Chapter Report 2: Risk Identification

City of Stirling Coastal Hazard Risk Management and Adaptation Plan

CW1195500

Prepared for
City of Stirling

23 June 2023

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1 Introduction

1.1 Overview

The City of Stirling (herein referred to as 'the City) is located approximately 6 km north-west of Perth's Central Business District (**Figure 1-2**). The City contains approximately 7km of Indian Ocean coastline, including iconic beaches, such as Scarborough, Trigg and Mettams Pool. The adjacent foreshore reserves support a variety of recreation, conservation and commercial land uses, including substantial built infrastructure situated in close proximity to the shoreline.

The City is undertaking a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP) to provide strategic guidance for coordinated, integrated and sustainable land use planning and management along its coastline. The CHRMAP will inform the City's future decision-making with respect to areas and assets identified as being at risk from coastal hazards.

1.2 Background

Globally, mean sea level (MSL) has risen since the nineteenth century and is predicted to continue to rise, at an increasing rate, through the twenty first century (Intergovernmental Panel on Climate Change [IPCC], 2021), bringing changes to the Western Australian (WA) coastline over the coming decades. To prepare for sea level rise (SLR) induced coastal hazards, such as coastal erosion and inundation, all levels of government are putting processes in place to ensure that communities understand the risks to values and assets on the coast, and to plan to adapt over time.

Changes to MSL over the past century have been observed for the coastline adjacent to the Perth Metropolitan Area. *Sea Level Change in Western Australia – Application to Coastal Planning* (Department of Transport [DoT], 2010a) reviewed information relating to SLR at a local scale and recommended an allowance for SLR be adopted for planning purposes. Recommendations were based on the upper bound of the global average SLR projections from *IPCC's Fourth Assessment Report* [AR4] (IPCC, 2007). In the intervening years, following release of the DoT document, advances in climate change science have been reflected in revisions to SLR projections, such as those documented in *IPCC's Sixth Assessment Report* [AR6] (IPCC, 2021). Current guidance on global SLR projections are derived from Shared Socioeconomic Pathways (SSP), characterising the trajectory of global society, demographics and economics over the coming century. Analogous to that used in DoT's recommendation is SSP5, which forecasts a SLR of 0.94m between 2020 and 2120 (**Figure 1-1**).

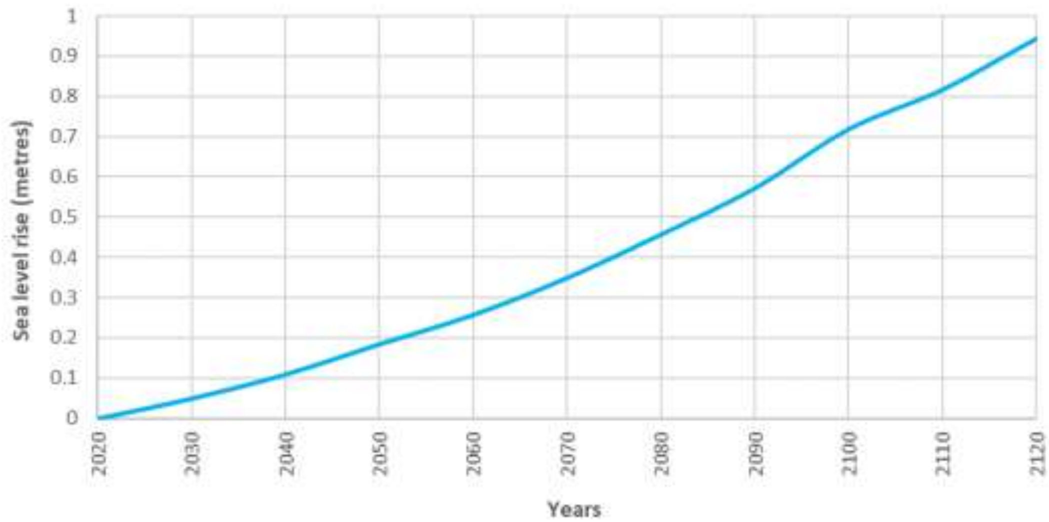

Figure 1-1 Projected sea level rise for planning purposes in Western Australia (based on IPCC, 2021 & DoT, 2010a).

The City's coastline to the south of Trigg Island is sandy, featuring coastal dunes, nearshore reefs and seagrass meadows. For sandy coastlines, increases in local MSL generally result in shoreline recession, with a "rule of thumb" often applied, that a 1 cm rise in MSL will result in 1 m of landward recession of the shoreline. It should be noted that this is based on the "Bruun Rule" which is generally considered a conservative (and simplified) approach (Rosati et al, 2013; Cooper & Pilkey, 2004).

North of Trigg Island, the coastline features pocket perched beaches, with nearshore reef platforms, visible rocky cliffs and subsurface rock formations. In these areas' special consideration of the height and integrity of the rock formations is required to ascertain the level of erosion protection that the rocky features will afford adjacent areas.

1.3 Overview of the CHRMAP Process

The key policy governing coastal planning in WA is the *State Planning Policy No. 2.6: State Coastal Planning Policy* (Western Australian Planning Commission [WAPC], 2013) (SPP2.6). SPP2.6 recommends that management authorities develop a CHRMAP, using a risk mitigation approach to planning, that identifies the hazards associated with existing and future development in the coastal zone. SPP2.6 and the *State Coastal Planning Policy Guidelines* (WAPC, 2020) contain prescriptive details, for example in relation to scales of assessment, storm event types and SLR allowances.

The WAPC (2019) has also developed the *Coastal hazard risk management and adaptation planning guidelines* (CHRMAP Guidelines) which are less prescriptive in terms of technical assessment of coastal processes, but are aimed to ensure that planning is carried out using a risk-based approach. This includes paying due regard to stakeholder engagement, community consultation and education, and requires that a full range of applicable adaptation options are considered. An overview of the typical CHRMAP process is shown in **Figure 1-3.**

Coastal planning in accordance with SPP2.6 also needs to take into consideration the requirements of other planning policies, including *Statement of Planning Policy No. 2: Environment and Natural Resources Policy* (WAPC, 2003) (SPP2), *State Planning Policy No. 2.8: Bushland policy for the Perth Metropolitan Region* (WAPC, 2010) (SPP2.8), *Statement of Planning Policy No. 3: Urban Growth and Settlement* (WAPC, 2006a) (SPP3.0) and *State Planning Policy No. 3.4. Natural Hazards and Disasters* (WAPC, 2006b) (SPP3.4).

1.4 Purpose of this Report

The City's CHRMAP has been developed by a staged approach, with the various stages documented in dedicated chapter reports. The chapter reports will be summarised and used to underpin the overall CHRMAP document. The purpose of the chapter reporting is to capture key technical detail, while the overall CHRMAP presents a more accessible and community-friendly document. The chapter reports prepared as part of the City's CHRMAP include:

- Chapter 1 – Establish the Context (Stage 1) (Cardno, 2023a);
- **Chapter 2 – Risk Identification (Stage 2)**;
- Chapter 3 – Vulnerability Analysis and Risk Evaluation (Stages 3 and 4) (Cardno, 2023b);
- Chapter 4 – Risk Treatment (Stage 5) (Cardno, 2023c); and
- Chapter 5 – Implementation (Stage 6) (Cardno, 2023d).

This document presents the *Risk Identification* chapter report, detailing the coastal hazard risk assessment for present day (2022), 2030, 2045, 2070 and 2122 planning horizons. This document also includes coastal hazard mapping and the identification of assets that may be impacted by coastal hazards over the next 100 years.

City of Stirling
City of Choice

N

1:22,000 Scale at A3

km
0 1

Study Area

CITY OF STIRLING CHRMAP

FIGURE 1-2

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-03-31
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_001_StudyLocality.mxd 02
Aerial imagery supplied by Esri et al.

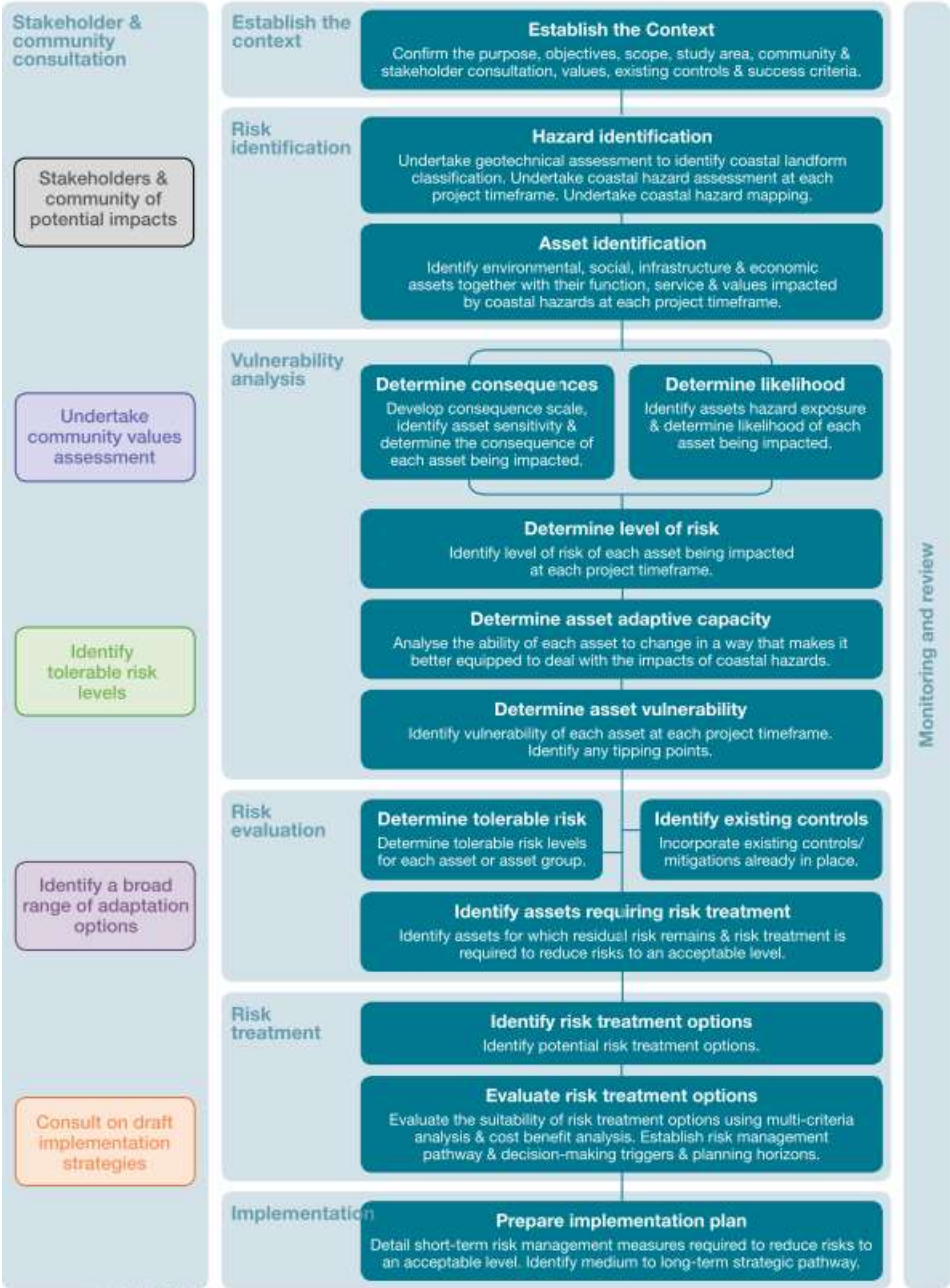

Figure 1-3 Risk management steps forming the CHRMAP process (WAPC, 2019)

2 Study Approach and Policy Guidance

2.1 Coastal Foreshore Reserve

SPP2.6 provides guidance on the planning principles and guidelines required for coastal development in Western Australia. A key policy objective of SPP2.6 is the provision of a coastal foreshore reserve. The coastal foreshore reserve is essentially a ‘space’ between the ocean and private land. It should accommodate a range of functions and values such as geomorphological integrity, biodiversity, heritage, public ownership and access.

Schedule One of SPP 2.6 provides guidance for calculating the coastal foreshore reserve to allow for coastal processes, incorporating acute (storm-based) erosion, historical shoreline movement trends, the future effects of sea level rise and storm tide inundation. The coastal foreshore reserve should be determined on a case by case basis and include allowances for additional functions provided by the coastal foreshore region associated with environmental, social and indigenous values.

The component of the coastal foreshore reserve to allow for coastal processes should be sufficient to mitigate the risks of coastal hazards by allowing for landform stability, natural variability and climate change. The coastal foreshore reserve is a critical input into the coastal hazard risk management and adaption planning framework outlined in SPP 2.6. The assessment considers allowances for coastal erosion and storm surge inundation in parallel.

2.2 Coastal Erosion

2.2.1 Sandy coasts

Sandy coastlines are, in general, very responsive to the climate and any changes that occur. The allowance for erosion on sandy coasts is calculated as the sum of the S1, S2 and S3 Erosion allowances, plus a 0.2 m per year allowance for uncertainty:

- (S1 Erosion) Allowance for the current risk of storm erosion;
- (S2 Erosion) Allowance for historic shoreline movement trends;
- (S3 Erosion) Allowance for erosion caused by future sea-level rise; and
- (Su Erosion) Allowance for uncertainty.

The erosion allowances are applied from a horizontal shoreline datum (HSD), defined by the active limit of the shoreline under storm activity. The HSD should be determined against the physical and biological features of the coast.

2.2.2 Rocky coasts

Rocky coasts comprise a continuous rocky substrate which extends to an elevation above the active limit of the shoreline. In most instances this elevation should be defined at least one metre above the HSD.

Part of the City’s coastline would be classified as weakly lithified sedimentary rock coast. These coasts comprise poorly cemented or semi-lithified, discontinuous, relatively soft or highly weathered, weak rock. They typically feature low steep cliffs which are easily undercut often forming wave cut platforms. Shoreline retreat is comparatively rapid compared to other types of rocky coasts and generally occurs by slumping, rock-falls, or slab collapse.

2.2.3 Mixed sandy and rocky coasts

Coasts with discontinuous or low elevation rock shall be classified as mixed sandy and rocky coasts. This is the case for parts of the City’s coastline, which would be described as discontinuous rocky shorelines. These coasts comprise discontinuous subtidal or intertidal rock on a predominantly sandy shoreline. The subtidal rock may be present as a pavement or discontinuous outcrops of reef close to the shore. Erosion of such coasts are to be considered on a case by case basis.

2.3 Coastal Inundation

The allowance for the extent of coastal inundation (S4) is calculated as the maximum extent of storm inundation, defined as the peak steady water level, plus wave run-up, for 500-years average recurrence interval (ARI) storm event. Consideration must be given to the likelihood of breaching any manmade structures, such as seawalls, or natural barriers, such as dune systems.

2.4 Climate Change Considerations

It is widely recognised in the scientific community that climate change is occurring and, as a result, forecast effects should be considered when planning for the future. For the City, the relevant effects will most likely be an increase in MSL, as well as possible changes to storm frequency, direction and intensity, changes to precipitation patterns and increased temperatures. For the purpose of this CHRMAP, only potential effects due to SLR are considered.

2.4.1 Sea Level Rise

Previously recommended allowances for SLR, to be adopted for planning purposes in WA (DoT, 2010a), have been updated to reflect advances in climate change science (as recommended in that report). The allowances adopted in this study are provided in **Table 2-1** and have been informed by IPCC (2021). In order to comply with SPP2.6, the upper bound of the SSP (SSP5-8.5) predictions has been adopted, analogous to that used to inform DoT (2010a).

Table 2-1 Sea level rise allowances adopted for this study, with respect to 2022 (IPCC, 2021 & DoT, 2010)

Timeframe	Present day (2022)	2030	2045	2070	2122
Sea Level Rise (m)	0.00	0.05	0.15	0.35	0.94

2.4.2 Planning timeframe

Adhering to the requirements of SPP2.6, this study will consider the present-day (2022) timeframe, as well as the years 2030, 2045, 2070 and 2122 planning timeframes/horizons.

2.5 Previous Coastal Hazard Assessment

2.5.1 Strategic Coastal Processes Study (BMT JFA Consultants, 2015)

The detailed coastal processes study and hazard assessment used to inform this CHRMAP, and underpinning this Risk Identification Chapter Report, has been presented in the *Strategic Coastal Processes Study* (BMT JFA Consultants, 2015). The study has analysed a wide range of data including shoreline movement, beach profiles, coastal bathymetry, wave modelling, perched beach dynamics and mapping of rock on beaches. The study has synthesised this information and developed a process-based understanding of the factors affecting the coastal response to sea level rise for the City's coastline, within the planning horizons of 2060 and 2110, having predicted increases in mean sea level of 0.3m and 0.9m, respectively.

While this report does include preliminary identification of potential "hot spots" along the coast, this assessment is based on a process study alone and does not satisfy the requirements of WA State Coastal Planning Policy 2.6. However, this study was intended to make a key contribution to the future development of the City of Stirling CHRMAP. The "hot spots" also indicate the areas along the sandy coast south of Trigg Is. where it is essential for development planning to include outcomes from the CHRMAP. Through this study, uncertainty with regards to coastal geology was highlighted, identifying the need for further geophysical investigation to properly characterise coastal risk (see **Section 2.6**).

2.5.2 Scarborough Redevelopment CHRMAP (MPRA, 2015)

A CHRMAP was undertaken to inform the Scarborough Beach Redevelopment (MPRA, 2015), which has now been developed immediately behind the coastal dunes at Scarborough. The main purpose of the CHRMAP was to define areas of the coastline which could be vulnerable to coastal hazards and to outline the preferred approach to the monitoring and management of these hazards where required. Specifically, the purpose of this CHRMAP is as follows:

> Confirm the potential coastal hazards for the Scarborough Beach Redevelopment and their extents;
> Outline the risks associated with the proposed development and how this risk may change over time;
> Establish the basis for present and future risk management and adaptation; and
> Provide guidance on appropriate management and adaptation planning for the future, including monitoring.

The hazard extents and coastal processes investigations that have informed them have been incorporated and compared with this Risk Identification, where appropriate.

2.6 Geophysical Investigation (GBGMAPS, 2018)

GBGMAPS Pty Ltd (GBGMAPS) carried out a geophysical subsurface investigation over a section of coastal dune system in May and June, 2018, covering a large portion of the study areas southern extent (i.e. north of Trigg Island).

During the investigation, 44 Seismic Refraction transects and 10 Multi-channel Analysis of Surface Waves (MASW) transects were acquired, processed and analysed. The objective of the investigation was to determine and model the interface between the underlying limestone rock and overlying sand strata. In particular the following was sought:

> The depth to competent limestone bedrock relative to the current mean sea level; and
> The density and thickness of the overlying sand cover.

Local Dynamic Cone Penetrometer (DCP) testing was also undertaken at Mettams Pool to confirm the depth of competent limestone bedrock in this area (MPRA, 2020). The DCP investigation results indicated that the actual rock level may be around 0.5 to 1.5 m lower than that inferred from the geophysical investigation results.

The results of these investigations have been incorporated into this Risk Identification (see **Section 4.3.1**) to properly characterise the coastline type and refine coastal hazard extents, given the presence of natural barriers to erosion.

3 Site Description

A detailed assessment of the City's coastal setting has been made by BMT JFA Consultants in the *Strategic Coastal Processes Study* (2015). A summary of the site's description has been provided below. Key coastline features are mapped in **Appendix A**.

3.1 Bathymetry

Regional bathymetry including the study area is presented in **Figure 3-1**. The nearshore bathymetry of the study area to the north of Trigg Island comprises a series of discontinuous shore parallel limestone reef systems. The presence of these systems provides some level of protection against the direct impact of offshore wave conditions, through processes such as shoaling, breaking, refraction and diffraction. The shelf underlying and offshore of these nearshore bathymetric variations is relatively gentle, with the 30 m depth contour approximately 10 km offshore (DoT, 2010b). The more exposed southern portion of the study area is characterised by a slightly steeper nearshore bathymetry, with nearshore bar formations becoming established during periods of elevated wave conditions (Short, 2006). While interrupted by commercial and public development, the Quindalup Dunes are present across much of the southern portion of the study area as beach ridges, parallel and parabolic dunes.

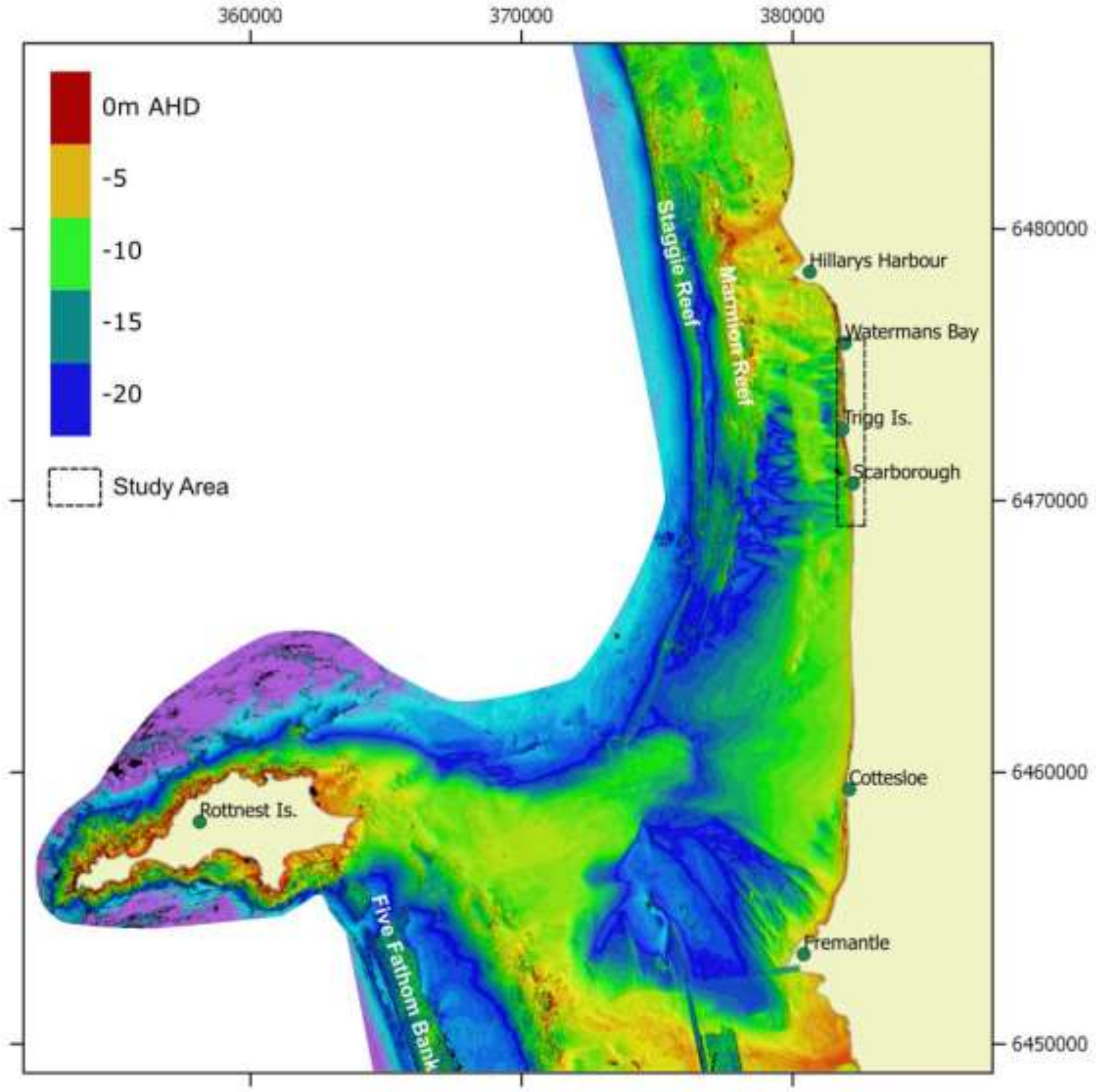

Figure 3-1 Regional bathymetry – from LiDAR and laser airborne depth sounder (DoT, 2009) presented in BMT (2015)

3.2 Geomorphological Setting

The City's beaches are comprised of unconsolidated sediments of the Quindalup geological system; principally white, medium grained and rounded calcium carbonate sands with variable amounts of silica. The calcareous component is largely skeletal - shell material recently produced in seagrass meadows and algal communities of offshore reefs, including from a substantial sediment transport pathway from Rottnest Island towards Perth's northern beaches. Ongoing supply of terrigenous sediment in the region is low, but a large quantity of such sediment has been retained in coastal barriers from the late Holocene (Gozzard, J.R., 2007).

According to Stul's (2015) review of physical characteristics of Perth beaches, the representative sediment grain size is medium to coarse sand (0.25-1.00 mm median diameter). Consistent with the greater Perth Metropolitan coastline, the beach and dune sediment deposits within the study area overlay or front Pleistocene Tamala Limestone. To the south of Trigg Island, this limestone is not present at, or near, the surface. The stretch of coastline, including Scarborough Beach, is comprised of relatively wide, sandy beaches, backed by a foredune of varying size and form. To the north of Trigg Island, limestone is present above or near the surface nearshore. The coastline along this stretch is comprised of limestone cliffs, outcrops and reefs, with intermittent perched and small bay beaches.

3.3 Oceanographic Conditions

3.3.1 Wind

The study area is located within the greater Perth Metropolitan Region and experiences the typical meteorological conditions of the region. It is influenced by two dominant seasonal weather patterns. The summer period is characterised by south to south-westerly sea breezes that generally increase through the afternoon and can be very strong at times. The winter period is characterised by intermittent storms attributed to mid-latitude low pressure systems, shifting the dominant wind direction to north-westerly (Bureau of Meteorology, 2022).

3.3.2 Water Levels

The City's coastline is located within a predominantly diurnal, microtidal environment. The tidal range varies from approximately 0.3 m during neap tides to 0.7 m during springs. The present-day astronomical tidal planes at Fremantle are provided in **Table 3-1**.

Table 3-1 Astronomical tide regime at Fremantle Fishing Boat Harbour (DoT, 2017)

Tidal Water Levels	m AHD	m CD
Highest Astronomical Tide (HAT)	0.63	1.40
Mean High Water Spring (MHWS)	0.38	1.15
Mean High Water Neap (MHWN)	0.27	1.04
Mean Sea Level (MSL)	0.00	0.81
Mean Low Water Neap (MLWN)	-0.20	0.57
Mean Low Water Spring (MHWN)	-0.30	0.47
Highest Astronomical Tide (LAT)	-0.51	0.26

3.3.3 Currents

The small tidal movement at the study area allows wind to be the major driver of currents, particularly within the nearshore zone. Longshore currents correspond to seasonal wind and wave conditions, predominantly propagating northward during summer and to the south briefly during winter. The interaction of these currents with shoreline features can form local eddy and rip currents, particularly when swell is present driving substantial water movement perpendicular to the shore (Pattiaratchi et al., 1997).

Current data was recently collected by the DoT at two locations offshore of the City's coastline (adjacent Mettams Pool). The data collected covers a 12-month period in 2021. The data has not been analysed as part of this study, but should be incorporated in future coastal hazard and processes assessments for the City.

3.3.4 Wave Climate

The regional offshore wave climate is bimodal with respect to period and direction. A persistent background swell is present all year round from the Indian and Southern Oceans. This swell is predominately from the south to south-west, with an increased westerly component during the winter period (Lemm et al., 1999).

Superimposed on the swell regime, is a highly-variable, locally-generated sea climate attributed to the seasonal wind patterns that characterise the region. The winter period waves are driven by west to north-westerly conditions, associated with intermittent mid-latitude low pressure systems. The summer period waves are driven by a frequent and strong south-westerly sea breeze, attributed to pressure differences between the ocean and land (Lemm et al., 1999).

Tropical cyclones that develop during the summer months off WA's north-west coast rarely track down to the study area's latitude, but have been recorded in the region (Tropical Cyclone Alby and Ned for example) and can cause significant wave conditions over relatively short durations (MPRA, 2018).

The City is afforded some protection from offshore wave conditions by Rottnest Island offshore to the west and, nearshore, by discontinuous limestone reef structures scattered adjacent to the coastline. BMT (2015) indicated that the depth of the reef structures played a significant role in dissipation of wave energy. This dissipation is expected to lessen in the future as mean sea level rises. The northern half of the study area is, therefore, more exposed to relative increases in wave energy at the shoreline, as a result of climate change.

3.4 Coastal Processes

3.4.1 Sediment Cells

Sediment cells are areas along the coastline which are likely to be connected through processes of sediment exchange. Stul et al. (2015) mapped sediment cell boundaries at three spatiotemporal scales along the Western Australian Vlamingh coastline (between Cape Naturalist and Moore River). The sediment cells relevant to the City's coastline are summarised below and have been presented in **Figure 3-2**, below.

> Primary cells are related to large landforms or land systems over longer coastal management timescales of more than 50 years. The study area falls in primary cell R06F which spans from the engineered section of the coast at Fremantle to Pinnaroo Point;

> Secondary cells incorporate contemporary sediment movement on the shoreface and potential landform responses to inter-decadal changes in coastal processes. The study area falls across two secondary cells:

- Secondary cell 26, which comprises a predominantly sandy stretch of coastline bound by rocky outcrops at Mudurup Rocks in Cottesloe and Trigg Point; and
- Secondary cell 27, extending from Trigg to Pinnaroo Point and containing predominantly low to moderately high cliffed coasts within the area relevant to the City.

> Tertiary cells are defined by the reworking and movement of sediment in the nearshore area and are the most relevant for seasonal to inter-annual changes to the beach face. The study area is spread across two tertiary cells, 26d and 27a. Cell 26d spans from Brighton Road to Trigg, cell 27a from Trigg to South Sorrento. This suggests that mechanisms of coastal change may differ between the north and south of the study area over the short term (i.e. inter-annual timescales).

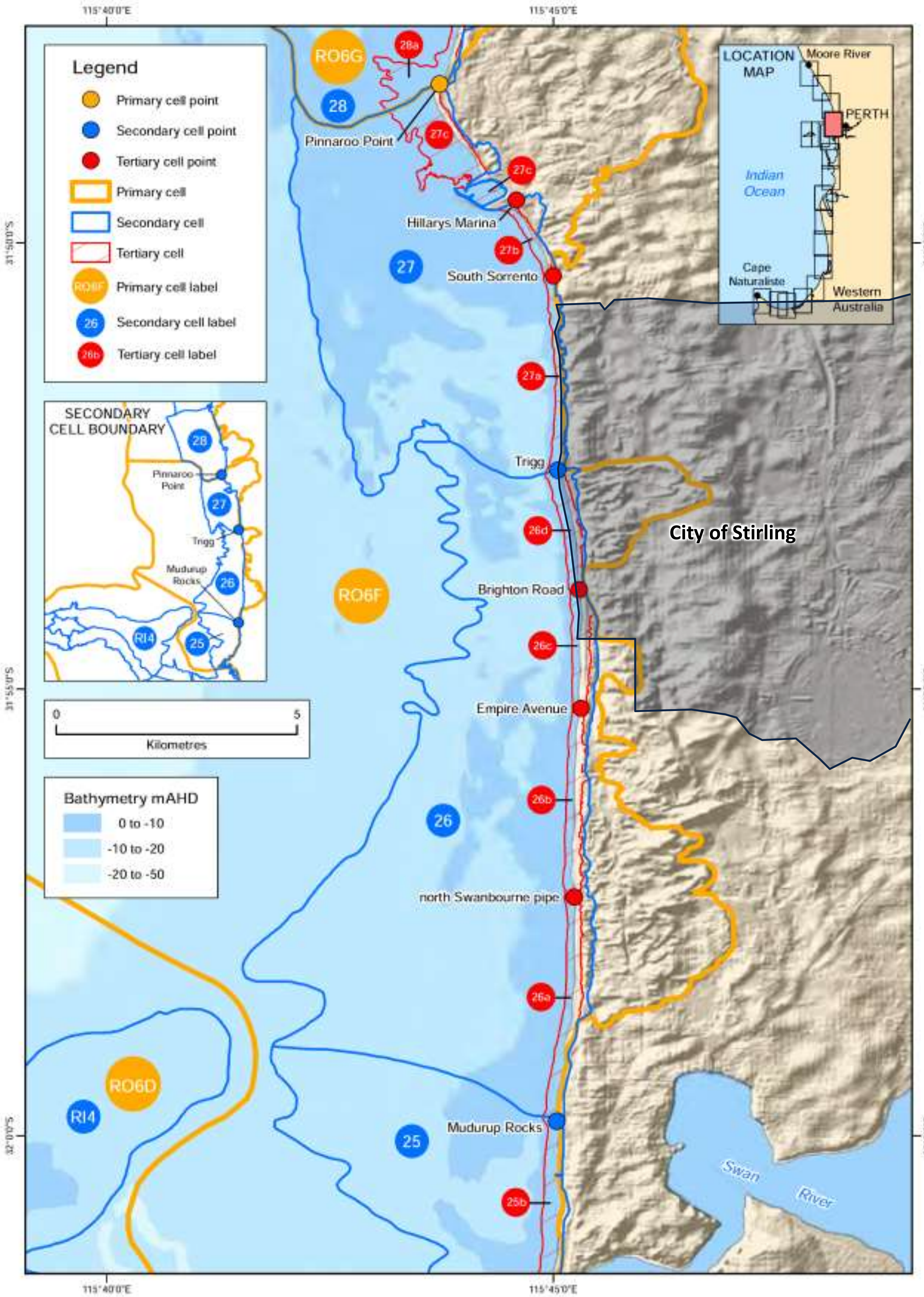

Figure 3-2 City of Stirling in the context of coastal sediment cells (Figure A.15 from Stul et al., 2015).

3.4.2 Sediment Transport

Along the Perth Metropolitan coastline, longshore sediment transport has been shown to be mainly northward from September to April, associated with prevailing currents over the summer period. A southward movement of sediment is usually observed during the winter months of June and July. The result is a net northward movement of material annually (Masselink & Pattiaratchi, 2001). Nearshore structures and natural shoreline features can direct and obstruct the movement of suspended sediment. The most notable examples of this in the study area is Trigg Point and Island, which typically exhibits seasonal accretion of the shoreline to its south during summer, and seasonal erosion of the shoreline to its south during winter (with the opposite effect to their north).

Cross-shore sediment movement in the Perth Metropolitan region is also seasonal, with sporadic periods of swell pushing sediment onto the shore, steepening the beach profile. Mid-year the beach is reformed by the energy of winter storms eroding the beach face and redepositing sediment to form sandbars just offshore. These formations become stable towards the end of winter and act as a buffer, preventing wave breaking at the shore and the substantial shifting of sediment that it can cause (Masselink & Pattiaratchi, 2001).

BMT JFA (2015) have interpreted local bathymetry and existing historical information to infer a sediment budget and transport regime for the City's coastline. Their investigations indicate that a net northerly littoral drift exists, transporting approximately 20,000 m^3 of sediment per year, with some interannual variability and seasonal reversal. Longshore transport (both marine and eolian) is interrupted by rocky outcrops from Trigg Island northward, and depleted or added to by cross-shore transfer between beaches and the nearshore environment. This leads to a partial, seasonal exchange cycle between the beach and subtidal areas. The net northward longshore transport past Trigg Island is estimated to be between 6,000 m^3 and 9,000 m^3 annually.

3.4.3 Existing Coastal Controls

3.4.3.1 Overview

Physical coastal controls, in the context of the CHRMAP's coastal hazard assessment, refer to any built structures that currently interact, or have the potential to interact in the future, with oceanographic conditions and coastal processes. Controls also include ongoing management/intervention such as nourishment programs and dune care. The existing controls for the study area are summarised in **Table 3-2** and discussed further in the sub-sections below. The existing controls have been incorporated in assessment of coastal erosion hazard extents, where appropriate – i.e. they create a continuous barrier to coastal hazards, for an extended period of time. An assumed 'management/control timeframe' has been allocated for each coastal control. The timeframe has been based on each structure's existing condition and/or design life/period, where documentation of this available. This timeframe is incorporated in the development of coastal erosion hazard extents by assuming the control is no longer in place after the allocated timeframe. This allows the identification of both:

- The effect on the coastline should/once the control be removed; and
- Any benefit the existing control provides in terms of reducing risk to landward assets.

Coastal controls that affect hazard extents have been included in coastline feature and hazard mapping (**Appendices A** and **B**). Minor protection of specific assets, such as the access stairs at Mettams Pool, is not of a large enough scale to be factored into hazard extent mapping, but is considered in the asset risk and vulnerability assessment (Stage 3). Similarly, the effect of nourishment, drainage outlets and dune management on coastal erosion is not incorporated into hazard extents, as these effects are localised, difficult to quantify and not confirmed to be in place for an extended period of time.

Table 3-2 Existing coastal controls in the study area

Control	Location(s)	Purpose	Year implemented	Assumed management/control timeframe
'Hard' engineering controls				
Watermans Bay GSC Revetment (**Figure 3-3**)	Watermans Bay, adjacent Elsie Street	Emergency protection works following severe erosion. Providing temporary protection to critical landward infrastructure.	2010	To 2030
Marine Lab rock protection (**Figure 3-6**)	Marine Lab, adjacent Elvire Street	Protection of access steps	Mid 2000s	To 2030
North Beach Jetty Seawall (**Figure 3-4**)	North Beach, between Castle and Malcolm Streets	Protection of landward assets (roads/paths) from overtopping impact.	2008	To 2030
Hamersley Pool rock protection (**Figure 3-7**)	Hamersley Pool, between Beachton and Hamersley Streets	Protect access steps	Mid 2000s	To 2030
Mettams Pool GSC Defence (**Figure 3-5**)	Mettams Pool, between Giles and Lynn Streets	Provide protection to access path/ramp.	2022	To 2042
Rock protection between Lynn and Bailey Streets (**Figure 3-8**)	Between Lynn and Bailey Streets	Provide protection to path and other landward infrastructure.	Early 2000s	To 2030
Retaining walls (**Figure 3-8**, **3-10**)	Various locations - Scarborough Beach, West Coast Drive	Retain landward material with built assets	Various	NA
'Soft' management controls				
Beach Nourishment (2,200 m^3) (**Figure 3-5**)	Mettams Pool (sourced from Sorrento Beach)	Create erosion buffer and enhance beach.	April 2021	Likely to continue into the future
Dune management / protection (**Figure 3-11**)	Various locations Scarborough and Trigg Beaches	Protect dunes and their vegetation from being accessed and degraded	Various	Likely to continue into the future
Dune restoration / revegetation (**Figure 3-7, 3-10, 3-12**)	Various locations	Restore, consolidate and enhance dunes	Various	Likely to continue into the future
Drainage outlets (**Figure 3-13**)	Various locations	Can influence local beach morphology	Various	Likely to be present into the future
Relevant adjacent controls outside the study area				
Hillarys Boat Harbour	Adjacent Hepburn Avenue	Safe harbour for boating access and penning.	1986	Likely to be present well into the future.
Sorrento Groynes (3)	375m, 645m and 930m alongshore to the south of Hillarys Boat Harbour, respectively.	Interrupt longshore drift, advance shoreline buffer and protect infrastructure.	1982	Originally to 2030 Likely to be refurbished and present into the future.

Floreat Groyne	500 m north of City Beach Groyne – between Floreat and City Beach	Interrupt longshore sediment transport to adjust shoreline position.	1958 (constructed) 2008 (refurbished)	To 2050
City Beach Groyne	West of Oceanic Drive	Interrupt longshore sediment transport to adjust shoreline position.	1935 (constructed) 2014 (refurbished)	To 2050

3.4.3.2 Watermans Bay GSC Revetment

Persistent coastal erosion at Watermans Bay led the City to construct a Geotextile Sand Container (GSC) revetment in 2010 (**Figure 3-3**). The revetment is approximately 170 m long and several meters in height, originally designed as emergency works with a minimum design life of 10 years (MPRA, 2009). The revetment remains in reasonable condition and is functional, however, areas of structural weakness have been observed, including some deformation at its toe. Assuming the structural integrity and functionality of the revetment remains and ongoing maintenance is undertaken, the geotextile material durability (including resistance to abrasion, hydrocarbons, impact damage and UV degradation) is typically 20 years. Past the recommended design life, GSC structure are expected to suffer from integrity issues (e.g., bag failure) and potentially create environmental hazards (e.g. release of microplastics into the natural environment).

Figure 3-3 Watermans Bay GSC Revetment

3.4.3.3 North Beach Jetty Seawall

North Beach Jetty is a local landmark, frequented by fisherman and recreational users. Since its establishment, due to degradation from regular coastal impact. The latest restoration was completed in 2018. The jetty abuts a ‘low’ level rock cliff surrounding the local headland. The natural limestone cliff top was capped by limestone rock protection (seawall) in 2008, reducing wave overtopping and damage to the landward access path (**Figure 3-4**).

Figure 3-4 North Beach Jetty Seawall

3.4.3.4 Mettams Pool GSC Defence

Mettams Pool is a popular recreational beach in North Beach, which has experienced ongoing coastal erosion. Winter storms regularly erode the beach exposing rocks, undermining the dunes and causing damage to access infrastructure. A review of possible long-term risk mitigation options was recently completed for the site (MPRA, 2020). Furthermore, temporary protection works have been installed in late 2021, in association with access upgrades and in response to the immediate threats posed by coastal hazards. Installation of GSC protection of the ramp leading from the parking area down to the coastline, which also incidentally protects infrastructure behind the ramp (**Figure 3-5**).

Figure 3-5 Mettams Pool GSC Defence during construction, as well as placed nourishment

3.4.3.5 Informal Rock Protection

Informal (i.e., not engineered) rock protection has been installed in various locations along the City's coastline during the early to mid-2000s. The placed rock has been identified at:

> Marine Lab (**Figure 3-6**). It appears the rock has been placed to raise the rock level at the shoreline above the existing natural rock, to retain (prevent the scour) of the adjacent land;

> Hamersley Pool (**Figure 3-7**). A single, grouted layer of limestone appears to perform the function of protecting and retaining the adjacent dune, which also has retainment (Geocells) overlayed; and

> Between Lynn and Bailey Streets (**Figure 3-8**). The rock has been placed to prevent scouring at the toe of a high retaining wall.

The rock structures lack the proper layering, interlock, toe foundation, crest height/form and (possibly) rock grade that would allow them to be classified as formal coastal protection structures. As such, their impediment to erosion has been assumed up to 2030, for the purpose of calculating hazard extents. However, they are likely to be in place and effective, to some extent, beyond this time.

Figure 3-6 Marine Lab rock protection

Figure 3-7 Hamersley Pool rock protection and dune retention/restoration (Geocells)

Figure 3-8 Rock protection and retaining wall between Lynn and Bailey Streets

3.4.3.6 Retaining Walls

The Scarborough Beach amphitheatre and retaining walls were constructed in 2006 with a design life of 50 years (**Figure 3-9**). It is unclear whether these structures have sufficient foundation scour protection or can withstand the direct impact of wave action (MPRA, 2015). As such, they are not included as formal barriers to coastal erosion in the calculation of hazard extents, although they are likely to restrict erosion landward of their location, to some extent.

Figure 3-9 Scarborough Beach amphitheatre and retaining walls (Image: Development WA).

Various retaining walls along the ocean side of West Coast Drive were built, as part of the road widening and recreational shared path construction works (**Figure 3-8** and **3-10**). Despite the presence of limestone bedrock in the vicinity of the retaining walls, it is understood that the retaining walls were founded on a shallow sand footing (Personal Communication with CoS, 2021). Therefore, it is unlikely that these structures have sufficient scour protection or can withstand the impact of wave actions and substantial erosion of the fronting dunes. As such, they are not included as formal barriers to coastal erosion in the calculation of hazard extents, although they are likely to restrict erosion landward of their location, to some extent.

Figure 3-10 Retaining wall along a section of West Coast Drive as well as dune revegetation (Watermans Bay).

3.4.3.7 Beach Nourishment

Responsive beach nourishment was undertaken at Mettams Pool in April 2021, to create an erosion buffer prior to winter storm impact. 2,200 m^3 of material was transported from Sorrento Beach, which can accumulate material to the north of Hillarys Boat Harbour and the Sorrento Groynes (**Figure 3-5**).

Further nourishment was undertaken at Mettams Pool in December 2021, as part of proactive sand management for the City's coastline. The works involved harvesting/scraping sand from Trigg Beach, to an approximate depth of 200mm, across a length of approximately 1 km of beach. This minimises local impacts to the beach and nearshore sand formations. Approximately 5,000 m^3 of sand was transferred and there are plans to repeat the management exercise in the future.

3.4.3.8 Dune Management / Protection

Fences have been installed along popular beach access tracks through the dunes and foreshore reserves. The foredunes of Brighton, Scarborough and Trigg are also fenced to limit pedestrian access, promoting coastal dune restoration and growth over time. **Figure 3-11** shows and example of dunce fencing at Scarborough Beach.

Figure 3-11 Example of dune fencing at Scarborough Beach

3.4.3.9 Dune Revegetation / Restoration

Coastal revegetation and restoration forms part of the City's ongoing environmental restoration projects, that are critical to ensuring the long-term survival of the native flora and fauna and their habitat. Direct planting in combination with a soil erosion controls is designed to assist revegetation and enhance the value of coastal reserves. Examples are shown in **Figures 3-7, 3-10** and **3-12**).

Figure 3-12 North Beach Hedland restoration. Comparison between 2006 (left) and 2012 (right) (Image source: Stirling Natural Environment Coastcare).

3.4.3.10 Drainage Outlets

Whilst not intended to act as coastal controls, drainage outlets discharge significant quantities of stormwater from inland catchments, having a minor, localised influence on beach morphology, longshore sediment transport, nearshore hydrodynamics and water quality. Scouring of the beach after large rainfall events is common. A total of 23 drainage outlets have been identified within close proximity of the water line along the City’s coastline. Examples are shown in **Figure 3-13**.

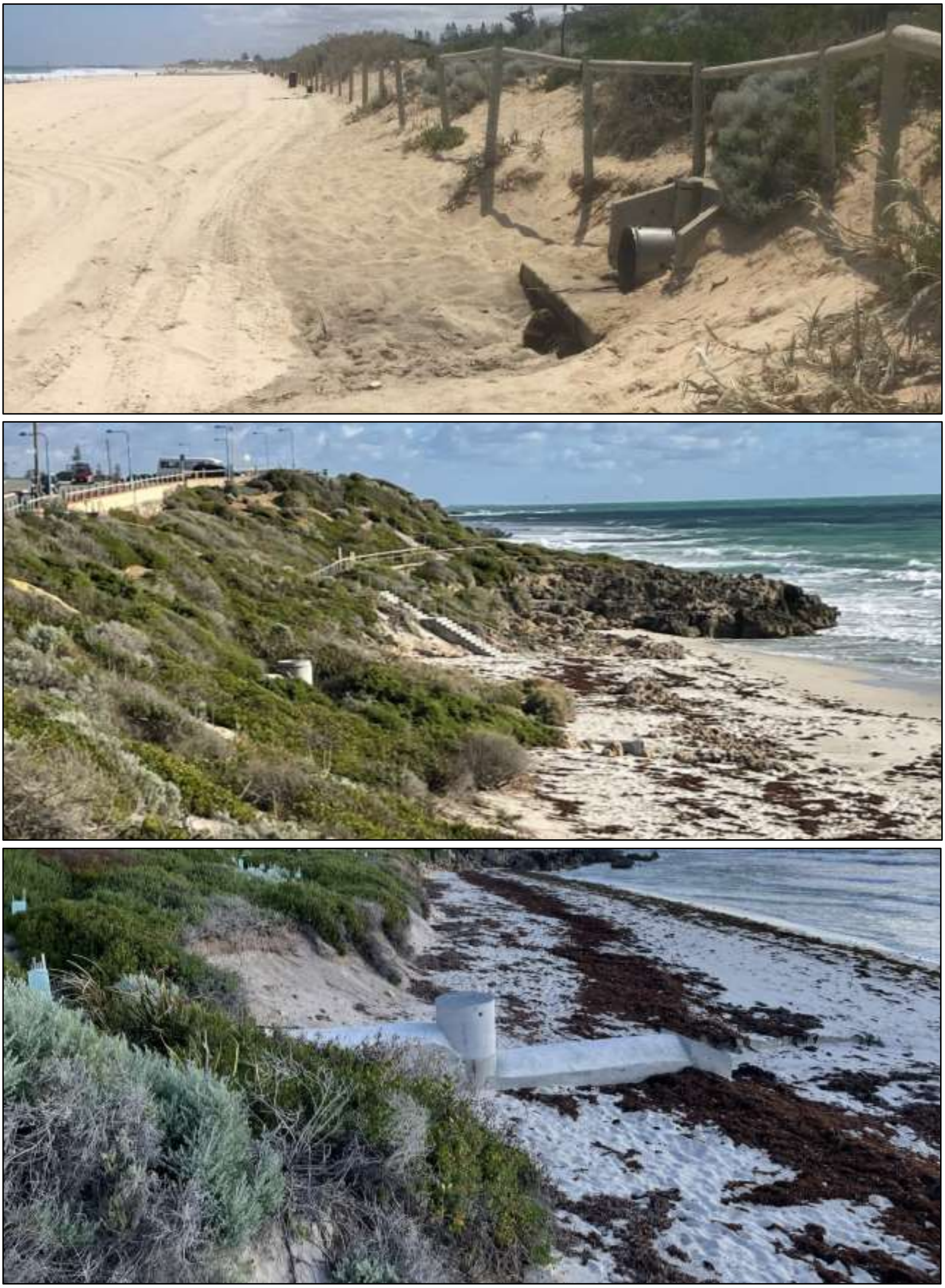

Figure 3-13 Example of drainage outlets at Scarborough (top), North Beach (middle) and Watermans Beach (bottom).

4 Coastal Hazard Extents

4.1 Overview

Coastal hazard extents have been determined and mapped by interpreting the results of previous coastline assessments for the City, including:

> *Strategic Coastal Processes Study* (BMT JFA Consultants, 2015) and further correspondence between BMT JFA Consultants and the City, regarding the application of this study in the CHRMAP context (see **Section 2.5.1**);

> *Scarborough Redevelopment CHRMAP* (MPRA, 2015) (see **Section 2.5.2**); and

> *Geophysical Investigation* (GBGMAPS, 2018) (see **Section 2.6**).

For the purpose of calculating hazard extents and given the outcomes of previous investigations, the City's coastline has been divided into north and south (of Trigg Island). The coastlines north and south generally exhibit distinguished features, coastal processes and expected response to coastal hazards. Mapping has been developed for the overall coastline, divided into 7 zones (for ease of viewing), and is provided in:

> **Appendix A** – Coastline Description and Features;

> **Appendix B** – Coastal Erosion Allowances; and

> **Appendix D** – Coastal Inundation Allowances.

The calculation of hazard extents is described in more detail below.

4.2 Horizontal Shoreline Datum

All coastal hazard allowances/extents are to be calculated from the present-day (2022) horizontal shoreline datum (HSD), as per the guidance of SPP2.6. The policy states that the HSD should define the active limit of the shoreline under storm activity, and should be defined as the seaward shoreline contour representing the peak steady water level under storm activity, during the adopted 100-year ARI erosion storm event. Based on the findings of previous studies (BMT JFA, 2015 & MPRA, 2015), the HSD has been nominated as the 2.0 m AHD contour throughout the study area.

4.3 Coastal Erosion Allowances

4.3.1 North of Trigg Island

North of Trigg Island, the shoreline has been classified as 'mixed sandy and rocky' per the guidance of SPP2.6 (see **Section 2.2.3**). Geophysical survey identified the presence of rock throughout the coastline to the north of Trigg Island, at varying distances from, and elevation above, the shoreline/HSD. If the elevation of visible, competent rock was identified above 3.0 m AHD (one metre above the HSD, in accordance with SPP2.6), or above 4.0 m AHD for subsurface rock inferred by geophysical survey (1 m added due to uncertainty), it has been considered as a barrier to erosion. These areas have subsequently been treated as per the required assessment of 'rocky coasts' in SPP2.6. Protective rock formations were delineated accordingly based on the geophysical survey results (GBGMPAS, 2018) and recent aerial imagery, depicted in **Appendix A** and **B** mapping.

The allowance for erosion North of Trigg Island has followed the 'sandy coast' assessment and associated allowances up until a rock barrier is encountered. Beyond the rock barrier, the erosion hazard extent continues inland at a much lower rate. This rate acknowledges the potential for coastal limestone to erode, but considers the gradual mechanisms of limestone erosion. The rates of erosion applied where rock is present (above 3.0 m AHD) are:

> 0.05 m/year where rock is continuous, visible at the surface and has demonstrated good historical longevity; and

> 0.2 m/year where rock has been identified below the ground surface by geophysical survey. The higher rate is a conservative approach, attributed to the uncertainty around the integrity and durability of the sub-surface rock.

Where an alongshore 'gap' in rock above 3.0 m AHD has been inferred by the geophysical survey, this has been assessed on a case-by-case basis, considering the following:

> Length of the discontinuity; and

> Elevation of rock, if present, in this location.

In general, smaller gaps have maintained the rock erosion rate of 0.2 m/year, as the presence of rock either side and below them is likely to control erosion.

Maps in **Appendix A** demonstrate the location of identified rock along the City's coastline.

Table 4-1 demonstrates the allowances for erosion to the north of Trigg Island, in accordance with SPP2.6, noting that beyond the presence of rock only Su is applied.

Table 4-1 North of Trigg Island.

Allowances \ Timeframe	2022	2030	2045	2070	2122
S1– Acute storm erosion (m) for 100 ARI (1%AEP)	20	20	20	20	20
S2- Historical shoreline trend (m)	0	2	4	8	15
S3 – Sea level rise recession (m)	0	5	15	38	97
Su* – Uncertainty (m)	0	1.6	4.6	9.6	20.0
Total erosion allowance (from HSD)	Varies depending on the location of rock.				

* Su the only allowance applied beyond identified rock, calculated from the location of rock (above 3.0 m AHD).

4.3.1.2 Consideration of coastal controls

Erosion extent mapping has been developed considering the coastline with (**Appendix B**) and without (**Appendix C**) coastal controls, as per the guidance of SPP2.6. Coastal controls within the study area have been described in **Table 3-2** (all to the north of Trigg Island). The controls have been considered only for the period of their design life, beyond which erosion rates revert to those in **Table 4-1**. The purpose of mapping erosion without coastal controls (even though this is unrealistic) is to demonstrate the effect on asset risk and vulnerability, with and without the controls.

4.3.2 South of Trigg Island

To the south of Trigg Island, the shoreline has been classified as 'sandy coast'. There are also some areas where rock has been identified inland by geophysical survey (in the north of the coastline portion) where assumptions detailed in **Section 4.3.1** have been applied, once sandy erosion extends to the location of rock.

Table 4-2 demonstrates the allowances for erosion to the south of Trigg Island, in accordance with SPP2.6.

Table 4-2 South of Trigg Island.

Allowances \ Timeframe	2022	2030	2045	2070	2122
S1– Acute storm erosion (m) for 100 ARI (1%AEP)	35	35	35	35	35
S2- Historical shoreline trend (m)	0	0	0	0	0
S3 – Sea level rise recession (m)	0	5	15	38	97
Su – Uncertainty (m)	0	1.6	4.6	9.6	20.0
Total erosion allowance (S1 + S2 + S3 + Su, distance in m from HSD)	35	41.6	54.6	82.6	152.0

4.4 Coastal Inundation Allowances

4.4.1 Design Storm Event

Schedule One of SPP2.6 describes four different geographical areas for the definition of the design storm event for the assessment of coastal inundation. Policy guidance for coastal inundation is that an event corresponding to the 500-year ARI ocean forces and coastal processes should be selected.

4.4.2 Measured Water Levels Analysis

The most reliable, long-term water level dataset in the area has been collected at Fremantle Fishing Boat Harbour. Cardno obtained approximately 56 years of water level data (1966-2021) at Fremantle from the DoT. An extreme value analysis was carried out on the dataset to estimate a 500-year ARI water level for the study area.

The tide gauge at Fremantle Fishing Boat Harbour is located approximately 16km south of the southern boundary of the study area. The measured water level record at Fremantle is one of the longest in Western Australia and is still operating, however DoT advised that the quality of the data recorded before 19/11/1986 cannot be assured. Accordingly, the measured water level record from 19/11/1986 to 31/12/2021 was analysed as part of this study, which represents a period of approximately 35 years and is essentially continuous with only a small gap in the record in mid-1987.

4.4.3 Sea Level Rise Detrending

The measured water level record at Fremantle Fishing Boat Harbour was modified to remove the historical sea level rise that is estimated to have occurred over the length of the data record by applying a rate of 2mm/year. This was done such that the measured water level record was made relative to the end date of the record so that the levels from the EVA are relative to the present day (2022).

4.4.4 Extreme Value Analysis

An extreme value analysis was undertaken to provide an estimate of extreme water levels at Fremantle. An EVA was conducted on the top 50, 40 and 30% of measured water levels above 0m AHD, with the values using the 40% threshold ultimately adopted. A 72-hour constraint (1.5 days either side of a peak water level) was applied to ensure all observations used in the EVA were statistically independent. A Weibull EVA was adopted and the results are presented in **Table 4-3** below. It should be noted that uncertainty exists in the outcomes of EVA, particularly where the return period assessed is longer than the length of the dataset being analysed. 95% confidence interval bounds are added as a quantification of this uncertainty.

Table 4-3 Extreme water levels at Fremantle from EVA analysis

ARI (years)	Extreme Water Level at Fremantle (mAHD)	95% Confidence Interval
1	0.96	0.94 – 0.99
10	1.17	1.10 – 1.23
50	1.29	1.19 – 1.39
100	1.34	1.22 – 1.46
500	1.45	1.29 – 1.61

4.4.5 Wave Setup Allowance

Wave set-up is the increase in ocean water level near to the coast due to wave breaking and the onshore conservation of momentum flux. It is particularly important during extreme events where strong winds can generate large waves. The tide gauge analysed to obtain extreme water levels is located in the protected environment of Fremantle Fishing Boat Harbour, and so it is not expected that the measured water level records will properly measure nearshore wave setup, which occurs close to shore due to wave breaking. Thus, it is appropriate and conservative to include an additional allowance for nearshore wave setup on top of the extreme water levels for the study area shoreline.

Wave setup allowances have been derived based on the findings of previous studies (BMT JFA, 2015 & MPRA, 2015). The allowances, presented in **Table 4-4**, have been distinguished for the coastlines to the north and south of Trigg Island. This is due to the effect of nearshore reef systems to the north of Trigg Island, which dissipate and lower wave energy reaching the shoreline, compared to the more exposed shoreline to the south. Setup has been estimated by BMT JFA (2015) for the overall study area based on existing information and literature. MPRA (2015) has quantified the setup component through wave transformation modelling for a southern portion of the study area (Scarborough Beach). The adopted values in **Table 4-4** include a level of professional judgement and interpretation, and have not been calculated by dedicated modelling, data collection or analysis throughout the study area.

Table 4-4 Storm tide level and wave set-up allowances

Return Period	Storm tide (mAHD)	Wave set-up allowance (m, South of Trigg Island)	Wave set-up allowance (m, North of Trigg Island)
1 ARI (63%AEP)	0.96	0.90	0.55
100 ARI (1%AEP)	1.34	1.23	0.95
500 ARI (0.2%AEP)	1.45	1.36	1.00

Overall S4 inundation allowances are presented for each timeframe in **Table 4-5**.

Table 4-5 Adopted inundation allowances (S4)

Allowances \ Timeframe	2022	2030	2045	2070	2122
Inundation allowance (S4, mAHD, 0.2%AEP) - South of Trigg Island	2.81	2.86	2.96	3.16	3.75
Inundation allowance (S4, mAHD, 0.2%AEP) - North of Trigg Island	2.45	2.5	2.6	2.8	3.39

4.4.6 Wave overtopping

As specified in SPP2.6 (Schedule One – Section 4.10.1):

On low permeability/impermeable coasts where wave run-up can result in wave overtopping, the coastal foreshore reserve width for this coastal process should be the maximum extent of wave overtopping.

Wave overtopping is important to consider in terms of safety risk, infrastructure damage and potential drainage issues (**Figure 4-1**). The amount of wave overtopping is likely to be highly variable along the City's coastline, due to varying shoreline type, form and level. A conservative overtopping allowance has been incorporated in addition to inundation extents, at the contour 1 metre above the levels presented in **Table 4-4** (see **Appendix D** mapping). This level is expected to be more temporary than the S4 inundation allowances, and will be treated as such during the risk assessment.

Figure 4-1 Example of wave overtopping of the north beach revetment

4.4.7 Dune breaching

As specified in SPP2.6 (Schedule One – Section 4.10.1):

Where a continuous barrier dune is present the capacity of the dune to provide protection from inundation should be assessed based on the cross-sectional area of the dune. If the dune reserve, the cross-sectional area of the dune above the peak steady water level, is less than 100 cubic metres, it should be assumed that the dune will be removed during storm activity and the maximum extent of storm inundation should be calculated without the dune.

An assessment of dune capacity was undertaken on this basis throughout the study area. Results indicate that limited dune breaching may occur towards the end of the planning timeframe, in the southernmost part of the study area (Brighton/Peasholm Beach). This has been included in inundation mapping in **Appendix C**.

4.4.8 Tsunami Allowance

SPP2.6 stipulates that an allowance for absorbing the current risk of inundation be adopted based on maximum inundation heights evidenced in tsunami prone areas. The Western Australia coastline is susceptible to tsunami impact from seismic activity, most prominently originating from the Sunda Arc on the southern edge of the Indonesian archipelago. The destructive effects of tsunami across the Indian Ocean was observed during the 2004 Sumatra–Andaman (Boxing Day) event, where maximum run-up height exceeded 30m on the coastline of Banda Aceh, Indonesia. Along the Perth Metropolitan coastline, the impact of tsunamis is substantially reduced, due to a combination of large propagation distances and offshore bathymetric features (Pattiaratchi, 2020).

Geoscience Australia has mapped the offshore tsunami hazard at various depth contours across the Australian coastline (Geoscience Australia, 2018). The predicted amplitude offshore from the Study Area for various tsunami ARIs are provided in **Table 4-5** below. The amplitudes have been predicted based on tsunami propagation of hypothetical earthquakes from major subduction zones around the world. It should be noted that due to limitations in the model resolution, there are inherent uncertainties in the predicted amplitude as the tsunami propagates into shallow water.

Table 4-6 Predicted tsunami wave amplitude above mean sea level at 100m depth contour (Geoscience Australia, 2018)

ARI (years)	Tsunami Amplitude Offshore Study Area	90% Confidence Interval
10	0.04	0.00 – 0.09
25	0.10	0.04 – 0.18
50	0.19	0.07 – 0.30
100	0.27	0.12 – 0.47
250	0.45	0.22 – 0.83
500	0.64	0.31 – 1.14
1000	0.89	0.39 – 1.48
2500	1.23	0.50 – 1.92
5000	1.53	0.57 – 2.26
10000	1.79	0.63 – 2.71

Given that the Perth Metropolitan coastline is relatively sheltered from the direct impact of tsunami waves originating from the Sunda Arc (Pattiaratchi, 2020), and the relatively high relief topography of the study area, a high-level correlation between the offshore tsunami recurrence interval and the resultant peak water level at the Fremantle Fishing Boat Harbour is considered to be appropriate for this study.

Using the tsunami propagation equation (USACE, 1989), it is estimated that the 500-year ARI tsunami would result in an amplitude of approximately 1.15m in 10m of water depth offshore from the study area. This water level would correlate to a recurrence interval between 1 and 10 years for tidal/meteorological water level variation at the Fremantle Fishing Boat Harbour.

The impact of tsunamis on the Perth Metropolitan coastline was recently demonstrated through observations of the peak water level observed as a result of the Sumatra–Andaman (Boxing Day) event in 2004. Using the same equation as above, and the observed peak water level of 0.78 m at the Fremantle Fishing Boat Harbour, it is estimated that the tsunami amplitude was in the order of 0.45m in 100m of water depth offshore from the Study Area, correlating to a tsunami recurrence interval of approximately 250 years.

Given the estimated peak water level at Fremantle Fishing Boat Harbour during the 500-year ARI tsunami event is significantly less than the predicted present day 500-year ARI storm induced inundation level, it is reasonable to provide no additional inundation allowance to absorb the current risk of tsunami-induced inundation.

5 Asset Identification

5.1 Assets at Risk

Assets at risk of coastal erosion and inundation have been identified by overlaying the hazard extents over recent aerial imagery of the City's coastline. All assets lying seaward of the 2122 erosion and/or inundation hazard extent (whichever is greater) have been identified. The assets have been assigned one of the following classifications:

- Built;
- Built (coastal protection);
- Built (beach access);
- Built (heritage);
- Natural; and
- Combination of built and natural.

The key assets identified are listed in **Table 5-1**. The City has also used the maximum hazard extents to compare to their internal asset register, identifying approximately 2000 built assets. These include assets that would be considered 'minor', and that will be grouped during the risk assessment. Further risk assessment has been undertaken for all assets, including minor assets not listed, in the next stage of the CHRMAP (Cardno, 2023b).

Key assets have also been mapped in **Appendix E** (relevant to erosion hazard extents) and **Appendix F** (relevant to inundation hazard extents).

Table 5-1 Assets identified as at risk of coastal hazards by the 2122 planning timeframe

Description	Asset classification	Map zone
Beach steps, Watermans Bay north	Built (Beach access)	Zone 1
GSC revetment, Watermans Bay	Built (Coastal protection)	Zone 1
West Coast Drive - between Beach Road and Mary Street	Built	Zone 1
West Coast Drive Services- between Beach Road and Ada Street	Built	Zone 1
West Coast Drive Footpath- between Beach Road and Ada Street	Built	Zone 1
Watermans Bay Beach	Natural	Zone 1
Watermans Bay Beach dunes and vegetation	Natural	Zone 1
Lookout and amenities, Watermans Bay	Built	Zone 1
Stormwater drain outflow, Watermans Bay south	Built	Zone 1
Beach access ramp, Watermans Bay south	Built (Coastal protection)	Zone 1
Walkway, Watermans Bay south	Built	Zone 1
Watermans (Dog Beach 1)	Natural	Zone 1
Watermans (Dog Beach 1) dunes and vegetation	Natural	Zone 1
Walkway and Ada St park	Built	Zone 1
Beach steps, Ada St	Built (Beach Access)	Zone 1
Car park and lookout, Margaret St	Built	Zone 1
Walkway and beach access ramp, Margaret St	Built (Beach Access)	Zone 1
Watermans (Dog Beach 2)	Natural	Zone 1
Watermans (Dog Beach 2) dunes and vegetation	Natural	Zone 1
Beach steps & revetment, Marine Lab	Built (Coastal protection / Beach access)	Zone 1
Walkway, perimeter Marine Labs	Built	Zone 1

Marine Research Laboratories	Built – Heritage (P19956)	Zone 1
Beach access track from Marine Labs south	Built (Beach access)	Zone 1
Watermans (Dog Beach 3)	Natural	Zone 1
Watermans (Dog Beach 2) dunes and vegetation	Natural	Zone 1
Storm water drain, Hale St	Built	Zone 1
Beach access paths, Lawley St	Built (Beach access)	Zone 1
North Beach (Dog Beach)	Natural	Zone 2
North Beach (Dog Beach) dunes and vegetation	Natural	Zone 2
Beach access steps, Castle St	Built (Beach access)	Zone 2
North Beach revetment	Built (Coastal protection)	Zone 2
North Beach walkway from carpark	Built	Zone 2
North Beach Jetty walkway	Built	Zone 2
North Beach Jetty	Built	Zone 2
North Beach access steps 1	Built (Beach access)	Zone 2
North Beach access steps 2	Built (Beach access)	Zone 2
West Coast Drive - Sorrento Street to Hamersley Street	Built	Zone 2
West Coast Drive Services - Sorrento Street to Hamersley Street	Built	Zone 2
West Coast Drive Footpath - Sorrento Street to Hamersley Street	Built	Zone 2
North Beach (North)	Natural	Zone 2
North Beach (North) dunes and vegetation	Natural	Zone 2
Walkway and beach steps, James St	Built (Beach access)	Zone 2
Walkway, James St	Built	Zone 2
Parking Area, Sorrento St	Built	Zone 2
Beach access ramp & steps, Sorrento St	Built (Beach access)	Zone 2
West Coast Drive - Malcolm Street to James Street	Built	Zone 2
West Coast Drive Services - Malcolm Street to James Street	Built	Zone 2
West Coast Drive Footpath - Malcolm Street to James Street	Built	Zone 2
North Beach (South)	Natural	Zone 2
North Beach (South) dunes and vegetation	Natural	Zone 2
Beach access ramp, North Beach Rd	Built (Beach access)	Zone 2
Revetment & walkway, Hamersley St	Built (Coastal protection / Beach access)	Zone 2
Hamersley Pool	Natural	Zone 2
Beach access steps, Hamersley St	Built (Beach access)	Zone 2
Paths & Public amenities, Hamersley St	Built	Zone 2
Beach walkway, Hamersley St	Built	Zone 2
Lookout, Hamersley St	Built	Zone 2
Parking near Hamersley Street	Built	Zone 2
Beach steps, Saunders St parking, north	Built (Beach access)	Zone 3
Parking Area - Saunders St	Built	Zone 3
Beach steps, Saunders St Parking, west	Built (Beach access)	Zone 3
Drainage outfall - Saunders St	Built	Zone 3
Beach walkway & steps, Saunders St parking, south	Built (Beach access)	Zone 3
Mettams Pool	Natural	Zone 3
Mettams Pool dunes and vegetation	Natural	Zone 3
West Coast Drive - from Sholl Avenue to Bailey Street	Built	Zone 3
West Coast Drive Services - from Sholl Avenue to Bailey Street	Built	Zone 3
West Coast Drive Footpath - from Sholl Avenue to Bailey Street	Built	Zone 3

Beach Access steps - Giles St	Built (Beach access)	Zone 3
Lookout - Giles St	Built	Zone 3
Storm Drain outlet - Giles St	Built	Zone 3
Beach access ramp north of Mettams Pool toilets	Built (Beach access)	Zone 3
Mettams Pool public toilets	Built	Zone 3
Beach access steps south of Mettams Pool toilets	Built (Beach access)	Zone 3
Lookout Giles St	Built	Zone 3
Mettams Pool retaining wall	Built	Zone 3
Mettams Pool change area and ramp to water	Built (Beach access)	Zone 3
Access Path to Mettams Pool	Built (Beach access)	Zone 3
Beach access path south of Mettams Pool	Built (Beach access)	Zone 3
Revetment between Lynn & Bailey St	Built (Coastal protection)	Zone 3
Beach access path Bailey St	Built (Beach access)	Zone 3
Lookout Bailey St	Built	Zone 3
Beach access path from Bennion St parking area	Built (Beach access)	Zone 3
Car park between Bennion and Bailey Streets	Built	Zone 3
Beach access paths Bennion St	Built (Beach access)	Zone 3
Bennion Beach	Natural	Zone 3
Bennion Beach dunes and vegetation	Natural	Zone 3
Lookout area Bennion St	Built	Zone 3
Beach access path at Kathleen St	Built (Beach access)	Zone 4
Trigg Beach (Dog Beach)	Natural	Zone 4
Trigg Beach (Dog Beach) dunes and vegetation	Natural	Zone 4
Beach access ramp from Clarko Park	Built (Beach access)	Zone 4
Clarko Reserve	Natural/Built	Zone 4
Beach access ramp from Clarko Park parking area	Built (Beach access)	Zone 4
Trigg Beach (North)	Natural	Zone 4
Trigg Beach (North) dunes and vegetation	Natural	Zone 4
Beach Access Path from Clarko Park parking area	Built (Beach access)	Zone 4
Parking area, Trigg Place	Built	Zone 4
North Trigg boat ramp	Built	Zone 4
Trigg Surf Lookout	Built	Zone 4
Beach House Trigg Island	Built – Heritage (P2150)	Zone 4
Beach access track, Trigg north	Built (Beach access)	Zone 4
Beachfront grass picnic areas, Trigg north	Natural/Built	Zone 4
Beach access track, Trigg north	Built (Beach access)	Zone 4
Parking area, Trigg Beach north	Built	Zone 4
Beach access track, Trigg north	Built (Beach access)	Zone 4
Trigg Beach Cafe	Built	Zone 4
Beachfront picnic area, Trigg central	Natural/Built	Zone 4
Surf lifeguard tower, Trigg Beach	Built	Zone 4
Trigg Beach Surf Lifesaving Club 1	Built	Zone 4
Showers, Trigg Beach central	Built	Zone 4
Trigg Beach Surf Lifesaving Club 2	Built	Zone 4
Trigg Beach	Natural	Zone 4
Trigg Beach dunes and vegetation (Bush Forever Site 308)	Natural	Zone 4
Parking area, Trigg Beach central	Built	Zone 4

South Trigg Park	Natural/Built	Zone 4
South Trigg Toilet Block	Built	Zone 4
Trigg Beach Car Park and Beach Showers	Built	Zone 5
Trigg Beach (South)	Natural	Zone 5
Trigg Beach (South) dunes and vegetation (Bush Forever Site 308)	Natural	Zone 5
West Coast Highway adjacent Trigg Beach (South)	Built	Zone 5
West Coast Highway footpath adjacent Trigg Beach (South)	Built	Zone 5
West Coast Highway services adjacent Trigg Beach (South)	Built	Zone 5
Scarborough Beach (North)	Natural	Zone 5
Scarborough Beach (North) dunes and vegetation (Bush Forever Site 308)	Natural	Zone 5
Scarborough Beach Carpark	Built	Zone 5/6
Scarborough Park and BBQ	Natural/Built	Zone 6
Scarborough Playground and BBQ	Built	Zone 6
Scarborough Amphitheatre	Built	Zone 6
Scarborough Clock Tower	Built – Heritage (P16764)	Zone 6
Tyrol Flats	Built – Heritage (P9942)	Zone 6
Scarborough Beach	Natural	Zone 6
Scarborough Beach dunes and vegetation	Natural	Zone 6
Scarborough Beach carpark south	Built	Zone 6
Scarborough Surf Life Saving Club	Built	Zone 6
Scarborough Beach Pool and Restaurants	Built	Zone 6
Brighton Beach Carpark	Built	Zone 6
Brighton Beach	Natural	Zone 6
Brighton Beach dunes and vegetation	Natural	Zone 6
Brighton Beach Park and amenities	Natural/Built	Zone 6/7
Peasholm (Dog Beach)	Natural	Zone 7
Peasholm (Dog Beach) dunes and vegetation (Bush Forever Site 310)	Natural	Zone 7

5.2 Beach Access

As part of the CHRMAP project, an audit of beach access has been undertaken. This is to identify the accessibility of the City's beaches, including for mobility impaired persons, and to understand any risk to accessibility from coastal hazards into the future. The audit has been presented in **Appendix G**.

6 Next Steps

The next steps for the City's CHRMAP are the Vulnerability Analysis (Stage 3) and Risk Evaluation (Stage 4), which have been documented in the third chapter report (Cardno, 2023b). The key activities and outcomes of this stage include:

> Characterising risk for each asset or asset group by combining the likelihood of impact (from the hazard extents presented in this Chapter Report) with the consequence of such impact;

> Determining each asset's adaptive capacity;

> Assessing overall asset vulnerability by introducing the adaptive capacity of each asset to its risk rating; and

> Identifying and ranking coastal areas in terms of their risk and vulnerability, to prioritise treatment.

7 References

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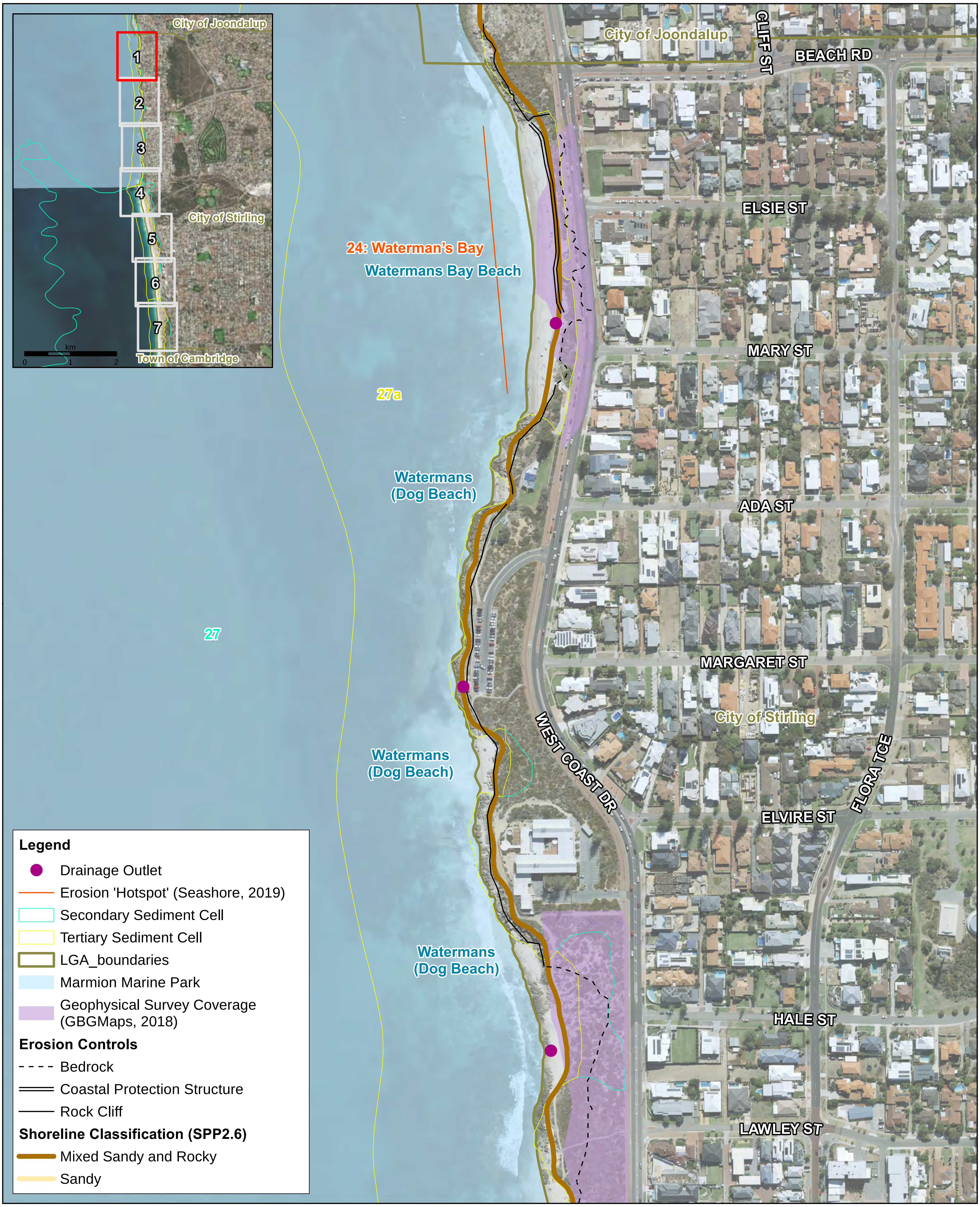
APPENDIX

A

COASTLINE FEATURES



N

1:3,000 Scale at A3

m
0 50 100

Coastal Features (Zone 1)

CITY OF STIRLING CHRMAP

FIGURE A-1

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_006_CoastalFeatures_TC.mxd 01
Aerial imagery supplied by Metromap (January, 2022)

City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

Coastal Features (Zone 2)

CITY OF STIRLING CHRMAP

FIGURE A-2

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_006_CoastalFeatures_TC.mxd 01
Aerial imagery supplied by Metromap (January, 2022)

City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

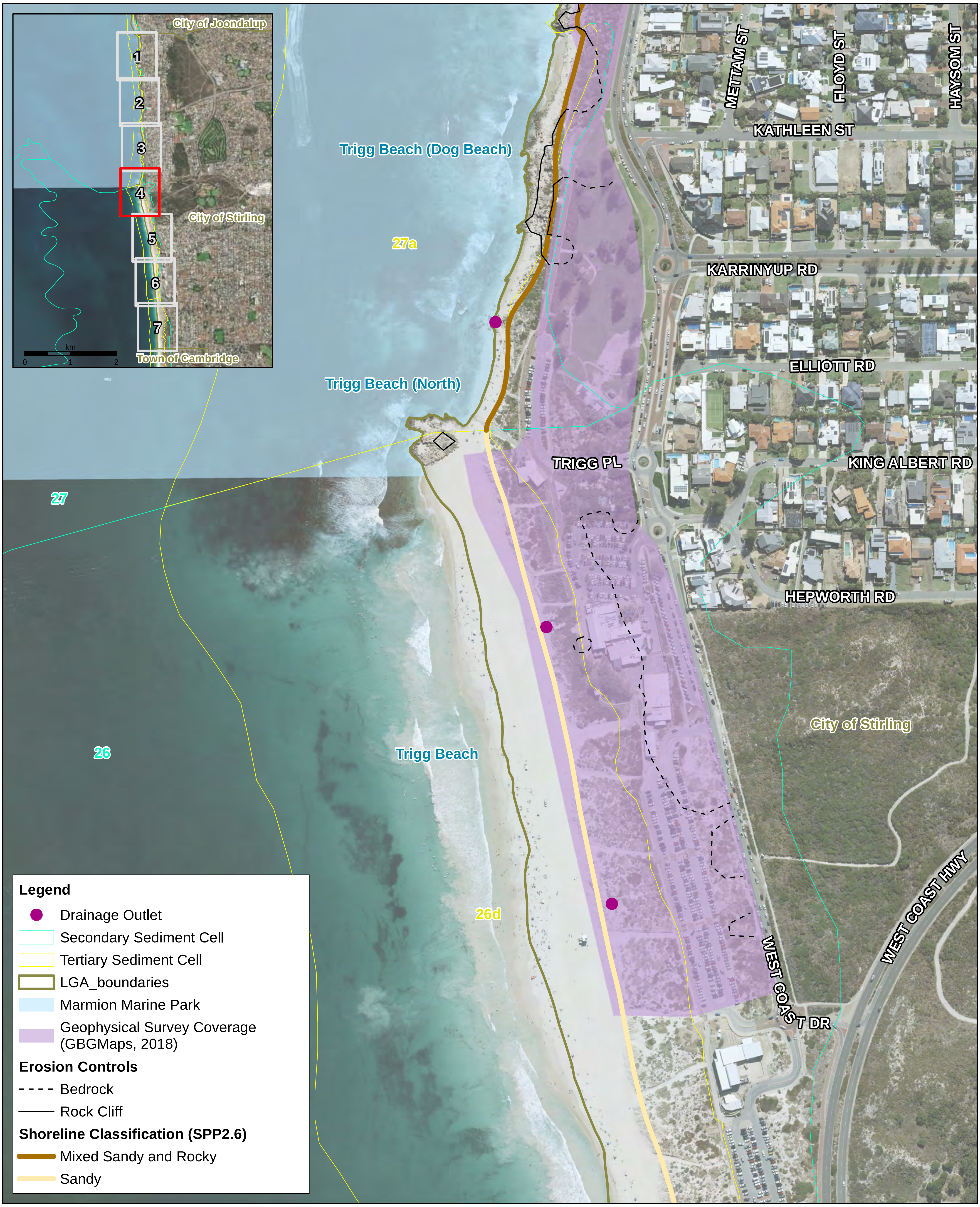
Coastal Features (Zone 3)

CITY OF STIRLING CHRMAP

FIGURE A-3

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_006_CoastalFeatures_TC.mxd 01
Aerial imagery supplied by Metromap (January, 2022)



N

1:3,000 Scale at A3

m 0 50 100

Coastal Features (Zone 4)

CITY OF STIRLING CHRMAP

FIGURE A-4

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_006_CoastalFeatures_TC.mxd 01
Aerial imagery supplied by Metromap (January, 2022)

N

City of Stirling
City of Choice

1:3,000 Scale at A3

m
0 50 100

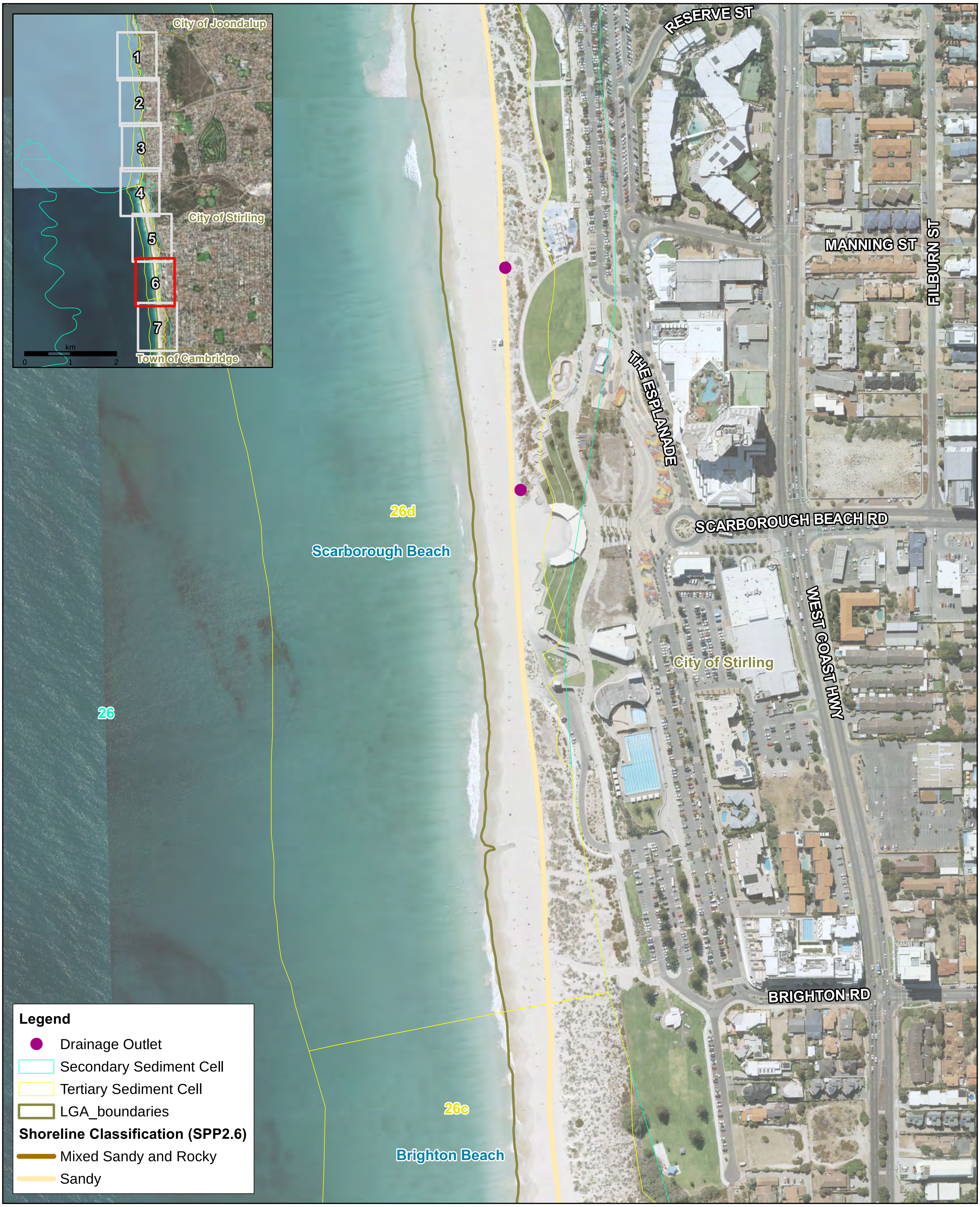
Coastal Features (Zone 5)

CITY OF STIRLING CHRMAP

FIGURE A-5

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_006_CoastalFeatures_TC.mxd 01
Aerial imagery supplied by Metromap (January, 2022)



City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

Coastal Features (Zone 6)

CITY OF STIRLING CHRMAP

FIGURE A-6

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_006_CoastalFeatures_TC.mxd 01
Aerial imagery supplied by Metromap (January, 2022)

N

1:3,000 Scale at A3

m
0 50 100

Coastal Features (Zone 7)

CITY OF STIRLING CHRMAP

FIGURE A-7

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_006_CoastalFeatures_TC.mxd 01
Aerial imagery supplied by Metromap (January, 2022)

APPENDIX

B

COASTAL EROSION HAZARD EXTENTS

City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

Coastal Erosion Hazard Extent (Zone 1)

CITY OF STIRLING CHRMAP

FIGURE B-1

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_003_Erosion2.mxd 04
Aerial imagery supplied by Metromap (January, 2022)

City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

Coastal Erosion Hazard Extent (Zone 2)

CITY OF STIRLING CHRMAP

FIGURE B-2

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_003_Erosion2.mxd 04
Aerial imagery supplied by Metromap (January, 2022)

Coastal Erosion Hazard Extent (Zone 3)

City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

CITY OF STIRLING CHRMAP

FIGURE B-3

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_003_Erosion2.mxd 04
Aerial imagery supplied by Metromap (January, 2022)

N

1:3,000 Scale at A3

m
0 50 100

Coastal Erosion Hazard Extent (Zone 4)

CITY OF STIRLING CHRMAP

FIGURE B-4

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-16
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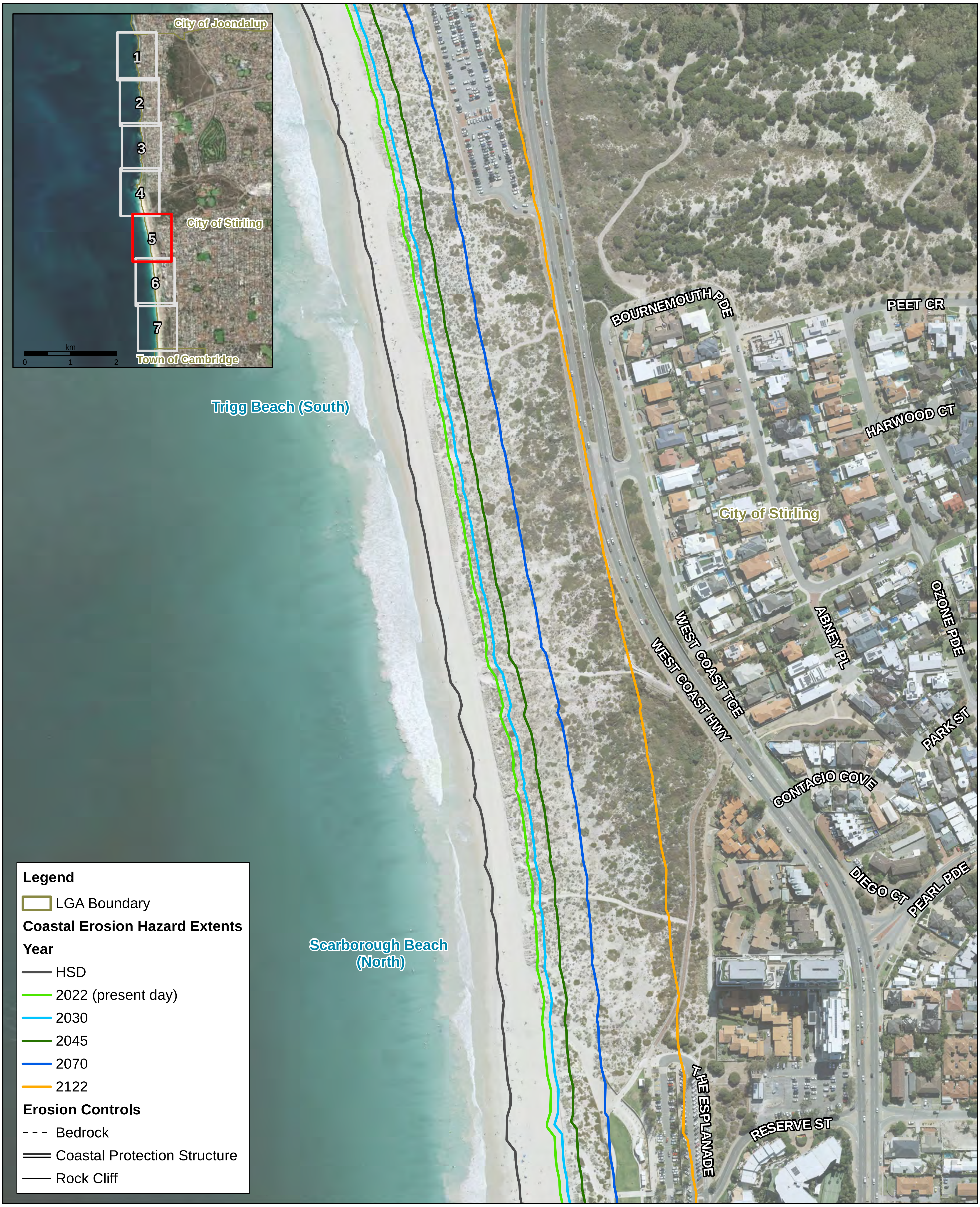
Project: CW1195500
Map: CW1195500_GS_003_Erosion2.mxd 04
Aerial imagery supplied by Metromap (January, 2022)



City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

Coastal Erosion Hazard Extent (Zone 5)

CITY OF STIRLING CHRMAP

FIGURE B-5

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-16
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_003_Erosion2.mxd 04
Aerial imagery supplied by Metromap (January, 2022)

City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

Coastal Erosion Hazard Extent (Zone 6)

CITY OF STIRLING CHRMAP

FIGURE B-6

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-16
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_003_Erosion2.mxd 04
Aerial imagery supplied by Metromap (January, 2022)

N

1:3,000 Scale at A3

m
0 50 100

Coastal Erosion Hazard Extent (Zone 7)

CITY OF STIRLING CHRMAP

FIGURE B-7

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-16
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_003_Erosion2.mxd 04
Aerial imagery supplied by Metromap (January, 2022)

APPENDIX

C

COASTAL EROSION HAZARD EXTENTS - UNCONTROLLED

City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

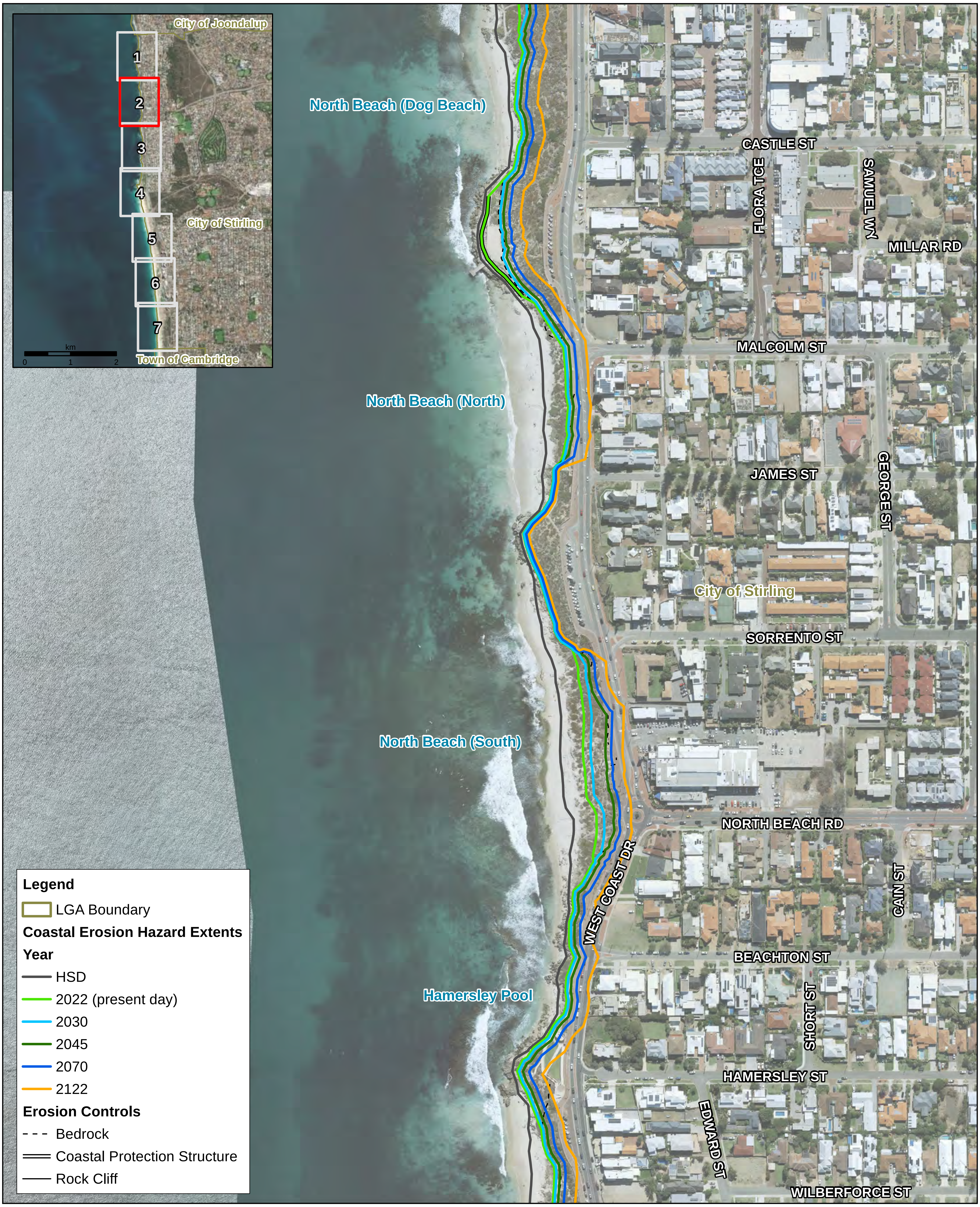
Coastal Erosion Hazard Extent (Zone 1)

CITY OF STIRLING CHRMAP

FIGURE C-1

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_003_Erosion2.mxd 04
Aerial imagery supplied by Metromap (January, 2022)



City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

Coastal Erosion Hazard Extent (Zone 2)

CITY OF STIRLING CHRMAP

FIGURE C-2

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_003_Erosion2.mxd 04
Aerial imagery supplied by Metromap (January, 2022)

APPENDIX

D

COASTAL INUNDATION HAZARD EXTENTS

City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

Coastal Inundation Hazard Extent (Zone 1)

CITY OF STIRLING CHRMAP

FIGURE D-1

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_004_Inundation.mxd 04
Aerial imagery supplied by Metromap (January, 2022)

N

1:3,000 Scale at A3

m 0 50 100

Coastal Inundation Hazard Extent (Zone 2)

CITY OF STIRLING CHRMAP

FIGURE D-2

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_004_Inundation.mxd 04
Aerial imagery supplied by Metromap (January, 2022)

N

1:3,000 Scale at A3

m
0 50 100

Coastal Inundation Hazard Extent (Zone 3)

CITY OF STIRLING CHRMAP

FIGURE D-3

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_004_Inundation.mxd 04
Aerial imagery supplied by Metromap (January, 2022)

City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

Coastal Inundation Hazard Extent (Zone 4)

CITY OF STIRLING CHRMAP

FIGURE D-4

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_004_Inundation.mxd 04
Aerial imagery supplied by Metromap (January, 2022)

Coastal Inundation Hazard Extent (Zone 5)

CITY OF STIRLING CHRMAP

FIGURE D-5

City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_004_Inundation.mxd 04
Aerial imagery supplied by Metromap (January, 2022)

City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

Coastal Inundation Hazard Extent (Zone 6)

CITY OF STIRLING CHRMAP

FIGURE D-6

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_004_Inundation.mxd 04
Aerial imagery supplied by Metromap (January, 2022)

Coastal Inundation Hazard Extent (Zone 7)

CITY OF STIRLING CHRMAP

FIGURE D-7

City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

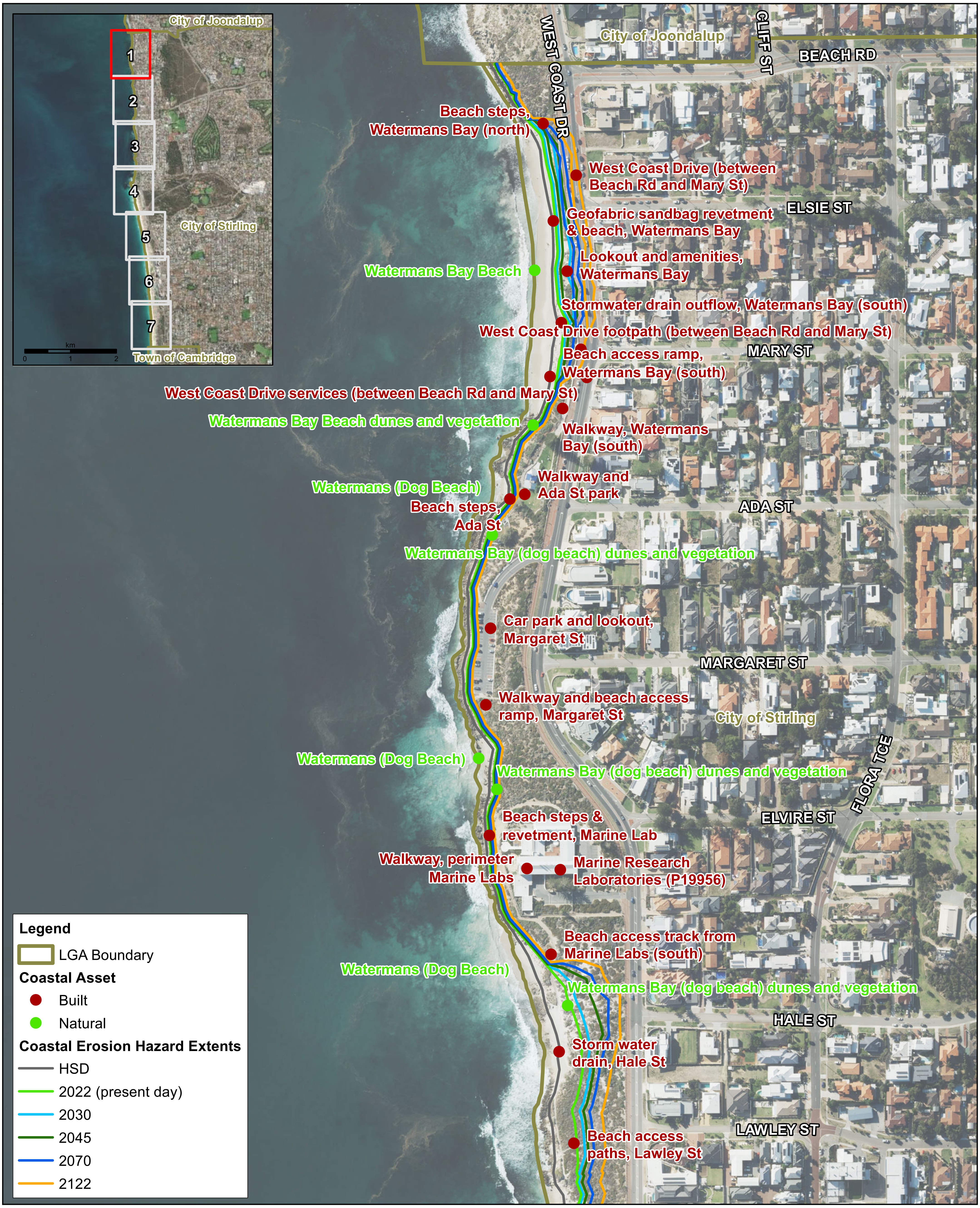
Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2022-06-10
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_004_Inundation.mxd 04
Aerial imagery supplied by Metromap (January, 2022)

APPENDIX

E

ASSET MAPPING (EROSION)



City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

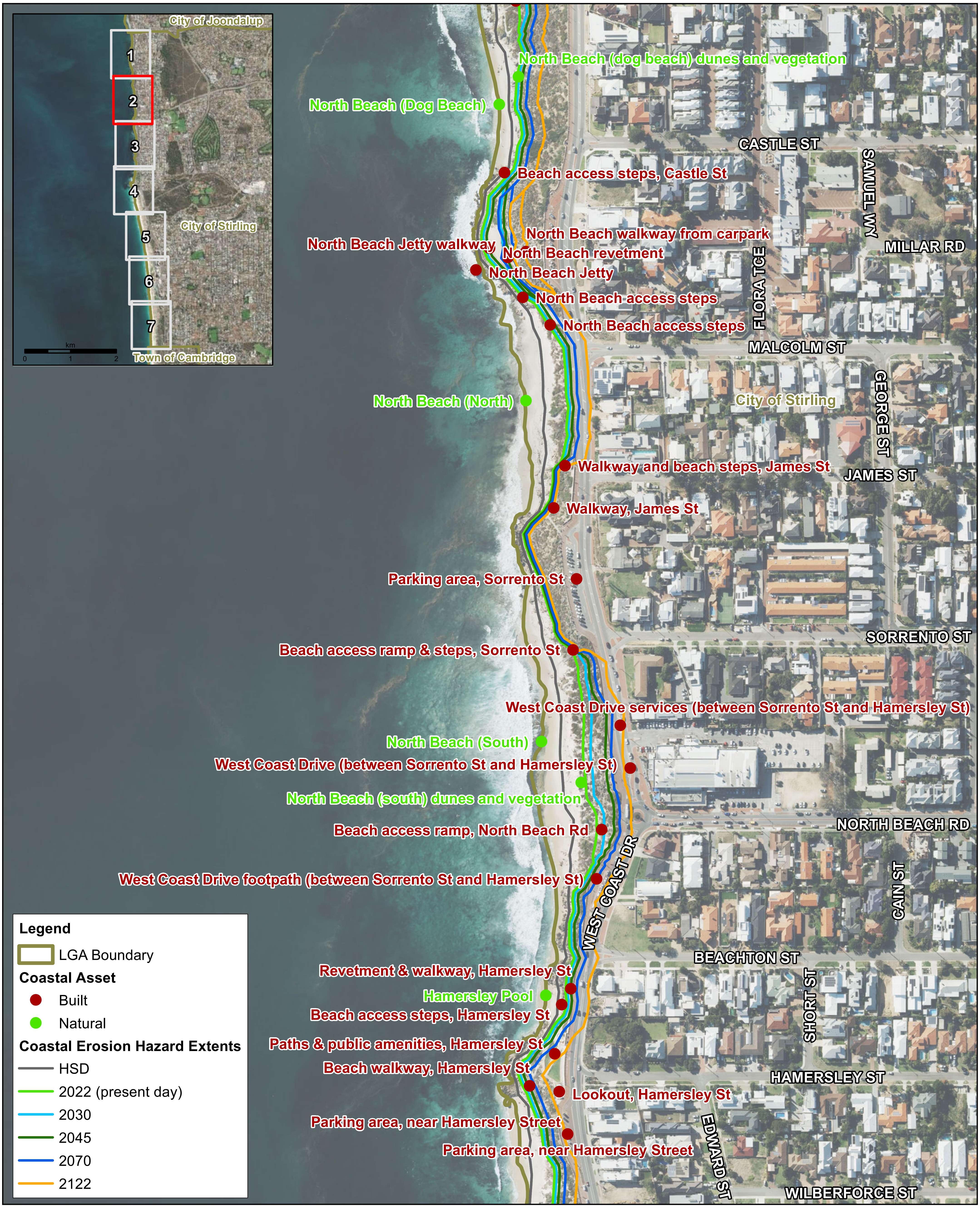
Coastal Erosion Hazard to Assets (Zone 1)

CITY OF STIRLING CHRMAP

FIGURE E-1

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2023-06-26
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_007_ErosionAssets.mxd 01
Aerial imagery supplied by Metromap (2022)



City of Stirling City of Choice

N

1:3,000 Scale at A3

m 0 50 100

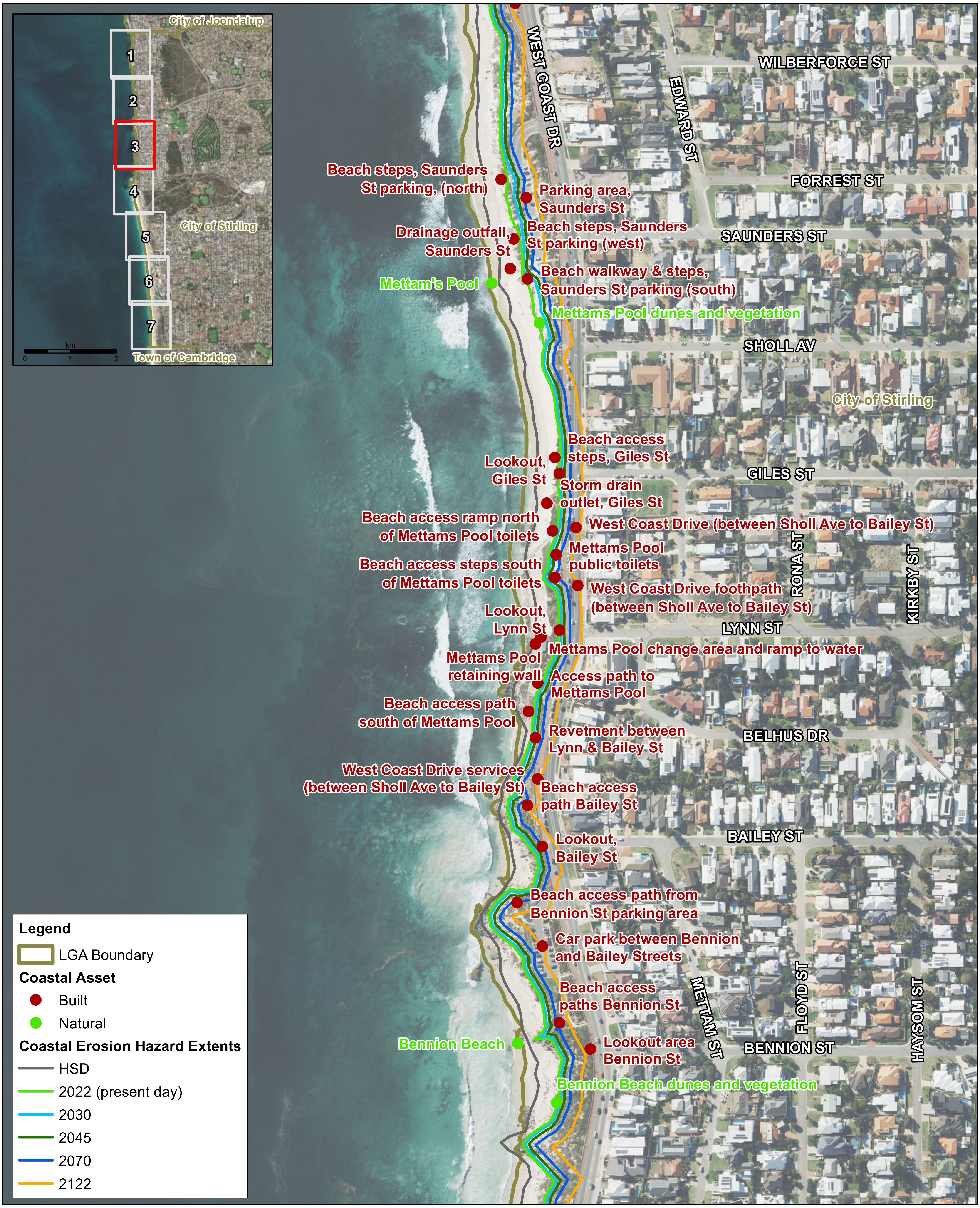
Coastal Erosion Hazard to Assets (Zone 2)

CITY OF STIRLING CHRMAP

FIGURE E-2

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2023-06-26
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_007_ErosionAssets.mxd 01
Aerial imagery supplied by Metromap (2022)



N

City of Stirling
City of Choice

1:3,000 Scale at A3

m
0 50 100

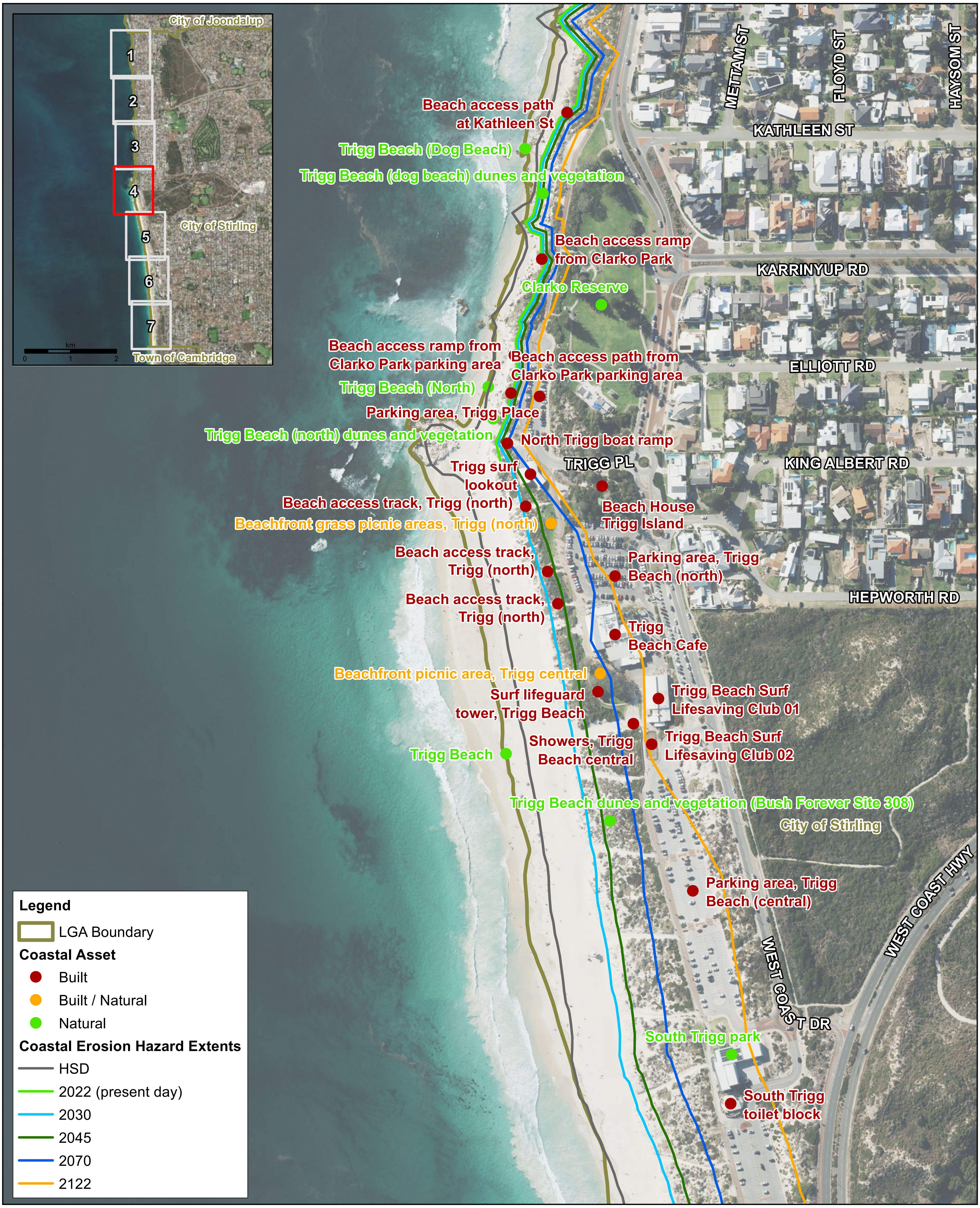
Coastal Erosion Hazard to Assets (Zone 3)

CITY OF STIRLING CHRMAP

FIGURE E-3

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2023-06-26
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_007_ErosionAssets.mxd 01
Aerial imagery supplied by Metromap (2022)



City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

Coastal Erosion Hazard to Assets (Zone 4)

CITY OF STIRLING CHRMAP

FIGURE E-4

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2023-06-26
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_007_ErosionAssets.mxd 01
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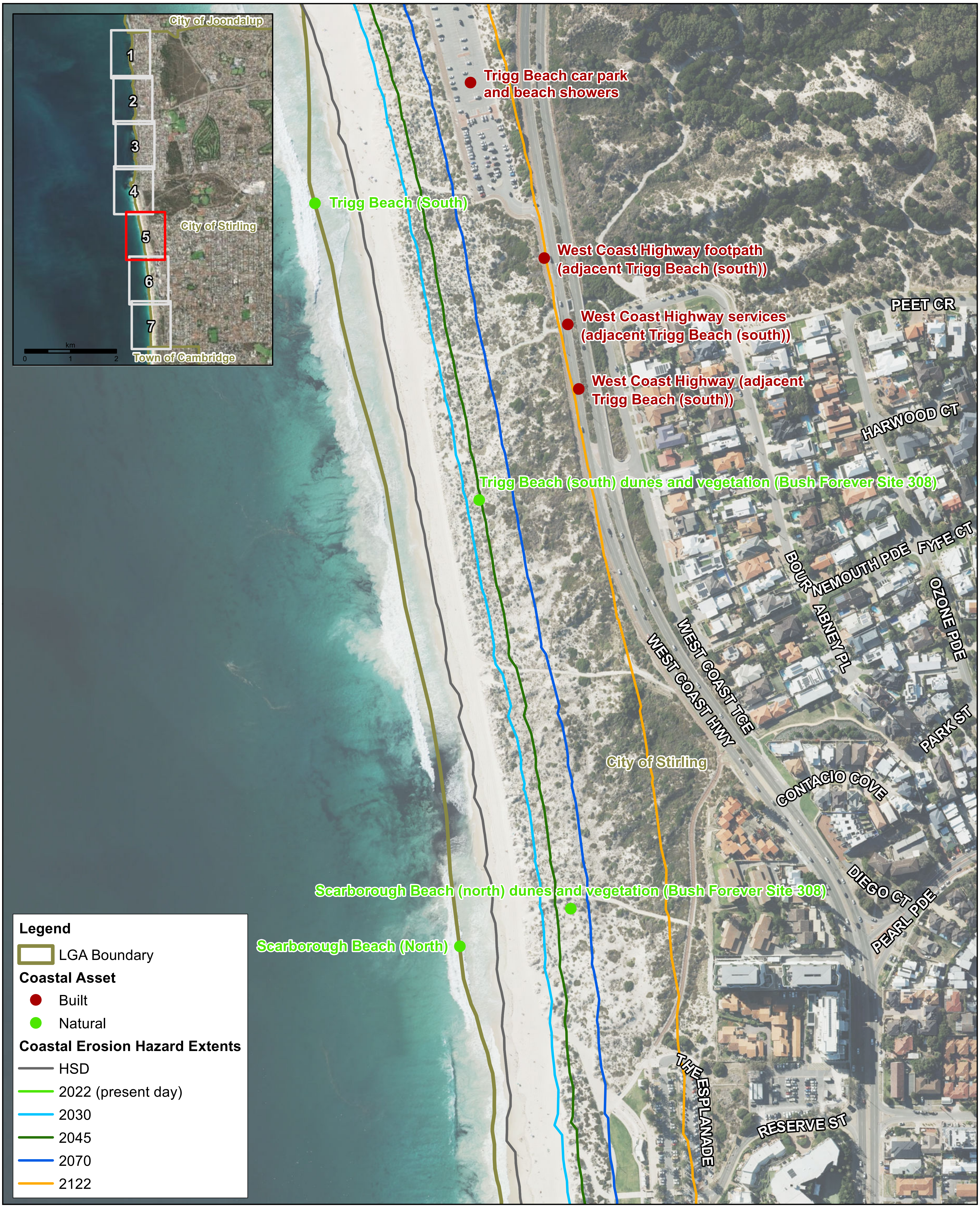


City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

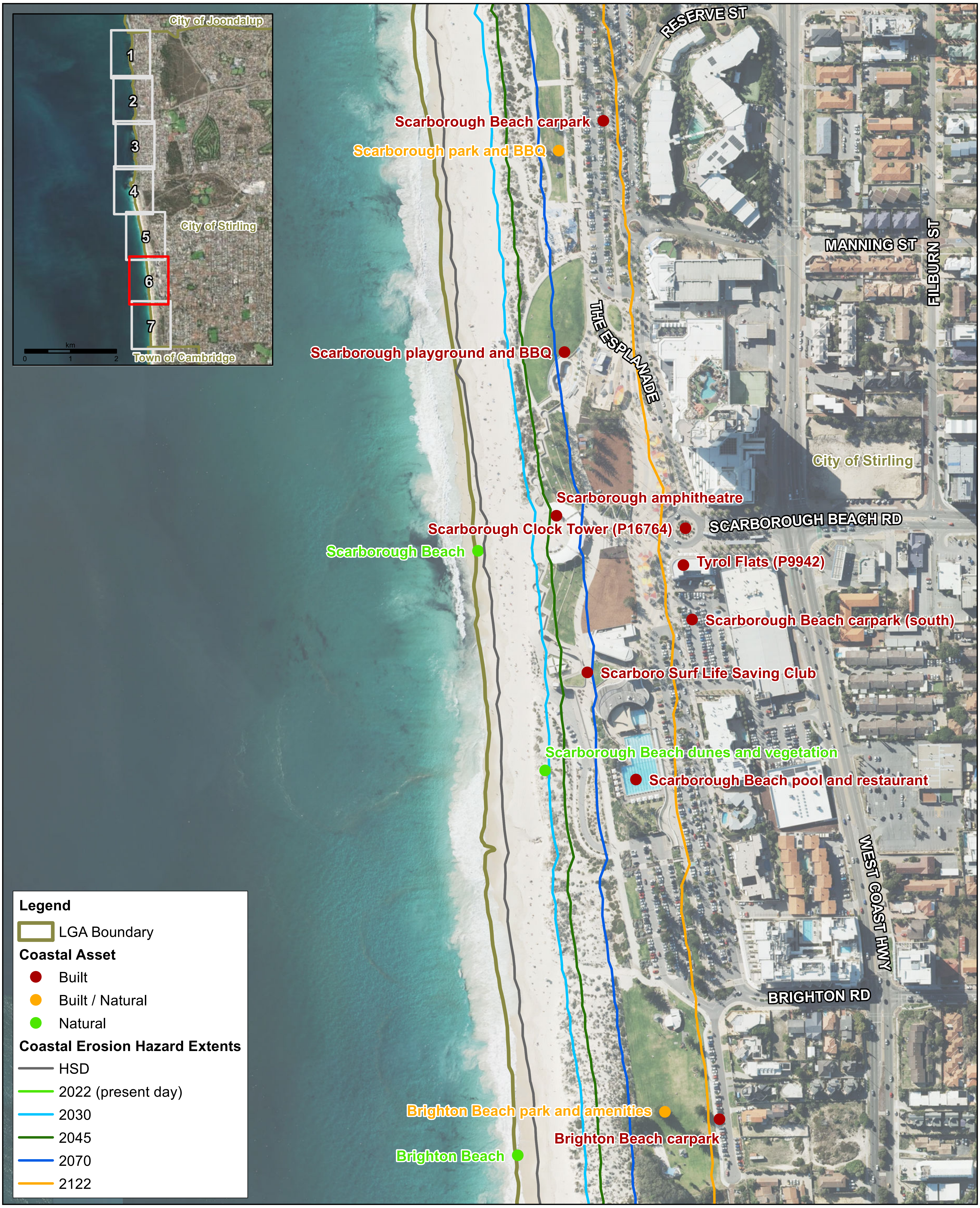
Coastal Erosion Hazard to Assets (Zone 5)

CITY OF STIRLING CHRMAP

FIGURE E-5

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2023-06-26
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_007_ErosionAssets.mxd 01
Aerial imagery supplied by Metromap (2022)



Coastal Erosion Hazard to Assets (Zone 6)

City of Stirling
City of Choice

N

1:3,000 Scale at A3

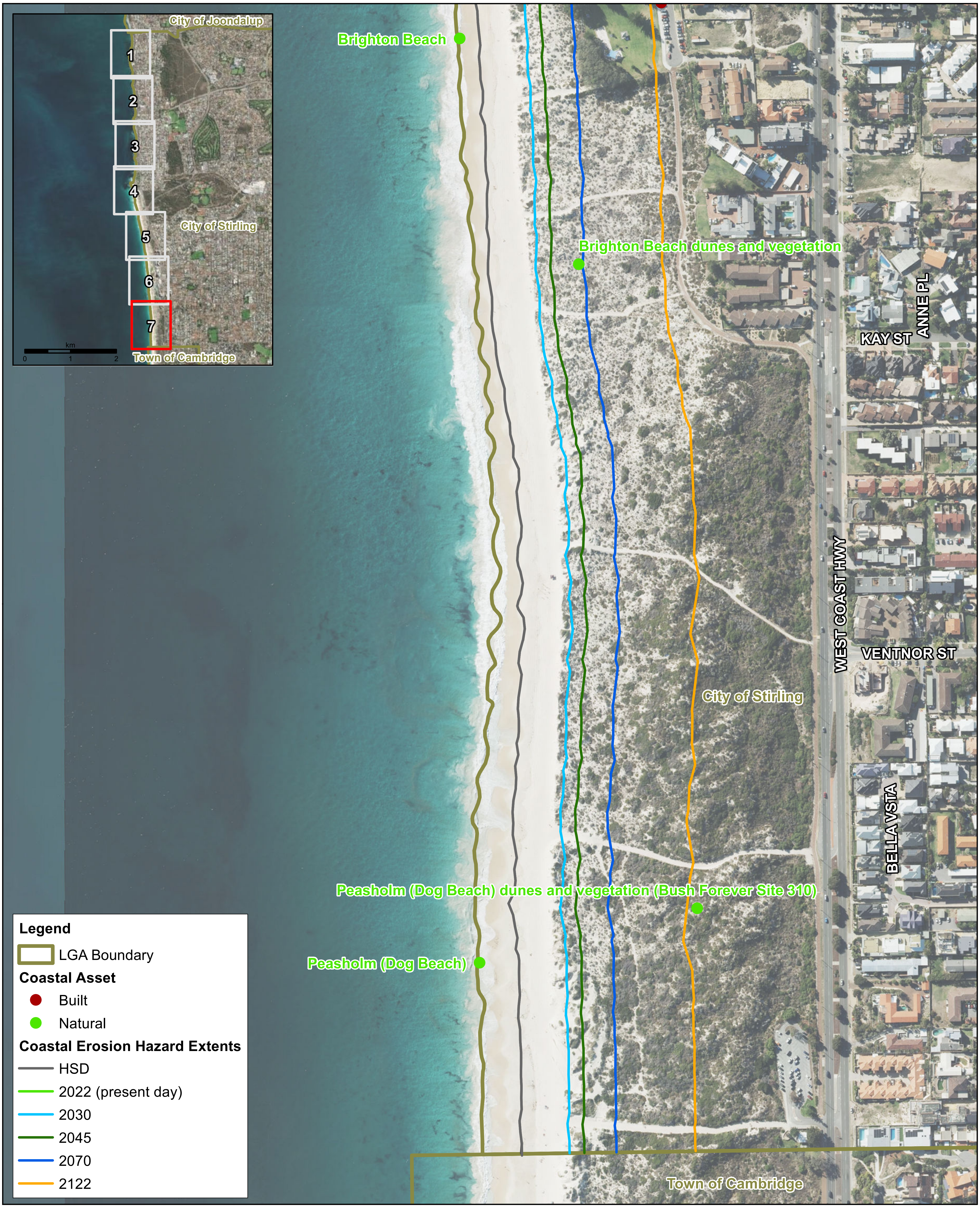
m
0 50 100

CITY OF STIRLING CHRMAP

FIGURE E-6

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2023-06-26
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_007_ErosionAssets.mxd 01
Aerial imagery supplied by Metromap (2022)



Coastal Erosion Hazard to Assets (Zone 7)

CITY OF STIRLING CHRMAP

FIGURE E-7

N

1:3,000 Scale at A3

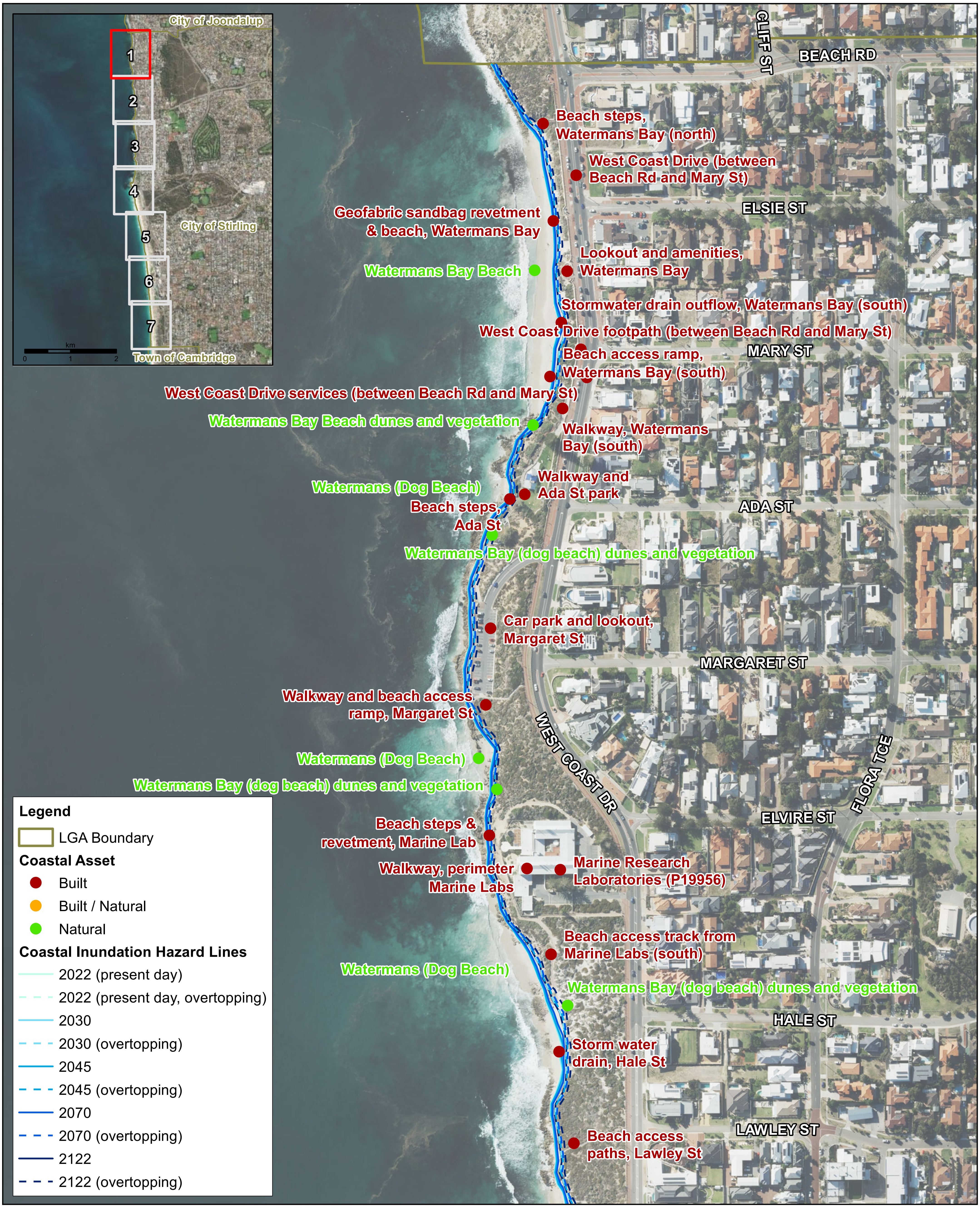
m
0 50 100

Map Produced by Cardno (WA) Pty Ltd
Date: 2023-06-26
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_007_ErosionAssets.mxd 01
Aerial imagery supplied by Metromap (2022)

APPENDIX

F

ASSET MAPPING (INUNDATION)



City of Stirling
City of Choice

1:3,000 Scale at A3

Coastal Inundation Hazard to Assets (Zone 1)

CITY OF STIRLING CHRMAP

FIGURE F-1

Map Produced by Cardno (WA) Pty Ltd
Date: 2023-06-27
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_008_InundationAssets.mxd 01
Aerial imagery supplied by Metromap (January, 2022)

City of Stirling
City of Choice

N

1:3,000 Scale at A3

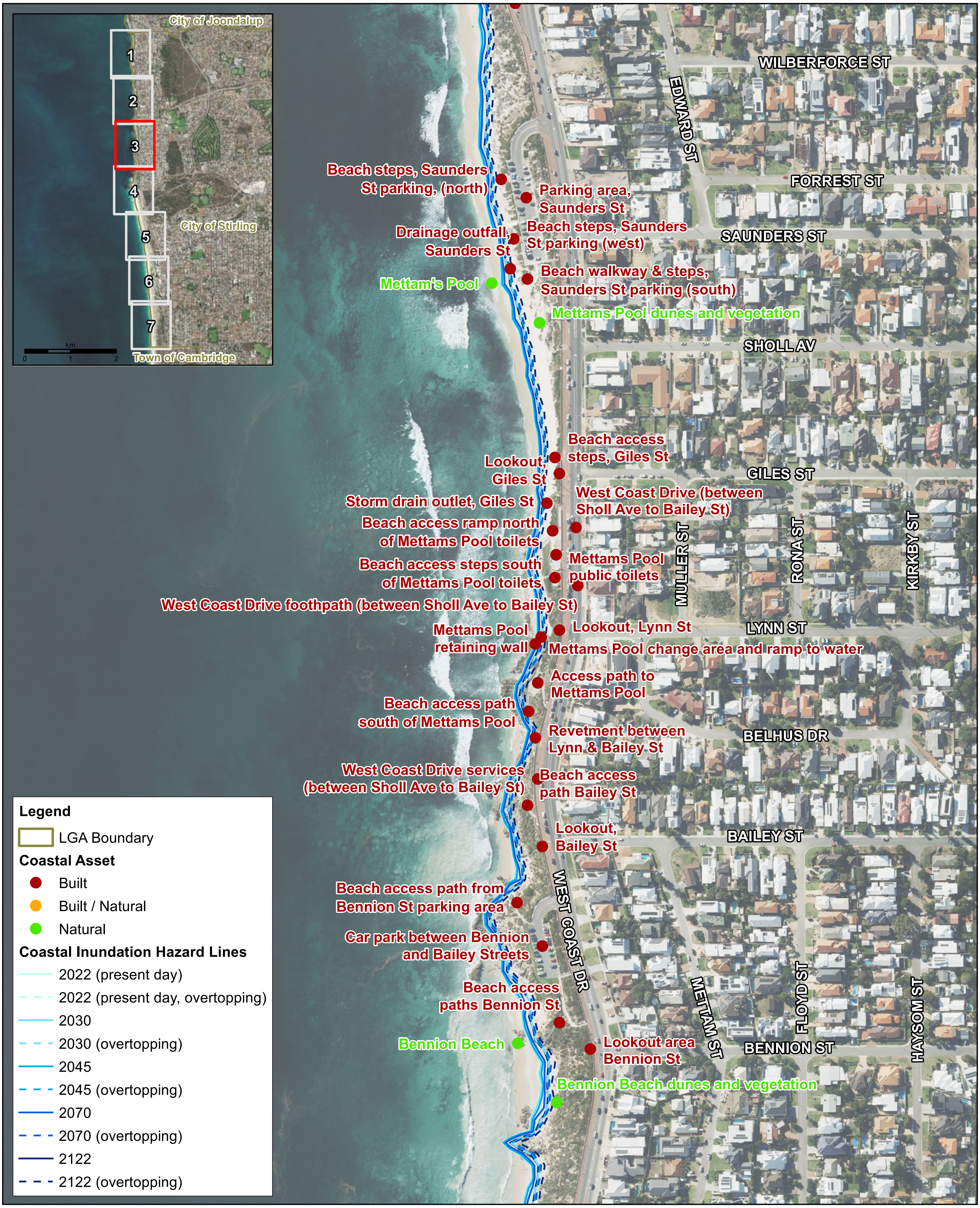
m
0 50 100

Coastal Inundation Hazard to Assets (Zone 2)

CITY OF STIRLING CHRMAP

FIGURE F-2

Map Produced by Cardno (WA) Pty Ltd
Date: 2023-06-27
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_008_InundationAssets.mxd 01
Aerial imagery supplied by Metromap (January, 2022)



City of Stirling
City of Choice

N

1:3,000 Scale at A3

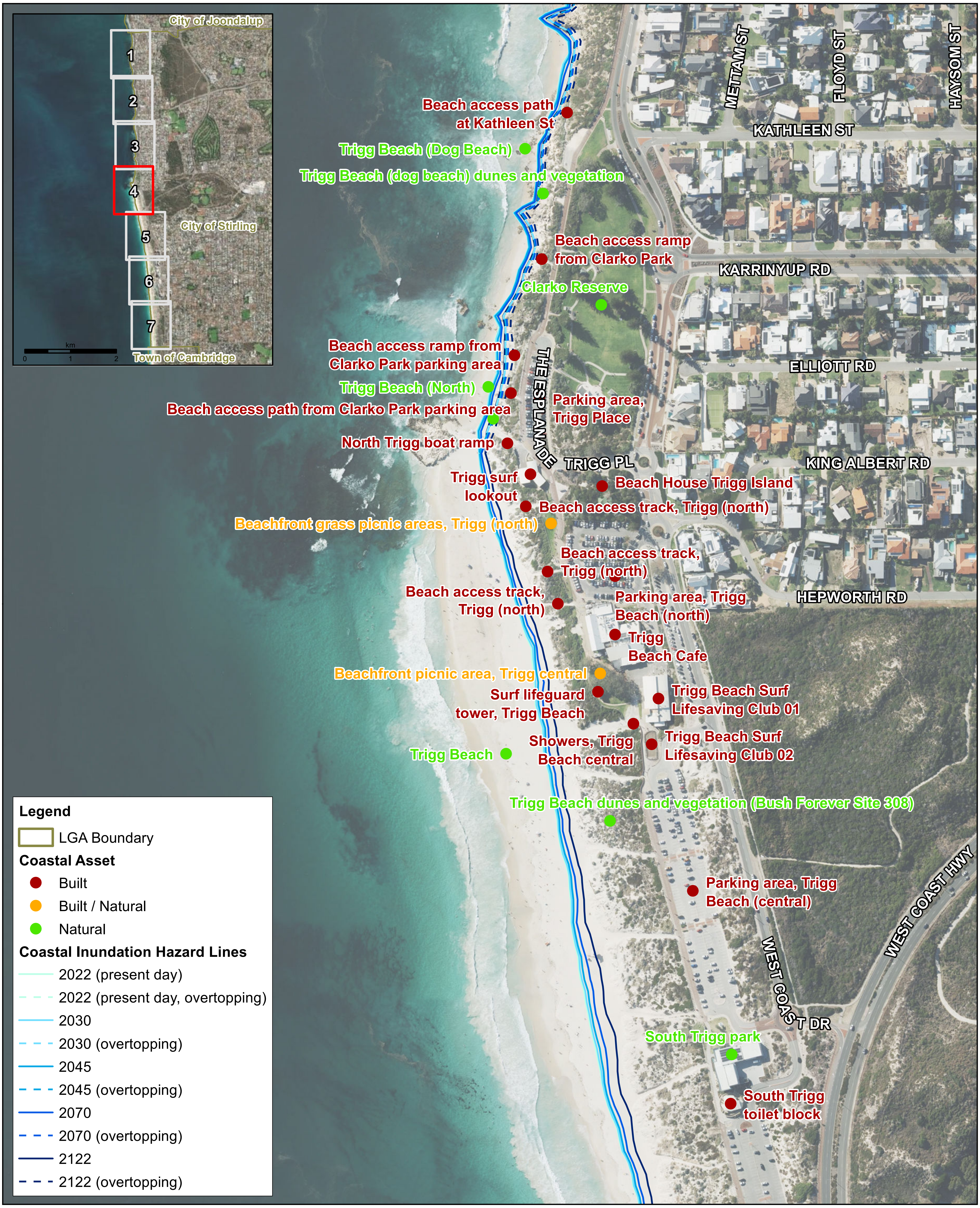
m
0 50 100

Coastal Inundation Hazard to Assets (Zone 3)

CITY OF STIRLING CHRMAP

FIGURE F-3

Map Produced by Cardno (WA) Pty Ltd
Date: 2023-06-27
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_008_InundationAssets.mxd 01
Aerial imagery supplied by Metromap (January, 2022)



City of Stirling
City of Choice

N

1:3,000 Scale at A3

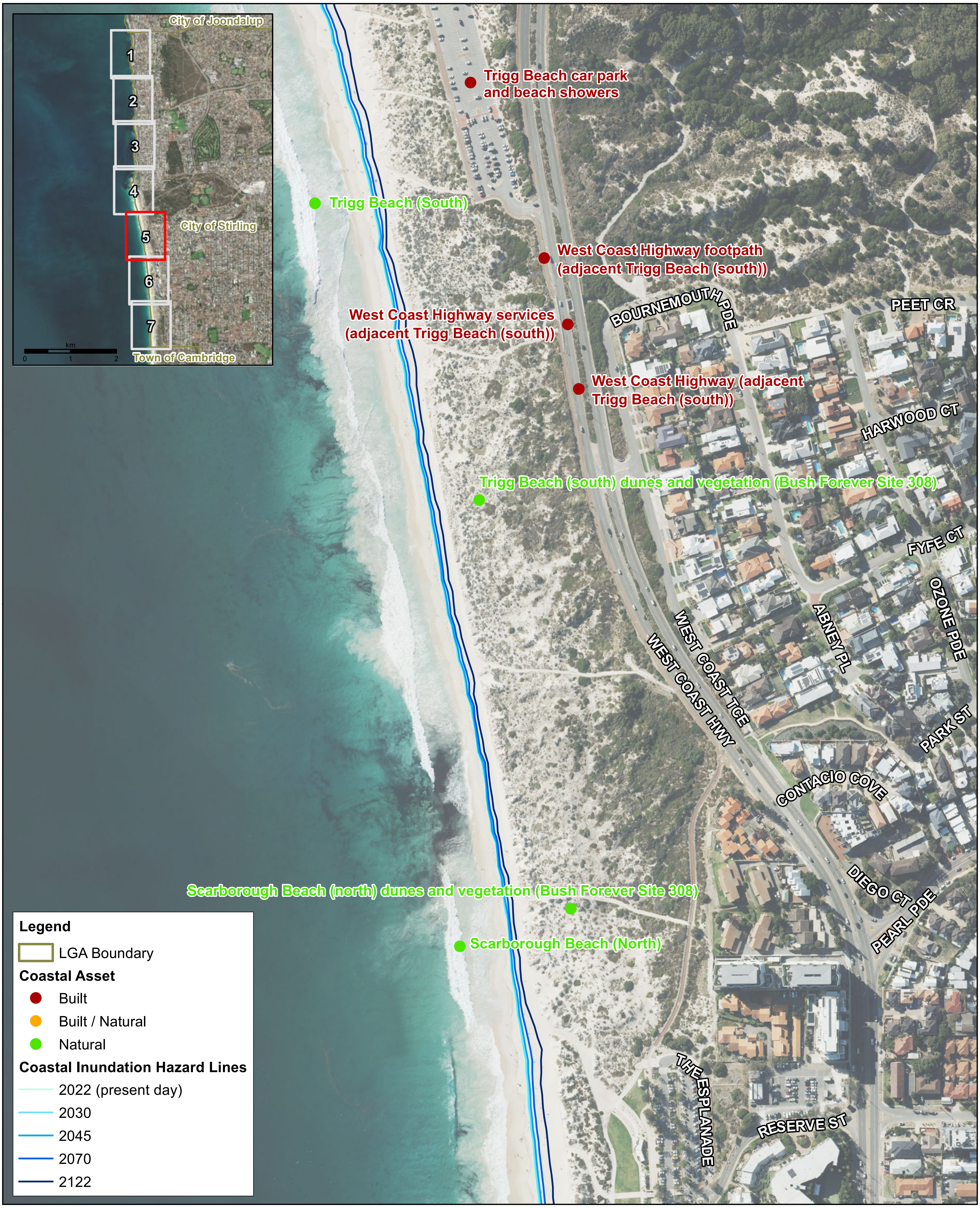
m
0 50 100

Coastal Inundation Hazard to Assets (Zone 4)

CITY OF STIRLING CHRMAP

FIGURE F-4

Map Produced by Cardno (WA) Pty Ltd
Date: 2023-06-27
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_008_InundationAssets.mxd 01
Aerial imagery supplied by Metromap (January, 2022)



Coastal Inundation Hazard to Assets (Zone 5)

CITY OF STIRLING CHRMAP

FIGURE F-5

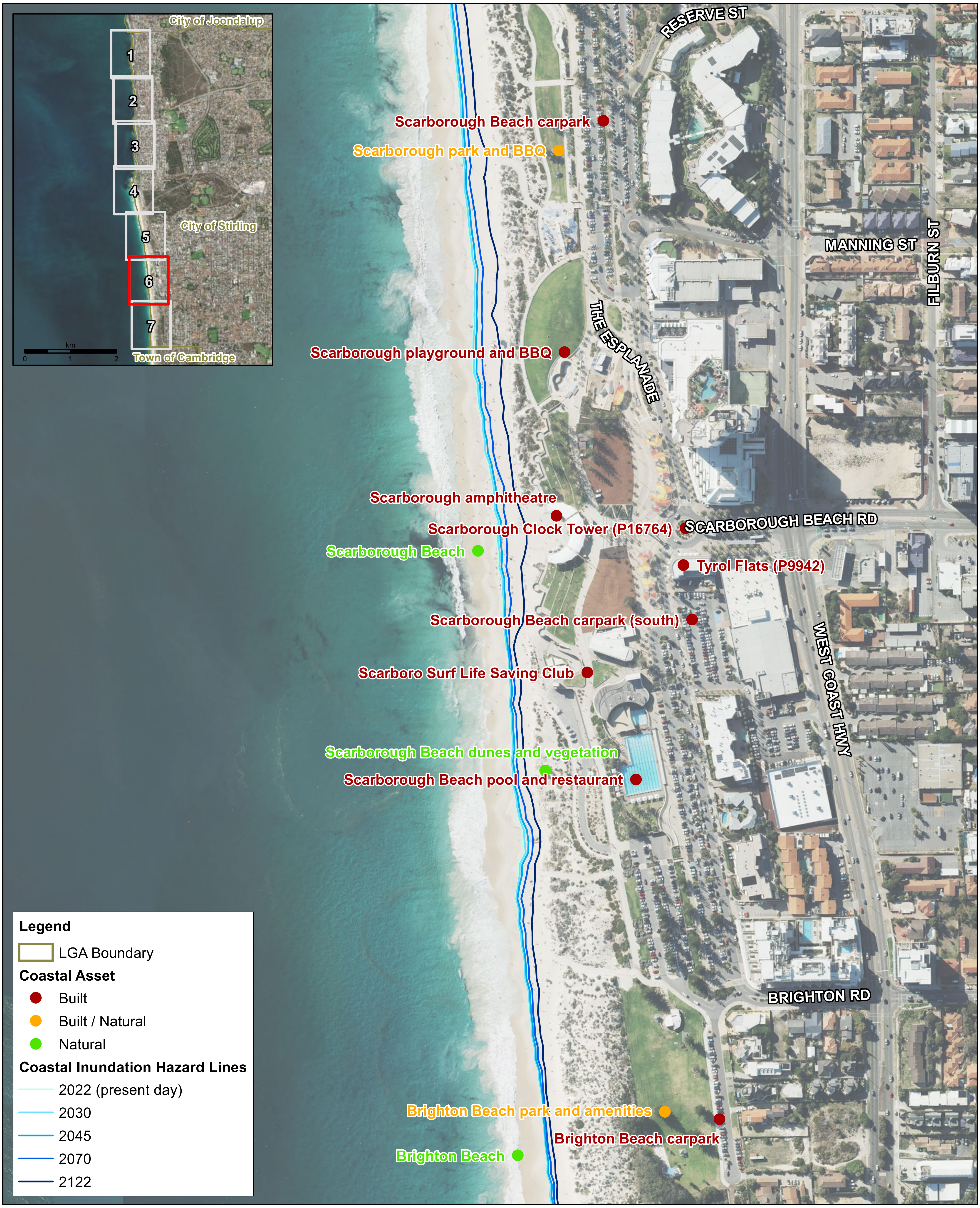
City of Stirling
City of Choice

N

1:3,000 Scale at A3

m
0 50 100

Map Produced by Cardno (WA) Pty Ltd
Date: 2023-06-27
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_008_InundationAssets.mxd 01
Aerial imagery supplied by Metromap (January, 2022)



Coastal Inundation Hazard to Assets (Zone 6)

City of Stirling
City of Choice

N

1:3,000 Scale at A3

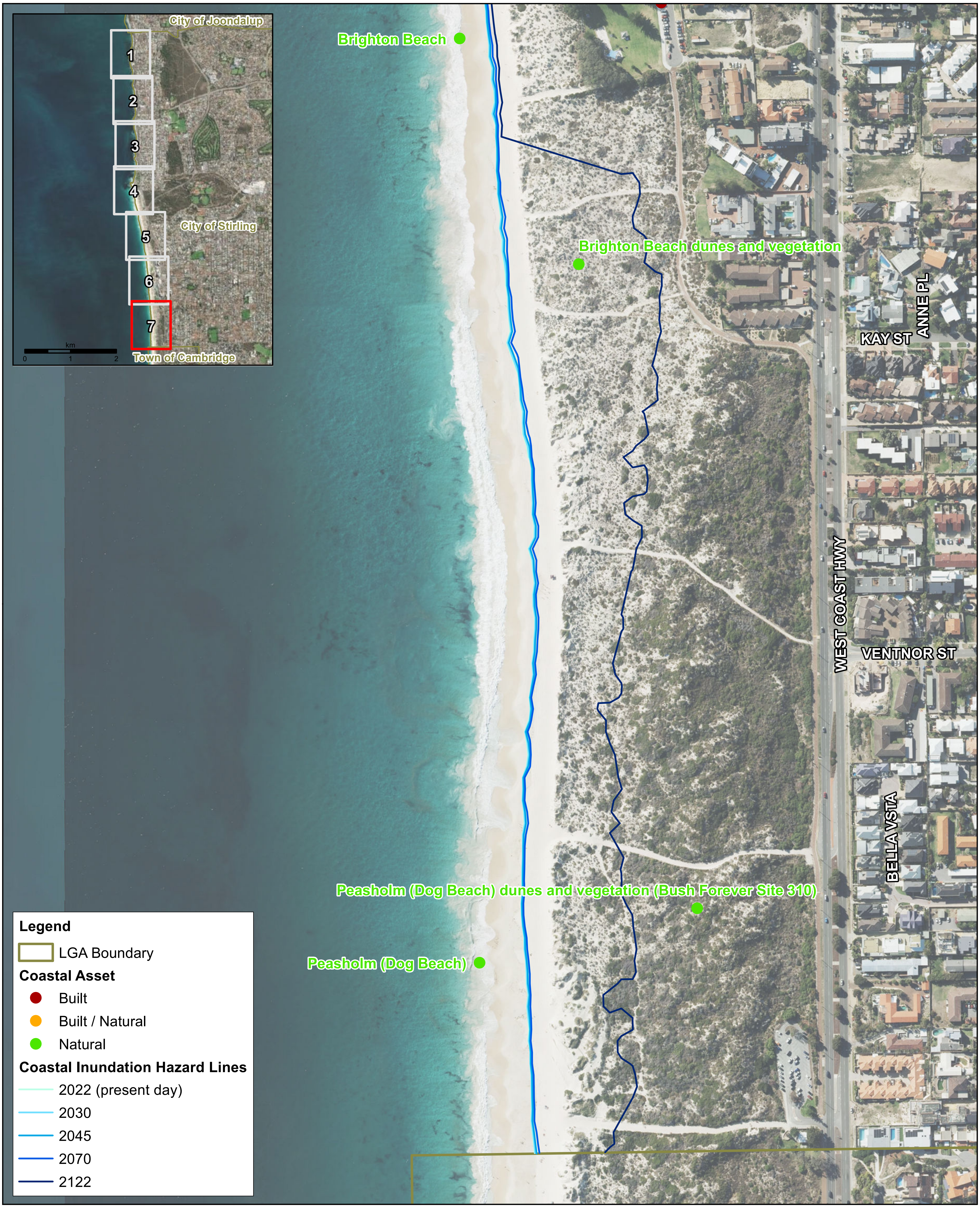
m
0 50 100

CITY OF STIRLING CHRMAP

FIGURE F-6

Cardno now Stantec

Map Produced by Cardno (WA) Pty Ltd
Date: 2023-06-27
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_008_InundationAssets.mxd 01
Aerial imagery supplied by Metromap (January, 2022)



Coastal Inundation Hazard to Assets (Zone 7)

City of Stirling
City of Choice

1:3,000 Scale at A3

N

m
0 50 100

CITY OF STIRLING CHRMAP

FIGURE F-7

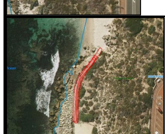
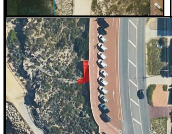
Map Produced by Cardno (WA) Pty Ltd
Date: 2023-06-27
Coordinate System: GDA 1994 MGA Zone 50
Project: CW1195500
Map: CW1195500_GS_008_InundationAssets.mxd 01
Aerial imagery supplied by Metromap (January, 2022)

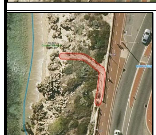
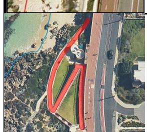
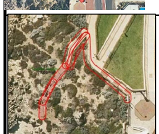
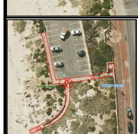
APPENDIX

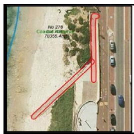
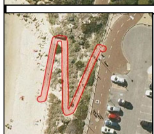
G

BEACH ACCESS AUDIT

Coastal Access Paths

Image	Path Asset Numbers	Location Description	Asset Notes	Handover of Coastal Access Paths with associated walls, Fences and Handrails	Materials Type	Disability Discrimination Act 1992 Compliant
	PW0000234 PW0000235	Watermans Northern Steps	Timber steps with integral handrails. Structurally sound requiring some cosmetic maintenance. Lower concrete landing and steps is sound with no immediate attention required.	Handover Engineering Services 2022-23	Timber Steps. Concrete Path.	No
	PW0000233	Watermans Toilet Steps	Concrete steps with integral S/S handrails. No immediate actions required (some minor step damage).	Handover Engineering Services 2022-23	Concrete Steps.	No
	PW0000237 PW0019035	Watermans Southern ramp/steps	Steep concrete access ramp terminating in (new) steps. Parallel brick steps to ramp. No immediate action required.	Handover Engineering Services 2022-23	Paved Steps. Concrete Ramp. Concrete Steps.	No
	PW0000229	Watermans 'Secret Beach' steps, access to summer beach from grassed play area	Concrete steps with S/S handrails. Functional but storm erosion undermining steps and spillway requires underpinning and slope protection.	Handover Engineering Services 2022-23	Concrete Steps.	No
	PW0019034	Southern end of Margaret Street Car Park. Steps accessing sandy path and easy rock descent to intermittent beach.	Brick/stone steps with integral wall. Some erosion to base requires minor grouting. Recommend some additional beach sand (400mm depth) to bottom landing area.	Handover Engineering Services 2022-23	Paved Steps.	No
	BR0000029 PW0000231	South from Margaret Street Car Park. Path and steps to (dog) beach. Does not include path between car park and RSP.	Functional concrete path to timber walkway/concrete steps with integral handrails. No immediate action required.	Handover Engineering Services 2022-23	Timber Boardwalk. Concrete Steps.	No
	PW0000143	West of Marine Labs. Steps from informal sand trail to sea and outflow from Marine centre (No recreational beach)	Limestone steps and sidewalls. Functional but poor condition. Access from NE corner of Marine Centre and possibly easement with 'ownership'.	Handover Engineering Services 2022-23. Query this as may be property of Marine Centre.	Limestone block Steps.	No
	PW0000142	South of Marine Labs to dog beaches.	Sandy track between timber fences.	Retained by Natural Areas.	Sand Path.	No
	PW0019038 PW0000216	Lawley Street access, path and steps from RSP to dog beach	Steep path between concrete steps. Meets and crosses interbeach track and terminates with (rounded) mass concrete steps to beach. Minor attention required.	Handover at end of asset life. Query as this is a well used beach access path.	Concrete Steps. Concrete Path.	
	PW0019041 PW0000207	North from Jetty, main path and steps to dog beach.	Conrete path terminating in concrete steps with integral handrail. Functional with minor improvements just completed. No immediate attention required.	Handover Engineering Services 2022-23	Concrete Path. Concrete Steps.	
	PW0000214	Redundant access steps to demolished toilet block. Now gated as landscaping access to headland. Potential to reopen by adding lower steps (demolished with toilets).	Upper landing acts as view platform. Steps closed by padlocked access gate Do not recommend removal as steps are integrated into RSP retaining wall.	Handover Engineering Services 2022-23	Paved Steps.	No
	PW0000214	North Beach Headland (Malcom St) Access 'road' to North Beach Jetty and beach access path/steps.	Public pedestrian use only (Authorised vehicles excepted) Includes Walls	Handover Engineering Services 2022-23	Bitumen Road	No

	PW0000211	North Beach, northern 'Summer Steps'	Brick steps, including integral wall and S/S handrail. Subject to repair work (Feb 2022) so no immediate attention required.	Handover Engineering Services 2022-23	Paved Steps.	No
	PW0000213 PW0000212	North Beach (swimming beach) - northern 'Winter Steps'	Recent upgrade to Composite/ FRP. Critical defect in that since dune regression and lower sand levels it terminates with a 1m drop. Will require concrete extension steps.	Handover Engineering Services 2022-23	Composite (FRP) Steps. Upper concrete steps.	No
	PW0000205 PW0000204	North Beach (swimming beach) - southern steps.	Recent upgrade to concrete steps from lower landing. Older ramp and brick steps from RSP to landing. No defects requiring immediate action.	Handover Engineering Services 2022-23	Concrete Path. Paved/Concrete Steps.	No
	PW0000202 PW0000203	Connecting steps/path from Car Park to North Beach (south)	Steps from Car park and connecting concrete path to southern steps to beach, includes S/S Handrails but not tomber fences.	Handover Engineering Services 2022-23	Concrete Steps. Concrete Path.	No
	PW0019063	North Beach (surfing beach) - northern steps	Recently installed composite/FRP steps, from car park to surfers beach. No defects identified requiring attention.	Handover Engineering Services 2022-23	Composite Steps.	No
	PW0000200	North Beach (surfing beach) - southern steps	Steep path and bottom steps from RSP to beach. No concrete defects however some undercutting and drop off at end. Consider sand filling/ planting to rectify erosion.	Handover at end of asset life	Concrete Path and steps.	No
	PW0000123	Beachton Street (access to nowhere) This has been closed for more than 3 years as it terminates at hazardous rock 'cliff'.	Recommend partial removal and termination as a viewing point. Integral to RSP retaining wall so retain that section. Includes Walls and Handrails.	Handover Engineering Services 2022-23	Concrete Steps. Concrete Path.	No
	PW0000122 PW0000121 PW0000120	Hamersley Pool beach access. (Note also northern spur to second closed access to Beachton area)	Steps from RSP to lower path connecting to new beach steps. Includes Walls and Handrails. Lower Wall FE7000184 should also be handed over as it supports RSP ret wall..	Handover Engineering Services 2022-23	Paved Steps. Concrete Steps. Concrete Path.	No
	PW0000119	Disabled access zig-zag ramp to Hamersley toilet block and beach steps.	Includes Walls and Handrails. In good order with no defects of current concern.	Handover Engineering Services 2022-23	Concrete Path.	Yes
	PW0000116 PW0000124 PW0019036 PW0000125	Steps from RSP to zig-zag and sloping path/steps to Saunders Street beach north.	A significnt access to a rugged beach. Steps and concrete paths terminating in sand/rock path to beach. Handrail to lower section corroded, unsafe to use and requires replacing.	Handover Engineering Services 2022-23	Paved Steps. Concrete Path. Concrete Steps.	No
	PW0000115	Northern access from car park, destroyed in storm in 2020.	Demolished 2020	Nothing to handover. Remove asset from register	Concrete Steps.	No
	PW0000114	Only surviving access of three. Steps from car park to Saunders Street beach.	Currently functional, no immediate action required.		Concrete Steps.	No
	PW0000111 PW0000113 PW0000112 PW0019067	Steps and path from RSP to beach steps PW0000115. Beach path and steps to south have been removed and replaced with a sand track for beach maintenance.	In functional condition except where crossover to beach track needs to be provided to repair kerb/path damage. Includes Walls and Handrails and access gate to track.	Handover Engineering Services 2022-23	Paved Steps. Concrete Steps. Concrete Path.	No
	PW0000110	Mettams Pool, north steps.	In good condition proving access from RSP to beach for all weather conditions. Includes S/S handrails which were upgraded with fence to protect fall from height.	Handover Engineering Services 2022-23	Concrete Steps.	No

	PW0000109 PW0000107	Access from RSP to toilet block plus beach access ramp to Mettams Pool.	Good condition. Beach access ramp recently underpinned and protected by GSC seawall. Includes Walls and Handrails. **Some damaged GSCs require repair**.	Handover Engineering Services 2022-23	Concrete Paths.	Yes
	PW0000105 PW0000106	Steps from RSP to toilet block plus beach access steps.	Steps to beach subject to short term underpinning and includes S/S handrails - no side protection for fall from height protection.	Handover Engineering Services 2022-23	Paved Steps. Concrete Steps.	No
	PW0000099 PW0017112 PW0000101 PW0000102 PW0000103	Disabled zig-zag access from RSP to Mettams Pool beach and gazebo. Water Access ramp (north) now removed. Beach access to south (un-named) is sloping concrete path	All in adequate functional condition. Includes Walls and S/S handrails to zig-zag but not timber fence to southern path.	Handover Engineering Services 2022-23	Concrete Paths.	Yes
	PW0018685 PW0000098	Brick/concrete steps, integrated with ret wall to RSP. Concrete path and timber fence terminates on rocky headland and only provides viewing 'deck'.	Steps Include timber handrails	Handover Engineering Services 2022-23	Paved Steps. Concrete Path.	No
	PW0000223 PW0019056 PW0000222 PW0019057	Kerbside path from RSP to car park, Beach access steps, then steep path, then S/S steps (timber treads) to beach (un-named).	Beach access includes S/S handrails to all elements. Functional condition no immediate repairs required.	Handover Engineering Services 2022-23	Concrete Paths. Concrete Steps. Stell and Timber Steps.	No
	PW0019204 PW0019203 PW0019205 PW0019206 PW0000224	Bennion Beach Access. New concrete steps and path from RSP and car park, connecting to new Composite/FRP steps to old timber steps.	Upper facilities as new and include Walls and S/S handrails. Old timber steps have footings undermined at bottom and may be structurally unsound.	Handover Engineering Services 2022-23	Concrete Steps. Concrete Paths. Composite Steps. Timber Steps.	No
	PW0001103	Concrete Beach Access path to Trigg Dog Beach	Steep concrete path with some minor slab misalignment. At beach splits into two short paths, across rock to sand/rock. Poor condition but 'safe'.	Handover at end of asset life	Concrete Path.	No
	PW0001105	Steep sloping concrete path to 'Clarko Beach'. Currently CLOSED following storm damage.	Dune erosion has exposed bottom of path to storm damage. Requires either removal of path or, installation of steps further back into dunes.	Handover at end of asset life - condition suggests the lower end is already at end of life.	Concrete Path.	No
	PW0001106	Concrete Zig-Zag access to Trigg Island beach.	Recent repairs following storm damage. Severe erosion occurs with waves under and over the zag eroding support to upper zig. Recommend GSC wall between zig and zag.	Handover Engineering Services 2022-23	Concrete Path.	Yes
	PW0001108	Concrete beach access path to Trigg Island Beach	Dunes have now receded and path extends into beach with potential hazard at low sand levels. Consider removal or shorten and replace with steps at lower end.	Handover at end of asset life	Concrete Path.	No
	Unknown	Trigg Island Boat Ramp	Concrete Boat Ramp heavy construction in good order except: Undermining to SW end requiring underpinning/counterfort wall. End apron to beach is poor. Includes Walls	Not recorded on any asset register.	Heavy duty concrete ramp with high traction integral studs - unsuitable for pedestrian use.	No