Fraser Coast Coastal Hazard Adaptation Strategy (CHAS)

Coastal Futures: Planning Our Changing Coastline

Phase 5 – Risk Assessment

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Synopsis: **This report presents a risk assessment for exposed to current and future coastal hazards within the Fraser Coast Regional Council area.**

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Executive Summary

As part of the development of the Fraser Coastal Hazard Adaptation Strategy (CHAS), known locally as the *Coastal Futures: Planning Our Changing Coastline* project, an understanding of the risks to key assets from coastal hazards is required. This information will be used in subsequent CHAS phases to develop adaptation options that avoid or reduce the exposure of people and property to an unacceptable or intolerable level of risk.

Risks have been assessed for assets and values exposed to erosion, storm tide inundation and projected sea level rise impacts for the present day (2019-2030), 2050 and 2100 planning horizons. Community values to inform the risk assessment have been sourced from engagement activities documented in the Phase 4 Engagement Report. The risk assessment outputs have been discussed and refined with key internal stakeholders.

The risk assessment identifies property and assets with potentially ‘low’, ‘medium’, ‘high’ and ‘extreme’ risk from coastal hazards. The different risk rankings help to identify priorities for adaptation action, with the ‘high’ and ‘extreme’ rankings representing the most pressing risks that should be prioritised for implementation of risk treatment responses. The high and extreme risks that may require more immediate action, further evaluation and/or monitoring are listed in Table 1.

Table 1 Assets at Extreme and High Risk

Reporting Area	Asset	Erosion			Sea Level Rise		Storm Tide		
		Present day	2050	2100	2050	2100	Present day	2050	2100
Burrum Heads & Surrounds	Open coast beach and foreshore areas				H	H			
	Bushnell Road (seaward end), Traviston Park				H	H			
	Cheeli Lagoon, Ivor Drive					H			
	Burrum Heads Fire Station						H	H	H
	Sewage pump stations (x 2)		E	E	H	H			
	Water storage protected by Burrum Heads weir			H					
	Burrum Heads Road (seaward end)	H	H	H		H		H	E
	Orchid Drive (seaward end)		H	H				H	E
	Ivor Drive					H		H	E
	Riverview Drive					**E**		H	E
	Ross Street							H	E
Toogoom	Pialba-Burrum Heads Road (O'Regan Creek crossing)				**E**	**E**	H	**E**	E
	Toogoom Road	H	H	H	H	**E**	H	**E**	E
	Lorikeet Avenue					**E**	H	**E**	E
	O'Regan Creek Road			H		H	H	**E**	E
	Toogoom Rural Fire Brigade								
	Toogoom Boat Ramp & Jetty				**E**	**E**		H	H
	Fixter Park					H			
Craignish & Dundowran Beach	Pialba-Burrum Heads Road								**E**
	Petersen Road								H
	Sawmill Road								H

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Reporting Area	Asset	Erosion			Sea Level Rise		Storm Tide		
		Present day	2050	2100	2050	2100	Present day	2050	2100
Eli Waters to Urangan	Open coast beach and foreshore areas				H	H			
	Piers		E	E	E	E			
	Urangan Boat Harbour & boat ramps	E	E	E	E	E	H	H	H
	Wetside Water Education Park	H	H	H					
	Pialba Oval			H		H			
	Dayman Park			H					
	Caravan & Holiday Parks (Scarness, Torquay & Urangan)								H
	Booral Road		H				H	E	E
	Esplanade (Point Vernon)				H	E	H	E	E
	Esplanade (Urangan)					E	H	E	E
	Serenity Drive (Eli Waters)					E	H	E	E
	Pier Street					H	H	E	E
	Sewage pump station (Pialba)			E		E			
	Pulgul Water Water Treatment Plant			H		H			
River Heads	Barge ramp and boat ramp	E	E	E	H	H			
	Booral Homestead Complex					E			
	Bunya Creek effluent reuse facility site			E		E			
Maaroom	Graville Road					H			H
	Maaroom Foreshore Reserve and beach			H		H			
	Maaroom Boat ramp			E					
Boonooroo	Boonooroo Boat ramp			E		H			
	Boonooroo Caravan Park			E		H			

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Reporting Area	Asset	Erosion			Sea Level Rise		Storm Tide		
		Present day	2050	2100	2050	2100	Present day	2050	2100
	Wilkinson Road	H	H	H		H			
	Eckert Road				H	H			
	Rawson Road					H			
Tuan	Tuan foreshore				H	H			
	Turton Street					H			H
	Wilkinson Road	H	H	H		E			H
Poona	Poona Foreshore Reserve and beach		H	E	H	E			
	Boronia Drive					H			H
Tinnanbar	Tinnanbar Foreshore Reserve and beach				H	H			
	Tinnanbar Boat ramp	H	H	H	E	E			
Mary River	Maryborough Hervey Bay Road	H	H	H					
	Bruce Highway	H	H	H					
	Tiger Street	H	H	H					
	Beaver Rock Road	H	H	H	H	H		E	E
	Island Plantation Road					E		H	E
	Boat ramps and jetties (numerous)	E	E	E	E	E			
	Queens Park			H		H			
	Prickett Aquatic Area			H		H			
	Aubinville Waste treatment plant	H	H	H	H	E			
	Maryborough Sailing Club and Rowing Club	H	H	H	E	E			
K'gari (Fraser Island)	Wangoolba Barge Landing	H	H	H	E	E			
	Transmitter Station	H	H	H	E	E			

Reporting Area	Asset	Erosion			Sea Level Rise		Storm Tide		
		Present day	2050	2100	2050	2100	Present day	2050	2100
	Kingfisher Bay Ferry Landing	E	E	E	E	E		H	H
	Beaches used as roads				H	H			
	North White Cliffs	E	E	E	H	H			H

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1 Introduction

1.1 Purpose of the Report

Fraser Coast Regional Council (FCRC) has commenced studies to support preparation of a Coastal Hazard Adaptation Strategy (CHAS) under the QCoast$_{2100}$ program, known locally as the *Coastal Futures: Planning Our Changing Coastline* project. Phase 2 of the CHAS identified potential risks to the community, assets and values associated with coastal hazards, specifically:

- Temporary flooding of coastal areas due to storm tide;
- Temporary loss of land due to coastal erosion; and
- Permanent loss of land due to coastal erosion and sea level rise.

The subsequent Phases 3 and 4 defined the hazard extents and identified the potentially vulnerable assets and values.

This report to support Phase 5 describes the assessment of risk for assets and values potentially exposed to hazards:

- A first-pass risk assessment designed to communicate the regional-scale change in risk profile over time is described in Appendix A with the outputs mapped in Appendix B and Appendix C.
- A more detailed, locality-based risk assessment. Specifically, the analysis focuses on key assets and values potentially exposed to coastal hazards for the current to short-term climate (2019 to 2030, referred to throughout this report as present climate), and medium to long-term (nominally 2050 and 2100) projected future climates.

The CHAS Phase 3 and 4 studies provide the basis for understanding the nature and extent of the coastal hazards and for identifying the potentially vulnerable assets and values. These preceding reports and mapping products provide important background information and context to the assessments presented in this report.

1.2 QCoast$_{2100}$ Program

The QCoast$_{2100}$ program has been designed to assist Queensland coastal councils with funding and technical support to progress the preparation of plans and strategies to address climate change related coastal hazard risks. Governed by a Board comprising members from LGAQ, DES and Department of Local Government, Racing and Multicultural Affairs (DLGRMA), the program is intended to guide decision-making across key areas of local government planning and operations, including:

- Corporate and operational planning and financial planning;
- Land use planning and development assessment;
- Infrastructure planning and management including roads, stormwater and foreshores;
- Asset management and planning including nature conservation, recreation, cultural heritage values and other public amenities;
- Community planning; and

- Emergency management.

The QCoast$_{2100}$ Minimum Standards & Guidelines (MS&G) (DEHP, 2016) provide guidance to local government on preparing a CHAS. The guidelines set minimum requirements that are to be included in a CHAS, as well as providing information on leading practices to facilitate continuous improvement.

The minimum standards set a benchmark for undertaking such studies in Queensland so that coastal hazard adaptation decision-making is approached in a consistent and systematic manner. The MS&G are structured to address the key phases of a CHAS which are illustrated in Figure 1-1. This report is a key output of Phase 5 – the assessment of risks to important assets from current and future coastal hazards.

This report provides critical inputs that will be used to inform where adaptation measures may be required.

Figure 1-1 QCoast$_{2100}$ Phases (DEHP, 2016)

1.3 Coastal Hazard Mapping (Phase 3)

Phase 3 of the CHAS included the production of coastal hazard maps which have been used to identify assets at risk from future coastal hazards and the consequences that may result. A brief summary of the hazard mapping products is provided below.

1.3.1 Erosion Hazard

A recalculation of the State's erosion prone area widths (which are nominally for the year 2100) was completed by Cardno (2012) for the Hervey Bay coastline between River Heads and Burrum Heads, and around the five Great Sandy Strait settlements (Tinnanbar, Poona, Tuan, Boonooroo and Maaroom). The approach used by Cardno for the Hervey Bay coastline involved the

interpolation of the State's open coast calculated 2100 erosion prone area (EPA) widths with the contributions for long-term erosion and sea level rise in the declared 2100 EPA widths reduced to reflect the shortened time periods.

Cardno's mapping for the Great Sandy Strait was identified as being inconsistent with the State's EPA definition. Phase 3 reporting discusses the updates that were made to mapping in those areas, as well as the mapping prepared for estuarine areas elsewhere within the local government area.

The Cardno assessment of erosion hazard areas was undertaken to inform the development of a shoreline erosion management plan for the region. No reduction in erosion prone area widths was applied to locations with coastal protection structures such as seawalls, which aligns with the approach used in the State's 2100 EPA mapping. As the protection offered by these structures relies on their condition and design suitability, their presence is considered during the risk assessment process.

To support the assessment of assets in other open coast areas not covered by the Cardno (2012) assessment (i.e. K'gari, Fraser Island), BMT applied the same methodology used by Cardno to complete the understanding of the open coast erosion hazard. For the present climate and the 2050 future climate, the contributions for long-term erosion and sea level rise in the declared 2100 EPA widths were reduced to reflect the shortened time periods.

In accordance with the definition of the erosion prone area (DEHP, 2013), the erosion prone area along the coast is the greater of:

(1) The calculated open coast erosion area;

(2) The nominated buffer distance inland of the line of highest astronomical tide (HAT) (wave action/tidal flow erosion buffer); and

(3) The plan position of projected sea level rise above the elevation of HAT (sea level rise erosion).

In estuarine areas, such as elsewhere in Great Sandy Strait and within the Mary and Burrum River catchments, the erosion prone area was determined as being the greater of:

(1) The nominated buffer distance inland of the line of highest astronomical tide (HAT) (wave action/tidal flow erosion buffer); and

(2) The plan position of projected sea level rise above the elevation of HAT (sea level rise erosion).

For the FCRC assessment, the allowances adopted for the buffer distance and sea level rise for present and future climates are set out in Table 1-1. Since the present climate covers the period from 2019 to 2030, an allowance for sea level rise has been included.

Table 1-1 Estuarine Erosion Prone Area Allowances

Allowance	Present Climate (2019 – 2030)	2050 Future Climate	2100 Future Climate
Buffer (m)	10	20	40
Sea level rise (m)	0.1	0.3	0.8

1.3.2 Storm Tide

A storm tide hazard assessment and associated mapping was prepared as part of Phase 3 work for the entire local government area, including Fraser Island (BMT, 2019).

The assessment provides statistics up to the 1,000 year Average Recurrence Interval (or 0.1% Average Exceedance Probability) across the local government area and considers extreme water levels associated with tropical cyclone and non-tropical cyclone weather systems.

Storm tide levels were assessed for the present climate and 2050 and 2100 future climates. The 1 in 100 year (1% AEP) storm tide event for each of these climates is used in this asset assessment. Mapping of hazard extents was developed using the storm tide elevations from the study and applied to the 2009 and 2015 LiDAR elevation data.

The modelling and mapping used in the asset assessment made the following key assumptions:

- Across the coastal floodplain the 'sustained peak' is determined by the 'tide plus surge' components which can persistent for long enough to inundate the coastal floodplain up to this level. For open coast locations (namely the Hervey Bay and Fraser Island coastlines), the sustained peak also includes an allowance for wave setup.
- The potential influence of wave runup processes is considered within a 200 m buffer landward of the open coast coastline, with decreasing influence from the shoreline to the 200 m landward buffer. This represents the potential threshold for an 'intermittent' (the order of seconds to minutes) water level associated with wave runup.
- The 'tide plus surge' peak water levels have been applied throughout the Great Sandy Strait and within the Mary and Burrum Rivers. The influence of wave processes through these areas is assumed to be negligible.
- Freeboard has not been applied as different freeboard allowances may apply to different areas depending on usage of the land and the relative exposure to coastal processes.

Additional details on the storm tide assessment and mapping can be found in the associated Phase 3 reports.

1.3.3 Sea Level Rise

Sea-level rise hazard mapping has been developed for the present climate and 2050 and 2100 future climates using the 2009 and 2015 LiDAR elevation data, based on increases relative to present climate HAT values along the coast developed in the storm tide study. Sea level rise allowances are in accordance with those set out in Table 1-1.

1.4 Vulnerable Asset Identification (Phase 4)

Phase 4 of the CHAS has:

- Identified and mapped assets – both tangible and intangible within the mapped coastal hazard areas;
- Identified and described potential impacts to interdependent infrastructure systems;
- Estimated the underlying value of affected assets; and

- Prioritised assets for risk analysis.

All identified assets were prioritised according to:

- Difficulty to replace an asset;
- The cost of replacing an asset;
- The value the community places on an asset;
- The scarcity of an asset across the Local Government Area;
- The remaining design life of an asset (i.e. a shorter design life may create opportunities for asset replacement or responding to a changing risk profile easier);
- The ability of an asset to withstand a hazard;
- The criticality of an asset i.e. is an essential service in an emergency;
- Biodiversity value;
- The role the asset plays in Fraser Coast's economy i.e. fiscal contribution; and
- The aesthetic value of an asset.

Any assets that received a score greater than 4 (one a scale of 0-5) were identified as key assets for consideration in the risk assessment. Assets include:

- Beaches;
- Foreshore parklands and associated infrastructure;
- Stormwater, wastewater and water supply assets;
- Transport infrastructure e.g. roads, bikeways etc.;
- Marinas, boat ramps, jetties etc.;
- Tourism and community facilities e.g. surf life-saving clubs, caravan parks and accommodation facilities;
- Environmental assets (e.g. national parks, environmental reserves);
- Commercial properties/businesses;
- Residential properties (multi-residential and detached dwellings); and
- Important coastal land (rural, residential, tourist development etc.).

2 Locality Based Risk Assessment Methodology

2.1 Introduction

This chapter describes the detailed locality-based risk assessment, focusing on key assets and values potentially exposed to coastal hazards for the present (2019 to 2030) and projected 2050 and 2100 future climates.

Prior to undertaking the locality-based risk assessment described below, a first-pass risk assessment was completed. The approach used the coastal hazard mapping developed as part of the CHAS Phase 3 with land use Planning Zones as defined by the Fraser Coast Planning Scheme 2014 as a proxy of vulnerability of the land parcel. This regional-scale assessment provides an overview coastal hazard risks to land and is described in Appendix A with the mapping outputs provided in Appendix B (storm tide risk) and Appendix C (erosion and sea level rise risk).

2.2 General Approach

A risk management approach following ISO31000:2018 Risk Management has been applied to assessing coastal hazards and future management, as required by the QCoast$_{2100}$ MS&G.

The risk assessment framework is a robust methodology for dealing with outcomes that are uncertain or have limited data, or for impacts with uncertain timeframes. Uncertainties associated with future climate change presents challenges to local government coastal managers and the wider community, who need to consider and manage future risks. Decisions made today are likely to have ramifications for up to 100 years (depending on the locality and/or asset), so consideration of an extended timeframe is essential, even though risks may not manifest for several decades.

The use of a risk-based approach to manage coastal hazards is a requirement of most state guidelines in Australia and accords with current international best practice for natural resource management. The steps involved in a risk assessment adjusted to suit the locality-based coastal hazard risk management process, include:

- **Establish the Context** – the requirements of a coastal hazard assessment are as set by state guideline documents and the QCoast$_{2100}$ Guidelines, which provide the context for the risk assessment and intended outcomes.
- **Identify the Hazards and Vulnerability** – hazards are identified and mapped in the Phase 3 coastal hazard assessment reports (BMT 2019), namely permanent inundation from sea level rise, storm tide inundation and coastal erosion. Assets exposed to these hazards are identified in the Phase 4 report (BMT 2020).
- **Analyse the Risks –** this involves considering the **likelihood** and **consequence** of the identified risks, to determine the overall level of risk. This includes the need to identify:
    - the **likelihood** of risks - the likelihood is based on the following climate change scenario-based planning horizons: present climate (2019 to 2030), 2050 and 2100.
    - The **consequence** of the risks will relate largely to the effect that a hazard has on assets that are of value (i.e. economic, community or environmental values) to Council and the community.

- The type of impact (e.g. short-term inundation compared with long term recession of land) is also considered when assessing the consequence of the different coastal hazards. It is both the likelihood and consequence of coastal risks combined that determines the level of risk.

Once risk levels for different assets have been determined from the combination of likelihood and consequence, **the risk level** for assets and land in the coastal hazard area is mapped using GIS. Existing controls (e.g. by Council or other state agencies) that may reduce the level of risk are then considered and included as required (allowing residual risk to be determined). A register of the level of risk to various assets inform the risk analysis and mapping process.

2.3 Fraser Coast-specific Approach

The risk assessment approach has been designed:

- To accommodate uncertainty that is inherent in climate change risk assessment (as well as coastal processes, local geomorphology and expected responses).
- To offer a decision-making framework to develop actions even when there is little data or high uncertainty.
- To meet ISO 31000:2018 Risk Management and QCoast$_{2100}$ Guidelines.
- To provide a process that supports incorporating improved data and risk knowledge over time.
- To focus effort and resources towards those aspects / areas at greatest risk (i.e. a risk-based prioritisation process).

The process represented below has been iterative and has involved revisiting or revising the CHAS Phases 1, 2, 3 and 4 on occasion in response to feedback from stakeholders and the consultation process, or as more detailed assessments were carried out.

2.4 Risk Framework

This section describes the locality-based risk framework tailored to the needs of the Fraser Coast region. The criteria have been developed specifically for this project to reflect the mapped hazards (Phase 3 reports) endorsed by DES and LGAQ. These reports defined the climate change scenarios and storm event return periods to be used for the CHAS.

This approach also seeks to align with Council's Corporate Risk Management Framework.

2.4.1 Analysis of Risk Likelihood

The likelihood scale used for the risk assessment reflects a changing climate in which the probability of a hazard occurring increases over time as sea levels rise. Three time periods are used, consisting of present day (2019 to 2030), 2050 and 2100. A separate assessment of the risk at each of these time horizons was undertaken for each asset, enabling temporal changes in risk profiles to be determined.

The probability of a hazard occurring in any given year is defined using terminology such as Average Recurrence Interval (ARI), or Annual Exceedance Probability (AEP). In its simplest form, a 1 in 100 year ARI (or 1% AEP) refers to a hazard event of a magnitude that it would only be

statistically likely to occur once every 100 years. It does not mean that it will only happen once every 100 years – storm occurrence can sometimes be clustered in a series of large storm events over a relatively short period of time, followed by a prolonged period of inactivity.

Generally, a hazard such as a water level that may occur rarely now (e.g. the 1 in 100 year ARI or 1% AEP) is expected to occur more frequently in the future. This is demonstrated by mapping hazards that have a consistent likelihood (e.g. 1 in 100 year ARI or 1% AEP) over progressive timeframes (e.g. present climate, 2050 and 2100). In this case, the spatial extents of the 1 in 100 (1%) AEP hazards increase over time. Another way to interpret the temporal change to the risk profile is to consider the relative likelihood of impact at a specific asset or location.

For example, under present day conditions, there may be a 1 in 100 (1%) chance that a storm tide water level threshold is reached in any year. By 2050, the likelihood of reaching this same water level may have increased to a 1 in 20 (5%) chance due to sea level rise, while by 2100 it may have increased further to a 1 in 5 (20%) chance of occurrence.

Table 2-1 presents the likelihood descriptions, aligning with Council's risk management terminology, and scale used as part of the risk assessment process. Importantly, sea levels are projected to continue rising well beyond the 2100 planning horizon, emphasising the need for long-term adaptation pathways that accommodate future climate conditions.

There is significant uncertainty associated with the magnitude and timing of the effects of sea level rise on coastal hazards. The risk assessment framework provides for areas of risk to be identified and for monitoring over time. Once certain agreed impacts are realised this will trigger the implementation of a different suite of management/adaptation responses (the focus of the Phase 6 and 7 of the CHAS). It is expected that over time climate change models will be improved, and uncertainty will be reduced, and this improved understanding can be used to underpin updated risk assessments.

For the Fraser Coast CHAS, hazards which have been based on a 1 in 100 (1%) AEP have been assigned a likelihood of "Possible" at each planning horizon. This statistical likelihood is commonly adopted for land use planning decision making and is consistent with the Queensland Government approach for assessing future climate coastal hazards. However, it is noted that climate change assumptions for other projects, such as coastal engineering design, should follow the best practice guidelines (e.g. Harper 2012, 2017) and relevant standards and may require consideration of different planning horizons and likelihoods than those adopted for the CHAS.

2.4.2 Analysis of Consequence Criteria

Table 2-2 describes potential coastal hazard consequence criteria for the Fraser Coast CHAS. The consequence criteria consider community, environmental and economic consequences should a hazard event occur and is a simplified version of Council's consequence definitions and guidance provided in Appendix D.

Table 2-1 Fraser Coast CHAS Likelihood Scale

Likelihood	Likelihood Description	*Planning Horizon/Climate*		
		Present Day to 2030	***2050 Future Climate***	***2100 Future Climate***
Almost Certain	The event is expected to occur or commonly occurs	**Storm tide:** below HAT level **Erosion:** seaward of HAT contour	**Storm tide:** below HAT + SLR level **Erosion:** seaward of HAT + SLR contour	**Storm tide:** below HAT + SLR level **Erosion**: seaward of HAT + SLR contour
Likely	The event will probably occur. Has happened before recently.	**Storm tide:** 1 in 20 (5%) AEP **Erosion:** 10 m buffer on present day HAT	**Storm tide:** 1 in 20 (5%) AEP in 2050 **Erosion:** 20 m buffer on present day HAT	**Storm tide:** 1 in 20 (5%) AEP in 2100 **Erosion:** 40 m buffer on present day HAT
Possible	The event might occur at some time. Has not happened recently.	**Storm tide:** 1 in 100 (1%) AEP **Erosion:** present day storm bite	**Storm tide:** 1 in 100 (1%) AEP in 2050 **Erosion:** storm bite in 2050	**Storm tide:** 1 in 100 (1%) AEP in 2100 **Erosion:** storm bite in 2100
Unlikely	The event could occur at some time but is not considered likely to occur.	**Storm tide:** 1 in 500 (0.2%) AEP **Erosion:** within present day erosion hazard area	**Storm tide:** 1 in 500 (0.2%) AEP in 2050 **Erosion:** within 2050 erosion hazard area	**Storm tide:** 1 in 500 (0.2%) AEP in 2100 **Erosion:** within 2100 erosion hazard area
Rare	Not likely to occur. Reasonable to assume it will not happen.	**Storm tide:** 1 in 1000 (0.1%) AEP **Erosion:** beyond present day erosion hazard area	**Storm tide:** 1 in 1000 (0.1%) AEP in 2050 **Erosion:** beyond 2050 erosion hazard area	**Storm tide:** 1 in 1000 (0.1%) AEP in 2100 **Erosion:** beyond 2100 erosion hazard area

Table 2-2 Consequence Criteria

Consequence	Community		Economic
	Social	Environment	
Catastrophic	Widespread and irreversible environmental damage Fatality or Irreversible and major health effects on the community		Failure of a significant industry or sector
Major	Severe environmental or community/planning impact requiring significant remedial action Wide spread health effects across the community Multiple serious injuries		Significant structural adjustment required by industry to respond and recover from emergency event
Moderate	Moderate impact on the environment and or community/planning; no long term or irreversible damage Injuries require expert medical treatment, or One or two people may suffer ongoing health effects		Significant industry or business sector is significantly impacted by the emergency event, resulting in medium-term (i.e. more than one year) profit reductions
Minor	Minor environmental or community/planning damage such as remote temporary pollution Injury requiring first aid		Significant industry or business sector is impacted by the emergency event, resulting in short-term (i.e. less than one year) profit reductions
Insignificant	Brief, non-hazardous, transient pollution or damage A minor site treated or no lost time injury possible		Inconsequential business sector disruption

2.4.3 Vulnerability Assessment

Assessing vulnerability is an essential part of risk assessment. The consequence on an asset to coastal hazards depends on how vulnerable the asset is to the hazards.

The vulnerability of an asset class to coastal hazards, specifically coastal erosion, storm tide (temporary) inundation and sea level rise (permanent) inundation, was estimated using the following framework. Assessing asset vulnerability to impacts from catchment flooding or other climate change hazards is outside the scope of this current assessment but should form part of broader floodplain risk management and climate change adaptation planning.

In line with the Intergovernmental Panel for Climate Change (IPCC 2014), an asset's vulnerability is a function of the asset's exposure to the hazard, its sensitivity to the impacts of that hazard as well as its ability to cope with, or adapt to, those impacts. Vulnerability assumptions to support the risk assessment process are described below.

2.4.3.1 Vulnerability of land parcels

The vulnerability of a system (i.e. asset) is determined by the interaction of the biophysical exposure of the system (i.e. asset) to a hazard and its resulting socioeconomic implications. Building a mechanistic model of vulnerability is complicated, therefore proxy indicators are often used for their estimation (Tonmoy et al., 2014; Hinkel, 2011). In this study, a broad estimation of the vulnerability to coastal hazards of different private, commercial, public and natural assets was made, using the vulnerability of the land use as a proxy. This approach is described in Appendix A and assumes a land parcel zoned as 'high density residential' is likely to be more vulnerable to temporary storm tide inundation compared to a land parcel zoned as 'open space'. This is mainly because the consequence of a storm tide event is likely to be higher in high density residential areas (e.g. economic loss, disruption to community life) compared to a suburban park.

Parcels used for "park" purposes are spread between conservation, open space and sport and recreation zonings. As the importance and usage of these areas varies from locality to locality, further refinement based on the types of usage and community value may be required as part of the socio-economic assessments completed during Phase 7 of the CHAS.

2.4.3.2 Vulnerability of specific assets

The fundamental approach to the risk assessment of other assets is like that for land parcel assets. The same likelihood, consequence and risk evaluation scales have been used for assessing the risk, however, the consequence of disruption varies across asset types. This has been considered using an adjusted vulnerability score to consider economic, social and environmental consequences in accordance with Table 2-2.

Following the general assessment of the vulnerability of various land uses, non-network critical assets and important community infrastructure such as emergency service locations, community facilities, council buildings, heritage places, waste facilities, beaches, boat ramps and caravan parks were also assessed.

The vulnerability of an asset was determined by its sensitivity (i.e. whether its structure, usage, operation etc. can be affected by coastal hazards) and its capacity to adapt to future hazards (i.e. existing hazard protections, the organisation's capacity to recover the asset if disrupted etc). Key assumptions across the asset classes and hazard exposure are provided in the tables below.

With the exception of roads, the consideration of consequence for all other assets follows the criteria in Table 2-2 (i.e. 5 = Catastrophic, 4 = Major, 3 = Moderate, 2 = Minor, 1 = Insignificant). The rating against each consequence criteria varies across the assets classes as summarised below.

Roads

The analysis of roads considered the length of road segment impacted (to inform indicative damage cost), the relative importance of the road in the road hierarchy and the depth of inundation (for inundation hazards only) to inform consequence.

Table 2-3 Road classification vulnerability

Vulnerability Scale (lowest number most vulnerable)	Road classification
2	Highway or evacuation route
4	Rural Arterial, Rural Arterial MRD, Urban Arterial MRD
4	Major Collector, Minor Collector, Sub Arterial Main Street
5	Controlled Distributor, Rural Road
5	Access Street/Place
7	Tracks
10	Unformed

Table 2-4 Road inundation vulnerability

Vulnerability	Depth of inundation (m)
5	> 1.2
4	0.5 to 1.2
3	0.3 to 0.5
2	0.1 to 0.3
1	< 0.1

Water and Sewerage

The analysis of water main and sewerage pipeline assets qualitatively considers consequence in accordance with the criteria in Table 2-2 and as summarised in Table 2-5 and Table 2-6.

Table 2-5 Water mains vulnerability (pipelines)

Consequence category	Sea Level Rise	Storm Tide	Erosion
Economic	4	1	3
Community/Social	1	3	5
Environmental	1	1	3

5 = Catastrophic, 4 = Major, 3 = Moderate, 2 = Minor, 1 = Insignificant

Table 2-6 Sewerage assets vulnerability (pipelines)

Consequence category	Sea Level Rise	Storm Tide	Erosion
Gravity mains			
Economic	4	1	3
Community/Social	1	3	4
Environmental	1	1	3
Effluent mains			
Economic	2	1	3
Community/Social	1	2	3
Environmental	1	1	3

5 = Catastrophic, 4 = Major, 3 = Moderate, 2 = Minor, 1 = Insignificant

The analysis of local (e.g. pump stations) and major (e.g. sewerage treatment plants) water and sewerage assets qualitatively considers consequence in accordance with the criteria in Table 2-2 and as summarised in Table 2-7.

Table 2-7 Water and sewerage site assets vulnerability

Consequence category	Sea Level Rise	Storm Tide	Erosion
Pump stations/local infrastructure			
Economic	4	1	4
Community/Social	1	3	4
Environmental	1	1	3
Major infrastructure e.g. STP			
Economic	4	1	5
Community/Social	1	3	5
Environmental	1	1	3

5 = Catastrophic, 4 = Major, 3 = Moderate, 2 = Minor, 1 = Insignificant

Stormwater & Drainage

The analysis of stormwater and drainage assets qualitatively considers consequence in accordance with the criteria in Table 2-2 and as summarised in Table 2-8.

Table 2-8 Stormwater assets vulnerability

Consequence category	Sea Level Rise	Storm Tide	Erosion
Pipelines			
Economic	2	1	3
Community/Social	2	3	3
Environmental	1	1	3
Open drains			
Economic	2	1	3
Community/Social	2	1	3
Environmental	2	1	3

5 = Catastrophic, 4 = Major, 3 = Moderate, 2 = Minor, 1 = Insignificant

Council & Community Facilities

The analysis of major (e.g. libraries) and minor (e.g. public amenities) council facilities qualitatively considers consequence in accordance with the criteria in Table 2-2 and as summarised in Table 2-9.

Table 2-9 Council facilities vulnerability

Consequence category	Sea Level Rise	Storm Tide	Erosion
Major facilities (e.g. libraries, aquatic centres etc)			
Economic	2	2	3
Community/Social	3	2	3
Environmental	1	1	1
Minor facilities (e.g. public amenities, parks)			
Economic	1	1	2
Community/Social	2	1	2
Environmental	2	1	2

5 = Catastrophic, 4 = Major, 3 = Moderate, 2 = Minor, 1 = Insignificant

The analysis of major (e.g. caravan parks) and minor (e.g. dog off-leash areas) community facilities qualitatively considers consequence in accordance with the criteria in Table 2-2 and as summarised in Table 2-10.

Table 2-10 Community facilities vulnerability

Consequence category	Sea Level Rise	Storm Tide	Erosion
Major facilities (e.g. caravan parks, sports clubs etc)			
Economic	2	1	3
Community/Social	2	2	3
Environmental	1	1	1
Minor facilities (e.g. dog off-leash areas)			
Economic	1	1	1
Community/Social	1	1	2
Environmental	1	1	1

5 = Catastrophic, 4 = Major, 3 = Moderate, 2 = Minor, 1 = Insignificant

Coastal Assets

The analysis of major (e.g. boat ramps) and minor (e.g. beach access) coastal infrastructure qualitatively considers consequence in accordance with the criteria in Table 2-2 and as summarised in Table 2-11.

Table 2-11 Coastal assets vulnerability

Consequence category	Sea Level Rise	Storm Tide	Erosion
Major infrastructure (e.g. boat ramps, piers, seawalls etc)			
Economic	2	2	3
Community/Social	3	2	3
Environmental	1	1	1
Minor infrastructure (e.g. beach accesses)			
Economic	1	1	2
Community/Social	2	1	2
Environmental	1	1	1

5 = Catastrophic, 4 = Major, 3 = Moderate, 2 = Minor, 1 = Insignificant

Emergency Services

The analysis of emergency services facilities qualitatively considers consequence in accordance with the criteria in Table 2-2 and as summarised in Table 2-11.

Table 2-12 Emergency services facilities vulnerability

Consequence category	Sea Level Rise	Storm Tide	Erosion
Economic	1	1	3
Community/Social	3	4	4
Environmental	1	1	1

5 = Catastrophic, 4 = Major, 3 = Moderate, 2 = Minor, 1 = Insignificant

2.4.4 Incorporating Existing Controls

Where possible, the risk assessment also considers the influence of existing coastal hazard protection measures that are already in place. Measures to limit inundation via raised land levels are by default included in the risk assessment as they are reflected in the LiDAR data used to develop the mapping (works completed after the LIDAR survey date are not included). Any measures on waterways such as tide gates are not included in this city-wide risk assessment as the very specific nature of these measures, e.g. gate elevations, need to be understood in the context of hydraulic connectivity and rising inundation levels. This more detailed assessment will need to be the subject of site-specific assessments that include more detailed hydraulic modelling and mapping of waterways and drainage networks.

For locations where a Council endorsed seawall exists, it is acknowledged that these structures provide a very tangible reduction in erosion risk to landward assets. As a case study example to illustrate the benefit provided by the seawalls, an assessment has been made of the reduction in risk to assets benefiting from the presence of a maintained, fit for purpose seawall. Assets within a zone 10m landward of the seawall crest have been assessed as being within the failure extent of the structure and therefore do not have a risk reduction applied. However, all other landward assets that derive a benefit from the presence of the seawall have been assessed as having a reduced risk. This has been presented graphically in the report in terms of planning zones only.

For assets benefitting from the presence of the seawall the risk assessment therefore includes an indication of the residual risk and future risks associated with each asset. In most cases there may still be substantial residual risk and existing controls may require some modification or update to decrease the assessed level of risk.

2.4.5 Resultant Risk Analysis

Table 2-13 provides the resultant risk for the combined likelihood and consequence of a hazard occurring.

Table 2-13 Risk Categories

Likelihood	Consequence Level				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost Certain	Medium	High	Extreme	Extreme	Extreme
Likely	Medium	High	High	Extreme	Extreme
Possible	Low	Medium	Medium	High	Extreme
Unlikely	Low	Low	Medium	Medium	High
Rare	Low	Low	Low	Medium	High

2.4.6 Prioritising Treatment

Determining which risks to treat is informed by Council and the community's tolerance to risk. In most cases, it would be expected that "low" risks can simply be monitored, while "high" or "extreme" risks require more immediate action and/or monitoring through setting of trigger levels for action. The risk tolerance scale in Table 2-14 outlines how the risk categories may be interpreted or acted upon.

Table 2-14 Risk Tolerance Scale

Risk Level	Action Required	Tolerance
High / Extreme	Immediate action required to eliminate or plan to reduce the risk or accept the risk.	Intolerable
Medium	Reduce the risk over time, or further investigate the risk.	Tolerable
Low	Accept the risk; manageable through existing processes or coastal hazard management actions.	Acceptable

3 Locality Based Risk Assessment Outcomes

3.1 Introduction

A coastal hazard risk assessment was performed on the priority sites identified in the Phase 4 report within each Fraser Coast locality potentially exposed to coastal hazards to the 2100 future climate. A summary of results for each Coastal Futures Management Zone, shown in Figure 3-1, is contained in Appendix E. Discussion on intolerable risks (i.e. high or extreme risks) communities within each Management Zone is provided in the following sections.

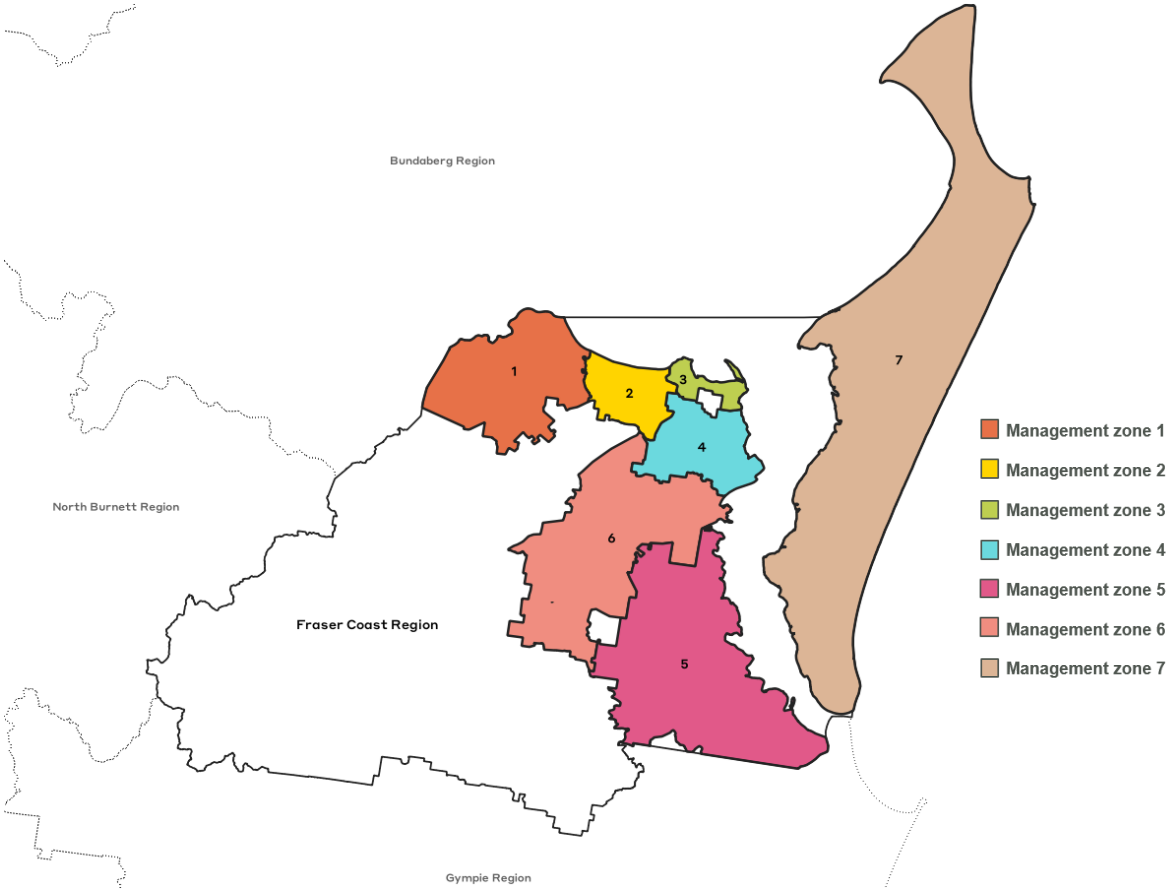

Figure 3-1 Coastal Futures Management Zone Definitions

The assessment of risk for land parcels has been conducted on the basis that any inundation or erosion of the parcel interferes with the use of the parcel for that purpose. This is a conservative assessment as no filtering has been applied to remove parcels identified as affected by only shallow water depths or with small extents in the hazard area. This approach is justified as each parcel will be unique in terms of the footprint of built or natural assets relative to the hazard area. It is acknowledged that where impacts affect just the periphery of a site that the overall risk to the land parcel is expected to be overstated. Further refinement of the risk assessment assumptions for individual land parcels would require more detailed site-based considerations and assessments.

The discussion on roads has focussed on intolerable risks to higher order roads. Additional roads including tracks will be affected but have not been reported.

Impacts on water supply, sewerage and stormwater pipelines are mainly associated with urbanised areas. Risk results for these assets has been provided at a Management Zone level in Appendix E.

Due to the nature of GIS analyses, the data associated with coastal assets such as boat ramps sometime places these facilities seaward of the cadastre, locality boundaries and/or hazard extents. Where this occurs, these assets have been manually assigned to the corresponding landside reporting area. As seawalls are intended to be used as protective structures, they have not been reported in the risk assessment, but have instead been considered in the context of the risk reduction benefit they provide.

3.2 Management Zone 1 – Burrum Heads & Surrounds

Localities within Management Zone 1 are shown in Figure 3-2. Intolerable risks within this management zone mainly occur around the community of Burrum Heads, with the number of properties at risk increasing significantly between the 2050 and 2100 future climates. Note that the suburb of Burrum Heads includes the settlement around Orchid Drive, approximately 3km south-east of the main community, although most of the intolerable risks are to the main community.

By the 2100 future climate, nearly 180 parcels of low density residential land are at high or extreme risk from sea level rise, and all are at extreme risk from erosion. Two properties in the local centre zone are exposed to intolerable risks by the 2100 climate. These are assessed as being at extreme risk from erosion and high risk from storm tide and sea level rise.

The presence of the existing seawall lining the Burrum River and adjacent open coast frontage of the community, if maintained to a “fit for purpose” standard, is assessed as nearly halving the number of properties at extreme risk from erosion.

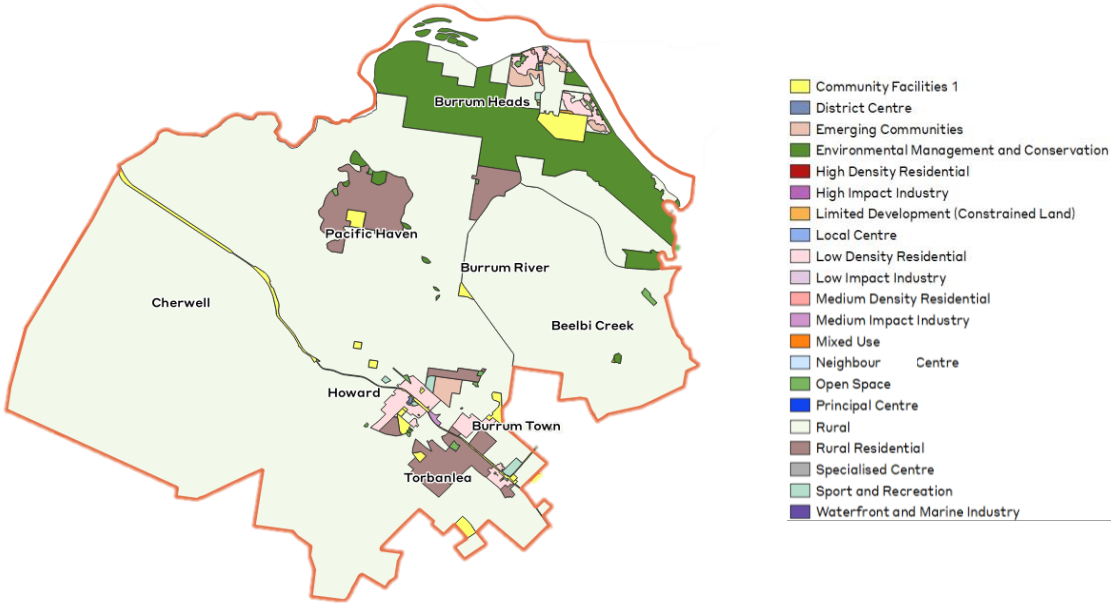

Figure 3-2 Management Zone 1 Localities & Planning Zones

Important community assets in the area at risk include the open coast beach and adjacent foreshore reserves in the environmental conservation and management zone, which are at medium risk from erosion and high risk from sea level rise under all climates. Traviston Park at the seaward end of Bushnell Road is at high risk from sea level rise by the 2050 future climate. Cheeli Lagoon on Ivor Drive is at high risk from sea level rise by the 2100 future climate.

Boat ramp facilities are at high risk from sea level rise and extreme risk from erosion under all climates, which typical for coastal dependent development. Lions Park is at high risk from sea level rise by the 2050 climate, although it must be noted that the elevation data used in the assessment was captured prior to the substantial redevelopment of this site to incorporate recreational boating infrastructure.

The Burrum Heads Beachfront Tourist Park site is at medium risk from erosion and storm tide from 2050 onwards, and medium risk from sea level rise by 2100. Burrum Heads Fire Station is at high risk from storm tide under all climates, while the Burrum Heads Library is at medium risk from storm tide under all climates.

One sewage pump station is at high risk from sea level rise and extreme risk from erosion by the 2050 future climate. By the 2100 future climate, two pump stations are at this risk level.

The water storage protected by the Burrum Weir is at high risk from erosion by the 2100 future climate.

The seaward end of Burrum Heads Road is at high risk from erosion under all climates and sea level rise by 2100, while Orchid Drive is at high risk from erosion from the 2050 future climate onwards. Ivor Drive and Riverview Drive are at high and extreme risk from sea level rise by the 2100 future climate, Riverview Drive is also at high risk from storm tide under the present climate. Storm tide risk to sections of all these roads as well as Ross Street are assessed as extreme under the 2100 future climate, and high under the 2050 climate.

Land in the emerging communities zone is assessed as being at extreme risk from sea level rise under the present climate.

Outside of the Burrum Heads community, high and extreme risks from all hazards under all climates are noted, particularly relating to inundation of rural or rural residential properties at Beelbi Creek, Burrum River, Cherwell, Howard and Pacific Haven. Except for Beelbi Creek properties, this elevated risk rating is generally associated with significant inundation depths along the river frontage of these properties, of which more than 90 rural or rural residential properties are within the present climate tidal extent. The number of rural and rural residential properties at high or extreme risk from sea level rise nearly doubles by 2050.

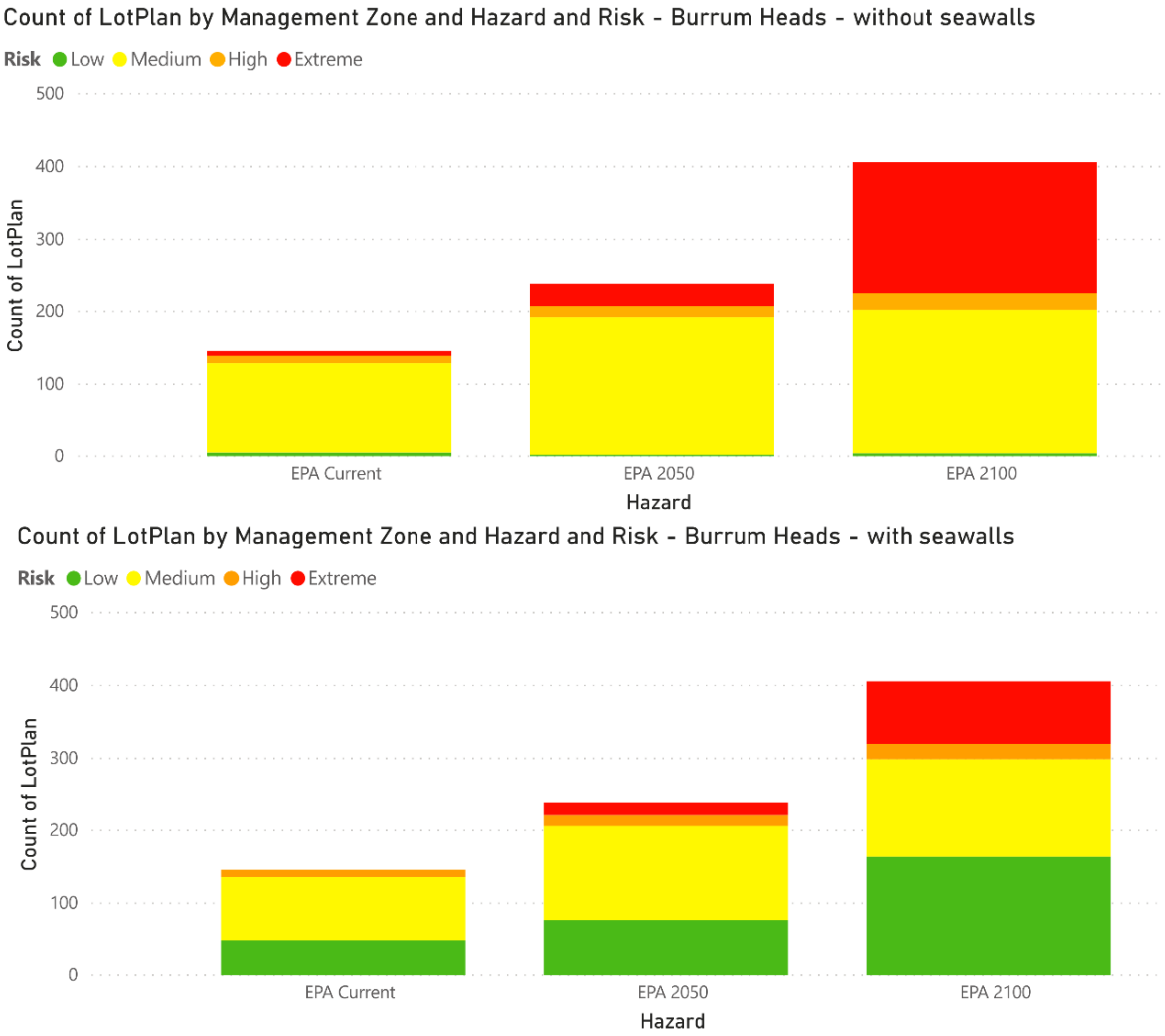

Figure 3-3 Influence of seawalls in reducing erosion risk on land parcels, Burrum Heads, all climates

Table 3-1 Burrum Heads Locality – Planning zone risk summary, count of land parcels

Planning Zones and Hazards	2019 climate				2050 climate				2100 climate			
	Low	Medium	High	Extreme	Low	Medium	High	Extreme	Low	Medium	High	Extreme
Community Facilities 2												
Erosion	1		1				2				8	
SLR				1				2			5	3
ST		2				7	2			7	3	
Community Facilities 5												
Erosion									1			
ST						1				2		
District Centre												
ST					1	1			1	1	1	
Emerging Communities												
Erosion			1				1				1	
SLR				1				1				1
ST			1				2				2	
Environmental Management and Conservation												
Erosion	1	16				17				17		
SLR		2	14				17				17	
ST	3				17				17			
Local Centre												
Erosion										5		2
SLR											2	
ST					1	7				6	2	
Low Density Residential												

Planning Zones and Hazards	2019 climate				2050 climate				2100 climate			
	Low	Medium	High	Extreme	Low	Medium	High	Extreme	Low	Medium	High	Extreme
Erosion		104		5		164		29		160		177
SLR			1	4			24	5			83	94
ST	10	8			278	387	4		62	1036	149	
Medium Density Residential												
Erosion				1			2	1			2	1
SLR			1					1				1
ST		1			2	1	1			3	3	
Neighbourhood Centre												
ST										1		
Open Space												
Erosion	3	4			2	9			2	16		
SLR		2	2			3	6			4	12	
ST	4				32				33			
Rural												
Erosion			8				10		1		12	
SLR			3	5		1	2	7		1	2	9
ST	1	10			2	12			2	14		
Sport and Recreation												
ST									2			
No zone provided												
Erosion				1				1				1
SLR				1				1				1
ST							1				1	

3.3 Management Zone 2 – Toogoom to Dundowran Beach

Localities within Management Zone 2 are shown in Figure 3-4. Risks within this zone are focussed on the community of Toogoom and the beachfront residential area from Craignish to Dundowran Beach.

The beach and dune area for this section of coastline are mostly outside of cadastral boundaries, and in most locations the dune is wide and well vegetated, although low. The risks to the beach and dune in this area from coastal hazards are low, regardless of the climate. Areas of conservation significance are generally at low to medium risk for all hazards and climates, although some conservation parcels already exposed to tidal inundation are at high risk from sea level rise under all climates.

Inland from the coastline, a substantial section of Pialba Burrum Heads Road is at extreme risk from sea level rise and storm tide and high risk from erosion under all planning climates at the crossing of O'Regan Creek. This includes nearly 250m of road at extreme risk from sea level rise increasing to over 1km at extreme risk by the 2100 future climate. Over 650m is at high risk from erosion under the present climate. This road is an evacuation route and is a critical link for several communities between Burrum Heads and the main population and commercial centre of Hervey Bay.

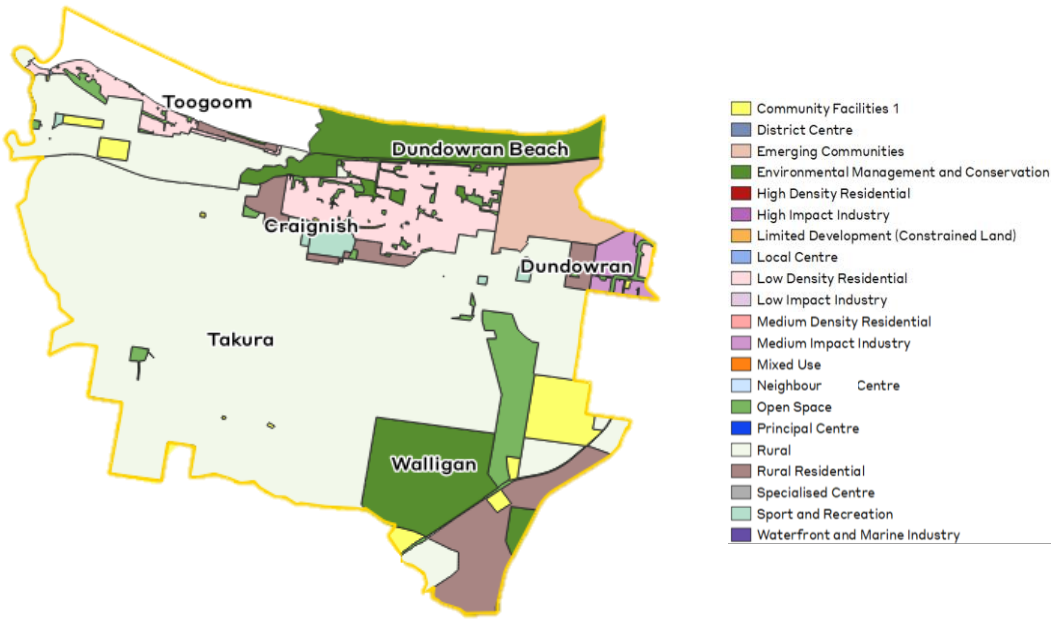

Figure 3-4 Management Zone 2 Localities & Planning Zones

3.3.1 Toogoom

Intolerable risks from coastal hazards at Toogoom mainly occur in the area around Toogoom Spit, and the residential properties lining the beachfront reserve between Beelbi Creek and O'Regan Creek.

Thirty-two (32) residential properties are assessed as being at high or extreme risk from sea level rise under the present climate, by the 2100 future climate this increases to nearly 140. These properties are also at high or extreme risks from erosion hazards over the same climates, and properties in the neighbourhood centre zone are similarly at risk for erosion and sea level rise (2050 future climate onwards).

The majority of properties within erosion and storm tide hazard extents are at low and medium risk respectively, regardless of the climate.

The two seawalls in place at Toogoom provide relatively little benefit to the reduction of risks more broadly throughout the community, largely due to the relatively low number of residential properties at high or extreme risk from erosion and continued erosion impacts on residential properties associated with sea level rise penetration up Beelbi Creek.

Sections of Toogoom Road are at high risk from erosion under all climates. By the 2050 future climate it is at high risk from sea level rise, and at extreme risk by the 2100 future climate. Lorikeet Avenue is also at extreme risk from sea level rise by the 2100 future climate. By the 2100 future climate, a small section of O'Regan Creek Road is also at high risk from erosion and sea level rise. All these roads and several other local roads are at high to extreme risk from storm tide under all climates, particularly from the 2050 future climate onwards.

The Toogoom Rural Fire Brigade site is at high risk from storm tide from the 2050 future climate onwards, and medium risk of erosion by the 2100 future climate. The boat ramp site and jetty at Toogoom are both at extreme risk from sea level rise and medium risk from erosion under all climates. Fixter Park is at high risk from sea level rise by the 2100 future climate.

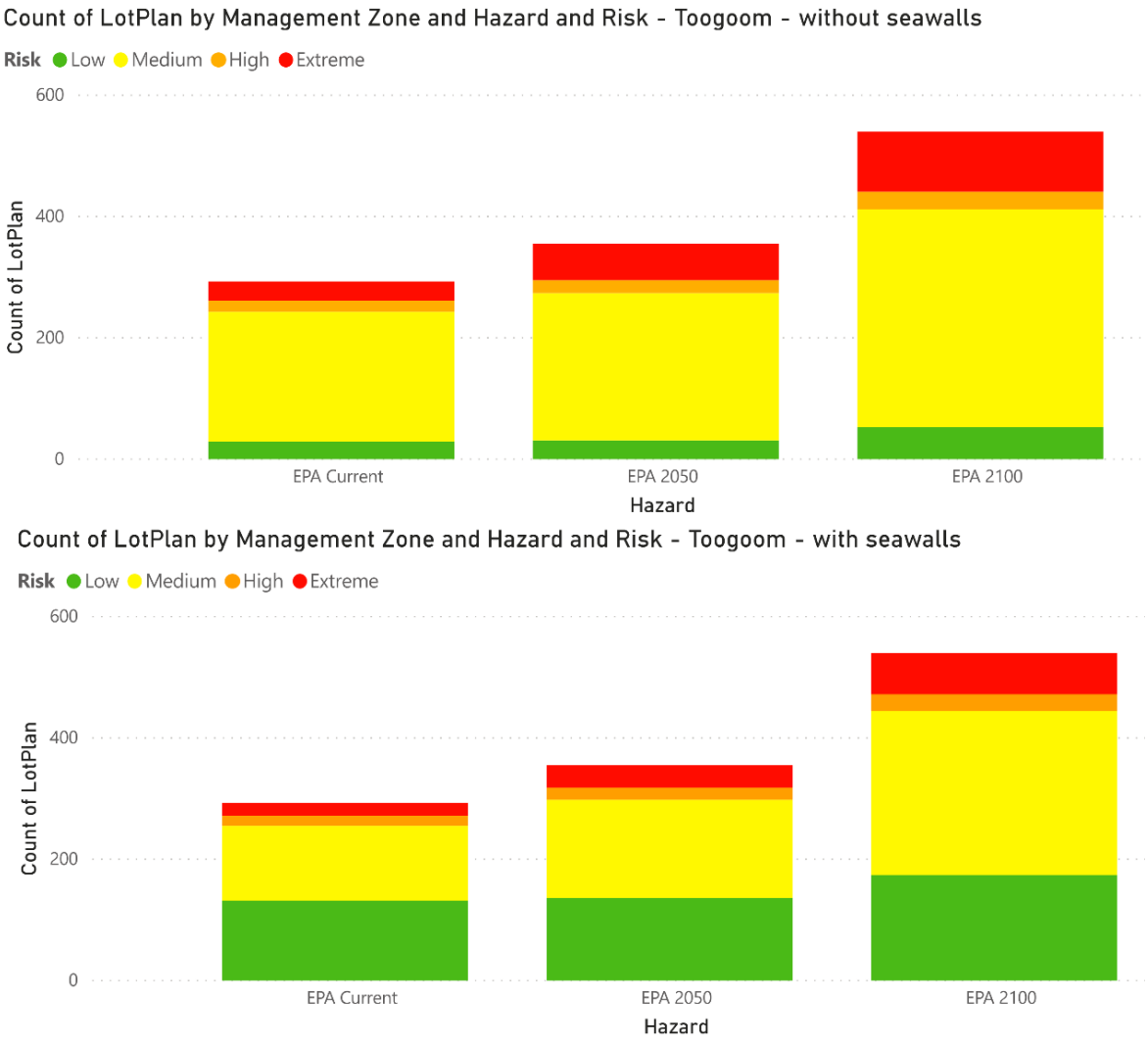

Figure 3-5 Influence of seawalls in reducing erosion risk on land parcels, Toogoom, all climates

3.3.2 Craignish & Dundowran Beach

Development in this area consists of a mixture of low density residential and rural residential land parcels, with low intensity of uses closer to the creek networks. Most of the more intensive residential development is buffered from the open coast by a wide and intact low elevation dune system. Forty low density residential land parcels are at extreme risk from erosion by the 2100 future climate.

There are large areas zoned as emerging communities within hazard extents, covering more than 100ha within the 2100 future climate erosion hazard area. Particularly around Eli Creek, these land parcels are low lying with some at high to extreme risk from sea level rise and erosion under all climates.

In addition to Pialba Burrum Heads Road, Petersen Rd and Sawmill Road are at high to extreme risk from storm tide under the 2100 future climate.

Table 3-2 Toogoom – Planning zone risk summary, count of land parcels

Planning Zones and Hazards	2019 climate				2050 climate				2100 climate			
	Low	Medium	High	Extreme	Low	Medium	High	Extreme	Low	Medium	High	Extreme
Community Facilities 2												
Erosion			1				1				1	
SLR				1				1				1
ST		1			1		1		1	2	2	
Environmental Management and Conservation												
Erosion	2				3				3			
SLR												
ST					3				3			
Local Centre												
ST					1					1		
Low Density Residential												
Erosion		207		32		238		58		351		97
SLR			22	10			24	34			17	80
ST	3	52	1		203	260	10		144	864	90	
Neighbourhood Centre												
Erosion		3				1		2		1		2
SLR							2					2
ST						3				1	2	
Open Space												
Erosion	5	4			7	4			7	7		
SLR			4				4			1	6	
ST	4				15				18			

Planning Zones and Hazards	2019 climate				2050 climate				2100 climate			
	Low	Medium	High	Extreme	Low	Medium	High	Extreme	Low	Medium	High	Extreme
Rural												
Erosion	5		17		3		20		6		28	
SLR		2	6	9		1	6	13		2	6	20
ST	2	19			7	25			4	30		
Rural Residential												
Erosion	17				18				37			
SLR												
ST	1	3			3	35	1			36	5	
Sport and Recreation												
Erosion												
SLR												
ST									1			

Table 3-3 Craignish & Dundowran Beach – Planning zone risk summary, count of land parcels

Planning Zones and Hazards	2019 climate				2050 climate				2100 climate			
	Low	Medium	High	Extreme	Low	Medium	High	Extreme	Low	Medium	High	Extreme
Emerging Communities												
Erosion	5		2		5		4		2		11	
SLR				2				4			3	8
ST		10				11	3			2	12	
Environmental Management and Conservation												
Erosion	5	6			8	6			11	8		
SLR			6				6			1	7	

Planning Zones and Hazards	2019 climate				2050 climate				2100 climate			
	Low	Medium	High	Extreme	Low	Medium	High	Extreme	Low	Medium	High	Extreme
ST	4				23				24			
Low Density Residential												
Erosion		13				40		1		120		40
SLR							1				17	23
ST	7	24			140	274	9		41	615	118	
Open Space												
Erosion	3	6			7	7			6	8		
SLR		1	5			1	6			1	7	
ST	8				21				27			
Rural												
Erosion			17				20				20	
SLR			4	13		1	2	17			1	19
ST	1	17				20			1	20		
Rural Residential												
Erosion	2		9		3		15				29	
SLR			2	7			4	11			4	25
ST		15	4		1	29	8			13	26	
Sport and Recreation												
Erosion			1				2				3	
SLR				1			1	1			1	2
ST	1	2				3				3		

3.4 Management Zone 3 – Eli Waters to Urangan

Localities within Management Zone 3 are shown in Figure 3-6. The intensive urban development throughout the coastal fringes of this management zone is exposed to intolerable risks from all coastal hazards over all climates.

The greatest number of land parcels at extreme (mixed use and medium impact industry zones) or high risk from erosion are in Urangan under the present climate, however by 2050 Torquay and Scarness have overtaken Urangan. The greatest number of parcels at extreme risk from erosion by the 2100 future climate are in Urangan and Eli Waters, most of which are low density residential.

Extreme risks in Eli Waters from sea level rise affect land parcels in the emerging communities zone under all climates. By the 2100 future climate, 90 low density residential parcels in Eli Waters are at high or extreme risk from sea level rise. Scarness is similarly affected, with more than 70 high and medium density residential land parcels at high or extreme risk under the same climate.

High risks from storm tide are notable by the 2050 future climate, mainly affecting low density residential parcels in Eli Waters and high density residential parcels in Scarness and Torquay. By the 2100 future climate, high risks affect significant numbers of land parcels in Eli Waters and from Scarness to Urangan.

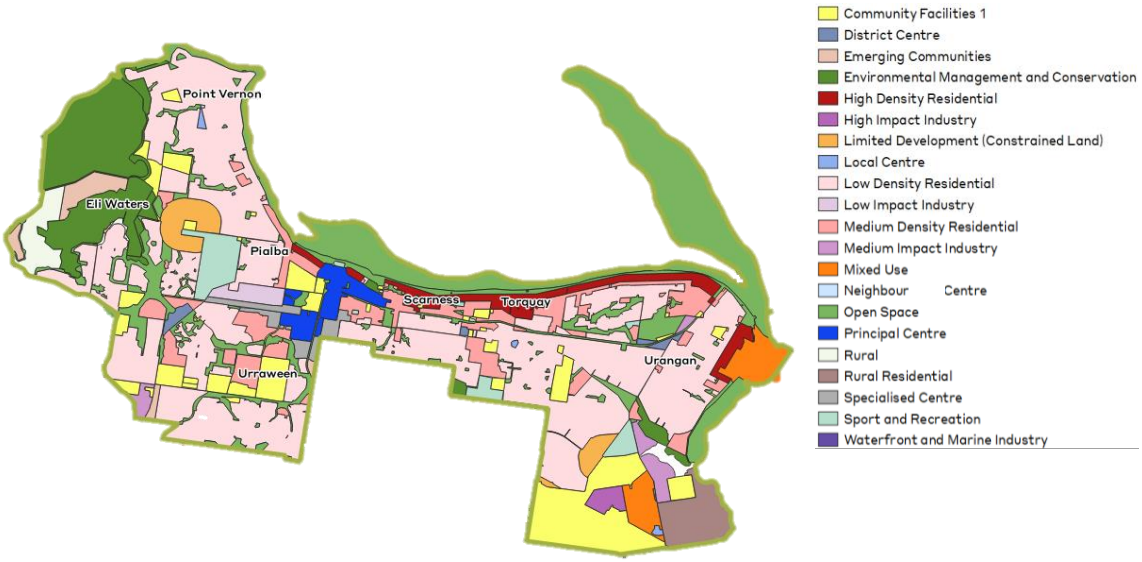

Figure 3-6 Management Zone 3 Localities & Planning Zones

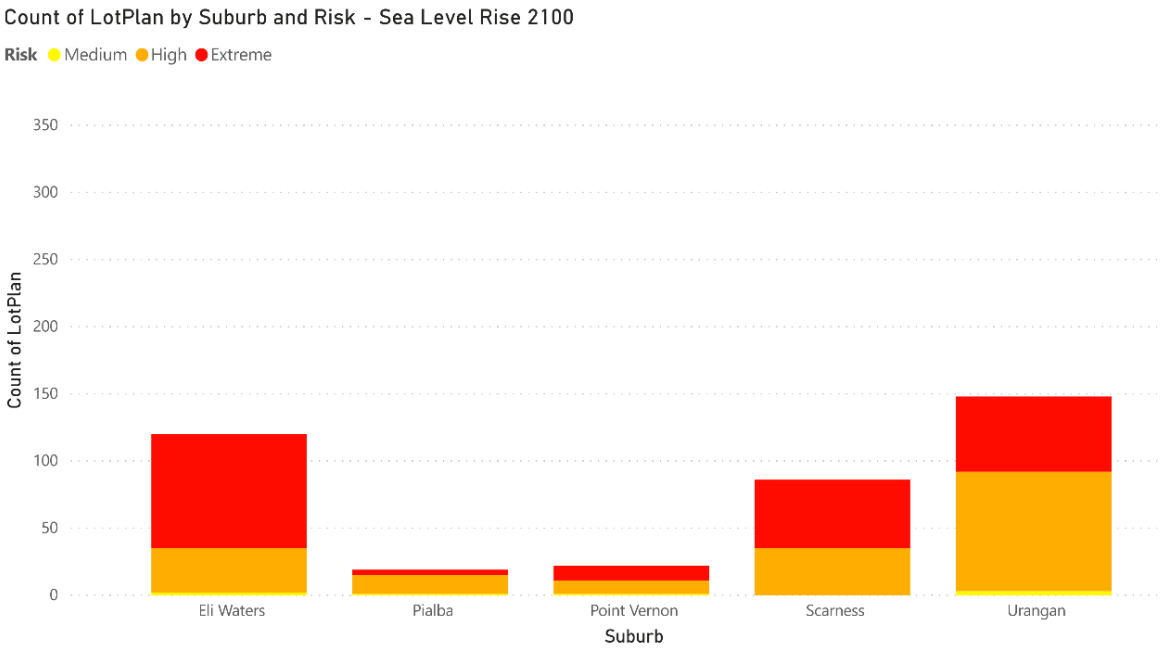

Figure 3-7 Risks to Management Zone 3 land parcels by suburb, sea level rise hazards, 2100 future climate

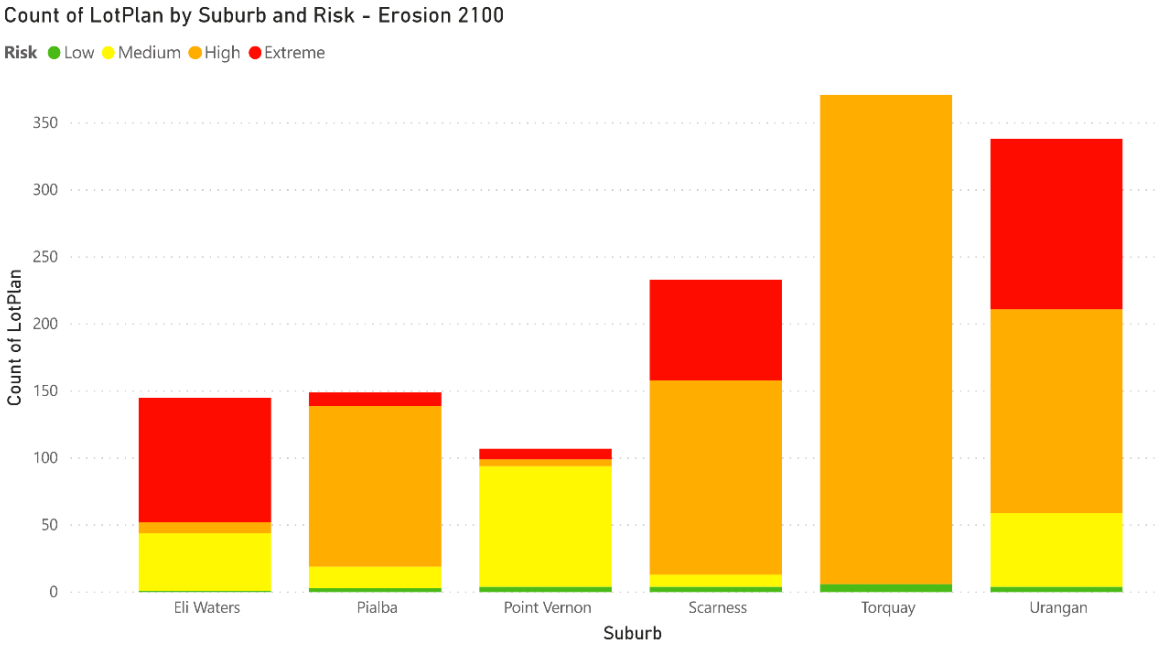

Figure 3-8 Risks to Management Zone 3 land parcels by suburb, erosion hazards, 2100 future climate

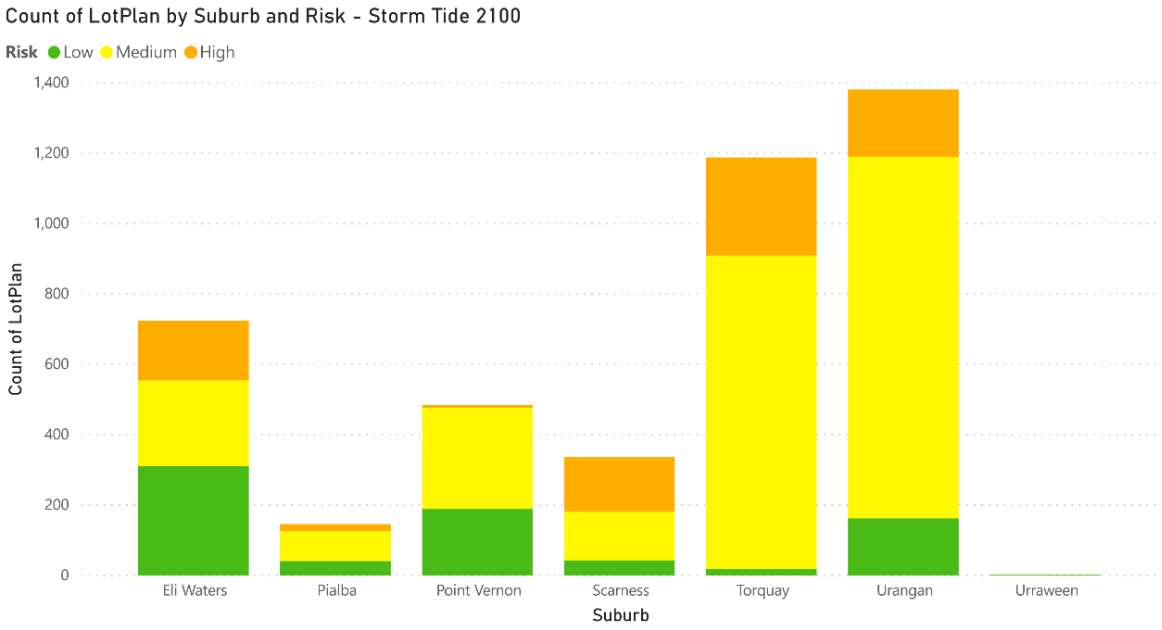

Figure 3-9 Risks to Management Zone 3 land parcels by suburb, storm tide hazard, 2100 future climate

The presence of a suitable and maintained seawall from Scarness to Urangan noticeably reduces the magnitude of properties with intolerable open coast erosion risk by the 2050 and 2100 future climates. The greatest benefit is in Torquay, where the number of lots at high risk under the 2100 future climate reduces from 365 to 49. In other suburbs, large numbers of land parcels are still exposed to erosion risks via the Tooan Tooan Creek network of waterways.

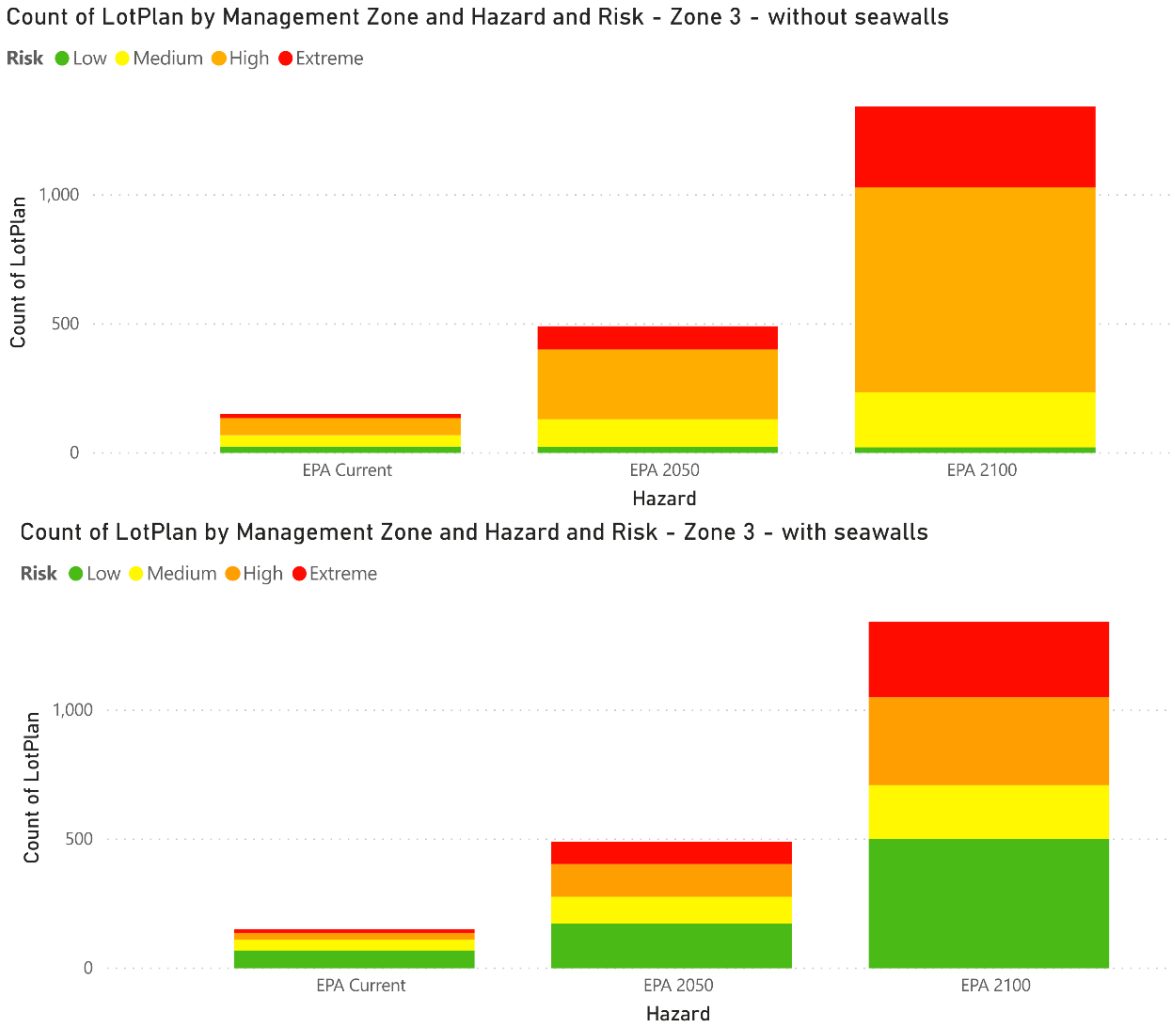

Figure 3-10 Influence of seawalls in reducing erosion risk on land parcels, Management Zone 3, all climates

Land within the open space zone is at high risk from sea level rise and medium risk from erosion throughout the management zone. This zone includes the beach and foreshore parkland lining the open coast from Point Vernon to Urangan. The three piers used for recreational purposes are all at extreme risk from sea level rise and erosion and at medium risk from storm tide under all climates.

The Urangan Boat Harbour site is at extreme risk from sea level rise and erosion under all climates, and high risk from storm tide under all climates. This includes the Volunteer Marine Rescue facility which is within the 2100 future climate storm tide hazard extent. The boat ramps in the harbour are at extreme risk from sea level rise and erosion under all climates.

Wetside Water Education Park is at high risk from erosion under all climates, and medium risk from storm tide by the 2100 future climate. The adjacent Pialba Oval is at high risk from sea level rise and erosion by 2100, and medium risk from storm tide by the 2050 future climate. Dayman Park is at high risk from erosion by the 2100 future climate.

The Hervey Bay Surf Lifesaving Club and Rhee Taekwando Club facilities are at medium risk of erosion under all climates.

Caravan and holiday parks throughout the management zone are at medium risk from storm tide under the 2050 and 2100 future climates, with beachfront caravan parks at Scarness, Torquay and Urangan at high risk from storm tide by the 2100 future climate. Pialba Caravan Park is at medium risk from erosion and sea level rise under the 2100 climate.

By the 2050 future climate, a short section of Booral Road is at high risk from erosion and extensive lengths of the Esplanade at Point Vernon are at high risk from sea level rise (260m) and medium risk (413m) from erosion. By 2100 future climate, Serenity Dr (Eli Waters), Esplanade (Point Vernon and Urangan) are at extreme risk from sea level rise and Pier St is at high risk. These roads are all at high risk from storm tide under the present climate and extreme risk under future climates, with increasing extents of the Esplanade at Pialba and Scarness at high and extreme risk from future climate storm tide hazards.

One sewage pump station at Pialba is at extreme risk from sea level rise and erosion under the 2100 future climate. The Pulgul Waste Water Treatment Plant site is at high risk from erosion and sea level rise by 2100.

3.5 Management Zone 4 – River Heads

Localities within Management Zone 4 are shown in Figure 3-11. Land parcels fringing the foreshore and waterways throughout Management Zone 4 are at highest risk from sea level rise and erosion over all climates. Most of these parcels are within present climate tidal extents in either the rural, rural residential, open space or environmental management and conservation zone, and are assessed as being at high to extreme risk from sea level rise under all climates. By the 2100 future climate, high and extreme risks are identified for fourteen (14) low density residential parcels adjoining these areas.

Parcels zoned as emerging communities are at extreme risk from sea level rise and high risk from erosion from the 2050 future climate onwards.

The barge and boat ramps at the end of the peninsula are important connections to Fraser Island and into Great Sandy Strait. These are all at high risk from sea level rise and extreme risk from erosion under all climates. The tourist information centre is at low risk from erosion by the 2100 future climate. The Booral Homestead Complex site is at extreme risk from sea level rise by the 2100 future climate.

No roads in this management zone are at intolerable risk from coastal hazards.

The effluent reuse facility site on Bunya Creek is at extreme risk from sea level rise and erosion by the 2100 future climate.

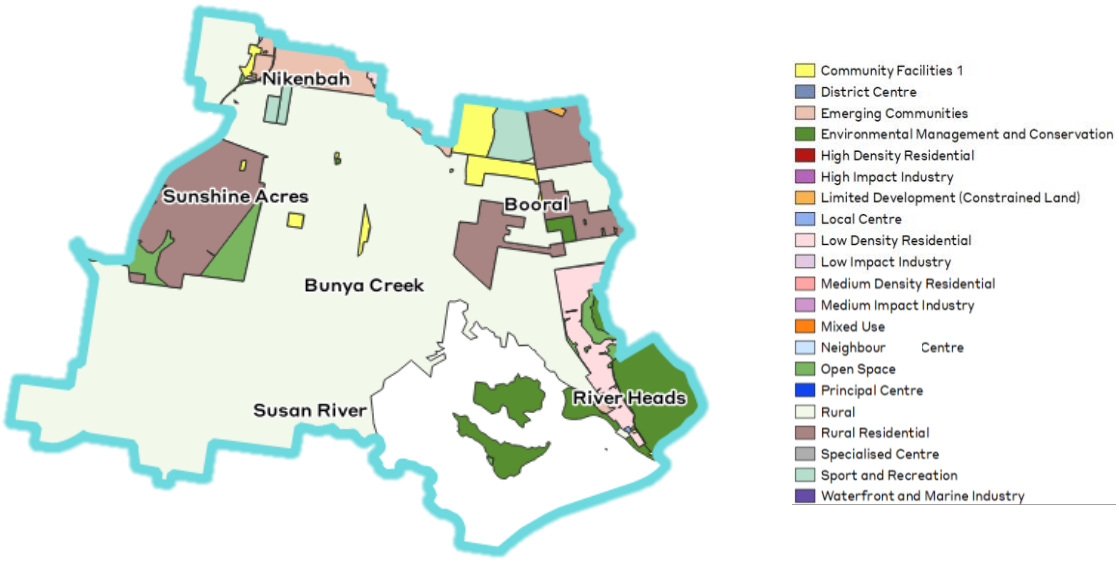

Figure 3-11 Management Zone 4 Localities & Planning Zones

3.6 Management Zone 5 – Great Sandy Strait Communities

Localities within Management Zone 5 are shown in Figure 3-12. Given the dispersed nature of the coastal settlements in the Great Sandy Strait Management Zone, a separate discussion focussed on each settlement area is provided. The assessed risks to the wider management zone are presented in Appendix E.

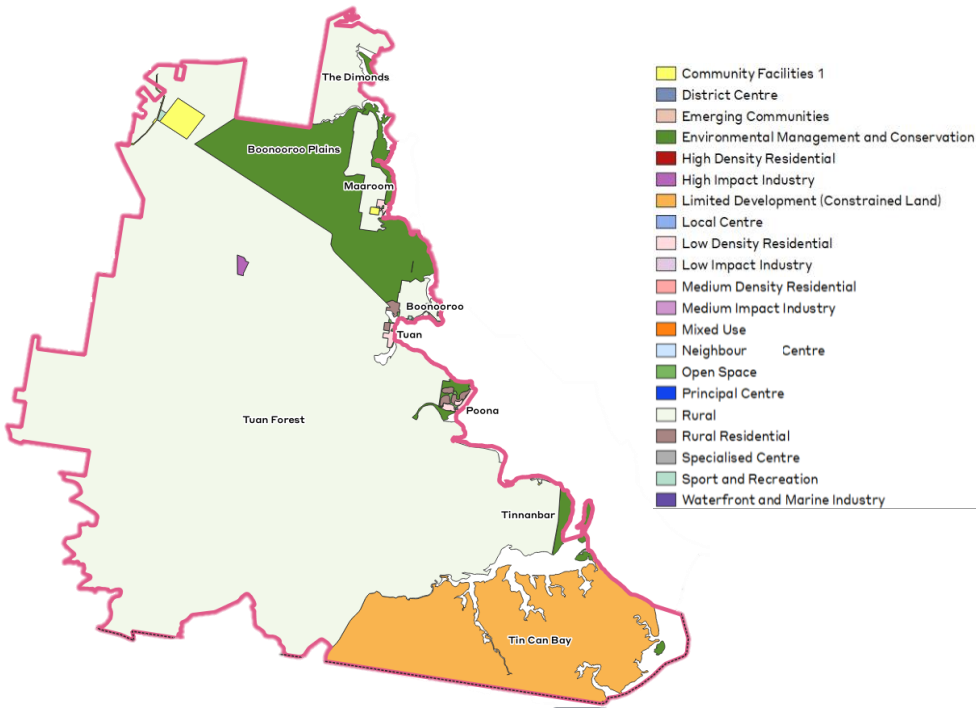

Figure 3-12 Management Zone 5 Localities & Planning Zones

3.6.1 Maaroom

The central area of Maaroom is the main part of the settlement at risk from coastal hazards. Seventeen (17) properties zoned as low density residential are at extreme risk from erosion by the 2050 future climate, increasing to 44 by the 2100 future climate. Many of these properties are at extreme risk from sea level rise by the 2100 future climate.

Rural properties at extreme risk of sea level impacts are heavily inundated under all climates.

Granville Rd is at high risk from sea level rise and storm tide by the 2100 future climate.

By the 2100 future climate, Maaroom Foreshore Reserve and the adjacent narrow beach area are at high risk from erosion and sea level rise, while the adjacent boat ramp is at extreme risk from erosion.

3.6.2 Boonooroo

A substantial portion of the Boonooroo community covering low density residential, rural residential and rural properties are at high to extreme risk from present and future climate coastal hazards. All of these planning zones are represented in the main settlement area.

While a small number of properties are already at high risk from tidal inundation under the present climate, nearly 30 residential land parcels are at high or extreme risk from sea level rise by the 2050 climate, increasing to nearly 90 parcels by the 2100 climate. More than 60 of these are at extreme risk.

At Boonooroo, erosion risk is closely linked to the impact of sea level rise. Under erosion hazards, the number of low density residential parcels at extreme risk significantly increases over time, while the increase in the number of rural residential and rural land parcels at high risk under all climates is more consistent.

The Boonooroo boat ramp facility at Boonooroo Point and the Boonooroo Caravan Park site are at high risk from sea level rise and extreme risk from erosion by the 2100 future climate. The Sandy Straits Coast Guard site is at medium risk from erosion by the 2100 climate.

No land parcels in the community are at high or extreme risk from storm tide impacts.

Wilkinson Rd, the local evacuation route, is at intolerable risk from erosion (all climates) and from sea level rise and storm tide by the 2100 future climate. Rawson St and Eckert Rd are also at intolerable risk from hazards, with Eckert Rd at high risk from sea level rise by the 2050 future climate.

3.6.3 Tuan

Residential land parcels at Tuan are at high to extreme risk from sea level rise and extreme risk from erosion under all climates, with approximately 100 parcels at risk from erosion by the 2100 climate, which is a notable increase from the 2050 climate.

The reserve lining the Tuan foreshore is zoned as open space; this land is at high risk from sea level rise under all climates.

Turton St and Wilkinson Rd are both important roads in the area at intolerable risk from coastal hazards. Sections of Wilkinson Rd are at high risk from erosion under all climates, and at extreme risk from sea level rise by the 2100 climate. Turton St is at high risk from sea level rise by the 2100 climate. Both roads are at high risk of impacts from storm tide under the 2100 climate.

3.6.4 Poona

The community of Poona is exposed to high and extreme risks from sea level rise and erosion, with the greatest increase in risk occurring between the 2050 and 2100 climates. Areas of higher risk exposure for the community are close to the foreshore north of the boat ramp site, and on the north-western frontage of the community.

By the 2100 climate, more than 100 low density residential parcels are assessed as being at high or extreme risk from sea level rise, and at extreme risk from erosion. The foreshore reserve which includes the beach is at medium risk from erosion under all climates.

Boronia Dr is at medium risk from erosion and high risk from sea level rise and storm tide by the 2100 climate.

3.6.5 Tinnanbar

There are limited risks to the settlement at Tinnanbar from coastal hazards, with the main risk at the boat ramp site which is assessed as being at extreme risk from sea level rise and high risk from erosion under all climates.

The open space zone, which includes consideration of the beach and the foreshore reserve, is at high risk from sea level rise and medium risk from erosion under all climates.

No roads or major extents of stormwater infrastructure are exposed to intolerable risks from coastal hazards.

Rural land parcels adjacent to the settlement area are at extreme risk from sea level rise under the present climate, largely as these parcels are already regularly and substantially inundated.

Table 3-4 Maaroom – Planning zone risk summary, count of land parcels

Planning Zones and Hazards	2019 climate				2050 climate				2100 climate			
	Low	Medium	High	Extreme	Low	Medium	High	Extreme	Low	Medium	High	Extreme
Environmental Management and Conservation												
Erosion		5				5				5		
SLR		1	4			1	4				5	
ST	4				5				5			
Low Density Residential												
Erosion		8				22		17		18		44
SLR							16	1			10	34
ST	4				22	17			8	45		
Open Space												
Erosion	1	1				2				2		
SLR			1			1	1				2	
ST	2				2				2			
Rural												
Erosion	2		6		1		8				9	
SLR		3	1	2		2	4	2			7	2
ST	5	2			7	2			3	6		

Table 3-5 Boonooroo – Planning zone risk summary, count of land parcels

Planning Zones and Hazards	2019 climate				2050 climate				2100 climate			
	Low	Medium	High	Extreme	Low	Medium	High	Extreme	Low	Medium	High	Extreme
Community Facilities 2												
Erosion			1				1				1	
SLR			1					1				1
ST		1				1				1		
Community Facilities 5												
Erosion											1	
SLR											1	
ST					1					1		
Environmental Management and Conservation												
Erosion	1	7				8				8		
SLR		3	4			2	6				8	
ST	5				8				8			
Low Density Residential												
Erosion		41		8		36		28		18		84
SLR			6	2			19	9			20	64
ST	9	3			38	29			44	91		
Medium Density Residential												
Erosion			1					1				1
SLR							1					1
ST	1					1				1		
Open Space												
Erosion	1	3				4				4		

Locality Based Risk Assessment Outcomes

Planning Zones and Hazards	2019 climate				2050 climate				2100 climate			
	Low	Medium	High	Extreme	Low	Medium	High	Extreme	Low	Medium	High	Extreme
SLR		2	1			1	3				4	
ST	3				4				4			
Rural												
Erosion	6		11		5		19		2		35	
SLR		4	6	1		6	12	1		3	27	5
ST	12	1			28	3			26	14		
Rural Residential												
Erosion	7		11		5		17		2		25	
SLR			11				6	11			3	22
ST	6	9			4	18			3	26		
Sport and Recreation												
Erosion			1				1				2	
SLR		1					1				2	
ST	1				2				2	1		

Table 3-6 Tuan – Planning zone risk summary, count of land parcels

Planning Zones and Hazards	2019 climate				2050 climate				2100 climate			
	Low	Medium	High	Extreme	Low	Medium	High	Extreme	Low	Medium	High	Extreme
Low Density Residential												
Erosion		6		6		10		24		1		99
SLR			2	4			15	9			31	68
ST	5	5			53	22			19	100		
Open Space												
Erosion		1				1				1		
SLR			1				1				1	
ST	1				1				1			
Rural												
Erosion	2		1				3				3	
SLR			1				2	1			1	2
ST	2	1			1	2				3		
Rural Residential												
Erosion									2		2	
SLR											2	
ST									3	4		

Table 3-7 Poona – Planning zone risk summary, count of land parcels

Planning Zones and Hazards	2019 climate				2050 climate				2100 climate			
	Low	Medium	High	Extreme	Low	Medium	High	Extreme	Low	Medium	High	Extreme
Environmental Management and Conservation												
Erosion	5	2			6	2			5	2		
SLR			2				2				2	
ST	2				2				2			
Low Density Residential												
Erosion		5				25		29		37		106
SLR							29				56	50
ST					32	24			26	110		
Medium Density Residential												
Erosion												1
SLR												1
ST										1		
Open Space												
Erosion										1		
SLR										1		
ST					1				2			
Rural Residential												
Erosion					1		3				11	
SLR							3				4	7
ST	3				6	3			5	12		

Table 3-8 Tinnanbar – Planning zone risk summary, count of land parcels

Planning Zones and Hazards	2019 climate				2050 climate				2100 climate			
	Low	Medium	High	Extreme	Low	Medium	High	Extreme	Low	Medium	High	Extreme
Community Facilities 2												
Erosion			1				1				1	
SLR				1				1				1
ST		1				1				1		
Environmental Management and Conservation												
Erosion		2				2				2		
SLR			2				2				2	
ST	2				2				2			
Low Density Residential												
Erosion		2				2				2		
Open Space												
Erosion		2				2				2		
SLR			2				2				2	
ST	2				2				2			
Rural												
Erosion			4				4				4	
SLR		1	1	2			2	2			1	3
ST	2	2			2	2				4		

3.7 Management Zone 6 – Mary River

Localities within Management Zone 6 are shown in Figure 3-13. Risks in this zone are generally confined to the fringes of the Mary River and its tributaries, particularly where the channel is well defined. Many land parcels extend across the riverbank and into the river, and so will be identified as being at risk even though there may be no active usage of the impacted portion of the land parcel.

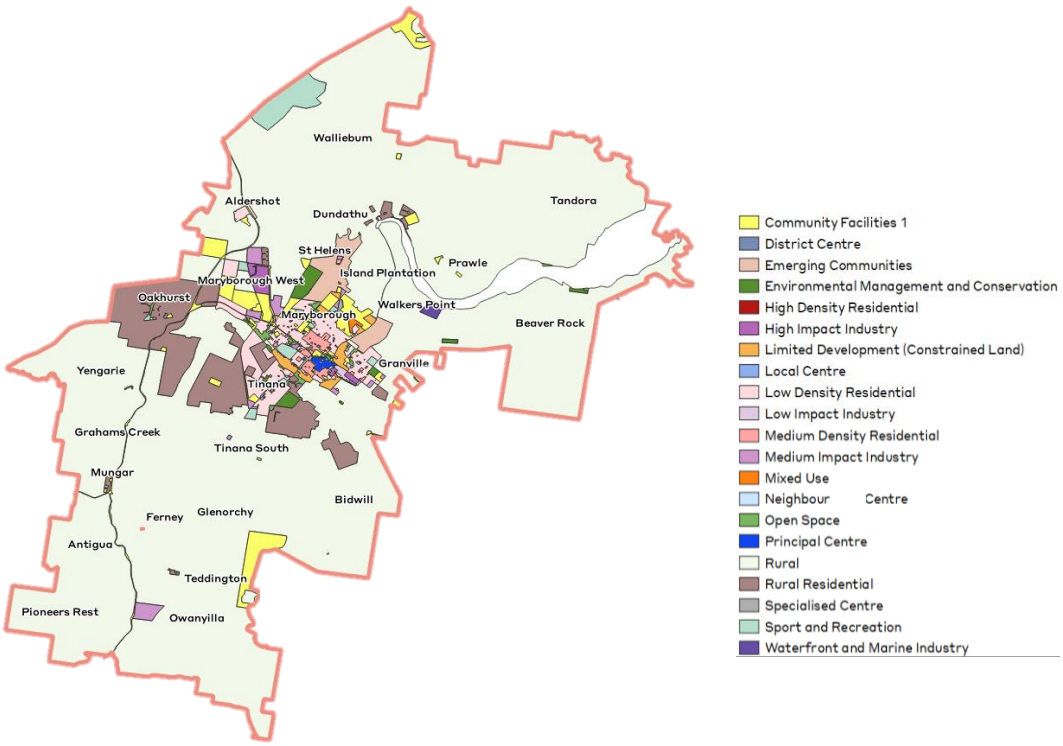

Figure 3-13 Management Zone 6 Localities & Planning Zones

For this reason land parcels in numerous zones are assessed as being at high or extreme risk under present climate tidal extents, with the majority of these occurring in Maryborough. Nearly 70% of land parcels at high or extreme risk under the present climate tidal extents are either in the rural or constrained land (limited development) zones. This trend remains relatively consistent over time to the 2100 future climate.

Approximately 35% of all land parcels at extreme risk from erosion under all climates in Maryborough are zoned as low density residential. Land parcels in the emerging communities zone in Granville and St Helens are at high risk from erosion under all climates. Industrial sites and a small number of principal centre zoned parcels in Maryborough are at high risk from storm tide impacts from 2050 onwards.

Important roads at high risk from erosion under all climates include Maryborough Hervey Bay Rd, Bruce Highway and Tiger St. Beaver Rock Rd is at high risk from erosion under all climates and high to extreme risk from sea level rise and storm tide from the 2050 future climate onwards. Island Plantation Road is at extreme risk from sea level rise by the 2100 future climate, and high to extreme risk from storm tide by the 2050 future climate onwards.

Numerous boat ramps and jetties on the river are at extreme risk from sea level rise and erosion under all climates. Queens Park and the Prickett Aquatic Area are at high risk from sea level rise and erosion by the 2100 future climate. The Huntsville Caravan Park site is at medium risk from erosion by the 2100 future climate.

The water storages created by the Mary River Barrage and Bidwill Weir are at extreme risk from sea level rise and high risk from erosion under all climates. The Aubinville Waste treatment plant site is at high risk from sea level rise under the present and 2050 future climates, extreme risk by the 2100 future climate, and high risk from erosion under all climates.

The Maryborough Sailing Club and Rowing club sites are at extreme risk from sea level rise and high risk from erosion under all climates. A small section of Queens Park is at high risk from sea level rise by 2100.

3.8 Management Zone 7 – K'gari (Fraser Island) & Great Sandy Strait Islands

Localities within Management Zone 7 are shown in Figure 3-14. Land parcels throughout this area at high risk of impacts from sea level rise are mainly zoned environmental management and conservation. On K'gari, unzoned land parcels associated with the Wangoolba barge landing and a transmitter station site are at high to extreme risk from erosion under all climates and at extreme risk from sea level rise under all climates.

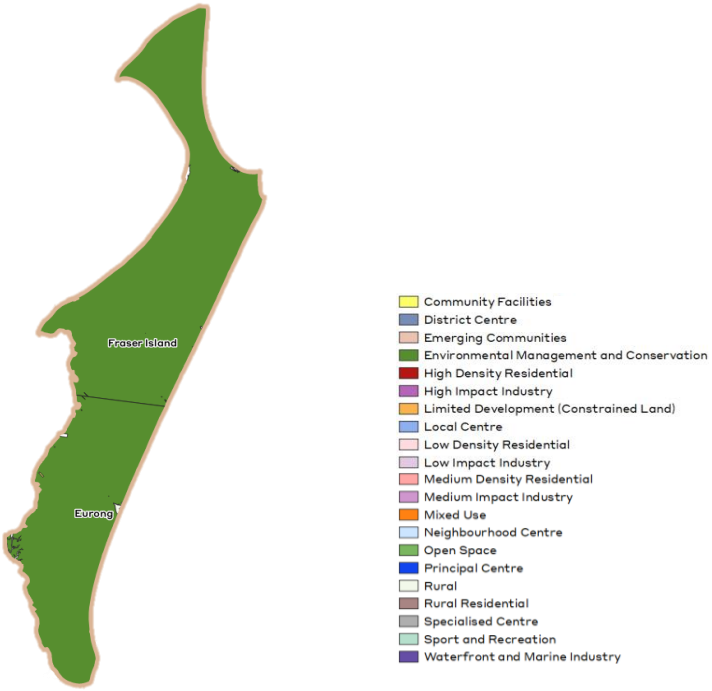

Figure 3-14 Management Zone 7 Localities & Planning Zones

The Fraser Island Police Station at Eurong is at medium risk from erosion under all climates. The Kingfisher Bay ferry site is at high risk from storm tide from the 2050 climate onwards and is at extreme risk from erosion and sea level rise under all climates.

The unzoned North White Cliffs site is at high risk from storm tide by the 2100 climate, and at high to extreme risks from sea level rise and erosion under all climates.

Low density residential development on Stewart Island in the Great Sandy Strait is at high to extreme risk from sea level rise and erosion from the 2050 future climate onwards.

No higher order roads are at risk on the island; however all of the beach areas are used as roads. While the risk profile of beaches used as roads has not been specifically mapped or assessed, these roads should be considered as high risk to impacts from sea level rise.

3.9 Summary

The risk assessment identified the assets listed in Table 3-9 as being at high or extreme risk, based on existing assets and present-day values. The intolerable risks are dominated by erosion or sea level hazards, with all assets identified at extreme risk either residential areas, important roads or key community infrastructure.

There are numerous adaptation options for mitigating the risks from current and future climate coastal hazards across the Fraser Coast region. Phase 6 of the CHAS includes the analysis and shortlisting of potential adaptation options to treat extreme and high risks to the assets listed in Table 3-9.

Table 3-9 Assets at Extreme and High Risk

Reporting Area	Asset	Erosion			Sea Level Rise		Storm Tide		
		Present day	2050	2100	2050	2100	Present day	2050	2100
Burrum Heads & Surrounds	Open coast beach and foreshore areas				H	H			
	Bushnell Road (seaward end), Traviston Park				H	H			
	Cheeli Lagoon, Ivor Drive					H			
	Burrum Heads Fire Station						H	H	H
	Sewage pump stations (x 2)		E	E	H	H			
	Water storage protected by Burrum Heads weir			H					
	Burrum Heads Road (seaward end)	H	H	H		H		H	E
	Orchid Drive (seaward end)		H	H				H	E
	Ivor Drive					H		H	E
	Riverview Drive					**E**		H	E
	Ross Street							H	E
Toogoom	Pialba-Burrum Heads Road (O'Regan Creek crossing)				**E**	**E**	H	**E**	E
	Toogoom Road	H	H	H	H	**E**	H	**E**	E
	Lorikeet Avenue					**E**	H	**E**	E
	O'Regan Creek Road			H		H	H	**E**	E
	Toogoom Rural Fire Brigade								
	Toogoom Boat Ramp & Jetty				**E**	**E**		H	H
	Fixter Park					H			
Craignish & Dundowran Beach	Pialba-Burrum Heads Road								**E**
	Petersen Road								H
	Sawmill Road								H

Locality Based Risk Assessment Outcomes

Reporting Area	Asset	Erosion			Sea Level Rise		Storm Tide		
		Present day	2050	2100	2050	2100	Present day	2050	2100
Eli Waters to Urangan	Open coast beach and foreshore areas				H	H			
	Piers		E	E	E	E			
	Urangan Boat Harbour & boat ramps	E	E	E	E	E	H	H	H
	Wetside Water Education Park	H	H	H					
	Pialba Oval			H		H			
	Dayman Park			H					
	Caravan & Holiday Parks (Scarness, Torquay & Urangan)								H
	Booral Road		H				H	E	E
	Esplanade (Point Vernon)				H	E	H	E	E
	Esplanade (Urangan)					E	H	E	E
	Serenity Drive (Eli Waters)					E	H	E	E
	Pier Street					H	H	E	E
	Sewage pump station (Pialba)			E		E			
	Pulgul Water Water Treatment Plant			H		H			
River Heads	Barge ramp and boat ramp	E	E	E	H	H			
	Booral Homestead Complex					E			
	Bunya Creek effluent reuse facility site			E		E			
Maaroom	Graville Road					H			H
	Maaroom Foreshore Reserve and beach			H		H			
	Maaroom Boat ramp			E					
Boonooroo	Boonooroo Boat ramp			E		H			
	Boonooroo Caravan Park			E		H			

Locality Based Risk Assessment Outcomes

Reporting Area	Asset	Erosion			Sea Level Rise		Storm Tide		
		Present day	2050	2100	2050	2100	Present day	2050	2100
	Wilkinson Road	H	H	H		H			
	Eckert Road				H	H			
	Rawson Road					H			
Tuan	Tuan foreshore				H	H			
	Turton Street					H			H
	Wilkinson Road	H	H	H		E			H
Poona	Poona Foreshore Reserve and beach		H	E	H	E			
	Boronia Drive					H			H
Tinnanbar	Tinnanbar Foreshore Reserve and beach				H	H			
	Tinnanbar Boat ramp	H	H	H	E	E			
Mary River	Maryborough Hervey Bay Road	H	H	H					
	Bruce Highway	H	H	H					
	Tiger Street	H	H	H					
	Beaver Rock Road	H	H	H	H	H		E	E
	Island Plantation Road					E		H	E
	Boat ramps and jetties (numerous)	E	E	E	E	E			
	Queens Park			H		H			
	Prickett Aquatic Area			H		H			
	Aubinville Waste treatment plant	H	H	H	H	E			
	Maryborough Sailing Club and Rowing Club	H	H	H	E	E			
K'gari (Fraser Island)	Wangoolba Barge Landing	H	H	H	E	E			
	Transmitter Station	H	H	H	E	E			

Locality Based Risk Assessment Outcomes

Reporting Area	Asset	Erosion			Sea Level Rise		Storm Tide		
		Present day	2050	2100	2050	2100	Present day	2050	2100
	Kingfisher Bay Ferry Landing	E	E	E	E	E		H	H
	Beaches used as roads				H	H			
	North White Cliffs	E	E	E	H	H			H

Appendix A Regional Risk Assessment Methodology

A.1 General Approach

The regional-scale, first-pass risk assessment methodology follows international best practice. It accommodates the scientific definition of risk proposed by the Intergovernmental Panel on Climate Change (IPCC) and incorporates that definition using a standard risk assessment framework presented in ISO31000:2018 (Risk Management). The conceptual definition of risk as a function of hazard, exposure and vulnerability defined by the IPCC is illustrated in Figure A-1.

$$\boldsymbol{Risk = f\ (Hazard, Exposure, Vulnerability)}$$

Equation 1

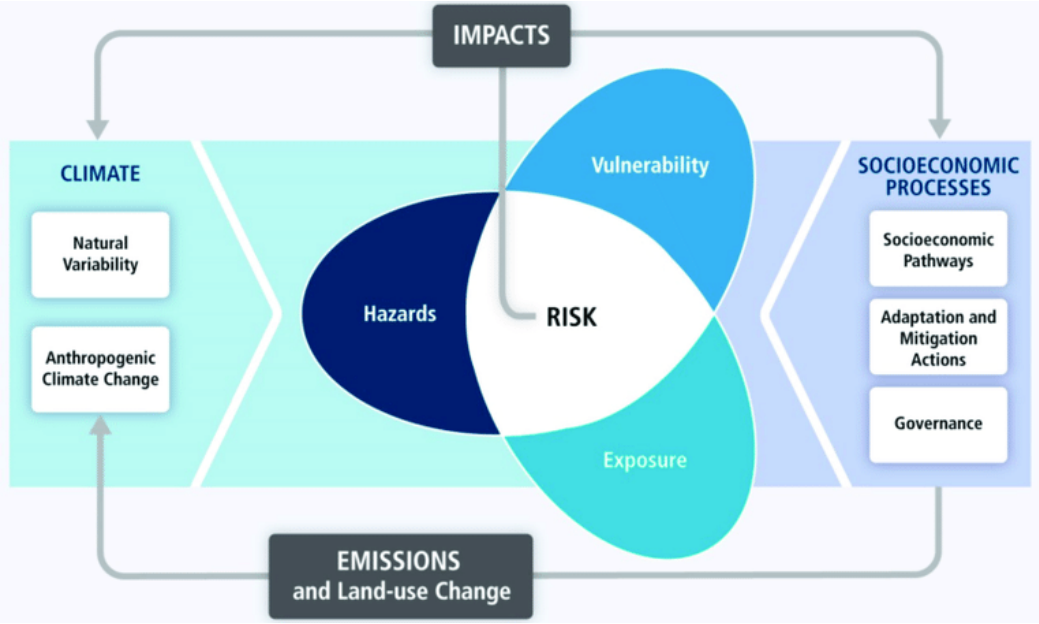

Figure A-1 IPCC definition of risk (IPCC 2014)

The IPCC definition of risk given in Equation 1 is applied here by using the standard risk assessment framework presented by ISO31000:2018 which defines risk as a function of likelihood and consequences:

$$\boldsymbol{Risk = f\ (Likelihood, Consequences)}$$

Equation 2

In this context, 'likelihood' refers to the probability of a coastal hazard threshold being exceeded. Consequence on the other hand, refers to what happens to the system if the hazard event occurs. Consequence not only depends on the extent of the hazard event (e.g. the depth of water on land or the extent of erosion) but also on the vulnerability of the system. To accommodate the concept of vulnerability, the IPCC risk framework in Equation 1 is combined with ISO31000:2018 framework in Equation 2. This allows us to measure consequence as function of hazard and vulnerability. By combining IPCC and ISO concepts, Equation 3 presents an operational measure of risk.

$$Risk = f\left(\begin{matrix}Likelihood\ of\ hazard\ event, Consequences\ of\ the\ hazard\ based\ on\ exposure\ of\ the\ hazard \\ and\ vulnerability\ of\ the\ land\ parcel\end{matrix}\right)$$

Equation 3

The first-pass coastal hazard risk assessment adopts land use Planning Zones as defined by the Fraser Coast Planning Scheme 2014 as a proxy of vulnerability of the land parcel. Operational definitions for the relevant terms are summarised in Table A-1.

Table A-1 Operational definition of first-pass risk for the Coastal Futures project

Component of risk	Operational definition
Hazard	Storm tide water level, erosion prone area or sea level rise likelihoods under different planning horizons (Present-day to 2030, 2050 and 2100)
Exposure	Land parcel exposed to a given event
Vulnerability	Damage potential of the land parcel based on land use
Consequence	Consequences based on exposure of the hazard and vulnerability of the land parcel
Likelihood	Likelihood of the hazard event

3.10 Operational model for first-pass risk assessment

The conceptual model described above and by Equation 3 has been used to develop and apply a first-pass coastal hazard risk assessment framework to the region. The adopted consequence and hazard scales are described below.

3.10.1 Consequence Scale

The consequence scale C_i of the land parcel is based on the extent of the hazard on that parcel (H_i) and the vulnerability of the land parcel:

$$\boldsymbol{C_i = H_i * VUL_i}$$

Equation 4

VUL_i is the vulnerability of the parcel i based on the land use zoning. Table A-2 shows the adopted vulnerability rating scale and assigned rating to the Fraser Coast Planning Scheme 2014 Planning Zones. Note that this allocation of vulnerability ratings is based on the principle that densely populated and/or high use areas have a greater potential for damage by coastal hazards compared to uninhabited areas such as parks and rural areas. Further consideration of the assets within these areas is the subject of the second-pass risk assessment described in Section 2 and 3 of this report.

Table A-2 Proxy vulnerability of different land use zones

Zones	Vulnerability Scale	Vulnerability Rating* VUL_i
Open Space, Environmental Management and Conservation	Low	1
Waterfront and Marine Industry, Low Impact Industry, Medium Impact Industry, Sport and Recreation, Community Facilities 6, Rural	Medium	2
Low Density Residential, Emerging Communities, Rural Residential, Specialised Centre, Local Centre, Neighbourhood Centre, Community Facilities 1, Community Facilities 2, Community Facilities 4, Community Facilities 5, Limited Development (Constrained Land), High Impact Industry	High	4
Medium Density Residential, High Density Residential, Community Facilities 3, Principal Centre, Mixed Use, District Centre	Very High	5

**vulnerability ratings are based on the principle that densely populated and/or high use areas have a greater potential for damage by coastal hazards compared to uninhabited areas such as parks and rural areas*

Consequence scores for a given parcel C_i, are normalised to a scale of 100 so that separate Consequence Zones can be classified.

$$NCI_i = \frac{C_i - C_{i\,min}}{C_{i\,max} - C_{i\,min}} * 100$$

Equation 5

Here, $C_{i\,min}$ and $C_{i\,max}$ are the minimum and maximum consequence scores and NCI_i is the Normalised Consequence Index of the parcel. NCI_i of the parcel is then used for determining the consequence for a given parcel in accordance with Table A-3.

Table A-3 Adopted Consequence Zone Categories

Consequence Zones	Normalised Consequence Index (NCI_i)
Insignificant Consequence Zone	<10
Minor Consequence Zone	10-30
Moderate Consequence Zone	30 - 50
Major Consequence Zone	50 - 75
Catastrophic Consequence Zone	>75

3.10.2 Erosion Hazard Area Scale

The erosion hazed area considers the three components defined by the State and summarised in Section 1.3.1, namely:

(1) The calculated open coast erosion area;

(2) The nominated buffer distance inland of the line of highest astronomical tide (HAT) (wave action/tidal flow erosion buffer); and

(3) The plan position of projected sea level rise above the elevation of HAT (sea level rise erosion).

For the purpose of the first-pass risk assessment, land parcels potentially exposed to open coast erosion (component 1) or within the HAT buffer zone (component 2) have been initially considered. The likelihood of impact from either of these erosion hazard components is 'possible', or equivalent to the 1 in 100 (1%) AEP likelihood for the present-day (2019 to 2030), 2050 and 2100. The potential exposure to sea level rise (component 3) is then considered independently, with the hazard scale further informed by the depth of inundation as described in the following section. The likelihood of low-lying land being impacted by sea level rise is considered 'almost certain' and therefore those land parcels can attract a higher risk rating than those only exposed to open coast erosion and/or are within the HAT buffer zone.

A.1.1 Storm Tide Hazard Scale

The storm tide inundation hazard scale illustrated in Figure A-2 is based on the general flood hazard vulnerability curves provided in *Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (AIDR 2017)*. Flood hazard is defined as a function of depth and velocity of flood water:

$$\boldsymbol{H_i = D_i * V_i}$$

Equation 6

H_i is the hazard index of the land parcel *i* which is determined by D_i the depth of flood on land parcel and V_i the velocity of the flood water. For the preliminary assessment, flood velocity information is not used however is assumed to be less than 1 m/s due to the flooding mechanism (i.e. flooding caused by increases to the coastal and estuary water levels). Under this scenario, the hazard scale is simply determined by the depth of inundation. The adopted hazard scale for this study is summarised in Table A-4. It is noted that for this assessment a depth of inundation exceeding 2.0 m is deemed as "extreme".

Table A-4 Adopted Hazard Scale

Hazard Zones	Depth of flooding (D_i)	Adopted Hazard Scale	Numeric Hazard Scale (H_i)
H0	0	No Hazard	0
H1	<0.3m	Insignificant	1
H2	0.3m to 0.5m	Low	2
H3	0.5m to 1.2m	Medium	3
H4	1.2m to 2.0m	High	4
H5	>2.0m	Extreme	5

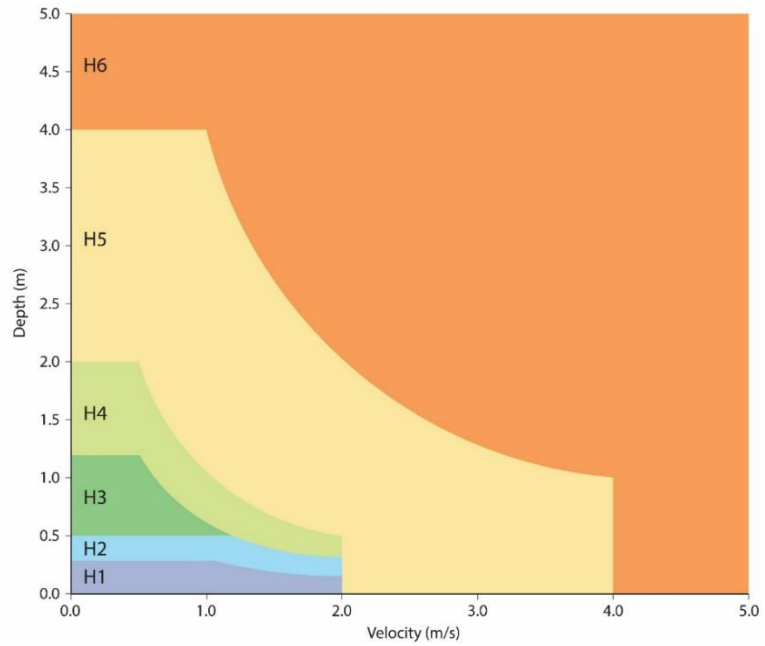

Figure A-2 General Flood Hazard Vulnerability Curves

A.1.2 Risk rating and mapping

The Risk Rating is a function of the likelihood of the hazard event and the expected consequence:

$$\boldsymbol{R_i = f(NCI_i, L_i)}$$

Equation 7

Here R_i is the risk rating of the parcel *i*, L_i is the likelihood of the hazard event, NCI_i is the Normalised Consequence Index considering hazard exposure and vulnerability of the parcel. The Risk (*Ri*) rating of a given land parcel is then calculated using the risk matrix which is presented in Table 2-13 and discussed further in Section 2.4.

To apply Equation 7 and develop a first-pass risk assessment mapping, the 1 in 100 (1%) AEP likelihood hazard for the present-day (2019 to 2030), 2050 and 2100 climate scenarios has been considered. This approach produces regional scale maps that communicate the changing risk profile over time. Risk mapping based on the storm tide hazard and coastal erosion hazard areas is presented in Appendix B and Appendix C.

Appendix B Regional Risk Assessment Mapping – Storm Tide

LEGEND

Cadastral Boundaries

Risk Rating

- Low
- Medium
- High

Title:

Regional Planning Zone and Land Parcel Assessment Present Day Storm Tide

Figure:

Rev: **A**

N

0 2 4km

Approx. scale

BMT

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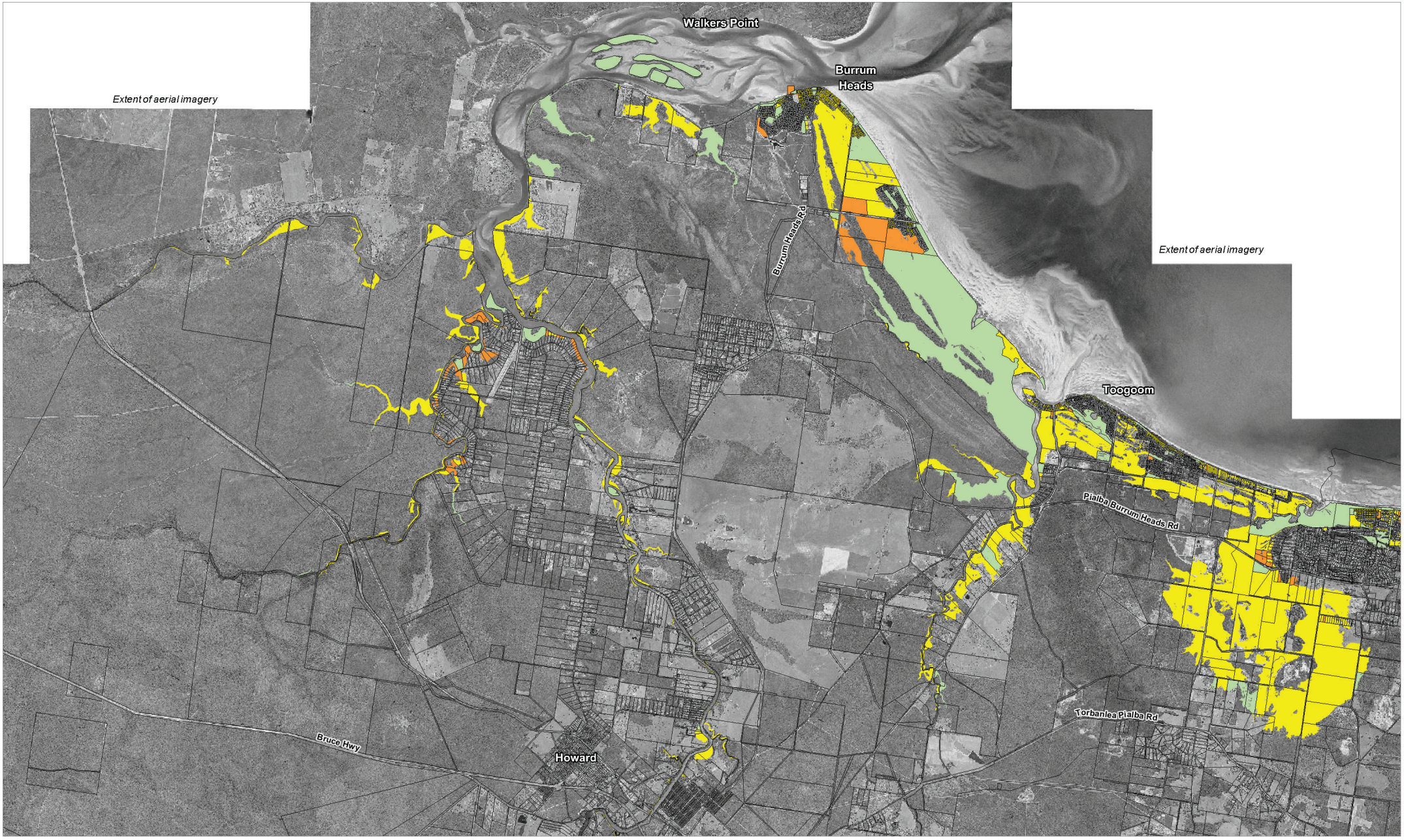

LEGEND

Cadastral Boundaries

Risk Rating

- Low
- Medium
- High

Title:

Regional Planning Zone and Land Parcel Assessment 2050 Storm Tide

Figure:

Rev: **A**

N

0 2 4km

Approx. scale

BMT

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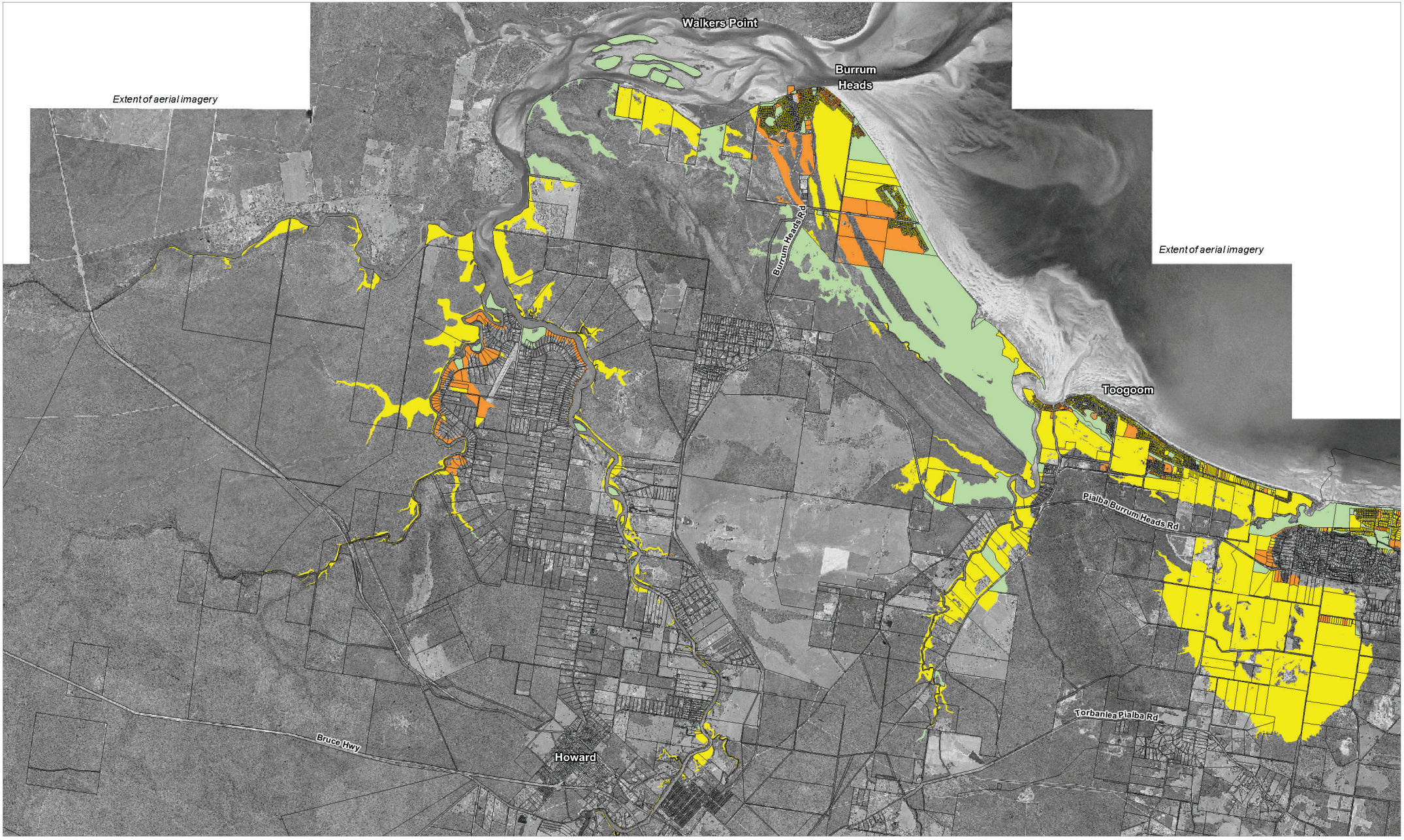

LEGEND

Cadastral Boundaries

Risk Rating

- Low
- Medium
- High

Title:

Regional Planning Zone and Land Parcel Assessment 2100 Storm Tide

Figure:

Rev: **A**

N

0 2 4km

Approx. scale

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LEGEND

Cadastral Boundaries

Risk Rating

- Low
- Medium
- High

Title:

Regional Planning Zone and Land Parcel Assessment Present Day Storm Tide

Figure:

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0 1 2km

Approx.Scale

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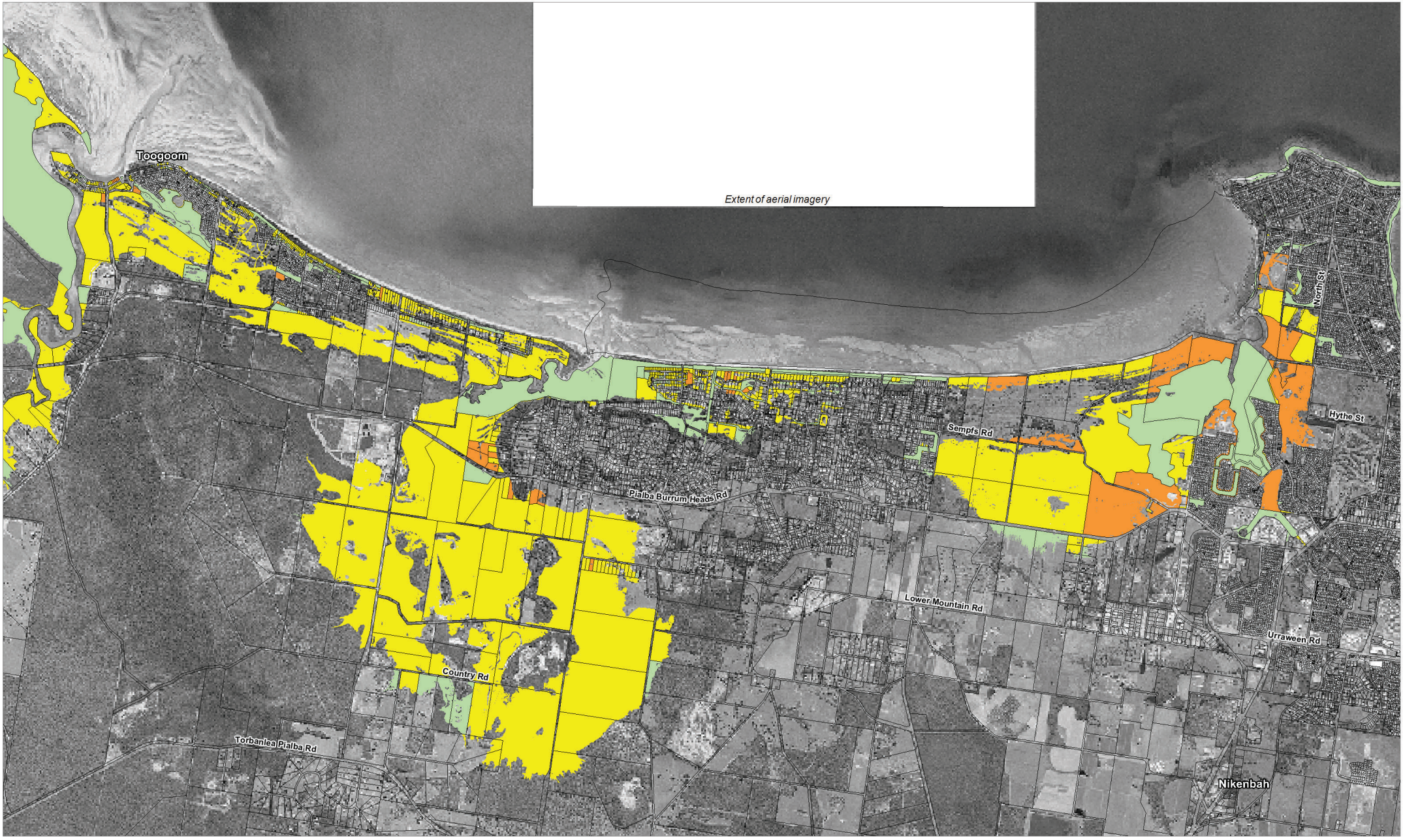

LEGEND

Cadastral Boundaries

Risk Rating

- Low
- Medium
- High

Title:

Regional Planning Zone and Land Parcel Assessment 2050 Storm Tide

Figure:

Rev: **A**

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Approx.Scale

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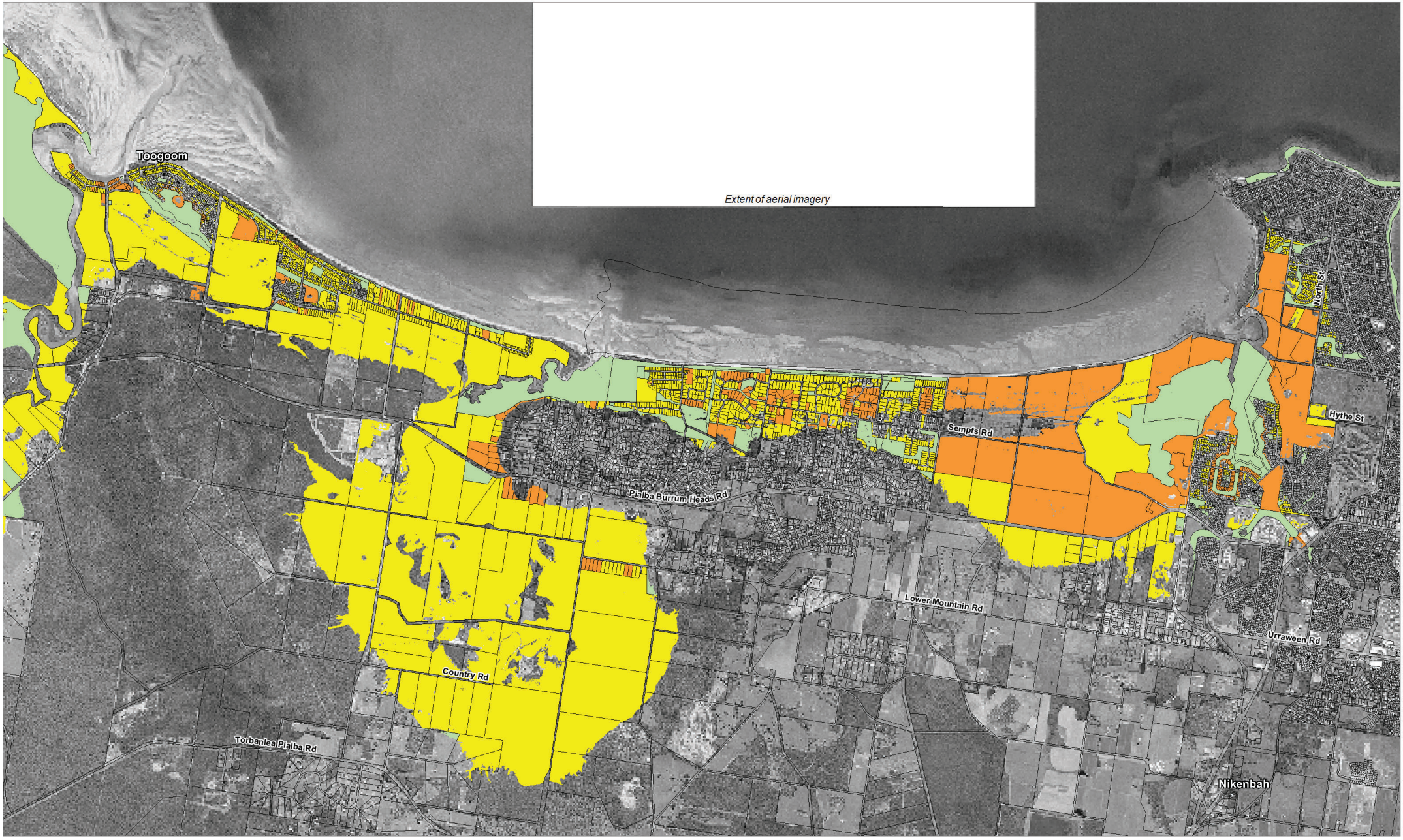

LEGEND

Cadastral Boundaries

Risk Rating

- Low
- Medium
- High

Title:

Regional Planning Zone and Land Parcel Assessment 2100 Storm Tide

Figure:

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LEGEND

Cadastral Boundaries

Risk Rating

- Low
- Medium
- High

Title:

Regional Planning Zone and Land Parcel Assessment Present Day Storm Tide

Figure:

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Approx. Scale

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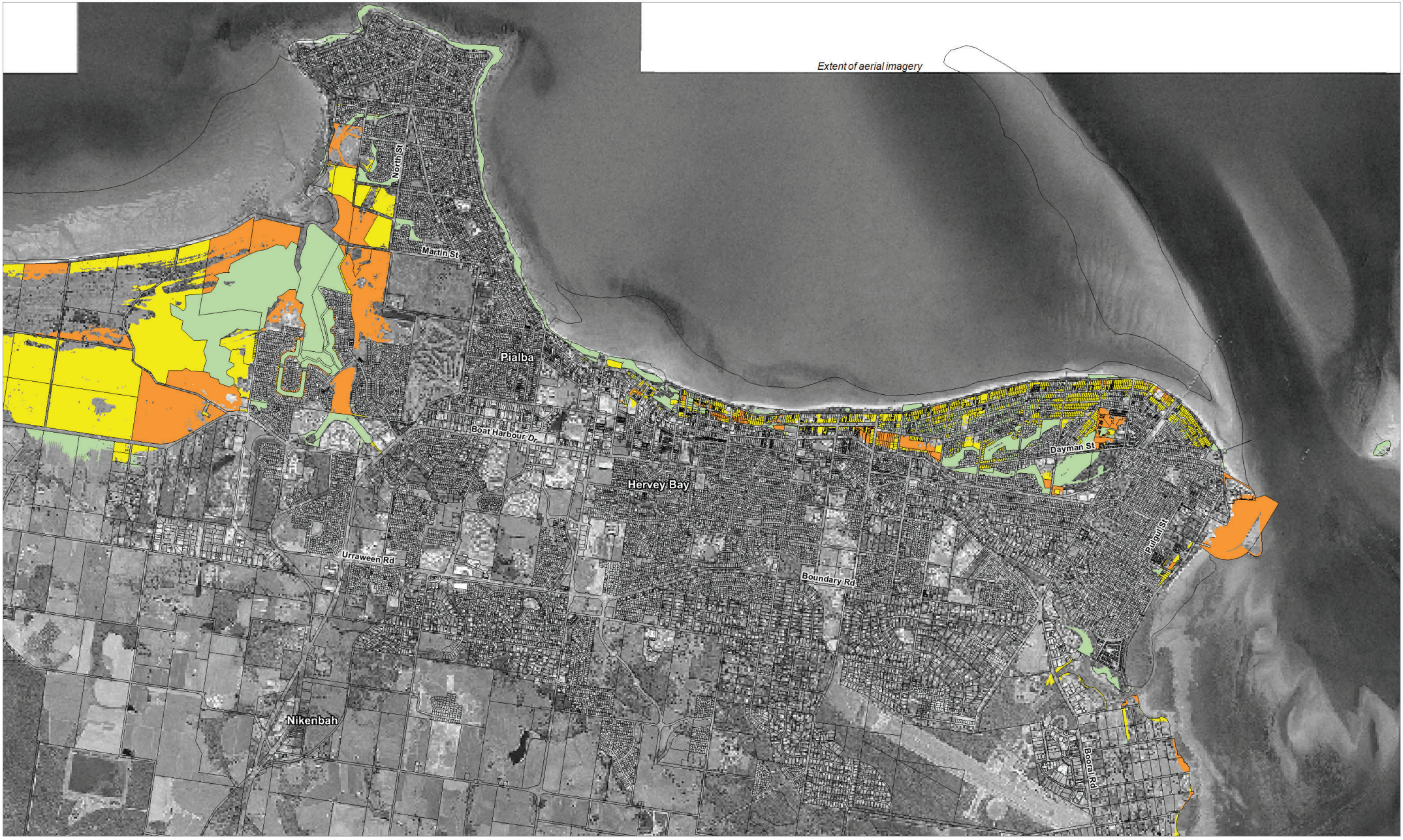

LEGEND

Cadastral Boundaries

Risk Rating

- Low
- Medium
- High

Title:

Regional Planning Zone and Land Parcel Assessment 2050 Storm Tide

Figure:

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Approx. Scale

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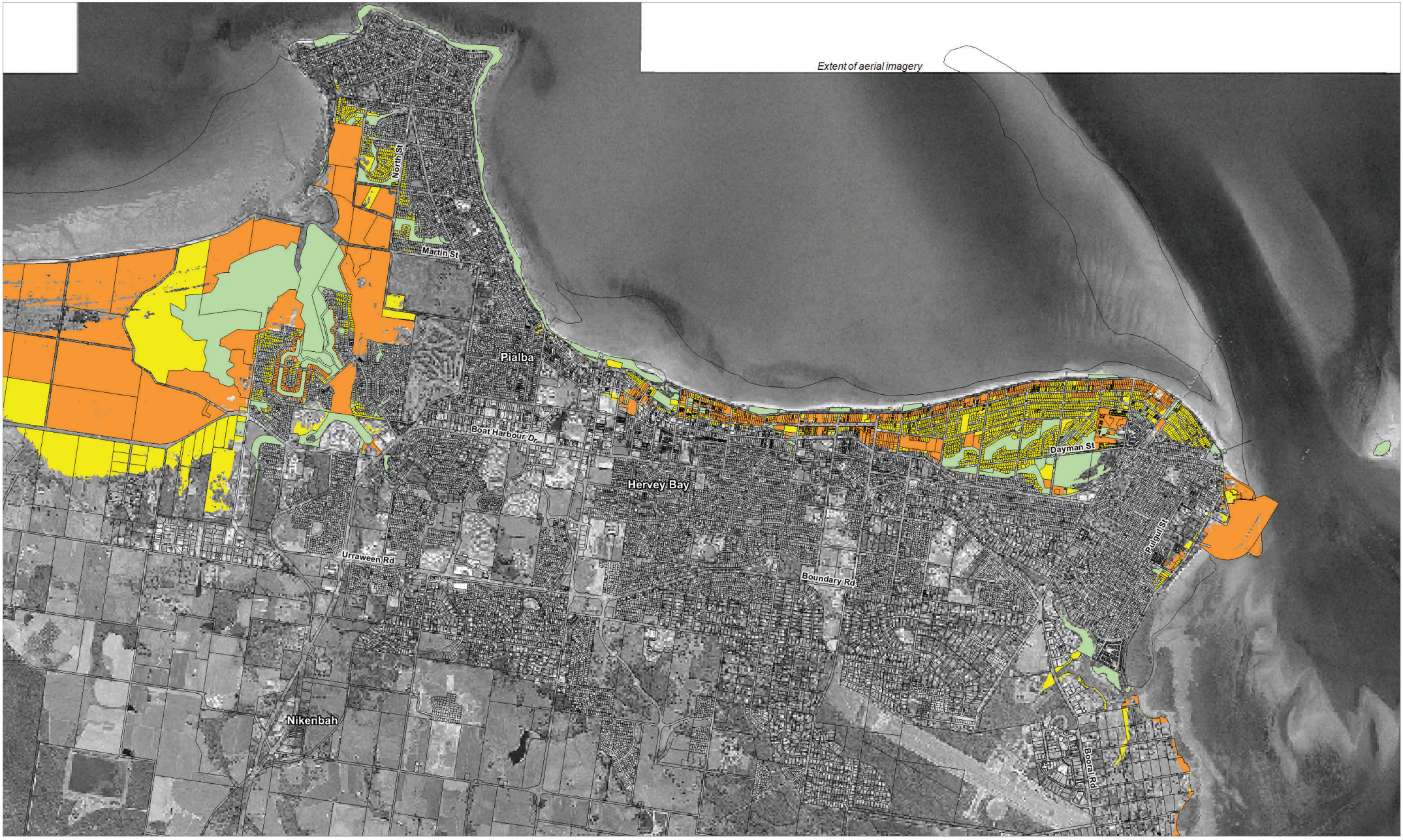

LEGEND

Cadastral Boundaries

Risk Rating

- Low
- Medium
- High

Title:

Regional Planning Zone and Land Parcel Assessment 2100 Storm Tide

Figure:

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Approx. Scale

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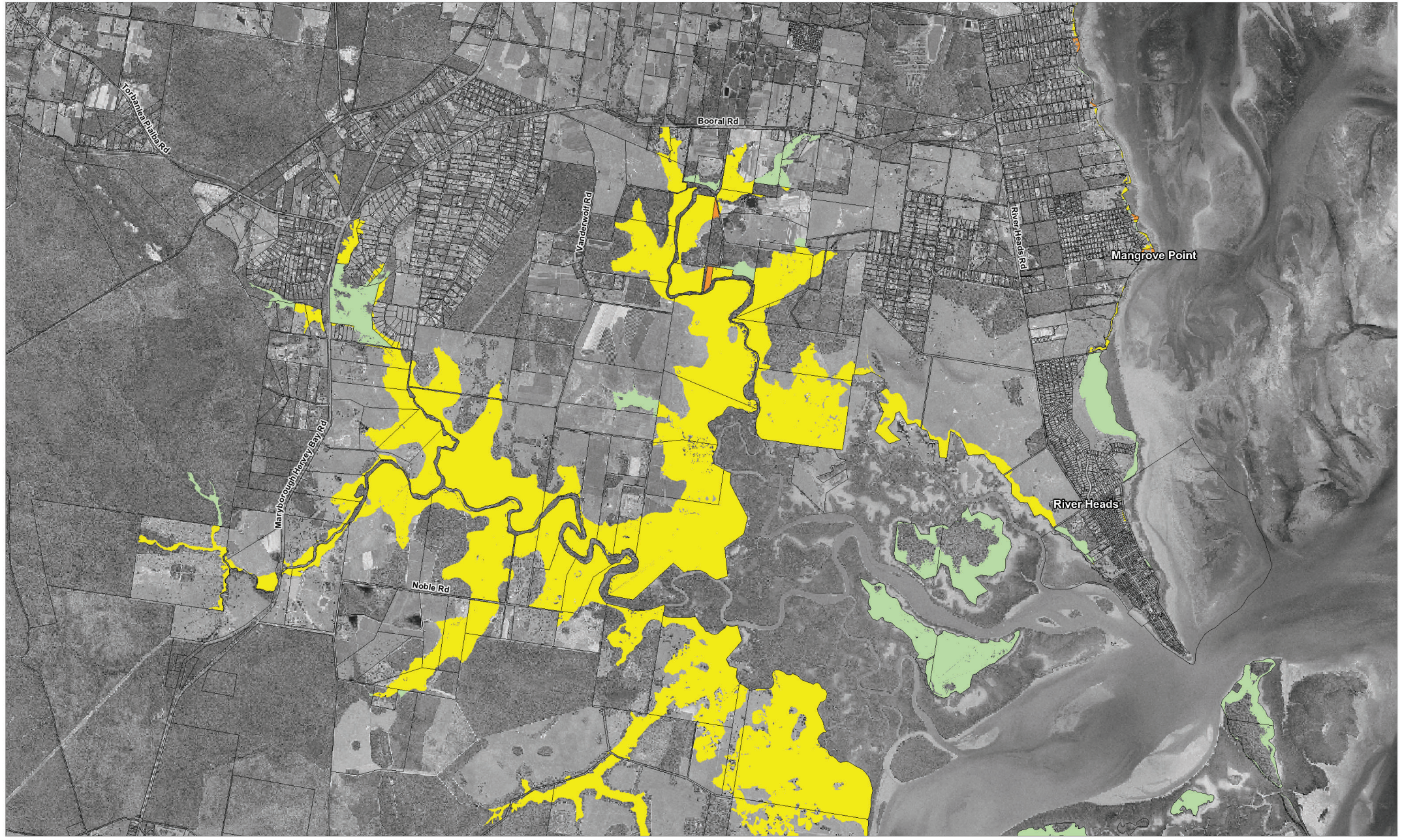

LEGEND

Cadastral Boundaries

Risk Rating

- Low
- Medium
- High

Title:

Regional Planning Zone and Land Parcel Assessment Present Day Storm Tide

Figure:

Rev: **A**

N

0 2 4km

Approx. scale

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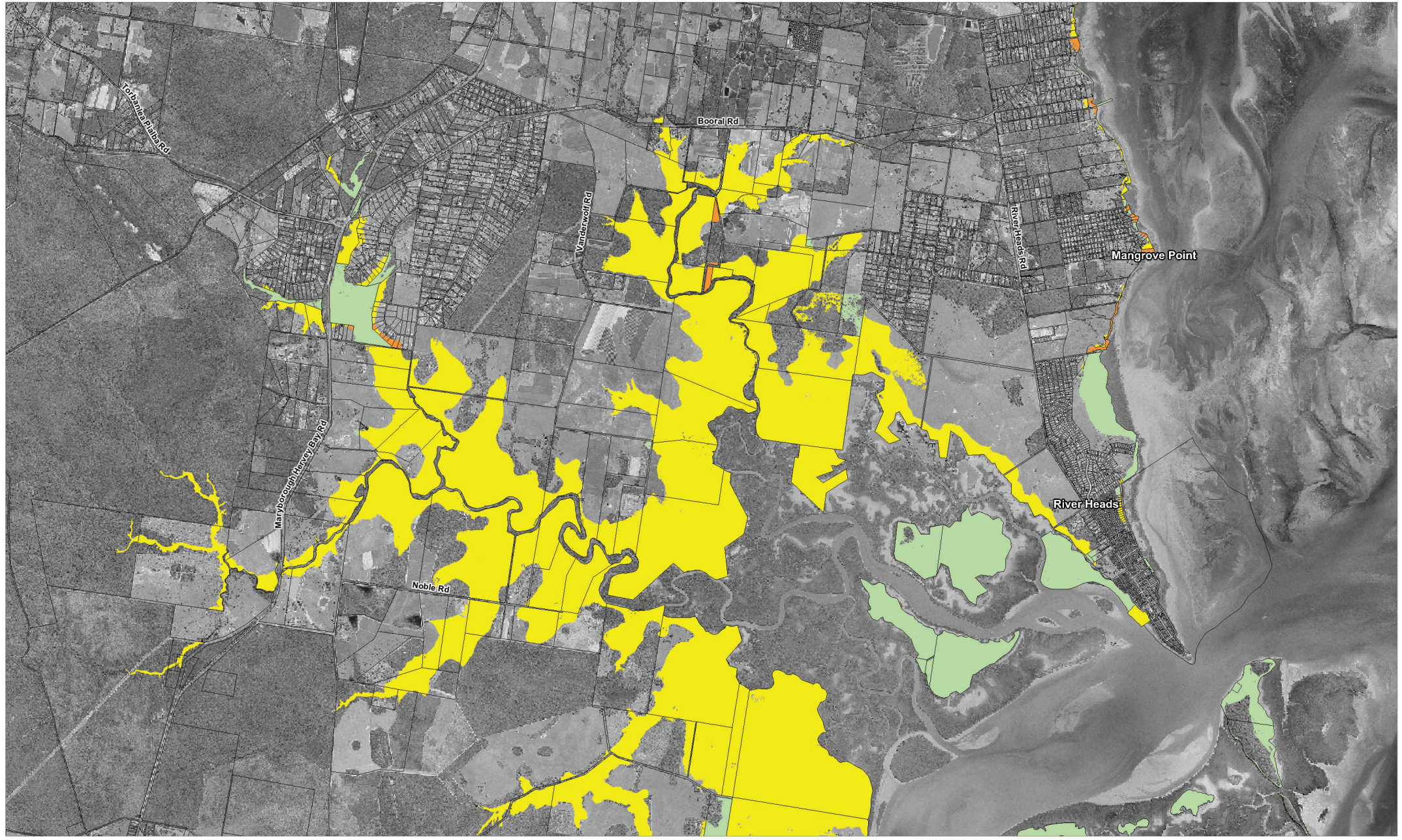

LEGEND

Cadastral Boundaries

Risk Rating

- Low
- Medium
- High

Title:

Regional Planning Zone and Land Parcel Assessment 2050 Storm Tide

Figure:

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Approx. scale

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LEGEND

Cadastral Boundaries

Risk Rating

- Low
- Medium
- High

Title:

Regional Planning Zone and Land Parcel Assessment 2100 Storm Tide

Figure:

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