaters affects the consequences of a flood. Situations where floodwaters rise rapidly are potentially far more dangerous and cause more damage than situations where flood levels increase slowly. Both the catchment and floodplain characteristics affect the rate of rise. Whilst the Brisbane Water catchment is relatively steep in some locations, it is quite large compared to the size of the estuary and the floodplain is relatively flat.

During coastal flooding, the estuary acts as a basin which "fills up" at slightly different rates according to location. The nature of the flooding within Brisbane Water (i.e. predominately coastal-driven) results in a slower rate of rise when compared to catchment flooding in other floodplains. The average rate of rise of floodwaters in the Brisbane Water foreshore floodplain for selected flood events is provided in **Table 6.4**.

Table 6.4: Average Rate of Rise of Floodwaters (calculated from Cardno 2013 Foreshore Flood Study)

Event	Rate of Rise (m/hr)
20 Year ARI	0.16
100 Year ARI	0.17
PMF	0.17

The rate of rise for the floodplain is relatively low and so no areas have been identified as having high risk as a result of fast rising floodwaters. Conversely, the rate of rise is not considered sufficiently low such that high hazard areas could be reduced to low hazard.

Depth and Velocity of Floodwaters

Provisional hazard mapping was determined from the depth velocity relationship defined in the *Floodplain Development Manual* (NSW Government, 2005). Given that flood velocities are relatively small (in the order of 0.2m/s in many locations around the estuary, and 1.2m/s at The Rip) high hazard areas for the majority of the Brisbane Water floodplain are largely dependent on depth.

Duration of Flooding

The duration of flooding or length of time a community, suburb or single dwelling is cut off by floodwaters can have a significant impact on the costs and disruption associated with flooding. The majority of the Brisbane Water foreshore floodplain generally has a similar duration of flooding. In a 100 year ARI event, the majority of the floodplain is likely to be inundated for approximately 5 hours, with a likely maximum duration of flooding of 9 hours. Only those areas very close to the foreshore would be inundated for longer. Because provisional hazard definition within the Brisbane Water estuary is primarily depth-driven, areas that are flooded for longer durations are already defined as high hazard.

Figure 6.3 gives an indication of the likely duration of flooding during a 100 year ARI event.

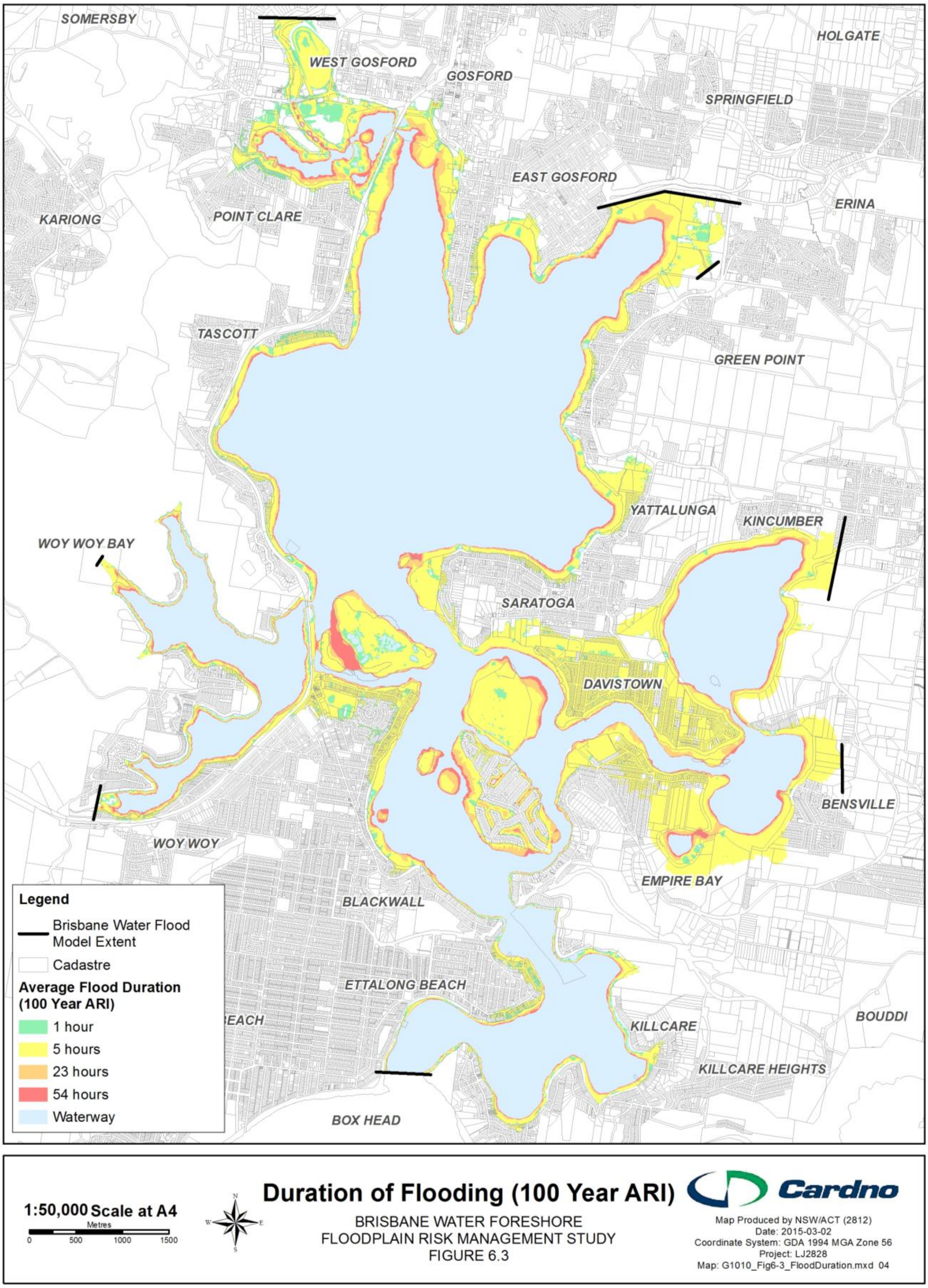

Figure 6.3: Duration of Flooding (100 Year ARI Event)

Evacuation Problems

The levels of damage and disruption caused by a flood are also influenced by the difficulty of evacuating flood-affected people and property. Evacuation may be difficult because of a number of factors, including:

- The number of people requiring assistance;
- Mobility of people;
- Time of day; and
- Lack of suitable evacuation equipment.

Generally, development types which would pose evacuation problems (such as aged care facilities, hospitals and schools) are not permitted within high flood hazard areas (as defined by the relevant development control plan and outlined in the draft development controls in **Appendix H**). Council's *Gosford Local Environment Plan (GCC, 2014a)* and *Gosford Development Control Plan 2013 (GCC 2013a)* specifies the types of developments that are prohibited on flood-prone land (including these types of facilities).

Flood warning and the implementation of an evacuation procedure by the NSW State Emergency Service (NSW SES), is widely used throughout NSW to reduce flood damages and the risk to life. Evacuation problems are an important factor in floodplain management and future planning controls, however as a true hazard factor it does not affect the hazard categorisation of the Brisbane Water floodplain.

Additional information regarding emergency response and evacuation is provided in **Section 9**.

Effective Flood Access

The availability of effective access routes from flood prone areas can directly influence personal danger and potential damage reduction measures. Effective access means an exit route that remains trafficable for sufficient time to evacuate people and possessions.

The majority of the Brisbane Water floodplain is dominated by coastal flooding and hence effective flood access is often not impeded significantly, since evacuation can occur uphill from foreshore areas. This is discussed as 'Areas with Rising Road Access' within the NSW Government's *Flood Risk Management Guideline* (DECC, 2007a). Further discussion on emergency response classification of the Brisbane Water foreshore floodplain is provided in **Section 9.6**.

Within the Brisbane Water foreshore floodplain a potentially hazardous situation can develop when rising floodwaters isolate an area of land prior to ultimate inundation (identified as a 'Flood Island' in DECC, 2007a). In some locations, access is impeded due to the flooding of major and minor access routes. The following locations are likely to experience issues:

- Due to several curved roads and cul-de-sacs, the north-eastern part of the Woy Woy peninsular can act as a flood island. In events greater than the 20 year ARI, and particularly in the 100 year ARI, access becomes inundated and roads are no longer able to be used for evacuation effectively "cutting off" areas not flooded. In events greater than the 100 year ARI, the area becomes increasingly inundated (leaving less area for refuge) and the area becomes fully inundated in the PMF event. Isolation can cause significant additional danger to personal safety due to the potential for these islands to be completely inundated in higher flood events. Once the initial opportunity to evacuate has passed, road evacuation might not be possible, and rescue by boat, helicopter or large vehicle may be necessary (however this puts rescuers' lives at risk also).

- Properties along Yallambee Avenue, West Gosford, including the nursing home/retirement village, which is above the floodplain but is likely to be surrounded by floodwaters and isolated during flood events, with road access cut off.
- Small areas in Davistown and Empire Bay. Filling in Davistown and Empire Bay means that some properties are located on higher ground. During flood events, this leads to a series of "islands" – areas surrounded by floodwaters and isolated.
- Properties along Boyd Close and Beachfront Parade, St Huberts Island. These properties are located on higher ground but would be surrounded by floodwaters and isolated during flood events. Road access is also likely to be cut off.

The duration of flooding in Brisbane Water is moderate (on average 5 hours in the 100 Year ARI) and so isolation risk would be experienced for hours rather than days. Rather than modifying the hazard mapping, the NSW SES need to be informed that this area in Brisbane Water would require prioritisation during evacuation from a flood event. In addition, development controls could be modified to incorporate the effects of flooding in these areas.

Type of Development

The degree of hazard to be managed is also a function of the type of development and resident mobility. This may alter the type of development considered appropriate in new development areas and modify management strategies in existing development areas. As specified in the "Evacuation Problems" section above, Council's *Gosford Local Environment Plan (GCC, 2014a)* and *Gosford Development Control Plan 2013 (GCC 2013a)* specifies the types of developments that are prohibited on flood-prone land.

A full list of applied controls is provided in Council's DCP and LEP documents. The draft development controls for Brisbane Water are provided in **Appendix H**.

Development in the floodplain is largely residential, with some areas of open space, commercial, industrial and special land uses. Much of the development has been present for some time, however, Council's current and future planning controls seek to restrict new development types to be more flood-compatible.

The hazard category of individual properties would not be altered due to current land use type, however it is useful to identify any properties currently located in the floodplain that may require special consideration in terms of flood impacts (e.g. schools, aged care facilities and community buildings). Further details on sensitive land uses such as schools and nursing homes is provided in **Section 9.6**.

A preliminary assessment was undertaken to identify facilities within the floodplain (PMF extent). Properties were identified through a preliminary search of street directories and Google Maps (Google, 2013), and this was supported by the critical infrastructure database provided to Cardno by Council in late 2013. This search identified the following facilities to be within the floodplain:

- Emergency Services:
  - Local SES Headquarters - Pateman Road, Erina;
  - Point Clare Ambulance Station - Coolarn Road, Point Clare;
  - Woy Woy Police Station - 49 Blackwall Rd, Woy Woy;
  - NSW Rural Fire Service - 7 Shelly Beach Road, Empire Bay;

- Childcare Centres:
  - Little Miracles Preschool - 2 Coolarn Ave, Point Clare;
- Schools:
  - St Edwards College - 13 Frederick Street, East Gosford (grounds only);
- Aged Care Facilities:
  - Gosford RSL Leisure Living - Yallambee Ave, West Gosford (grounds and access roads); and
  - Legacy Brisbane Water - 57 Masons Parade, Gosford.

Summary of True Hazard

Due to the nature of flooding in the Brisbane Water foreshore floodplain, the above factors do not alter the provisional hazard mapping.

Consequently, for the purposes of this report, the terms true hazard and provisional hazard are used interchangeably as the true hazard does not deviate from the provisional hazard.

Over time, the provisional hazard and true hazard categories may change over time with projected sea level rise. The outcome of the true hazard assessment provides useful information related to emergency response management, planning controls and the development of appropriate future education campaigns. A summary of the factors which affect flood hazard and the findings of the true hazard assessment are presented in **Table 6.5**.

Table 6.5: Summary of True Hazard Assessment

Factor	Outcome of True Hazard Assessment
Size of flood	The 100 Year ARI hazard mapping forms the basis of the draft development controls (Appendix H). The hazard extents for the other events provide a useful indication of areas where large water level depths are experienced, and this may be useful information for the NSW SES in emergency response.
Effective warning time	The effective warning time available to the floodplain is not considered of such a significant duration that it would enable areas of high hazard to be reduced to low hazard. However, the effective warning time has been considered when developing appropriate development controls related to emergency management.
Flood readiness	The outcome of the community consultation combined with the substantial amount of time elapsed since the 1974 flood event and limited nature of the 2007 event, would suggest that it is not appropriate to assume that the community is “flood ready”. As such, the flood hazard definition has not been altered to reflect a high level of flood readiness.
Rate of rise of floodwaters	The rate of rise for the floodplain is relatively low and so no areas have been identified as having high risk as a result of fast rising floodwaters. Conversely, the rate of rise is not considered sufficiently low such that high hazard areas could be reduced to low hazard.
Depth and velocity of floodwaters	Provisional flood hazard mapping is based upon depths and velocities and is provided in **Appendix D**.
Duration of flooding	Because provisional hazard definition within the Brisbane Water floodplain is primarily depth-driven, areas that are flooded for longer durations are already defined as high hazard.

Factor	Outcome of True Hazard Assessment
Evacuation problems	Rather than modifying the hazard mapping to account for potential evacuation problems (such as flood islands), the NSW SES need to be informed that this area in Brisbane Water would require prioritisation during evacuation from a flood event. In addition, development controls could be modified to incorporate the effects of flooding in these areas. Additional information relating to evacuation of the floodplain is provided in **Section 9.5**.
Effective flood access	Most areas within the Brisbane Water foreshore floodplain have effective access during a flood event, allowing for evacuation and emergency access. However, access to areas of the Woy Woy peninsular is likely to be impeded during flood events, and isolation of some areas is possible. The NSW SES should be aware of the potential issues in this location.
Type of development	Development in the floodplain is largely residential, with some areas of open space, commercial, industrial and special land uses. Much of the development has been present for some time; however, Council's current and future planning controls seek to restrict new development types to be more flood-compatible.

6.2.6 Flood Hydraulic Categorisation (Existing Scenario)

Hydraulic categorisation of the floodplain is commonly used in the development of a *Floodplain Risk Management Plan* and for planning purposes. The *Floodplain Development Manual* (2005) defines flood prone land to fall into one of the following three hydraulic categories:

- Floodway – Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas;
- Flood Storage – Areas that are important in the temporary storage of the floodwater during the passage of the flood. In catchment dominated floodplains, if the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. However, due to the linkage of the floodplain to the ocean, assessments of filling in the Brisbane Water foreshore floodplain have found that even widespread filling has very little impact on flood levels. Therefore, flood storage areas in the Brisbane Water foreshore floodplain have been defined as areas of significant depth which do not comprise of floodway; and
- Flood Fringe – Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

Based on the findings of the Foreshore Flood Study (Cardno, 2013) the floodway was assumed to follow the waterway from bank to bank, as a minimum. In addition, the following depth and velocity criteria were used to define a floodway (however it is noted that these areas represent only a small portion of the floodplain since coastal flooding is primarily depth-driven):

- Velocity x Depth must be greater than $0.25m^2/s$ and velocity must be greater than 0.25m/s; OR
- Velocity is greater than 1m/s.

For flood storage, the criteria used to determine the flood storage was:

- Depth greater than 0.2m; AND
- Not classified as floodway.

All areas that were not categorised as floodway or flood storage, but still fell within the flood extent, are described as flood fringe.

Flood categorisation maps for the 5, 20, 100 and 200 year ARI and PMF events are provided in **Appendix E**.

6.2.7 Property Flooding (Existing Scenario)

The number of properties affected by flooding across the entire floodplain is provided in **Table 6.6**. These numbers include any flood inundation (even minimal) of all property types (residential, commercial, industrial, open space etc.).

Table 6.6: Properties Affected by Flooding – Existing Scenario (Properties that Intersect Flood Extents)

Flood Event	Total
5 Year ARI	**3182**
20 Year ARI	**3828**
100 Year ARI	**4304**
200 Year ARI	**4512**
PMF	**5213**

The number of properties affected by over-floor flooding for each event is shown in **Table 6.7**. These numbers have been derived from the damages assessment (**Section 7**) and the floor levels survey provided by Council (2014).

Table 6.7: Properties Affected by Over-Floor Flooding – Existing Scenario (from Damages Assessment)

Flood Event	Residential	Commercial	Total
2 Year ARI	16	3	**19**
5 Year ARI	63	14	**77**
20 Year ARI	169	33	**202**
100 Year ARI	426	47	**473**
200 Year ARI	566	50	**616**
500 Year ARI	813	61	**874**
PMF	1127	71	**1198**

Note: There were no properties classed as industrial in the property survey provided to Cardno by Council in July 2014.

The range of over-floor flooding depths for the range of design events assessed is shown in **Table 6.8**.

Table 6.8: Existing Range of Over-Floor Flood Depths – Existing Scenario (from Damages Assessment)

Depth (m)	Number of Properties						
	2yr ARI	5yr ARI	20yr ARI	100yr ARI	200yr ARI	500yr ARI	PMF
0 to 0.2	18	76	177	331	393	469	483
0.2 to 0.4	1	0	24	127	182	293	398
0.4 to 0.6	-	1	1	14	40	100	230
0.6 to 0.8	-	-	-	1	0	11	74
0.8 to 1.0	-	-	-	-	1	1	12
>1.0	-	-	-	-	-	-	1
Total	**19**	**77**	**202**	**473**	**616**	**874**	**1198**

Figure 6.4-6.6 show over-ground flood depths at affected properties for the 100 year ARI flood event under existing conditions, averaged for each property.

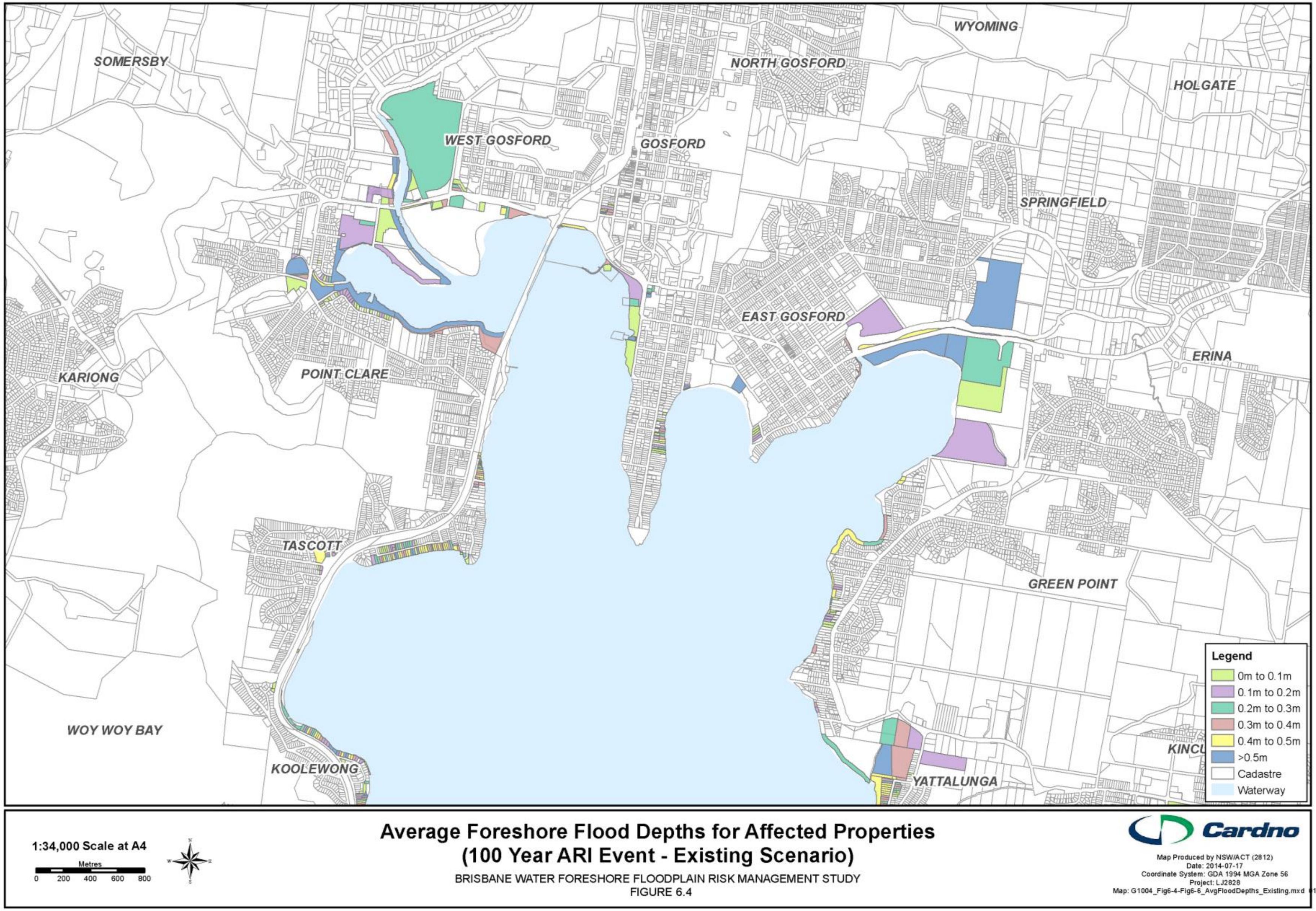

Figure 6.4: Average Foreshore Flood Depths for Affected Properties (100 Year ARI Event – Existing Scenario)

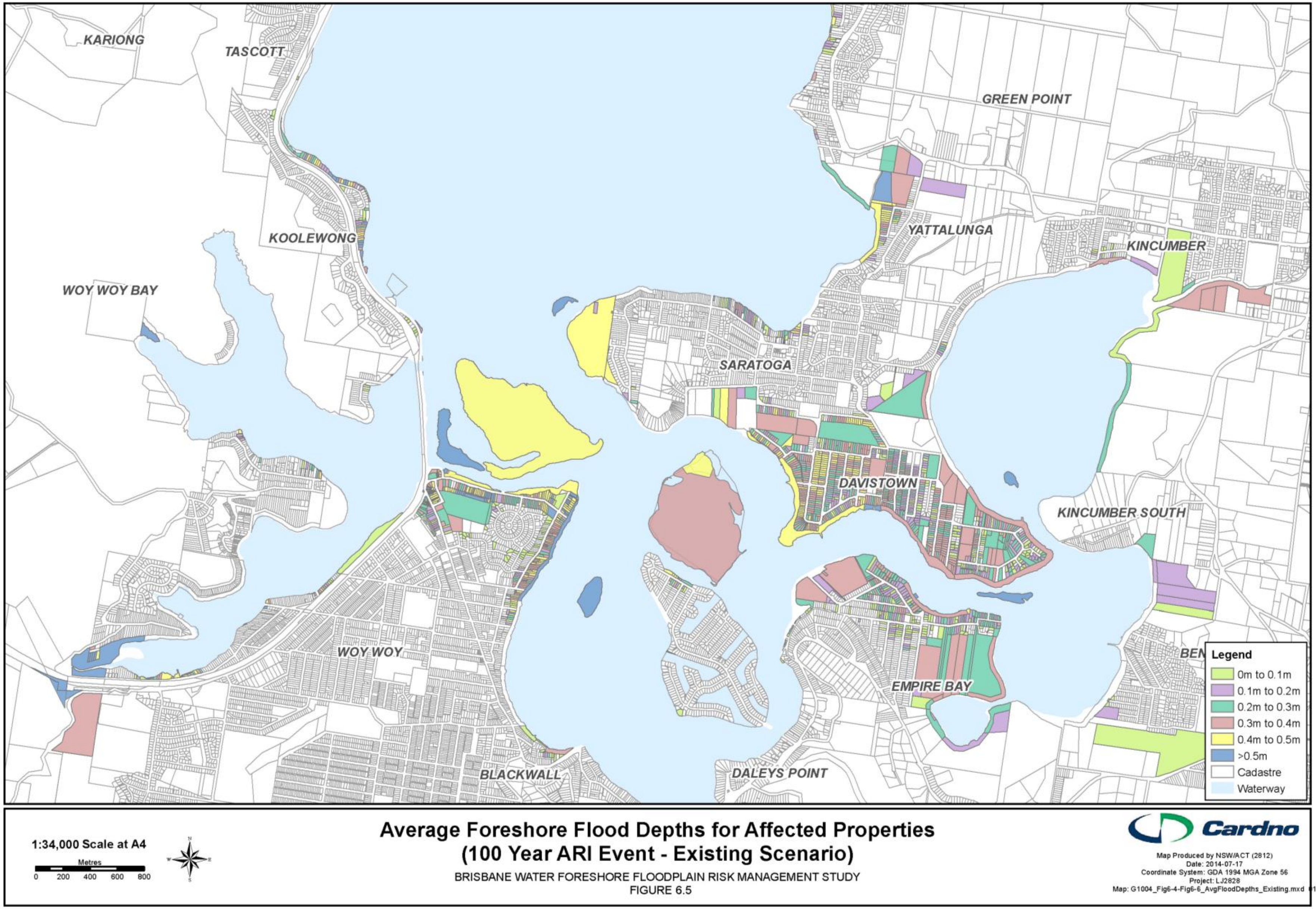

Figure 6.5: Average Foreshore Flood Depths for Affected Properties (100 Year ARI Event – Existing Scenario)

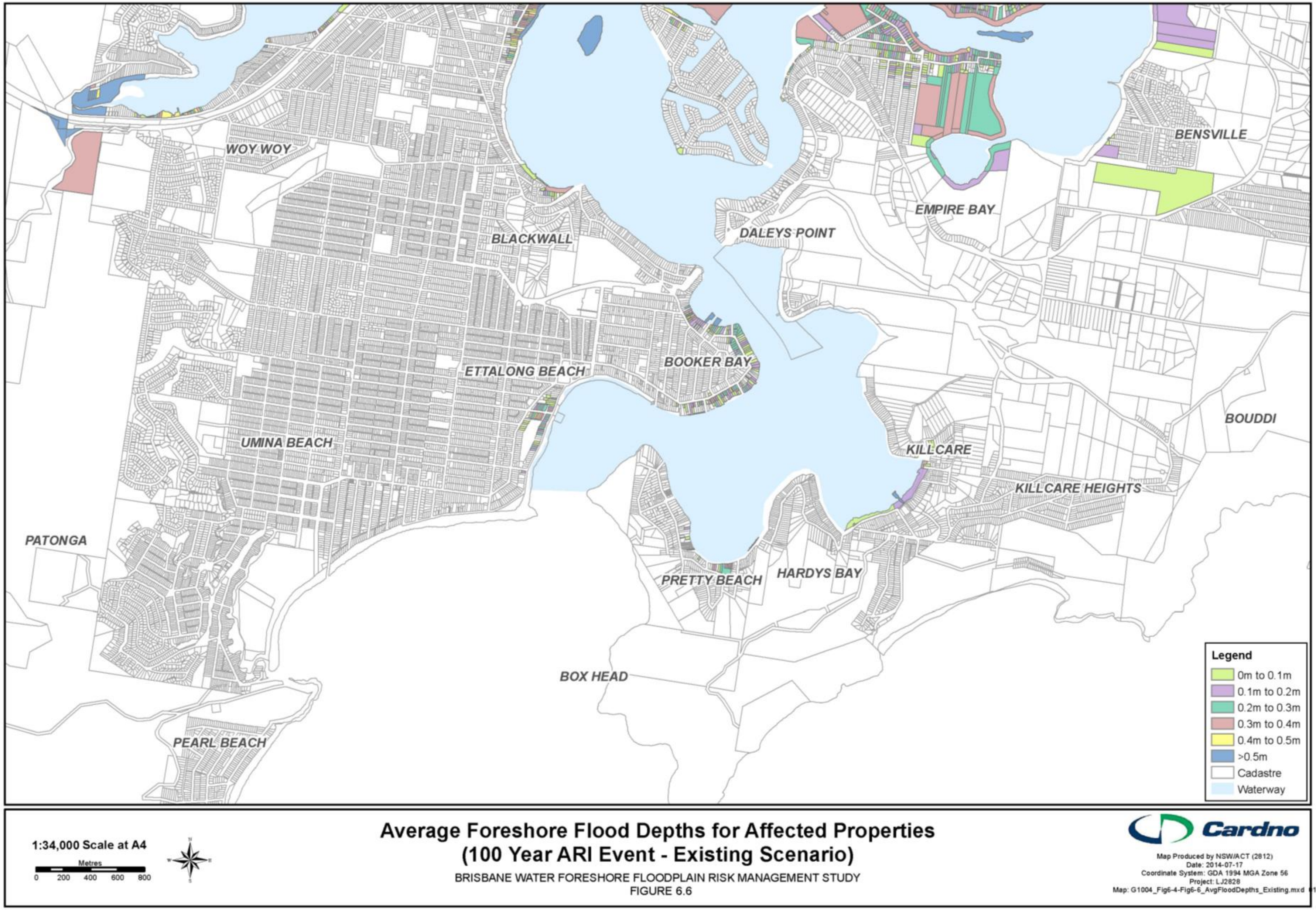

Figure 6.6: Average Foreshore Flood Depths for Affected Properties (100 Year ARI Event – Existing Scenario)

6.2.8 Access Road Flooding (Existing Scenario)

There are a number of access roads that traverse the Brisbane Water foreshore floodplain and may be partially inundated during a flood event. In some cases these roads provide the only route out of a particular area. Access roads that lie within the floodplain include:

- Araluen Drive
- Blackwall Road
- Booker Bay Road
- Brick Wharf Road
- Brisbane Water Drive
- Central Coast Highway
- Coolarn Avenue
- Davistown Road
- Greenfield Road
- Helmsman Boulevard
- Malinya Road
- Manooka Road
- Norma Crescent
- North Burge Road
- Pateman Road
- Pretty Beach Road
- The Entrance Road
- The Esplanade
- Woy Woy Road
- Yallambee Ave

These roads are inundated to different depths for different flood events, and this is discussed in the context of emergency response and evacuation in **Section 9.5.1**.

The Australian Rainfall and Runoff (ARR) (Smith and Cox, 2013) review provides guidance on the safety design criteria for vehicles in flood conditions. Safety is compromised in flood conditions when vehicles become unstable by becoming buoyant or by losing traction. Small passenger vehicles (under 4.3 m in length) may become buoyant in still water at a depth of 0.3 m. In high velocity water (at 3 m/s), small passenger vehicles may lose traction in waters of depth 0.1 m.

6.3 Hydraulic Controls

As described in the *Brisbane Water Foreshore Flood Study* (Cardno, 2013), water levels in Fagans Bay are dominated by catchment flows (as opposed to ocean storms) in events greater than the 100 year ARI. This is due to the northern railway bridge which acts as a hydraulic control and limits the amount of flow from Fagans Bay into the rest of the estuary. The hydraulic control also restricts the amount of ocean storm surge that flows into the bay during a storm event.

As a result of this, additional modelling was undertaken to investigate the effect that the blockage of this hydraulic control would have on flood levels within Fagans Bay and in addition, Woy Woy Bay. During catchment events, large amounts of debris are often swept downstream, and due to the narrow nature of these two bridge structures (each opening is approximately 50m wide) it is possible for swept debris to accumulate around the structures and block the flowpath.

The results of this modelling for the 100 year ARI event indicates that the blockage of these openings can lead to significant increases in the localised flood levels within Fagans Bay (1.6m increase) and Woy Woy Bay (0.6m increase).

6.4 Flood Behaviour with Projected Sea Level Rise

Changes to climate conditions are expected to have adverse impacts on sea levels and rainfall intensities. The NSW Department of Environment and Climate Change (DECC, now OEH) guideline, *Practical Consideration of Climate Change* (2007), provides advice for consideration of climate change in flood investigations. The guideline recommended sensitivity analysis is conducted for:

- Projected sea level rise – for low (0.18 m), medium (0.55 m), and high level impacts up to 0.91 m; and
- Rainfall intensities – for 10%, 20%, and 30% increase in peak rainfall and storm volume

The *NSW Sea Level Rise Policy Statement* (October 2009) prepared by the Department of Environment, Climate Change and Water (DECCW, now OEH) listed that the best projections of sea level rise along the NSW coast are for a rise relative to the 1990 mean sea levels of 0.4 m by 2050 and 0.9 m by 2100. It was acknowledged that potentially higher rates are possible. The supporting Technical Note by DECCW identified the components of the sea level rise estimates were sea level rise, accelerated ice melt and regional sea level rise variation. The Policy Statement recommends these sea level rise benchmarks for use in coastal hazard and flood risk assessments.

In September 2012, the NSW Government announced its Stage 1 Coastal Management Reforms. As part of these reforms, the NSW Government no longer recommends state-wide sea level rise benchmarks for use by local councils, but instead provides councils with the flexibility to consider local conditions when determining future hazards within their LGA.

Accordingly, it is recommended by the NSW Government that councils should consider information on historical and projected future sea level rise that is widely accepted by scientific opinion. This may include information in the NSW Chief Scientist and Engineer's Report entitled *Assessment of the Science Behind the NSW Government's Sea Level Rise Planning Benchmarks* (NSW CSE, 2012).

The NSW Chief Scientist and Engineer's Report (2012) acknowledges the evolving nature of climate science, which is expected to provide a clearer picture of the changing sea levels into the future. The report identified that:

- The science behind sea level rise benchmarks from the 2009 NSW Sea Level Rise Policy Statement was adequate;
- Historically, sea levels have been rising since the early 1880's;
- There is considerable variability in the projections for future sea level rise; and
- The science behind the future sea level rise projections is continually evolving and improving.

In response to this position by State Government, a paper by Whitehead & Associates Environmental Consultants (2014) was undertaken (during the public exhibition period of the Brisbane Water Floodplain Risk Management Study) to develop regionally relevant sea-level rise projections for the NSW South Coast. The key scientific findings of the paper were:

- There is no compelling reason to not adopt the projections of the IPCC as the most widely accepted and competent information presently available.

- Recent sea level rise trends offshore of NSW over the past 130 years are similar to the global average. Future NSW sea level rise will be similar to the global average, with only minor variation.
- A projected increase in global mean sea level between 2015 and 2050 of 0.24m (high) and an increase of 0.4m (high) between 2015 and 2065 (50 year period, which represents a “typical” design life of a residential building).

Council's commitment to considering future risks associated with Sea Level Rise (SLR) is contained within Council’s Climate Change Policy D2.11 (May 2010). Council has considered and accepted competent scientific opinion at the Ordinary Meeting in August 2013 with the endorsement of Climate Change Scenarios for SLR recommended by HCCREMS (2010) *Potential Impacts of Climate Change on the Hunter, Central and Lower North Coast of NSW*.

As this study had commenced prior to the announcement of the NSW Government's Coastal Management Reforms in September 2012 and Councils Climate Change Policy, the potential impacts of sea level rise have been based on sea level rise projections from the 2009 NSW Sea Level Rise Policy Statement. Given that the Chief Scientist and Engineer's Report finds the science behind these sea level rise projections adequate, it was agreed between Council and Cardno that the potential impacts of sea level rise for the Brisbane Water foreshore floodplain were based on the best available information at hand during preparation of this report.

6.4.1 Climate Change

6.4.1.1 Overview

In the future, climate change may affect catchment and coastal processes with flow-on effects for the Brisbane Water estuary and foreshores. It has been suggested that the intensity and frequency of extreme daily rainfall events for the east coast of Australia is likely to increase with climate change in many areas (CSIRO, 2007; Hennessy *et al.,* 2004). Additionally, changes in average annual flows in the order of 30% have been projected, along with effects on coastal erosion including changes in coastal sediment supply and storm intensity and frequency (IPCC, 2007). On the northern NSW coast, linkages between the Inter-decadal Pacific Oscillation (IPO) and El Niño-Southern Oscillation, and changes in coastal geomorphology, have been demonstrated (IPCC, 2007).

The effects of climate change have also been considered specifically for the Hunter-Central Rivers catchments in a report prepared by the NSW Government and CSIRO (2007). It is thought that average temperatures will be warmer, and projected changes in average rainfall may increase but this is not clear. In particular, extreme seasonal rainfall events may potentially increase in frequency and intensity with climate change.

6.4.1.2 Projected and Observed Mean Sea Level Rise

Predictions of global sea level rise due to global warming vary considerably, and the outcome of global sea level rise for any specific region and location also varies depending on a wide range of factors. The potential impact of sea level rise on the existing 100 year ARI design flood event was investigated in the *Brisbane Water Foreshore Flood Study* (Cardno, 2013). It was found that a rise in mean sea level (MSL) would propagate fully into Brisbane Water. Apart from some minor changes in waterway conveyance and over-bank storage associated with a permanent water level rise, existing flood levels presented in the Cardno (2013) *Flood Study* would increase by an amount equivalent to the previously adopted sea level rise benchmarks.

Subsequent to discussions with Council and DECCW (now OEH), Cardno (2013) assessed flood planning levels under four projected sea level rise scenarios. These cases included 0.18m, 0.3m, 0.55m and 0.91m rises over a planning period of 100 years. In accordance with the more recent (but now repealed) *NSW Government's Sea Level Rise Policy* (DECCW, 2009b), the highest projected sea level rise of 0.9 metres was assessed to provide an indication of the long-term implications of sea level rise. The *Projected Sea Level Rise Discussion Paper* (**Appendix G**) builds on the findings of the *Brisbane Water Foreshore Flood Study* (Cardno, 2013) with additional tidal mapping of scenarios with +0.4m and +0.9m sea level rise.

In recent decades modern satellite records have demonstrated that mean sea level is a dynamic, spatially variable quantity and it does not rise uniformly around the globe (Church and White, 2011). National tide gauge records show that there is significant spatial variability in the observed rate of mean sea level rise around Australia (BoM, n.d). In order to provide a regional and local context to the analysis described in the preceding paragraph, the historical local tide gauge data available for Brisbane Water Estuary was analysed and compared with the regional tide gauge records from Fort Denison (~40 km to the south) and Newcastle (~70 km to the north) (**Appendix G.3.1**). Data for Brisbane Water was sourced from Manly Hydraulics Laboratory (MHL) in the form of water level time series with a sample interval of 15 minutes. It is important to note that the reported accuracy of the MHL tide gauge data in the Brisbane Water Estuary is approximately +/-20mm. Comparatively, the tide gauges at Newcastle and Fort Denison are calibrated to a high level of accuracy (+/-2mm) by the operators (Newcastle Port Corporation and Sydney Ports, respectively). The estimated rates of MSLR from the MHL gauges should be considered as indicative and used for contextual purposes only.

Data was available for one tide gauge near the Brisbane Water Entrance (Ettalong), two in the Broadwater (Koolewong and Punt Bridge). Tide data was also available for three tide gauges located in creeks further upstream (New Erina Bridge, Old Erina Bridge and Manns Rd), however, due both to the very short record lengths and the frequency and magnitude of *non-tidal* water level variations recorded by the creek gauges it was considered that these records were inappropriate for trend analysis (**Appendix G.3.1**). In addition to the limited accuracy of the Brisbane Water tide gauges stated above, the record lengths of 20-28 years from these gauges also limits their value in quantitatively estimating MSLR rise.

Both monthly and yearly mean sea levels were calculated for each tide gauge record, and the mean long term trend calculated.

Table 6.9 shows that the rates of MSLR based on monthly and annual data are very similar. Historical MSLR at Ettalong, Koolewong and Punt Bridge are in the range of 3.1-3.7 mm per year, with the highest recorded mean water levels generally having occurred in the time period 2007-2014. Historical rates of mean sea level rise for the same period were lower for Fort Denison and Newcastle, with recorded MSLR of approximately 1.4 and 2.0 mm per year respectively. While caution is required in interpreting the MSLR estimates from Brisbane Water, it is possible that local factors might result in a marginally higher MSLR than the observed regional values.

Table 6.9: Historical Sea Level Rise Analysis for Brisbane Water Estuary (See Appendix G.3.1)

Gauge Location	Date Records Commenced	Most Recent Record	Length of Records	MSLR Based on Monthly Data (mm/year)	MSLR Based on Annual Data (mm/year)
Ettalong	Jul-86	Mar-14	28 Years	3.7	3.7
Koolewong	Jul-86	Mar-14	28 Years	3.1	3.1
Punt Bridge	Feb-94	Mar-14	20 Years	3.5	3.6
Manns Road	Mar-96	Mar-14	18 Years	N/A	N/A
New Erina Bridge	Jun-07	Mar-14	7 Years	N/A	N/A
Old Erina Bridge	Jul-97	Jun-06	9 Years	N/A	N/A
Newcastle	Jul-86	Dec-12	28 Years	2.1	2.0
Fort Denison	Jul-86	Dec-12	28 Years	1.4	1.4

6.4.1.3 Storm Intensity and Frequency

There is no current consensus on the impact of climate change on coastal storms in the Central Coast region of NSW. While the IPCC (2007) warns of a potential increase in the frequency and intensity of coastal storms and cyclone events, recent studies, for example CSIRO (2007) and Hennessy *et al* (2007), present climate change predictions which indicate both increased and decreased wind speeds along the NSW coast, depending on the model and/or climate change scenario applied.

Although an increase in the frequency of cyclones occurring off the Central Coast within the next 50 to 100 years is not expected (CSIRO, 2007), a change in east coast low (ECL) event frequency or intensity may take place due to climate change. Study results are generally inconclusive, and there are limited studies that predict the likely changes to wind conditions generated by small scale systems such as ECL events. Although current understanding on ECL events is limited, it is widely supposed that the El Nino Southern Oscillation (ENSO) cycle has a significant influence on the frequency of ECL events. However, the impact of climate change on ENSO is also inconclusive, with some studies pointing to more frequent and intense ENSO events in the future and others pointing toward fewer ENSO events.

Due to the lack of consensus related to climate change impacts on the frequency and/or intensity of these events it is appropriate to adopt coastal storm conditions based on the current climatology and historical records.

6.4.1.4 Change in Rainfall Patterns

DECCW (2010b) found that summer rainfall is projected to increase across the Central Coast region by 20–50%, with a smaller increase (10–20%) in spring. Winter rainfall is projected to decrease by 10–20% with higher temperatures and increased evaporation, while no significant change in rainfall is projected for autumn. Overall, some redistribution of runoff across the seasons is likely, with increases in summer and autumn and decreases in winter and spring.

Changes in rainfall patterns may affect the likelihood and/or intensity of joint occurrence which may affect coastal flooding.

6.4.2 Flood Extents (Projected Sea Level Rise Scenario)

Flood extents were prepared that incorporate the effects of projected sea level rise. These were prepared without hydraulic modelling, whereby a sea level rise of 0.9m was added to the existing flood levels with no change to catchment inflows. This was considered an appropriate approach since a long-term change to offshore water levels due to sea level rise would translate throughout the whole estuary (i.e. the long-term mean water level will be 0.9m AHD throughout the whole estuary). Once a storm occurs under sea level rise conditions, the change in storm surge penetration up the estuary is considered to be negligible. A sensitivity analysis was undertaken based on the 100 year ARI which confirmed that the proposed approach was appropriate.

Flood extents for the 0.4m and 0.9m SLR scenarios (5, 10, 20, 50, 100, 200 and 500 year ARI and PMF events) are provided in **Appendix F**.

A series of representative cross-sections were prepared to visually demonstrate the flooding issues that are typical of each management area. A cross-section for each management area is provided as **Appendix B**.

6.4.3 Flood Hazard and Hydraulic Categories (Projected Sea Level Rise Scenario)

As described in **Section 0**, projected sea level rise was not hydraulically modelled as part of the scope of this FRMS. Since velocity and depth model results are required for flood hazard and hydraulic categorisation, hazard and hydraulic category extents under projected sea level rise conditions have not been included in this report.

However, as previously mentioned, it is noted that with projected sea level rise, areas currently mapped as low hazard are likely to transition over time to high hazard, which has implications for planning and development.

6.4.4 Property Flooding (Projected Sea Level Rise Scenario)

The number of properties affected by over-ground flooding across the entire floodplain is provided in **Table 6.10**. These numbers include all property types (residential, commercial, industrial, open space etc.).

Table 6.10: Properties Affected by Flooding – 0.9m Projected Sea Level Rise Scenario (properties that Intersect Flood Extents)

Flood Event	Total
5 Year ARI	**5777**
20 Year ARI	**5963**
100 Year ARI	**6111**
200 Year ARI	**6187**
PMF	**6554**

The number of properties affected by over-floor flooding for each event is shown in **Table 6.11**. These numbers have been derived from the damages assessment (**Section 7**).

Table 6.11: Properties Affected by Over-Floor Flooding – 0.9m Projected Sea Level Rise Scenario (from Damages Assessment)

Flood Event	Residential	Commercial	Total
2 Year ARI	1677	114	**1791**
5 Year ARI	1849	123	**1972**
20 Year ARI	2271	138	**2409**
100 Year ARI	2839	164	**3003**
200 Year ARI	3067	169	**3236**
500 Year ARI	3405	184	**3589**
PMF	3742	203	**3945**

Note: There were no properties classed as industrial in the property survey provided to Cardno by Council in July 2014. Survey data was only available for properties affected by flooding up to the Existing PMF.

The range of over-floor flooding depths for the range of design events assessed is shown in **Table 6.12**.

Table 6.12: Range of Over-Floor Flood Depths – 0.9m Projected Sea Level Rise Scenario (from Damages Assessment)

Depth	Number of Properties						
	2yr ARI	5yr ARI	20yr ARI	100yr ARI	200yr ARI	500yr ARI	PMF
0 to 0.2	378	386	518	721	737	694	509
0.2 to 0.4	495	438	403	483	556	661	718
0.4 to 0.6	537	521	523	446	447	490	560
0.6 to 0.8	290	442	540	544	505	477	485
0.8 to 1.0	87	163	319	507	538	550	547
1.0 to 1.2	1	19	98	243	334	462	524
1.2 to 1.4	1	1	5	55	106	203	391
1.4 to 1.6	-	-	1	1	10	49	153
1.6 to 1.8	-	-	-	1	1	-	52
1.8 to 2.0	1	1	-	-	-	1	3
>2.0	1	1	2	2	2	2	3
Total	**1791**	**1972**	**2409**	**3003**	**3236**	**3589**	**3945**

Figure 6.7 - 6.9 show the over-ground flood depths at affected properties for the 100 year ARI flood event with 0.9m SLR, averaged for each property.

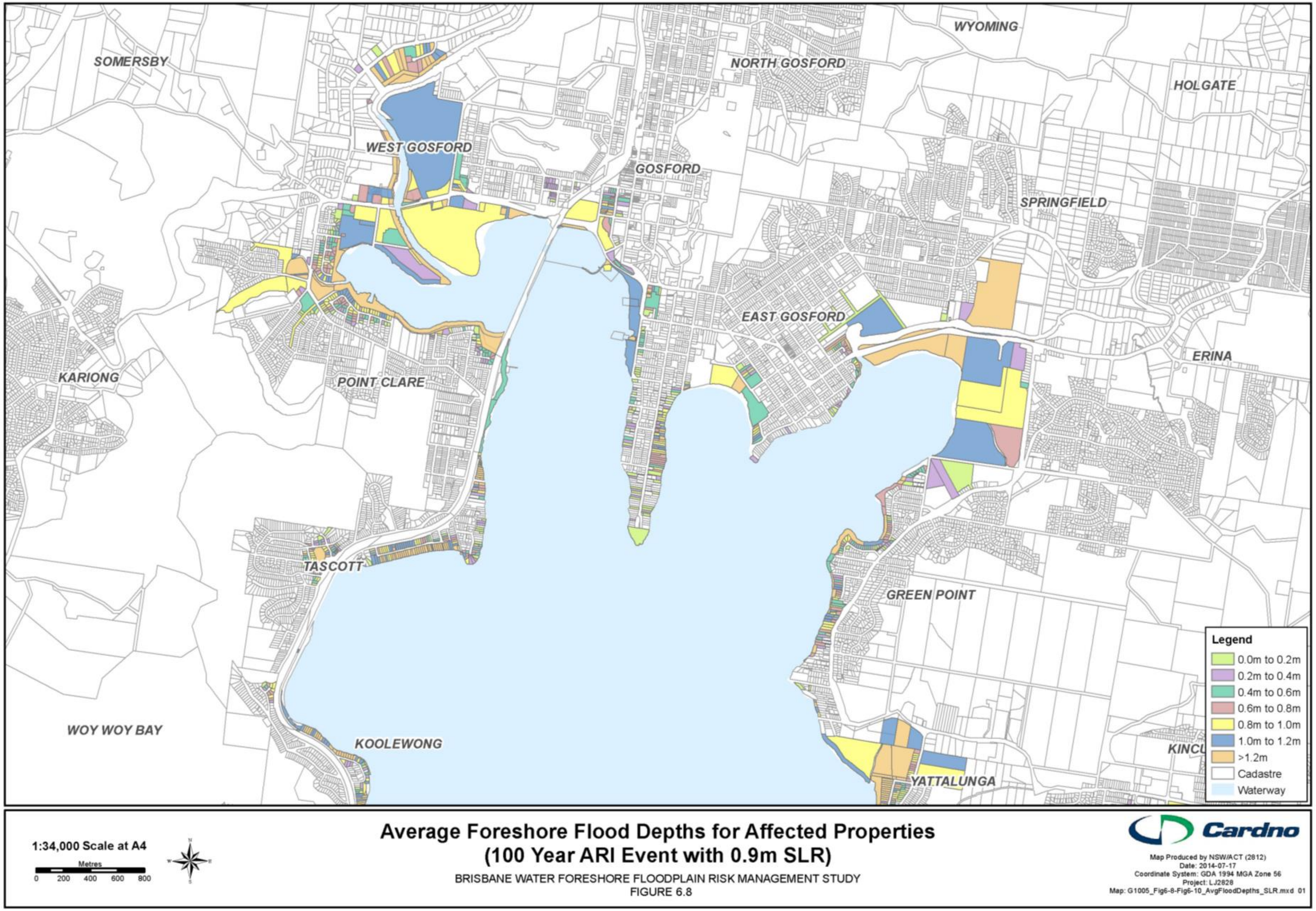

Figure 6.7: Average Foreshore Flood Depths for Affected Properties (100 Year ARI Event with 0.9m SLR)

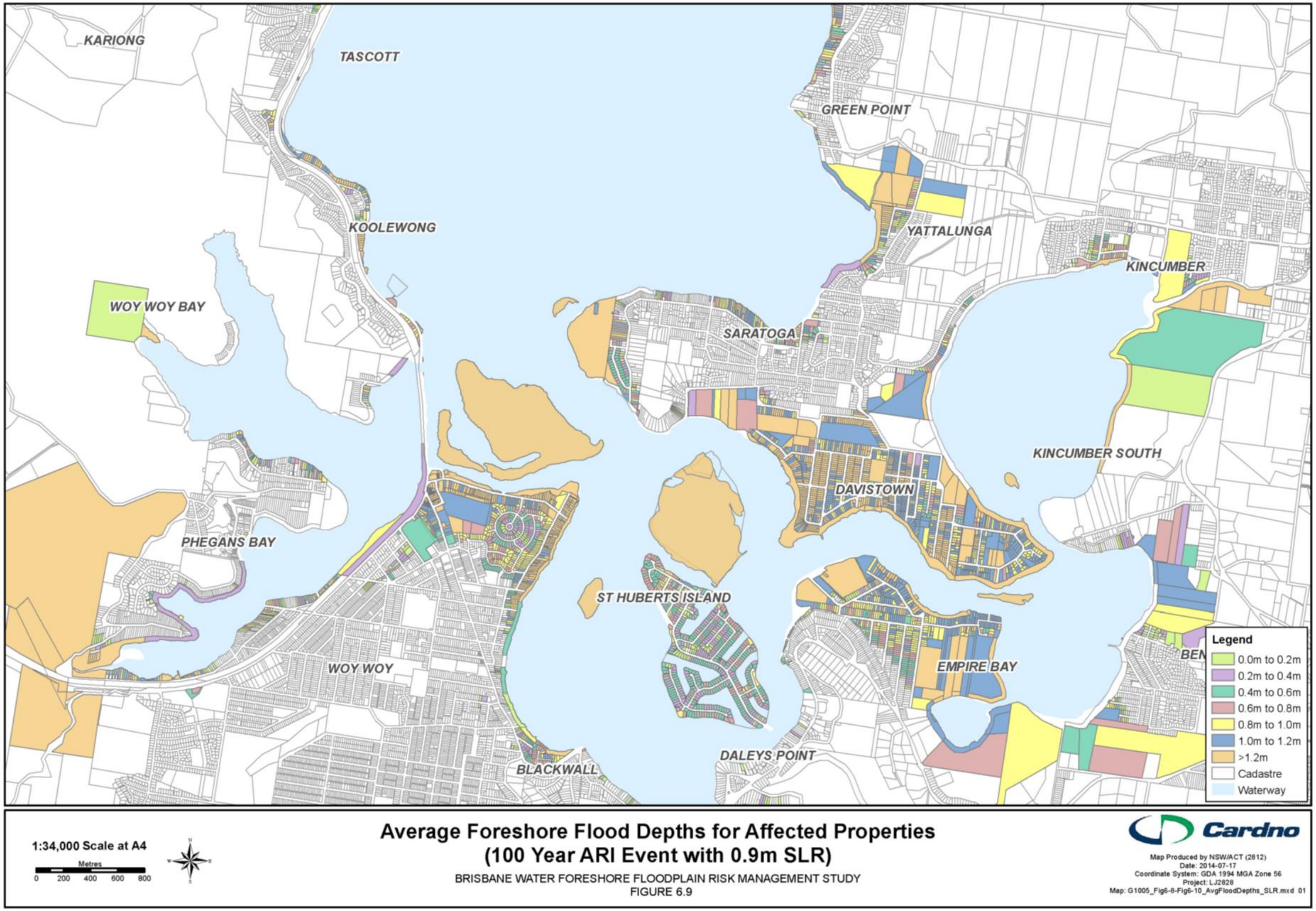

Figure 6.8: Average Foreshore Flood Depths for Affected Properties (100 Year ARI Event with 0.9m SLR)

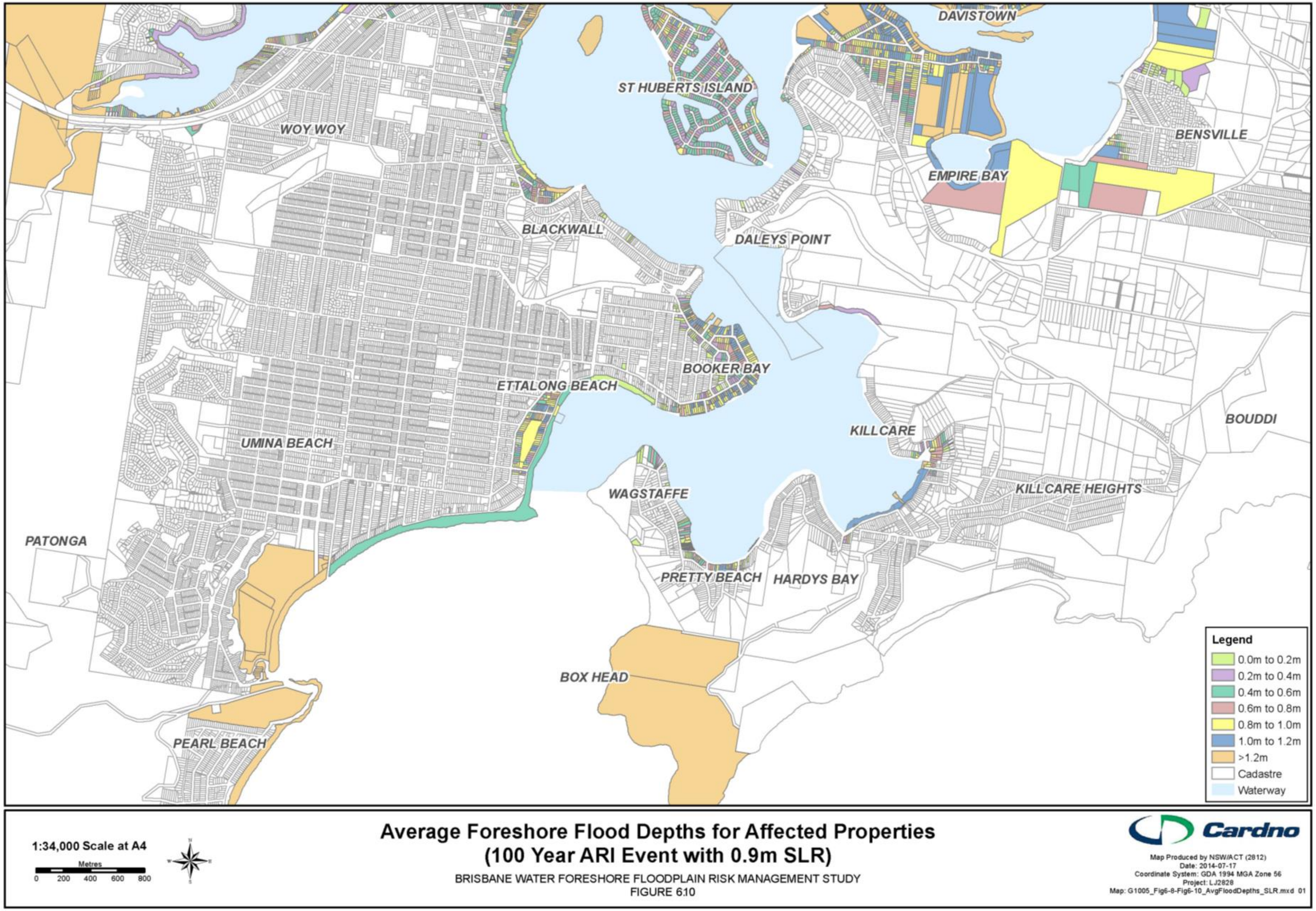

Figure 6.9: Average Foreshore Flood Depths for Affected Properties (100 Year ARI Event with 0.9m SLR)

6.4.5 Access Road Flooding (Projected Sea Level Rise Scenario)

In addition to the roads listed in **Section 6.2.8**, a number of additional roads may be partially inundated in a PMF event under the 0.9m projected sea level rise scenario, including:

- Brisbane Water Drive, Koolewong; and
- Davistown Road, Yattalunga.

These two roads currently provide major routes for evacuation and emergency access.

6.4.6 Tidal Inundation (Projected Sea Level Rise Scenario)

A discussion paper outlining anticipated tidal inundation as a result of sea level rise (i.e. the day to day effects, rather than the effects occurring concurrently with a coastal flood event) has been included as **Appendix G**. This type of inundation will also form part of the proposed CCAPs to be undertaken.

7 Economic Impact of Flooding

7.1 Overview

Major historical flood events in Brisbane Water include the severe ocean storm of 1974 and a more recent but less severe event in 2007. Past flooding of the Brisbane Water foreshore floodplain has caused property damage, impeded emergency access and inconvenienced residents.

The economic impact of flooding can be defined by what is commonly referred to as 'flood damages'. There are several types of flood damages, as outlined in **Table 7.1**.

Table 7.1: Types of Flood Damages

	Type	Description
Tangible	Direct	Building contents (internal) Structural (building repair and clean) External items (vehicles, contents of sheds etc)
	Indirect	Clean-up (immediate removal of debris) Financial (loss of revenue, extra expenditure) Opportunity (non-provision of public services)
Intangible		Social - increased levels of insecurity, depression, stress General inconvenience in post-flood stage

Financial and community attitude surveys and analysis undertaken in other areas of NSW (e.g. Gillespie *et al*, 2002) suggests that many people would have real difficulties dealing with the cost of recovering from severe flooding.

The direct damage costs, as indicated in **Table 7.1**, are just one component of the entire cost of a flood event. There are also indirect costs. Both direct and indirect costs are referred to as 'tangible' costs. In addition to this there are also 'intangible' costs such as social distress. The flood damage values discussed in this report are the tangible damages and do not include an assessment of the intangible costs which are difficult to calculate in economic terms.

Flood damages can be assessed by a number of methods including the use of computer programs such as FLDAMAGE or ANUFLOOD or via spreadsheets. For the purposes of this project, a specialised damages tool has been used with assistance from GCC and OEH on the adoption of appropriate damage curves.

7.2 Damage Analysis

Damages were calculated for the existing case, the 0.9m projected sea level rise scenario and for a number of flood risk management options (**Section 11**). It should be noted that damages calculated under projected sea level rise are unlikely to accurately represent the AAD in the future due to the huge range of variables that can occur between now and when sea level rise reaches 0.9m (such as property modifications, retreat and coastal protection works). It is strongly recommended that the damages results under projected sea level rise be utilised as an indication only.

The flood damage assessment for Brisbane Water was undertaken utilising floor level survey provided by Council to Cardno in July 2014. The floor level survey recorded a range of data for each property, including ground and floor levels (reduced to Australian Height Datum) and other key features. Approximately 4,000 properties were surveyed. The damages assessment is based on damage curves that relate the depth of flooding on a property to the likely damage within the property. Ideally, the damage curves should be prepared on a floodplain by floodplain basis. However, damage data for many floodplains is not available and recourse is generally made to damage curves from other floodplains. OEH carried out research and prepared a methodology to develop damage curves based on state-wide historical data (DECC, 2007a). This methodology is only for residential properties and does not cover commercial or industrial properties.

The OEH methodology is only a recommendation and there are currently no strict guidelines regarding the use of damage curves in NSW. However, correspondence with GCC at the outset of the economic damages component of this study confirmed that the use of OEH curves was appropriate.

The following sections set out the methodology for the determination of damages within the Brisbane Water foreshore floodplain.

7.3 Damage Curves

7.3.1 Residential Damage Curves

The *Floodplain Management Guideline Residential Flood Damage and Supporting Calculation Spreadsheet* (DECC, 2007a) was used for this assessment. These guidelines include a template spreadsheet program that determines damage curves for three types of residential buildings:

- Single Storey, slab on ground
- Two Storey, slab on ground
- Single Storey, high-set.

See **Section 7.3.4** for the adopted residential damage curves, which were produced using a specialised damages tool created by Cardno.

Damages are generally incurred on a property prior to any over-floor flooding. The OEH curves allow for a damage of $11,009 (March 2014 dollars) to be incurred when the water level reaches the base of the house (the base of the house is determined by 0.3m below the floor level for slab on ground). We have assumed that this remains constant until over-floor flooding occurs. A nominal value of $3,000 has been allowed to represent damage to gardens where the ground level of the property is overtopped but no over-floor flooding occurs.

In addition, the following parameters were adopted:

- **Floor areas and associated damage:** Floor areas for residential properties were not provided in the 2014 detailed property survey data. Based on a brief aerial photograph investigation, the average residential floor area in the Brisbane Water foreshore floodplain was approximated for small, medium and large premises. Results indicated an average of 180m^2 for small premises, 240m^2 for medium and 310m^2 for large. These values were adopted for residential dwellings in the floodplain. For a floor area of 310m^2, the default contents value is $70,500 (in 2014 dollars);
- **Flood warning times:** Since it is unlikely that a flood warning would be successfully received by all flood-affected residents in the floodplain, the effective warning time has been assumed to be zero. A short effective warning time does not allow residents to prepare for flooding by moving valuable household contents (e.g. the placement of valuables on top of tables and benches).

7.3.1.1 Rapid Property Survey

In August 2009, a rapid property survey was carried out by Cardno to ascertain the character and provide an indication of average floor levels of residential properties on the Brisbane Water foreshore floodplain.

Selected representative properties were visually surveyed in the following suburbs:

- West Gosford;
- Point Clare;
- Koolewong;
- Woy Woy;
- Ettalong Beach;
- Booker Bay;
- St Huberts Island;
- Empire Bay;
- Killcare;
- Bensville;
- Kincumber;
- Davistown;
- Green Point; and
- East Gosford.

Survey results indicated that floor heights vary between suburbs. However, given the nature of the flood damages assessment process and the limited floor survey data, an average floor height of 0.4m above the ground level was considered representative.

7.3.1.2 Detailed Property Survey

In early 2014, Council commissioned a detailed property survey for all affected properties on the Brisbane Water foreshores within the existing PMF extent. This survey included records of property type, premises size, and ground and floor level data for each property. This data was provided to Cardno in July 2014 and supersedes the rapid property survey data (**Section 7.3.1.1**). It is noted that for those properties beyond the limit of the detailed property survey, data from the rapid property survey has been used since it is the only available information.

The method adopted for those properties *beyond the limit of the detailed property survey* was as per the methodology undertaken for the rapid property survey (**Section 7.3.1.1**), as summarised below:

- The average ground level for each property was determined using GIS and LiDAR data;
- The floor level of each property was estimated using the average ground level added to the adopted 0.4m floor height; and
- The category of property (residential, commercial or industrial) was identified using Council's most recent LEP zone mapping (2014).

7.3.1.3 Average Weekly Earnings

OEH damage curves were derived for late 2001. It is recommended that values in residential damage curves be adjusted to 2014 using Average Weekly Earnings (AWE) rather than the inflation rate as measured by the Consumer Price Index (CPI). AWE is considered a better representation of societal wealth, and hence an indirect measure of the building and contents value of a home.

While the month was not specified, it was assumed that the curves provided guidelines were derived in November 2001, which allows us to use November 2001 AWE statistics (issued quarterly) for comparison purposes. November 2001 AWE is provided in a worksheet within the OEH calculation spreadsheet. June 2014 AWE was taken from the Australian Bureau of Statistics website (www.abs.gov.au). **Table 7.2** shows a comparison of AWE statistics.

Table 7.2: AWE Statistics

Month	Year	AWE
November	2001	$676.40
June	2014	$1,114.20

Consequently, damages on the base curves from OEH have been increased by 64.7%.

7.3.2 Commercial Damage Curves

Commercial property damage curves have been adopted from the FLDamage Manual (Water Studies, 1992). FLDamage allows for three types of commercial properties:

- Low Value Commercial;
- Medium Value Commercial; and
- High Value Commercial.

For the purpose of this assessment all commercial properties have been classified as medium value. In determination of the damage curves, it has been assumed that the effective warning time is zero and the loss of trading days as a result of the flooding has been taken as 10. See **Section 7.3.4** for the adopted commercial damage curves.

The Consumer Price Index (CPI) was used to bring the 1990 data to March 2014 dollars (this data was obtained from the Australian Bureau of Statistics website (www.abs.gov.au). It was assumed that the Water Studies Pty Ltd data was in June 1990 dollars. The CPI data is shown in **Table 7.3**.

Table 7.3: CPI Statistics

Month	Year	CPI
June	1990	102.50
March	2014	189.20

Consequently, damages on the FLDamage curves have been increased by 84.8% and GST has been included compared to 1990 values.

7.3.3 Industrial Damage Curves

Based on the detailed survey data provided to Cardno in July 2014, no surveyed properties were classified as industrial. However, a small number of industrial properties were noted to be affected by Brisbane Water flooding in the sea level rise scenario.

In a previous study, Cardno conducted a survey of industrial properties for Wollongong City Council (Cardno, 2006). The damage curves derived from this survey are more recent than those presented in the FLDamage Manual (Water Studies Pty Ltd, 1992) and have been used in a number of other floodplain management studies. These damage curves have therefore been adopted for this study.

The curves were previously prepared for three categories:

- Low Value Industrial;
- Medium Value Industrial; and
- High Value Industrial.

For the purpose of this assessment all industrial properties were classified as medium value industrial, as no other information was available.

In addition to direct structural and contents costs, clean-up costs and indirect financial costs were estimated based on the FLDamage Manual (Water Studies, 1992). Actual internal damage could be estimated, along with potential internal damage, using various factors within FLDamage. Using both the actual and potential internal damages, estimation of both the clean-up costs and indirect financial costs could be made. The values were adjusted to March 2014 dollars using the CPI statistics shown in **Table 7.4**.

Table 7.4: CPI Statistics

Month	Year	CPI
June	1998	121.00
March	2014	189.21

Consequently, damages on the base industrial curves have been increased by 56.4% and GST has been included compared to 1998 values.

7.3.4 Adopted Damage Curves

The adopted damage curves are shown in **Figure 7.1** and **Figure 7.2.** The commercial damage curves are for a property with a floor area of 100m^2.

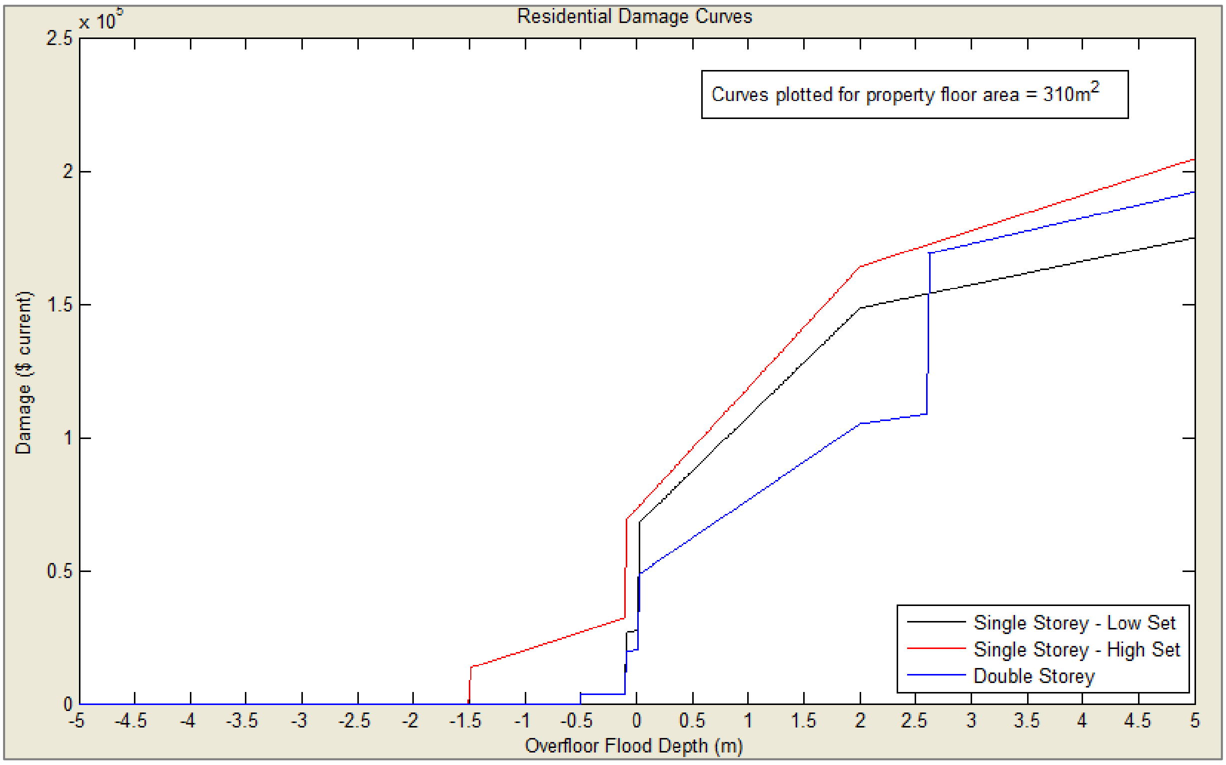

Figure 7.1: Residential Damage Curves

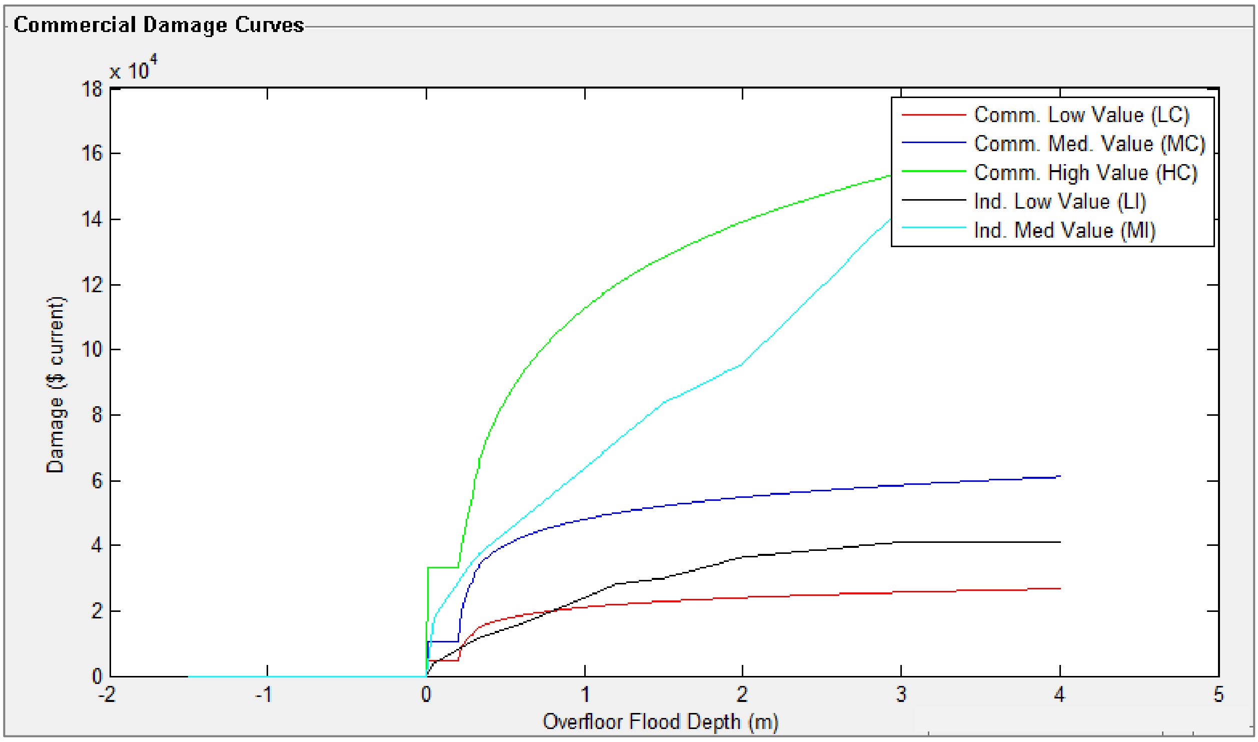

Figure 7.2: Commercial and Industrial Damage Curves

7.4 Average Annual Damage

Average Annual Damage (AAD) provides an estimate of flood damages for a particular floodplain in any given year. It is a probability approach based on the flood damages calculated for each design event.

Over a long period of time, a flood liable community will be subject to a succession of floods. This succession can generally be broken down into the following:

- Most years – flooding does not occur, or, flooding is too small to cause damage;
- Some years – flooding occurs that is large enough to cause damage, but the damage will generally be small because the floods are small to medium sized; and
- On rare occasions – major floods will occur that cause great damage.

The average annual damage (AAD) incorporates all of the above and is equal to the total damage caused by all floods over a long period of time divided by the number of years in that period. This equates to the area under the 'damage – annual likelihood of occurrence' curve by event. It is assumed that the development situation is constant over the analysis period.

7.4.1 Calculating AAD

It is not known how a sequence of flood events might occur at a particular flood liable community. However, it is known that on average, the 20 year average recurrence interval (ARI) event will occur once every 20 years (an annual exceedance probability (AEP) of 5%), the 50 year event will occur on average once every 50 years (an AEP of 2%), etc.

By using a probability approach, AAD attempts to quantify the flood damage that a floodplain would receive on average during a single year. By examining a range of floods, the potential and actual damages caused by floods of different severities can be estimated. The variation of flood damage with the annual likelihood of occurrence of the flood (AEP) can then be plotted, as shown in **Figure 7.3**, **Figure 7.4** and **Figure 7.5**. These plots are known as probability or total flood damage curves. This information is provided in tabulated format in **Table 7.5** and **Table 7.6**.

These curves attempt to define the damage experienced on a property for varying depths of flooding so that flood damages for a design event can be calculated. For example, the 100 year ARI design event has a probability of occurring of 1% in any given year, and as such the 100 year ARI flood damage is plotted at this point on the AAD curve (**Figure 7.5**). The total damage for a design event is determined by adding all the individual property damages for that event. The total area under the damage curve for all events up to and including the PMF is the total AAD. For the purposes of calculation of AAD it has been assumed that no damage occurs at the 1 year ARI event and the change in damage between calculated points is assumed to be linear.

Further information on the calculation of AAD is provided in Appendix M of the *Floodplain Development Manual* (NSW Government, 2005).

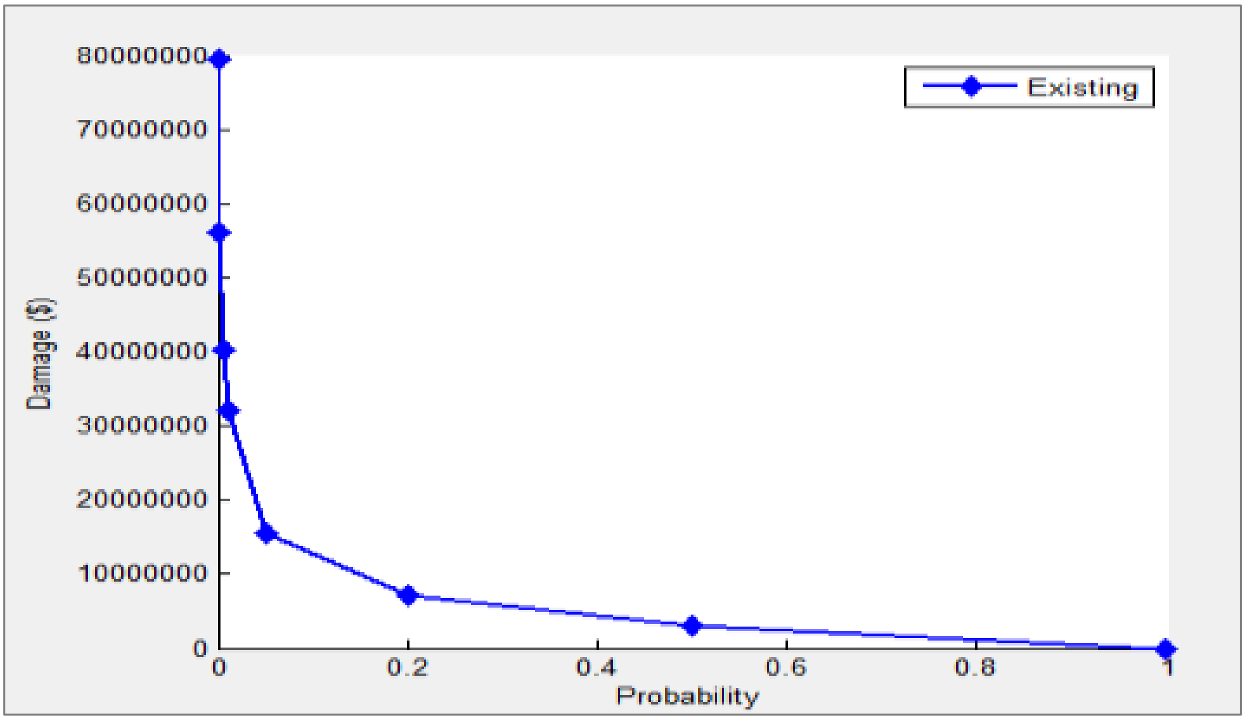

Figure 7.3: Total Damage Curve to calculate Average Annual Damage Curve for Brisbane Water – Existing Scenario (2014)

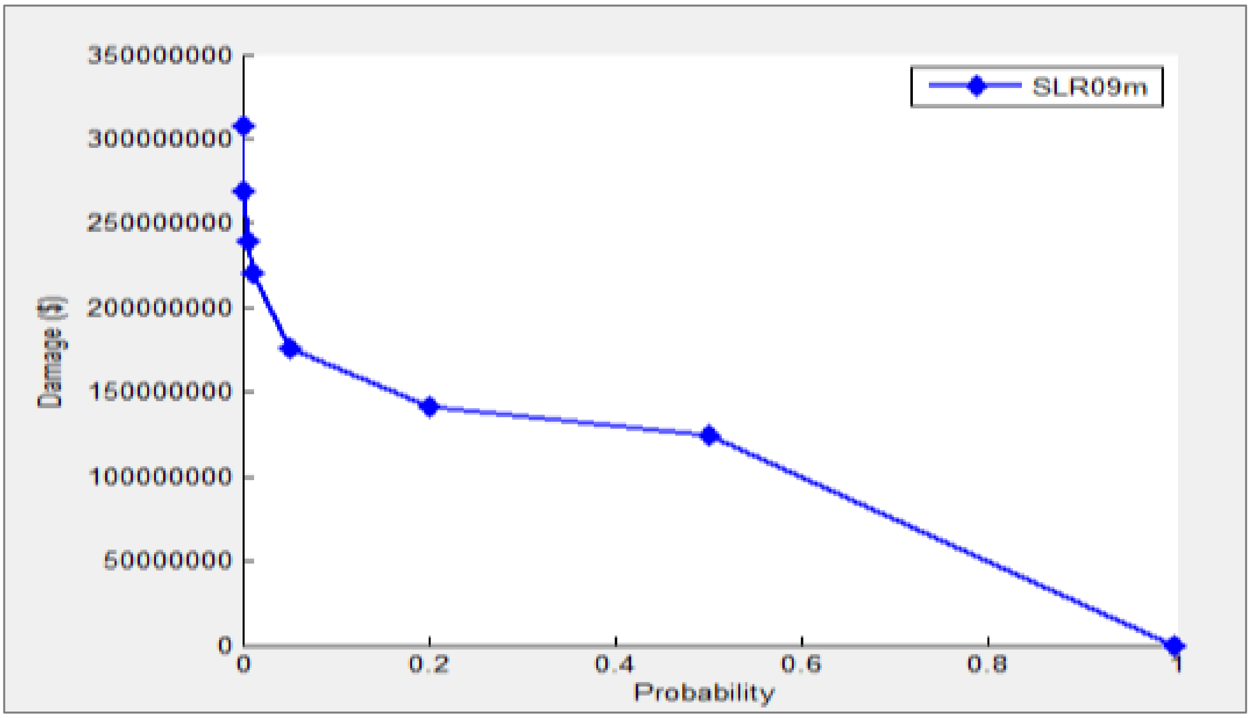

Figure 7.4: Total Damage Curve to calculate Average Annual Damage Curve for Brisbane Water – 0.9m SLR Scenario (2100)

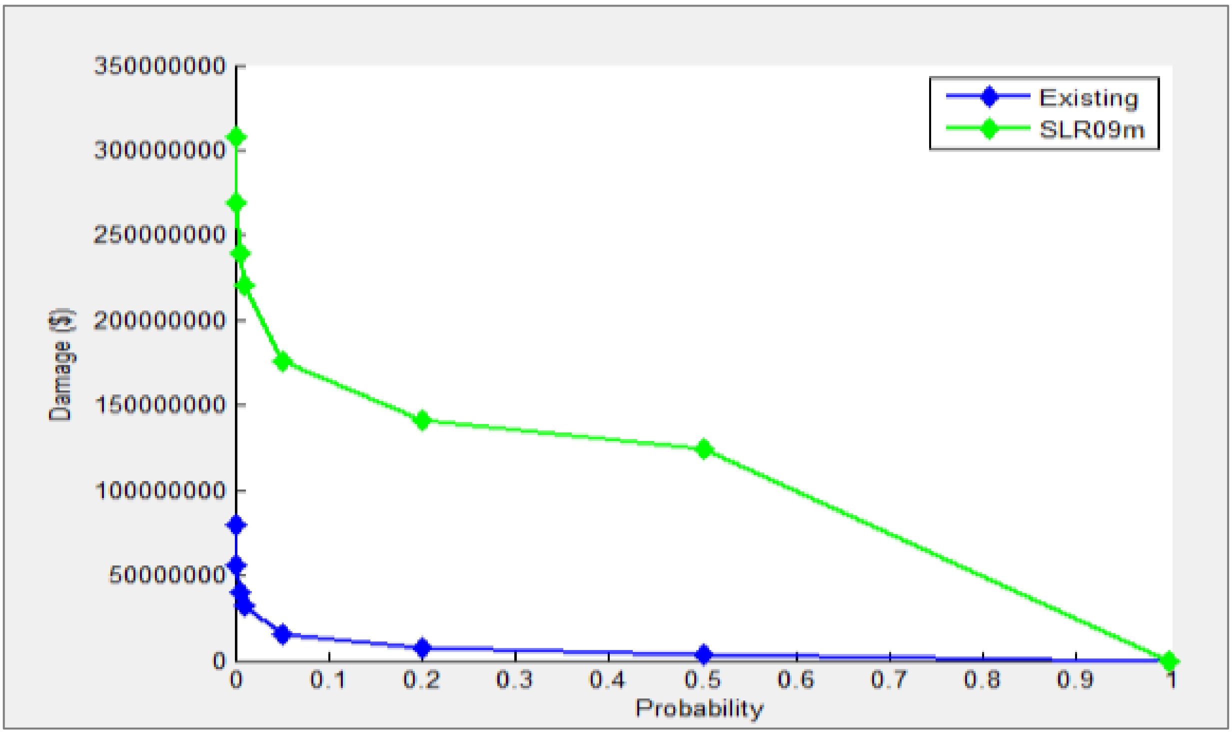

Figure 7.5: Total Damage Curve to calculate Average Annual Damage Curve for Brisbane Water – Existing Scenario (2014) and 0.9m SLR Scenario (2100) Comparison

7.5 Results

The results of the damages assessment are described below, noting that a range of assumptions and qualifications apply, as described in **Section 7.6.**

It is noted that for the existing scenario, the survey provided to Cardno by Council in July 2014 did not categorise any properties as industrial, hence no industrial properties were found to incur flood damages. For the SLR scenario, there were a few properties that were categorised as industrial, however none were found to incur flood damages based on their average ground level.

7.5.1 Existing Scenario

Table 7.5 shows the results of the flood damage assessments for the existing scenario (represented by 2010 ocean levels) (**Figure 7.5**). Based on the analysis described in **Section 7.4** above, the average annual damage for the Brisbane Water foreshore floodplain under existing conditions is approximately **$5,448,989**. **Table 7.5** shows that while only a small number of properties are affected by overfloor flooding in the 2 and 5 year ARI events, hundreds of properties are affected by overground flooding, significantly contributing to the total damages. The number of properties affected by overfloor flooding increases significantly for events greater than the 5 year ARI flood event. **Figure 7.5** shows the incremental variation for damages for the floodplain.

Table 7.5: Properties with Damages Incurred (Existing Scenario)

Event/ Property Type	No. of Properties with Overfloor Flooding	Avg Depth of Overfloor Flooding (m)	Max. Depth of Overfloor Flooding (m)	No. of Properties with overground flooding	Total Damage
PMF (0.0001 % AEP)					
Residential	1127	0.27	1.16	2453	$71,153,388
Commercial	71	0.46	0.82	85	$8,290,782
PMF Total	**1198**			**2538**	**$79,444,171**
500yr ARI (0.2 % AEP)					
Residential	813	0.2	0.94	2147	$50,975,212
Commercial	61	0.34	0.63	79	$5,106,944
500 Year ARI Total	**874**			**2226**	**$56,082,157**
200yr ARI (0.5 % AEP)					
Residential	566	0.16	0.82	1852	$36,952,948
Commercial	50	0.27	0.5	74	$3,354,151
200 Year ARI Total	**616**			**1926**	**$40,307,099**
100yr ARI (1 % AEP)					
Residential	426	0.14	0.75	1678	$29,535,457
Commercial	47	0.22	0.43	74	$2,616,896
100 Year ARI Total	**473**			**1752**	**$32,152,353**
20yr ARI (5 % AEP)					
Residential	169	0.1	0.57	1260	$14,510,734
Commercial	33	0.13	0.28	65	$959,882
20 Year ARI Total	**202**			**1325**	**$15,470,615**
5yr ARI (20 % AEP)					
Residential	63	0.07	0.42	861	$6,914,946
Commercial	14	0.06	0.14	50	$308,205
5 Year ARI Total	**77**			**911**	**$7,223,151**
2yr ARI (50 % AEP)					
Residential	16	0.06	0.33	550	$3,073,000
Commercial	3	0.04	0.05	33	$51,974
2 Year ARI Total	**19**			**583**	**$3,124,974**
AVERAGE ANNUAL DAMAGE (AAD)					**$5,448,989**

7.5.2 0.9m SLR Scenario

The damages results under 0.9m SLR conditions showed that the damages were highly influenced by the damages incurred in a 2 year ARI event (50% AEP). This influence was considered to be disproportionate because by such time as the 0.9m SLR has occurred, most of those low lying properties would be uninhabitable in their existing condition due to inundation from increased tidal levels (**Section 6.4.6, Appendix G**). In reality, these highly affected properties would have either undergone retreat or protection. Therefore, the 2 year ARI damages under projected sea level rise conditions would in fact be much lower. In addition, damages calculations for the 0.9m SLR scenario were based on the current development situation and utilise the data for surveyed properties (as per the survey data issued to Cardno in July 2014). This survey data was collected for the purpose of assessing the flood damages associated with the existing ocean conditions and as such do not include all properties affected by projected flooding conditions with SLR.

As such, the economic damages with projected sea level rise (**Figure 7.5**) should only be considered as an indication of the scale of modification, protection or retreat that would need to occur in the future to protect against these projected impacts.

Table 7.6 shows the results of the flood damage assessments for the 0.9m SLR scenario. Based on the analysis described in **Section 7.4** above, the AAD for the Brisbane Water foreshore floodplain under a projected 0.9m sea level rise scenario is approximately **$105,260,924**. Note that for properties not included in the 2014 detailed property survey, average ground levels (and not minimum ground levels) were used in the damages assessment so that damages were not disproportionally high in this regard (otherwise properties that were only minimally affected, e.g. a very small area of shallow floodwaters on one corner of the lot, would be picked up and full damages allocated, which is clearly over-conservative).

The potential longer term damages projected to be associated with sea level rise will be addressed in the CCAPs that are proposed to be undertaken. It is noted that these CCAPs will also consider the potential impacts and associated with more frequent events such as tidal inundation, which is beyond the scope of this Floodplain Risk Management Study.

Table 7.6: Properties with Damages Incurred (0.9m Projected Sea Level Rise Scenario)

Event/ Property Type	No. of Properties with Overfloor Flooding*	Avg Depth of Overfloor Flooding (m)*	Max. Depth of Overfloor Flooding (m)*	No. of Properties with overground flooding^	Total Damage
PMF (0.0001 % AEP)					
Residential	3742	0.69	3.98	4314	$264,955,965
Commercial	203	1.0	1.73	250	$42,876,070
PMF Total	**3945**			**4565**	**$307,832,034**
500yr ARI (0.2 % AEP)					
Residential	3405	0.6	3.84	4132	$234,518,419
Commercial	184	0.86	1.54	213	$34,847,300
500 Year ARI Total	**3589**			**4345**	**$269,365,719**
200yr ARI (0.5 % AEP)					
Residential	3067	0.55	3.75	4006	$209,204,307
Commercial	169	0.8	1.41	201	$30,287,710
200 Year ARI Total	**3236**			**4207**	**$239,492,017**
100yr ARI (1 % AEP)					
Residential	2839	0.53	3.68	3886	$193,019,151
Commercial	164	0.74	1.34	191	$27,576,661
100 Year ARI Total	**3003**			**4077**	**$220,595,812**
20yr ARI (5 % AEP)					
Residential	2271	0.49	3.56	3600	$155,453,156
Commercial	138	0.67	1.19	167	$20,946,067
20 Year ARI Total	**2409**			**3767**	**$176,399,222**
5yr ARI (20 % AEP)					
Residential	1849	0.45	3.44	3236	$124,887,224
Commercial	123	0.57	1.05	150	$16,699,431
5 Year ARI Total	**1972**			**3386**	**$141,586,655**
2yr ARI (50 % AEP)					
Residential	1677	0.4	3.35	3015	$109,692,301
Commercial	114	0.51	0.96	148	$14,682,419
2 Year ARI Total	**1791**			**3163**	**$124,374,720**
AVERAGE ANNUAL DAMAGE (AAD)					**$105,260,924**

*Based on an assumed floor level of 0.4m for those properties where survey information was not available.

^Based on an assumed average ground level across the cadastral lot for those properties where survey information was not available.

7.5.3 Present Value Calculations

In order to gain an appreciation of flood damages in the future, present value calculations were undertaken over an 86 year time frame (i.e. assuming a 0.9m SLR by 2100). Net present value (NPV) can be defined as *today's value* of a *future cost* (in this case AAD), discounted at an appropriate discount rate (normally in accordance with guidance from NSW Treasury), i.e. it is the current worth of a particular amount of money in the future. NPV is a standard method of economic evaluation over the long-term. For this report, a discount rate of 7% was used in accordance with NSW Treasury (2007) guidelines. Given the variability in actual change in sea level rise between now and 2100, a standard linear interpolation was considered to be the most appropriate interpolation for use in this study. Net present value calculations were therefore undertaken using a linear interpolation between the 2014 and 2100 values of AAD. The net present value of AAD across the 90 year time frame equates to **$83,060,367**. This value is based on a number of assumptions, as described in **Section 7.6**.

The NPV of AAD is very sensitive to the discount rate adopted for this calculation. Whilst this study has been undertaken in accordance with the NSW treasury (2007) guidelines, there is very little guidance with regards to long term analysis for the evaluation of sea level rise impacts. As such, it is important that this be reviewed in detail as part of the CCAPs (PM9).

7.6 Assumptions and Qualifications

These damage estimates are considered to be conservative estimates of the actual flood damages associated with flooding on the Brisbane Water foreshore floodplain. The following assumptions and qualifications apply to the damages assessment:

Existing Scenario:

- Floor areas for residential properties were based on averages interpreted from aerial photographs (as described in Section 7.3) as these were not available in the survey data.
- Residential properties where the lowest habitable floor level is greater than 1m above the ground level at that location were considered to be High Set;
- Damages in the 1 year ARI design event were assumed to be zero, with a linear increase in damage up to the 2 year ARI design event. The event assumed to have zero AAD can significantly impact on the value of the AAD (Thomson *et al*, 2006), however a 1 year ARI design event was considered to be a reasonable estimate of zero damage for the Brisbane Water foreshore floodplain. It is worth noting that there is very little guidance in the *Floodplain Development Manual* (NSW Government, 2005) as to how the high probability end of the AAD curve should be established.

0.9m SLR Scenario:

- Where survey data was not available, property types (i.e. residential, commercial or industrial) were determined using 2014 LEP zonings. In some instances, the actual land use of a property may not align with the land use in the damages database;
- After brief consideration of aerial photographs, properties zoned as Recreational were considered to be vacant lots. Additionally, vacant lots were determined through cadastral interpretation (properties that had a street number of “0” in the electronic database). This method may not have identified all vacant lots.
- In the absence of floor survey data, an average floor level of 0.4m was used, as described in **Section 7.3.1.1**;
- Where property survey was not available, floor areas for residential, commercial and industrial properties were based on averages interpreted from aerial photographs (as described in **Section 7.3**);

- Where property survey was not available, average ground levels across each cadastral lot were used, since the use of minimum ground levels was considered to be overly conservative in accordance with best practice.
- Where property survey was available, residential properties where the lowest habitable floor level is greater than 1m above the ground level at that location were considered to be High Set. Where property survey was not available, residential properties have been assumed to be Low Set;
- Damages calculations for the 0.9m SLR scenario were based on the current development situation and it is assumed that properties remain in their existing state in the future; and
- Damages in the 1 year ARI design event were assumed to be zero, with a linear increase in damage up to the 2 year ARI design event. The event assumed to have zero AAD can significantly impact on the value of the AAD (Thomson et al, 2006), however a 1 year ARI design event was considered to be a reasonable estimate of zero damage for the Brisbane Water foreshore floodplain. It is worth noting that there is very little guidance in the Floodplain Development Manual (NSW Government, 2005) as to how the high probability end of the AAD curve should be established.

AAD reflects the likelihood of each design flood event in one year and the damages likely to occur as a result of that event. Whilst this is a useful tool for evaluating the benefit of flood management options and assessing the flood damage to an area over a long period of time, it is also important to note the actual damages estimated to occur as a result of each design flood event. The cost to the community of flood damage is not incurred as an average annual amount; the costs will be borne at one time by the damage incurred by a specific flood event.

8 Flood Planning Level Review

8.1 Overview

The Flood Planning Level (FPL) for the majority of floodprone areas across New South Wales has been traditionally based on the 100 year ARI flood level plus a freeboard which is generally set between 0.3 - 0.6 m for habitable floor levels. The *Guideline on Development Controls on Low Risk Areas – Floodplain Development Manual* (DoP, 2007) states that unless there are 'exceptional circumstances', councils should adopt the 100 year ARI (plus an appropriate freeboard) for residential development. A variety of factors are worthy of consideration in determining an appropriate FPL and whether 'exceptional circumstances' exist for the selection of a FPL other than the 100 year ARI. Most importantly, the flood behaviour and the risk posed by the flood behaviour to life and property in different areas of the floodplain and different types of land use need to be accounted for in the setting of a FPL.

As part of the review of the FPL, the following elements were considered:

- The current FPL applied to the Brisbane Water foreshore;
- Factors influencing FPLs;
- The potential consequences of adopting the Probable Maximum Flood (PMF) as the FPL (the upper bound of flood risk);
- The effect of climate change projections on FPLs; and
- Potential options for freeboard selection.

On the basis of the outcomes of this review, a recommendation is provided as to a suitable FPL to be considered for adoption in the Floodplain Risk Management Plan, and consequently by Gosford City Council as part of their requirements under environmental planning instruments for strategic planning and development control.

8.2 Current Flood Planning Level

8.2.1 Properties Affected

Gosford City Council currently applies a FPL to all properties within the relevant Flood Planning Area. The Flood Planning Area is defined in NSW Government Floodplain Development Manual (2005) as the area of land below the FPL and thus subject to flood related development controls.

8.2.2 Current Flood Event and Freeboard Used in Flood Planning Level

Gosford City Council currently uses the existing 100 year ARI flood level associated with observations from an historical event in the absence of detailed flood modelling as the basis for determining the FPL for the Brisbane Water foreshore. The flood event used to determine the existing FPL for the Brisbane Water foreshore floodplain was the May 1974 severe ocean storm which resulted in a recorded flood level of 1.92m AHD (taken as 1.95 mAHD for planning purposes). The current flood planning level is set at 2.45m AHD. This planning level incorporates the 1.95m AHD observed 1974 level, with the addition of 0.5m freeboard to account for uncertainty (e.g. additional flood impacts resulting from wave and wind set-up, wave run-up and potential climate change).

The Brisbane Water Flood Study (Cardno, 2013) determined that the 1974 storm event is likely to have been close to the 150 - 200 year ARI event. As such, using this event to determine the FPL may be somewhat conservative for existing conditions in some locations as compared to the commonly applied 100 year ARI event outlined in **Section 8.1** (presuming no allowance for projected sea level rise).

Figure 8.1 provides an overview of the current FPL compared against the *Flood Study* (Cardno, 2013) numerical modelling results for ocean flooding and wave conditions extracted from specific locations designed to represent the length of the entire foreshore (Locations 1 – 119, which can be located using Figure 6.1 of the Flood Study (Cardno, 2013)). The datasets for the information presented in **Figure 8.1** are sourced directly from the Cardno (2013) Flood Study results and therefore the analysis is considered to be robust.

Overall, **Figure 8.1** shows that the current FPL of 2.45mAHD is higher than the 100 year ARI storm peak water level plus 0.5m freeboard at all locations. However, when sea level rise is considered, the current flood planning level may not be adequate to protect properties against flooding. This is dependent on the level of sea level rise adopted for inclusion in the FPL and the freeboard selection. These factors are discussed in more detail in the following sections.

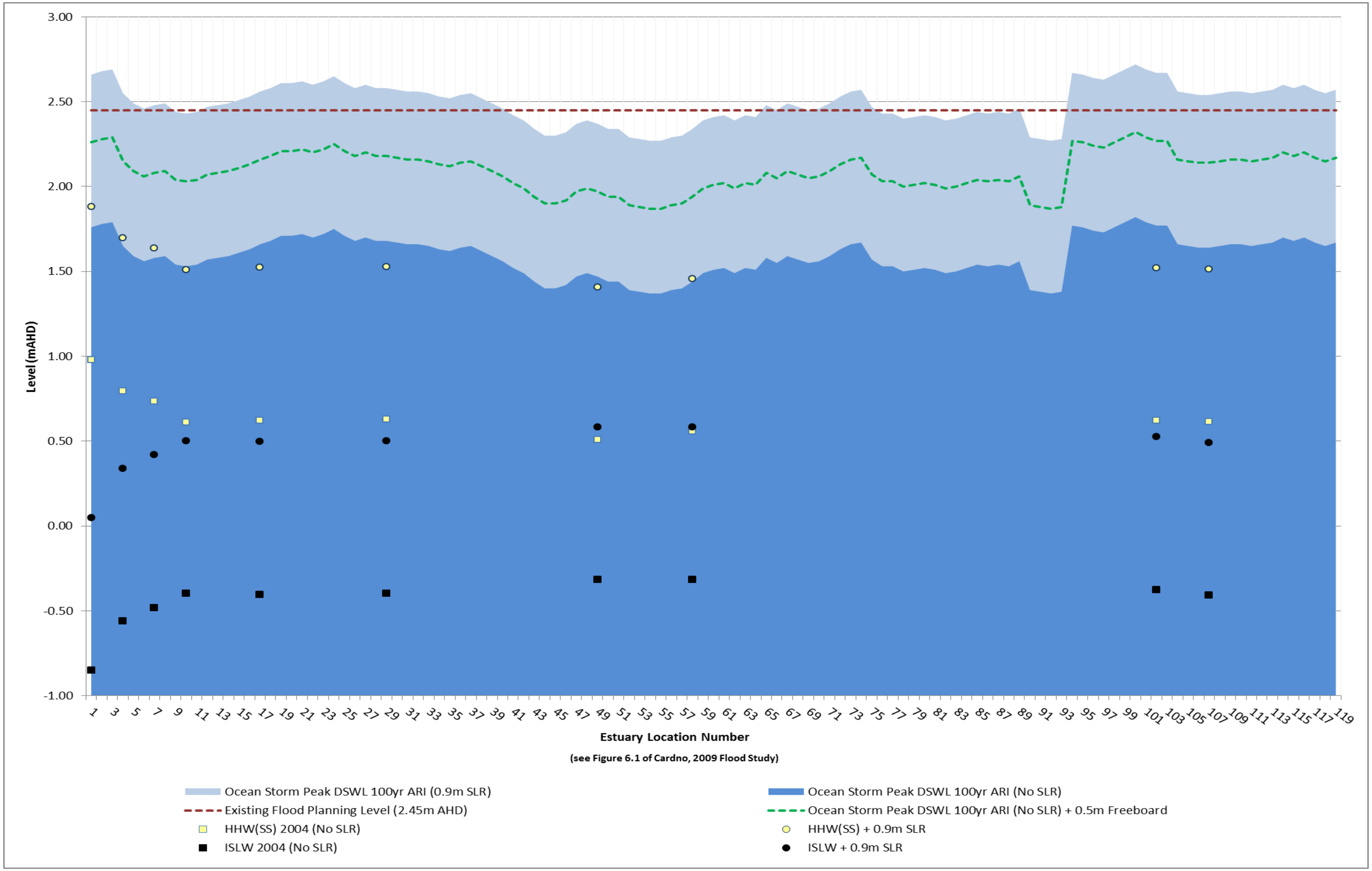

Figure 8.1: Current Flood Planning Level compared to Results of Flood Study (Cardno, 2013) and Other Standard Tidal Levels

8.3 Factors Influencing Flood Planning Levels

Councils are responsible for determining the appropriate flood planning levels for land within their local government area. Whilst the flood used to determine the residential FPL is a decision of the local council, the Floodplain Development Manual (NSW Government, 2005) highlights that FPLs for typical residential development would generally be based around the 100 year ARI flood plus an appropriate freeboard (typically 0.5m).

The Guideline on Development Controls on Low Risk Areas – Floodplain Development Manual (DoP, 2007) confirms that, unless there are exceptional circumstances, councils should adopt the 100 year ARI flood as the basis FPL for residential development. In proposing a case for exceptional circumstances, a Council would need to demonstrate that a different FPL was required for the management of residential development. Appendix K of the *Floodplain Development Manual* (NSW Government, 2005) outlines a range of issues relating to risk which may be considered, including social factors, economic factors, environmental factors (including sea level rise), cultural factors and planning and governance.

Table 8.1 gives a summary of how these factors relate to the Brisbane Water foreshore floodplain in the context of projected sea level rise. Further discussion on each of the issue types is provided in the following sections.

Table 8.1: Factors Influencing Flood Planning Levels

Type of Issue	Factor	Relevance to the Brisbane Water Foreshore Floodplain
Risk	Risk to life	➢ The selection of the event upon which the FPL is based needs to ensure that risk to life is effectively managed for the full range of floods. A flood larger than that used to derive the FPL will result in increased risk to life. ➢ **Section 8.3.1** looks at the probabilities associated with different events and **Section 8.3.2** looks at the incremental height differences between events to assist in determining the risk to life associated with various events.
	Flood behaviour	➢ Flood behaviour is more likely to impact upon areas for development or the location of mitigation works rather than a final decision on FPLs. ➢ However, it is noted that flooding in the Brisbane Water foreshore floodplain is dominated by low velocity coastal flooding and as such flood events greater than the FPL would primarily result in increased depths and hence potentially not a significantly increased risk to life.
Social	Land availability and needs	➢ The *Central Coast Regional Strategy* (DoP, 2008) has a requirement for residential expansion within areas surrounding Brisbane Water (primarily Gosford and Woy Woy). ➢ The selection of an appropriate FPL should be aimed at protecting/ promoting flood-compatible development in these areas not restricting it.
	Existing level of development	➢ The Brisbane Water foreshore floodplain generally consists of developed land (residential, commercial, industrial and infrastructure) and nature reserves / open space. Flood-affected land therefore, is generally either developed or protected from development, and broad scale changes in land use are generally not expected in the short to medium term.
	Current FPLs for planning purposes	➢ The single recorded level of 1.95 mAHD from the 1974 severe ocean storm is currently used as a basis for flood planning levels in the Brisbane Water Floodplain. This flood planning level does not account for variations in flood levels around the foreshore.

Type of Issue	Factor	Relevance to the Brisbane Water Foreshore Floodplain
	Land values and social equity	➢ The implementation of a change in planning levels has the potential to be of concern to landowners. Community consultation and substantiation would be likely to assist in the understanding of the reasoning behind new planning levels.
	Period of inundation	➢ Average period of inundation for much of the Brisbane Water floodplain is approximately 5 hours.
Economic	Future development	➢ Future development, particularly in Gosford and Woy Woy, is likely to increase in the future in accordance with the DoP's (2008) *Central Coast Regional Strategy*. ➢ The consideration of a reduction in the FPL for new development can have social equity implications as damages will be borne by future residents and owners whilst any cost savings related to lower fill and floor levels are made by developers. ➢ Future development is likely to incorporate a combination of residential, commercial, industrial and other uses. The greater flexibility of business in managing risk and recovering financially from flooding, means that FPLs for industrial and commercial development may be based upon a more frequent flood event.
	Mitigation works	➢ The cost-benefit of mitigation works (management options) is discussed in **Section 11**.
Environmental	Environmental issues	➢ The FPL in itself does not necessarily limit development in environmentally sensitive areas. Land use limits and the like are a more appropriate tool for this application. However, the use of a high FPL may result in more extensive filling and potentially increased impacts and resource usage. ➢ For some land use types, a flood planning level can be used to control environmentally hazardous materials (e.g. chemical storage and associated bunding arrangements).
Cultural	Cultural issues	➢ The FPL in itself does not necessarily limit development in culturally sensitive areas. Land use limits and the like are a more appropriate tool for this application. However, the use of a high FPL may result in more extensive filling, which in turn may pose impacts on culturally sensitive locations.
Planning and Governance	Freeboard	➢ Freeboard is discussed in **Section 8.7**.
	Duty of Care	➢ In accordance with the *Floodplain Development Manual* (NSW Government, 2005), Council has a duty of care in advising property owners, occupiers and developers on the extent and level of flooding, making decisions with regard to an appropriate FPL and documenting the basis for FPL selection.

8.3.1 Likelihood of Flooding

As a guide, **Table 8.2** has been reproduced from the *NSW Floodplain Development Manual* (NSW Government, 2005) to indicate the likelihood of occurrence of an event in an average lifetime to indicate the potential risk to life.

Analysis of the data presented in **Table 8.1** gives a perspective on the flood risk over an average lifetime. The data indicates that there is a 50% chance of a 100 year ARI event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 100 year ARI flood event as the basis for the flood planning level. Given the social issues associated with a flood event and the non-tangible effects (such as stress and trauma), it is appropriate to limit the exposure of people to floods.

Note that there still remains a 30% chance of exposure to at least one flood of a 1 in 200 year magnitude over a 70 year period (e.g. the 1974 event). This gives rise to the consideration of the adoption of a rarer flood event (such as the 200 year ARI or up to the PMF) as the flood planning level for some types of development.

Table 8.2: Probability of Experiencing a Given Flood Event or Higher in an Average Lifetime (70 years)

Year ARI	Likelihood of Occurrence in any Year	Probability of Experiencing Flood Event in a Period of 70 Years	
		At least once (%)	At least twice (%)
10	10%	99.9	99.3
20	5%	97	86
50	2%	75	41
100	1%	50	16
200	0.5%	30	5

8.3.2 Incremental Height Difference between Events

Consideration of the average height difference between various design flood levels can provide another guide to assist with selecting an appropriate FPL.

Based on the existing flood behaviour (**Section 6** and Cardno, 2013) the incremental peak height differences between the design still water levels for selected events (as averaged across the floodplain) are shown in **Table 8.3**.

Table 8.3: Differences in Design Event Flood Levels*

Event	PMF (m)		200 year ARI (m)		100 year ARI (m)		20 year ARI (m)	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD
200 year ARI	0.29	0.20	-	-	-	-	-	-
100 year ARI	0.36	0.26	0.07	0.05	-	-	-	-
20 year ARI	0.51	0.36	0.22	0.16	0.15	0.11	-	-
5 year ARI	0.65	0.46	0.36	0.25	0.29	0.20	0.14	0.10

*	Does not include local wave run-up (see **Section 8.5**)
Avg	Average Difference.
SD	Standard Deviation of Differences, assuming the results are normally distributed, gives an indication of the spread of the differences between flood levels.

Table 8.3 indicates a larger difference in flood levels of the PMF event compared to other events. The adoption of the 100 year ARI level as the basis of determining the FPL is not significantly different from that of the 20 year ARI (on average 0.15m higher). Therefore the adoption of the 100 year ARI level would provide an increased level of risk reduction over the 20 year ARI without a significant difference in flood planning level. Equally, there is not much difference between the 100 year ARI and 200 year ARI; therefore, consideration of using the historical flood of 1974 as the basis for determining the flood planning level should be taken into account (since this event was found to be of the order of a 200 year ARI event as discussed in **Section 8.2**).

8.3.3 Social Factors

The social implications of adopting a FPL based on a smaller, higher probability event (e.g. 20 year ARI event) would be unacceptable because communities would experience risk to life, disruption to livelihood and tangible and intangible damages on a fairly consistent basis. Conversely, adoption of a much larger, lower probability event (e.g. PMF event) could result in a number of other social implications and issues.

Stricter development controls and higher FPLs are not likely to achieve broad scale community acceptance. In locations where some property raising has taken place in a "checkerboard" manner (i.e. some houses raised with adjacent houses not raised) perceived social inequity may be an issue for those residents who are not in a financial position to raise their house associated with a redevelopment. In addition, imposing planning controls on properties that are outside the 100 year ARI flood extent may create an issue relating to perceived property values. Property owners may feel that their property is being devalued by the adoption of stricter planning controls (even though the offset is that the damage to property is substantially curtailed if redevelopment is consistent with flood planning controls).

However, some longer term benefits may be observed where floor levels are raised (e.g. for new developments or renovations), particularly in areas that are likely to have longer term coastal flooding issues. For example, if roads are raised in the future, this may have the potential to impact on those properties that have lower floor levels.

8.3.4 Damage Cost Differential Between Events

Based on the flood behaviour and the assessment of flood damages, the incremental difference in Average Annual Damage for different recurrence intervals was calculated for the existing case, as shown in **Table 8.4**.

Table 8.4: Damage Differential Costs

Event	Incremental AAD	Properties with Over-Floor Flooding	Average AAD per Property
Up to 2 year ARI	$781,087	19	$41,110
2 year to 5 year ARI	$1,552,219	77	$20,159
5 year to 20 year ARI	$1,702,032	202	$8,426
20 year to 100 year ARI	$952,459	473	$2,014
100 year to 200 year ARI	$181,149	616	$294
200 year to 500 year ARI	$144,584	874	$165
500 year ARI to PMF	$135,459	1198	$113
AAD (Total)	**$5,448,989**		

8.3.5 Environmental Factors

The implementation of flood risk management options to accommodate a lower probability event would likely cause more significant disruption to estuary or catchment processes than accommodating a higher probability event. It is also likely that more materials and services would potentially be required to adequately modify existing properties (e.g. fill material, labour etc.), thus increasing the carbon footprint of the works.

However, development or re-development that is undertaken in accordance with an adopted FPL would be subject to the standard environmental assessment process, and any conflicts under environment or heritage legislation would need to be addressed at that stage.

Environmental considerations have been incorporated into the multi-criteria matrix (**Section 13**) and consideration has also been given to the recommendations of the *Brisbane Water Estuary Management Plan* (Cardno, 2011b).

8.3.6 Cultural Factors

In general, the application of FPLs is unlikely to result in major impacts on cultural factors. However, in some circumstances, cultural and heritage items and places may be negatively impacted by development and the implementation of flood risk management options. However, development that is undertaken in accordance with an adopted FPL would be subject to the standard environmental assessment process, and any conflicts under the *National Parks and Wildlife Act 1974* or the *Heritage Act 1977* would need to be addressed at that stage.

8.3.7 Planning and Governance

Flood planning levels inform planning measures and development controls in the floodplain and should be considered in the context of other planning controls.

8.4 Consequence of Adopting the PMF as a Flood Planning Level

Flood planning levels are usually based on the 100 year ARI flood event and aim to minimise risk to life and reduce the tangible and intangible damages to a property. Over time, the ongoing process of redevelopment should ultimately result in all properties being raised to a suitable level and a significant reduction in risk to the community. In theory, risk could be reduced to negligible if a lower probability event was used as a basis for flood planning levels, such as the PMF event. Completely safeguarding development against the PMF would be ideal in terms of reducing existing and future risk to life and property, however it is not likely to be feasible and in many cases, not likely to be economically, socially or environmentally desirable (NSW Government, 2005).

Analysis of the flood damages (**Table 8.4**) indicates that the choice of the PMF event over the 100 year ARI event would result in limited economic benefits (in annualised terms) to the community. The difference in average flood levels between the 100 year ARI and the PMF event (**Table 8.3**) indicate that the use of the PMF as the FPL would result in higher levels (0.36m on average), and as a result higher economic costs and inconvenience to the community in the process of seeking development consent. In addition, the incremental AAD per building from the 100 year ARI to the PMF is relatively low (approximately $572).

Given this, the economic costs may in fact outweigh the benefits of using the PMF as the FPL. The use of the PMF level as the FPL may also conflict with other development/building controls in Councils DCP and planning directions from the NSW Government. As outlined in **Section 8.1**, Council would need to apply for an exemption from the NSW Government if the PMF were to be put forward as the FPL for residential development.

Although using the PMF as a basis for FPLs is not generally acceptable for all development types, in some instances it is reasonable to use the PMF event as a planning level to reduce risk to life. Given the risk of exposure outlined in **Table 8.2**, the following may be considered:

- Location of critical infrastructure – emergency services such as police, ambulance, hospitals and NSW SES facilities should be situated outside the floodplain;
- Access to critical infrastructure – flood-free access along main roads to and from critical facilities in any flood event is integral in allowing emergency services to operate and reduce risk to life; and
- Instances where it is possible to provide protection against the PMF for minimal additional cost (e.g. land raising in some areas).

8.5 Wave Run-up Height

The results for local wave run-up are presented in Table J2 of Appendix J of the Flood Study (Cardno, 2013). These levels vary around the foreshore of Brisbane Water.

Wave run-up depends upon the height of the approaching wave and the edge treatment of the foreshore and is irregular in its character. Five idealised edge treatment cases have been addressed in the Flood Study (Cardno, 2013) each for two crest levels. They are described below:-

- 1 in 20 natural slope
- 1 in 10 beach face
- 1 in 5 embankment
- 1 in 2 seawall
- Vertical wall

The magnitude of wave run-up is also dependant on the finish material of the foreshore edge treatment. Generally, the higher the porosity or roughness of the edge treatment, the lower the run-up height.

Calculations were undertaken for two edge treatment crest heights, being 1.5mAHD and 2.5mAHD, for each edge treatment type, resulting in 10 overall wave run-up height calculations at each location (and therefore 10 wave run-up results, which require interpretation to determine their application for an individual property). The two selected crest levels are considered to cover the vast majority of foreshore levels around Brisbane Water. Where the Design Still Water Level (see **Section 8.8.1**) exceeds the crest level of the foreshore, the wave height is assumed to be equal to half the approaching wave height.

The wave run-up height includes the local wave set-up height. The process of wave set-up refers to the deviation of the mean water level as a result of wave shoaling, breaking and momentum flux conservation as it progresses shoreward across the breaker zone. Regional wave set-up caused by shoreward propagating swell has been included in the ocean storm modelling.

Where a block slopes upward back from the shoreline edge structure, flooding may affect only a small part of the block. However, where a block is relatively flat, wave run-up may penetrate some distance inland, but is attenuated by percolation and friction. This landward reduction of wave run-up cannot be estimated with great confidence, and is on observational experience. For local sea cases it is assumed that wave run-up diminishes to zero at a point 20m inland from the edge structure (all Management Areas, except for Management Areas 11 and 12), whilst swell energy has a greater overland penetration capacity and may be in the order of 40m (Management Areas 11 and 12).

The application of wave run-up should therefore be done over this 20m wide area, 40m when considering swell, of the foreshore.

In defining the wave run-up, the design wave height, either sea or swell that provides the greater run-up height is to be used, generally. However, consideration of possible boat waves that may approach the shore when design water levels are present needs attention.

Review of the NSW Maritime (2007) area map shows the presence of both 4 and 8 knots speed restriction and no-wash zones at various locations around the Brisbane Water foreshore floodplain. Along these shorelines consideration of boat waves can therefore be ignored. However, outside these areas the foreshore may be subject to wash of larger boats, like ferry services. It is estimated that boat wash from these types of vessels could reach a height of 0.5m with a wave period in the order of 5 seconds. To this end, the wave run-up assessment was undertaken for both the local design wind wave, either sea or swell, and the boat-wash wave of 0.5m with the larger run-up value adopted for each location. This would also allow for the consideration of emergency boats creating wash during a flood event.

8.6 Climate Change – Projected Sea Level Rise

Sea level rise associated with climate change, is projected to increase flood levels and the extent of floodwaters over coastal floodplains (DECCW, 2010a). As sea levels rise, a FPL based on the existing 100 year ARI flood event will become progressively less effective in providing the same level of protection against flood events as in the present day.

Historically, the freeboard included in FPLs has generally included a relatively small component related to climate change impacts on flood levels in coastal areas (of the order of 0.2 m, see also **Section 8.7**). Given this small allowance compared to current projected sea level rise (e.g. 0.4 m by 2050 and 0.9 m by 2100) the use of only this small provision of SLR embedded in the freeboard may not be appropriate going forward in coastal floodplain such as Brisbane Water.

There are three common options for addressing sea level rise in flood planning:

- No provision for sea level rise (not considered appropriate and inconsistent with available projections and information about climate change)
- Plan for projected sea level rise at 2050 (an increase of 0.4 m in mean sea level over 1990 levels)
- Plan for projected sea level rise at 2100 (an increase of 0.9 m in mean sea level over 1990 levels).

As discussed in **Section 6.4**, the use of the 0.4 m by 2050 and 0.9 m by 2100 benchmarks are reasonable going forward in the absence of new or updated information.

In order to balance the negative and positive impacts on risk, social, economic, environmental, cultural and planning and governance factors described above, the FPL should incorporate an explicit prediction for sea level rise. It may be appropriate to do this incrementally (i.e. adopt short-term projected sea level rise (e.g. 2050 projections) followed by adoption of long-term sea level rise (e.g. 2100 projections) at a later time). As sea level rise data and information is updated (e.g. as a result of research or publication and as adopted by Council, in a manner consistent with Council's Climate Change Policy, D2.11, 2013), the SLR incorporated in FPLs should also be revised to accommodate this.

When applying a staged approach to the incorporation of SLR into planning levels, the design life of the subject development should be considered. Whilst it is generally accepted that the typical design life of a residential building is in the order of 50 years, critical infrastructure such as hospitals and schools can be considered to have a longer design life and be more vulnerable to flood impacts.

Council's current policy (D2.11, 2013) recommends the use of 0.4m of SLR as a minimum. A recent study undertaken by Whiteheads & Associated for the NSW South Coast identified a high level projection of SLR by 2065 (50 years from 2015) to be 0.4m, which is in accordance with Council's policy position. However, projections of SLR over the longer term have a higher degree of uncertainty. Considering this uncertainty, it may be prudent to apply the long term estimate of 0.9m to appropriate development types (e.g. hospitals, schools, emergency services).

Figure 8.1 shows that the current flood planning level (1.95mAHD plus 0.5m freeboard) affords protection against ocean flooding including 0.9m SLR at some locations. However, this does not include any allowance for local effects and other uncertainties, generally allowed for in a freeboard (see **Section 8.7**).

Section 7.5 shows the difference in the number of properties affected by projected sea level rise as calculated in the flood damages assessment. Comparing the results shows that the total number of properties (residential, commercial and industrial) affected in the 100 year ARI will increase from approximately 4,300 to 6,100 under a 0.9 m sea level rise scenario.

Given the magnitude of change in flood impacts associated with climate change it would be appropriate to consider the application of a minimum of 0.4 m in any flood planning level, with a view to extending this to 0.9 m or updating this value based on the outcomes of Council's proposed *Brisbane Water Foreshore Climate Change Adaptation Plans* (CCAPs).

As mentioned above, where the longevity of the proposed development is considered to extend beyond the typical lifespan of a structure, it may be appropriate to adopt a high allowance for SLR. This may include development types such as iconic buildings (e.g. cultural centres), shopping centres and other community facilities.

8.7 Freeboard Selection

The concept of a freeboard is to account for uncertainties in deriving design flood levels or local effects beyond the scope of the method of estimation and as such is generally used as a 'safety margin' to ensure that the design flood event that is planned for is not exceeded due to uncertainties or local effects. This consideration may result in the adopted FPL being higher than the design PMF level in certain cases. However, given the inherent purpose of freeboard, the FPL (inclusive of an appropriate freeboard) should still be used in such cases.

When deriving the freeboard for Brisbane Water, the following factors should be considered:

- Accuracy of model input data (e.g. ground survey):
  - The model comprised of a combination of 5m and 2m contours, ground survey and bathymetric survey. As such, some locations may not incorporate all local features that may impact on flooding.
- Model sensitivity:
  - Sensitivity analysis of the hydrological model found that the flood levels were moderately impacted by the catchment roughness, losses and rainfall intensity.
- Local factors that can result in differences in water levels across the floodplain. These factors can often not be determined in flood modelling, because they are too difficult, complex or expensive to incorporate:
  - The Brisbane Water flood model covers a large area and as such, is not able to account for all local factors which may impact upon flood levels. The model comprised of a 10 x 10m grid.
- The cumulative effect of subsequent infill development of existing zoned land:

  - Hydraulic modelling of region filling in the floodplain (Option FM9) identified that regional filling did not have a significant impact on flood levels as a result of storm surge.
- Climate change (e.g. changes in rainfall intensity, changes in sea level):
  - As outlined in Section 8.5, consideration of projected sea level rise as a separate element to freeboard is warranted. However, only the short term 2050 estimate for SLR has been recommended for inclusion in the FPL, resulting in a remaining level of uncertainty regarding SLR.
  - It should also be noted, that the impacts of climate change on rainfall intensities have not been quantified as part of this study.
  - As stated in the *2010 Flood Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessment*, the freeboard also provides a relatively small allowance to accommodate some of the projected increases in rainfall intensity and sea level rise associated with climate change.
- Existing freeboard and standards:
  - As discussed in **Section 8.2.2**, a freeboard of 0.5m has been applied to the historical flood level of 1.95 mAHD for planning purposes around the Brisbane Water foreshore for several decades. This freeboard is in line with standard practice across NSW.

There are many circumstances in which a freeboard of 0.3–0.6 m may be considered acceptable. The lower freeboard is generally only considered acceptable for use in very shallow water where the potential for other effects is limited. A freeboard higher than 0.6 m may be necessary due to particular local circumstances, such as where estimated design flood levels are particularly sensitive to modelling assumptions (Australian Government, 2013).

The Floodplain Development Manual (NSW Government, 2005) recommends that typically a freeboard of 0.5m is adopted. Reducing the freeboard from this value effectively reduces the factor of safety that is applied to the FPL, and therefore has the potential to increase losses in future flooding events and so should not be undertaken without careful deliberation.

Given the broad scale nature of the Brisbane Water flood model and the uncertainties associated with flood risk from climate change, it recommended that a freeboard greater than 0.3m be considered for inclusion in the FPL for Brisbane Water.

8.8 Flood Planning Level Components

Based on the outcomes of the Flood Study (Cardno, 2013) and the review above, the estimation of flood planning levels for the Brisbane Water foreshore floodplain is recommended to include a number of components, which are:

- Design Still Water Level.
  - Design Storm Tide Level from ocean modelling scenarios that include ***ocean storm-tide, swell set-up and wind set-up***.
- Projected sea level rise.
- Freeboard.

As discussed in **Section 8.5** local wave run-up may need to be incorporated into proposed floor levels in the immediate vicinity of the foreshore (up to 40m from the foreshore edge depending on the location in the floodplain). However, wave run-up may also be managed through foreshore treatment and / or barriers.

The elements contributing to the flood planning level are shown schematically in **Figure 8.2**. Refer to **Section 8.1** for details on the historical use of flood planning levels in Brisbane Water.

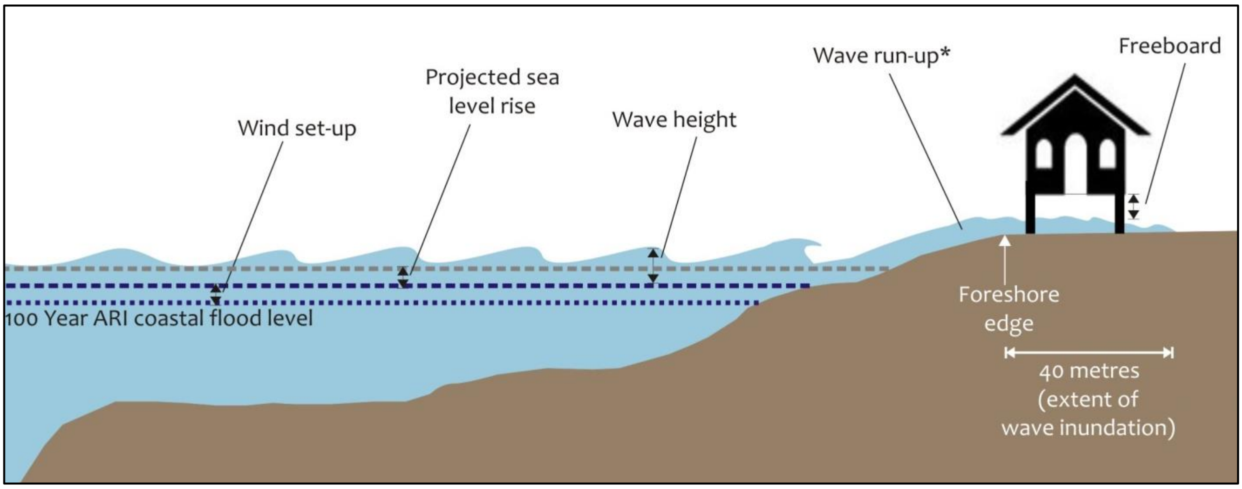

Figure 8.2: Components of Flood Planning Level

The definition of the flood planning levels for Brisbane Water can therefore be undertaken using the following calculation:

$$FPL = DSWL + SLR + Freeboard$$

Where:
FPL: Flood Planning Level
DSWL: Design Still Water Level = Design Storm Tide Level
SLR: Allowance for Projected Mean Sea Level Rise
*Freeboard: A 'safety margin' to ensure that the design flood event that is planned for is not exceeded due to uncertainties or local effects (see **Section 8.7**)*

An overview of these components is provided in the following sections.

8.8.1 Design Still Water Level

The results and calculation details for design still water levels are presented in Table I4 of Appendix I of the Flood Study (Cardno, 2013). These levels vary around the foreshore of Brisbane Water. This would be the source to obtain the appropriate Design Still Water Level for an individual property in the Brisbane Water Foreshore floodplain.

The Design Still Water Level is equal to the storm tide level, which is defined as the water level rise due to the combination of storm surge and the astronomical tide.

The calculation of storm tide levels was based on analysis of Fort Denison water level data, analyses of long term offshore Botany Bay wave data and Sydney Airport wind data, all in terms of probability of exceedance. Simulations using this data produced peak water levels for the Brisbane Water foreshore floodplain.

Based on the discussion and review outlined in the previous sections, it is recommended that the following design events are adopted when determining the design still water level:

- For the majority of development types, the FPL design still water level should be determined using the 100 year ARI event.
- Within the floodplain, it is not unreasonable for the PMF still water level to be used to determine the FPL for:
    - Critical infrastructure, vulnerable development types (e.g. aged care, seniors living, child care) and emergency services;
    - Road raising for critical infrastructure; and
    - Construction of levees.

8.8.2 Sea Level Rise

As outlined in **Section 8.6** and with reference to **Section 6.4**, an allowance for sea level rise of between 0.4 m by 2050 and 0.9 m by 2100 is appropriate.

Given the magnitude of change in flood impacts associated with climate change it would be appropriate to consider the application of the 2050 prediction of sea level rise as a minimum in any flood planning level, with a view to extending this to 2100 predictions of sea level rise or updating this value based on the outcomes of Council's proposed *Brisbane Water Foreshore Climate Change Adaptation Plans* (CCAPs).

It would be appropriate to consider the application of the 2100 prediction of sea level rise for vulnerable or longer term development types, such as:

- Critical infrastructure, vulnerable development types (e.g. aged care, seniors living, child care) and emergency services;
- Road raising for critical infrastructure; and
- Construction of levees.

The additional uncertainty and future risk associated with adopting a lower estimate of sea level rise could be addressed using a higher freeboard.

8.8.3 Freeboard

Whilst, a freeboard of 0.3m is often applied to coastal modelling for the purposes of FPLs, the Brisbane Water foreshore floodplain is not a purely coastal system and the discussion provided in **Section 8.7**, identified that there are several factors which contribute to the consideration of the adoption of a freeboard greater than this. In particular:

- The broad-scale nature of the hydraulic model;
- The significant risk associated with sea level rise as a result of climate change. Even though, SLR is applied to the FPL as a separate component (Section 8.8.2), only the minimum estimate of SLR has been recommended and as such, there is a significant remaining degree of uncertainty and risk; and
- The inclusion 0.5m freeboard in the definition of the Flood planning Level in the existing LEP (GCC, 2014a) and accepted standard across NSW.

The application of a freeboard of 0.3m, 0.4m and 0.5m have been considered in the following scenarios:

- 100 year ARI DSWL + 0.4m SLR + 0.5m Freeboard.
    - Utilises the minimum recommended component for SLR and the standard freeboard applied across NSW and is included in the current definition of FPL in Council's LEP (2014).

  - This provides a varying FPL across the floodplain, which has an average of 2.51m AHD.
- 100 year ARI DSWL + 0.4m SLR + 0.4m Freeboard.
  - Utilises the minimum recommended component for SLR and a moderate freeboard allowance.
  - This provides a varying FPL across the floodplain, which has an average of 2.41m AHD.
- 100 year ARI DSWL + 0.4m SLR + 0.3m Freeboard.
  - Utilises the minimum recommended component for SLR and the minimum recommended freeboard allowance.
  - This provides a varying FPL across the floodplain which is in most locations lower than the existing FPL of 2.45m AHD. The average FPL would be 2.31m AHD.

The proposed average FPL for each suburb is shown in **Table 8.5** along with the difference from the existing FPL (2.45m AHD).

Table 8.5: Comparison of Possible FPLs

	100 year ARI DSWL 0.4m SLR 0.5m Freeboard		100 year ARI DSWL 0.4m SLR 0.4m Freeboard		100 year ARI DSWL 0.4m SLR 0.3m Freeboard	
Suburb	FPL (m AHD)	Difference (m) from 2.45m AHD	FPL (m AHD)	Difference (m) from 2.45m AHD	FPL (m AHD)	Difference (m) from 2.45m AHD
BENSVILLE	2.30	-0.15	2.20	-0.25	2.10	-0.35
KINCUMBER SOUTH	2.31	-0.14	2.21	-0.24	2.11	-0.34
EMPIRE BAY	2.36	-0.09	2.26	-0.19	2.16	-0.29
KINCUMBER	2.37	-0.08	2.27	-0.18	2.17	-0.28
DAVISTOWN	2.38	-0.07	2.28	-0.17	2.18	-0.27
DALEYS POINT	2.42	-0.03	2.32	-0.13	2.22	-0.23
ST HUBERTS ISLAND	2.43	-0.02	2.33	-0.12	2.23	-0.22
BLACKWALL	2.45	0.00	2.35	-0.10	2.25	-0.20
KILLCARE	2.47	+0.02	2.37	-0.08	2.27	-0.18
SARATOGA	2.47	+0.02	2.37	-0.08	2.27	-0.18
YATTALUNGA	2.48	+0.03	2.38	-0.07	2.28	-0.17
HARDYS BAY	2.49	+0.04	2.39	-0.06	2.29	-0.16
BOOKER BAY	2.49	+0.04	2.39	-0.06	2.29	-0.16
WOY WOY	2.52	+0.07	2.42	-0.03	2.32	-0.13
PRETTY BEACH	2.52	+0.07	2.42	-0.03	2.32	-0.13
WAGSTAFFE	2.53	+0.08	2.43	-0.02	2.33	-0.12
PHEGANS BAY	2.56	+0.11	2.46	+0.01	2.36	-0.09
GREEN POINT	2.56	+0.11	2.46	+0.01	2.36	-0.09
ETTALONG BEACH	2.56	+0.11	2.46	+0.01	2.36	-0.09
HORSFIELD BAY	2.56	+0.11	2.46	+0.01	2.36	-0.09
WOY WOY BAY	2.56	+0.11	2.46	+0.01	2.36	-0.09
SPRINGFIELD	2.57	+0.12	2.47	+0.02	2.37	-0.08
UMINA BEACH	2.57	+0.12	2.47	+0.02	2.37	-0.08
ERINA	2.57	+0.12	2.47	+0.02	2.37	-0.08
KOOLEWONG	2.57	+0.12	2.47	+0.02	2.37	-0.08

	100 year ARI DSWL 0.4m SLR 0.5m Freeboard		100 year ARI DSWL 0.4m SLR 0.4m Freeboard		100 year ARI DSWL 0.4m SLR 0.3m Freeboard	
Suburb	FPL (m AHD)	Difference (m) from 2.45m AHD	FPL (m AHD)	Difference (m) from 2.45m AHD	FPL (m AHD)	Difference (m) from 2.45m AHD
EAST GOSFORD	2.59	+0.14	2.49	+0.04	2.39	-0.06
POINT FREDERICK	2.61	+0.16	2.51	+0.06	2.41	-0.04
TASCOTT	2.62	+0.17	2.52	+0.07	2.42	-0.03
GOSFORD	2.64	+0.19	2.54	+0.09	2.44	-0.01
POINT CLARE	2.65	+0.20	2.55	+0.10	2.45	0.00
WEST GOSFORD	2.67	+0.22	2.57	+0.12	2.47	+0.02

8.9 Flood Planning Level Recommendations

Due to the sensitivity of the Brisbane Water floodplain to sea level rise and the uncertainty associated with the sea level rise projections, it is proposed that the flood planning level be defined in a two stage approach:

- **Interim Flood Planning Level:** to be adopted until the outcomes of the CCAPs are known.
- **Long Term Flood Planning Level:** to be adopted after the outcomes of the CCAPs are known.

8.9.1 Interim Flood Planning Level

Due to the uncertainty associated with applying the risk of sea level rise into planning considerations, it is recommended that a short term approach to considering sea level rise be adopted as part of an interim FPL until the outcomes of the CCAPs are known.

The adoption of the 2050 sea level rise prediction would account for the predicted increases in flood levels over the next 35 years. Whilst this does not fully account for the typical lifespan of a residential building (50 years), it does afford some protection against sea level rise until the outcomes of CCAPs are known. The sea level rise component of the FPL should be reviewed at that stage, or before if relevant information becomes available.

Therefore the recommended interim FPL for the Brisbane Water foreshore floodplain is:

FPL = 100 year ARI DSWL + 2050 Projection of SLR + 0.5m Freeboard

Further, it is recommended that vulnerable or longer term development types such as critical infrastructure consider the application of the 2100 projected sea level rise as part of the FPL.

8.9.2 Long Term Flood Planning Level

Following the completion of the CCAPs, it is the intent that Council will have a more detailed recommendation for the inclusion of the impacts of climate change on planning considerations. This will assist Council with defining an appropriate component of SLR into the FPL for Brisbane Water floodplain. It is recommended that the FPL for Brisbane Water be reviewed at that time.

8.10 Recommendations for Floodplain Risk Management Plan

In light of the information presented in the previous sections, it is recommended that the following interim measures are applied until the CCAPs are complete:

- The flood planning level (FPL) for the majority of development types be equal to:
  FPL = 100 year ARI DSWL + 2050 Projection of SLR + 0.5m Freeboard
- At locations where the adopted FPL is higher than the existing PMF, the adopted FPL should still be used.
- It would be appropriate to consider the application of a minimum of 0.9m of sea level rise for vulnerable or longer term development types, such as:
  - Critical infrastructure, vulnerable development types (e.g. aged care, seniors living, child care) and emergency services;
  - Road raising for critical infrastructure; and
  - Construction of levees.

- Within the floodplain, where the PMF is higher than the FPL, it is not unreasonable for the PMF level to be used as a planning level when considering:
  - Critical infrastructure, vulnerable development types (e.g. aged care, seniors living, child care) and emergency services;
  - Road raising for critical infrastructure; and
  - Construction of levees.

Specific recommendations for design levels for all development types are provided in the Draft Development Control Matrix provided in **Appendix H**.

9 Flood Emergency Response Arrangements

9.1 Flood Emergency Response

For the 100 year ARI flood event in Brisbane Water, the time to peak (the time after high tide where storm surge becomes a dominant mechanism) is around 18 hours. The peak event for the study area is based on the dominant flood process - storm surge (coastal) flooding. For catchment flooding, reference should be made to catchment FRMPs. The time to peak represents a moderate to long amount of time before the peak of the flood event and warning and mobilisation time is therefore likely to be relatively long. Refer to **Section 9.5** regarding 'significant' periods of time during which emergency response would be delayed from attending some locations.

Forecasts for storm surge and coastal flooding are generally available further in advance than for catchment flooding due to the nature of meteorological predictions. Warning time for the floodplain can be up to a few days in advance if the flooding is related to an event such as an east-coast low but may be shorter depending on the accuracy of predictions. Due to the nature of flooding in the floodplain, evacuation (rather than shelter-in-place) would be considered the priority for emergency response management. However, it also should be acknowledged that should people become stranded by flood waters there may be a significant period of time until emergency response services can access them.

9.2 Emergency Response Documentation

9.2.1 EMPLAN

The NSW State Emergency Management Plan (EMPLAN) describes the New South Wales approach to emergency management, the governance and coordination arrangements and roles and responsibilities of agencies (Emergency Management NSW, 2012). For flood emergencies, the responsible agency is the NSW State Emergency Service (NSW SES) (**Section 9.3**).

For the purposes of emergency management, NSW is broken up into a series of management districts. It should be noted that Emergency Management Districts were changed to Emergency Management Regions in 2012. Regional Emergency Management Plans are being developed. Until the new plans are passed and available the District Emergency Management Plans remain in place (Ministry for Police and Emergency Services, 2013).

The Brisbane Water foreshore floodplain lies within the Hunter-Central Coast Emergency Management District and has its own District Disaster Plan, the *Hunter Central Coast Emergency Management District DISPLAN* (Emergency Management NSW, 2007) that incorporates the emergency preparedness, response and recovery arrangements for emergencies that require a district level response. The *DISPLAN* provides a basic hazard assessment for the district and also includes more specific information relating to the district, such as local waterways and intercity transport routes in and out of the district.

The Gosford City Local Government Area also has a DISPLAN; the *Gosford City DISPLAN* (Gosford LEMC, 2009) that details arrangements that prevent or mitigate, prepare for, respond to and recover from emergencies within the Gosford Local Government Area.

Both the District and the Gosford DISPLAN have been issued under the authority of the *State Emergency and Rescue Management Act 1989* and the *State Emergency Services Act 1989* and adopt a similar format to the NSW Plan. The Gosford City DISPLAN was last updated in 2009 (Gosford LEMC, 2009).

Figure 9.1 shows an organisational chart that seeks to reflect operations guided by the State EMPLAN.

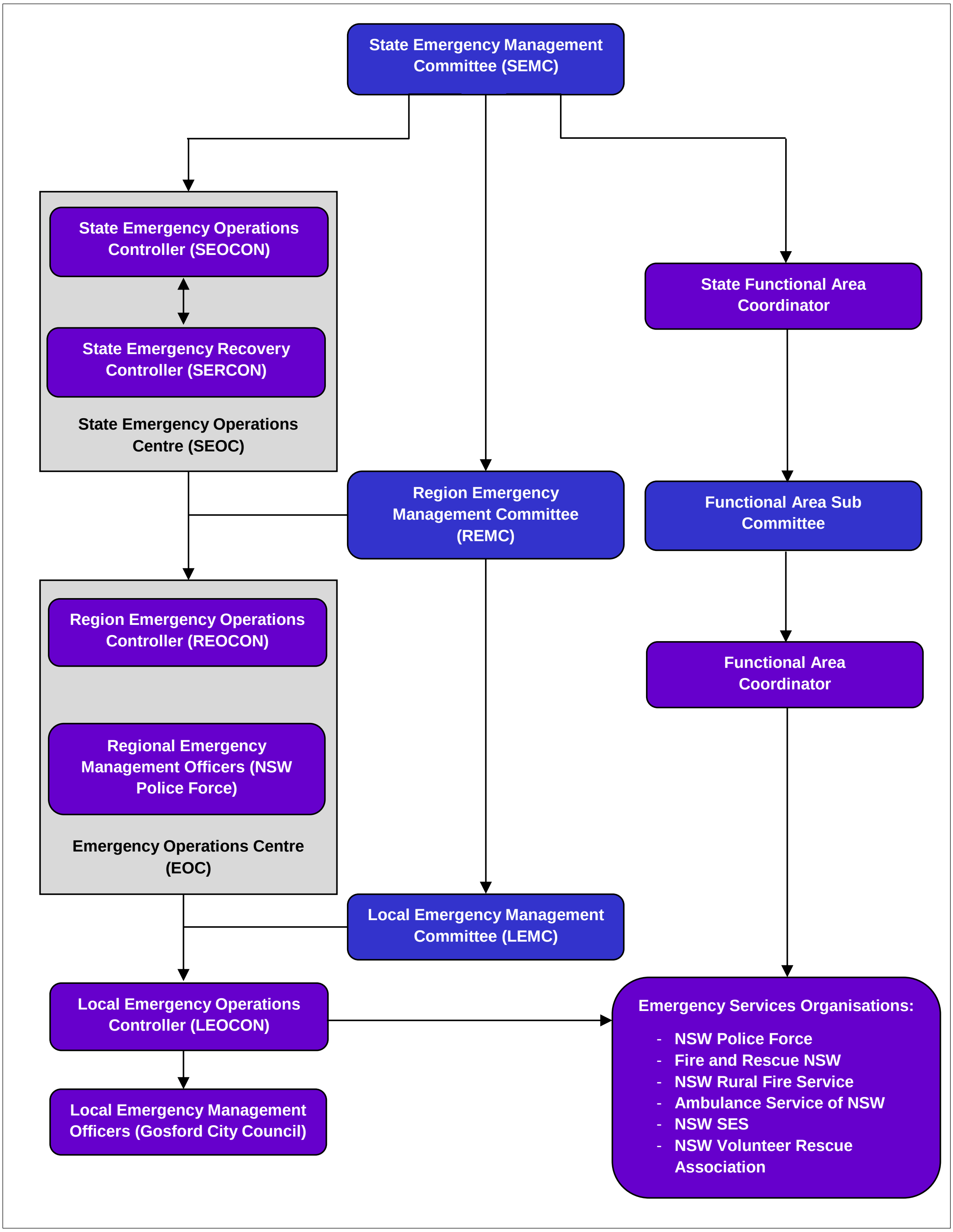

Figure 9.1: EMPLAN – Organisational Chart

9.2.2 Local Flood Plan

The *Gosford City Flood Emergency Sub Plan* (SES, 2012) is a sub plan of the Gosford City DISPLAN and was prepared in 2012 by the SES, in conjunction with Council.

The Local Flood Plan focuses exclusively on flooding emergencies in the context of preparedness, response and recovery for the Gosford LGA. The roles and responsibilities of various state and local agencies during a flood event are defined, in addition to the roles of other parties.

The Local Flood Plan states that a number of roads are affected by flooding, however details are not provided and it is states that “NSW SES maintains details of these roads”. It is also stated that in the event of a flood Gosford City Council closes and re-opens its own roads but also closes a number of roads as an agent for RMS, including Brisbane Water Drive, Central Coast Highway, Empire Bay Drive and Woy Woy Road.

The Local Flood Plan outlines locations that are suitable for evacuation during flood events. Two of these listed centres are within the Brisbane Water foreshore floodplain.

It is understood that a review of the Flood Plan is currently underway. It is recommended that the Local Flood Plan be updated to reflect the outcomes of this FRMS as a priority (once this FRMS is adopted by Council). It is recommended that the following updates be incorporated into the Flood Plan:

- Review the whole document to ensure that flooding occurring due to coastal flood mechanisms is appropriately incorporated;
- Remove Central Coast Leagues Club and Gosford RSL Club from the list of flood evacuation centres, since these are within the Brisbane Water foreshore floodplain;
- Incorporation of flood evacuation centres provided in **Section 9.5.3**;
- Note that Surf Life Saving Clubs may not be appropriate evacuation centres during coastal flooding associated with oceanic storm surge, due to the general proximity of these clubs to the ocean; and
- Incorporate the details of road flooding as outlined in **Section 9.5.1**.

9.3 NSW SES/Emergency Service and Operations

The NSW State Emergency Service (NSW SES) is an emergency and rescue service that provides community assistance during emergencies. The NSW SES undertakes rescue operations primarily during flood and storm events, but also provides for other forms of specialist rescue (NSW SES, 2009). The NSW SES is primarily a volunteer organisation. In times of emergency, the NSW SES utilises SMS and email for activating volunteers. However, more experienced crew know when to mobilise based on their understanding of the local area.

The local NSW SES unit for the Brisbane Water foreshore floodplain is located at Pateman Road, Erina. This site is where NSW SES vehicles and equipment is located. NSW SES headquarters are located within the Brisbane Water foreshore floodplain (access road flooding occurs in the existing 100 year ARI event). **Table 9.1** indicates that the peak flood depth on Pateman Road is 0.15m in the 20 year ARI event, 0.32m in the 100 year ARI event and 0.73m in the PMF.

It is noted that the SES facility at Erina is located in the floodplain and this Floodplain Risk Management Study recommends that the flood risk to this facility is removed (e.g. through road raising or relocation of the facility. The raising of Pateman Road (and the connecting The Entrance

Road, Option 4_FM1b, already included in the assessment) would be most appropriate if the SES site is to be retained at its current location.

The following outlines the roles and responsibilities of the NSW SES within the context of the Prevention, Preparation, Response and Recovery (PPRR) methodology as set out in the NSW EMPLAN (Emergency Management NSW, 2012). The NSW SES

- Prevention: To work with landuse planning and consent authorities to advocate that the risks arising from flood, storm and tsunami are considered so as to prevent the creation of intolerable impacts of these hazards on the community.
- Prevention: To work with the community to assist them in building their own resilience with the aim of risk avoidance in respect of flood, storm and tsunami.
- Preparation: To undertake research, risk assessment, emergency planning for flood, storm and tsunami, to develop and implement educational and other community capacity building programs, and to establish public warning and information management systems for these hazards,
- Preparation: To develop operational capability development including; the recruitment and training of members, equipping of Units, establishment of facilities and management systems for flood, storm, tsunami and the rescue functions assigned to the SES.
- Response: To lead the response to actual or imminent threats of flood, storm or tsunami so as to protect persons from danger to their safety and health and to protect property from damage in respect of these hazards and to provide rescue services as directed by the State Rescue Board.
- Response: As directed by the State Emergency Operations Controller to deal with an emergency where no other agency has lawful authority to assume command of the emergency operation.
- Recovery: To ensure that there is a seamless transition between SES-led response operations and any related recovery activities in the event of flood, storm or tsunami.
- Recovery: To ensure that after all significant flood, storm and tsunami events there is a focus on learning from these experiences aimed at continuous improvement in the PPRR cycle.

OEH recommends that wherever possible, protection of infrastructure and heritage buildings, structures, places and items should be maintained during the course of emergency action. For example, use of vehicles, equipment and machinery on the foreshore edge may have negative impacts on foreshore heritage. It is recognised that the protection of infrastructure and heritage may not be achievable depending on the level of emergency. In the event that damage is caused to historical or heritage items, OEH should be notified as soon as practicable.

9.4 Flood Warning Systems

The Brisbane Water Foreshore has a critical duration flood event of 9 hours for the 100 Year ARI flood event. This represents a moderate to long amount of time before the peak of a flood event and effective warning time is therefore likely to be relatively long. In addition, forecasts for storm surge and coastal flooding are generally available further in advance than for catchment flooding due to the nature of meteorological predictions. Warning time for the floodplain can be up to a few days in advance if the flooding is related to an event such as an east-coast low but may be shorter depending on the accuracy of predictions.

The NSW Bureau of Meteorology (BoM) is responsible for issuing warnings when potential flood emergencies are imminent. The New South Wales and Australian Capital Territory Flood Warning Centre is the specialised organisation within the BoM which carries out these warnings for NSW.

The Centre has a website (http://www.bom.gov.au/hydro/flood/nsw/) and also notifies major local media organisations as appropriate to broadcast warnings.

There are a number of sources of information regarding potential flooding. These are:

- Observation of local rainfall and flood gauges;
- State Emergency Service;
- Manly Hydraulics Laboratory;
- Bureau of Meteorology;
- Police; and
- Local television stations and radio stations.

It is noted that technology currently exists to incorporate water level monitoring into flood warning signage (e.g. Portable Variable Messaging Signage (VMS)).

9.5 Access and Movement During Flood Events

Any flood response suggested for the study area must take into account the availability of flood free access, and the ease with which movement may be accomplished. Movement may be evacuation from flood affected areas, medical personnel attempting to provide aid, or NSW SES personnel installing flood defences.

9.5.1 Access Road Flooding

Table 9.1 provides a summary of road flooding in the Brisbane Water floodplain. Time to peak flooding is in the order of 18 hours from high tide assuming continuing storm surge conditions (for example, storm surges associated with an east coast low).

There are a number of methods that may be utilized to warn motorists of flooded roads and road closures. Portable Variable Messaging Signage (VMS) may be deployed along RMS controlled roads (such as the Central Coast Highway) to warn motorists of inundated roads and alternative routes. For non-RMS roads, Council and the NSW SES can have portable VMS ready for deployment in times of flood. Permanent "Road Floods" signage may also be used to indicate that roads may be inundated in the event of a flood.

Depth indicators are used to indicate to drivers the maximum depth of floodwaters across the road. The zero mark on the depth indicators is set at the lowest pavement level on the section of road liable to flooding. While this device will indicate the maximum depth of water it does not indicate how fast the water is moving or if the road surface under water is still intact and trafficable. The water level may also still be rising. Motorists should generally not attempt to drive through water covering the road.

Table 9.1: Major Access Road Flooding (Existing Scenario)

ID[1]	Road Name	20 Year ARI		100 Year ARI		PMF	
		Peak Flood Depth (m)	Duration of Flooding (hrs)	Peak Flood Depth (m)	Duration of Flooding (hrs)	Peak Flood Depth (m)	Duration of Flooding (hrs)
1	Araluen Drive	N/A	0.0	N/A	0.0	0.14	3.3
2	Blackwall Road	0.45	6.4	0.61	8.7	1.01	16.8
3	Booker Bay Road	N/A	0.0	N/A	0.0	0.06	2.4
4	Brick Wharf Road	0.42	6.3	0.59	8.4	0.95	16.6
5	Brisbane Water Drive	0.02	0.7	0.23	4.0	0.78	8.6

ID[1]	Road Name	20 Year ARI		100 Year ARI		PMF	
		Peak Flood Depth (m)	Duration of Flooding (hrs)	Peak Flood Depth (m)	Duration of Flooding (hrs)	Peak Flood Depth (m)	Duration of Flooding (hrs)
6	**Central Coast Highway**	0.33	5.0	0.53	6.8	1.01	12.4
7	**Coolarn Avenue**	N/A	0.0	0.16	3.2	0.70	8.0
8	**Davistown Road**	0.24	4.3	0.37	5.9	0.63	11.5
9	**Greenfield Road**	0.25	4.5	0.37	5.9	0.58	11.8
10	**Helmsman Boulevard**	0.00	0.1	0.14	3.0	0.43	6.4
11	**Malinya Road**	0.25	4.6	0.39	6.0	0.68	11.8
12	**Manooka Road**	N/A	0.0	0.20	3.6	0.74	8.3
13	**Norma Crescent**	N/A	0.0	0.12	2.7	0.46	6.6
14	**North Burge Road**	0.39	5.8	0.55	7.3	0.89	14.6
15	**Pateman Road**	0.15	3.1	0.32	5.0	0.73	8.7
16	**Pretty Beach Road**	0.23	4.3	0.33	5.2	0.59	11.1
17	**The Entrance Road**	0.19	3.6	0.36	5.4	0.77	9.1
18	**The Esplanade**	0.15	3.0	0.30	4.3	0.60	6.8
19	**Woy Woy Road**	0.20	3.7	0.37	5.5	0.78	9.1
20	**Yallambee Ave**	0.46	6.3	0.67	8.2	1.19	15.3

[1] Locations shown in **Figure 9.2.**
N/A - Not flooded in specified event.

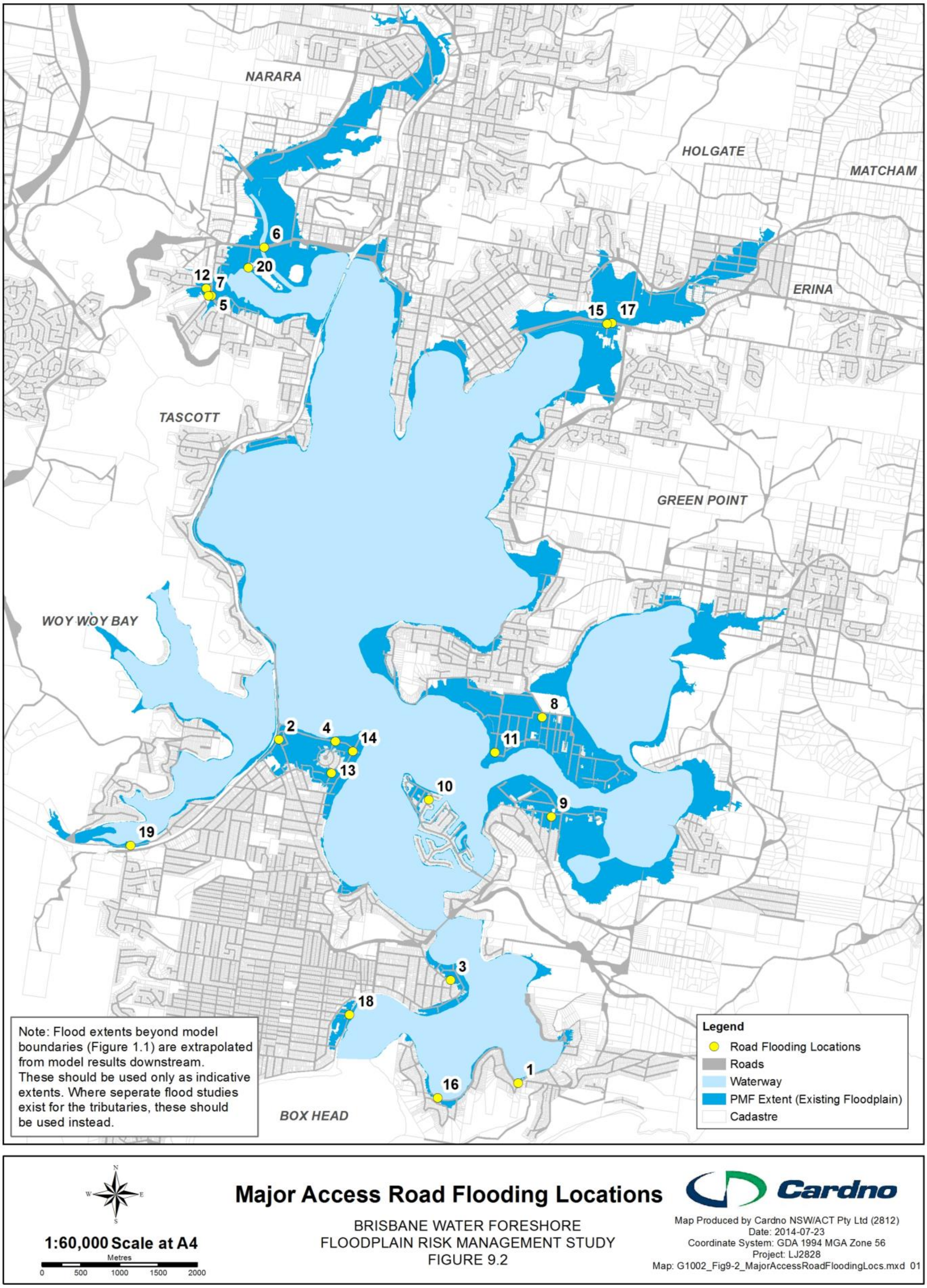

Figure 9.2: Major Access Road Flooding Locations

9.5.2 Duration of Flooding

The majority of the Brisbane Water foreshore floodplain generally has a similar duration of flooding. In a 100 year ARI event, the majority of the floodplain is likely to be inundated for approximately 5 hours, with a likely maximum duration of flooding of 9 hours. Only those areas very close to the foreshore would be inundated for longer. An indication of the likely duration of flooding during a 100 year ARI event is provided in **Figure 6.3**.

9.5.3 Evacuation Centres

The aim of evacuation is to minimise the risk to public safety when a natural disaster such as a flood occurs. When evacuation is required, evacuees should be directed to centres for temporary refuge and accommodation. Evacuation centres for all disasters (including flooding) in the Gosford LGA have been identified by the Department of Community Services (DoCS, 2007). The NSW State Flood Plan 2008 (NSW SES, 2008a) outlines the Evacuation Strategy to be adopted during flood events. It states:

- Evacuations will take place when there is a risk to public safety. Circumstances may include:
    - Evacuation of people when their homes or businesses are likely to flood.
    - Evacuation of people who are unsuited to living in isolated circumstances, due to flood water closing access.
    - Evacuation of people where essential energy and utility services have failed or where buildings have been made uninhabitable.

Results of the flood extent mapping (**Section 6.2.4**) suggest that a number of these evacuation centres lie within a floodplain (either the Brisbane Water floodplain or a creek floodplain) and are therefore not suitable for use as an evacuation centre during a flood event. In addition, many of the suggested evacuation locations are surf life-saving centres (SLSCs). SLSCs may not provide appropriate evacuation centres during flooding associated with ocean storms, due to their general proximity to the ocean.

The Department of Community Services (DoCs) holds a list of recommended evacuation centres to be used in times of severe hazard or disaster. Of the full list of evacuation centres, **Table 9.2** lists clubs and community centres that have the potential to be flood evacuation centres for the Brisbane Water floodplain because they lie outside of the PMF extent (and the PMF extent with 0.9m SLR), are not likely to be isolated during a flood event, are not likely to be inundated during catchment or lagoon flooding, and are located within reasonable driving distance from flood-affected areas. These facilities have been mapped on **Figure 9.3.**

Table 9.2: Evacuation Locations and Capacity.

Centre Name	Address	Capacity for Evacuees (no. of persons)
Gosford City Sports Stadium, Terrigal	Duffy’s Road, Terrigal	1,000
Gosford/Narara Community Centre	2 Pandala Road, Narara	250
Green Point Community Centre	96 Koolang Road, Green Point	125
Kariong Community Centre	10 Langford Drive, Kariong	50
Kincumber and District Neighbourhood Centre	20 Kincumber Street, Kincumber	300
La Salle Youth Camp	1 Mackillop Rd, Kincumber South	1,310

Centre Name	Address	Capacity for Evacuees (no. of persons)
Niagara Park Community Centre	Washington Avenue, Niagara Park	400
Peninsula Community Centre	93 McMasters Road, Woy Woy	500
Senior Citizens Centre, Terrigal	Cnr Terrigal Drive and Duffys Road, Terrigal	200
Umina Beach PCYC	101 Osborne Ave, Umina Beach	400
Wyoming Community Centre	147 Maidens Brush Road, Wyoming	50
	Total:	**3,406**

The total number of evacuees that could be housed at these facilities is 3,406. Given the number of properties affected by over-floor flooding in the existing PMF event (1198, **Table 6.7**) and the average household size (2.2 persons, **Table 5.1**), these evacuation facilities are likely to be adequate in housing all evacuees in such an event.

Some additional, alternative centres in the Davistown area have been suggested as an outcome of community engagement in the project and include:

- Davistown RSL Club;
- Brisbania School; and
- Saratoga Shopping Centre.

If evacuation becomes necessary during a flood event, the NSW SES and other emergency services may door-knock to advise residents and businesses of what to do and where to go. Other notification methods may also be employed, such as broadcasts via radio and social media (NSW SES, 2008b).

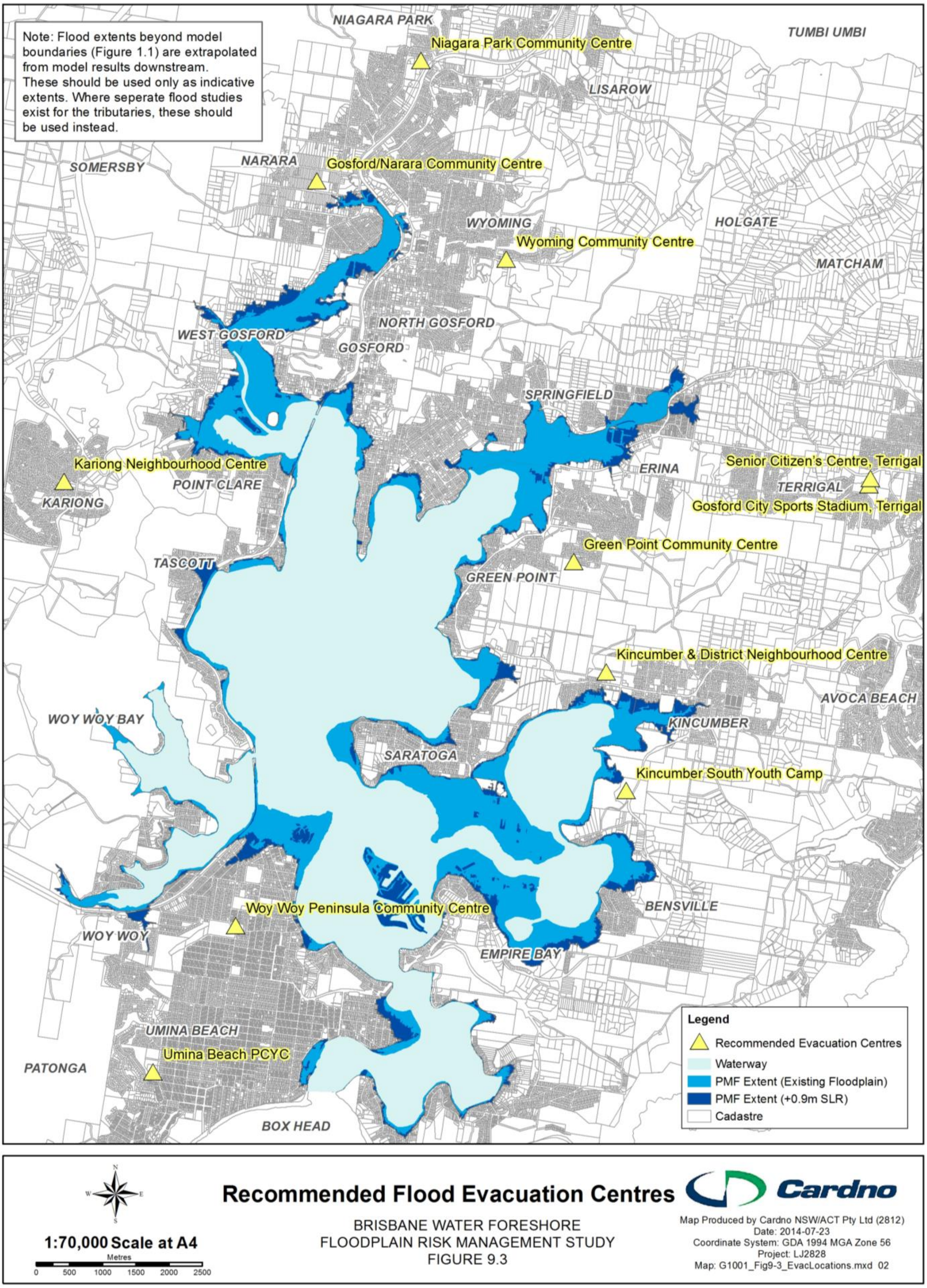

Figure 9.3: Recommended Flood Evacuation Centres

9.6 Flood Emergency Response Planning Classification

To assist in the planning and implementation of response strategies the NSW State Emergency Service (NSW SES) classifies communities according to the impact of flooding experienced. Flood-affected communities are 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. The classifications adopted by the NSW SES are (DECC, 2007b):

- **Flood Islands** – These are inhabited or potentially habitable areas of high ground within a floodplain linked to the flood-free valley sides by a road across the floodplain and with no alternative overland access. The road can be cut by floodwater, closing the only evacuation route and creating an island. Flood islands can be further classified as:
  - High Flood Island (the flood island contains enough flood free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground).
  - Low Flood Island (the flood island does not have enough flood free land to cope with the number of people in the area or the island will eventually become inundated by flood waters).
- **Trapped Perimeter Areas** – These would generally be inhabited or potentially habitable areas at the fringe of the floodplain where the only practical road or overland access is through flood prone land and unavailable during a flood event. The ability to retreat to higher ground does not exist due to topography or impassable structures. Trapped Perimeter Areas are further classified according to their evacuation route:
  - High Trapped Perimeter (the area contains enough flood free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground).
  - Low Trapped Perimeter (the area does not have enough flood free land to cope with the number of people in the area or the island will eventually become inundated by flood waters).
- **Areas able to be Evacuated** – These are inhabited areas on flood prone ridges jutting into the floodplain or on the valley side that are able to be evacuated.
  - Areas with Overland Escape Route (access roads to flood free land cross lower lying flood prone land).
  - Areas with Rising Road Access (access roads rise steadily uphill and away from the rising floodwaters).
- **Indirectly Affected Areas** – These are areas which are outside the limit of flooding and therefore will not be inundated nor will they lose road access. However, they may be indirectly affected as a result of flood damaged infrastructure or due to the loss of transport links, electricity supply, water supply, sewage or telecommunications services and they may therefore require resupply or in the worst case, evacuation.
- **Overland Refuge Areas** – These are areas that other areas of the floodplain may be evacuated to, at least temporarily, but which are isolated from the edge of the floodplain by floodwaters and are therefore effectively flood islands or trapped perimeter areas.

The majority of the floodplain falls into the classification of “Areas Able to be Evacuated”, either as Areas with Overland Escape Route or Areas with Rising Road Access. Specific locations that are subject to isolation during flood events are outlined in **Table 9.3** and shown on **Figure 9.4**.

A preliminary assessment was undertaken to identify facilities within the floodplain (PMF extent) that are likely to be particularly sensitive to flooding. Properties were identified through a preliminary search of a street directory and Google Maps (Google, 2013). Locations where critical infrastructure may become isolated are included in **Table 9.3**.

Table 9.3: Key Potentially Isolated Locations

Location	Description	Classification and Response
Several residential properties in the vicinity of Camellia Circle, Woy Woy	As floodwaters rise, access to and from these properties is likely to be cut off prior to the properties being inundated.	This area represents a Trapped Perimeter Area since residential lands are initially surrounded by floodwaters before being inundated at the PMF event. Vehicle evacuation must be completed before routes close. After closure, any persons not already evacuated must be rescued by air or boat, before inundation occurs.
Properties along Yallambee Avenue, West Gosford	Including the nursing home/retirement village, which is above the floodplain but is likely to be surrounded by floodwaters and isolated during flood events, with road access cut off.	These areas represent Low Flood Islands. Vehicle evacuation must be completed before routes close. After route closure, resupply may not be required, but should be assessed depending on the severity of the flood. Low Flood Island: flood island is lower than the limit of flooding (i.e. below the PMF) or does not have enough land above the limit of flooding to cope with the number of people in the area. During a flood event the area is isolated by floodwater and property will be inundated. If floodwater continues to rise after it is isolated, the island will eventually be completely covered. People left stranded on the island may drown and property will be inundated (DECC 2007b).
Some areas in Davistown and Empire Bay	Filling in Davistown and Empire Bay means that some properties are located on higher ground. During flood events, this leads to a series of "islands" – areas surrounded by floodwaters and isolated.	
Properties along Boyd Close and Beachfront Parade, St Huberts Island	These properties are located on higher ground but would be surrounded by floodwaters and isolated during flood events. Road access is also likely to be cut off.	
NSW SES Headquarters (Gosford), Erina	This property is located on higher ground but would be surrounded by floodwaters and isolated during flood events. Road access is also likely to be cut off. Existing PMF event does not inundate whole area.	This area represents a High Flood Island. Emergency response from this location is unlikely to be efficient in a severe flood event.

Table 9.4 provides a summary of the response required for different flood emergency response planning classifications.

Table 9.4: Emergency Response Requirements (DECC, 2007b)

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
Area 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
High Flood Island	Yes	Possibly	Possibly

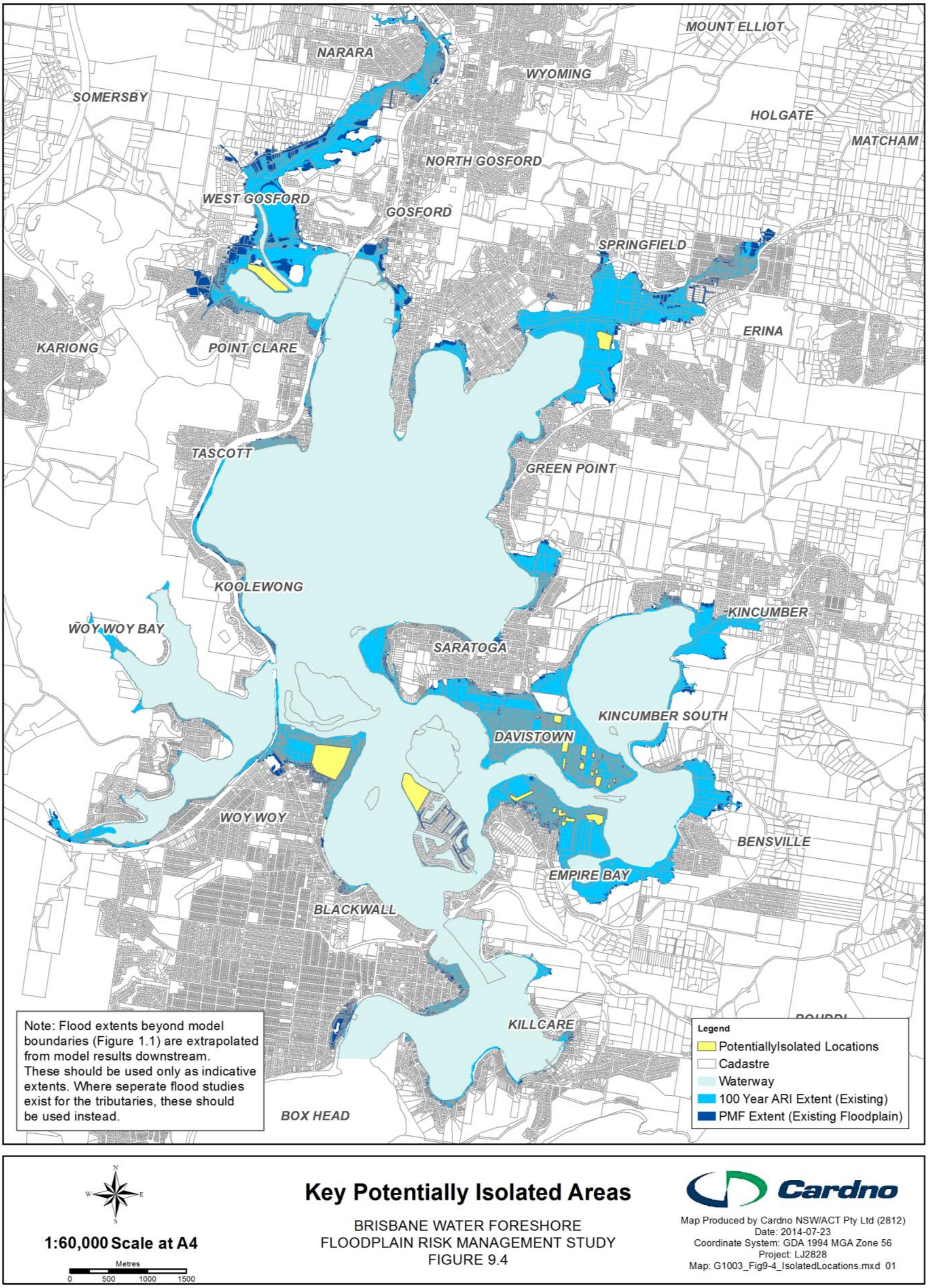

Figure 9.4: Key Potentially Isolated Areas

9.7 Recovery

The *Gosford Local Flood Emergency Sub-Plan 2013* (Gosford LEMC, 2013) sets out the recovery arrangements for operations after a flood event. Support and disaster recovery services are provided by NSW Community Services State Disaster Recovery Centre to help people and communities recover from major incidents and disasters such as floods. Immediate assistance to those affected can be provided through locally-established evacuation centres as described in **Section 9.5.3**, whilst medium and long term support is available from *disaster recovery centres*, which are set up in the event of a larger scale disaster. Services include the provision of necessities such as food, accommodation and clothing, and the provision of advice and guidance, and financial and personal support (NSW Community Services, 2009a). Additionally, the NSW Disaster Relief Scheme provides financial assistance to eligible persons and families who have been affected by flooding (NSW Community Services, 2009b).

The recovery and redevelopment of infrastructure and property subsequent to a flood event often represents a massive undertaking. Funding for the recovery of infrastructure and property can be derived from a variety of sources including state and federal government funding, insurance claims and charity organisations.

10 Floodplain Risk Management Options

10.1 Overview

Floodplain risk management options provide opportunities for the flood risk within a floodplain to be removed or reduced. A series of possible management options for the Brisbane Water foreshore floodplain have been identified and assessed in accordance with the *Floodplain Development Manual* (NSW Government, 2005).

There are a range of complex issues involved in floodplain risk management at Brisbane Water. This study considers the flooding that results from coastal processes, such as significant coastal wave events and surges associated with large ocean storms (e.g. those experienced in May 1974 and more recently in June 2007 when the *Pasha Bulker* ran aground in Newcastle). Management options identified in this FRMS have been developed based on the type of risks associated with coastal flooding that is relevant to Brisbane Water. Severe ocean storms are driven by east coast lows and are characterised by elevated ocean water levels, intense rainfall and strong winds. These events often generate severe beach erosion, creek flooding (due to rainfall), reduced power reliability and property damage due to strong winds, and road closures due to flooding. These are the types of risks that are currently faced by the Brisbane Water floodplain.

To address existing and residual risks, this FRMS provides a series of options for short term flood risk management. For future flood risks, long term management options and tools have been identified for use in further investigations and studies. A series of *Climate Change Adaptation Plans* (CCAPs) are proposed to be undertaken in the future to establish appropriate land use patterns in response to climate change.

10.2 Management Areas

The nature of flooding and the impacts associated with flooding vary around Brisbane Water, and because of this, the management of flooding cannot always be applied in the same manner on a regional basis. To assist with identifying options relevant to all flood-affected locations within the Brisbane Water Floodplain, 15 management areas were established. These management areas were delineated to incorporate areas of similar flood impact characteristics. The outcome of this FRMS will be management strategies for each of the management areas as well as recommendations for Brisbane Water as a whole.

The 15 management areas are as follows (**Figure 10.1**):

1. West Gosford and Point Clare
2. Gosford
3. Point Frederick, East Gosford, Green Point, Koolewong and Tascott
4. Erina
5. Yattalunga and Saratoga
6. Davistown
7. Kincumber, Kincumber South and Bensville
8. Empire Bay
9. St Huberts Island
10. Daleys Point, Killcare and Hardys Bay
11. Pretty Beach and Wagstaffe
12. Ettalong
13. Booker Bay

14. Woy Woy and Blackwall
15. Horsfield Bay, Phegans Bay and Woy Woy Bay.

A description of the existing flooding conditions for these 15 management areas is provided in **Section 6.2.2**.

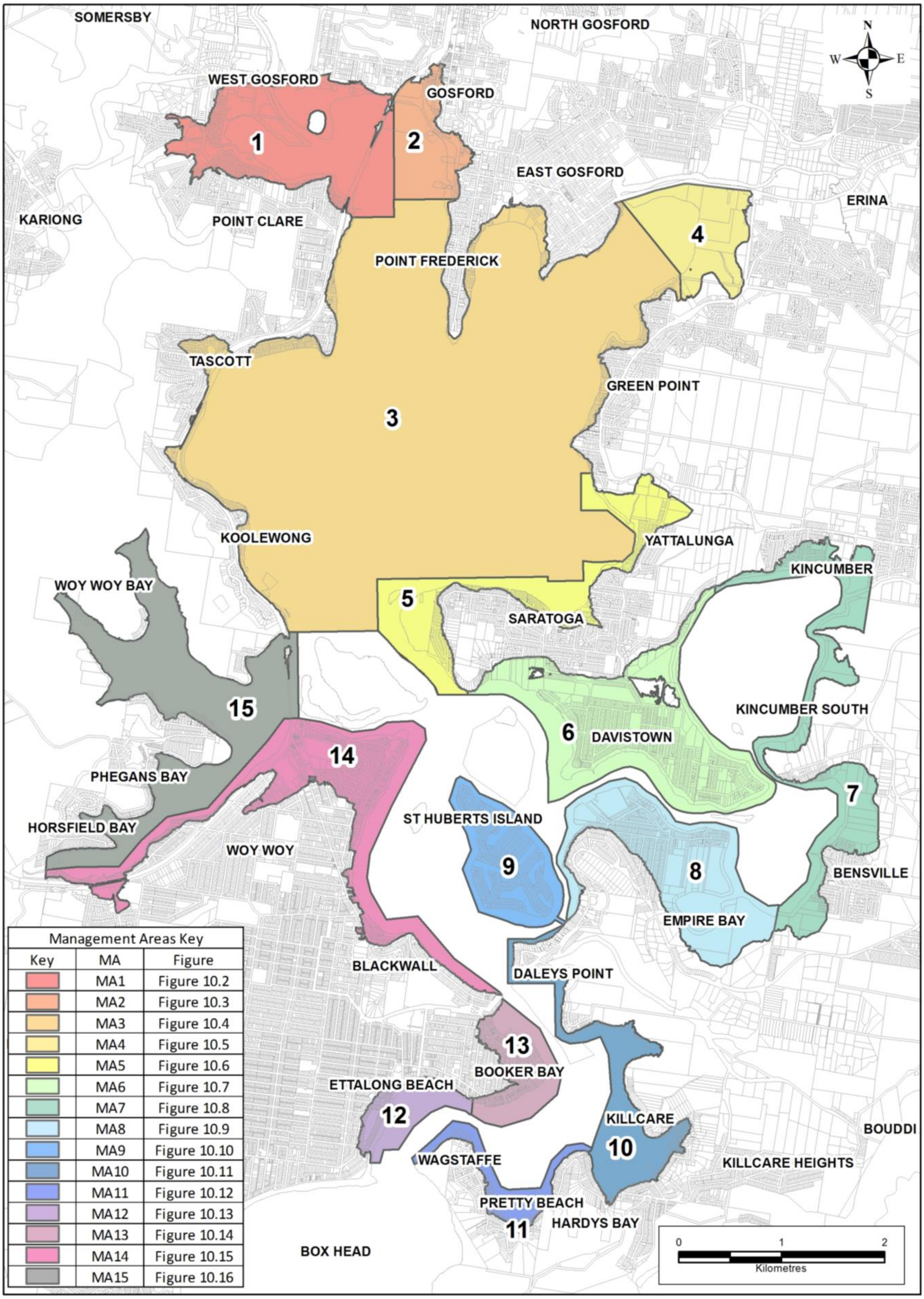

Figure 10.1: Foreshore Flood Risk Management Areas

10.3 Managing Flood Risk

Flood risk can be classified as existing, future or residual, and these three categories are integral in addressing the flood risks for the Brisbane Water floodplain:

- **Existing Flood Risk** – existing buildings and developments on flood prone land. Such buildings and developments by virtue of their presence and location are exposed to an 'existing' risk of flooding.
- **Future Flood Risk** – buildings and developments that may be built on flood prone land. Such buildings and developments would be exposed to a flood risk when they are built.
- **Residual Flood Risk** – buildings and development that would be at risk if a flood were to exceed management measures already in place. Unless a floodplain management measure is designed to withstand the PMF, it may be exceeded by a sufficiently large event at some time in the future.

The alternate approaches to managing risk are outlined in **Table 10.1**.

Table 10.1: Flood Risk Management Alternatives (SCARM, 2000)

Alternative	Examples
Preventing / Avoiding Risk	Appropriate development within the flood extent, setting suitable planning levels. Setting the planning level at the probable maximum flood (PMF) or not allowing development to be within the floodplain is the only way to prevent or avoid risk completely.
Reducing Likelihood of Risk	Structural measures to reduce flooding risk such as levees. The potential for implementation of flood modification options is limited by economic, social and environmental constraints.
Reducing Consequence of Risk	Development controls to ensure structures are built to withstand flooding. Allows a floodplain to be developed in a flood compatible manner.
Transferring Risk	Via insurance – not viable given the non-insurability of some flood-prone areas.
Financing Risk	Natural disaster funding.
Accepting Risk	Regardless of the options implemented, a continuing risk will be present. Accepting the risk of flooding as a consequence of having the structure where it is.

Measures available for the management of flood risk can be categorised according to the way in which the risk is managed. There are three broad categories of management:

- **Flood Modification (FM) measures** – Flood modification measures are options aimed at preventing / avoiding or reducing the likelihood of flood risks. These options reduce the risk through modification of the flood behaviour in the catchment.
- **Property Modification (PM) measures** – Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks. Rather than necessarily modify the flood behaviour, these options aim to modify properties (both existing and future) so that there is a reduction in flood risk.
- **Emergency Response Modification (EM) measures** – Emergency response modification measures aim to reduce the consequences of flood risks. These measures generally aim to modify the behaviour of people during a flood event.

Due to the nature of flooding in the floodplain (i.e. dominated by coastal processes) and the sensitivity of flood levels and the foreshore to projected sea level rise, the development of flood management options for the Brisbane Water foreshore floodplain has considered a holistic approach to managing current flood behaviour and flood behaviour as a result of projected sea level rise. The following summarises the range of options considered for the existing scenario and projected sea level rise scenario:

- *Options that address the current flood risks (existing scenario) only* – These options aim to address the risk of coastal flooding that is currently experienced in the floodplain. It is anticipated that some of these options will form the basis of the FRMP.
- *Options that address the current flood risks but also benefit conditions under sea level rise* – These options aim to address the existing risk of coastal flooding but also have some incidental benefit under projected sea level rise conditions.
- *Options that relate to sea level rise only* – These options aim to consider the potential impacts of coastal flooding under sea level rise conditions in areas currently not impacted by flooding. It is anticipated that these options will not generally be recommended for inclusion in the FRMP.

Note that options that provide protection against existing coastal flood risk may also incidentally provide protection against *tidal inundation* risk with projected sea level rise (inundation occurring on a regular basis, aligned with the tides). This is simply because the levels for future everyday tidal inundation may be lower than for existing infrequent flood events.

10.4 Option Identification

As part of the floodplain risk management process for the Brisbane Water foreshore floodplain, possible floodplain risk management options were identified based on the following:

- Review of appropriate management approaches as described in the *Floodplain Development Manual* (NSW Government, 2005);
- Suggestions by:
  - GCC technical personnel;
  - The Catchments and Coasts Committee (CCC);
  - Community representatives (via the FRMC);
  - The wider community (via the resident questionnaire, **Section 4.3.1**);
- Observations from site inspections; and
- Results of the *Foreshore Flood Study* (Cardno, 2013).

Where technically possible, and within the scope of the study commissioned, all feasible options were included for assessment. In accordance with the *Floodplain Development Manual* and as discussed above, measures identified were separated into flood, property and emergency response modification options and are discussed in more detail below and in **Appendix I**.

It is noted that other Flood Studies and Floodplain Risk Management Studies and Plans have been completed for tributaries of the Brisbane Water Estuary and should be considered in the future development and detailed design of any options impacted by these Flood Studies. For example, Golder Associates (2012) recently undertook a *Review of the Narara Creek Flood Study*.

10.4.1 Floodplain-Wide Management Options

Table 10.2 provides a summary of management options identified for the whole floodplain. These options do not have specific locations and hence have not been mapped.

10.4.2 Options by Management Area

Table 10.3 to Table 10.17 provide a summary of the identified management options for each management area. Where mappable, options locations are shown on **Figure 10.2** to **Figure 10.16**.

10.4.3 Action Timeline

Table 10.2 to Table 10.17 include reference to an "Action Timeline". This corresponds to the timeframe over which the option would be implemented:

- **Immediate** – this indicates options that could be implemented in the short term. Feasibility of the option is generally high and additional investigations or further development of the management strategy would be minimal;
- **Staged** – this indicates options that could be undertaken in the short to medium term. However, additional investigations, feasibility studies or further development of the management strategy are likely to be required. Where appropriate, interim policy and planning measures could be employed in the intervening time.
- **Trigger** – this indicates options that could be undertaken over the long term. Further investigations are required and the implementation of the option would be based on a predefined sea level rise "trigger level" to indicate when implementation is viable. Where appropriate, interim policy and planning measures could be employed until the trigger level is reached.

For each option, **Table 10.2 to Table 10.17** show a series of ticks to indicate the tidal inundation scenario or coastal flood event that is addressed. For those options identified as having an action timeline of "staged" or "trigger", the option could be undertaken to address existing risk in the first instance, but over the medium to long term (as more information and/or trigger levels become available) could be modified to incorporate SLR. This concept particularly relates to large structural options. For example, a levee could be built in the short term to withstand the existing flood risk (no SLR), and once an appropriate trigger level had been reached, the levee could be raised to incorporate SLR (the levee footing and other elements would need to be designed appropriately at the outset in order for levee-raising to succeed). In **Table 10.2 to Table 10.17**, black ticks (✓) indicate the scenarios that the option would address for the existing flood risk (i.e. no SLR) whilst grey ticks (✓) indicate the scenarios that the option would provide protection under sea level rise if the option was modified appropriately (e.g. levee-raising).

10.4.4 Naming Convention

All options identified were assigned a code depending on their type:

- The letters 'FM' indicate flood modification options;
- The letters 'PM' indicate property modification options;
- The letters 'EM' indicate emergency response modification options; and
- The letters 'DN' indicate the do nothing option.

Within each of the first three categories, each option has been assigned a consecutive number (starting at 1) to provide a unique code for each option, e.g. FM1. A letter was also assigned if two options were similar but still assessed individually, e.g. FM2a and FM2b. There is only one DN option (do nothing). Where an option applies to a specific management area (**Figure 10.1**), a prefix number was also assigned (e.g. 2_FM3). This number prefix denotes the management area that the option applies to (e.g. a prefix of 2 means the option 2_FM3 applies to management area 2, i.e. West Gosford and Point Clare).

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Table 10.2: All Identified Floodplain-Wide Management Options (Including Preferred)

Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	Tidal/Flood Event Addressed: Tidal: MHWS	+SLR (0.4m)	+SLR (0.9m)	Foreshore Flood: 5 yr ARI (20%)	100 yr ARI (1%)	PMF	100 yr ARI (0.4m SLR)	5 yr ARI (0.9m SLR)	100 yr ARI (0.9m SLR)	PMF (0.9m SLR)	Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAPs (PM9)
FM2a	Construct a storm surge barrier at the entrance to BW (Half Tide Rocks) that could be activated during severe offshore storm surge events.	Trigger	$2,400,000,000	$1,400,000		✓	✓		✓	✓	✓	✓	✓	✓	1996	1225	0.00	GCC/ State	Economic costs would be large. Option is not currently economically viable but would become viable as sea levels rise, depending on the adaptation response of the community. Environmental and visual amenity issues would also be considerable. Community pressure to close the barrier more frequently as sea levels rise.	Y
FM2b	Construct a storm surge barrier at The Rip that could be activated during severe offshore storm surge events.	Trigger	$1,800,000,000	$1,100,000		✓	✓		✓	✓	✓	✓	✓	✓	1856	1139	N/A	GCC/ State	Economic costs would be large. Option is not currently economically viable but would become viable as sea levels rise, depending on the adaptation response of the community. Environmental and visual amenity issues would also be considerable. Community pressure to close the barrier more frequently as sea levels rise.	Y
FM4	Install flood gates on stormwater pipe outlets as required.	Staged	$100,000	$35,000											Unkn.	Unkn.	N/A	GCC	Protection may be reduced under projected sea level rise scenarios. Small levees may also be required in some areas to complement the flood gates.	N
FM10	Raise railway infrastructure to above the 100 Year ARI flood level (with 0.9m SLR).	Trigger	$25,000,000	$500,000	✓	✓	✓	✓	✓	✓	✓	✓	✓		0	0	N/A	State	State government expenditure.	Y
PM1	Implement a voluntary house purchase program for properties that meet specified criteria. Utilise purchased flood prone properties as open space (e.g. recreational or wetland areas).	Staged	$9,800,000	$0		✓	✓	✓	✓	✓	✓	✓	✓	✓	19	19	0.11	GCC/ State	State government expenditure.	Y
PM2	Implement a voluntary house raising program for identified dwellings that meet specified criteria.	Staged	$630,000	$0		✓	✓	✓	✓	✓	✓	✓	✓	✓	21	21	1.14	GCC/ State	Number of properties to be raised would depend on funding availability and the findings of the *Climate Change Adaptation Plans*.	Y
PM3	Investigate a land swap program for properties that meet specified criteria with land that Council owns in non flood-prone areas.	Staged	$380,000	$0		✓	✓	✓	✓	✓	✓	✓	✓	✓	19	19	2.87	GCC/ State	Number of properties to be swapped would depend on availability of swappable land and the findings of the *Climate Change Adaptation Plans*.	Y
PM4	Conduct a program of strategic, balanced and socially sensitive education to advise the local community and prospective property purchasers about the risk and effects of coastal flooding.	Staged	$20,000	$4,000		✓	✓	✓	✓	✓	✓	✓	✓	✓	0	0	N/A	GCC/ NSW SES	This option has the potential to have a social impact for existing property-owners that hold flood-affected land (e.g. a perception of impacts on property prices).	N
PM5	Continue to monitor sea levels and perform periodic analyses to ascertain the rate of sea level rise within Brisbane Water. Periodically communicate results to the community.	Immediate	$15,000	$4,500		✓	✓				✓	✓	✓	✓	0	0	N/A	GCC/ State	Responsibility for monitoring and data management/analysis could be taken on by the state government.	Y
PM7	Review and amend planning instruments and development controls across the floodplain to ensure consistency with coastal flooding. Review every five years.	Immediate	$50,000	$10,000	✓	✓	✓	✓	✓	✓					All	Unkn.	N/A	GCC/ State	Interim development controls for the Brisbane Water foreshore floodplain are provided in Appendix H. The recommendations in this option do not include SLR. This should be reviewed by Council in the near future.	Y
PM8	Develop development controls and planning measures for all management areas via two stages - 1. Interim Development Control Measures to be implemented until further investigations are completed; and 2. Review interim measures following completion of Climate Change Adaptation Plans.	Staged	$100,000	$15,000	✓	✓	✓	✓	✓		✓	✓	✓		All	Unkn.	N/A	GCC/ State	Interim development controls for the Brisbane Water foreshore floodplain are provided in Appendix H. The recommendations in this option include the consideration of sea level rise. It is noted that there is potential for the classification of areas to transition over time from low hazard to high hazard as a result of sea level rise, and this should be carefully considered.	Y

Table 10.2 (cont.): All Identified Floodplain-Wide Management Options (Including Preferred)

Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	Tidal/Flood Event Addressed: Tidal: MHWS	Tidal: +SLR (0.4m)	Tidal: +SLR (0.9m)	Foreshore Flood: 5 yr ARI (20%)	Foreshore Flood: 100 yr ARI (1%)	Foreshore Flood: PMF	Foreshore Flood: 100 yr ARI (0.4m SLR)	Foreshore Flood: 5 yr ARI (0.9m SLR)	Foreshore Flood: 100 yr ARI (0.9m SLR)	Foreshore Flood: PMF (0.9m SLR)	Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAPs (PM9)
PM9	Develop management strategies (as part of Climate Change Adaptation Plans for each management area) to adapt to the impacts of projected sea level rise on tidal inundation.	Staged	$480,000	$72,000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Unkn.	Unkn.	N/A	GCC/ State	Preliminary mapping and assessments have been undertaken and are presented in Appendix E.	Y
PM10	Evaluate utilities infrastructure relative to flood risk and projected sea level rise benchmarks. Partner with private utilities managers to better understand the risks to assets and formulate a plan of management over the long term for integration into Council's planning objectives.	Staged	$150,000	$7,500		✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC / State (utilities) / Private (utilities)	Utilities and services are generally designed to withstand intermittent inundation by flooding, however the impact of projected sea level rise on such assets is potentially a major issue within the floodplain. Trigger levels may be established utilising results of option PM5 (monitoring sea level rise).	Y
PM12	Implement managed retreat in critical areas to avoid the impacts of projected sea level rise.	Trigger	$1,300,000,000	$0		✓	✓	✓	✓	✓	✓	✓	✓	✓	1774^	2283^	0.00	GCC/ State	Further details of this option would be based on the findings of future investigations and the *Climate Change Adaptation Plans.*	Y
EM1	Conduct targeted flood education programs for flood-affected residents.	Staged	$250,000	$25,000				✓	✓	✓	✓	✓	✓	✓	Unkn.	Unkn.	N/A	GCC / NSW SES	Programs of education to be implemented by part-time staff member.	N
EM3	Review the Gosford Local Flood Emergency Sub-Plan (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results.	Immediate	$20,000	$0				✓	✓	✓	✓	✓	✓	✓	0	0	N/A	GCC / NSW SES	Inclusion of flood study results, access road flooding, duration of inundation, high risk areas and proposed evacuation centres.	N
EM4	Review flood warning systems on a periodic basis and update as necessary.	Immediate	$35,000	$7,000				✓	✓	✓	✓	✓	✓	✓	Unkn.	Unkn.	N/A	BoM/ NSW SES	Program of review/updates to be developed.	N
EM7	Review evacuation centre locations with a view to upgrading key evacuation centres that lie outside the floodplain.	Immediate	$50,000	$2,500				✓	✓	✓	✓	✓	✓	✓	0	0	N/A	GCC/ State / NSW SES	A number of emergency evacuation centres lie within the floodplain. Decommissioning of centres would also be required as sea levels rise.	Y
EM8	Enhance road evacuation through the development of an alternative route plan for implementation during flood events.	Immediate	$40,000	$2,000				✓	✓	✓	✓	✓	✓	✓	0	0	N/A	GCC/ NSW SES	Provides a more affordable and more feasible alternative to road-raising.	N
DN	Do nothing. No management options are implemented.	N/A	$0	$0											0	0	N/A	N/A	Highly inappropriate.	N

Legend

(blue)	**FRMS / FRMP Preferred Options**	Action Timeline:	**Immediate** - Short term, minimal further investigations required
(green)	**Options Preferred for Investigation in CCAPs**		**Staged** - Short/medium term, further investigations required
✓	Water level addressed by option		**Trigger** - Longer term, sea level rise trigger level to initiate management response
✓	Stage / trigger level response		

^ assumes that this option equates results in 33% of the floodplain being raised/retreating out of the floodplain.

* assumes that this option provides for the the purchase/raising/swap of two properties only. Further properties could be protected if funding or swappable land is available.

Unkn. Unknown

Table 10.3: Management Area 1 (Fagans Bay) Options (Including Preferred)

Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	Tidal/Flood Event Addressed										Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAP (PM9)
					Tidal			Foreshore Flood												
					MHWS	+SLR (0.4m)	+SLR (0.9m)	5 yr ARI (20%)	100 yr ARI (1%)	PMF	100 yr ARI (0.4m SLR)	5 yr ARI (0.9m SLR)	100 yr ARI (0.9m SLR)	PMF (0.9m SLR)						
					0.39m AHD	0.79m AHD	1.29m AHD	1.39m AHD	1.74m AHD	2.23m AHD	2.16m AHD	2.31m AHD	2.68m AHD	3.19mAHD						
1_FM1a	Raise all flood-affected roads in Point Clare and West Gosford to above the 100 year ARI +0.9 m level.	Staged	$18,000,000	$370,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. The future increase in road height to account for SLR needs to be considered in the initial design.	Y
1_FM1b	Raise only the Central Coast Highway, Brisbane Water Drive, Coolarn Avenue, Manooka Road and Yallambee Avenue to above the 100 year ARI +0.9 m level.	Staged	$16,000,000	$320,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. The future increase in road height to account for SLR needs to be considered in the initial design.	Y
1_FM6a	Construct a levee (3.2km) around West Gosford/Point Clare above the PMF level.	Staged	$11,000,000	$220,000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	247	343	0.04	GCC/ State	Susceptible to breaches. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
1_FM6b	Construct a levee (3.2km) around West Gosford/Point Clare to the 5 year ARI level.	Staged	$5,400,000	$110,000	✓	✓	✓	✓				✓			3	141	0.00	GCC/ State	Susceptible to breaches and overtopping. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
1_FM7a	Increase the size of the opening under the rail bridge linking Point Clare and Gosford (Fagans Bay).	Staged	$10,000,000	$500,000	Likely to reduce catchment flooding only (in events greater than 100year ARI)										-5	-6	0.00	GCC/ State	Flooding may be worsened in some locations.	N
1_FM7b	Install manually-operated floodgates at the openings under the rail bridge linking Point Clare and Gosford (Fagans Bay).	Staged	$19,000,000	$560,000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	9	2	-0.08	GCC/ State	The impacts of catchment flooding on Fagans Bay foreshore may be worsened.	Y
1_FM9	Raise land areas affected by coastal flooding.	Trigger	$110,000,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	247	343	N/A	GCC/ State/Private	Without masterplanning, consultation and effective staging, this option is unlikely to be feasible on a regional scale.	Y
1_PM6	Relocate Point Clare Ambulance Station out of the floodplain.	Staged	$5,900,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	0	0	N/A	State	The section of Brisbane Water Drive adjacent to Point Clare ambulance station is inundated in the existing 100 year ARI flood event. The Ambulance Station itself is subject to flooding in the existing PMF event.	N
1_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in West Gosford and Point Clare.	Immediate	$100,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y
1_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in West Gosford and Point Clare.	Immediate	$30,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y
1_EM2	Install and maintain "Road Floods" signs at the Central Coast Highway, and Yallambee Avenue, West Gosford	Immediate	$2,400	$360	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	0	0	N/A	GCC/ State	Nearby residents may feel that their property will be devalued because flood markers indicate the presence of flood risk.	N

Legend

FRMS / FRMP Preferred Options

✓ Water level addressed by option

✓ Stage / trigger level response

Action Timeline: **Immediate** - Short term, minimal further investigations required
Staged - Short/medium term, further investigations required
Trigger - Longer term, sea level rise trigger level to initiate management response

Fagans Bay is dominated by catchment flooding in events greater than the 100 Year ARI event. This is due to large catchment flows from Narara Creek and the the local hydraulic control (the northern railway bridge), which reduce the rate of discharge of catchment flows into the estuary. In this management area, the existing 100 Year ARI event affects roads, open space and some residential properties, some of which may be cut off from evacuation routes. With projected sea level rise, this area is likely to become more affected by flooding. Future 100 Year ARI events are likely to affect larger open space areas with more and more residential properties being affected as sea levels continue to rise. The number of affected properties is likely to double by 2100 with projected sea level rise.

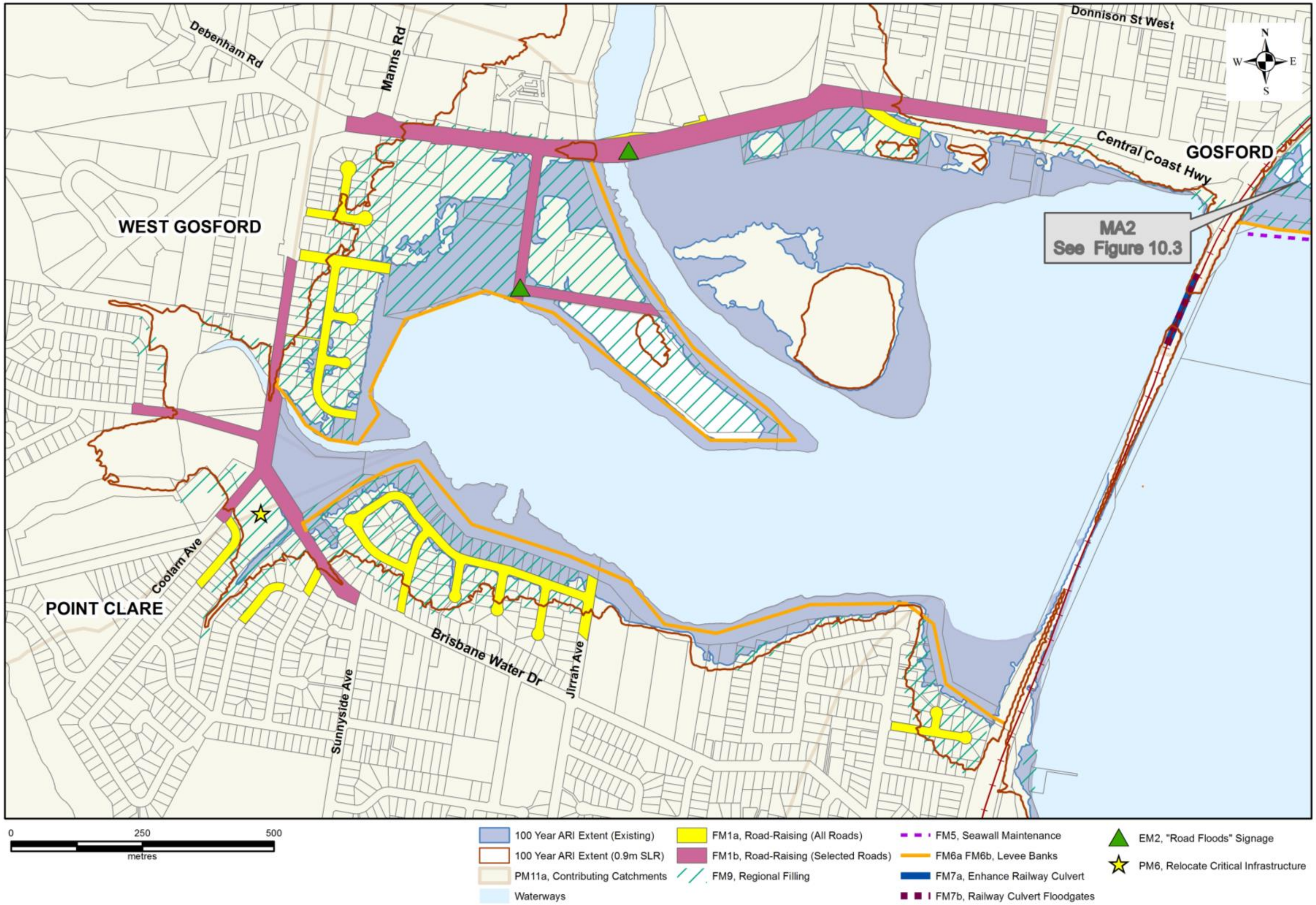

Figure 10.2 Management Area 1 (Fagans Bay)

Table 10.4: Management Area 2 (Gosford) Options (No Preferred)

Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	Tidal/Flood Event Addressed: Tidal: MHWS 0.39m AHD	+SLR (0.4m) 0.79m AHD	+SLR (0.9m) 1.29m AHD	Foreshore Flood: 5 yr ARI (20%) 1.39m AHD	100 yr ARI (1%) 1.75m AHD	PMF 2.23m AHD	100 yr ARI (0.4m SLR) 2.16m AHD	5 yr ARI (0.9m SLR) 2.29m AHD	100 yr ARI (0.9m SLR) 2.64m AHD	PMF (0.9m SLR) 3.11m AHD	Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAP (PM9)
2_FM1a	Raise all flood-affected roads in Gosford to above the 100 year ARI +0.9 m level.	Staged	$13,000,000	$260,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
2_FM1b	Raise only the Central Coast Highway, Gosford above the 100 year ARI +0.9 m level.	Staged	$4,700,000	$93,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
2_FM3	Modify the existing foreshore at Gosford in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$240,000	$7,200	Likely to assist in reducing wave run-up-inundation only.										2	0	N/A	GCC/ State/Private	Small number of locations/properties identified.	N
2_FM5	Undertake a program of seawall maintenance and raising along the Gosford foreshore.	Staged	$540,000	$5,400	✓	✓	✓								0	0	N/A	Private	Further investigation into seawall condition would be necessary. This option is relevant to any redevelopment of the foreshore as part of the Gosford Waterfront (The Landing) redevelopment. The cost associated with this option is for the entire length of sea wall proposed. This cost could be shared by private developers.	Y
2_FM6a	Construct a levee (1.5km) around Gosford above the PMF level.	Staged	$5,300,000	$110,000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	80	119	0.00	GCC/ State	Susceptible to breaches. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. Levees may be incompatible with the Gosford City Centre Masterplan. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
2_FM6b	Construct a levee (1.5km) around Gosford to the 5 year ARI level.	Staged	$2,600,000	$51,000	✓	✓	✓	✓				✓			10	58	0.02	GCC/ State	Susceptible to breaches and overtopping. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. Levees may be incompatible with the Gosford City Centre Masterplan. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
2_FM9	Raise areas in Gosford that fall under the boundary of the Gosford City Masterplan and are at risk of coastal flooding.	Trigger	$42,000,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	80	119	N/A	GCC/ State/Private	Some ground level raising could be undertaken as part of the Gosford Foreshore (The Landing) redevelopment.	Y
2_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Gosford.	Immediate	$100,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y
2_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Gosford.	Immediate	$30,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y

Legend

No Preferred Options

Action Timeline: **Immediate** - Short term, minimal further investigations required
Staged - Short/medium term, further investigations required
Trigger - Longer term, sea level rise trigger level to initiate management response

✓ Water level addressed by option
✓ Stage / trigger level response

Existing high high tides in this area may cause inundation, especially with joint occurrence of storm conditions. Wave overtopping over the Gosford sea wall has occurred in past storm events. Flooding in this area would primarily affect commercial land uses, foreshore open space and infrastructure (e.g. Central Coast Highway and Blue Tongue Stadium), however there are currently a very low proportion of residential properties in this area. The number of affected properties of any type is likely to double by 2100 with projected sea level rise.

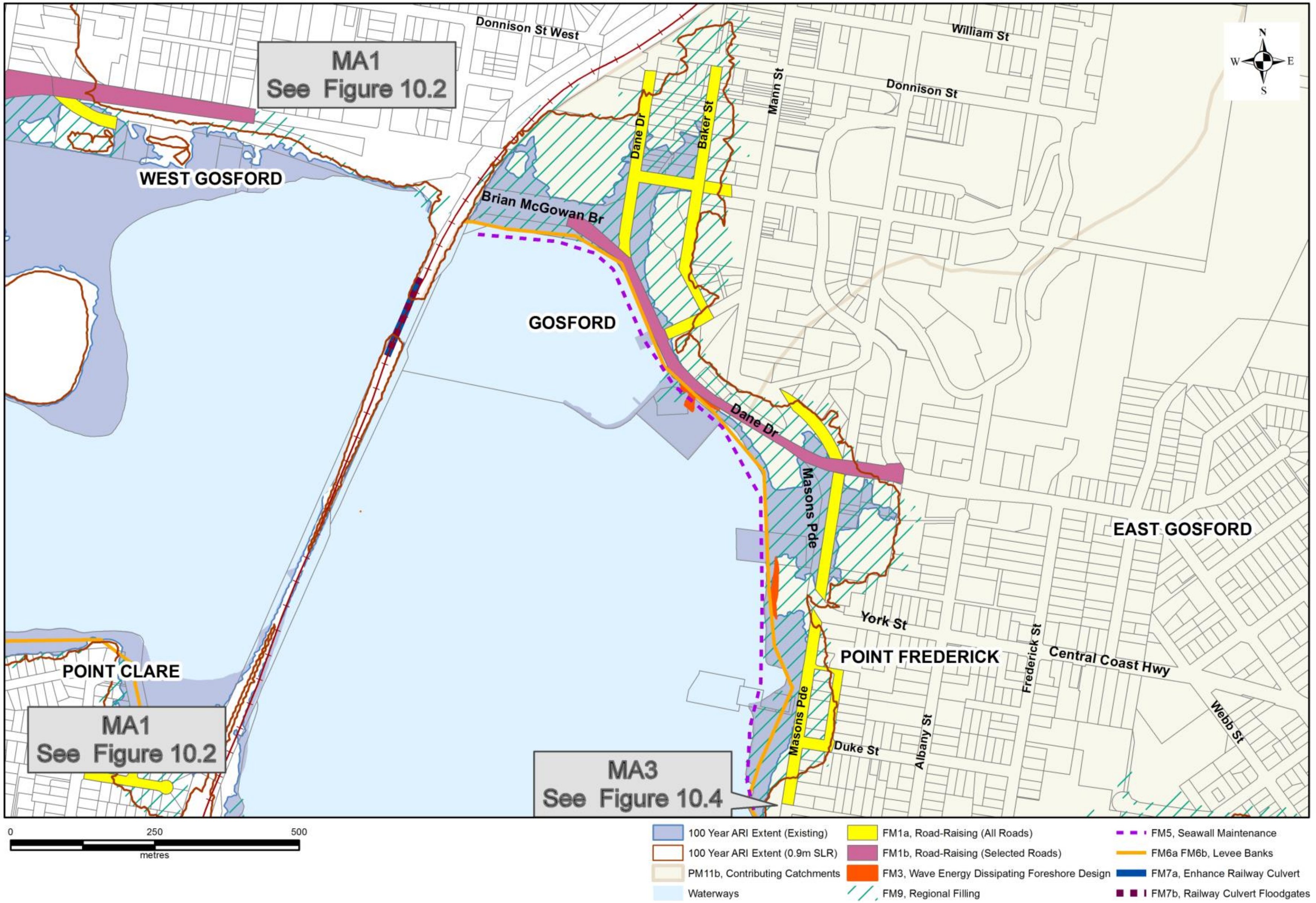

Figure 10.3 Management Area 2 (Gosford)

Table 10.5: Management Area 3 (Koolewong, Tascott, Point Clare, Point Frederick and Green Point) Options (Including Preferred)

Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	Tidal/Flood Event Addressed – Tidal: MHWS 0.39m AHD	Tidal: +SLR (0.4m) 0.79m AHD	Tidal: +SLR (0.9m) 1.29m AHD	Foreshore Flood: 5 yr ARI (20%) 1.35m AHD	Foreshore Flood: 100 yr ARI (1%) 1.68m AHD	Foreshore Flood: PMF 2.10m AHD	Foreshore Flood: 100 yr ARI (0.4m SLR) 2.15m AHD	Foreshore Flood: 5 yr ARI (0.9m SLR) 2.26m AHD	Foreshore Flood: 100 yr ARI (0.9m SLR) 2.59m AHD	Foreshore Flood: PMF (0.9m SLR) 3.02m AHD	Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAP (PM9)
3_FM1a	Raise all flood-affected roads above the 100 year ARI +0.9 m level.	Staged	$30,000,000	$590,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
3_FM1b	Raise only Brisbane Water Drive above the 100 year ARI +0.9 m level.	Staged	$19,000,000	$380,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
3_FM3	Modify the existing foreshore at Point Frederick, East Gosford, Green Point, Koolewong, Tascott and Point Clare in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$4,800,000	$140,000	Likely to assist in reducing wave run-up-inundation only.										59	7	N/A	GCC/ State/Private	Would only assist in reducing wave run-up in excess of flood events.	N
3_FM5	Undertake a program of seawall maintenance and raising along the foreshore.	Staged	$3,300,000	$33,000	✓	✓	✓								Unkn.	Unkn.	N/A	Private	Further investigation into seawall condition would be necessary. Seawall maintenance could be undertaken incrementally in conjunction with public infrastructure upgrades including foreshore roads and footpaths. The cost associated with this option is for the entire length of sea wall proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
3_FM6a	Construct levees (10.6km) around affected areas to above the PMF level.	Staged	$37,000,000	$740,000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	614	717	0.04	GCC/ State	Susceptible to breaches. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
3_FM6b	Construct levees (10.6km) around affected areas to above the 5 year ARI level.	Staged	$18,000,000	$360,000	✓	✓	✓	✓				✓			80	378	0.01	GCC/ State	Susceptible to breaches and overtopping. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
3_FM9	Raise land areas affected by coastal flooding.	Trigger	$260,000,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	614	778	N/A	State/ Private	Without masterplanning, consultation and effective staging, this option is unlikely to be feasible on a regional scale.	Y
3_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Koolewong and Tascott.	Immediate	$100,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y
3_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Point Frederick, East Gosford and Green Point.	Immediate	$30,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y

Legend

FRMS / FRMP Preferred Options

✓ Water level addressed by option

✓ Stage / trigger level response

Action Timeline: **Immediate** - Short term, minimal further investigations required
Staged - Short/medium term, further investigations required
Trigger - Longer term, sea level rise trigger level to initiate management response
Unkn. Unknown

Existing high tides in this area may cause inundation, especially high high tides with joint occurrence of storm conditions. Some areas of Tascott are also affected by catchment flows from Tascott Creek. Flooding in this management area primarily affects residential properties and open space areas. Some access roads are inundated in the existing 100 Year ARI flood event, e.g. parts of Brisbane Water Drive Projected sea level rise will be limited in some areas by steep terrain (e.g. where Point Clare, Tascott and Koolewong back onto the Brisbane Water National Park), however the number of affected properties of any type is still likely to increase substantially by 2100 with projected sea level rise.

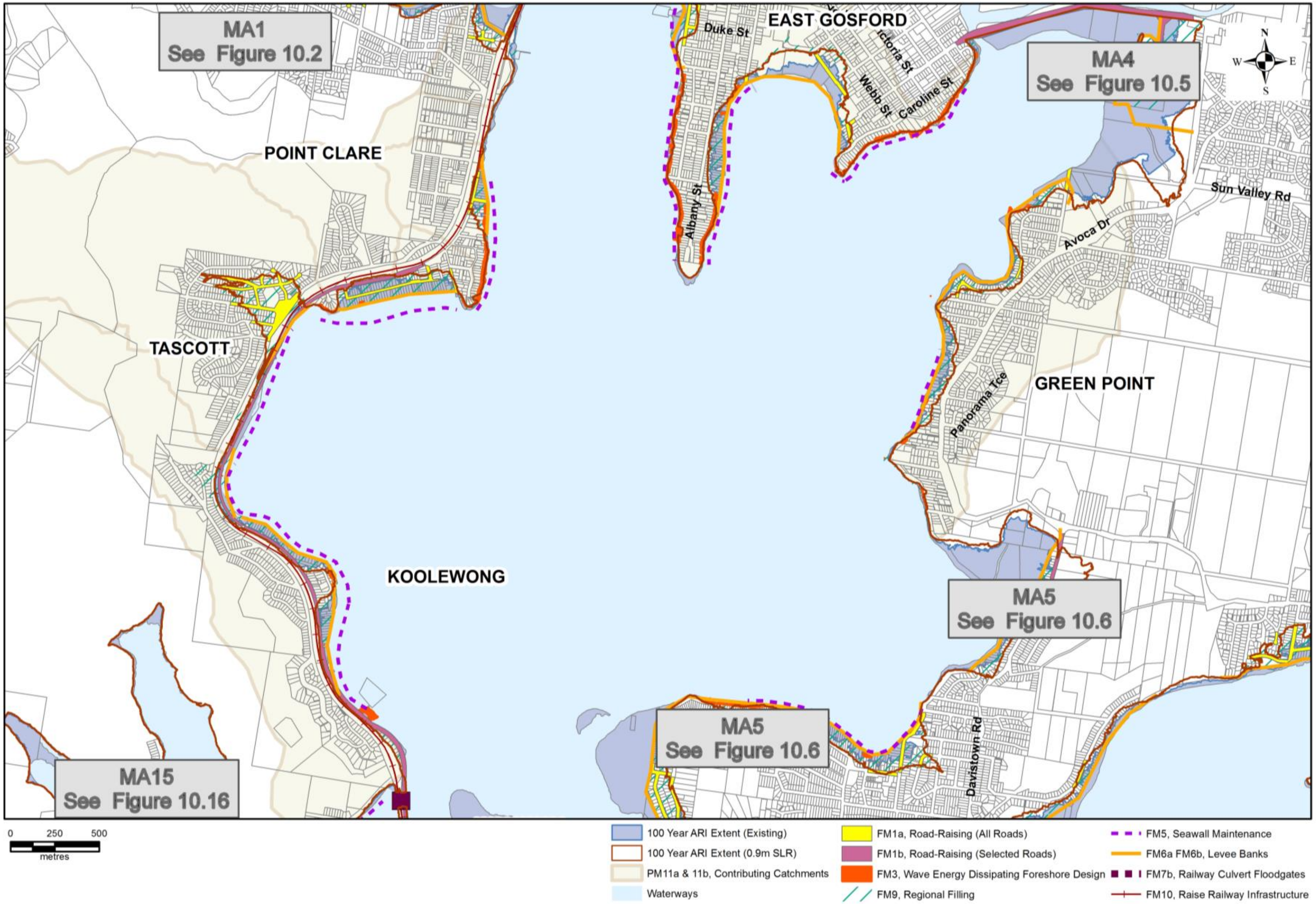

Figure 10.4 Management Area 3 (Koolewong, Tascott, Point Clare, Point Frederick & Green Point)

Table 10.6: Management Area 4 (Erina) Options (Including Preferred)

					Tidal/Flood Event Addressed															
					Tidal			Foreshore Flood												
Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	MHWS 0.39m AHD	+SLR (0.4m) 0.79m AHD	+SLR (0.9m) 1.29m AHD	5 yr ARI (20%) 1.35m AHD	100 yr ARI (1%) 1.67m AHD	PMF 2.08m AHD	100 yr ARI (0.4m SLR) 2.02m AHD	5 yr ARI (0.9m SLR) 2.26m AHD	100 yr ARI (0.9m SLR) 2.58m AHD	PMF (0.9m SLR) 2.98m AHD	Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAP (PM9)
4_FM1b	Raise Pateman Road and The Entrance Road above the 100 year ARI +0.9 m level.	Staged	$7,800,000	$160,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Depth of flooding in 100yr ARI likely to be suitable for vehicle access, however PMF depths (>0.5m) may prevent safe vehicle access. SLR will increase flood depths. Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. The future increase in road height to account for SLR needs to be considered in the initial design.	Y
4_FM6a	Construct a levee (1.3km) around the low-lying industrial area at Erina to above the PMF level.	Staged	$4,600,000	$91,000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	9	9	0.01	GCC/ State	Susceptible to breaches. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
4_FM6b	Construct a levee (1.3km) around around the low-lying industrial area at Erina to above the 5 year ARI level.	Staged	$2,200,000	$44,000	✓	✓	✓	✓				✓			1	6	0.01	GCC/ State	Susceptible to breaches and overtopping. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
4_FM9	Raise land areas affected by coastal flooding.	Trigger	$6,700,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	9	9	N/A	GCC/ State/Private	Without masterplanning, consultation and effective staging, this option is unlikely to be feasible on a regional scale.	Y
4_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Erina.	Immediate	$100,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts. Cost may be reduced if structural options are only implemented in localised areas (e.g. levee constructed around the SES building only).	Y
4_PM6	Relocate NSW SES (Gosford) headquarters out of the floodplain.	Staged	$4,500,000	$0					✓	✓	✓	✓	✓	✓	0	0	N/A	NSW SES/ State	This station is inundated in the existing 100 year ARI flood event.	N

Legend

FRMS / FRMP Preferred Options

✓ Water level addressed by option

✓ Stage / trigger level response

Action Timeline: **Immediate** - Short term, minimal further investigations required

Staged - Short/medium term, further investigations required

Trigger - Longer term, sea level rise trigger level to initiate management respons

High tides and higher probability ARI events may cause inundation in this area. It is is also likely to be affected by catchment flows from Erina Creek. The area consists primarily of mangrove swamps and industrial/special land uses, including Gosford NSW SES headquarters and the Council depot on Pateman Road. In the existing 100 year ARI flood event, only a few properties are affected by flooding. With projected sea level rise, the number of properties affected is likely to stay fairly constant, however flooding is expected to worsen in this location in terms of flood depths (and potentially flood damages).

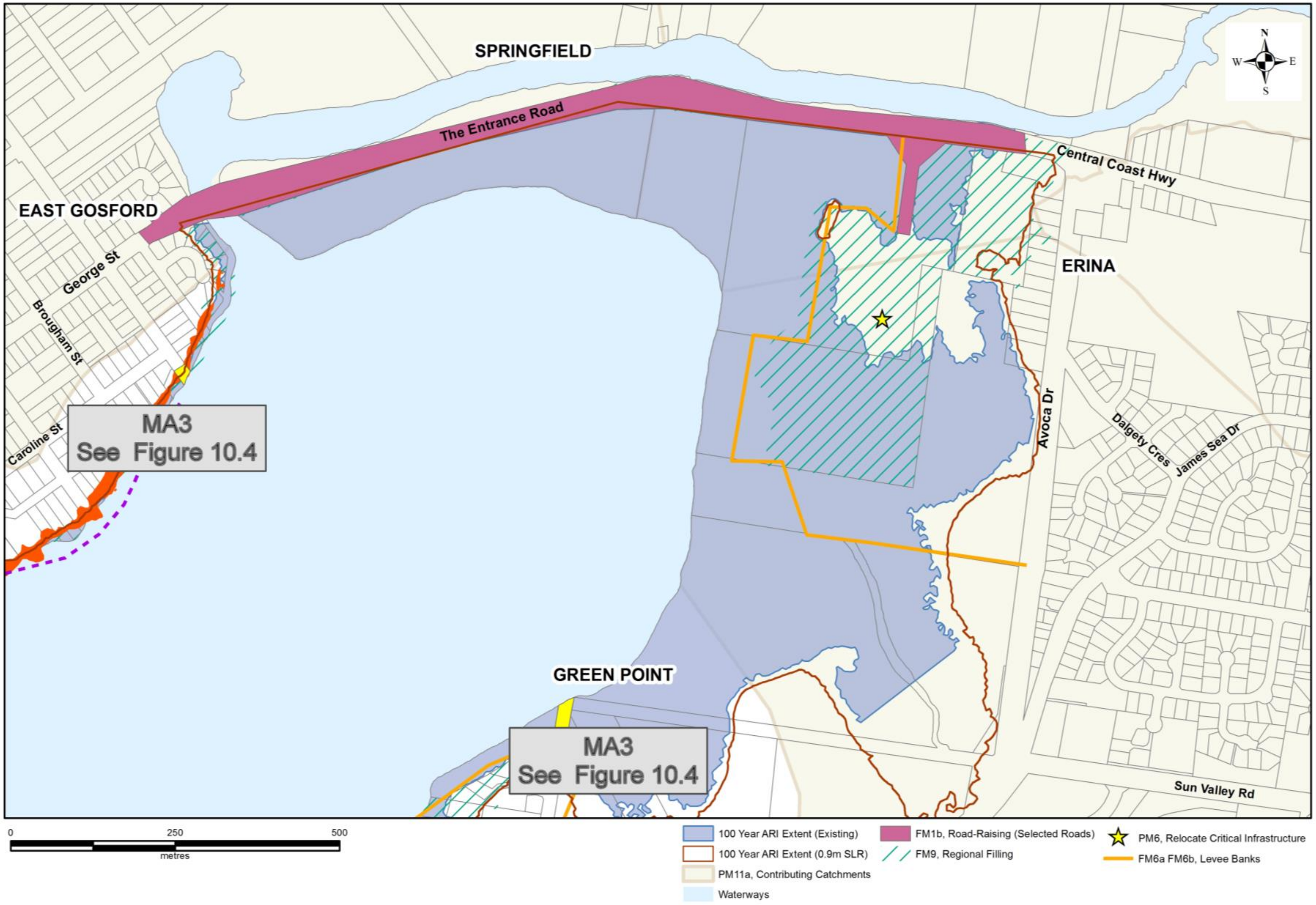

Figure 10.5 Management Area 4 (Erina)

Table 10.7: Management Area 5 (Saratoga and Yattalunga) Options (No Preferred)

Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	Tidal/Flood Event Addressed: Tidal			Foreshore Flood							Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAP (PM9)
					MHWS	+SLR (0.4m)	+SLR (0.9m)	5 yr ARI (20%)	100 yr ARI (1%)	PMF	100 yr ARI (0.4m SLR)	5 yr ARI (0.9m SLR)	100 yr ARI (0.9m SLR)	PMF (0.9m SLR)						
					0.39m AHD	0.79m AHD	1.29m AHD	1.33m AHD	1.64m AHD	2.02m AHD	1.98m AHD	2.23m AHD	2.53m AHD	2.91m AHD						
5_FM1a	Raise all flood-affected roads in Saratoga and Yattalunga above the 100 year ARI +0.9 m level.	Staged	$6,800,000	$140,000	✓	✓	✓	✓	✓		(✓)	(✓)	(✓)		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
5_FM1b	Raise only Davistown Road, Yattalunga above the 100 year ARI +0.9 m level.	Staged	$1,800,000	$36,000	✓	✓	✓	✓	✓		(✓)	(✓)	(✓)		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
5_FM3	Modify the existing foreshore at Yattalunga and Saratoga in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$600,000	$18,000	Likely to assist in reducing wave run-up-inundation only.										23	0	N/A	GCC/ State/ Private	Would only assist in reducing wave run-up in excess of flood events.	N
5_FM5	Undertake a program of seawall maintenance and raising along the Davistown foreshore.	Staged	$750,000	$7,500	✓	(✓)	(✓)								Unkn.	Unkn.	N/A	Private	Further investigation into seawall condition would be necessary. The cost associated with this option is for the entire length of sea wall proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
5_FM6a	Construct a levee (3.6km) around low-lying areas to above the PMF level.	Staged	$13,000,000	$250,000	✓	✓	✓	✓	✓	✓	(✓)	(✓)	(✓)	(✓)	305	370	0.05	GCC/ State	Susceptible to breaches. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
5_FM6b	Construct a levee (3.6km) around low-lying areas to above the 5 year ARI level.	Staged	$6,100,000	$120,000	✓	✓	✓	✓				(✓)			22	216	0.01	GCC/ State	Susceptible to breaches and overtopping. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
5_FM9	Raise land areas at risk of coastal flooding.	Trigger	$110,000,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	305	370	N/A	State/ Private	Without masterplanning, consultation and effective staging, this option is unlikely to be feasible on a regional scale.	Y
5_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Yattalunga and Saratoga.	Immediate	$100,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y
5_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Yattalunga and Saratoga.	Immediate	$30,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y

Legend

No Preferred Options

Action Timeline: **Immediate** - Short term, minimal further investigations required
Staged - Short/medium term, further investigations required
Trigger - Longer term, sea level rise trigger level to initiate management response
Unkn. Unknown

✓ Water level addressed by option
(✓) Stage / trigger level response

Existing high tides in these areas can cause inundation, especially with joint occurrence of storm conditions. This area primarily consists of residential properties and mangrove swamps (including the Saratoga wetland area which lies adjacent to the Saratoga Nature Reserve). In addition to residential properties, some roads are also affected by flooding. The number of flood-affected properties is likely to increase by 2100 with projected sea level rise. It is likely that flood risk within this management area can be sufficiently managed through the implementation of floodplain-wide management options. This includes development controls and the incorporation of provisions for wave run-up protection designs for dwellings and infrastructure.

Figure 10.6 Management Area 5 (Saratoga & Yattalunga)

Table 10.8: Management Area 6 (Davistown) Options (No Preferred)

Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	Tidal/Flood Event Addressed: Tidal – MHWS (0.31m AHD)	Tidal – +SLR (0.4m) (0.71m AHD)	Tidal – +SLR (0.9m) (1.21m AHD)	Foreshore Flood – 5 yr ARI (20%) (1.24m AHD)	Foreshore Flood – 100 yr ARI (1%) (1.49m AHD)	Foreshore Flood – PMF (1.75m AHD)	Foreshore Flood – 100 yr ARI (0.4m SLR) (1.97m AHD)	Foreshore Flood – 5 yr ARI (0.9m SLR) (2.14m AHD)	Foreshore Flood – 100 yr ARI (0.9m SLR) (2.38m AHD)	Foreshore Flood – PMF (0.9m SLR) (2.61m AHD)	Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAP (PM9)
6_FM1a	Raise all affected roads in Davistown above the 100 year ARI +0.9 m level.	Staged	$71,000,000	$1,400,000	✓	✓	✓	✓	✓		*✓*	*✓*	*✓*		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels. This option would most likely need to be implemented concurrently with Option 6_FM9 given the flat nature of the terrain and the likely impacts on overland flow of road upgrades	Y
6_FM1b	Raise only Davistown Road and Mallinya Road above the 100 year ARI +0.9 m level.	Staged	$12,000,000	$240,000	✓	✓	✓	✓	✓		*✓*	*✓*	*✓*		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
6_FM5	Undertake a program of seawall maintenance	Staged	$570,000	$5,700	✓	*✓*	*✓*								Unkn.	Unkn.	N/A	Private	Further investigation into seawall condition would be necessary. The cost associated with this option is for the entire length of sea wall proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
6_FM6a	Construct a levee (6.4km) around Davistown above the PMF level	Staged	$22,000,000	$450,000	✓	✓	✓	✓	✓	✓	*✓*	*✓*	*✓*	*✓*	979	*996*	0.11	GCC/ State	Susceptible to breaches. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. It is noted that levess could be incorporated in conjunction with public infrastructure upgrades, e.g. road, footpath/cycleway or seawall upgrades, with potential for flood gates to be installed at locations such as boat ramps. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
6_FM6b	Construct a levee (6.4km) around Davistown to the 5 year ARI	Staged	$11,000,000	$220,000	✓	✓	✓	✓				*✓*			464	*955*	0.12	GCC/ State	Susceptible to breaches and overtopping. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. It is noted that levess could be incorporated in conjunction with public infrastructure upgrades, e.g. road, footpath/cycleway or seawall upgrades, with potential for flood gates to be installed at locations such as boat ramps. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
6_FM9	Raise land affected by coastal flooding.	Trigger	$340,000,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	979	996	0.01	State/ Private	Without masterplanning, consultation and effective staging, this option is unlikely to be feasible on a regional scale. Development controls (e.g. PM8) could consider longer term management strategies such as incremental filling including inter-allotment drainage. It is noted that the potential change in the classification of this management area from low hazard to high hazard, as a result of sea level rise, should be carefully considered.	Y
6_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Davistown.	Immediate	$30,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y

Legend

No Preferred Options

✓ Water level addressed by option

✓ Stage / trigger level response

Action Timeline: **Immediate** - Short term, minimal further investigations required

Staged - Short/medium term, further investigations required

Trigger - Longer term, sea level rise trigger level to initiate management respons

Unkn. Unknown

In this management area, existing high tides can cause inundation especially with joint occurrence of storm conditions. Even in small ARI events for the existing case, a large number of residential properties are flood-affected. Davistown comprises mainly single storey, detached dwellings and for the existing 100 Year ARI event, Davistown has the largest number of inundated properties of all management areas. There is very little difference between the number of properties affected in existing flood events compared to sea level rise scenarios and this is due to very flat terrain that allows floodwaters to penetrate further landward even in the existing case. However, the depth of flooding increases significantly with projected sea level rise.

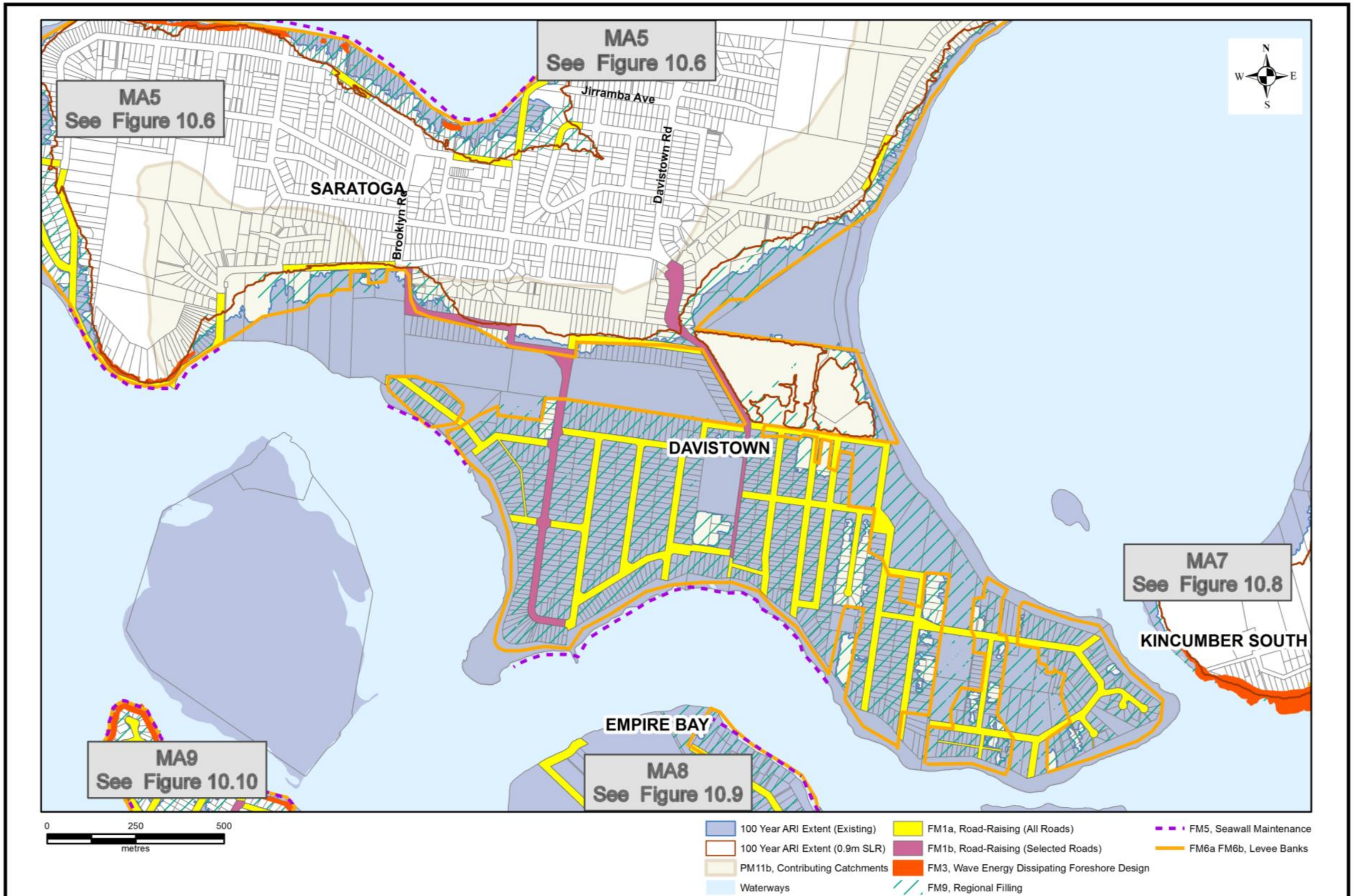

Figure 10.7 Management Area 6 (Davistown)

Table 10.9: Management Area 7 (Kincumber and Bensville) Options (Including Preferred)

Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	Tidal/Flood Event Addressed – Tidal: MHWS 0.31m AHD	Tidal: +SLR (0.4m) 0.71m AHD	Tidal: +SLR (0.9m) 1.21m AHD	Foreshore Flood: 5 yr ARI (20%) 1.22m AHD	Foreshore Flood: 100 yr ARI (1%) 1.44m AHD	Foreshore Flood: PMF 1.64m AHD	Foreshore Flood: 100 yr ARI (0.4m SLR) 1.98m AHD	Foreshore Flood: 5 yr ARI (0.9m SLR) 2.12m AHD	Foreshore Flood: 100 yr ARI (0.9m SLR) 2.33m AHD	Foreshore Flood: PMF (0.9m SLR) 2.50m AHD	Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAP (PM9)
7_FM1a	Raise all flood-affected roads in Kincumber and Bensville above the 100 year ARI +0.9 m level.	Staged	$4,100,000	$82,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
7_FM3	Modify the existing foreshore at Kincumber, Kincumber South and Bensville in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$600,000	$18,000	Likely to assist in reducing wave run-up-inundation only.										25	0	N/A	GCC/ State/ Private	Would only assist in reducing wave run-up in excess of flood events.	N
7_FM5	Undertake a program of seawall maintenance and raising along the foreshore.	Staged	$74,000	$740	✓	✓	✓								Unkn.	Unkn.	N/A	Private	Further investigation into seawall condition would be necessary. The cost associated with this option is for the entire length of sea wall proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
7_FM6a	Construct a levee (3km) around low-lying areas to above the PMF level.	Staged	$11,000,000	$210,000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	88	198	0.00	GCC/ State	Susceptible to breaches. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. It is noted that levess could be incorporated in conjunction with public infrastructure upgrades, e.g. the Kincumber foreshore cycleway. This management area is predominantly rural foreshores, and natural flood barriers could be enhanced. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
7_FM6b	Construct a levee (3km) around low-lying areas to above the 5 year ARI level.	Staged	$5,100,000	$100,000	✓	✓	✓	✓				✓			0	80	0.00	GCC/ State	Susceptible to breaches and overtopping. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. It is noted that levess could be incorporated in conjunction with public infrastructure upgrades, e.g. the Kincumber foreshore cycleway. This management area is predominantly rural foreshores, and natural flood barriers could be enhanced. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
7_FM9	Raise land areas at risk of coastal flooding in Kincumber and Bensville.	Trigger	$65,000,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	88	198	N/A	State/ Private	Without masterplanning, consultation and effective staging, this option is unlikely to be feasible on a regional scale.	Y
7_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Kincumber, Kincumber South and Bensville.	Immediate	$30,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y

Legend

FRMS / FRMP Preferred Options (shaded)

✓ Water level addressed by option

✓ (pink) Stage / trigger level response

Action Timeline: **Immediate** - Short term, minimal further investigations required
Staged - Short/medium term, further investigations required
Trigger - Longer term, sea level rise trigger level to initiate management respons
Unkn. Unknown

Existing high tides in this area can cause inundation, especially high high tides with joint occurrence of storm conditions. This area primarily consists of residential properties and mangrove swamps. A fairly small number of residential properties are affected by flooding in this area. In addition to waterfront residences, some roads are affected by flooding. Only fairly small areas of these suburbs are affected in the existing scenario due to surrounding topography. The number of affected properties is anticipated to increase with projected sea level rise.

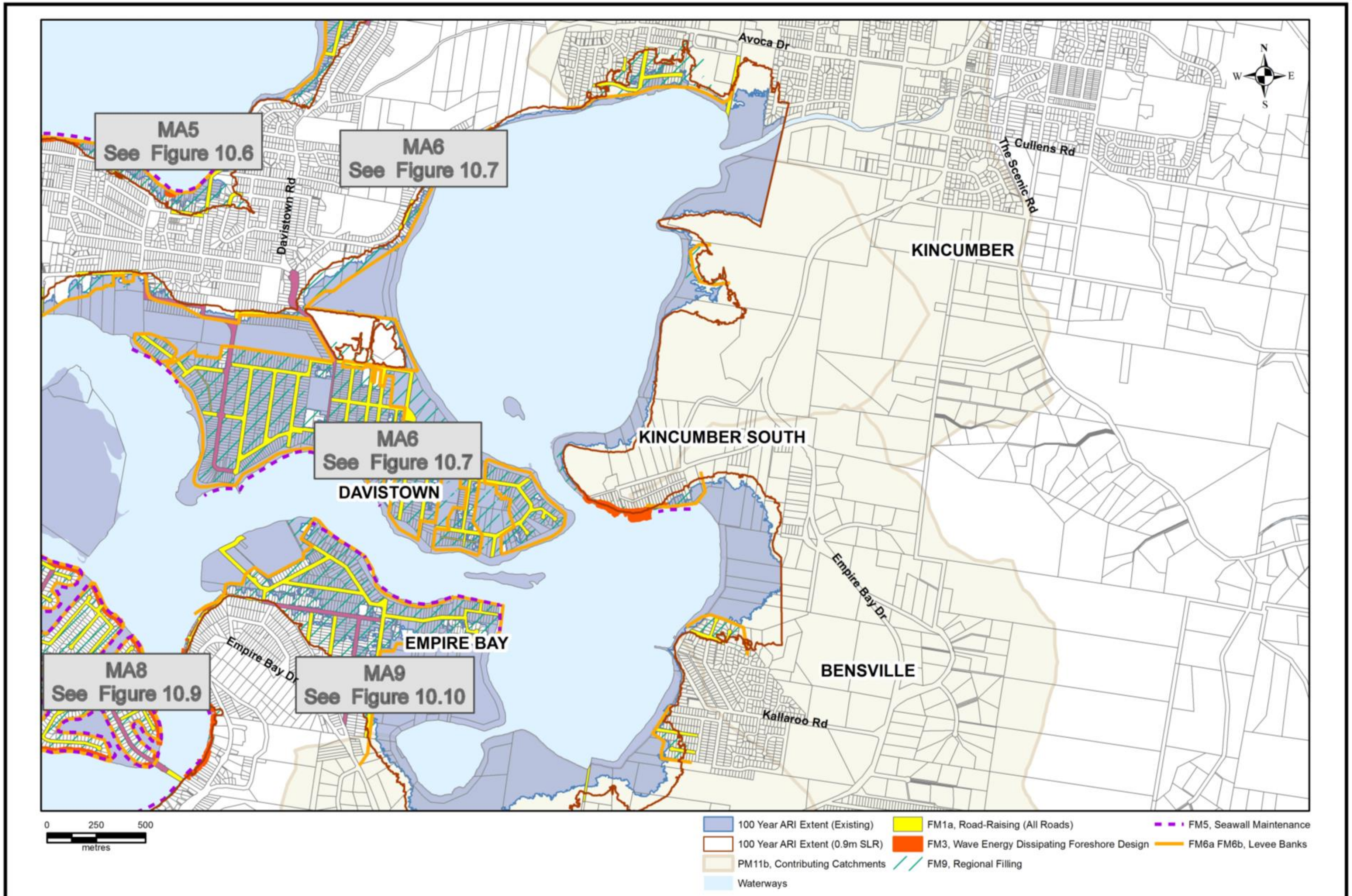

Figure 10.8 Management Area 7 (Kincumber & Bensville)

Table 10.10: Management Area 8 (Empire Bay) Options (No Preferred)

Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	Tidal/Flood Event Addressed: Tidal			Foreshore Flood							Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAP (PM9)
					MHWS 0.31m AHD	+SLR (0.4m) 0.71m AHD	+SLR (0.9m) 1.21m AHD	5 yr ARI (20%) 1.21m AHD	100 yr ARI (1%) 1.44m AHD	PMF 1.65m AHD	100 yr ARI (0.4m SLR) 1.99m AHD	5 yr ARI (0.9m SLR) 2.12m AHD	100 yr ARI (0.9m SLR) 2.34m AHD	PMF (0.9m SLR) 2.52m AHD						
8_FM1a	Raise all flood-affected roads within Empire Bay above the 100 year ARI +0.9 m level.	Staged	$16,000,000	$320,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels. This option would most likely need to be implemented concurrently with Option 6_FM9 given the flat nature of the terrain and the likely impacts on overland flow of road upgrades.	Y
8_FM1b	Raise only Greenfield Road and Rickard Road above the 100 year ARI +0.9 m level.	Staged	$5,800,000	$120,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
8_FM3	Modify the existing foreshore at Empire Bay in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$1,300,000	$40,000	Likely to assist in reducing wave run-up-inundation only.										24	0	N/A	GCC/ State/ Private	Would only assist in reducing wave run-up in excess of flood events.	N
8_FM5	Undertake a program of seawall maintenance and raising along the Empire Bay foreshore.	Staged	$530,000	$5,300	✓	✓	✓								Unkn.	Unkn.	N/A	Private	Further investigation into seawall condition would be necessary. The cost associated with this option is for the entire length of sea wall proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
8_FM6a	Construct a levee (3.6km) around Empire Bay to above the PMF level.	Staged	$13,000,000	$250,000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	391	493	0.07	GCC/ State	Susceptible to breaches. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. It is noted that Empire Bay has substantial foreshore open spaces that could be utilised. Levees could be incorporated in conjunction with public infrastructure upgrades including roads, footpaths/cycleways or seawalls. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
8_FM6b	Construct a levee (3.6km) around Empire Bay to above the 5 year ARI level.	Staged	$6,100,000	$120,000	✓	✓	✓	✓				✓			76	419	0.04	GCC/ State	Susceptible to breaches and overtopping. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
8_FM9	Raise land areas at risk of coastal flooding within Empire Bay.	Trigger	$170,000,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	391	493	0.00	State/ Private	Without masterplanning, consultation and effective staging, this option is unlikely to be feasible on a regional scale.	Y
8_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Empire Bay.	Immediate	$30,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y

Legend
No Preferred Options

Action Timeline: **Immediate** - Short term, minimal further investigations required
Staged - Short/medium term, further investigations required
Trigger - Longer term, sea level rise trigger level to initiate management respons
Unkn. Unknown

✓ Water level addressed by option
✓ Stage / trigger response
✓* Assessment was only undertaken for the 100 year ARI event

Existing high tides in this area can cause inundation, especially with joint occurrence of storm conditions. Some residential properties are affected even in more regular floods (i.e. lower ARIs). Empire Bay comprises mainly single storey, detached dwellings. For the existing 100 Year ARI event, this management area has one of the largest number of inundated properties of all management areas. This number is likely to increase with projected sea level rise scenarios.

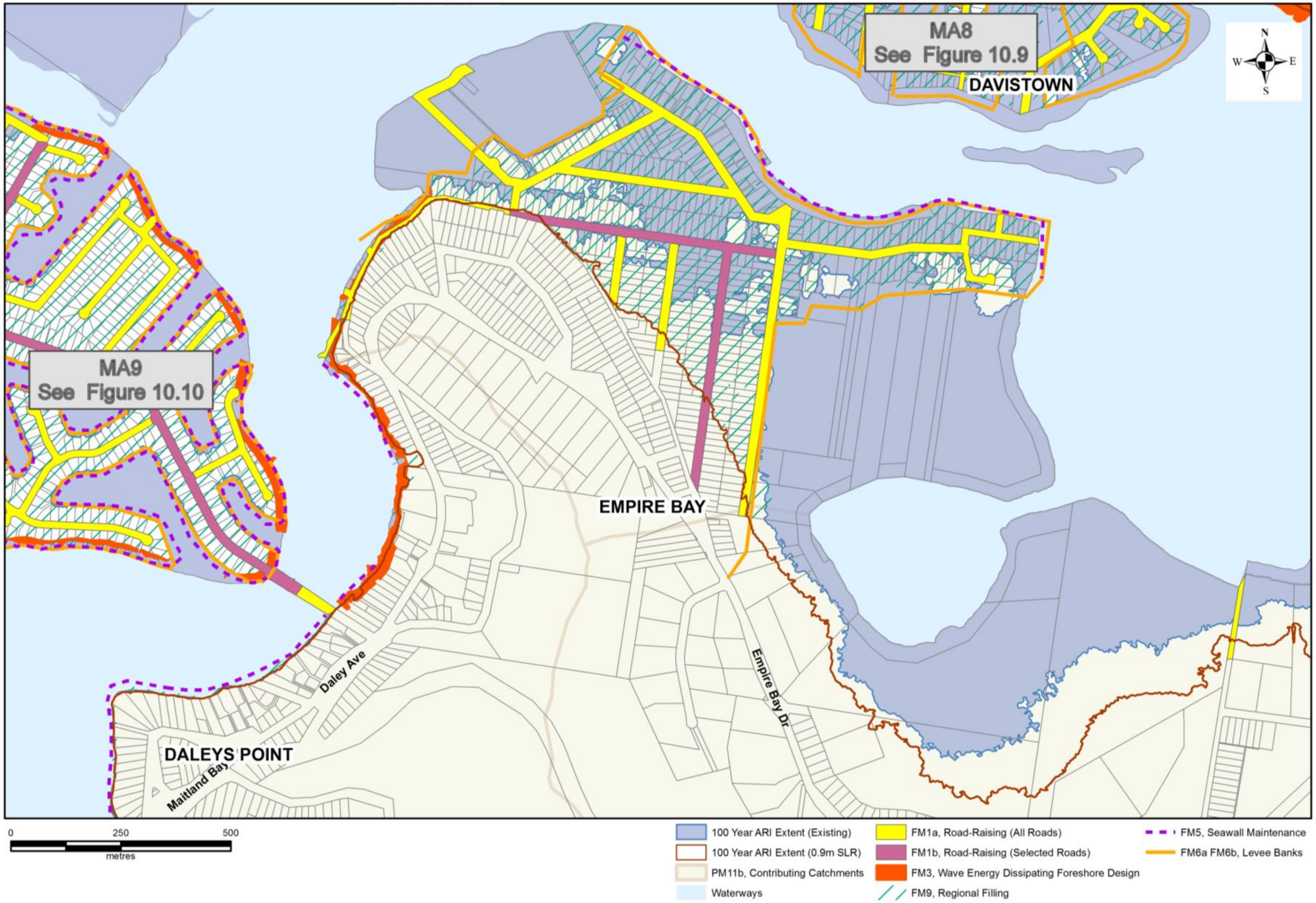

Figure 10.9 Management Area 8 (Empire Bay)

Table 10.11: Management Area 9 (St Huberts Island) Options (Including Preferred)

Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	Tidal/Flood Event Addressed: Tidal – MHWS 0.37m AHD	Tidal – +SLR (0.4m) 0.77m AHD	Tidal – +SLR (0.9m) 1.27m AHD	Foreshore Flood – 5 yr ARI (20%) 1.27m AHD	Foreshore Flood – 100 yr ARI (1%) 1.54m AHD	Foreshore Flood – PMF 1.84m AHD	Foreshore Flood – 100 yr ARI (0.4m SLR) 1.94m AHD	Foreshore Flood – 5 yr ARI (0.9m SLR) 2.18m AHD	Foreshore Flood – 100 yr ARI (0.9m SLR) 2.44m AHD	Foreshore Flood – PMF (0.9m SLR) 2.72m AHD	Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAP (PM9)
9_FM1a	Raise all flood-affected roads on St Huberts Island above the 100 year ARI +0.9 m level.	Staged	$18,000,000	$360,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
9_FM1b	Raise only Helmsman Boulevard above the 100 year ARI +0.9 m level.	Staged	$8,000,000	$160,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
9_FM3	Modify the existing foreshore at St Huberts Island in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$2,900,000	$88,000	Likely to assist in reducing wave run-up-inundation only.										114	0	N/A	GCC/ State/Private	Would only assist in reducing wave run-up in excess of flood events.	N
9_FM5	Undertake a program of seawall maintenance and raising along the St Huberts Island foreshore.	Staged	$3,200,000	$32,000	✓	✓	✓								Unkn.	Unkn.	N/A	Private	Further investigation into seawall condition would be necessary. The cost associated with this option is for the entire length of sea wall proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
9_FM6a	Construct a levee (8km) around St Huberts Island to above the PMF level.	Staged	$28,000,000	$560,000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	465	532	0.04	GCC/ State	Susceptible to breaches. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
9_FM6b	Construct a levee (8km) around St Huberts Island to above the 5 year ARI level.	Staged	$14,000,000	$270,000	✓	✓	✓	✓				✓			1	354	0.00	GCC/ State	Susceptible to breaches and overtopping. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
9_FM9	Raise land areas at risk of coastal flooding on St Huberts Island.	Trigger	$170,000,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	465	532	N/A	State/ Private	Without masterplanning, consultation and effective staging, this option is unlikely to be feasible on a regional scale.	Y
9_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows on St Huberts Island.	Immediate	$100,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y
9_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows on St Huberts Island.	Immediate	$30,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y

Legend

(shaded)	**FRMS / FRMP Preferred Options**	Action Timeline:	**Immediate** - Short term, minimal further investigations required
✓	Water level addressed by option		**Staged** - Short/medium term, further investigations required
✓ (pink)	Stage / trigger level response		**Trigger** - Longer term, sea level rise trigger level to initiate management response
✓*	Assessment was only undertaken for the 100 year ARI event		Unkn. Unknown

St Huberts Island is a unique location because it is an island suburb that has only one access road. Over-floor flooding and hence property damages on the island are generally limited by floor levels having been set to above the 100 Year ARI event. High tide events in conjunction with storms can cause surcharge of the stormwater system which affects local roads, and storm surge events greater than the existing 100 Year ARI have the potential to inundate this area. Due to floor levels, residential properties are more likely to experience over-ground flooding than over-floor flooding for smaller ARIs up to the 100 Year ARI, however with projected sea level rise, flood impact is likely to be greatly increased.

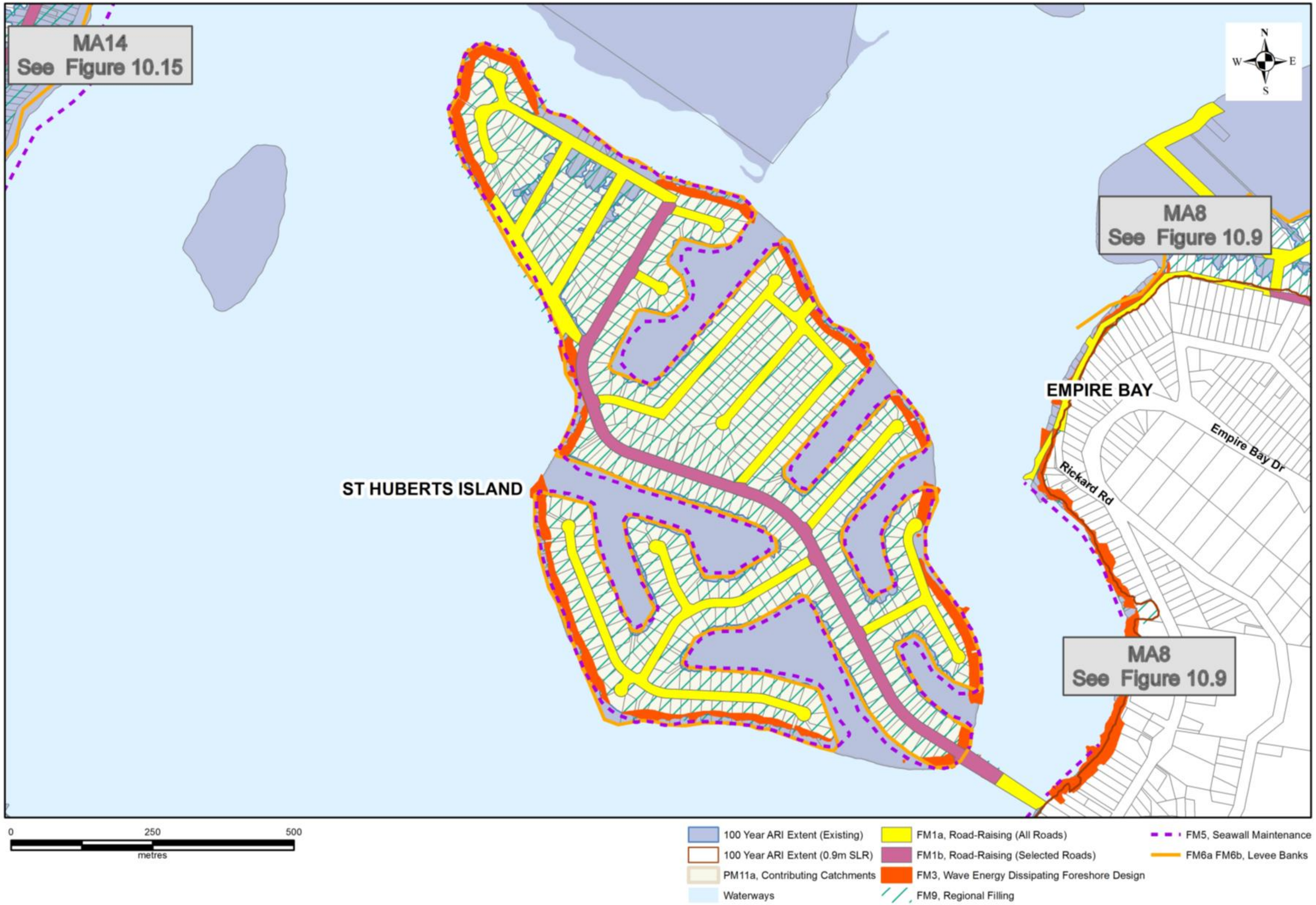

Figure 10.10 Management Area 9 (St Huberts Island)

Table 10.12: Management Area 10 (Daleys Point, Hardys Bay and Kilcare) Options (No Preferred)

Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	Tidal/Flood Event Addressed – Tidal: MHWS 0.50m AHD	Tidal: +SLR (0.4m) 0.90m AHD	Tidal: +SLR (0.9m) 1.40m AHD	Foreshore Flood: 5 yr ARI (20%) 1.36m AHD	Foreshore Flood: 100 yr ARI (1%) 1.55m AHD	Foreshore Flood: PMF 1.77m AHD	Foreshore Flood: 100 yr ARI (0.4m SLR) 1.93m AHD	Foreshore Flood: 5 yr ARI (0.9m SLR) 2.23m AHD	Foreshore Flood: 100 yr ARI (0.9m SLR) 2.46m AHD	Foreshore Flood: PMF (0.9m SLR) 2.73m AHD	Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAP (PM9)
10_FM1a	Raise all flood-affected roads above the 100 year ARI +0.9 m level.	Staged	$7,100,000	$140,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels. Raising Noble Road and Hardys Bay Parade would need careful consideration due to the confluence with Mud Flat Creek and reference should be made to the Mud Flat Creek Floodplain Risk Mangement Plan as part of any further assessments.	Y
10_FM1b	Raise only Araluen Drive above the 100 year ARI +0.9 m level.	Staged	$2,700,000	$54,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
10_FM5	Undertake a program of seawall maintenance and raising along the foreshore.	Staged	$820,000	$8,200	✓	✓	✓								Unkn.	Unkn.	N/A	Private	Further investigation into seawall condition would be necessary. Seawall maintenance could be undertaken incrementally in conjunction with public infrastructure upgrades including foreshore roads and footpaths. The cost associated with this option is for the entire length of sea wall proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
10_FM6a	Construct a levee (1.1km) around affected areas to above the PMF level.	Staged	$3,900,000	$77,000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	55	192	0.01	GCC/ State	Susceptible to breaches. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. Levees (particularly in the vicinity of Araluen Reserve) could be incorporated in conjunction with public infrastructure upgrades including roads, footpaths/cycleways or seawalls. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
10_FM6b	Construct a levee (1.1km) around affected areas to above the 5 year ARI level.	Staged	$1,900,000	$37,000	✓	✓	✓	✓				✓			0	29	0.00	GCC/ State	Susceptible to breaches and overtopping. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. Levees (particularly in the vicinity of Araluen Reserve) could be incorporated in conjunction with public infrastructure upgrades including roads, footpaths/cycleways or seawalls. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
10_FM9	Raise land areas within Kilcare and Hardys Bay most at risk of coastal flooding.	Trigger	$68,000,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	55	192	N/A	State/ Private	Without masterplanning, consultation and effective staging, this option is unlikely to be feasible on a regional scale. Any filling in the vicinity of Mudflat Creek would need to consider effects on catchment flooding and be consistent with the Mudflat Creek Floodplain Risk Management Plan	Y
10_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Daleys Point, Killcare and Hardys Bay.	Immediate	$100,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts. Any option in the vicinity of Mudflat Creek would require consideration of the Mudflat Creek Floodplain Risk Management Pla	Y
10_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Daleys Point, Killcare and Hardys Bay.	Immediate	$30,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y

Legend

No Preferred Options

✓ Water level addressed by option
✓ Stage / trigger level response
✓* Assessment was only undertaken for the 100 year ARI event

Action Timeline: **Immediate** - Short term, minimal further investigations required
Staged - Short/medium term, further investigations required
Trigger - Longer term, sea level rise trigger level to initiate management response
Unkn. Unknown

Foreshore inundation at Daleys Point is confined to very small foreshore areas and is limited by very steep terrain. Killcare and Hardys Bay are generally more vulnerable to flooding, but only fairly small areas are affected. Flooding is also limited in these areas due to fairly steep terrain. Flooding would mainly affect residential properties and some commercial properties and open space. Due to shallow depths of flooding, properties are more likely to experience over-ground flooding than over-floor flooding in these areas. The number of affected properties in existing flood events is quite low; however this is expected to increase with projected sea level rise, particularly in Killcare and Hardys Bay.

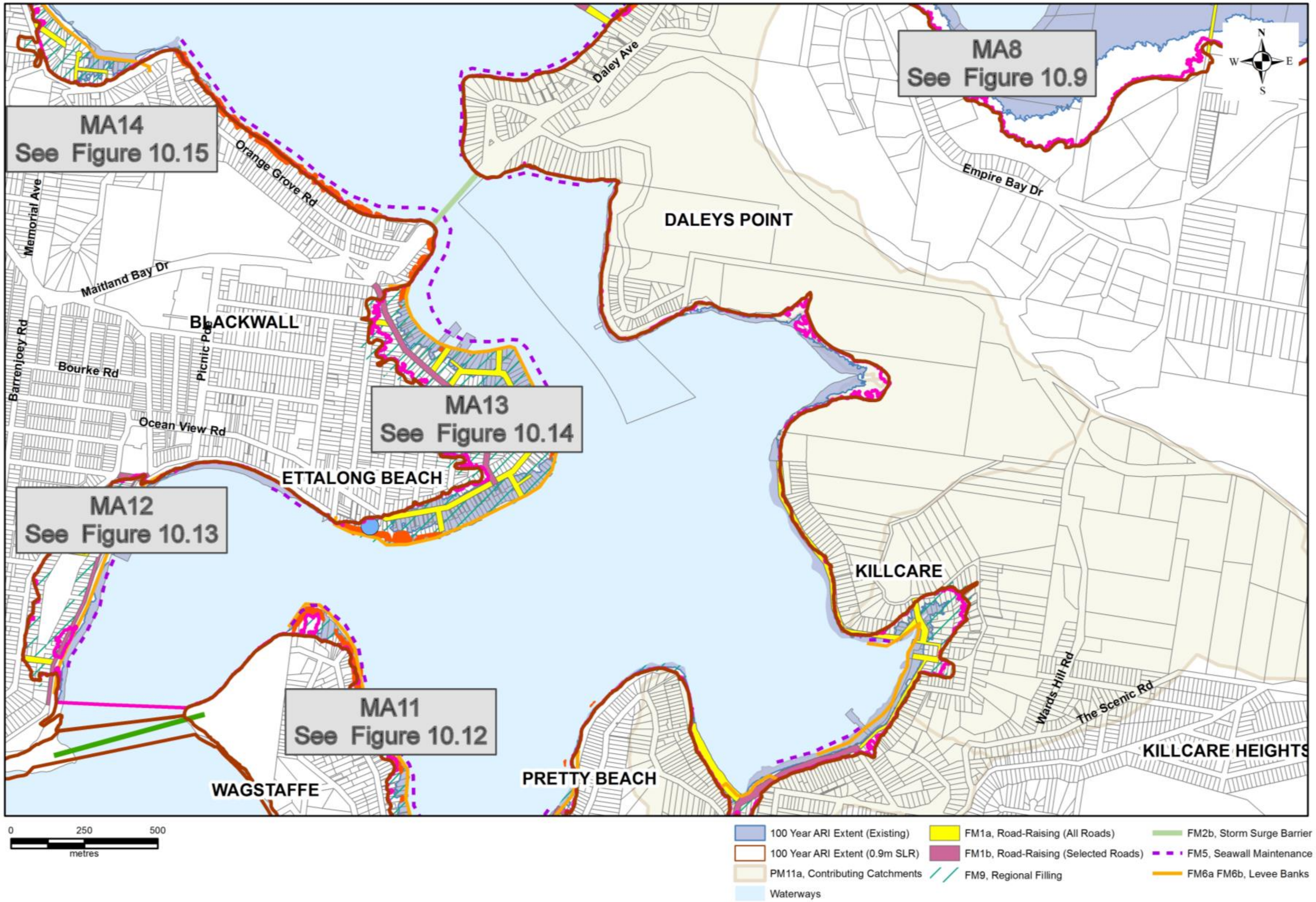

Figure 10.11 Management Area 10 (Daleys Point, Hardys Bay & Killcare)

Table 10.13: Management Area 11 (Pretty Beach and Wagstaffe) Options (Including Preferred)

Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	Tidal: MHWS 0.50m AHD	Tidal: +SLR (0.4m) 0.90m AHD	Tidal: +SLR (0.9m) 1.40m AHD	Foreshore Flood: 5 yr ARI (20%) 1.38m AHD	Foreshore Flood: 100 yr ARI (1%) 1.59m AHD	Foreshore Flood: PMF 1.85m AHD	Foreshore Flood: 100 yr ARI (0.4m SLR) 1.95m AHD	Foreshore Flood: 5 yr ARI (0.9m SLR) 2.31m AHD	Foreshore Flood: 100 yr ARI (0.9m SLR) 2.53m AHD	Foreshore Flood: PMF (0.9m SLR) 2.80m AHD	Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAP (PM9)
11_FM1a	Raise all flood-affected roads above the 100 year ARI +0.9 m level.	Staged	$4,400,000	$88,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.. Any road raising in the vicinity of Turo Creek would require consideration of the behaviour of Turo Creek and the Turo Creek Floodplain Risk Management Plan	Y
11_FM1b	Raise only Pretty Beach Road above the 100 year ARI +0.9 m level.	Staged	$3,700,000	$74,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels. Any road raising in the vicinity of Turo Creek would require consideration of the behaviour of Turo Creek and the Turo Creek Floodplain Risk Management Plan	Y
11_FM3	Modify the existing foreshore at Pretty Beach and Wagstaffe in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$840,000	$25,000	Likely to assist in reducing wave run-up-inundation only.										49	0	N/A	GCC/ State/Private	Would only assist in reducing wave run-up in excess of flood events.	N
11_FM5	Undertake a program of seawall maintenance and raising along the foreshore.	Staged	$620,000	$6,200	✓	✓	✓								Unkn.	Unkn.	N/A	Private	Further investigation into seawall condition would be necessary. The cost associated with this option is for the entire length of sea wall proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
11_FM6a	Construct a levee (1.8km) around Pretty Beach and Wagstaffe to above the PMF level.	Staged	$6,300,000	$130,000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	104	141	0.01	GCC/ State	Susceptible to breaches. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. Any levee structure in the vicinity of Turo Creek would require consideration of the behaviour of Turo Creek and the Turo Creek Floodplain Risk Management Plan. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
11_FM6b	Construct a levee (1.8km) around Pretty Beach and Wagstaffe to above the 5 year ARI level.	Staged	$3,100,000	$61,000	✓	✓	✓	✓				✓			5	63	0.01	GCC/ State	Susceptible to breaches and overtopping. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. Any levee structure in the vicinity of Turo Creek would require consideration of the behaviour of Turo Creek and the Turo Creek Floodplain Risk Management Plan. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
11_FM9	Raise land areas within Pretty Beach and Wagstaffe at risk of coastal flooding.	Trigger	$44,000,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	104	141	N/A	State/ Private	Without masterplanning, consultation and effective staging, this option is unlikely to be feasible on a regional scale.	Y
11_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Pretty Beach and Wagstaffe.	Immediate	$100,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts. Any option in the vicinity of Turo Creek would require consideration of the Turo Creek Floodplain Risk Management Plan	Y
11_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Pretty Beach and Wagstaffe.	Immediate	$30,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y

Legend

FRMS / FRMP Preferred Options
✓ Water level addressed by option
✓ Stage / trigger level response

Action Timeline: **Immediate** - Short term, minimal further investigations required
Staged - Short/medium term, further investigations required
Trigger - Longer term, sea level rise trigger level to initiate management response
Unkn. Unknown

Existing high tides in this area can cause inundation, especially high high tides with joint occurrence of storm conditions. Pretty beach road, which provides the only access road to and from these areas, is affected by flooding even in smaller events (e.g. 20 Year ARI). This area primarily consists of residential properties. The number of affected properties is expected to increase with projected sea level rise.

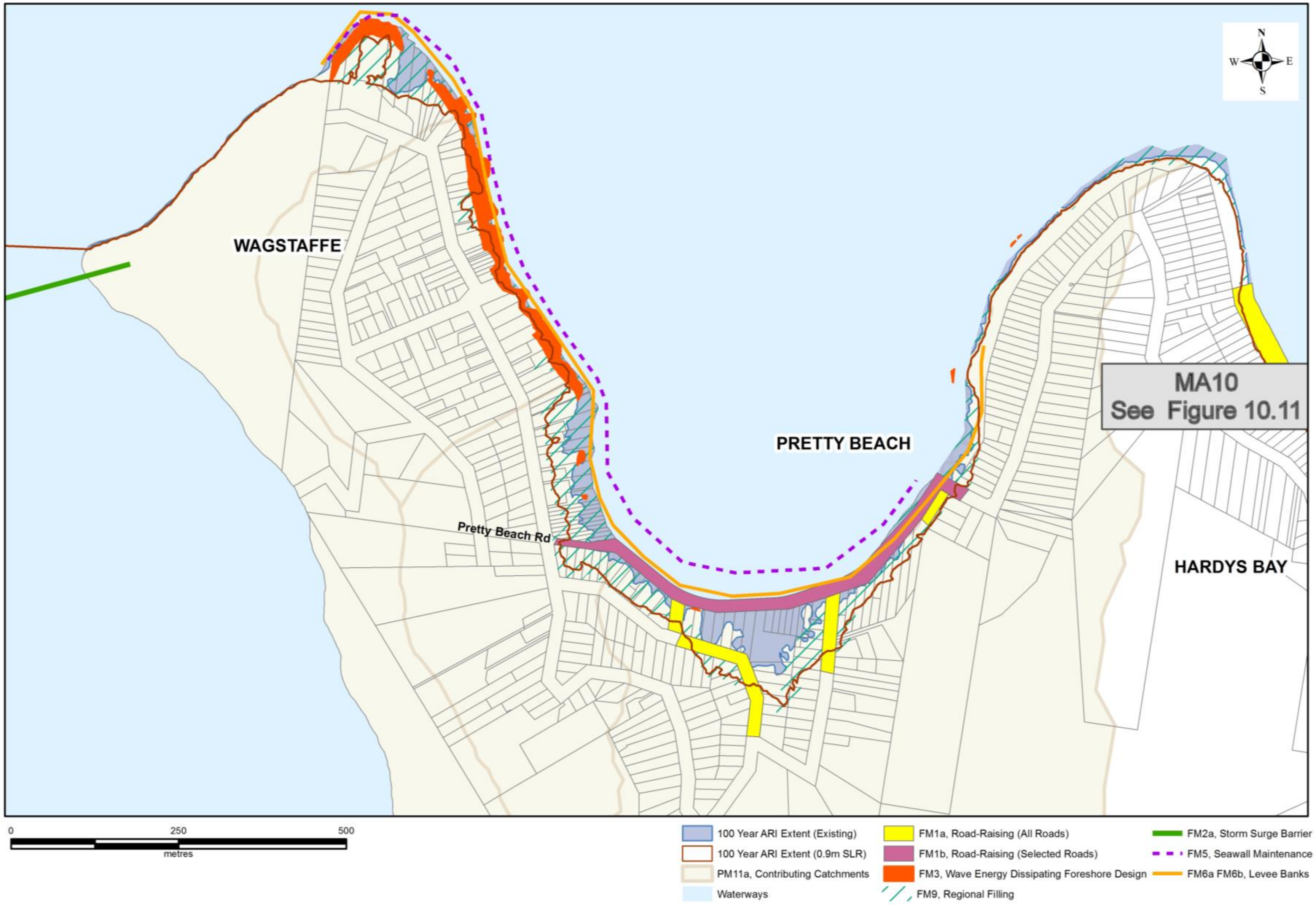

Figure 10.12 Management Area 11 (Pretty Beach & Wagstaffe)

Table 10.14: Management Area 12 (Ettalong) Options (No Preferred)

Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	Tidal/Flood Event Addressed – Tidal: MHWS 0.50m AHD	+SLR (0.4m) 0.90m AHD	+SLR (0.9m) 1.40m AHD	Foreshore Flood: 5 yr ARI (20%) 1.51m AHD	100 yr ARI (1%) 1.78m AHD	PMF 2.08m AHD	100 yr ARI (0.4m SLR) 1.97m AHD	5 yr ARI (0.9m SLR) 2.41m AHD	100 yr ARI (0.9m SLR) 2.66m AHD	PMF (0.9m SLR) 2.94m AHD	Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAP (PM9)
12_FM1a	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Pretty Beach and Wagstaffe.	Immediate	$30,000	$0	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
12_FM1b	Raise only The Esplanade, Bangalow Street and Beach Street above the 100 year ARI +0.9 m level.	Staged	$5,200,000	$100,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
12_FM5	Undertake a program of seawall maintenance and raising along the foreshore.	Staged	$260,000	$2,600	✓	✓	✓								Unkn.	Unkn.	N/A	Private	Further investigation into seawall condition would be necessary. The cost associated with this option is for the entire length of sea wall proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP. It is noted that upgrades to the Ettalong foreshore have already been undertaken including the installation of rock revetment to the 100 year ARI level.	Y
12_FM6a	Construct a levee (0.9km) around Ettalong to above the PMF level.	Staged	$3,200,000	$63,000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	100	110	0.02	GCC/ State	Susceptible to breaches. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
12_FM6b	Construct a levee (0.9km) around Ettalong to above the 5 year ARI level.	Staged	$1,500,000	$31,000	✓	✓	✓	✓				✓			10	91	0.03	GCC/ State	Susceptible to breaches and overtopping. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
12_FM9	Raise areas within Ettalong at risk of coastal flooding.	Trigger	$36,000,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	100	110	N/A	State/ Private	Without masterplanning, consultation and effective staging, this option is unlikely to be feasible on a regional scale.	Y
12_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Ettalong.	Immediate	$100,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y
12_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Ettalong.	Immediate	$30,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y

Legend

No Preferred Options

Action Timeline: **Immediate** - Short term, minimal further investigations required
Staged - Short/medium term, further investigations required
Trigger - Longer term, sea level rise trigger level to initiate management respons
Unkn. Unknown

✓ Water level addressed by option
✓ Stage / trigger level response

Residential properties are generally not affected in smaller ARI flood events, however some open space areas are affected. A large low-lying area extends from Lemon Grove Park out to surrounding residential properties and some roads. Although not directly connected to floodwaters in existing ARI events, this area may be affected by surcharges of the stormwater system, particularly in the existing 100 Year ARI event. The number of affected properties is expected to increase with projected sea level rise.

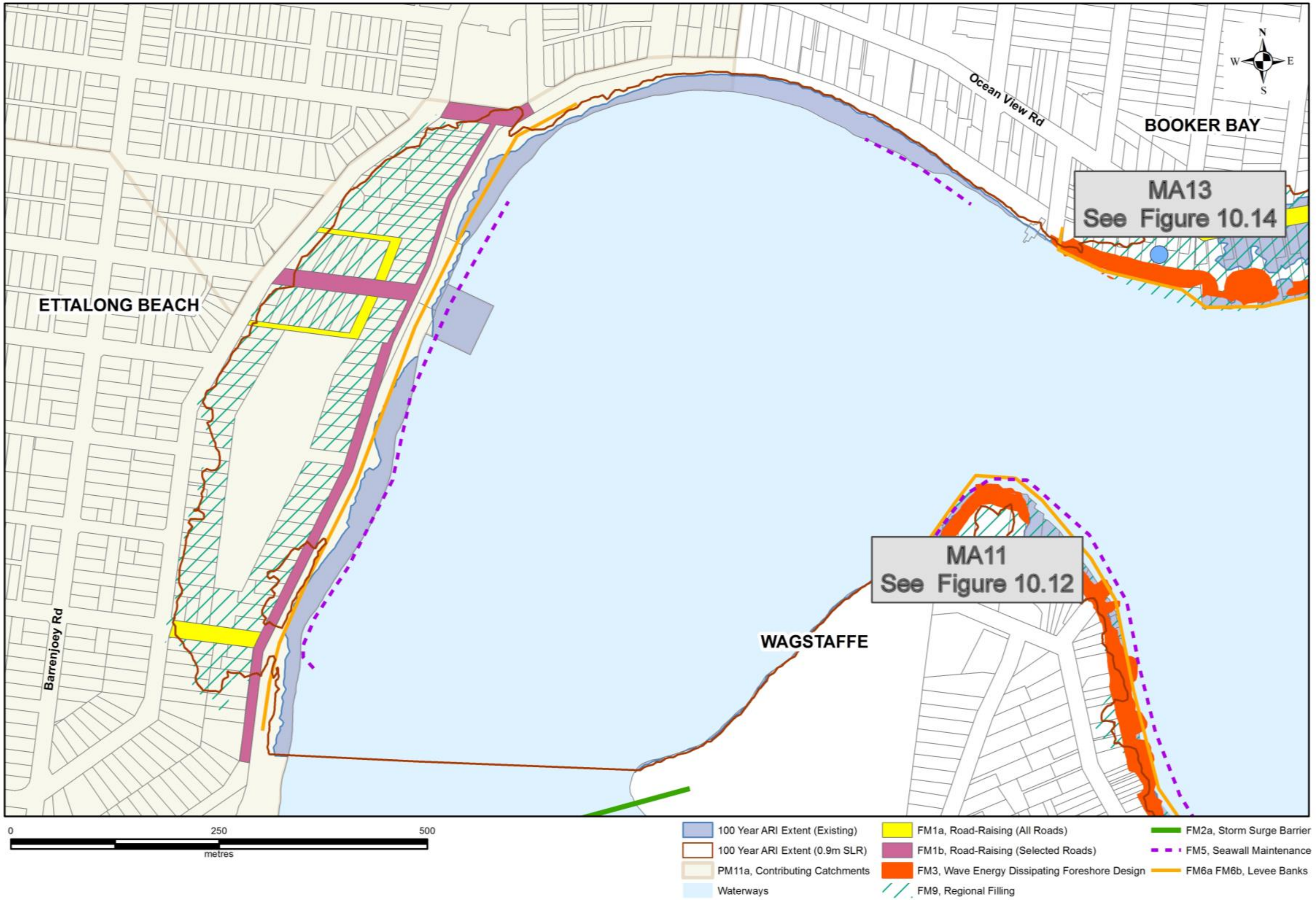

Figure 10.13 Management Area 12 (Ettalong)

Table 10.15: Management Area 13 (Booker Bay) Options (Including Preferred)

Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	Tidal/Flood Event Addressed: Tidal: MHWS 0.50m AHD	+SLR (0.4m) 0.90m AHD	+SLR (0.9m) 1.40m AHD	Foreshore Flood: 5 yr ARI (20%) 1.35m AHD	100 yr ARI (1%) 1.58m AHD	PMF 1.87m AHD	100 yr ARI (0.4m SLR) 1.99m AHD	5 yr ARI (0.9m SLR) 2.25m AHD	100 yr ARI (0.9m SLR) 2.48m AHD	PMF (0.9m SLR) 2.77m AHD	Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAP (PM9)
13_FM1a	Raise all flood-affected roads in Booker Bay to above the 100 year ARI +0.9 m level.	Staged	$8,900,000	$180,000	✓	✓	✓	✓	✓		*✓*	*✓*	*✓*		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
13_FM1b	Raise only portions of Bogan Road and Booker Bay Road above the 100 year ARI +0.9 m level.	Staged	$4,600,000	$92,000	✓	✓	✓	✓	✓		*✓*	*✓*	*✓*		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
13_FM3	Modify the existing foreshore at Booker Bay in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$720,000	$22,000	Likely to assist in reducing wave run-up-inundation only.										56	0	N/A	GCC/ State/Private	Would only assist in reducing wave run-up in excess of flood events. Wave run-up reduction could be incorporated incrementally over time through development controls on private property.	N
13_FM5	Undertake a program of seawall maintenance and raising along the foreshore.	Staged	$970,000	$9,700	✓	*✓*	*✓*								Unkn.	Unkn.	N/A	Private	Further investigation into seawall condition would be necessary. The cost associated with this option is for the entire length of sea wall proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
13_FM6a	Construct a levee (1.9km) around Booker Bay to above the PMF level.	Staged	$6,700,000	$130,000	✓	✓	✓	✓	✓	✓	*✓*	*✓*	*✓*	*✓*	224	*360*	0.06	GCC/ State	Susceptible to breaches. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. It is noted that waterfront land is primarily private land and so traditional levees are unlikely to be well-accepted by the community. Alternative barrier-type structures may instead be incrementally incorporated as properties are redeveloped over time. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
13_FM6b	Construct a levee (1.9km) around Booker Bay to above the 5 year ARI level.	Staged	$3,200,000	$65,000	✓	✓	✓	✓				*✓*			30	*237*	0.03	GCC/ State	Susceptible to breaches and overtopping. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. It is noted that waterfront land is primarily private land and so traditional levees are unlikely to be well-accepted by the community. Alternative barrier-type structures may instead be incrementally incorporated as properties are redeveloped over time. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
13_FM9	Raise land areas within Booker Bay at risk of coastal flooding.	Trigger	$120,000,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	224	360	N/A	State/ Private	Without masterplanning, consultation and effective staging, this option is unlikely to be feasible on a regional scale. As properties are redeveloped along Booker Bay Road, DCP controls could include filling opportunities for waterfront properties including wave run-up if appropriate.	Y
13_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Booker Bay.	Immediate	$100,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y
13_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Booker Bay.	Immediate	$30,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y
13_EM5	Implement a pumping station near residences along Booker Bay Road.	Staged	$120,000	$12,000					✓*						6	0	N/A	GCC/ Private	Very small number of properties protected.	N

Legend

(shaded)	**FRMS / FRMP Preferred Options**	Action Timeline:	**Immediate** - Short term, minimal further investigations required
✓	Water level addressed by option		**Staged** - Short/medium term, further investigations required
✓	Stage / trigger level response		**Trigger** - Longer term, sea level rise trigger level to initiate management respons
✓*	Assessment was only undertaken for the 100 year ARI event		Unkn. Unknown

Existing high tides in this area can cause inundation, especially high high tides with joint occurrence of storm conditions. In these instances, roads and some residential properties are affected. Projected sea level rise is anticipated to increase the number of affected properties.

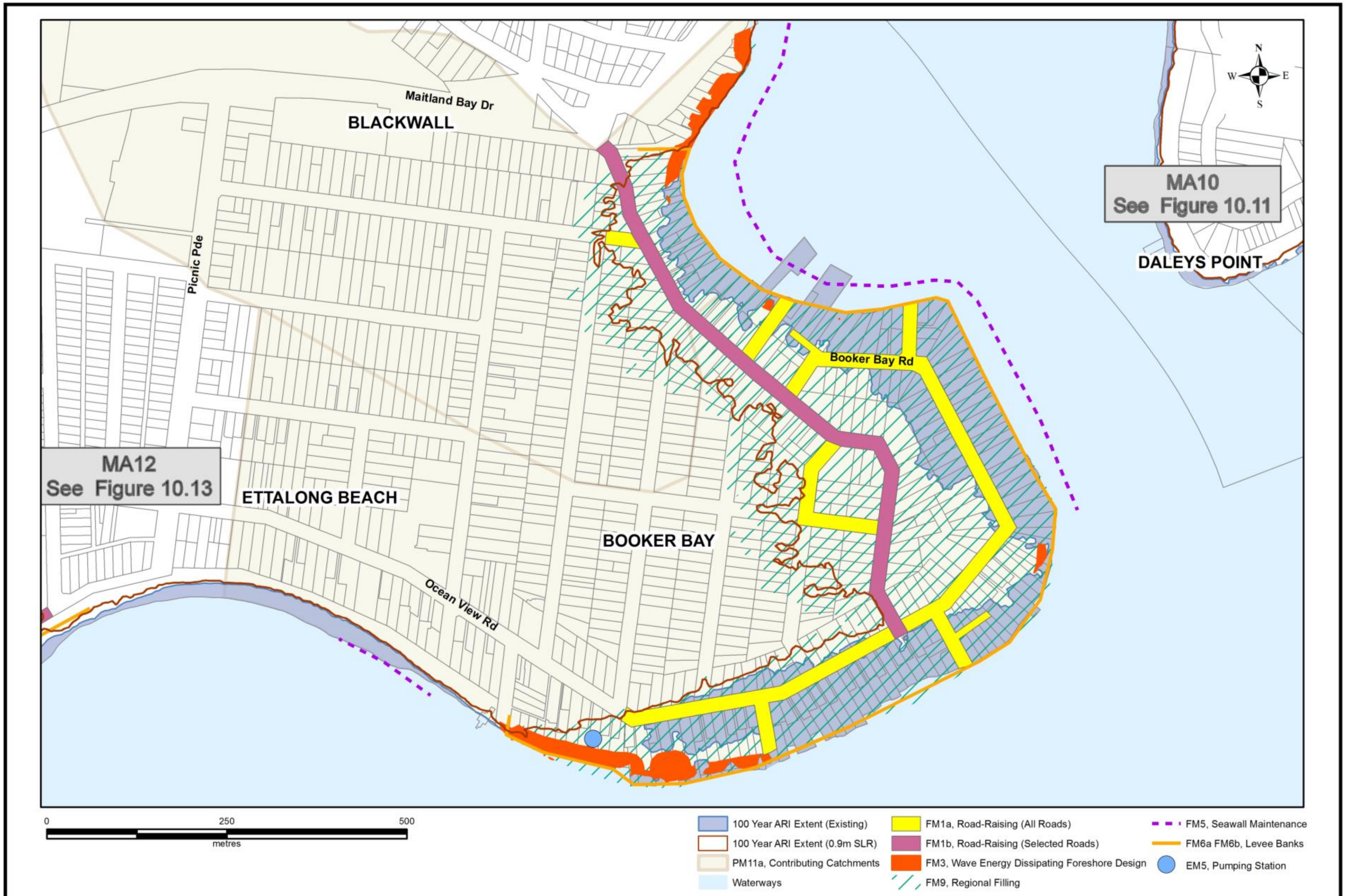

Figure 10.14 Management Area 13 (Booker Bay)

Table 10.16: Management Area 14 (Woy Woy and Blackwall) Options (Including Preferred)

Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	Tidal: MHWS 0.37m AHD	Tidal: +SLR (0.4m) 0.77m AHD	Tidal: +SLR (0.9m) 1.27m AHD	Foreshore Flood: 5 yr ARI (20%) 1.29m AHD	Foreshore Flood: 100 yr ARI (1%) 1.58m AHD	Foreshore Flood: PMF 1.92m AHD	Foreshore Flood: 100 yr ARI (0.4m SLR) 2.00m AHD	Foreshore Flood: 5 yr ARI (0.9m SLR) 2.22m AHD	Foreshore Flood: 100 yr ARI (0.9m SLR) 2.51m AHD	Foreshore Flood: PMF (0.9m SLR) 2.86m AHD	Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAP (PM9)
					Tidal/Flood Event Addressed															
14_FM1a	Raise all flood-affected roads in Woy Woy to above the 100 year ARI +0.9 m level.	Staged	$32,000,000	$630,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
14_FM1b	Raise only Woy Woy Road, Blackwall Road, The Boulevarde, Brick Wharf Road, Railway Street, North Burge Road, Park Road, Norma Crescent, Sonter Avenue and Brisbane Water Drive/Railway Street above the 100 year ARI +0.9 m level.	Staged	$23,000,000	$450,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
14_FM3	Modify the existing foreshore at Woy Woy and Blackwall in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$2,200,000	$65,000	Likely to assist in reducing wave run-up-inundation only.										127	0	N/A	GCC/ State/Private	Would only assist in reducing wave run-up in excess of flood events.	N
14_FM5	Undertake a program of seawall maintenance and raising along the Woy Woy foreshore.	Staged	$2,100,000	$21,000	✓	✓	✓								Unkn.	Unkn.	N/A	Private	Further investigation into seawall condition would be necessary. The cost associated with this option is for the entire length of sea wall proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
14_FM6a	Construct a levee (8.2km) around Woy Woy to above the PMF level.	Staged	$29,000,000	$570,000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	196	745	0.01	GCC/ State	Susceptible to breaches. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
14_FM6b	Construct a levee (8.2km) around Woy Woy to above the 5 year ARI level.	Staged	$14,000,000	$280,000	✓	✓	✓	✓				✓			797	1059	0.16	GCC/ State	Susceptible to breaches and overtopping. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
14_FM9	Raise land areas within Woy Woy at risk of coastal flooding.	Trigger	$340,000,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	196	745	0.00	State/ Private	Without masterplanning, consultation and effective staging, this option is unlikely to be feasible on a regional scale.	Y
14_PM6	Relocate Woy Woy Police Station out of the floodplain.	Staged	$4,300,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	0	0	N/A	State	This station is inundated in the existing 100 year ARI flood event.	N
14_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Woy Woy and Blackwall.	Immediate	$30,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y
14_EM2	Install and maintain "Road Floods" signs at Blackwall Road, Brick Wharf Road and North Burge Road, Woy Woy.	Immediate	$3,600	$540	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	0	0	N/A	GCC/ State	Nearby residents may feel that their property will be devalued because flood markers indicate the presence of flood risk.	N
14_EM6	Upgrade Woy Woy Road to facilitate more effective evacuation from, and emergency services access to, the Woy Woy area.	Trigger	$52,000,000	$520,000	✓	✓	✓	✓	✓		✓	✓	✓		0	0	N/A	GCC/ State	Large economic cost.	N

Legend

FRMS / FRMP Preferred Options

✓ Water level addressed by option

✓ Stage / trigger level response

Action Timeline: **Immediate** - Short term, minimal further investigations required

Staged - Short/medium term, further investigations required

Trigger - Longer term, sea level rise trigger level to initiate management response

Unkn. Unknown

Existing high tides in this area can cause inundation, especially with joint occurrence of storm conditions. Some residential and commercial properties are affected even in higher probability ARIs events. For the existing 100 Year ARI event, Woy Woy and Blackwall have one of the largest numbers of inundated properties of all management areas. This number is likely to increase with projected sea level rise scenarios. Infrastructure is also affected (including some roads and critical infrastructure) and with proejcted sea level rise, railway infrastructure may also be affected. However, Woy Woy has been named a "town centre" under the DoP's Central Coast Regional Strategy (DoP, 2008) and is expected to provide future housing development and continue to provide retail, health, professional and transport services to surrounding residential areas into the future.

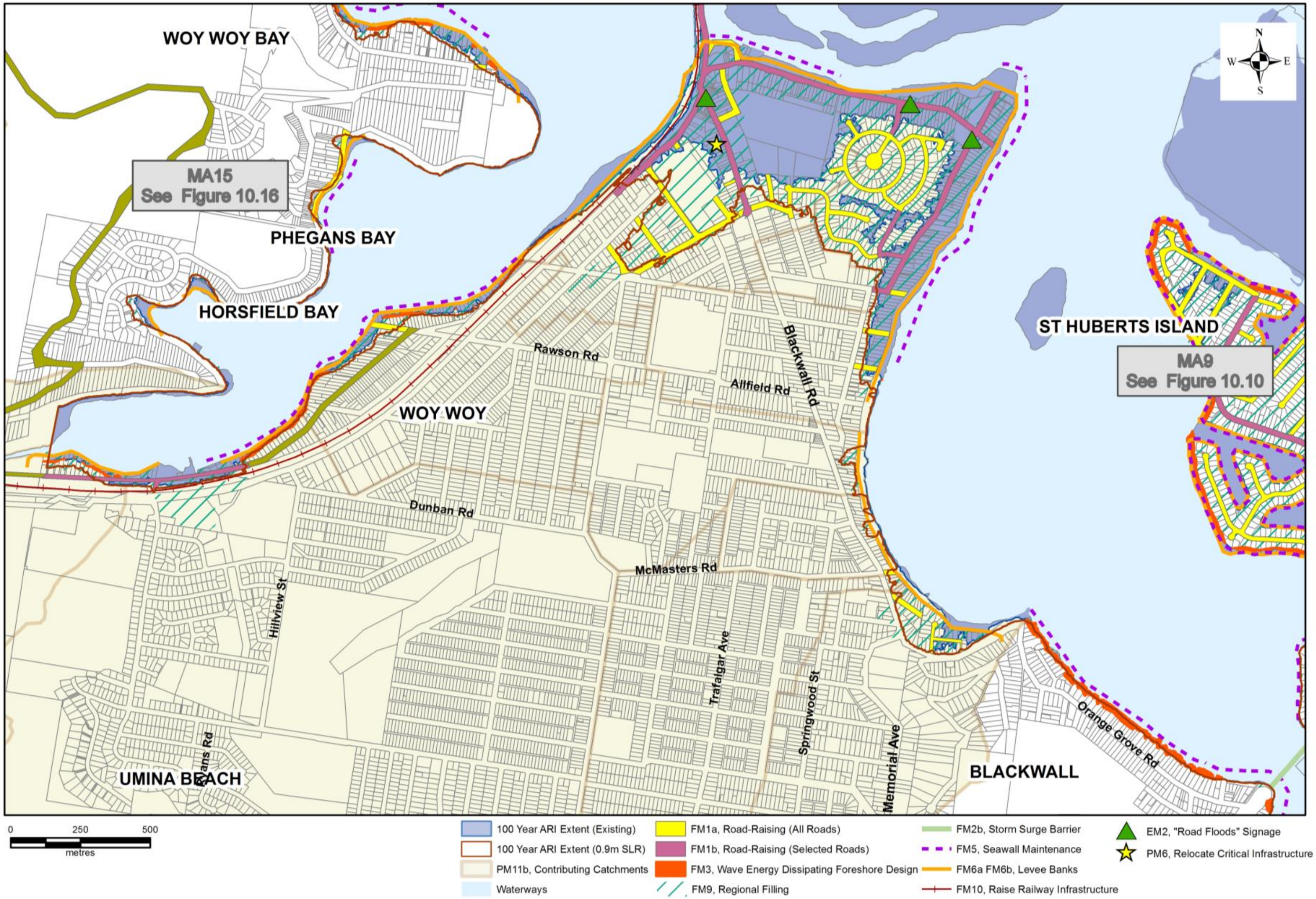

Figure 10.15 Management Area 14 (Woy Woy & Blackwall)

Table 10.17: Management Area 15 (Horsfield Bay, Phegans Bay and Woy Woy Bay) Options (No Preferred)

Option ID	Management Strategy	Action Timeline	Estimated Cost	Annual Cost	Tidal/Flood Event Addressed: Tidal			Foreshore Flood							Properties Protected (Existing PMF)	Properties Protected (PMF+0.9m SLR)	Cost : Benefit Ratio (Existing)	Responsibility	Key Issues / Comments	Option to be investigated further in CCAP (PM9)
					MHWS	+SLR (0.4m)	+SLR (0.9m)	5 yr ARI (20%)	100 yr ARI (1%)	PMF	100 yr ARI (0.4m SLR)	5 yr ARI (0.9m SLR)	100 yr ARI (0.9m SLR)	PMF (0.9m SLR)						
					0.38m AHD	0.78m AHD	1.28m AHD	1.35m AHD	1.66m AHD	2.07m AHD	2.02m AHD	2.26m AHD	2.58m AHD	3.00m AHD						
15_FM1a	Raise all flood-affected roads to above the 100 year ARI +0.9 m level.	Staged	$3,500,000	$71,000	✓	✓	✓	✓	✓		✔	✔	✔		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
15_FM1b	Raise only Brisbane Water Drive above the 100 year ARI +0.9 m level.	Staged	$3,500,000	$71,000	✓	✓	✓	✓	✓		✔	✔	✔		0	0	N/A	GCC/ State	Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. Potential future increase in road height to account for SLR should be considered in the initial design. It is noted that 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels.	Y
15_FM3	Modify the existing foreshore at Horsfield Bay, Phegans Bay and Woy Woy Bay in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$600,000	$18,000	Likely to assist in reducing wave run-up-inundation only.										42	0	N/A	GCC/ State/Private	Would only assist in reducing wave run-up in excess of flood events.	N
15_FM5	Undertake a program of seawall maintenance and raising along the foreshore.	Staged	$730,000	$7,300	✓	✔	✔								Unkn.	Unkn.	N/A	Private	Further investigation into seawall condition would be necessary. The cost associated with this option is for the entire length of sea wall proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
15_FM6a	Construct a levee (0.2km) around low-lying areas to above the PMF level.	Staged	$6,000,000	$120,000	✓	✓	✓	✓	✓	✓	✔	✔	✔	✔	95	127	0.01	GCC/ State	Susceptible to breaches. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. Levees would assist road access to Phegans Bay and could be incorporated in conjunction with public infrastructure upgrades including roads, footpaths/cycleways or seawalls. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
15_FM6b	Construct a levee (0.2km) around low-lying areas to above the 5 year ARI level.	Staged	$2,900,000	$58,000	✓	✓	✓	✓				✔			4	6	0.01	GCC/ State	Susceptible to breaches and overtopping. Drainage and stormwater retention required behind levee. May impact on catchment flooding. Community perception of safety behind levee may lead to increased risk if breach occurs. The future increase in levee height to account for SLR needs to be considered in the initial design. Levees would assist road access to Phegans Bay and could be incorporated in conjunction with public infrastructure upgrades including roads, footpaths/cycleways or seawalls. The cost associated with this option is for the entire length of levee proposed. This cost could be shared by private developers through the implementation of development controls associated with filling and protection from SLR. This can be investigated as part of CCAP.	Y
15_FM8	Install manually-operated floodgates at the openings under the rail bridge linking Woy Woy and Koolewong.	Staged	$19,000,000	$560,000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-6	-30	-0.05	GCC/ State	Catchment flooding may be worsened.	Y
15_FM9	Raise land areas within Horsfield Bay, Phegans Bay and Woy Woy Bay at risk of coastal flooding.	Trigger	$44,000,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	95	127	N/A	State/ Private	Without masterplanning, consultation and effective staging, this option is unlikely to be feasible on a regional scale.	Y
15_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Horsfield Bay, Phegans Bay and Woy Woy Bay.	Immediate	$100,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y
15_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Horsfield Bay, Phegans Bay and Woy Woy Bay.	Immediate	$30,000	$0											0	0	N/A	GCC/ State	Large structural options have the potential to impact on overland flows. Investigations are needed to fully understand these impacts.	Y

Legend

No Preferred Options

✓ Water level addressed by option
✔ Stage / trigger level response

Action Timeline: **Immediate** - Short term, minimal further investigations required
Staged - Short/medium term, further investigations required
Trigger - Longer term, sea level rise trigger level to initiate management respons
Unkn. Unknown

This management area has a fairly low number of affected properties in the existing scenario. Foreshore inundation is confined to small areas within these three bays and is limited by steep terrain. Because of this, residential properties are generally more likely to experience over-ground flooding than over-floor flooding. Projected sea level rise is likely to have an impact on this area, but again, steep terrain will limit the influence of foreshore inundation. It is likely that flood risk within this management area can be managed through the implementation of floodplain-wide management options. In addition, Option EM6 (raise Woy Woy Road) which is recommended for management area 14, would benefit management area 15 as well (if implemented), since Woy Woy Road represents the only access route for residents in Horsfield Bay, Phegans Bay and Woy Woy Bay.

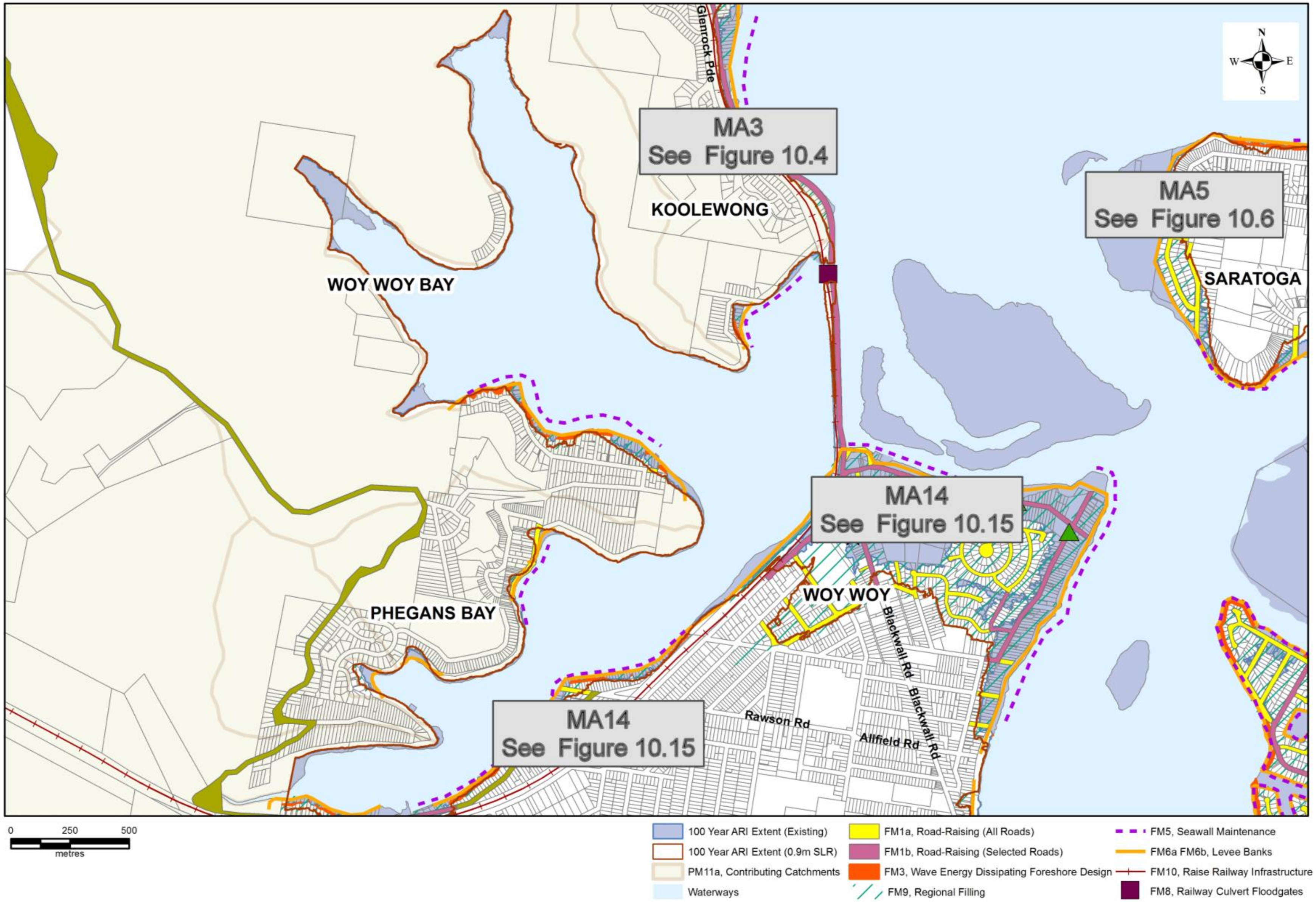

Figure 10.16 Management Area 15 (Horsfield Bay, Phegans Bay & Woy Woy Bay)

11 Options Assessment

11.1 Overview

The primary purpose of this *Floodplain Risk Management Study* is to identify all flood risk management options that could be suitable for the floodplain and undertake an assessment of those options to identify the most appropriate strategies. The outcomes of this assessment form the basis for the *Brisbane Water Floodplain Risk Management Plan* which will follow this FRMS.

Potential management options have been assessed using a quadruple-bottom-line approach, assessing the economic, social, environmental and governance benefits and impacts associated with each option. More specifically, the following assessments have been undertaken:

- **Benefit Cost Analysis:** an economic analysis has been undertaken for key options to assess the reduction in average annual damages that could be achieved by implementing each option. Ten options were considered for this assessment only (the options which could be quantitatively assessed using hydraulically assessments). This assessment was undertaken in the same manner as for the economic damages assessment undertaken for the base case (**Section 7.5.1**). The outcomes of this analysis were compared against the life-cycle cost of implementing the option to determine the benefit cost ratio for the option. Further details are provided in **Section 11.2**.
- **Multi-criteria matrix assessment:** a multi-criteria matrix has been developed specifically for assessing the relative benefits of implementing floodplain risk management options in the Brisbane Water floodplain. The matrix assessment involves allocating a score to economic, social and environmental criteria for all considered options. Further details are provided in **Section 11.3**.

The following sections provide a description of each of the options including an assessment of their potential benefits and impacts. For those options that are location-specific, additional information has been provided regarding the characteristics, benefits and limitations of the option in the context of each management area.

The outcomes of the flood options assessment (specifically the damages assessment and multi-criteria matrix assessment) are provided in **Section 12**. This section provides a discussion of options recommended for implementation.

The options assessment provided in this study has been designed to provide a comparative assessment of potentially viable floodplain risk management options. A preliminary environmental constraints analysis has been undertaken and this is incorporated into the options assessment matrix. It should be noted that detailed environmental and economic assessment would need to be undertaken prior to the implementation of all options (e.g. geotechnical investigations or environmental assessments).

The options developed in this study place a high priority on improving planning and development controls. Through the redevelopment process, a reduction in flood risk can be achieved in a large number of cases as property owners upgrade their buildings in accordance with development controls. This will be one of the main methods of overcoming and preventing flood dangers and flood losses due to the benefits the property owner receives in damage prevention, safety and increased property value.

Insurance is not an option that is normally considered within a floodplain management study in Australia as it is outside the control of Council or other agencies (apart from public buildings/facilities). Unlike the USA, Australia does not have a national flood insurance scheme and the government response to the National Disaster Insurance Review of 2011 was to not require compulsory opt-out flood insurance across the board. A large number of properties are likely to be un-insurable by some insurance agencies based on their flood affected nature.

11.1.1 Environmental Considerations

According to State Environmental Planning Policy (SEPP) (Infrastructure) 2007, flood mitigation works "may be carried out by or on behalf of a public authority without consent on any land". These works include construction, routine maintenance and environmental management works. Although consent is not required, most flood mitigation works will require further environmental assessment.

The determining authority, in this case Gosford City Council, is required to "examine and take into account to the fullest extent possible all matters affecting or likely to affect the environment by reason of that activity" complying with Section 111 of the EP&A Act, most likely in the form of a Review of Environmental Factors (REF).

When carrying out flood mitigation works, Council will be required to take out further permits, licenses and approvals such as:

- Flood mitigation works which emit into a water body will need an Environment Protection Licence complying with the Protection of the Environment Operations Act (POEO) 1997,
- Any removal of vegetation and debris in the water body may need a Threat Abatement Plan complying with the Fisheries Management Act 1999,
- A license to harm threatened species, population or ecological community or damage habitat under the Fisheries Management Act 1999.

It is important to consider the implication of any proposed flood management works on heritage items or the constraints that may apply due to the presence of heritage items. Four heritage items that are listed under the NSW Heritage Act are located in suburbs that make up the study area. A further 79 items located in these suburbs have been listed by local council and state government agencies. The *Gosford Local Environment Plan* (GCC, 2014) outlines the provisions which must be followed in relation to heritage items in the LGA.

11.2 Economic Assessment of Options

An assessment of the economic damages incurred by flooding was undertaken in the manner described in **Section 7.** The same approach was then used to assess the benefits of several identified management options. Hydraulic models were created based on the same conditions but with the installation of the option to provide an indication of the effectiveness of the option compared to the base case.

The economic assessment of the floodplain risk management options involved:

- A preliminary cost estimate of the implementation and maintenance costs associated with each option (i.e. life cycle costs);
- Assessment of the reduction in average annual damages resulting from the implementation of the proposed options. This was done using hydraulic modelling and detailed damages calculations for several applicable options.
- Calculation of benefit cost ratios was undertaken for several options; and

- Incorporation of the damages associated with flooding under projected sea level rise conditions.

11.2.1 Preliminary Costing of Options

A preliminary cost estimate of all proposed options has been prepared to assist with the comparative assessment of options. The costs were prepared using engineering judgment and the *Rawlinsons Australian Construction Handbook* (Rawlinsons, 2011) where appropriate. However, prior to an option being implemented, it is recommended that in addition to detailed analysis and design of the options, costs should be revised prior to budget allocation to allow for a more accurate assessment. Detailed rates and quantities will also be required at the detailed design stage.

Preliminary costings for all of the identified options are provided in **Table 10.2 to Table 10.17**. **Costs are indicative only and have been prepared for comparative purposes**. Although care has been taken to provide some level of accuracy in the above values, actual costs are likely to be highly dependent on site-specific variations such as geotechnical characteristics, hydraulic and storm forces and ecological constraints.

Costings for options FM2a and FM2b have been calculated on a pro rata basis using the unit cost for the Thames River Barrier. Note that the Thames Barrier unit cost is purely the construction cost and for the purpose of this report, additional fees have been included for detailed design and environmental assessment. The cost estimates are for feasibility evaluation only and are not at a detailed design phase. The purpose is only for comparative analysis.

It was possible to quantitatively assess the economic benefit of some of the options (i.e. those which were hydraulically modelled and those with known benefits such as voluntary house purchase). For those options, a benefit-cost ratio can be calculated and is provided in **Table 10.2 to Table 10.17**.

11.2.2 Average Annual Damage for Quantitatively Assessed Options

In a similar fashion to the damages assessment in **Section 7**, the total damage costs were evaluated for each of the quantitatively assessed options (i.e. those options assessed using hydraulic assessments). For each option the average annual damages (AAD) were calculated for the existing case and the 0.9m SLR scenario.

AAD is a convenient method of comparing the economic benefits of various proposed flood mitigation measures. As a hypothetical example, consider two structural measures, a proposed house raising scheme and a proposed levee, the two approaches reduce the existing case AAD by $0.5 M per year and $1.5 M per year respectively. The levee is clearly more effective in reducing flood damages (i.e. it generates greater benefits than the proposed house raising scheme) however it also costs more to construct and maintain. Therefore, both the economic costs and benefits of proposed options must be considered.

In addition to economic costs, there may also be different environmental and social costs associated with both schemes. All of these cost factors have to be weighed up and evaluated in determining the relative economics of possible mitigation measures. AAD therefore provides a consistent means of evaluating the physical economic benefits of different mitigation measures.

It should also be noted that unless the environmental impacts of the various measures under consideration are also included in the assessment, then the end result of the assessment will not truly reflect the overall costs and benefits of the proposal (the other factors are considered in the multi-criteria matrix in **Appendix J**).

11.2.2.1 Net Present Value

A net present value of AAD was calculated for each modelled option. Net present value (NPV) can be defined as *today's value* of a *future cost* (in this case AAD), discounted at some appropriate discount rate (7% in accordance with NSW Treasury [2007] guidelines). The net present value of AAD in Brisbane Water for the period 2014 to 2100 was determined by the summation of the present value for the AAD of each year between 2014 and 2100. **Section 7.5.3** provides further explanation. The Existing AAD and NPV AAD were compared against the existing case (i.e. with no options implemented) to determine what the likely reduction in damages would be as a result of the option.

As described in **Section 7**, the existing case damages (no options implemented) were:

2014 AAD = $5,448,989
NPV AAD = $83,060,367

Since options that are focused on the projected sea level rise scenario do not reduce existing flood risks, the net present value of the potential flood damages over the next 90 years was calculated to give more weight to options that provide a reduction in *existing* AAD rather than *future* AAD.

11.2.2.2 Change in Incurred Damages

Table 11.1 provides a summary of the reduction in damages as a result of each option (in order of greatest reduction in Existing AAD). Change in Existing AAD was calculated by comparing the existing case AAD (i.e. no options implemented) with the AAD for a case where one option (and only that option) was implemented. Change in NPV AAD was calculated by comparing the existing case net present value (NPV) AAD (i.e. no option implemented for 90 years) with the option case NPV AAD (i.e. option implemented now and maintained over 90 years). Note that:

- A negative value in one of the "Change in AAD" columns represents a net decrease in damages (a reduction in AAD); and
- A positive value in one of the "Change in AAD" columns represents a net increase in damages (a negative reduction in AAD), which means the option cannot be recommended for implementation.

Table 11.1: Average Annual Damage for Quantitatively Assessed Options

Option ID	Existing AAD (with option implemented)	Change in Existing AAD*	NPV AAD (with option implemented)	Change in NPV AAD#
FM2a (Storm Surge Barrier)	$2,124,650	-$3,324,339	$32,386,602	-$50,673,765
1_FM7a (Enhance Fagans Bay Railway Bridge)	$5,471,283	+$22,294	$83,400,199	+$339,832
1_FM7b (Floodgates at Fagans Bay Railway Bridge)	$7,041,438	+$1,592,449	$107,334,483	+$24,274,115
15_FM8 (Floodgates at Woy Woy Railway Culvert)	$6,484,343	+$1,035,354	$98,842,547	+$15,782,180
6_FM9 (regional filling of the floodplain at in MA6)	$3,096,394	-$2,352,595	$47,199,144	-$35,861,224
8_FM9 (regional filling of the floodplain in MA8)	$5,056,136	-$392,853	$77,072,008	-$5,988,359
14_FM9 (regional filling of the floodplain in MA14)	$4,244,033	-$1,204,955	$64,692,916	-$18,367,451
6_FM6a (PMF Levee for large area)	$3,043,583	-$2,405,405	$46,394,141	-$36,666,227
6_FM6b (5 year ARI Levee for large area)	$4,151,277	-$1,297,712	$63,279,006	-$19,781,361
7_FM6a (PMF year ARI Levee for smaller area)	$5,417,748	-$31,241	$82,584,160	-$476,208
7_FM6b (5 year ARI Levee for smaller area)	$5,432,114	-$16,875	$82,803,133	-$257,235
PM1 (Voluntary House Purchase of 19 properties)	$4,359,086	-$1,089,903	$66,446,689	-$16,613,678

* Change in AAD was calculated by comparing the existing case AAD (i.e. no options implemented) with the option case AAD (i.e. with that option implemented).
# Change in NPV AAD was calculated by comparing the existing case net present value (NPV) AAD (i.e. no option implemented for 90 years) with the option case NPV AAD (i.e. option implemented now and maintained over 90 years).

The results shown in **Table 11.1** indicate that the maximum reduction in average annual damage (AAD) was $3,324,339 for the storm surge barrier at Half Tide Rocks (FM2a), with an Existing AAD (option implemented) of $2,124,650 compared with the existing case AAD (no option implemented) of $5,448,989. This is a substantial decrease in damages (61% reduction). Option FM2a was followed closely by a PMF levee for a large area (6_PM6a) with a 44% reduction in damages, and the filling of areas within the floodplain (FM9) with a 43% reduction in damages. These reductions in damages appear logical given the nature of these management options and the reduction in flood risk associated with them.

Three of the options (1_FM7a, 1_FM7b and 1_FM8) in **Table 11.1** indicate an increase in AAD. For 1_FM7a, this is likely to be as a result of increased storm surge flows into Fagans Bay, causing a relatively small amount of additional damages. For 1_FM7b and 15_FM8 the larger increases in damages are likely to be as a result of an increase in flood levels at surrounding properties as a result of “trapping” of catchment flows.

11.2.3 Benefit Cost Ratio of Options

The economic evaluation of each modelled option was assessed by considering the reduction in the amount of flood damage incurred by various events and comparing this value with the cost of implementing the option. As part of this evaluation the PMF, 500, 200, 100, 20 and 5 Year ARI events were considered for both the existing scenario and the 0.9m SLR. Preliminary costs for each option were prepared and a benefit-cost analysis of each option was undertaken on a purely economic basis.

Table 11.2 summarises the overall economics of each option with regards to the Existing Case AAD. **Table 11.3** summarises the overall economics of each option with regards to the NPV of the damages (assessing existing and future scenarios).

The indicator adopted to rank options on economic merit is the benefit-cost ratio (B/C) where:

- B/C > 1, the economic benefits are greater than the cost of implementing the option;
- 0 < B/C < 1, there is some economic benefit from implementing the option but the cost of implementing the option is greater than the economic benefit;
- B/C = 0, there is no economic benefit from implementing the option; and
- B/C < 0, there is a negative economic impact of implementing the option (i.e. a cost).

Table 11.2: Summary of Economic Assessment of Management Options (Existing AAD)

Option ID	Change in Existing AAD (B)*	Capital Cost Estimate	Recurrent Cost Estimate	Existing Cost (C)	B/C
FM2a (Storm Surge Barrier)	-$3,324,339	$2,356,889,494	$1,414,134	$2,358,303,628	0.001
1_FM7a (Enhance Fagans Bay Railway Bridge)	$22,294	$10,000,000	$500,000	$10,500,000	-0.002
1_FM7b (Floodgates at Fagans Bay Railway Bridge)	$1,592,449	$18,700,000	$561,000	$19,261,000	-0.083
15_FM8 (Floodgates at Woy Woy Railway Culvert)	$1,035,354	$18,700,000	$561,000	$19,261,000	-0.054
6_FM9 (regional filling of the floodplain at in MA6)	-$2,352,595	$338,374,605	$0	$338,374,605	0.007
8_FM9 (regional filling of the floodplain in MA8)	-$392,853	$166,913,835	$0	$166,913,835	0.002
14_FM9 (regional filling of the floodplain in MA14)	-$1,204,955	$342,921,015	$0	$342,921,015	0.004
6_FM6a (PMF Levee for large area)	-$2,405,405	$22,400,000	$448,000	$22,400,000	0.105
6_FM6b (5 year ARI Levee for large area)	-$1,297,712	$10,880,000	$217,600	$10,880,000	0.117
7_FM6a (PMF year ARI Levee for smaller area)	-$31,241	$10,500,000	$210,000	$10,500,000	0.003
7_FM6b (5 year ARI Levee for smaller area)	-$16,875	$5,100,000	$102,000	$5,100,000	0.003
PM1 (Voluntary House Purchase of 19 properties)	-$1,089,903	$9,785,000	$0	$9,785,000	0.111

* Change in AAD was calculated by comparing the existing case 2009 AAD (i.e. no options implemented) with the option case 2009 AAD (i.e. with that option implemented).

Table 11.3: Summary of Economic Assessment of Management Options (NPV AAD)

Option ID	Change in NPV AAD (B)*	Capital Cost Estimate	Recurrent Cost Estimate	NPV of Cost (7%, 90 yrs) (C)	B/C
FM2a (Storm Surge Barrier)	-$50,673,765	$2,356,889,494	$1,414,134	$2,377,068,123	0.02
1_FM7a (Enhance Fagans Bay Railway Bridge)	$339,832	$10,000,000	$500,000	$17,134,625	-0.02
1_FM7b (Floodgates at Fagans Bay Railway Bridge)	$24,274,115	$18,700,000	$561,000	$26,705,050	-0.91
15_FM8 (Floodgates at Woy Woy Railway Culvert)	$15,782,180	$18,700,000	$561,000	$26,705,050	-0.59
6_FM9 (regional filling of the floodplain at in MA6)	-$35,861,224	$338,374,605	$0	$338,374,605	0.11
8_FM9 (regional filling of the floodplain in MA8)	-$5,988,359	$166,913,835	$0	$166,913,835	0.04
14_FM9 (regional filling of the floodplain in MA14)	-$18,367,451	$342,921,015	$0	$342,921,015	0.05
6_FM6a (PMF Levee for larger area)	-$36,666,227	$22,400,000	$448,000	$28,792,624	1.27
6_FM6b (5 year ARI Levee for larger area)	-$19,781,361	$10,880,000	$217,600	$13,984,989	1.41
15_FM6a (PMF year ARI Levee for smaller area)	-$476,208	$10,500,000	$210,000	$13,496,543	0.04
15_FM6b (5 year ARI Levee for smaller area)	-$257,235	$5,100,000	$102,000	$6,555,464	0.04
PM1 (Voluntary House Purchase of 19 properties)	-$16,613,678	$9,785,000	$0	$9,785,000	1.70

* Change in NPV AAD was calculated by comparing the existing case net present value (NPV) AAD (i.e. no option implemented for 90 years) with the option case NPV AAD (i.e. option implemented now and maintained over 90 years).

The benefit-cost analysis shown in **Table 11.2** and **Table 11.3** indicate that whilst no options provide a benefit cost ration greater than 1 when assessing the benefits for the existing flooding scenario, the benefits for several options improve considerably when assessing the future flood scenario under 2100 SLR. The results show that Option 6_FM6b (5 year ARI levee for a relatively large area) has the greatest economic benefit for expenditure. The remaining options listed in **Table 11.2** and **Table 11.3** show varied levels of economic benefit. Those with benefit-cost ratios below zero are unlikely to be recommended. Those with benefit-cost ratios less than 1, although not economically effective, may provide other social or environmental benefits. These factors are considered in the multi-criteria matrix assessment in **Section 11.3**.

11.2.4 Economic Assessment of Desktop Assessed Options

Where a desktop assessment was utilised for options (as opposed to hydraulic modelling), a detailed economic analysis was not undertaken. Instead, a judgement on the likely economic benefits of the options was made. This is described in **Section 11.3**.

11.2.5 Deferred Commencement of Works

The economic assessment undertaken in this study considered the impacts of projected sea level rise of flood damages. Management options relating to projected sea level rise may not be viable under existing conditions but may become viable once sea levels rise to a certain level. An assessment of the benefit cost ratios was undertaken to identify works which may warrant further assessment in the future. The assessment allows the identification of when (i.e. the year) that an option achieves a benefit cost ratio greater than 1 (i.e. when the option becomes viable for implementation). The assessment found that no options were identified at this time. However, further investigation may be undertaken as part of the CCAPs and future FRMSs, where options may be able to be recommended once sea level rise trigger levels or events have been established.

11.3 Multi-Criteria Matrix Assessment

A multi-criteria matrix assessment was undertaken for the comparative assessment of all options identified for the floodplain, using a similar approach to that recommended in the *Floodplain Development Manual* (NSW Government, 2005). This approach assesses the merits and draws comparisons between various (and often vastly different) management options through the use of a subjective and transparent pre-defined scoring system. However, this approach does not provide a definitive answer as to what should be included in the *Floodplain Risk Management Plan* and what should be omitted. Rather, it provides a method by which stakeholders can re-examine options and, if necessary, debate the relative scoring assigned.

The matrix is shown in its entirety in **Appendix J.**

11.3.1 Scoring System

A scoring system was devised to subjectively rank each option against a range of criteria given the background information on the nature of the catchment and floodplain outlined in **Section 6.2** as well as the community preferences outlined in **Section 4**. The scoring is based on a quadruple bottom line approach, incorporating economic, social and environmental and planning/governance criterion. **Table 11.4** presents each criterion, including weightings applied to each (established using engineering judgement). **Table 11.5** presents the scoring system developed so that a reasonably standard score could be applied to management options in a methodical manner.

11.3.2 Scoring Methodology

For each option, each criterion was assigned a score based on the scoring system shown in **Table 11.5**. The total score for each management option was then calculated by summing the scores for each constituent criterion (and incorporating associated weightings). The total scores are shown in **Appendix J**.

Management options were ranked according to three categories:

- All options (the highest ranking options, regardless of type or management area);
- Floodplain-wide options (the highest ranking options that apply to many/all locations); and
- Management area options (the highest ranking options for each management area);

The rankings are proposed to be used as the basis for the implementation strategy to be provided of the *Floodplain Risk Management Plan*, which is discussed in **Section 12**. The option ranking is also shown in **Appendix J**.

Table 11.4: Quadruple Bottom Line Assessment Criteria

Criterion Type	Weight	Weighting Explanation
Economic		
Score on Reduction in AAD (Private Property)	1	Establishes the tangible benefit of an option.
Affordability (based on capital and recurrent costs)	1	Establishes the viability of an option.
Feasibility	1	Establishes the feasibility of an option.
Protection of Public Infrastructure (Existing PMF)	0.5	Existing risks to public infrastructure are important.
Protection of Public Infrastructure (PMF +0.9m SLR)	0.1	When compared to the existing flood risk, the risks associated with flooding in the future are of lower significance.
The above criteria were utilised in the multi-criteria matrix to undertake a qualitative assessment of economic factors. This is in addition to the quantitative economic assessment undertaken (**Section 11.2**). Capital and operating costs were used in assessing the "affordability" criteria (see **Table 11.5**). A benefit cost ratio has only been provided for those options assessed quantitatively (**Section 11.2**). For all other options, engineering judgement was used to provide a score on the likely reduction in AAD.		
Social		
Reduction in Risk to Life (Existing PMF)	1	Key concept underpinning the flood risk management process.
Reduction in Risk to Life (PMF +0.9m SLR)	0.1	When compared to the existing flood risk, the risks associated with flooding in the future are not as significant.
Emergency Access (Existing PMF)	0.5	Availability of emergency access is important now.
Emergency Access (PMF +0.9m SLR)	0.1	When compared to the existing flood risk, the risks associated with flooding in the future are not as significant.
Likely Community Acceptance	0.5	Acceptance by the community is important in flood risk management.
The population of the Brisbane Water foreshore floodplain is expanding, within continued growth anticipated (DoP, 2008). The social impacts of flooding may increase in the future due to projected population growth and sea level rise. Social disruption due to flooding includes risk to life and emergency access (critical), as well as aspects such as the effects of property flooding, traffic disruption and intangible impacts such as social angst (less critical). The risk to life and emergency access criteria are fairly subjective as it is difficult to assess the behaviour of persons under extreme conditions such as flooding. Likely community support was assessed using judgement based on past experience and will be verified through the consultation process.		
Environmental		
Water Quality	0.5	Neutral or positive environmental impacts are preferred.
Habitat (Including Future Intertidal Habitat)	0.5	Neutral or positive environmental impacts are preferred.
These environmental factors are particularly significant for flood modification options, which often alter the hydraulic regime of a waterway. Water quality may be affected if parts of a waterway are blocked (e.g. the installation of flood gates may reduce flushing in an area). Alterations to the hydraulic regime may also have broader implications for the surrounding natural environment (e.g. intertidal vegetation may be impacted by the installation of a levee).		
Planning and Governance		
Compatibility with other Policies and Plans	0.5	Incompatibility with other adopted policies or plans may indicate that the option is not suitable.
Compatibility with Catchment Flooding	0.5	Incompatibility with catchment flows may indicate that the option is not suitable (and may in fact worsen flooding)
Compatibility with Projected Sea Level Rise	0.5	Options that have coincident benefits under projected sea level rise (in addition to mitigating flooding in the existing scenario) are preferred.
The compatibility of flood risk management options with other management plans and policies is integral in ensuring the consistent management and future planning of these areas. Plans that were considered in the context of the floodplain risk management options include the *Brisbane Water Estuary Management Plan* (Cardno, 2011b), the *Gosford City Masterplan* (GCC and LPMA, 2010), and several catchment flood risk management plans. The integration of catchment and foreshore flood risk was also considered such that an option that is likely to worsen catchment flooding was not considered appropriate for implementation. Similarly, the compatibility of options with projected sea level rise has been considered such that an option will rank marginally highly if it is effective in the future with projected sea level rise as well as in the existing flood scenario.		

Table 11.5: Summary of Adopted Scoring System

Category	Criteria	Weighting	Score										
			-5,-4*		**-3**	**-2,-1^**		**0**	**1,2^**		**3**	**4,5***	
Economic	Reduction in AAD (for NPV in 2100)	1	<$-30M	<$-15M	<-$7M	<-$3M	<-$1M	>0 and <$1M	>$1M	>$3M	>$7M	>$15M	>$30M
	Affordability (for NPV in 2100)	1	>$100M	>$10M	>$1M	>$500K	>$250K	>$125K and <$250K	<$125K	<$100K	<$75K	<$50K	<$25K
	Feasibility	1	Extremely likely to not be feasible		Very likely to not be feasible.	Likely to not be feasible.		May or may not be feasible	Likely to be feasible.		Very likely to be feasible.	Extremely likely to be feasible	
	Protection of Infrastructure (assessed for existing 100yr ARI)	0.5	Significant damages to public infrastructure		Moderate damage to public infrastructure	Minor damage to public infrastructure		No impact on public infrastructure	Minor protection of public infrastructure.		Moderate protection of public infrastructure.	Significant protection of public infrastructure.	
	Protection of Infrastructure (assessed for 100yr ARI +0.9m SLR)	0.1	Significant damages to public infrastructure		Moderate damage to public infrastructure	Minor damage to public infrastructure		No impact on public infrastructure	Minor protection of public infrastructure.		Moderate protection of public infrastructure.	Significant protection of public infrastructure.	
Social	Risk To Life (assessed for existing PMF)	1	Major increase in risk to life		Moderate increase in risk to life	Slight increase in risk to life		No change in risk to life	Slight reduction of risk to life		Moderate reduction of risk to life	Major reduction of risk to life	
	Risk To Life (assessed for 2100 +0.9m SLR)	0.1	Major increase in risk to life		Moderate increase in risk to life	Slight increase in risk to life		No change in risk to life	Slight reduction of risk to life		Moderate reduction of risk to life	Major reduction of risk to life	
	Emergency Access (assessed for Existing PMF)	0.5	Significant limitation on emergency access.		Moderate limitation on emergency access.	Minor limitation on emergency access.		No change to emergency access.	Minor improvement to emergency access		Moderate improvement to emergency access	Significant improvement to emergency access	
	Emergency Access (assessed for PMF +0.9m SLR)	0.1	Significant limitation on emergency access.		Moderate limitation on emergency access.	Minor limitation on emergency access.		No change to emergency access.	Minor improvement to emergency access		Moderate improvement to emergency access	Significant improvement to emergency access	
	Likely Community Support	0.5	Likely strong objections from the community.		Likely moderate objections from the community.	Likely minor objections from the community.		Likely neutral response from the community.	Likely minor support from the community.		Likely moderate support from the community.	Likely strong support from the community.	
Environmental	Water Quality (tributary, estuarine or ocean water quality)	0.5	Significant negative impacts on water quality.		Moderate negative impacts on water quality.	Minor negative impacts on water quality.		No impacts on water quality.	Minor improvements to water quality.		Moderate improvements to water quality.	Significant improvements to water quality.	
	Habitat	0.5	Significant loss of existing habitat or potential future intertidal habitat.		Moderate loss of existing habitat or potential future intertidal habitat.	Minor loss of existing habitat or potential future intertidal habitat.		No impacts on habitat.	Minor improvements to or protection of habitat.		Moderate improvements to or protection of habitat.	Significant improvements to or protection of habitat.	

Category	Criteria	Weighting	Score						
			-5,-4*	-3	-2,-1^	0	1,2^	3	4,5*
Planning and Governance	Compatibility with catchment flooding	0.5	Likely to significantly worsen the impacts of catchment flooding.	Likely to moderately worsen the impacts of catchment flooding.	Likely minor worsening of the impacts of catchment flooding.	No likely change in the impacts of catchment flooding.	Likely minor reduction of the impacts of catchment flooding.	Likely to moderately reduce the impacts of catchment flooding.	Likely to significantly reduce the impacts of catchment flooding.
	Compatibility with other Policies and Plans	0.5	Conflicts with the recommendations of one or several other policies and plans	Moderate conflict with the recommendations of one or several other policies and plans	Minor conflict with the recommendations of one or several other policies and plans	No conflict with the recommendations of other policies and plans	Minor assistance in achieving the goals set by one or several other policies and plans	Moderately assists in achieving the goals set by one or several other policies and plans	Significantly assists in achieving the goals set by one or several other policies and plans.
	Compatibility with Projected Sea Level Rise (Tidal Inundation)	0.5	Significantly worsens tidal inundation as a result of SLR.	Moderately worsens tidal inundation as a result of SLR.	Minor worsening of tidal inundation as a result of SLR.	No impact on tidal inundation as a result of SLR.	Minor level of protection from tidal inundation level as a result of SLR.	Moderate level of protection from tidal inundation level as a result of SLR.	High level of protection from tidal inundation level as a result of SLR.

^ Values of 1 and 2 were differentiated through consideration of the geographical and temporal scales of the impact. A score of 1 (or -1) equates to a smaller scale of impact.
* Values of 4 and 5 were differentiated through consideration of the geographical and temporal scales of the impact. A score of 4 (or -4) equates to a smaller scale of impact.

12 Outcomes and Recommendations

12.1 Overview

As identified in previous sections of this document, the Brisbane Water floodplain is subject to complex flooding issues. With respect to coastal flooding in the existing scenario, the floodplain is reasonably well-protected by the current flood planning level of 2.45m AHD for proposed developments (refer **Section 8**). However, many properties are likely to experience over-ground flooding and many older buildings are likely to experience over-floor flooding. In addition, wave run-up is not adequately addressed by the current planning level in several locations. More detailed consideration of appropriate planning levels for various development types and components would allow for a better balance between economic costs of development and potential flood risks. The study also found that some locations are likely to become flood islands, whereby floodwaters surround and isolate residential areas and road access is likely to be impeded in several areas.

The assessment of potential management options has facilitated the identification of the most beneficial options for managing flood risk in the floodplain in terms of hydraulic, economic, environmental and social issues. The implementation of recommended management options should assist in further reducing current flood risks and also in some cases also addressing the potential flood risks associated with projected sea level rise.

12.2 Key Outcomes

Overall, the implementation of management options that provide a large reduction in economic damages is generally not achievable within given social, environmental, feasibility and other constraints. To address existing and residual risks, this FRMS provides a series of recommendations for short and medium term flood risk management. As an outcome of the multi-criteria matrix assessment (**Section 11.3** and **Appendix J**), emergency response management options, property modification options and small flood modification options generally ranked higher than large structural flood modification options such as levees. Several planning and education measures have been recommended for implementation. Some smaller hard structural options have also been recommended. Due to the limited viability of large structural flood management measures and the significant impact of flooding on some properties, voluntary house purchase and raising is likely to be appropriate. Updates to planning measures and development controls have also been recommended to manage flood risks over the longer term.

The information and recommendations within this FRMS document are to be incorporated into further investigations and studies. In particular, *Climate Change Adaptation Plans* (CCAPs) are proposed to be completed in the future to address projected sea level rise issues in the floodplain. The CCAPs are planned to assist in providing appropriate sea level rise “trigger levels” that may be utilised to initiate a particular response or inform planning documents, Gosford City Council policy, LEP and DCP documents. It is important to note that whilst the DCP matrix is in preparation, a DCP is only a guide to the controls that can be imposed on a development (EP&A Act, Section 74BA and Section 74C). Unless an LEP specifically makes reference to controls on a specific location then even site-specific controls in a DCP are a guide only.

It should be emphasised that one of the main methods of overcoming flood issues will be through individual property modification, as owners upgrade or redevelop their properties. As development controls are implemented by Council, property owners will upgrade their properties in accordance with the new development controls and receive benefits in damage prevention, safety and increased property value.

12.3 Recommended Options

The top ranking options resulting from the options assessment are recommended for inclusion in the *Floodplain Risk Management Plan* (**Table 12.1**). Key recommendations for the study area are primarily focused on Development Controls (refer **Appendix H**) and the implementation of interim flood planning levels until the CCAPs are completed.

The outcome of the assessment sets the direction for the FRMP suggesting that the most effective approach to the management of the floodplain should include:

- An emphasis on updating planning and development controls;
- Alternative emergency access routes;
- Education campaigns,
- Small structural options such as tidal flaps (flood gates) to prevent stormwater surcharge;
- Voluntary acquisition, house-raising or land swap for severely affected properties;
- Maintenance or enhancement of existing seawall structures (environmentally-friendly seawalls);
- Relocation of key facilities (e.g. police station) out of the floodplain where possible;
- Detailed investigations of impacts of proposed options on overland flows (this may identify additional potential management measures);
- Consultation with private utilities managers to ensure services can be maintained to properties in the floodplain (e.g. water, sewerage, electricity, gas and telecommunications); and
- Projected sea level rise – lobby the State Government to provide additional information, conduct further investigations and undertake the CCAPs to assist in considering management options for projected sea level rise.

In cases when investigated options for a particular management area were not appropriate or viable, no management options have been recommended for that management area. However, the floodplain-wide management options would assist with flood risk mitigation in those areas. A summary of recommended management actions is provided in **Appendix K**. The estimated total capital cost of implementing the options would be approximately **$20M**. It is important to note that this stated cost is preliminary only. Some management options require further investigation and this is likely to lead to a change in the stated implementation cost. The implementation of any of the management options will be dependent on funding availability. **Figure 12.1** shows the makeup of the estimated total capital cost of implementing all recommended options. The majority of funding is likely to come from Council and the State Government.

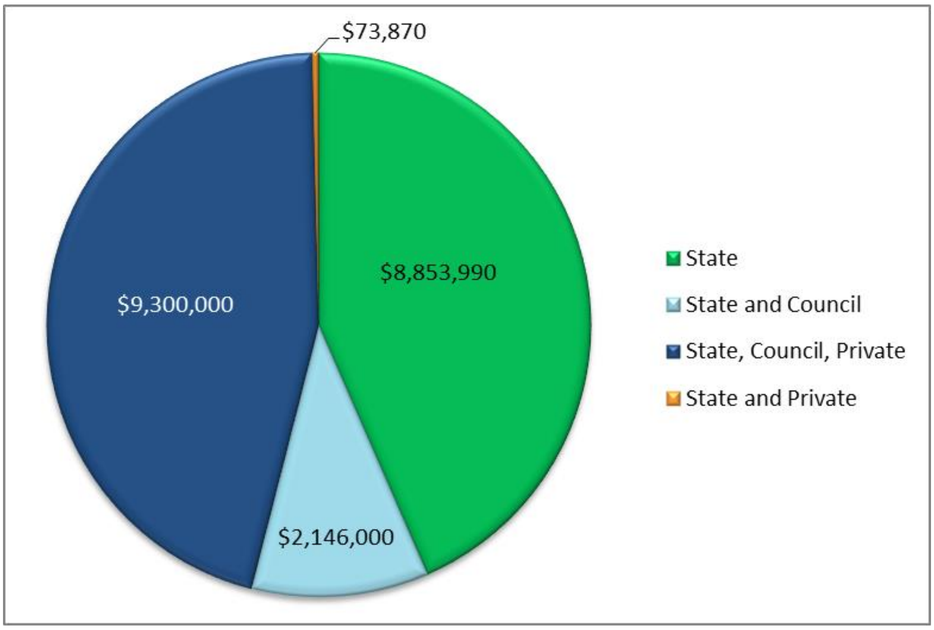

Figure 12.1: Distribution of Total Capital Costs Associated with Recommended Options – Funding Source

The makeup of this cost in terms of the three management option categories is shown in

Figure 12.2. The distribution of costs is clearly weighted towards property modification options because there are a large number of recommended options in this category. Property modification options generally ranked highly in the assessment process, as did emergency management options. However, emergency management options comprise a relatively small portion of the costs since these options generally relate to education and planning rather than hard structural development (and are therefore lower in cost). Emergency modification options are more likely to be able to be implemented in the short term, whereas the generally higher cost flood modification and property modification options are more likely to be implemented over the medium to long term, either via a staged implementation approach or once appropriate sea level rise trigger levels have been reached. Higher capital costs may therefore be spread over the longer time frame.

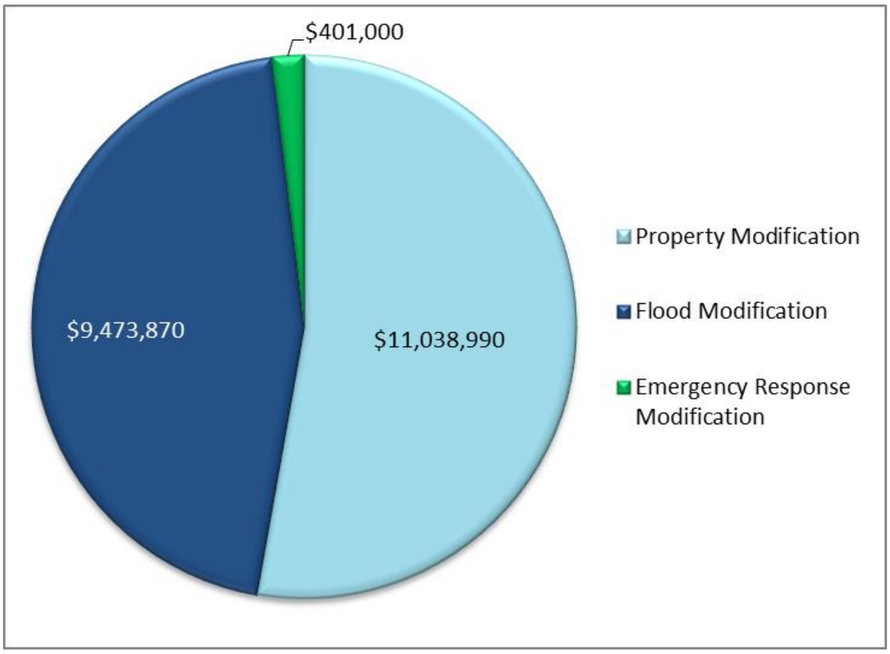

Figure 12.2: Distribution of Total Capital Costs Associated with Recommended Options – Option Category

A third pie graph is provided as **Figure 12.3** and shows the distribution of costs according to the implementation timeframe (action timeline). This demonstrates that a relatively small portion of the implementation costs would be incurred immediately, whilst a substantial portion of the costs would be incurred at a later stage, in accordance with further investigations. No management options with trigger action timelines have been recommended for inclusion in the *Brisbane Water Floodplain Risk Management Plan* but the proposed CCAPs would address these types of options. The distribution of costs may change once further investigations are completed.

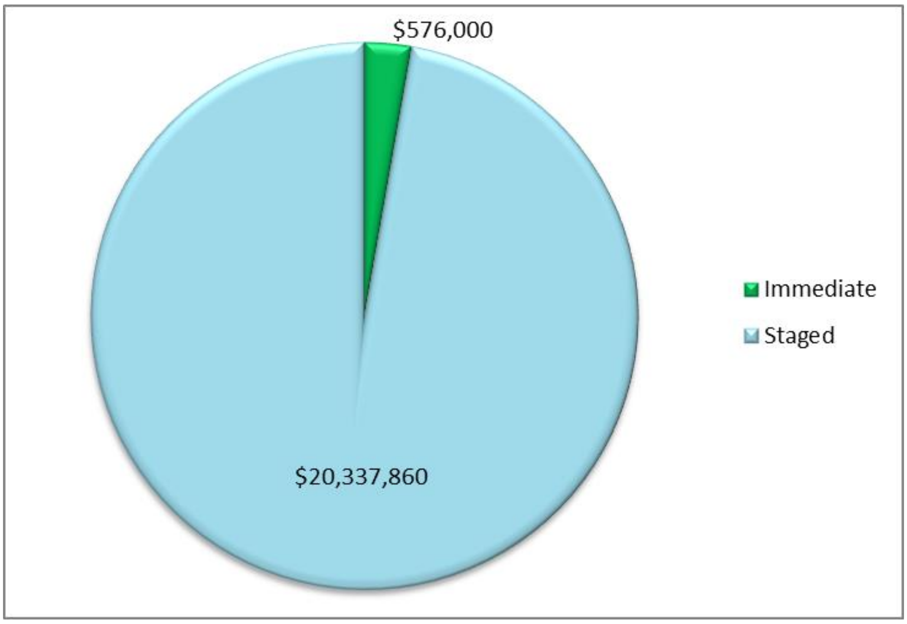

Figure 12.3: Distribution of Total Capital Costs Associated with Recommended Options – Action Timeline

Table 12.1: Brisbane Water Foreshore Floodplain Preferred Management Options – Floodplain-wide (Ranked Order)

Option ID	Management Strategy	Action Timeline	Capital Cost	Annual Cost	Tidal/Flood Event Addressed – Tidal: MHWS	Tidal: +SLR (0.4m)	Tidal: +SLR (0.9m)	Flood: 5 yr ARI (20%)	Flood: 100 yr ARI (1%)	Flood: PMF	Flood: 100 yr ARI (0.4m SLR)	Flood: 5 yr ARI (0.9m SLR)	Flood: 100 yr ARI (0.9m SLR)	Flood: PMF (0.9m SLR)	Properties Protected (Existing)	Properties Protected (0.9m SLR)	Rank (Within Floodplain-wide Category, or within MA)*	Rank (Overall)	GCC Responsibility	Private Responsibility	State Responsibility	Feasibility / Integrated Planning R'qd	To be Included in CCAP?
Floodplain-Wide																							
EM7	Review evacuation centre locations with a view to upgrading key evacuation centres that lie outside the floodplain.	Immediate	$50,000	$2,500				✓	✓	✓	✓	✓	✓	✓	0	0	1	1	Y	N	Y	Y	Y
EM8	Enhance road evacuation through the development of an alternative route plan for implementation during flood events.	Immediate	$40,000	$2,000				✓	✓	✓	✓	✓	✓	✓	0	0	2	2	Y	N	Y	N	N
EM3	Review the Gosford Local Flood Emergency Sub-Plan (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results.	Immediate	$20,000	$0				✓	✓	✓	✓	✓	✓	✓	0	0	3	3	Y	N	Y	Y	N
EM4	Review flood warning systems on a periodic basis and update as necessary.	Immediate	$35,000	$7,000				✓	✓	✓	✓	✓	✓	✓	Unkn.	Unkn.	4	4	Y	N	N	N	N
PM7	Review and amend planning instruments and development controls across the floodplain to ensure consistency with coastal flooding. Review every five years.	Immediate	$50,000	$10,000	✓	✓	✓	✓	✓		✓	✓	✓		All	Unkn.	5	5	Y	N	N	N	Y
PM5	Continue to monitor sea levels and perform periodic analyses to ascertain the rate of sea level rise within Brisbane Water. Periodically communicate results to the community.	Immediate	$15,000	$4,500		✓	✓				✓	✓	✓	✓	0	0	6	6	Y	N	N	N	Y
PM10	Evaluate utilities infrastructure relative to flood risk and projected sea level rise benchmarks. Partner with private utilities managers to better understand the risks to assets and formulate a plan of management over the long term for integration into Council's planning objectives.	Staged	$150,000	$7,500		✓	✓	✓	✓		✓	✓	✓		0	0	7	7	Y	N	N	Y	Y
PM8	Develop development controls and planning measures for all management areas via two stages - 1. Interim Developent Control Measures to be implemented until further investigations are completed; and 2. Review interim measures following completion of Climate Adaptation Plans.	Staged	$100,000	$15,000	✓	✓	✓	✓	✓		✓	✓	✓		All	Unkn.	8	18	Y	N	N	Y	Y
PM4	Conduct a program of strategic, balanced and socially sensitive education to advise the local community and prospective property purchasers about the risk and effects of coastal flooding.	Staged	$20,000	$4,000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	0	0	9	19	Y	N	Y	Y	N
EM1	Conduct targeted flood education programs for flood-affected residents.	Staged	$250,000	$25,000	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Unkn.	Unkn.	10	24	Y	N	Y	Y	N
PM9	Develop management strategies (as part of Climate Change Adaptation Plans for each management area) to adapt to the impacts of projected sea level rise on tidal inundation.	Staged	$480,000	$72,000		✓	✓				✓	✓	✓	✓	Unkn.	Unkn.	11	26	Y	N	N	N	Y
PM3	Investigate a land swap program for properties that meet specified criteria with land that Council owns in non flood-prone areas.	Staged	$380,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	19	19	12	30	Y	Y	Y	Y	Y
PM2	Implement a voluntary house raising program for identified dwellings that meet specified criteria.	Staged	$630,000	$0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	21	21	13	31	Y	Y	Y	Y	Y
FM4	Install flood gates on stormwater pipe outlets as required.	Staged	$100,000	$35,000	Depends on location										Unkn.	Unkn.	14	43	Y	N	Y	N	N

Notes:

Action Timeline: Immediate – Short term, minimal further investigations required; Staged – Short/medium term, further investigations required; Trigger – Longer term, sea level rise trigger level to initiate management respons

Capital Costs have been calculated using the future scenario (sea level rise of 0.9m)

Legend

✓ Water level addressed by option

✓ Stage / trigger level response

Y - Yes N - No

^ assumes that this option equates results in 33% of the floodplain being raised/retreating out of the floodplain.

assumes that this option provides for the the purchase/raising/swap of two properties only. Further properties could be protected if funding available.

Table 12.2: Brisbane Water Foreshore Floodplain Preferred Management Options – Specific Locations (Ranked Order)

Option ID	Management Strategy	Action Timeline	Capital Cost	Annual Cost	Tidal/Flood Event Addressed										Properties Protected (Existing)	Properties Protected (0.9m SLR)	Rank (Within Floodplain-wide Category, or within MA)*	Rank (Overall)	GCC Responsibility	Private Responsibility	State Responsibility	Feasibility / Integrated Planning R'qd	To be Included in CCAP?
					Tidal			Flood															
					MHWS	+SLR (0.4m)	+SLR (0.9m)	5 yr ARI (20%)	100 yr ARI (1%)	PMF	100 yr ARI (0.4m SLR)	5 yr ARI (0.9m SLR)	100 yr ARI (0.9m SLR)	PMF (0.9m SLR)									
Management Areas																							
1_EM2	Install and maintain "Road Floods" signs at the Central Coast Highway, and Yallambee Avenue, West Gosford	Immediate	$2,400	$360	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	0	0	1	11	Y	N	Y	Y	N
3_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Point Frederick, East Gosford and Green Point.	Immediate	$30,000	$0											0	0	1	14	Y	N	N	N	Y
3_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Koolewong and Tascott.	Immediate	$100,000	$0											0	0	2	19	Y	N	N	N	Y
3_FM3	Modify the existing foreshore at Point Frederick, East Gosford, Green Point, Koolewong, Tascott and Point Clare in areas most affected by wave runup to	Staged	$4,800,000	$140,000	Likely to assist in reducing wave run-up only.										59	7	3	47	Y	N	Y	Y	N
4_PM6	Relocate NSW SES (Gosford) headquarters out of the floodplain.	Staged	$4,500,000	$0					✓	✓	✓	✓	✓	✓	0	0	2	25	Y	N	N	N	N
7_PM11b	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Kincumber, Kincumber South and Bensville.	Immediate	$30,000	$0											0	0	1	19	Y	N	N	N	Y
7_FM5	Undertake a program of seawall maintenance and raising along the foreshore.	Staged	$74,000	$740	✓	✓	✓								Unkn.	Unkn.	2	46	Y	Y	Y	Y	Y
9_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows on St Huberts Island.	Immediate	$100,000	$0											0	0	1	14	Y	N	N	N	Y
9_FM3	Modify the existing foreshore at St Huberts Island in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$2,900,000	$88,000	Likely to assist in reducing wave run-up only.										114	0	3	48	Y	N	Y	Y	N
11_FM3	Modify the existing foreshore at Pretty Beach and Wagstaffe in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$840,000	$25,000	Likely to assist in reducing wave run-up only.										49	0	3	45	Y	N	Y	Y	N
13_PM11a	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Booker Bay.	Immediate	$100,000	$0											0	0	1	14	Y	N	N	N	Y
13_FM3	Modify the existing foreshore at Booker Bay in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$720,000	$22,000	Likely to assist in reducing wave run-up only.										56	0	3	48	Y	N	Y	Y	N
14_EM2	Install and maintain "Road Floods" signs at Blackwall Road, Brick Wharf Road and North Burge Road, Woy Woy.	Immediate	$3,600	$540	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	0	0	2	11	Y	N	Y	N	N
14_PM6	Relocate Woy Woy Police Station out of the floodplain.	Staged	$4,300,000	$0				✓	✓	✓	✓	✓	✓	✓	0	0	3	29	N	N	Y	Y	N

Notes:

Action Timeline: Immediate – Short term, minimal further investigations required Staged – Short/medium term, further investigations required Trigger – Longer term, sea level rise trigger level to initiate management respons

Capital Costs have been calculated using the future scenario (sea level rise of 0.9m)

Legend

✓ Water level addressed by option

✓ Stage / trigger level response

Shading indicates Options grouped by Management Area

Y - Yes N - No

^ assumes that this option equates results in 33% of the floodplain being raised/retreating out of the floodplain.

assumes that this option provides for the the purchase/raising/swap of two properties only. Further properties could be protected if funding available.

Unkn. Unknown

*Those options where mutual exclusivity were found to apply have been removed from this list, hence rankings may jump or not begin at 1.

13 Conclusions and Next Steps

This report presents the findings of the *Floodplain Risk Management Study* stage of the Flood Risk Management Process for the Brisbane Water foreshore floodplain, in accordance with the *Floodplain Development Manual* (NSW Government, 2005). The investigations and consultation undertaken as part of this process identified a number of issues within the floodplain. Based on these issues, a series of floodplain management options were developed and recommended.

The recommended options described in **Section 12** will be incorporated into the *Brisbane Water Floodplain Risk Management Plan* as proposed management actions. This forthcoming document will recommend a cost-effective plan to manage flood risk and will outline the process of implementation for recommended management actions within the floodplain.

As previously discussed, additional investigations and studies will be undertaken following this FRMS, particularly regarding the projected impacts of sea level rise and appropriate adaptation strategies. A *Climate Change Adaptation Plan* is proposed to be undertaken and the results would flow into a review of this FRMS and subsequent review of Gosford City Council policy, LEP and DCP documents.

Public consultation is to be undertaken during the exhibition of this *Floodplain Risk Management Study* and the forthcoming *Floodplain Risk Management Plan*. This consultation and review will lead to the final recommended floodplain risk management actions for implementation as part of the Management Plan.

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15 Qualifications

This report has been prepared by Cardno for Gosford City Council and as such should not be used by a third party without prior approval.

The results of the study are based on the following assumptions / conditions:

- The report relies on the accuracy of the data provided by Council;
- Legislation and planning policies are correct at the time of report issue but are subject to change;
- Cost estimates provided for options in this report are preliminary only and more detailed cost estimates should be prepared during the concept and detailed design phases; and
- The data and modelling assumptions noted in *the Brisbane Water Foreshore Flood Study* (Cardno, 2013).

The investigation and modelling procedures adopted for this study follow industry standards and considerable care has been applied to the preparation of the results. However, model set-up depends on the quality of data available. The flow regime and the flow control structures are complicated and can only be represented by schematised model layouts. Hence there will be a level of uncertainty in the results and this should be kept in mind in the application of model results.

The flood mapping provided in this document has been based on regional land survey data captured via aerial laser survey in 2007 and 2013 that was provided to Cardno for use by Gosford City Council. It is also noted that flood mapping beyond model boundaries (**Figure 1.1**) has been extrapolated from model results downstream. These should be used only as indicative extents, and any available flood study information for the tributaries should be used instead. If required, property owners can determine a more accurate and detailed representation of flood extents on their properties by obtaining an independent property ground survey. Study results should not be used for purposes other than those for which they were prepared.

Appendix A

Stakeholder Consultation Letter and Responses

Our Ref LJ2828/L1940: SCA

Contact Sean Garber/Louise Collier

3 December 2009

[Agency Name and Address]

Cardno Lawson Treloar Pty Ltd
ABN 55 001 882 873

Level 2, 910 Pacific Highway
Gordon New South Wales
2072 Australia
Telephone: 02 9499 3000
Facsimile: 02 9499 3033
International: +61 2 9499 3000
Email: cltnsw@cardno.com.au
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Cairns
Townsville
Mackay
Rockhampton
Hervey Bay
Sunshine Coast
Toowoomba
Gold Coast
Gosford
Baulkham Hills
Wollongong
Busselton

Papua New Guinea
Indonesia
Vietnam
China
Kenya
United Arab Emirates
United Kingdom
United States

Dear [Name],

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

We are writing to inform you that Cardno Lawson Treloar has been engaged by Gosford City Council and the Department of Environment, Climate Change and Water (DECCW) to prepare the Brisbane Water Foreshore Floodplain Risk Management Study and Plan. You may also be aware that Cardno Lawson Treloar is currently undertaking the Brisbane Water Estuary Management Study and Plan (due for exhibition in early 2010). Details of the Brisbane Water Estuary Management Study and Plan can be found at: http://www.gosford.nsw.gov.au/customer/document_gallery/alpha_listing.

The Floodplain Risk Management Study and Plan represents the final stages in the Flood Risk Management Process for the Brisbane Water Foreshore, as outlined in the Floodplain Development Manual (NSW Government, 2005). The study area incorporates the Brisbane Water foreshore and estuary as indicated in the attached figure.

The aim of the Brisbane Water Foreshore Floodplain Risk Management Study and Plan is to identify and recommend appropriate actions to manage the flood risk around the foreshore of the Brisbane Water Estuary. The Management Study will set the context for the Management Plan by providing details on:

- The consultation process;
- The outcomes of the Brisbane Water Foreshore Flood Study (completed in 2008);
- The regulatory and management context;
- Possible Flood Modification Options;
- Possible Property Modification Options;
- Possible Emergency Response Modification Options; and
- An evaluation (using modelling or qualitative methods) of options.

We would be grateful for your comments and input into the development of the Floodplain Risk Management Study and Plan, particularly with respect to identification of any flooding issues relating to the Brisbane Water foreshore. In addition, we would also appreciate your assistance in identifying (and providing, where possible) any additional flood-related studies which have been undertaken since the completion of the Brisbane Water Foreshore Flood Study.

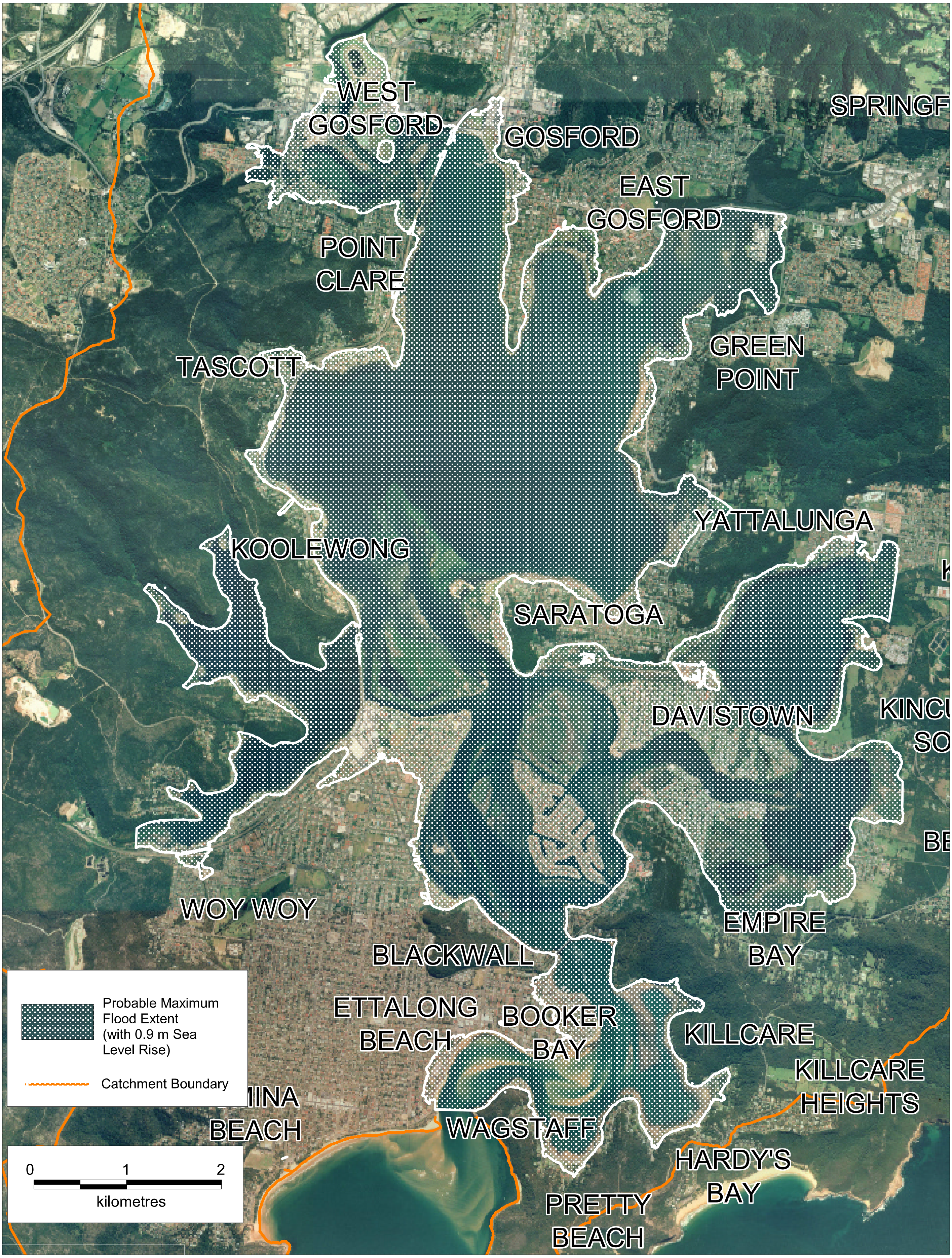
We would appreciate your response by **23 December 2009** to assist with the subsequent stages of the study.

Please do not hesitate to contact either myself or Sean Garber on 9499 3000 or at sean.garber@cardno.com.au should you require any further information.

Yours faithfully

Louise Collier
Manager – Sustainability and Climate Change
for **Cardno Lawson Treloar**

Enclosed: Figure - Brisbane Water Catchment and Study area



Cardno Lawson Treloar

December 2009
J:\ENV\LJ2828 - Brisbane Water Floodplain Risk Mgmt Study & Plan\Stakeholder Consultation

Industry & Investment

LCC
4/1/2010

Our ref: OUT09/16773; Your ref: LJ2828/L 1940: SCA

Cardno Lawson Treloar
(Attn: Louise Collier)
Level2, 910 Pacific Highway
GORDON NSW

Dear Louise

Re: Brisbane Water Foreshore Floodplain Risk Management Study and Plan

Thank you for your letter dated 9 December 2009 requesting Industry and Investment NSW - Fisheries (formerly NSW Department of Primary Industries - Fisheries) comment and input into your preparation of the above mentioned study and plan.

When considering the provisions of the *Fisheries Management Act* 1994, the main issue concerning flood management in Brisbane Water is the impact of proposed flood mitigation options on aquatic habitats (mangroves, seagrasses and saltmarsh), water quality and water flow. The Department recommends that where such impacts cannot be avoided, that management options are discussed with the Department's Aquatic Habitat Protection Unit, particularly if it is proposed to harm aquatic habitat.

The Department does not have any flood related studies of Brisbane Water to contribute to this project. However, the following study and policy and guidelines may be useful in finalising management options.

- *Mapping the Habitats of NSW Estuaries.* Creese et al. Industry & Investment NSW, 2009 (Available from: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/306625/AE_2009_Output-1575_Creese-et-al_Habitat-Mapping-Final-Report-113_REPORT.pdf)

- *Policy and guidelines Aquatic Habitat Management and Fish Conservation 1999.* (Available from: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0020/202691/Policyand-Guidelines-for-aquatic-habitat-management-and-fish-conservation-1999.pdf)

For any questions you may have concerning this matter, please contact Carla Ganassin on (02) 9527 8552 or Carla.Ganassin@industry.nsw.gov.au.

Yours sincerely,

Carla Ganassin
Conservation Manager
Aquatic Habitat Protection Unit

18 December 2009

NSW GOVERNMENT | Planning

Contact: Cathy Colville
Telephone: 02 9873 8588
Catherine.colville@planning.nsw.gov.au
File:
Our Ref:
Your Ref:

The Managing Director
Cardno Lawson Treloar Pty Ltd
Level 2, 910 Pacific Highway
GORDON NSW 2072

Attention: Louise Collier, Manager – Sustainability & Climate Change
Sean Garber

Dear Sir/Madam

RE: Brisbane Water Foreshore Floodplain Risk Management

I refer to your letter of 3rd December, 2009 requesting comments and input into the development of the above mentioned Floodplain Risk Management Study and Plan.

The Brisbane Water study area includes many remnant historic shipbuilding and river transport structures such as slipways, piers, jetties etc. It is recommended that a field survey be undertaken as part of the preparation of the Floodplain Risk Management Study to identify the location of such extant foreshore infrastructure. It is suggested that a number of resources and references sources could be used to assist in the undertaking of the field survey including:

- the Shipwreck Search Results from the NSW Maritime Heritage Online Database (copy of a Brisbane Water search attached for your information);
- the book titled *The Shipbuilders of Brisbane Water NSW* by Gwen Dundon (available through Gosford Libraries – details attached); and
- any relevant local council heritage studies and other references.

It is recommended that once the field survey has identified the location of remnant shipbuilding and river transport structures, the information is translated into practical guidelines within the Floodplain Risk Management Plan. For example, during a flood event, emergency services often need to create roads and use plant machinery and equipment on the foreshore edges. The impact of this equipment can have a detrimental effect on the historic infrastructure, but can often be minimised or avoided if practical guidelines and mitigation measures are included as recommendations in the Floodplain Risk Management Plan. Further, if such remnant historic structures are damaged, destabilised or become a safety hazard following a flood event, guidelines and recommendations should be included in the Plan that detail the processes that should be followed (including contacting the Heritage Branch of the Department of Planning). An appropriate stability and structural integrity assessment should be undertaken prior to any decision to completely demolish such structures being made.

Requirements and obligations under the NSW Heritage Act should also be included in the Study and Plan.

Other Aboriginal and non-aboriginal heritage items that may exist within the study area and potentially affected by future flood events should also be identified and similar recommendations made in the Study and Plan as outlined above. These can be identified by consulting with the relevant local council(s).

The Heritage Branch would be happy to review and provide comment on the draft Study and Plan once prepared. The Heritage Branch would also be happy to review the Brisbane Water Estuary Management Study and Plan in early 2010 when it is ready for exhibition.

If you have any further enquiries regarding this matter, please contact Cathy Colville on 9873 8588.

Yours faithfully

24/12/09

Vincent Sicari
Manager
Conservation Team
Heritage Branch
Department of Planning

Attachments: Shipwreck Database Search (1 Page) and
Details of Reference Book titled *The Shipbuilders of Brisbane Water NSW* by Gwen Dundon

MARITIME HERITAGE ONLINE
NEW SOUTH WALES

REGIONS
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1

Site Title	Date Wrecked	Type	Region	Where Lost	Comments
Brothers	1876/09/11	Ketch	Central Coast	Brisbane Water, ashore on 'Half Tide Rocks'	Wrecked during the 'Dandenong Gale'.
Caroline	1869/02/12	Ketch	Central Coast	Brisbane Water, bar, west spit	This vessel was 'supposed' lost in 1866 but the owner, Thomas Kehoe was the registered owner at that time and was also the owner in 1869.
Dora	1871/9/30	Schooner	Central Coast	Broken Bay Bar (Brisbane Water)	Previous incident 1871/05/12 at Jervis Bay.
Leisure Hour	1869/01/25	Ketch	Central Coast	Brisbane Water, bar, west side	.
Midshipman	1857/09/09	Ketch	Central Coast	Broken Bay, Brisbane Water entrance	.
Plover	1855/04	Schooner	Central Coast	Brisbane Water bar, west spit	.
Power Chief	1934/10/21	Launch	Central Coast	Brisbane Water, at Green Point, near Woy Woy	.
Traveller	1868/11/22	Schooner	Central Coast	Brisbane Water bar	.
Venus	1920<	Schooner	Central Coast	Brisbane Water, Broken Bay, ashore	RBS states 'Registry noted 30 June 1920.

1

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TOP

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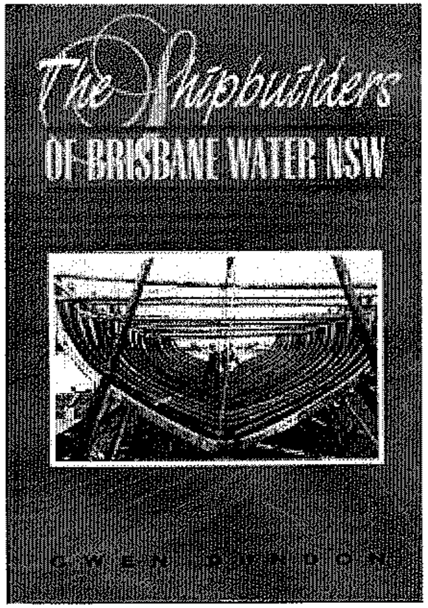

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Our Ref LJ2828/L1958: LCC/SJG

Contact Louise Collier/Sean Garber

[Mail Merge]

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14 September 2009

Dear [Insert Mail Merge Field Name]

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Cardno Lawson Treloar has been commissioned by Gosford City Council to prepare the Brisbane Water Foreshore Floodplain Risk Management Study and Plan.

We are now seeking the assistance of the community in order to identify and evaluate possible options to manage the existing flood risks. Therefore, we would like to ask you to take a few moments to read the enclosed information and forward your response using the reply paid envelope.

Enclosed you will find an information brochure which will provide some background on flooding within the local area and what stage we are currently at in the Floodplain Management Process. In addition, you will find a short questionnaire which will provide you with an opportunity to express your opinions. The information which you provide will be used for the preparation of the Floodplain Risk Management Study and will ultimately go towards the development of a series of flood management options to be adopted by Council.

Cardno and Gosford City Council trust that you find this information beneficial and thank you in advance for your assistance with this project.

Should you have any further queries with regards to the information provided please do not hesitate to contact Cardno or Gosford City Council at the below details, or via email brisbanewater@cardno.com.au.

Cardno	**Gosford Council**
Louise Collier/Sean Garber	Erensa Shrestha
P: (02) 9496 7700	P: (02) 4304 7087
F: (02) 9499 3033	F: (02) 4323 2528
E: louise.collier@cardno.com.au	E: erensa.shrestha@gosford.nsw.gov.au

Yours faithfully

Louise Collier
Manager – Sustainability and Climate Change
for **Cardno Lawson Treloar**

ACEA The Association of Consulting Engineers Australia

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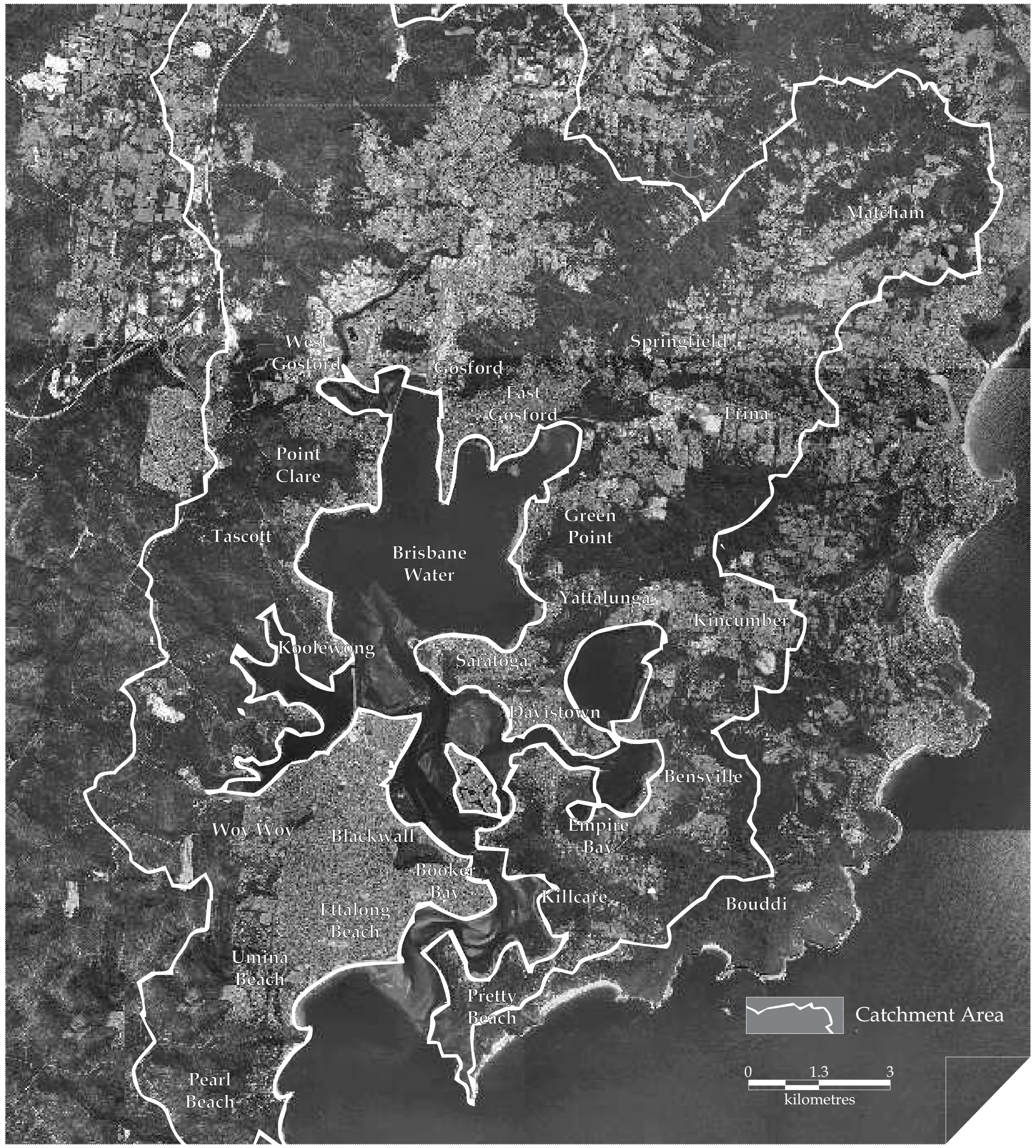

If you have any further comments that relate to the Brisbane Water Foreshore Floodplain Risk Management Study and Plan, please express them in the space below:

....

....

....

....

....

Thank you for providing the above information. Please remember to put these pages back in the reply paid envelope by 16 October 2009. A representative from Cardno Lawson Treloar may contact you in the near future to discuss your response.

YOUR PERSONAL INFORMATION WILL REMAIN CONFIDENTIAL

If you have any queries, please contact:

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SEPTEMBER 2009

Brisbane Water Foreshore Floodplain Risk Management Study & Plan

Local Resident/Land Owner Survey

On behalf of Gosford City Council, Cardno is in the process of preparing a Floodplain Risk Management Study and Plan for the Brisbane Water Foreshore (a map is attached showing the study area). The process involves a comprehensive community consultation program, which began in August 2006 during the preparation of the Brisbane Water Foreshore Flood Study. Newsletters and brochures were distributed to residents within the catchment that described the purpose, aim, and progress of the study. The Flood Study has been adopted by Council and the information is now being used for planning purposes. A copy of the Flood Study can be viewed at Council's offices on request & on Council's website http://www.gosford.nsw.gov.au/customer/document_gallery/public_studies/.

This survey is the next stage of the community consultation program. We would like to gather information on the flooding issues that you are aware of, including your experiences with flooding in the catchment, and your opinion on which floodplain risk management measures you might prefer. If you assisted with the 2006 survey then you may notice that some questions may seem similar to those in the 2006 survey but we would appreciate you answering those questions again.

Local residents' knowledge is very valuable; please take the time to answer the following questions as best you can, even if you have completed similar surveys in the past. Please return these pages in the enclosed "reply paid" envelope by 16 October 2009.

Your personal information will remain completely confidential. We thank you for taking the time to complete this survey.

Gosford City Council Central Coast

Cardno Shaping the Future

Our team appreciates the diverse effects of flooding – from its dynamic shaping of the environment through to its potential negative social and economic impact. With this knowledge we analyse and develop comprehensive plans.

Q 1. Could you please provide us with the following details? We may wish to contact you to discuss some of the information you have provided us.

Name: ....

Address ....

....

Daytime Ph: ....

Email: ....

Q 2. Is your property (please tick).

- [ ] Owner occupied
- [ ] Occupied by a tenant
- [ ] A business

Q 3. How long have you lived, worked and/or owned your property?

.... Months .... Years

Q 4. Have you ever experienced flooding since living/working/owning your property? (please tick relevant boxes).

- [ ] Yes, floodwaters entered my house/business
- [ ] Yes, floodwaters entered my yard/surrounding property
- [ ] Yes, the road was flooded and I couldn't drive my car
- [ ] Yes, the creek broke is banks
- [ ] Yes, other parts of my neighborhood were flooded
- [ ] No, I haven't experienced a flood (go to Q.6)

Q 5. If you have experienced a flood, how did the flooding affect you and your family/business? (please tick relevant boxes).

- [ ] Parts of my house/business building were damaged
- [ ] The contents of my house/business were damaged
- [ ] My garden, yard, and/or surrounding property were damaged
- [ ] My cars was damaged
- [ ] Other property was damaged (specify ....)
- [ ] I couldn't leave my the house/business
- [ ] Family members/work mates couldn't return to the house/business
- [ ] My family had to evacuate the house/business
- [ ] The flood disrupted my daily routine
- [ ] The flood affected me in other ways (specify ....)
- [ ] No, the flood didn't affect me

Q 6. Do you think your property would be flooded sometime in the future? (please tick relevant boxes).

- [ ] No
- [ ] Yes, but only a small part of my yard
- [ ] Yes, most of my yard/outdoor areas of business could be flooded
- [ ] Yes, my house/office/business could flood over the floor

Q 7. Have you looked for information about flooding on your property? (please tick relevant boxes).

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

Q 8. What do you think are the best ways to get input and feedback from the local community about the options being considered to manage flooding and the results of this project? (please tick relevant boxes).

- [ ] 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

Q 9. As a local resident and (probably) having witnessed a number of flooding/drainage problems, you may have your own ideas on how to reduce flood risks. Which of the following management options would you prefer for Brisbane Water (1=least preferred, 5=most preferred)? Please also provide comments as to the location where you think the option might be suitable.

Proposed Option	Preference (please circle)	Location/Other Comments?
Retarding or detention basins; these temporarily hold water and reduce peak flood flows	1 2 3 4 5	
Stormwater harvesting, such as rainwater tanks	1 2 3 4 5	
Improved flood flow paths	1 2 3 4 5	
Culvert/ bridge/pipe enlarging	1 2 3 4 5	
Levee banks	1 2 3 4 5	
Environmental channel improvements, including removal of weeds & bank stabilisation	1 2 3 4 5	
Planning and flood-related development controls	1 2 3 4 5	
Education of community, providing greater awareness of potential hazards	1 2 3 4 5	
Flood forecasting, flood warning, evacuation planning and emergency response	1 2 3 4 5	
Other (please specify any options you believe are suitable). Please attach extra pages for other suggestions	1 2 3 4 5	

Document ID	Suburb of Residence	Summary of Submission	Response to Submission
		It is my opinion that an fpl of 2.45 will fall over in court the first time it is challenged as it does not appear to be based on science, just personal preference of the committee. There only appears to be reference to FPL and not NFL - I am assuming the NFL will also be 2.45? Council should note the committees preference then make their own depiction in line with best practice.	After careful consideration of the submissions received, collaboration with the committee and discussions with OEH, Council is proceeding with the recommendation of an FPL as follows: 1. A Flood Planning Level based on the derived 100-year flood level (Brisbane Water Foreshore Flood Study Cardno, 2013) plus a freeboard and projected sea level rise (SLR) component as per Council's adopted Sea Level Rise Scenario at 2050 for residential development. 2. The recommended freeboard = 0.5 metres.
19886030/19873962	Davistown	The current Flood Planning Level (FPL) 2.45m Australian Height Datum (AHD) should be retained for residential building development. This FPL is based on a 1.95m AHD Flood Design Level (FDL) adopted by Gosford City Council since the late 1970's and has been implemented with several different freeboard heights. The height has become generally accepted and will provide a sufficient level of protection for all areas of Brisbane Water with some slight variations in freeboard. It is important that the certainty that this FPL provides is maintained. Introducing new changed levels for each suburb will create uncertainty in the perceptions of many people regarding future coastal hazards and will consequently impact on the wellbeing of the Gosford Local Government Area (LGA)	After careful consideration of the submissions received, collaboration with the committee and discussions with OEH, Council is proceeding with the recommendation of an FPL as follows: 1. A Flood Planning Level based on the derived 100-year flood level (Brisbane Water Foreshore Flood Study Cardno, 2013) plus a freeboard and projected sea level rise (SLR) component as per Council's adopted Sea Level Rise Scenario at 2050 for residential development. 2. The recommended freeboard = 0.5 metres.
19886030/19873962	Davistown	Option PM7 (Review planning instruments and development controls) should be prioritized and immediately implemented, rather than waiting until an adaptation plan is developed because these areas are affected now by current coastal flooding. This would offers a unique opportunity for Council to secure the long term wellbeing of flood liable suburbs by allowing lot-by-lot filling to a height slightly above current 1in 100 flood levels. It does not mean that Council would be immediately obligated to respond by raising roads and modifying services - many roads in existing flood liable suburbs are already above the level of adjacent residential land. Allowing existing roads to be at levels below adjacent land would complement the concept of floodways which direct floodwater away from residential properties and improve stormwater drainage.	Option PM7 has been actioned as "Immediate" in the document. Wording has been updated in detailed description of PM7 in Appendix I to 'encourage' filling rather than only 'allowing' filling in areas compatible with filling.
19886030/19873962	Davistown	The floor level survey undertaken indicates approximately 400 homes have floor levels below the current 1in 100 flood event level. Development incentives should be implemented to encourage the demolition and replacement of these homes and any homes that have floor levels below the current FPL 2.45m AHD resulting in a significant reduction in freeboard. Such incentives could include: - A change to current Council Policy to allow single lot subdivision provided that the land is raised above the current 1in 100 flood level. It is noted that expert advice in many cases does not support punitive restrictions rather it encourages a risk based case by case approach, e.g. the "shelter in place" strategy is acceptable for a limited duration flood event such as that experienced in Brisbane Water. - Slight intensification of development by allowing duplexes to replace existing homes that have floor levels below the current FDL. - Grants for house raising. - Federal rebates on GST and state rebates on stamp duty for people who buy homes and demolish and rebuild to decrease the total number of homes that would be adversely affected by a 1in 100 flood.	Subdivision and construction of duplex residences are restricted in some flood areas due to the risk associated with additional people being introduced to the floodplain rather than the additional damages incurred on a property. Subdivision recommendations have been provided in the FRMS based on flood risk. House raising grants have been considered in the FRMS for the worst affected properties with appropriate construction type. Option PM2 has been recommended for inclusion in the FRMP. PM2 (in Appendix I) has been modified to state that Council may consider the use of the house raising subsidy to be used for redevelopment purposes of those properties at highest flood risk. This would include the properties identified for voluntary purchase (PM1) and voluntary house raising (PM2). The suggestion for rebates on GST and stamp duty has been provided to Council for consideration outside of this study.
19886030/19873962	Davistown	Walkways/cycleways should be created to form a protective flood levy for low lying flood liable areas to mitigate the current 1in 100 flood. Such protection has the potential to reduce home insurance premiums and would provide a benchmark level for future land raising over time. This option has been identified as suitable for Davistown & Empire Bay in the current study, should be acted on in the short term and should attract NSW State Government funding.	The consideration of levees at both the 5 Year ARI flood and PMF level were included in the FRMS as Options 6_FM6a and 6_FM6b. It was noted that these levees could be incorporated with public infrastructure upgrades such as walkways and cycleways. Both of these options were not recommended for inclusion in the FRMP as they did not have an appropriate benefit - cost ratio under existing sea levels. However, it is noted that these options may be further investigated as part of the CCAP for their benefits with regards to SLR. It should be noted that the FRMS has identified that there is a flood benefit as a result fo levees. Therefore, if funding becomes available for the implementation or upgrade of cycleways and walkways, then they could be constructed in a manner as to provide flood protection.

Document ID	Suburb of Residence	Summary of Submission	Response to Submission
19886030/19873962	Davistown	The recently completed floor level survey has identified around 400 homes that have floor levels below the current 1in 100 flood event for the Brisbane Water Foreshore. Council has decided to place this information into the public domain and make it available to home insurers. Gosford Council did not advise property owners or occupiers that this information would be treated in this manner and there is the potential for owners of homes with low floor levels to lose the ability to insure their homes due to unreasonably high compulsory flood insurance premiums. This issue has been raised before and it is recommended that Gosford City Council refer to that earlier submission.	Noted. This matter has been referred to Council and will be responded to accordingly.
19886030/19873962	Davistown	The NSW State Government and the Chief Scientist both called for the inclusion of localized scientifically based information in assessing sea level rise projections for planning purposes. Eurobodalla Shire Council and Shoalhaven City Council jointly engaged expert coastal consultants to review legal opinions, state government advice and the latest science in a local context and to advise appropriate sea level allowances for use in a coastal planning framework. Gosford City Council should act in good faith and review its own SLR benchmark of 400mm by 2050 considering the recent decision by Shoalhaven Council and the advice of the IPCC.	Additional text has been included in the document to discuss the outcomes of the Shoalhaven document and IPCC advice. The CCAPs may include a review of local SLR projections. Additional text has been included in the FRMS to reflect this.
19886030/19873962	Davistown	Time limited development consent is highly contentious and unless Council is suggesting that it will impose this type of constraint on future development of Brisbane Water Foreshore then it is strongly recommended that all reference to time limited development consent and planned retreat be removed. Alternatively, Gosford City Council must declare its intentions and explain how development constraints would be imposed on all future development including proposed development of Brisbane Water Foreshore adjacent to Gosford Central Business District. Refer to recent land and Environment Court Decision for Jimmy's Beach.	No recommendations have been provided for the inclusion of time limited consent to be included in Council's planning documents. As such, due to the contentious nature of this matter, all reference to this issue has been removed from the FRMS document. This issue may be investigated further as part of the CCAP.
19878488	Gosford	Under the Executive Summary and sub heading Management issues and Options on page xii - it is not clear in this section or the document whether the options that address increases in sea level rise for the whole of Brisbane Water e.g. Storm Surge Barrier at Half Tide Rocks, will be addressed under a future individual Climate Change Adaptation Plan (CCAP) for the whole of Brisbane Water or under individual CCAPs for specific areas of Brisbane Water. I would have thought that it would be addressed under a CCAP for the whole of Brisbane Water at such an option needs to assessed holistically.	Council has yet to confirm their approach to undertaken the CCAP. This comment has been referred to Council for their consideration.
19878488	Gosford	Development Control Matrix under Appendix H needs to be reviewed to overcome some confusion with wording of headings.	Deinitions for the headings within the Matrix have been provided that link them to the development types within the LEP. The headings used for the flood risk areas have been modified to avoid confusion.
19878488	Gosford	The assessment, scoring and ranking of Levee Banks around various sections of the foreshore seem to have addressed only the impact of sea level rise and not the existing flood risk benefits. More information on the benefits of levee banks to address the existing flood risk needs to be included in the study. Benefits include assistance with evacuation and emergency management; assist in lowering flood insurance premiums for buildings behind the levee banks; sets example land fill level heights for areas located behind the levee banks that need to be filled to over time; and provides a guide for future compatible development along the foreshore i.e. footpath/cycle ways, sea walls, etc.	Additional text has been included in the document to discuss the benefits of levee banks in addressing the existing risk of flooding.
19878488	Gosford	I consider that the Flood Planning Level for residential development should reflect the new 1% flood levels and include a general freeboard of 0.5m (as recommended in the Floodplain Development Manual) plus a sea level rise allowance of 0.4m. This FPL would be an interim FPL until a CCAP can be undertaken for specific areas. The FPL that would result is similar to what is now the FPL, plus or minus 150mm. The determination of the FPL that will be adopted under the Brisbane Water Floodplain	After careful consideration of the submissions received, collaboration with the committee and discussions with OEH, Council is proceeding with the recommendation of an FPL as follows: 1. A Flood Planning Level based on the derived 100-year flood level (Brisbane Water Foreshore Flood Study Cardno, 2013) plus a freeboard and projected sea level rise (SLR) component as per Council's adopted Sea Level Rise Scenario at 2050 for residential development. 2. The recommended freeboard = 0.5 metres.
19876441	Davistown	Option EM7 (a review of the evacuation centres and suitability) should take place and we note alternatives to the Kincumber and district neighbourhood centre overlooked include: • Davistown RSL Club • Brisbania School • Saratoga Shopping Centre. Members note that the RSL Club has the capacity to cater for a large extent of the population, is accessible and has full amenities and back-up power and adjoins Alloura Waters: That retirement village built at and above are all 2.45.	Noted. Reference to these locations has been provided in the document.

Document ID	Suburb of Residence	Summary of Submission	Response to Submission
19876441	Davistown	Option EM4: The flood warning system for MA6 is sufficient. There is no demonstrable need for additional need for flood warnings within the roadways given the acknowledged shallow depth, low velocity and short duration of predictable events.	Noted. This option would be implemented across the floodplain and locations requiring updated flood warning systems would be identified more specifically at that time.
19876441	Davistown	Option EM8: There are two alternate routes for evacuation of the Davistown peninsular namely Davistown Road and Malinya Road. In major flood events Davistown Road may well be flooded at Yattalunga which highlights the importance of a road maintenance programme which will ensure that the levels of these two roads be elevated to facilitate long term utility of local roads as evacuation routes. However again due to the shallow depth the short duration and the low flood velocity and the fact that a majority of houses have floor levels above the acknowledged flood level reduces the need for this review to place significant weight on local roads as evacuation routes.	*Noted. This option refers to the development of an alternative route plan for implementation during flood events and does not include road maintenance or raising. Discussion of these matters would be included in the route plan.No changes made to report.*
19876441	Davistown	Option EM3 (review of the Gosford local flood emergency sub plan (LEMC2013)) has little benefit to MA6 with the knowledge that in a major flood event other areas in the LGA will have a higher priority than MA6 due to the flood nature. Due to the low level and low velocity nature of flooding.	Noted. This option would be implemented across the floodplain rather than on a location-by-location basis, and any benefits to MA6 (Davistown) would be identified at that point.
19876441	Davistown	Option PM5 (monitoring of sea levels): we disagree with this option. More information and supporting documentation will be needed. This conclusion has been derived from previous Cardno reports which focused on climate change and sea level rise which identified concerns with the accuracy of some of the current gauges. A better estimation on the costs and ongoing maintenance schedules will be required. Therefore in relation to the measurements for sea level rise this responsibility should be left to the Manly Hydraulic Laboratories and the measurements taken from Fort Dennison.	The importance of local level monitoring and a better understanding of local SLR has been raised throughout the duration of the project and this option has been included in response to this and other factors. This option has been recommended for investigation in the CCAPs. It is noted in Table 10.2 that the responsibility for monitoring and data management should be taken on by state government.
19876441	Davistown	Option PM7 (): spot filling: an option that should not be delayed or reviewed or left to become dependent on CCAP outcomes. This would address many of the current flooding issues and would give ongoing assurances on predicted sea level rises, the DPA feels that the existing planning and development controls are functioning in a sufficient manner to accommodate and protect resident's expectation and rights. Our concern is that the review and enforcement of amendments every five years to planning infrastructure and development controls (which involves statutory protocols) protect the rights and expectations of property owners.	Option PM7 has been actioned as "Immediate" in the document. Wording has been updated to 'recommend' filling rather than only 'allowing' filling in areas compatible with filling.
19876441	Davistown	Option PM10: The DPA agrees with this process but notes the obligation on council to at all times to maintain a fair and equitable balance of private and owner entitlements and its own obligations with respect to maintenance of utilities and services.	Noted.
19876441	Davistown	Option PM2: The DPA agrees with this process, provided that MA6 is not excluded due to the flooding nature and the effects of sea level rise.	Properties would be eligible for house-raising where a need has been identified - no management area has been ruled out of the process.
19876441	Davistown	Option PM3 (land swap program) should be a last resort as it is a complex option and the usual outcomes are impractical and inequitable without significant government funding.	This is noted. Only the worst affected properties have been considered and house raising has been considered as a priority for those properties with suitable construction type. The implementation of this options would be largely dependant on available flood free land, agreement of property owners to participate and availability of state government funding.
19876441	Davistown	Option PM8: The DPA is unsure given the uncertainties of this approach. The DPA does support maintenance of existing land use controls as per the current (LEP2013) together with existing safe guard. A proposal for MA6 could be to maintain a minimum freeboard of 500 mm above the now known flood level could be beneficial. This would improve street presence, ramp and stair access and would work well with the spot fill proposal and future (minor) elevation of local streets and the installation of a promenade walk way to the perimeter of the village.	The interim recommendations in Appendix H do not provide any management area specific controls at this stage. Option PM8 has been identified as a "staged" option for consideration of management area specific controls as part of the CCAPs.
19876441	Davistown	Option PM4 (education surrounding s149 certificates): The DPA strongly disagrees with this program. Most importantly Council should be sure not to publish inaccurate information on S149 Certificates. Any information should relate to known flood levels. Advice should not reference predictions in relation to sea level rise. An example may be that a property, prone to low level flooding is identified and the RL and flood level for the site identified. Whatever information is provided and displayed in relation to property sales should only be used at a benefit to both the purchaser and the seller.	This option does not recommend the inclusion of any inaccurate information on S149 certificates. The option provides an opportunity to provide education in terms of protection of property (rather than risk to life and emergency response like in EM1). The option recommends a program of strategic, balanced and socially sensitive education to advise the local community and prospective property purchases about the risk and effects of coastal flooding. This may include a requirement for flood risk brochures to be available / on display at real-estate agencies and a brochure title "What does my S149 Certificate mean?" to be included with all S149 certificates received by property owners.

Document ID	Suburb of Residence	Summary of Submission	Response to Submission
19876441	Davistown	Option PM9 (sea level rise management strategies): We note the report's author's advice that an assessment of the impacts associated with increased tidal inundation, as a result of sea level rise is beyond the scope of the FRMS and suggests to the DPA that there is a more important need to ensure resources should be devoted to more immediate threats, responses and strategies. The concerns and issues and options outlined in PM9 would be best addressed at a much later date when more accurate date and information is available.	Although the impacts associated with increased tidal inundation as a result of sea level rise is beyond the scope of the Floodplain Risk Management Study, it is still a component to be considered in terms of future coastal flooding associated with storm surge. As such, this option remains valid as a means to facilitate future investigations (including Climate Change Adaptation Plans).
19876441	Davistown	Option EM1: The DPA disagrees with this point; however we do accept a requirement for a flood education program the need for a target education programme at Alloura Waters Retirement Village would only distress the aged members of the community. As the published mapping shows that the retirement village is well above the flood extent.	Noted. This option would be implemented across the floodplain, and relevant organisations that require education would be identified at the time of implementation.
19876441	Davistown	Option FM4: The DPA agrees with this proposal however a schedule maintenance program would be required due to the low velocity discharge and elevation of the storm water pipe outlets. There is a risk that any blocking of the flood gates could have the reverse affect. The drains at Davistown are in a poor state and council doesn't appear to have a current maintenance program. A current maintenance program would reduce any of the current flooding and pending issues that occur at Davistown.	Noted. This option would be implemented across the floodplain, and relevant locations where flood gates would be required would be identified at the time of implementation. A detailed maintenance program would be developed by Council. However, an estimate of the cost of maintenance has been included in the assessment.
19876441	Davistown	General: The DPA has for the last twelve months been developing a plan of management (POM) for the village. Matters identified as high priority items for attention include: **1)** The development of the paved walking / cycle pathway along the foreshore. **2)** Road maintenance routine and regular road maintenance should see a gradual increase in road surface levels reducing our rates to zero over twenty years flood impact of access. **3)** Maintenance of the existing low density residential character consistent with the R2 zone objectives will limit the need for major infrastructure upgrades and permit council to focus resources on elements that will enhance the village identity and quality of life for visitors and residents **4)**Improvements of public reserves including Davistown oval, Illoura Reserve. **5)** To improve road surface conditions through management of traffic volumes and speeds also enhanced pedestrian safety **6)** Maintain minimum freeboard 500mm above flood levels to reflect the now known risk of flooding in the knowledge that at RL 1.95 sufficient freeboard exists to protect assets from flood and predicted sea level rise. **7)** Permit filling of land to save RL 1.6 in redevelopment proposals where proponents demonstrate nil impact on adjacent properties. **8)** Sea level adaptation (while not part of the Brisbane Water FRMS) - adaptation can easily be accommodated at Davistown by adoption of the above measures. Measures that in the short term by construction of the foreshore cycle way would forward protect against storm surge flooding and in the longer term resolve in flood free access via the local road	1) outside scope of FRMS, comment referred to Council. 2) gradual road raising may be considered by Council as part of the CCAPs. 3) outside scope of FRMS, comment referred to Council. 4) outside scope of FRMS, comment referred to Council. 5) outside scope of FRMS, comment referred to Council. 6) After careful consideration of the submissions received, collaboration with the committee and discussions with OEH, Council is proceeding with the recommendation of an FPL as follows: *1. A Flood Planning Level based on the derived 100-year flood level (Brisbane Water Foreshore Flood Study Cardno, 2013) plus a freeboard and projected sea level rise (SLR) component as per Council's adopted Sea Level Rise Scenario at 2050 for residential development. 2. The recommended freeboard = 0.5 metres.* 7) permissible filling in the floodplain is discussed in Appendix H and has been recommended for inclusion in the FRMP. 8) to be considered as part of the CCAPs.
19660495		The issue of Insurance has arisen numerous times and appears no closer to achieving clarity even though there has been a lot of discussion and co-operation with the insurance industry. The problems caused by the insurance industry defining a "Riverine or Overland" flood separately from the "Storm Surge" flood in Brisbane will undoubtedly cause tremendous uncertainty for the public in regard to whether they are covered for water entering their homes. The high water levels are certainly likely to be caused by Storm Surge meaning many people may have paid highly for ineffective insurance cover. Resolution of this problem is not really the business of this Draft Study. However the Council could alleviate the problem by devising a system that allows all affected property owners to know, with proper accuracy, the extent to which their house is affected by potential flooding, namely through the use of certified surveyors and the issuing of a "Flood Level Certificate" to be used by residents in determining insurance requirements or negotiating insurance cover. I suggest that, for a fee, Council could provide a certificate showing 20%AEP, 100%AEP and PMF flood levels at the property, the flood planning level, and sea level rise and freeboard allowances. The certificate would need to be dated and would be valid for an initial period of 10 years or possibly until a significant (measured amount) of sea level rise (say 5cm) has occurred. The certificate should also show: - The height of the house in relation to the flood and planning levels; - Whether the house is likely to flood at present sea levels - Whether the house is likely to flood with sea level rise in the short or long term - The current and future freeboard or safety margin if the house is above	Noted. This matter has been referred to Council and will be responded to accordingly.

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19611278	Umina	Overall objective "to minimise the risk to life and damage to property" is a very narrow objective - please expand.	The risk to human life and damage to property caused by flooding should be managed so as to ensure the future well-being of the community. In this case it refers to the community in times of flood. Where possible, these risks should be reduced through controlling development on land affected by potential floods and applying a "merit-based approach" to all development decisions which take account of social, economic and ecological considerations, and also their effect on infrastructure and services. Additional text to this effect has been added into the document.
19611278	Umina	No comments regarding the natural environment, in particular the factsheet.	The key purpose of the consultation materials was to highlight and explain the proposed floodplain risk management measures for the purposes of community comment with the ability for the community to refer back to the main document at any point. Section 5 of the Draft document discusses the environmental and social characteristics of the estuary and its foreshores. In addition, a summary of potential environmental impacts for each of the proposed options is provided in Appendix I of the Draft document, under the "Considerations/Impacts" - "Environmental" section of each table.
19611278	Umina	Planned retreat and abandonment must be included in Council's message	This may be considered as part of the CCAP in response to SLR. However, the risk and flood behaviour associated with the existing flood risk does not warrant planned retreat.
19611278	Umina	Information presented is more about sea level rise than climate change, without considering the damage and infrastructure failure of both scenarios.	Section 6.4.1 of the draft document discusses climate change in terms of observed and projected sea level rise; changes in storm intensity and frequency; and changes in rainfall. Additional text to be added to explain that sea level rise impacts have been included in accordance with the previously adopted State Government benchmarks of 0.4m and 0.9m, however rainfall joint occurrence with climate change has not been considered since flooding in the Brisbane Water Estuary is predominantly estuary-driven rather than catchment-driven. Also, there is not a large degree of scientific consensus on this type of increase.
19611278	Umina	Raising of infrastructure such as roads and railway will perform as a second levee. Any engineering works will affect the environment e.g. mangroves and marine system near Woy Woy railway station. PM2 (house raising) - how many properties affected?	Noted. Engineering works have not generally been recommended as outcomes of the management study as an outcome of the MCA. Any proposed engineering works would be subject to the requirements of the Environmental Planning and Assessment Act in terms of environmental assessment. 24 dwelling have been identified a potentially suitable for house raising.
19611278	Umina	What are the finite details of PM3 - how will it work and will it work? State government population policy will only exacerbate climate change issues and coastal squeeze.	Land swap would involve no net gain in development, but would rather include a "swap" process whereby a parcel of Council' owned land not affected by flooding is swapped with a parcel of privately owned land that is affected by flooding. The previously Council-owned property would then become private and be developed, whilst the previously privately-owned property would be modified to allow public usage such as open space or a park.
19611278	Umina	The Land and Environment Court has deliberated over what is a "floodway" and "floodpath". Residents face financial loss there is action for reimbursement. Confrontation between the council and beachfront property owners is common over development applications. Will L&E Court referrals increase parallel with climate change and test the Council's planning policies and administration?	"Floodway" has been defined for the Brisbane Water Foreshore in accordance with the Floodplain Development Manual. Council will consider the impact of SLR on planning controls further through the CCAPs.
19611278	Umina	Wamberal beach revetment wall has been an issue since 1997. The Council and state government have not resolved this matter. Funding is an issue with Councils programs - how does this dictate priorities.	Wamberal beach is beyond the scope of the Brisbane Water Foreshore Floodplain Risk Management Study. This matter has been referred on to Council.
19611278	Umina	PM4 - education option needs more realistic descriptions rather than euphemisms. The Coastal Management Strategy considered the social, recreational and environmental and character of the coastline, whilst beachfront residents are more concerned about property protection and valuation/development. Is it now possible to have socially sensitive education?	The option provides an opportunity to provide education in terms of protection of property (rather than risk to life and emergency response like in EM1). The option recommends a program of strategic, balanced and socially sensitive education to advise the local community and prospective property purchases about the risk and effects of coastal flooding. This may include a requirement for flood risk brochures to be available / on display at real-estate agencies and a brochure title "What does my S149 Certificate mean?" to be included with all S149 certificates received by property owners.
19611278	Umina	Will floodplain management influence the DA for Woy Woy Oval?	This matter has been referred on to Council.
19611278	Umina	Did the staff comment on the Gosford Waterfront redevelopment in the draft study? What impact will ocean acidification have on property?	This is beyond the scope of the floodplain risk management process. This matter has been referred on to Council.
19611278	Umina	More detail is required on the Narara Creek Catchment. Both floodplain and catchment need further studies linked to the broadwater and estuary.	Narara Creek is the subject of a separate study (Narara Creek Floodplain Risk Management Study and Plan).

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19611278	Umina		The impacts, risks and constructability of levees for the protection against existing flood risk has been undertaken as part of the FRMS. They were not found to be cost effective for existing flood risk benefits. Further assessment of the benefits of levees for protection against SLR will be considered in the CCAPs.
198661682	Davistown	We face the waterfront Reserve and we look towards Rileys Island. The Reserve in this area has many highs and lows, if this area was to be filled to the highest areas (the same as the reserve around the Pippi Point corner, in front of Paringa Rd}, we would rarely experience any tidal inundation on this section of the Reserve.	Protection against tidal inundation for future SLR scenarios will be considered further under the CCAPs. Two levee scenarios were investigated for this section of foreshore. The construction of which could involve filling in the reserve. Neither levee option were found to be suitable for inclusion in the FRMP for protection against existing flood risk.
19727377	Hardys Bay	Flood planning levels - I strongly support the option Design Still Water Level+ 0.4 metres Sea level rise allowance+ 0.3metres freeboard be the option adopted. Council has adopted a projected rise of 0.4 metres by 2050 and 0.9 metres by 2100. Other councils have adopted lower levels, and little or no allowance has been made for mitigating circumstances that may occur over this period of time. I would therefore support the recommendation that was made at the last meeting that a trigger method be employed to plan for sea level rise. Allowance for sea level rise should be 0.2 metres until sea level rises 0.1metres. After the sea level rise reaches the O.llevel by measurement, the allowance for sea level rise is triggered to 0.3 metres. A 0.2 metre measurement in sea level rise triggers a 0.4 metre allowance in planning etc. The use of trigger method of planning and management would provide fairer and more realistic regulations and controls for the community in the floodplain. It is therefore requested that the 0.3 metre freeboard option for flood planning levels be adopted by Council in the BWFRM Plan.	After careful consideration of the submissions received, collaboration with the committee and discussions with OEH, Council is proceeding with the recommendation of an FPL as follows: 1. A Flood Planning Level based on the derived 100-year flood level (Brisbane Water Foreshore Flood Study Cardno, 2013) plus a freeboard and projected sea level rise (SLR) component as per Council's adopted Sea Level Rise Scenario at 2050 for residential development. 2. The recommended freeboard = 0.5 metres.
19857390	Davistown	I believe that those who have purchased houses in Davistown should have more say to any changes to the waterfront reserve. We understand that we do not "own" the waterfront reserve but we are the most affected as opposed to other locals and visitors who come here on an irregular basis. I understand that Council needs to mitigate erosion and the impact of sea level rise and is considering levee types of structures combined with seawalls and would implore Council to consider natural materials, scale and to stage same until we have more conclusive information regarding sea level rises which is somewhat in the future anyway. Structures at the Yattalunga and Ettalong foreshores would not be suitable at Davistown foreshore as it is a very different waterfront.	Noted. This matter has been referred to Council with respect to any future proposed changes to the waterfront reserve at Davistown. The visual and access impacts associated with sea walls have been considered in the scoring within the MCA.
19857390	Davistown	All the immediate actions presented in the Cardno Reports are excellent work and to be commended being mostly emergency/evacuation and necessary education of same.	Noted. This comment has contributed to "community support" scoring of these types of options.
19857390	Davistown	I strongly oppose concrete pathways and/or cycleways particularly as some have suggested "raised" all weather access (even in conjunction with levee banks). Cyclists should use Malinya and Lenora roadways generally and Council could consider lowering the overall speed limits here and throughout Davistown as we share the road with ducks, dog walkers and pedestrians with prams as it is. Pathways and cyclists are not compatible with other recreational activities that are undertaken along the waterfront.	Noted. No cycleways are currently proposed for the waterfront reserve at Davistown. This matter has been referred to Council with respect to any future proposed changes to the waterfront reserve at Davistown.
19857390	Davistown	The drainage outlet near Pippi point needs some sort of timber walkway, similar to a jetty, as access here is sometimes limited and difficult. Near Lintern wharf could have a similar low and low impact ramp/walkway to the road and carpark.	The purpose of the floodplain risk management process is to reduce risk to life and property in times of flood. Access for recreational purposes is beyond the scope of the floodplain risk management study process, however this matter has been referred on to Council.
19857390	Davistown	Council should in the longer term consider a non-continuous seawall of sandstone similar to near Pippi Point (and Empire Bay), if necessary and raised over time if necessary only where erosion is actually occurring and still allow easy access for residents with kayaks and dinghies. Some areas of the waterfront reserve could be filled minimally. Residents I know would be happy to share maintenance in co-operation with Council, planting and maintaining the correct reeds and removing weeds to prevent erosion in front of their homes. Older residents could "adopt" a more able neighbour to assist in "their" area.	The impacts, risks and constructability of levees for the protection against existing flood risk has been undertaken as part of the FRMS. They were not found to be cost effective for existing flood risk benefits. Further assessment of the benefits of levees for protection against SLR will be considered in the CCAPs. A "shared" approach to management can be included in the assessment.
19857390	Davistown	I understand the only gauge for measuring sea level rise is at Koolewong. Council should consider gauges in more areas as this information seems to be inadequate at this point and we are already 25 years into the 110 year period being discussed (from 1990) and we do not seem to have any quoted history and levels (SLRs) of this period in the documentation although covering near 25% of the period. I am pleased to see this PM5 as an immediate timeline and also PM9.	Noted. Although sea level rise is not intended to be the focus of the document, PM5 (continue to monitor sea level rise) is a recommended action as part of the draft study. Part of this option would include a review of water level gauge locations in the estuary.
19857390	Davistown	I understand some "Staged Options" have taken place, (PM2) for example, a floor level survey, however this information at this stage is not available to homeowners. When will this be available to homeowners?	This matter has been referred on to Council.

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19857390	Davistown	There is mention of high soil erosion in the catchment areas of the rising topography but no mention of mitigation in these areas in the documentation that I can see. With the Brisbane Water area being covered 50% by natural forest we should be mitigating this erosion. Nor does there seem to be any included action regarding re-instatement of original natural wetlands that effectively contained flowing waters until storm events had passed.	The purpose of the floodplain risk management process is to reduce risk to life and property in times of flood. Soil erosion in the catchment areas is beyond the scope of the floodplain risk management study process, however this matter has been referred on to Council.
19857390	Davistown	Much more proven (as opposed to forecasted) information is required before many issues can be addressed. Council's 149 Certificates should only state known facts and current planning instruments and controls. For the same reason "low" risk areas should not be classified as "high" risk impacting on homeowners insurance policies on forecasts as opposed to facts. The 5 year reviews may be too short - 10 years may be more reasonable if no new facts are evident in the lesser time.	The FRMS does not make recommendations for the information to be included on S149 certificates. This matter has been referred to Council.
18961664		Council's planning department should ensure that absolutely no further developments are allowed in any possible flood prone or storm surge affected areas. My concern is that we as ratepayers will be asked to foot the bill for poor planning decisions, in addition to increases to house insurance (this has already increased due to recent floods in this state and others). I am concerned that residents will have to pay for sandbagging or building of sea walls which are not a long term fix given the potential for greater damage to such facilities with climate change.	Council has prepared the FRMS in accordance with the State Government's Flood Prone Land Policy. The Policy's objective is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods. At the same time the policy recognises the benefits flowing from the use, occupation and development of flood prone land. The policy promotes the use of a merit approach which balances social, economic, environmental and flood risk parameters to determine whether particular development or use of the floodplain is appropriate and sustainable. In this way the policy avoids the unnecessary sterilisation of flood prone land. Equally it ensures that flood prone land is not the subject of uncontrolled development inconsistent with its exposure to flooding.
19621984	Gosford	Your Draft Study doesn't seem to acknowledge, credit or allow for the fact that the actual air pressure at a location (like Gosford) would have had a direct effect on sea level rise, limited only by restricted openings to Brisbane Water- this is presumably what drives the "surge"- the study makes it sound like the surge is totally related to offshore effects, large ocean waves and SE winds (that no doubt help). It is my understanding is that 1 atmosphere of air pressure is equivalent to 10m water so that, on the open ocean (or wherever water flow is not restricted), if air pressure drops from 1000 to 900hPa then water level will aim to rise by about 1m. I'd like your study to provide the actual conditions at the peak of the critical storms (like 1974). What was: o the actual air pressure in Gosford (or Sydney) at time of worst flooding; o what predicted tide for Gosford at time (tide tables ?O.Om -low, or ?1.7-king high, or enough to show how far above the no-storm tide level) probably expressed in AHD (rather than tide levels that are not AHD; and o what magnitude of stormwater event at the time of peak flooding in Brisbane Water (1:10yr event at the time, or maybe right at the peak of a 1:100yr event)? Also, the study and design needs to state the assumed minimum air pressure used in the modelling, e.g. 850,900,950.	1 hPa drop in barometric pressure can correspond to 1 cm of surge (this is known as the inverse barometer effect) in the open ocean provided that the low pressure cell in question is moving slow enough for this process to fully take effect. However, the increase in water level in the estuary is not a simple response to the drop in pressure. The water levels in the estuary rise because water has flowed into the estuary from a region of higher pressure (the additional water has to come from somewhere – and that somewhere can only be the ocean). And in estuaries this process is often inhibited as that pressure induced flow into the estuary is commonly attenuated by hydraulic controls (similar to the tidal flows). This process is implicitly included in the modelling in the water level boundary condition - which is based on design still water levels that include a pressure surge component.
19621984	Gosford	It is a bit hard to see how Brisbane Water Foreshore should be considered in isolation of the feeder creek flooding. I would have thought the study might need to be looking for solutions to the whole tidal area- as one effects the other. Brisbane Water backup the creeks and effect flood levels long the creeks, like flooding in Narara from Narara Creek. Siltation in the creeks must result in increased and higher flooding of the floodplain, and probably effects the time and height of inflows to Brisbane Water. It is noted that Narara Creek is highly silted/sedimented in places- to the point where it might only have the cross section it had a century ago.	The FRMS has investigated the areas primarily affected by storm surge. Within the feeder creek, individual flood studies and FRMS have been or will be undertaken to assess the impacts of catchment flooding. Those studies also consider the interaction between storm surge and catchment flooding within those creeks.
19569458	Woy Woy	I was in Woy Woy shopping centre during a king tide in January. Water did come up slowly through some low lying drains and onto a few streets in the town centre. There was no panic or pandemonium, and the water receded quickly as the tide moved on.	Noted. The floodplain risk management study does not intend to consider or address tidal inundation (e.g. during king tide events). Rather, it aims to consider the impacts of much less frequent, but more severe inundation, such that would occur on average once every 20-100 years.

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19569458	Woy Woy	I believe Gosford Council is partially responsible for the demise of Gosford Town Centre, I would strongly object to the same being done to Woy Woy Town Centre. Inappropriate restrictions, and an inappropriate focus on potential flooding over commercial well being would be disastrous. To me it may be appropriate to move proposed future high density housing development (being so close to a major transport node) to the areas unaffected immediately adjacent to the main commercial area. Lismore shopping centre is subject to flood, but appears to have never been held back as a commercial centre. Good governance in my view.	Council has prepared the FRMS in accordance with the State Government's Flood Prone Land Policy. The Policy's objective is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods. At the same time the policy recognises the benefits flowing from the use, occupation and development of flood prone land. The policy promotes the use of a merit approach which balances social, economic, environmental and flood risk parameters to determine whether particular development or use of the floodplain is appropriate and sustainable. In this way the policy avoids the unnecessary sterilisation of flood prone land. Equally it ensures that flood prone land is not the subject of uncontrolled development inconsistent with its exposure to flooding. The recommendations in Appendix H intend to achieve this balance.
19569458	Woy Woy	Council itself invested significant funds along the Woy Woy waterfront with new facilities and a cycleway. It has produced only positive results in promoting the tourism and lifestyle options of residents. If it went under water occasionally in 100 years time it has long paid for itself in community benefit. Why should affected residents not be able to access the same benefits. Waterfront properties are valuable by nature and many will be changed or adapted over time to meet conditions.	The floodplain risk management study considers the impacts of much less frequent, but more severe inundation, such that would occur on average once every 20-100 years. Such an event could occur at any time, not just in the distant future. The study aims to address the potential risks to life and property as a result of these events.
19569458	Woy Woy	I would appreciate easy to understand updated flood maps that give useful information, a realistic assessment of the time frame involved, and then left to make my own decisions in regard my property. Council can make its own decisions about public land. I am not convinced about science projecting so far ahead, I make no more than a 5 year plan for anything affecting me. So for the next 5 years, I would agree to a bit of monitoring, and the giving of clear information to residents, along with a few flood signs. I cannot agree with any of the options in your handout, nor do I see any great benefit in spending huge amounts of ratepayer funds when there are more realistic needs.	The recommendations in the FRMS do not seek to impact on existing dwellings, except for the purposes of emergency response and protection. The planning considerations for individual properties regarding the existing flood risk are relevant primarily when a property owner seeks to undertake a significant development on their property. Council's response to sea level rise will be considered in more detail in the CCAPs.
19844739	Empire Bay	I support the proposal to build low level discrete levy banks around Empire Bay village and parts of Davistown as this would address the current 1% flood hazard if combined with one way valves on the (currently tidal)storm water systems. These levees would be a relatively low cost solution and could incorporate a walking or bike path, they could attract State government funding as part of a flood alleviation solution. Should projected sea level rise become an issue in the future these levees could be raised easily and cost effectively. Used in combination with land raising per my previous submission these projects could eventually remove Empire Bay and Davistown from the flood plain. Council should not wait another 10-20 years for the result of a future climate change adaptation plan before addressing the current flood problem, to do so is simply avoiding councils legislated responsibilities to its residents.	The impacts, risks and constructability of levees for the protection against existing flood risk has been undertaken as part of the FRMS. They were not found to be cost effective for existing flood risk benefits. Further assessment of the benefits of levees for protection against SLR will be considered in the CCAPs. It should be noted that the FRMS has identified that there is a flood benefit as a result fo levees. Therefore, if funding becomes available for the implementation or upgrade of cycleways and walkways, then they could be constructed in a manner as to provide flood protection.
19857409	Green Point	We would just like to express our concerns with regard the waterfront reserve areas of Green Point i.e.: MA3, but particularly the zone between Elfin Hill & Lexington Pde Green Point. We have lived near this location for approx. 12 years and have noticed a gradual erosion of the shoreline in this area. It has removed or threatened a substantial amount of the vegetation. In the past twelve months there has been more substantial damage but particularly during the period July/August 2014 where we experienced a great deal of inclement weather and the occurrence of King Tides which had a severe impact on the shoreline. On one particular evening we saw approximately 1m of the shoreline eroded overnight. We reinstated some of the worse effected area around our stormwater outlet, with rocks and vegetation, but this was only a temporary fix. Council officers and consultants alike have seen this impact and one strategy mentioned which was being considered was the installation of twin lines of rock (breakwall) as installed recently at Yattalunga foreshore zone. This seems to be a sensible approach and one we would support to minimise the future impact in this location.	Erosion of the foreshore is not directly considered under the Brisbane Water foreshore floodplain risk management study. This matter has been referred on to Council and will be responded to accordingly.
19749997	Point Clare	Insurance needs to be addressed in the consultation process. Premiums are too high, and companies take advantage of owners on the water.	Concerns regarding insurance have been referred to Council for their consideration when liaising with the ICA.
19521979	Empire Bay	We are writing on behalf of the local community to express our concerns regarding the use of Timed Consent & Planned Retreat as a strategy for dealing with future climate change rising water levels. We feel that consequences of this plan would be detrimental for Empire Bay residents. It would be far better to address the current 1% flood and drainage issues in the very near future and not leave it for years down the track.	Timed consent and planned retreat will be investigated as part of the CCAPs and have not been recommended for implementation for protection against existing flood risk.

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19521979	Empire Bay	We support the retention of the existing FLP of 2.45M AHD as this gives very high protection levels for property.	After careful consideration of the submissions received, collaboration with the committee and discussions with OEH, Council is proceeding with the recommendation of an FPL as follows: 1. A Flood Planning Level based on the derived 100-year flood level (Brisbane Water Foreshore Flood Study Cardno, 2013) plus a freeboard and projected sea level rise (SLR) component as per Council's adopted Sea Level Rise Scenario at 2050 for residential development. 2. The recommended freeboard = 0.5 metres.
19480125		BLANK	NA
19480118		BLANK	NA
19853611	Davistown	Erosion is being caused by wave action made mainly by boats. The placement of rocks between Pipi Point on Pyang Avenue would assist in reducing the erosion. See attached map of Lintern Channel.	Erosion of the foreshore is not directly considered under the Brisbane Water foreshore floodplain risk management study. This matter has been referred on to Council and will be responded to accordingly.
19633828		For a range of reasons detailed in the original submission, it is strongly recommended that the option Design Still Water Level + 0.4 metres Sea level rise allowance + 0.3metres freeboard be the option adopted and included in the Brisbane Water Floodplain Risk Management Plan. It is requested that the 0.3 metre freeboard option for flood planning levels be adopted by Council in the BWFRM Plan. Alternatively a less preferred but acceptable second option would be maintenance of the 2.45 metre AHD. However it should be stressed that this option is only acceptable if the 2.45 AHD is rigidly adhered to with no additional supplementations. The only perceived permissible increase to the 2.45 AHD level would be as part of a Development Application strategy for wave run up protection issues.	After careful consideration of the submissions received, collaboration with the committee and discussions with OEH, Council is proceeding with the recommendation of an FPL as follows: 1. A Flood Planning Level based on the derived 100-year flood level (Brisbane Water Foreshore Flood Study Cardno, 2013) plus a freeboard and projected sea level rise (SLR) component as per Council's adopted Sea Level Rise Scenario at 2050 for residential development. 2. The recommended freeboard = 0.5 metres.
19633828		Concern has been expressed at Catchment and Coast committee meetings and working parties re identifying estimates for sea level rise in the long term. Council has adopted a projected rise of 0.4 metres by 2050 and 0.9 metres by 2050. South Coast councils with more recent data have predicted a 0.26 metre rise by 2050. The BWFRMS document indicates that the 0.4 and 0.9 metre figures are most probably overestimates and that sea levels will probably not reach these levels by the prescribed times. It is therefore recommended that a trigger method is employed to plan for sea level rise. Allowance for sea level rise should be 0.2 metres until sea level rises 0.1 metres. After the sea level rise reaches the 0.1 level by measurement, the allowance for sea level rise triggered to 0.3 metres. A 0.2 metre measurement in sea level rise triggers a 0.4 metre allowance in planning etc. Sea level in the Brisbane Water estuary system is rising at 2.2 millimetres per year at present. At this rate it will take 180years to reach the prescribed 0.4 metre level adopted by Council for 2050. The use of trigger method of planning and management would provide fairer and more realistic regulations and controls for the community in the floodplain.	Councils existing sea level rise policy adopts estimates of SLR of 0.4m by 2050 and 0.9m by 2100. The FRMS has been based upon this policy. Review of this policy will be undertaken as part of the CCAPs. Reference to the recent south coast study has been included in the FRMS.
19727463	Avoca Beach	In summary, after finalising this Cardno risk report, Council should proceed simultaneously with: • Preparing the proposed flood plan for Brisbane Water residences • Preparing a risk assessment on exposure of assets other than housing in the Brisbane flood water • Implementing the small set of priority Immediate flood measures to be identified in the final risk report, which should include an active community education program (including information about accessing hazard mapping) • Commence development of a Climate Change Adaptation Plan (drawing upon the outcomes of the steps above as they are completed). It is pertinent here to note that the Commonwealth Government has just assigned funding ($9m over 3 years to mid-2017) to the National Climate Change Adaptation Research Facility to develop national guidelines (framed particularly to meet local governments' needs) addressing climate change adaptation in coastal areas. Gosford Council should consider being an active contributor to that process, including through its established engagement with other local governments in the Hunter-Central Coast region. • Preparing a public communication product describing Council's overall approach to managing extreme natural hazard events. The following comments discuss these in more detail.	This has been noted and will form an input to the preparation of the FRMP.

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19727463	Avoca Beach	An indication should be provided of the damage cost incurred from an event producing over floor flooding of that set of properties. The draft report presents the damage cost as an annual average for a 1:100 ARI event ($S.Sm pa currently and rising greatly as sea levels rise)- it seems misleading to present the damage result only in that way. When a flood event of this size happens, the community instantly takes the damage hit and the costs of recovery- especially when (see discussion later) home insurance cover does not protect the home owner against ocean driven flooding (as is the case in the Brisbane Water). The one-off damage bill should be indicated. (Table 7.5 seems to indicate a damage cost of $32m for a 1:100 year event.)	flood damages have been reported as both average annual damages and total damages for each design event.
19727463	Avoca Beach	I suggest that in the final report there is included some discussion to put the number of at risk properties in perspective. In particular- - Identify the total number of residential properties located within the 100 year ARI zone; and the fraction of them at risk of over floor inundation. - Be clear that all houses not having floor levels of at least 2.45m AHD are more than 34 years old. And discuss what the implications for this age of buildings might be in terms of the prospects for property management by the owner, e.g. a decision by the owner to knock down an old residence and undertake a new build to the current control standard, instead of undertaking a refurbishment or making extensions.	Additional text has been included in the document, including the executive summary.
19727463	Avoca Beach	There is only fleeting or no mention in the report of risks, policy and mitigation options for other classes of key assets in the flood zone: special residential facilities for retirees, aged care etc.; critical public services e.g. schools, transport depots, hospitals; utility services like sewerage pumping stations, power distribution equipment, and telecommunications; and commercial premises. (Section 4.2.2 explains that private utilities chose not to make input to the survey conducted.) It is understandable why the Cardno report has been restricted largely to discussion of residential exposure. However, it should be made clear up front in the report that this is the case. And there then should be fuller explanation about how the risk analysis will be expanded to deal with these other assets. The flooding risk analysis presented in the report provides a head-start in evaluating the risks and mitigation options for these other asset classes. Preparation of the planned Climate Change Adaptation Plans will be assisted if the comprehensive risk assessment of assets has been completed for the threat to all significant assets on the foreshore. (The GeoScience Australia databases on infrastructure locations may be of assistance here, and were used in the 2011 coastal vulnerability assessment released by the then Commonwealth Department of Climate Change and Energy Efficiency).	Additional text has been included in the document to discuss why the document predominantly considers properties more so than other assets. The risks to sensitive uses (such as aged care and schools) have been considered in the development of emergency response options and appropriate planning controls for these uses.
19727463	Avoca Beach	The analysis of flood mitigation options (cost-benefit and multi-criteria matrix) is addressed through this same narrow window of benefit to at risk residences. In fact, there are wider considerations for cost-benefit, feasibility and the specific design of risk mitigation options that enter the equation when risks to these other assets are included. For example, emergency management planning is likely to be affected if, in addition to evacuation of residences at threat of over floor flooding, there must be evacuation of schools, facilities for older people, and there is likelihood of failure of sewerage, power or other utility services.	Consideration has been given to schools, facilities for older people, and other critical infrastructure in terms of the possible management options identified, (e.g. PM6). In terms of the options assessment criteria, feasibility has been included as a score, as has the reduction in risk to life and emergency access. Section 9 considers emergency management planning and evacuation during flood emergencies.
19727463	Avoca Beach	By way of improving community understanding and the context for some of the potential risk mitigation options, the Cardno report should include a short discussion of the context of the overall hazard risks for the Gosford LGA that would be associated with an extreme flood event in the Brisbane Water. This could discuss the attributes of a severe ocean storm (such as occurred in 1974 or the 'Pasha Bulka' storm) driven by an East Coast Low- high seas eroding beach fronts, intense rainfall producing creek flooding and high winds affecting power reliability and wind damage to properties, and road closures. So, for example, in designing an emergency response plan there is likely to be a need to consider that emergency services will be dealing simultaneously with events on the Brisbane Water foreshore, and in other parts of the Gosford LGA. Likewise, such information will help to underpin community understanding about the need for Council policies that are coherent and consistent between related extreme natural hazard events (discussed below).	Historical flood events are referenced in the executive summary. Additional text has been added to relevant sections in the report.

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19727463	Avoca Beach	As commented above the current Gosford Council policy, introduced in 1981, requiring habitable floor levels at 2.45m AHD minimum, has served the community well in protecting foreshore residential areas from flooding associated with historic sea levels. Consequently, I strongly support the Recommendation in the draft Cardno report (Section 8) that this development control standard should continue to apply. That standard was informed by water levels occurring during the 1974 ocean storm. Sea levels have risen in the 50 years since, so effectively residences built to the current standard are already experiencing a reducing freeboard margin of safety as time has passed, and the freeboard to floor level will reduce further as sea levels continue inexorably to rise. It would be negligent to move to a new building standard with weaker floor level requirements; for example the different options canvassed (but rejected) in the draft report (Section 8.9.1). The draft report correctly identifies (p91) social equity considerations that would result from a weakened development standard The report notes the commitment of Gosford Council to prepare Climate Change Adaptation Plans. They would likely entail requirements at some point for stronger building design standards to address inundation risk driven by rising sea levels and intensifying ocean storm events. It would constitute maladaptation to embark now on a temporary course of weaker building standards.	After careful consideration of the submissions received, collaboration with the committee and discussions with OEH, Council is proceeding with the recommendation of an FPL as follows: 1. A Flood Planning Level based on the derived 100-year flood level (Brisbane Water Foreshore Flood Study Cardno, 2013) plus a freeboard and projected sea level rise (SLR) component as per Council's adopted Sea Level Rise Scenario at 2050 for residential development. 2. The recommended freeboard = 0.5 metres.
19727463	Avoca Beach	I recommend that high priority be assigned to an education program to educate the community about flood risk and response- and contrary to the rankings assigned (nos. 22 and 26 in the Table of Preferred Options (ES4). (The materials circulated are conflicting as to whether this measure is seen as an Immediate Option (Table 10.2) or a deferred Staged Option (the pack provided for the Community Forum). It should be an Immediate Option. The need for this is borne out by: the floodplain community survey results; likely unfamiliarity that flooding in the Brisbane Water is driven mostly by ocean events rather than catchment rainfall; and the need to have an educated community consideration of how the Gosford LGA should maturely decide policies for the future through the Climate Change Adaptation Plans. As part of this education program, I suggest it would help community understanding if Council were to produce an information product that presented an integrated picture of the approach taken by Council to manage the range of natural hazards (particularly flooding and inundation inland and on the coast, and bushfire). At present this is embedded in a great many different hazard plans and reports on the Council website, and does not enable a citizen to obtain a coherent single picture on questions like: are the 'safety standards' the same for fire and flood; what hazards are insurable and what not; is there a common emergency management plan applying for all climate hazards.	In regards to Options PM4 and EM1, Table 10.2 and other references in the document show these options as having a staged action timeline. A check has been undertaken to ensure constancy of terms throughout the document. Additional text has been included in the document to further explain why these options have a staged timeline.
19727463	Avoca Beach	Council's policies and practices on flood mapping access are not described in the Cardno report- this gap should be remedied in the final report. Access to information is highly relevant to risk management. Likewise, the report should address current Council policy and practice regarding information available to property owners and potential buyers via the internet and a property Planning Certificate (S. 149). The assessment of flood mitigation options should identify what steps should be taken to improve this practice. The community will best engage in formulating policies to deal with future flood risks if it is educated and has access to risk information in the form of maps and similar. Likewise, property owners and potential buyers of properties need access to spatial risk information for them to be able to make informed decisions about how they manage risks.	Council may review its access policies on an LGA wide scale. Public exhibition of the draft documents is a key component of the project. Additional text will be incorporated into the Brisbane Water Floodplain Risk Management Plan.
19727463	Avoca Beach	it is a critical gap in discussion of flood risk in the Brisbane Water foreshore when the Cardno report does not identify the absence of insurance cover for a waterway where flooding is clearly identified as mostly resulting from ocean storms. The issue of insurance should be an element in the above proposed education program, so that the community knows where they stand should a flood event happen. The risk mitigation options presented should include action by the Gosford Council to have addressed at national level by the Commonwealth and State Governments, and the insurance industry on provision of insurance cover for action of the sea. This is a bigger issue for the Gosford LGA than just the Brisbane Water- consequently, it should be taken up more fully in the simultaneous Open Coast and Broken Bay Beaches hazard and planning process.	The issue of insurance is being discussed in more detail between Council and the ICA. This comment has been provided to Council for further consideration.

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19727463	Avoca Beach	With sea level already rising, and at an accelerated rate in recent decades, and confidently projected to rise further in future, a very different engineering design approach will be needed -engineering standards that will cope with future sea levels (not the past sea level). The Climate Change Adaptation Plans process being instigated by Gosford Council is the correct way to embark on this step.	Noted.
19727463	Avoca Beach	Reducing risk of harm to homes built in high hazard locations in a time when building standards were not commensurate with the risks is a key issue for Gosford Council. But this should not be done in a piecemeal way, to address only the Brisbane Water foreshore floodplain. A better way would be for Council to approach this in a systemic way. It could do so via a stocktake of the number of properties across the LGA facing acute exposure from natural hazards; identifying whether they have access to affordable insurance cover; and then to frame an integrated policy.	Council has been and continue to undertake flood studies and FRMS&P across all of it's floodplains to gather information on flood affected properties and flood behaviour for the whole LGA. Any approach to flood management is the Brisbane Water floodplain is not done in isolation of the recommendations of the other studies.
19727463	Avoca Beach	Council should be cautious about the extent and circumstances in which it embarks on a path of public subsidies for home owners (e.g. voluntary house purchase, raising and land swap). This is one of the reasons a community education program and access to spatial hazard information is so important, in enabling property owners and potential buyers to make informed decisions about what risk they are willing to take on and how they manage their own risk in making building decisions. Decisions taken now over how to best address action on the most acutely exposed properties will serve as precedent for longer term liabilities. With 426 existing properties on the Brisbane Water foreshore exposed to over floor flooding (100 year AFI), the Cardno report indicates that number increases to 2,839 as sea level rise proceeds to reach 0.9m. The policy framework established needs to be capable of dealing with present and future levels of exposure and financial liability. Social equity will be one factor to consider, e.g. should the community subsidise a property owner who could afford themselves to undertake a property management action to provide then with flood protection.	Public subsidies are unlikely to be provided on a large scale (if at all) and have only been assessed for the worst affected properties. Community education and access to data options are highly ranked options due to the benefits associated with them. Property subsidies are likely to be considered in any future CCAPs but are unlikely for form a large component a strategic plan to address the risks associated with SLR for the reasons outlined in this submission.
19727463	Avoca Beach	Emergency management planning should be framed in terms of all assets and community flooding exposures in the Brisbane Water (not only homes). Emergency management planning should also consider what other exposures will likely be occurring in the LGA at the time of an ocean storm event of a magnitude causing substantial flooding in the Brisbane Water.	Additional text has been included in the document to discuss why the document predominantly considers properties more so than other assets. The risks to sensitive uses (such as aged care and schools) have been considered in the development of emergency response options and appropriate planning controls for these uses.
19656958	Davistown	My major concern is there are no effective sea walls at all on this end of the Illoura Walk.	Sea wall upgrades at Davistown was identified as an option in the study, but was not found to be preferred option for flood management, based on the multi-criteria matrix assessment contained in the study. These works may be facilitated in other management processes, such as the Coastal Management Process.
19830483	St Huberts Island	In summary, good foreshore management is not common knowledge or understanding. In fact, we find that people's view of what they think is good foreshore management is the complete reverse of what it should be. As such, we suggest that Council be proactive in educating foreshore owners on what is an environmentally friendly sea wall structure (sloping) and what is not an environmentally friendly structure (vertical wall) so as to enhance general understanding and to minimise scouring in front and often into adjoining areas and other properties. We recognise that these issues are quite complex, but we have found the document written by the Catchment Management Authority Sydney (DECC, 2009 - Environmentally-friendly seawalls) to be very useful as it highlights the essentially simple facts.	Noted. This matter is beyond the scope of the Floodplain Risk Management process but has been referred to Council and will be responded to accordingly.
19830344	St Huberts Island	Along most sections of the island the planners installed publicly owned easements (approx. 6m wide) to give access to the waterway and the foreshore from the road. There are more than 20 of these access blocks on St Huberts Island. On survey documents they are noted as 'ROAD'. We suggest that Council write to owners adjacent to these blocks and advise them that these blocks should be treated as easements and should not contain fixed structures. We write this as we note cases where adjoining owners have placed hard structures permanently on these public 'roads', thereby effectively giving the appearance that they are a part of the adjoining owners property and impeding access.	Noted. This matter is beyond the scope of the Floodplain Risk Management process but has been referred to Council and will be responded to accordingly.
19666538	St Huberts Island	I am interested in advice from Council regarding assistance in raising sea wall levels.	Sea wall upgrades at St Huberts island was identified as an option in the study, but was not found to be a preferred option for flood management, based on the multi-criteria matrix assessment contained in the study. These works may be facilitated in other management processes, such as the Coastal Management Process.

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19666538	St Huberts Island	Consideration should be given to floodgates on storm water system for the Island.	The installation of flood gates on stormwater pipe outlets (as required) is a recommended management option as part of the study. We understand that St Huberts Island has several locations where this may be feasible and appropriate. Further consideration of the location of these structures will be given during the concept design when the option is implemented.
19666538	St Huberts Island	Consider working with RMS on lowering water speeds in front of the Island to mitigate erosion of foreshore.	Noted. This matter is beyond the scope of the Floodplain Risk Management process but has been referred to Council and will be responded to accordingly.
19622572	Davistown	Option EM7 suggests that evacuation centre locations are not to be used during emergencies. Surely that's why they should be used plus school halls etc. Maybe you should have written "are not utilised by other parties during…"	Option EM7 refers to evacuation centres that are located in the floodplain, i.e. those at risk of being inundated. Since evacuation centres for other natural hazards (e.g. bushfire) may be located in the floodplain, when evacuating from a flood emergency, only those evacuation centres outside the flood liable areas should be used. Additional explanation has been added into option description.
19622572	Davistown	The installation of a tidal surge barrier at Brisbane Water's outlet to the sea would solve all surge problems for possibly hundreds of years. The surge barrier could also incorporate a tidal hydroelectric station which would produce carbon-free electricity. If it is such a huge problem for such a small ocean outlet/interface, ask Dutch engineers how they protect an entire nation from tidal surge.	This was identified as an option in the study, but was not found to be a preferred option for flood management, based on the multi-criteria matrix assessment contained in the study given the large environmental and economic costs.
19634375	Koolewong	For a range of reasons detailed in the original submission, it is strongly recommended that the option Design Still Water Level + 0.4 metres Sea level rise allowance + 0.3metres freeboard be the option adopted and included in the Brisbane Water Floodplain. Higher freeboard options will have an adverse affect on property owners in the floodplain for a range of reasons also detailed in the original submission.	After careful consideration of the submissions received, collaboration with the committee and discussions with OEH, Council is proceeding with the recommendation of an FPL as follows: 1. A Flood Planning Level based on the derived 100-year flood level (Brisbane Water Foreshore Flood Study Cardno, 2013) plus a freeboard and projected sea level rise (SLR) component as per Council's adopted Sea Level Rise Scenario at 2050 for residential development. 2. The recommended freeboard = 0.5 metres.
19848410	St Huberts Island	In respect to our location, we advise that we have been observing the water levels in front of our property for almost 30 years. From the living areas of our home we have been looking at the water levels under the same jetty structure for those years. In the early years it was quite common for us to see the water over the top of our jetty i.e. we could only see the posts (at times of king tides together with low air pressure,etc). We almost never see water over our jetty anymore. All we can therefore say is that we have seen no evidence of sea level rise in our location over the past 30 years. We add that it, unfortunately, appears that our jetty has sunk a little also, which further adds to this conclusion.	Noted. The floodplain risk management process is primarily concerned with current flood risks to the community, rather than future sea level rise.
19763048	Parramatta	A number of items of local heritage significance listed on Schedule 5 of Gosford Local Environmental Plan 2014 have been identified within the study area and given the breadth of the study area, there is potential for additional items of heritage significance to be affected by the implications of the Probable Maximum Flood (PMF) level. Section 5.7.3 identifies the likely risks and potential damage to heritage items and places caused by flooding. It is recommended that consideration should be given to establishing management measures and strategies to assist in the protection of heritage items and places and to mitigate the potential risks and damage from flooding within the study area.	Noted. It is anticipated that Commonwealth, state and local heritage items would be managed in accordance with the outcomes of the FRMS and that this information can be used in future planning and modifications for relevant heritage items and place. No specific heritage management options have been identified since this is not a key objective of the study.

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19528178	Wagstaffe	A claim is made in the Cardno Brisbane Water Floodplain Management draft report about dredging of the entrance to Brisbane Water (inferred to be south of Half Tide Rocks). The reference should be deleted. The designated study area extends upstream from Half lide Rocks, only. Formally, Brisbane Water ends at Half lide Rocks (i.e. it extends upstream/northwards from there). In the draft BWFM study, it does not appear that modelling has occurred of the north Broken Bay area since before the earlier dredging decision. Further, no studies appear to have been undertaken (presumably because the area is outside the Brisbane Water Floodplain Management study area) of the previous dredging's impacts on fishing, the surf break, Ettalong sand spit (which disappeared, possibly with its sand being relocated via the area's modelled clockwise sand movement to the bigger and better sandbar off the south- western end of Lobster Beach; to the detriment of Ettalong's own shoreline), while Lobster Beach continues to erode (soil embankments as well as sand loss). The sand from Lobster Beach and from Ettalong (sand spit and probably the shoreline itself), as well as the rest of the triangle of estuarine sandbanks, filling and overflowing the targeted sandbank*. For some years immediately after dredging, the south-western Lobster Beach sandbank was bigger (longer, wider, higher) than in living memory. This has always been and remains a dynamic seafloor. The volumes and locations of sand are continually shifting. Dredging assumes a single intervention will change the dynamic, although the modelling suggested that at most 15 years' benefit (from memory) would result - which has proven fundamentally incorrect.	Noted. It is assumed that the reference being made here relates to that in Section 4.3.4 of the draft document. It is noted that this section provides a description of the results of the resident survey that was conducted, and as such we do not feel it is appropriate to remove. The options referred to in this section represent resident's opinions rather than recommendations from the study. Dredging in the Brisbane Water Entrance may be considered as part of the Estuary Management Process rather than the Floodplain Risk Management Process.
19528178	Wagstaffe	Has the unintended impact* been analysed? It is most unlikely that it was part of the brief for the BWFM study.	It is assumed that "unintended impact" relates to the dredging of the Brisbane Water Entrance as described in comment #93. Dredging in the Brisbane Water Entrance was not considered to be a floodplain risk management option for the estuary and was therefore not included in the options assessment for the draft study. Dredging in the Brisbane Water Entrance is not relevant to the Floodplain Risk Management Process in this instance however it may be considered as part of the Estuary Management Process instead.
19528178	Wagstaffe	What consultation has occurred since the failed dredging with the relevant stakeholder groups, including fishers, marine rescue, Surfrider Foundation, National Parks & Wildlife Service, yacht owners, commercial boat operators, relevant surf clubs, marine biologists who have been studying the estuary, historians etc., in preparation for any potential changes in north Broken Bay? Where would such consultation, and impact assessment, occur within a study whose delineated area is elsewhere?	This matter is beyond the scope of the draft Floodplain Risk Management Study and has been referred on to Council.
19528178	Wagstaffe	The modelling undertaken prior to the failed dredging specifically excluded the impact of commercial craft in the estuary between Umina and Bouddi Peninsula, according to one of the modellers. Some of those craft were explicitly trying to create a short cut with a predictable result (picture attached). The inputs to the modelling were "too hard" to produce, so it was not undertaken. That was reported to Council at the time.	This matter is beyond the scope of the draft Floodplain Risk Management Study and has been referred on to Council.
19528178	Wagstaffe	Historically (i.e. since 1788) the estuary has always had a shifting shallow entrance. Dredging is only one of a number of possible responses to the shifting sands of the estuary. Any actions within the estuary, downstream of Half lide Rocks, will probably require a full Environmental Impact Statement. The brief for the BWFM probably did not extend geographically to this area, nor were consequences of the magnitude of an EIS in north Broken Bay probably anticipated as part of the BWFM.	This matter is beyond the scope of the draft Floodplain Risk Management Study and has been referred on to Council.
19528178	Wagstaffe	If Council wants to address the naturally shallow estuary, do it properly, with a correct brief, stakeholder engagement, deep pockets, user pays principle, legal environmental impact assessment etc. Otherwise leave the estuary alone -the natural forces are massive. Let the humans adapt, rather than assuming this community can pay the cost of trying to force nature to do what just a few humans want.	This matter is beyond the scope of the draft Floodplain Risk Management Study and has been referred on to Council.
	DAVISTOWN, NS	Start by sacking all of the incompetent council employees. This should leave only the cleaners left employed there Over the years 99% of council employees have proved to be typical Government benefactors enjoying the protectionism of a government department because they all know that no one in PRIVATE industry would ever employ them MY ADVICE TO COUNCIL EMPLOYEES.= "DON"T EVER GIVE UP YOUR DAYTIME JOB"	NA
	Point Clare	Our family have for the past nearly 100 years closely watched the seasons and tides in our area and helped with clean-up of neighbours properties. We would be happy to discuss with council of any information in the local area that could be of any assistance. We have a map which could be of some help that has the depths of the waterways registered in the year 1901.	Noted and appreciated.
	ST HUBERTS ISLA	We are new to the Island (moved in August 2014) and were unaware of any flooding possibility other than the 1 in 100 year - would have appreciated more of a 'heads up' before exchange of contracts.	Noted. Option PM4 of the draft study recommends the implementation of an education program to facilitate wider awareness of flooding including understanding the information on flood certificates.

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	WOY WOY, NSW	It is true that seawater comes from the storm water pipes at the corner of Brickwarf Road and North Burge Road, covering most of that corner during king tides. I have lived in Burge Road and Park Road for the last 33 years and have seen the water level come over the wall by a foot or two on two occasions due to large seas and south-eastern winds plus heavy flooding rain which causes the tide to back up at The Rip bridge, thus raising the level of the flooding. I think that two times in 33 years is not something to stress about even if rising sea level is true.	Noted. The floodplain risk management study does not intend to consider or address tidal inundation (e.g. during king tide events). Rather, it aims to consider the impacts of much less frequent, but more severe inundation, such that would occur on average once every 20-100 years. Coastal flooding in a 100 year event would cause much higher water levels and a much larger area of Woy Woy and other suburbs around the estuary to be inundated compared to most events in living memory (the exception being the 1974 event).
	BLACKWALL, NS	I find it extraordinary that Council is trying to re-introduce it's previous "Flooding due to sea rise from global warming" under another guise. When this was first introduced back in circa 2009 it saw property values in my area PLUMMET 40 to 50% after the warning was placed on the 149 certificates. Since the removal of this from the 149 certificates we have seen property sales values start to improve , however they are significantly lower than prior to the initial introduction. My family have lived on the waterfront reserve at Blackwall for around 30 years and have never had a problem with flooding, inundation. For every scientist / expert that says sea level rise due to global warming is a fact there are others with an opposing view. Yes the area where I live was probably underwater thousands of years ago and probably will be again in another thousand years, however knee jerk reactions to a flawed science is not the path that council should be following in my view. Any changes to 149 certificates in the future will be met with strong opposition as it was in the past.	This Floodplain Risk Management Study has the aim of considering current flooding risks rather than the future risks associated with climate change. This is so that potential flood risks to life and property may be addressed as a priority in preference to future risks. References to climate change have been included to give context to this process and provide some initial forethought in this regard. Flood risk management options that have been recommended as part of the Draft Study are predominately associated with immediate risks.
	BLACKWALL, NS	Councils efforts and money would be better spent in improving roads and providing curb and gutters particularly in my area, Plane Street Blackwall, not causing angst and additional expense for ratepayers.	Curb and guttering was not considered as a viable flood risk management option in this Floodplain Risk Management Study. This matter has been referred on to Council.
	BLACKWALL, NS	In addition I only became aware of the community forum which was held on the 8 October , today 12 October as an elderly neighbour showed me the piece of Junk Mail she had received in her mail box!!! I queried 4 other neighbours about this leaflet and none had seen it, the reason for this is Council failed to mail this extremely important information to the owners. As was the case with me, this leaflet would have been amongst other JUNK MAIL and placed in the bin where it rightly belonged. There is no excuse for information like this NOT to be addressed to the owner and delivered in the appropriate manner.	The letterbox drops were one form of communication for the Community Forums. Advertisements were made in the local newspaper prior to the Forum, and information was available on Council's website. This matter has been referred on to Council.
	WOY WOY BAY,	Raising sea walls on water front properties. More regular maintenance of storm water drains and grates. Review road verges to ensure rain water does fall to storm water drains and pits	Raising sea walls was considered as an option in the Draft Floodplain Risk Management Study but did not generally score well in the options assessment. This is primarily due to the need for a whole section of foreshore property owners to come to an agreement in regards to raising seawalls to a specified height, which would likely prove difficult. Raising seawalls in an ad-hoc manner is unlikely to provide an appropriate floodplain risk management option. In addition, maintenance and raising of seawalls conflicts with the management actions recommended in the Brisbane Water Estuary Management Plan. With respect to the maintenance of stormwater drains and grates, this was not considered as a viable flood risk management option in this Floodplain Risk Management Study. This matter has been referred on to Council.
		I would like to know more about the value of sea wall development and possible levee construction. This could be very successful.	Levees were considered as part of the options assessment for the Draft Floodplain Risk Management Study however they were not recommended in any location. It is considered that the concerns surrounding levees outweigh the benefits in the case of the Brisbane Water floodplain. Appendix I, Table *FM6a – Levees above PMF - Additional Information* and *Considerations/Impacts* (page I12 and I13 of the Draft Document) provide an explanation of the potential risks and concerns associated with levees. In times of flood, a levee breach (failure of the levee to withstand the floodwaters) could occur, and high velocity floodwaters would enter the low-lying area behind the levee, creating an extreme flood hazard. Community perception of levees presents a risk, as members of the community may not feel the need to evacuate given the perceived protection that the levee provides. In addition, drainage and infrastructure upgrades would be required as part of the levee construction so as to maintain day to day function within the area, e.g. raising of roads, relocation or upgrading of utilities/services and reconfiguration of stormwater drainage through the levee.
	Yattalunga	Evacuation centre near Springfield requires people to drive through flood waters so needs to be reviewed.	It is unclear which evacuation centre is being referred to in this instance. Recommended evacuation centres during flood emergencies are mapped in Figure 9.3 of the Draft report. No reference to a Springfield evacuation Centre is provided in Figure 9.3.

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	DAVISTOWN, NS	Start by sacking all of the incompetent council employees. This should leave only the cleaners left employed there Over the years 99% of council employees have proved to be typical Government benefactors enjoying the protectionism of a government department because they all know that no one in PRIVATE industry would ever employ them MY ADVICE TO COUNCIL EMPLOYEES.= "DON"T EVER GIVE UP YOUR DAYTIME JOB"	NA
	DAVISTOWN, NS	HAND ALL OF COUNCIL FUNCTIONS TO A PRIVATE CONSORTIUM AND PUT ALL OF US RATEPAYERS OUT OF OUR MISERY YOU KNOW I AM CORRECT, GO ON, ADMIT IT TO YOURSELVES. I worked for a government dept. for 40 years so I know the facts as well as you guys do, SAD, SAD, SAD NO ONE ELSE IN PRIVATE ENTERPRISE WOULD EVER GIVE YOU MOB A JOB	NA
	DAVISTOWN, NS	Concerned that Council is over-reacting for a 100 year flood that may never occur in our lifetime and it will mean that our house and lifestyle will be taken away. I don't want to be relocated to somewhere like Kariong.	The Draft Floodplain Risk Management Study is focused on recommending options for managing flood risk, primarily through planning and development controls. Voluntary purchase and land swap were only considered for the worst affected properties and would only be undertaken with the property owners consent.
	DAVISTOWN, NS	Perhaps kerb and gutter and appropriate drains on roads to stop water pooling.	Due to the nature of flooding curb and guttering was not considered as a viable flood risk management option in this Floodplain Risk Management Study. This matter has been referred on to Council.
	DAVISTOWN, NS	The sea wall should be extended from Pippi Point along the western foreshore of Davistown.	Sea wall upgrades at Davistown was identified as an option in the study, but was not found to be preferred option for flood management, based on the multi-criteria matrix assessment contained in the study. These works may be facilitated in other management processes, such as the Coastal Management Process.
	DAVISTOWN, NS	Council should form an alliance with other coastal councils affected by flooding issues to press for an infrastructure programme by the Federal Government for major flood mitigation works such as storm barriers etc. at strategic locations.	This comment has been referred to Council for consideration.
	DAVISTOWN, NS	All new or additions to dwellings should be at the current AHD levels. No exemptions for old dwellings.	Only minor additions to dwellings are given exemption from raising floor levels. This is to ensure constructability with the existing dwelling and to minimise any excessive financial burdens on minor property improvements. The recommendation allows for dwelling where the existing habitable floor level is below the FPL and provided that the proposed floor level is no lower than the existing floor level, then a one-off addition may be considered up to: (i) 40m2 if the existing residential floor is at or above the FPL less the applicable freeboard; (ii) 20m2 if the existing residential floor is below the FPL less the applicable freeboard; (iii) 10% increase in floor area for commercial and industrial additions.
	DAVISTOWN, NS	Council should seek substantial funding for a detailed study of drainage systems in Davistown to ensure that a new, standard and effective system is constructed to provide maximum efficient movement of water. The current system is a hotch potch of various designs that have basically been left to individual property owners to control. This is completely inappropriate. It is ugly, untidy and almost completely ineffective.	Drainage as a stand-alone option for management of coastal flooding for the Brisbane Water Foreshore Floodplain was not considered to be viable. This matter has been referred on to Council and will be responded to accordingly.
	DAVISTOWN, NS	Council needs to take great care in reviewing Development Control plans for this suburb. The area will be very adversely affected by any proposal that would see draconian controls imposed on development. Common sense needs to prevail and actions taken to cater for future sea level rise needs to be activated only by absolute trigger events that prove, beyond doubt , the need for action.	Significant discussions with planners, engineers and scientists have occurred in the preparation of the planning recommendations in Appendix H. Any future recommendations would be undertaken with due care and consideration.
	DAVISTOWN, NS	The most immediate concern is that erosion is being caused by boat wash The placement of rocks along the foreshore between Pippi Point & Pyang Ave would assist in reducing erosion.	Erosion of the foreshore is not directly considered under the Brisbane Water foreshore floodplain risk management study. This matter has been referred on to Council and will be responded to accordingly.
		Option PM9 should be an immediate measure.	This option has been classified as a Staged approach since it will need to be undertaken by incorporating updated data as sea levels rise, and cannot be fully implemented immediately.
		Option FM4 - should commence planning now.	This option has been classified as a Staged approach since additional information is required prior to implementation, i.e. the best locations of the stormwater floodgates/tidal valves has not been assessed. FM4 is a recommended option so planning will commence once the option is implemented.

Document ID	Suburb of Residence	Summary of Submission	Response to Submission
		We need a seawall levee installed around much of the Woy Woy peninsular.	Levees at Woy Woy were considered as part of the options assessment for the Draft Floodplain Risk Management Study however they were not recommended in any location. It is considered that the concerns surrounding levees outweigh the benefits in the case of the Brisbane Water floodplain. Appendix I, Table *FM6a – Levees above PMF - Additional Information* and *Considerations/Impacts* (page I12 and I13 of the Draft Document) provide an explanation of the potential risks and concerns associated with levees. In times of flood, a levee breach (failure of the levee to withstand the floodwaters) could occur, and high velocity floodwaters would enter the low-lying area behind the levee, creating an extreme flood hazard. Community perception of levees presents a risk, as members of the community may not feel the need to evacuate given the perceived protection that the levee provides. In addition, drainage and infrastructure upgrades would be required as part of the levee construction so as to maintain day to day function within the area, e.g. raising of roads, relocation or upgrading of utilities/services and reconfiguration of stormwater drainage through the levee.
	Green Point	Change the name to "Storm Surge Management Plan"	Council has advised that the title will remain as per the draft report.
19565765	Empire Bay	In relation to PM7, I request Council give consideration to the immediate investigation and adoption of Spot Filling concurrent with redevelopment of residential and business premises in suitable areas. I believe that the concept of spot filling residential land to a level above the current 1% flood should be strongly encouraged and preferably required for new development by Council at the earliest opportunity and should not be delayed further by waiting for the outcome of a future Climate Change Adaptation Plan (CCAP) which could be 10 to 20 years from implementation.	Option PM7 has been actioned as "Immediate" in the document. Wording has been updated in detailed description of PM7 in Appendix I to 'encourage' filling rather than only 'allowing' filling in areas compatible with filling.
19565765	Empire Bay	I support the retention of the current FPL at 2.45M AHD as it places homes significantly above the projected 1% flood level and also allows for significant sea level change that may appear with future climate change.	After careful consideration of the submissions received, collaboration with the committee and discussions with OEH, Council is proceeding with the recommendation of an FPL as follows: 1. A Flood Planning Level based on the derived 100-year flood level (Brisbane Water Foreshore Flood Study Cardno, 2013) plus a freeboard and projected sea level rise (SLR) component as per Council's adopted Sea Level Rise Scenario at 2050 for residential development. 2. The recommended freeboard = 0.5 metres.
19565765	Empire Bay	To mandate that upon redevelopment (rebuild) of existing residential sites within the 1% flood zone of Empire Bay village, that the land be raised to an agreed level above the 1% flood level. A level of circa 1.6MAHD is suggested (Empire Bay). This would result in fill levels of 30cm to 60cm above existing ground levels in most locations.	Filling has been recommended to be permissible within the Brisbane Water floodplain with some exceptions. However, filling has not been recommended as a mandatory component of redevelopment as the need is not significant for existing flood risk. However, this approach will be considered as part of the CCAPs to manage the future flood risk associated with SLR.
19565765	Empire Bay	The relevant NSW Minister should be requested to investigate the redrafting of the Flood Plain Manual to provide more appropriate guidance specific to areas affected by storm surge.	This comment has been referred to Council for consideration.
19565765	Empire Bay	The Cardno Consultant has chosen to highlight once again the issue of Time Limited Development Consent within the document. To date, Time Limited Development Consent when applied to existing residential development has NEVER been successfully applied! Does Gosford Council really want to "Lead the Pack" with this kind of policy? Is Council prepared for the public reaction?	No recommendations have been provided for the inclusion of time limited consent to be included in Council's planning documents. As such, due to the contentious nature of this matter, all reference to this issue has been removed from the FRMS document. This issue may be investigated further as part of the CCAP.
	NA	The recurrent cost for Option FM 2a (storm surge barrier at half tide rocks) is only 0.05% of the capital cost. This seems low compared to recurrent cost to the capital cost % of other infrastructure (approx. 1.5% - 4%).	Noted. As the option is not recommended for inclusion in the FRMP, a change in cost does not affect the outcome of the study. An increase in cost would further reduce the ranking of this option.
	NA	Why are the recurrent cost and the capital costs for option EM2 the same?	These costs have been reviewed and updated.
	NA	Figure 12.1 has listed the State Government as a major funding source. To ensure that the community expectations, contact with the relevant state government agency should be initiated to ascertain the possibility that the funding being made available in the future. The relocation of the police and ambulance station should be discussed with the relevant organisation before inclusion into a management plan.	To be considered by Council prior to preparation of the FRMP.
	NA	Benefit-cost ratios of PM2 and PM3 need revision – numbers indicated for PM2 and PM3 seem unrealistic.	The BCR for house raising is similar to that for other studies. The BCR for PM3 has been revised due to an error in the estimated cost.

Document ID	Suburb of Residence	Summary of Submission	Response to Submission
	NA	Responsibilities in Table 10.2 need to be reviewed for options FM4, PM4, PM10, EM1, EM3, EM7.	The responsibilities have been reviewed and updated.
	NA	Not sure how PM4 and EM1 are different.	PM4 provides an opportunity to provide education in terms of protection of property (rather than risk to life and emergency response like in EM1). The option recommends a program of strategic, balanced and socially sensitive education to advise the local community and prospective property purchases about the risk and effects of coastal flooding. This may include a requirement for flood risk brochures to be available / on display at real-estate agencies and a brochure title "What does my S149 Certificate mean?" to be included with all S149 certificates received by property owners.
	NA	Comments for PM8 need updating as option does include consideration for SLR.	PM8 has been reviewed to mention SLR as a component of FPL only in the interim controls.
	NA	In some of the management areas the option 'undertake a detailed investigation of the impacts of structural floodplain risk management options on overland flows" has been preferred. As there are no structural options preferred in this FRMS, what will the detailed investigation review? This option should be included in the future CCAP if structural options are recommended as part of that process.	Although the structural options proposed in this study are not recommended to inclusion in the FRMP, this has often been due to perceived impacts on catchment flows (e.g. levees and associated drainage issues). Council would like to investigate whether modified version of these options could be incorporated in some manner (e.g. minor road raising to provide extended evacuation time and possibly also acting as a levee for smaller flood events), whilst iteratively considering the catchment impacts in the concept design. This level of detailed assessment was beyond the scope of the FRMS.
	NA	The Executive Summary and Preamble are quite long with 19 pages. If table ES4 is included, which ranks the preferred management options, then I am sure that Tables ES1, ES2 and ES3 do not need to be included as well.	Due to the long and complex nature of the document, it is considered necessary to have a comprehensive executive summary. Some refinement has been undertaken in response to this submission.
	NA	the "implementation" section of the Executive Summary includes a discussion on "Trigger" based timeframes for implementation of management options, however this concept is not reflected in any of the discussions in Chapter 12, except to say that they will be considered in the CCAP's. Thus, do they need to be discussed in the Executive Summary if they are not part of the recommended actions?	This has been reviewd and updated.
	NA	Table ES4 and section 12.3 – It really is unclear as to why undertaking CCAP's ranks so low in the study and recommended works. I would have thought that the undertaking of the CCAP's was one of the highest priorities for this project, after the highest ranked recommendation of updating of planning controls. The ranking of options in section 12.3 states "an emphasis on updating planning and development controls" whereas I thought this was the main, and highest, priority for this project. To this degree, it is unclear why the wording of "emphasis" has been used – shouldn't it be making it clear that these needs to happen? This issue is also referred to in point 12 below. Currently, there are 5 options of "detailed investigation of the impacts of structural floodplain risk management options" ranking above the option of CCAP's in Table ES4. If these structural options are not being recommended/undertaken in this FRMS and intend to be investigated as part of the CCAP's, it is unclear as to why their impacts are being investigated. Ditto the enhancement of existing seawall structures.	The CCAPs does not address the issue of existing risk, which has been weighted as the key issue in the MCA and this study.
	NA	section 8 – Flood Planning Level – We have held discussions with OEH's Principal Flood Specialist regarding the issues around selection of the FPL for this area. It is OEH's general opinion that exceptional circumstances would not need to be sought if the FPL selected maintains a minimum freeboard of 500mm for residential development. It would be good to strengthen the discussion in this section regarding the FPL that is selected, and OEH is happy to work with GCC on this issue.	After careful consideration of the submissions received, collaboration with the committee and discussions with OEH, Council is proceeding with the recommendation of an FPL as follows: 1. A Flood Planning Level based on the derived 100-year flood level (Brisbane Water Foreshore Flood Study Cardno, 2013) plus a freeboard and projected sea level rise (SLR) component as per Council's adopted Sea Level Rise Scenario at 2050 for residential development. 2. The recommended freeboard = 0.5 metres.
	NA	the CCAP's are referred to as Climate Change Adaptation Plan and Climate Adaption Plans. Consistency is required.	Text has been reviewed for consistency.
	NA	Table ES1 – Why are some costs highlighted?	Noted at the bottom of Table ES1 - *Costs represent the TOTAL estimated cost of implementing the option across ALL management areas. However costs marked in grey may be lower depending on which (and how many) management areas are recommended for implementation of the option"* .

Appendix B

Management Area Cross Sections

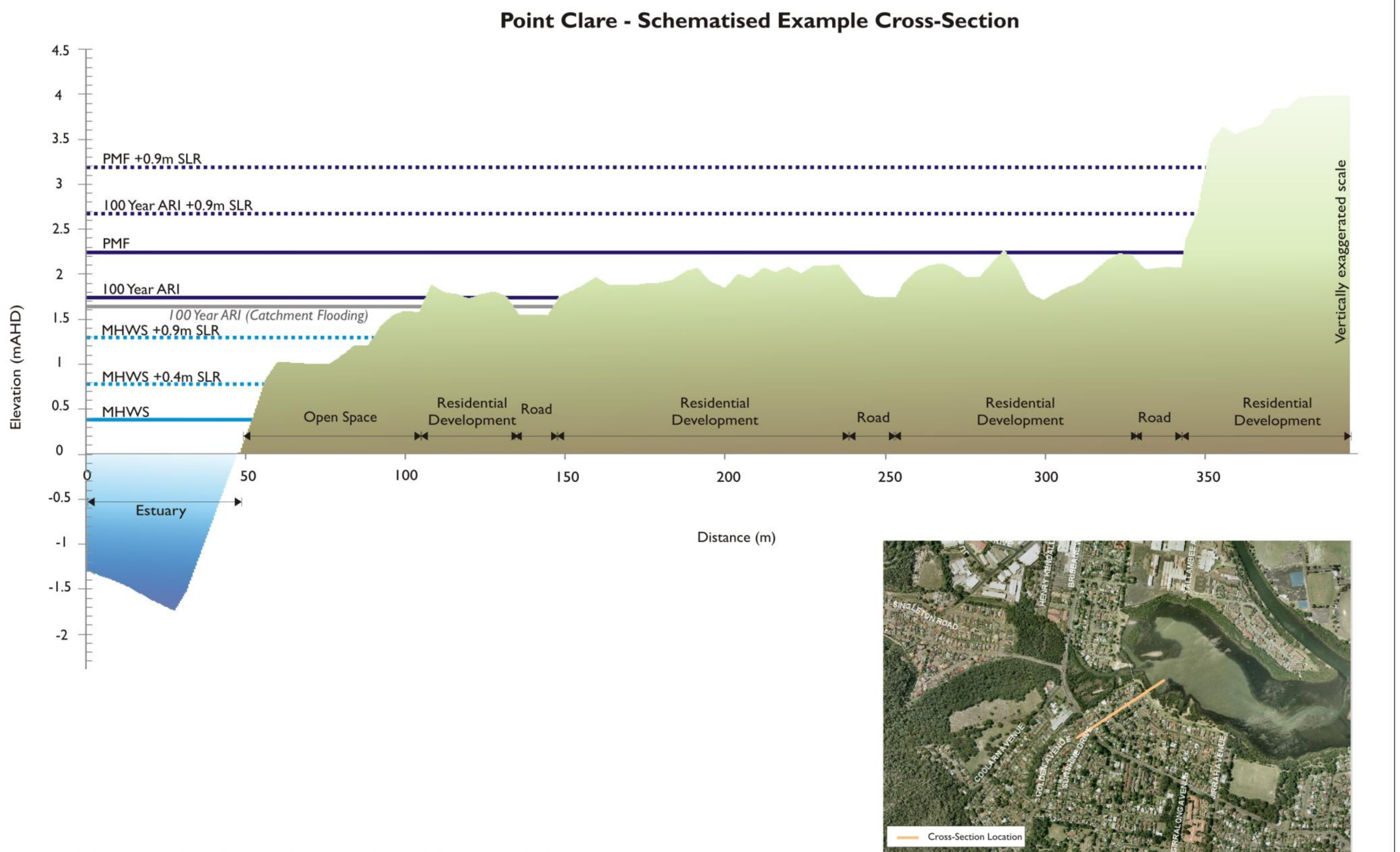


Figure B.1: Schematised Example Cross-Section – Point Clare (MA1)

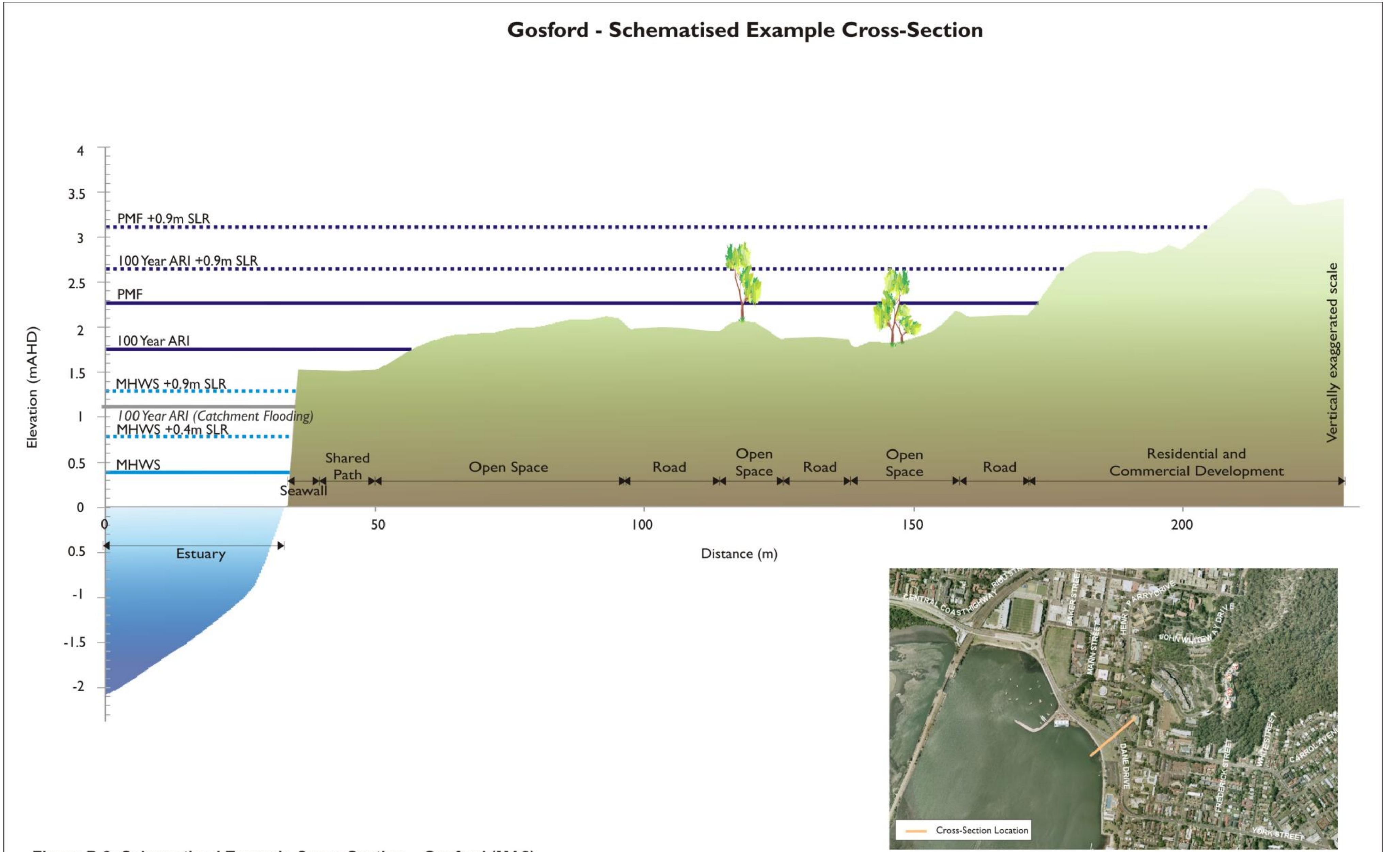


Figure B.2: Schematised Example Cross-Section – Gosford (MA2)

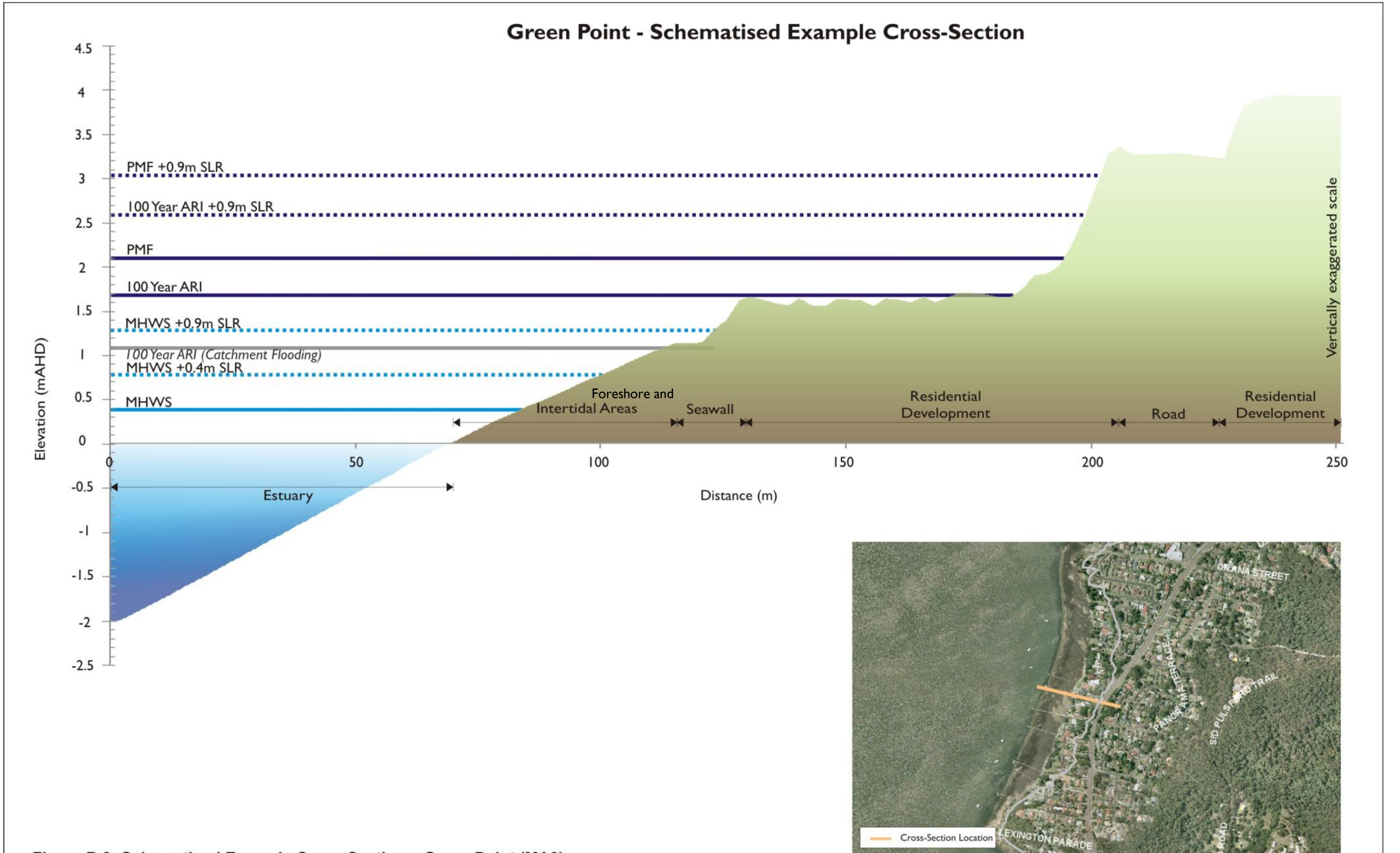


Figure B.3: Schematised Example Cross-Section – Green Point (MA3)

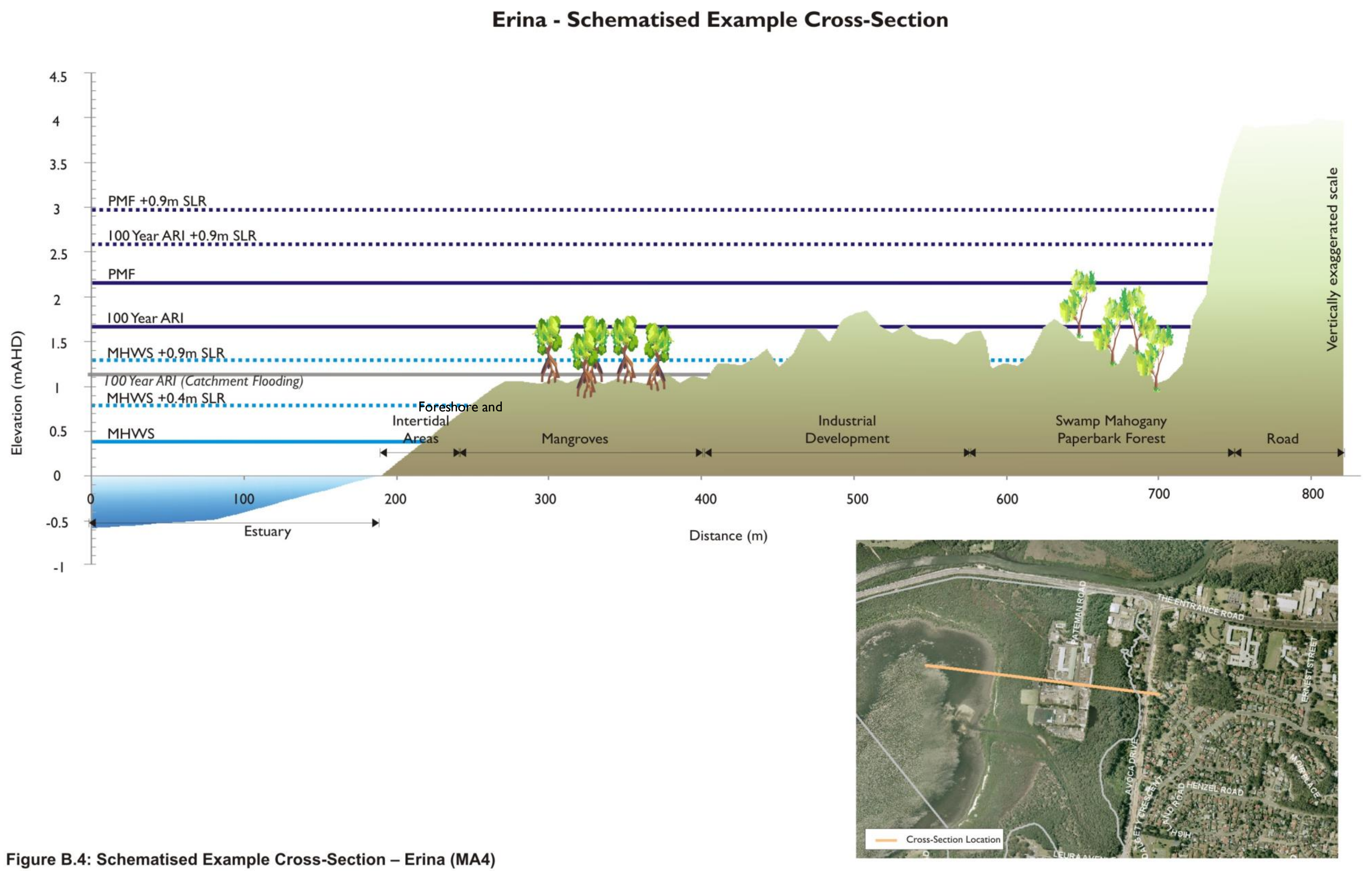


Figure B.4: Schematised Example Cross-Section – Erina (MA4)

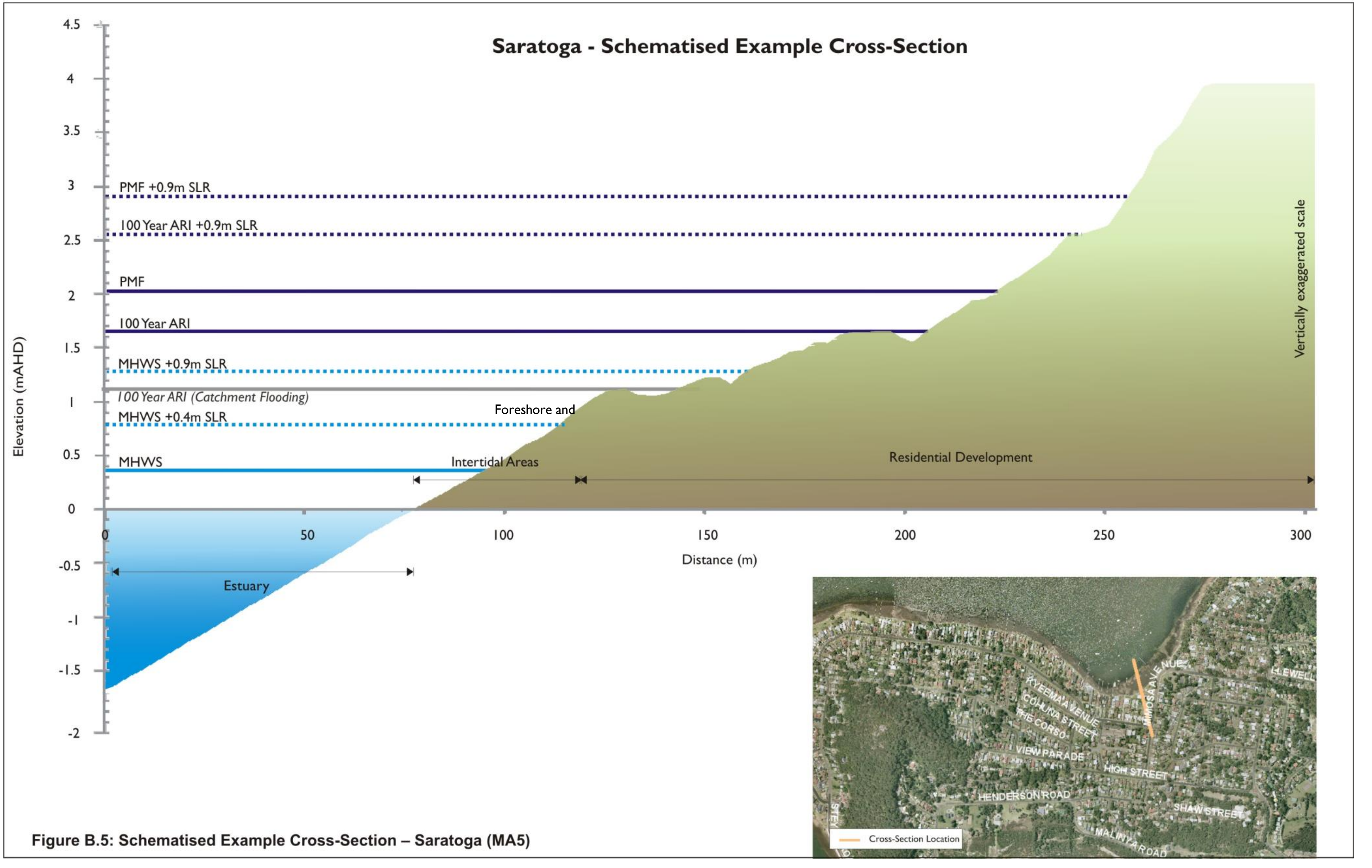


Figure B.5: Schematised Example Cross-Section – Saratoga (MA5)

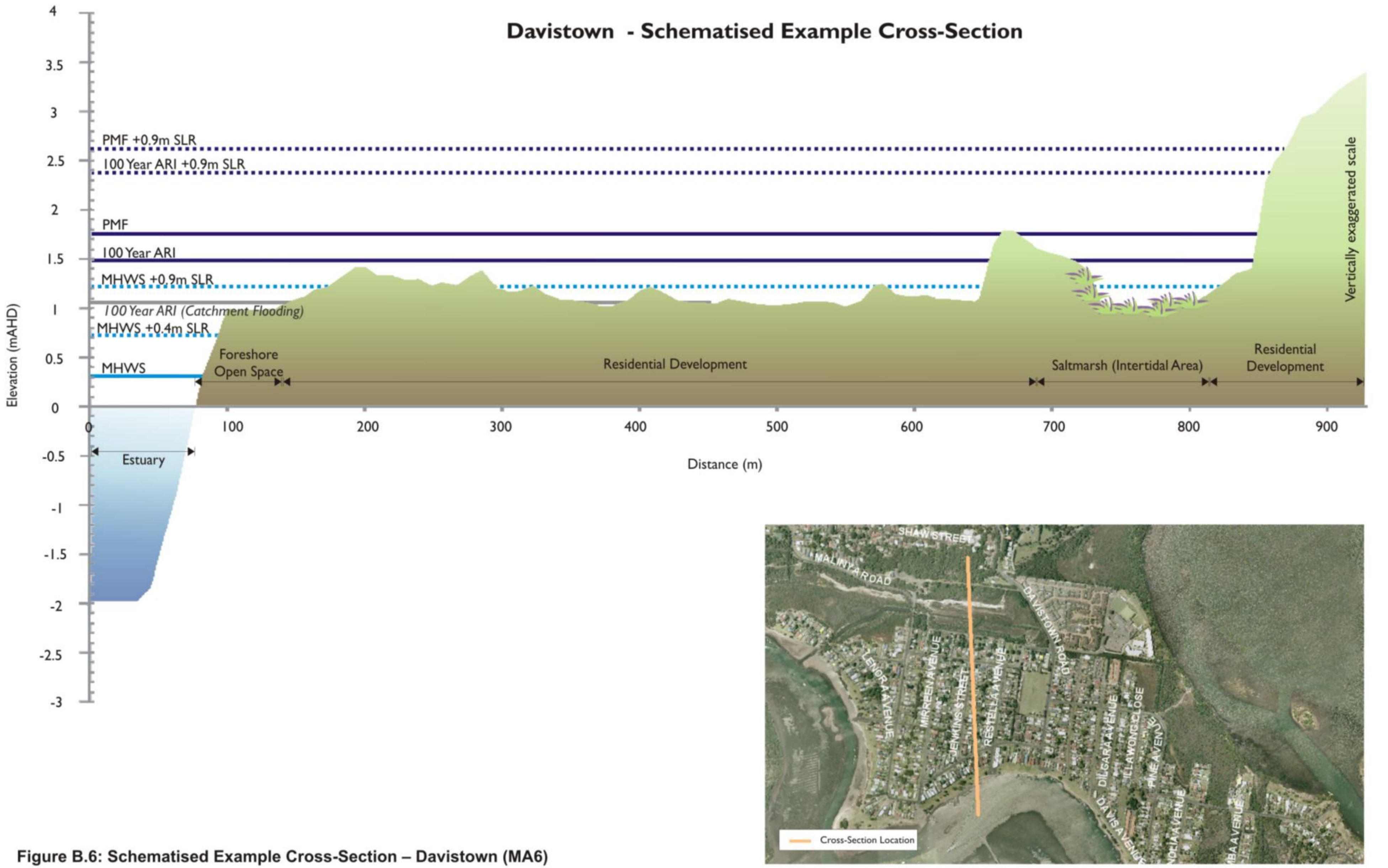


Figure B.6: Schematised Example Cross-Section – Davistown (MA6)

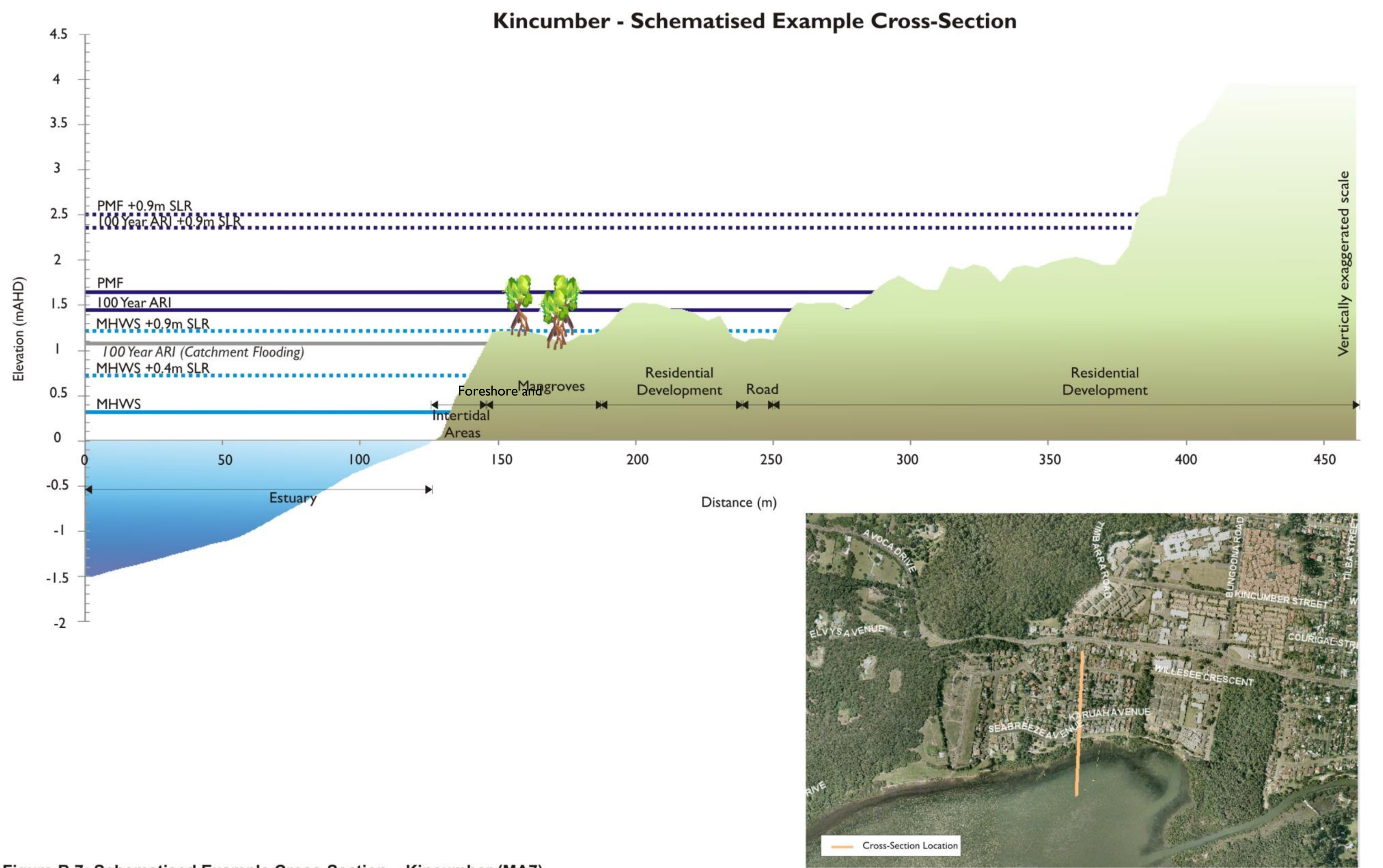


Figure B.7: Schematised Example Cross-Section – Kincumber (MA7)

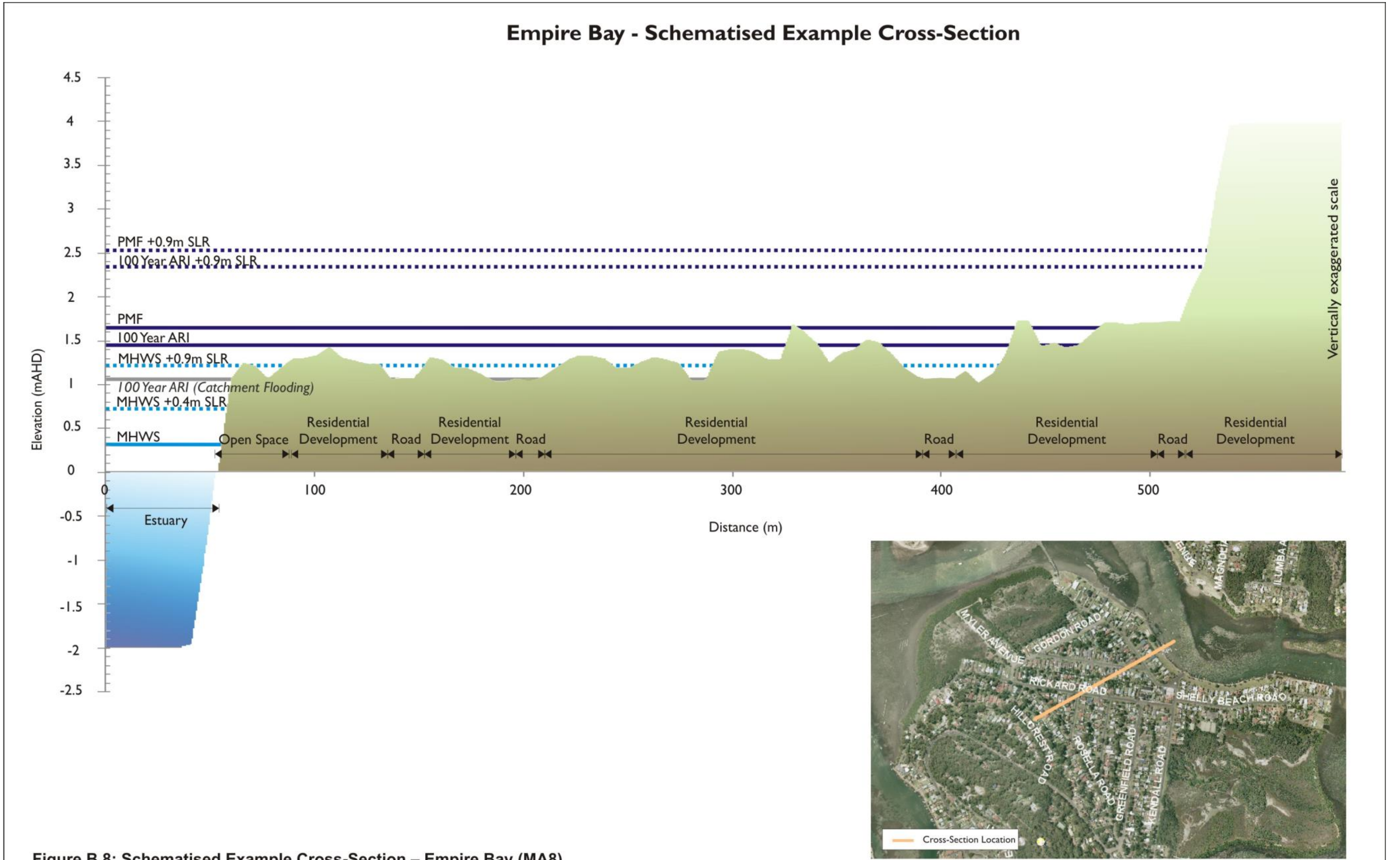


Figure B.8: Schematised Example Cross-Section – Empire Bay (MA8)

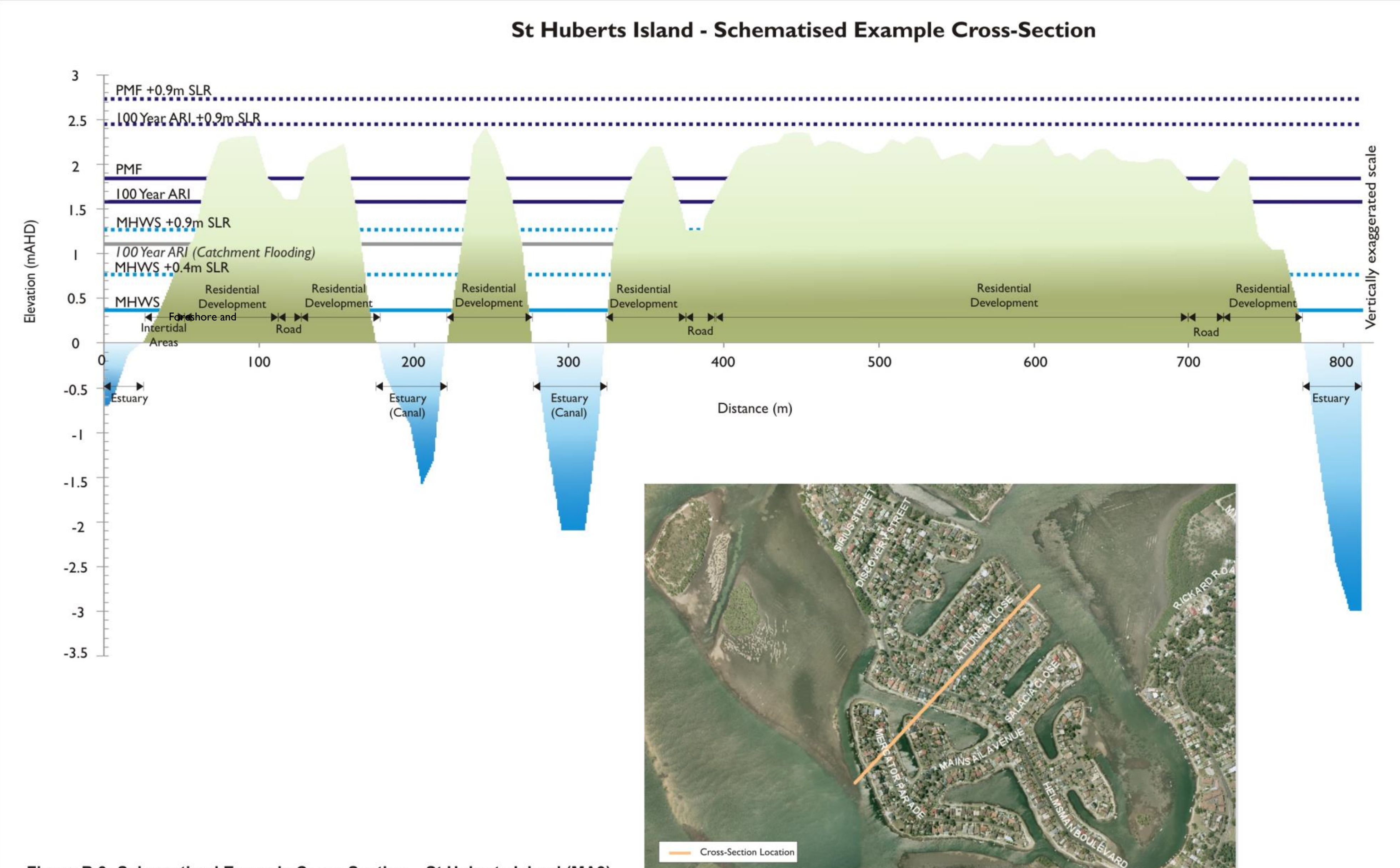


Figure B.9: Schematised Example Cross-Section – St Huberts Island (MA9)

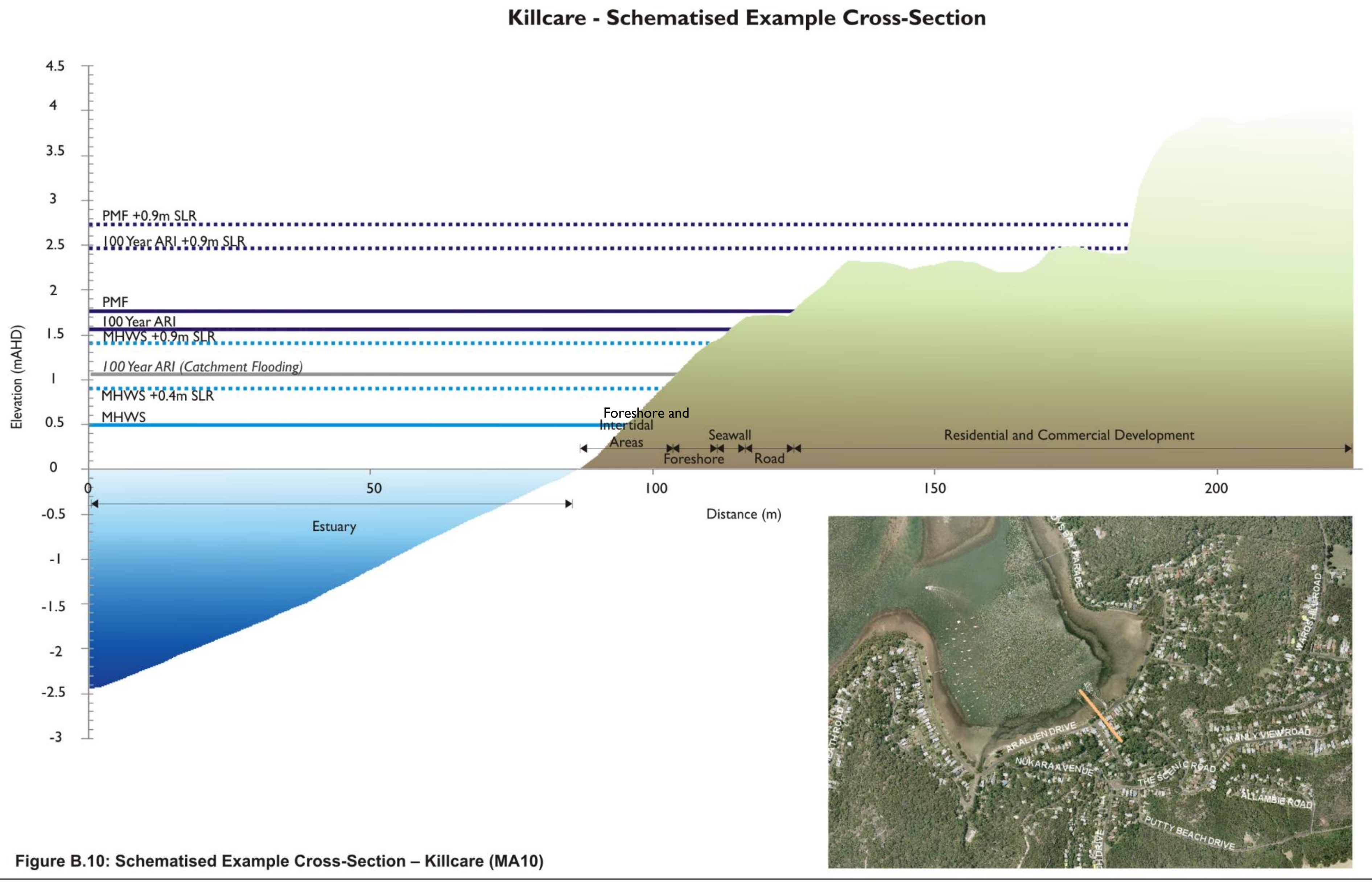


Figure B.10: Schematised Example Cross-Section – Killcare (MA10)

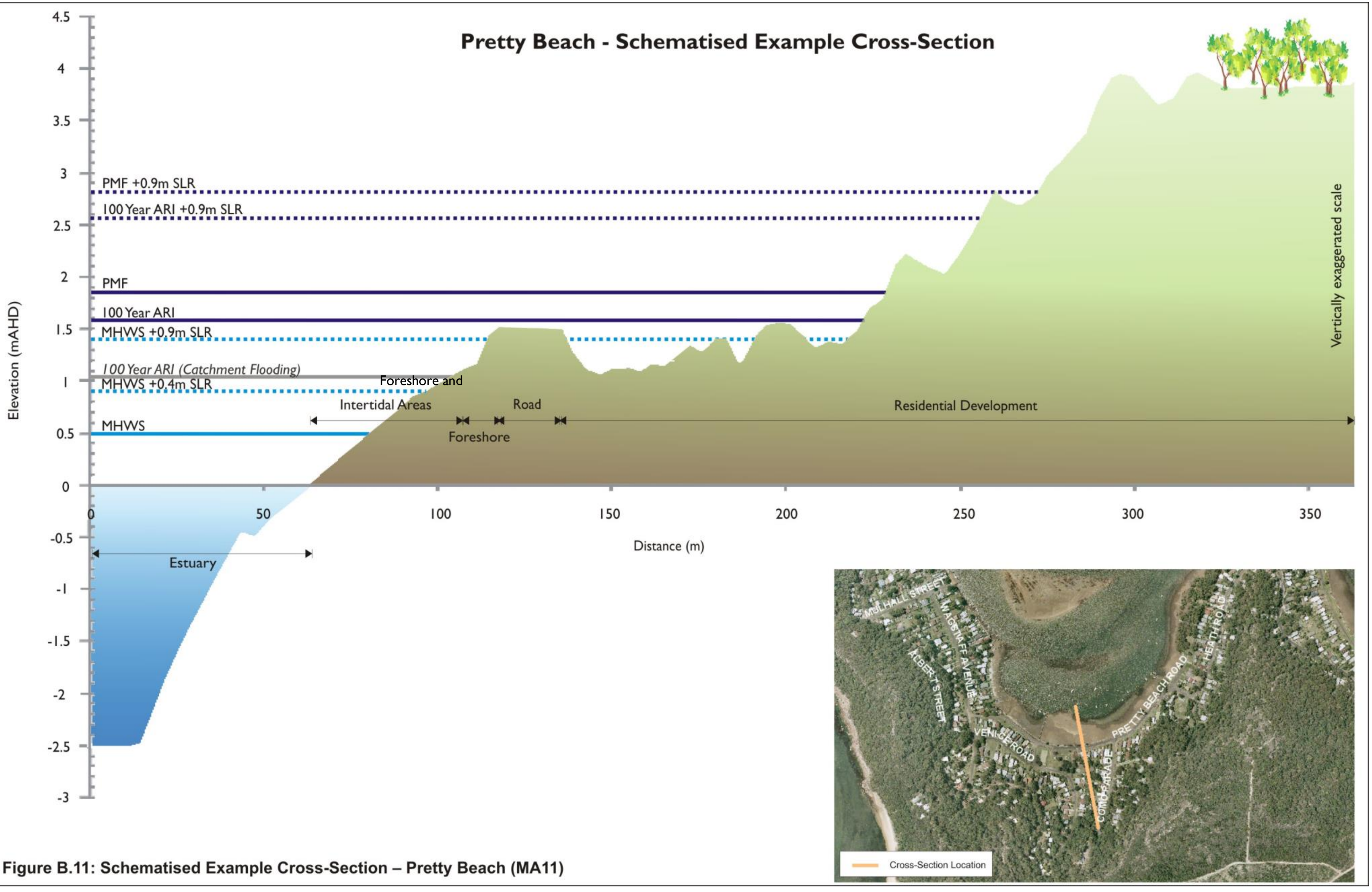


Figure B.11: Schematised Example Cross-Section – Pretty Beach (MA11)

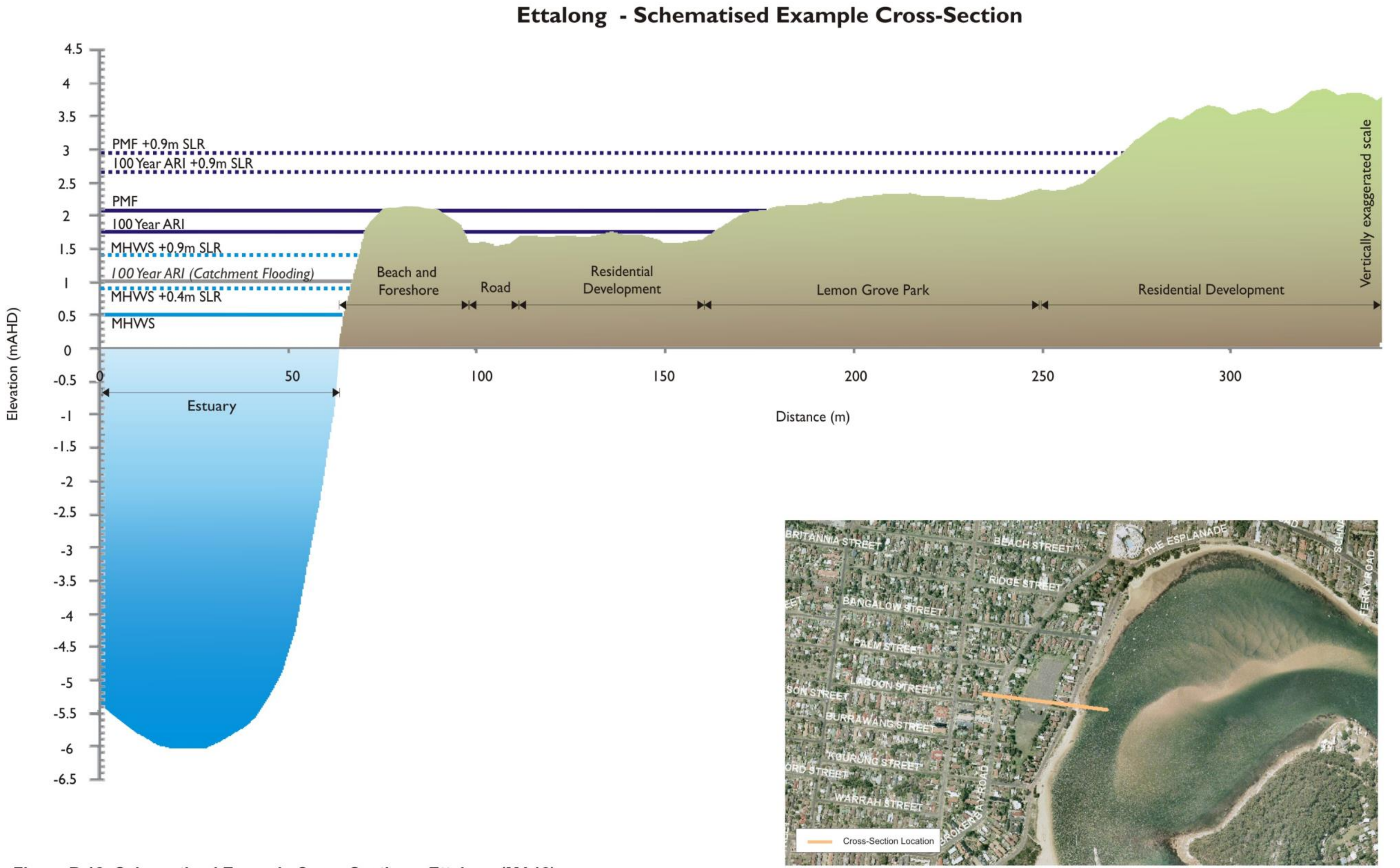


Figure B.12: Schematised Example Cross-Section – Ettalong (MA12)

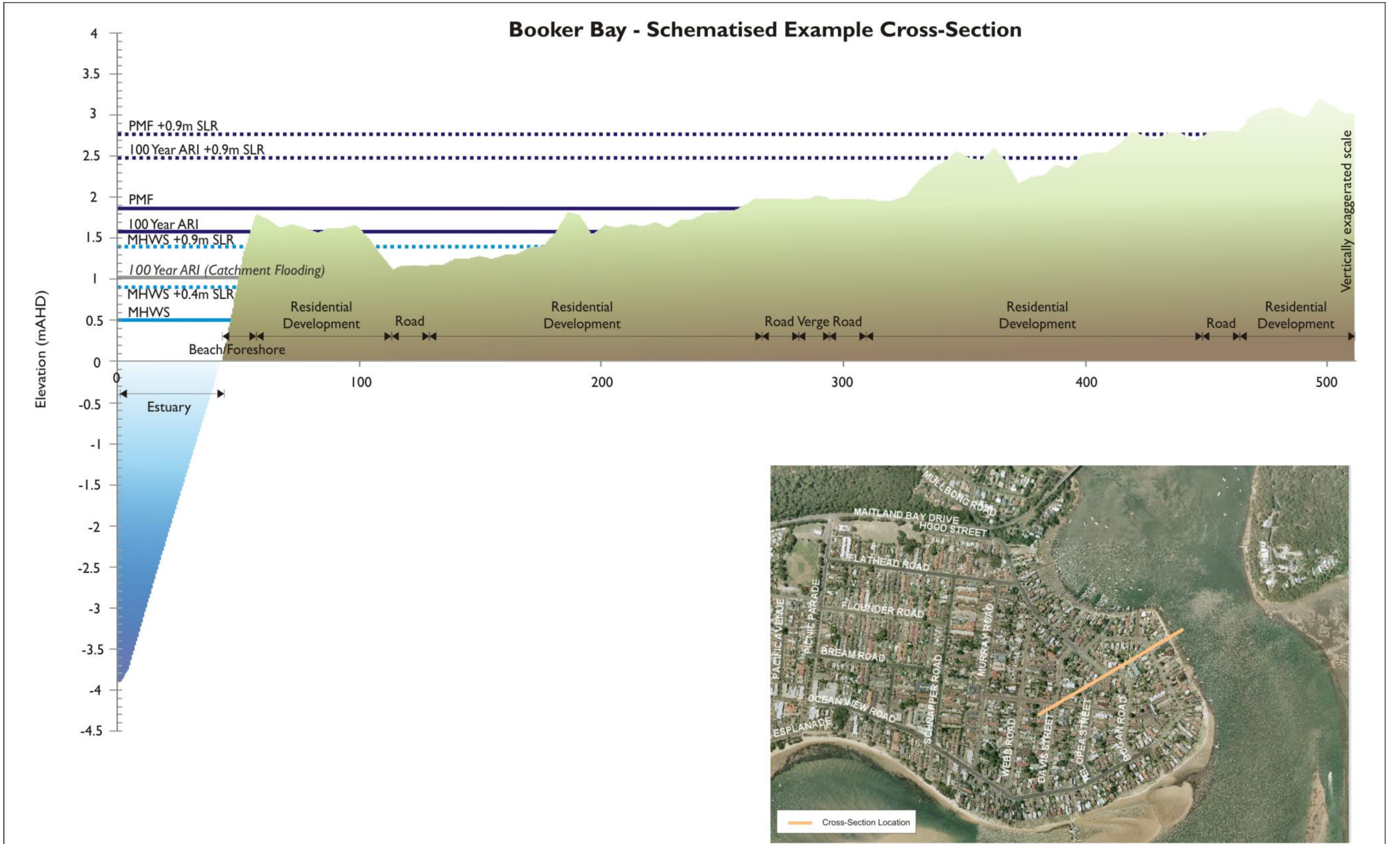


Figure B.13: Schematised Example Cross-Section – Booker Bay (MA13)

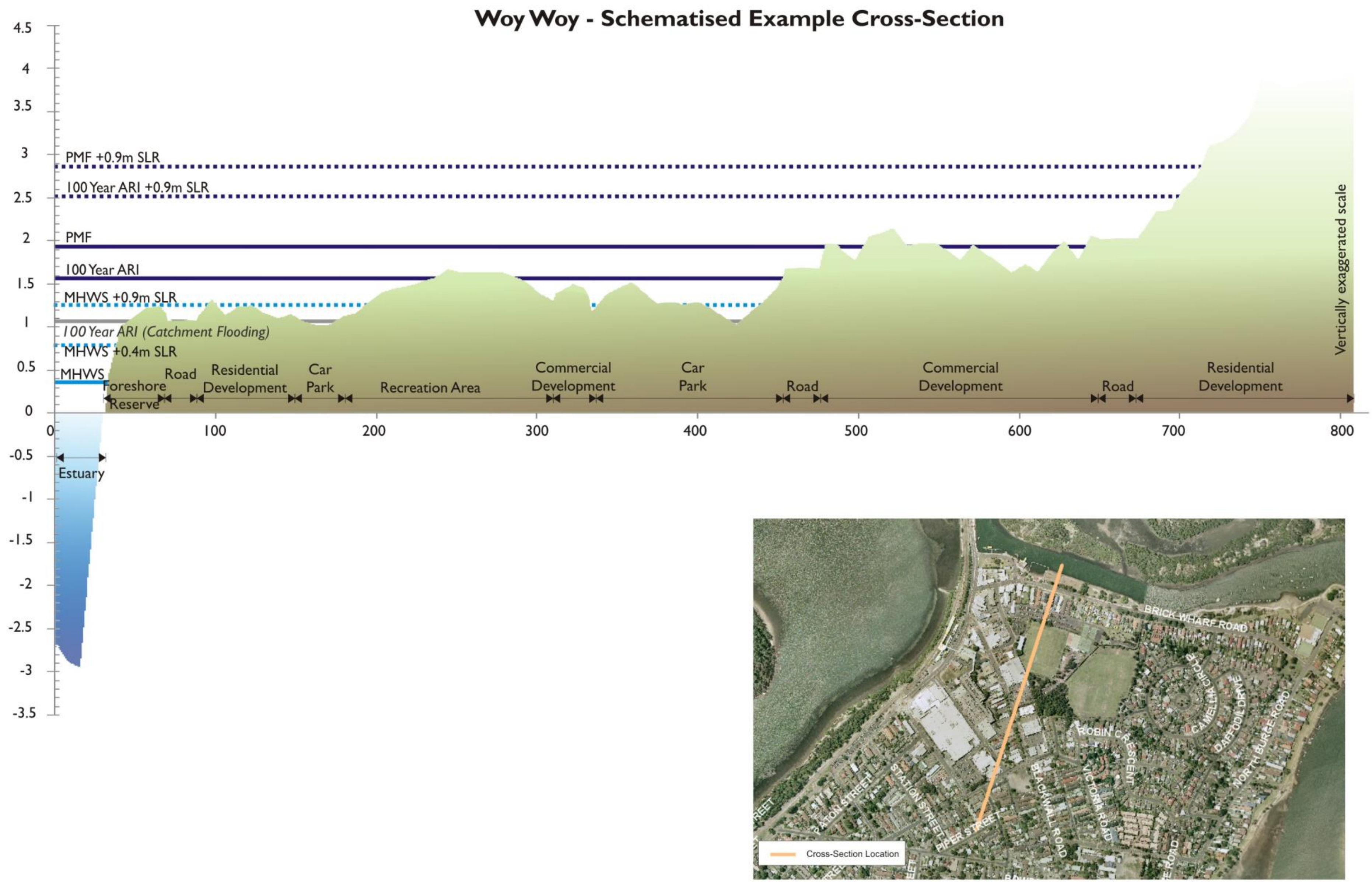


Figure B.14: Schematised Example Cross-Section – Woy Woy (MA14)

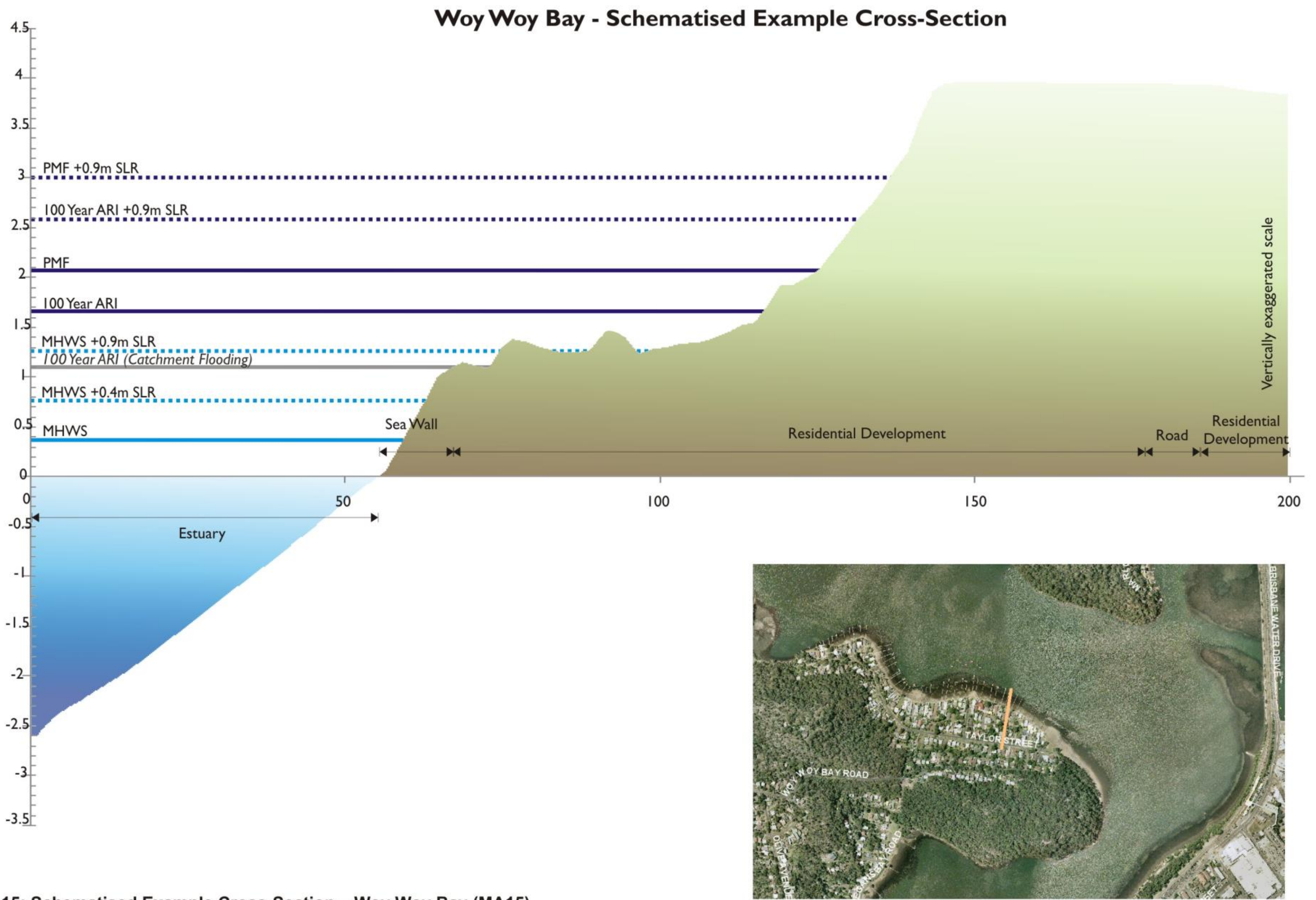
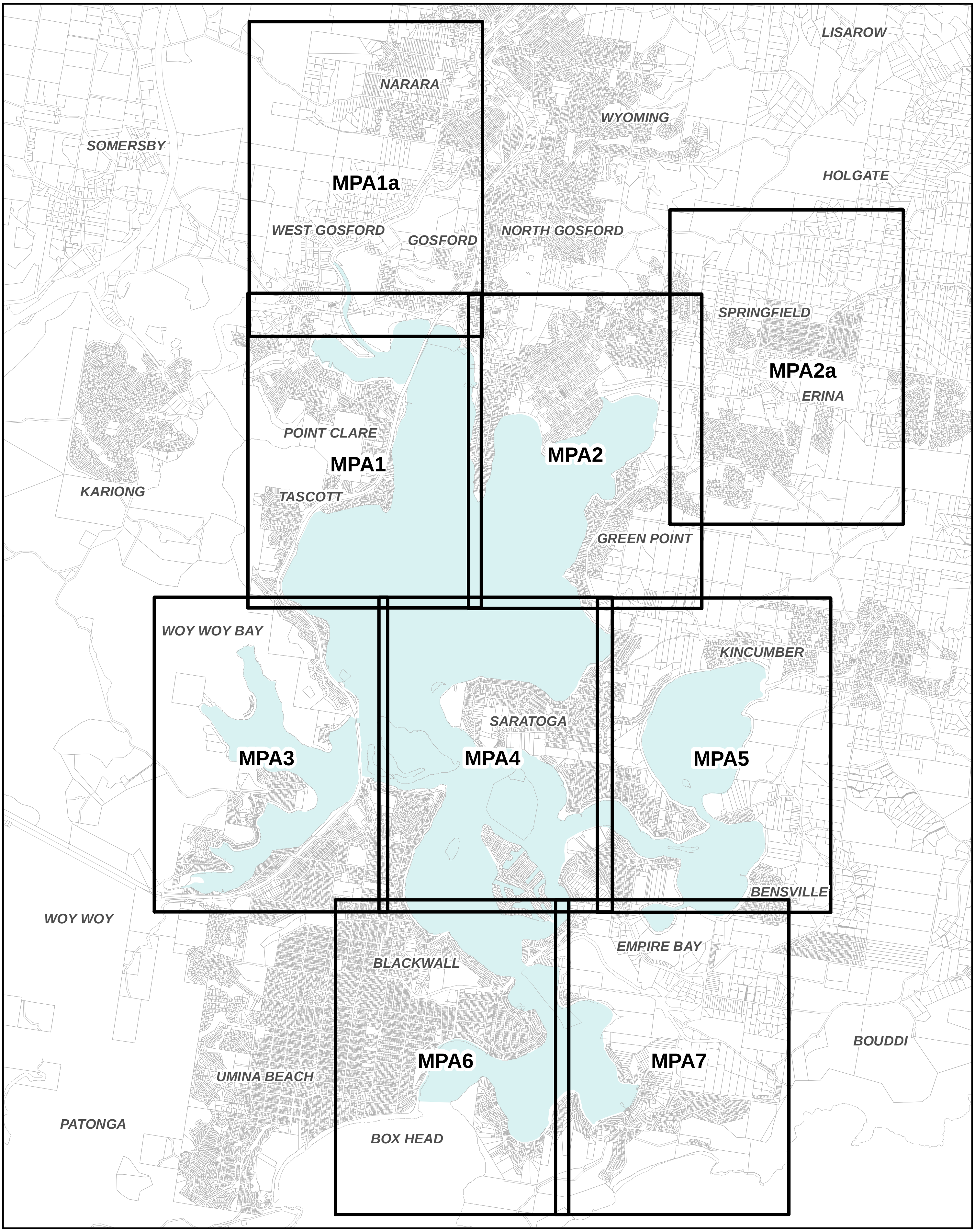


Figure B.15: Schematised Example Cross-Section – Woy Woy Bay (MA15)

Appendix C

Flood Extents



Legend

- Mapping Areas
- Cadastre
- Waterway

1:65,000 Scale at A4

Metres
0 500 1000 1500

N W E S

Mapping Area Index

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE C1.0

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
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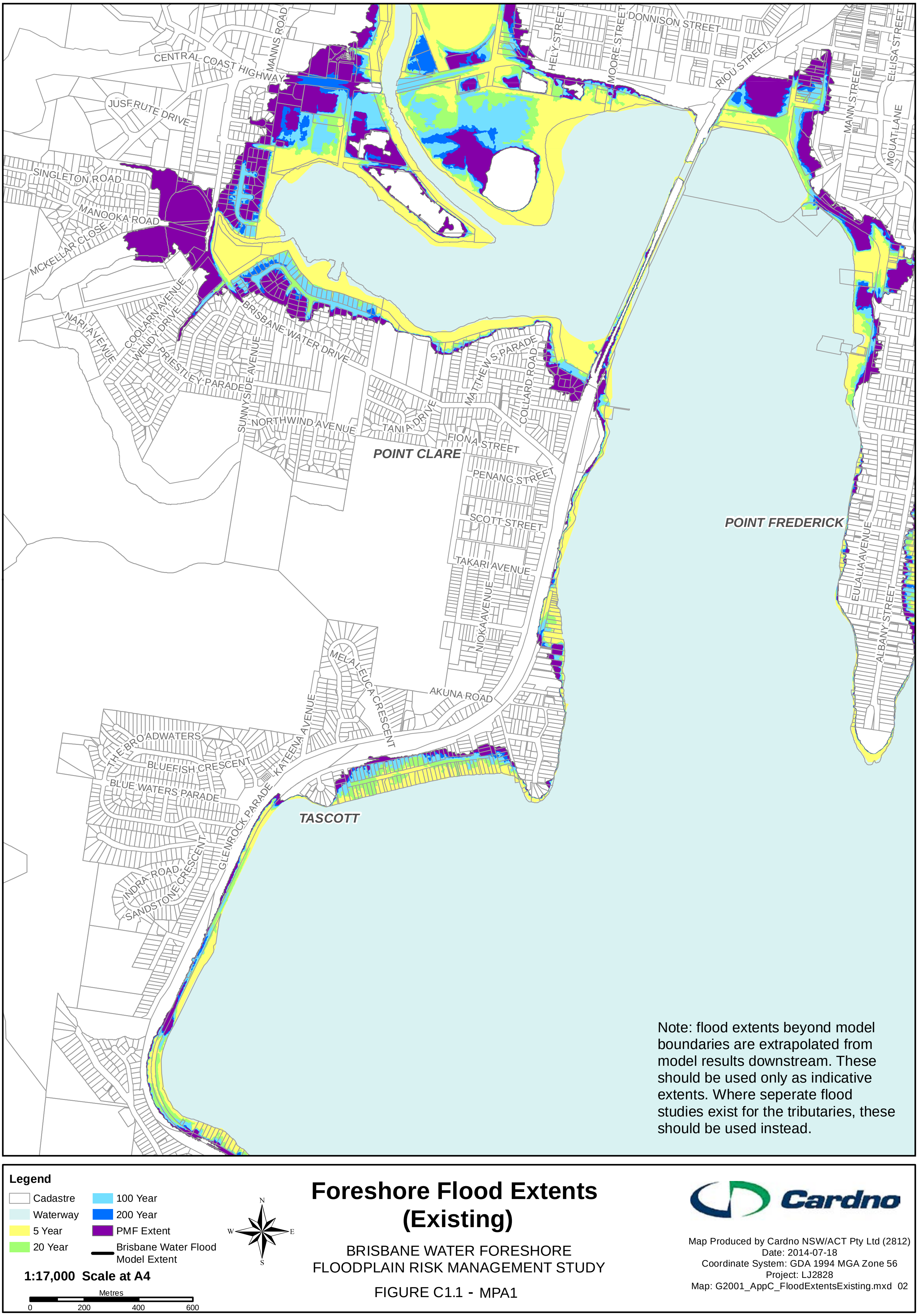
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2000_AppC_F_MappingAreas.mxd 01



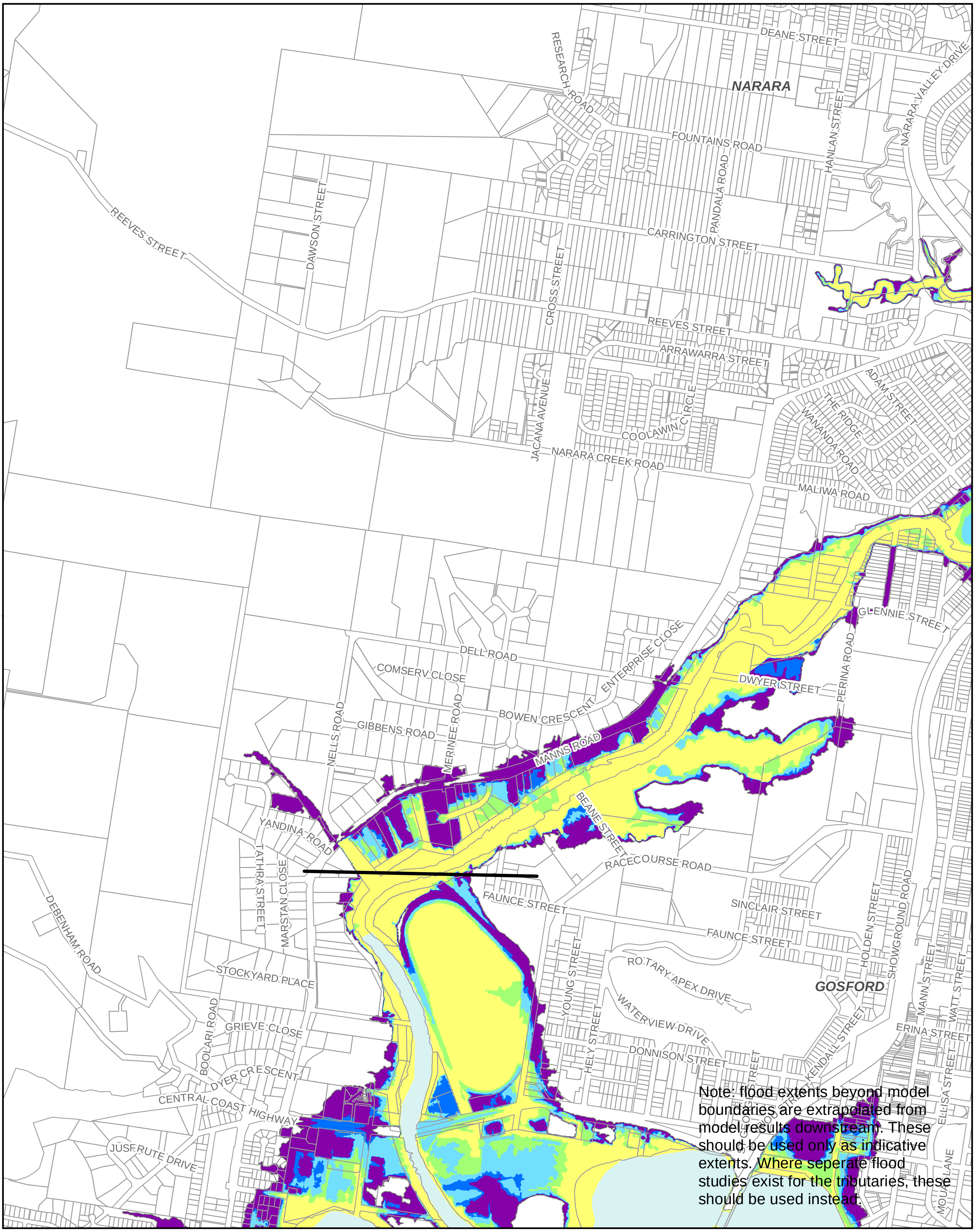
Foreshore Flood Extents (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE C1.1 - MPA1

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2001_AppC_FloodExtentsExisting.mxd 02



Legend

- Cadastre
- Waterway
- 5 Year
- 20 Year
- 100 Year
- 200 Year
- PMF Extent
- Brisbane Water Flood Model Extent

1:17,000 Scale at A4

Metres

0 200 400 600

N E S W

Foreshore Flood Extents (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE C1.2 - MPA1a

Cardno

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Project: LJ2828
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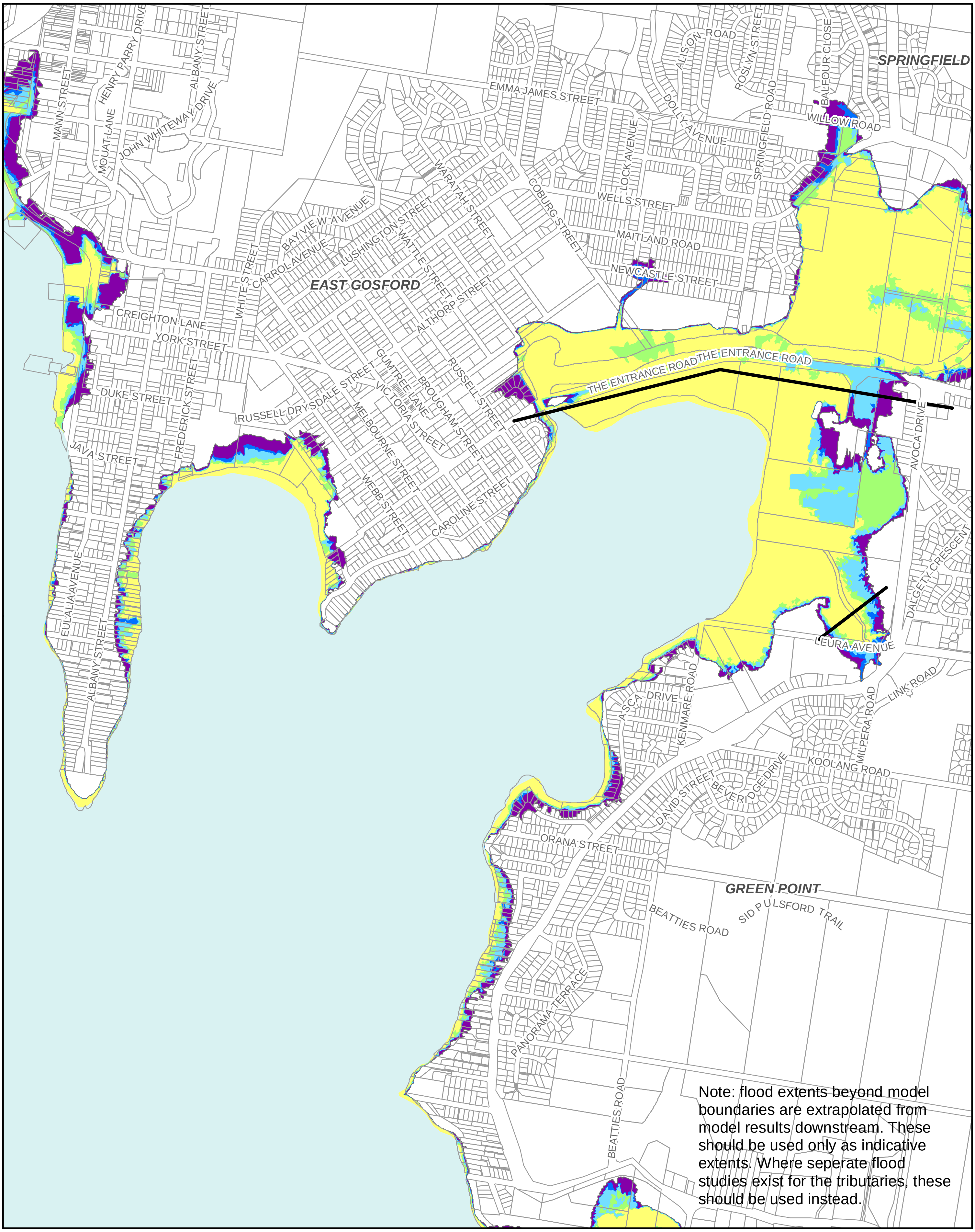

Legend

- Cadastre
- Waterway
- 5 Year
- 20 Year
- 100 Year
- 200 Year
- PMF Extent
- Brisbane Water Flood Model Extent

N W E S

1:17,000 Scale at A4

Metres
0 200 400 600

Foreshore Flood Extents (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE C1.3 - MPA2

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
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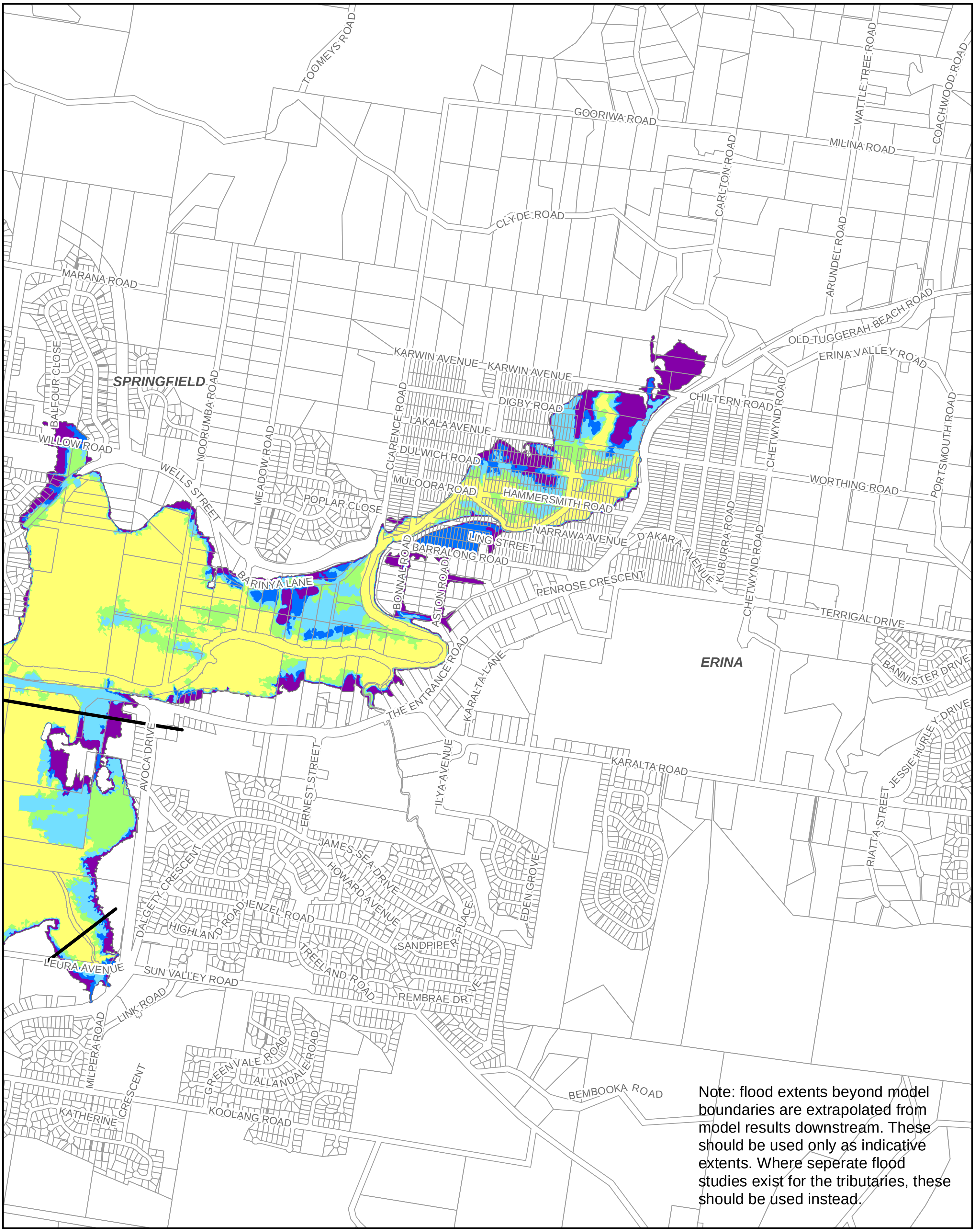
Project: LJ2828
Map: G2001_AppC_FloodExtentsExisting.mxd 02



Note: flood extents beyond model boundaries are extrapolated from model results downstream. These should be used only as indicative extents. Where seperate flood studies exist for the tributaries, these should be used instead.

Legend

- Cadastre
- Waterway
- 5 Year
- 20 Year
- 100 Year
- 200 Year
- PMF Extent
- Brisbane Water Flood Model Extent

1:17,000 Scale at A4

Metres

0 200 400 600

N W E S

Foreshore Flood Extents (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE C1.4 - MPA2a

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
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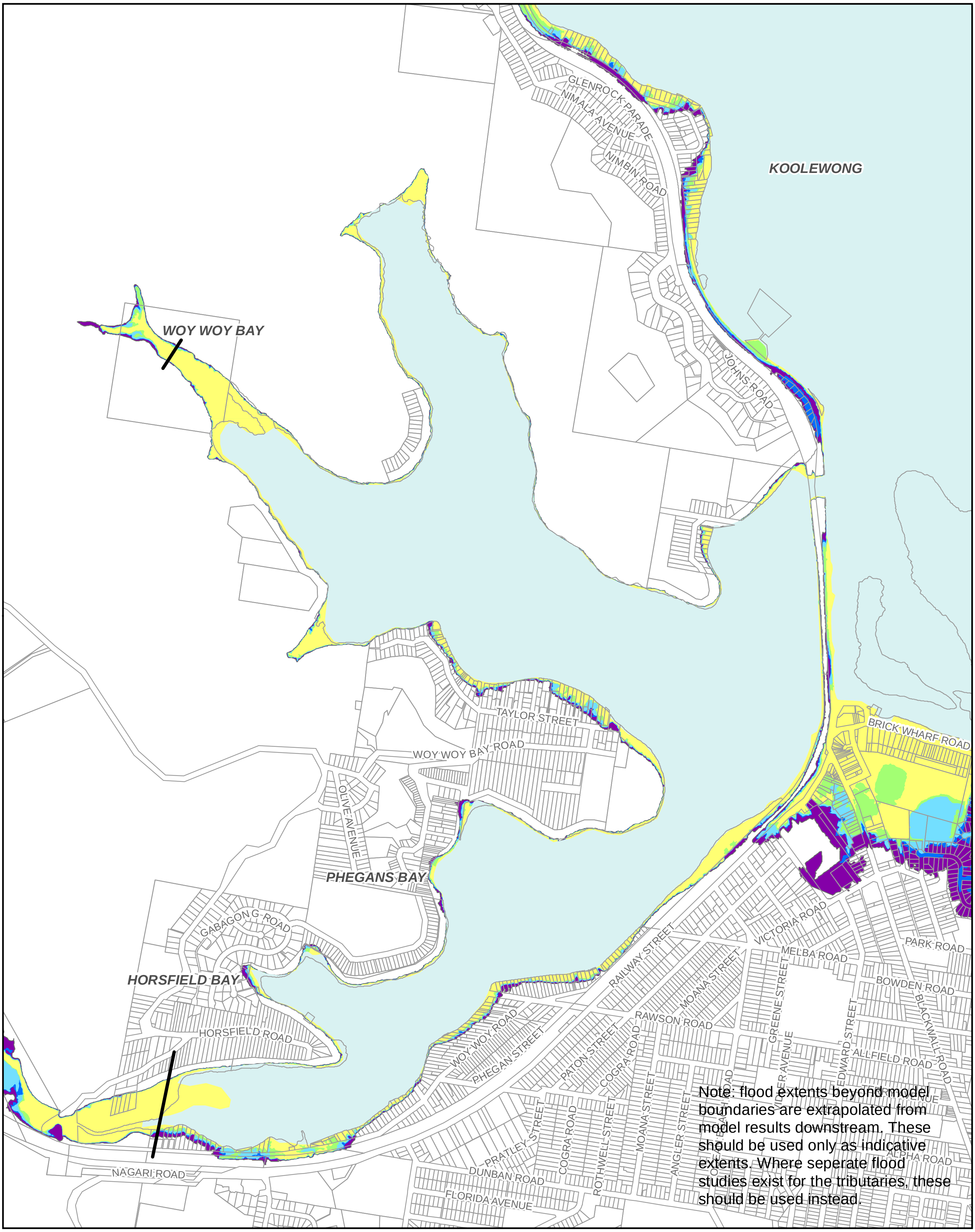

Legend

- Cadastre
- Waterway
- 5 Year
- 20 Year
- 100 Year
- 200 Year
- PMF Extent
- Brisbane Water Flood Model Extent

1:17,000 Scale at A4

Metres 0 200 400 600

Foreshore Flood Extents (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE C1.5 - MPA3

Cardno

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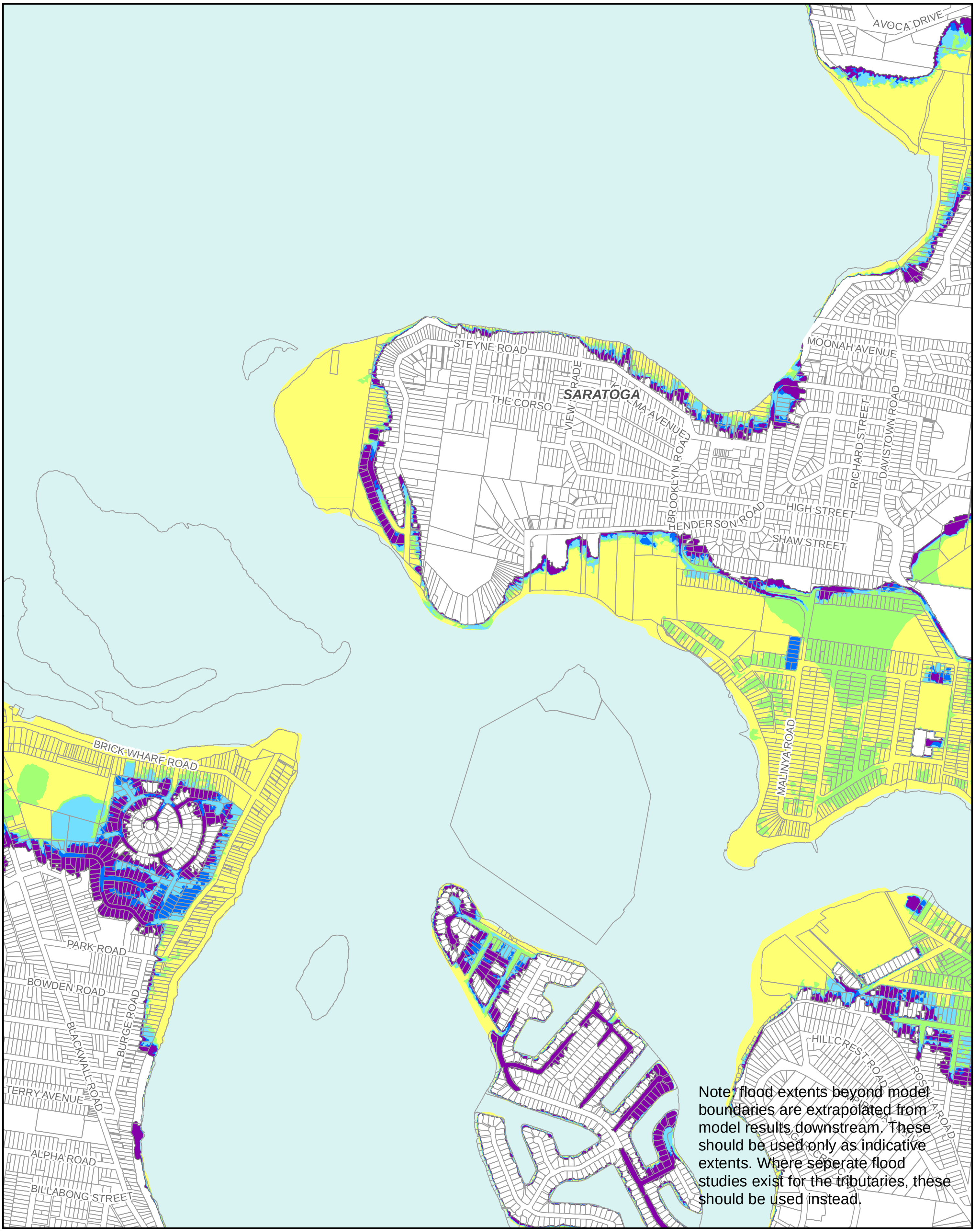

Legend

- Cadastre
- Waterway
- 5 Year
- 20 Year
- 100 Year
- 200 Year
- PMF Extent
- Brisbane Water Flood Model Extent

1:17,000 Scale at A4

Metres

0 200 400 600

Foreshore Flood Extents (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE C1.6 - MPA4

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
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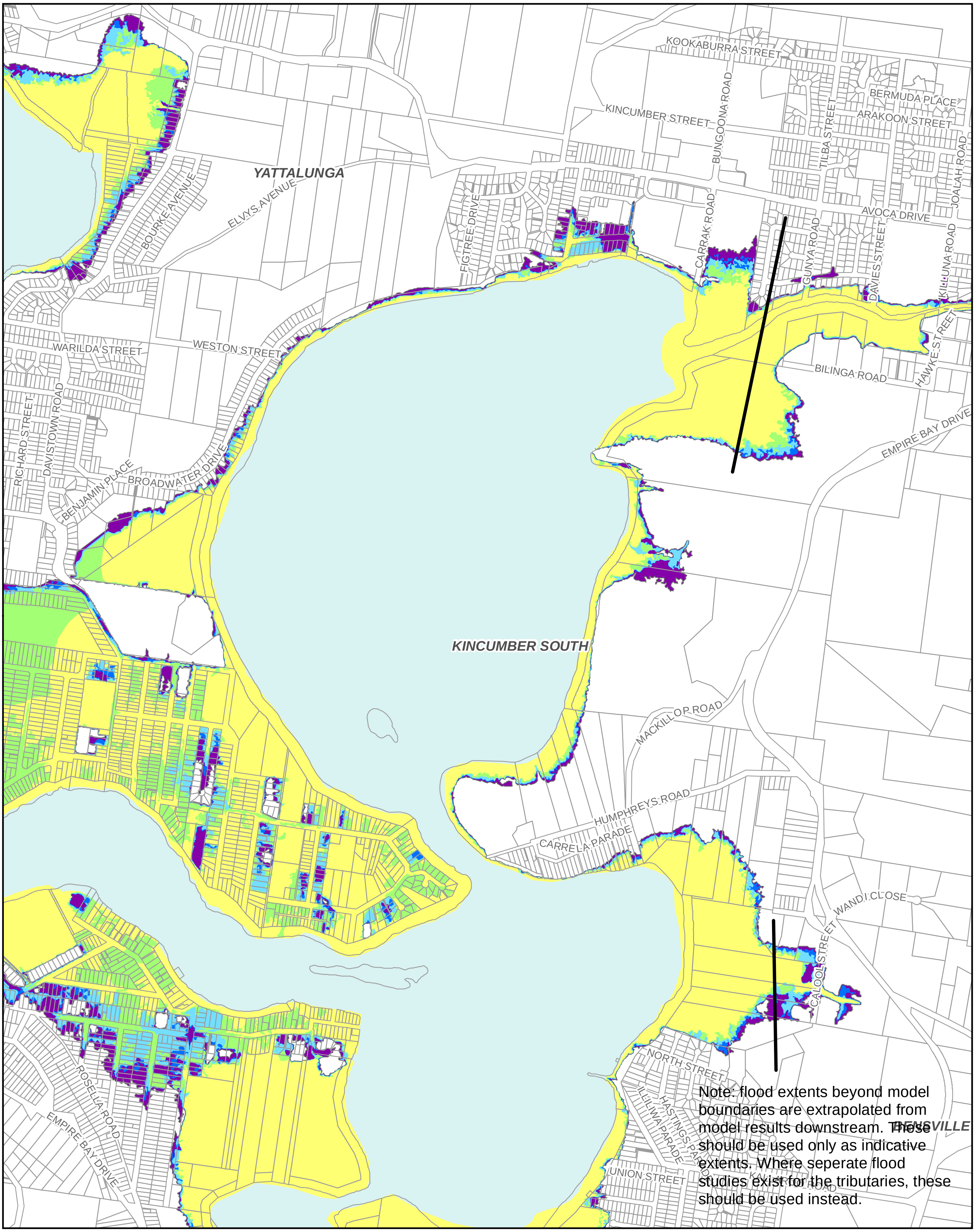

Legend

- Cadastre
- Waterway
- 5 Year
- 20 Year
- 100 Year
- 200 Year
- PMF Extent
- Brisbane Water Flood Model Extent

N
W E
S

1:17,000 Scale at A4

Metres

0 200 400 600

Foreshore Flood Extents (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE C1.7 - MPA5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
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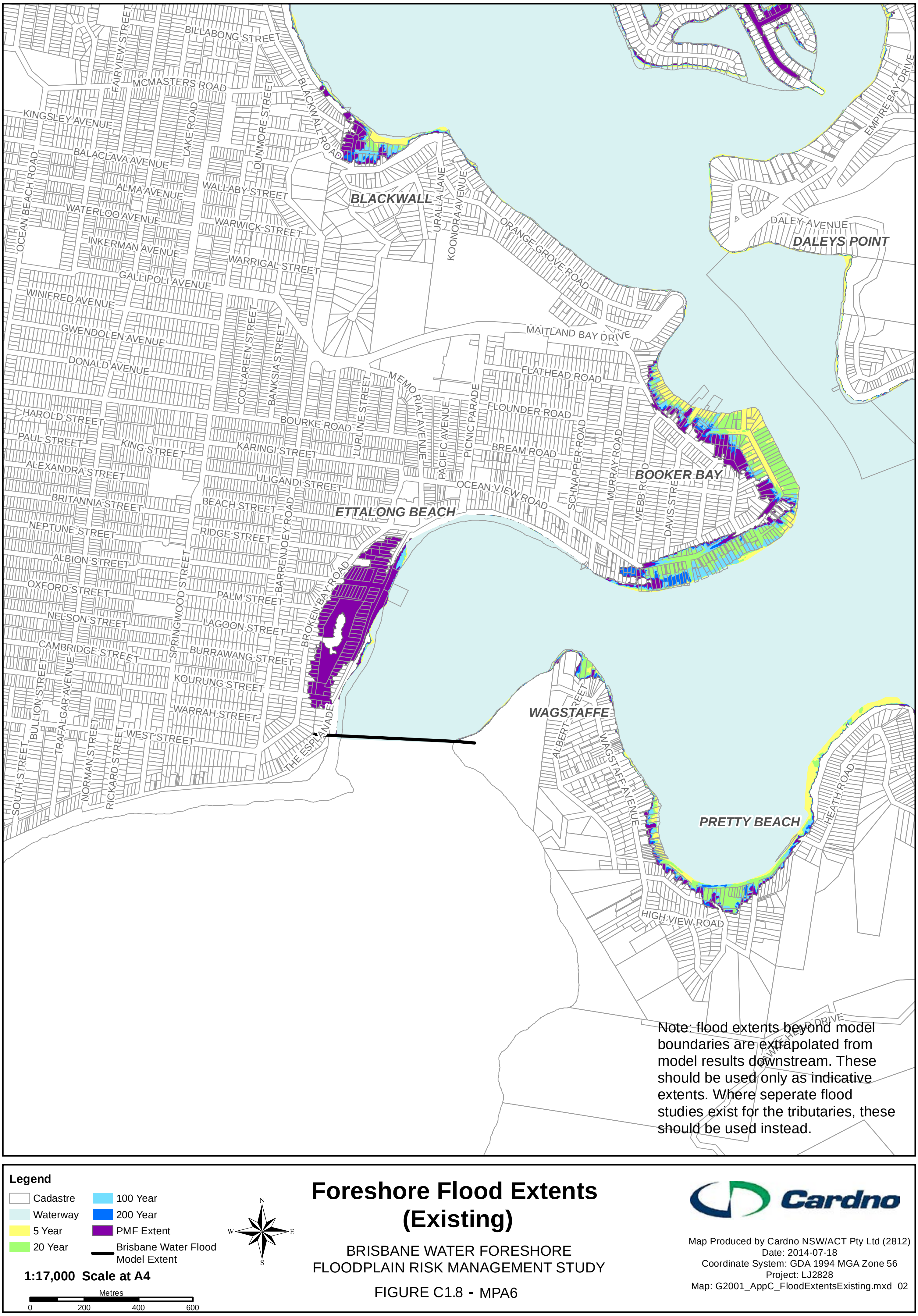
Project: LJ2828
Map: G2001_AppC_FloodExtentsExisting.mxd 02



Foreshore Flood Extents (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE C1.8 - MPA6

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
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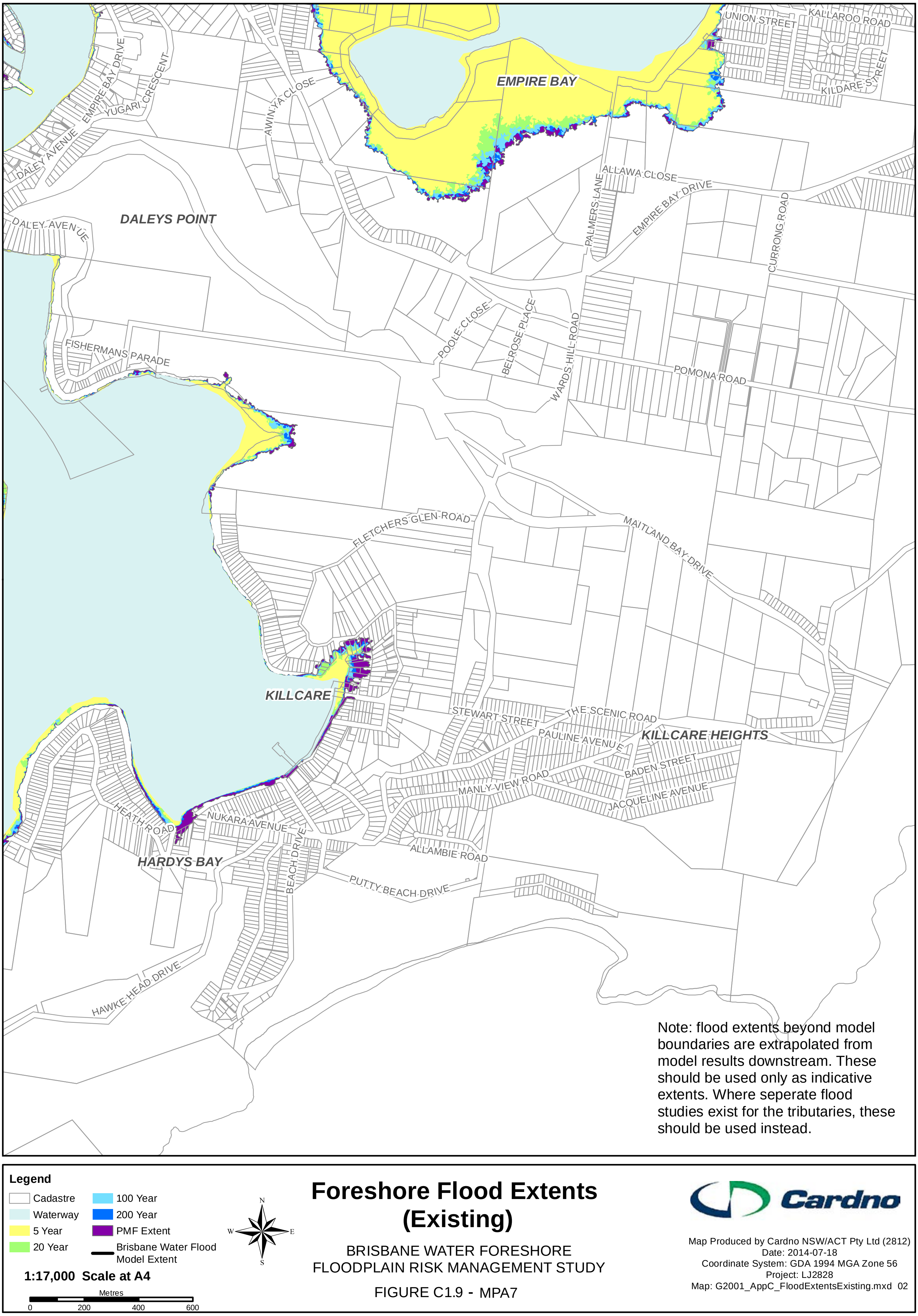
Project: LJ2828
Map: G2001_AppC_FloodExtentsExisting.mxd 02



Foreshore Flood Extents (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE C1.9 - MPA7

Cardno

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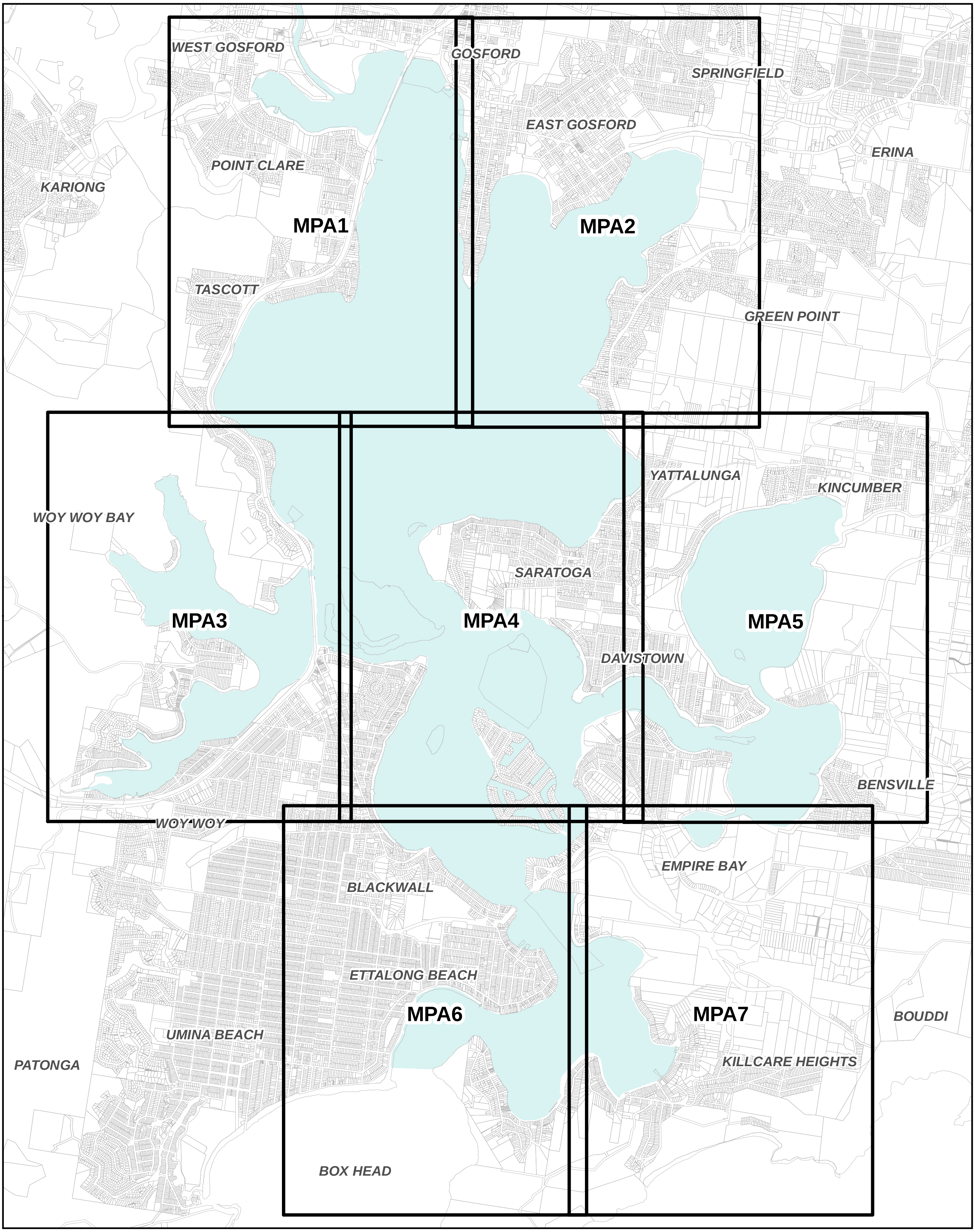
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2001_AppC_FloodExtentsExisting.mxd 02

Appendix D

Flood Hazard Extents



Legend
Mapping Areas
Cadastre
SuburbLabels
Waterway

1:50,000 Scale at A4

Metres
0 500 1000 1500

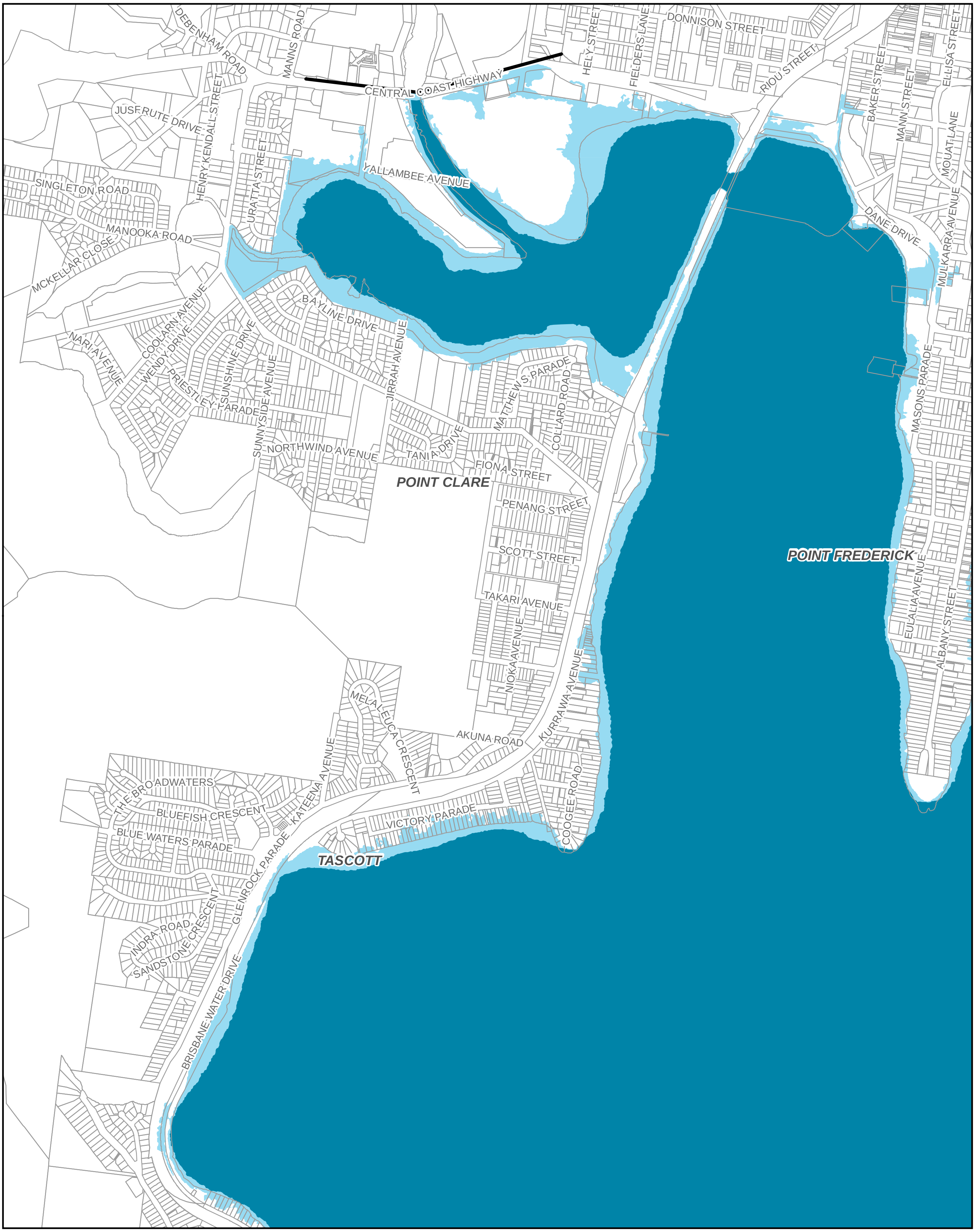
Mapping Area Index

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D1.0

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-17
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2000_AppD_E_MappingAreas.mxd 01



Legend

- Cadastre
- High Hazard
- Low Hazard
- Brisbane Water Flood Hazard Mapping Extent

1:17,000 Scale at A4

Metres
0 200 400 600

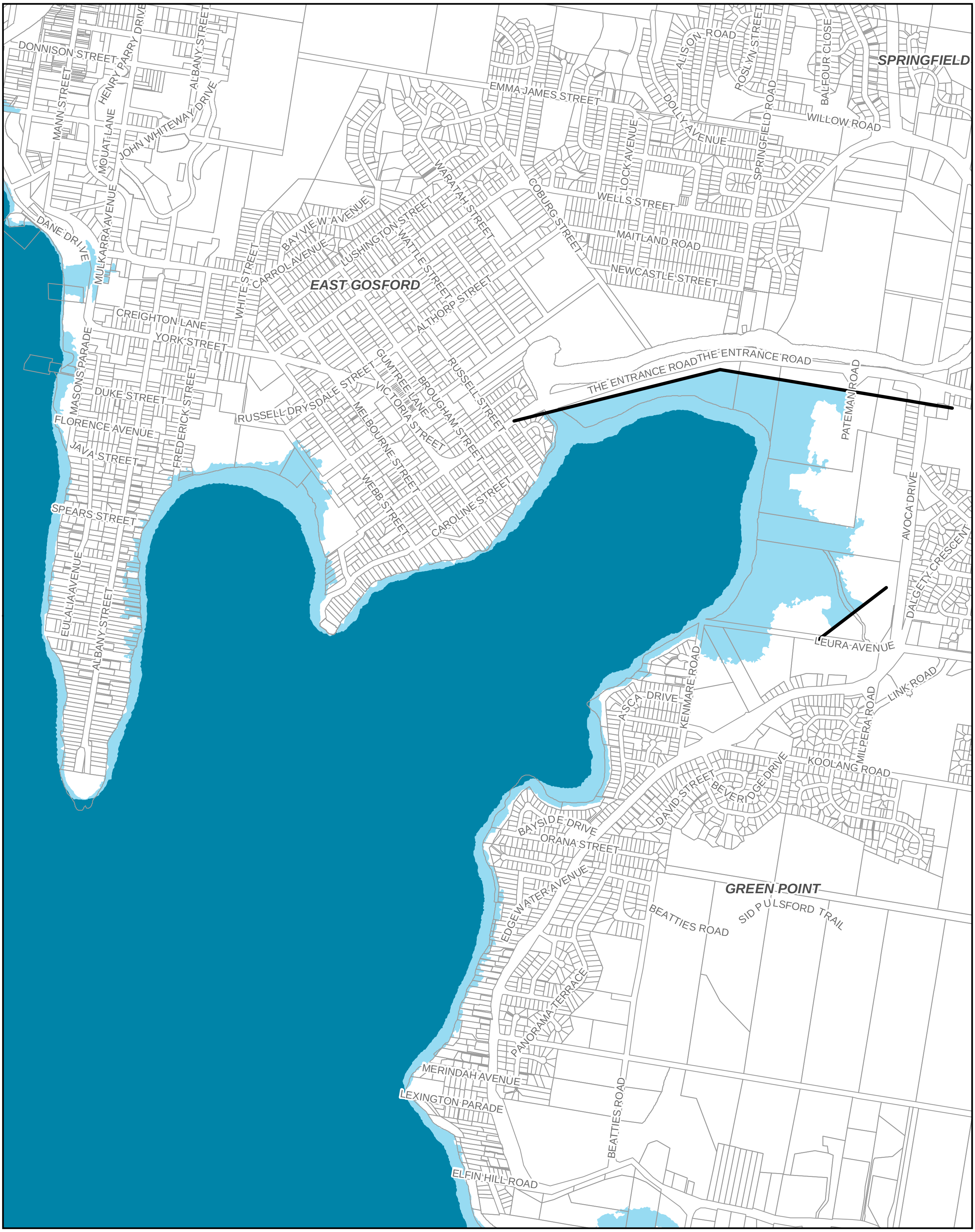
Provisional Flood Hazard
5 Year ARI (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D1.1 - MPA1

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2002_AppD_ProvisionalFloodHazard_5yrARI.mxd 01



Legend

- Cadastre
- High Hazard
- Low Hazard
- Brisbane Water Flood Hazard Mapping Extent

1:17,000 Scale at A4

Metres: 0, 200, 400, 600

N, E, S, W

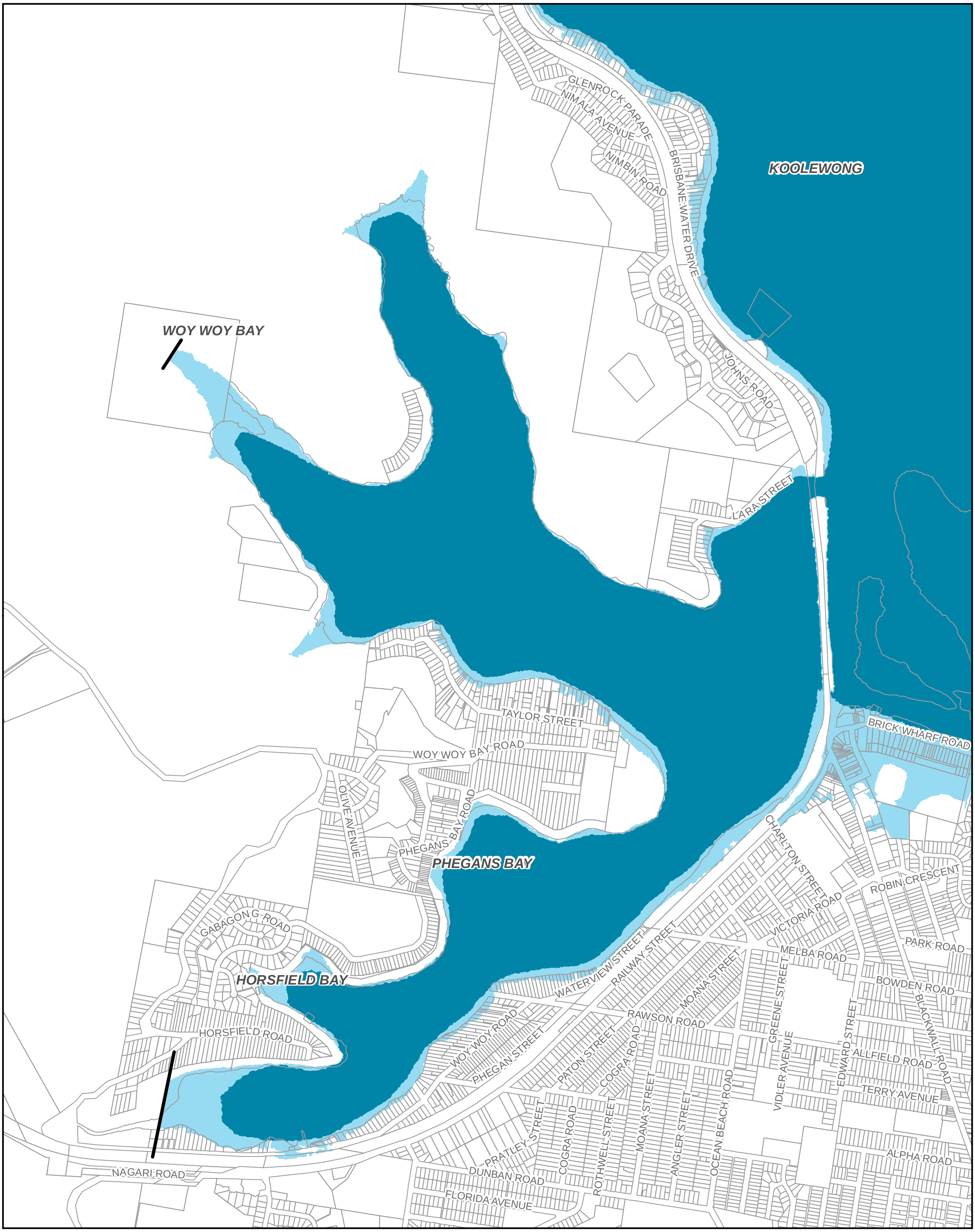
Provisional Flood Hazard 5 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D1.3 - MPA2

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2002_AppD_ProvisionalFloodHazard_5yrARI.mxd 01



Legend

- Cadastre
- High Hazard
- Low Hazard
- Brisbane Water Flood Hazard Mapping Extent

1:17,000 Scale at A4

Metres
0 200 400 600

N E S W

Provisional Flood Hazard 5 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D1.5 - MPA3

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2002_AppD_ProvisionalFloodHazard_5yrARI.mxd 01

Legend

- Cadastre
- High Hazard
- Low Hazard
- Brisbane Water Flood Hazard Mapping Extent

1:17,000 Scale at A4

Metres
0 200 400 600

Provisional Flood Hazard 5 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D1.6 - MPA4

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2002_AppD_ProvisionalFloodHazard_5yrARI.mxd 01

Legend

- Cadastre
- High Hazard
- Low Hazard
- Brisbane Water Flood Hazard Mapping Extent

1:17,000 Scale at A4

Metres

0 200 400 600

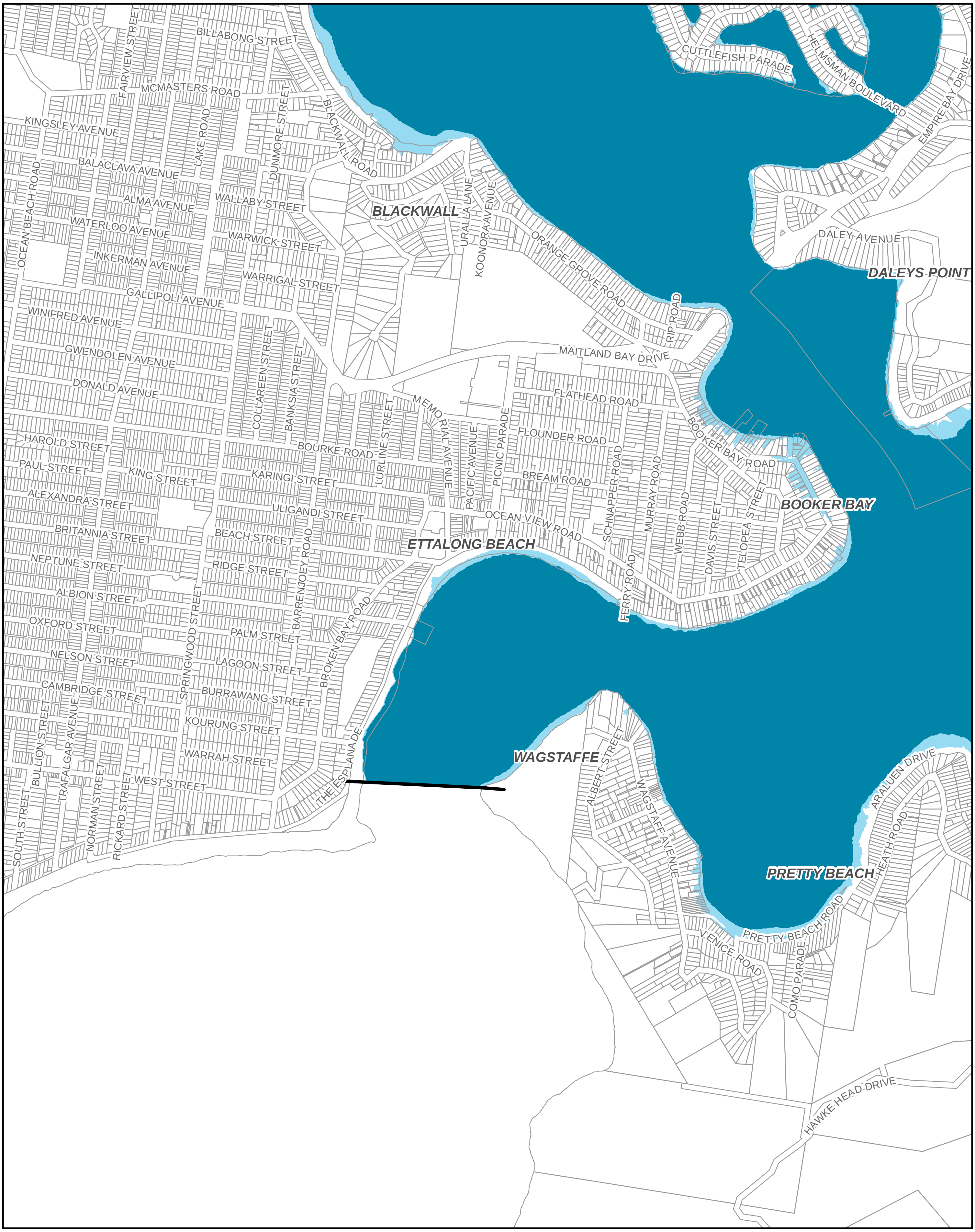
Provisional Flood Hazard 5 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D1.7 - MPA5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2002_AppD_ProvisionalFloodHazard_5yrARI.mxd 01



Legend

- Cadastre
- High Hazard
- Low Hazard
- Brisbane Water Flood Hazard Mapping Extent

1:17,000 Scale at A4

Metres

0 200 400 600

N W E S

Provisional Flood Hazard
5 Year ARI (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D1.8 - MPA6

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2002_AppD_ProvisionalFloodHazard_5yrARI.mxd 01

Legend

- Cadastre
- High Hazard
- Low Hazard
- Brisbane Water Flood Hazard Mapping Extent

1:17,000 Scale at A4

Metres

0 200 400 600

N E S W

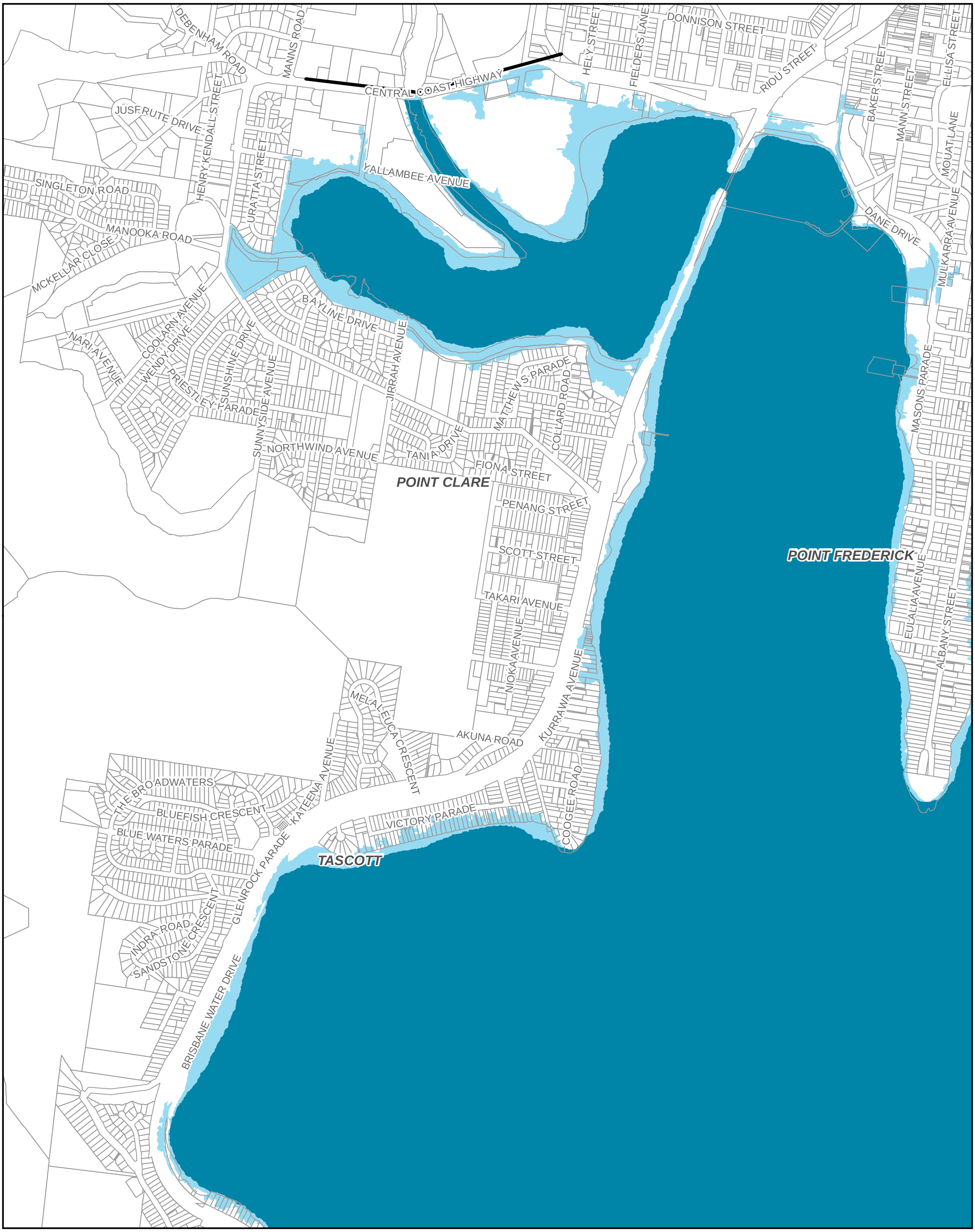
Provisional Flood Hazard
5 Year ARI (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D1.9 - MPA7

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2002_AppD_ProvisionalFloodHazard_5yrARI.mxd 01



Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres

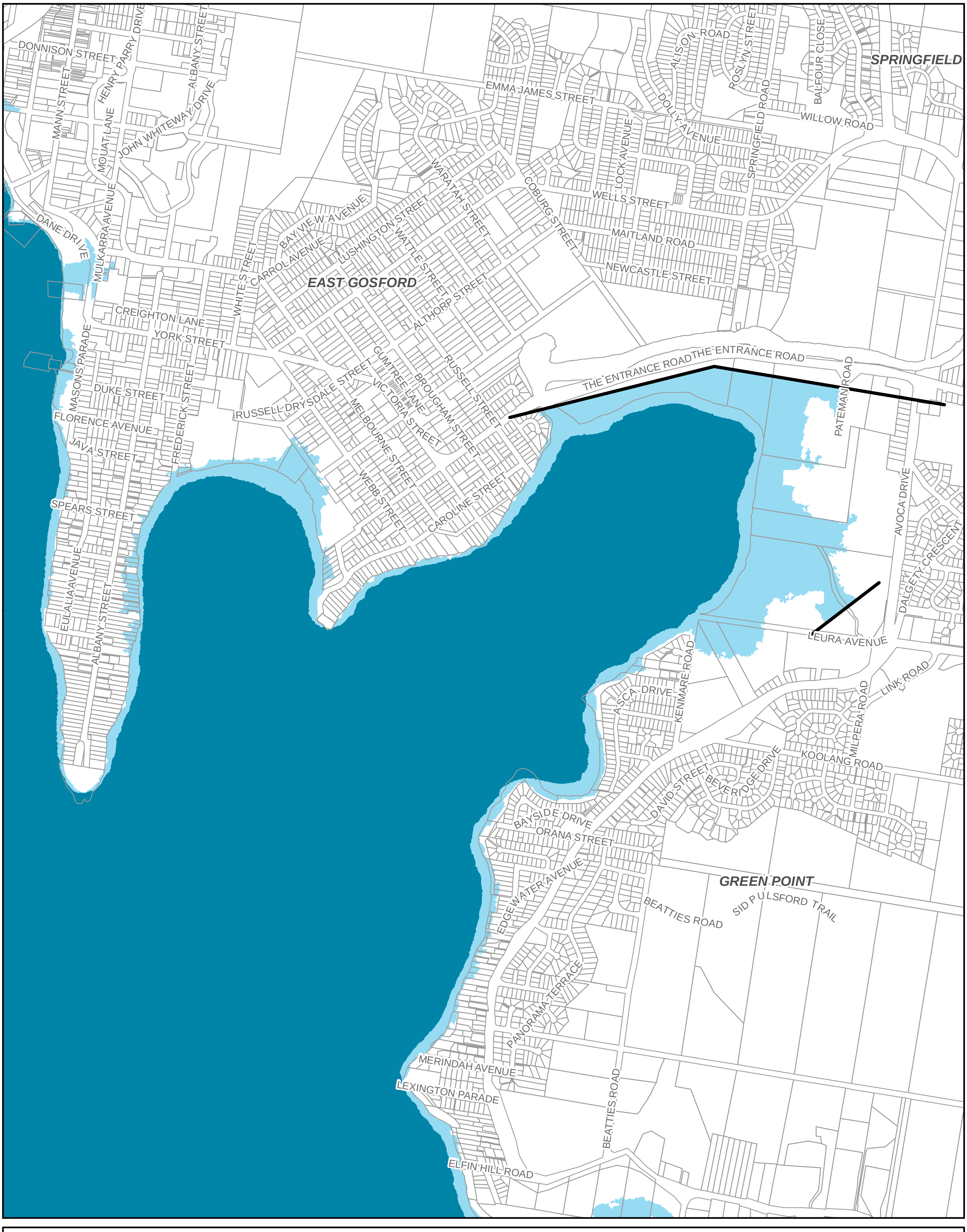
0 200 400 600

Provisional Flood Hazard 20 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D2.1 - MPA1

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2003_AppD_ProvisionalFloodHazard_20yrARI.mxd 01



Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres
0 200 400 600

N
W E
S

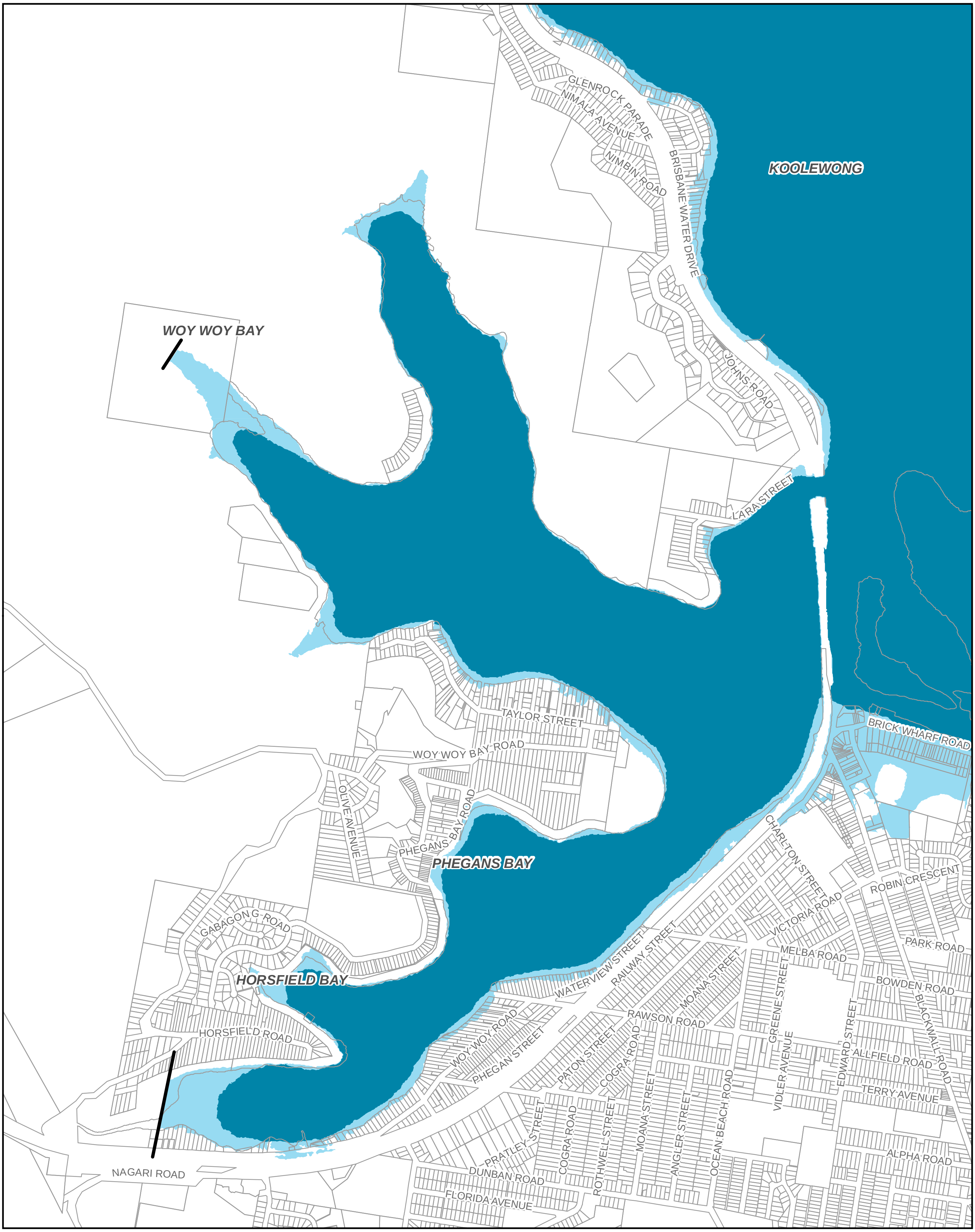
Provisional Flood Hazard 20 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D2.3 - MPA2

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2003_AppD_ProvisionalFloodHazard_20yrARI.mxd 01



Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres

0 200 400 600

Provisional Flood Hazard
20 Year ARI (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D2.5 - MPA3

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2003_AppD_ProvisionalFloodHazard_20yrARI.mxd 01

Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres

0 200 400 600

Provisional Flood Hazard 20 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D2.6 - MPA4

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2003_AppD_ProvisionalFloodHazard_20yrARI.mxd 01

Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres 0 200 400 600

N E S W

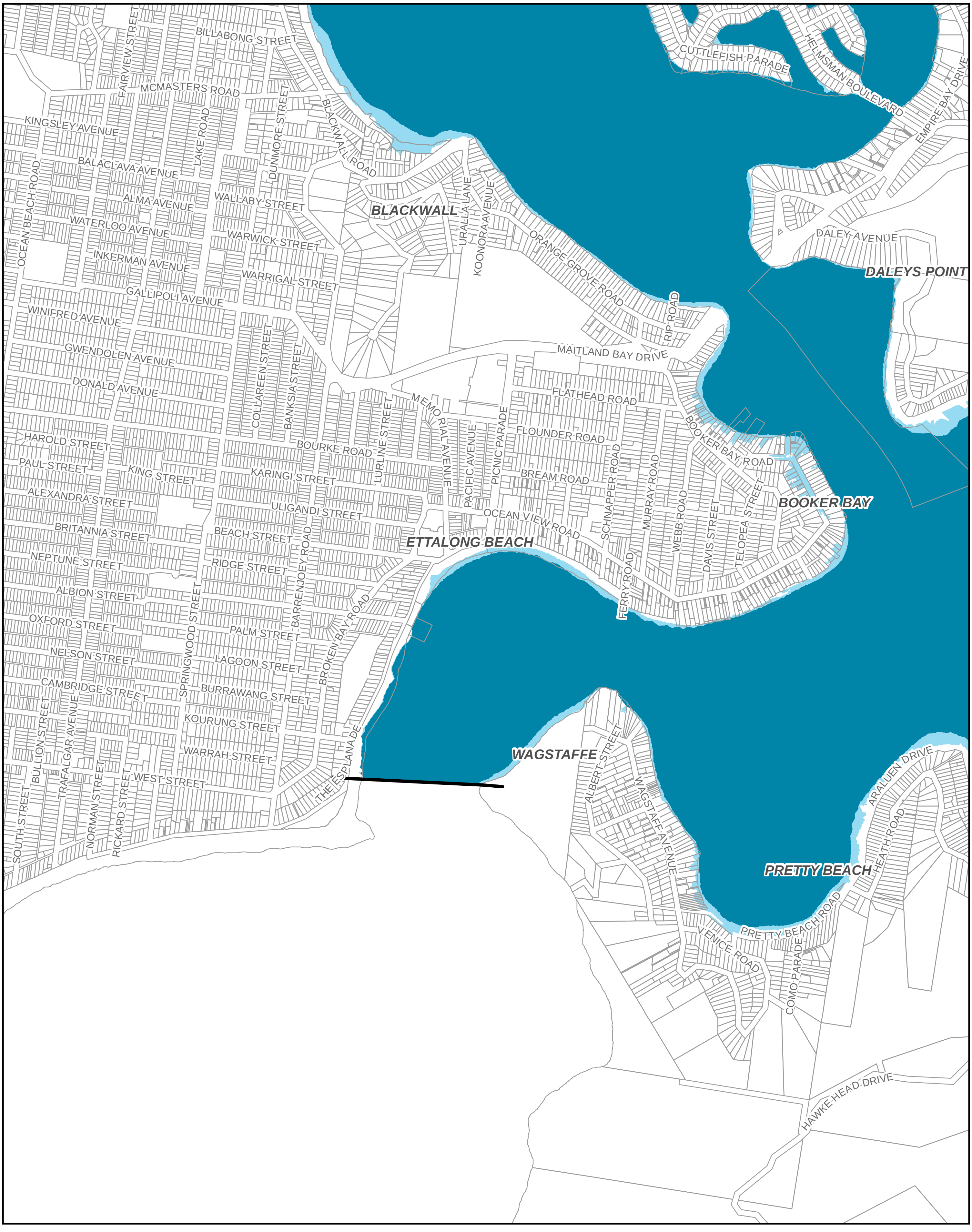
Provisional Flood Hazard 20 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D2.7 - MPA5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2003_AppD_ProvisionalFloodHazard_20yrARI.mxd 01



Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres
0 200 400 600

N
W E
S

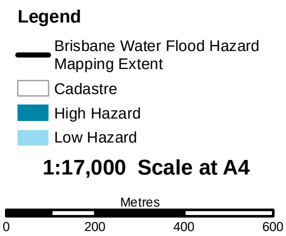
Provisional Flood Hazard
20 Year ARI (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D2.8 - MPA6

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2003_AppD_ProvisionalFloodHazard_20yrARI.mxd 01



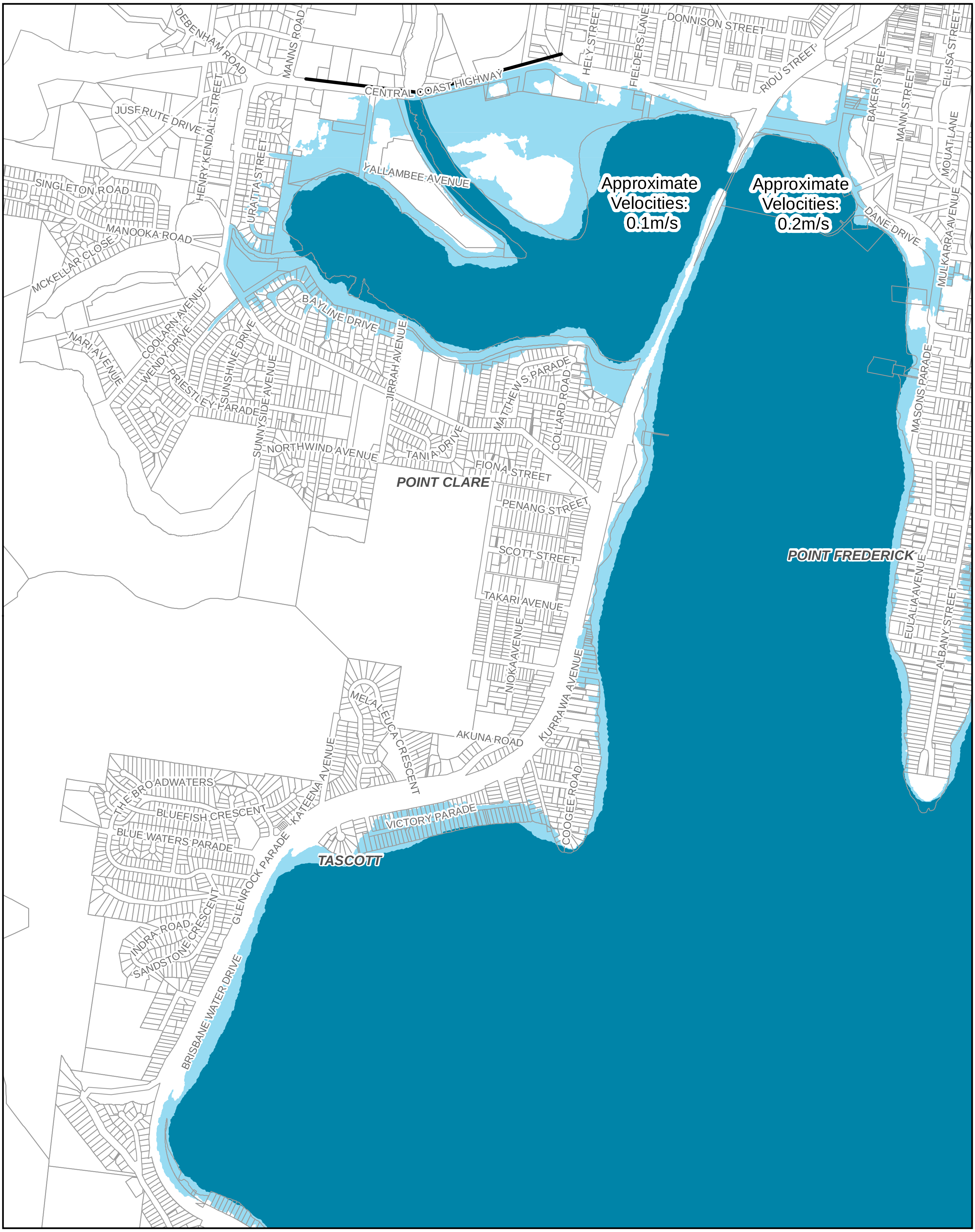
Provisional Flood Hazard
20 Year ARI (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D2.9 - MPA7

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2003_AppD_ProvisionalFloodHazard_20yrARI.mxd 01



Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres

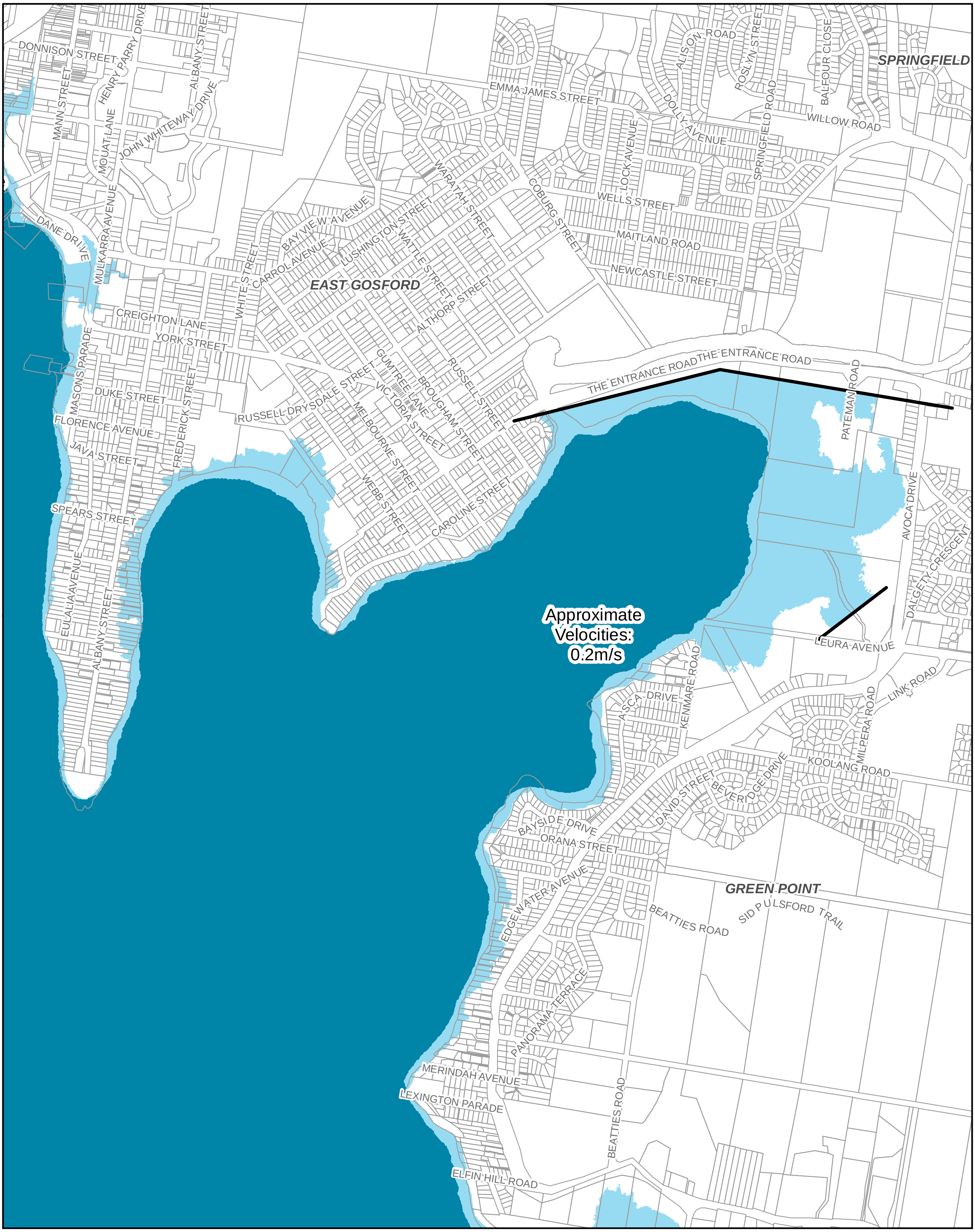
0 200 400 600

Provisional Flood Hazard 100 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D3.1 - MPA1

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2004_AppD_ProvisionalFloodHazard_100yrARI.mxd 01



Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres

0 200 400 600

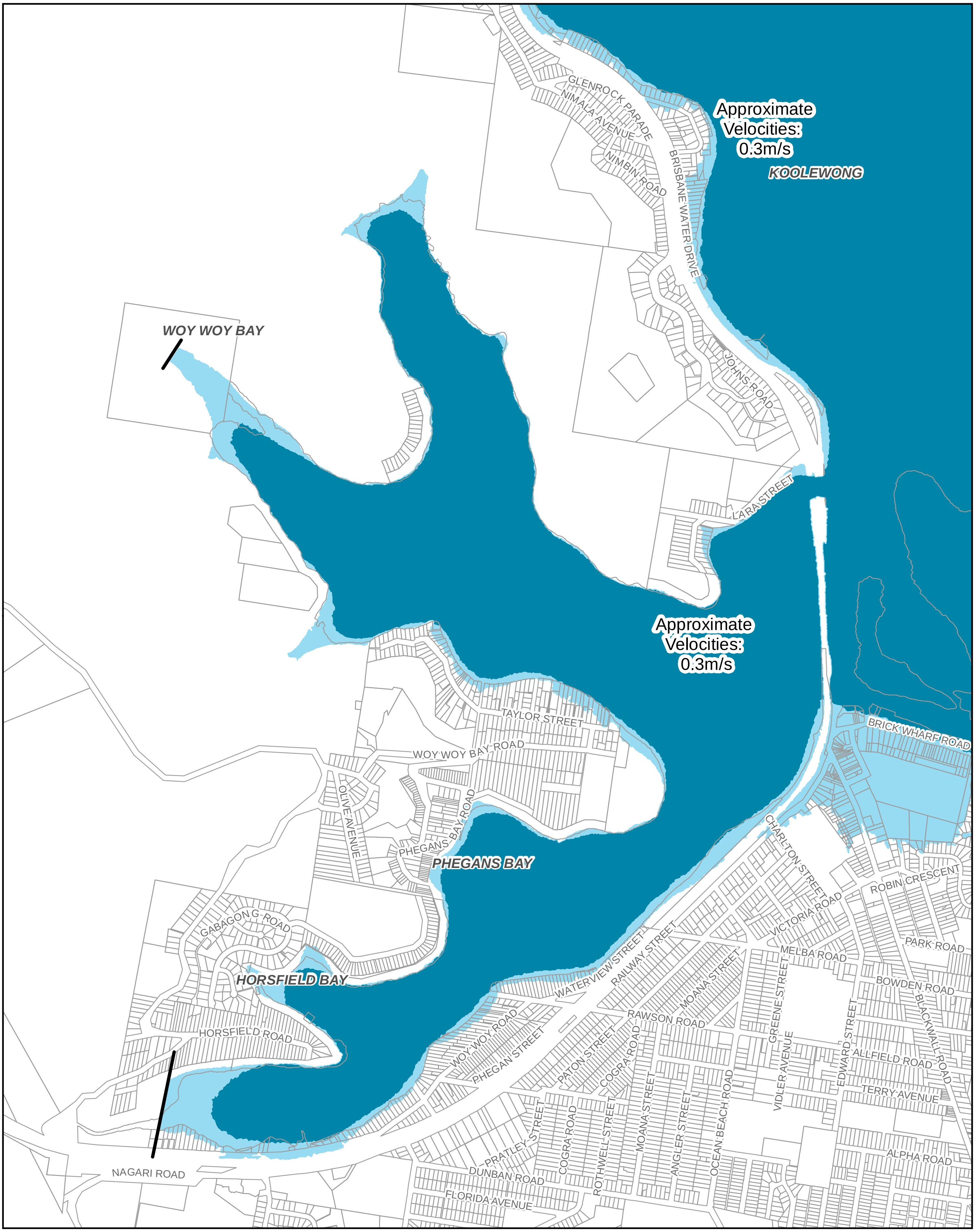
Provisional Flood Hazard 100 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D3.3 - MPA2

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2004_AppD_ProvisionalFloodHazard_100yrARI.mxd 01



Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres

0 200 400 600

N W E S

Provisional Flood Hazard
100 Year ARI (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D3.5 - MPA3

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2004_AppD_ProvisionalFloodHazard_100yrARI.mxd 01

Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres

0 200 400 600

Provisional Flood Hazard 100 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D3.6 - MPA4

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2004_AppD_ProvisionalFloodHazard_100yrARI.mxd 01

Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres

0 200 400 600

N E S W

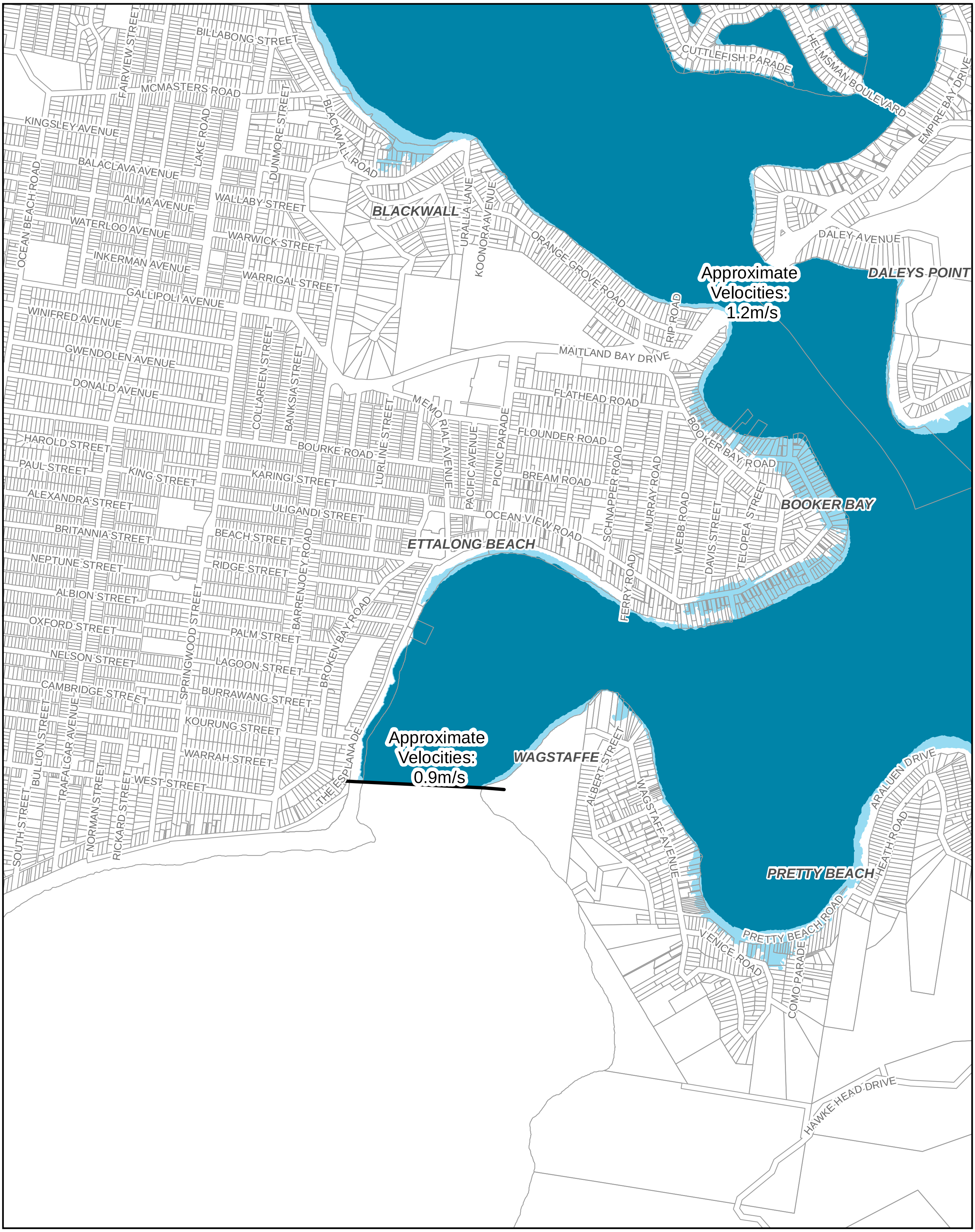
Provisional Flood Hazard 100 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D3.7 - MPA5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2004_AppD_ProvisionalFloodHazard_100yrARI.mxd 01



Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres

0 200 400 600

Provisional Flood Hazard 100 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D3.8 - MPA6

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2004_AppD_ProvisionalFloodHazard_100yrARI.mxd 01

Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres

0 200 400 600

N E S W

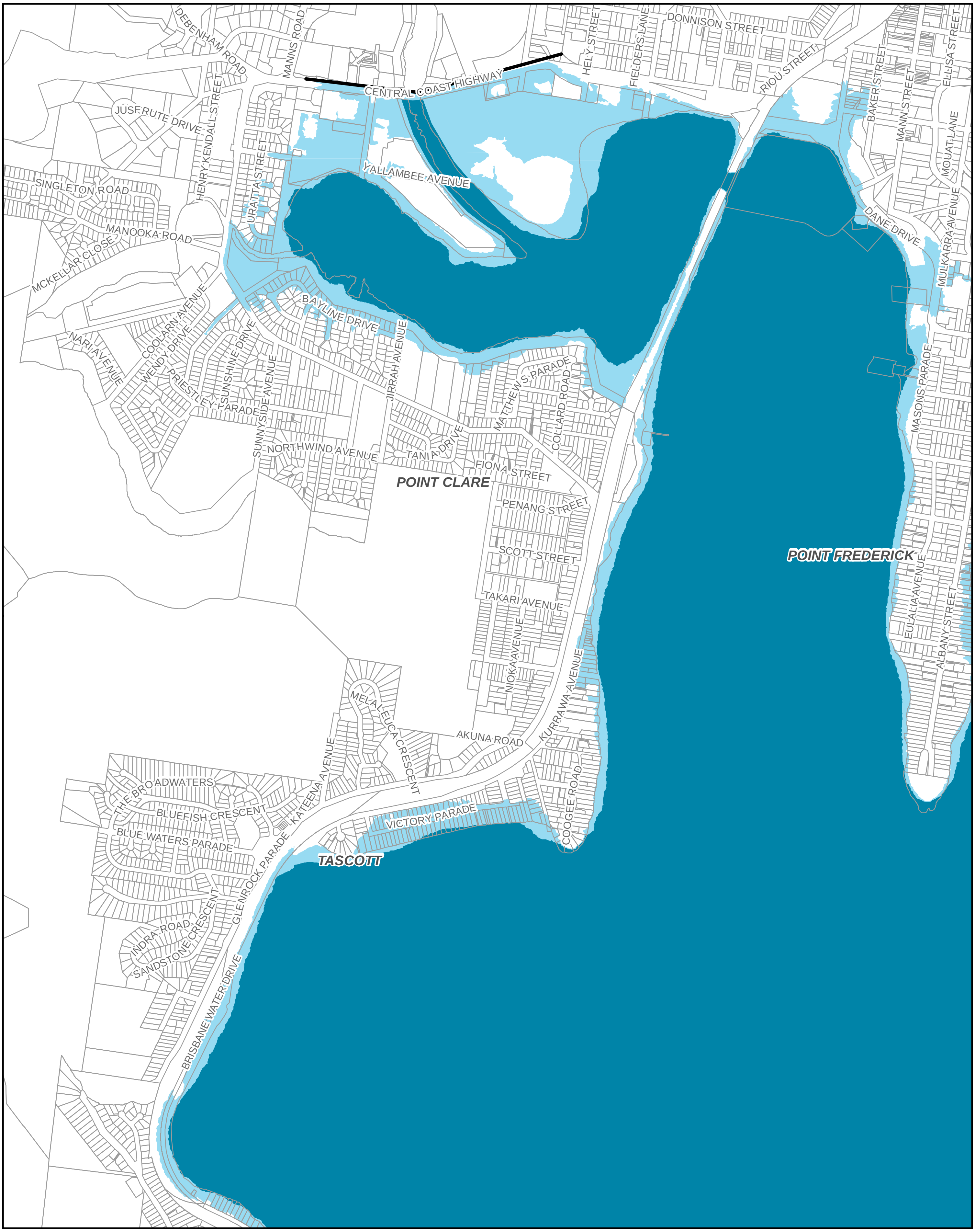
Provisional Flood Hazard 100 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D3.9 - MPA7

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2004_AppD_ProvisionalFloodHazard_100yrARI.mxd 01



Legend

- Cadastre
- High Hazard
- Low Hazard
- Brisbane Water Flood Hazard Mapping Extent

1:17,000 Scale at A4

Metres: 0 200 400 600

N E S W

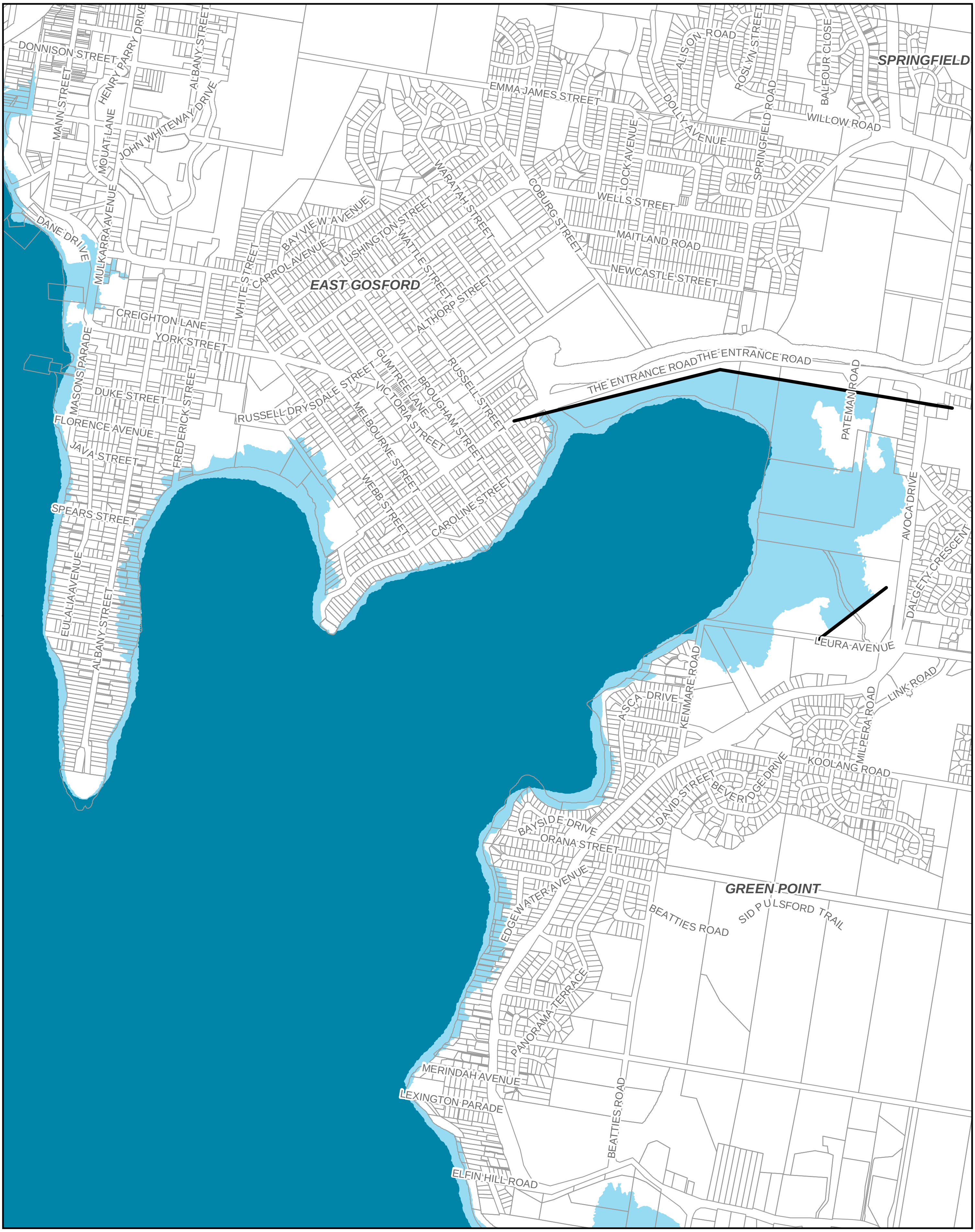
Provisional Flood Hazard 200 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D4.1 - MPA1

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2005_AppD_ProvisionalFloodHazard_200yrARI.mxd 01



Legend

- Cadastre
- High Hazard
- Low Hazard
- Brisbane Water Flood Hazard Mapping Extent

1:17,000 Scale at A4

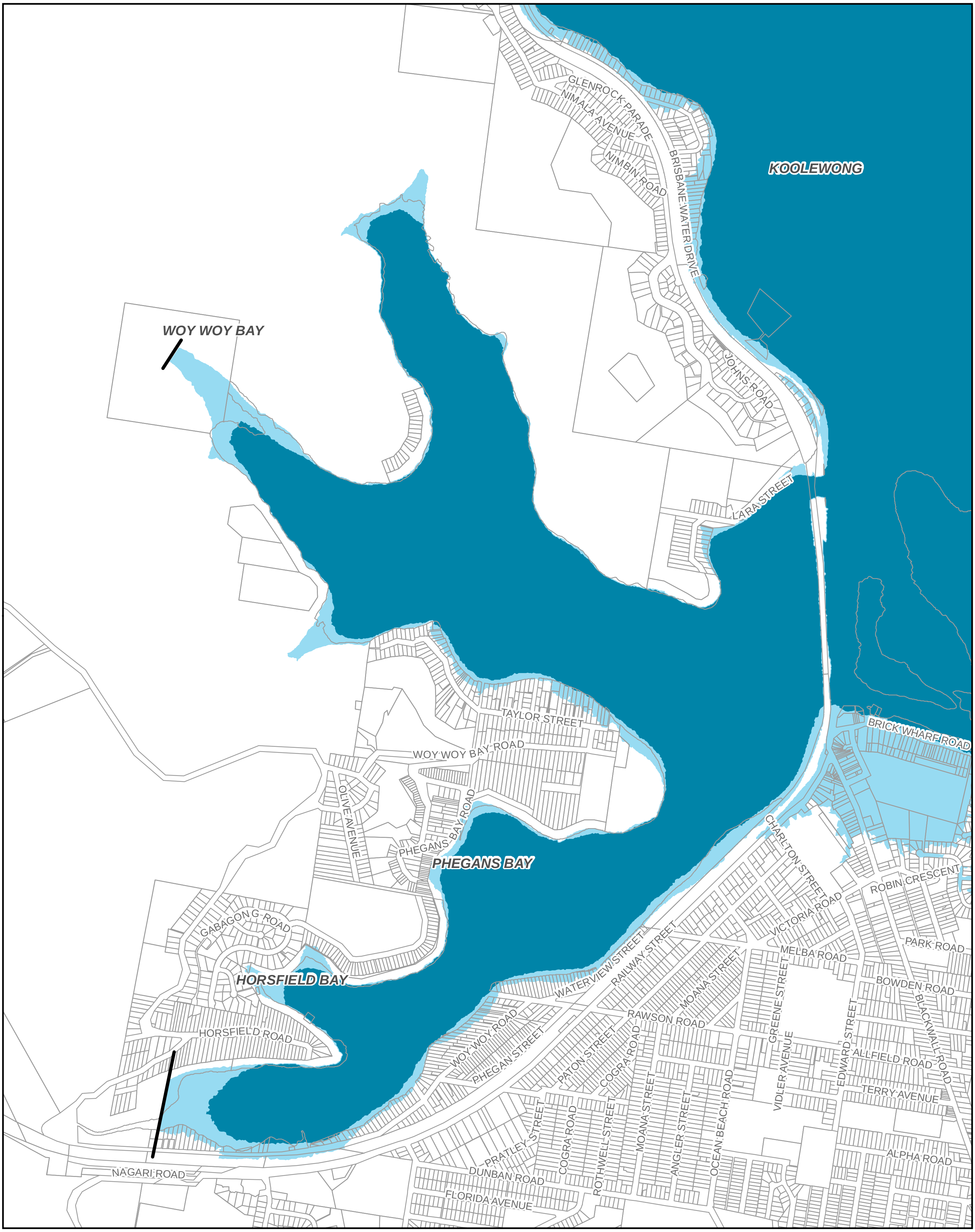
Metres: 0, 200, 400, 600

Provisional Flood Hazard 200 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D4.3 - MPA2

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2005_AppD_ProvisionalFloodHazard_200yrARI.mxd 01



Legend

- Cadastre
- High Hazard
- Low Hazard
- Brisbane Water Flood Hazard Mapping Extent

1:17,000 Scale at A4

Metres
0 200 400 600

Provisional Flood Hazard 200 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D4.5 - MPA3

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2005_AppD_ProvisionalFloodHazard_200yrARI.mxd 01

Legend

- Cadastre
- High Hazard
- Low Hazard
- Brisbane Water Flood Hazard Mapping Extent

1:17,000 Scale at A4

Metres

0 200 400 600

N S E W

Provisional Flood Hazard
200 Year ARI (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D4.6 - MPA4

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2005_AppD_ProvisionalFloodHazard_200yrARI.mxd 01

Legend

- Cadastre
- High Hazard
- Low Hazard
- Brisbane Water Flood Hazard Mapping Extent

1:17,000 Scale at A4

Metres

0 200 400 600

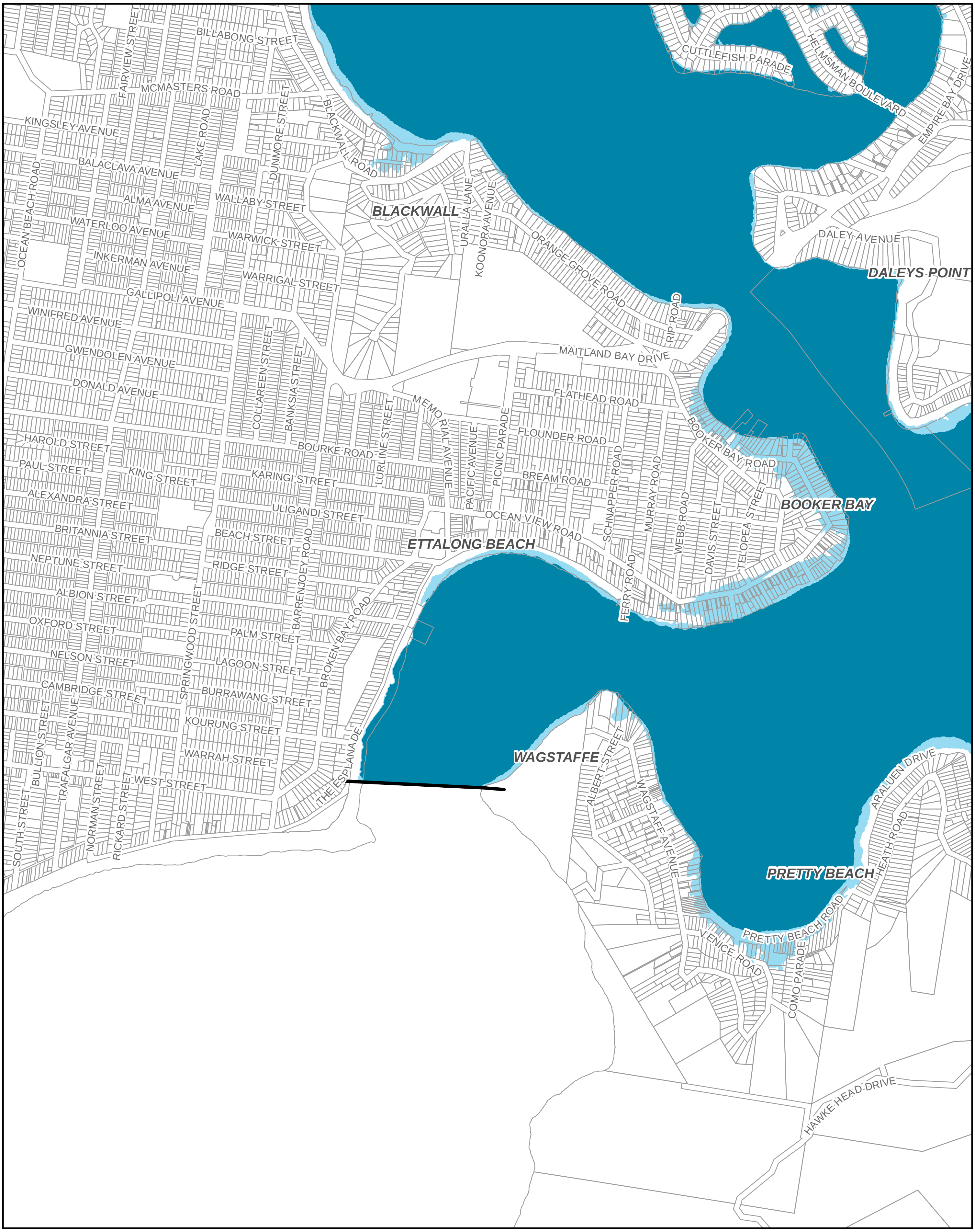
Provisional Flood Hazard 200 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D4.7 - MPA5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2005_AppD_ProvisionalFloodHazard_200yrARI.mxd 01



Legend

- Cadastre
- High Hazard
- Low Hazard
- Brisbane Water Flood Hazard Mapping Extent

1:17,000 Scale at A4

Metres

0 200 400 600

N W E S

Provisional Flood Hazard
200 Year ARI (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D4.8 - MPA6

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2005_AppD_ProvisionalFloodHazard_200yrARI.mxd 01

Legend

- Cadastre
- High Hazard
- Low Hazard
- Brisbane Water Flood Hazard Mapping Extent

1:17,000 Scale at A4

Metres
0 200 400 600

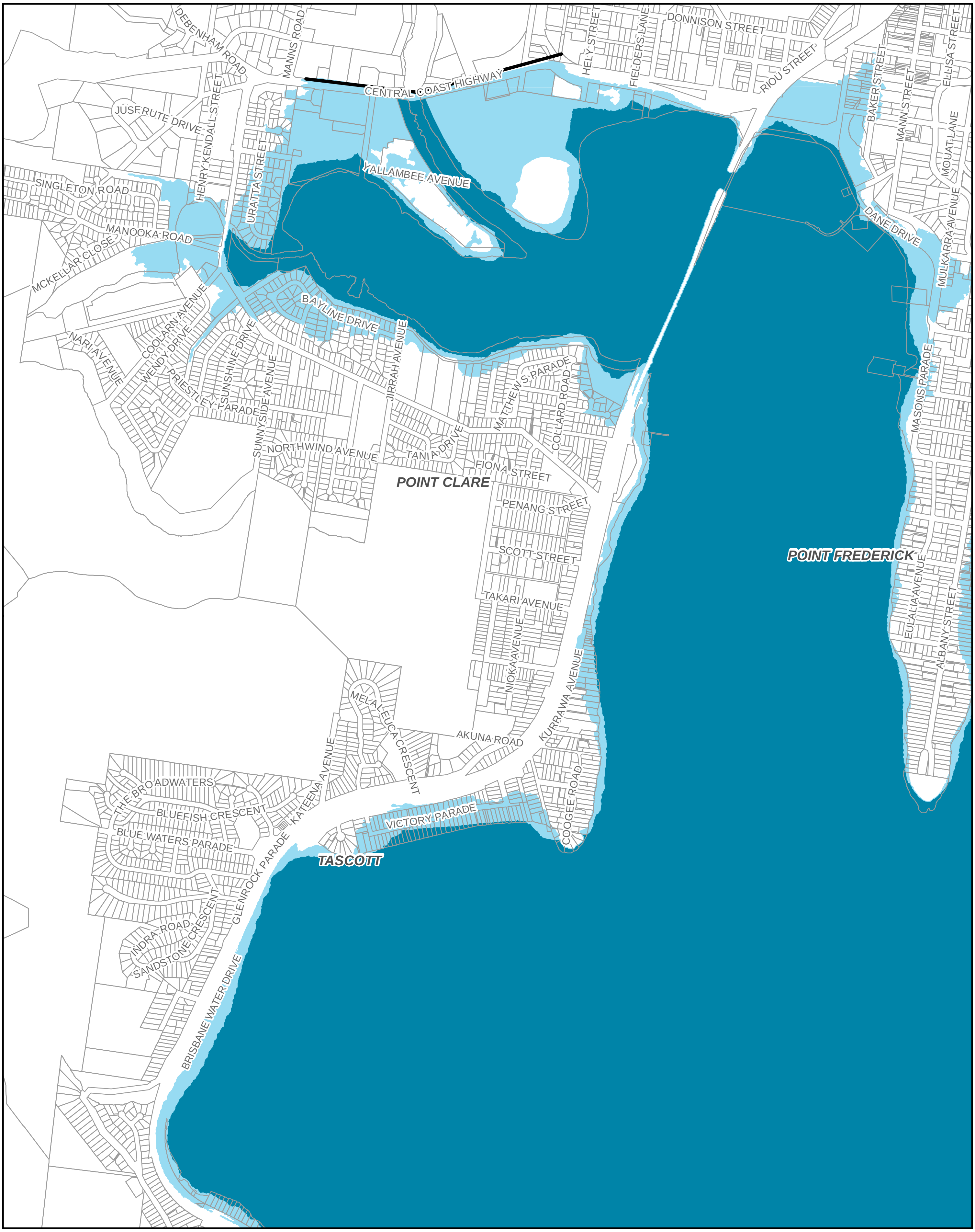
Provisional Flood Hazard 200 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D4.9 - MPA7

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2005_AppD_ProvisionalFloodHazard_200yrARI.mxd 01



Legend

Brisbane Water Flood Hazard Mapping Extent

Cadastre

High Hazard

Low Hazard

1:17,000 Scale at A4

Metres

0 200 400 600

N E S W

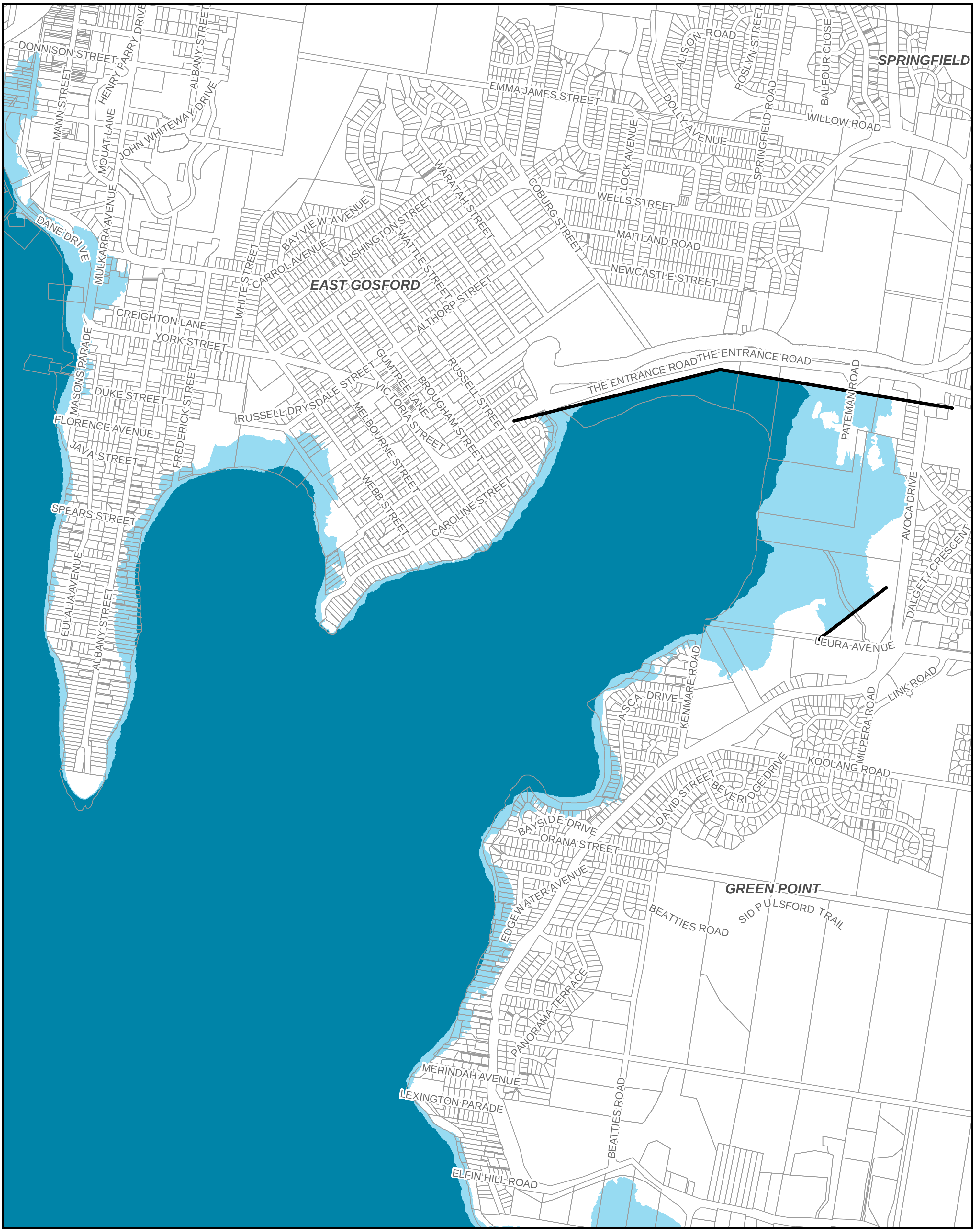
Provisional Flood Hazard PMF (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D5.1 - MPA1

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2006_AppD_ProvisionalFloodHazard_PMF.mxd 01



Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres

0 200 400 600

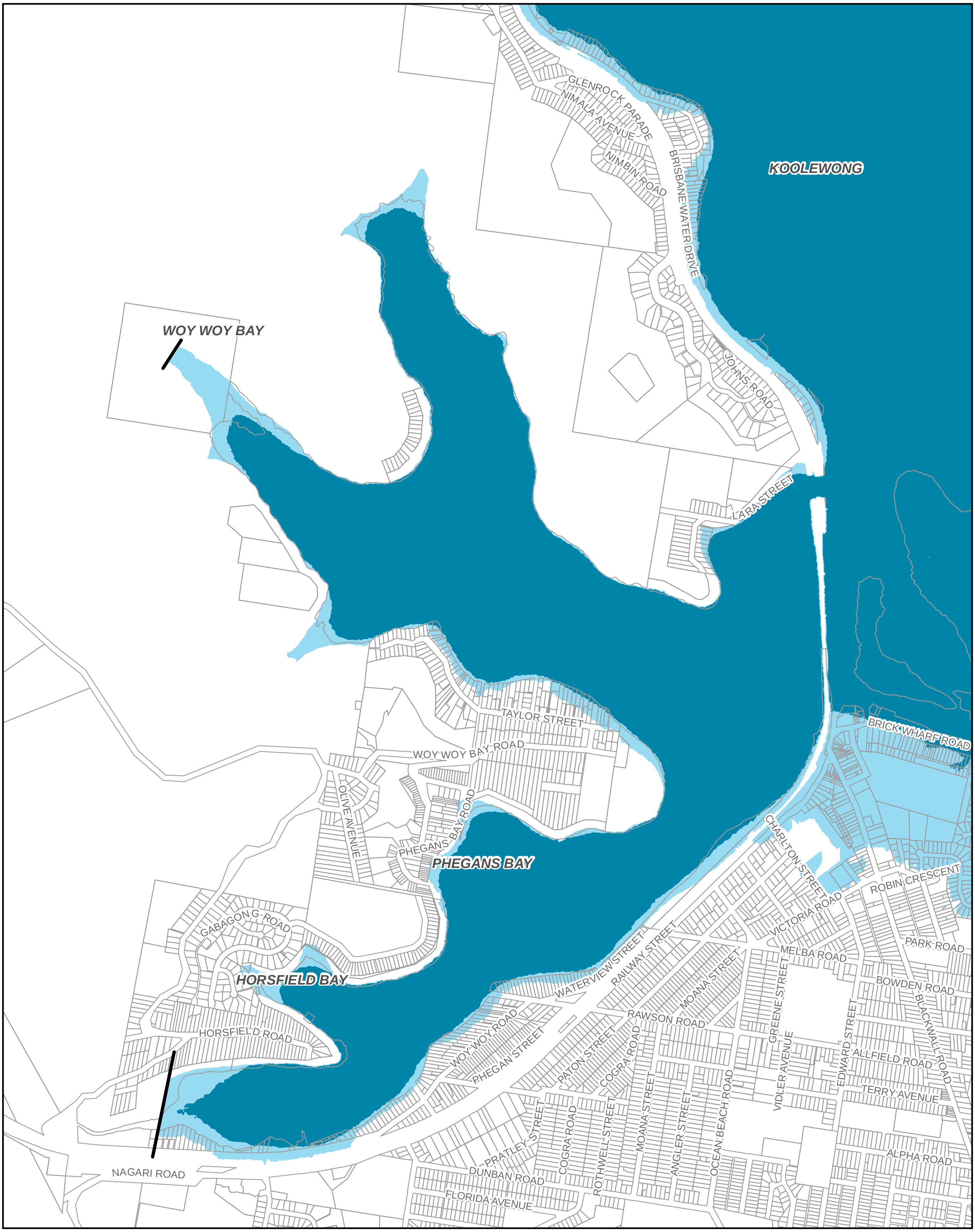
Provisional Flood Hazard PMF (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D5.3 - MPA2

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2006_AppD_ProvisionalFloodHazard_PMF.mxd 01



Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres

0 200 400 600

Provisional Flood Hazard PMF (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D5.5 - MPA3

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2006_AppD_ProvisionalFloodHazard_PMF.mxd 01

Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres
0 200 400 600

N W E S

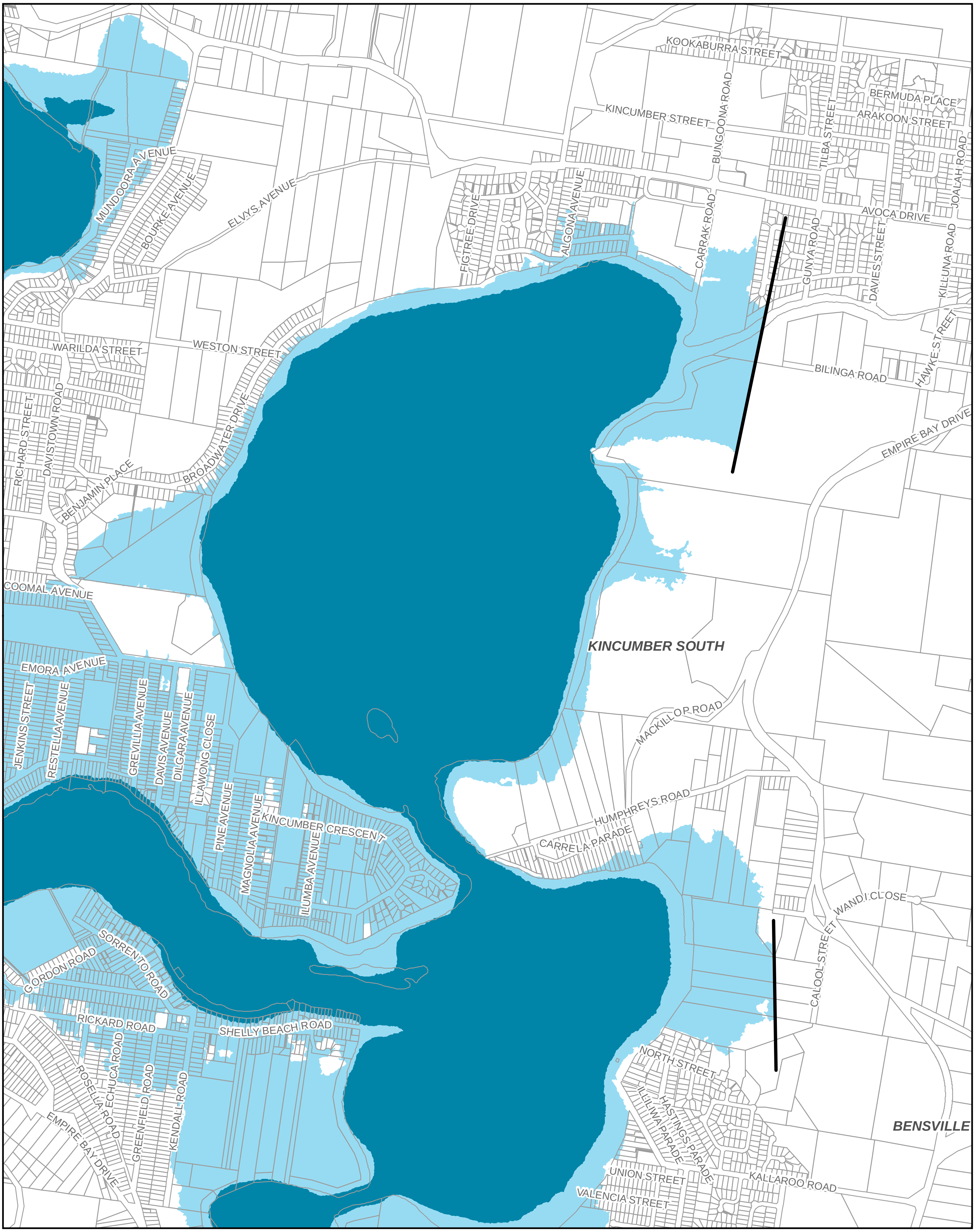
Provisional Flood Hazard PMF (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D5.6 - MPA4

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2006_AppD_ProvisionalFloodHazard_PMF.mxd 01



Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres

0 200 400 600

N W E S

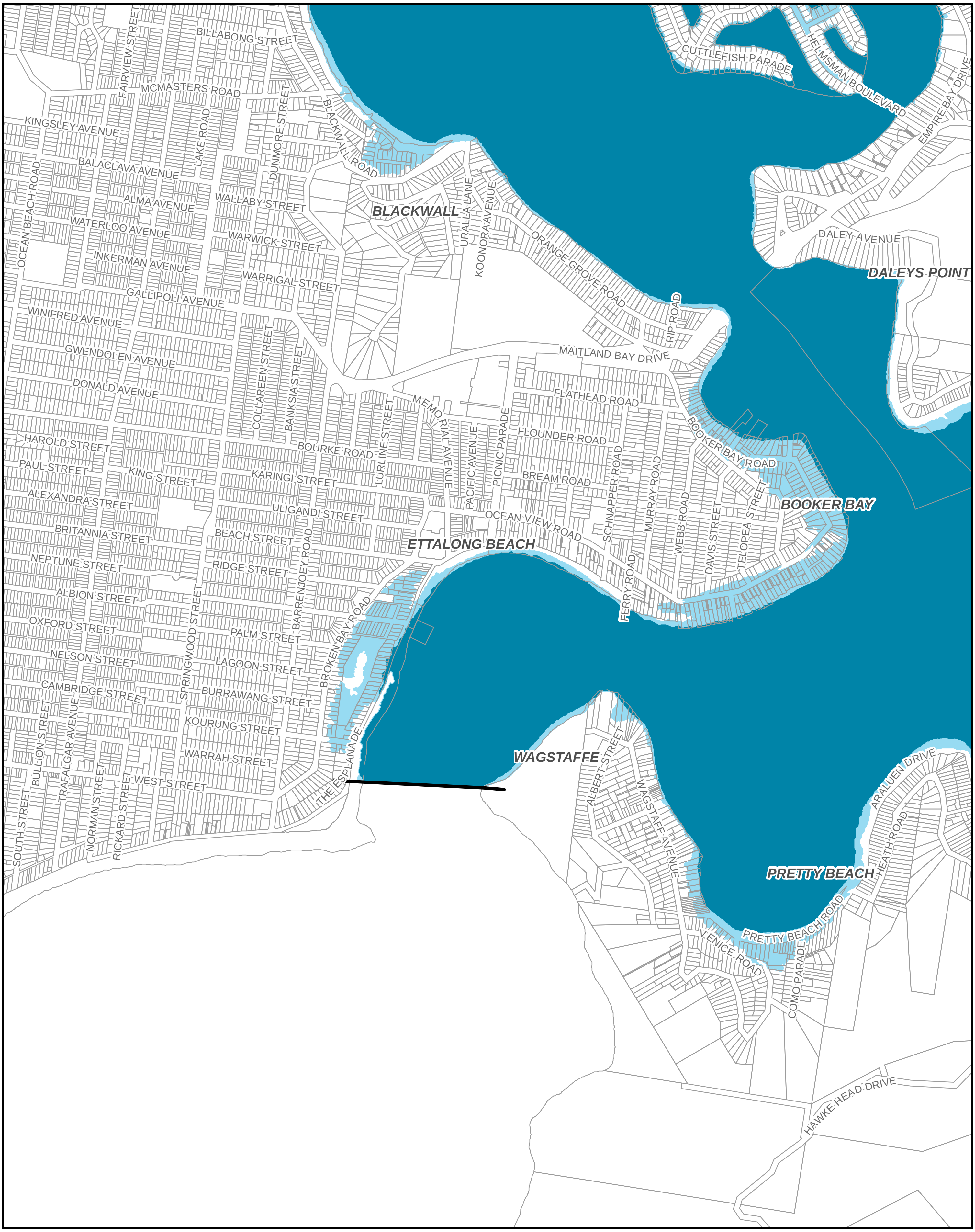
Provisional Flood Hazard PMF (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D5.7 - MPA5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2006_AppD_ProvisionalFloodHazard_PMF.mxd 01



Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres

0 200 400 600

Provisional Flood Hazard PMF (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE D5.8 - MPA6

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2006_AppD_ProvisionalFloodHazard_PMF.mxd 01

Legend

- Brisbane Water Flood Hazard Mapping Extent
- Cadastre
- High Hazard
- Low Hazard

1:17,000 Scale at A4

Metres
0 200 400 600

Provisional Flood Hazard PMF (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

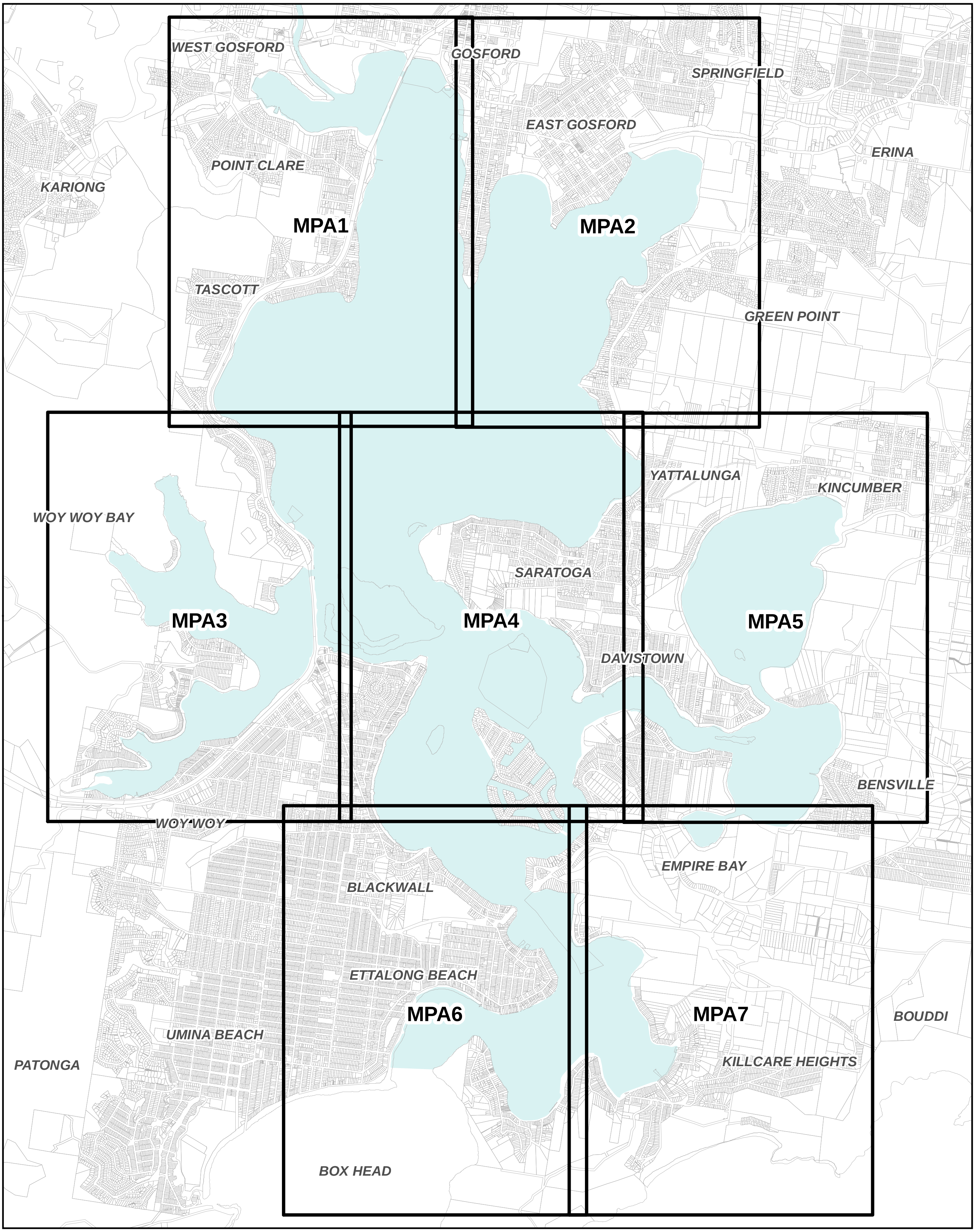
FIGURE D5.9 - MPA7

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2006_AppD_ProvisionalFloodHazard_PMF.mxd 01

Appendix E

Hydraulic Categorisation Extents



Legend

- Mapping Areas
- Cadastre
- SuburbLabels
- Waterway

1:50,000 Scale at A4

Metres
0 500 1000 1500

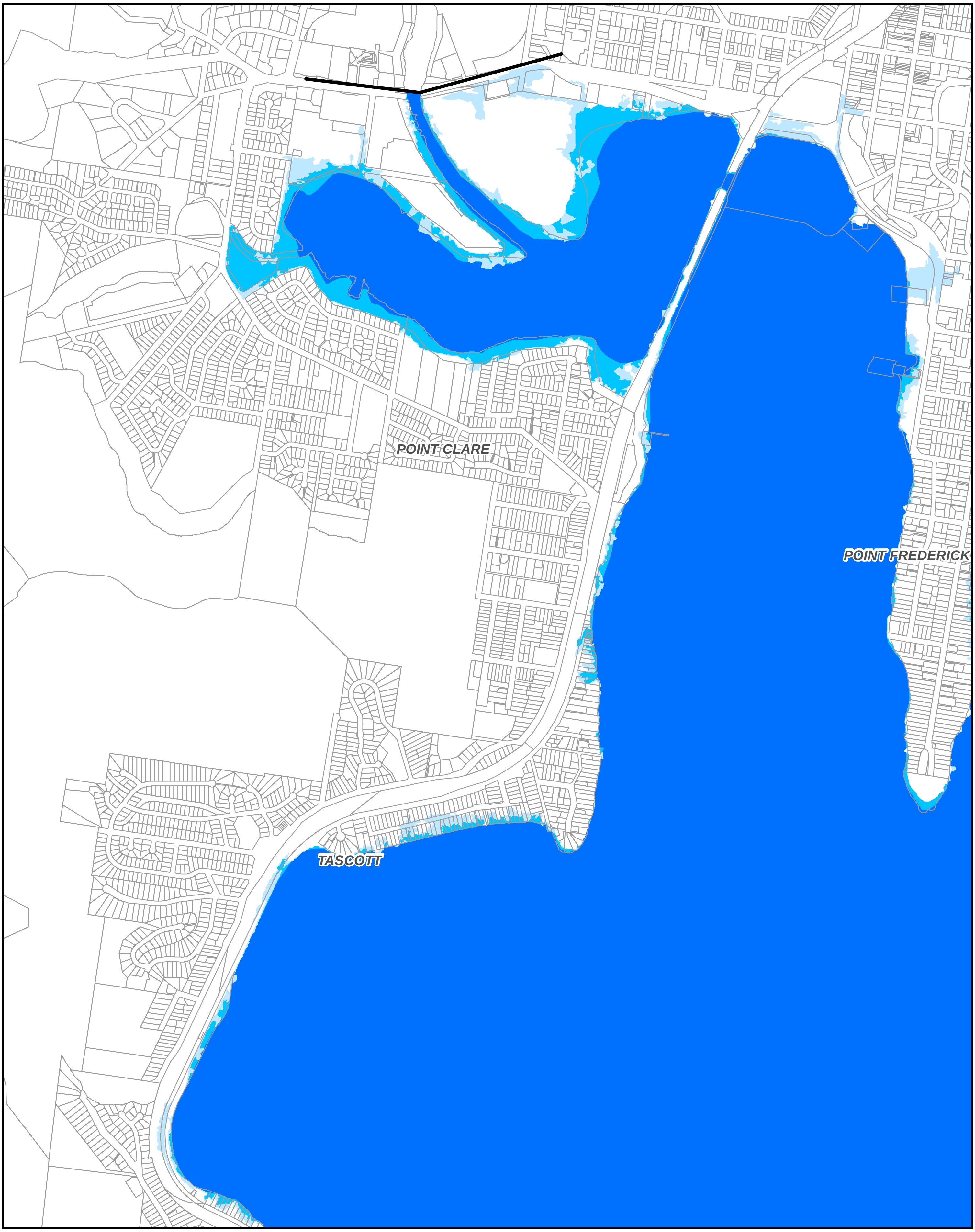
Mapping Area Index

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E1.0

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-17
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2000_AppD_E_MappingAreas.mxd 01



Legend

- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

N S E W

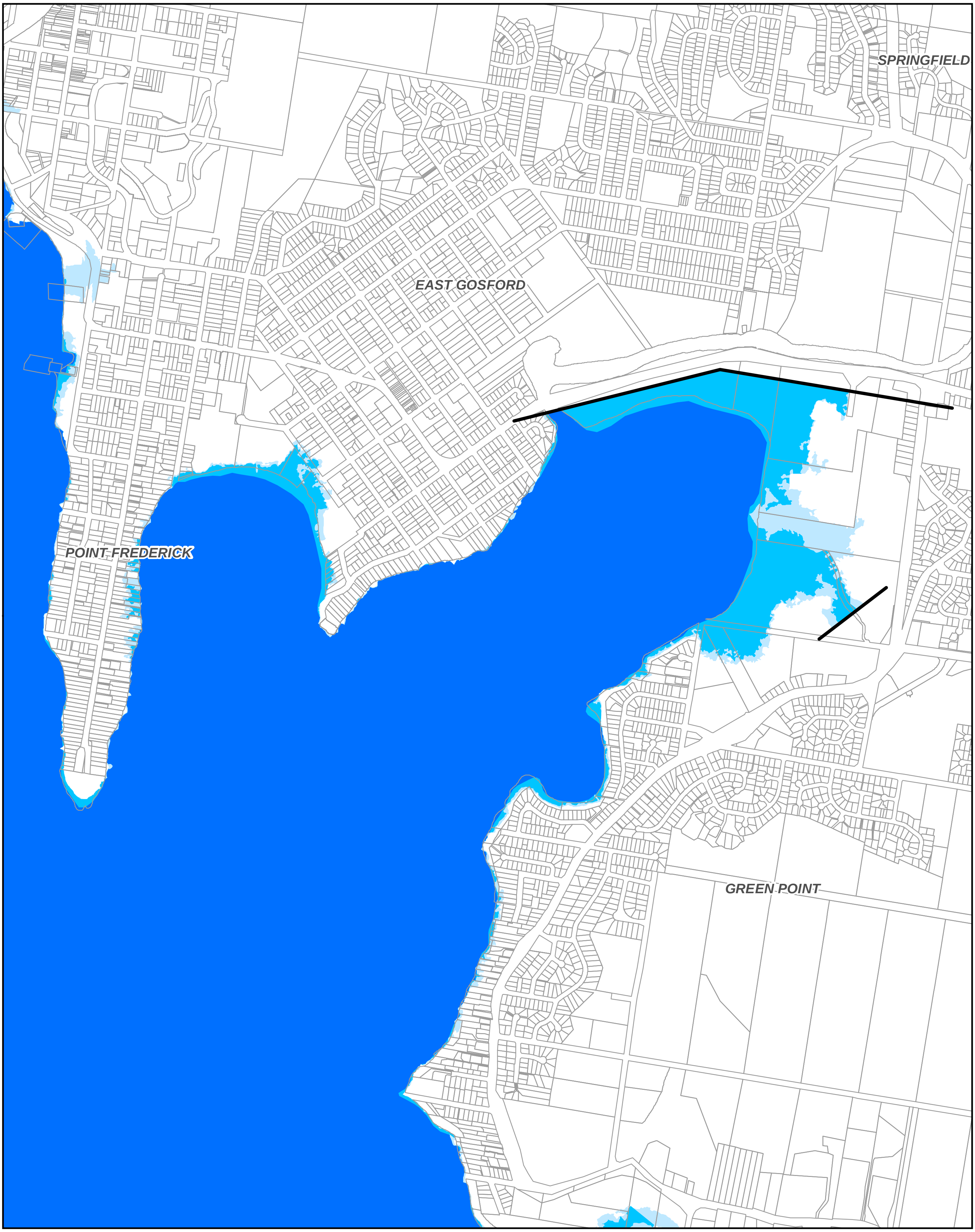
Hydraulic Categorisation
5 Year ARI (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E1.1 - MPA1

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2007_AppE_HydraulicCategories_5yrARI.mxd 01



Legend
Brisbane Water Flood Hydraulic Mapping Extent
Cadastre
Floodway
Flood Storage
Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

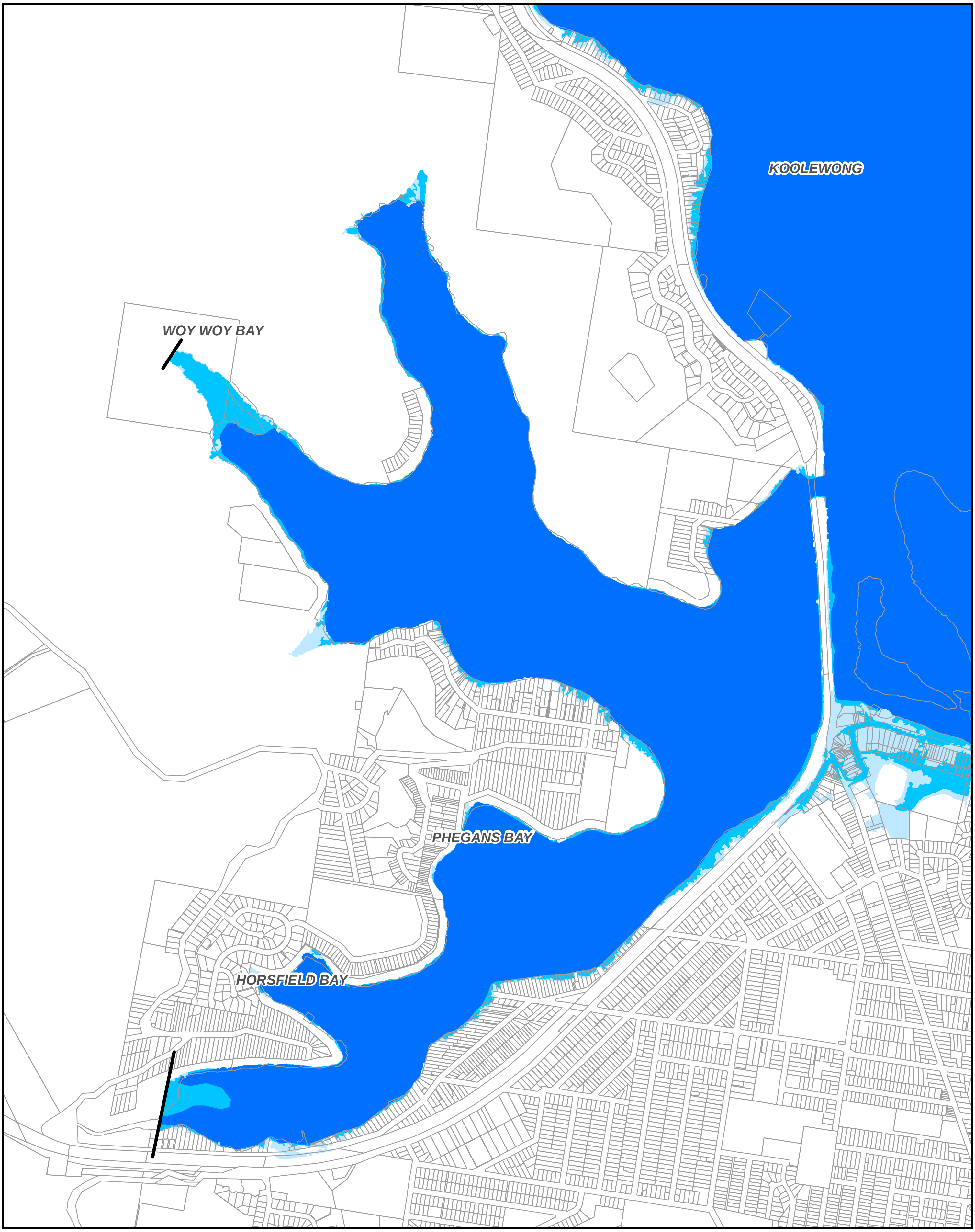
Hydraulic Categorisation
5 Year ARI (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E1.3 - MPA2

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2007_AppE_HydraulicCategories_5yrARI.mxd 01



Legend

- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

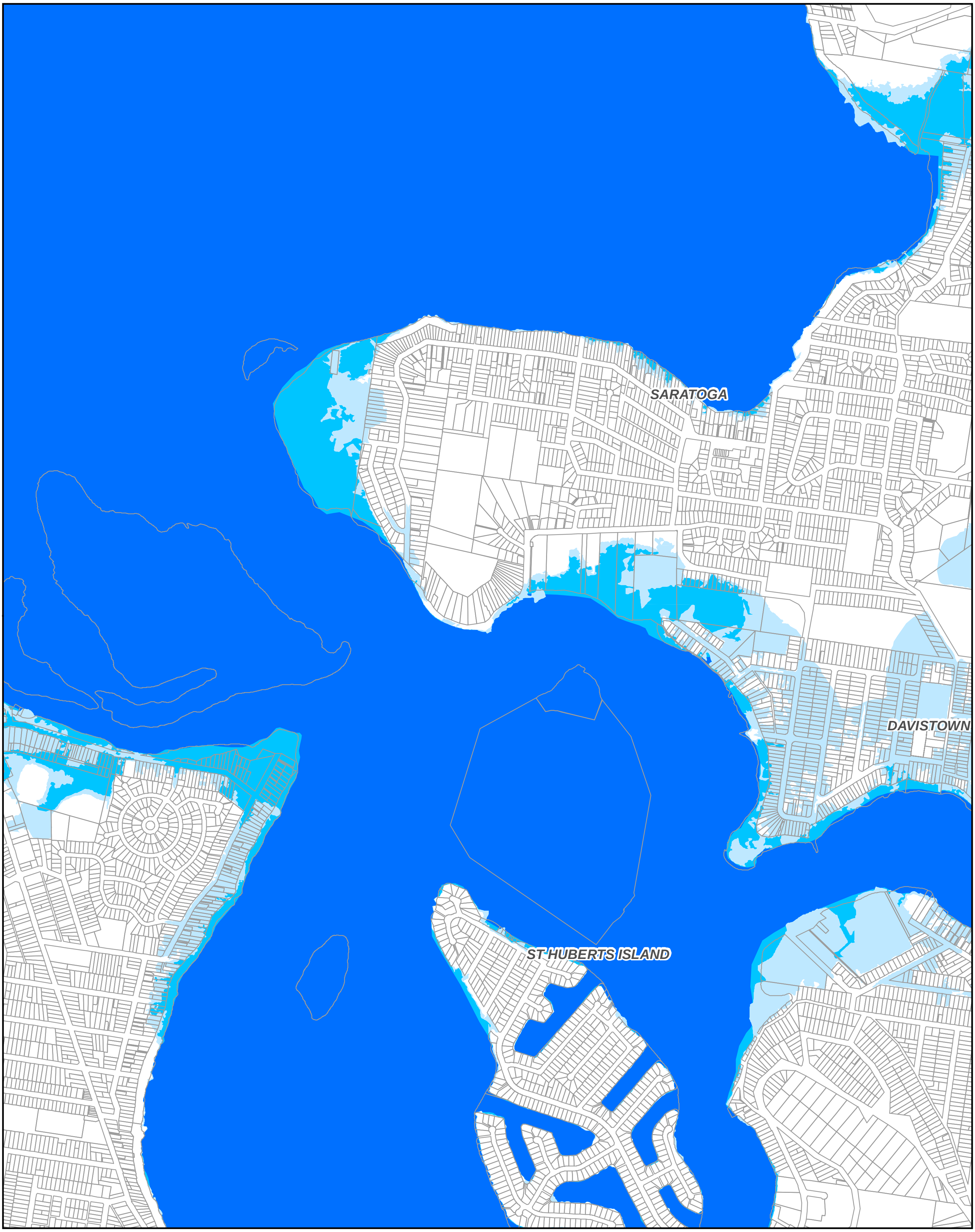
0 200 400 600

Hydraulic Categorisation 5 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E1.5 - MPA3

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2007_AppE_HydraulicCategories_5yrARI.mxd 01



Legend
- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres
0 200 400 600

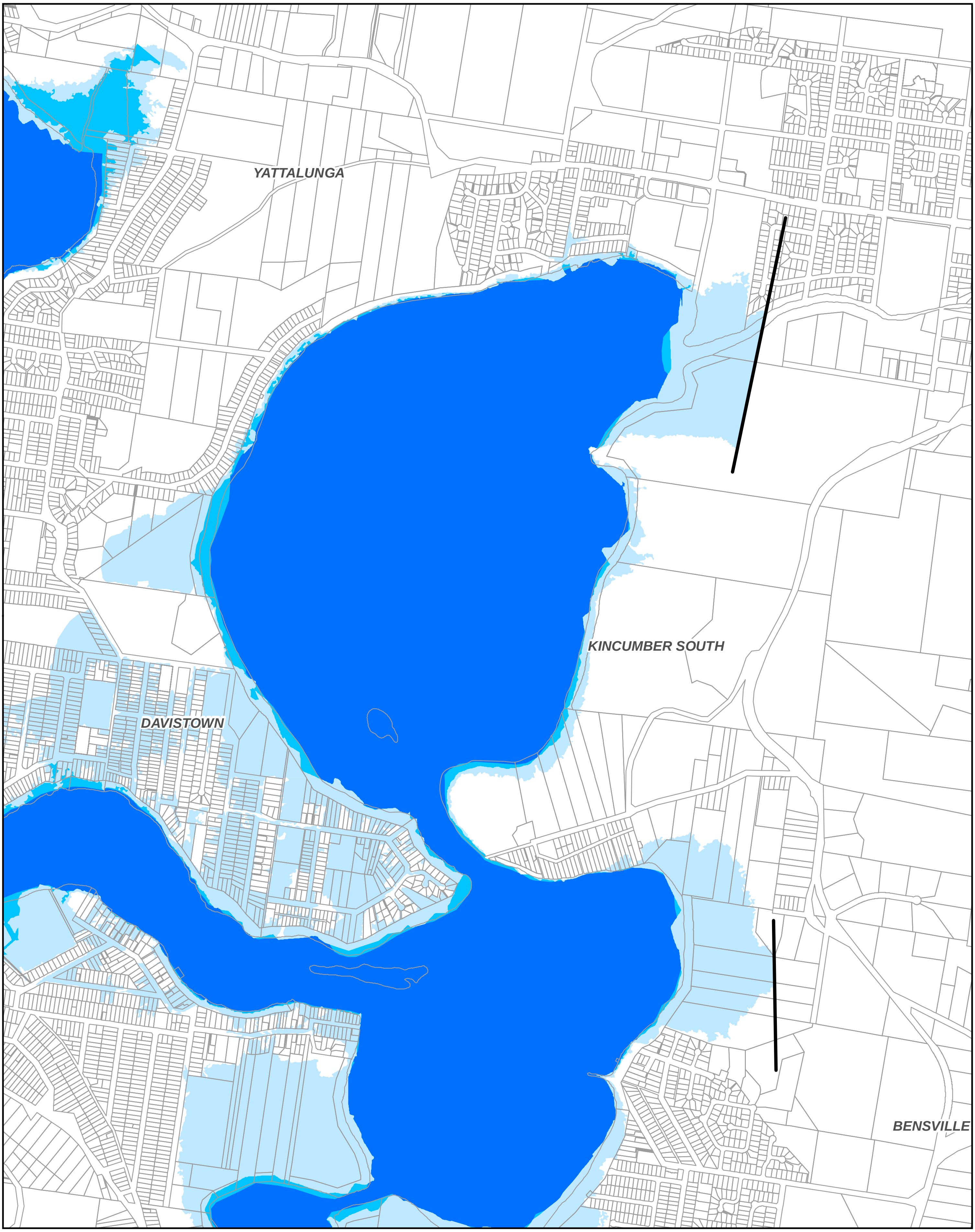
Hydraulic Categorisation
5 Year ARI (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E1.6 - MPA4

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2007_AppE_HydraulicCategories_5yrARI.mxd 01



Legend
- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

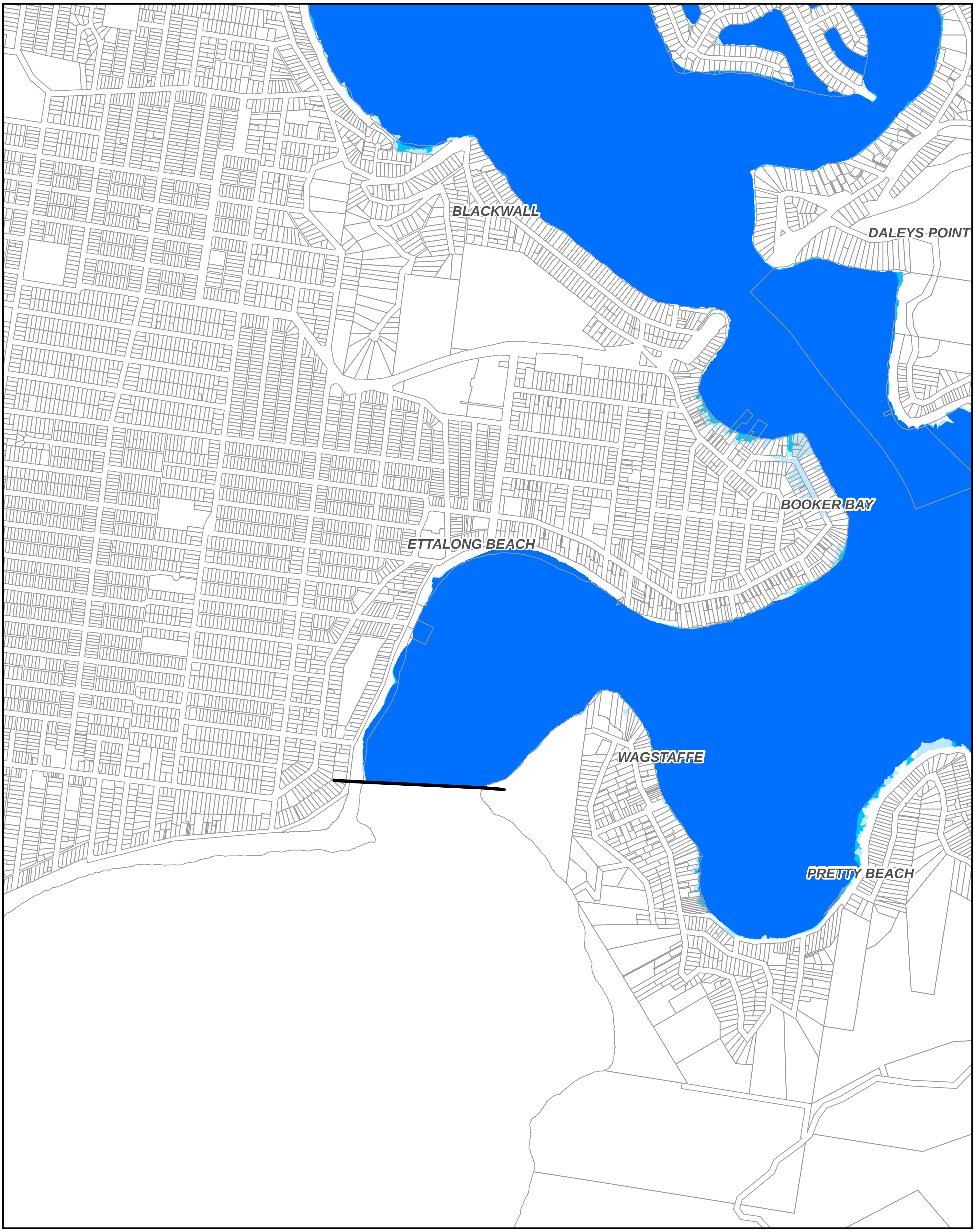
N E S W

Hydraulic Categorisation
5 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E1.7 - MPA5

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2007_AppE_HydraulicCategories_5yrARI.mxd 01



Legend
Brisbane Water Flood Hydraulic Mapping Extent
Cadastre
Floodway
Flood Storage
Flood Fringe

1:17,000 Scale at A4

Metres
0 200 400 600

N E S W

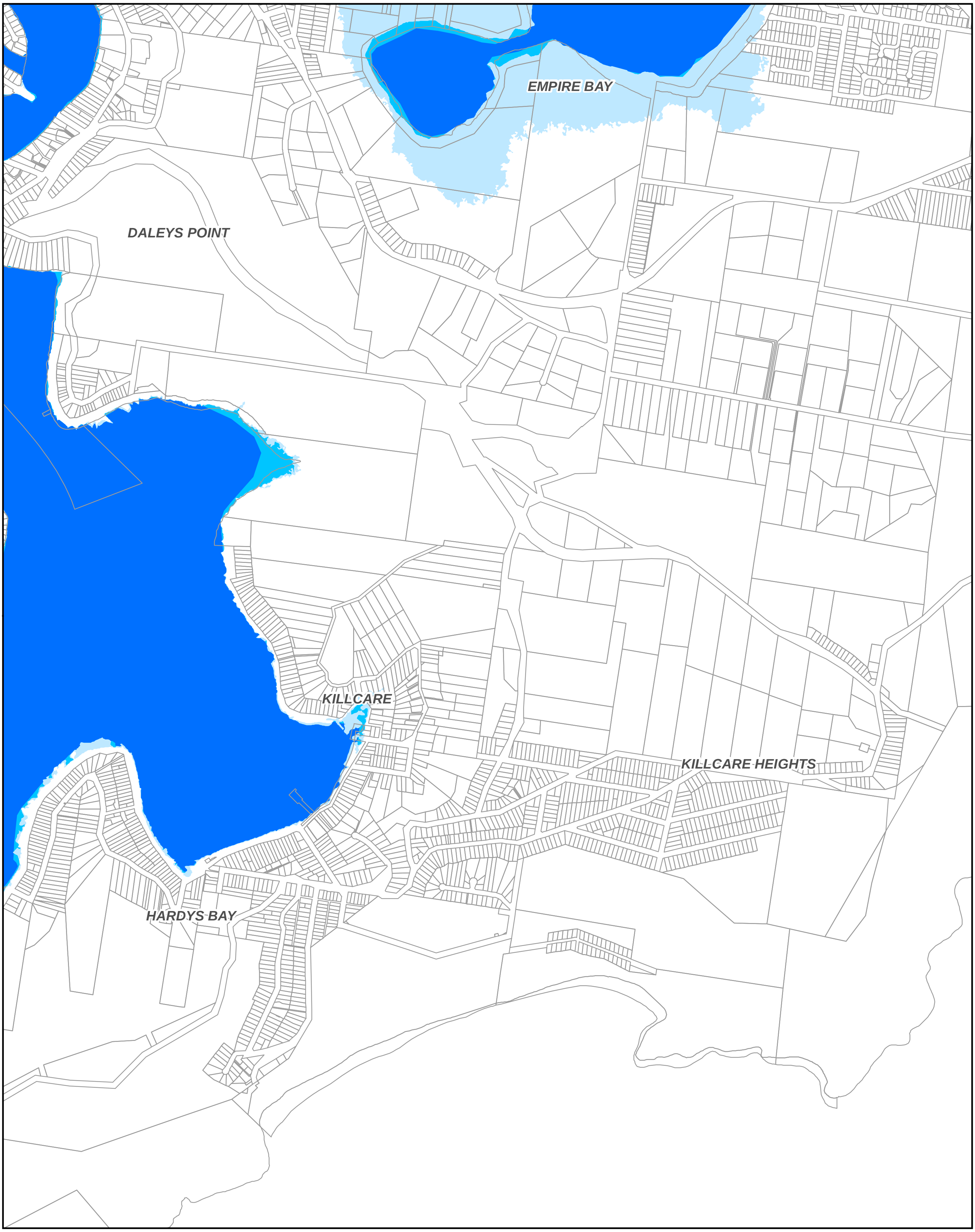
Hydraulic Categorisation 5 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E1.8 - MPA6

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2007_AppE_HydraulicCategories_5yrARI.mxd 01



Legend
- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

N
W
E
S

1:17,000 Scale at A4

Metres

0 200 400 600

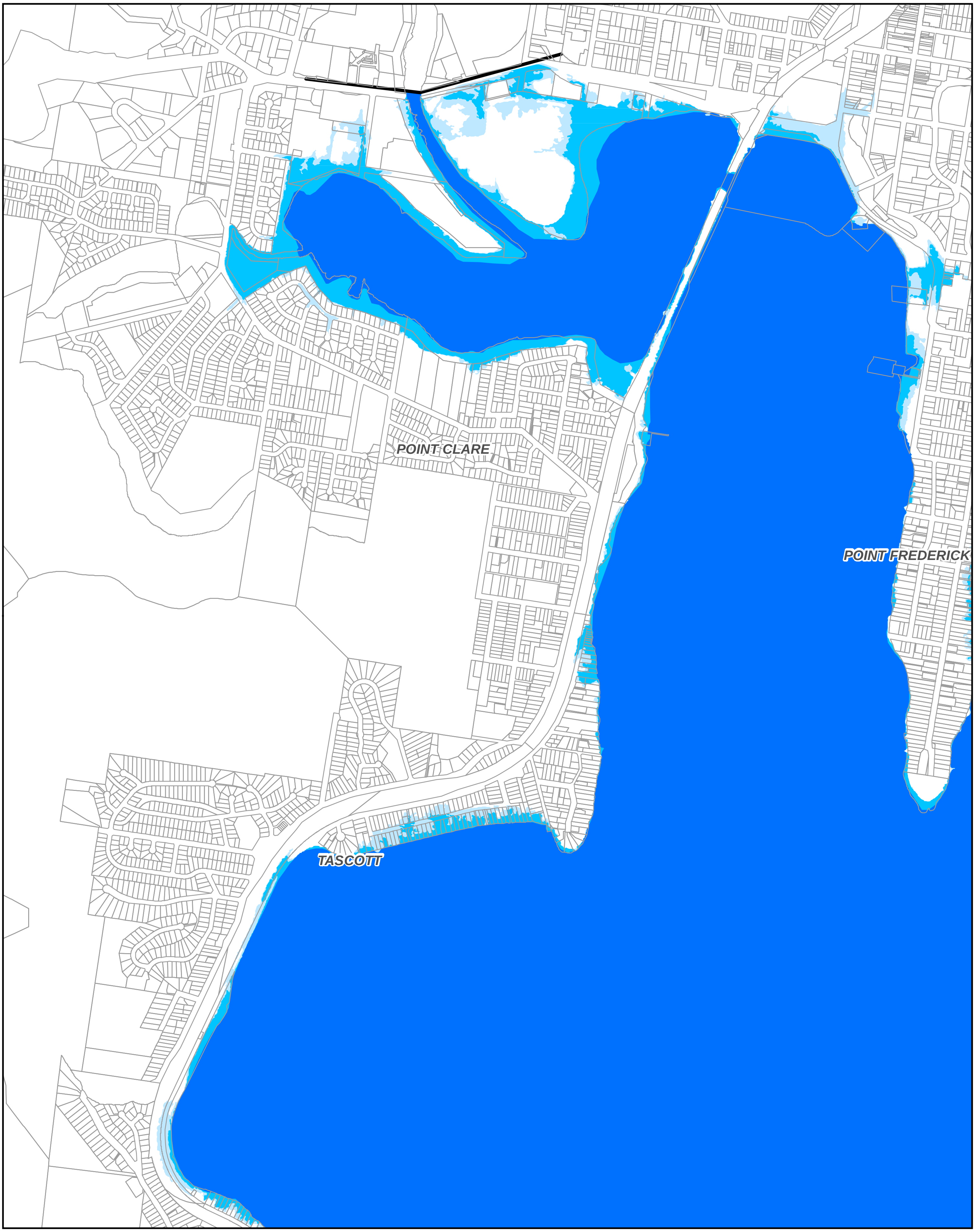
Hydraulic Categorisation
5 Year ARI (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E1.9 - MPA7

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2007_AppE_HydraulicCategories_5yrARI.mxd 01



Legend

- Cadastre
- Brisbane Water Flood Hydraulic Mapping Extent
- Floodway
- Flood Storage
- Flood Fringe

N
W E
S

1:17,000 Scale at A4

Metres

0 200 400 600

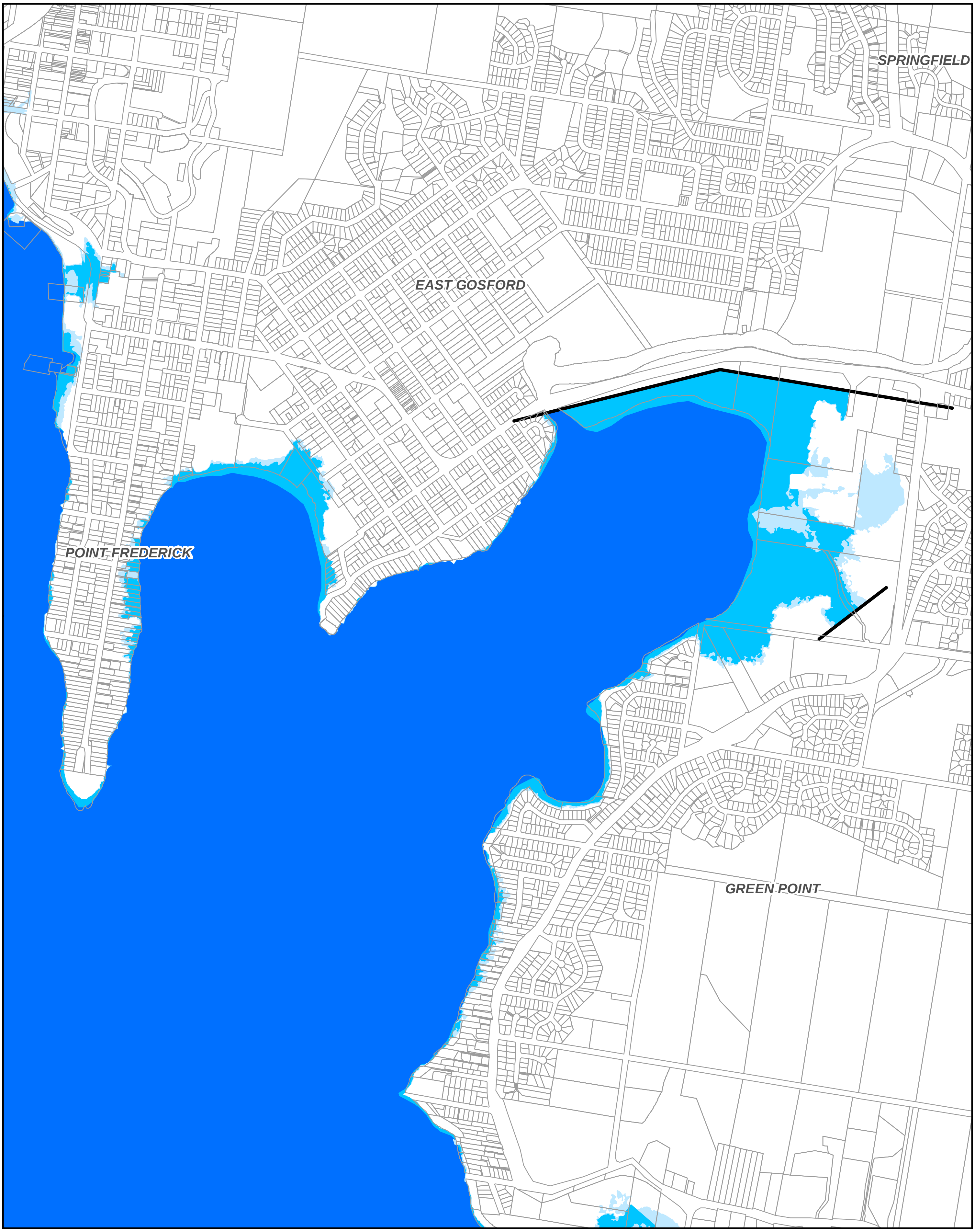
Hydraulic Categorisation 20 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E2.1 - MPA1

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2008_AppE_HydraulicCategories_20yrARI.mxd 01



Legend
- Cadastre
- Brisbane Water Flood Hydraulic Mapping Extent
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

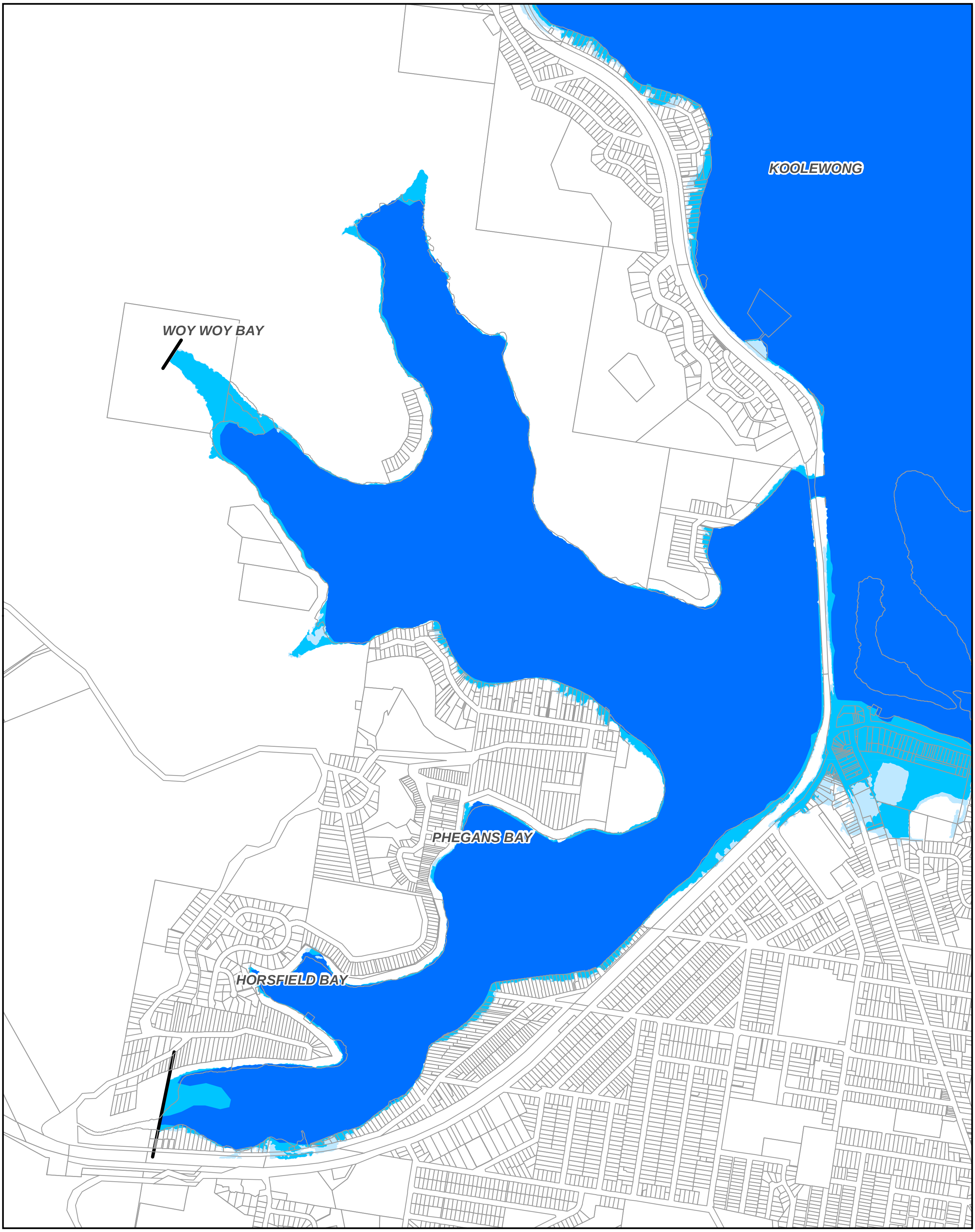
Hydraulic Categorisation
20 Year ARI (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E2.3 - MPA2

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2008_AppE_HydraulicCategories_20yrARI.mxd 01



Legend

- Cadastre
- Brisbane Water Flood Hydraulic Mapping Extent
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

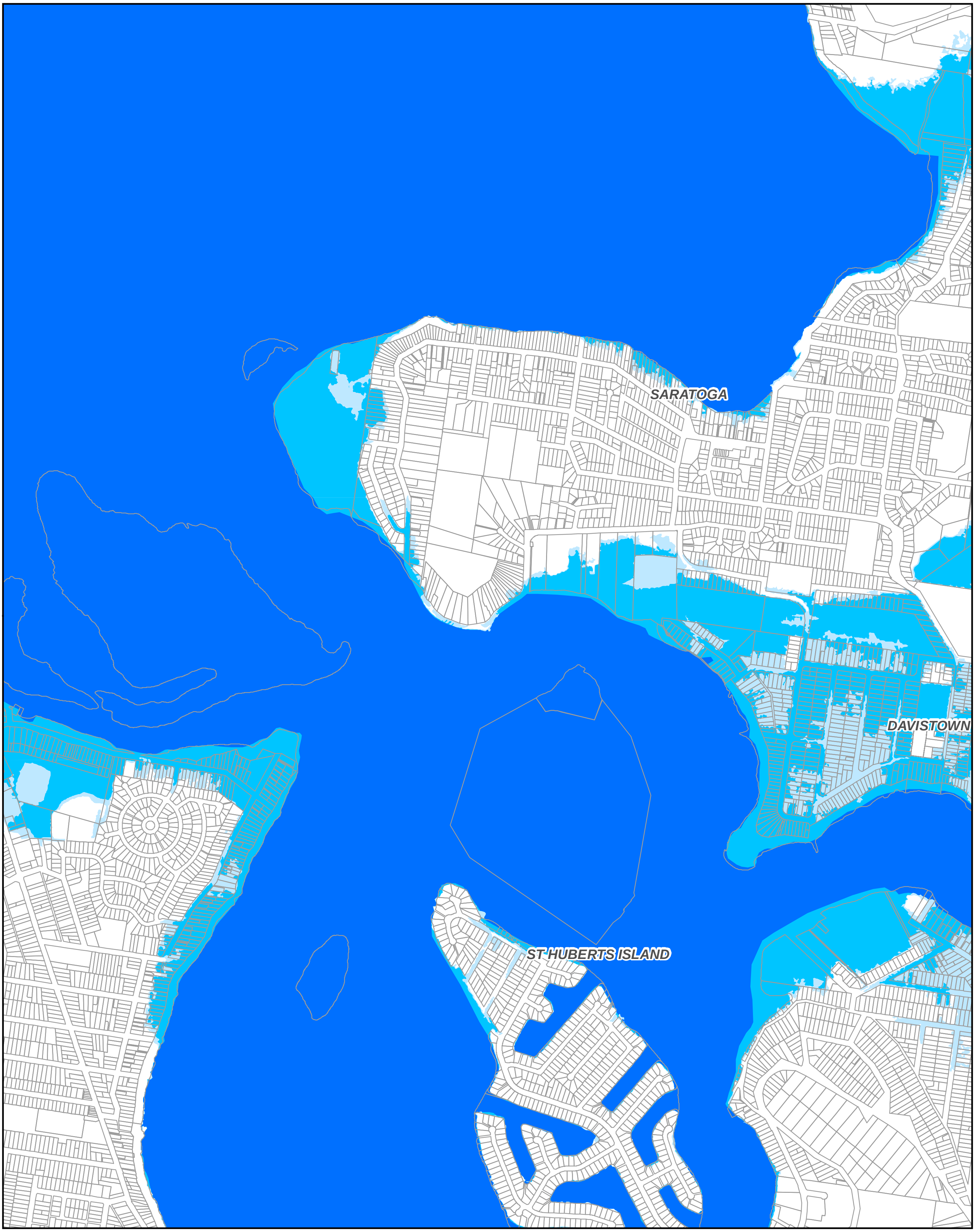
Hydraulic Categorisation 20 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E2.5 - MPA3

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2008_AppE_HydraulicCategories_20yrARI.mxd 01



Legend
- Cadastre
- Brisbane Water Flood Hydraulic Mapping Extent
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

N W E S

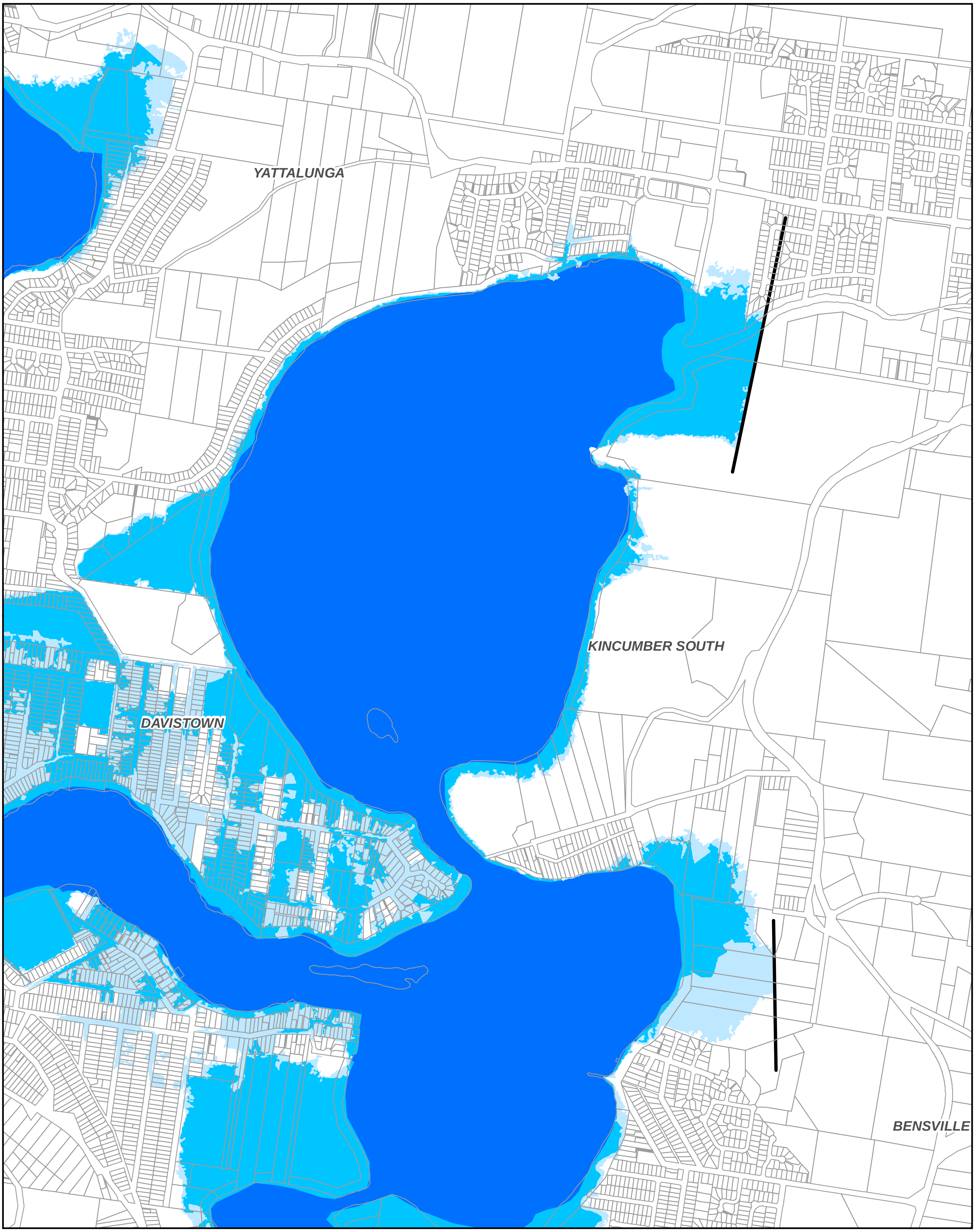
Hydraulic Categorisation 20 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E2.6 - MPA4

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2008_AppE_HydraulicCategories_20yrARI.mxd 01



Legend

- Cadastre
- Brisbane Water Flood Hydraulic Mapping Extent
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

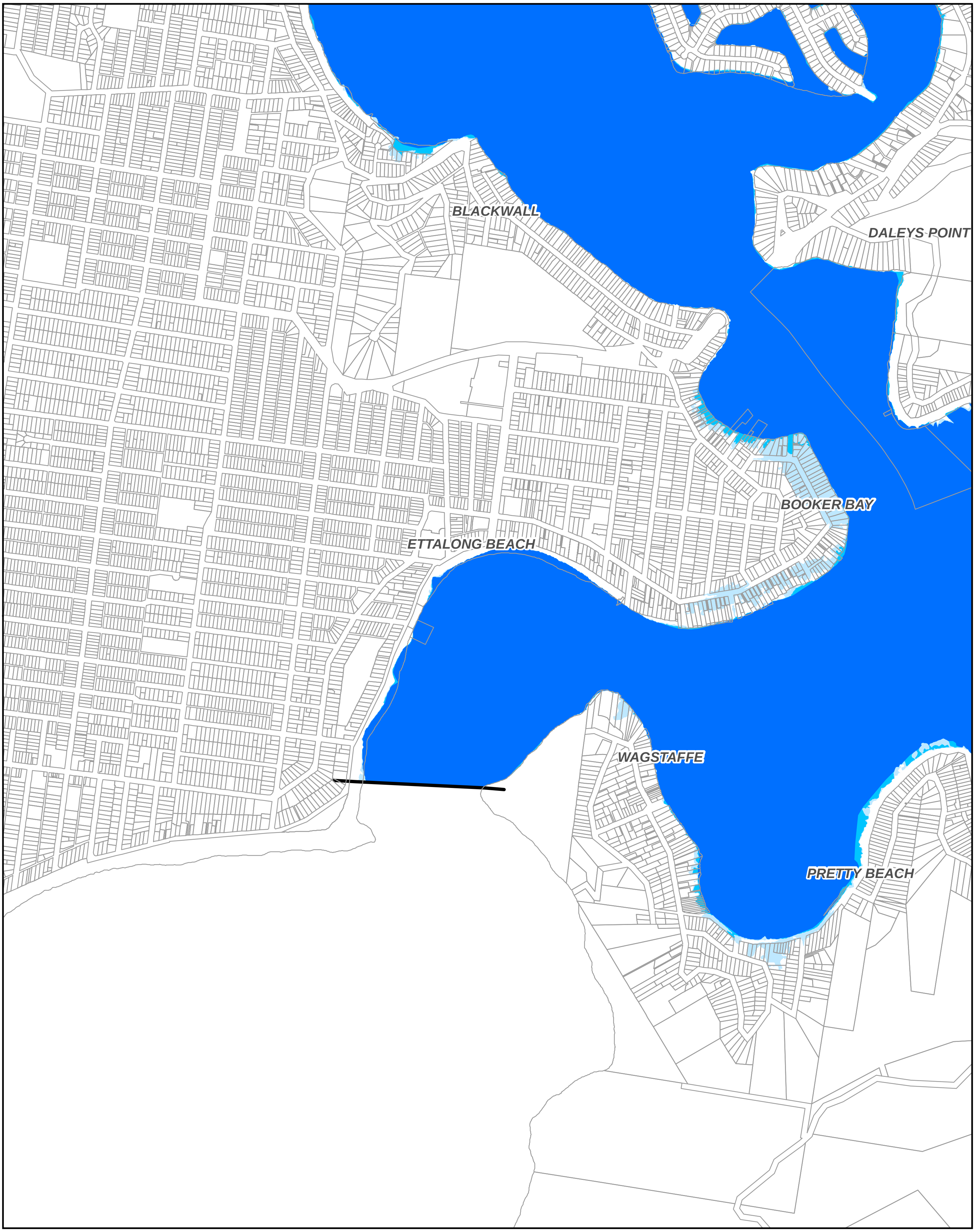
0 200 400 600

Hydraulic Categorisation
20 Year ARI (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E2.7 - MPA5

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2008_AppE_HydraulicCategories_20yrARI.mxd 01



Legend

Cadastre

Brisbane Water Flood Hydraulic Mapping Extent

Floodway

Flood Storage

Flood Fringe

1:17,000 Scale at A4

Metres

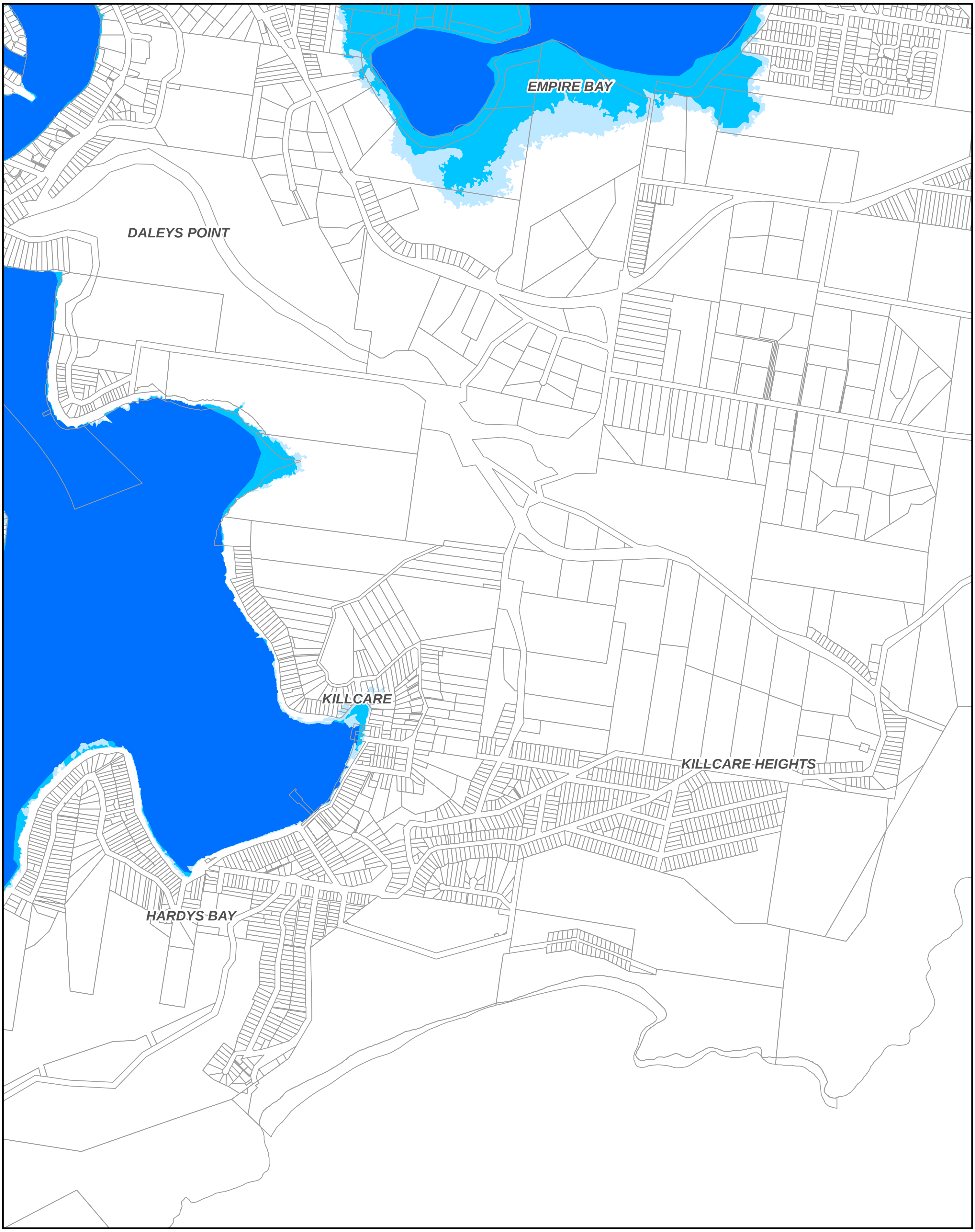
0 200 400 600

Hydraulic Categorisation 20 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E2.8 - MPA6

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2008_AppE_HydraulicCategories_20yrARI.mxd 01



Legend
- Cadastre
- Brisbane Water Flood Hydraulic Mapping Extent
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

N S W E

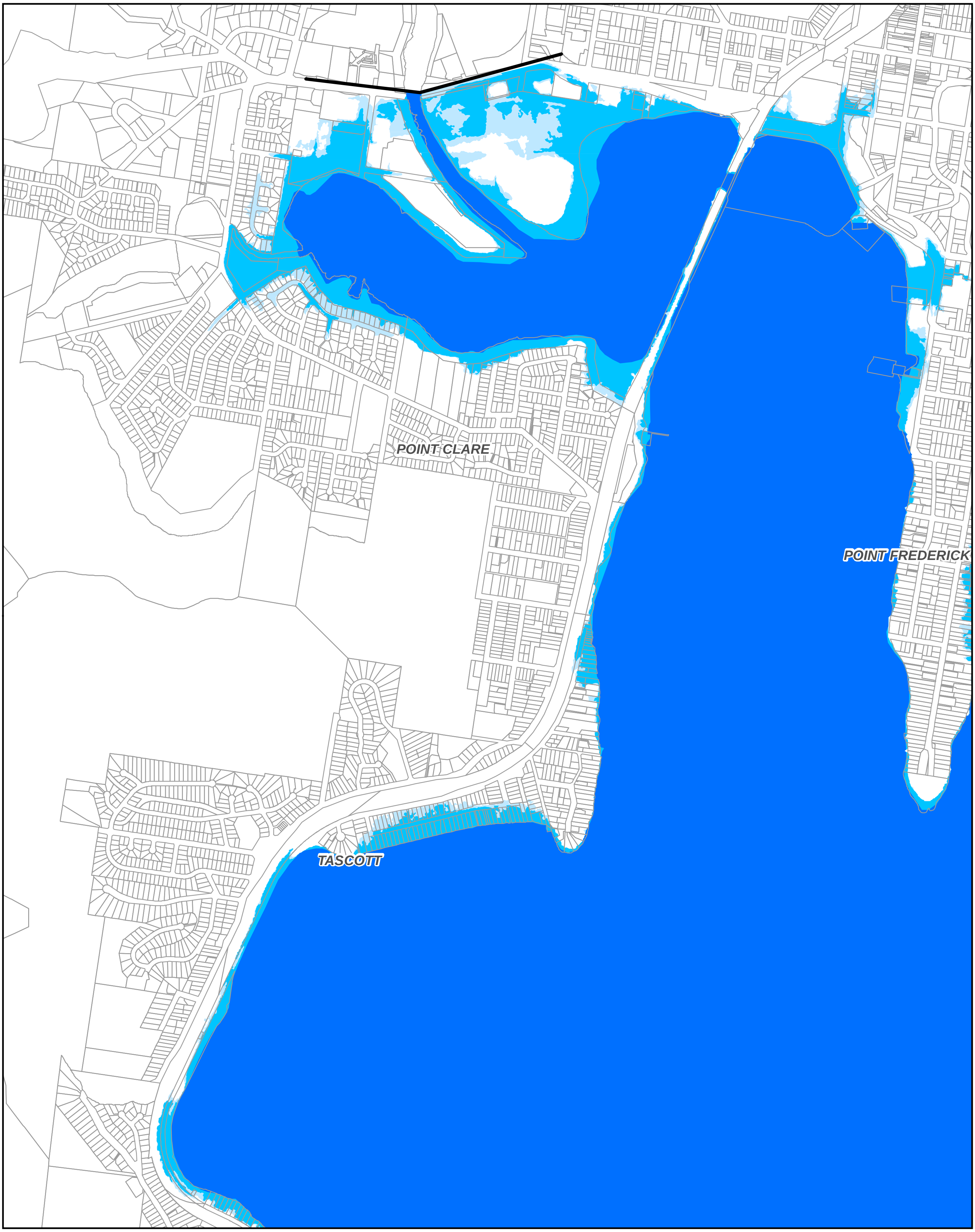
Hydraulic Categorisation 20 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E2.9 - MPA7

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2008_AppE_HydraulicCategories_20yrARI.mxd 01



Legend

- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

N E S W

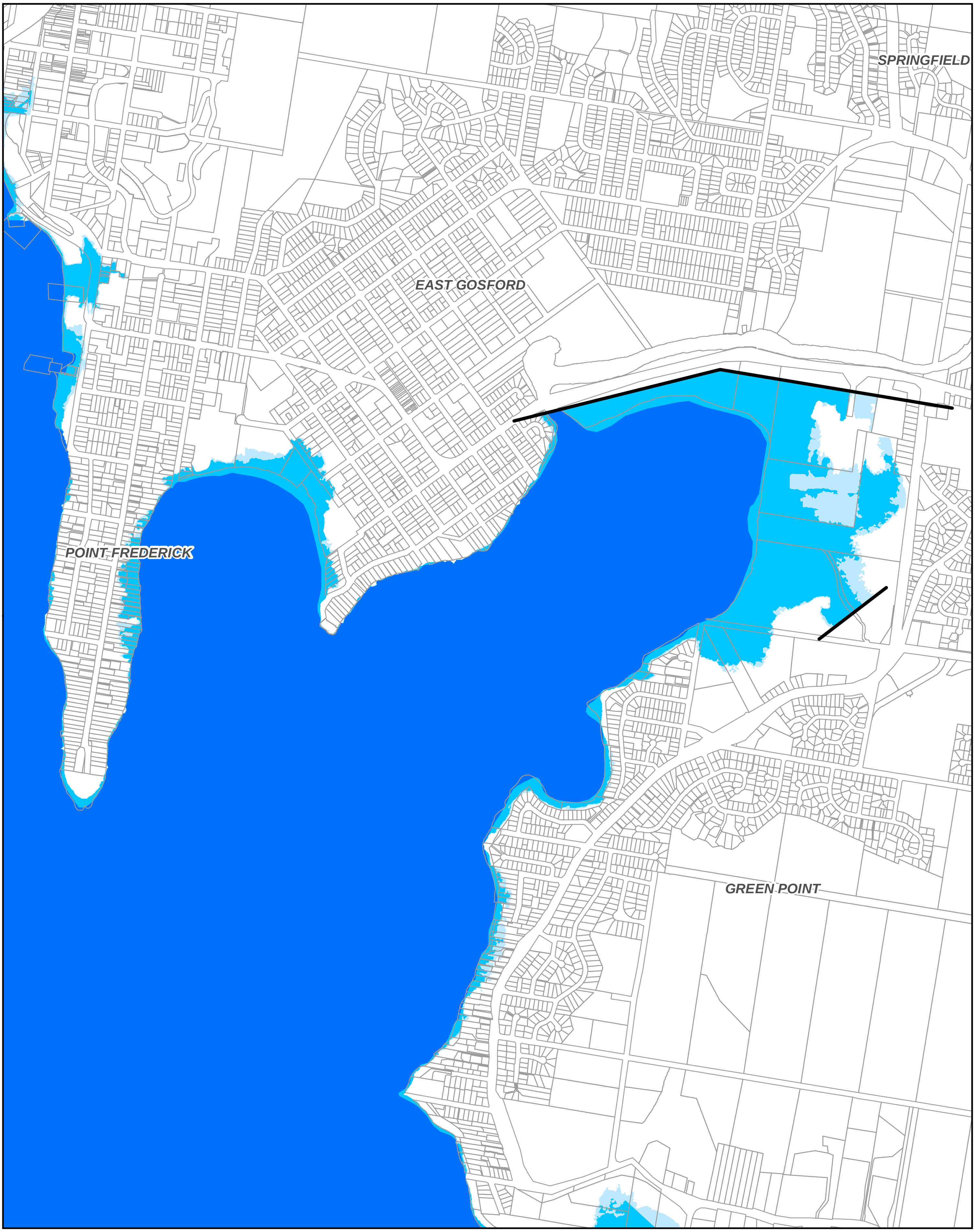
Hydraulic Categorisation 100 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E3.1 - MPA1

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2009_AppE_HydraulicCategories_100yrARI.mxd 01



Legend

- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

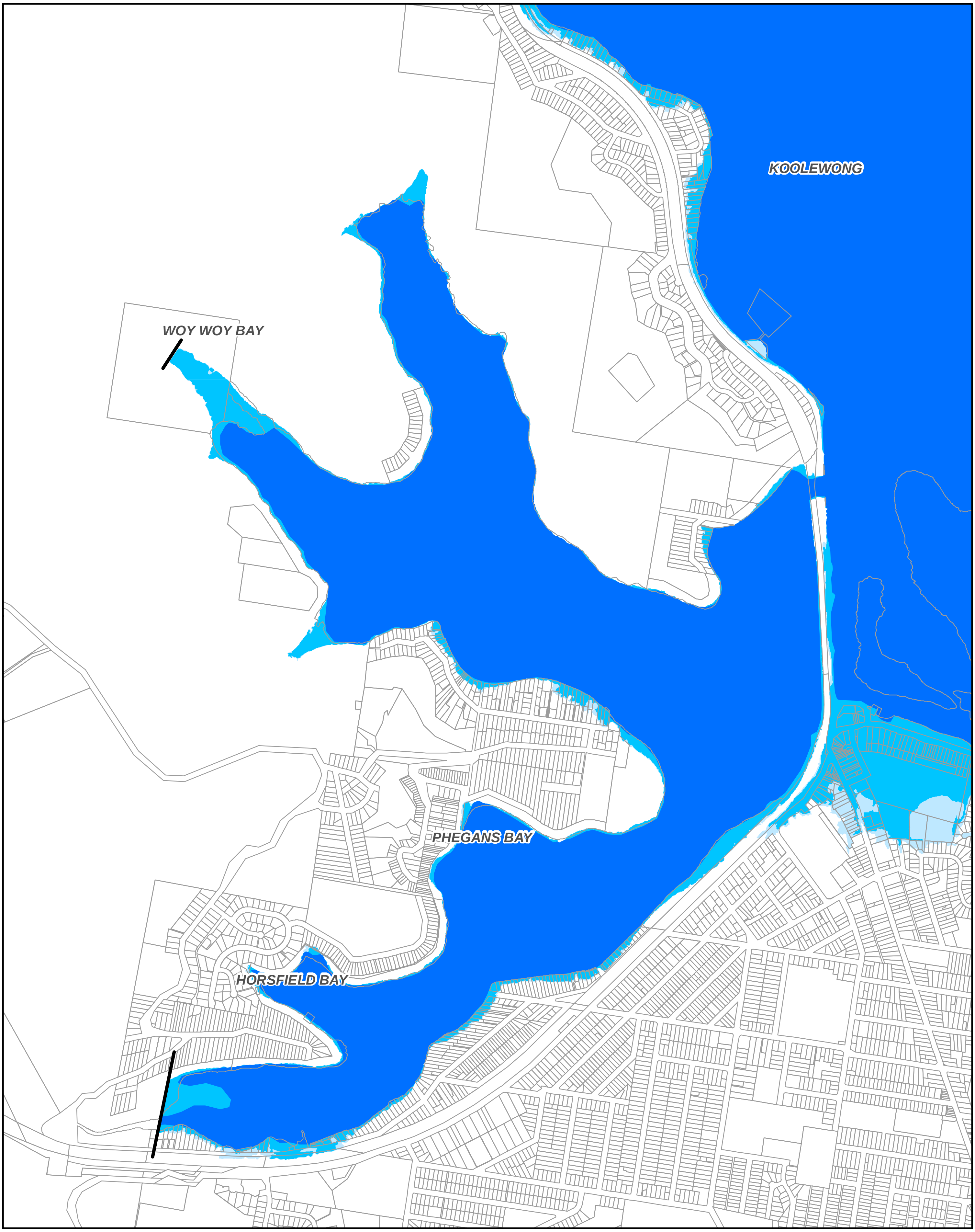
Hydraulic Categorisation 100 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E3.3 - MPA2

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2009_AppE_HydraulicCategories_100yrARI.mxd 01



Legend

Brisbane Water Flood Hydraulic Mapping Extent
Cadastre
Floodway
Flood Storage
Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

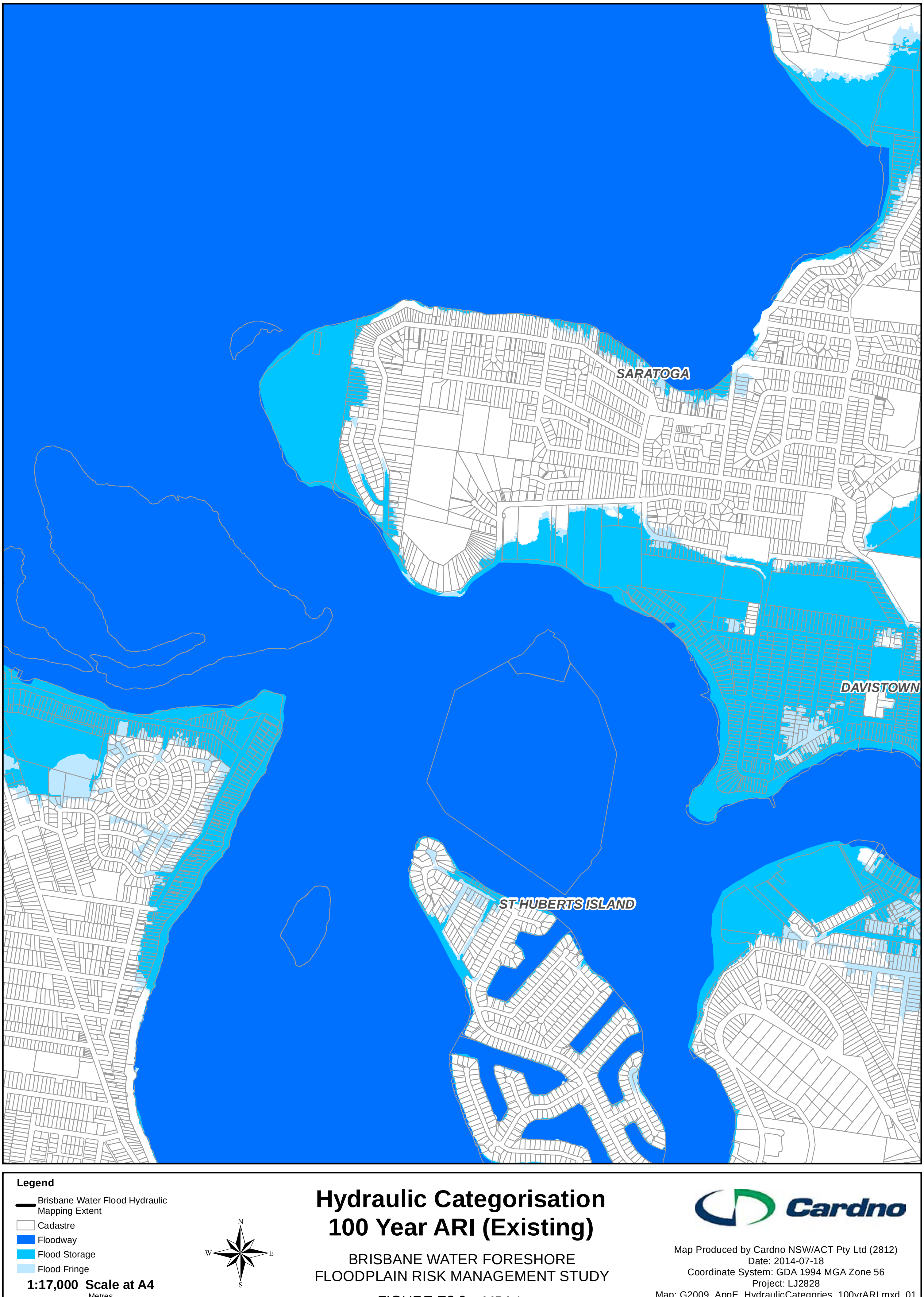
Hydraulic Categorisation 100 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E3.5 - MPA3

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2009_AppE_HydraulicCategories_100yrARI.mxd 01



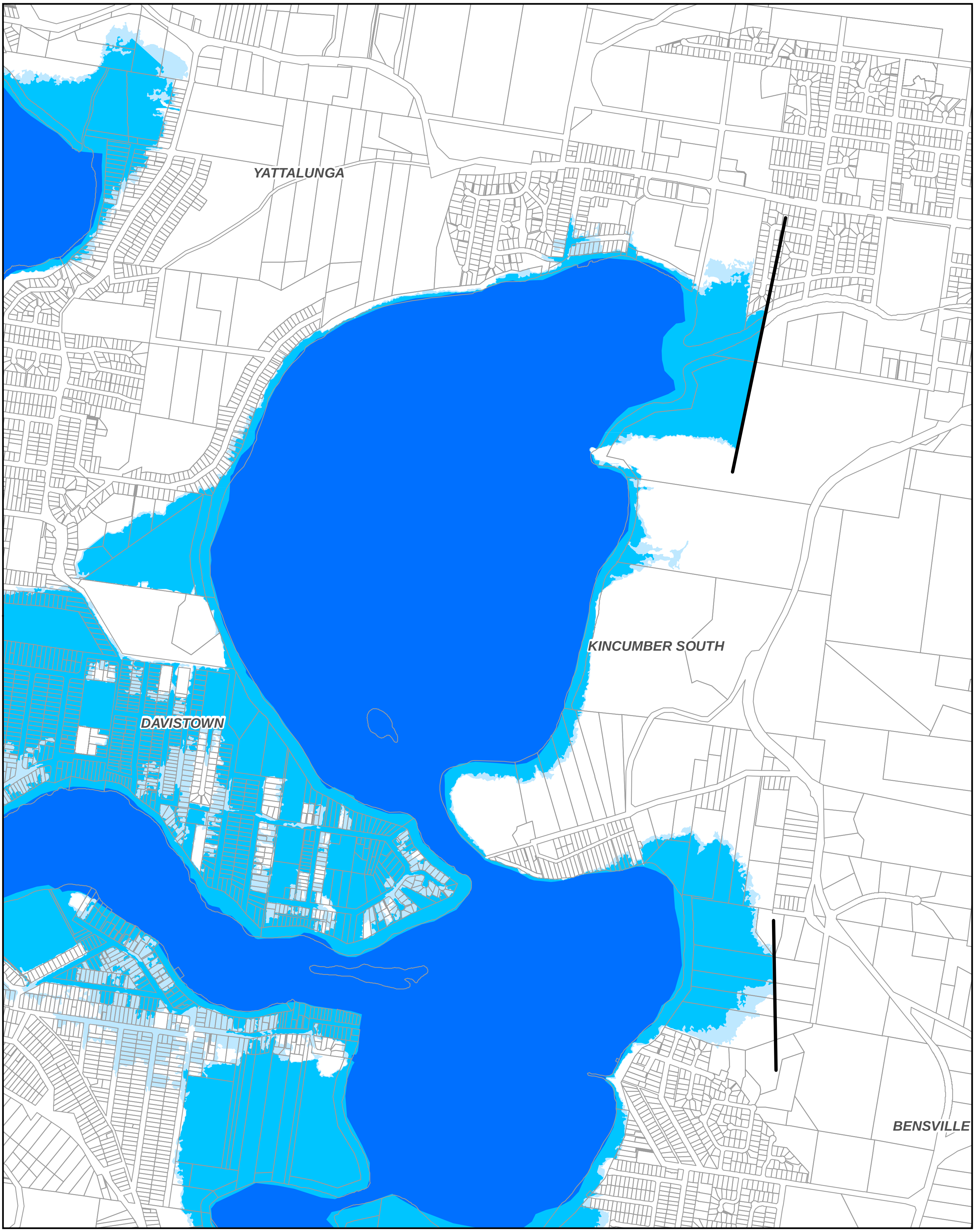
Hydraulic Categorisation 100 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E3.6 - MPA4

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2009_AppE_HydraulicCategories_100yrARI.mxd 01



Legend

- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

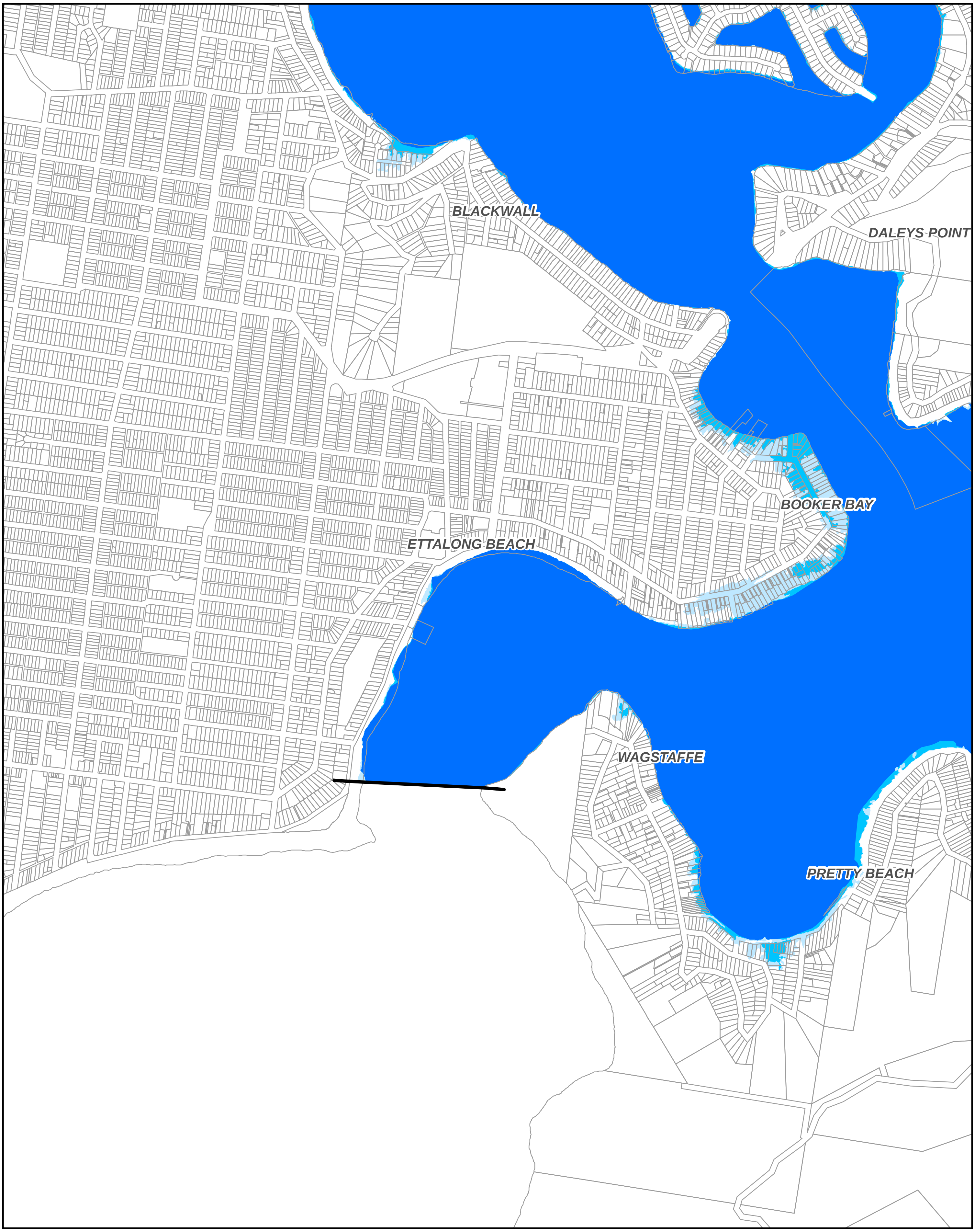
Hydraulic Categorisation 100 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E3.7 - MPA5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2009_AppE_HydraulicCategories_100yrARI.mxd 01



Legend

- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

N W E S

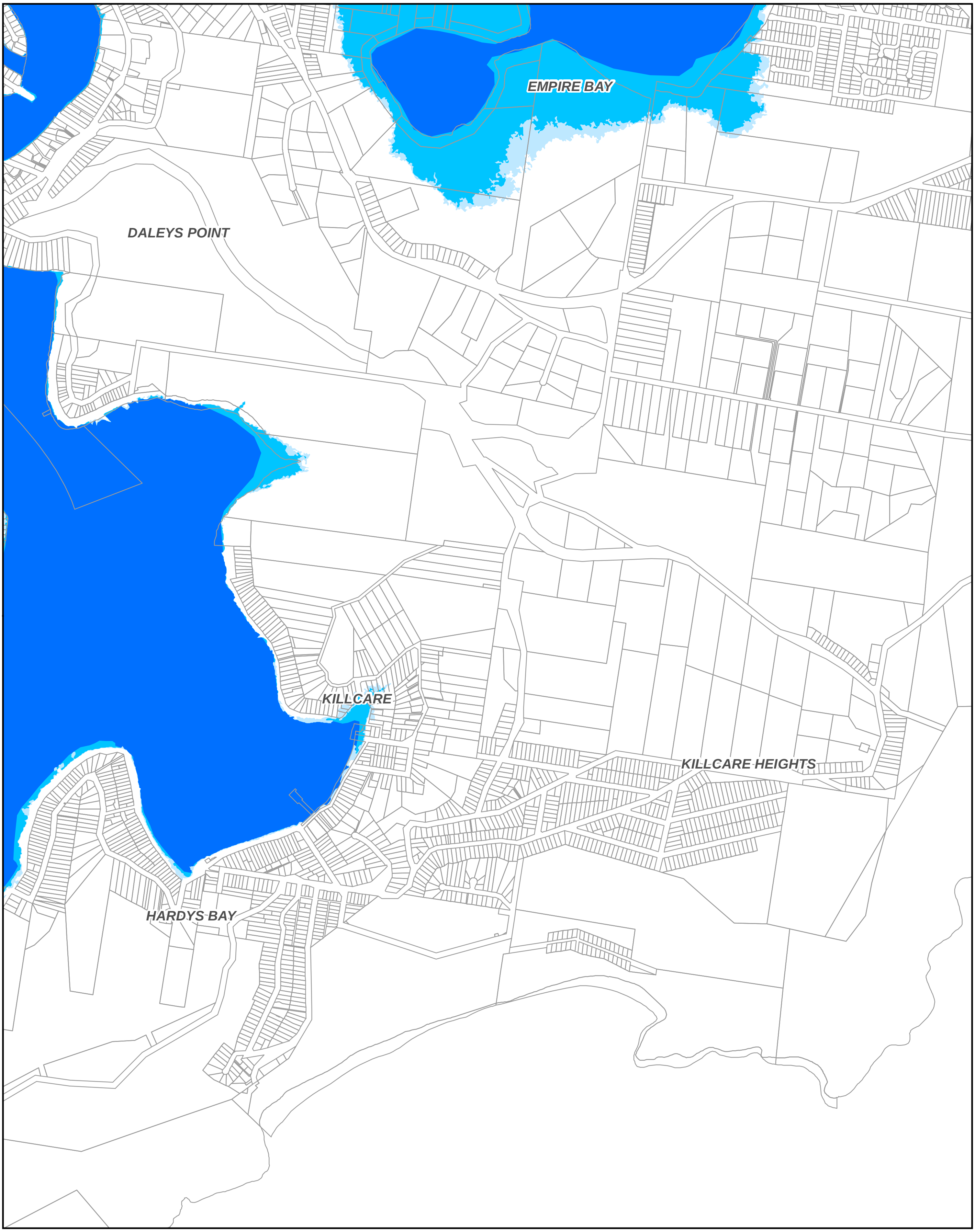
Hydraulic Categorisation 100 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E3.8 - MPA6

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2009_AppE_HydraulicCategories_100yrARI.mxd 01



Legend

- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

N W E S

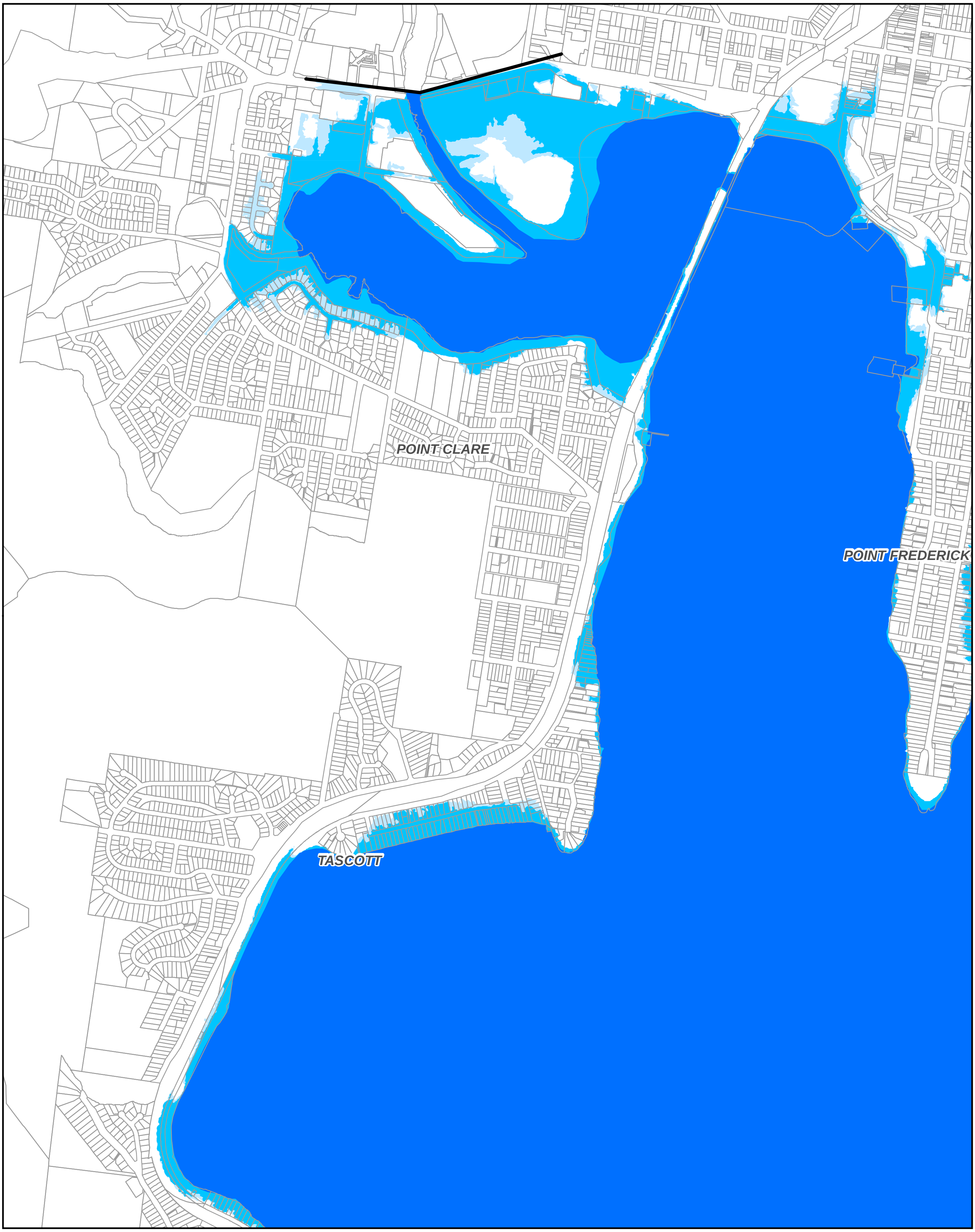
Hydraulic Categorisation 100 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E3.9 - MPA7

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2009_AppE_HydraulicCategories_100yrARI.mxd 01



Legend

- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

N E S W

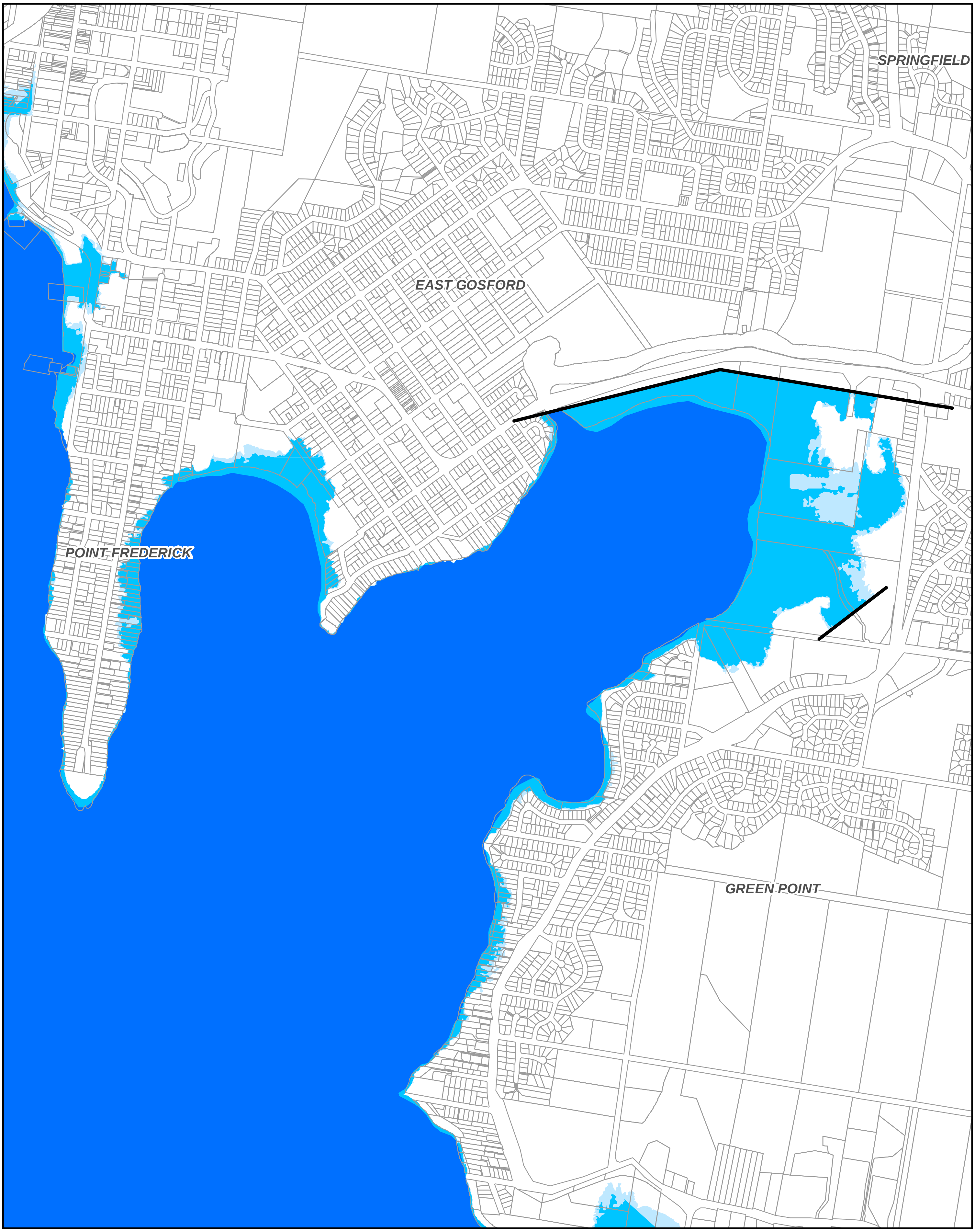
Hydraulic Categorisation 200 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E4.1 - MPA1

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2010_AppE_HydraulicCategories_200yrARI.mxd 01



Legend
- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

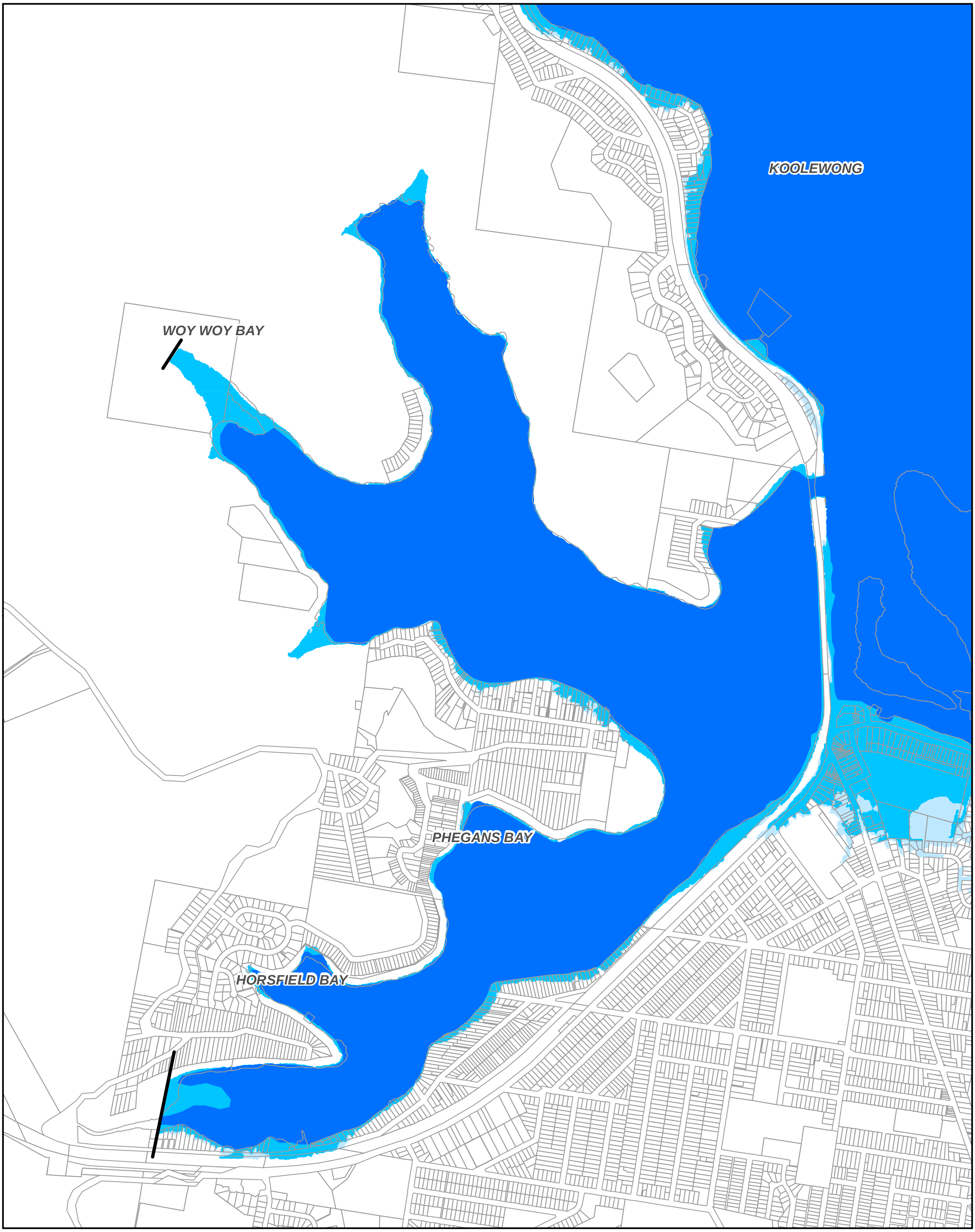
Hydraulic Categorisation 200 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E4.3 - MPA2

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2010_AppE_HydraulicCategories_200yrARI.mxd 01



Legend

- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres: 0, 200, 400, 600

N, E, S, W

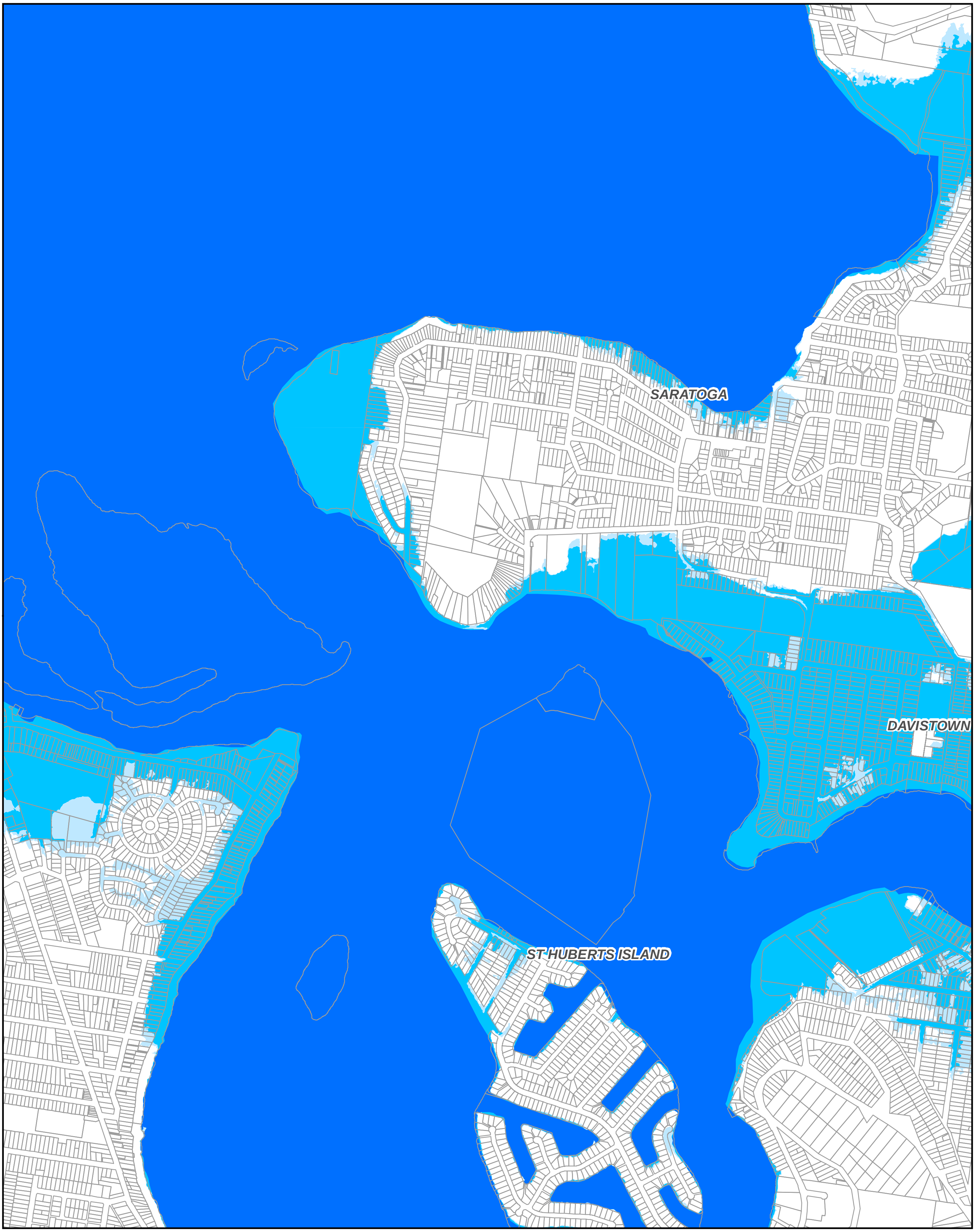
Hydraulic Categorisation 200 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E4.5 - MPA3

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2010_AppE_HydraulicCategories_200yrARI.mxd 01



Legend

Brisbane Water Flood Hydraulic Mapping Extent
Cadastre
Floodway
Flood Storage
Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

N E S W

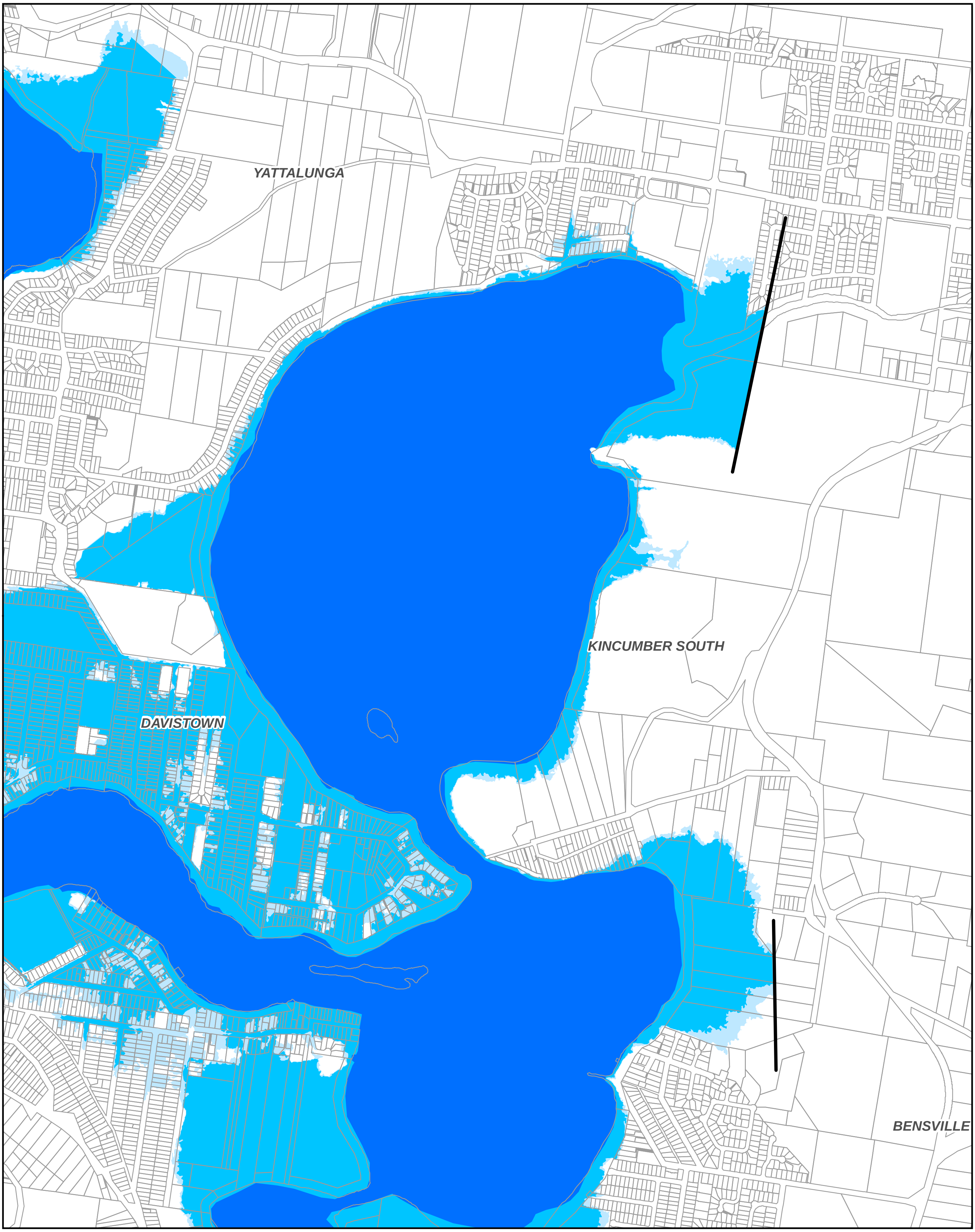
Hydraulic Categorisation 200 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E4.6 - MPA4

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2010_AppE_HydraulicCategories_200yrARI.mxd 01



Legend

- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

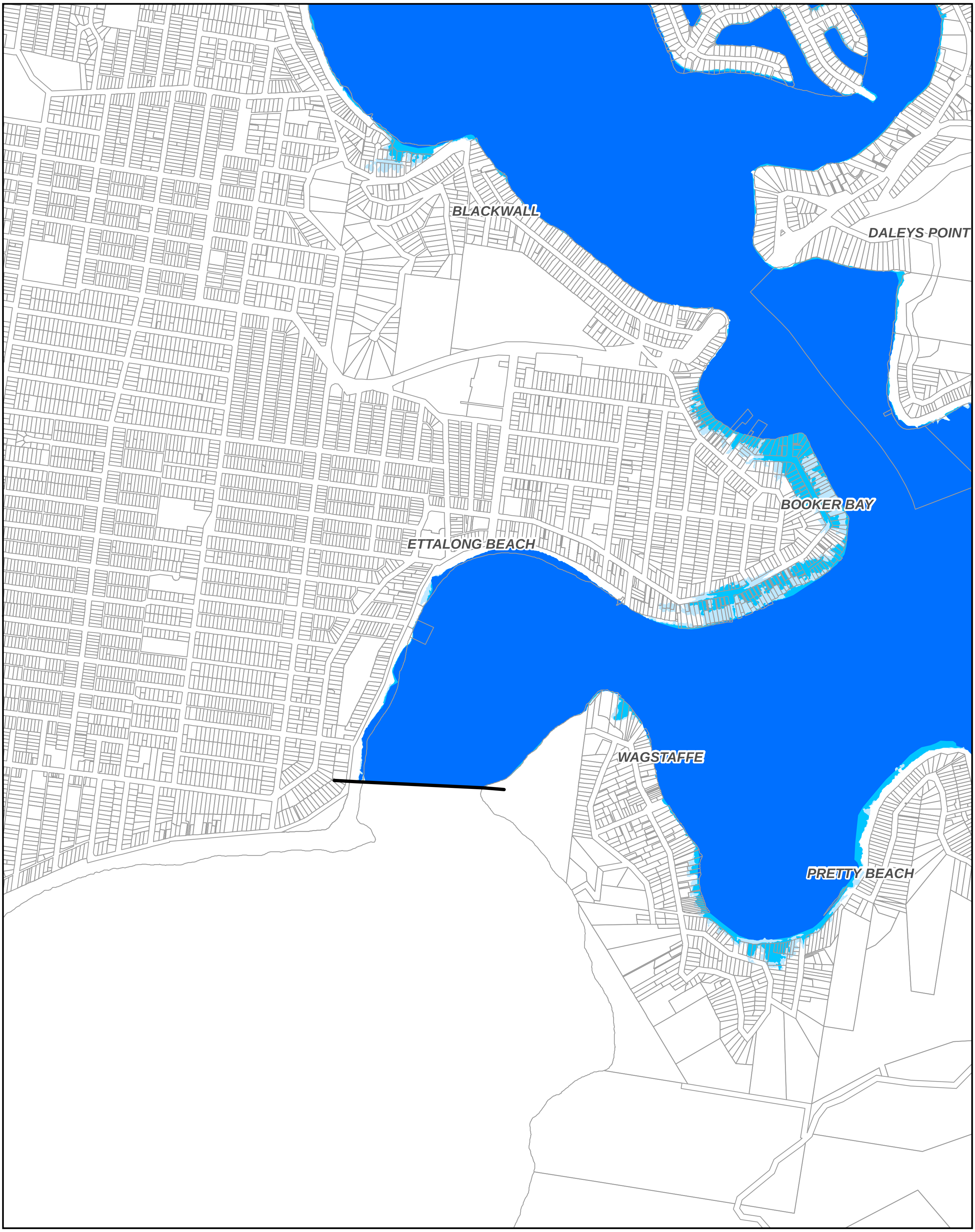
Hydraulic Categorisation 200 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E4.7 - MPA5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2010_AppE_HydraulicCategories_200yrARI.mxd 01



Legend
Brisbane Water Flood Hydraulic Mapping Extent
Cadastre
Floodway
Flood Storage
Flood Fringe

1:17,000 Scale at A4
Metres
0 200 400 600

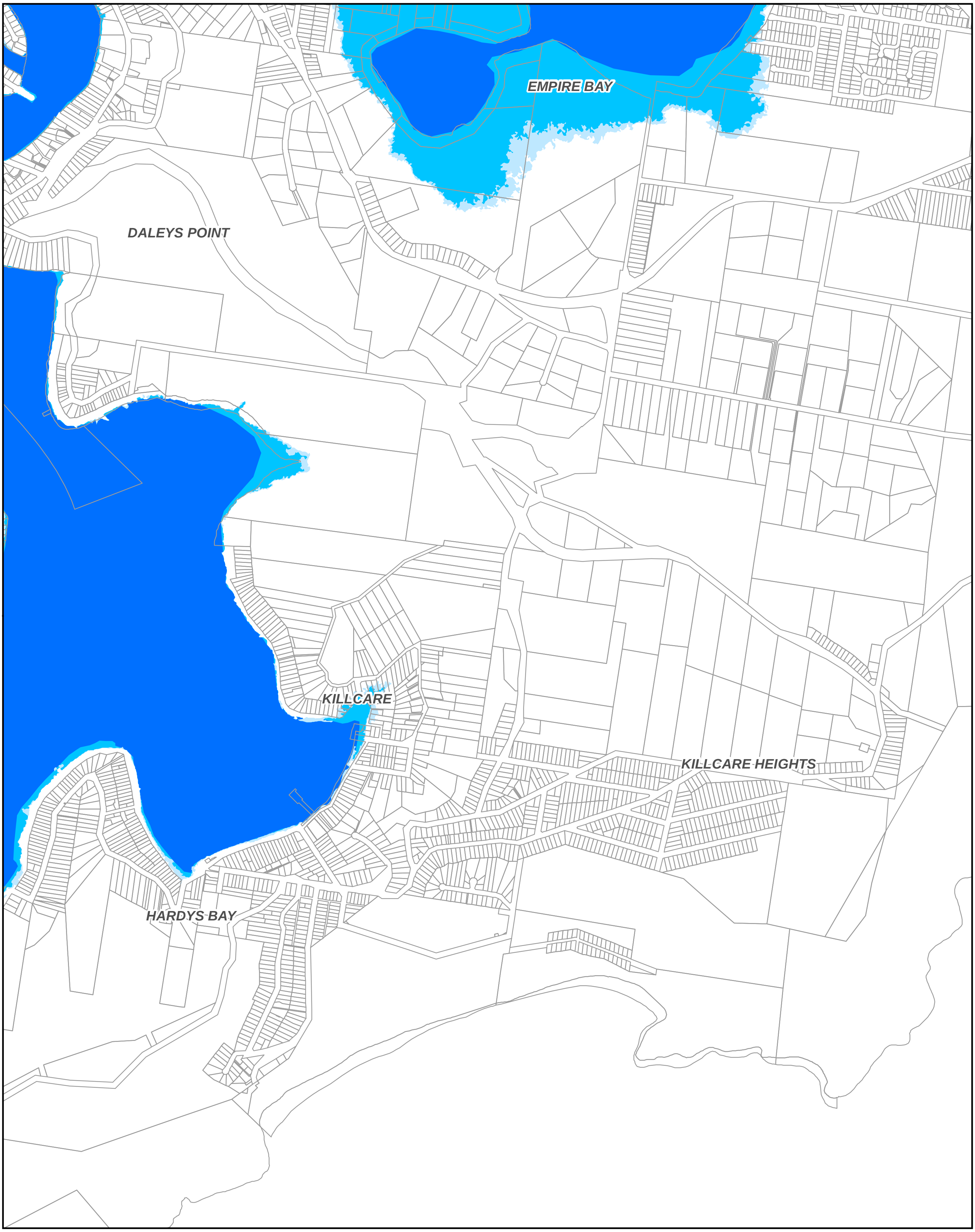
Hydraulic Categorisation
200 Year ARI (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E4.8 - MPA6

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2010_AppE_HydraulicCategories_200yrARI.mxd 01



Legend
- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres 0 200 400 600

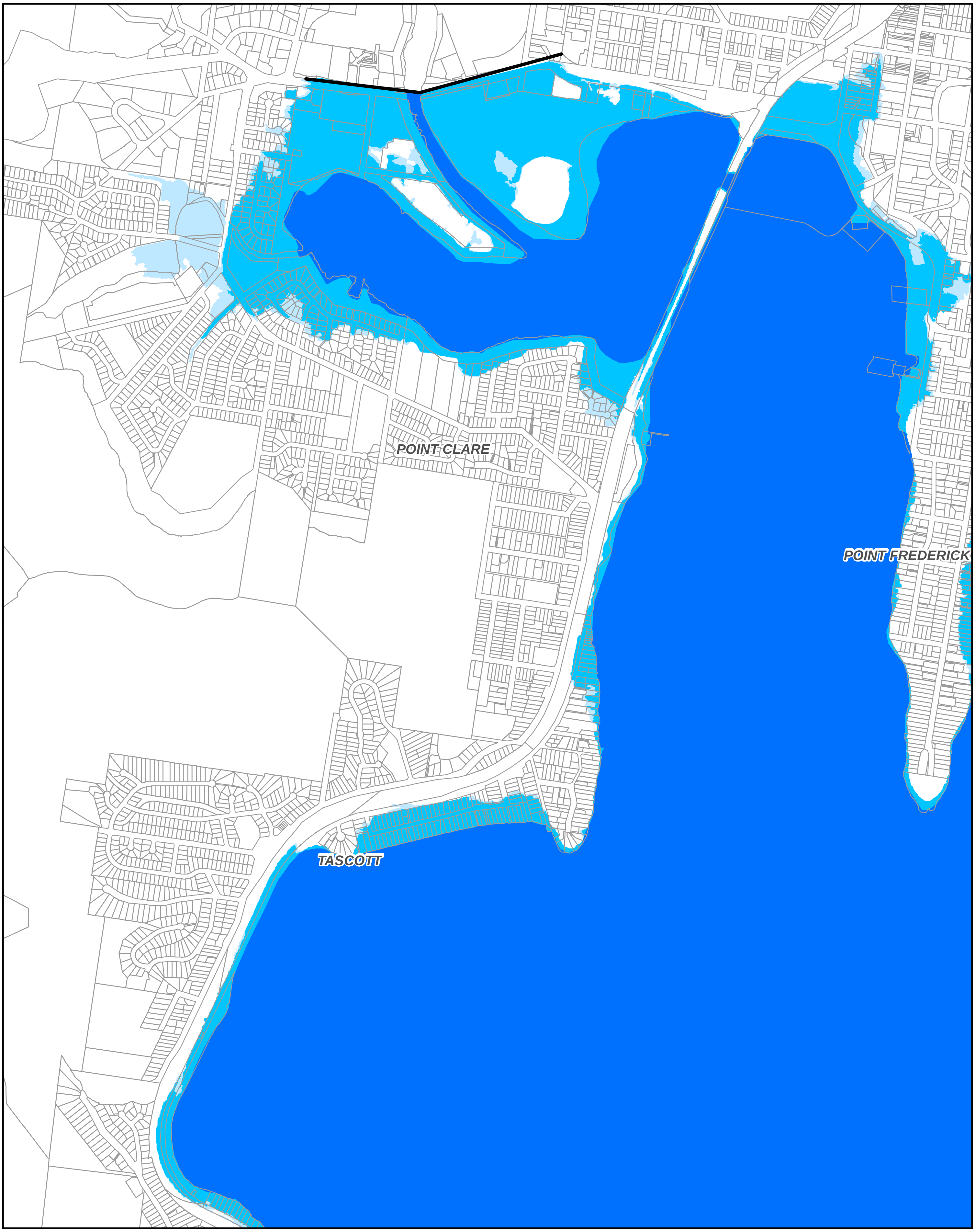
N E S W

Hydraulic Categorisation 200 Year ARI (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E4.9 - MPA7

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2010_AppE_HydraulicCategories_200yrARI.mxd 01



Legend

- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

N W E S

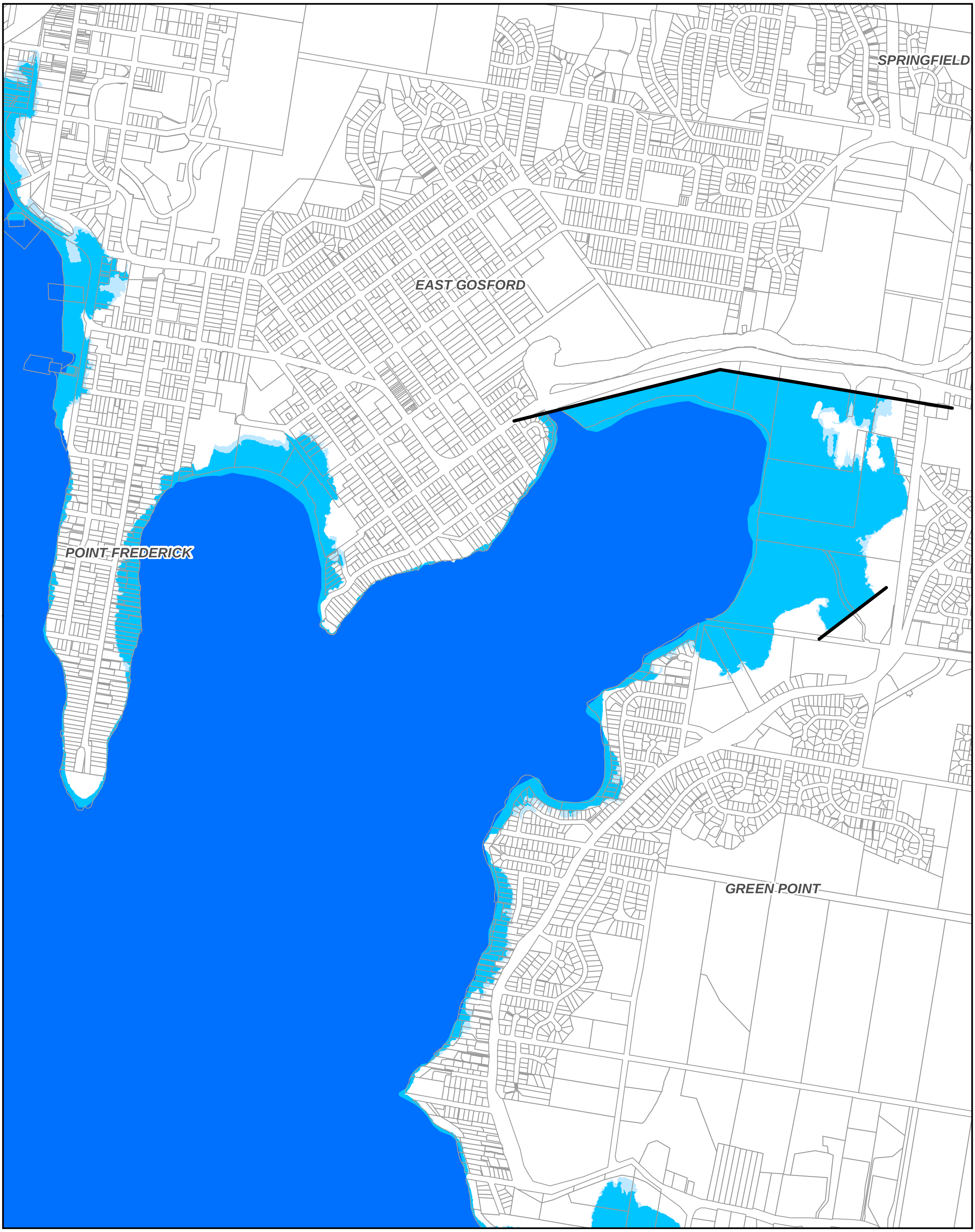
Hydraulic Categorisation PMF (Existing)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E5.1 - MPA1

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2011_AppE_HydraulicCategories_PMF.mxd 01



Legend
- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

N W E S

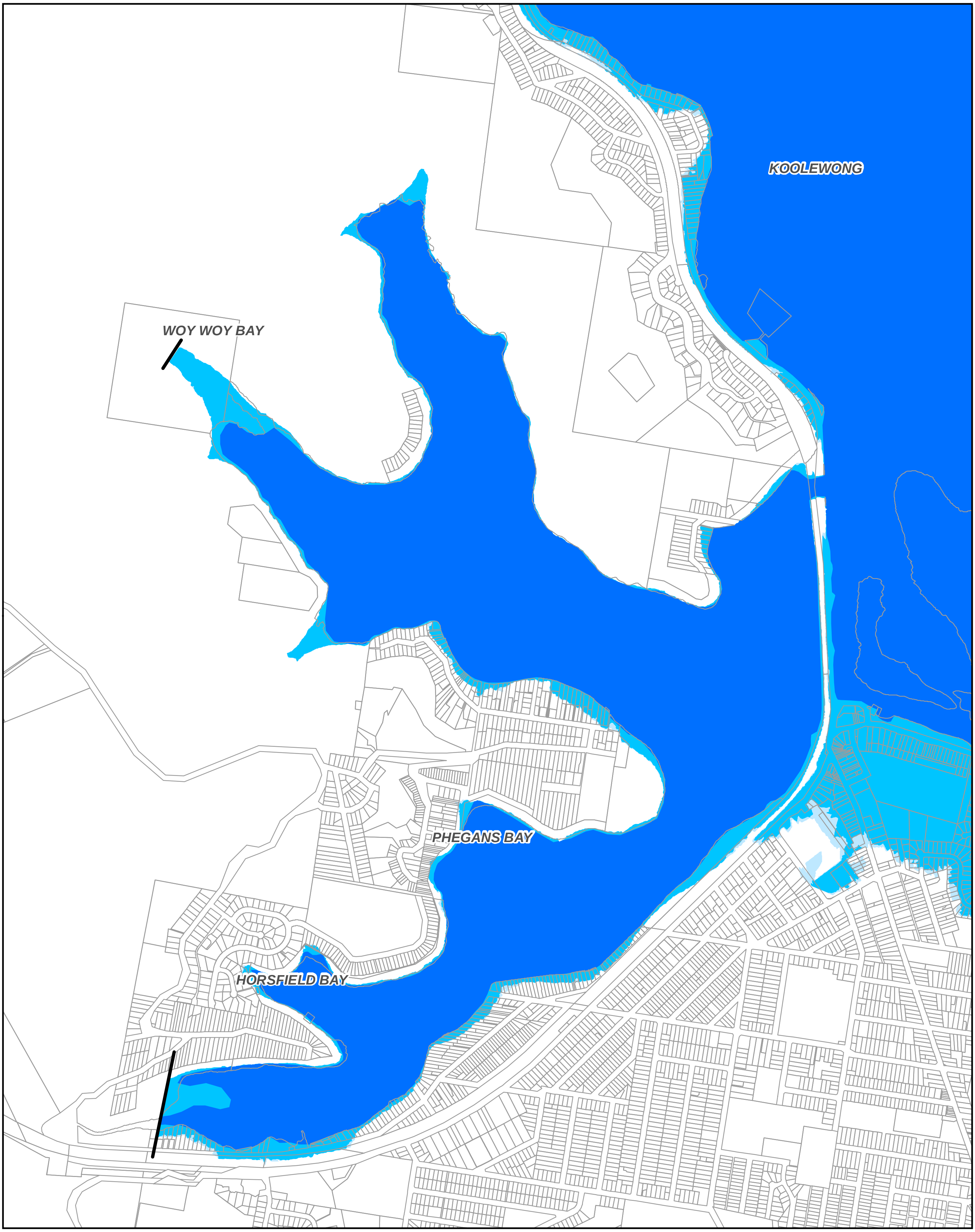
Hydraulic Categorisation PMF (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E5.3 - MPA2

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2011_AppE_HydraulicCategories_PMF.mxd 01



Legend
- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

N W E S

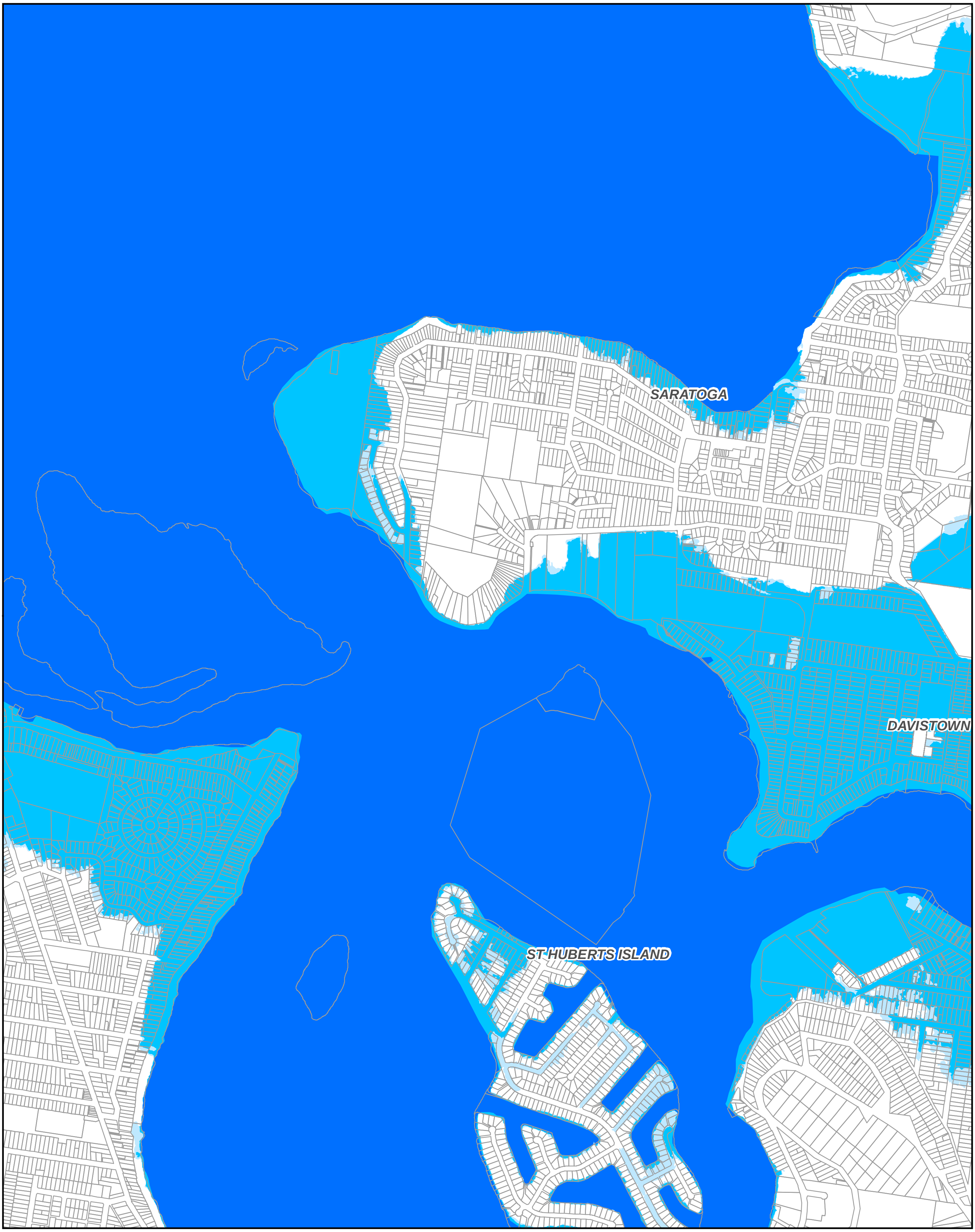
Hydraulic Categorisation PMF (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E5.5 - MPA3

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2011_AppE_HydraulicCategories_PMF.mxd 01



Legend

- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

N W E S

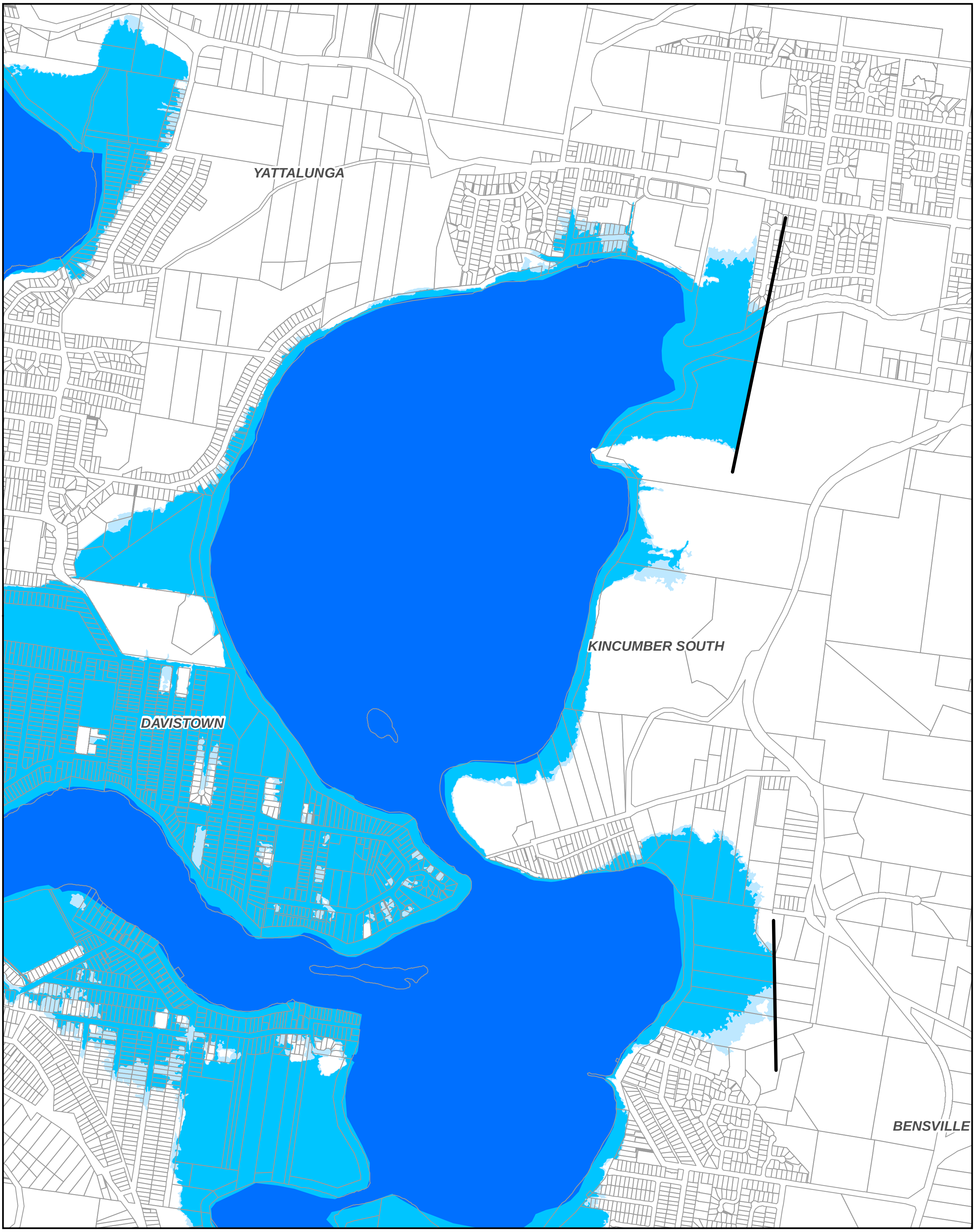
Hydraulic Categorisation PMF (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E5.6 - MPA4

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2011_AppE_HydraulicCategories_PMF.mxd 01



Legend
- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

N W E S

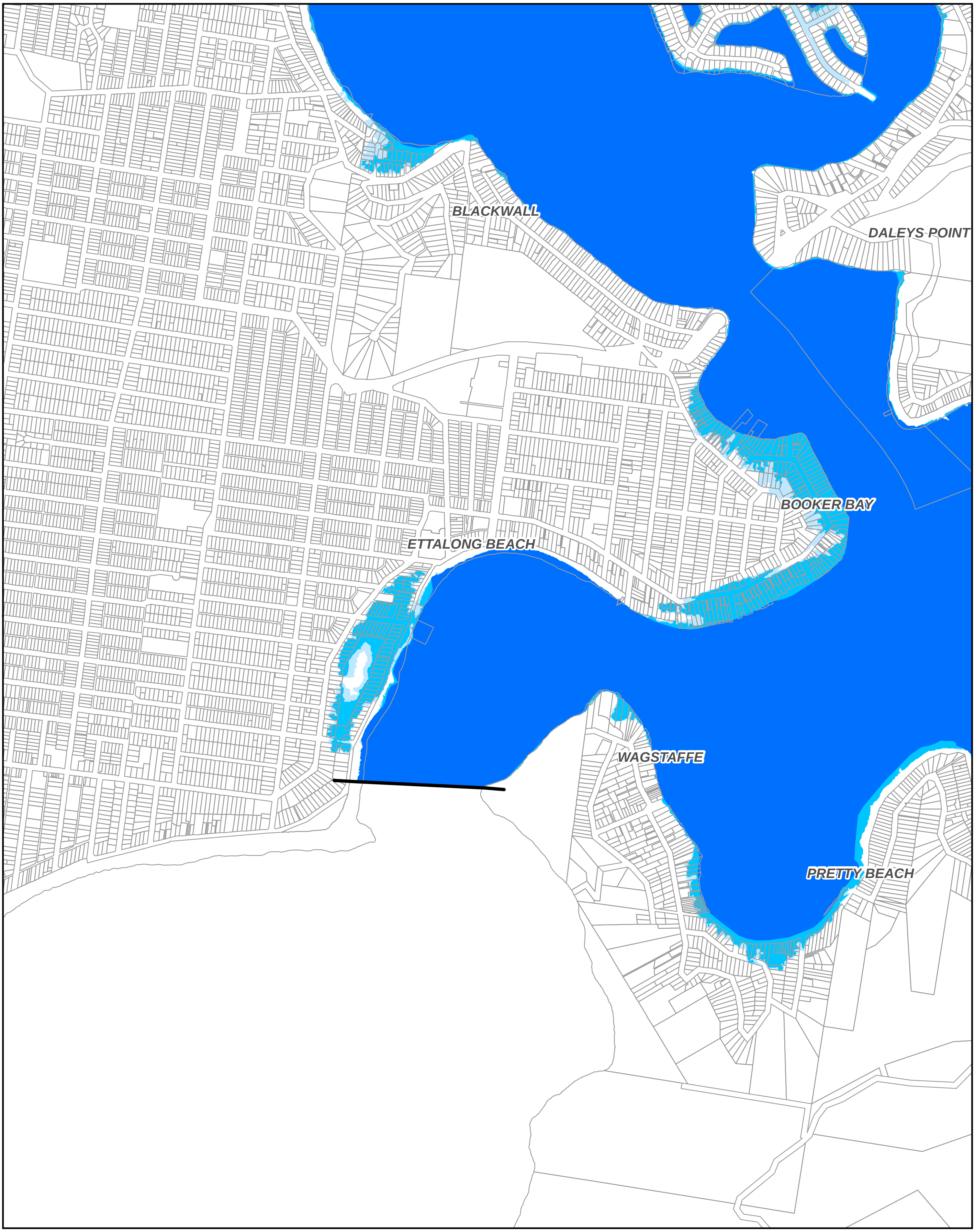
Hydraulic Categorisation PMF (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E5.7 - MPA5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2011_AppE_HydraulicCategories_PMF.mxd 01



Legend

- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres

0 200 400 600

N W E S

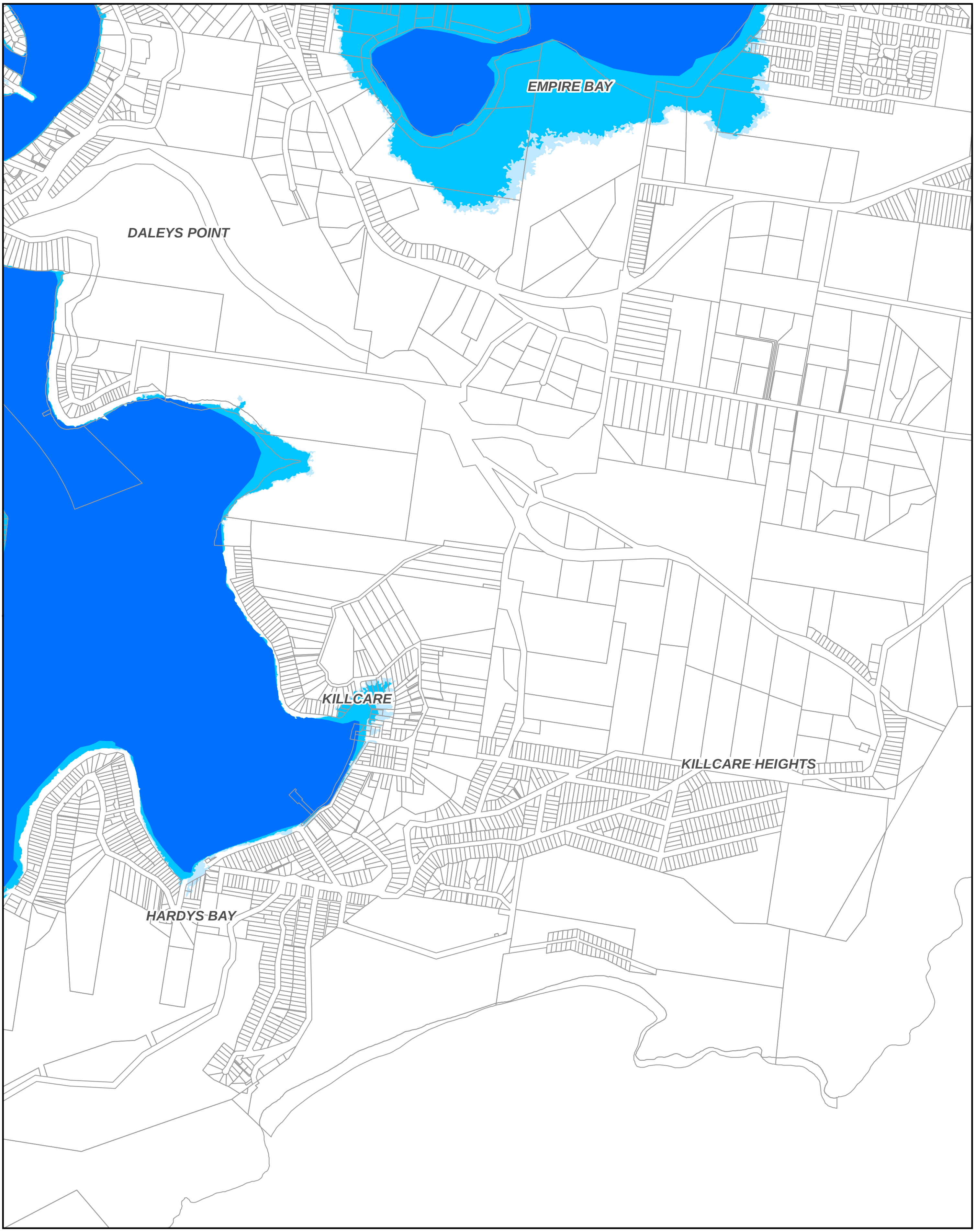
Hydraulic Categorisation PMF (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE E5.8 - MPA6

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2011_AppE_HydraulicCategories_PMF.mxd 01



Legend

- Brisbane Water Flood Hydraulic Mapping Extent
- Cadastre
- Floodway
- Flood Storage
- Flood Fringe

1:17,000 Scale at A4

Metres 0 200 400 600

Hydraulic Categorisation PMF (Existing)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

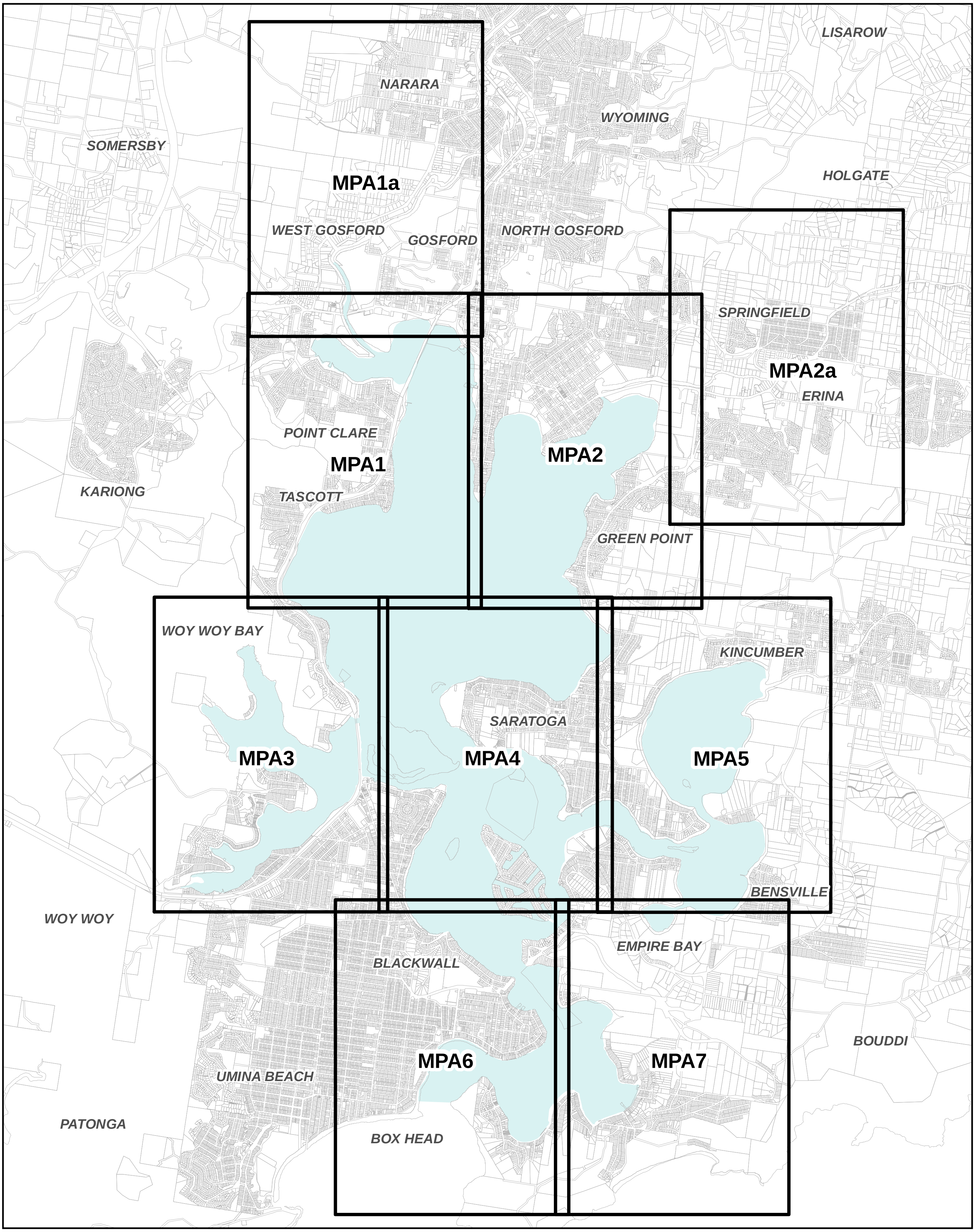
FIGURE E5.9 - MPA7

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2011_AppE_HydraulicCategories_PMF.mxd 01

Appendix F

Flood Extents (with 0.4m and 0.9m SLR)



Legend

Mapping Areas
Cadastre
Waterway

1:65,000 Scale at A4

Metres
0 500 1000 1500

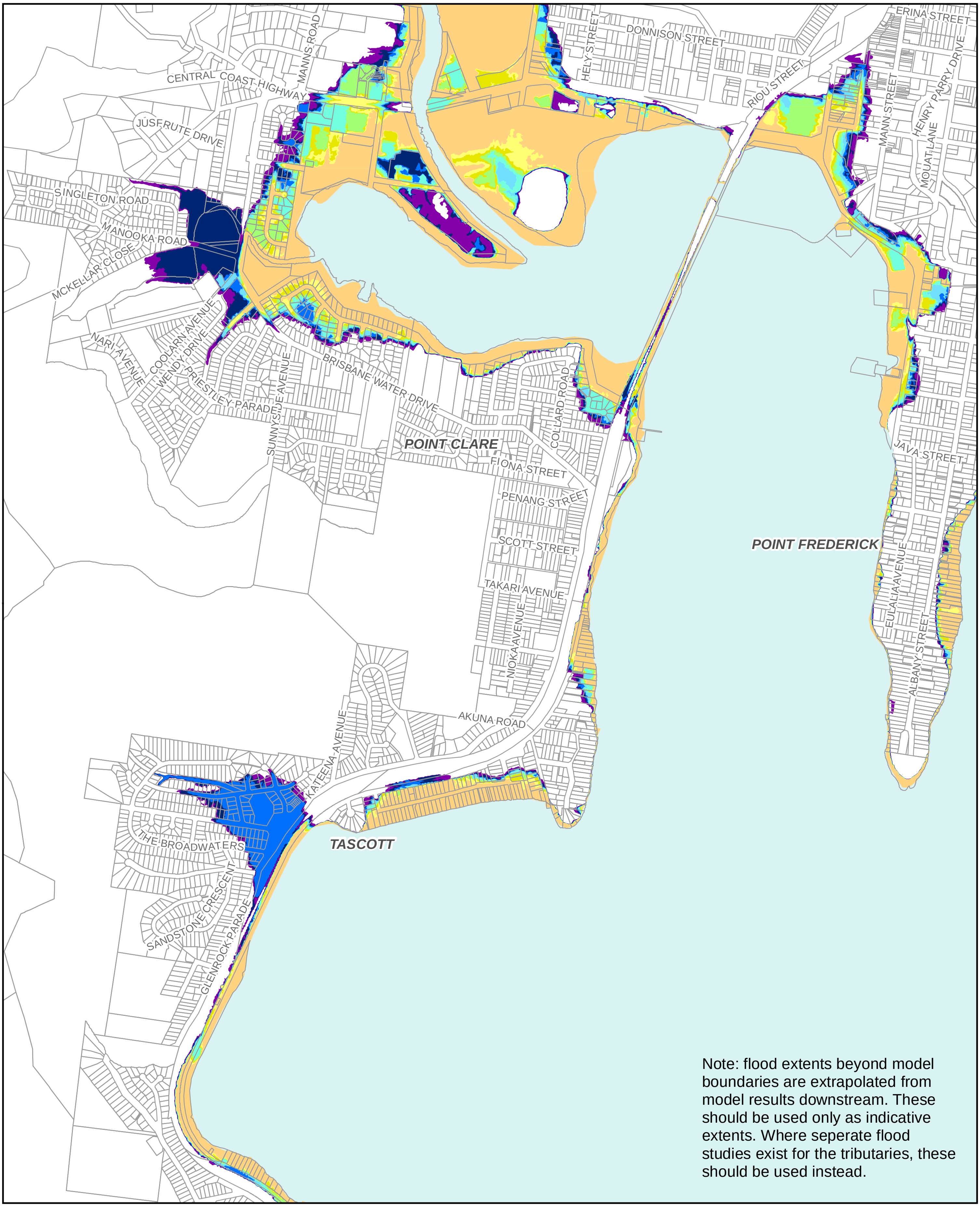
Mapping Area Index

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F1.0

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-17
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2000_AppC_F_MappingAreas.mxd 01



Legend

Cadastre	50 Year ARI
Waterway	100 Year ARI
2 Year ARI	200 Year ARI
5 Year ARI	500 Year ARI
10 Year ARI	PMF Extent
20 Year ARI	Brisbane Water Flood Model Extent

1:18,000 Scale at A4

Metres
0 200 400 600

N E S W

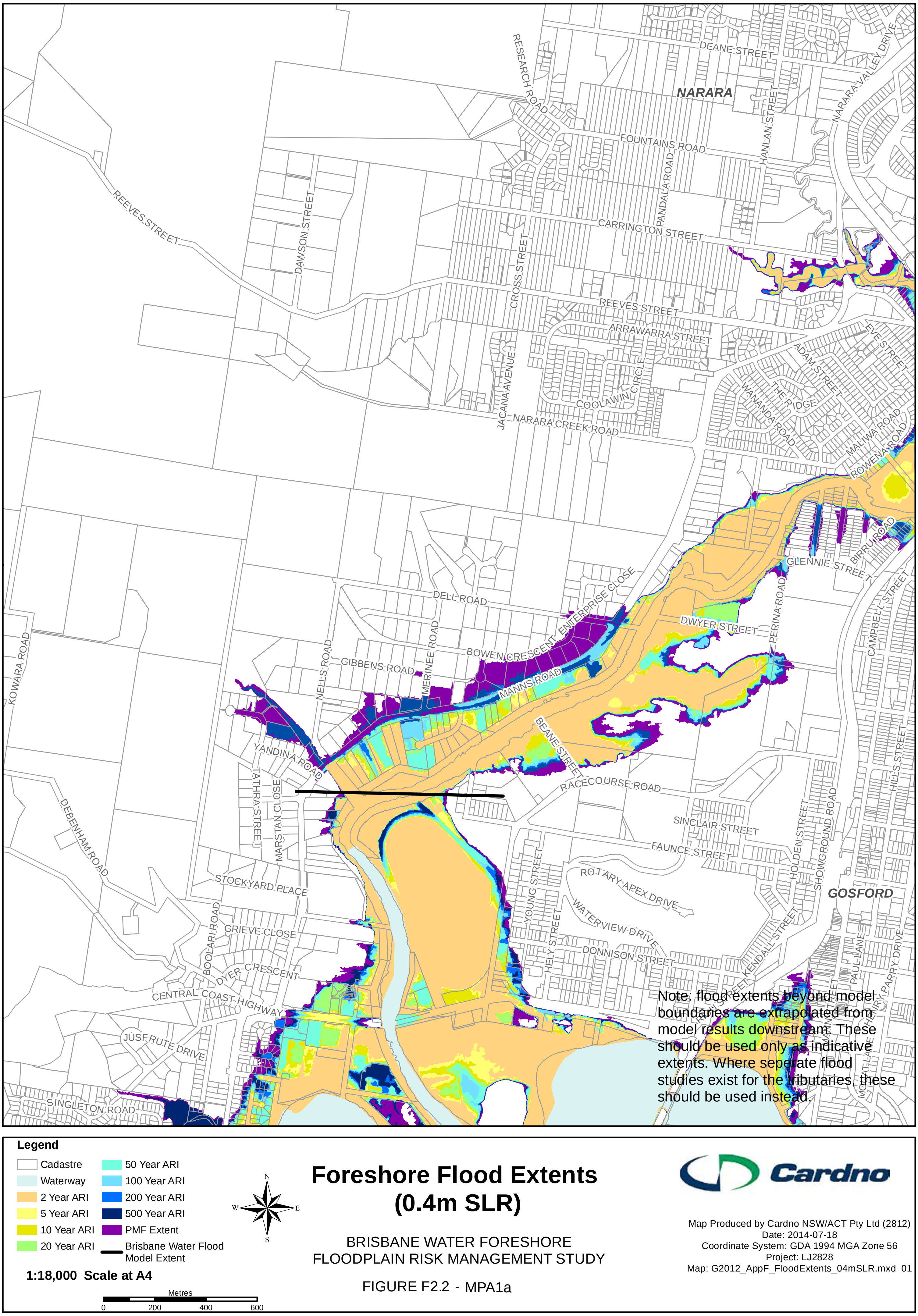
Foreshore Flood Extents (0.4m SLR)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F2.1 - MPA1

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2012_AppF_FloodExtents_04mSLR.mxd 01



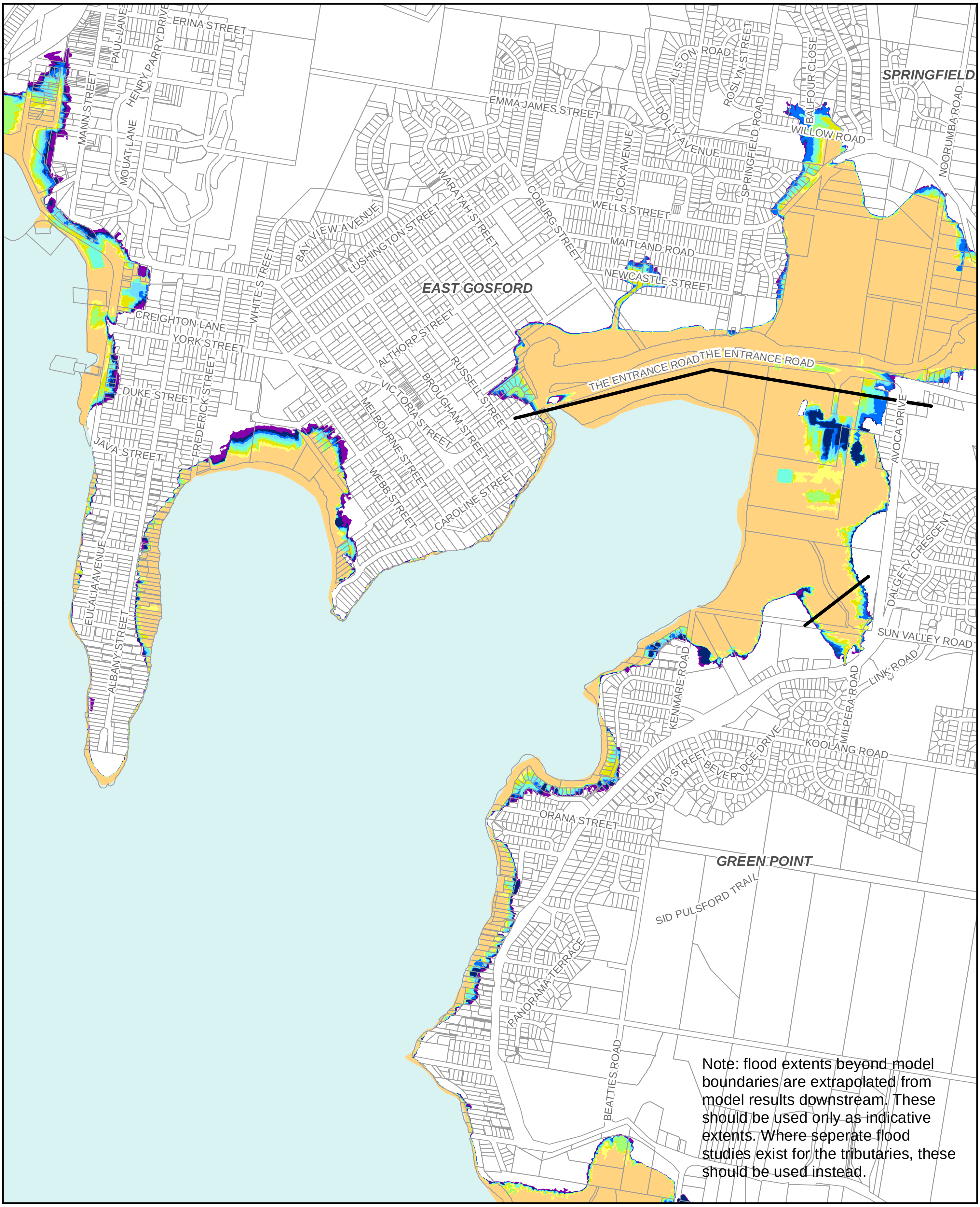
Foreshore Flood Extents (0.4m SLR)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F2.2 - MPA1a

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2012_AppF_FloodExtents_04mSLR.mxd 01



Note: flood extents beyond model boundaries are extrapolated from model results downstream. These should be used only as indicative extents. Where seperate flood studies exist for the tributaries, these should be used instead.

Legend

- Cadastre
- Waterway
- 2 Year ARI
- 5 Year ARI
- 10 Year ARI
- 20 Year ARI
- 50 Year ARI
- 100 Year ARI
- 200 Year ARI
- 500 Year ARI
- PMF Extent
- Brisbane Water Flood Model Extent

1:18,000 Scale at A4

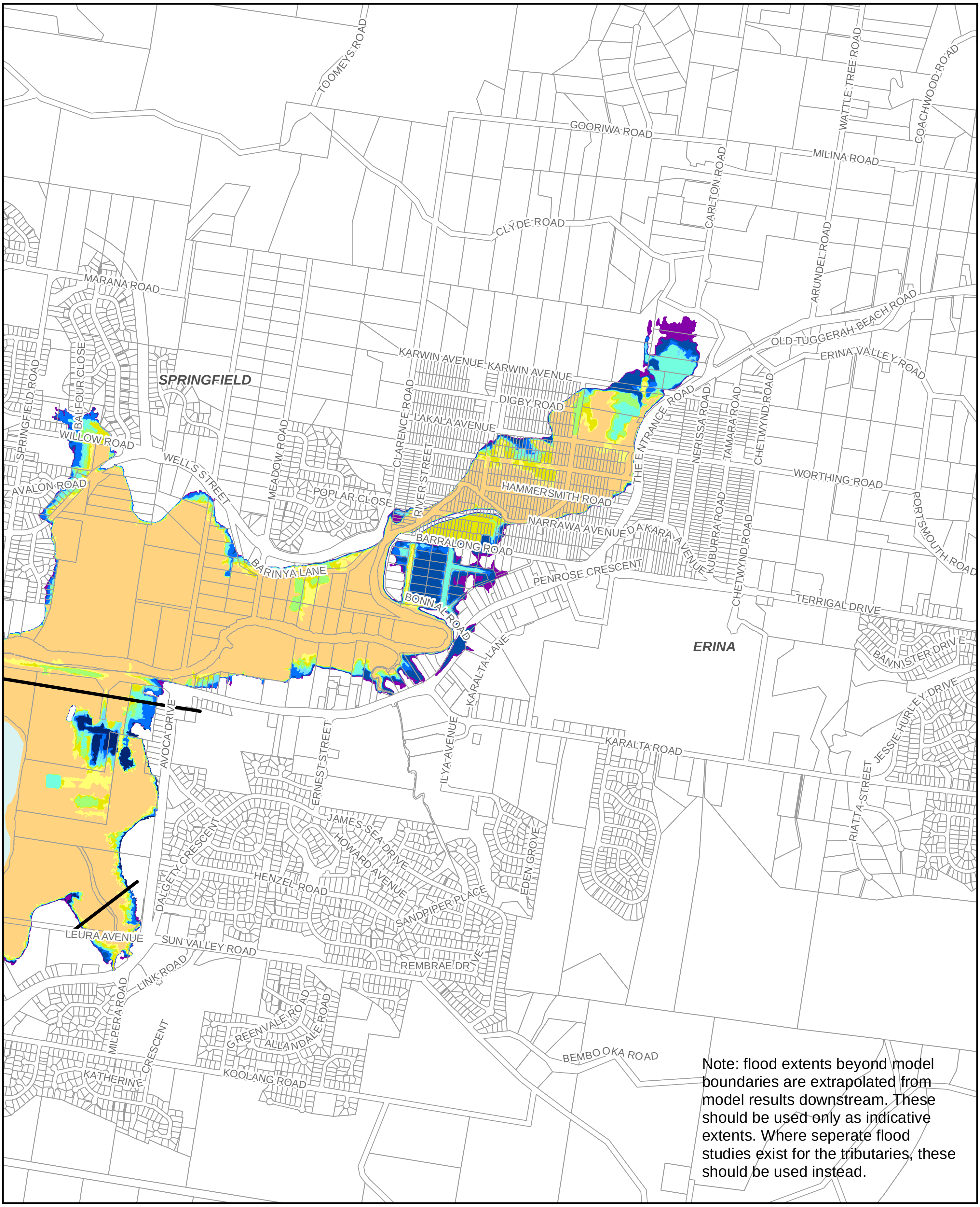
Metres
0 200 400 600

Foreshore Flood Extents (0.4m SLR)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F2.3 - MPA2

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2012_AppF_FloodExtents_04mSLR.mxd 01



Note: flood extents beyond model boundaries are extrapolated from model results downstream. These should be used only as indicative extents. Where seperate flood studies exist for the tributaries, these should be used instead.

Legend

Cadastre	50 Year ARI
Waterway	100 Year ARI
2 Year ARI	200 Year ARI
5 Year ARI	500 Year ARI
10 Year ARI	PMF Extent
20 Year ARI	Brisbane Water Flood Model Extent

1:18,000 Scale at A4

Metres 0 200 400 600

N E S W

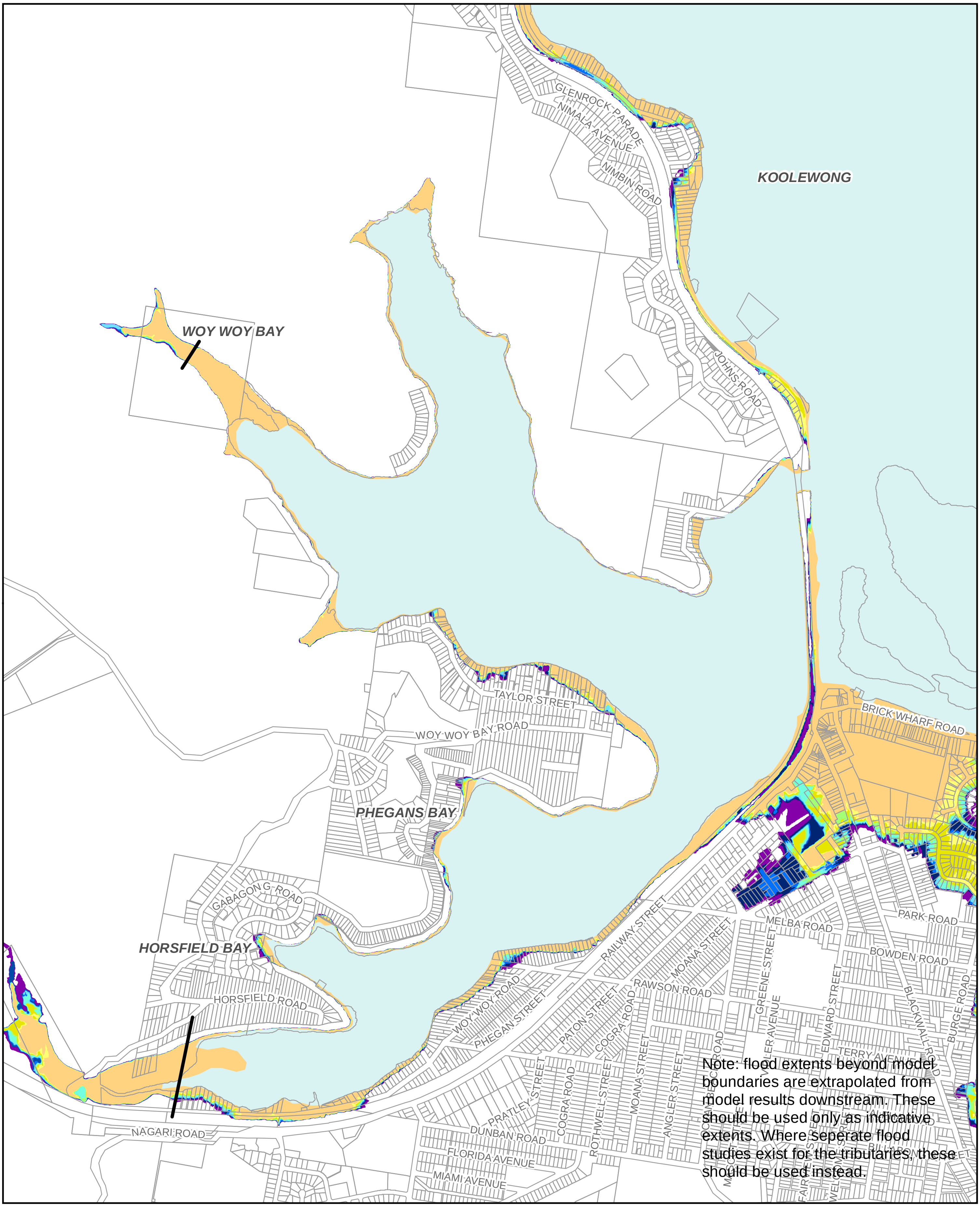
Foreshore Flood Extents (0.4m SLR)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F2.4 - MPA2a

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2012_AppF_FloodExtents_04mSLR.mxd 01



Legend

- Cadastre
- Waterway
- 2 Year ARI
- 5 Year ARI
- 10 Year ARI
- 20 Year ARI
- 50 Year ARI
- 100 Year ARI
- 200 Year ARI
- 500 Year ARI
- PMF Extent
- Brisbane Water Flood Model Extent

1:18,000 Scale at A4

Metres
0 200 400 600

N W E S

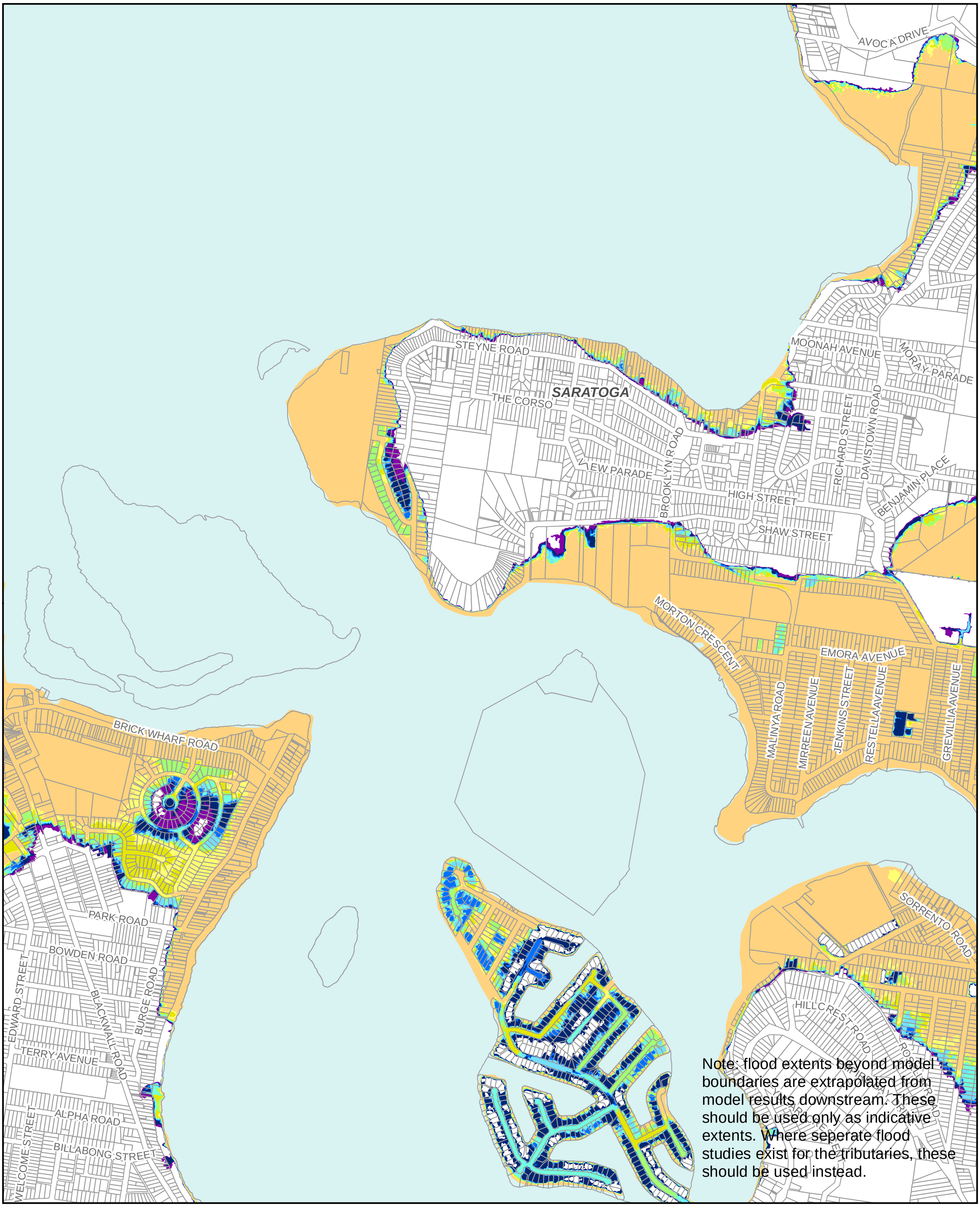
Foreshore Flood Extents (0.4m SLR)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F2.5 - MPA3

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2012_AppF_FloodExtents_04mSLR.mxd 01



Legend

Cadastre	50 Year ARI
Waterway	100 Year ARI
2 Year ARI	200 Year ARI
5 Year ARI	500 Year ARI
10 Year ARI	PMF Extent
20 Year ARI	Brisbane Water Flood Model Extent

1:18,000 Scale at A4

Metres
0 200 400 600

N
W E
S

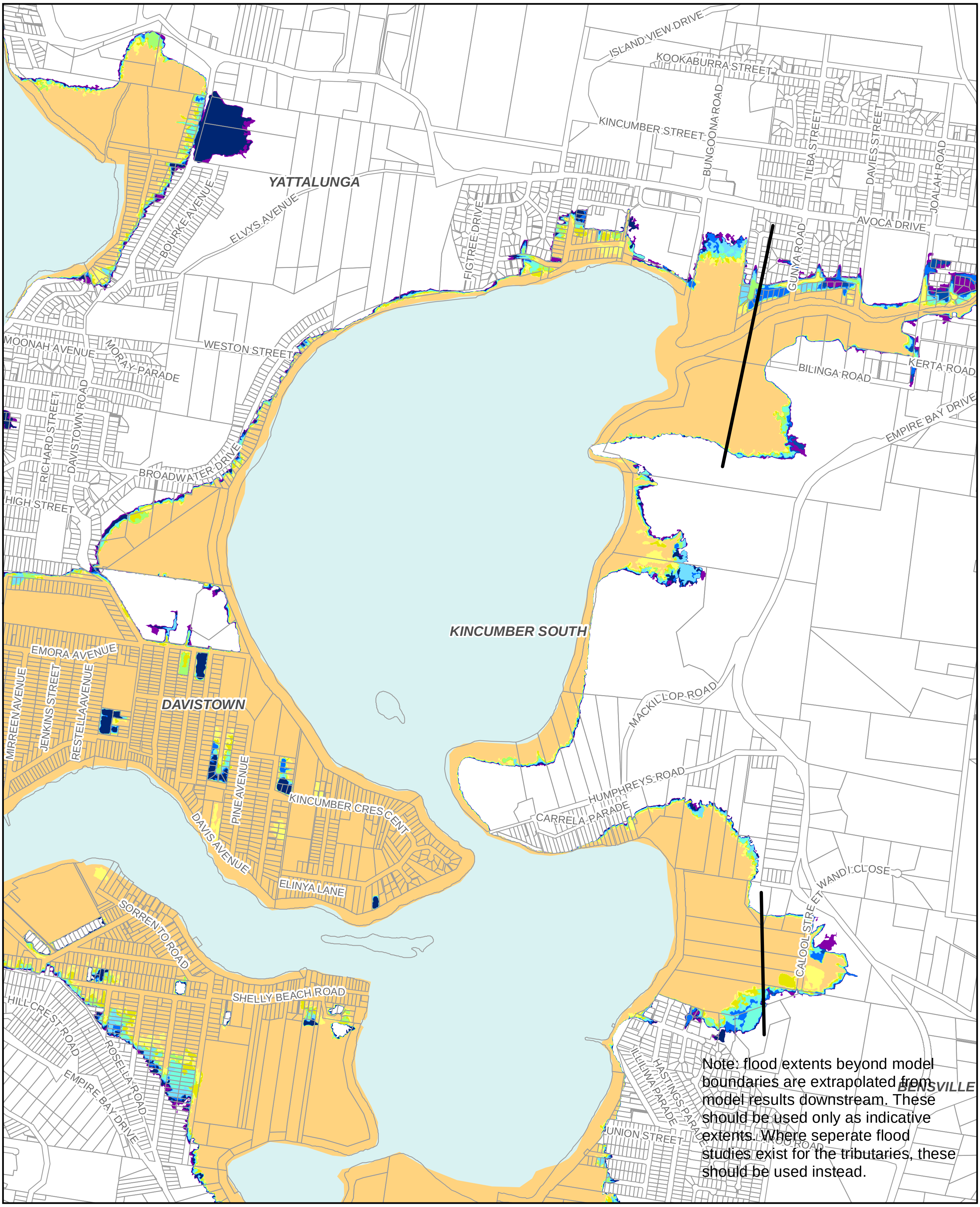
Foreshore Flood Extents (0.4m SLR)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F2.6 - MPA4

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2012_AppF_FloodExtents_04mSLR.mxd 01



Legend

- Cadastre
- Waterway
- 2 Year ARI
- 5 Year ARI
- 10 Year ARI
- 20 Year ARI
- 50 Year ARI
- 100 Year ARI
- 200 Year ARI
- 500 Year ARI
- PMF Extent
- Brisbane Water Flood Model Extent

1:18,000 Scale at A4

Metres
0 200 400 600

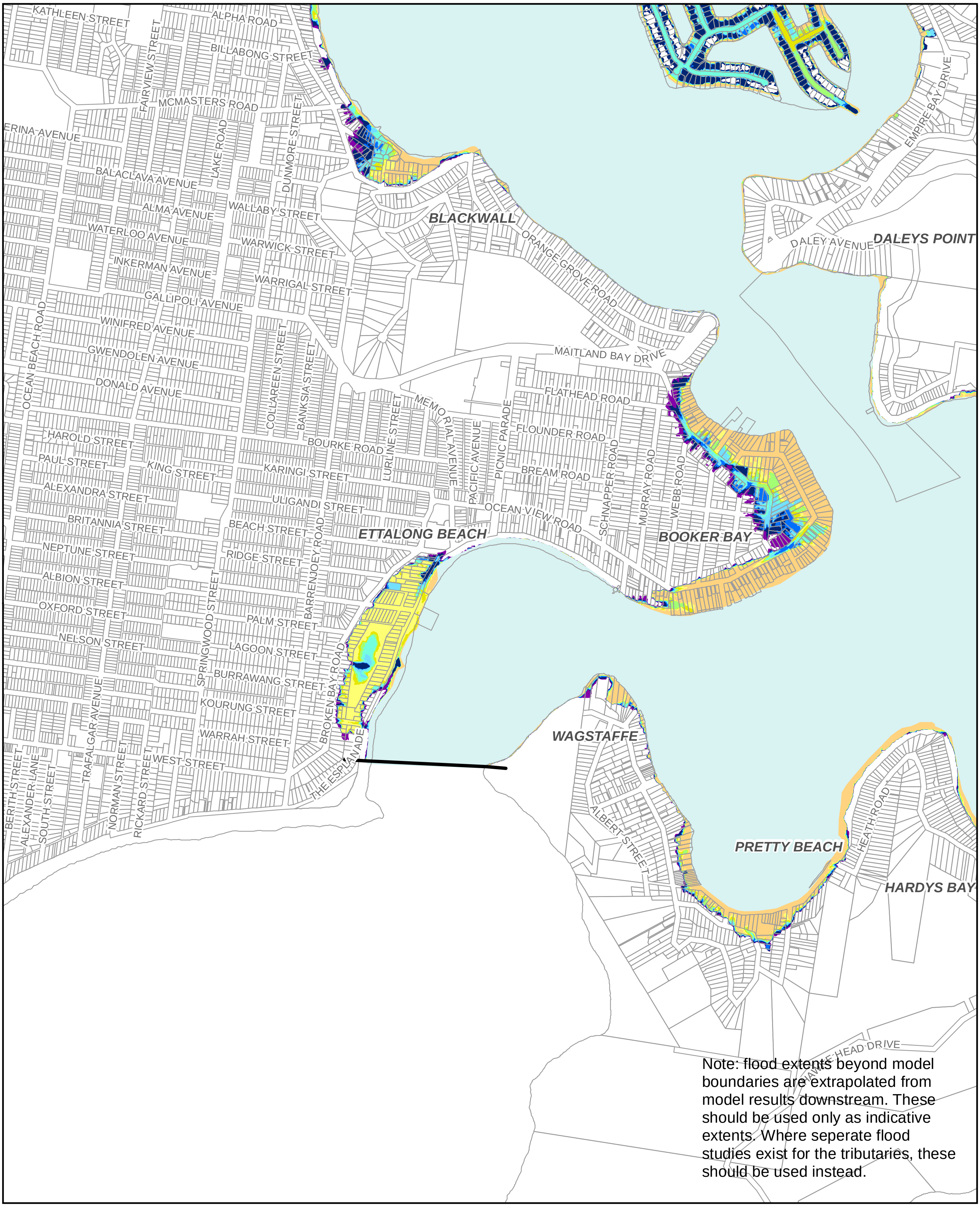
Foreshore Flood Extents (0.4m SLR)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F2.7 - MPA5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2012_AppF_FloodExtents_04mSLR.mxd 01



Note: flood extents beyond model boundaries are extrapolated from model results downstream. These should be used only as indicative extents. Where seperate flood studies exist for the tributaries, these should be used instead.

Legend

- Cadastre
- Waterway
- 2 Year ARI
- 5 Year ARI
- 10 Year ARI
- 20 Year ARI
- 50 Year ARI
- 100 Year ARI
- 200 Year ARI
- 500 Year ARI
- PMF Extent
- Brisbane Water Flood Model Extent

1:18,000 Scale at A4

Metres

0 200 400 600

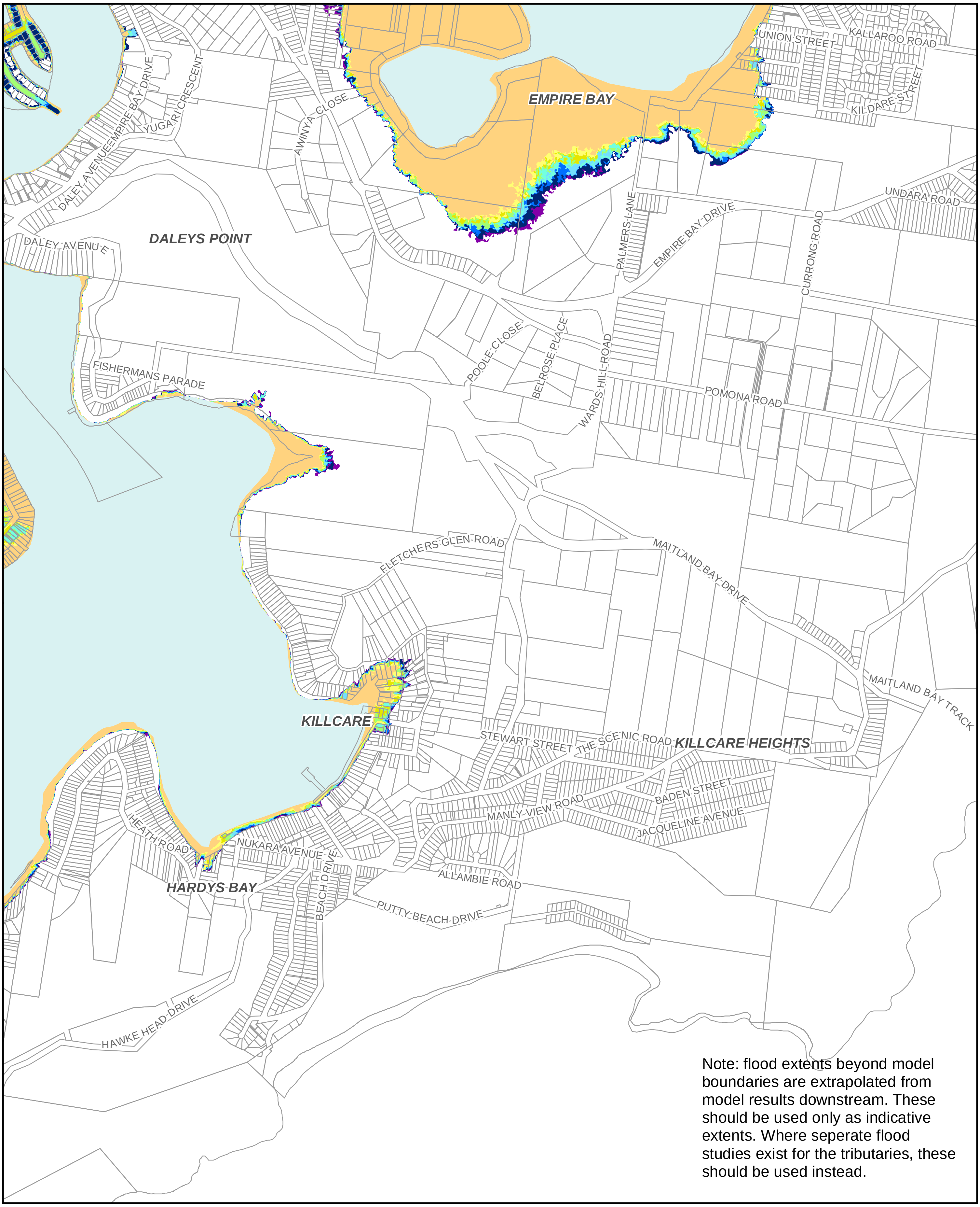
Foreshore Flood Extents (0.4m SLR)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F2.8 - MPA6

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2012_AppF_FloodExtents_04mSLR.mxd 01



Note: flood extents beyond model boundaries are extrapolated from model results downstream. These should be used only as indicative extents. Where seperate flood studies exist for the tributaries, these should be used instead.

Legend

- Cadastre
- Waterway
- 2 Year ARI
- 5 Year ARI
- 10 Year ARI
- 20 Year ARI
- 50 Year ARI
- 100 Year ARI
- 200 Year ARI
- 500 Year ARI
- PMF Extent
- Brisbane Water Flood Model Extent

1:18,000 Scale at A4

Metres
0 200 400 600

N E S W

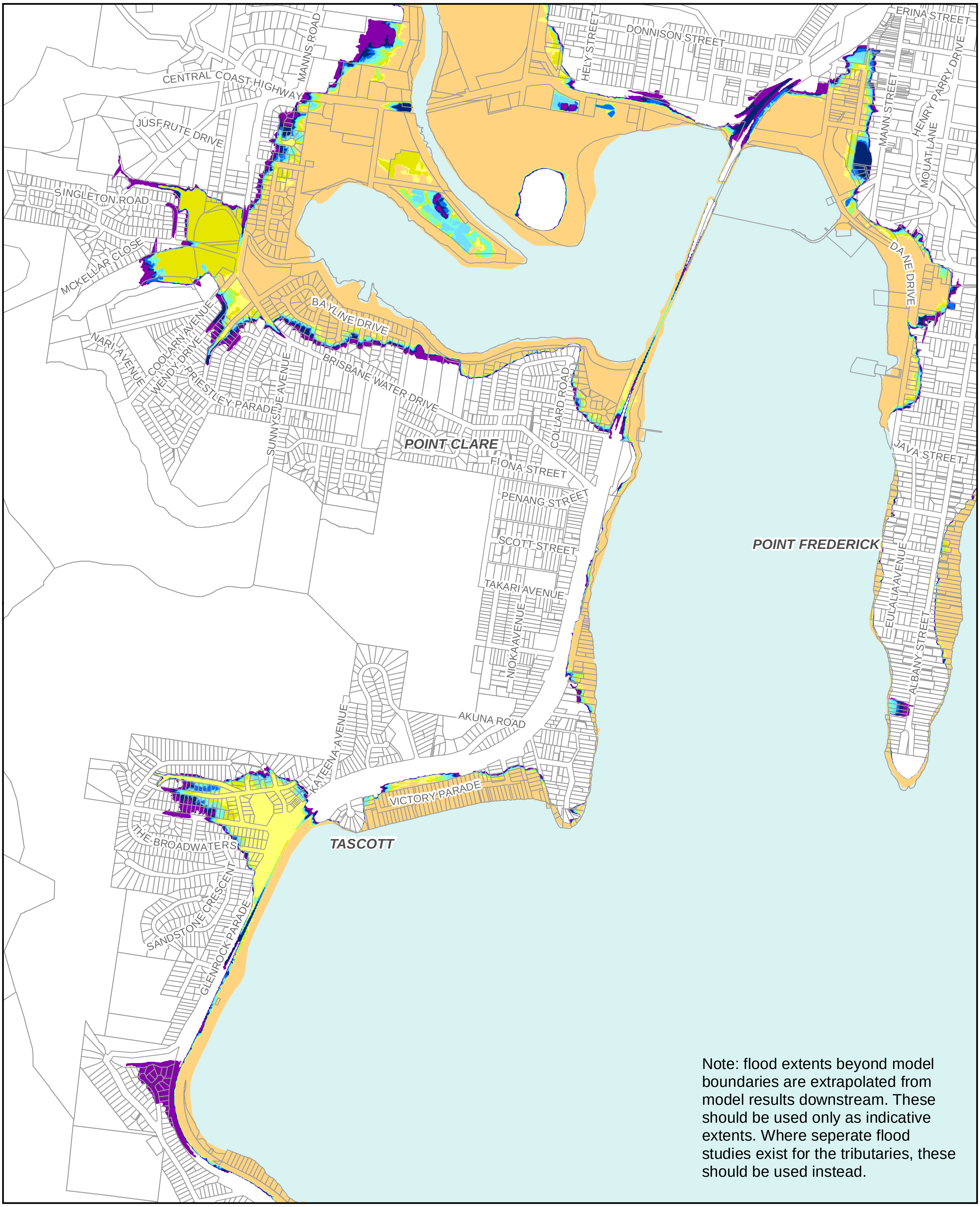
Foreshore Flood Extents (0.4m SLR)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F2.9 - MPA7

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2012_AppF_FloodExtents_04mSLR.mxd 01



Legend

- Cadastre
- Waterway
- 2 Year
- 5 Year ARI
- 10 Year
- 20 Year ARI
- 50 Year
- 100 Year
- 200 Year
- 500 Year
- PMF Extent
- Brisbane Water Flood Model Extent

1:18,000 Scale at A4

Metres
0 200 400 600

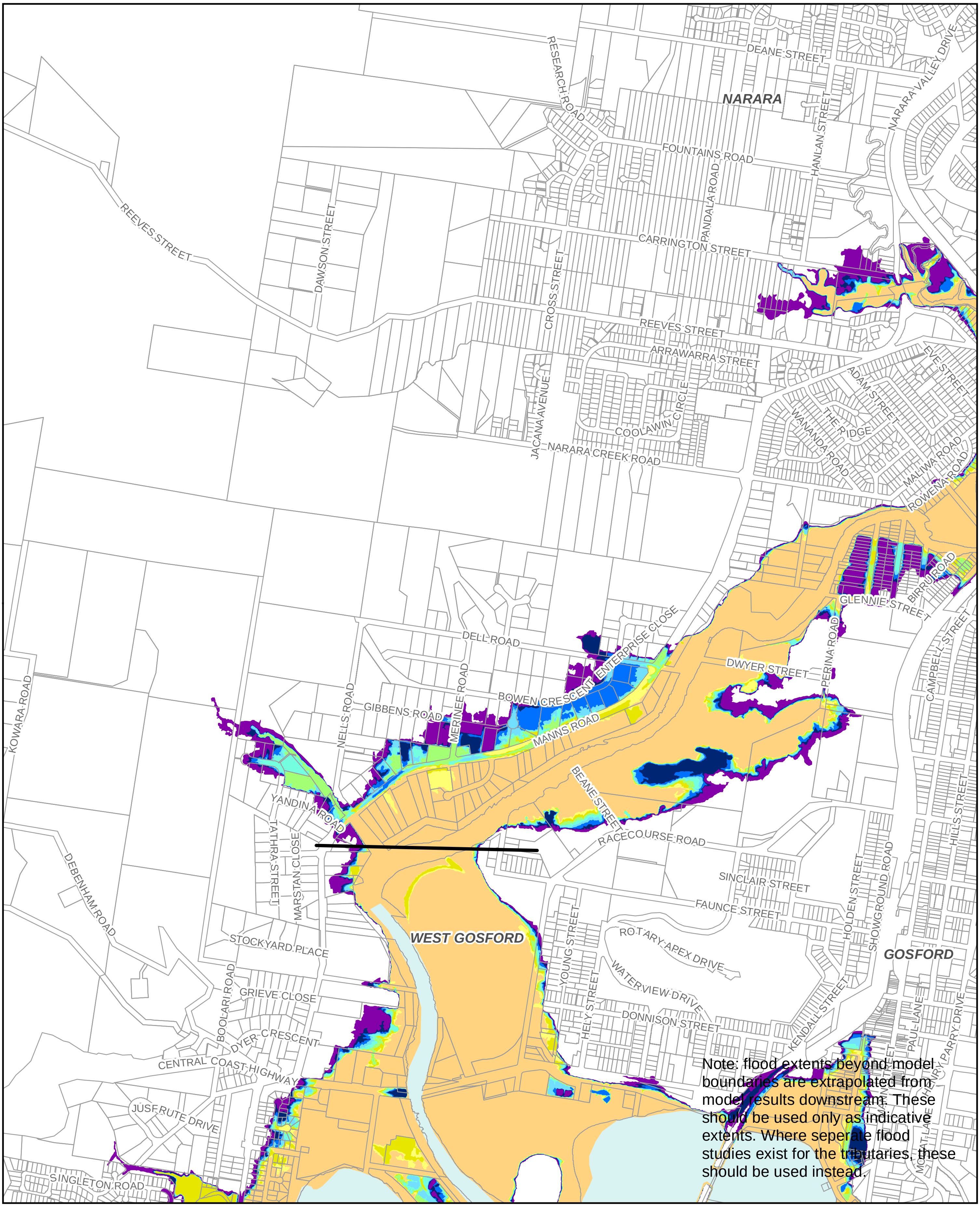
N W E S

Foreshore Flood Extents (0.9m SLR)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F1.1 - MPA1

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2013_AppF_FloodExtents_09mSLR.mxd 01



Legend

- Cadastre
- Waterway
- 2 Year
- 5 Year ARI
- 10 Year
- 20 Year ARI
- 50 Year
- 100 Year
- 200 Year
- 500 Year
- PMF Extent
- Brisbane Water Flood Model Extent

1:18,000 Scale at A4

Metres
0 200 400 600

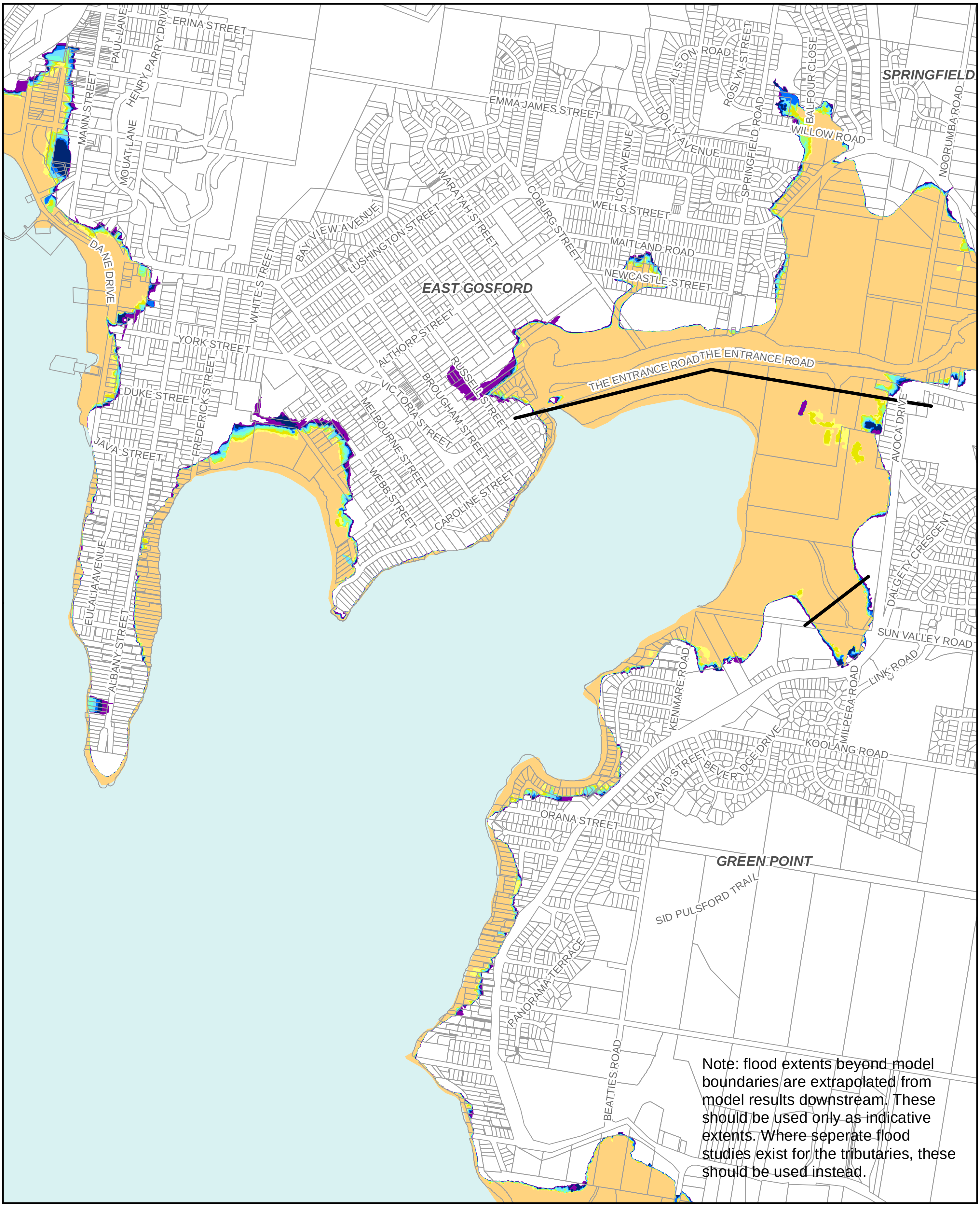
Foreshore Flood Extents (0.9m SLR)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F1.2 - MPA1a

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2013_AppF_FloodExtents_09mSLR.mxd 01



Legend

- Cadastre
- Waterway
- 2 Year
- 5 Year ARI
- 10 Year
- 20 Year ARI
- 50 Year
- 100 Year
- 200 Year
- 500 Year
- PMF Extent
- Brisbane Water Flood Model Extent

1:18,000 Scale at A4

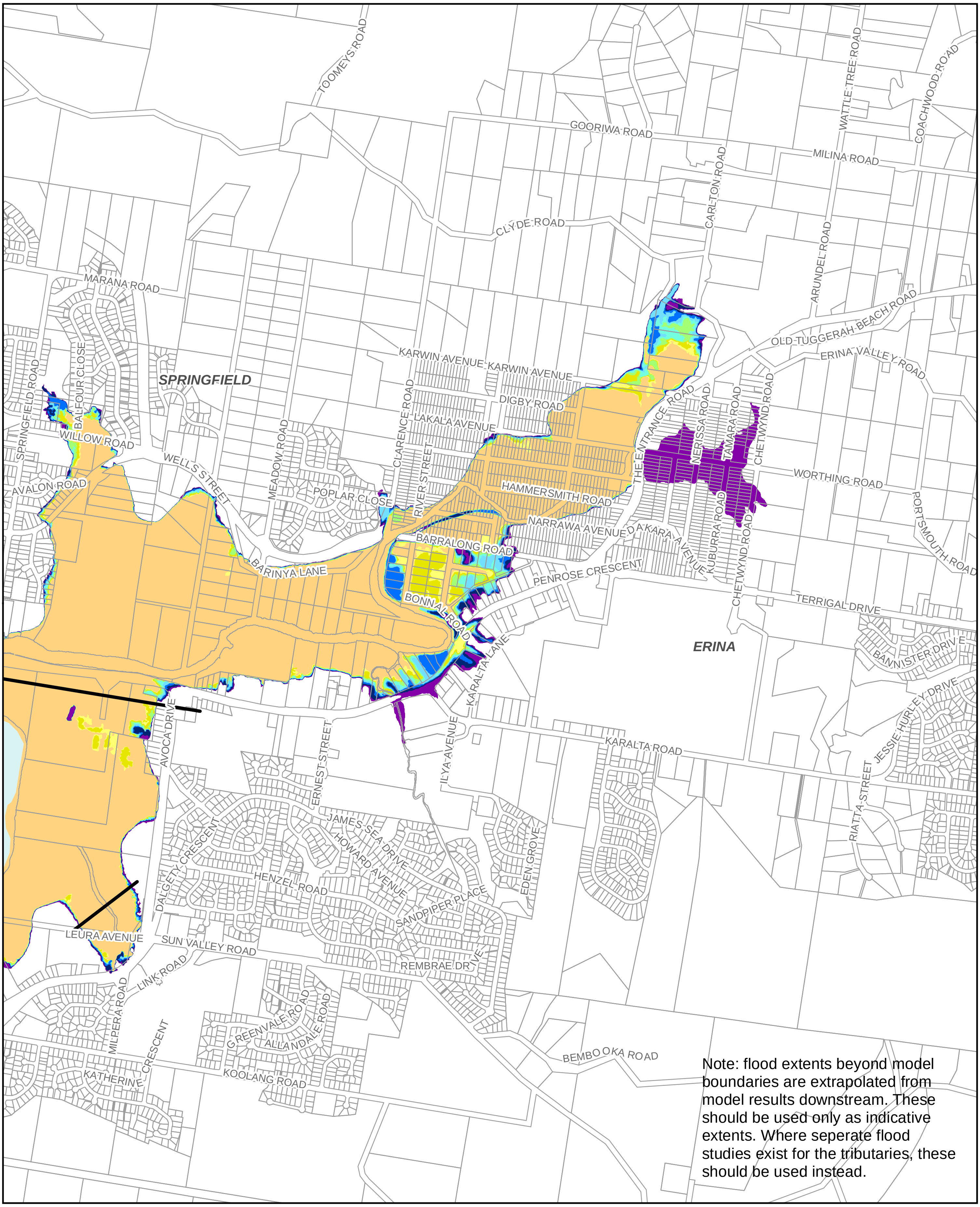
Metres
0 200 400 600

Foreshore Flood Extents (0.9m SLR)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F1.3 - MPA2

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2013_AppF_FloodExtents_09mSLR.mxd 01



Legend

- Cadastre
- Waterway
- 2 Year
- 5 Year ARI
- 10 Year
- 20 Year ARI
- 50 Year
- 100 Year
- 200 Year
- 500 Year
- PMF Extent
- Brisbane Water Flood Model Extent

1:18,000 Scale at A4

Metres
0 200 400 600

N W E S

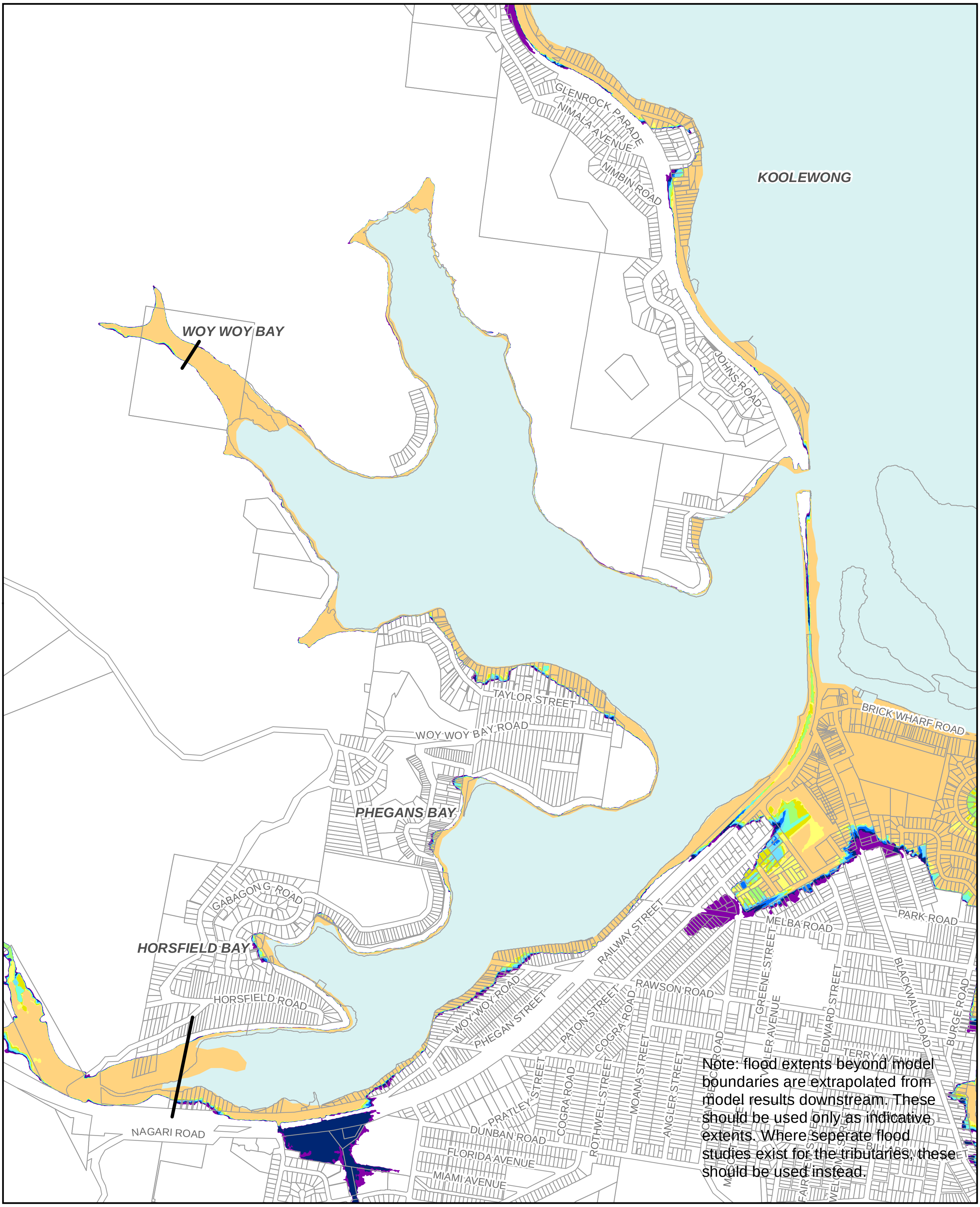
Foreshore Flood Extents (0.9m SLR)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F1.4 - MPA2a

Cardno

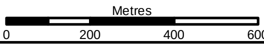
Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2013_AppF_FloodExtents_09mSLR.mxd 01

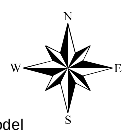


Legend

Cadastre	50 Year
Waterway	100 Year
2 Year	200 Year
5 Year ARI	500 Year
10 Year	PMF Extent
20 Year ARI	Brisbane Water Flood Model Extent

1:18,000 Scale at A4



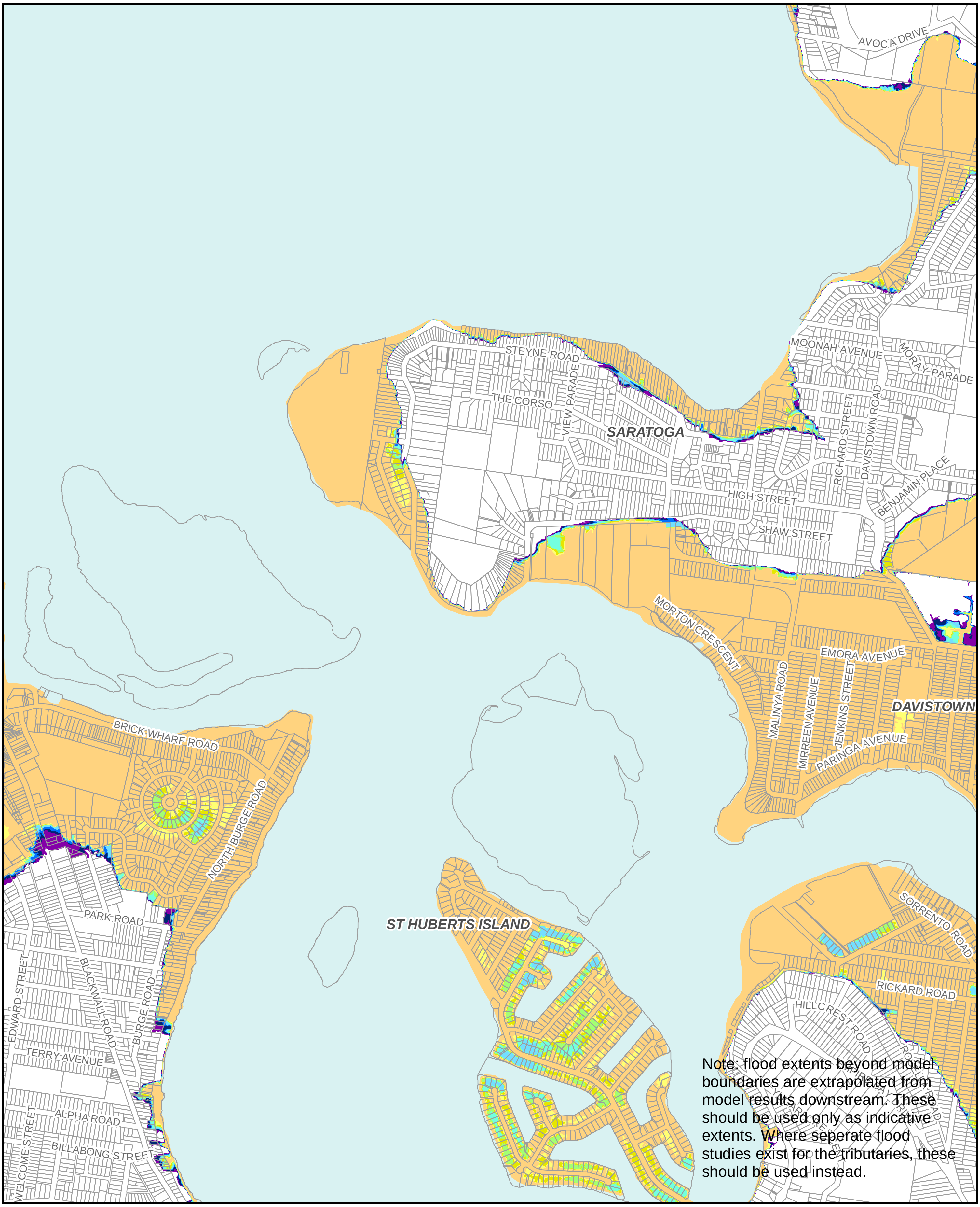


Foreshore Flood Extents (0.9m SLR)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F1.5 - MPA3

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2013_AppF_FloodExtents_09mSLR.mxd 01



Legend

- Cadastre
- Waterway
- 2 Year
- 5 Year ARI
- 10 Year
- 20 Year ARI
- 50 Year
- 100 Year
- 200 Year
- 500 Year
- PMF Extent
- Brisbane Water Flood Model Extent

1:18,000 Scale at A4

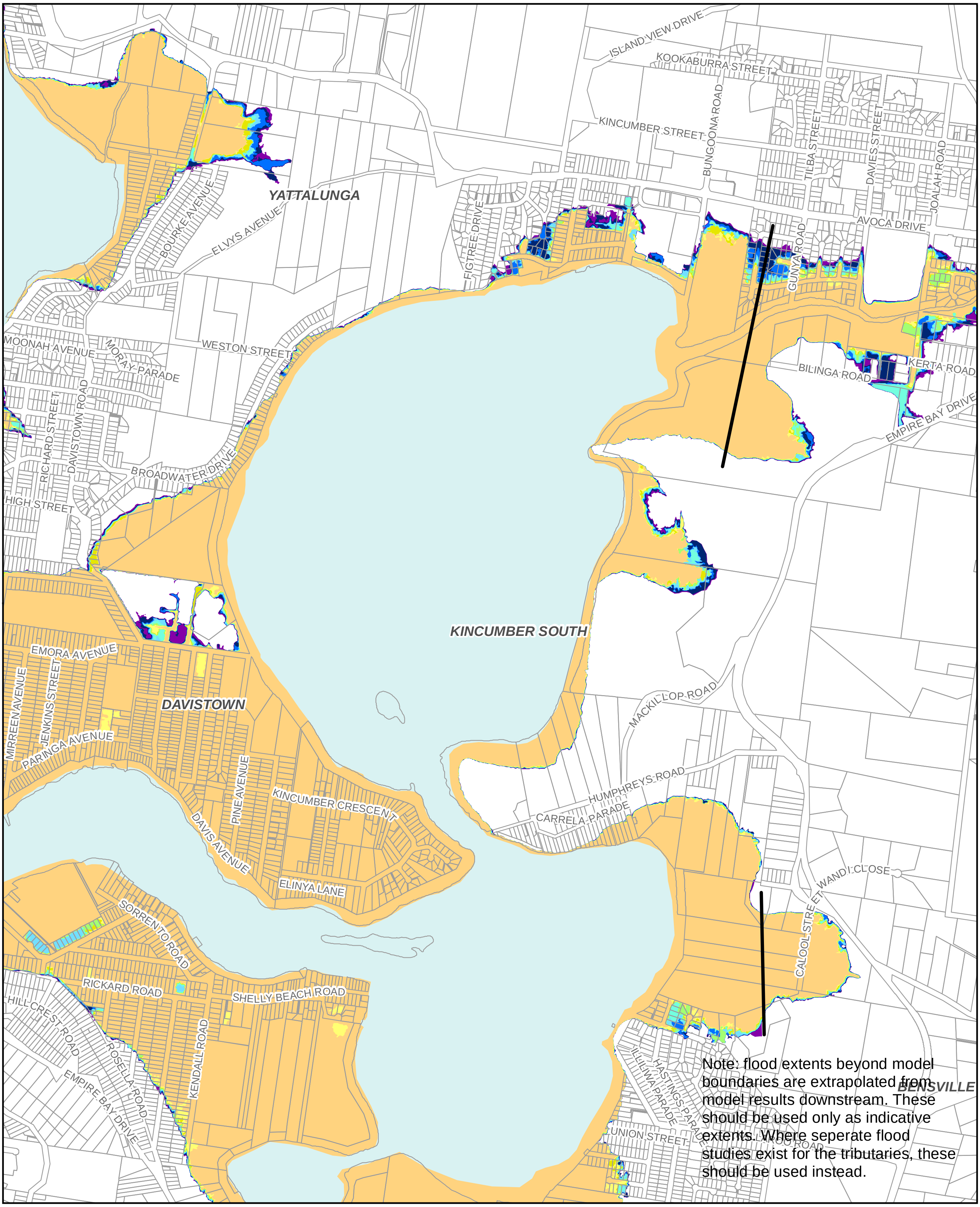
Metres
0 200 400 600

Foreshore Flood Extents (0.9m SLR)

BRISBANE WATER FORESHORE
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F1.6 - MPA4

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2013_AppF_FloodExtents_09mSLR.mxd 01



Legend

Cadastre	50 Year
Waterway	100 Year
2 Year	200 Year
5 Year ARI	500 Year
10 Year	PMF Extent
20 Year ARI	Brisbane Water Flood Model Extent

1:18,000 Scale at A4

Metres

0 200 400 600

N E S W

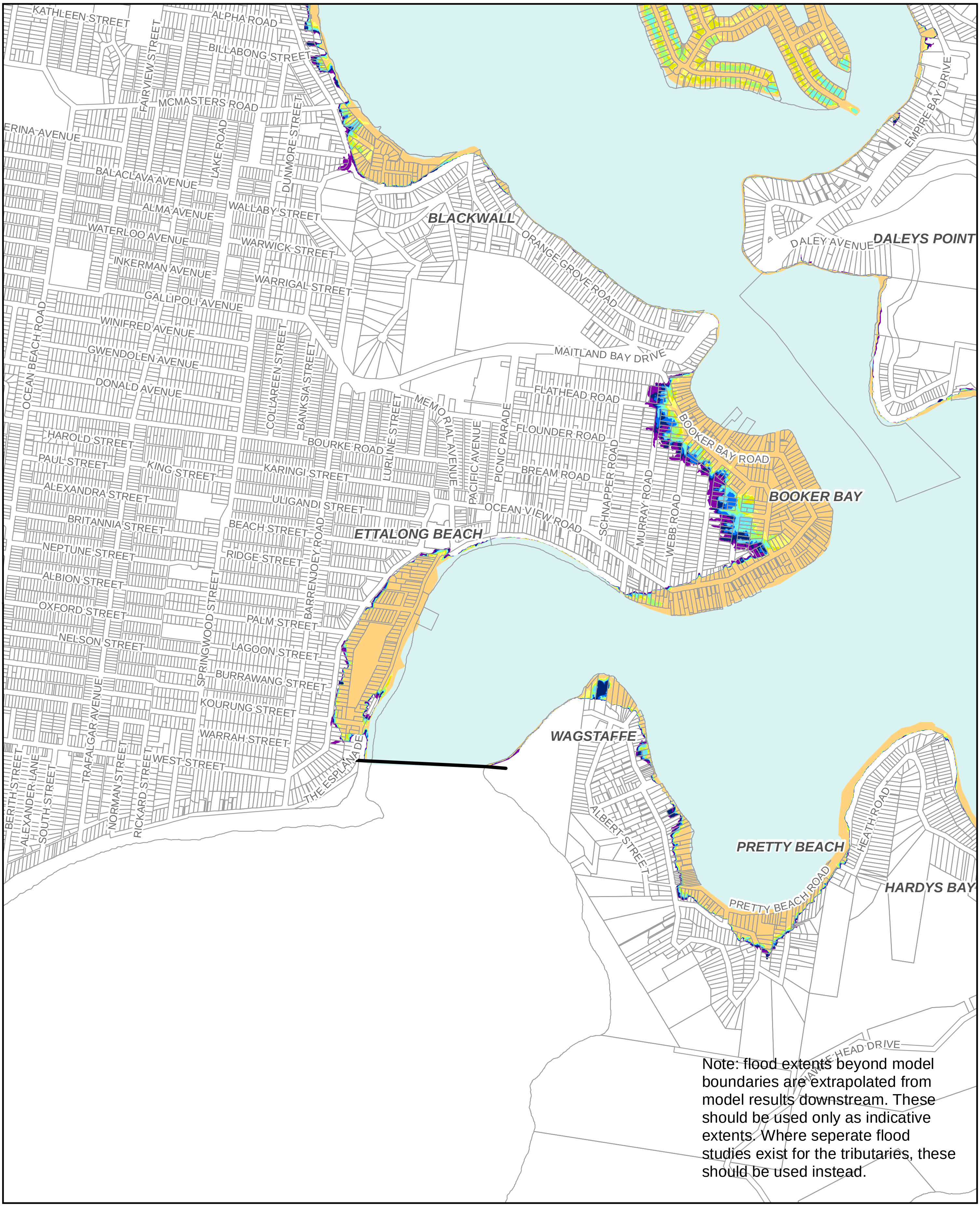
Foreshore Flood Extents (0.9m SLR)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F1.7 - MPA5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2013_AppF_FloodExtents_09mSLR.mxd 01



Note: flood extents beyond model boundaries are extrapolated from model results downstream. These should be used only as indicative extents. Where seperate flood studies exist for the tributaries, these should be used instead.

Legend

- Cadastre
- Waterway
- 2 Year
- 5 Year ARI
- 10 Year
- 20 Year ARI
- 50 Year
- 100 Year
- 200 Year
- 500 Year
- PMF Extent
- Brisbane Water Flood Model Extent

1:18,000 Scale at A4

Metres: 0, 200, 400, 600

N, E, S, W

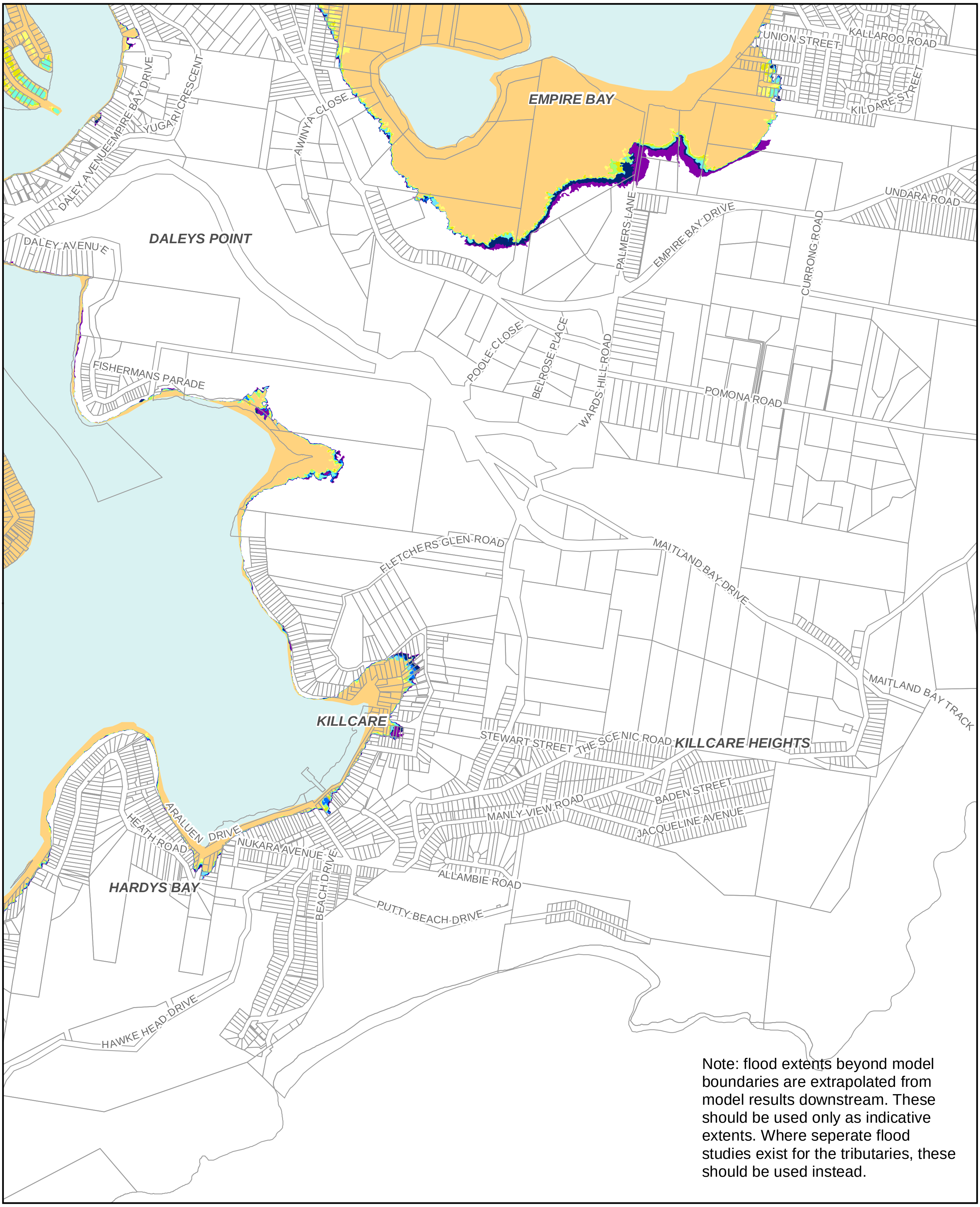
Foreshore Flood Extents (0.9m SLR)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F1.8 - MPA6

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2013_AppF_FloodExtents_09mSLR.mxd 01



Legend

- Cadastre
- Waterway
- 2 Year
- 5 Year ARI
- 10 Year
- 20 Year ARI
- 50 Year
- 100 Year
- 200 Year
- 500 Year
- PMF Extent
- Brisbane Water Flood Model Extent

1:18,000 Scale at A4

Metres

0 200 400 600

Foreshore Flood Extents (0.9m SLR)

BRISBANE WATER FORESHORE FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE F1.9 - MPA7

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd (2812)
Date: 2014-07-18
Coordinate System: GDA 1994 MGA Zone 56
Project: LJ2828
Map: G2013_AppF_FloodExtents_09mSLR.mxd 01

Appendix G

Projected Sea Level Rise Discussion Paper (August 2014)

Projected Sea Level Rise and Tidal Inundation – Discussion Paper

G.1 Introduction

G.1.1 Projected Sea Level Rise and Flood Risk in Brisbane Water

The Intergovernmental Panel on Climate Change (IPCC) and the NSW Department of Environment, Climate Change and Water (DECCW) recognise the reality of rising sea levels in coastal areas of New South Wales. In response, DECCW released a Sea Level Rise Policy Statement (DECCW, 2009b) outlining planning benchmarks of 0.4m of sea level rise by 2050 and 0.9m by 2100.

Sea level rise as a result of climate change represents a substantial challenge for flood risk management on the Brisbane Water foreshore floodplain. Increased flood risk along the Brisbane Water foreshore floodplain as result of sea level rise involves both:

- The increased flood levels during storm surge events; and
- Increased tidal inundation during regular tidal events such as spring and neap tides and more infrequent event (i.e. several times yearly) such as high tides during the summer and equinox periods (i.e. king tides).

The first issue has been discussed in detail in the Floodplain Risk Management Study (FRMS) through the incorporation of projected sea level rise into flood modelling and flood risk management assessments. However, the second issue relates to a more frequent and likely occurrence and needs to be dealt with in a separate manner to storm surge flooding. The flood risk associated with tidal inundation is the subject of this discussion paper.

G.1.2 Purpose of Discussion Paper

The *Brisbane Water Foreshore Flood Study* (Cardno 2013) explored the effects of 0.3m of projected sea level rise (SLR) on tidal signal change throughout Brisbane Water (the DECCW benchmarks had not yet been published at that time). Modelling undertaken as part of Cardno (2013) included the change in conveyance through the estuary at the higher water levels. However, the possibility of changing estuarine morphology was not considered. In addition, a need was identified for additional tidal mapping under the +0.4m and +0.9m SLR scenarios.

This discussion paper also builds on the findings of the *Sea Level Rise and the Estuarine Intertidal Zone* discussion paper (Cardno, 2010b) which was included as an Appendix to the *Brisbane Water Estuary Management Study* undertaken by Cardno (2010a). In contrast to this previous paper which focused on the environmental implications of sea level rise (such as the impacts on intertidal vegetation), the purpose of this discussion paper is to identify the impacts of projected sea level rise on tidal inundation and to assist Council, State Government and the community in planning for these impacts.

G.1.3 Approach

Coastal estuaries tend to be dynamic in nature, with shifting of sediment in response to changes in the environment including the waves, tides, river flows, physical properties of the water and water depth. The bathymetry of a coastal estuary may be subjected to significant changes from scour (removal of sediment from the estuary bed), sedimentation (addition of sediment to the estuary bed) or shifting of existing sediment to an alternative configuration of the bed profile to better reflect equilibrium with the environmental conditions. Sea level rise is one potential contributor to such morphological change, particularly in the region of the entrance to Brisbane Water at the northern end of Broken Bay.

Since a detailed study of the likely changes in morphology near the entrance to the estuary would be costly and time-consuming, it was resolved to assume some simple bathymetric adjustments to test the sensitivity of tidal attenuation within the estuary to the entrance (bathymetric) condition. While not definitive, this approach will provide an indication as to whether or not a detailed investigation is warranted.

This discussion paper presents the result of sensitivity testing of four morphological conditions at the entrance with regards to the impacts of those conditions on tidal levels within the estuary. These conditions were tested for a +0.4m projected sea level rise (in preference to the 0.9m projected sea level rise scenario) as it is likely to be more relevant for Council's planning purposes (i.e. will occur sooner).

The outcomes of this assessment were used to map the likely tidal inundation areas for selected tides under projected sea level rise scenarios. The mapping was then used to identify at risk areas with regards to inundation impacts on land use and transport links. This information can be used by Council and State Government Departments for planning for future risk associated with projected sea level rise.

In addition, trends in mean sea level rise (MSLR) were investigated with tide gauge data from several locations in the Brisbane Water estuary.

G.1.4 Data Sources

This discussion paper draws on available data sources including tidal planes information sourced from the Manly Hydraulics Laboratory (MHL, 2004), water level time series for tide gauges in the estuary provided by Manly Hydraulics Laboratory (April 2014), geographic information system (GIS) layers provided by Council and the projected sea level rise benchmarks outlined in the NSW Government Sea Level Rise Policy Statement (DECCW, 2009b).

G.2 Methodology

G.2.1 Adopted Sea Level Rise Predictions

The IPCC has recorded a global trend in average sea level rise between 1961 and 2003 of 1.8 mm/year (the range being 1.3 to 2.3 mm/year). More accelerated sea level rise occurred between 1993 and 2003 with an average global rate of rise of 3.1 mm/year (the range being 2.4 to 3.8 mm/year) (Bindoff and Willebrand, 2007).

At Sydney (Fort Denison), annual mean sea level estimates showed a linear increase of 0.9 mm/year with the 20-year running average over the period 1915 to 2004 (varying between -2 and +3 mm/year) (van Senden, 2005). The DECCW (2009b) sea level rise policy translates to a linear increase of 10 mm/year which, when compared to the Sydney data set, will require a rapid acceleration of the rate of rise in sea level to attain the projected values. For this reason, projected sea level rise benchmarks (i.e. 0.4m and 0.9m) have been referred to in this document rather than specific years (i.e. 2050 and 2100).Further information on projected sea level rise can be found in DECCW (2009b) and Cardno (2010a).

G.2.2 Mean Sea Level Rise Analysis

Trends in MSLR were investigated with tide gauge data from several locations in the Brisbane Water estuary. These data were obtained from the Manly Hydraulics Laboratory (MHL) in the form of water level time series with a sample interval of 15 minutes. Data was available for one tide gauge near the Brisbane Water Entrance (Ettalong – Figure G3, Site 2), two in the Broadwater (Koolewong – Figure G3, Site 9; and Punt Bridge – Figure G3, Site 10) and three tide gauges located in creeks further upstream (New Erina Bridge, Old Erina Bridge –Figure G3, Site 18; and Manns Rd – Figure G3, Site 22). The Old Erina Bridge gauge was replaced by the New Erina Bridge gauge in 2007.

Mean sea level in the Brisbane Water Estuary regularly undergoes seasonal and inter-annual variations due to the effects of ocean circulation including the East Australian Current (EAC), variations in air pressure, and the El Niño Southern Oscillation (ENSO). In order to reliably calculate a long term rate of mean sea level rise, a multi-decadal record length is required to account for these processes.

The lengths of the water level records available from Brisbane Water are, for the purposes of calculating an historical rate of mean sea level rise, relatively short. The longest records exist at Ettalong and Koolewong, where records extend back 28 years to 1986. Records at Punt Bridge and Manns Rd extend back almost 20 years to the mid 1990's, while records obtained from Old Erina Bridge and New Erina Bridge tide gauges are each less than 10 years in length. Records from Old Erina Bridge and New Erina Bridge are too short to calculate a reliable historical rate of long term mean sea level rise.

In order to determine the historical rate of long term mean sea level rise at the tide gauge locations, the historical trends of both the monthly mean water levels and annual mean water levels were assessed.

G.2.3 Tidal Modelling Methodology

G.2.3.1 Modelling Method

The Delft3D hydrodynamic model was used to investigate the tidal response to climate change and entrance morphology. The model setup used for the *Brisbane Water Foreshore Flood Study* (Cardno, 2013) was employed for these tasks. This model setup was calibrated against measured water level and discharge signals from within the estuary and showed excellent agreement.

The potential change in tidal attenuation was investigated for the 0.4m projected sea level rise scenario, and this was achieved by raising the water level boundary condition by 0.4m to account for the rise in sea level. To ensure sufficient water level record length for tidal constituent analysis (**Section G.2.3.4**), models were run for a period of 43 days. This length of time was considered sufficient to analyse the full range of tidal constituents over the full tidal cycle. This length of 'record' leads to about 35 tidal constants with good confidence in the principal constants. No wave or storm surge aspects were included and the model was driven solely by the influence of the tide at the boundary of the model domain in the Tasman Sea.

G.2.3.2 Entrance Morphology

It cannot be said definitively how the entrance bathymetry (from northern Broken Bay to Booker Bay) will respond to projected sea level rise. The actual outcome will depend on a number of factors including available sediment, rate of sea level rise and changes in the wave climate. **Figure G1** compares maximum tidal velocities through the entrance under existing and future sea levels. Peak velocities increase in some areas from 0.5m/s to 0.7m/s (approximately). These velocities exceed the threshold speed for sediment movement and there would likely be some 'smoothing' of the seabed. This smoothing may reduce crest levels of the dominant bars and cause infilling of deeper areas. Such a smoothing would increase the conveyance of the estuary and thereby potentially lead to increased tidal propagation. This postulated scenario was one case considered in this investigation.

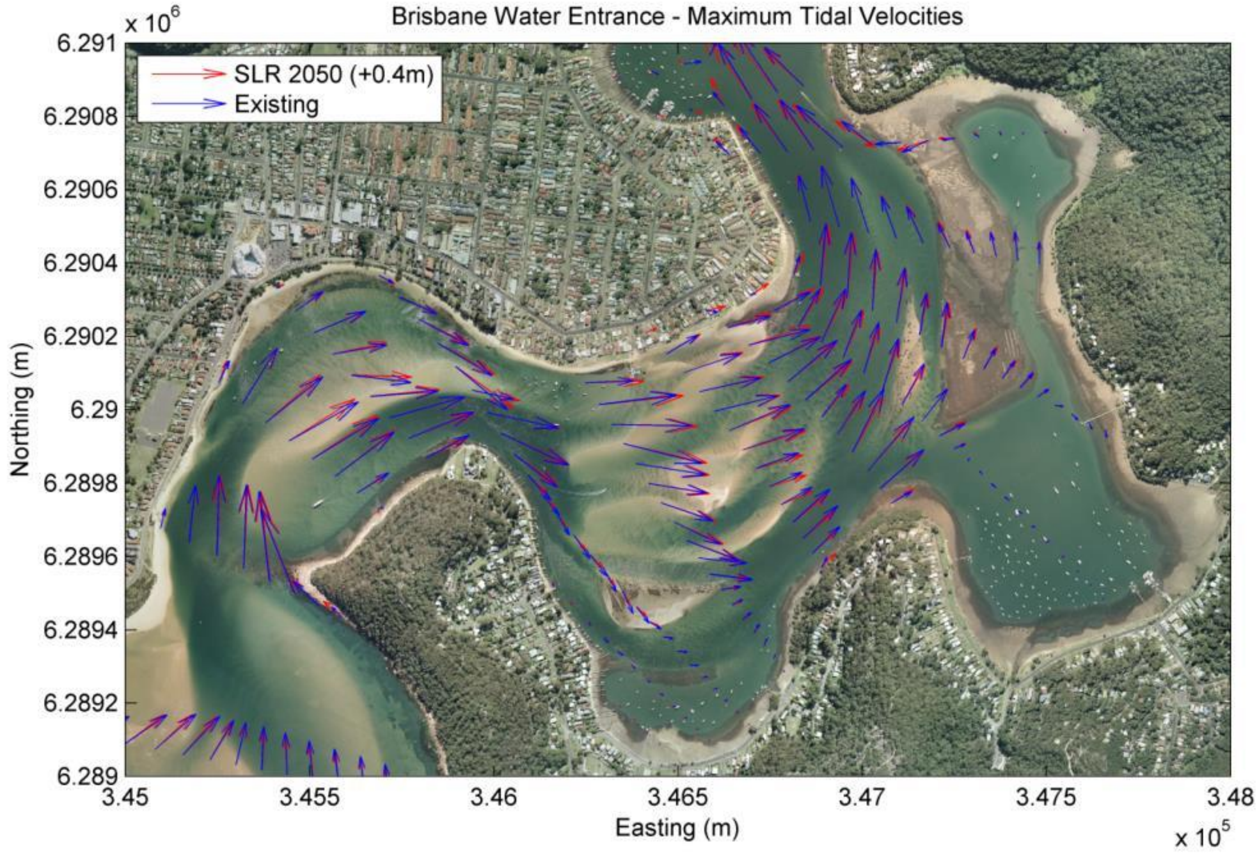


Figure G1: Vector Plot comparing Peak Tidal Velocities within Brisbane Water Entrance under Existing and Future (+0.4m SLR) Sea Levels. Aerial Image Source: Google 2010.

The magnitude and form of any changes to the estuarine entrance bed forms is generally unknown at this stage. Therefore, four different entrance conditions were investigated for the 0.4m SLR scenario. It is considered that the following entrance condition scenarios cover the likely range of possible responses to the 0.4m projected sea level rise scenario:

- **Existing bed level case** – Bed levels within the entrance region to the Brisbane Water estuary are unaffected by projected sea level rise and the general existing bathymetric levels remain;
- **0.2m bed level rise case** – Bed levels around the entrance to the Brisbane Water estuary respond by rising by half the projected sea level rise increment and an increase of 0.2m to the general existing bathymetric level occurs. This increase was applied to bed levels in the area depicted in **Figure G2**. That is, the crest and trough areas were all raised;
- **0.4m bed level rise case** – Bed levels around the entrance to the Brisbane Water estuary respond by rising in accordance with projected sea level rise and an increase of 0.4m to the general existing bathymetric level occurs. This increase was applied to all bed levels in the area depicted in **Figure G2**; and
- **A smoothing of the seabed** within the entrance area caused by the higher tidal current speeds. This smoothing was introduced by removing the tops of the bars and filling the bases of the valleys in between. This process marginally increases the conveyance of the waterway.

Figure G2 shows the area of bathymetry to which the above entrance conditions were applied as an assumed response to SLR. Only the estuary entrance area was considered as this is the area affected by the incursion of marine sands (from tidal and wave forcing) and thus the area most likely to respond to a change in mean sea levels. The Brisbane Water Estuary Process Study (Cardno, 2010a) describes how the remainder of the estuary is slowly infilling through the discharge of sediments from the surrounding catchment areas. This process is gradual and independent of sea level rise and thus was not considered in this assessment.

Figure G2: Area of Bathymetry to Which the Above Entrance Conditions were Applied. Aerial Image Source: Google 2010.

G.2.3.3 Tidal Plane Paths

Manly Hydraulics Laboratory (2004) conducted a tidal planes analysis of recorded water levels at a number of sites within the Brisbane Water estuary (**Figure G3**). One of their objectives was to compare the tidal planes at a series of these locations to describe the attenuation of the tidal signal as it propagated through various parts of the estuary. A number of tidal plane paths were identified allowing a perspective of tidal attenuation through the majority of the estuary:

- Tidal Plane Path 1 – Woy Woy Inlet: Stations 0, 2, 4, 6, 9, 16;
- Tidal Plane Path 2 – Narara Creek: Stations 0, 2, 4, 6, 9, 20, 22; and
- Tidal Plane Path 3 – Kincumber Broadwater: Stations 0, 2, 4, 6, 11, 14.

Station 0 is a gauge located at Fort Denison, Sydney, and this has been included in order to provide an ocean tide reference location. For this investigation, the Delft3D model output did not include station 22 as it was located outside the study area (near the tidal extent of Narara Creek) and was therefore not considered relevant for the investigation. Water level data was extracted from the Delft3D model output and analysed at all other locations with water level recorders (2, 4, 6, 9, 10, 11, 14, 16, 18 and 20).

Figure G3: Location of MHL Water Level Measuring Stations in the Brisbane Water Estuary (About: MHL, 2004). Note that Station 0 is not shown as it is located at Fort Denison, Sydney.

G.2.3.4 Harmonic Analysis

A harmonic analysis was undertaken on the water level data at the locations with water level recorders. Harmonic analysis disaggregates the signal components of the tide (tidal constituents) so that a meaningful tidal interpretation can be undertaken. Tidal constituents represent a number of different cosine functions superimposed over one another. Tidal constituents are caused by the non-uniform nature of tides in most locations, over varying time scales.

In general, the four constituents that account for most of the variation in water levels are M2, S2, K1 and O1 (Bowden, 1983). M2 and S2 describe the effects of the moon orbiting the earth and the sun as the earth rotates on its axis. Both have a period of approximately half a day and are known as semi-diurnal constituents. K1 and O1 together describe the effect of lunar declination and have a period of approximately one day and are known as diurnal constituents (MHL, 2011). Lunar declination is the position of the Moon relative to the Earth's equator which varies due to the Earth's tilt, as shown in **Figure G4**. Essentially, M2 and S2 account for two high and two low tides in a day, while K1 and O1 account for the difference between the two high tides each day (and also between the two low tides) (NPS, 2011).

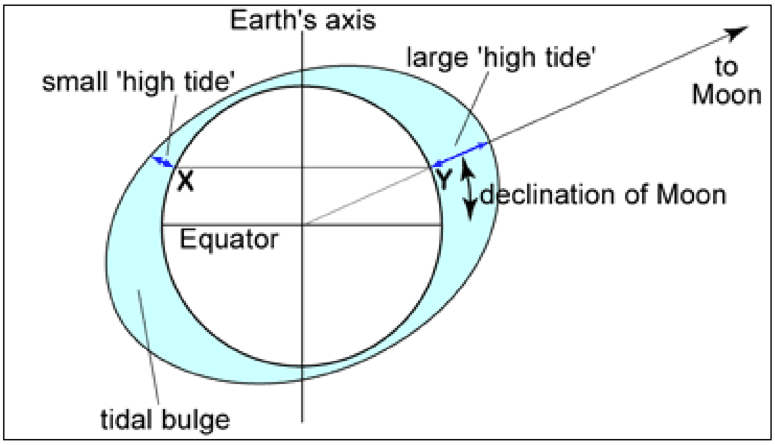


Figure G4: Schematic Demonstrating the Effect of the Moon's Declination on the Tidal 'Bulge' around the Earth. Source: NPS (2011).

The harmonic analysis for Brisbane Water revealed a number of tidal constituents, namely Z0, M2, S2, K1 and O1 where Z0 is elevation of Mean Sea Level above Australian Height Datum (AHD). Six key tidal planes were then estimated from combinations of the constituents listed above. This was completed at each location for the four scenarios. Calculated tidal planes included:

- Higher High Water - Spring Solstice (HHWSS);
- Mean High Water Springs (MHWS);
- Mean High Water Neaps (MHWN);
- Mean Low Water Neaps (MLWN);
- Mean Low Water Springs (MLWS); and
- Indian Springs Low Water (ISLW).

G.2.4 Tidal Mapping Methodology

G.2.4.1 Tidal Events Mapped

The tidal events selected for mapping represent:

- High High Water Spring Solstices (HHWSS) – Rarer high tides occurring approximately twice a year, during the June and December solstices ("king tides"); and
- Mean High Water Springs (MHWS) – "Every day" tidal inundation caused by high tides.

The HHWSS tidal plane was chosen to be modelled and mapped as it represents a "worst case scenario" in terms of tidal inundation events, i.e. HHWSS or "king tides" occur only twice very year (approximately) but have higher water levels than everyday tides.

The MHWS tidal plane was mapped as part of Cardno (2010b) but has been included in the mapping for this discussion paper as a comparison.

HHWSS and MHWS have been mapped for the existing scenario as well as the 0.4m SLR and 0.9m SLR scenarios. For the purposes of mapping, the tidal planes under the 0.9m SLR scenario were derived based on the outcomes of the modelling for the 0.4m SLR case.

High High Water (Spring Solstices)

Solstice tides (often referred to as King Tides) occur in June and December of each year, when the sun is directly over the Tropic of Cancer and Capricorn respectively. During normal weather conditions, the height of the king tides will be similar from year to year. However, in abnormal weather conditions such as severe storms or cyclones, low air pressure systems and strong winds can elevate the sea level above the expected height.

The HHWSS tide levels used in this assessment are summarised in **Table G2** (**Section G.3**). The existing bed level case provides the most conservative estimate of tidal planes under the 0.4m SLR scenario because it gives the highest high tides (this is further discussed in **Section G.3**). Therefore, the levels associated with this entrance condition were adopted for mapping.

Mean High Water Springs

The MHWS tide is the average of all high water observations at the time of spring tide over a period time (generally 19 years). As in the case of the HHWSS mapping, the tide levels for the existing bed level entrance condition (**Table G2**, **Section G.3**) were used to map the MHWS tidal plane.

G.2.4.2 Mapping Methodology

The methodology for mapping MHWS outlined in Cardno (2010b) provided the foundations for mapping the HHWSS tidal extent for this discussion paper. The following summarises that methodology.

Mapping tidal levels proved to be a challenge due to a lack of topographic and bathymetric data in the vicinity of 0m AHD. This data gap was found to extend from approximately MHWS (where the ALS data ends or becomes progressively more inaccurate in a seaward direction) to approximately MLWS (where the hydrosurvey data begins). Through an analysis of historical water level data (MHL, 2004) and study of aerial photographs, a mean tide contour was generated (representing approximately 0m AHD). Linear interpolation between the available ALS, hydrosurvey data points and the newly created mean tide level contour was then undertaken in GIS to generate a new digital elevation model (DEM).

MHWS and HHWSS levels were then delineated from the newly created DEM. In a similar fashion, MHWS and HHWSS levels for each climate change scenario were delineated by adding 0.4m and 0.9m respectively to the current levels to account for sea level rise.

It is important to note that both the horizontal and vertical resolution and accuracy of the newly created DEM is a product of the resolution and accuracy of the input data. Hence the accuracy of the derived tidal levels is likely to be somewhat variable. Nonetheless, derived tidal levels are considered adequate to inform a preliminary assessment of indicative tidal inundation areas.

G.2.5 Identification of Indicative Tidal inundation Areas

In order to provide an indication of the effects of increased tidal inundation due to projected sea level rise, a series of “indicative tidal inundation areas” were delineated. These include areas which, with projected sea level rise:

- Are likely to be inundated very regularly (approximately daily, i.e. within MHWS);
- Are likely to be inundated fairly regularly (approximately twice per year, i.e. within HHWSS);
- Contain transport links including roads and railways which are likely to be inundated (at any rate of recurrence); and
- May not be directly affected by tidal inundation but which may be indirectly affected due to inundation of utilities and services (at any rate of recurrence).

This is discussed further in **Section G.4**.

G.3 Results

G.3.1 Mean Sea Level Rise Estimation

In order to provide a regional and local context to the sea level rise scenarios applied in this study (**Section 6.4**), the tide gauge data available for Brisbane Water Estuary was analysed and compared with the regional tide gauge records from Fort Denison (~40 km to the south) and Newcastle (~70 km to the north). Interpretation and relevant caveats on the analysis is presented in **Section 6.4.1.2**, this section presents the data used in the analysis. The estimated rates of MSLR from the MHL gauges should be considered as indicative and used for contextual purposes only.

The raw water level data and 30 day moving average (for clarity) from the Brisbane Water data gauges are shown in **Figures G5 to G12** together with the trends in monthly and annual mean sea levels. Note that trends were not calculated on the moving averages, but rather the block average (monthly and annual) to maintain statistical independence.

The three creek tide gauges (New Erina Bridge, Old Erina Bridge and Manns Rd) displayed a significant amount of non-tidal behaviour. In these locations catchment run-off from rainfall events affected both the upper and lower limits of recorded water levels. During significant catchment events peak water levels were recorded well above highest astronomical tide (HAT), and elevated water levels continued for several days to weeks afterwards.

Furthermore, water levels from the creek tide gauges showed a flattening or levelling off during low tide. This can be seen in **Figures G11 and G12**, which depict recorded water levels at Manns Rd and Old Erina Bridge respectively. This water level behaviour can be explained by persistent base flow into the creek from groundwater after persistent rainfall, and/or the tide gauges emerging during low water events. Due to the short record length and the frequency and magnitude of non-tidal water level variations recorded by the creek gauges, they were not analysed to estimate MSLR.

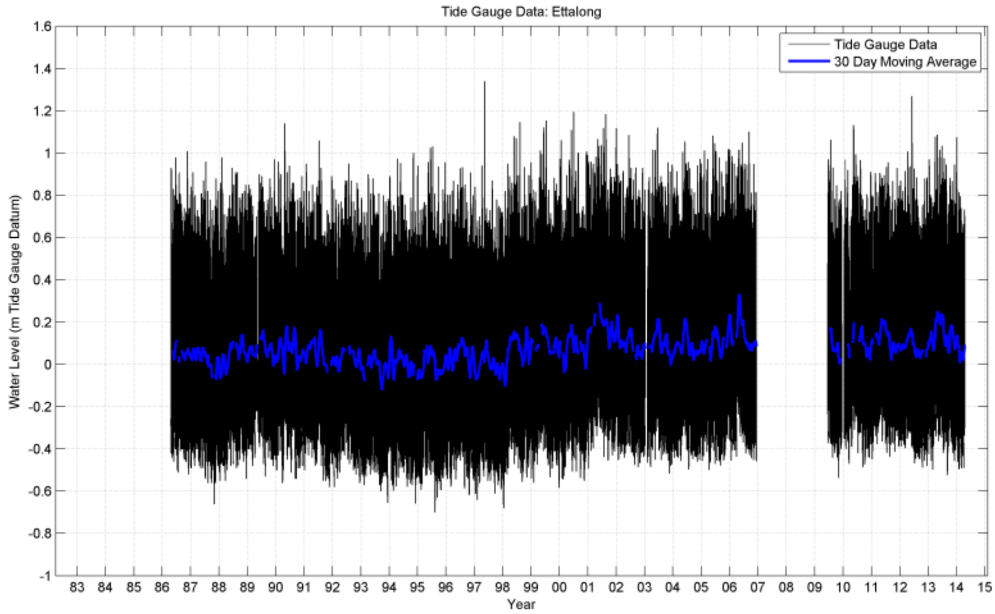


Figure G5 – Tide gauge record from Ettalong: 1986-2014

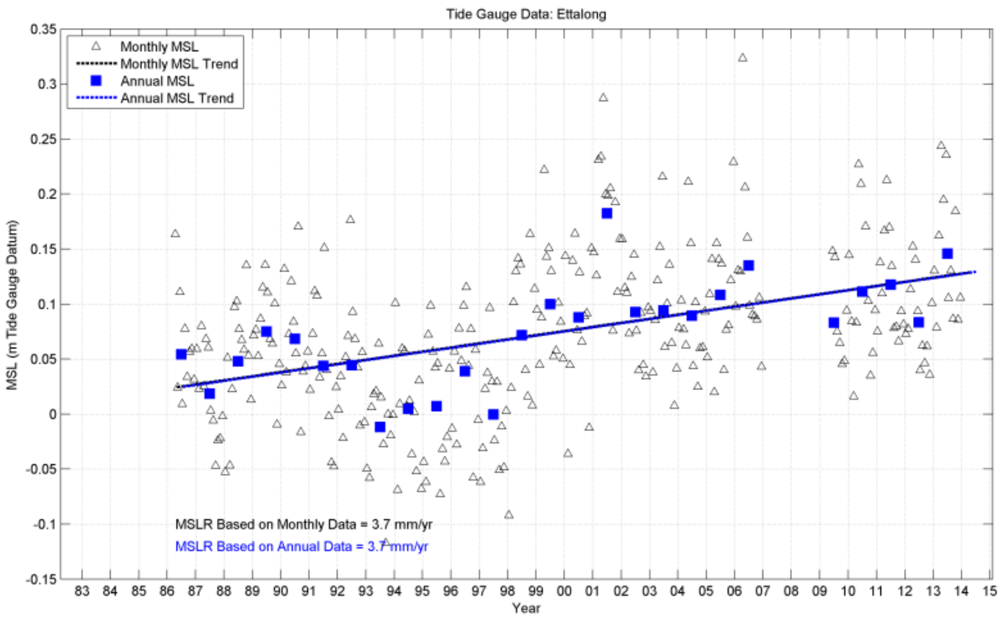


Figure G6 – Monthly and annual MSL analysis of Ettalong gauge data: 1986-2014

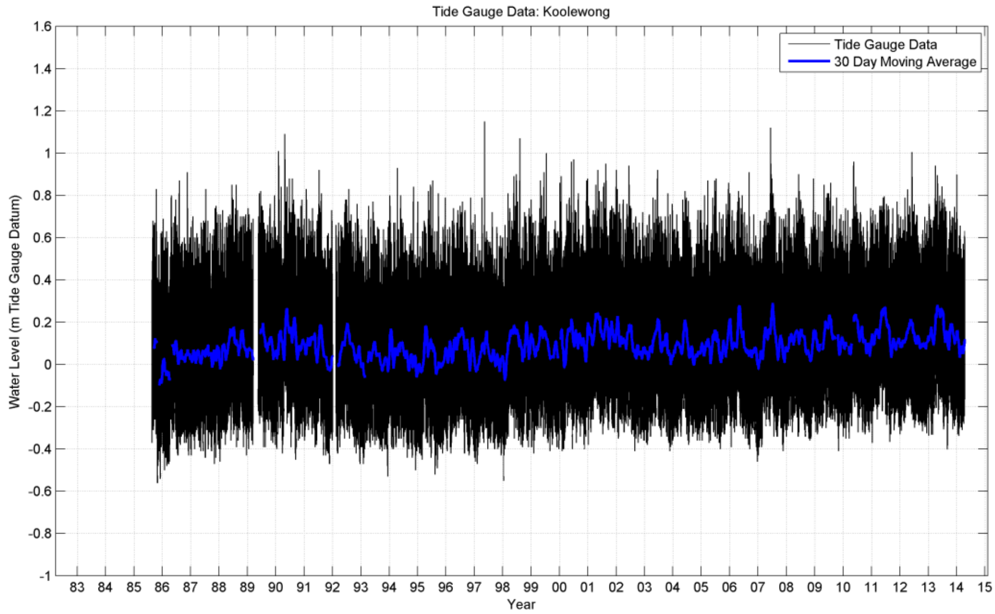


Figure G7 – Tide gauge record from Koolewong: 1986-2014

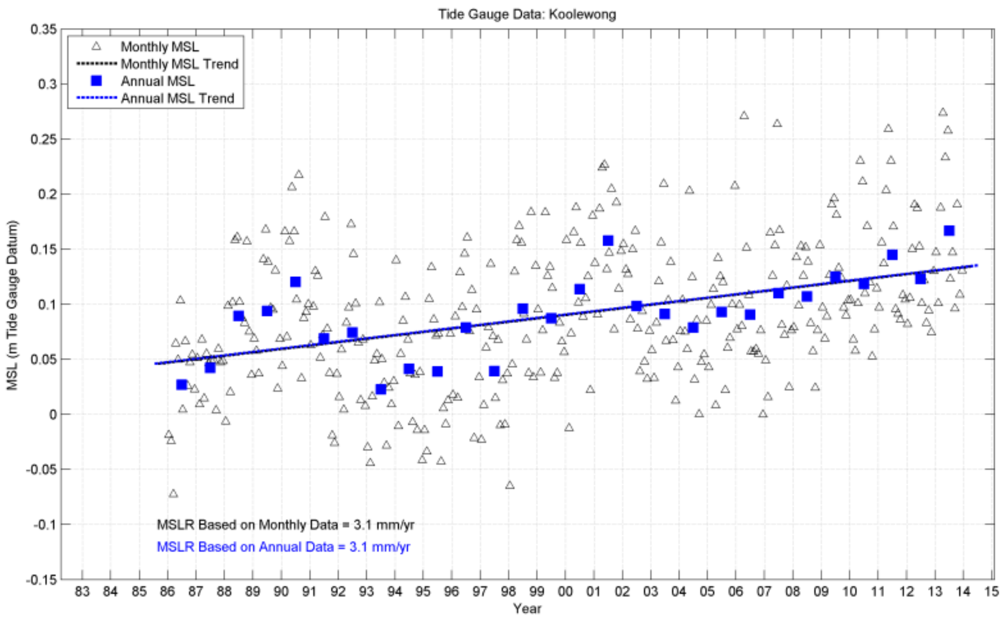


Figure G8 –Monthly and annual MSL analysis of Koolewong gauge data: 1986-2014

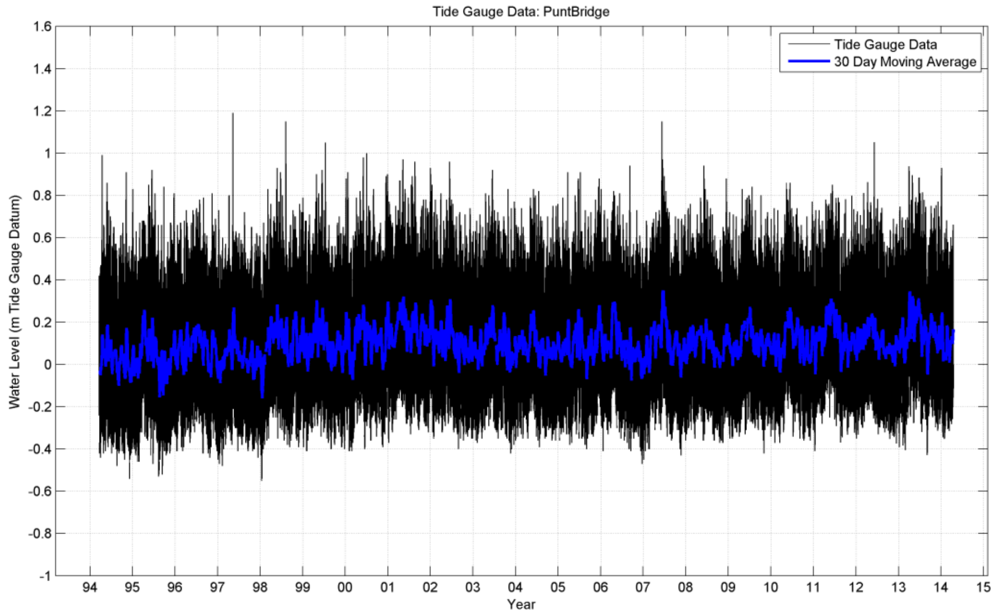


Figure G9 – Tide gauge record from Punt Bridge: 1994-2014

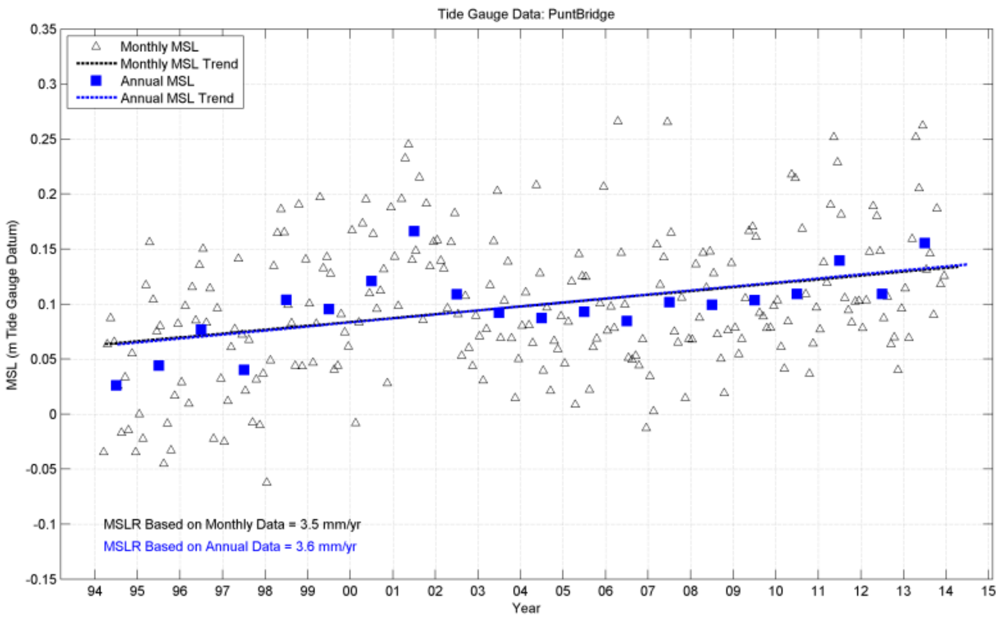


Figure G10 – Monthly and annual MSL analysis of Punt Bridge gauge data: 1994-2014

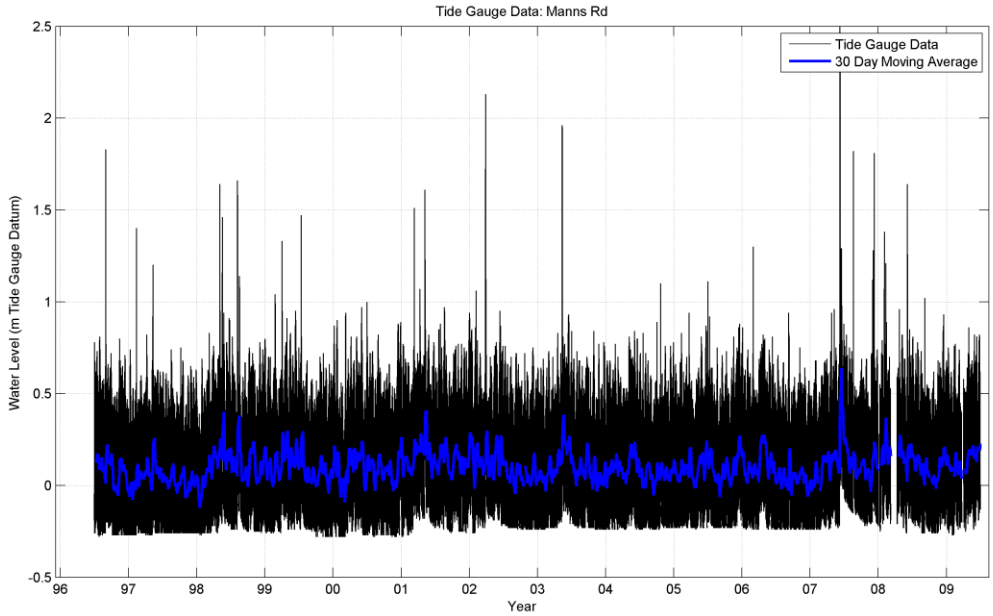


Figure G11 - Recorded water levels at Manns Rd gauge from 1996:2009

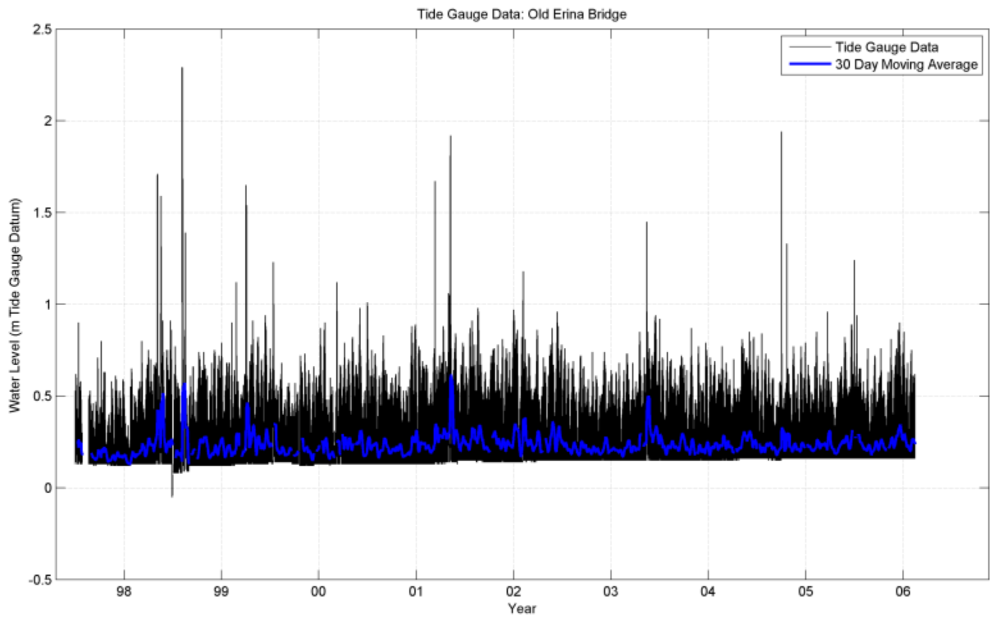


Figure G12 - Recorded water levels at Old Erina Bridge gauge from 1997:2006

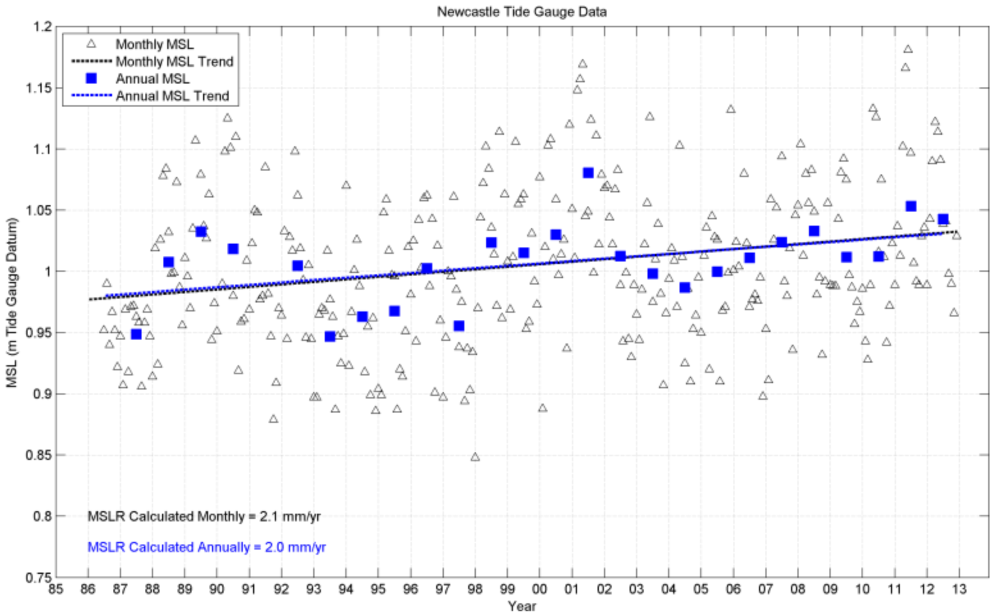


Figure G13 - Recorded water levels at Newcastle from 1986:2012

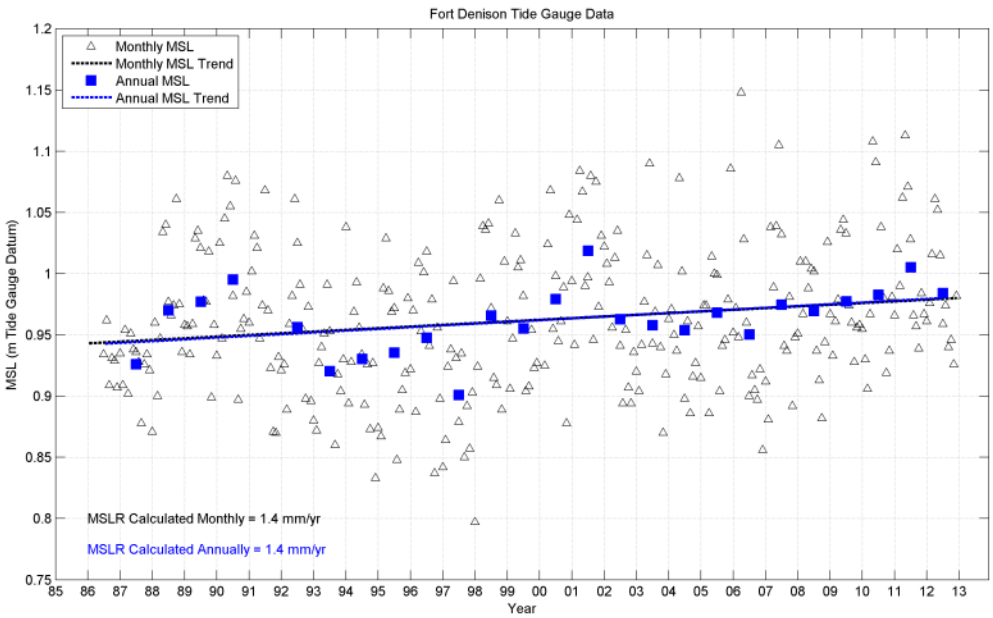


Figure G14 - Recorded water levels at Fort Denison from 1986:2012

G.3.2 Tidal Modelling Results

Figures G13 to G15 compare the tidal planes of the four bathymetry scenarios along the three MHL (2004) tidal plane paths, whilst **Tables G2 to G5** show the tabulated tidal planes including the tidal range (MHWS-MLWS).

Figures G13 to G15 demonstrate that there is some variation in tidal attenuation along the estuary due to changing the entrance bed level, with that variation being more significant towards the extremes of the tidal range, HHWSS and ISLW. For each 0.2m rise in the bed level, the tidal range is narrowed by approximately the same amount, and this generally results in lower water levels at high tide and higher water levels at low tide. Around MHWN, very little effect of the raised bed levels is observed. The bed smoothing case shows a small variation in tidal range that varies between the existing and 0.2m bed level rise cases. The four cases are concurrent at Site 0 as this site is outside the influence of the entrance bathymetry.

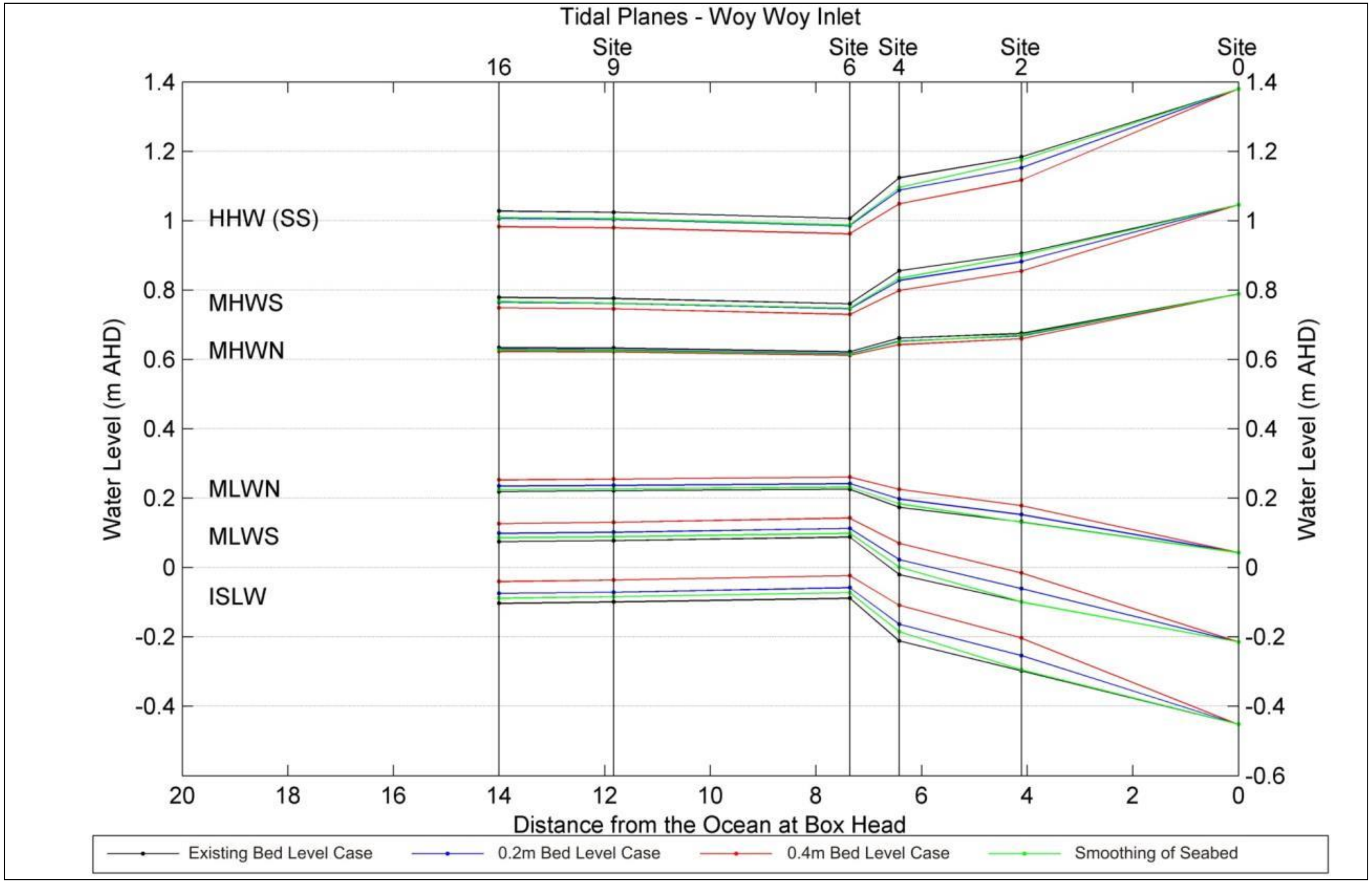


Figure G13: Woy Woy Tidal Plane Path – Comparing Tidal Planes under 0.4m SLR with Four Varying Bathymetry Cases. Site Locations as per Figure G3.

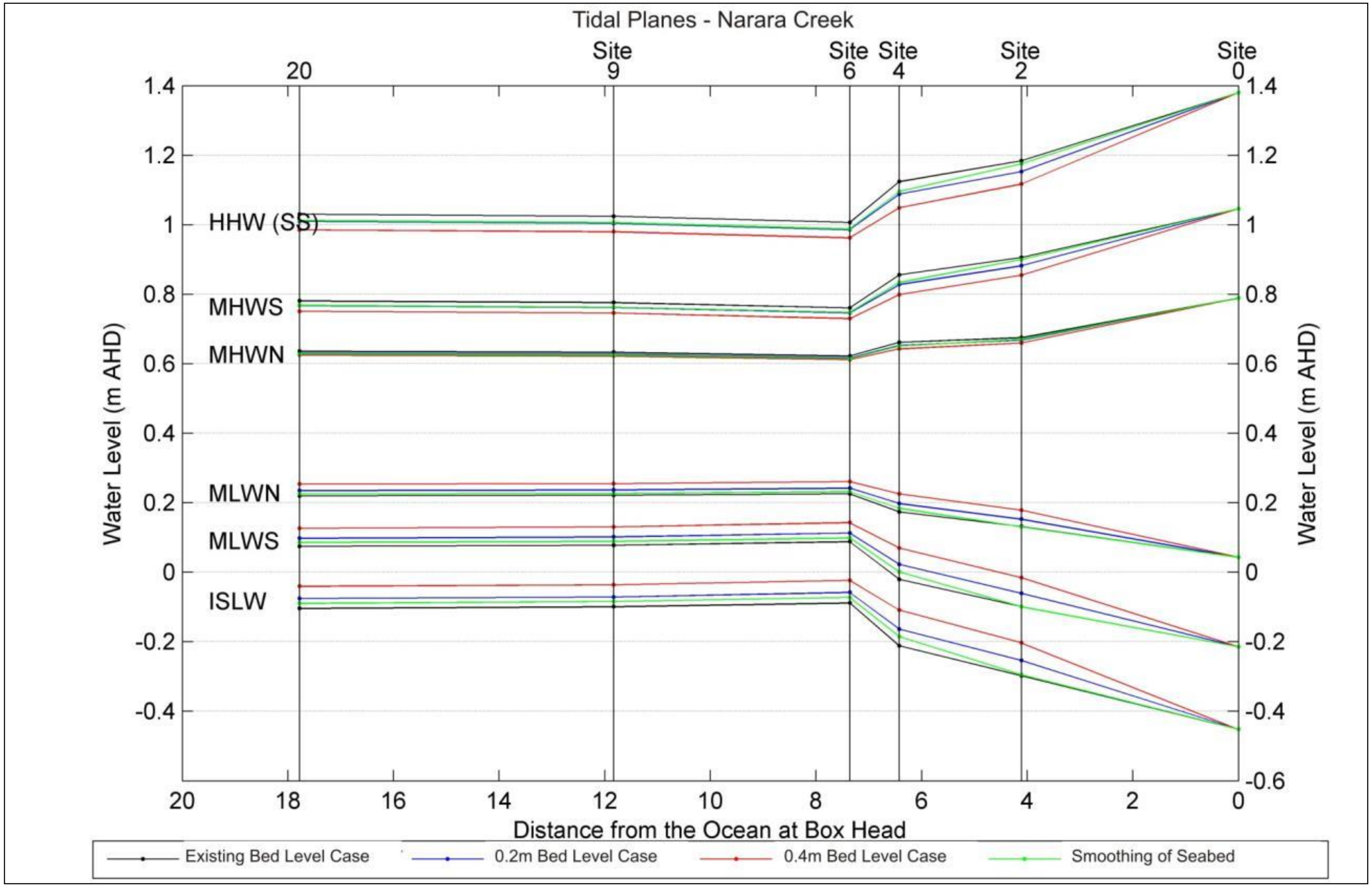


Figure G14: Narara Creek Tidal Plane Path - Comparing Tidal Planes under 0.4m SLR with Four Varying Bathymetry Cases. Site Locations as per Figure G3.

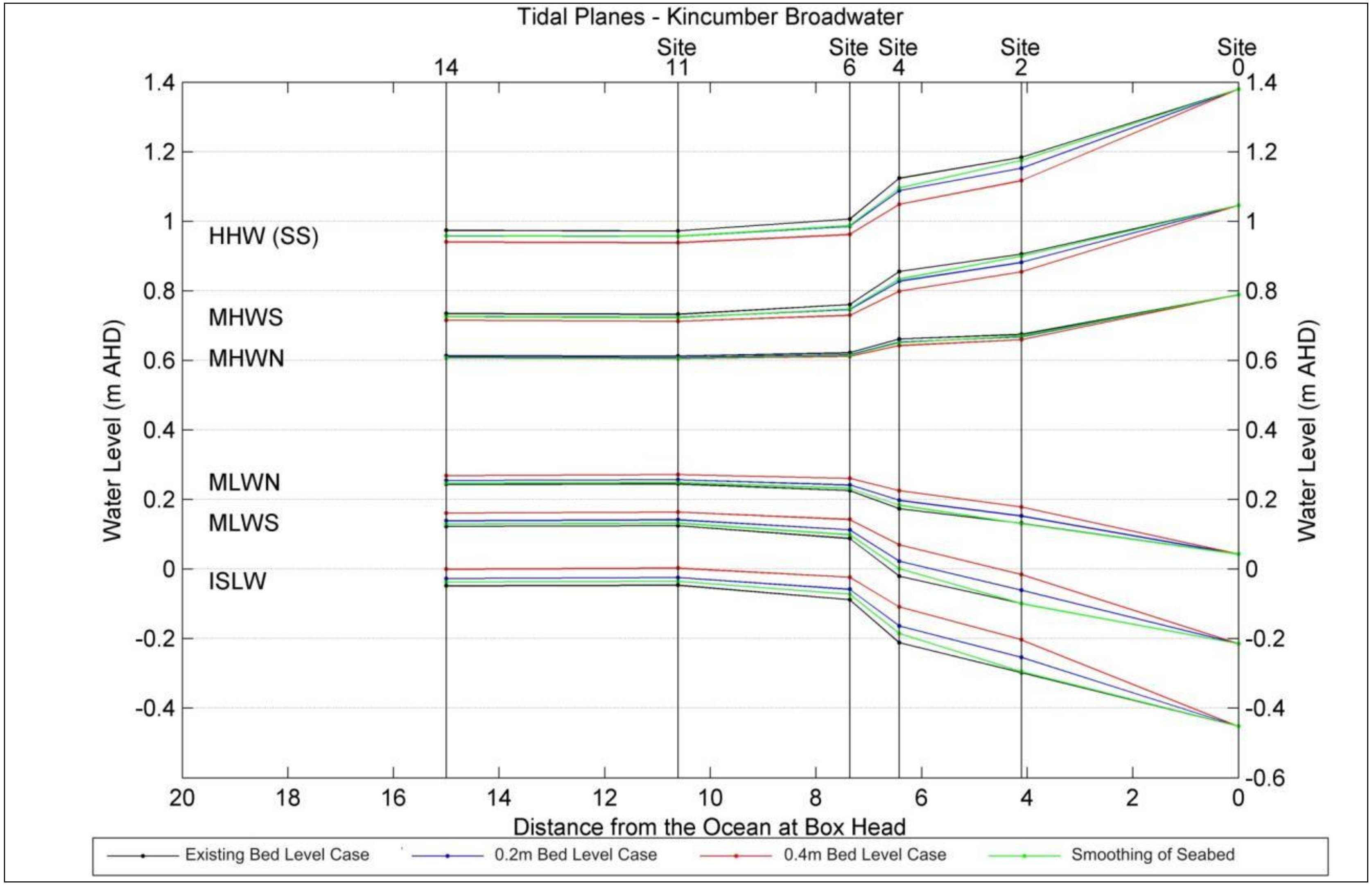


Figure G15: Kincumber Broadwater Tidal Plane Path - Comparing Tidal Planes under 0.4m SLR with Four Varying Bathymetry Cases. Site Locations as per Figure G3.

Table G2: Tidal Planes at Water Level Recorder Sites for the Existing Bathymetric Case (m AHD).

Site	HHWSS	MHWS	MHWN	MLWN	MLWS	ISLW	Range
0	1.380	1.046	0.789	0.043	-0.214	-0.452	1.260
2	1.184	0.906	0.675	0.132	-0.099	-0.298	1.004
4	1.124	0.856	0.662	0.174	-0.020	-0.211	0.875
6	1.007	0.761	0.622	0.226	0.088	-0.088	0.673
9	1.025	0.776	0.633	0.222	0.078	-0.099	0.698
10	1.029	0.780	0.635	0.222	0.077	-0.101	0.702
11	0.973	0.733	0.613	0.245	0.125	-0.046	0.609
14	0.974	0.735	0.614	0.244	0.123	-0.048	0.613
16	1.028	0.779	0.634	0.219	0.075	-0.103	0.704
20	1.030	0.781	0.636	0.220	0.075	-0.104	0.706

Table G3: Tidal Planes at Water Level Recorder Sites for the 0.2m Bathymetric Rise Case (m AHD).

Site	HHWSS	MHWS	MHWN	MLWN	MLWS	ISLW	Range
0	1.380	1.046	0.789	0.043	-0.214	-0.452	1.260
2	1.153	0.882	0.668	0.153	-0.061	-0.254	0.942
4	1.088	0.828	0.653	0.198	0.023	-0.163	0.806
6	0.986	0.746	0.617	0.242	0.113	-0.058	0.633
9	1.004	0.762	0.627	0.237	0.102	-0.071	0.660
10	1.008	0.765	0.630	0.237	0.101	-0.073	0.664
11	0.957	0.724	0.609	0.257	0.142	-0.024	0.581
14	0.959	0.726	0.611	0.255	0.139	-0.027	0.587
16	1.007	0.765	0.629	0.235	0.099	-0.074	0.666
20	1.010	0.767	0.630	0.235	0.098	-0.075	0.669

Table G4: Tidal Planes at Water Level Recorder Sites for the 0.4m Bathymetric Rise Case (m AHD).

Site	HHWSS	MHWS	MHWN	MLWN	MLWS	ISLW	Range
0	1.380	1.046	0.789	0.043	-0.214	-0.452	1.260
2	1.117	0.855	0.660	0.179	-0.015	-0.203	0.870
4	1.049	0.799	0.643	0.226	0.070	-0.109	0.729
6	0.962	0.730	0.612	0.261	0.143	-0.023	0.588
9	0.980	0.746	0.622	0.255	0.131	-0.036	0.615
10	0.984	0.749	0.624	0.255	0.130	-0.038	0.619
11	0.939	0.713	0.605	0.272	0.164	0.003	0.548
14	0.941	0.716	0.607	0.269	0.161	0.000	0.555
16	0.983	0.749	0.623	0.253	0.127	-0.040	0.622
20	0.985	0.751	0.625	0.254	0.127	-0.040	0.624

Table G5: Tidal Planes at Water Level Recorder Sites for the Bathymetric Smoothing Case (m AHD).

Site	HHWSS	MHWS	MHWN	MLWN	MLWS	ISLW	Range
0	1.3800	1.046	0.789	0.043	-0.214	-0.452	1.260
2	1.1748	0.900	0.670	0.131	-0.099	-0.295	0.999
4	1.0954	0.834	0.651	0.184	0.001	-0.185	0.833
6	0.9879	0.748	0.615	0.232	0.099	-0.072	0.648
9	1.0063	0.763	0.625	0.227	0.089	-0.084	0.674
10	1.0105	0.767	0.628	0.227	0.088	-0.086	0.679
11	0.9573	0.723	0.606	0.249	0.132	-0.035	0.591
14	0.9590	0.726	0.608	0.247	0.130	-0.037	0.596
16	1.0096	0.767	0.627	0.225	0.086	-0.088	0.681
20	1.0121	0.768	0.628	0.226	0.086	-0.089	0.683

As illustrated in **Figures G13 to G15**, the existing bed level case provides the most conservative estimate of tidal planes under the 0.4m SLR scenario because it gives the highest high tides. The existing bed level case was therefore adopted in this investigation.

Table G6 compares each of the calculated tidal planes between the existing conditions and the 0.4m SLR scenario outcomes. Given that the offshore sea level was increased by 0.4m, the expected change in tidal planes is +0.4m so any departures from this value are noteworthy. The last column in **Table G6** (□ Range), refers to the change in tidal range (the difference between high water level and low water level). Results indicate a slight increase of the tidal range under SLR (in the order of 7 to 11cm) across all stations. This means that as sea levels rise, estuarine levels also rise and the tidal range increases. Effects on individual tidal planes are reasonably consistent over all stations. MHWS and HHWSS show only small increases above 0.4m (less than 4.5cm), while MHWN shows only a small decrease below 0.4m (less than 2cm). Low water tidal planes experience more significant decreases below the expected 0.4m SLR. These decreases are more significant heading towards ISLW with the maximum being 10cm at Station 20 at ISLW.

Table G6: Tidal Plane Comparison (SLR 0.4m SLR (Existing Bed Level) – Present Sea Level) Cases.

Site	HHWSS	MHWS	MHWN	MLWN	MLWS	ISLW	□ Range
2	0.4100	0.3992	0.3806	0.3492	0.3306	0.3229	0.0686
4	0.4168	0.4038	0.3846	0.3460	0.3268	0.3175	0.0770
6	0.4164	0.4017	0.3867	0.3487	0.3337	0.3232	0.0680
9	0.4241	0.4076	0.3910	0.3498	0.3332	0.3214	0.0744
10	0.4244	0.4077	0.3909	0.3493	0.3325	0.3206	0.0752
11	0.4396	0.4187	0.3967	0.3375	0.3155	0.3006	0.1032
14	0.4445	0.4221	0.3989	0.3365	0.3133	0.2973	0.1088
16	0.4243	0.4074	0.3908	0.3492	0.3326	0.3205	0.0748
20	0.4424	0.4210	0.3958	0.3420	0.3168	0.3015	0.1042

G.3.2 Tidal Mapping Results

Results of the mapping are presented in **Section G.4** in the form of both tidal extents and indicative tidal inundation areas which provide an indication of the impacts of projected sea level rise on the key locations that may be affected by tidal inundation in the future.

G.4 Indicative Tidal Inundation Areas

G.4.1 Delineation of Indicative Areas

In order to provide an indication of the effects of increased tidal inundation due to projected sea level rise, a series of indicative tidal inundation areas were delineated. As outlined in **Section G.2.5**, these include areas which, with projected sea level rise:

- Are likely to be inundated very regularly (approximately daily, i.e. within MHWS);
- Are likely to be inundated fairly regularly (approximately twice per year, i.e. within HHWSS);
- Contain transport links including roads and railways which are likely to be inundated (at any rate of recurrence); and
- May not be directly affected by tidal inundation but which may be indirectly affected due to inundation of utilities and services (at any rate of recurrence).

In addition, affected areas have only been delineated in locations where development or infrastructure is present (i.e. affected open space or mangrove areas have been disregarded). This is so that only the areas of priority are highlighted (i.e. managing tidal inundation for an affected dwelling is much more complex than for an open space area, so affected residential areas have therefore been given priority over open space areas).

These indicative tidal inundation areas provide a broad indication of the key locations in the Brisbane Water foreshore floodplain that are likely to be vulnerable to increased tidal inundation and equate to "investigation areas" or "areas to be managed" in the future. These terms suggest that there is a requirement for further investigation into these areas to ascertain the most appropriate projected sea level rise mitigation and/or adaptation measures for each of these areas on a location-by-location basis. It is not the intention of this discussion paper to present all potentially affected properties on a lot-by-lot basis.

Figures G16A-B show the indicative tidal inundation areas for the 0.4m SLR scenario (up to HHWSS), whilst **Figures G17A-B** show the indicative tidal inundation areas for the 0.9m SLR scenario (up to HHWSS).

Note that in the delineation of these indicative areas it has been assumed that no changes to the existing foreshore will take place, i.e. the current foreshore situation has been assumed in all projected sea level rise scenarios. In reality, this is unlikely to be the case, since ground levels and foreshore structures are highly likely to be modified in the future, particularly in response to projected sea level rise.

The tidal extents for HHWSS for the existing, 0.4m SLR and 0.9m SLR scenarios are provided in **Figures G18A-B** and tidal extents for MHWS are provided in **Figures G19A-B**.

G.4.2 Discussion

The mapping of indicative areas demonstrates that there is only a relatively small increase in the extent of tidal inundation for up to 0.4m SLR, however a much larger increase occurs between 0.4m SLR and 0.9m SLR. This is likely to be due to the topography of the foreshore and adjacent areas. Results indicate that the foreshore is fairly steep up to the HHWSS level with 0.4m of SLR, and then flattens out beyond this level. This is shown conceptually in the diagram below (**Figure G20**). As mentioned above, it has been assumed that ground levels and existing foreshore structures (e.g. seawalls) remain the same in all SLR scenarios.

It is anticipated that a "threshold level" may exist between 0.4m SLR and 0.9m SLR, i.e. a maximum level of projected sea level rise that the floodplain can cope with before the extent of tidal inundation expands significantly. However, this threshold level cannot be determined from the available data and model results.

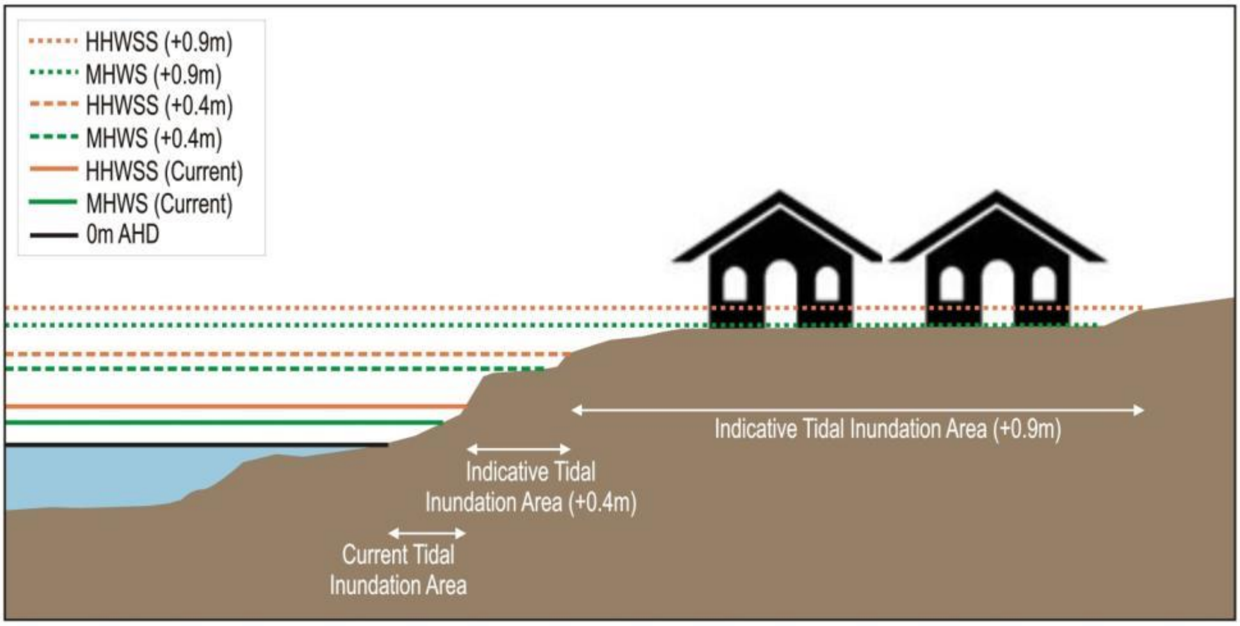


Figure G20: Conceptual Representation of Indicative Inundation Areas for current, +0.4m SLR and +0.9m SLR Scenarios.

Table G7 outlines the key characteristics of tidal inundation areas in the current, 0.4m SLR and 0.9m SLR scenarios.

Table G7: Characteristics of Indicative Tidal Inundation Areas.

Scenario	Characteristics
Current	High high tides currently affect locations in Davistown, Empire Bay and Woy Woy, particularly areas within HHWSS. Most other locations are not generally affected.
0.4m SLR Scenario	Mainly backyards of residential properties affected, mostly just grassed areas, some waterfront dwellings likely to be affected but number is fairly minimal. Roads minimally affected, railway lines not affected. Services and utilities likely to be fairly minimally affected.
0.9m SLR Scenario	Substantially increased area of land affected, especially in the key areas of Davistown, Empire Bay and Booker Bay, where mostly residential land uses are likely to be affected. In Woy Woy, both commercial and residential properties are likely to be affected. Roads in these suburbs are likely to be inundated. Services and utilities are also likely to be impacted in these areas. Train lines are not likely to be affected, however road and pedestrian access to Woy Woy station from the east may be impeded.

G.5 Conclusions

G.5.1 Tidal Modelling

The tidal modelling assessment presented in this discussion paper identified that any changes in entrance morphology as a result of projected sea level rise are unlikely to have a significant impact on the attenuation of tides through the estuary. The assessment also identified that tidal levels within Brisbane Water are likely to increase relative to the increases in projected sea level rise.

Tidal planes were predicted to be little affected by the 0.4m increase in sea level predicted under the DECCW (2009b) benchmark with variations between -10 and +2.5cm, depending on the tidal plane and location within the Brisbane Water estuary. While there is expected to be some narrowing of the tidal range due to potential morphological change in the estuary entrance, the highest high tides are experienced under the existing entrance bed level case and so can be considered conservative.

Although the mean water level within the estuary would rise 0.4m, the highest high tides would rise slightly more, with the largest increase being in the upper estuary areas, for example, Site 20 in Fagans Bay. The highest high tides will rise about 4cm more than the mean SLR, that is, there will be an increase in the tidal range as well. As a result of this rise in mean sea level and the increase in tidal range, tidal penetration may be 5 to 10m further inland than currently observed (at least where shoreline slopes are very flat).

G.5.2 Tidal Mapping and Indicative Areas

The mapping of MHWS and HHWS tidal inundation areas identified that:

- There is likely to be only a fairly minimal increase in the foreshore area affected by tidal inundation with a projected sea level rises of up to 0.4m. However, larger increases are likely to occur with projected sea level rises of between 0.4m and 0.9m. This suggests that the Brisbane Water foreshore floodplain may be reasonably prepared for projected sea level rises of up to 0.4m;
- In terms of developed areas, mainly residential land uses and some commercial land uses are likely to be affected. Open space areas are likely to be affected particularly since this land use type is often located on the foreshore however inundation of open space is more manageable than inundation of dwellings;
- Road transport is likely to be impacted, particularly residential roads in areas of Davistown, Empire Bay, Woy Woy and Booker Bay. Train transport is not likely to be affected.

This information may be useful in assisting Council with planning for tidal inundation as a result of projected sea level rise in the future. Results indicate that the Brisbane Water foreshore is likely to be reasonably prepared for sea level rises of up to 0.4m but rises of 0.9m are likely to have more significant implications so planning for this more critical scenario should begin right away. It is anticipated, however, that the planning process will be a highly dynamic and iterative one given the speculative nature of current projected sea level rise predictions. Planning for projected sea level rise will require regular review as new observations, data and projections become available into the future.

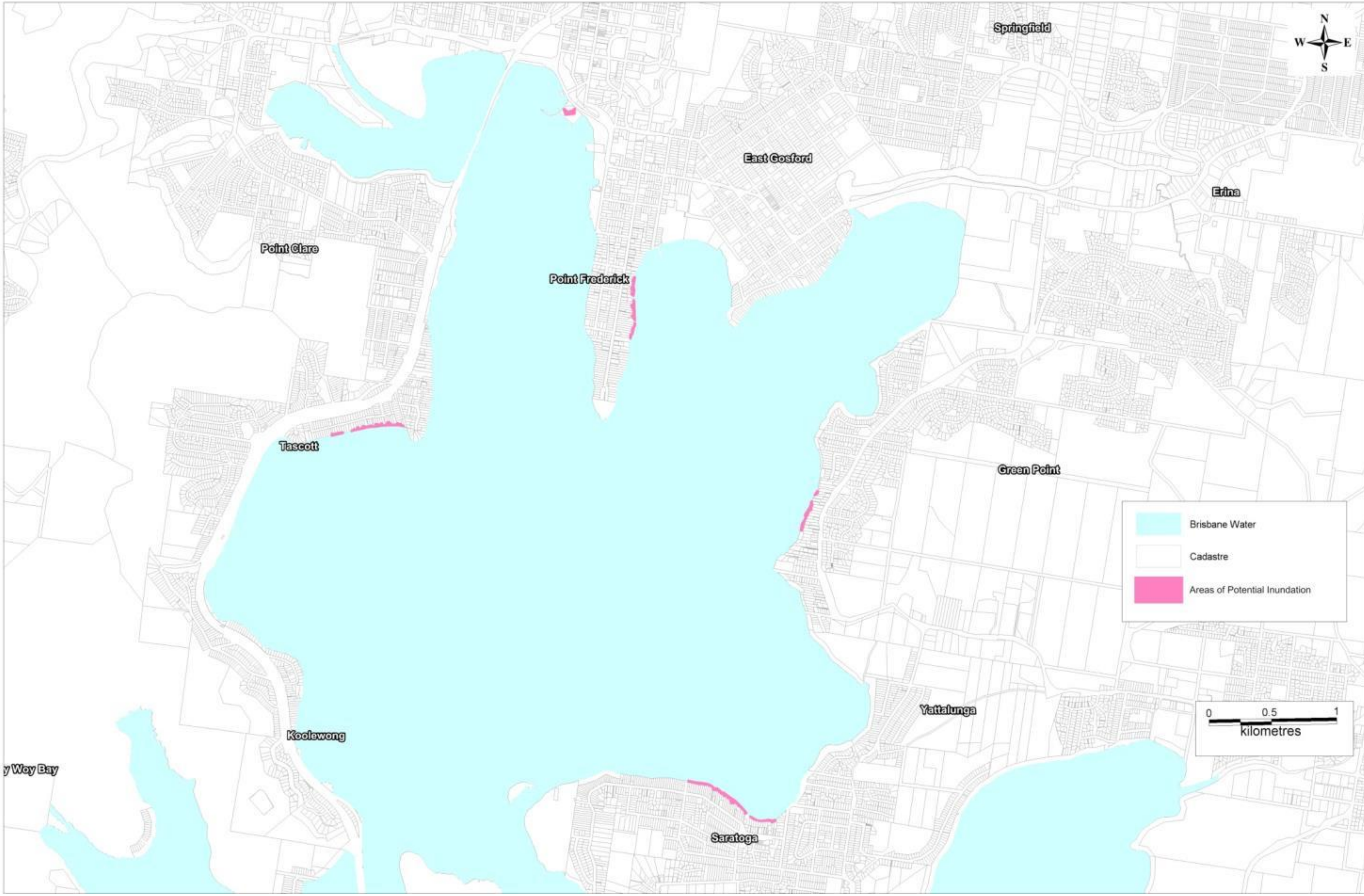


Figure G16A: Indicative Tidal Inundation Areas (Areas of Potential Inundation, 0.4m SLR)

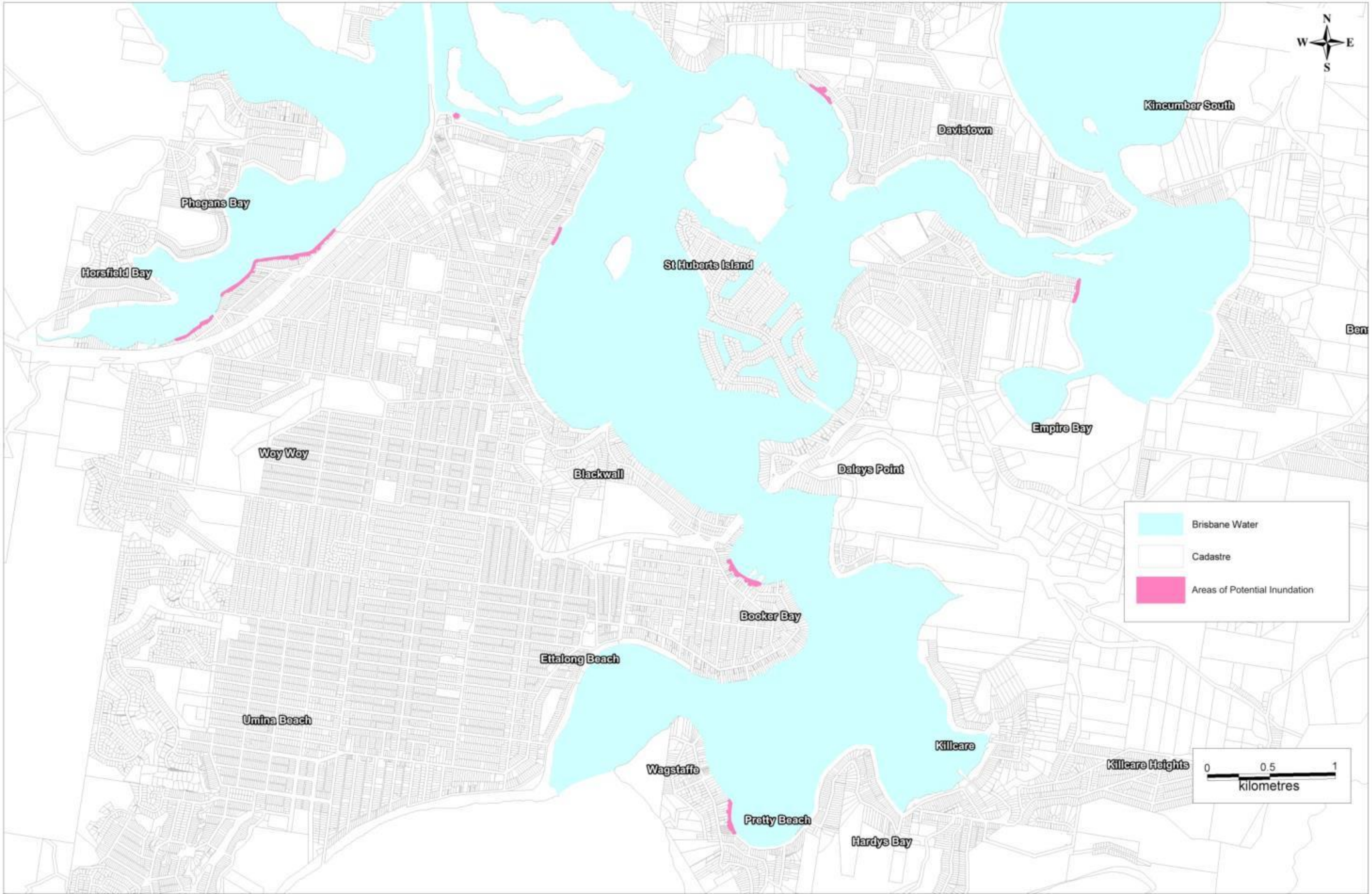


Figure G16B: Indicative Tidal Inundation Areas (Areas of Potential Inundation, 0.4m SLR)

Figure G17A: Indicative Tidal Inundation Areas (Areas of Potential Inundation, 0.9m SLR)

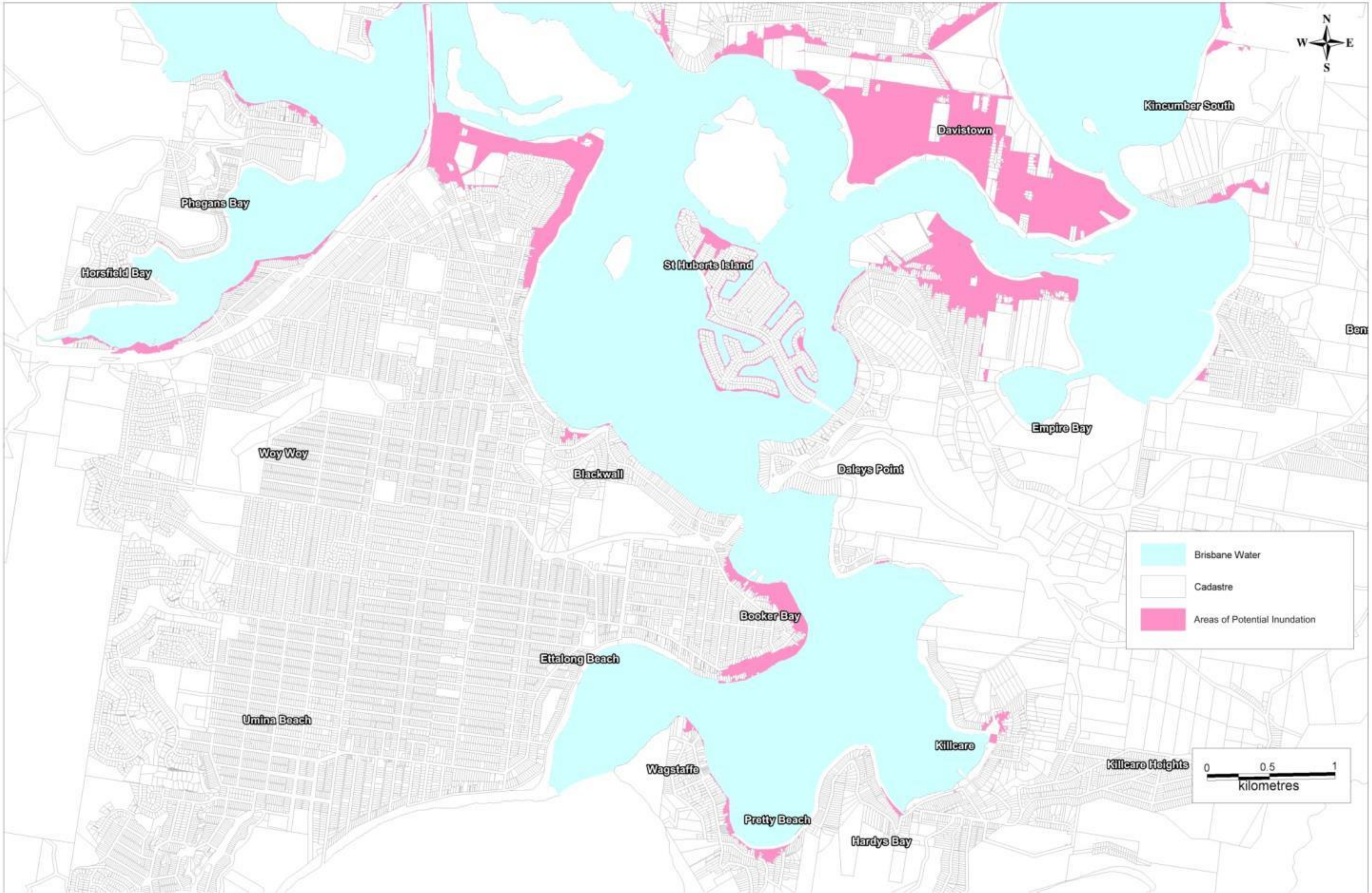


Figure G17B: Indicative Tidal Inundation Areas (Areas of Potential Inundation, 0.9m SLR)

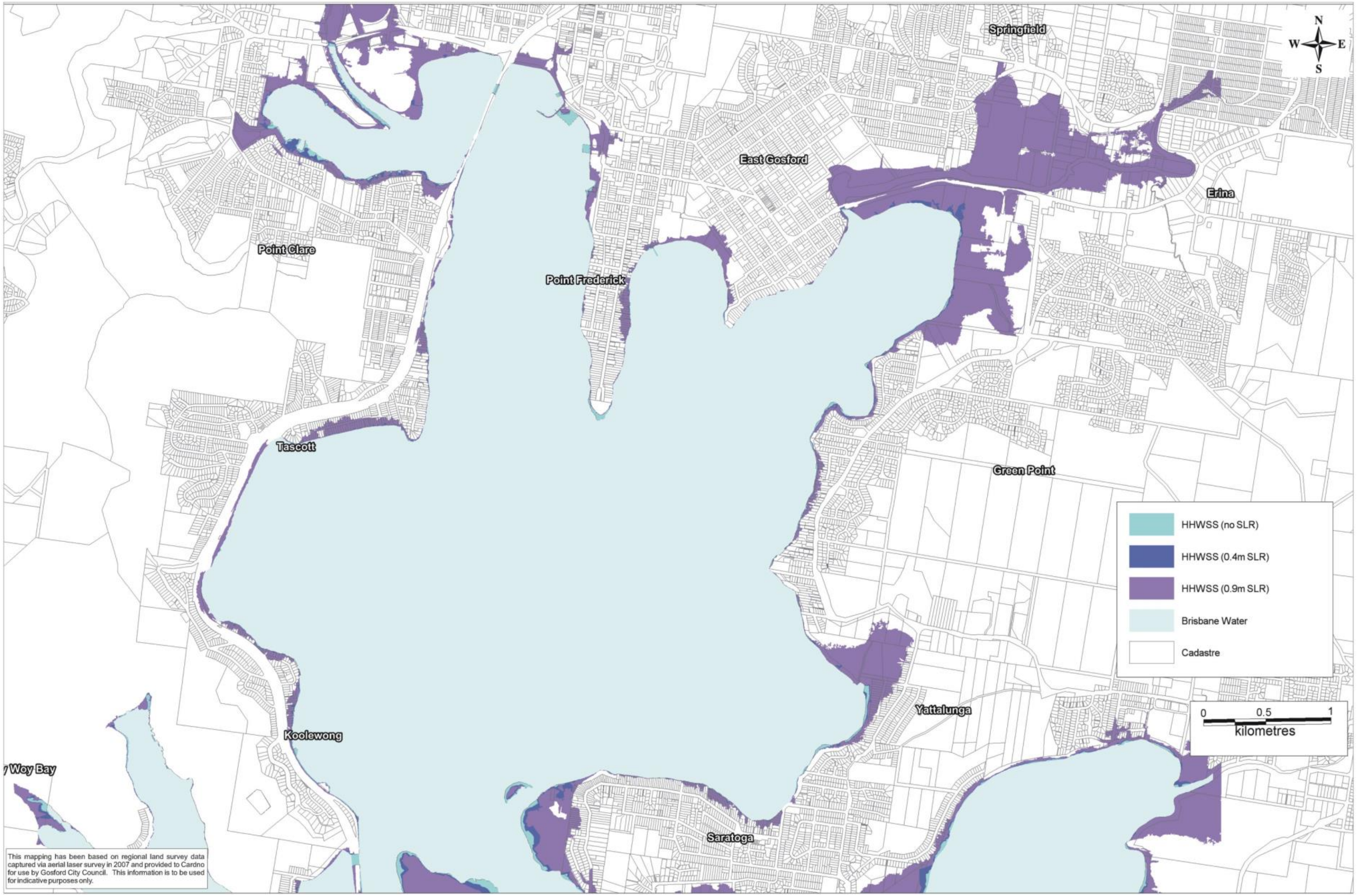


Figure G18A: HHWSS Tidal Extents

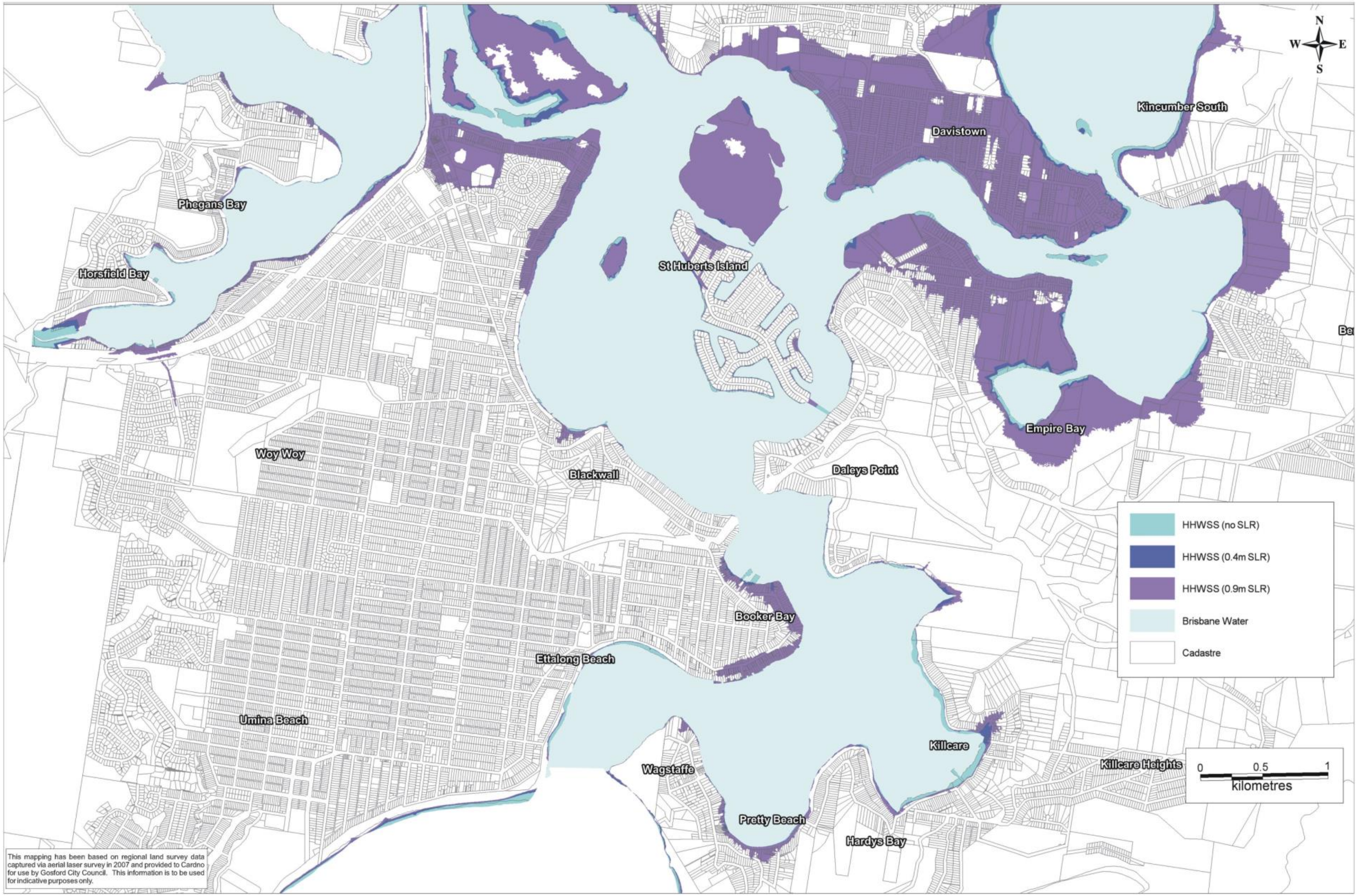


Figure G18B: HHWSS Tidal Extents

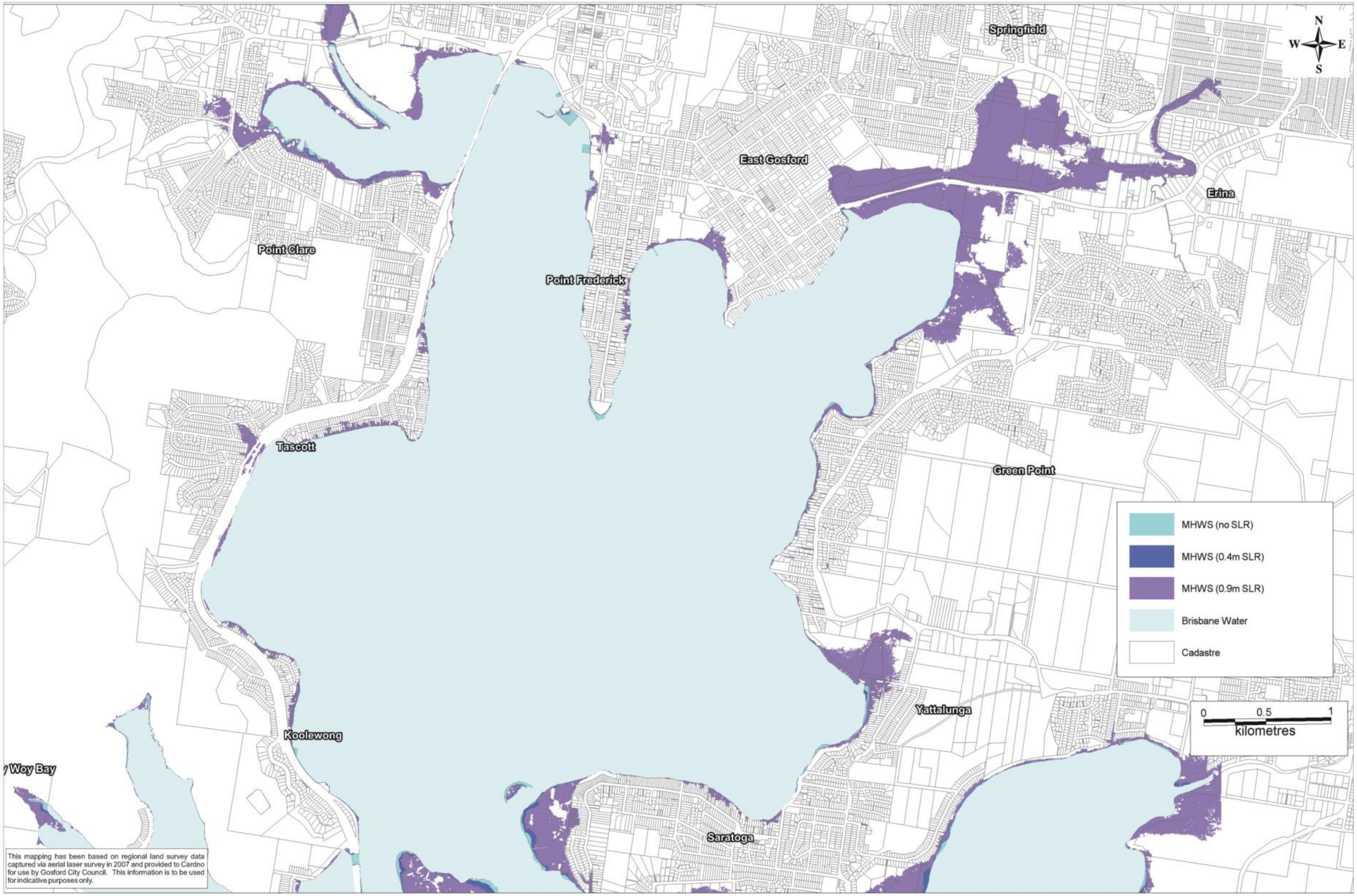


Figure G19A: MHWS Tidal Extents

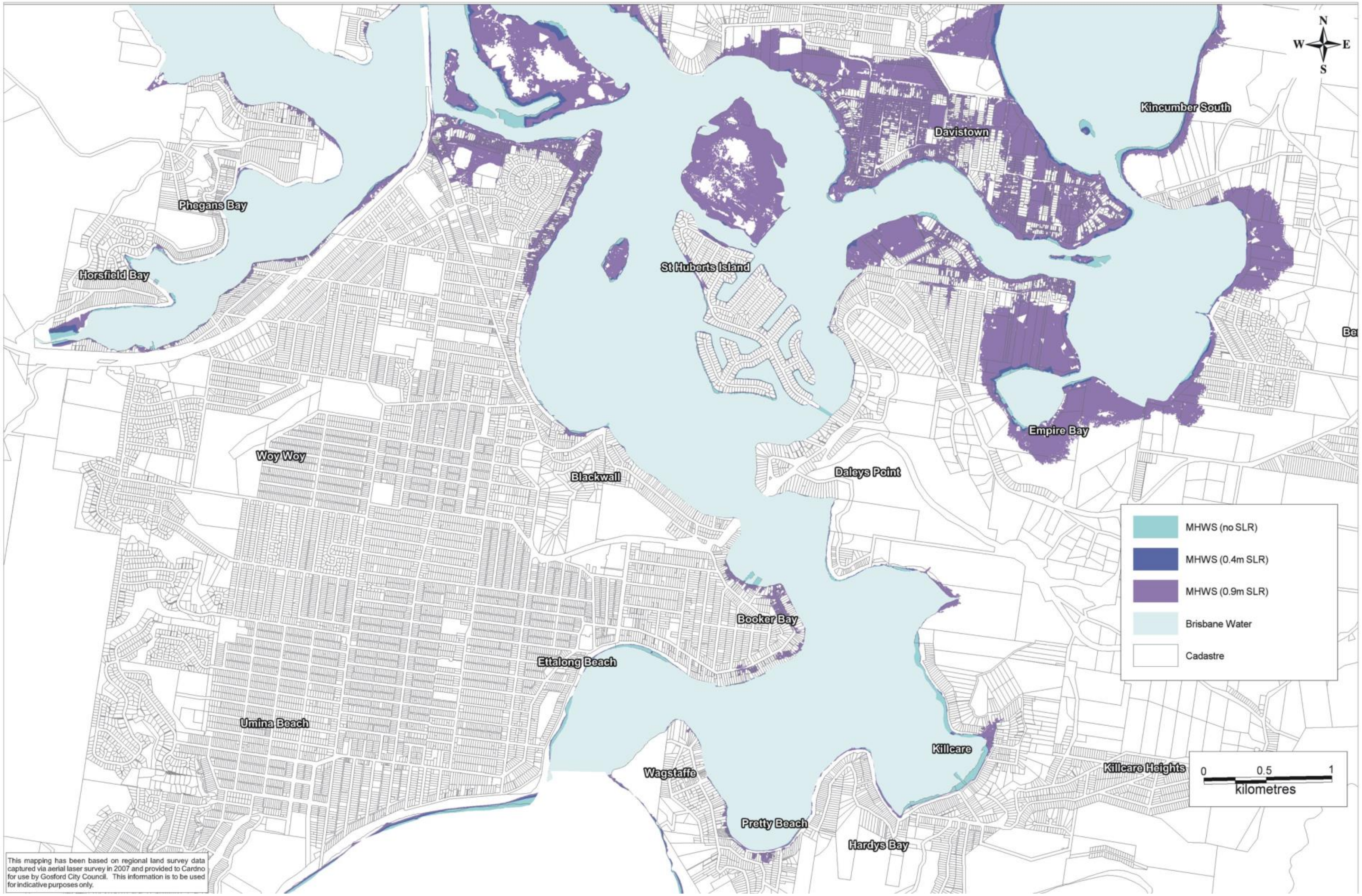


Figure G19B: MHWS Tidal Extents

Appendix H

Development Control Matrix

Probable Maximum Flood (PMF) Extent (Excluding the Flood Planning Area)

Planning Consideration	Sensitive Uses and Emergency Facilities	High Intensity Uses	Critical Utilities	Land Subdivision	High Density Residential	Low Density Residential (Urban)	Low Density Residential (Rural)	High Density Commercial & Industrial	Low Density Commercial & Industrial	Non Habitable Recreational Facilities	Concessional Development
New Development/Redevelopment	1, 3	1, 3	1, 3	2	2	2	2	2	2	2	
Floor Level	2	2	2								
Building Components	2	2	2								
Structural Soundness	2	2	2								
Flood Affectation	2,3	2,3	2,3	3,4	3	3	3	3	3	3	3
Emergency Management	1,3,4, 5	1,3,4, 5	1,3	3,6	4,5			4,5			
Car Parking	2,3	2,3	2,3		2,3	2,3	2,3	2,3	2,3	2,3	2,3
Management & Design	4,5,7, 9, 10	4,5,7, 9, 10	4,5,7, 9, 10	1,2				5, 10	5, 10	5, 10	
Wave Impacts	1	1	1		1	1	1	1	1	1	1

Flood Planning Area (Excluding the 100 Year ARI High Hazard Extent)

Planning Consideration	Sensitive Uses and Emergency Facilities	High Intensity Uses	Critical Utilities	Land Subdivision	High Density Residential	Low Density Residential (Urban)	Low Density Residential (Rural)	High Density Commercial & Industrial	Low Density Commercial & Industrial	Non Habitable Recreational Facilities	Concessional Development
New Development/Redevelopment					2	2	2	2	2	2	
Floor Level					1	1	1	1	1	5,6,7	3
Building Components					1	1	1	1	1	1	1
Structural Soundness					1,3	1,3	1,3	1,3	1,3	1	1
Flood Affectation					1,3	2,3	2,3	1,3	2,3	2,3	2,3
Emergency Management					1,4,5	1	1	1,4,5	1	1	
Car Parking					1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
Management & Design					5,6,8, 10	5,6,8	5,6,8	3,5,6, 8,10	3,5,6, 8,10	5,6,8, 10	5,6
Wave Impacts					1	1	1	1	1	1	1

100 Year ARI High Hazard Extent

Planning Consideration	0	High Intensity Uses	Critical Utilities	Land Subdivision	High Density Residential	Low Density Residential (Urban)	Low Density Residential (Rural)	High Density Commercial & Industrial	Low Density Commercial & Industrial	Non Habitable Recreational Facilities	Concessional Development
New Development/Redevelopment					3	4	4	3	3	2	
Floor Level					1,4	1,4	1,4	1,4	1,4	5,6,7	1
Building Components					1,3	1,3	1,3	1,3	1,3	1	1,3
Structural Soundness					1,3	1,3	1,3	1,3	1,3	1	1
Flood Affectation					1,3	1,3	1,3	1,3	1,3	1,3	2,3
Emergency Management					1,4,5	1	1	1,4,5	1	1	1
Car Parking					1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3	1,2,3
Management & Design					5,6,8, 10	5,6,8	5,6,8	3,5,6, 8,10	3,5,6, 8,10	5,6,8, 10	5,6
Wave Impacts					1	1	1	1	1	1	1

	Not Relevant		Unsuitable Land Use

New Development/Redevelopment	
1	New developments not suitable. Controls in this matrix apply to redevelopment and replacement only.
2	New developments suitable.
3	Where redevelopment may extend the design life of the structure / facility, this may be considered on a merits basis. However, relocation to an area outside of the floodplain should be considered as a priority.
4	Where the flood hazard can be reasonably mitigated, new developments may be approved by Council on merits based approach. Any proposed mitigation measures would need to be supported by a hydraulic engineers report and emergency response arrangements should be considered in accordance with this DCP.
Floor Level	
1	Habitable floor levels to be equal to or greater than the FPL.
2	Habitable floor levels to be equal to or greater than the PMF or FPL (whichever is higher).
3	Habitable floor levels to be as close to FPL as practical & no lower than existing floor level.
4	All habitable floor levels (proposed and existing) to be raised above the FPL.
5	Floor levels to be 300mm above the ground level or equal to or greater than the 20 Year ARI flood level (whichever is higher)
6	Floor level of boatsheds should be equal to or greater than the FPL. Consideration may be given on a merit basis to a floor level of a boat shed at a level lower than the FPL where it can be demonstrated through an Flood Management Report that the boat shed is structurally designed to withstand inundation up to the FPL and wave impacts.
7	No planning levels apply to jetties, bridging ramps or pontoons located on the seaward side of the foreshore edge.

Building Components & Method	
1	All structures to have flood compatible building components below or at the FPL.
2	All structures to have flood compatible building components below or at the PMF or FPL (whichever is higher).
3	Where possible, flood compatible building components are to be incorporated into the existing structure below or at the FPL.
4	Where possible, flood compatible building components are to be incorporated into the existing structure below or at the PMF or FPL (whichever is higher).
Structural Soundness	
1	All structures must be designed and constructed to ensure structural integrity for immersion and impact of velocity and debris up to the level of the 100 Year ARI flood (including wave run up and over topping).
2	All structures must be designed and constructed to ensure structural integrity for immersion and impact of velocity and debris up to the level of the PMF (including wave run up and over topping).
3	If the structure is to be relied upon for 'shelter-in-place' evacuation then structural integrity must be ensured up to the level of the Probable Maximum Flood (including wave run up and overtopping) or the FPL (whichever is higher).
Flood Affectation	
1	Hydraulic Engineers report required to certify that the development will not increase flood affectation elsewhere.
2	The impact of the development on flooding elsewhere to be considered.
3	Filling that impacts on active flow areas in the stream networks feeding Brisbane Water is not permitted. Filling operations must include adequate provision for drainage of surface water erosion and siltation control and be so placed and graded as to prevent the shedding of surface water direct to adjoining properties.
4	Hydraulic engineers report is required to certify that the subdivision will not exacerbate flood levels, velocities or flow distributions at any other location, including cumulative impacts of incremental development, should all the proposed lots be fully developed in the future.
Emergency Management	
1	Pedestrian access is required at or above the FPL from habitable floors to a suitable area of refuge above the PMF level or FPL (whichever is higher), either on site (e.g. second storey) or off site.
2	Pedestrian access is required at or above the PMF or FPL (whichever is higher) from habitable floors to a suitable area of refuge above the PMF level or FPL (whichever is higher), either on site (e.g. second storey) or off site.
3	Reliable vehicle access is required during a PMF event.
4	A site emergency response plan (approved by Council) is required.
5	The development is to be consistent with the site emergency response plan.
6	Applicant to demonstrate that evacuation of potential development as a consequence of the subdivision proposal can be undertaken.
Car Parking	
1	Enclosed garage and enclosed car park: floor levels shall be at or above 'FPL minus 150mm'.
2	Covered basement car parking: all possible water entry points (e.g. access and ventilation) shall be above the FPL or PMF (whichever is higher). Pedestrian access (separate to vehicle access) shall be provided via a low flood hazard area to a 'safe haven' above the FPL.
3	Open car park areas (including covered car park areas) and carports: floor levels to be at the 100 Year ARI level or 300mm above the ground level, whichever is higher.
Management and Design	
1	Applicant to demonstrate that potential development as a consequence of a subdivision proposal can be undertaken in accordance with DCP.
2	The subdivision of land requires the building platforms for each additional allotment created to be at or above the FPL or PMF (whichever is higher).
3	Applicant to demonstrate that area is available to store goods above the FPL.
4	Applicant to demonstrate that area is available to store goods above the FPL or PMF level (whichever is higher).
5	No external storage of materials below the design floor level which may cause pollution or be hazardous during any flood.
6	All electrical equipment, wiring, fuel lines or any other service pipes and connections must be waterproofed to the FPL
7	All electrical equipment, wiring, fuel lines or any other service pipes and connections must be waterproofed to the FPL or PMF (whichever is higher)
8	Sewer and water services within the site should be designed to have continued function up to the FPL. If the development is being used as flood refuge, design should function up to the FPL or PMF (whichever is higher).
9	Sewer and water services within the site should be designed to have continued function up to the FPL or PMF (whichever is higher).
10	Internal storage of materials that may cause pollution or be hazardous during any flood to be waterproofed to the FPL or PMF or located above the FPL or PMF (whichever is the higher).
Wave Impacts	
1	Wave run-up (as calculated in the Flood Study, Cardno 2014) should be managed in development is within 40m of the foreshore. This may be done through foreshore management (i.e. wave dissipation devices) or construction management (i.e. floor levels, structural soundness)

DEFINITIONS

Term	Definition
Sensitive Uses and Emergency Facilities	Emergency service facilities, group homes, hospitals, disabled housing/seniors living, residential care facilities, schools, preschools. Identified in Council's LEP as "Essential Community Facilities".
High Intensity Uses	Uses that can have a high density of people present (often tourists or visitors): e.g. caravan parks, correctional facilities, tourist and visitor accommodation, community facilities (i.e. churches, public halls and other places of congregation). May be identified in Council's LEP as "Tourist Related Development" or "Recreation or Non-Urban Uses".
Critical Utilities	Assets that are essential for the functioning of a society and economy such as electricity, gas, oil, telecommunications, water and sewerage. Identified in Council's LEP as "Critical Utilities and Uses".
Land Subdivision	Subdivision of existing parcels of land excluding strata and community subdivision. Identified in Council's LEP as "Subdivision".
High Density Residential	Multi-unit dwellings. Identified in Council's LEP as "Residential".
Low Density Residential (Urban)	Single or dual occupancy dwellings on urban zoned land. Identified in Council's LEP as "Residential".
Low Density Residential (Rural)	Single or dual occupancy dwellings on rural zoned land. Identified in Council's LEP as "Residential".
High Density Commercial & Industrial	Multi-unit commercial and industrial development. Identified in Council's LEP as "Commercial or Industrial".
Low Density Commercial & Industrial	Single-unit commercial and industrial development. Identified in Council's LEP as "Commercial or Industrial".
Non Habitable Recreational Facilities	Non habitable recreational structural facilities such as ablutions blocks, kiosk, sports storage facilities. Identified in Council's LEP as "Recreational or Non-Urban Uses".
Concessional Development	Where the existing habitable floor level is below the FPL and provided that the proposed floor level is no lower than existing floor level, then a one-off addition may be considered up to: (i) 40m2 if the existing residential floor is at or above the FPL less the applicable freeboard; (ii) 20m2 if the existing residential floor below the FPL less the applicable freeboard; (iii) 10% increase in floor area for commercial or industrial additions.
Flood Planning Level (FPL)	As defined in the Brisbane Water Floodplain Risk Management Plan.
Flood Planning Area (FPA)	The area below the flood planning level. Shown on attached map.
Probable Maximum Flood (PMF)	The flood calculated to be the maximum that is likely to occur. Also refered to as the extent of the floodplain. This area is not relevant to planning controls under the existing FPL (100 Year ARI + 2050 SLR + 0.5m Freeboard). The proposed FPL is higher than the PMF at all locations within the floodplain and as such the FPA is greater than the PMF extent. Therefore the PMF extent is not shown on the attached map.
100 Year ARI High Hazard	Defined as part of the Flood Study (2013). Shown on the attached map.
Reliable vehicle access	Reliable safe flood access is considered satisfactory when the depth of floodwater over vehicular access routes (roads and legal right of ways) allows the safe and stable movement of vehicles. The access route is to be legal and permanent, fail safe and maintenance free.
Habitable floor levels	• In a residential situation: a bedroom, living room, lounge room, music room, television room, kitchen, dining room, sewing room, study, playroom, family room, home theatre and sunroom; but excludes a bathroom, laundry, water closet, pantry, walk-in wardrobe, corridor, hallway, lobby, photographic darkroom, clothes-drying room, vehicle parking area, storage area and other spaces of a specialised nature occupied neither frequently nor for extended periods (ABCB, 2013). • In an industrial or commercial situation: an area used for offices or to store equipment, materials or valuable possessions susceptible to flood damage in the event of a flood.
Suitable area of refuge	The suitability of the refuge area will be confirmed by Council dependent on the number of people seeking refuge and the type of development. The refuge area should have access to clean water, toilets, heat and food.
Wave Run-Up	The increase in water level within the foreshore zone above the Design Still Water Level (see Flood Study (Cardno, 2013) from waves across a natural foreshore or structure (e.g. sea wall). Wave run-up heights calculated in the Flood Study also include provision for Wave Set-Up. (see below)
Wave Set-Up	The increase in water level within the foreshore zone above the Design Still Water Level (see Flood Study (Cardno, 2013) caused by the breaking action of waves.

NOTES

There are several locations which are considered flood islands in the 100yr event (Woy Woy, Davistown). However, they still have significant evacuation and access issues during a flood event. Intensification of development at these locations would therefore not be appropriate. It is recommended that provision for flood islands be included in Management Area-Specific DCP provisions (to be developed) to include appropriate development controls for these locations.
It is important to note that whilst the DCP matrix is in preparation, a DCP is only a guide to the controls that can be imposed on a development (EP&A Act, Section 74BA and Section 74C). Unless an LEP specifically makes reference to controls on a specific location then even site-specific controls in a DCP are a guide only.
Controls have been established based on existing flood risks, with consideration of the effects of projected sea level rise incorporated in the allowance incorporated in the flood planning level, as established in the Floodplain Risk Management Plan. Supplementary controls specifically relating to the effects of sea level rise alone would be addressed as an outcome of the Climate Change Adaptation Plan.

Appendix I

Detailed Description of Options

Detailed Description of Options

The following descriptions and assessment of the floodplain risk management options are separated into:

- Flood modification (FM) options (**Section I.1**);
- Property modification (PM) options (**Section I.2**); and
- Emergency response modification (EM) options (**Section I.3**).

Details regarding the relevance of implementing the options within specific management areas have also been discussed.

I.1 Flood Modification Options

FM1a – Raise All Flood-Affected Roads		
Option Type: Flood Risk Modification	**Action Timeline:** Staged	**CCAP:** Included
Background: Many roads around Brisbane Water can be inundated during a flood event. These include main roads such as the Central Coast Highway, Brisbane Water Drive and Woy Woy Road. Flooding of major roads such as these can cause issues with respect to evacuation (egress) and emergency response vehicle access (ingress). In some cases, access to and from critical infrastructure (such as SES facility at Erina) would be impeded during a flood event.		
Option Overview: Raise flood-affected sections of all roads within the floodplain up to the 100 year ARI level +0.9m SLR.		
Flood Mitigation Outcomes: The impacts of flood events on access and evacuation would be reduced.		
Management Areas: All.		
Projected Sea Level Rise: This option proposes to raise all flood-affected roads to above the 100 year ARI flood level (staged to the 100 year ARI +0.9m SLR). As such, it would benefit both the existing case and the 0.9m SLR flooding scenario. The future increase in road height to account for projected sea level rise needs to be considered in the initial design.		
Additional Information		
Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. The assessment has assumed that all works could be undertaken within the existing road reserve (i.e. the elevated roads would be graded such that access to individual properties was retained).		
Considerations/Impacts		
Economic	**Social**	**Environmental**
Significant costs would be associated with this option. Associated costs would include service and utility upgrades and connection of driveways to the raised road. Estimated capital (initial) and recurrent (per year) costs range from approximately \$3M and \$70,000 respectively to \$71M and \$1.4M respectively, depending on the location. Residential roads reconstruction calculated at \$2180 per linear metre. Main road reconstruction calculated at \$5115 per linear metre. Highway reconstruction calculated at \$6200 per linear metre. 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels, and costs would vary depending on location. A notable road upgrade project is proposed for Rawson Road and Woy Woy Road in Woy Woy. If this project is undertaken these economic costs would be substantially reduced in this location. There are not likely to be significant direct economic benefits as a result of this option as this option focuses on flood access and the reduction in risk to life (provides indirect and intangible economic benefits).	The practicality of raising many roads would be difficult with regards to retaining streetscape, residential access and maintaining efficient drainage.	The environmental impacts of this option would be manageable in most cases assuming that the works are undertaken within the existing road reserve.

FM1b – Raise Major and Critical Flood-Affected Roads		
Option Type: Flood Risk Modification	**Action Timeline:** Staged	**CCAP:** Included

Background:

As for FM1a.

Option Overview:

Raise flood-affected sections of selected roads within the floodplain up to the 100 year ARI level +0.9m SLR. Roads included in this option can be categorised into three types:
- Major Access – Roads that provide access and evacuation routes for numerous people;
- Critical Access – Roads that provide access to and from critical infrastructure, such as hospitals and ambulance stations; and
- Only Access – Roads that provide the only road-based route in or out of an area. Flooding of such access routes would lead to isolation of an area during a flood event.

Flood Mitigation Outcomes:

The impacts of flood events on access and evacuation would be reduced for major, critical and only access roads.

Management Areas:

MA	Road Name (Road Type M - Major, C - Critical, O - Only)	MA	Road Name (Road Type M - Major, C - Critical, O - Only)
1	Central Coast Highway (M), Brisbane Water Drive (M), Coolarn Avenue (C), Manooka Road (O), Yallambee Avenue (O)	9	Helmsman Boulevard (M)
2	Central Coast Highway (M)	10	Araluen Drive (M)
3	Brisbane Water Drive (M)	11	Pretty Beach Road (O)
4	Pateman Road (C), The Entrance Road (M,C)	12	The Esplanade (M), Bangalow Street (M) and Beach Street (M)
5	Davistown Road, Yattalunga (M)	13	Bogan Road (M)
6	Davistown Road, Davistown (M) and Malinya Road (M)	14	Woy Woy Road (M), Blackwall Road (M), The Boulevard (M), Brick Wharf Road (M), North Burge Road (M), Park Road (O), Norma Crescent (O), Sonter Avenue (O) and Brisbane Water Drive/Railway Street (M)
7	*No Major Access, Critical Access or Only Access roads are located within this Management Area.*		
8	Greenfield Road (M) and Rickard Road (M)	15	Brisbane Water Drive (M)

Projected Sea Level Rise:

This option proposes to raise all flood-affected roads to above the 100 Year ARI flood level (staged to the 100 Year ARI +0.9m SLR). As such, it would benefit both the existing case and up to 0.9m SLR flooding scenario, after staging is complete. The future increase in road height to account for projected sea level rise should be considered in the initial design.

Additional Information

Roads, if raised, may act as a weir and increase flooding associated with catchment runoff on the upstream side of the road. The assessment has assumed that all works could be undertaken within the existing road reserve (i.e. the elevated roads would be graded such that access to individual properties was retained).

Considerations/Impacts

Economic	Social	Environmental
Less costly than raising all roads but still a significant cost. Estimated capital (initial) and recurrent (per year) costs range from approximately $1.8M and $36,000 respectively to $23M and $450,000 respectively, depending on the location. There are not likely to be significant direct economic benefits as a result of this option as it focuses on flood access and the reduction in risk to life (intangible benefits). 1m of fill has been assumed across all locations to provide an indication of a "worst-case" scenario, however actual fill levels are likely to be much lower depending on gradients and flood levels, and costs would vary depending on location. A notable road upgrade project is proposed for Rawson Road and Woy Woy Road in Woy Woy. If this project is undertaken economic costs would be substantially reduced in this location.	If this option were implemented flood-free access would not be achieved in all areas. However, there would be a significant improvement in flood free access for rare floods during such events. Raising some roads may be difficult with regards to retaining streetscape, residential access and maintaining efficient drainage.	As for FM1a.

FM2a – Storm Surge Barrier at Half Tide Rocks		
Option Type: Flood Risk Modification	**Action Timeline:** Trigger	**CCAP:** Included

Background:

Storm surge barriers are large structures that regulate the flow of water into a water body (e.g. river or estuary) from the ocean. Barriers have been used overseas in places such as the River Thames, London (the Thames Barrier) and The Netherlands (the Maeslant Barrier). The design of these structures can vary substantially but most barriers comprise a movable gate structure that opens and closes according to the conditions of the water body and the ocean.

Option Overview:

Construct a storm surge barrier at the entrance to BW (Half Tide Rocks) that could be activated during severe offshore storm surge events.

Flood Mitigation Outcomes:

Propagation of elevated ocean water levels up the estuary would be reduced in 100% of locations.

Management Areas:

This management option affects all management areas since the option is located at the entrance to the estuary. Flood damages in all management areas would be reduced significantly if this option were to be implemented.

Projected Sea Level Rise:

This option could benefit both the existing flood scenario in Brisbane Water and also the 0.9m SLR scenario, if appropriate design considerations for projected sea level rise were included. However, it is likely that barrier closure would take place more frequently as sea levels rise.

Additional Information

The storm surge barrier would only be closed prior to and during storm surge events from the ocean. Prior to a storm event, the gates would close to prevent water from the ocean entering Brisbane Water. Elevated water levels caused by the storm would therefore not be able to propagate up the estuary. Once the storm event had passed, the barrier gates would re-open and the normal hydraulic regime would return to Brisbane Water. Figures I.1A and I.1B demonstrate the effect of the storm surge barrier in the open and closed state.

Catchment flows would not be able to escape from the estuary at times when the barrier was closed. This would contribute to rises in the estuary water levels from catchment flows to the estuary. Therefore, the barrier should only be closed in times when ocean inundation is expected to exceed catchment runoff.

Hydraulic modelling of this option as part of the economic assessment (**Section 11.2**) suggests that the effects on flood storage and flood levels in other areas would be large in the Brisbane Water floodplain if this option were to be implemented (a peak reduction of approximately 67cm in the current PMF event). The number of affected properties would also be reduced:
- For the existing PMF, properties with over-ground flooding would be reduced from 2,934 properties to 938 properties (1,996 properties protected); and
- For the PMF +0.9m SLR, properties with over-ground flooding would be reduced from 4,897 to 3,672 (1,225 properties protected, although this should be considered an exaggerated estimate as it is likely that a significant number of these properties would have already been modified or abandoned due to sea level rise impact on tidal levels).
In both cases, some flooding would still occur with the storm surge barrier in place (due to catchment inflows building up behind the barrier). In addition, the hydraulic modelling looks a ‘worst case’ scenario, which assumes that the barrier is closed at the high tide.

A tide energy power generation station could be incorporated into the design of the barrier to offset the incurred costs of implementation. Tidal power generation is being prototyped in several locations across the world, including Kvalsund, Norway; Lynmouth, England; and East River in New York City, USA and has also been suggested as part of the recent concept design for a storm surge barrier at Arthur Kill in New York City, USA (Lawrence *et al*, 2009). There are two main types of tidal power generation:
- Stream Generation – Energy from tidal currents is harnessed through the use of underwater turbines. Generally, a minimum of $1ms^{-1}$ tidal currents are required for tidal power generation (Lawrence et al, 2009). Currents within Brisbane Water vary, however at the Entrance (Half Tide Rocks) tidal currents tend to be in the order of 0.97 ms_{-1} (maximum) and 0.47 ms_{-1} (average) which is below the stated minimum requirement of $1ms_{-1}$. However, these tidal current speeds are based on the existing case, and may change if a storm surge barrier was implemented; and
- Barrage Generation – Energy from differences in tide levels is harnessed through the use of a barrage, often a lock and weir system. This type of generation may be appropriate depending on design and closure frequency of the barrier.
If harnessed effectively, tidal currents can generate large amounts of power, in the order of hundreds of megawatts, depending on the nature of the power generation station (which would need to be located on-shore near the barrier).
The economic and environmental benefits of tidal energy have not been incorporated into the assessment of this option.

Considerations/Impacts		
Economic	**Social**	**Environmental**
Significant implementation costs in addition to operation and maintenance costs. Based on similar structures elsewhere, estimated capital (initial) and recurrent (per year) costs are likely to be approximately $2,356M+ and $1.4M respectively but would vary greatly depending on a range of site factors. Reduction in average annual damage (AAD) associated with the implementation of this option would likely be in the vicinity of $3.3M (with an NPV AAD reduction of $50M), which represents a substantial economic benefit, but would not offset the costs of implementation. Since flow velocities after the implementation of a storm surge barrier are not currently known, power generation potential requires further investigation. As such, no benefits associated with this aspect have been assumed.	Social impacts associated with this option may include: - Visual impacts due to the size of the large structure and the visual impacts on natural landscape features; - Potential impacts on navigability through Half Tide Rocks due to impacts on sediment movement; and - Possible loss of foreshore land and possible property acquisition (design-dependent). This option would need to address navigability of vessels through the barrier, otherwise the option would conflict with the recommendations of the *Brisbane Water Estuary Management Study* (Cardno, 2011a).	Significant impacts are likely due to the size of the structure and its hydraulic impact. There is potential to impact on flow velocities through Half Tide Rocks resulting in scour near the structure, redistribution of sediment and altered sediment transport. Hydrodynamic impacts could also be amplified in the future as sea levels rise, due to more frequent barrier gate closure. Impacts on benthic habitats and other marine species as well as on maritime artifacts are likely, as is decreased estuarine flushing as sea levels rise and the barrier is closed more frequently. Property owners may lobby to have the gates closed on a permanent basis as sea levels rise, and this would have a significant impact on the ecology of Brisbane Water due to changes in tidal exchange, salinity and flushing. Operational aspects of this option are in conflict with the recommendations of the *Brisbane Water Estuary Management Study* (Cardno, 2011a) with regards to achieving environmental objectives.

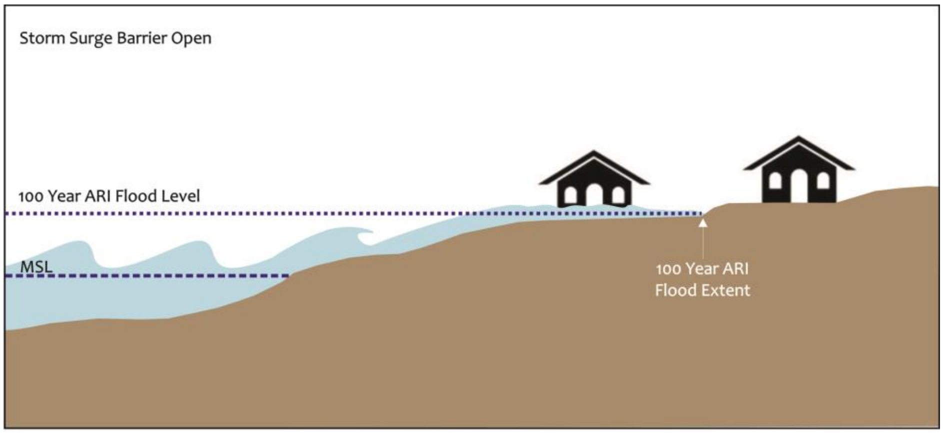


Figure I.1A: Storm Surge Barrier Open (Not to Scale)

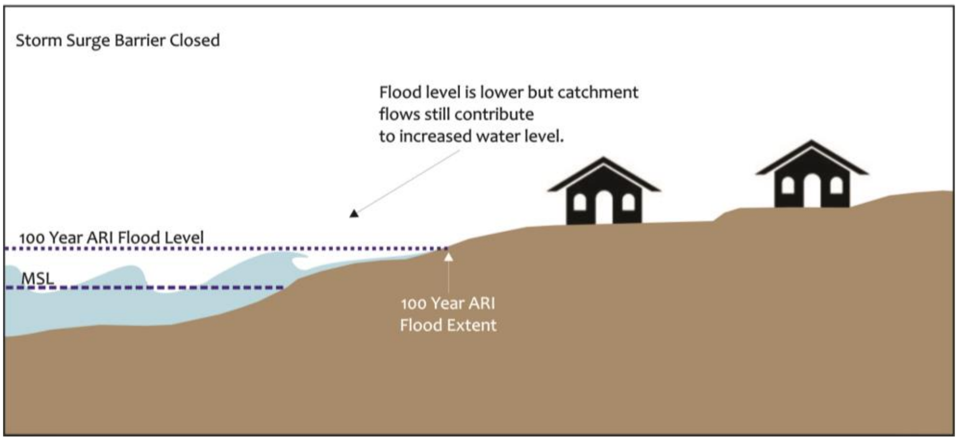


Figure I.1B: Storm Surge Barrier Closed (Not to Scale)

FM2b – Storm Surge Barrier at The Rip		
Option Type: Flood Risk Modification	**Action Timeline:** Trigger	**CCAP:** Included
Background: As for FM2a.		
Option Overview: Construct a storm surge barrier at The Rip that could be activated during severe offshore storm surge events.		
Flood Mitigation Outcomes: Propagation of elevated ocean water levels up the estuary would be reduced in 93% of locations.		
Management Areas: Affects all management areas upstream of The Rip (i.e. management areas 1-10 and 14-15). Coastal flood damages in these management areas would be reduced significantly if this option were to be implemented.		
Projected Sea Level Rise: As for FM2a.		

Additional Information
Hydraulic modeling was not undertaken for this option and was only undertaken for Option 2a. The floodplain area upstream of The Rip represents approximately 93% of the total area of the Brisbane Water foreshore floodplain. This option would therefore be likely to reduce water levels in 93% of the floodplain, whilst the remaining 7% downstream of The Rip would be likely to experience minimal changes in water levels, and would still experience flooding and flood damages. For the existing PMF, properties with over-ground flooding would be reduced from 2,934 properties to 1,078 properties (1856 properties protected). For the PMF +0.9m SLR, properties with over-ground flooding would be reduced from 4,897 to 3,758 (1,139 properties protected, although this should be considered an exaggerated estimate as it is likely that a significant number of these properties would have already been modified or abandoned due to sea level rise impact on tidal levels). In both cases, some flooding would still occur with the storm surge barrier in place (due to catchment inflows building up behind the barrier). In addition, the hydraulic modelling looks a 'worst case' scenario, which assumes that the barrier is closed at the high tide. Due to the constriction caused by The Rip, there are a number of tidal currents in this location are in the order of 1.75 ms^{-1} (maximum) and 0.91 ms^{-1} (average) so tidal power generation at this location is likely to be more viable than at Half Tide Rocks. However, further investigations would be required.

Considerations/Impacts		
Economic	**Social**	**Environmental**
Significant implementation costs in addition to operation and maintenance costs. Based on similar structures elsewhere, estimated capital (initial) and recurrent (per year) costs are likely to be approximately $1,800M and $1.1M respectively but would vary greatly depending on a range of site factors. Reduction in average annual damage (AAD) associated with the implementation of this option would likely be similar to, but higher than that of FM2a, since properties on the ocean side of the Rip Bridge would still be subject to storm surge flooding impacts. The substantial economic benefit of this option is unlikely to offset the costs of implementation. Since flow velocities after the implementation of a storm surge barrier are not currently known, power generation potential requires further investigation. As such, no benefits associated with this aspect have been assumed.	As for FM2a.	As for FM2a.

Plate I.1: The Thames Barrier; and Maeslant Barrier (open and closed).
Photograph Sources: http://www.deltawerken.com/modules/mediagallery/images and http://en.wikipedia.org/wiki/Thames_Barrier

FM3 – Wave Energy Dissipating Foreshore Design		
Option Type: Flood Risk Modification	**Action Timeline:** Staged	**CCAP:** Not included
Background: Wave run-up can increase the impacts associated with flooding from ocean storm events. In particular, some properties around the periphery of the floodplain are not identified as flood affected. However, depending on swell and wind conditions, these properties may be impacted by wave run-up. This option proposes to implement dissipation devices in these locations to reduce the impact of wave run-up.		
Option Overview: Modify the existing foreshore in areas most affected by wave run-up to incorporate wave energy dissipating designs.		
Flood Mitigation Outcomes: Individual properties protected from wave run-up to the 100 year ARI (with 0.9m SLR). Only a small number of properties protected.		
Management Areas: All management areas except 1, 6 and 10 (see below "Additional Information" section of this table).		
Projected Sea Level Rise: The wave run-up zones were initially delineated based on the 100 year ARI extent with 0.9m SLR and then refined using the existing flood extent only.		
Additional Information		
Locations identified for implementation of this option were selected using the following criteria: - Within 20 metres of the foreshore (this is the likely extent of wave run-up); AND - Below 3m AHD (this is the likely maximal wave height); AND - Above the existing 100 Year ARI flood level (these areas may pick up properties that do not already have development controls to appropriately manage flooding). A schematic showing the application of these criteria is provided as Figure I.2. Aerial photographs and a site inspection conducted on 6 April 2011 revealed that several of the identified locations would not provide benefit or be suitable for the construction of wave energy dissipation devices. The following criteria were used to subjectively assess and remove those locations that were not considered suitable. A location was removed if: - The area was located in was open space and dwellings were not located in the vicinity; OR - Continuous foreshore vegetation was present (mangroves provide natural wave-dissipation so there is no need to add further structures). Additional subjective criteria were then applied, including the potential for significant run-up. It is noted that the subjective criteria did not consider the amount of physical space available at each location to construct a wave dissipation structure. The resulting areas found to be affected by wave run-up were located in all management areas except 1 and 6 and are shown in Figure I.3.		
Considerations/Impacts		
Economic	**Social**	**Environmental**
Estimated capital (initial) and recurrent (per year) costs start from approximately $240,000 and $7200 to $4.8M and $144,000 respectively. Construction of dissipation structures were calculated at $1200 per linear metre and assume rockfill extends 4m from the shoreline at average 1m depth. The economic benefit of these structures would be reasonably small and only received on a reasonably infrequent basis.	This option is not likely to have substantial negative social impacts due to the small and generally localised scale of the option. To limit any visual impacts the design of these structures should be compatible with the landscape at each location.	Site-specific investigations would need to be undertaken to assess environmental impacts, particularly with regard to the cumulative impact of several adjacent structures. In order to minimise the impact on the estuary environment, foreshore structures would need to be designed in accordance with the DECC (2009a) guideline, *Environmentally Friendly Seawalls – A Guide to Improving the Environmental Value of Seawalls and Seawall-lined Foreshores in Estuaries*. A method described in the DECC (2009a) guideline involves installing wave barriers (such as thin rock groynes, anchored timber logs, coir logs or temporary plastic mesh fencing) roughly parallel to and about three to five metres seaward of the foreshore bank to dissipate wave action. Gaps between solid barriers are preferable to allow fish passage and recruitment of mangrove seedlings.

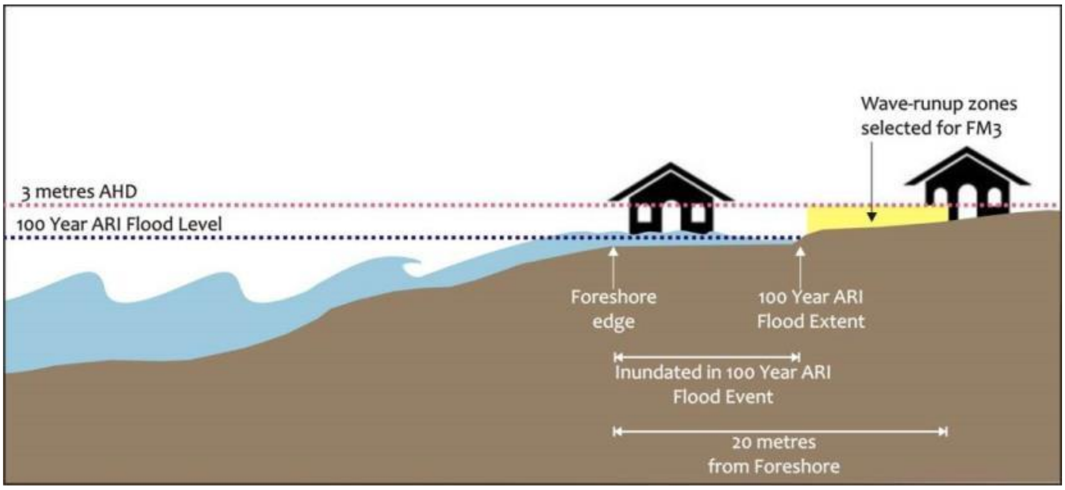


Figure I.2: Schematic of Wave Run-up Zones (Not to Scale).

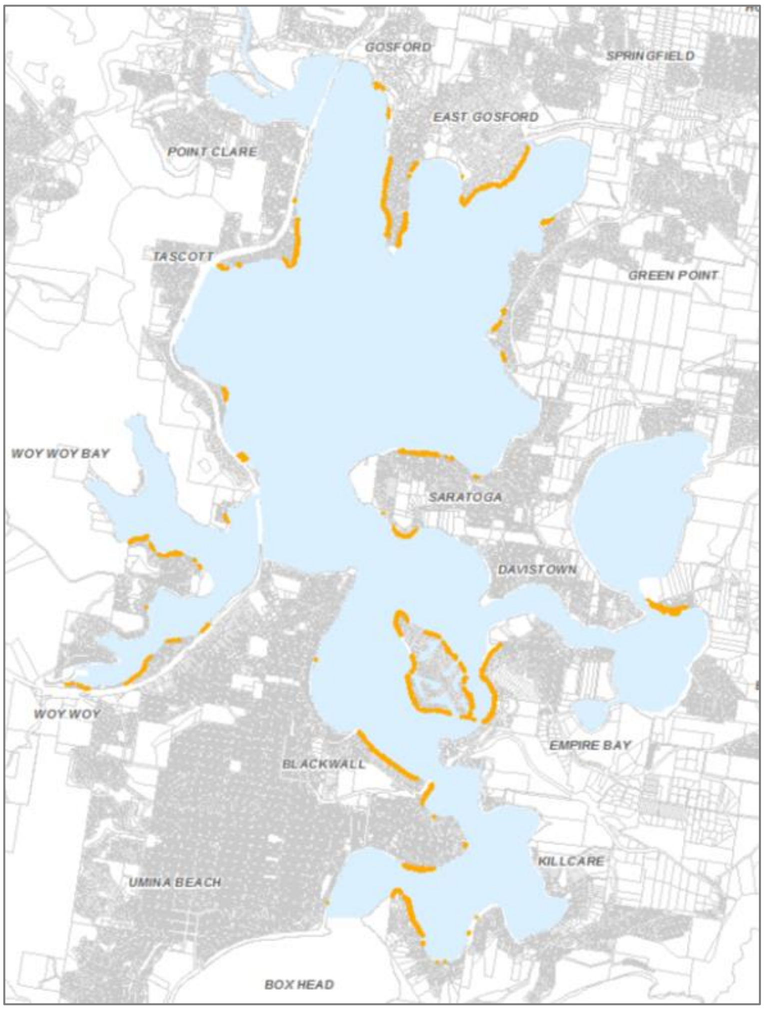


Figure I.3: Identified Wave Run-up Zones Potentially Suitable for Wave Dissipation Structures.

FM4 – Stormwater Floodgates/Tidal Valves		
Option Type: Flood Risk Modification	**Action Timeline:** Staged	**CCAP:** Not included
Background: Some low-lying areas are protected from direct coastal flooding due to a naturally higher portion of land that lies along the foreshore (between the location of interest and the estuary, basically functioning like a natural levee). However, many of these locations are connected to Brisbane Water by the stormwater system. As estuary water levels rise, the stormwater system is inundated and effectively 'backs up' into the previously unaffected areas. Flap-type valves or small floodgates fitted to the outlets of stormwater pipes can be used in these instances to minimise surcharge of the stormwater system in a flood event.		
Option Overview: Install flood gates/valves on stormwater pipe outlets in locations affected by surcharge of the stormwater system.		
Flood Mitigation Outcomes: Protection for locations affected by surcharge of the stormwater system (up to existing 100 year ARI).		
Management Areas: This option is floodplain-wide. One area that may be of particular note is East of Lemon Grove Park, Ettalong. The foredune at Ettalong is likely to provide protection from the direct impacts of coastal flooding in this area. However, stormwater surcharge may be an issue for properties on low-lying land behind the dune. **Projected Sea Level Rise:** This option would not provide protection for properties in the future once sea levels rise to a level above that of the stormwater outlet.		
Considerations/Impacts		
Economic	**Social**	**Environmental**
The installation of stormwater floodgates or valves is likely to be reasonably inexpensive. Maintenance of floodgates may incur some cost over time, particularly since in some areas in NSW, floodgates are known to be somewhat prone to vandalism. Estimated capital (initial) and recurrent (per year) costs are likely to be $5000 and $1500 respectively (per structure) but would vary depending on the type and size of the outlet.	The floodgates would be installed in locations that already have stormwater infrastructure and therefore social impacts are expected to be negligible.	The environmental impacts associated with the installation of floodgates are likely to be minimal as in most cases the flood gates would be implemented on drains which do not provide fish passage. However, if fish passage is identified at any of the proposed locations, the floodgates should be designed in a "fish-friendly" manner. Guidelines on fish-friendly structures are provided in the Queensland Government's *Fisheries Guidelines for Fish-Friendly Structures* (DPIF, 2006).


Plate I.3: Examples of floodgates.

Photograph Sources: http://www.dpi.qld.gov.au/documents/Fisheries_Habitats/Water-barriers-Fact_Sheets.pdf and http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/208851/KEY-TIPS-FOR-A-FISH-FRIENDLY-FARM.pdf

<table>
<tr><th colspan="3">FM5 – Seawall Maintenance and Raising</th></tr>
<tr><td>Option Type: Flood Risk Modification</td><td>Action Timeline: Staged</td><td>CCAP: Included</td></tr>
<tr><td colspan="3">Background:
Seawalls do not necessarily provide protection in large flood events (due to their generally discontinuous nature) but may assist in reducing the impact of smaller flood events and wave run-up.</td></tr>
<tr><td colspan="3">Option Overview:
Undertake a program of seawall maintenance and raising for existing seawalls in appropriate locations along the foreshore, ensuring that seawalls are maintained in accordance with Guidelines for Environmentally Friendly Seawalls (DECCW, 2009a).</td></tr>
<tr><td colspan="3">Flood Mitigation Outcomes:
Maintains existing flood protection and provides some protection from wave run-up.</td></tr>
<tr><td colspan="3">Management Areas:
This option applies to locations within all management areas except 1, 4 and 15 (as seawalls were not found to be significant features in these MAs).</td></tr>
<tr><td colspan="3">Projected Sea Level Rise:
Seawalls can provide some protection against the tidal inundation impacts of projected sea level rise.</td></tr>
<tr><th colspan="3">Additional Information</th></tr>
<tr><td colspan="3">This option does not propose the introduction of additional seawalls around Brisbane Water but rather the maintenance, and in some areas raising, of existing seawalls to improve flood protection.

The proposed locations of this option are shown in Figures 11.1-11.15. These figures show approximate locations of all sea walls around Brisbane Water (delineated from aerial photographs); but an investigation of the quality of seawalls (e.g. construction type, evidence of slumping or other failures) was not undertaken. Therefore only some locations within those shown are likely to be viable for this option. Further investigation is necessary.</td></tr>
<tr><th colspan="3">Considerations/Impacts</th></tr>
<tr><th>Economic</th><th>Social</th><th>Environmental</th></tr>
<tr><td>The cost of seawall maintenance and raising would vary according to the location and condition of existing sea walls. Estimated capital (initial) and recurrent (per year) costs range from approximately $73,000 and $1000 respectively to $3.3M and $33,000 respectively, depending on the location. Costs were calculated at an average of $415 per linear metre, however costs are likely to be highly dependent on the current condition of the wall and the amount of raising implemented</td><td>Raising of seawalls may impact on visual amenity and connectivity to the foreshore, particularly for recreational purposes. In several locations, the maintenance and raising of seawalls conflicts with the management actions recommended in the Brisbane Water Estuary Management Plan</td><td>This option is not likely to have substantial negative environmental impacts due to the fact that this option is only proposed where seawalls already exist. In several locations, the maintenance and raising of seawalls conflicts with the management actions recommended in the Brisbane Water Estuary Management Plan.</td></tr>
</table>

FM6a – Levees above PMF		
Option Type: Flood Risk Modification	**Action Timeline:** Staged	**CCAP:** Included

Background:

Levees are structures designed to regulate water levels on one side of the levee (behind the levee) via the construction of a physical barrier around a flood-affected area, with a crest height that is higher than the design flood event. Levees are generally constructed of either soil, rock and/or concrete.

Levees cannot be considered as a method of removing flood risk. Levees, in fact, create a number of inherent risks to life and property and also create associated drainage and environmental issues. These are discussed further in the below "Additional Information" section of this table.

Option Overview: Construct levees around affected areas to above the PMF level (staged to the PMF level with SLR).

Flood Mitigation Outcomes: Levees regulate flooding up to the design level of the levee. Levee options in this report are assessed up to the PMF event (with SLR). Potential benefits of levees include assistance with evacuation and emergency management, since residents behind a levee are afforded additional time to evacuate during times of flood.

Management Areas: All

Projected Sea Level Rise:

If associated drainage and infrastructure upgrades were undertaken, PMF levees would provide some level of protection against future increases in tidal inundation. This option has been designed and costed to address the future scenario (with projected sea level rise). Design of the levee could incorporate the ability to raise the crest level if sea levels continue to rise (a wider levee footing would be required at the outset so that the levee crest could be increased later without structural undermining). Figure I.4 demonstrates the levee being raised in this way.

Whilst a levee would be capable of preventing tidal inundation of foreshore lands during rare high tide events in the short term, frequent and permanent tidal inundation associated with projected sea level rise would be more difficult to manage through the use of levees. Groundwater levels in the primarily sandy soils of the area would likely rise in accordance with the rising water levels in Brisbane Water and this would need to be managed through constant pumping out of the water behind the levees (in a manner similar to that which operates in The Netherlands for "polder" areas). Pumps are liable to failure and permanent pump operations have a considerable electricity demand (with associated costs and carbon emissions for non-renewable energy sources). In addition, this is likely to only provide protection of surface assets and property, underground services and building footings are likely to still be inundated unless drawdown pumping occurs.

Additional Information

This option proposes several levees to be constructed to a level above the PMF level. Constructing a levee to this height reduces the risk associated with overtopping in larger flood events than that for which the levee was designed for (discussed in more detail below). However, in some locations the PMF level may be significantly higher than the existing ground levels. In the multi-criteria matrix assessment it has been assumed that levee crest heights will be raised in the future to protect against the PMF event with 0.9m SLR.

In addition to the levee itself, a whole host of associated infrastructure would be required so that the surrounding area is not adversely affected on a day to day basis. Associated infrastructure could include raising of roads, relocation or upgrading of utilities/services and reconfiguration of stormwater drainage through the levee. In addition, it is likely that acquisition or dedication of land for detention basins and storage for pumping of local catchment flows would also be required. Appropriate drainage through a levee is particularly important so that catchment flooding does not worsen as a result of levee construction. Some key drainage issues and recommendations described in the NSW Government (2007) *Floodplain Risk Management Guideline - Drainage Behind and Through Levees* are provided below.

The drainage system through a levee typically comprises both pumped drainage systems (to discharge water when estuarine water levels are higher than the water level behind the levee) and a gravity drainage system (to discharge water when the estuary level is below the water level behind the levee). Major drainage problems typically involve the floodplains of original watercourses or trunk drainage systems or sloping areas where overland flows occur along alternative paths once system capacity is exceeded. Water depths generally in excess of 0.3m may result in danger to personal safety and damage to property. Major overland flowpaths through developed areas outside of defined drainage reserves and the potential to flood a number of buildings along the major flow path are also issues that require addressing. Local drainage problems occur randomly throughout urban areas but can generally be minimised by adoption of general urban building controls requiring a minimum difference between finished floor and finished ground levels (to cope with shallow water depths) and adequate site drainage. Areas without these controls may have damage potential but the level of damages is generally relatively small. Therefore, benefits of remediation cannot be justified on economic cost alone. The construction of a levee can affect major and local drainage problems with significant impacts for flooding at low points in the vicinity of the levee. This is an essential consideration in the investigation and design of a levee.

Plate I.4: Levee assisting in evacuation and providing some protection for roads and properties

Photograph Source: http://contribute.abc.net.au/_Maclean-Flood-Levee/photo/3857598/32422.html

Considerations/Impacts		
Economic	**Social**	**Environmental**
Installation and maintenance costs would be substantial and have been calculated based on raising to the PMF level with 0.9m SLR. Costs were calculated at an average of $3500 per linear metre. Costs do not include any road or pavement works, and assume an average 1.5m raise, 1m crest and 1 in 5 batters. Estimated capital (initial) and recurrent (per year) costs for each management area range from approximately $700,000 and $14,000 respectively to $37M and $742,000 respectively, depending on the location. If a 5 year ARI levee had been constructed previously in a particular location, the costs of constructing the PMF levee would be considerably less. The construction and maintenance of associated infrastructure would be required (e.g. stormwater drainage, road raising, service and utility upgrades, etc.) and would be likely to involve very large financial costs. It would be imperative that private asset and utility managers agree to any proposed levees. Responsibility for the cost of relocating/raising assets in these locations would lie with the private asset managers and coordination between Council and private asset managers would be required. Levee raising to protect against projected sea level rises would come at a comparatively lower cost - the main costs would be in the initial construction of a levee. Significant reductions in economic damages could be gained as a result of implementing levees. The likely economic benefits are discussed in more detail in Section 12.	Potential Benefits Levees can provide additional time for evacuation for residents behind a levee, however there are potential concerns associated with this (see "Potential Concerns" below). Levees can be seen to provide a visual indication of future potential fill levels for areas behind a levee, where filling may become a viable option in terms of flood risk or future projected sea level rise. In a similar manner, the levee itself provides a guide for future potentially compatible development along the foreshore, such as footpath/cycle ways, sea walls, etc. Levees may assist in lowering flood insurance premiums for buildings behind the levee banks which can be perceived as a social benefit Potential Concerns Despite the potential benefits, there are significant concerns associated with levees that relate to the endangerment of life. The risk of a levee overtopping (when flood levels exceed the levee crest / wave overtopping) can be reduced by building a levee to the PMF level, however, a PMF levee will not remove all flood risk from the area it protects. A levee breach (failure of the levee to withstand the floodwaters) could occur, and high velocity floodwaters would enter the low-lying area behind the levee, creating an extreme flood hazard. Levees only provide an opportunity for improved evacuation time for residents within the area. Community perception of levees presents a risk, as the community may feel completely protected by the levee and be less concerned when water levels rise. Members of the community may not feel the need to evacuate as quickly or at all in a flood event. Other social impacts of levee construction include reduced access to foreshores and a reduction in lines of sight and visual amenity if the levee crest is high. There are likely to be conflicts between the installation of levees and public access/amenity for all management areas. In several locations, the installation of levees would conflict with the management	The construction of levees can result in direct and indirect loss of foreshore habitat. The construction of the levee itself may result in the removal of vegetation. In addition, the presence of the levee may inhibit tidal inundation into previously inundated areas resulting in a change in ecology and a likely loss of valuable intertidal species, such as mangroves and saltmarsh. The presence of the levee may also affect the form of the foreshore, removing habitat niches that would otherwise exist. In several locations, the installation of levees would conflict with the management actions recommended in the *Brisbane Water Estuary Management Plan*.

	actions recommended in the *Brisbane Water Estuary Management Plan*.	

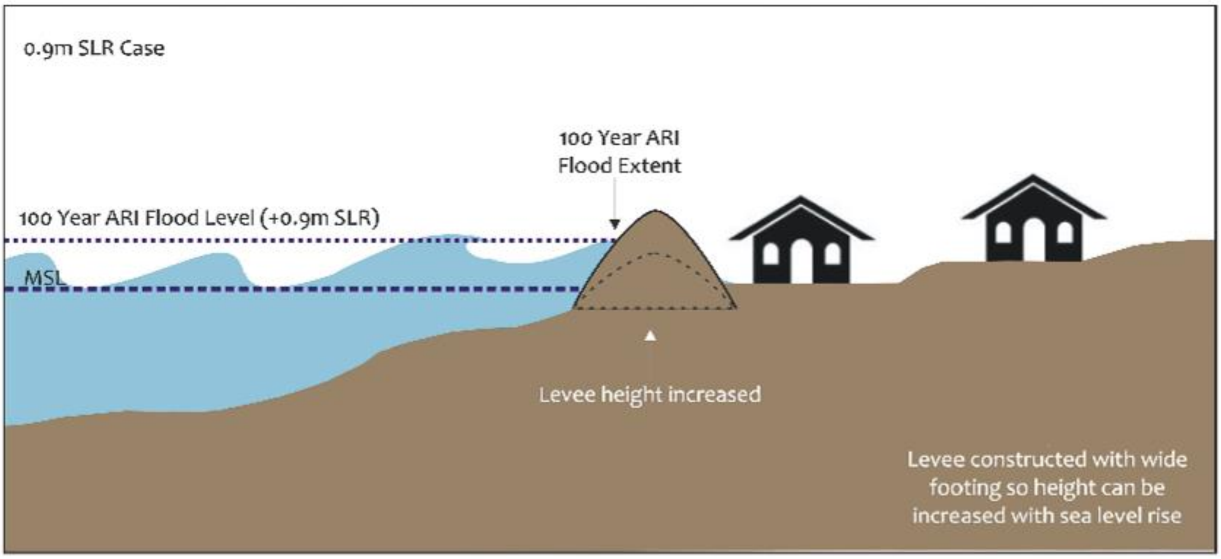


Figure I.4: Levee Raised, 0.9m SLR Case (Not to Scale).

<table>
<tr><th colspan="3">FM6b – Levees to 5 year ARI Level</th></tr>
<tr><td>Option Type: Flood Risk Modification</td><td>Action Timeline: Staged</td><td>CCAP: Included</td></tr>
<tr><td colspan="3">Background:
A levee of this size provides an alternative to the PMF levee and would allow for some flood protection in smaller events and increased evacuation and flood preparation time during larger events. It is considered that constructing levees to levels less than the 5 year ARI event would be a significant financial cost for minimal flood protection.</td></tr>
<tr><td colspan="3">Option Overview:
Construct levees around affected areas to above the 5 year ARI level (staged to the 5 year ARI level with SLR).</td></tr>
<tr><td colspan="3">Flood Mitigation Outcomes:
Regulates flooding up to the 5 year ARI event (with SLR) and increases evacuation time for larger events.</td></tr>
<tr><td colspan="3">Management Areas:
All.</td></tr>
<tr><td colspan="3">Projected Sea Level Rise:
As for FM6a.</td></tr>
<tr><th colspan="3">Additional Information</th></tr>
<tr><td colspan="3">It has been assumed that levee crest heights will be raised in the future to protect against the 5 year ARI flood event with 0.9m SLR.</td></tr>
<tr><th colspan="3">Considerations/Impacts</th></tr>
<tr><th>Economic</th><th>Social</th><th>Environmental</th></tr>
<tr><td>Costs have been calculated based on raising to the 5 year ARI level with 0.9m SLR.
This option is likely to have somewhat lower implementation costs than option FM6a since the levee would be smaller. However, additional costs associated with reconfiguration of stormwater drainage through the levee, raising of roads, relocation or upgrading of utilities and services, etc. would still apply. Costs were calculated at an average of $1700 per linear metre. Costs do not include any road or pavement works, and assume an average 0.5m raise, 1m crest and 1 in 5 batters. Costs are highly dependent on construction method. Estimated capital (initial) and recurrent (per year) costs per levee range from approximately $340,000 and $7,000 respectively to $18M and $360,400 respectively, depending on the location.
Although the economic benefits associated 5 year ARI levees would not be as significant as for PMF levees, reductions in economic damages could be gained as a result of implementing these levees. The likely economic benefits are discussed in more detail in Section 12.</td><td>The risks associated with building a levee at the 5 year ARI level are similar to those for a PMF levee with regards to levee breach, overtopping and community perception. However, there is a certainty that the levee will be overtopped in events greater than the 5 year ARI so it is imperative that residents are made aware of the existing risk and need for appropriate evacuation and property protection. In several locations, the installation of levees may conflict with the management actions recommended in the Brisbane Water Estuary Management Plan.</td><td>As for FM6a.</td></tr>
</table>

<table>
<tr><th colspan="3">FM7a – Enhance the Northern Railway Bridge</th></tr>
<tr><td>Option Type: Flood Risk Modification</td><td>Action Timeline: Staged</td><td>CCAP: Not included</td></tr>
<tr><td colspan="3">Background:
Fagans Bay is the only area that, in some flood events, is dominated by catchment flooding. This only occurs in events greater than the 100 year ARI (Cardno, 2013) and is due to the constriction created by the railway crossing between Point Clare and Gosford. Catchment flows are contained within Fagans Bay due to this construction increasing flood levels around the Fagans Bay foreshore.</td></tr>
<tr><td colspan="3">Option Overview:
Increase the size of the culvert under the rail bridge linking Point Clare and Gosford (Fagans Bay) to reduce the impact of catchment flooding in this area.</td></tr>
<tr><td colspan="3">Flood Mitigation Outcomes:
Improves conveyance of catchment flows to the estuary from the areas surrounding Fagans Bay.</td></tr>
<tr><td colspan="3">Management Areas:
This option only applies to management area 1.</td></tr>
<tr><td colspan="3">Projected Sea Level Rise:
This management option would not provide any protection from the impacts of increased tidal inundation due to projected sea level rise. In fact, this option would allow increased penetration of storm surge floodwaters into Fagans Bay.</td></tr>
<tr><th colspan="3">Additional Information</th></tr>
<tr><td colspan="3">The railway crossing currently comprises of a bridge, approximately 50 metres in length and 900 metres of embankment (the combined length would have once been part of the open water body). The embankment (and to some degree the bridge piers) constrict flow into and out of the bay. This option proposes to increase the length of the bridge (by double) to improve the conveyance of flood waters out of Fagans Bay. It is likely that a temporary rail bridge would need to be constructed for use whilst works are being undertaken and then demolished after completion of the works.

Although this option is likely to improve flooding conditions during larger storm events, during more frequent events, when storm surge dominates flood impacts in the bay, the impacts of flooding may be worsened due to the increased conveyance of storm surge into Fagans Bay. Hydraulic modelling of this option as part of the economic assessment (Section 12) suggests that if implemented, this option would cause minimal changes to flood levels in most areas. In fact, small increases in water levels (approximately 5cm) may occur. Therefore, this option is not considered to be viable as it does not achieve an overall hydraulic benefit.</td></tr>
<tr><th colspan="3">Considerations/Impacts</th></tr>
<tr><th>Economic</th><th>Social</th><th>Environmental</th></tr>
<tr><td>The financial cost of implementation of this option is likely to be substantial. Estimated capital and recurrent costs are approximately $10M and $500,000 respectively. Costs would be highly dependent on the design and construction methodology.</td><td>Social impacts would primarily be as a result of potential disruption to train services along the Central Coast railway line during the works.</td><td>Environmental impacts for this option would be generally minimal, and it would be expected that this option would have a positive environmental outcome by improving tidal flushing to Fagans Bay.</td></tr>
</table>

FM7b – Flood Gates at the Northern Railway Bridge		
Option Type: Flood Risk Modification	**Action Timeline:** Staged	**CCAP:** Included
Background: The purpose of Option 1_FM7a (above) is to alleviate flooding in events greater than the 100 year ARI event (when catchment flooding dominates flood impacts). However, in all events less than this, the flood impacts are dominated by storm surge. As such, option 1_FM7b proposes the implementation of flood gates at the culverts under the railway crossing between Point Clare and Gosford. The purpose of these flood gates would be to protect the properties on the foreshore of Fagans Bay from coastal flooding.		
Option Overview: Install manually-operated floodgates at the culvert under the rail bridge linking Point Clare and Gosford (Fagans Bay) to reduce the impacts of storm surge on Fagans Bay.		
Flood Mitigation Outcomes: Improves protection from storm surge events for locations west of the Fagans Bay rail bridge.		
Management Areas: This option only applies to management area 1.		
Projected Sea Level Rise: This option would provide some level of protection for properties in Fagans Bay from storm surge events as sea levels rise, since the flood gates could be closed during storm surge events. However, catchment flows (which dominate in events greater than the 100 year ARI event) would not be able to discharge to the estuary and as a result, catchment flooding may worsen.		
Additional Information		
When an ocean storm event is predicted to create elevated ocean levels the floodgates could be shut to maintain relatively lower water levels within Fagans Bay. When the water levels return to normal, floodgates could be opened again and the normal hydraulic regime would return. Only manually operated floodgates have been considered for this option. It should be noted that options 1_FM7a and 1_FM7b are mutually exclusive, that is, it is not appropriate to implement both options. The reason for this is that the flood gates would need to be activated when an ocean storm is predicted. However, it is not possible to only activate the gates for storm events of a particular size (i.e. ARI) as it is difficult to predict the size of an ocean storm. This becomes even more difficult when considering a coinciding catchment rainfall event. As such, it is only feasible to activate the gates when any significant ocean storm is predicted. Therefore, if the culvert enhancement proposed in Option 1_FM7a was also implemented, the flood gates would effectively, make the culvert enhancements useless. Both options 1_FM7a and 1_FM7b have been assessed to determine their viability and compare their benefits against each other. Hydraulic modelling of this option as part of the economic assessment (Section 11.2) suggests that impacts on flood storage and flood levels in other areas would be fairly minimal in the Brisbane Water floodplain if this option were to be implemented, however, flood levels in Fagans Bay itself may increase due to the restriction of catchment flows from Fagans Bay out into the estuary.		
Considerations/Impacts		
Economic	**Social**	**Environmental**
Estimated capital (initial) and recurrent (per year) are likely to be approximately $18,700,000 and $561,000 respectively, based on information provided by a floodgates manufacturer. Costs are highly dependent on the design and construction methodology.	Negative social impacts are not likely to be significant and would primarily be as a result of potential disruption to train services along the Central Coast railway line during the works.	The environmental impacts of floodgates at the railway culvert primarily relate to changes to hydraulic regime and water quality, especially within the Fagans Bay area. The frequency and duration of floodgate closures would directly affect these attributes. Present-day closures are likely to be fairly infrequent and as such the impacts would be minimal, but as sea levels rise closures may become more frequent and therefore future environmental impacts may become more pronounced. This option may conflict with actions recommended in *Brisbane Water Estuary Management Plan* (depending on frequency of use) and may therefore not be appropriate.

FM8 – Floodgates at the Woy Woy Railway Bridge		
Option Type: Flood Risk Modification	**Action Timeline:** Staged	**CCAP:** Included
Background: This option is similar to Option 1_FM7b. However, this option proposes to implement flood gates at the Woy Woy railway culvert to protect properties along the Woy Woy Bay foreshore (including Phegans Bay and Horsfield Bay) from flood impacts associated with storm surge. Woy Woy Bay differs from Fagans Bay in that storm surge dominates the peak flood levels for all flood events (i.e. catchment flows are not the dominant flooding mechanism). As such, it would not be suitable to propose to enhance the culverts at the railway for this location as this would not provide any benefit and could worsen flooding by allowing increased propagation of storm surge waves into Woy Woy Bay.		
Option Overview: Install manually-operated floodgates at the culvert under the rail bridge linking Woy Woy and Koolewong to reduce the impacts of storm surge on Woy Woy Bay.		
Flood Mitigation Outcomes: Improves protection from storm surge events for locations west of the Woy Woy rail bridge.		
Management Areas: This option only applies to management area 15.		
Projected Sea Level Rise: This option would provide some level of protection for properties in Woy Woy Bay as sea levels rise, since the flood gates could be closed during storm surge events. However, catchment flows would not be able to discharge to the estuary and as a result, catchment flooding may worsen in areas west of the railway bridge.		
Additional Information		
As for option 1_FM7b, when an ocean storm event is predicted to create elevated ocean levels the floodgates could be shut to maintain relatively lower water levels west of the railway bridge. When the water levels return to normal, floodgates could be opened again and the normal hydraulic regime would return. Only manually operated floodgates have been considered for this option. Hydraulic modelling of this option as part of the economic assessment (Section 12) suggests that impacts on flood storage and flood levels in other areas would be fairly minimal in the Brisbane Water floodplain if this option were to be implemented, however, the impacts of catchment flows on areas to the west of the railway bridge may be amplified. This is reflected in the hydraulic modelling, which found a peak increase of approximately 6cm at one property to the west of the bridge in the existing case PMF event. As such, there was a marginal increase in the number of affected properties and this makes the option unlikely to be viable.		
Considerations/Impacts		
Economic	**Social**	**Environmental**
Estimated capital (initial) and recurrent (per year) are likely to be approximately $18,700,000 and $561,000 respectively, based on information provided by a floodgates manufacturer. Costs are highly dependent on the design and construction methodology.	Negative social impacts are not likely to be significant and would primarily be as a result of potential disruption to train services along the Central Coast railway line during the works.	The environmental impacts of floodgates at the Woy Woy railway culvert primarily relate to changes to hydraulic regime and water quality, especially within the Woy Woy Bay area. The frequency and duration of floodgate closures would directly affect these attributes. Present-day closures are likely to be fairly infrequent and as such the impacts would be minimal, but as sea levels rise closures may become more frequent and therefore future environmental impacts may become more pronounced.

FM9 – Regional Filling of the Floodplain		
Option Type: Flood Risk Modification	**Action Timeline:** Trigger	**CCAP:** Included
Background: This option would necessitate filling of urban areas to elevate them to an appropriate level above a particular flood event level (e.g. PMF +0.9m SLR). In significantly flood-affected areas, land raising would allow a large reduction in flood damages and would significantly reduce (and in some cases, remove) the risk of flooding in a particular area (Figure I.5).		
Option Overview: Implement regional filling of areas at risk of coastal flooding.		
Flood Mitigation Outcomes: Provides protection of properties up to the PMF with 0.9m SLR.		
Management Areas: Locations have been identified in all management areas as being potentially suitable for filling. The criteria for identifying these areas were: - Within the 100 year ARI (with 0.9m SLR) extent; and - Not within the floodway or flood storage areas associated with catchment flooding in the Narara Creek catchment, Turo Creek catchment, Davistown catchment and Empire Bay catchment. At the time of writing, data for other creeks / catchments in the area was not available.		
Projected Sea Level Rise: In the multi-criteria matrix assessment it has been assumed that land-raising will take place to above the 100 year ARI event (with 0.9m SLR) plus freeboard. This option would considerably reduce storm surge-related flood risk in the raised areas. It would also remove the risk of increased tidal inundation due to projected sea level rise.		
Additional Information		
Filling on a regional basis would mean either waiting until all property owners want to fill (highly unlikely) or imposing the filling on an area (likely to cause massive social disruption). As such, without masterplanning, consultation and effective staging, this option is unlikely to be feasible on a regional scale for most areas. An exception is Gosford and the proposed Gosford Waterfront (The Landing) redevelopment. Broad-scale filling of this area could be undertaken as part of this redevelopment. Any filling would need to be undertaken in conjunction with the raising of utilities and infrastructure (e.g. roads, water and sewer). This would therefore require support from not only Council but also the private infrastructure sector. Hydraulic modelling of this option as part of the economic assessment (Section 12) suggests that impacts on flood storage and flood levels in other areas would be minimal (peak increase of 1cm in the existing PMF event). The benefit cost ratio for this option under existing flood conditions does not indicate a significant benefit for expenditure. The economic benefits are greater under the 2100 sea level scenario but the calculated benefit still does not outweigh the cost of implementing the option.		
Considerations/Impacts		
Economic	**Social**	**Environmental**
High costs are likely to make this option infeasible in most locations. Estimated capital costs range from \$6.6M to \$313M, depending on the location. Recurrent costs would be negligible. Costs include clean sand fill (1m deep), redevelopment of properties and raising of services and utilities. Assumes a 1m raise for raised land. Includes clearing, demolition of pavements, reconstruction of pavements, clean sand filling, compaction and drainage. Includes engineering judgment cost for relocating Utilities. Does not include cost of raising roads outside of the areas considered. An allowance of \$300,000 per property has been included for master planning, consultation and other aspects of the land raising process that would not otherwise be accommodated through the redevelopment process by NSW UrbanGrowth or a private developer.	The social implications of filling properties on a broad-scale basis are likely to include widespread social disruption, personal costs and social discord.	Any filling would be subject to Councils' development approvals should be undertaken within existing developed areas only. It has been assumed that there would not be any adverse environmental impacts however this may not be the case. It is very difficult to ascertain the potential environmental impacts without further investigation.

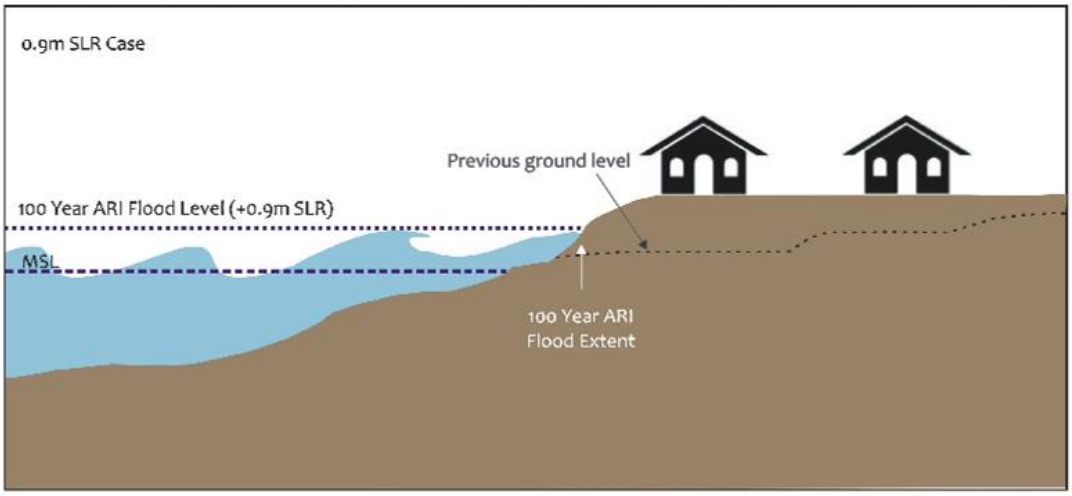


Figure I.5: Regional Filling Implemented, 0.9m SLR Case (Not to Scale).

FM10 – Raising of Railway Infrastructure		
Option Type: Flood Risk Modification	**Action Timeline:** Trigger	**CCAP:** Included
Background: This option relates to the raising of railway lines and associated station upgrades to reduce flood risk and accommodate the impacts of projected sea level rise. Railway infrastructure is already raised above the current 100 year ARI level. This option assumes raising infrastructure to above the 100 year ARI flood level with 0.9m SLR (an approximate raise of 0.9m).		
Option Overview: Raise railway infrastructure between Woy Woy and Gosford to above the 100 Year ARI flood level (with 0.9m SLR).		
Flood Mitigation Outcomes: Protection of state railway infrastructure above the 100 year ARI (with 0.9m SLR).		
Management Areas: This option relates to those management areas which contain railway infrastructure, i.e. 1, 2, 3, 14, 15.		
Projected Sea Level Rise: This option would provide protection of railway infrastructure during storm surge events and tidal inundation associated with sea level rise. However, the opening under the rail bridges at Woy Woy and Fagans Bay would increase in height and therefore allow increased flood conveyance through these hydraulic controls. This is beneficial for the conveyance of catchment flows out of the catchment (into the estuary and out to the ocean), however storm surge conveyance from the ocean into these areas may also increase and serve to worsen flooding in some cases.		
Considerations/Impacts		
Economic	**Social**	**Environmental**
The economic costs of this option would be immense, especially considering the height of raising required in accordance with sea level rise benchmarks (0.9m). Estimated minimum capital (initial) and recurrent (per year) are likely to be approximately $25M and $495,000 respectively (for the length of railway in the Brisbane Water study area only). Cost includes clearing and grubbing, track removal, earthworks, laying down of rail line and raising overhead wiring for 15km of the rail line. Costs do not include raising of substations. The cost would be highly dependent on the design and construction method. The cost is likely to be wholly or primarily funded by the state government since it is responsible for this infrastructure. Economic benefits would be incurred as a result of the protection of the railway during flood events and therefore the	The likely social impacts would be associated with impeded views along the waterfront in the vicinity of the railway line. This impact is likely to be pronounced considering the distribution of residential properties along the railway line between Woy Woy and Gosford. In some cases, views of the water may be completely obstructed. Other groups are likely to be much more accepting of this option, e.g. commuters.	There is likely to be some environmental impacts associated with raising of the railway line, however, these would be minimised if construction was undertaken within the existing railway infrastructure footprint.

I.2 Property Modification Options

PM1 – Voluntary House Purchase Program		
Option Type: Property Modification	**Action Timeline:** Staged	**CCAP:** Included
Background: Voluntary purchase is the optional purchase of pre-selected properties funded jointly by Council and the State Government. Those properties are commonly converted into public open space or other flood compatible uses whilst the original property owner finds an alternate, flood-free place to live. The resultant land use of the property is intended to be more compatible with the flood risk and therefore the resultant flood damages are negated for those properties.		
Option Overview: Implement a voluntary house purchase program for existing dwellings that meet specified criteria. Where appropriate, utilise purchased flood prone properties as open space (e.g. recreational or wetland areas).		
Flood Mitigation Outcomes: Eliminates flood risk to residential property and significantly reduces risk to life at selected properties.		
Management Areas: This option may apply to any management area.		
Projected Sea Level Rise: Under projected sea level rise, this option would also eliminate flood risk to residential property and significantly reduce risk to life at selected properties.		
Additional Information		
This option identifies the worst affected properties on the floodplain and, through state government assistance; properties become eligible for voluntary purchase so that the flood risk for these properties can be removed. The following criteria have been established to identify properties suitable for voluntary purchase: - Overfloor flooding greater than 0.3m in the existing 100 year ARI; and - Overfloor flooding greater than 0.1m in the existing 5 year ARI event; - Comprises a residential dwelling/building not suitable for house-raising (PM2).		
Considerations/Impacts		
Economic	**Social**	**Environmental**
Voluntary House Purchase is funded by Council with assistance from the State Government. However, due to the relatively expensive nature of such a program, limited availability of Government and/or Council funding can be a major constraint to undertaking Voluntary House Purchases. Typically, only a small number of properties within a floodplain can be considered for Voluntary Purchase, however more can be assisted if funding is available. This option involves the consideration of voluntary purchase of 19 properties with an estimated combined capital cost of $9.79M (with no recurrent costs).	Social impacts would be generally localised to the individuals selling their property. However, as this program is voluntary, the property owners are likely to be happy with the agreement. If properties are purchased within smaller floodplains dominated by catchment flooding, the conversion of a property from a dwelling to open space may also alleviate flooding from overland and catchment flows on neighbouring properties.	Environmental impacts are likely to be generally low. In some cases, (e.g. if the current residence was converted to coastal open space after the voluntary purchase) there may be environmental benefits. The matrix assessment, however, has assumed that the net environmental impact of the removal of the dwelling would be negligible.

PM2 – Voluntary House Raising Program		
Option Type: Property Modification	**Action Timeline:** Staged	**CCAP:** Included
Background: House raising involves elevating an existing house by progressively raising the piers and associated floor area to a level above the flood planning level. The construction sequence to achieve required raising will be dependent on the individual dwelling. This option is not applicable for properties which are "slab on ground" construction		
Option Overview: Implement a voluntary house raising program for identified dwellings that meet specified criteria.		
Flood Mitigation Outcomes: Reduces flood risk to residents (selected properties only).		
Management Areas: This option may apply to any management area.		
Projected Sea Level Rise: It is proposed to raise selected properties to the flood planning level (FPL). This level includes an allowance for sea level rise. As such, under projected sea level rise, this option would reduce the flood risk for those selected properties.		
Additional Information		
This option identifies the worst affected properties on the floodplain and, through state government assistance, properties become eligible for voluntary raising so that the flood risk for these properties can be reduced. This option can only be applied to houses that are not of slab-on-ground construction. The following criteria have been established to identify properties suitable for voluntary house-raising: - Overfloor flooding greater than 0.3m in the existing 100 year ARI; and - Overfloor flooding greater than 0.1m in the existing 5 year ARI event; - Comprises a residential dwelling/building of construction type suitable for house-raising. Properties were selected for voluntary house raising (rather than purchase – PM1) if they were identified as being constructed on piers according to the property survey provided to Cardno by Council in July 2014. The suitability of house raising would be dependent not only on the building construction type, but also on the levels of the surrounding infrastructure and landform. House-raising may become unsuitable for some properties that are highly affected under sea level rise (e.g. if regular tidal inundation becomes dominant at the property and access becomes restricted). Council may consider the use of the house raising subsidy to be used for redevelopment purposes of those properties at highest flood risk. This would include the properties identified for voluntary purchase (PM1) and voluntary house raising (PM2).		
Considerations/Impacts		
Economic	**Social**	**Environmental**
Voluntary house raising is generally funded by Council with assistance from the State Government. The cost of raising one house is in the order of $30,000. If a number of dwellings are proposed to be raised, a significant cost would be incurred. It has been assumed in this assessment that 21 dwellings would be raised at a capital cost of $630,000.	Social impacts would generally only occur on a localised scale. Long-term impacts on visual amenity may result, particularly for adjacent properties. However, it is likely that the floor levels will be raised to similar or slightly higher levels to surrounding properties, and raising must be undertaken within relevant development controls.	Environmental impacts would be minimal if the modifications took place only within the existing building footprint.

Plate G.5: Example of raised house.

Photograph Source:
http://www.australiantraveller.com/images/galleries/3616/029-Coast-Exterior.jpg

PM3 – Investigate a Land-Swap Program		
Option Type: Property Modification	**Action Timeline:** Staged	**CCAP:** Included

Background:

This option would involve an investigation into the "swapping" of privately-owned flood-affected land with Council, state or nationally-owned land that is not flood affected. Flood-affected properties that fulfill particular criteria (such as being located in a high hazard flood area) could then be eligible for land swap. Flood-affected land could be swapped with public land that does not have a high value in terms of features such as ecology, visual amenity or recreation.

Option Overview:

Investigate potential for implementation of a land swap program for properties that meet specified criteria (e.g. inundated by sea level rise and flooding in regular events) with land that Council owns in non flood-prone areas.

Flood Mitigation Outcomes:

Based on the findings of the investigation, flood risk could be eliminated for those selected properties.

Management Areas:

This option would apply to the same properties suitable for voluntary purchase.

Projected Sea Level Rise:

The investigation is focused on existing flood risk but could incorporate projected sea level rise.

Additional Information

An investigation into the availability of Council-owned land that is suitable for swapping is the basis of this option. Suggested land-swap sites could include the Somersby area.

The following criteria have been established to identify properties suitable for land swap:
- Overfloor flooding greater than 0.3m in the existing 100 year ARI; and
- Overfloor flooding greater than 0.1m in the existing 5 year ARI event; and
- Comprises a residential dwelling/building not suitable for house-raising (PM2).

These criteria are the same as for voluntary purchase, so the same properties were identified for both voluntary purchase and land swap. These options are therefore mutually exclusive for each property, that is, only voluntary purchase OR land swap would apply to the identified properties. Land swap is likely to be more cost effective, as a property purchase would not be required. However, the limitations of this option include the availability of flood free land for land swap. In many cases, government owned land is either currently flood affected or of high ecological value or value to the community.

Considerations/Impacts

Economic	Social	Environmental
The investigation into the feasibility of land-swap and coordination with private and public land holders would incur some economic costs. Costs would be dependent upon a rigorous evaluation, and are also dependent on the availability of swappable properties. Investigation cost is estimated to be at $20,000 per property.	Social impacts of the investigation would be minimal. Social impacts of an implemented land-swap arrangement would primarily include the impacts of land use change, e.g. land being swapped and no longer available for public use.	Environmental impacts of the investigation would be minimal. Environmental impacts of an implemented land-swap arrangement would depend on a range of factors including location and current/future land use.

PM4 – Property Flood Risk Education Program		
Option Type: Property Modification	**Action Timeline:** Staged	**CCAP:** Not included
Background: As compared to Option EM1 (which provides an opportunity for education mainly relating to emergency response and evacuation), Option PM4 provides an opportunity for education in terms of protection of property. It is considered that there is a need for property owners and potential buyers of properties need access to risk information for them to be able to make informed decisions about how they manage risks. This could include measures such as ensuring that spatial risk information is readily available to members of the public, providing flood risk brochures at real-estate agencies, and brochures titled "What does my S149 Certificate mean?" to be included with all S149 certificates when received by property purchasers.		
Option Overview: Conduct a program of strategic, balanced and socially sensitive education to advise the local community and prospective property purchasers about the risk and effects of coastal flooding.		
Flood Mitigation Outcomes: Educates the wider community on the impacts of flood events.		
Management Areas: This is a floodplain-wide option that applies to all management areas.		
Projected Sea Level Rise: This option could include information relating to sea level rise but it would not result in any direct protection from coastal flooding or tidal inundation associated with sea level rise.		
Considerations/Impacts		
Economic	**Social**	**Environmental**
Economic impacts would be fairly minor, but would include costs for preparation and distribution of information materials. Actual costs would be dependent upon the program adopted, estimated to be a $20,000 initial cost and $4000 recurring annual cost.	This option has the potential to have a social impact, especially for property-owners that hold flood-affected land. However, the benefits of an informed community and future property owners should also be considered. This option has been assigned an action timeline of "staged" since additional consideration may be required prior to undertaking this option given its potential sensitivity in the community, particularly with property owners in the floodplain.	Environmental impacts would be negligible.

PM5 – Monitor Sea Levels		
Option Type: Property Modification	**Action Timeline:** Immediate	**CCAP:** Included
Background: This option includes the continued monitoring of sea levels and periodic data analyses to ascertain the rate of sea level rise within Brisbane Water. The gauges would need to meet strict standards set by the National Tidal Facility to ensure the data is reliable and fully quality controlled. Responsibility of maintenance and reporting could be transferred to the State Government as part of the NSW *Monitoring, Evaluation and Reporting Strategy*. Water level gauges would need to be maintained accordingly. It is noted that technology currently exists that incorporates sea level monitoring gauges into flood warning signage (such as Portable Variable Message Signage (VMS)) which is used on roads to alert the community of hazards including floods. This could be considered in conjunction with Option EM2 and Option EM4 to combine technologies and potentially save on option costs. This has not been incorporated into the costing of this option. In addition, this option incorporates the periodic provision of sea level rise updates to the community to maintain awareness. This could be undertaken by advertising in the local media and providing water level data on Council's website and in hard copy in local libraries.		
Option Overview: Continue to monitor sea levels and perform periodic analyses to ascertain the rate of sea level rise within Brisbane Water. Maintain gauges as required. Periodically communicate results to the community in an effective manner.		
Flood Mitigation Outcomes: Monitoring data can be used to establish trigger levels for use in land use planning options.		
Management Areas: Existing flood gauges are located in management areas 3 and 12.		
Projected Sea Level Rise: This option relates directly to sea level rise however it would not result in any direct protection from storm surge or tidal inundation associated with sea level rise.		
Additional Information		
This option aligns with the *Brisbane Water Estuary Management Study* (Cardno, 2011a), which also recommended the continued monitoring of sea levels into the future. Existing water level gauges are located at the Punt Bridge (Erina), Wharf Street (Erina) and at Koolewong and Ettalong. These gauges are shown on Figure I.6.		
Considerations/Impacts		
Economic	**Social**	**Environmental**
The economic impact of this management option would be fairly minimal. Estimated capital cost is estimated at $15,000. Economic impacts would consist of a recurrent maintenance and monitoring cost in addition to the costs associated with information distribution estimated at $4500.	Social impacts may include negative reactions to the release of sea level rise data. Reactions may include rejection of the concept of sea level rise and concern that release of information may devalue private properties.	Sea level rise is predicted to affect the whole of the Brisbane Water foreshore floodplain. As such, option PM5 applies to all management areas in terms of monitoring, analysis and communication of results to the public.

Figure I.6: Gauge Locations (see Appendix G for details of Each Gauge)

PM6 – Relocate Critical Infrastructure and Facilities		
Option Type: Property Modification	**Action Timeline:** Staged/Trigger	**CCAP:** Included for some locations

Background:

Critical infrastructure and facilities such as ambulance stations are often required during flood events to assist injured and displaced people. Despite this, some critical infrastructure and facilities may be located in the floodplain. Relocation of such facilities is important so that these facilities do not become inundated or isolated during a flood event. It has been assumed for this option that relocation takes place to a location outside the PMF flood extent (with 0.9m SLR).

Option Overview:

Relocate critical infrastructure out of the floodplain.

Flood Mitigation Outcomes:

Elimination of flood risk for critical infrastructure, and enhancement of emergency services to operate in flood emergencies.

Management Areas:

MA	Location	Notes
1	Point Clare Ambulance Station, Point Clare	Ambulances and paramedics are often required during flood events to assist those who have been injured. The facility is located in the existing case floodplain (although only likely to be affected by events greater than the 100 year ARI). The section of Brisbane Water Drive adjacent to the Point Clare ambulance station is likely to be inundated in events greater than the 20 year ARI (existing case), however the facility itself is not subject to existing flood risk.
4	NSW SES Headquarters (Gosford), Erina	The NSW State Emergency Service provides emergency assistance during floods and storms. Although some of the grounds and buildings are likely to be unaffected, mobilisation via Pateman Road and The Entrance Road would be impeded due to flooding.
14	Woy Woy Police Station, Woy Woy	This facility is likely to be subject to coastal flooding in events greater than the existing 20 year ARI. Relocating this infrastructure to a location outside the floodplain would provide flood-free access to and from the station so that more reliable assistance could be provided to those in need of police assistance during a flood event.

Projected Sea Level Rise:

Under projected sea level rise, this option would remove the flood risk for those selected properties and/or allow flood-free access for emergency services.

Considerations/Impacts		
Economic	**Social**	**Environmental**
This option is likely to have estimated capital (initial) costs ranging from approximately $4.3M to $5.9M, depending on the infrastructure. Recurrent (per year) costs would be zero. Costs include relocation and new property costs for each facility. Costs would be highly dependent on the cost of the new facility. Costs would primarily be funded by the state government.	Social impacts would be relatively minor, and would probably be primarily dependent on how far away the new site was to be from the community accessing it. If a more central location is identified, this may have social benefits.	Environmental impacts would depend on the existing land use of the new site and the future land use of the current site. For example, infrastructure being relocated to an existing building with the land use of the original infrastructure site remaining as was, environmental impacts would be negligible since no actual change has taken place to building structures. However, if the new site had to be cleared, then environmental impacts would obviously be higher. If the original infrastructure site was to be converted to coastal open space after relocation, a positive environmental outcome could apply. The matrix assessment has assumed that the net environmental impact of the infrastructure relocation would be negligible.

PM7 – Review and Amend Planning Instruments and Development Controls		
Option Type: Property Modification	**Action Timeline:** Immediate	**CCAP:** Included

Background:

This option involves a review of planning instruments and development controls. Amendments would be made accordingly to ensure consistency with coastal flooding and the impacts of predicted sea level rise on coastal flooding. A draft development control matrix (Appendix H) for the Brisbane Water floodplain has been prepared for inclusion in the Gosford Development Control Plan (DCP) 2013.

Option Overview:

Review and amend planning instruments and development controls to ensure consistency with coastal flooding and the impacts of predicted sea level rise on coastal flooding and tidal inundation. Enforce amendments and review development controls every five years in accordance with updated sea level rise data and trigger levels.

Flood Mitigation Outcomes:

Properties progressively protected to the Flood Planning Level or PMF (as appropriate).

Management Areas:

This is a floodplain-wide option that applies to all management areas.

Projected Sea Level Rise:

The LEP 2014 and DCP 2013 consider climate change in broad terms. In the future Council may wish to include specific sea level rise predictions in the definition of hazard areas utilized within the planning instruments and development controls. This option proposes to include an allowance for SLR (in accordance with Council’s Climate Change Policy, D2.11, 2013) in the Flood Planning Level (see Section 8). This will provide protection for properties from the impacts of storm surge and increased tidal inundation related to sea level rise by changing the way that the floodplain is developed.

Additional Information

The following planning measures are recommended for the Brisbane Water floodplain:

- Allow filling on a lot-by lot basis within the Brisbane Water foreshore floodplain (but not within catchment floodways or catchment flood storage areas);
- Restrict subdivision within the Brisbane Water flood planning area where the proposed subdivision does not have suitable emergency access or the development is likely to have adverse impacts on flood behaviour;
- Make provisions for wave run-up protection designs for dwellings and infrastructure; and
- Consideration of the interim development controls for the Brisbane Water foreshore floodplain prepared as part of the FRMS.

Filling

Due to the impracticalities of implementing filling on a regional basis (as described in Option FM9), increasing the capacity of landowners to fill individual lots within the floodplain is likely to be more appropriate, assuming drainage requirements are adequately met and environmental impacts are suitable managed.

Filling of the land within the Flood Planning Area is not permitted under the current DCP unless it is allowable as part of an adopted Floodplain Risk Management Plan. It is the recommendation of this FRMS that appropriate filling is permissible except in those areas defined as flood storage or flood fringe areas for catchment flooding.

This option may assist with planning into the future for the projected impacts of tidal inundation as a result of sea level rise. If over time, most lots have been raised substantially, there may be opportunities for Council to raise the infrastructure supporting the properties (e.g. roads, water and sewer) resulting in the areas remaining viable into the future. As such, Council may seek to encourage filling as part of development applications in suitable locations within the Brisbane Water floodplain.

Subdivisions

The current DCP does not permit subdivision for the purposes of creating additional lots within the flood planning area. It is recommended that this control be reviewed to consider permitting appropriate subdivisions that provide building platforms at or above the Flood Planning Level and that do not exacerbate flood levels, velocities or flow distributions at any other location, including cumulative impacts of incremental development should all the proposed lots become fully developed. Consideration should also be given to emergency access and evacuation.

Make provisions for wave run-up protection designs for dwellings and infrastructure

This would incorporate a provision in Council's DCP that relates to wave run-up protection designs for new and existing dwellings and infrastructure. This could include recommendations for designs such as enhanced window and door seals or raised floor levels on new dwellings located in wave run-up zones.

Interim Development Control Matrix

An interim development control matrix has been prepared as part of this FRMS and is provided in **Appendix H**. The matrix has been developed to incorporate the issues outlined above and to consider the DCP 2013 and LEP 2014. Future amendments to DCP documentation should include this matrix.

The development control matrix has identified controls relating to three management areas:

- 100 Year ARI High Hazard
- Flood Planning Area (equal to land below the Flood Planning Level and excluding the High Hazard area)
- PMF Extent (excluding the Flood Planning Area)

The proposed Flood Planning Level (FPL) is equal to the 100 Year ARI Flood level + 2050 allowance for sea level rise + 0.5m Freeboard. This level is above the PMF at all locations in the Brisbane Water foreshore floodplain. As such, there will be no PMF extent with regards to development controls. However, if there are changes to Council's existing sea level rise policy or the proposed FPL, the PMF area controls may be relevant.

Considerations/Impacts		
Economic	**Social**	**Environmental**
Estimated costs are $50,000 capital cost and $10,000 recurrent cost. Cost includes an initial review and future updates every five years. Studies associated with the further investigation areas would be supplementary to this. Some budget allocation is included in Council's annual budget	The social impacts of modifying Council's development controls would not be substantial; however impacts from implementing options under the new development controls (e.g. filling properties) may have social implications.	The environmental impacts of modifying Council's development controls would not be substantial; however impacts from implementing options under the new development controls (e.g. filling properties) may have environmental implications.

PM8 – Develop Management Area Specific Development Controls		
Option Type: Property Modification	**Action Timeline:** Staged	**CCAP:** Included

Background:

Develop Development Controls and Planning measures for all Management Areas and integrate into Council's Planning documents. This could be undertaken in TWO stages:

- Stage 1: Interim Development Control measures adopted until further investigations are completed within the terms of reference of a Climate Adaption Plan for the Brisbane Water Foreshore that will consider the unique characteristic of individual Management Areas.
- Stage 2 : On completion of a Climate Adaption Plan review interim measures determined in Stage 1

Option Overview:

Development control measures to be implemented on a staged basis that will allow existing property owners to develop under the Gosford 2013 LEP and associated controls. Development controls measures specific to flood impacts in the Brisbane Water floodplain are to be determined within the Flood Planning Matrix as part of PM7. This option would identify any appropriate modifications to the matrix to reflect the unique characteristics of each management area.

Flood Mitigation Outcomes:

Planning outcomes should progressively minimise the impact of flooding for existing and future developments in and around the Brisbane Water Foreshores while recognising the current constraints of existing infrastructure such as road networks and utilities. Measures should consider the unique characteristics of the MA without increasing the risk to the occupants, while still recognising Gosford Council's policy relating to sea level rise and appropriate NSW Coastal Planning Guidelines (August 2010) provided by the NSW Government.

Management Areas:
All

Projected Sea Level Rise:

Impacts of sea level rise need to be considered as part of the option implementation. Over time, this option should provide protection for properties from the impacts of storm surge and increased tidal inundation related to sea level rise by changing the way that the floodplain is developed, particularly in key, critically-affected areas.

Additional Information

The following matters require consideration as part of this option:

Flood behaviour and flood modification:

- Confluence of mainstream and overland flooding.
- Impacts of SLR.
- Performance based measures to reduce the effect of wave run-up. Concessional allowance would be considered natural or structural features act as energy dissipation of wave run-up and overtopping.
- Develop methods and measures to address wave run-up impacts on both private and public areas.
- Avoid intensifying land use in areas that will transition from low hazard category (existing 100 year) to high hazard due to the potential impacts of Climate Change.
- Filling at an allotment basis can be considered where it can be determined that the overland flood behaviour will not be detrimental to other landholders.
- Additional development controls may need to be considered to ensure appropriate development occurs in low hazard and / or flood free areas which have emergency access issues (e.g. flood islands).

Planning controls and documents:

- FPLs for the floodplain based on the recommendations in **Chapter 8**.
- Department of Planning's *Central Coast Regional Strategy* (DoP, 2008);
- Building Code of Australia – Construction of Buildings in Flood Hazard Areas

Emergency Response:

- Rising access to above the PMF.
- Emergency responses for flood islands (**Figure 9.4**).
- Safe and Reliable Evacuation Routes from residential subdivisions to a regional evacuation route are critical for public safety. Evacuation routes should consider the duration time of the flood events and the capacity to safely evacuate the whole area;
- Consideration should be given to the capacity and levels of the existing road networks;
- Subdivision of existing lots below the FPL should be discouraged where safe and reliable evacuation routes cannot be achieved; and
- Consideration should be given to the Flood Emergency Response Planning Classification of the Community DECC (2007) - Office of Environment & Heritage.

The draft Development Control Matrix for the whole Brisbane Water Floodplain (**Appendix H**) could be modified for each of the Management Areas.

Considerations/Impacts		
Economic	**Social**	**Environmental**
The economic impacts on future developments would be minor in the short term. There may be more moderate impacts associated with development controls that result from the development of the CCAPs (PM9). The costs associated with undertaking the preparation of the development controls and reviewing them as appropriate would be in the order of \$100,000 capital cost and \$15,000 recurrent cost. Costs would be highly dependent on the level of detail required.	Social impacts of would not be substantial, however resulting actual property modifications may have social implications, e.g. decreased visual amenity. It has been assumed in the multi-criteria matrix assessment that social impacts would be minimal. This option will allow for incremental change and provide short to medium term certainty for existing and future owners as to what development is permissible.	Any property modifications would be subject to Councils' development approvals process including environmental controls, as appropriate. As such, it has been assumed in this assessment that there would not be any adverse environmental impacts.

PM9 – Develop Sea Level Rise Management Strategies		
Option Type: Property Modification	**Action Timeline:** Staged	**CCAP:** Included
Background: The detailed assessment of the impacts associated with increased tidal inundation as a result of sea level rise is beyond the scope of this FRMS. However, preliminary mapping and assessments have been undertaken and are presented in **Appendix G**. Option PM9 recommends that the information provided is used to assist in future investigations and *Climate Change Adaptation Plans*. This could include a policy position from Gosford Council and specific development controls (in some cases, location-specific).		
Option Overview: Develop management strategies to adapt to the impacts of sea level rise on tidal inundation. This should include a policy position from Gosford Council and specific development controls (in some cases location specific).		
Flood Mitigation Outcomes: Mitigation of the impacts on properties, infrastructure, fauna, flora and heritage.		
Management Areas: This is a floodplain-wide option that applies to all management areas.		
Projected Sea Level Rise: This option relates directly to sea level rise and, over time, should provide protection for properties from the impacts of storm surge and increased tidal inundation related to projected sea level rise by changing the way that the floodplain is developed.		
Additional Information		
It is understood that Council are planning on preparing a series of *Climate Change Adaptation Plans* for the area ensure an integrated approach to dealing with the risks associated with climate change. Option PM9 relates more specifically to projected sea level rise, which forms one of the many aspects to be considered in the CCAPs. It is envisaged that a LGA-wide *Climate Change Adaptation Plan* would be prepared in the first instance as an overarching document for subsequent plans. Projected sea level rise priority areas would then be identified (based on both flood affectation and the relevance of strategies and plans) and more location-specific plans would be formulated. It is anticipated that the Hunter & Central Coast Regional Environmental Management Strategy (HCCREMS) *Decision Support for Adaptation: The Handbook* would be used to facilitate the preparation of the CCAPs. This decision support tool includes a handbook to provide ensure consistency and transparency in decision-making and collaboration, engagement and communication processes so as to manage relevant climate change risks, The projected impacts of sea level rise on the following assets could be incorporated into the investigations: - Residential areas, both existing and proposed (i.e. identified growth areas) and the long term viability of these areas for development both with and without adaptation strategies. - Public infrastructure – investigate the long term viability of the infrastructure servicing potentially affected areas. Strategies should be identified for works to protect these assets from the impacts of sea level rise and how this may be incorporated into the existing maintenance regime. - Heritage items and places – Investigate the impacts of future flooding and emergency response arrangements on heritage buildings, structures, items and places This should include a field survey of historic infrastructure and archaeological items and review of known heritage database records for both Aboriginal and non-Aboriginal heritage. Recommendations for the mitigation of negative impacts on heritage items should also be formulated. - Flora, fauna and other natural resources – Investigate the impacts of projected sea level rise on flora and fauna, with particular emphasis on changes in foreshore vegetation. Reference can be made to Appendix D of Cardno (2010b) *Sea Level Rise and the Estuarine Intertidal Zone – Discussion Paper*. - A report on adaptation to sea level rise by design (Clouston Associates, 2012) may be of assistance in consideration of management strategies as part of this option. - Council's climate change policy and predictions of sea level rise should be reviewed.		
Considerations/Impacts		
Economic	**Social**	**Environmental**
Economic impacts would be in the order of $500,000capital cost and $70,000recurrent cost. This assumes the preparation of an initial LGA-wide plan and then the preparation of plans for two subsequent priority areas. Recurrent cost would comprise future amendments to strategies and policies as new climate change and sea level rise data becomes available. Costs would be highly dependent on the level of detail adopted.	Negative social impacts would be negligible; some social benefits would be likely.	Environmental impacts of strategy development would be small, however there may be potential environmental implications associated with the implementation of these strategies.

PM10 – Evaluate Utilities Infrastructure		
Option Type: Property Modification	**Action Timeline:** Staged	**CCAP:** Included
Background: The Brisbane water foreshore floodplain comprises a range of above-ground and underground infrastructure assets including electricity, water, sewer, natural gas and telecommunications infrastructure. These assets are predominately managed by private companies, with the exception of water and sewer assets which are managed by Gosford City Council's Water and Sewer department. Many of these assets are designed to withstand intermittent flooding, however the impact of projected sea level rise on utilities and services is potentially a major issue within the floodplain. In accordance with the Floodplain Development Manual, this FRMS incorporates economic damages for private properties (i.e. residential, commercial, industrial land uses) however economic damages for infrastructure and utilities has not been assessed. This option would aim to ascertain levels of impact on assets, especially in the context of sea level rise. Planning for sea level rise requires the involvement of private asset holders so that integrated decision-making can be undertaken for affected areas and appropriate management strategies implemented.		
Option Overview: Evaluate utilities infrastructure relative to flood risk and sea level rise benchmarks. Partner with private utilities managers to better understand the risks to assets and formulate a plan of management over the long term for integration into Council's planning objectives.		
Flood Mitigation Outcomes: Evaluation outcomes should progressively minimise the impacts of flooding on utilities infrastructure, particularly with sea level rise.		
Management Areas: This is a floodplain-wide option that applies to all management areas.		
Projected Sea Level Rise: Over time, this option should provide protection for utilities infrastructure and allow the floodplain to continue to have access to utilities and services infrastructure.		
Additional Information		
Consultation with and collaboration between private utility/service owners, Council asset managers and other infrastructure managers (e.g. RMS) would be necessary as part of this option. Consideration would need to be given to how partnering and collaboration can be achieved efficiently. Strategies for integrated management of assets should be formulated with recommendations made regarding the implementation of flood modification options (structural works) in the future.		
Considerations/Impacts		
Economic	**Social**	**Environmental**
Economic impacts would be fairly minimal and would relate to investigations and consultation undertaken. Economic impacts would be in the order of $150,000 capital cost and $7500 recurrent cost.	Social impacts of the review itself would be negligible, however the implications of the findings of the review may have some indirect social impacts, such as disruption to utilities and services.	Environmental impacts of the review would be negligible.

PM11a, PM11b – Impacts of Structural Options on Overland Flows		
Option Type: Property Modification	**Action Timeline:** Immediate	**CCAP:** Not Included

Background:

As part of this FRMS, a series of floodplain risk management options have been identified, some of which will be recommended for subsequent implementation. However, it is important to understand that large structural options undertaken to manage the impacts of storm surge (foreshore) flooding may have concurrent negative impacts on overland flows and overland flooding within the catchment. This option seeks to undertake a detailed assessment of major structural management options and their associated potential impacts on overland flooding. This option may be able to identify modifications to options which have been recommended and those which have not to make them more appropriate in the local Management Area.

One study has been proposed in each Management Area. Some Management Areas already have overland flow studies in place which could be updated / reviewed for this purpose.

Option Overview:

PM11a – Undertake a detailed assessment of overland flow impacts of major structural options.
PM11b – Update/review detailed assessment of overland flow impacts of major structural options.

Flood Mitigation Outcomes:

No direct flood mitigation options, however the results of the investigation will allow the implementation of options where impacts on overland flooding is not experienced.

Management Areas:

This is a floodplain-wide option that applies to all management areas. However, several management areas have already been subject to previous investigations, and as such, only an update would be required. All other management areas would require a full investigation.

MA	Location	Option Description
MA1	West Gosford and Point Clare	PM11a – Undertake detailed investigation
MA2	Gosford	PM11b – Undertake review/updated investigation
MA3	Koolewong and Tascott	PM11a – Undertake detailed investigation
MA3	Point Frederick, East Gosford and Green Point	PM11b – Undertake review/updated investigation
MA4	Erina	PM11a – Undertake detailed investigation
MA5	Yattalunga and Saratoga	PM11a – Undertake detailed investigation
MA6	Davistown	PM11b – Undertake review/updated investigation
MA7	Kincumber, Kincumber South and Bensville	PM11b – Undertake review/updated investigation
MA8	Empire Bay	PM11b – Undertake review/updated investigation
MA9	St Huberts Island	PM11a – Undertake detailed investigation
MA10	Daleys Point, Killcare and Hardys Bay	PM11a – Undertake detailed investigation
MA11	Pretty Beach and Wagstaffe	PM11a – Undertake detailed investigation
MA12	Ettalong	PM11a – Undertake detailed investigation
MA13	Booker Bay	PM11a – Undertake detailed investigation
MA14	Woy Woy and Blackwall	PM11b – Undertake review/updated investigation
MA15	Horsfield Bay, Phegans Bay and Woy Woy Bay.	PM11a – Undertake detailed investigation

Projected Sea Level Rise:

This option is relevant in the existing flood scenario and does not relate to projected sea level rise.

Considerations/Impacts		
Economic	**Social**	**Environmental**
Estimated costs for management areas where a full investigation is required would be $100,000 per management area. Estimated costs would be lower ($30,000) for those management areas requiring only an updated investigation.	Social impacts of the review itself would be negligible.	Environmental impacts of the investigations would be negligible.

PM12 – Implement Managed Retreat		
Option Type: Flood Risk Modification	**Action Timeline:** Trigger	**CCAP:** Included
Background: This option involves the implementation of managed retreat to avoid the projected impacts of sea level rise in critical areas. This option requires further investigation as part of the *Climate Change Adaptation Plan*.		
Option Overview: Implement managed retreat to avoid the projected impacts of sea level rise in critical areas.		
Flood Mitigation Outcomes: Provides protection of properties up to the PMF with 0.9m SLR.		
Management Areas: This option applies to all management areas.		
Projected Sea Level Rise: This option directly relates to sea level rise and would provide protection against the projected impacts of storm surge and tidal inundation as a result of increasing sea levels for those areas that retreat.		
Additional Information		
Much further investigation and a feasibility assessment of this option is necessary. It has been assumed that this option includes the relocation/retreat of 33% of the Brisbane Water foreshore floodplain to areas outside the PMF event with 0.9m SLR.		
Considerations/Impacts		
Economic	**Social**	**Environmental**
The economic impacts of undertaking managed retreat (applied as a blanket rule) would be astronomical. Estimated capital costs would be $1,301M to implement managed retreat (for one third of the floodplain). Cost assumes an average new property cost of $515,000.	The social impacts of this option, namely social disruption, social angst and displacement of individuals and communities, would be substantive if managed relocation/retreat was undertaken. However, increased tidal inundation due to sea level rise is likely to mean that properties in the future are constantly inundated, which would also cause significant social disruption and angst. In such a case, the social impacts of climate change adaptation are likely to be much more tolerable.	The environmental impacts of this option would be variable depending on the location of the existing properties and the location of new properties that are to become inhabited as a result of retreat. It is likely that there would be overall negative impacts, given that a large number of new properties would become inhabited in a new flood-free location. However, the remaining, disused, flood-affected land may provide space for intertidal migration and estuarine vegetation growth which may possibly provide some level of offset to any negative environmental impacts.

I.3 Emergency Response Modification Options

<table>
<tr><th colspan="3">EM1 – Emergency Response Education Program</th></tr>
<tr><td>Option Type: Emergency Response Modification</td><td>Action Timeline: Staged</td><td>CCAP: Not included</td></tr>
<tr><td colspan="3">Background:
Flood-risk education can serve as a tool for indirectly reducing risk to life during flood events. Preparedness for a flood event is likely to improve as a result of increased community flood-awareness.
This option has been assigned an action timeline of “staged” since it is anticipated that implementation would take place progressively over the course of time. An initial education program based on the results of this FRMS can be undertaken immediately, however it is anticipated that additional and modified educational material would be required to be disseminated subsequent to the results of the CCAPs.</td></tr>
<tr><td colspan="3">Option Overview:
Conduct targeted flood education programs for flood-affected residents.</td></tr>
<tr><td colspan="3">Flood Mitigation Outcomes:
Educates the wider community about the impacts of flood events on access and evacuation.</td></tr>
<tr><td colspan="3">Management Areas:
This option applies to all management areas. Flood-affected residents within each management area would form the target audience for the education program.</td></tr>
<tr><td colspan="3">Projected Sea Level Rise:
This option is relevant in the existing flood scenario and does not provide protection under projected sea level rise.</td></tr>
<tr><th colspan="3">Additional Information</th></tr>
<tr><td colspan="3">This option involves conducting targeted flood education programs for flood-affected residents through a variety of means, such as the distribution of brochures to households in the area or advertisements in the local newspaper advising residents of flood-related resources (e.g. held at Council or the library). Residents could be provided with an informative overview of what to expect during a flood (e.g. flood evacuation procedures, access to evacuation centres etc.). Residents could be referred on to the current Gosford City Flood Plan for further information and details. A multi-lingual education program is desirable, as cultural and language barriers may inhibit emergency response during a flood event. Education for specific groups of residents such as older people in retirement villages/aged care homes (e.g. Leisure Living Retirement Village and Aged Care, West Gosford), or residents with properties that may be cut off from transport routes (e.g. Camellia Circuit, Woy Woy), should also be targeted by the program.</td></tr>
<tr><th colspan="3">Considerations/Impacts</th></tr>
<tr><th>Economic</th><th>Social</th><th>Environmental</th></tr>
<tr><td>Economic impacts would be in the order of $250,000 capital cost and $25,000 recurrent cost. Recurrent costs likely to be higher (based on salary for one part-time employee). Costs would be highly dependent on the program adopted. The strategy would need to be reviewed annually and reinforced with community knowledge.</td><td>Negative social impacts are likely to be minimal. Positive social outcomes may result from an increased understanding of flood emergency procedures.</td><td>Environmental impacts would be minimal.</td></tr>
</table>

EM2 – "Road Floods" Signage

Option Type: Emergency Response Modification	**Action Timeline:** Immediate	**CCAP:** Not included

Background:

Flood signage along roads that are liable to flood allow residents to be aware of whether it is dangerous to traverse a particular section of road during a flood event.
It is noted that technology currently exists that incorporates sea level monitoring gauges into flood warning signage (such as Portable Variable Message Signage (VMS)) which is used on roads to alert the community of hazards including floods. This could be considered in conjunction with Option PM5 and Option EM4 to combine technologies and potentially save on option costs.

Option Overview:

Survey, install and maintain flood signage at selected locations.

Flood Mitigation Outcomes:

Assists in indicating to residents that roads may not be safe to cross during flood events.

Management Areas:
The locations identified for this option were based on a threshold of >0.3m peak flood depth (vehicle stability depth) for the 20 year ARI event (refer **Table 9.1**).

MA	Location (approximate distance to closest residences)
1	Yallambee Avenue, West Gosford (120m) and Central Coast Highway, Gosford (120m)
14	Brick Wharf Road, Woy Woy (10m)
	North Burge Road, Woy Woy (10m)
	Blackwall Road, Woy Woy (200)

Projected Sea Level Rise:

This option is relevant in the existing flood scenario. Under projected sea level rise, many more roads would be affected.

Considerations/Impacts

Economic	Social	Environmental
Estimated capital (initial) and recurrent (per year) costs are approximately $1200 and $200 (per structure).	This option may not be well-received by residents who live nearby to a location earmarked for flood signage. Residents may feel that their property will be devalued because flood signage may indicate to prospective property purchasers the presence of flood risk. For each location above, the distance to the closest residences has been calculated, giving an indication of how acceptable the flood signage is likely to be among nearby residents.	Environmental impacts would be minimal due to the small scale of the works.

Plate G.6: Example signage.

Photo Source:
https://www.flickr.com/photos/abcnews_au/6664508599/in/photostream/

EM3 – Review NSW SES Flood Plan		
Option Type: Emergency Response Modification	**Action Timeline:** Immediate	**CCAP:** Not included

Background:

The *Gosford City Flood Plan* is described in Section 9. The following provides suggestions for matters to be included in a revised Plan:

- Review the whole document to ensure that flooding occurring due to coastal flood mechanisms is appropriately incorporated;
- If evacuation from residences is required, then evacuees should be directed to those locations which are outside of the floodplain, via non-flood affected roads;
- Remove Central Coast Leagues Club and Gosford RSL Club from the list of flood evacuation centres, since these are within the Brisbane Water foreshore floodplain;
- Incorporation of flood evacuation centres provided in Section 9.5.3 of this FRMS;
- Note that Surf Life Saving Clubs may not be appropriate evacuation centres during coastal flooding associated with oceanic storm surge, due to the general proximity of these clubs to the ocean;
- Incorporate the details of road flooding as outlined in Section 9.5.1 of this FRMS; and

The implications of projected sea level rise and the impact on future flooding should be incorporated into the Plan where possible.

Option Overview:

Undertake a review of the *Gosford City Flood Plan* with regards to the updated *Brisbane Water Foreshore Floodplain Risk Management Study* results.

Flood Mitigation Outcomes:

Community emergency services better prepared to assist the community during flood events.

Management Areas:

This is a floodplain-wide option that does not apply to any specific management area.

Projected Sea Level Rise:

The implications of projected sea level rise are to be incorporated into the *Flood Plan* so that this option is relevant for the future sea level rise scenario.

Considerations/Impacts

Economic	Social	Environmental
Economic impacts would be in the order of $20,000 capital cost with no recurrent cost. Includes one review and one update of the document.	Social impacts would be minimal.	Environmental impacts would be minimal.

EM4 – Review Flood Warning Systems		
Option Type: Emergency Response Modification	**Action Timeline:** Immediate	**CCAP:** Not included

Background:

The NSW Bureau of Meteorology (BoM) is responsible for issuing warnings when potential flood emergencies are imminent. The New South Wales and Australian Capital Territory Flood Warning Centre is the specialised organisation within the BoM which carries out these warnings for NSW.
Dissemination of information received from BoM is integral in allowing flood-affected residences to evacuate appropriately and safely from their properties. The following recommendations apply to a review of flood warning systems for Brisbane Water:

- Ensure that warnings for storm-surge flooding are appropriately distributed (in addition to warnings for catchment flooding) by acknowledging the similarities and differences between the two flooding types;
- Liaise with the NSW RMS (especially the RMS office at Woy Woy) so that light-emitting diode (LED) variable messaging signage (VMS) (both permanent and demountable) can be utilised to provide flood warnings. It is noted that a permanent VMS exists at Kariong and this could be utilised. The location and availability of permanent and demountable VMS's would need to be ascertained through liaison with RMS. This also links into Option PM5, where flood warning signage may be integrated into water level monitoring;
- Integrate the results of this FRMS into NSW SES flood planning (e.g. sharing of GIS data for use by NSW SES);
- Develop/review alternative routes and detours and distribute plans as appropriate;
- Undertake periodic liaison (between BoM, NSW SES and Council) to ensure consistency.

Option Overview:

Review flood warning systems on a periodic basis and update as necessary.

Flood Mitigation Outcomes:

Assists in optimising flood warning and evacuation processes.

Management Areas:

This is a floodplain-wide option that does not apply to any specific management area.

Projected Sea Level Rise:

This option is more relevant for the existing flood scenario and for people who are at risk right now.

Considerations/Impacts

Economic	Social	Environmental
Economic impacts would be in the order of $35,000 capital cost with $7,000 recurrent cost. Cost includes initial review, implementation of updates and further reviews as necessary. Costs are difficult to determine and would be dependent upon the nature of any system gaps and the program adopted.	Social impacts would be minimal.	Environmental impacts would be minimal.

EM5 – Pumping Station for Residual Flood Waters		
Option Type: Emergency Response Modification	**Action Timeline:** Staged	**CCAP:** Not included
Background: This option involves pumping water out of lower-lying areas where ponding of floodwaters from storm surge may remain for long periods of time after water levels have receded. The utilisation of movable, demountable flood pumps could be a viable option in these locations. This option would assist in improving access after a flood and also relates to reducing opportunities for communicable diseases to be transmitted.		
Option Overview: Implement pumping stations in locations where ponding of floodwaters may remain for long periods after storm surge levels have receded.		
Flood Mitigation Outcomes: Assists in removing ponded floodwaters that may otherwise remain for long periods. Due to the localised nature of the area and the shallow depth of ponding, this option is unlikely to provide substantial benefit.		
Management Areas: This option applies only to one management area (MA13) for a relatively small area located across six residential properties. This area was defined using GIS and represents a low-lying area surrounded by higher areas that are not well-connected to the stormwater system. This area may not drain effectively as floodwaters recede.		
Projected Sea Level Rise: The locations for this option were delineated based on the 100 year ARI flood level with 0.9m SLR. However, this option would not provide any protection for increased tidal inundation as a result of sea level rise.		
Considerations/Impacts		
Economic	**Social**	**Environmental**
Economic impacts would be in the order of $123,000 capital cost with $2400 recurrent cost. Costs would be highly dependent on the design of the pumping station.	Social impacts would be minimal.	Environmental impacts would be minimal, presuming floodwaters do not become contaminated prior to their pump out (assuming pump out is to a creek or direct to the estuary).

EM6 – Woy Woy Road Upgrade		
Option Type: Emergency Response Modification	**Action Timeline:** Trigger	**CCAP:** Not included
Background: Woy Woy Road, in management area 14, represents a major route into and out of Woy Woy and joins into the Central Coast Highway at its northern end. Large areas of Woy Woy are flood-affected, and therefore Woy Woy Road is likely to be heavily utilised for evacuation (egress) and emergency response (ingress) during a flood event. Woy Woy Road is currently a narrow, winding road that is not particularly conducive to large traffic volumes, such as those created during flood evacuation. An upgrade to Woy Woy Road would assist in allowing more efficient transportation, including evacuation and emergency response access along this road.		
Option Overview: Upgrade Woy Woy Road to facilitate more effective evacuation from, and emergency services access to, the Woy Woy area.		
Flood Mitigation Outcomes: Facilitates more effective evacuation from, and emergency services access to sensitive areas such as residences.		
Management Areas: This option applies to management area 14, however residents in other areas may also benefit if they use the road to evacuate.		
Projected Sea Level Rise: This option would provide flood-free access along this evacuation route in both the existing case and with projected sea level rise.		
Considerations/Impacts		
Economic	**Social**	**Environmental**
Upgrades to Woy Woy Road could include road widening, intersection upgrades and surface maintenance. The terrain that Woy Woy Road traverses is steep and rocky in many parts. Rock blasting and other excavation techniques would potentially be necessary if road-widening was to take place, adding to the estimated cost. Estimated minimum capital (initial) and recurrent (per year) costs are approximately $52M and $520,000 respectively. It is noted that, separate to the Floodplain Risk Management process, a road upgrade project has been proposed for Rawson Road and Woy Woy Road.	During construction, social impacts may include impeded access to residences in Horsfield Bay, Phegans Bay, Woy Woy Bay and Kariong, and disruptions in traffic flow along this road. It is likely that there would be positive social outcomes once the works were complete	The construction techniques described above is likely to also have significant environmental impacts. Any work undertaken would be subject to the standard environmental assessment process and management plans would need to be prepared to mitigate impacts.

EM7 – Review Evacuation Centres		
Option Type: Emergency Response Modification	**Action Timeline:** Immediate	**CCAP:** Included
Background: The results of the flood extent mapping (Section 6.2.4) suggest that a number of evacuation centres currently listed as being suitable for evacuation lie within a floodplain (either the Brisbane Water floodplain or a creek floodplain) and are therefore not suitable for use during a flood event since they are actually at risk of inundation. In addition, evacuation locations that are situated in open coast locations (e.g. surf life-saving centres) may not be appropriate during storm surge events, particularly with projected sea level rise. As such, a review of evacuation centres is required. Evacuation centres suitable for flood emergencies are mapped in Section 9.5.3. The total number of evacuees that could be housed at these facilities is 3,406. Given the number of properties affected by over-floor flooding in the existing PMF event (1198, Table 6.7) and the average household size (2.2 persons, Table 5.1), these evacuation facilities are likely to be adequate in housing all evacuees in such an event. As part of the review, investigation into the feasibility of upgrading evacuation centres in key areas to multi-purpose centres that can be used more readily in non-flood times could be undertaken. Implementation of this option may reduce the need for road upgrades to assist evacuation from an area (e.g. Woy Woy Road).		
Option Overview: Review evacuation centre locations with a view to utilising other suitable locations, and upgrading key evacuation centres that lie outside the floodplain, as required.		
Flood Mitigation Outcomes: Facilitates more effective evacuation from flood-affected areas and provides a hub for emergency services.		
Management Areas: This option applies to all management areas.		
Projected Sea Level Rise: Existing evacuation centres would also need to be reviewed in the context of sea level rise. Over the long term, some evacuation centres that are currently suitable for evacuation (i.e. out of the floodplain) are projected to become unsuitable due to sea level rise. As such, a regular (e.g. 5 year) review should be undertaken so that evacuation centres can be decommissioned when they are no longer outside the floodplain. Any new evacuation centres identified as a result of this option should consider projected sea level rise predictions.		
Considerations/Impacts		
Economic	**Social**	**Environmental**
Economic impacts would be in the order of $50,000 capital cost with $2500 recurrent cost. Costs would relate to investigations and a review of evacuation locations. The results of the review may lead to the upgrade of evacuation centres in key locations to allow increased evacuation space. Evacuation centre upgrades would have much more significant costs mainly relating to construction materials and labour.	Social impacts would be minimal.	Environmental impacts would be minimal as it is envisaged that existing buildings would be utlised.

EM8 – Enhance Road Evacuation		
Option Type: Emergency Response Modification	**Action Timeline:** Immediate	**CCAP:** Not included

Background:
As an alternative to road-raising or upgrades which have high economic costs, this option aims to enhance road evacuation through the forward planning of alternative routes. A corresponding addition to this option would be the integration of flood data into future road designs (however this does not address emergency response).

It is recommended that the following be undertaken as part of this option:

- Develop/review alternative routes and detours in accordance with the results of this FRMS;
- Distribute alternative route plans to relevant organisations and authorities (e.g. Council, NSW SES, Police) as appropriate. Electronic data transfer is desirable (e.g. GIS data);
- Integrate the results of this FRMS into future road planning undertaken by the RMS;
- Engage with the RMS office at Woy Woy to utilise a local knowledge base and achieve relevant results.

Option Overview:

Liaise with the NSW RMS and the NSW SES to develop and review detours and alternative routes to be used during times of coastal flooding.

Flood Mitigation Outcomes:

Assists in optimising road evacuation.

Management Areas:

This is a floodplain-wide option that does not apply to any specific management area.

Projected Sea Level Rise:

This option is primarily relevant for the existing flood scenario, however forward planning should include sea level rise predictions.

Considerations/Impacts		
Economic	**Social**	**Environmental**
The economic cost of this option would be variable depending on the program adopted, however estimated capital costs are in the order of $40,000 to produce a plan and a $2000 recurrent cost.	Social impacts would be minimal.	Environmental impacts would be minimal.

DN – Do Nothing		
Option Type: Do Nothing	**Action Timeline:** Immediate	**CCAP:** Not Included
Option Overview: Do nothing – no flood mitigation options are implemented.		
Flood Mitigation Outcomes: The impacts of flooding on the thousands of properties in the floodplain remains unchanged.		
Management Areas: All.		
Projected Sea Level Rise: No mitigation of sea level rise.		
Additional Information		
This option is not appropriate with respect to NSW Flood Policy.		
Considerations/Impacts		
Economic	**Social**	**Environmental**
The economic cost of this option is significant, and equates to the economic damages associated with the Brisbane Water floodplain, namely an AAD of approximately $5.4M or an NPV AAD (2100) of approximately $83M. Note that these values represent costs to private property only.	Social impacts of flooding would remain unchanged, and include loss of life, injury, loss of property, degradation of property, displacement, separation from family and friends, mental anguish, financial loss etc.	Environmental impacts would remain unchanged. Flooding is a natural occurrence and is of minimal concern in terms of environmental values.

Option ID	M'ment Area	Category of Measure	Location	Option Description	Action Timeline	Estimate of Capital Cost	Estimate of Recurrent Cost	Total Cost (2014)	Net Present Value (7%, 90 years, i.e. 2100)	Change in 2014 AAD if option implemented	Change in NPV AAD* if option implemented	Benefit - Cost Ratio (2014)	Benefit - Cost Ratio (NPV)	Score on Change in AAD^	Affordability
EM7	Various	Emergency Response Modification	Floodplain-wide	Review evacuation centre locations with a view to upgrading key evacuation centres that lie outside the floodplain.	Immediate	$50,000	$2,500	$52,500	$85,673	#N/A	#N/A	N/A	N/A	0	2
EM8	Various	Emergency Response Modification	Floodplain-wide	Enhance road evacuation through the development of an alternative route plan for implementation during flood events.	Immediate	$40,000	$2,000	$42,000	$68,539	#N/A	#N/A	N/A	N/A	0	3
EM3	Various	Emergency Response Modification	Floodplain-wide	Review the Gosford Local Flood Emergency Sub-Plan (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results.	Immediate	$20,000	$0	$20,000	$20,000	#N/A	#N/A	N/A	N/A	0	5
EM4	Various	Emergency Response Modification	Floodplain-wide	Review flood warning systems on a periodic basis and update as necessary.	Immediate	$35,000	$7,000	$42,000	$134,885	#N/A	#N/A	N/A	N/A	0	0
PM7	Various	Property Modification	Floodplain-wide	Review and amend planning instruments and development controls across the floodplain to ensure consistency with coastal flooding. Review every five years.	Immediate	$50,000	$10,000	$60,000	$192,693	#N/A	#N/A	N/A	N/A	3	0
PM5	Various	Property Modification	Floodplain-wide	Continue to monitor sea levels and perform periodic analyses to ascertain the rate of sea level rise within Brisbane Water. Periodically communicate results to the community.	Immediate	$15,000	$4,500	$19,500	$79,212	#N/A	#N/A	N/A	N/A	0	2
14_PM11b	14	Property Modification	Woy Woy and Blackwall	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Woy Woy and Blackwall.	Immediate	$30,000	$0	$30,000	$30,000	#N/A	#N/A	N/A	N/A	0	4
6_PM11b	6	Property Modification	Davistown	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Davistown.	Immediate	$30,000	$0	$30,000	$30,000	#N/A	#N/A	N/A	N/A	0	4
8_PM11b	8	Property Modification	Empire Bay	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Empire Bay.	Immediate	$30,000	$0	$30,000	$30,000	#N/A	#N/A	N/A	N/A	0	4
PM10	Various	Property Modification	Floodplain-wide	Evaluate utilities infrastructure relative to flood risk and projected sea level rise benchmarks. Partner with private utilities managers to better understand the risks to assets and formulate a plan of management over the long term for integration into Council's planning objectives.	Staged	$150,000	$7,500	$157,500	$257,019	#N/A	#N/A	N/A	N/A	0	-1
1_EM2	1	Emergency Response Modification	West Gosford and Point Clare	Install and maintain "Road Floods" signs at the Central Coast Highway, and Yallambee Avenue, West Gosford	Immediate	$2,400	$360	$2,760	$7,537	#N/A	#N/A	N/A	N/A	0	5
14_EM2	14	Emergency Response Modification	Woy Woy and Blackwall	Install and maintain "Road Floods" signs at Blackwall Road, Brick Wharf Road and North Burge Road, Woy Woy.	Immediate	$3,600	$540	$4,140	$11,305	#N/A	#N/A	N/A	N/A	0	5
1_PM11a	1	Property Modification	West Gosford and Point Clare	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in West Gosford and Point Clare.	Immediate	$100,000	$0	$100,000	$100,000	#N/A	#N/A	N/A	N/A	0	2
13_PM11a	13	Property Modification	Booker Bay	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Booker Bay.	Immediate	$100,000	$0	$100,000	$100,000	#N/A	#N/A	N/A	N/A	0	2
3_PM11b	3	Property Modification	Point Frederick, East Gosford, Green Point, Koolewong, Tascott and Point Clare	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Point Frederick, East Gosford and Green Point.	Immediate	$30,000	$0	$30,000	$30,000	#N/A	#N/A	N/A	N/A	0	4
4_PM11a	4	Property Modification	Erina	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Erina.	Immediate	$100,000	$0	$100,000	$100,000	#N/A	#N/A	N/A	N/A	0	2
9_PM11a	9	Property Modification	St Huberts Island	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows on St Huberts Island.	Immediate	$100,000	$0	$100,000	$100,000	#N/A	#N/A	N/A	N/A	0	2
PM8	Various	Property Modification	Floodplain-wide	Develop development controls and planning measures for all management areas via two stages - 1. Interim Developent Control Measures to be implemented until further investigations are completed; and 2. Review interim measures following completion of Climate Adaptation Plans.	Staged	$100,000	$15,000	$115,000	$314,039	#N/A	#N/A	N/A	N/A	0	-1
11_PM11a	11	Property Modification	Pretty Beach and Wagstaffe	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Pretty Beach and Wagstaffe.	Immediate	$100,000	$0	$100,000	$100,000	#N/A	#N/A	N/A	N/A	0	2
12_PM11a	12	Property Modification	Ettalong	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Ettalong.	Immediate	$100,000	$0	$100,000	$100,000	#N/A	#N/A	N/A	N/A	0	2
3_PM11a	3	Property Modification	Point Frederick, East Gosford, Green Point, Koolewong, Tascott and Point Clare	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Koolewong and Tascott.	Immediate	$100,000	$0	$100,000	$100,000	#N/A	#N/A	N/A	N/A	0	2
7_PM11b	7	Property Modification	Kincumber, Kincumber South and Bensville	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Kincumber, Kincumber South and Bensville.	Immediate	$30,000	$0	$30,000	$30,000	#N/A	#N/A	N/A	N/A	0	4
PM4	Various	Property Modification	Floodplain-wide	Conduct a program of strategic, balanced and socially sensitive education to advise the local community and prospective property purchasers about the risk and effects of coastal flooding.	Staged	$20,000	$4,000	$24,000	$77,077	#N/A	#N/A	N/A	N/A	0	2
EM1	Various	Emergency Response Modification	Floodplain-wide	Conduct targeted flood education programs for flood-affected residents.	Staged	$250,000	$25,000	$275,000	$606,731	#N/A	#N/A	N/A	N/A	0	-2
4_PM6	4	Property Modification	Erina	Relocate NSW SES (Gosford) headquarters out of the floodplain.	Staged	$4,531,970	$0	$4,531,970	$4,531,970	#N/A	#N/A	N/A	N/A	0	-3
PM9	Various	Property Modification	Floodplain-wide	Develop management strategies (as part of Climate Change Adaptation Plans for each management area) to adapt to the impacts of projected sea level rise on tidal inundation.	Staged	$480,000	$72,000	$552,000	$1,507,386	#N/A	#N/A	N/A	N/A	0	-3
15_PM11b	15	Property Modification	Horsfield Bay, Phegans Bay and Woy Woy Bay	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Horsfield Bay, Phegans Bay and Woy Woy Bay.	Immediate	$30,000	$0	$30,000	$30,000	#N/A	#N/A	N/A	N/A	0	4
2_PM11b	2	Property Modification	Gosford	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Gosford.	Immediate	$30,000	$0	$30,000	$30,000	#N/A	#N/A	N/A	N/A	0	4
14_PM6	14	Property Modification	Woy Woy and Blackwall	Relocate Woy Woy Police Station out of the floodplain.	Staged	$4,322,020	$0	$4,322,020	$4,322,020	#N/A	#N/A	N/A	N/A	0	-3
PM3	Various	Property Modification	Floodplain-wide	Investigate a land swap program for properties that meet specified criteria with land that Council owns in non flood-prone areas.	Staged	$380,000	$0	$380,000	$380,000	-$1,089,903	-$16,613,678	2.868	43.72	4	-1

Option ID	Feasibility	Protection of Public Infrastructure (2009 PMF)	Protection of Public Infrastructure (2100 PMF)	Reduction in Risk to Life (2009 PMF)	Reduction in Risk to Life (2100 PMF)	Emergency Access (2009 PMF)	Emergency Access (2100 PMF)	Water Quality	Habitat (Including Future Intertidal Habitat)	Sea Level Rise	Catchment Flooding	Compatibility with other Policies and Plans	Likely Community Acceptance	TOTAL SCORE	RANK on TOTAL SCORE (Whole Floodplain)	RANK on TOTAL SCORE (per MA)	To be included in FRMP?	Priority	Capital Cost	Recurrent Cost
EM7	5	0	0	4	4	4	4	0	0	0	0	2	2	**15.8**	**1**	**1**	YES	H	$50,000	$2,500
EM8	5	0	0	3	3	3	3	0	0	0	0	1	1	**14.1**	**2**	**2**	YES	H	$40,000	$2,000
EM3	5	0	0	2	2	2	2	0	0	0	0	0	0	**13.4**	**3**	**3**	YES	H	$20,000	$0
EM4	5	0	0	3	3	2	2	0	0	0	0	3	3	**12.5**	**4**	**4**	YES	H	$35,000	$7,000
PM7	5	0	0	2	2	0	0	0	0	2	0	0	2	**12.2**	**5**	**5**	YES	H	$50,000	$10,000
PM5	5	0	0	0	0	0	0	0	0	0	0	5	5	**12.0**	**6**	**6**	YES	H	$15,000	$4,500
14_PM11b	*2*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*3*	*4*	*3*	***11.0***	***7***	***1***	*NO*		*$0*	*$0*
6_PM11b	*2*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*3*	*4*	*3*	***11.0***	***7***	***1***	*NO*		*$0*	*$0*
8_PM11b	*2*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*3*	*4*	*3*	***11.0***	***7***	***1***	*NO*		*$0*	*$0*
PM10	5	4	5	0	0	0	0	0	0	5	0	5	-1	**11.0**	**7**	**7**	YES	H	$150,000	$7,500
1_EM2	5	0	0	1	1	0	0	0	0	0	0	0	-2	**10.1**	**11**	**1**	YES	H	$2,400	$360
14_EM2	5	0	0	1	1	0	0	0	0	0	0	0	-2	**10.1**	**11**	**2**	YES	H	$3,600	$540
1_PM11a	*2*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*4*	*4*	*3*	***9.5***	***13***	***2***	*NO*		*$0*	*$0*
13_PM11a	2	0	0	0	0	0	0	0	0	0	3	4	3	**9.0**	**14**	**1**	YES	H	$100,000	$0
3_PM11b	0	0	0	0	0	0	0	0	0	0	3	4	3	**9.0**	**14**	**1**	YES	H	$30,000	$0
4_PM11a	*2*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*3*	*4*	*3*	***9.0***	***14***	***1***	*NO*		*$0*	*$0*
9_PM11a	2	0	0	0	0	0	0	0	0	0	3	4	3	**9.0**	**14**	**1**	YES	H	$100,000	$0
PM8	5	0	2	1	2	1	2	0	0	3	0	2	0	**8.6**	**18**	**8**	YES	H	$100,000	$15,000
11_PM11a	*2*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*2*	*4*	*3*	***8.5***	***19***	***1***	*NO*		*$0*	*$0*
12_PM11a	*2*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*2*	*4*	*3*	***8.5***	***19***	***1***	*NO*		*$0*	*$0*
3_PM11a	2	0	0	0	0	0	0	0	0	0	2	4	3	**8.5**	**19**	**2**	YES	H	$100,000	$0
7_PM11b	0	0	0	0	0	0	0	0	0	0	2	4	3	**8.5**	**19**	**1**	YES	H	$30,000	$0
PM4	5	0	0	0	0	0	0	0	0	0	0	0	3	**8.5**	**19**	**9**	YES	H	$20,000	$4,000
EM1	5	0	0	3	3	0	0	0	0	0	0	0	3	**7.8**	**24**	**10**	YES	M	$250,000	$25,000
4_PM6	2	1	2	2	2	4	4	0	0	1	2	0	2	**6.8**	**25**	**2**	YES	M	$4,531,970	$0
PM9	5	0	0	0	0	0	0	0	0	4	0	2	3	**6.5**	**26**	**11**	YES	M	$480,000	$72,000
15_PM11b	*2*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***6.0***	***27***	***1***	*NO*		*$0*	*$0*
2_PM11b	*2*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	***6.0***	***27***	***1***	*NO*		*$0*	*$0*
14_PM6	2	2	2	1	1	5	5	0	0	1	0	0	2	**5.8**	**29**	**3**	YES	M	$4,322,020	$0
PM3	0	0	0	0.5	0	0.5	0	0	0.5	1	0	0	1	**5.0**	**30**	**12**	YES	M	$380,000	$0

Option ID	M'ment Area	Category of Measure	Location	Option Description	Action Timeline	Estimate of Capital Cost	Estimate of Recurrent Cost	Total Cost (2014)	Net Present Value (7%, 90 years, i.e. 2100)	Change in 2014 AAD if option implemented	Change in NPV AAD* if option implemented	Benefit - Cost Ratio (2014)	Benefit - Cost Ratio (NPV)	Score on Change in AAD^	Affordability
1_PM11b	1	Property Modification	West Gosford and Point Clare	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in West Gosford and Point Clare.	Immediate	$30,000	$0	$30,000	$30,000	#N/A	#N/A	N/A	N/A	0	4
10_PM11a	10	Property Modification	Daleys Point, Killcare and Hardys Bay	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Daleys Point, Killcare and Hardys Bay.	Immediate	$100,000	$0	$100,000	$100,000	#N/A	#N/A	N/A	N/A	0	2
10_PM11b	10	Property Modification	Daleys Point, Killcare and Hardys Bay	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Daleys Point, Killcare and Hardys Bay.	Immediate	$30,000	$0	$30,000	$30,000	#N/A	#N/A	N/A	N/A	0	4
11_PM11b	11	Property Modification	Pretty Beach and Wagstaffe	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Pretty Beach and Wagstaffe.	Immediate	$30,000	$0	$30,000	$30,000	#N/A	#N/A	N/A	N/A	0	4
12_PM11b	12	Property Modification	Ettalong	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Ettalong.	Immediate	$30,000	$0	$30,000	$30,000	#N/A	#N/A	N/A	N/A	0	4
13_PM11b	13	Property Modification	Booker Bay	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Booker Bay.	Immediate	$30,000	$0	$30,000	$30,000	#N/A	#N/A	N/A	N/A	0	4
15_PM11a	15	Property Modification	Horsfield Bay, Phegans Bay and Woy Woy Bay	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Horsfield Bay, Phegans Bay and Woy Woy Bay.	Immediate	$100,000	$0	$100,000	$100,000	#N/A	#N/A	N/A	N/A	0	2
2_PM11a	2	Property Modification	Gosford	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Gosford.	Immediate	$100,000	$0	$100,000	$100,000	#N/A	#N/A	N/A	N/A	0	2
5_PM11a	5	Property Modification	Yattalunga and Saratoga	Undertake detailed investigation of the impacts of structural floodplain risk management options on overland flows in Yattalunga and Saratoga.	Immediate	$100,000	$0	$100,000	$100,000	#N/A	#N/A	N/A	N/A	0	2
5_PM11b	5	Property Modification	Yattalunga and Saratoga	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows in Yattalunga and Saratoga.	Immediate	$30,000	$0	$30,000	$30,000	#N/A	#N/A	N/A	N/A	0	4
9_PM11b	9	Property Modification	St Huberts Island	Undertake a review/updated investigation of the impacts of structural floodplain risk management options on overland flows on St Huberts Island.	Immediate	$30,000	$0	$30,000	$30,000	#N/A	#N/A	N/A	N/A	0	4
PM2	Various	Property Modification	Floodplain-wide	Implement a voluntary house raising program for identified dwellings that meet specified criteria.	Staged	$630,000	$0	$630,000	$630,000	-$718,991	-$10,959,774	1.141	17.40	3	-2
FM4	Various	Flood Modification	Floodplain-wide	Install flood gates on stormwater pipe outlets as required.	Staged	$100,000	$35,000	$135,000	$599,424	#N/A	#N/A	N/A	N/A	0	-2
PM1	Various	Property Modification	Floodplain-wide	Implement a voluntary house purchase program for properties that meet specified criteria. Utilise purchased flood prone properties as open space (e.g. recreational or wetland areas).	Staged	$9,785,000	$0	$9,785,000	$9,785,000	-$1,089,903	-$16,613,678	0.111	1.698	4	-3
11_FM3	11	Flood Modification	Pretty Beach and Wagstaffe	Modify the existing foreshore at Pretty Beach and Wagstaffe in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$840,000	$25,200	$865,200	$1,199,585	#N/A	#N/A	N/A	N/A	0	-3
7_FM5	7	Flood Modification	Kincumber, Kincumber South and Bensville	Undertake a program of seawall maintenance and raising along the foreshore.	Staged	$73,870	$739	$74,609	$84,411	#N/A	#N/A	N/A	N/A	0	2
3_FM3	3	Flood Modification	Point Frederick, East Gosford, Green Point, Koolewong, Tascott and Point Clare	Modify the existing foreshore at Point Frederick, East Gosford, Green Point, Koolewong, Tascott and Point Clare in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$4,800,000	$144,000	$4,944,000	$6,854,772	#N/A	#N/A	N/A	N/A	0	-3
13_FM3	13	Flood Modification	Booker Bay	Modify the existing foreshore at Booker Bay in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$720,000	$21,600	$741,600	$1,028,216	#N/A	#N/A	N/A	N/A	0	-3
9_FM3	9	Flood Modification	St Huberts Island	Modify the existing foreshore at St Huberts Island in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$2,940,000	$88,200	$3,028,200	$4,198,548	#N/A	#N/A	N/A	N/A	0	-3
14_EM6	14	Emergency Response Modification	Woy Woy and Blackwall	Upgrade Woy Woy Road to facilitate more effective evacuation from, and emergency services access to, the Woy Woy area.	Trigger	$52,019,550	$520,196	$52,539,746	$59,442,350	#N/A	#N/A	N/A	N/A	0	-4
1_PM6	1	Property Modification	West Gosford and Point Clare	Relocate Point Clare Ambulance Station out of the floodplain.	Staged	$5,890,180	$0	$5,890,180	$5,890,180	#N/A	#N/A	N/A	N/A	0	-3
5_FM3	5	Flood Modification	Yattalunga and Saratoga	Modify the existing foreshore at Yattalunga and Saratoga in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$600,000	$18,000	$618,000	$856,847	#N/A	#N/A	N/A	N/A	0	-2
12_FM5	12	Flood Modification	Ettalong	Undertake a program of seawall maintenance and raising along the foreshore.	Staged	$260,205	$2,602	$262,807	$297,334	#N/A	#N/A	N/A	N/A	0	-1
13_EM5	13	Emergency Response Modification	Booker Bay	Implement a pumping station near residences along Booker Bay Road.	Staged	$122,850	$12,285	$135,135	$298,148	#N/A	#N/A	N/A	N/A	0	-1
15_FM3	15	Flood Modification	Horsfield Bay, Phegans Bay and Woy Woy Bay	Modify the existing foreshore at Horsfield Bay, Phegans Bay and Woy Woy Bay in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$600,000	$18,000	$618,000	$856,847	#N/A	#N/A	N/A	N/A	0	-2
7_FM3	7	Flood Modification	Kincumber, Kincumber South and Bensville	Modify the existing foreshore at Kincumber, Kincumber South and Bensville in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$600,000	$18,000	$618,000	$856,847	#N/A	#N/A	N/A	N/A	0	-2
8_FM3	8	Flood Modification	Empire Bay	Modify the existing foreshore at Empire Bay in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$1,320,000	$39,600	$1,359,600	$1,885,062	#N/A	#N/A	N/A	N/A	0	-3
14_FM3	14	Flood Modification	Woy Woy and Blackwall	Modify the existing foreshore at Woy Woy and Blackwall in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$2,160,000	$64,800	$2,224,800	$3,084,647	#N/A	#N/A	N/A	N/A	0	-3
10_FM5	10	Flood Modification	Daleys Point, Killcare and Hardys Bay	Undertake a program of seawall maintenance and raising along the foreshore.	Staged	$822,945	$8,229	$831,174	$940,373	#N/A	#N/A	N/A	N/A	0	-2
4_FM1b	4	Flood Modification	Erina	Raise Pateman Road and The Entrance Road above the 100 year ARI +0.9 m level.	Staged	$7,774,800	$155,496	$7,930,296	$9,993,611	#N/A	#N/A	N/A	N/A	0	-3
11_FM5	11	Flood Modification	Pretty Beach and Wagstaffe	Undertake a program of seawall maintenance and raising along the foreshore.	Staged	$621,255	$6,213	$627,468	$709,903	#N/A	#N/A	N/A	N/A	0	-2
15_FM5	15	Flood Modification	Horsfield Bay, Phegans Bay and Woy Woy Bay	Undertake a program of seawall maintenance and raising along the foreshore.	Staged	$727,495	$7,275	$734,770	$831,303	#N/A	#N/A	N/A	N/A	0	-2

Option ID	Feasibility	Protection of Public Infrastructure (2009 PMF)	Protection of Public Infrastructure (2100 PMF)	Reduction in Risk to Life (2009 PMF)	Reduction in Risk to Life (2100 PMF)	Emergency Access (2009 PMF)	Emergency Access (2100 PMF)	Water Quality	Habitat (Including Future Intertidal Habitat)	Sea Level Rise	Catchment Flooding	Compatibility with other Policies and Plans	Likely Community Acceptance	TOTAL SCORE	RANK on TOTAL SCORE (Whole Floodplain)	RANK on TOTAL SCORE (per MA)	To be included in FRMP?	Priority	Capital Cost	Recurrent Cost
1_PM11b	0	0	0	0	0	0	0	0	0	0	0	0	0	4.0	31	3	NO		$0	$0
10_PM11a	2	0	0	0	0	0	0	0	0	0	0	0	0	4.0	31	1	NO		$0	$0
10_PM11b	0	0	0	0	0	0	0	0	0	0	0	0	0	4.0	31	1	NO		$0	$0
11_PM11b	0	0	0	0	0	0	0	0	0	0	0	0	0	4.0	31	2	NO		$0	$0
12_PM11b	0	0	0	0	0	0	0	0	0	0	0	0	0	4.0	31	2	NO		$0	$0
13_PM11b	0	0	0	0	0	0	0	0	0	0	0	0	0	4.0	31	2	NO		$0	$0
15_PM11a	2	0	0	0	0	0	0	0	0	0	0	0	0	4.0	31	2	NO		$0	$0
2_PM11a	2	0	0	0	0	0	0	0	0	0	0	0	0	4.0	31	2	NO		$0	$0
5_PM11a	2	0	0	0	0	0	0	0	0	0	0	0	0	4.0	31	1	NO		$0	$0
5_PM11b	0	0	0	0	0	0	0	0	0	0	0	0	0	4.0	31	1	NO		$0	$0
9_PM11b	0	0	0	0	0	0	0	0	0	0	0	0	0	4.0	31	2	NO		$0	$0
PM2	1	0	0	0.5	0	0.5	0	0	0.5	1	0	0	1	4.0	31	13	YES	M	$630,000	$0
FM4	2	2	0	1	1	2	0	0	0	0	0	0	0	3.1	43	14	YES	M	$100,000	$35,000
PM1	0	0	0	0.5	0	0.5	0	0	0.5	1	0	0	1	3.0	44	15	NO		$0	$0
11_FM3	4	0.5	0	0.5	0	0	0	0	0	0	0	0	0	1.8	45	3	YES	L	$840,000	$25,200
7_FM5	2	0	0	0	0	0	0	0	-2	0	0	-3	0	1.5	46	2	YES	L	$73,870	$739
3_FM3	3	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0.8	47	3	YES	L	$4,800,000	$144,000
13_FM3	3	0.5	0	0.5	0	0	0	0	0	0	0	0	0	0.8	48	3	YES	L	$720,000	$21,600
9_FM3	3	0.5	0	0.5	0	0	0	0	0	0	0	0	0	0.8	48	3	YES	L	$2,940,000	$88,200
14_EM6	-1	1	1	2	3	5	5	0	-3	1	0	0	1	0.4	50	4	NO		$0	$0
1_PM6	0	0	2	1	1	2	2	0	0	1	0	0	0	0.0	51	4	NO		$0	$0
5_FM3	1	0	0	0.5	0	0	0	0	0	0	0	0	0	-0.5	52	3	NO		$0	$0
12_FM5	2	0	0	0	0	0	0	0	-1	0	0	-3	0	-1.0	53	3	NO		$0	$0
13_EM5	0	0	0	0	0	0	0	0	0	0	0	0	0	-1.0	53	4	NO		$0	$0
15_FM3	1	0	0	0	0	0	0	0	0	0	0	0	0	-1.0	53	3	NO		$0	$0
7_FM3	1	0	0	0	0	0	0	0	0	0	0	0	0	-1.0	53	3	NO		$0	$0
8_FM3	2	0	0	0	0	0	0	0	0	0	0	0	0	-1.0	53	2	NO		$0	$0
14_FM3	1	0.5	0	0.5	0	0	0	0	0	0	0	0	0	-1.3	58	5	NO		$0	$0
10_FM5	2	0	0	0	0	0	0	0	-1	0	0	-3	0	-2.0	59	3	NO		$0	$0
4_FM1b	-3	3	3	3	3	4	4	0	0	1	-3	-1	-4	-2.0	59	3	NO		$0	$0
11_FM5	2	0	0	0	0	0	0	0	-2	0	0	-3	0	-2.5	61	4	NO		$0	$0
15_FM5	2	0	0	0	0	0	0	0	-2	0	0	-3	0	-2.5	61	4	NO		$0	$0

Option ID	M'ment Area	Category of Measure	Location	Option Description	Action Timeline	Estimate of Capital Cost	Estimate of Recurrent Cost	Total Cost (2014)	Net Present Value (7%, 90 years, i.e. 2100)	Change in 2014 AAD if option implemented	Change in NPV AAD* if option implemented	Benefit - Cost Ratio (2014)	Benefit - Cost Ratio (NPV)	Score on Change in AAD^	Affordability
2_FM5	2	Flood Modification	Gosford	Undertake a program of seawall maintenance and raising along the Gosford foreshore.	Staged	$538,255	$5,383	$543,638	$615,060	#N/A	#N/A	N/A	N/A	0	-2
5_FM5	5	Flood Modification	Yattalunga and Saratoga	Undertake a program of seawall maintenance and raising along the Davistown foreshore.	Staged	$747,830	$7,478	$755,308	$854,540	#N/A	#N/A	N/A	N/A	0	-2
6_FM5	6	Flood Modification	Davistown	Undertake a program of seawall maintenance	Staged	$573,945	$5,739	$579,684	$655,843	#N/A	#N/A	N/A	N/A	0	-2
2_FM3	2	Flood Modification	Gosford	Modify the existing foreshore at Gosford in areas most affected by wave runup to incorporate wave energy dissipating designs.	Staged	$240,000	$7,200	$247,200	$342,739	#N/A	#N/A	N/A	N/A	0	-1
2_FM9	2	Flood Modification	Gosford	Raise areas in Gosford that fall under the boundary of the Gosford City Masterplan and are at risk of coastal flooding.	Trigger	$42,026,970	$0	$42,026,970	$42,026,970	#N/A	#N/A	N/A	N/A	2	-4
8_FM5	8	Flood Modification	Empire Bay	Undertake a program of seawall maintenance and raising along the Empire Bay foreshore.	Staged	$525,805	$5,258	$531,063	$600,833	#N/A	#N/A	N/A	N/A	0	-2
9_FM5	9	Flood Modification	St Huberts Island	Undertake a program of seawall maintenance and raising along the St Huberts Island foreshore.	Staged	$3,244,055	$32,441	$3,276,496	$3,706,957	#N/A	#N/A	N/A	N/A	0	-3
15_FM6b	15	Flood Modification	Horsfield Bay, Phegans Bay and Woy Woy Bay	Construct a levee (0.2km) around low-lying areas to above the 5 year ARI level.	Staged	$2,890,000	$57,800	$2,947,800	$3,714,763	-$27,917	-$1,393,949	0.009	0.38	1	-3
13_FM5	13	Flood Modification	Booker Bay	Undertake a program of seawall maintenance and raising along the foreshore.	Staged	$968,195	$9,682	$977,877	$1,106,349	#N/A	#N/A	N/A	N/A	0	-3
2_FM1b	2	Flood Modification	Gosford	Raise only the Central Coast Highway, Gosford above the 100 year ARI +0.9 m level.	Staged	$4,650,000	$93,000	$4,743,000	$5,977,040	#N/A	#N/A	N/A	N/A	0	-3
3_FM5	3	Flood Modification	Point Frederick, East Gosford, Green Point, Koolewong, Tascott and Point Clare	Undertake a program of seawall maintenance and raising along the foreshore.	Staged	$3,259,410	$32,594	$3,292,004	$3,724,503	#N/A	#N/A	N/A	N/A	0	-3
3_FM6b	3	Flood Modification	Point Frederick, East Gosford, Green Point, Koolewong, Tascott and Point Clare	Construct levees (10.6km) around affected areas to above the 5 year ARI level.	Staged	$18,020,000	$360,400	$18,380,400	$23,162,638	-$237,709	-$6,906,594	0.013	0.30	2	-4
13_FM6b	13	Flood Modification	Booker Bay	Construct a levee (1.9km) around Booker Bay to above the 5 year ARI level.	Staged	$3,230,000	$64,600	$3,294,600	$4,151,794	-$99,688	-$3,760,421	0.030	0.91	2	-3
8_FM6b	8	Flood Modification	Empire Bay	Construct a levee (3.6km) around Empire Bay to above the 5 year ARI level.	Staged	$6,120,000	$122,400	$6,242,400	$7,866,556	-$226,667	-$7,821,439	0.036	0.99	3	-3
3_FM6a	3	Flood Modification	Point Frederick, East Gosford, Green Point, Koolewong, Tascott and Point Clare	Construct levees (10.6km) around affected areas to above the PMF level.	Staged	$37,100,000	$742,000	$37,842,000	$47,687,784	-$1,432,824	-$24,013,325	0.038	0.50	4	-4
14_FM5	14	Flood Modification	Woy Woy and Blackwall	Undertake a program of seawall maintenance and raising along the Woy Woy foreshore.	Staged	$2,103,635	$21,036	$2,124,671	$2,403,808	#N/A	#N/A	N/A	N/A	0	-3
15_FM1a	15	Flood Modification	Horsfield Bay, Phegans Bay and Woy Woy Bay	Raise all flood-affected roads to above the 100 year ARI +0.9 m level.	Staged	$3,549,200	$70,984	$3,620,184	$4,562,088	#N/A	#N/A	N/A	N/A	0	-3
7_FM6b	7	Flood Modification	Kincumber, Kincumber South and Bensville	Construct a levee (3km) around low-lying areas to above the 5 year ARI level.	Staged	$5,100,000	$102,000	$5,202,000	$6,555,464	-$16,875	-$257,235	0.003	0.04	0	-3
7_FM9	7	Flood Modification	Kincumber, Kincumber South and Bensville	Raise land areas at risk of coastal flooding in Kincumber and Bensville.	Trigger	$64,773,555	$0	$64,773,555	$64,773,555	#N/A	#N/A	N/A	N/A	4	-4
11_FM1a	11	Flood Modification	Pretty Beach and Wagstaffe	Raise all flood-affected roads above the 100 year ARI +0.9 m level.	Staged	$4,393,400	$87,868	$4,481,268	$5,647,211	#N/A	#N/A	N/A	N/A	0	-3
1_FM6b	1	Flood Modification	West Gosford and Point Clare	Construct a levee (3.2km) around West Gosford/Point Clare to the 5 year ARI level.	Staged	$5,440,000	$108,800	$5,548,800	$6,992,494	-$25,157	-$2,588,773	0.005	0.37	1	-3
10_FM6b	10	Flood Modification	Daleys Point, Killcare and Hardys Bay	Construct a levee (1.1km) around affected areas to above the 5 year ARI level.	Staged	$1,870,000	$37,400	$1,907,400	$2,403,670	$0	-$105,689	0.000	0.04	0	-3
PM12	Various	Flood Modification	Floodplain-wide	Implement managed retreat in critical areas to avoid the impacts of projected sea level rise.	Trigger	$1,301,405,000	$0	$1,301,405,000	$1,301,405,000	-$3,950,403	-$60,217,034	0.003	0.05	5	-5
6_FM6b	6	Flood Modification	Davistown	Construct a levee (6.4km) around Davistown to the 5 year ARI	Staged	$10,880,000	$217,600	$11,097,600	$13,984,989	-$1,297,712	-$19,781,361	0.117	1.41	4	-4
10_FM1a	10	Flood Modification	Daleys Point, Killcare and Hardys Bay	Raise all flood-affected roads above the 100 year ARI +0.9 m level.	Staged	$7,107,800	$142,156	$7,249,956	$9,136,260	#N/A	#N/A	N/A	N/A	0	-3
2_FM1a	2	Flood Modification	Gosford	Raise all flood-affected roads in Gosford to above the 100 year ARI +0.9 m level.	Staged	$13,209,525	$264,191	$13,473,716	$16,979,325	#N/A	#N/A	N/A	N/A	0	-4
3_FM1a	3	Flood Modification	Point Frederick, East Gosford, Green Point, Koolewong, Tascott and Point Clare	Raise all flood-affected roads above the 100 year ARI +0.9 m level.	Staged	$29,628,900	$592,578	$30,221,478	$38,084,544	#N/A	#N/A	N/A	N/A	0	-4
5_FM1a	5	Flood Modification	Yattalunga and Saratoga	Raise all flood-affected roads in Saratoga and Yattalunga above the 100 year ARI +0.9 m level.	Staged	$6,823,650	$136,473	$6,960,123	$8,771,017	#N/A	#N/A	N/A	N/A	0	-3
5_FM6b	5	Flood Modification	Yattalunga and Saratoga	Construct a levee (3.6km) around low-lying areas to above the 5 year ARI level.	Staged	$6,120,000	$122,400	$6,242,400	$7,866,556	-$77,605	-$3,291,842	0.012	0.42	2	-3
7_FM1a	7	Flood Modification	Kincumber, Kincumber South and Bensville	Raise all flood-affected roads in Kincumber and Bensville above the 100 year ARI +0.9 m level.	Staged	$4,076,600	$81,532	$4,158,132	$5,240,001	#N/A	#N/A	N/A	N/A	0	-3
12_FM6b	12	Flood Modification	Ettalong	Construct a levee (0.9km) around Ettalong to above the 5 year ARI level.	Staged	$1,530,000	$30,600	$1,560,600	$1,966,639	-$44,480	-$502,681	0.029	0.26	0	-3
6_FM9	6	Flood Modification	Davistown	Raise land affected by coastal flooding.	Trigger	$338,374,605	$0	$338,374,605	$338,374,605	-$2,352,595	-$35,861,224	0.007	0.11	5	-5
15_FM1b	15	Flood Modification	Horsfield Bay, Phegans Bay and Woy Woy Bay	Raise only Brisbane Water Drive above the 100 year ARI +0.9 m level.	Staged	$3,529,350	$70,587	$3,599,937	$4,536,574	#N/A	#N/A	N/A	N/A	0	-3
12_FM6a	12	Flood Modification	Ettalong	Construct a levee (0.9km) around Ettalong to above the PMF level.	Staged	$3,150,000	$63,000	$3,213,000	$4,048,963	-$63,216	-$3,514,672	0.020	0.87	2	-3
13_FM6a	13	Flood Modification	Booker Bay	Construct a levee (1.9km) around Booker Bay to above the PMF level.	Staged	$6,650,000	$133,000	$6,783,000	$8,547,810	-$393,627	-$7,823,053	0.058	0.92	3	-3
1_FM7a	1	Flood Modification	West Gosford and Point Clare	Increase the size of the opening under the rail bridge linking Point Clare and Gosford (Fagans Bay).	Staged	$10,000,000	$500,000	$10,500,000	$17,134,625	$22,294	$339,832	-0.002	-0.02	-1	-4
DN	Various	Do Nothing	Floodplain-wide	Do nothing. No management options are implemented.	N/A	$0	$0	$0	$0	#N/A	#N/A	N/A	N/A	0	5
14_FM9	14	Flood Modification	Woy Woy and Blackwall	Raise land areas within Woy Woy at risk of coastal flooding.	Trigger	$342,921,015	$0	$342,921,015	$342,921,015	-$1,204,955	-$18,367,451	0.004	0.05	4	-5
9_FM9	9	Flood Modification	St Huberts Island	Raise land areas at risk of coastal flooding on St Huberts Island.	Trigger	$168,673,905	$0	$168,673,905	$168,673,905	#N/A	#N/A	N/A	N/A	3	-5
10_FM9	10	Flood Modification	Daleys Point, Killcare and Hardys Bay	Raise land areas within Killcare and Hardys Bay most at risk of coastal flooding.	Trigger	$67,740,105	$0	$67,740,105	$67,740,105	#N/A	#N/A	N/A	N/A	2	-4
12_FM9	12	Flood Modification	Ettalong	Raise areas within Ettalong at risk of coastal flooding.	Trigger	$35,546,760	$0	$35,546,760	$35,546,760	#N/A	#N/A	N/A	N/A	2	-4

Option ID	Feasibility	Protection of Public Infrastructure (2009 PMF)	Protection of Public Infrastructure (2100 PMF)	Reduction in Risk to Life (2009 PMF)	Reduction in Risk to Life (2100 PMF)	Emergency Access (2009 PMF)	Emergency Access (2100 PMF)	Water Quality	Habitat (Including Future Intertidal Habitat)	Sea Level Rise	Catchment Flooding	Compatibility with other Policies and Plans	Likely Community Acceptance	TOTAL SCORE	RANK on TOTAL SCORE (Whole Floodplain)	RANK on TOTAL SCORE (per MA)	To be included in FRMP?	Priority	Capital Cost	Recurrent Cost
2_FM5	2	0	0	0	0	0	0	0	-2	0	0	-3	0	**-2.5**	**61**	**3**	NO		$0	$0
5_FM5	2	0	0	0	0	0	0	0	-2	0	0	-3	0	**-2.5**	**61**	**4**	NO		$0	$0
6_FM5	2	0	0	0	0	0	0	0	-2	0	0	-3	0	**-2.5**	**61**	**2**	NO		$0	$0
2_FM3	-2	0.5	0.5	0	0	0	0	0	0	0	0	0	0	**-2.7**	**66**	**4**	NO		$0	$0
2_FM9	-3	4	4	3	3	3	3	0	-2	1	-3	-2	-5	**-3.0**	**67**	**5**	NO		$0	$0
8_FM5	2	0	0	0	0	0	0	0	-3	0	0	-3	0	**-3.0**	**67**	**3**	NO		$0	$0
9_FM5	2	0	0	0	0	0	0	0	-1	0	0	-3	0	**-3.0**	**67**	**4**	NO		$0	$0
15_FM6b	-3	0	3	3	1	3	3	0	-1	1	-1	-3	-3	**-3.3**	**70**	**5**	NO		$0	$0
13_FM5	2	0	0	0	0	0	0	0	-2	0	0	-3	0	**-3.5**	**71**	**5**	NO		$0	$0
2_FM1b	-5	3	3	4	4	3	3	0	0	1	-3	-1	-4	**-3.5**	**71**	**6**	NO		$0	$0
3_FM5	2	0	0	0	0	0	0	0	-2	0	0	-3	0	**-3.5**	**71**	**4**	NO		$0	$0
3_FM6b	-4	2	3	3	1	3	3	0	-1	1.5	-2	-3	-3	**-3.6**	**74**	**5**	NO		$0	$0
13_FM6b	-3	0	3	3	1	3	3	0	-1	1.5	-4	-3	-3	**-3.6**	**75**	**6**	NO		$0	$0
8_FM6b	-3	2	3	1.5	0.5	3	3	0	-3.5	2	-3	-3	-3	**-3.6**	**76**	**4**	NO		$0	$0
3_FM6a	-4	5	5	-1	-1.5	5	5	0	-1	1.5	-2	-4	-4	**-3.9**	**77**	**6**	NO		$0	$0
14_FM5	2	0	0	0	0	0	0	0	-3	0	0	-3	0	**-4.0**	**78**	**6**	NO		$0	$0
15_FM1a	-5	3	3	2	2	5	5	0	0	1	-2	-1	-4	**-4.0**	**78**	**6**	NO		$0	$0
7_FM6b	-3	2	3	3	1	3	3	0	-1	1	-2.5	-3	-3	**-4.1**	**80**	**4**	NO		$0	$0
7_FM9	-5	3	3	3.5	3.5	3	3	0	-4	1	-3	-2	-5	**-4.1**	**80**	**4**	NO		$0	$0
11_FM1a	-5	3	3	2	2	5	5	0	-0.5	1	-2	-1	-4	**-4.3**	**82**	**5**	NO		$0	$0
1_FM6b	-4	2	3	3	1	3	3	0	-1	1	-3	-3	-3	**-4.3**	**83**	**5**	NO		$0	$0
10_FM6b	-3	0	3	3	1	3	3	0	-1	1	-1	-3	-3	**-4.3**	**83**	**4**	NO		$0	$0
PM12	-5	2	2	2	2	2	2	0	0	2	0	-5	-5	**-4.4**	**85**	**16**	NO		$0	$0
6_FM6b	-3	2	2	1.5	0.5	3	3	0	-5	3	-4	-3	-3	**-4.5**	**86**	**3**	NO		$0	$0
10_FM1a	-5	3	3	2	2	5	5	0	-1	1	-2	-1	-4	**-4.5**	**87**	**5**	NO		$0	$0
2_FM1a	-5	3	3	2	2	5	5	0	-1	3	-2	-1	-4	**-4.5**	**87**	**7**	NO		$0	$0
3_FM1a	-5	3	3	2	2	5	5	0	-1	3	-2	-1	-4	**-4.5**	**87**	**7**	NO		$0	$0
5_FM1a	-5	3	3	2	2	5	5	0	-1	1	-2	-1	-4	**-4.5**	**87**	**5**	NO		$0	$0
5_FM6b	-3	0	3	3	1	1	1	0	-1	1	-3	-3	-3	**-4.5**	**87**	**5**	NO		$0	$0
7_FM1a	-5	3	3	2	2	5	5	0	-1	1	-2	-1	-4	**-4.5**	**87**	**6**	NO		$0	$0
12_FM6b	-3	0	3	3	1	3	3	0	-0.5	1	-2	-3	-3	**-4.6**	**93**	**4**	NO		$0	$0
6_FM9	-5	3	3	3.5	3.5	3	3	0	-5	1	-3	-2	-5	**-4.6**	**93**	**4**	NO		$0	$0
15_FM1b	-5	3	3	3	3	3	3	0	0	0.5	-3	-1	-4	**-4.9**	**95**	**7**	NO		$0	$0
12_FM6a	-4	5	5	-1	-1.5	5	5	0	-0.5	1	-2	-4	-4	**-4.9**	**96**	**5**	NO		$0	$0
13_FM6a	-4	5	5	-1	-1.5	5	5	0	-1	1.5	-4	-4	-4	**-4.9**	**96**	**7**	NO		$0	$0
1_FM7a	-3	0	0	0	0	0	0	3	0	-1	2	2	0	**-5.0**	**98**	**6**	NO		$0	$0
DN	-5	0	0	0	0	0	0	0	0	0	0	-5	-5	**-5.0**	**98**	**17**	NO		$0	$0
14_FM9	-5	3	3	3.5	3.5	3	3	0	-4	1	-3	-2	-5	**-5.1**	**100**	**7**	NO		$0	$0
9_FM9	-5	3	3	3.5	3.5	3	3	0	-2	1	-3	-2	-5	**-5.1**	**100**	**5**	NO		$0	$0
10_FM9	-5	3	3	3	3	3	3	0	-1	1	-3	-2	-5	**-5.1**	**102**	**6**	NO		$0	$0
12_FM9	-5	3	3	3	3	3	3	0	-1	1	-3	-2	-5	**-5.1**	**102**	**6**	NO		$0	$0

Option ID	M'ment Area	Category of Measure	Location	Option Description	Action Timeline	Estimate of Capital Cost	Estimate of Recurrent Cost	Total Cost (2014)	Net Present Value (7%, 90 years, i.e. 2100)	Change in 2014 AAD if option implemented	Change in NPV AAD* if option implemented	Benefit - Cost Ratio (2014)	Benefit - Cost Ratio (NPV)	Score on Change in AAD^	Affordability
3_FM9	3	Flood Modification	Point Frederick, East Gosford, Green Point, Koolewong, Tascott and Point Clare	Raise land areas affected by coastal flooding.	Trigger	$260,994,045	$0	$260,994,045	$260,994,045	#N/A	#N/A	N/A	N/A	4	-5
11_FM1b	11	Flood Modification	Pretty Beach and Wagstaffe	Raise only Pretty Beach Road above the 100 year ARI +0.9 m level.	Staged	$3,708,375	$74,168	$3,782,543	$4,766,690	#N/A	#N/A	N/A	N/A	0	-3
9_FM1a	9	Flood Modification	St Huberts Island	Raise all flood-affected roads on St Huberts Island above the 100 year ARI +0.9 m level.	Staged	$18,209,700	$364,194	$18,573,894	$23,406,475	#N/A	#N/A	N/A	N/A	0	-4
14_FM1a	14	Flood Modification	Woy Woy and Blackwall	Raise all flood-affected roads in Woy Woy to above the 100 year ARI +0.9 m level.	Staged	$31,644,200	$632,884	$32,277,084	$40,674,980	#N/A	#N/A	N/A	N/A	0	-4
6_FM1a	6	Flood Modification	Davistown	Raise all affected roads in Davistown above the 100 year ARI +0.9 m level.	Staged	$71,002,050	$1,420,041	$72,422,091	$91,264,971	#N/A	#N/A	N/A	N/A	0	-4
8_FM1a	8	Flood Modification	Empire Bay	Raise all flood-affected roads within Empire Bay above the 100 year ARI +0.9 m level.	Staged	$15,794,000	$315,880	$16,109,880	$20,301,371	#N/A	#N/A	N/A	N/A	0	-4
11_FM6b	11	Flood Modification	Pretty Beach and Wagstaffe	Construct a levee (1.8km) around Pretty Beach and Wagstaffe to above the 5 year ARI level.	Staged	$3,060,000	$61,200	$3,121,200	$3,933,278	-$30,677	-$122,091	0.010	0.03	0	-3
2_FM6b	2	Flood Modification	Gosford	Construct a levee (1.5km) around Gosford to the 5 year ARI level.	Staged	$2,550,000	$51,000	$2,601,000	$3,277,732	-$44,480	-$233,658	0.017	0.07	0	-3
9_FM6b	9	Flood Modification	St Huberts Island	Construct a levee (8km) around St Huberts Island to above the 5 year ARI level.	Staged	$13,600,000	$272,000	$13,872,000	$17,481,236	-$19,636	-$6,371,075	0.001	0.36	2	-4
14_FM6b	14	Flood Modification	Woy Woy and Blackwall	Construct a levee (8.2km) around Woy Woy to above the 5 year ARI level.	Staged	$13,940,000	$278,800	$14,218,800	$17,918,267	-$2,216,933	-$22,101,943	0.156	1.23	4	-4
4_FM9	4	Flood Modification	Erina	Raise land areas affected by coastal flooding.	Trigger	$6,686,865	$0	$6,686,865	$6,686,865	#N/A	#N/A	N/A	N/A	3	-3
12_FM1b	12	Flood Modification	Ettalong	Raise only The Esplanade, Bangalow Street and Beach Street above the 100 year ARI +0.9 m level.	Staged	$5,191,725	$103,835	$5,295,560	$6,673,366	#N/A	#N/A	N/A	N/A	0	-3
6_FM1b	6	Flood Modification	Davistown	Raise only Davistown Road and Mallinya Road above the 100 year ARI +0.9 m level.	Staged	$12,224,850	$244,497	$12,469,347	$15,713,639	#N/A	#N/A	N/A	N/A	0	-4
13_FM1a	13	Flood Modification	Booker Bay	Raise all flood-affected roads in Booker Bay to above the 100 year ARI +0.9 m level.	Staged	$8,861,150	$177,223	$9,038,373	$11,389,989	#N/A	#N/A	N/A	N/A	0	-4
14_FM1b	14	Flood Modification	Woy Woy and Blackwall	Raise only Woy Woy Road, Blackwall Road, The Boulevarde, Brick Wharf Road, Railway Street, North Burge Road, Park Road, Norma Crescent, Sonter Avenue and Brisbane Water Drive/Railway Street above the 100 year ARI +0.9 m level.	Staged	$22,685,025	$453,701	$23,138,726	$29,158,991	#N/A	#N/A	N/A	N/A	0	-4
FM2a	Various	Flood Modification	Floodplain-wide	Construct a storm surge barrier at the entrance to BW (Half Tide Rocks) that could be activated during severe offshore storm surge events.	Trigger	$2,356,889,494	$1,414,134	$2,358,303,628	$2,377,068,123	-$3,324,339	-$50,673,765	0.001	0.02	5	-5
1_FM9	1	Flood Modification	West Gosford and Point Clare	Raise land areas affected by coastal flooding.	Trigger	$110,493,870	$0	$110,493,870	$110,493,870	#N/A	#N/A	N/A	N/A	4	-5
5_FM9	5	Flood Modification	Yattalunga and Saratoga	Raise land areas at risk of coastal flooding.	Trigger	$114,420,315	$0	$114,420,315	$114,420,315	#N/A	#N/A	N/A	N/A	3	-5
FM10	Various	Flood Modification	Floodplain-wide	Raise railway infrastructure to above the 100 Year ARI flood level (with 0.9m SLR).	Trigger	$24,767,900	$495,358	$25,263,258	$31,836,287	#N/A	#N/A	N/A	N/A	0	-4
8_FM1b	8	Flood Modification	Empire Bay	Raise only Greenfield Road and Rickard Road above the 100 year ARI +0.9 m level.	Staged	$5,779,950	$115,599	$5,895,549	$7,429,461	#N/A	#N/A	N/A	N/A	0	-3
10_FM6a	10	Flood Modification	Daleys Point, Killcare and Hardys Bay	Construct a levee (1.1km) around affected areas to above the PMF level.	Staged	$3,850,000	$77,000	$3,927,000	$4,948,732	-$45,353	-$1,836,919	0.012	0.37	1	-3
15_FM6a	15	Flood Modification	Horsfield Bay, Phegans Bay and Woy Woy Bay	Construct a levee (0.2km) around low-lying areas to above the PMF level.	Staged	$5,950,000	$119,000	$6,069,000	$7,648,041	-$49,893	-$2,743,706	0.008	0.36	1	-3
10_FM1b	10	Flood Modification	Daleys Point, Killcare and Hardys Bay	Raise only Araluen Drive above the 100 year ARI +0.9 m level.	Staged	$2,710,950	$54,219	$2,765,169	$3,484,615	#N/A	#N/A	N/A	N/A	0	-3
13_FM1b	13	Flood Modification	Booker Bay	Raise only portions of Bogan Road and Booker Bay Road above the 100 year ARI +0.9 m level.	Staged	$4,603,500	$92,070	$4,695,570	$5,917,270	#N/A	#N/A	N/A	N/A	0	-3
1_FM1b	1	Flood Modification	West Gosford and Point Clare	Raise only the Central Coast Highway, Brisbane Water Drive, Coolarn Avenue, Manooka Road and Yallambee Avenue to above the 100 year ARI +0.9 m level.	Staged	$15,933,225	$318,665	$16,251,890	$20,480,329	#N/A	#N/A	N/A	N/A	0	-4
3_FM1b	3	Flood Modification	Point Frederick, East Gosford, Green Point, Koolewong, Tascott and Point Clare	Raise only Brisbane Water Drive above the 100 year ARI +0.9 m level.	Staged	$18,772,050	$375,441	$19,147,491	$24,129,312	#N/A	#N/A	N/A	N/A	0	-4
9_FM6a	9	Flood Modification	St Huberts Island	Construct a levee (8km) around St Huberts Island to above the PMF level.	Staged	$28,000,000	$560,000	$28,560,000	$35,990,780	-$1,035,797	-$15,623,408	0.036	0.43	4	-4
FM2b	Various	Flood Modification	Floodplain-wide	Construct a storm surge barrier at The Rip that could be activated during severe offshore storm surge events.	Trigger	$1,767,667,121	$1,060,600	$1,768,727,721	$1,782,801,092	#N/A	#N/A	N/A	N/A	5	-5
4_FM6b	4	Flood Modification	Erina	Construct a levee (1.3km) around around the low-lying industrial area at Erina to above the 5 year ARI level.	Staged	$2,210,000	$44,200	$2,254,200	$2,840,701	-$19,636	-$69,697	0.009	0.02	0	-3
11_FM9	11	Flood Modification	Pretty Beach and Wagstaffe	Raise land areas within Pretty Beach and Wagstaffe at risk of coastal flooding.	Trigger	$43,740,105	$0	$43,740,105	$43,740,105	#N/A	#N/A	N/A	N/A	1	-4
5_FM1b	5	Flood Modification	Yattalunga and Saratoga	Raise only Davistown Road, Yattalunga above the 100 year ARI +0.9 m level.	Staged	$1,815,825	$36,317	$1,852,142	$2,334,034	#N/A	#N/A	N/A	N/A	0	-3
15_FM9	15	Flood Modification	Horsfield Bay, Phegans Bay and Woy Woy Bay	Raise land areas within Horsfield Bay, Phegans Bay and Woy Woy Bay at risk of coastal flooding.	Trigger	$44,060,070	$0	$44,060,070	$44,060,070	#N/A	#N/A	N/A	N/A	2	-4
11_FM6a	11	Flood Modification	Pretty Beach and Wagstaffe	Construct a levee (1.8km) around Pretty Beach and Wagstaffe to above the PMF level.	Staged	$6,300,000	$126,000	$6,426,000	$8,097,926	-$73,874	-$2,108,794	0.011	0.26	1	-3
2_FM6a	2	Flood Modification	Gosford	Construct a levee (1.5km) around Gosford above the PMF level.	Staged	$5,250,000	$105,000	$5,355,000	$6,748,271	-$9,924	-$3,106,514	0.002	0.46	2	-3
1_FM1a	1	Flood Modification	West Gosford and Point Clare	Raise all flood-affected roads in Point Clare and West Gosford to above the 100 year ARI +0.9 m level.	Staged	$18,439,800	$368,796	$18,808,596	$23,702,243	#N/A	#N/A	N/A	N/A	0	-4
8_FM9	8	Flood Modification	Empire Bay	Raise land areas at risk of coastal flooding within Empire Bay.	Trigger	$166,913,835	$0	$166,913,835	$166,913,835	-$392,853	-$5,988,359	0.002	0.04	2	-5
13_FM9	13	Flood Modification	Booker Bay	Raise land areas within Booker Bay at risk of coastal flooding.	Trigger	$116,800,350	$0	$116,800,350	$116,800,350	#N/A	#N/A	N/A	N/A	2	-5
1_FM6a	1	Flood Modification	West Gosford and Point Clare	Construct a levee (3.2km) around West Gosford/Point Clare above the PMF level.	Staged	$11,200,000	$224,000	$11,424,000	$14,396,312	-$454,913	-$6,494,453	0.040	0.45	2	-4
4_FM6a	4	Flood Modification	Erina	Construct a levee (1.3km) around the low-lying industrial area at Erina to above the PMF level.	Staged	$4,550,000	$91,000	$4,641,000	$5,848,502	-$35,853	-$1,619,023	0.008	0.28	1	-3
14_FM6a	14	Flood Modification	Woy Woy and Blackwall	Construct a levee (8.2km) around Woy Woy to above the PMF level.	Staged	$28,700,000	$574,000	$29,274,000	$36,890,550	-$319,018	-$25,283,150	0.011	0.69	4	-4
6_FM6a	6	Flood Modification	Davistown	Construct a levee (6.4km) around Davistown above the PMF level	Staged	$22,400,000	$448,000	$22,848,000	$28,792,624	-$2,405,405	-$36,666,227	0.105	1.27	5	-4

Option ID	Feasibility	Protection of Public Infrastructure (2009 PMF)	Protection of Public Infrastructure (2100 PMF)	Reduction in Risk to Life (2009 PMF)	Reduction in Risk to Life (2100 PMF)	Emergency Access (2009 PMF)	Emergency Access (2100 PMF)	Water Quality	Habitat (Including Future Intertidal Habitat)	Sea Level Rise	Catchment Flooding	Compatibility with other Policies and Plans	Likely Community Acceptance	TOTAL SCORE	RANK on TOTAL SCORE (Whole Floodplain)	RANK on TOTAL SCORE (per MA)	To be included in FRMP?	Priority	Capital Cost	Recurrent Cost
3_FM9	-5	3	3	3	3	3	3	0	-3	1	-3	-2	-5	**-5.1**	**102**	**8**	NO		$0	$0
11_FM1b	-5	3	3	3	3	3	3	0	-1	1	-3	-1	-4	**-5.1**	**105**	**6**	NO		$0	$0
9_FM1a	-5	1	3	2	2	5	5	0	-0.5	3	-2	-1	-4	**-5.3**	**106**	**6**	NO		$0	$0
14_FM1a	-5	3	3	2	2	5	5	0	-2.5	3	-2	-1	-4	**-5.3**	**107**	**8**	NO		$0	$0
6_FM1a	-5	3	3	2	2	5	5	0	-2.5	3	-2	-1	-4	**-5.3**	**107**	**5**	NO		$0	$0
8_FM1a	-5	3	3	2	2	5	5	0	-2.5	3	-2	-1	-4	**-5.3**	**107**	**5**	NO		$0	$0
11_FM6b	-3	0	3	3	1	3	3	0	-1	1	-3	-3	-3	**-5.3**	**110**	**7**	NO		$0	$0
2_FM6b	-3	2	3	3	1	3	3	0	-1	1	-5	-3	-3	**-5.3**	**110**	**8**	NO		$0	$0
9_FM6b	-3	0	3	3	1	3	3	0	-1	1	-5	-3	-3	**-5.3**	**110**	**7**	NO		$0	$0
14_FM6b	-4	2	3	1	0.5	3	3	0	-3.5	2.5	-4	-3	-3	**-5.4**	**113**	**9**	NO		$0	$0
4_FM9	-5	5	2	1.5	1.5	3	3	0	-4	1	-3	-2	-5	**-5.4**	**113**	**4**	NO		$0	$0
12_FM1b	-5	2	3	3	3	3	3	0	0	0.5	-3	-1	-4	**-5.4**	**115**	**7**	NO		$0	$0
6_FM1b	-5	3	3	3	3	3	3	0	0	1.5	-3	-1	-4	**-5.4**	**115**	**6**	NO		$0	$0
13_FM1a	-5	3	3	2	2	5	5	0	-1	1	-2	-1	-4	**-5.5**	**117**	**8**	NO		$0	$0
14_FM1b	-5	3	3	4	4	3	3	0	-3	2	-3	-1	-4	**-5.5**	**117**	**10**	NO		$0	$0
FM2a	-5	5	5	5	5	0	0	-4	-4	2	-4	-5	-3	**-5.5**	**117**	**18**	NO		$0	$0
1_FM9	-5	3	3	3	3	3	3	0	-4	1	-3	-2	-5	**-5.6**	**120**	**7**	NO		$0	$0
5_FM9	-5	3	3	3	3	3	3	0	-2	1	-3	-2	-5	**-5.6**	**120**	**7**	NO		$0	$0
FM10	-5	0	5	0	1	0	3	0	0	5	0	0	0	**-5.6**	**120**	**19**	NO		$0	$0
8_FM1b	-5	3	3	3	3	3	3	0	-1.5	0.5	-3	-1	-4	**-5.6**	**123**	**6**	NO		$0	$0
10_FM6a	-4	5	5	-1	-1.5	5	5	0	-1	1	-1	-4	-4	**-5.7**	**124**	**7**	NO		$0	$0
15_FM6a	-4	5	5	-1	-1.5	5	5	0	-1	1	-1	-4	-4	**-5.7**	**124**	**8**	NO		$0	$0
10_FM1b	-5	3	3	2	2	3	3	0	0	1	-3	-1	-4	**-5.7**	**126**	**8**	NO		$0	$0
13_FM1b	-5	3	3	2	2	3	3	0	0	1	-3	-1	-4	**-5.7**	**126**	**9**	NO		$0	$0
1_FM1b	-5	3	3	3	3	3	3	0	-0.5	1	-3	-1	-4	**-5.9**	**128**	**8**	NO		$0	$0
3_FM1b	-5	3	3	3	3	3	3	0	0	0.5	-3	-1	-4	**-5.9**	**128**	**9**	NO		$0	$0
9_FM6a	-4	5	5	-1	-4	5	5	0	-1	1	-5	-4	-4	**-5.9**	**130**	**8**	NO		$0	$0
FM2b	-5	4	4	4	4	0	0	-4	-3	2	-1.5	-5	-4	**-6.0**	**131**	**20**	NO		$0	$0
4_FM6b	-3	2	3	2	1	3	3	0	-1	1	-4.5	-3	-3	**-6.1**	**132**	**5**	NO		$0	$0
11_FM9	-5	3	3	3	3	3	3	0	-1	1	-3	-2	-5	**-6.1**	**133**	**8**	NO		$0	$0
5_FM1b	-5	0	5	3	3	3	3	0	0	0.5	-3	-1	-4	**-6.2**	**134**	**8**	NO		$0	$0
15_FM9	-5	3	3	3	3	3	3	0	-4	1	-3	-2	-5	**-6.6**	**135**	**9**	NO		$0	$0
11_FM6a	-4	5	5	-1	-1.5	5	5	0	-1	1	-3	-4	-4	**-6.7**	**136**	**9**	NO		$0	$0
2_FM6a	-4	5	5	-1	-1.5	5	5	0	-1	1	-5	-4	-4	**-6.7**	**136**	**9**	NO		$0	$0
1_FM1a	-5	3	3	2	2	3	3	0	-0.5	1	-3	-1	-4	**-7.0**	**138**	**9**	NO		$0	$0
8_FM9	-5	3	3	3.5	3.5	3	3	0	-4	1	-3	-2	-5	**-7.1**	**139**	**7**	NO		$0	$0
13_FM9	-5	3	3	3	3	3	3	0	-3	1	-3	-2	-5	**-7.1**	**140**	**10**	NO		$0	$0
1_FM6a	-4	5	5	-1	-1.5	5	5	0	-1	1	-4	-4	-4	**-7.2**	**141**	**10**	NO		$0	$0
4_FM6a	-4	5	5	-1	-1.5	5	5	0	-1	1	-4.5	-4	-4	**-7.4**	**142**	**6**	NO		$0	$0
14_FM6a	-4	5	5	-3	-4	5	5	0	-3.5	2.5	-4	-4	-4	**-7.9**	**143**	**11**	NO		$0	$0
6_FM6a	-4	5	5	-3	-4	5	5	0	-5	3	-5	-4	-4	**-7.9**	**143**	**7**	NO		$0	$0

Option ID	M'ment Area	Category of Measure	Location	Option Description	Action Timeline	Estimate of Capital Cost	Estimate of Recurrent Cost	Total Cost (2014)	Net Present Value (7%, 90 years, i.e. 2100)	Change in 2014 AAD if option implemented	Change in NPV AAD* if option implemented	Benefit - Cost Ratio (2014)	Benefit - Cost Ratio (NPV)	Score on Change in AAD^	Affordability
9_FM1b	9	Flood Modification	St Huberts Island	Raise only Helmsman Boulevard above the 100 year ARI +0.9 m level.	Staged	$8,030,550	$160,611	$8,191,161	$10,322,349	#N/A	#N/A	N/A	N/A	0	-4
8_FM6a	8	Flood Modification	Empire Bay	Construct a levee (3.6km) around Empire Bay to above the PMF level.	Staged	$12,600,000	$252,000	$12,852,000	$16,195,851	-$838,616	-$13,854,723	0.065	0.86	3	-4
1_FM7b	1	Flood Modification	West Gosford and Point Clare	Install manually-operated floodgates at the openings under the rail bridge linking Point Clare and Gosford (Fagans Bay).	Staged	$18,700,000	$561,000	$19,261,000	$26,705,050	$1,592,449	$24,274,115	-0.083	-0.91	-4	-4
15_FM8	15	Flood Modification	Horsfield Bay, Phegans Bay and Woy Woy Bay	Install manually-operated floodgates at the openings under the rail bridge linking Woy Woy and Koolewong.	Staged	$18,700,000	$561,000	$19,261,000	$26,705,050	$1,035,354	$15,782,180	-0.054	-0.59	-4	-4
5_FM6a	5	Flood Modification	Yattalunga and Saratoga	Construct a levee (3.6km) around low-lying areas to above the PMF level.	Staged	$12,600,000	$252,000	$12,852,000	$16,195,851	-$609,460	-$8,276,562	0.047	0.51	3	-4
7_FM6a	7	Flood Modification	Kincumber, Kincumber South and Bensville	Construct a levee (3km) around low-lying areas to above the PMF level.	Staged	$10,500,000	$210,000	$10,710,000	$13,496,543	-$31,241	-$476,208	0.003	0.04	0	-4

Indicates recommended options
Indicates options not recommended
Indicates detailed economic assessment used (i.e. where options could be hydraulically modelled)
PM11a Indicates options that are not recommended due to mutual exclusivity (e.g. another option that ranked higher).
^ Shown as an assumed score where no BCR exists
result of storm surge,

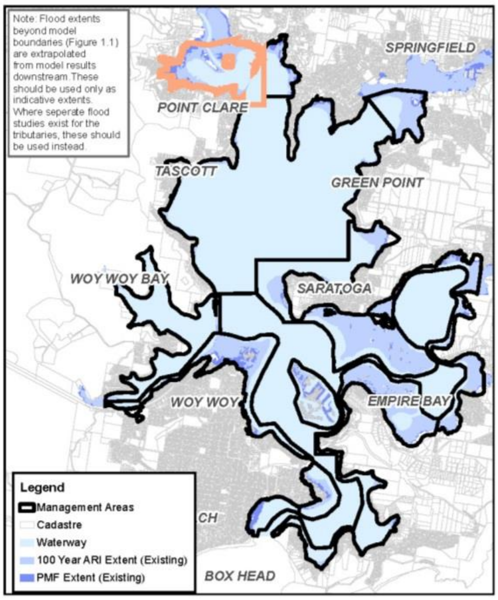
Option ID	Feasibility	Protection of Public Infrastructure (2009 PMF)	Protection of Public Infrastructure (2100 PMF)	Reduction in Risk to Life (2009 PMF)	Reduction in Risk to Life (2100 PMF)	Emergency Access (2009 PMF)	Emergency Access (2100 PMF)	Water Quality	Habitat (Including Future Intertidal Habitat)	Sea Level Rise	Catchment Flooding	Compatibility with other Policies and Plans	Likely Community Acceptance	TOTAL SCORE	RANK on TOTAL SCORE (Whole Floodplain)	RANK on TOTAL SCORE (per MA)	To be included in FRMP?	Priority	Capital Cost	Recurrent Cost
9_FM1b	-5	0	4	2	2	3	3	0	0	1	-3	-1	-4	**-8.1**	**145**	**9**	NO		$0	$0
8_FM6a	-4	5	5	-3	-4	5	5	0	-3.5	2	-3	-4	-4	**-8.7**	**146**	**8**	NO		$0	$0
1_FM7b	-2	0	0	0	0	0	0	-1.5	0	4	-1	-2	0	**-10.3**	**147**	**11**	NO		$0	$0
15_FM8	-2	0	0	0	0	0	0	-1.5	0	4	-1	-2	0	**-10.3**	**147**	**10**	NO		$0	$0
5_FM6a	-4	0	0	-1	-1.5	1	1	0	-1	1	-3	-4	-4	**-11.1**	**149**	**9**	NO		$0	$0
7_FM6a	-4	1	2	-1	-1.5	1	2	0	-1	1	-1	-4	-4	**-12.3**	**150**	**7**	NO		$0	$0

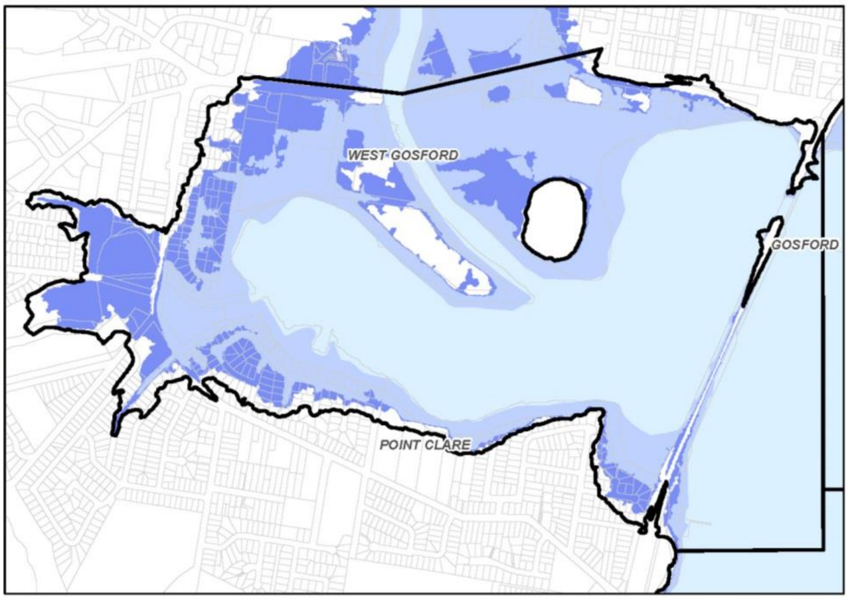
TOTAL COST FOR IMPLEMENTATION $20,913,860 $465,139

Appendix K

Summary of Recommended Management Actions

Management Area 1 – West Gosford and Point Clare





Management Area Details

Land Use

This area consists primarily of residential land uses, with some areas of industrial land uses and open space. A retirement village/ aged care facility is located in West Gosford. There are substantial areas of wetlands along the foreshores. This management area also incorporates part of the central coast railway line.

Flooding Mechanisms

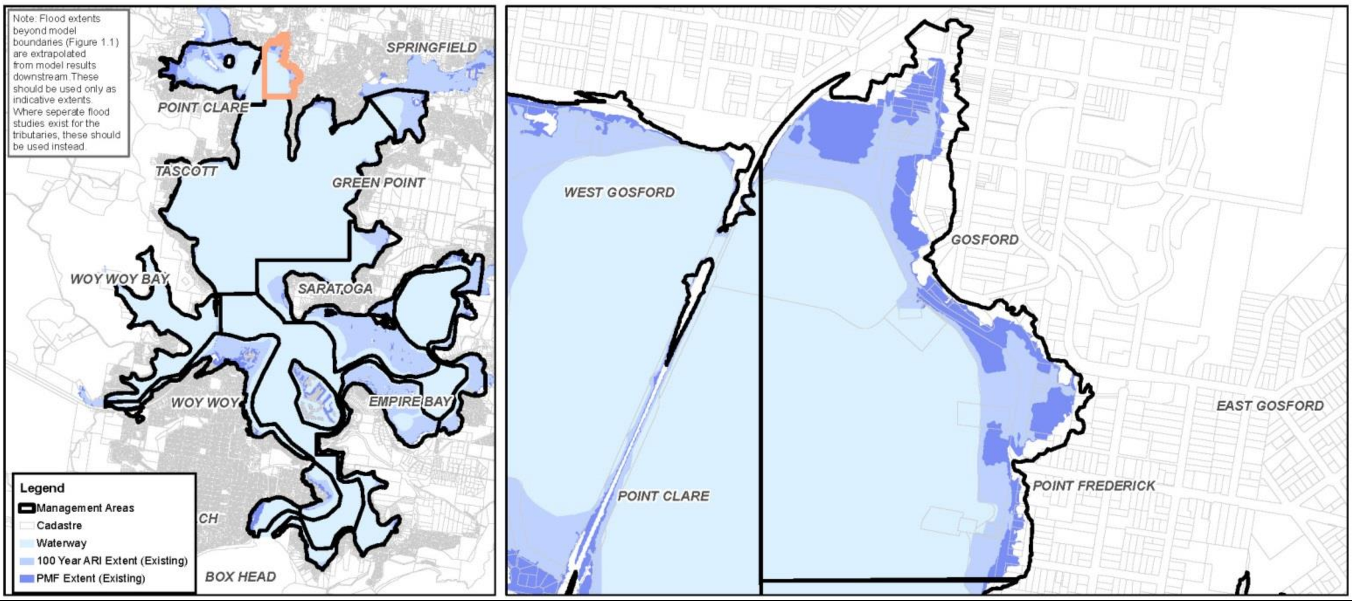
Existing Scenario (no SLR):	**Future Scenario (0.9m SLR):**
Fagans Bay is dominated by catchment flooding in events greater than the 100 year ARI event. This is due to large catchment flows from Narara Creek and the local hydraulic control (the northern railway bridge). These reduce the rate of discharge of catchment flows into the estuary.	High tides are likely to affect roads in the area, whilst some properties are likely to be impacted in higher probability ARI events.

Recommended Actions – Management Area-Specific	Implementation
1_EM2: Install and maintain "Road Floods" signs at the Central Coast Highway, and Yallambee Avenue, West Gosford . Flood signage along roads that are liable to flood allow residents to be aware of whether it is dangerous to traverse a particular section of road during a flood event.	Immediate

Recommended Actions – Floodplain-Wide	Implementation
EM7: **Review evacuation centre locations** to ensure that evacuation centres that lie within the floodplain are not utilised during flood emergencies. The evacuation centre nearest to MA1 that is not within the floodplain is Kariong Community Centre.	Immediate
EM4: **Review flood warning systems** on a periodic basis and update as necessary. This could include a provision for demountable road sign flood warnings on roads such as Brisbane Water Drive and the Central Coast Highway.	Immediate
EM8: Develop and review detours and alternative routes to be used during times of coastal flooding to **enhance road evacuation**. Roads that are subject to flooding in this management area include Central Coast Highway and Brisbane Water Drive.	Immediate
EM3: **Review the Gosford Local Flood Emergency Sub-Plan** (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results. This will allow community emergency services to be better prepared to assist the community during storm surge flood events.	Immediate
PM7: **Review and amend planning instruments and development controls** across the floodplain to ensure consistency with ocean flooding. Review every five years.	Staged
PM5: **Continue to monitor sea levels** in Brisbane Water. There are no water level gauges in MA1, however the results of water level analyses would still need to be communicated to residents in this management area. The nearest gauges are in Erina.	Immediate

PM10: **Evaluate utilities infrastructure** and partner with private utilities managers to better understand the coastal flood and sea level rise risks to assets. Formulate a plan of management over the long term for integration into Council's planning objectives. A range of utilities exist in MA1, including electricity, telecommunications, water and sewer.	**Staged**
PM3: Investigate the potential for implementation of a **land swap program** for properties that meet specified criteria (e.g. inundated by sea level rise and flooding in regular events) with land that Council owns in non flood-prone areas.	**Staged**
PM8: Develop a series of **management-area specific development controls**, customised to suit each locality.	**Staged**
PM4: Conduct a program of strategic, **balanced and socially sensitive education** to advise the local community and prospective property purchasers about the risk and effects of coastal flooding. This could include the provision of additional information regarding s149 Certificates.	**Staged**
PM9: **Develop sea level rise management strategies**, particularly with regard to tidal inundation. This management action should be considered as the basis of the proposed *Climate Change Adaptation Plan* for this management area.	**Staged**
EM1: Conduct targeted **flood education programs** for flood-affected residents, with an emphasis on access and evacuation during storm surge flood events. Targeted education should be undertaken for specific groups of residents, e.g. residents of the Leisure Living Retirement Village and Aged Care, West Gosford.	**Staged**
PM2: **Implement a voluntary house raising program** for identified dwellings that meet specified criteria. Some properties have been identified in this management area as being eligible for voluntary house raising. A detailed floor survey would be required prior to the final selection of properties.	**Staged**
FM4: **Install flood gates on stormwater pipe outlets** as required.	**Staged**

Management Area 2 – Gosford



Management Area Details

Land Use

This area consists primarily of commercial land uses. Open space areas are located along the foreshore. The Gosford Olympic Pool is located in this management area.

Flooding Mechanisms

Existing Scenario (no SLR):	Future Scenario (0.9m SLR):
Existing high tides in the Gosford area may cause inundation at the foreshore edge, especially with joint occurrence of storm conditions. Wave overtopping over the sea wall has occurred in past storm events.	High tides are likely to affect roads in the area, whilst properties are likely to be impacted in higher probability ARI events. Further inundation will occur in high water level events.

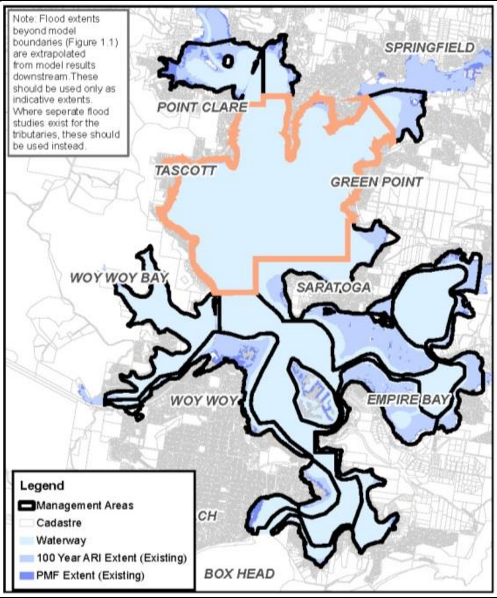
Recommended Actions – Management Area-Specific

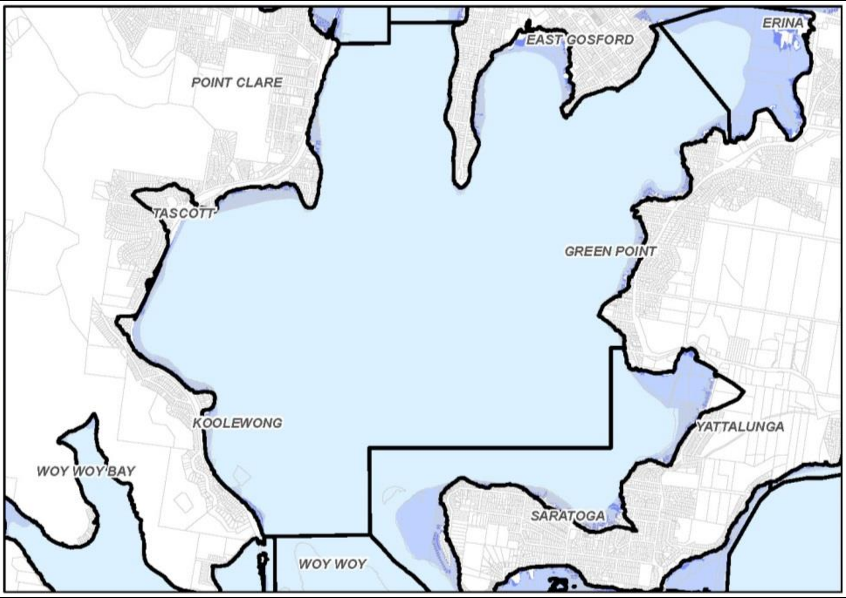
No management area-specific actions recommended.

Recommended Actions – Floodplain-Wide	Implementation
EM7: **Review evacuation centre locations** to ensure that evacuation centres that lie within the floodplain are not utilised during flood emergencies. The evacuation centre nearest to MA2 that is not within the floodplain is Kariong Community Centre.	**Immediate**
EM4: **Review flood warning systems** on a periodic basis and update as necessary. This could include a provision for demountable road sign flood warnings on roads such as the Central Coast Highway.	**Immediate**
EM8: Develop and review detours and alternative routes to be used during times of coastal flooding to **enhance road evacuation**. Roads that are subject to coastal flooding in this management area include the Central Coast Highway.	**Immediate**
EM3: **Review the Gosford Local Flood Emergency Sub-Plan** (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results. This will allow community emergency services to be better prepared to assist the community during storm surge flood events.	**Immediate**
PM7: **Review and amend planning instruments and development controls** across the floodplain to ensure consistency with ocean flooding. Review every five years.	**Staged**
PM5: **Continue to monitor sea levels** in Brisbane Water. There are no water level gauges in MA2, however the results of water level analyses would still need to be communicated to residents in this management area. The nearest gauges are in Erina.	**Immediate**
PM10: **Evaluate utilities infrastructure** and partner with private utilities managers to better understand the coastal flood and sea level rise risks to assets. Formulate a plan of management over the long term for integration into Council's planning objectives. A range of utilities exist in MA2, including electricity, telecommunications, water and sewer.	**Staged**

PM3: Investigate the potential for implementation of a **land swap program** for properties that meet specified criteria (e.g. inundated by sea level rise and flooding in regular events) with land that Council owns in non flood-prone areas.	**Staged**
PM8: Develop a series of **management-area specific development controls**, customised to suit each locality.	**Staged**
PM4: Conduct a program of strategic, **balanced and socially sensitive education** to advise the local community and prospective property purchasers about the risk and effects of coastal flooding. This could include the provision of additional information regarding s149 Certificates.	**Staged**
PM9: **Develop sea level rise management strategies**, particularly with regard to tidal inundation. This management action should be considered as the basis of the proposed *Climate Change Adaptation Plan* for this management area.	**Staged**
EM1: Conduct targeted **flood education programs** for flood-affected residents, with an emphasis on access and evacuation during storm surge flood events. Targeted education should be undertaken for specific groups of residents.	**Staged**
PM2: **Implement a voluntary house raising program** for identified dwellings that meet specified criteria. Some properties have been identified in this management area as being eligible for voluntary house raising. A detailed floor survey would be required prior to the final selection of properties.	**Staged**
FM4: **Install flood gates on stormwater pipe outlets** as required.	**Staged**

Management Area 3 – Point Frederick, East Gosford, Green Point, Koolewong and Tascott





Management Area Details

Land Use

MA3 consists of mostly residential land uses, with some open space and foreshore mangrove areas. This management area is larger than many of the management areas but similar flooding characteristics are experienced across it.

Flooding Mechanisms

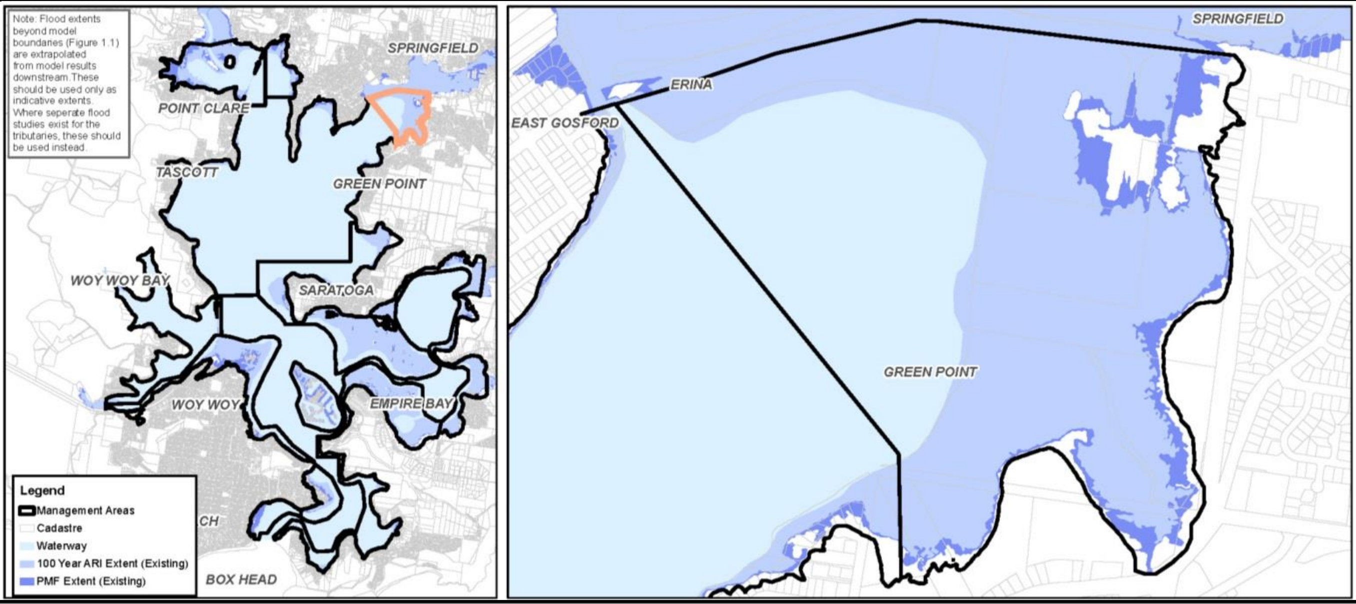
Existing Scenario (no SLR):	Future Scenario (0.9m SLR):
Higher probability ARI events may cause inundation in this area. Some areas of Tascott are also affected by catchment flows from Tascott Creek.	High tides in this area are likely to cause inundation. Areas of Tascott will continue to be affected by catchment flows from Tascott Creek.

Recommended Actions – Management Area-Specific	Implementation
3_PM11a: Undertake detailed investigation of the **impacts of structural floodplain risk management options on overland flows in Koolewong and Tascott.**	**Immediate**
3_PM11b: Undertake a review/updated investigation of the **impacts of structural floodplain risk management options on overland flows** in Point Frederick, East Gosford and Green Point.	**Immediate**
3_FM3: Modify the existing foreshore in areas most affected by wave run-up to **incorporate wave energy dissipating designs**. This will assist in the protection of individual properties not already identified as flood affected (as they lie outside the 100 year ARI extent, but may be impacted by wave run-up depending on swell and wind conditions). Areas that may require dissipation designs are Point Frederick, East Gosford, Point Clare, and smaller areas in Green Point, Tascott and Koolewong. On-the-ground surveys will be required to ascertain the exact locations where dissipation designs will be appropriate within associated environmental constraints.	**Staged**

Recommended Actions – Floodplain-Wide	Implementation
EM7: **Review evacuation centre locations** to ensure that evacuation centres that lie within the floodplain are not utilised during flood emergencies. The evacuation centres nearest to MA3 that are not within the floodplain are Kariong Community Centre or Green Point Community Centre.	**Immediate**
EM4: **Review flood warning systems** on a periodic basis and update as necessary. This could include a provision for demountable road sign flood warnings on roads such as Brisbane Water Drive.	**Immediate**
EM8: Develop and review detours and alternative routes to be used during times of coastal flooding to **enhance road evacuation**. Roads that are subject to coastal flooding in this management area include Brisbane Water Drive and Manooka Road.	**Immediate**
EM3: **Review the Gosford Local Flood Emergency Sub-Plan** (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results. This will allow community emergency services to be better prepared to assist the community during storm surge flood events.	**Immediate**

PM7: **Review and amend planning instruments and development controls** across the floodplain to ensure consistency with ocean flooding. Review every five years.	**Staged**
PM5: **Continue to monitor sea levels** in Brisbane Water. There are no water level gauges in MA3, however the results of water level analyses would still need to be communicated to residents in this management area. The nearest gauges are at Erina.	**Immediate**
PM10: **Evaluate utilities infrastructure** and partner with private utilities managers to better understand the coastal flood and sea level rise risks to assets. Formulate a plan of management over the long term for integration into Council's planning objectives. A range of utilities exist in MA3, including electricity, telecommunications, water and sewer.	**Staged**
PM3: Investigate the potential for implementation of a **land swap program** for properties that meet specified criteria (e.g. inundated by sea level rise and flooding in regular events) with land that Council owns in non-flood-prone areas.	**Staged**
PM8: Develop a series of **management-area specific development controls**, customised to suit each locality.	**Staged**
PM4: Conduct a program of strategic, **balanced and socially sensitive education** to advise the local community and prospective property purchasers about the risk and effects of coastal flooding. This could include the provision of additional information regarding s149 Certificates.	**Staged**
PM9: **Develop sea level rise management strategies**, particularly with regard to tidal inundation. This management action should be considered as the basis of the proposed *Climate Change Adaptation Plan* for this management area.	**Staged**
EM1: Conduct targeted **flood education programs** for flood-affected residents, with an emphasis on access and evacuation during storm surge flood events. Targeted education should be undertaken for specific groups of residents.	**Staged**
PM2: **Implement a voluntary house raising program** for identified dwellings that meet specified criteria. Several properties have been identified in this management area as being eligible for voluntary house raising. A detailed floor survey would be required prior to the final selection of properties.	**Staged**
FM4: **Install flood gates on stormwater pipe outlets** as required.	**Staged**

Management Area 4 – Erina



Management Area Details

Land Use

This area consists of mangrove areas, industrial land uses and special uses/infrastructure.

Flooding Mechanisms

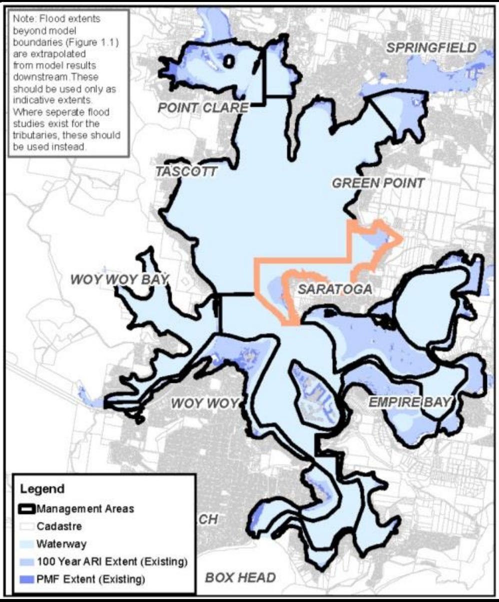
Existing Scenario (no SLR):	Future Scenario (0.9m SLR):
Higher probability ARI events may cause inundation in this area. Some areas are affected by catchment flows from Erina Creek.	High tides and higher probability ARI events are likely to cause inundation in this area.

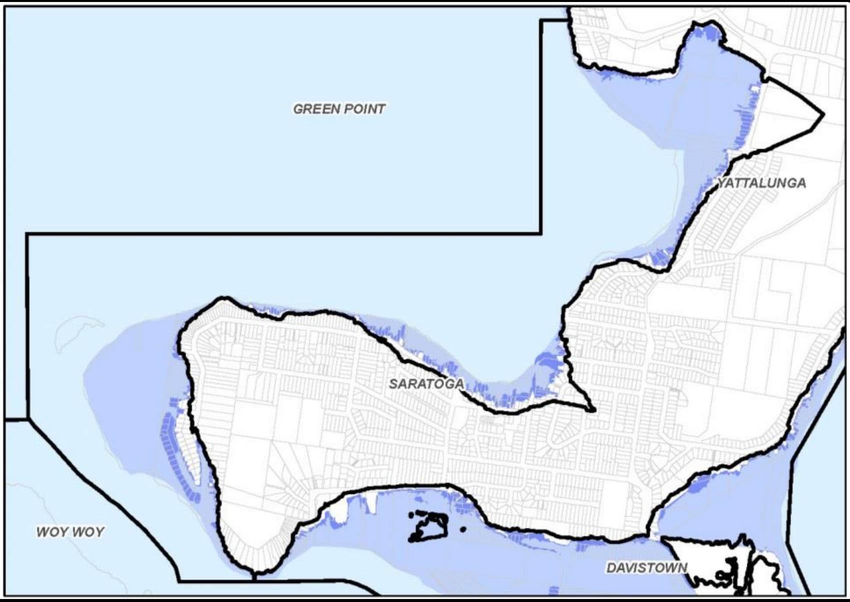
Recommended Actions – Management Area-Specific	Implementation
4_PM6: **Relocate NSW SES (Gosford) headquarters** out of the floodplain. This critical infrastructure is currently located in an area that is cut-off by floodwaters during the PMF event.	**Staged**

Recommended Actions – Floodplain-Wide	Implementation
EM7: **Review evacuation centre locations** to ensure that evacuation centres that lie within the floodplain are not utilised during flood emergencies. The evacuation centre nearest to MA4 that is not within the floodplain is the Green Point Community Centre.	**Immediate**
EM4: **Review flood warning systems** on a periodic basis and update as necessary. This could include a provision for demountable road sign flood warnings on roads in nearby areas, such as the Central Coast Highway.	**Immediate**
EM8: Develop and review detours and alternative routes to be used during times of coastal flooding to **enhance road evacuation**. Roads that are subject to coastal flooding in this management area include Pateman Road and the Entrance Road.	**Immediate**
EM3: **Review the Gosford Local Flood Emergency Sub-Plan** (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results. This will allow community emergency services to be better prepared to assist the community during storm surge flood events.	**Immediate**
PM7: **Review and amend planning instruments and development controls** across the floodplain to ensure consistency with ocean flooding. Review every five years.	**Staged**
PM5: **Continue to monitor sea levels** in Brisbane Water. There are several water level gauges in MA4 (Erina). The results of water level analyses from these and other gauges would need to be communicated to residents in this management area.	**Immediate**

PM10: **Evaluate utilities infrastructure** and partner with private utilities managers to better understand the coastal flood and sea level rise risks to assets. Formulate a plan of management over the long term for integration into Council's planning objectives. A range of utilities exist in MA4, including electricity, telecommunications, water and sewer.	**Staged**
PM3: Investigate the potential for implementation of a **land swap program** for properties that meet specified criteria (e.g. inundated by sea level rise and flooding in regular events) with land that Council owns in non flood-prone areas.	**Staged**
PM8: Develop a series of **management-area specific development controls**, customised to suit each locality.	**Staged**
PM4: Conduct a program of strategic, **balanced and socially sensitive education** to advise the local community and prospective property purchasers about the risk and effects of coastal flooding. This could include the provision of additional information regarding s149 Certificates.	**Staged**
PM9: **Develop sea level rise management strategies**, particularly with regard to tidal inundation. This management action should be considered as the basis of the proposed *Climate Change Adaptation Plan* for this management area.	**Staged**
EM1: Conduct targeted **flood education programs** for flood-affected residents, with an emphasis on access and evacuation during storm surge flood events. Targeted education should be undertaken for specific groups, e.g. workers at the Council depot in Erina.	**Staged**
PM2: **Implement a voluntary house raising program** for identified dwellings that meet specified criteria. This option is unlikely to apply in this management area given that there are no residential land uses. A detailed floor survey would be required prior to the final selection of properties for voluntary house raising.	**Staged**
FM4: **Install flood gates/valves on stormwater pipe outlets** as required.	**Staged**

Management Area 5 – Yattalunga and Saratoga





Management Area Details

Land Use	
This management area consists primarily of residential land uses. Many residences in this management area are waterfront properties. There are also some areas of open space.	

Flooding Mechanisms	
Existing Scenario (no SLR): Existing high tides in these areas can cause inundation, especially with joint occurrence of storm conditions.	**Future Scenario (0.9m SLR):** High tides are likely to impact properties, with further inundation occurring in higher probability ARI events.

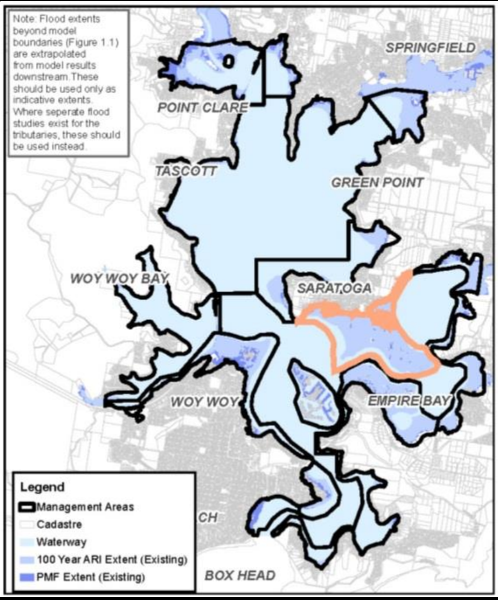
Recommended Actions – Management Area-Specific

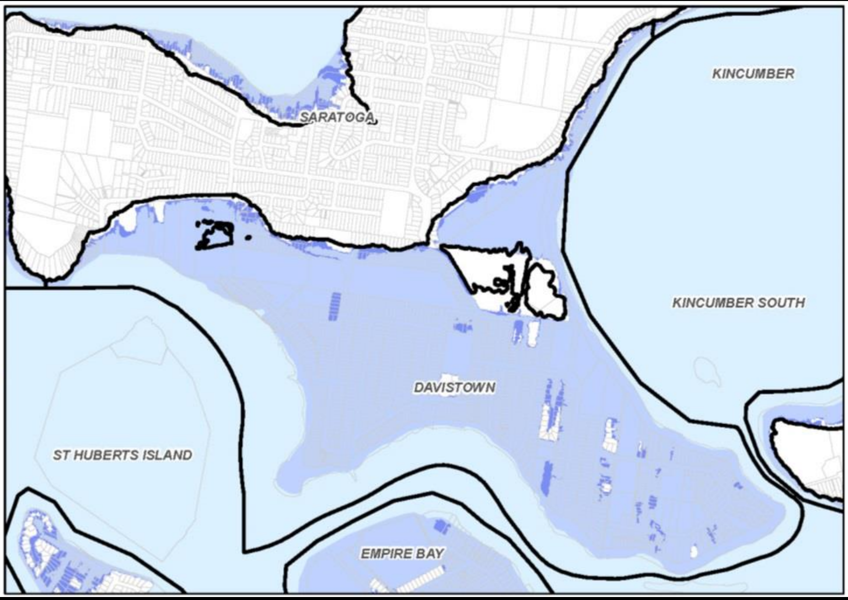
No management area-specific actions recommended.

Recommended Actions – Floodplain-Wide	Implementation
EM7: **Review evacuation centre locations** to ensure that evacuation centres that lie within the floodplain are not utilised during flood emergencies. The evacuation centre nearest to MA5 that is not within the floodplain is the Kincumber and District Neighbourhood Centre.	**Immediate**
EM4: **Review flood warning systems** on a periodic basis and update as necessary. This could include a provision for demountable road sign flood warnings on roads in nearby areas.	**Immediate**
EM8: Develop and review detours and alternative routes to be used during times of coastal flooding to **enhance road evacuation**.	**Immediate**
EM3: **Review the Gosford Local Flood Emergency Sub-Plan** (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results. This will allow community emergency services to be better prepared to assist the community during storm surge flood events.	**Immediate**
PM7: **Review and amend planning instruments and development controls** across the floodplain to ensure consistency with ocean flooding. Review every five years.	**Staged**
PM5: **Continue to monitor sea levels** in Brisbane Water. There are no water level gauges in MA5, however the results of water level analyses would still need to be communicated to residents in this management area. The nearest gauge is at Koolewong.	**Immediate**
PM10: **Evaluate utilities infrastructure** and partner with private utilities managers to better understand the coastal flood and sea level rise risks to assets. Formulate a plan of management over the long term for integration into Council's planning objectives. A range of utilities exist in MA5, including electricity, telecommunications, water and sewer.	**Staged**

PM3: Investigate the potential for implementation of a **land swap program** for properties that meet specified criteria (e.g. inundated by sea level rise and flooding in regular events) with land that Council owns in non flood-prone areas.	**Staged**
PM8: Develop a series of **management-area specific development controls**, customised to suit each locality.	**Staged**
PM4: Conduct a program of strategic, **balanced and socially sensitive education** to advise the local community and prospective property purchasers about the risk and effects of coastal flooding. This could include the provision of additional information regarding s149 Certificates.	**Staged**
PM9: **Develop sea level rise management strategies**, particularly with regard to tidal inundation. This management action should be considered as the basis of the proposed *Climate Change Adaptation Plan* for this management area.	**Staged**
EM1: Conduct targeted **flood education programs** for flood-affected residents, with an emphasis on access and evacuation during storm surge flood events. Targeted education should be undertaken for specific groups.	**Staged**
PM2: **Implement a voluntary house raising program** for identified dwellings that meet specified criteria. Some properties have been identified in this management area as being eligible for voluntary house raising. A detailed floor survey would be required prior to the final selection of properties.	**Staged**
FM4: **Install flood gates/valves on stormwater pipe outlets** as required.	**Staged**

Management Area 6 – Davistown





Management Area Details

Land Use

This management area consists primarily of residential land uses. Some areas of wetlands and open space are also present. Alloura Waters retirement home/aged care facility also exists in this management area.

Flooding Mechanisms

Existing Scenario (no SLR):
Existing high tides in this area can cause inundation, especially with joint occurrence of storm conditions. A large number of residential properties are affected,, even in small flood events. Flood penetration is larger due to very flat terrain.

Future Scenario (0.9m SLR):
A large number of residential properties are likely to be affected by high tides, with inundation depths increasing in higher probability ARI events. High flood depths are more common due to very flat terrain.

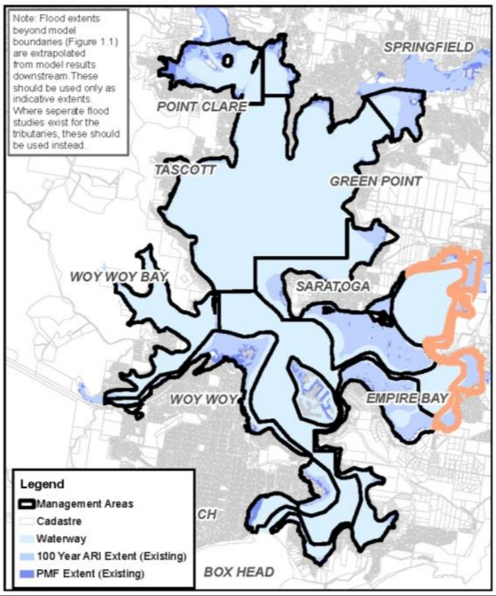
Recommended Actions – Management Area-Specific

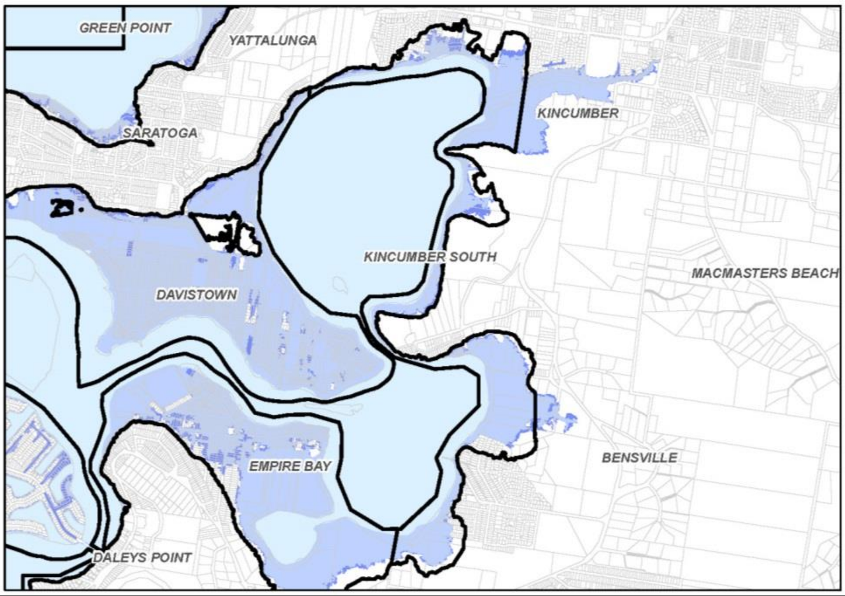
No management area-specific actions recommended.

Recommended Actions – Floodplain-Wide	Implementation
EM7: **Review evacuation centre locations** to ensure that evacuation centres that lie within the floodplain are not utilised during flood emergencies. The evacuation centre nearest to MA6 that is not within the floodplain is the Kincumber and District Neighbourhood Centre.	**Immediate**
EM4: **Review flood warning systems** on a periodic basis and update as necessary. This could include a provision for demountable road sign flood warnings on roads in nearby areas.	**Immediate**
EM8: Develop and review detours and alternative routes to be used during times of coastal flooding to **enhance road evacuation**. Roads that are subject to coastal flooding in this management area include Davistown Road and Malinya Road, Davistown.	**Immediate**
EM3: **Review the Gosford Local Flood Emergency Sub-Plan** (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results. This will allow community emergency services to be better prepared to assist the community during storm surge flood events.	**Immediate**
PM7: **Review and amend planning instruments and development controls** across the floodplain to ensure consistency with ocean flooding. Review every five years.	**Staged**
PM5: **Continue to monitor sea levels** in Brisbane Water. There are no water level gauges in MA6, however the results of water level analyses would still need to be communicated to residents in this management area. The nearest gauge is at Koolewong.	**Immediate**

PM10: **Evaluate utilities infrastructure** and partner with private utilities managers to better understand the coastal flood and sea level rise risks to assets. Formulate a plan of management over the long term for integration into Council's planning objectives. A range of utilities exist in MA6, including electricity, telecommunications, water and sewer.	**Staged**
PM3: Investigate the potential for implementation of a **land swap program** for properties that meet specified criteria (e.g. inundated by sea level rise and flooding in regular events) with land that Council owns in non flood-prone areas.	**Staged**
PM8: Develop a series of **management-area specific development controls**, customised to suit each locality.	**Staged**
PM4: Conduct a program of strategic, **balanced and socially sensitive education** to advise the local community and prospective property purchasers about the risk and effects of coastal flooding. This could include the provision of additional information regarding s149 Certificates.	**Staged**
PM9: **Develop sea level rise management strategies**, particularly with regard to tidal inundation. This management action should be considered as the basis of the proposed *Climate Change Adaptation Plan* for this management area.	**Staged**
EM1: **Conduct targeted flood education programs for flood-affected residents**, with an emphasis on access and evacuation during storm surge flood events. Targeted education should be undertaken for specific groups, e.g. residents at Alloura Waters retirement home/aged care facility.	**Staged**
PM2: **Implement a voluntary house raising program** for identified dwellings that meet specified criteria. Several properties have been identified in this management area as being eligible for voluntary house raising. A detailed floor survey would be required prior to the final selection of properties.	**Staged**
FM4: **Install flood gates/valves on stormwater pipe outlets** as required.	**Staged**

Management Area 7 – Kincumber, Kincumber South and Bensville





Management Area Details

Land Use

This management area consists of open space, residential areas, and some special uses such as caravan parks.

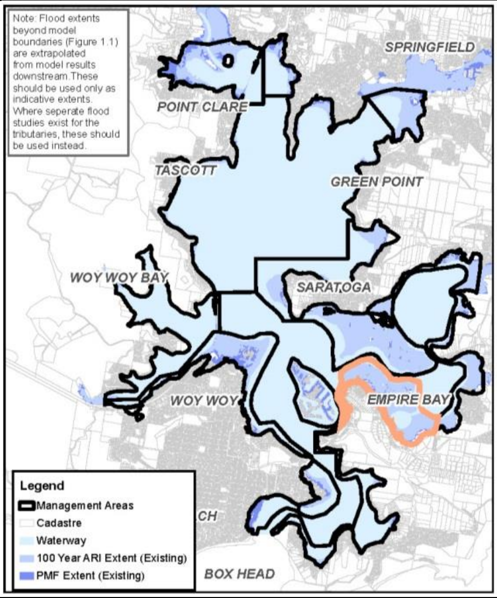
Flooding Mechanisms

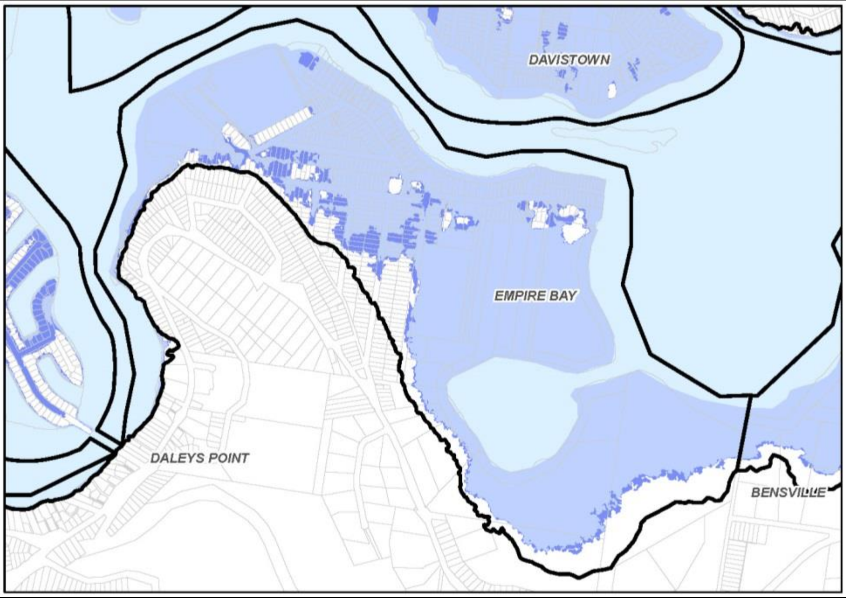
Existing Scenario (no SLR):	Future Scenario (0.9m SLR):
Existing high tides in this area can cause inundation, especially high tides with joint occurrence of storm conditions. Only fairly small areas of the suburbs in this management area are affected.	Some roads and properties likely to be affected by high tides. Further inundation will occur in higher probability ARI events.

Recommended Actions – Management Area-Specific	
7_PM11b: Undertake a review/updated investigation of the **impacts of structural floodplain risk management options on overland flows** in Kincumber, Kincumber South and Bensville.	**Immediate**
7_FM5: Undertake a program of **maintenance and raising for existing seawalls** in appropriate locations along the foreshore. This action will assist in maintaining existing flood protection and providing some protection from wave run-up.	**Staged**
Recommended Actions – Floodplain-Wide	**Implementation**
EM7: **Review evacuation centre locations** to ensure that evacuation centres that lie within the floodplain are not utilised during flood emergencies. The evacuation centres nearest to MA7 that are not within the floodplain are the Kincumber and District Neighbourhood Centre and La Salle Youth Camp.	**Immediate**
EM4: **Review flood warning systems** on a periodic basis and update as necessary. This could include a provision for demountable road sign flood warnings on roads in nearby areas.	**Immediate**
EM8: Develop and review detours and alternative routes to be used during times of coastal flooding to **enhance road evacuation**.	**Immediate**
EM3: **Review the Gosford Local Flood Emergency Sub-Plan** (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results. This will allow community emergency services to be better prepared to assist the community during storm surge flood events.	**Immediate**
PM7: **Review and amend planning instruments and development controls** across the floodplain to ensure consistency with ocean flooding. Review every five years.	**Staged**
PM5: **Continue to monitor sea levels** in Brisbane Water. There are no water level gauges in MA7, however the results of water level analyses would still need to be communicated to residents in this management area. The nearest gauge is at Koolewong.	**Immediate**

PM10: **Evaluate utilities infrastructure** and partner with private utilities managers to better understand the coastal flood and sea level rise risks to assets. Formulate a plan of management over the long term for integration into Council's planning objectives. A range of utilities exist in MA7, including electricity, telecommunications, water and sewer.	**Staged**
PM3: Investigate the potential for implementation of a **land swap program** for properties that meet specified criteria (e.g. inundated by sea level rise and flooding in regular events) with land that Council owns in non flood-prone areas.	**Staged**
PM8: Develop a series of **management-area specific development controls**, customised to suit each locality.	**Staged**
PM4: Conduct a program of strategic, **balanced and socially sensitive education** to advise the local community and prospective property purchasers about the risk and effects of coastal flooding. This could include the provision of additional information regarding s149 Certificates.	**Staged**
PM9: **Develop sea level rise management strategies**, particularly with regard to tidal inundation. This management action should be considered as the basis of the proposed *Climate Change Adaptation Plan* for this management area.	**Staged**
EM1: Conduct targeted **flood education programs** for flood-affected residents, with an emphasis on access and evacuation during storm surge flood events. Targeted education should be undertaken for specific groups.	**Staged**
PM2: **Implement a voluntary house raising program** for identified dwellings that meet specified criteria. This option is unlikely to apply in this management area because properties tend to have only relatively minor flood affectation. A detailed floor survey would be required prior to the final selection of properties for voluntary house raising.	**Staged**
FM4: **Install flood gates/valves on stormwater pipe outlets** as required.	**Staged**

Management Area 8 – Empire Bay





Management Area Details

Land Use

This management area comprises mostly residential land uses, with some areas of open space and wetlands.

Flooding Mechanisms

Existing Scenario (no SLR):	Future Scenario (0.9m SLR):
Existing high tides in this area can cause inundation, especially with joint occurrence of storm conditions. Some residential properties are affected even in higher probability ARIs.	A large number of residential properties are likely to be affected by high tides, with inundation depths increasing in higher probability ARI events. High flood depths are more common due to very flat terrain.

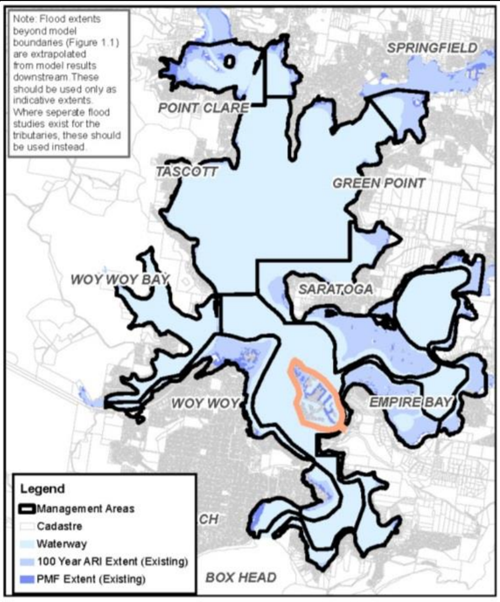
Recommended Actions – Management Area-Specific

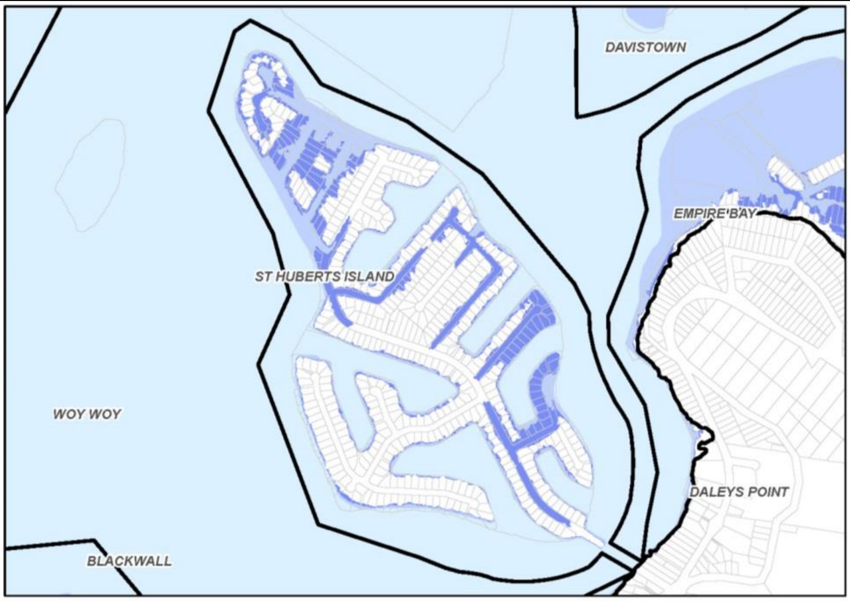
No management area-specific actions recommended.

Recommended Actions – Floodplain-Wide	Implementation
EM7: **Review evacuation centre locations** to ensure that evacuation centres that lie within the floodplain are not utilised during flood emergencies. The evacuation centres nearest to MA8 that are not within the floodplain are the La Salle Youth Camp and the Ettalong War Memorial Club.	**Immediate**
EM4: **Review flood warning systems** on a periodic basis and update as necessary. This could include a provision for demountable road sign flood warnings on roads in nearby areas.	**Immediate**
EM8: Develop and review detours and alternative routes to be used during times of coastal flooding to **enhance road evacuation**. Roads that are subject to coastal flooding in MA8 include Greenfield Road and Rickard Road.	**Immediate**
EM3: **Review the Gosford Local Flood Emergency Sub-Plan** (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results. This will allow community emergency services to be better prepared to assist the community during storm surge flood events.	**Immediate**
PM7: **Review and amend planning instruments and development controls** across the floodplain to ensure consistency with ocean flooding. Review every five years.	**Staged**
PM5: **Continue to monitor sea levels** in Brisbane Water. There are no water level gauges in MA8, however the results of water level analyses would still need to be communicated to residents in this management area. The nearest gauge is at Koolewong.	**Immediate**
PM10: **Evaluate utilities infrastructure** and partner with private utilities managers to better understand the coastal flood and sea level rise risks to assets. Formulate a plan of management over the long term for integration into Council's planning objectives. A range of utilities exist in MA8, including electricity, telecommunications, water and sewer.	**Staged**

PM3: Investigate the potential for implementation of a **land swap program** for properties that meet specified criteria (e.g. inundated by sea level rise and flooding in regular events) with land that Council owns in non flood-prone areas.	**Staged**
PM8: Develop a series of **management-area specific development controls**, customised to suit each locality.	**Staged**
PM4: Conduct a program of strategic, **balanced and socially sensitive education** to advise the local community and prospective property purchasers about the risk and effects of coastal flooding. This could include the provision of additional information regarding s149 Certificates.	**Staged**
PM9: **Develop sea level rise management strategies**, particularly with regard to tidal inundation. This management action should be considered as the basis of the proposed *Climate Change Adaptation Plan* for this management area.	**Staged**
EM1: Conduct targeted **flood education programs** for flood-affected residents, with an emphasis on access and evacuation during storm surge flood events. Targeted education should be undertaken for specific groups.	**Staged**
PM2: **Implement a voluntary house raising program** for identified dwellings that meet specified criteria. Some properties have been identified in this management area as being eligible for voluntary house raising. A detailed floor survey would be required prior to the final selection of properties.	**Staged**
FM4: **Install flood gates/valves on stormwater pipe outlets** as required.	**Staged**

Management Area 9 – St Huberts Island





Management Area Details

Land Use

This management area consists of residential land uses within a canal estate development.

Flooding Mechanisms

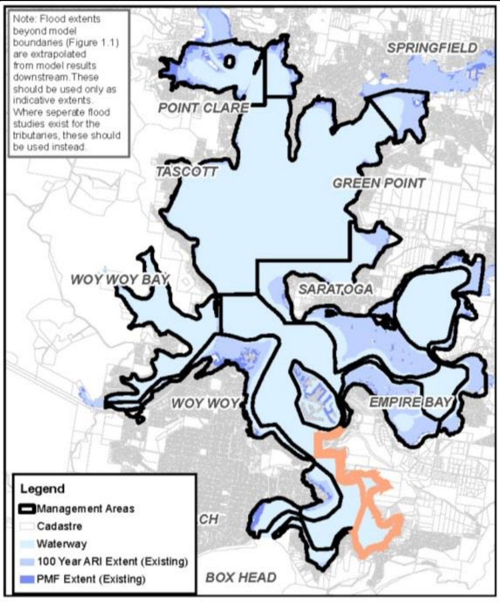
Existing Scenario (no SLR):	**Future Scenario (0.9m SLR):**
Flooding is generally limited by floor levels on the island having been set to above the 100 year ARI event. A large number of properties are affected, however in most instances only the very edges of properties are affected. High tide events in conjunction with storms can cause surcharge of the stormwater system which affects local roads. Residential properties are more likely to experience over-ground flooding than over-floor flooding. Storm surge events greater than 100 year ARI have the potential to inundate this area.	Small number of properties and roads likely to be affected by high tides. Larger number of properties and all roads likely to be affected in higher probability ARI events.

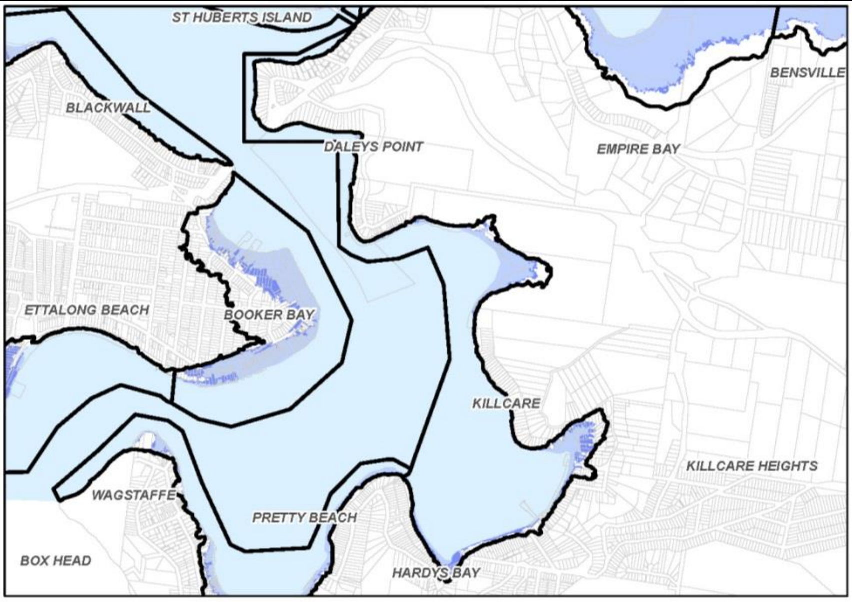
Recommended Actions – Management Area-Specific	
9_PM11a: Undertake detailed investigation of the **impacts of structural floodplain risk management options on overland flows** on St Huberts Island.	**Immediate**
9_FM3; Modify the existing foreshore in areas most affected by wave run-up to **incorporate wave energy dissipating designs**. This will assist in the protection of individual properties not already identified as flood affected (as they lie outside the 100 year ARI extent, but may be impacted by wave run-up depending on swell and wind conditions). The majority of the foreshore of St Huberts Island may require dissipation designs. On-the-ground surveys will be required to ascertain the exact locations where dissipation designs will be appropriate within associated environmental constraints.	**Staged**

Recommended Actions – Floodplain-Wide	Implementation
EM7: **Review evacuation centre locations** to ensure that evacuation centres that lie within the floodplain are not utilised during flood emergencies. The evacuation centre nearest to MA9 that is not within the floodplain is the Ettalong War Memorial Club.	**Immediate**
EM4: **Review flood warning systems** on a periodic basis and update as necessary. This could include a provision for demountable road sign flood warnings on roads in nearby areas.	**Immediate**
EM8: Develop and review detours and alternative routes to be used during times of coastal flooding to **enhance road evacuation**. Roads that are subject to coastal flooding in MA9 include Helmsman Boulevard.	**Immediate**

EM3: **Review the Gosford Local Flood Emergency Sub-Plan** (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results. This will allow community emergency services to be better prepared to assist the community during storm surge flood events.	**Immediate**
PM7: **Review and amend planning instruments and development controls** across the floodplain to ensure consistency with ocean flooding. Review every five years.	**Staged**
PM5: **Continue to monitor sea levels** in Brisbane Water. There are no water level gauges in MA9, however the results of water level analyses would still need to be communicated to residents in this management area. The nearest gauges are at Ettalong and Koolewong.	**Immediate**
PM10: **Evaluate utilities infrastructure** and partner with private utilities managers to better understand the coastal flood and sea level rise risks to assets. Formulate a plan of management over the long term for integration into Council's planning objectives. A range of utilities exist in MA9, including electricity, telecommunications, water and sewer.	**Staged**
PM3: Investigate the potential for implementation of a **land swap program** for properties that meet specified criteria (e.g. inundated by sea level rise and flooding in regular events) with land that Council owns in non flood-prone areas.	**Staged**
PM8: Develop a series of **management-area specific development controls**, customised to suit each locality.	**Staged**
PM4: Conduct a program of strategic, **balanced and socially sensitive education** to advise the local community and prospective property purchasers about the risk and effects of coastal flooding. This could include the provision of additional information regarding s149 Certificates.	**Staged**
PM9: **Develop sea level rise management strategies**, particularly with regard to tidal inundation. This management action should be considered as the basis of the proposed *Climate Change Adaptation Plan* for this management area.	**Staged**
EM1: Conduct targeted **flood education programs** for flood-affected residents, with an emphasis on access and evacuation during storm surge flood events.	**Staged**
PM2: **Implement a voluntary house raising program** for identified dwellings that meet specified criteria. This option is unlikely to apply in this management area because properties tend to have only relatively minor flood affectation in the existing scenario. A detailed floor survey would be required prior to the final selection of properties for voluntary house raising.	**Staged**
FM4: **Install flood gates/valves on stormwater pipe outlets** as required.	**Staged**

Management Area 10 – Daleys Point, Killcare and Hardys Bay





Management Area Details

Land Use

This management area consists primarily of residential land uses and open space areas.

Flooding Mechanisms

Existing Scenario (no SLR):	Future Scenario (0.9m SLR):
Coastal flooding is confined to small areas within these locations. Flooding is limited by fairly steep terrain at Killcare and Hardys Bay and very steep terrain at Daleys Point. Residential properties are more likely to experience over-ground flooding than over-floor flooding.	Tidal inundation from high tides is likely to affect small areas within these locations. A few additional properties are likely to be affected in higher probability ARI events. Flooding is limited by fairly steep terrain at Killcare and Hardys Bay and very steep terrain at Daleys Point.

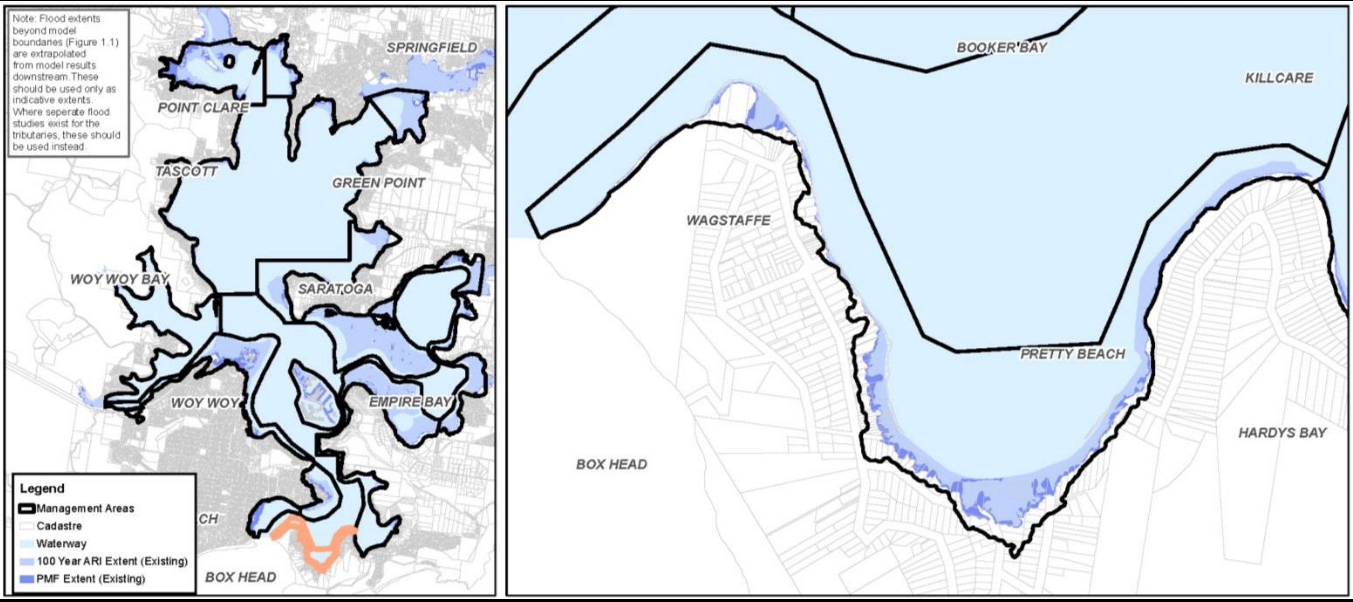
Recommended Actions – Management Area-Specific

No management area-specific actions recommended.

Recommended Actions – Floodplain-Wide	Implementation
EM7: **Review evacuation centre locations** to ensure that evacuation centres that lie within the floodplain are not utilised during flood emergencies. The evacuation centre nearest to MA10 that is not within the floodplain is the Ettalong War Memorial Club.	**Immediate**
EM4: **Review flood warning systems** on a periodic basis and update as necessary. This could include a provision for demountable road sign flood warnings on roads in nearby areas.	**Immediate**
EM8: Develop and review detours and alternative routes to be used during times of coastal flooding to **enhance road evacuation**. Roads that are subject to coastal flooding in MA10 include Araluen Drive.	**Immediate**
EM3: **Review the Gosford Local Flood Emergency Sub-Plan** (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results. This will allow community emergency services to be better prepared to assist the community during storm surge flood events.	**Immediate**
PM7: **Review and amend planning instruments and development controls** across the floodplain to ensure consistency with ocean flooding. Review every five years.	**Staged**
PM5: **Continue to monitor sea levels** in Brisbane Water. There are no water level gauges in MA10, however the results of water level analyses would still need to be communicated to residents in this management area. The nearest gauge is at Ettalong.	**Immediate**
PM10: **Evaluate utilities infrastructure** and partner with private utilities managers to better understand the coastal flood and sea level rise risks to assets. Formulate a plan of management over the long term for integration into Council's planning objectives. A range of utilities exist in MA10, including electricity, telecommunications, water and sewer.	**Staged**

PM3: Investigate the potential for implementation of a **land swap program** for properties that meet specified criteria (e.g. inundated by sea level rise and flooding in regular events) with land that Council owns in non flood-prone areas.	**Staged**
PM8: Develop a series of **management-area specific development controls**, customised to suit each locality.	**Staged**
PM4: Conduct a program of strategic, **balanced and socially sensitive education** to advise the local community and prospective property purchasers about the risk and effects of coastal flooding. This could include the provision of additional information regarding s149 Certificates.	**Staged**
PM9: **Develop sea level rise management strategies**, particularly with regard to tidal inundation. This management action should be considered as the basis of the proposed *Climate Change Adaptation Plan* for this management area.	**Staged**
EM1: Conduct targeted **flood education programs** for flood-affected residents, with an emphasis on access and evacuation during storm surge flood events.	**Staged**
PM2: **Implement a voluntary house raising program** for identified dwellings that meet specified criteria. This option is unlikely to apply in this management area because properties tend to have only relatively minor flood affectation. A detailed floor survey would be required prior to the final selection of any properties for voluntary house raising.	**Staged**
FM4: **Install flood gates/valves on stormwater pipe outlets** as required.	**Staged**

Management Area 11 – Pretty Beach and Wagstaffe



Management Area Details

Land Use

This management area consists primarily of residential land uses.

Flooding Mechanisms

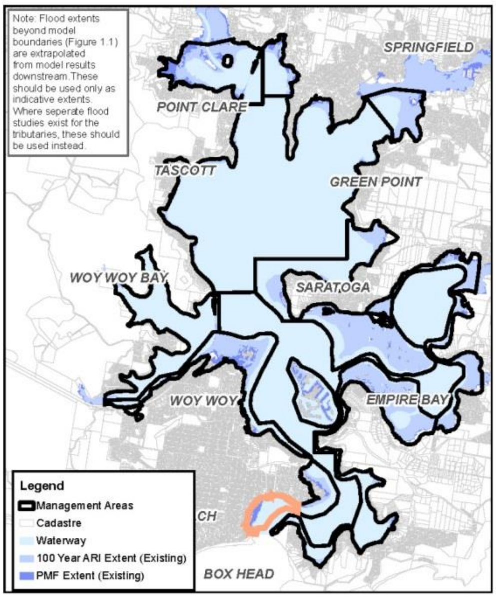
Existing Scenario (no SLR):	**Future Scenario (0.9m SLR):**
Existing high tides in this area can cause inundation, especially high tides with joint occurrence of storm conditions.	High tides in this area are likely to affect some properties. Further inundation is likely to occur in higher probability ARI events.

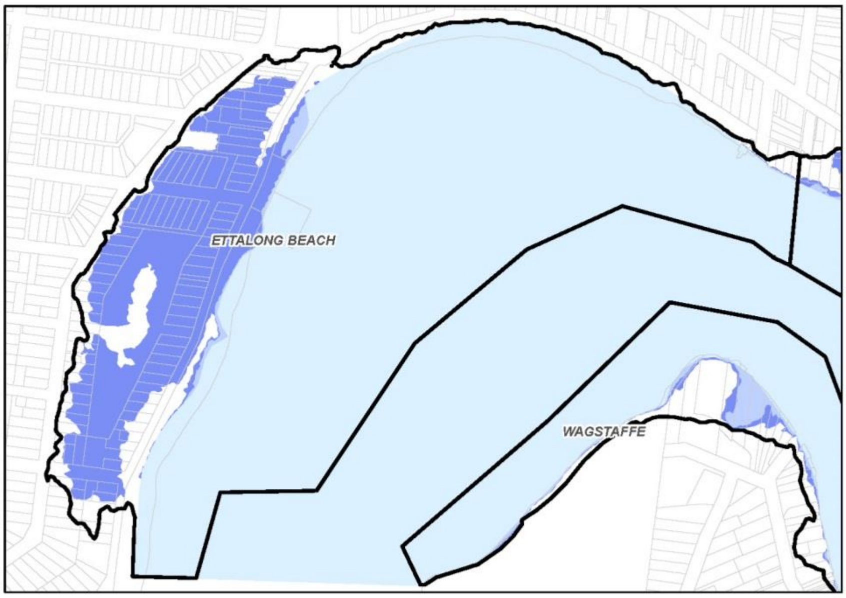
Recommended Actions – Management Area-Specific	
11_FM3: Modify the existing foreshore in areas most affected by wave run-up to **incorporate wave energy dissipating designs**. This will assist in the protection of individual properties not already identified as flood affected (as they lie outside the 100 year ARI extent, but may be impacted by wave run-up depending on swell and wind conditions). Areas that may require dissipation designs include the foreshores of Wagstaffe. On-the-ground surveys will be required to ascertain the exact locations where dissipation designs will be appropriate within associated environmental constraints.	**Staged**

Recommended Actions – Floodplain-Wide	Implementation
EM7: **Review evacuation centre locations** to ensure that evacuation centres that lie within the floodplain are not utilised during flood emergencies. The evacuation centre nearest to MA11 that is not within the floodplain is the Ettalong War Memorial Club.	**Immediate**
EM4: **Review flood warning systems** on a periodic basis and update as necessary. This could include a provision for demountable road sign flood warnings on roads in nearby areas.	**Immediate**
EM8: Develop and review detours and alternative routes to be used during times of coastal flooding to **enhance road evacuation**. Roads that are subject to coastal flooding in this management area include Pretty Beach Road.	**Immediate**
EM3: **Review the Gosford Local Flood Emergency Sub-Plan** (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results. This will allow community emergency services to be better prepared to assist the community during storm surge flood events.	**Immediate**
PM7: **Review and amend planning instruments and development controls** across the floodplain to ensure consistency with ocean flooding. Review every five years.	**Staged**
PM5: **Continue to monitor sea levels** in Brisbane Water. There are no water level gauges in MA11, however the results of water level analyses would still need to be communicated to residents in this management area. The nearest gauge is at Ettalong.	**Immediate**

PM10: **Evaluate utilities infrastructure** and partner with private utilities managers to better understand the coastal flood and sea level rise risks to assets. Formulate a plan of management over the long term for integration into Council's planning objectives. A range of utilities exist in MA11, including electricity, telecommunications, water and sewer.	**Staged**
PM3: Investigate the potential for implementation of a **land swap program** for properties that meet specified criteria (e.g. inundated by sea level rise and flooding in regular events) with land that Council owns in non flood-prone areas.	**Staged**
PM8: Develop a series of **management-area specific development controls**, customised to suit each locality.	**Staged**
PM4: Conduct a program of strategic, **balanced and socially sensitive education** to advise the local community and prospective property purchasers about the risk and effects of coastal flooding. This could include the provision of additional information regarding s149 Certificates.	**Staged**
PM9: **Develop sea level rise management strategies**, particularly with regard to tidal inundation. This management action should be considered as the basis of the proposed *Climate Change Adaptation Plan* for this management area.	**Staged**
EM1: Conduct targeted **flood education programs** for flood-affected residents, with an emphasis on access and evacuation during storm surge flood events.	**Staged**
PM2: **Implement a voluntary house raising program** for identified dwellings that meet specified criteria. A small number of properties have been identified in this management area as being eligible for voluntary house raising. A detailed floor survey would be required prior to the final selection of properties.	**Staged**
FM4: **Install flood gates/valves on stormwater pipe outlets** as required.	**Staged**

Management Area 12 – Ettalong





Management Area Details

Land Use

This management area consists primarily of residential and open space and some commercial land uses.

Flooding Mechanisms

Existing Scenario (no SLR):	Future Scenario (0.9m SLR):
High tides do not affect many areas within Ettalong. Residential properties are generally not affected in higher probability ARIs events. In the existing 100 year ARI event, the majority of affected properties are inundated due to surcharge of the stormwater system.	High tides are unlikely to affect properties or roads. Residential properties and some roads are likely to be impacted in higher probability ARI events.

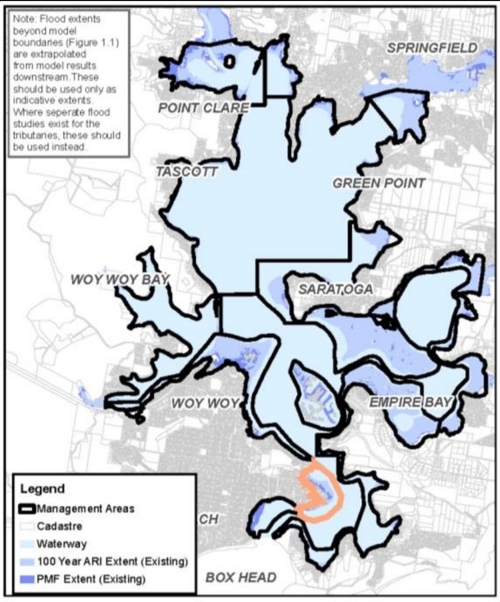
Recommended Actions – Management Area-Specific

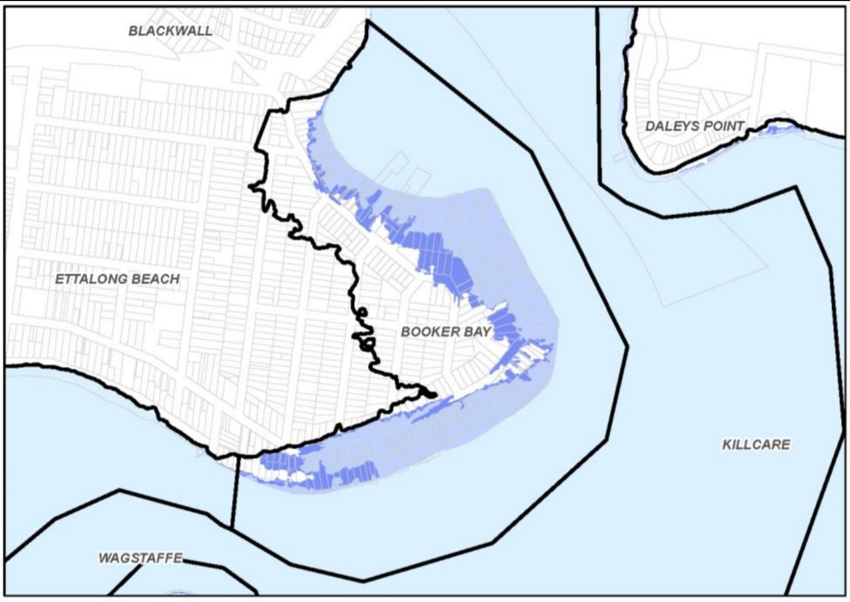
No management area-specific actions recommended.

Recommended Actions – Floodplain-Wide	Implementation
EM7: **Review evacuation centre locations** to ensure that evacuation centres that lie within the floodplain are not utilised during flood emergencies. The evacuation centres nearest to MA12 that are not within the floodplain are the Ettalong War Memorial Club and Umina Bowling Club.	**Immediate**
EM4: **Review flood warning systems** on a periodic basis and update as necessary. This could include a provision for demountable road sign flood warnings on roads in nearby areas.	**Immediate**
EM8: Develop and review detours and alternative routes to be used during times of coastal flooding to **enhance road evacuation**. Roads subject to coastal flooding in MA12 include The Esplanade.	**Immediate**
EM3: **Review the Gosford Local Flood Emergency Sub-Plan** (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results. This will allow community emergency services to be better prepared to assist the community during storm surge flood events.	**Immediate**
PM7: **Review and amend planning instruments and development controls** across the floodplain to ensure consistency with ocean flooding. Review every five years.	**Staged**
PM5: **Continue to monitor sea levels** in Brisbane Water. A water level gauge is located at Ettalong, and the results of water level analyses from this and other gauges would need to be communicated to residents in this management area.	**Immediate**
PM10: **Evaluate utilities infrastructure** and partner with private utilities managers to better understand the coastal flood and sea level rise risks to assets. Formulate a plan of management over the long term for integration into Council's planning objectives. A range of utilities exist in MA12, including electricity, telecommunications, water and sewer.	**Staged**

PM3: Investigate the potential for implementation of a **land swap program** for properties that meet specified criteria (e.g. inundated by sea level rise and flooding in regular events) with land that Council owns in non flood-prone areas.	**Staged**
PM8: Develop a series of **management-area specific development controls**, customised to suit each locality.	**Staged**
PM4: Conduct a program of strategic, **balanced and socially sensitive education** to advise the local community and prospective property purchasers about the risk and effects of coastal flooding. This could include the provision of additional information regarding s149 Certificates.	**Staged**
PM9: **Develop sea level rise management strategies**, particularly with regard to tidal inundation. This management action should be considered as the basis of the proposed *Climate Change Adaptation Plan* for this management area.	**Staged**
EM1: Conduct targeted **flood education programs** for flood-affected residents, with an emphasis on access and evacuation during storm surge flood events.	**Staged**
PM2: **Implement a voluntary house raising program** for identified dwellings that meet specified criteria. A detailed floor survey would be required prior to the final selection of any properties for voluntary house raising.	**Staged**
FM4: **Install flood gates/valves on stormwater pipe** outlets as required.	**Staged**

Management Area 13 – Booker Bay





Management Area Details

Land Use

This management area consists primarily of residential land uses, and includes many waterfront properties.

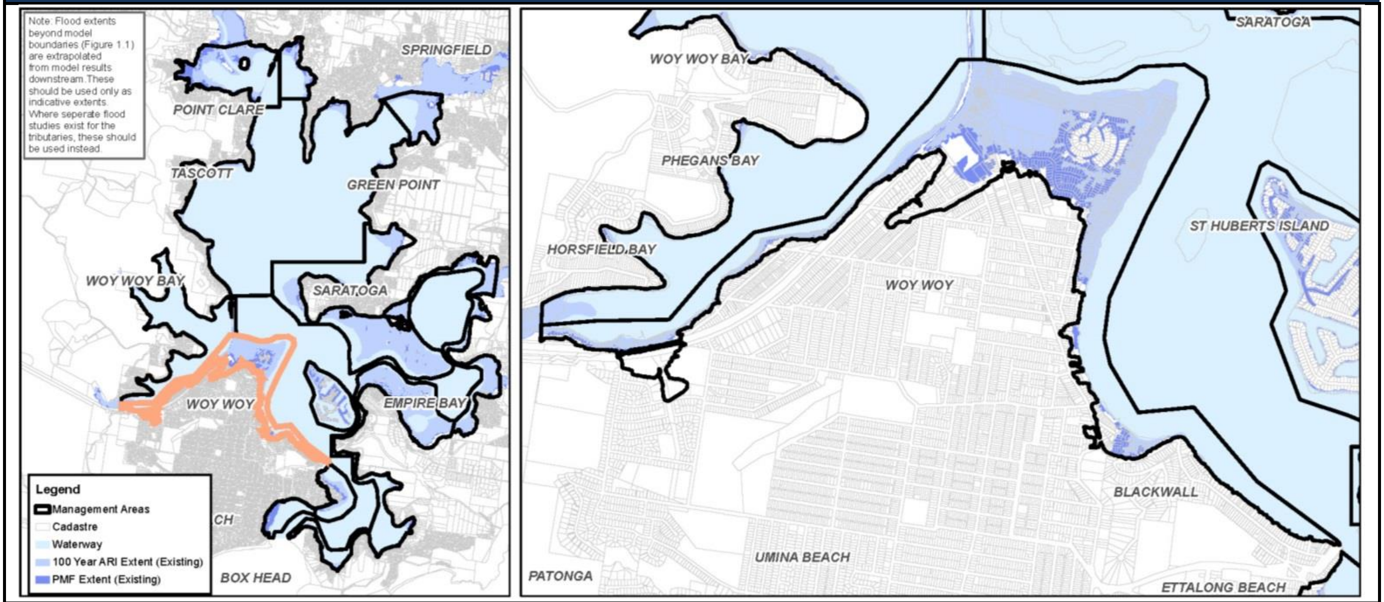
Flooding Mechanisms

Existing Scenario (no SLR):	Future Scenario (0.9m SLR):
Existing high tides in this area can cause inundation, especially high tides with joint occurrence of storm conditions. In these instances, roads and some residential properties are affected.	High tides in this area are likely to cause inundation of properties and roads. Further inundation of properties and roads, is likely to occur in higher probability ARI events.

Recommended Actions – Management Area-Specific	
13_PM11a: Undertake detailed investigation of the **impacts of structural floodplain risk management options on overland flows** in Booker Bay.	**Immediate**
13_FM3: Modify the existing foreshore in areas most affected by wave run-up to **incorporate wave energy dissipating designs**. This will assist in the protection of individual properties not already identified as flood affected (as they lie outside the 100 year ARI extent, but may be impacted by wave run-up depending on swell and wind conditions). On-the-ground surveys will be required to ascertain the exact locations where dissipation designs will be appropriate within associated environmental constraints.	**Staged**
Recommended Actions – Floodplain-Wide	**Implementation**
EM7: **Review evacuation centre locations** to ensure that evacuation centres that lie within the floodplain are not utilised during flood emergencies. The evacuation centres nearest to MA13 that are not within the floodplain are the Ettalong War Memorial Club and Umina Bowling Club.	**Immediate**
EM4: **Review flood warning systems** on a periodic basis and update as necessary. This could include a provision for demountable road sign flood warnings on roads in nearby areas.	**Immediate**
EM8: Develop and review detours and alternative routes to be used during times of coastal flooding to **enhance road evacuation**. Roads subject to coastal flooding in MA13 include Booker Bay Road..	**Immediate**
EM3: **Review the Gosford Local Flood Emergency Sub-Plan** (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results. This will allow community emergency services to be better prepared to assist the community during storm surge flood events.	**Immediate**
PM7: **Review and amend planning instruments and development controls** across the floodplain to ensure consistency with ocean flooding. Review every five years.	**Staged**

PM5: **Continue to monitor sea levels** in Brisbane Water. There are no water level gauges in MA13, however the results of water level analyses would still need to be communicated to residents in this management area. The nearest gauge is at Ettalong.	**Immediate**
PM10: **Evaluate utilities infrastructure** and partner with private utilities managers to better understand the coastal flood and sea level rise risks to assets. Formulate a plan of management over the long term for integration into Council's planning objectives. A range of utilities exist in MA13, including electricity, telecommunications, water and sewer.	**Staged**
PM3: Investigate the potential for implementation of a **land swap program** for properties that meet specified criteria (e.g. inundated by sea level rise and flooding in regular events) with land that Council owns in non flood-prone areas.	**Staged**
PM8: Develop a series of **management-area specific development controls**, customised to suit each locality.	**Staged**
PM4: Conduct a program of strategic, **balanced and socially sensitive education** to advise the local community and prospective property purchasers about the risk and effects of coastal flooding. This could include the provision of additional information regarding s149 Certificates.	**Staged**
PM9: **Develop sea level rise management strategies**, particularly with regard to tidal inundation. This management action should be considered as the basis of the proposed *Climate Change Adaptation Plan* for this management area.	**Staged**
EM1: Conduct targeted **flood education programs** for flood-affected residents, with an emphasis on access and evacuation during storm surge flood events.	**Staged**
PM2: **Implement a voluntary house raising program** for identified dwellings that meet specified criteria. Some properties have been identified in this management area as being eligible for voluntary house raising. A detailed floor survey would be required prior to the final selection of properties.	**Staged**
FM4: **Install flood gates/valves on stormwater pipe outlets** as required.	**Staged**

Management Area 14 – Woy Woy and Blackwall



Management Area Details

Land Use

This management area consists primarily of residential land uses, commercial land uses, open space and infrastructure (including the Central Coast railway line).

Flooding Mechanisms

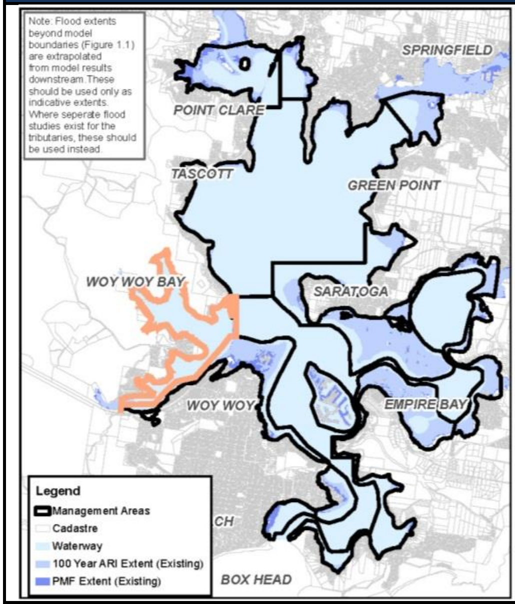
Existing Scenario (no SLR)	Future Scenario (0.9m SLR)
Existing Scenario (no SLR): Existing high tides in this area can cause inundation, especially with joint occurrence of storm conditions. Some residential and commercial properties are affected even in higher probability ARIs events.	**Future Scenario (0.9m SLR):** Roads and a large number of residential properties are likely to be affected by high tides. Further inundation is likely in higher probability ARI events. High flood depths are more common due to very flat terrain.

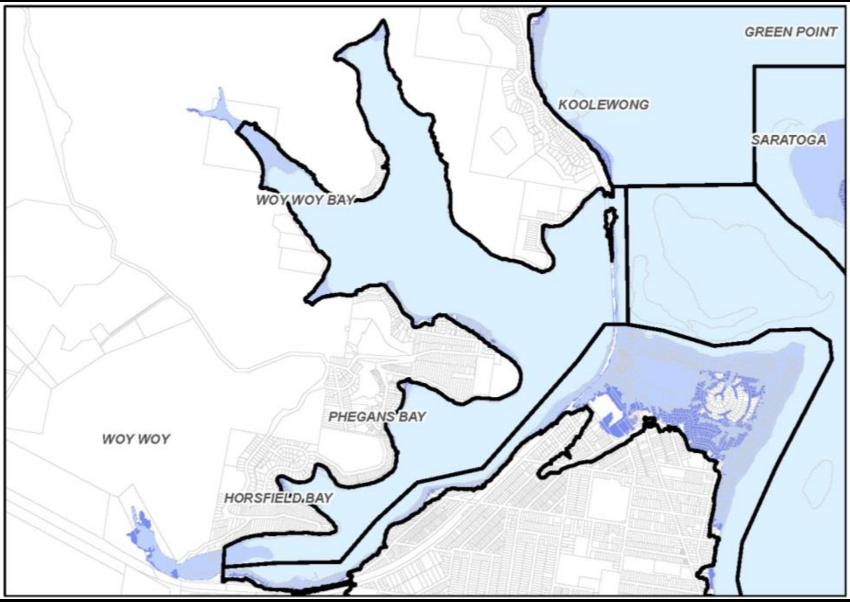
Recommended Actions – Management Area-Specific	
14_EM2: Install and maintain "Road Floods" signs at Blackwall Road, Brick Wharf Road and North Burge Road, Woy Woy. Flood signage along roads that are liable to flood allow residents to be aware of whether it is dangerous to traverse a particular section of road during a flood event.	**Immediate**
14_PM6: **Relocate Woy Woy Police Station** to a location outside of the floodplain. This facility is likely to be subject to coastal flooding in events greater than the 20 year ARI (existing case). Relocating this infrastructure to a location outside the floodplain would provide access to and from the station so that more reliable assistance could be provided to those in need of police assistance during a flood event.	**Staged**

Recommended Actions – Floodplain-Wide	Implementation
EM7: **Review evacuation centre locations** to ensure that evacuation centres that lie within the floodplain are not utilised during flood emergencies. The evacuation centre nearest to MA14 that is not within the floodplain is the Woy Woy Peninsula Community Centre.	**Immediate**
EM4: **Review flood warning systems** on a periodic basis and update as necessary. This could include a provision for demountable road sign flood warnings on roads such as Woy Woy Road.	**Immediate**
EM8: Develop and review detours and alternative routes to be used during times of coastal flooding to **enhance road evacuation**. Roads subject to coastal flooding in MA14 include Woy Woy Road, Blackwall Road, Brick Wharf Road, North Burge Road and Brisbane Water Drive.	**Immediate**
EM3: **Review the Gosford Local Flood Emergency Sub-Plan** (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results. This will allow community emergency services to be better prepared to assist the community during storm surge flood events.	**Immediate**
PM7: **Review and amend planning instruments and development controls** across the floodplain to ensure consistency with ocean flooding. Review every five years.	**Staged**

PM5: **Continue to monitor sea levels** in Brisbane Water. There are no water level gauges in MA14, however the results of water level analyses would still need to be communicated to residents in this management area. The nearest gauge is at Koolewong.	**Immediate**
PM10: **Evaluate utilities infrastructure** and partner with private utilities managers to better understand the coastal flood and sea level rise risks to assets. Formulate a plan of management over the long term for integration into Council's planning objectives. A range of utilities exist in MA14, including electricity, telecommunications, water and sewer.	**Staged**
PM3: Investigate the potential for implementation of a **land swap program** for properties that meet specified criteria (e.g. inundated by sea level rise and flooding in regular events) with land that Council owns in non flood-prone areas.	**Staged**
PM8: Develop a series of **management-area specific development controls**, customised to suit each locality.	**Staged**
PM4: Conduct a program of strategic, **balanced and socially sensitive education** to advise the local community and prospective property purchasers about the risk and effects of coastal flooding. This could include the provision of additional information regarding s149 Certificates.	**Staged**
PM9: **Develop sea level rise management strategies**, particularly with regard to tidal inundation. This management action should be considered as the basis of the proposed *Climate Change Adaptation Plan* for this management area.	**Staged**
EM1: Conduct targeted **flood education programs** for flood-affected residents, with an emphasis on access and evacuation during storm surge flood events.	**Staged**
PM2: **Implement a voluntary house raising program** for identified dwellings that meet specified criteria. Some properties have been identified in this management area as being eligible for voluntary house raising. A detailed floor survey would be required prior to the final selection of properties.	**Staged**
FM4: **Install flood gates/valves on stormwater pipe outlets** as required.	**Staged**

Management Area 15 – Woy Woy Bay, Phegans Bay and Horsfield Bay





Management Area Details

Land Use

This management area consists primarily of residential land uses, with many waterfront properties.

Flooding Mechanisms

Existing Scenario (no SLR):	Future Scenario (0.9m SLR):
Foreshore inundation is confined to small areas within these three bays and is limited by steep terrain. Residential properties are more likely to experience over-ground flooding than over-floor flooding.	One road and several properties are likely to be impacted by high tides. Further inundation will occur in higher probability ARI events. Inundation is limited by steep terrain.

Recommended Actions – Management Area-Specific

No management area-specific actions recommended.

Recommended Actions – Floodplain-Wide	Implementation
EM7: **Review evacuation centre locations** to ensure that evacuation centres that lie within the floodplain are not utilised during flood emergencies. The evacuation centre nearest to MA15 that is not within the floodplain is the Woy Woy Peninsula Community Centre, however road access to this location may be impeded from floodwaters, so Kariong Community Centre may be a more appropriate location.	**Immediate**
EM4: **Review flood warning systems** on a periodic basis and update as necessary. This could include a provision for demountable road sign flood warnings on roads such as Woy Woy Road.	**Immediate**
EM8: Develop and review detours and alternative routes to be used during times of coastal flooding to **enhance road evacuation**.	**Immediate**
EM3: **Review the Gosford Local Flood Emergency Sub-Plan** (Gosford LEMC, 2013) with regards to the updated Brisbane Water Floodplain Risk Management Study results. This will allow community emergency services to be better prepared to assist the community during storm surge flood events.	**Immediate**
PM7: **Review and amend planning instruments and development controls** across the floodplain to ensure consistency with ocean flooding. Review every five years.	**Staged**
PM5: **Continue to monitor sea levels** in Brisbane Water. There are no water level gauges in MA15, however the results of water level analyses would still need to be communicated to residents in this management area. The nearest gauge is at Koolewong.	**Immediate**
PM10: **Evaluate utilities infrastructure** and partner with private utilities managers to better understand the coastal flood and sea level rise risks to assets. Formulate a plan of management over the long term for integration into Council's planning objectives. A range of utilities exist in MA15, including electricity, telecommunications, water and sewer.	**Staged**

PM3: Investigate the potential for implementation of a **land swap program** for properties that meet specified criteria (e.g. inundated by sea level rise and flooding in regular events) with land that Council owns in non flood-prone areas.	**Staged**
PM8: Develop a series of **management-area specific development controls**, customised to suit each locality.	**Staged**
PM4: Conduct a program of strategic, **balanced and socially sensitive education** to advise the local community and prospective property purchasers about the risk and effects of coastal flooding. This could include the provision of additional information regarding s149 Certificates.	**Staged**
PM9: **Develop sea level rise management strategies**, particularly with regard to tidal inundation. This management action should be considered as the basis of the proposed *Climate Change Adaptation Plan* for this management area.	**Staged**
EM1: Conduct targeted **flood education programs** for flood-affected residents, with an emphasis on access and evacuation during storm surge flood events.	**Staged**
PM2: **Implement a voluntary house raising program** for identified dwellings that meet specified criteria. A small number of properties have been identified in this management area as being eligible for voluntary house raising. A detailed floor survey would be required prior to the final selection of properties.	**Staged**
FM4: **Install flood gates/valves on stormwater pipe outlets** as required.	**Staged**