Moyne Amendment C69

Flood Summary Report

Version 1.2

11 August 2021

Document status

Client	Moyne Shire Council
Project	Moyne Amendment C69
Report title	Flood Summary Report
Version	Version 1.2
Authors	Rob Swan
Project manager	Rob Swan
File name	FPM00041_r01v1_1_PortFairy_SummaryReport_C69.docx
Project number	FPM00041

Document history

Version	Date issued	Reviewed by	Approved by	Sent to	Comment
A	23/06/21	MC	RCS	Moyne Shire	Initial release for discussion
B	23/06/21	MC	RCS	Moyne Shire	Minor Updates and Clarifications
1	14/7/21	MC	RCS	Moyne Shire	Inclusion of Planning Numbers
1.1	22/07/21	MC	RCS	Moyne Shire	Minor updates to mapped extents and planning numbers
1.2	11/08/21	MC	RCS	Moyne Shire	Minor typographical edits

Copyright and Limitation

Contents

1. Introduction

Port Fairy is a coastal town in south-western Victoria, 28 kilometres west of Warrnambool and 290 kilometres west of Melbourne, at the point where the Moyne River enters the Great Australian Bight. The area is impacted by both coastal inundation and riverine flooding, especially around the South Beach and Belfast Lough areas.

Council adopted the Port Fairy Coastal and Structure Plan in August 2018. Moyne Shire Council prepared the Amendment C69moyn (the Amendment) to the Moyne Planning Scheme to implement the land use and development framework of the Structure Plan. The Amendment proposes to correct zone mapping anomalies on individual sites within the Port Fairy township. It also proposes to inform and guide the future growth and development of Port Fairy. One of the constraints to development in and around Port Fairy is inundation, that is predicted to increase under future climate conditions.

This report has been written at the request of the Moyne Shire Council to provide information and assessment on the expected flooding at Port Fairy under a range of sea level rise and river flow conditions. The assessment builds on the analysis from a number of previous studies undertaken over the last 15 years.

Previous assessments of flood behaviour in the area have included:

- Port Fairy Regional Flood Study, 2008, undertaken by Water Technology
- Port Fairy Regional Flood Study – Sea Level Rise Modelling, 2010, undertaken by Water Technology
- Port Fairy Coastal Hazard Vulnerability Assessment, Water Research Laboratory of the University of NSW, 2013
- Translation of Port Fairy Coastal Hazard Assessment, Cardno, 2019

There has also been additional assessment undertaken as part of works post the delivery of the 2019 Cardno report to further inform decision making and appropriate overlay delineation. This report summarises the intention, procedures and outcomes of each of these projects.

In the planning context, the assessment of the combination of sea level rise and riverine flooding in estuary floodplains is difficult. In an estuary floodplain like the Moyne River at Port Fairy, a coastal storm surge flood event may be loosely correlated with a riverine flood event, but the practical timing of events, consideration of the tidal cycle and the type of storm/weather event may all contribute to the flood level of flood risk. This report examines the commonly used combinations of probability events to guide adoption of an envelope of storm tide and riverine flood levels. The analysis undertaken and described in this report provides an appropriate basis for the adoption of new flood related planning controls into the Moyne Planning Scheme that account for increasing flood risk at Port Fairy as a consequence of rising sea level

1.1 Project Aims

The aim of this report is to provide improved flood risk information at Port Fairy including:

- the change in ocean boundary level estimates based on best available information;
- the logic applied to the determination of appropriate river/storm tide coincident events in the Moyne River estuary (including Belfast Lough),
- the analysis of relative dominance of storm tide versus riverine flood risk in the Moyne River estuary portion of the floodplain and
- update mapping and digital data to support the amendment process.

The project brief also required additional modelling of a number of scenarios as directed by the Glenelg Hopkins CMA. These are provided as digital datasets and are described in Sections 3 and 5 of this report.

2. Previous Studies

There are four main studies that have been completed in and around Port Fairy. These include:

- Port Fairy Regional Flood Study, 2008, undertaken by Water Technology
- Port Fairy Regional Flood Study – Sea Level Rise Modelling, 2010, undertaken by Water Technology
- Port Fairy Coastal Hazard Vulnerability Assessment, Water Research Laboratory of the University of NSW, 2013
- Translation of Port Fairy Coastal Hazard Assessment, Cardno, 2019

Each of these projects built on the outcomes and analysis of the previous studies. This section provides an overview of each project and what the intention of each project was in the context of combined ocean and riverine flooding at Port Fairy.

2.1 Port Fairy Regional Flood Study, 2008

The Port Fairy Flood study was delivered in 2008 by Water Technology. The aim of the study was to assess riverine flood impacts associated with the Moyne River more widely and provide flood information in and around Port Fairy. The study did not undertake any modelling of the offshore wind and wave conditions at Port Fairy to identify ocean boundary levels as this was outside the scope of works.

Whilst the study did investigate the consequences of rising sea level on flood risk associated with the Moyne estuary (including Belfast Lough), it used ocean boundary level estimates that did not account for the dynamic nature of tidal influence on flood levels. The study did not account for the difference offshore wind and wave conditions in that exist between the Moyne River entrance and the Southwest passage and the influence of these factors in producing different ocean boundary levels between these locations. As a consequence, the study applied the same ocean boundary level for both the Moyne River entrance and the Southwest Passage. The significance of this is discussed in more detail below.

2.1.1 Riverine Inputs

This project used a calibrated RORB model to developed expected inflows for use in the hydraulic model. The majority of flows into Port Fairy are from the Moyne River, but there are also a number of smaller streams and creeks plus local catchment inflows that were considered. All modelling was undertaken in accordance with the procedures described in Australian Rainfall and Runoff 1987. For the Moyne River, the estimates of the Annual Exceedance Probability (AEP) flows have been derived from flood frequency analysis and are unlikely to be significantly different under Australian Rainfall and Runoff 2019.

Inflows were produced for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events.

2.1.2 Ocean Inputs

The ocean boundary conditions are taken from communications with Kathleen McInnes of CSIRO. The levels adopted were later published in CSIRO's 2009 report *"The Effect of Climate Change on Extreme Sea Levels along Victoria's Coast",* completed as part of the Future Coasts program. The levels adopted are shown in Figure 1 and 2.

Table 4-2 Tide + Surge Levels

AEP (%)	ARI (1 in Yr)	Portland Level (m AHD)	CSIRO Portland (m AHD)	CSIRO Port Fairy (m AHD)
50	2	0.70	NA	NA
20	5	0.85	NA	NA
10	10	0.93	0.83 ± 0.03	0.86 ± 0.03
0.5	20	0.98	0.93 ± 0.03	0.96 ± 0.03
2	50	1.03	1.02 ± 0.04	1.06 ± 0.04
1	100	1.07	1.07 ± 0.05	1.12 ± 0.05

Figure 1 – Tide and Storm Surge levels adopted in the Port Fairy Regional Flood Study

Table 4-3 Design Ocean Level Summary

Source	1% AEP Ocean Level (m AHD)	Ocean Level for Planning Purposes (Rounded) (m AHD)
Water Technology (2007)	1.07	1.1
CSIRO (McInnes, pers. communication 2008)	1.12	1.1

Figure 2 – Design Ocean levels adopted in the Port Fairy Regional Flood Study

In the modelling, these levels were applied as a static water level boundary. This means that the downstream level did not vary over time.

2.1.3 Event combinations

As described above, the project predominantly assessed riverine flooding. The project adopted at 10% AEP ocean boundary for all flood events regardless of their AEP. This was the recommended approach from the 2000 document Floodplain Management in Australia: Best Practice Principles and Guidelines (Standing Committee on Agriculture and Resource Management (SCARM), 2000). The reports states that:

> *This practice is based on the assumption that, whilst storm-surge and flood events are somewhat correlated, using coincident 1% AEP sea level and flood peaks would have an overall AEP of much less than 1%. This approach is considered to recognise that, in broad terms, the meteorological conditions that generate large rainfall totals and subsequent flooding at Port Fairy could also potentially generate a storm surge. However, the complexities relating to the timing and magnitude of the two separate*

effects is considered unlikely to result in both achieving a similar level of severity simultaneously.

There is some consideration of the potential for other combinations of events in the WaterTechnology's 2008 analysis. The report assesses the expected tidal residual (effectively the storm surge) for each of the peak flood events from 13 years between 1983 and 1998 against the flood peak in the Moyne River at Toolong. There was no clear correlation between a large storm event and an elevated sea state. For the available observed records, significant storm surges have not occurred at the critical period required to impact catchment flooding in Port Fairy.

Sensitivity testing was undertaken to assess the implications of increasing the ocean boundary level to the 1% AEP for the design 1% river storm. The assessment found that this increased levels upstream of the Gipps Street bridge by less than 0.1 metres.

It is noted that for events larger than the 1% AEP river inflows, the ocean water levels were also increased. For the 0.5% AEP river flow, the 2% AEP ocean level was adopted as the boundary. For the PMP river flow, the 1% ocean level was adopted at the boundary.

2.1.4 Climate Change

The project provided assessment of three climate change scenarios, described as moderate, intermediate and high for a nominal year 2100 planning scenario. The scenarios were:

1. Moderate Scenario
    a. 0.4m sea level rise
    b. Additional 0.03m of storm surge
    c. Rainfall intensity increase of 30% in the 1% AEP event
2. Intermediate Scenario
    a. 0.8m sea level rise
    b. Additional 0.07m of storm surge
    c. Rainfall intensity increase of 50% in the 1% AEP event
3. High Scenario
    a. 1.2m sea level rise
    b. Additional 0.1m of storm surge
    c. Adopt the expected 1946 hydrograph as the design flood event (the 1946 event is considered to have been larger than a 0.2% AEP event)

The intensity of rainfall increase across all scenarios is considered significantly greater than what is recommended under the current ARR2019 guidance, where rainfall intensity increases at 2100 under the highest emission pathways are in the order of 20%. %. As mentioned above, the assessment did not consider the contribution of higher tidal surge levels along South Beach and the Southwest Passage that would impact the Moyne River outlet. The primary aim of this analysis was to assess if mitigation works could protect areas of the township from the impacts of climate change.

2.1.5 Key Outcomes

The results of the project are consistent with the aims of the project. The assessment of climate change is conservative, and there is no consideration of the difference in ocean water levels between the Moyne River entrance and the Southwest Passage/ South Beach portion of the coastline. The hydrology element of the study is considered robust and formed the baseline river inputs for all following studies.

2.2 Port Fairy Regional Flood Study – Sea Level Rise Addendum Modelling, 2010

After the finalisation of the Flood Mapping study, the Victorian Coastal Strategy was updated to provide a framework for the assessment of sea level rise, suitable for use in long term planning. The hydraulic model schematisation and riverine boundary conditions were unchanged from the 2008 Port Fairy Regional Flood Study (the 2008 Study).

2.2.1 Ocean Inputs

In contrast to the 2008 Study, the 2010 sea level rise addendum modelling adopted a dynamic tidal boundary. This means that the tide level changes with time and is considered more representative of actual conditions. The adoption of a dynamic boundary tends to lower the expected flood levels compared to a static boundary, as there is more available flow area as the tide falls. At Port Fairy, the available storage in Belfast Lough is influenced by the tide level.

The dynamic tide boundary was developed for a 72-hour period by superimposing a sinusoidal storm surge curve onto a typical predicted tide signal. Sea level rise was added to the signal as appropriate.

2.2.2 Event Combinations

The study included additional assessment of the combination of ocean and riverine extreme events at Port Fairy. It concluded that the most likely tidal residual (measured water level above the expected astronomical tide) at the annual flood peak was commonly less than the 1-year ARI of 0.4m. This included the 1946 flood event.

The project then assessed four combinations of sea level rise, riverine inputs and ocean tide conditions, as shown in Figure 3.

Scenario	Riverine Boundary Conditions	Ocean Boundary Conditions
SLR1 100 yr Flood	1% AEP (100 year ARI) design flow hydrographs for the Moyne River at Toolong, Reedy Creek, Holcombe's Drain and the Murray Brooke catchments	Dynamic boundary condition of CSIRO 10 year ARI storm tide at 2100 1.86 m AHD at peak
SLR2 100 yr Flood	1% AEP (100 year ARI) design flow hydrographs for the Moyne River at Toolong, Reedy Creek, Holcombe's Drain and the Murray Brooke catchments	Dynamic boundary condition of CSIRO 10 year ARI storm tide at 2010 plus an additional 0.4 m sea level rise 2.26 m AHD at peak
SLR1 100 yr Storm Tide	No flow	Dynamic boundary condition of CSIRO 100 year ARI storm tide at 2100 2.09 m AHD at peak
SLR2 100 yr Storm Tide	No flow	Dynamic boundary condition of CSIRO 100 year ARI storm tide at 2100 plus an additional 0.4 m sea level rise 2.49 m AHD at peak

Figure 3 – Boundary Condition Combinations, Sea Level Rise addendum

In the table above, SLR1 refers to a sea level rise of 0.8 metres and SLR2 refers to a sea level rise of 1.2m.

It is noted that the assessment of flooding from the ocean (storm tide assessment) did not include any contribution from coincident riverine flood flows.

2.2.3 Key Outcomes

The results of this assessment provided further insight into the potential consequences of sea level rise at Port Fairy. The adoption of a time varying boundary is considered to be a best practice approach, as the storage characteristics of Belfast Lough can be critical for the timing of flood behaviour.

As the schematisation of this model is identical to that used in the regional flood study, the same limitations with regard to the varying ocean levels apply.

2.3 Port Fairy Coastal Hazard Vulnerability Assessment

The Port Fairy Coastal Hazard Vulnerability Assessment (PFCHVA) was undertaken by the Water Research Laboratory (WRL) of the University of NSW, as part of the Future Coasts program, led by the Victorian Department of Sustainability and Environment and the Department of Planning and Community Development. The main objective was to provide Moyne Shire Council and other land and asset managers with information to assist in planning and establishing effective adaptive management options in response to present day coastal erosion and flooding risks and the projected impacts of climate change. Specifically, the information will assist management agencies in strategic and business planning, infrastructure maintenance and replacement schedules, natural asset management and budgetary processes.

A main difference when compared to the previous assessments of coastal processes at Port Fairy was the consideration of coastlines coastline recession (erosion) risk and pure coastal flooding (ie locations subject to coastal/storm tide flood risk only) as well as flood risk in the Moyne River estuary (subject to coastal/storm tide flood risk and riverine flood risk). The assessment included all coastline form Cape Reamur to Cape Killarney.

2.3.1 Model Schematisation

The project adopted two methods for the assessment of coastal inundation – a static water level (bathtub mapping) method, where the projected ocean sea level is extended onto the land; and a dynamic method which considers the change in flooding over time due to the combination of flood hydrographs, storm surge, sea level rise, wave setup and wave overtopping.

The MIKE FLOOD hydraulic model developed for the 2008 Port Fairy Regional Flood Study was adopted as the base for the assessment, with some modifications. These modifications were:

- An extension to the model area to encompass the coastal areas south of Port Fairy
- Minor modifications to the roughness layers to account for buildings and road layouts.
- Changes to the ocean inputs (discussed below)

2.3.2 Riverine Inputs

The riverine and catchment inputs for the assessment were taken directly from the 2008 project. The project used the 10% and 5% AEP flood events.

2.3.3 Ocean Inputs

The PHCVA included a detailed assessment of the coastal processes and dynamics around Port Fairy under a range of future climate scenarios. These included consideration of the expected climate conditions at 2040, 2080 and 2100. The project adopted sea level rise predictions, that were agreed with the Technical Review Panel of the project, as per table 1.

Table 1 – PHCVA Sea Level Rise Assumptions

Planning Period	Sea Leve Rise (m) (above 1990 level)
2040	0.4
2080	0.8
2100	1.2

The project notes that the sea level rise is independent of the adopted Planning Period (or horizon) and the modelling is reflective of the sea level rise amount only. For example, if the sea level rise was expected to be 0.8m at 2100, the modelling for the nominal 2080 scenario would be reflective of the flood extents. The assessment of expected water levels, excluding wave setup and runup were taken from CSIRO 2009, identical to those used in the regional flood study.

The assessment extended the analysis by additionally considering the effects of wave setup and wave runup. These items were not considered in the regional flood study or its addendum (Water Technology 2008, 2010) and have to be accurately determined through data and/or modelling. They are intrinsically dependent on the nearshore wave conditions and the foreshore geometry.

Nearshore wave conditions were assessed using the SWAN (Simulating WAves Nearshore) model. The assessment found that that East Beach and Moyne River entrance has a lower wave climate than more exposed southern coastline including the Southwest Passage. This is because it is sheltered from the south west swell that produces the largest incoming waves. Wave setup causes a local increase in water level as a result of the transfer of wave momentum. This was calculated at 20 locations along the Port Fairy coastline.

The majority of beaches within the Port Fairy study area are backed by sand dunes or seawalls. During storm events, waves frequently impact these features backing the beach and overtopping of the crests occurs in the form of bores of water being discharged inland or splashes of water being projected upwards and eventually transported inland by onshore winds. Wave overtopping can cause damage to the seawall crest and to beachfront structures. Wave runup is defined as the extreme level the water reaches on a structure or shoreline slope by wave action.

The project calculated the expected volume of water discharged over the dune or shoreline crest level on average over the storm duration. These time series could then be included as an inflow to the hydraulic model. Calculations were completed for 20 locations along the coast.

Specific changes to the model boundaries were:

- Implementation of separate water level boundaries for the Moyne River entrance and the Southwest Passage. Importantly, the analysis found that water levels in the southwest passage were between 1-1.5m higher than those at the Moyne River entrance, due to wave setup.
- Inclusion of wave overtopping as a flow input. These were implemented behind the dune system, as the dynamics of the wave overtopping flow cannot be considered by the hydraulic model

2.3.4 Event combinations

As previously described, the project adopted two types of simulation – a static (bathtub mapping) method and a dynamic method. The static method did not include hydraulic modelling or consideration of wave runup and overtopping. The cases assessed as part of the project are shown in Figure 4, along with the likelihood of occurrence in the expected planning horizon (as per Table 5.1 of the PFCHVA). It is understood that these combinations were recommended by the Technical Steering Committee and required under the project scope.

Combination of Environmental Conditions				Likelihood of Modelled Scenario over Specific Planning Period			
SLR[1] (m)	Tide	Coastal storm (year ARI)	Catchment Flow (year ARI)[2]	Current	2050	2080	2100
0	MHWS	50	10	Likely	Virtually Certain		
0.4	MHWS	100	10	Unlikely	About as likely as not	Likely	Virtually Certain
0.8	MHWS	100	20			Exceptionally Unlikely	About as likely as not
1.2	MWHS	100	20				Unlikely

Notes:
(1) Increase above 1990 Mean Sea Level.
(2) The impact on flooding of combined extreme coastal and catchment events was investigated in Section 8.

Figure 4, Event combinations, PFCHVA

The dynamic modelling included consideration of four of the scenarios above (Figure 5).

Scenario #	Riverine Boundary Conditions	Ocean Boundary Conditions	Planning Period & SLR	Comments
1	10 year ARI	50 year ARI	Present Day 0 m SLR	
2	10 year ARI	100 year ARI	2050 0.4 m SLR	
3	20 year ARI	100 year ARI	2080 0.8 m SLR	Dune breach extent (180 m) next to East Beach rock revetment end
5	20 year ARI	100 year ARI	2080 0.8 m SLR	Extended dune breach (385 m) next to East Beach rock revetment end

Figure 5, Dynamically modelled events, PFCHVA

When compared to the regional flood study, this assessment included consideration of combined storm tide and riverine flood events. This is accordance with the practice at the time and was consistent with Floodplain Management in Australia: Best Practice Principles and Guidelines (SCARM, 2000).

“Thus, if an extreme rainfall situation is adopted for analysis (e.g. 1% AEP rainfalls), a considerable less extreme accompanying storm surge situation is typically selected (e.g. 10% AEP storm surge) and vice versa.” (SCARM, 2000)

The reverse combinations of ocean and river event probabilities were not considered in this report.

2.3.5 Key Outcomes

The project properly defined the expected current and future coastal processes applicable to the Port Fairy coast. Importantly, assessment of the South Beach/Southwest Passage area found that ocean levels are likely to be significantly higher through this area than at the Moyne River entrance. This interaction effectively raises the downstream water level experienced in the Moyne River estuary and Belfast Lough under a catchment flood event scenario. It also showed that dynamic modelling of scenarios produced to lower flood level estimates than the static (bathtub) assessments for the same event combinations.

2.4 Translation of Port Fairy Coastal Hazard Assessment

This project has extended and further developed the PFCHVA modelling and datasets. It has dynamically modelled all the scenarios from the PFCHVA, not just the four shown above in Figure 5. Cardno undertook the initial assessment in 2016-17.

The key outcome of the project is datasets that provide the best available information for understanding the likely change in Port Fairy's flood risk profile for the purpose of climate change adaptation planning.

The project comprised the following tasks

- Extract and provide additional hydrodynamic modelling of the township of Port Fairy to provide comprehensive data for depths, velocities, flow paths and estimated length of time for inundation for the Port Fairy township.
- In addition to, and including Port Fairy West, map present day 1% AEP (Annual Exceedance Probability) and the 0.2m sea level rise scenario storm tide flood levels.
- Present the findings using a single set of GIS (geographic information system) layers for a range of scenarios including various sea level rise and catchment flooding scenarios.

2.4.1 Model Schematisation

The MIKE21 model developed by WRL was intended to be extended and used for this project. However, for unknown reasons, the project was unable to get the WRL model to successfully run, despite using identical input files. As such, the model schematisation was imported into the functionally equivalent SOBEK model.

Some areas were added to the model domain, specifically in the west of the project area including the coastline and floodplain to 300 m west of the Southern Ocean Mariculture site. This was done to ensure all potential inflows giving rise to flood risk in Port Fairy West are fully accounted for in the flood risk mapping, which wasn't the case in the PFCHVA as the model domain left out this western extension of the Port Fairy west wetland system. As shown by Figure 6 below, this resulted in 2 additional inflow boundaries being added to the hydraulic model.

As part of the update process, it was also noted that some culverts on tributaries of the Moyne River had not been properly included in the MIKE model and these minor errors were rectified. It was considered that these issues would not have had an impact on the overall results of the PFCHVA.

The SOBEK model was run and the results compared against the outputs from the 2012 WRL MIKE FLOOD model. In general, differences in peak water level between the models were less than 3 cm and the SOBEK model results were considered appropriate for use in the project. For context, this change is of the same magnitude as that considered acceptable for the PFCHVA project, in the updated of the 2008 MIKE model to the 2012 MIKE model. The extended model area is shown in Figure 6

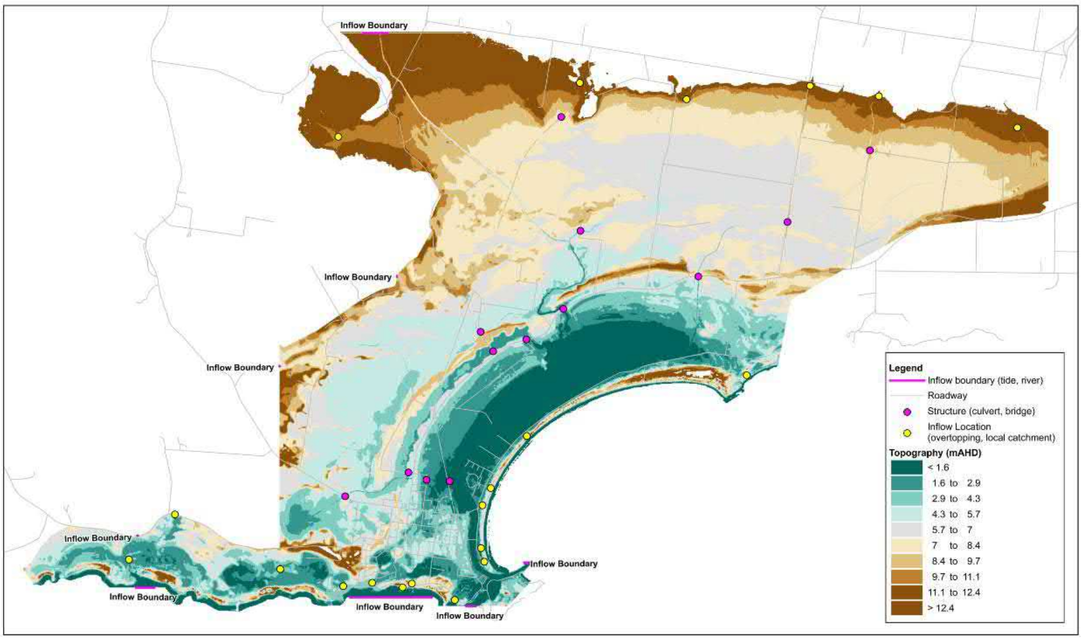


Figure 6, SOBEK model area

Other changes to the model included updates of the Reedy Creek drain area to accurately reflect the recent reinstatement of the drain to an open channel between the Princes Highway and Osmonds Lane. This portion of the drain had been piped just prior to the 2008 flood study. Removal of the pipe has significantly reduced flood risk in the area between Albert Road and the Princes Highway. These are not reflected in the previous Water Technology or WRL reports.

2.4.2 Riverine Inflows

As per the PFCHVA, riverine inputs were adopted from the 2008 regional flood study. There were some minor flows added near the Southern Mariculture site to the west. These were applied as a steady state flow based on the expected capacity of the channel upstream of the Princes Highway.

2.4.3 Ocean Inputs

The ocean water level and wave overtopping boundaries for the project were provided by WRL for all scenarios. These had been calculated as part of the PFCHVA, but not run dynamically. No additional analysis was undertaken for the coastal inputs as the PFCHVA PFCHVA provides the best available information on coastal processes at Port Fairy.

2.4.4 Event Combinations

The project was intended to extend the PFCHVA area and dynamically model all scenarios, the event combinations assessed were:

- Present Day (2% Ocean AEP, 10% catchment AEP)
- Present Day (1% Ocean AEP, 10% catchment AEP)
- 2030 (1% Ocean AEP with 0.2 m SLR rel. 1990, 10% catchment AEP)
- 2050 (1% Ocean AEP with 0.4 m SLR rel. 1990, 10% catchment AEP)
- 2080 (1% Ocean AEP with 0.8 m SLR rel. 1990, 5% catchment AEP)
- 2100 (1% Ocean AEP with 1.2 m SLR rel. 1990, 5% catchment AEP)

During the project, the Glenelg Hopkins CMA requested that the following additional events be assessed:

- Present Day (1% Ocean AEP, 1% catchment AEP)
- Future Conditions 1 (1% Ocean AEP with 0.8 m SLR rel. 1990, 1% catchment AEP)
- Future Conditions 2 (1% Ocean AEP with 1.2 m SLR rel. 1990, 1% catchment AEP)

All events were modelled dynamically, and a range of outputs were produced for each scenario to facilitate decisions on the adoption of appropriate planning controls.

2.4.5 Key Outcomes

This project provides contemporary assessment of various inundation scenarios at Port Fairy. The project adopted the 2100 (1% Ocean AEP with 1.2 m SLR rel. 1990, 5% catchment AEP) scenario outputs as the planning flood shape as directed by Council.

3. Additional Assessment

Since the completion of the translation project, the model used in that project has been further reviewed and additional modelling undertaken to assist in the derivation of flood planning controls. The processes applied and scope of the updates are discussed below.

3.1.1 Model Review

The SOBEK model was peer reviewed in 2020 by Water Modelling Solutions at the request of the GHCMA to provide additional confidence in the flood extents prepared for amendment C69. The outcomes of the peer review were:

- Additional assessment of the hydrology in the western areas should be considered
- The Gipps Street Bridge needed to be explicitly defined in the model.
- The validation of the SOBEK model needed to be expanded upon in the reporting
- An envelope approach to the derivation of the final flood extent should be used for delineating the updated planning controls that account for rising sea level.

Cardno provided commentary on each of these items in their response to the peer review.

- Additional hydrological assessment was not considered necessary for the areas west of the Port Fairy township. The intention of the modelling was not to provide detailed flood assessment of these areas, but to assess the potential impact of climate change induced sea level rise. The areas in question are trapped low points behind the dune system, with complicated upstream hydrology. Any development should consider the flood behaviour on a case by case basis.
- Cardno indicated that the effect of the Gipps Street Bridge was not likely to have a significant impact on flood levels in very large storm surge events under sea level rises of 0.8 and 1.2m. It was later agreed to include the GIPPS Street Bridge explicitly in the updated modelling.
- The SOBEK model was validated against the results from the MIKE21 model for the present day conditions (50 Year ARI case) and the 2080 conditions (100 year ARI with 0.8 m SLR rel. 1990) case. Cardno indicated that, with the exception of minor changes around structures that were modified to reflect catchment conditions, the two models effectively returned the same peak water surface levels (within +/- 3cm) at most locations.
- An envelope approach is typically used for the derivation of flood extents. Cardno was not asked to provide an envelope flood extent in the original project brief and the choice of events to envelope is a policy driven decision.

3.1.2 Additional Events

The Glenelg Hopkins CMA requested additional flood events to be considered for the derivation of planning extents. The events modelled for this process include:

- 1% Ocean AEP with 0.4 m SLR rel. 1990, 10% catchment AEP
- 10% Ocean AEP with 0.4 m SLR rel. 1990, 1% catchment AEP

- 1% Ocean AEP with 0.4 m SLR rel. 1990, 5% catchment AEP
- 5% Ocean AEP with 0.4 m SLR rel. 1990, 1% catchment AEP
- 1% Ocean AEP with 0.8 m SLR rel. 1990, 10% catchment AEP
- 10% Ocean AEP with 0.8 m SLR rel. 1990, 1% catchment AEP
- 1% Ocean AEP with 0.8 m SLR rel. 1990, 5% catchment AEP
- 5% Ocean AEP with 0.8 m SLR rel. 1990, 1% catchment AEP
- 1% Ocean AEP with 1.2 m SLR rel. 1990, 10% catchment AEP
- 10% Ocean AEP with 1.2 m SLR rel. 1990, 1% catchment AEP
- 1% Ocean AEP with 1.2 m SLR rel. 1990, 5% catchment AEP
- 5% Ocean AEP with 1.2 m SLR rel. 1990, 1% catchment AEP

3.1.3 Model Changes

The Glenelg Hopkins CMA requested additional events to be modelled to ensure a thorough understanding of the change in risk as sea level rises and to enable development of an adaptable planning control logic. The peer review also indicated that the Gipps Street Bridge should be explicitly included in the model.

This required a single change to the model schematisation, which was the inclusion of the Gipps Street Bridge. This was undertaken in accordance with the requirements of Sobek and adopted a conservative bridge modelling approach where the head loss through the bridge is more likely to be overestimated than underestimated. It is noted that once water levels exceed the bridge deck level, the effect of the bridge on water level is significantly reduced.

The bridge was estimated using the bridge deck parameters and surveyed cross sections obtained from the Water Technology model and by estimating the blockage due to piers to reduce the cross-sectional area. Entry and exit losses were also applied. Assessment of the results showed that head losses were being appropriately accounted for in the model, especially on falling tides.

3.1.4 Ocean Input changes

The PFCHVA did not provide detailed assessments of wave setup and runup for the 10% and 5% AEP ocean conditions. To provide appropriate model boundaries, the ocean boundary water level series at the Moyne River mouth and the along southern coastline have been adjusted by lowering the level in accordance with the difference indicated between the 1% AEP event and the 10% or 5% event levels shown in CSIRO (2009). It is acknowledged that this is a conservative approach for the southerly facing coast, but is considered reasonable in the absence of more detailed information.

The water level series were adjusted by applying a shift of minus 0.12m from the 1% AEP tide series to obtain the 5% AEP level across all ocean boundaries. A minus 0.22m shift from the 1% AEP tide series was applied for the 10% AEP scenario. Conservatively, the wave overtopping was unchanged from the 1% AEP cases.

3.1.5 Results

The models were run and the results processed for delivery in accordance with the mapping provided for the Port Fairy Translation project. For these results, an envelope approach has been used for the derivation of planning flood extents, based on the combination of events at equivalent sea level rise and AEP boundary.

Six scenarios were mapped based on the combinations shown in Table 2. These scenarios provide the envelope of the highest flood levels from each event at all locations in the hydraulic model.

Table 2 – Flood events modelled and scenario envelopes

Scenario ID	SLR (+m relative 1990)	River Event (AEP)	Ocean Event (AEP)
A	0.4	1%	10%
	0.4	10%	1%
B	0.4	1%	5%
	0.4	5%	1%
C	0.8	1%	10%
	0.8	10%	1%
D	0.8	1%	5%
	0.8	5%	1%
E	1.2	1%	10%
	1.2	10%	1%
F	1.2	1%	5%
	1.2	5%	1%

Maps of these scenarios are found in Appendix A. Draft LSIO and Floodway overlays maps have also been determined for each of the scenarios, again, shown in Appendix A. Also shown is the dominant event, based on the AEP of the river or ocean boundary, in each scenario where the highest water level is returned.

To provide context to the results, flood levels in Belfast Lough (500m upstream of the Gipps Street Bridge) and in the Moyne River adjacent to Banks Street have been extracted from the model. These are provided in Table 3 for the 12 models considered in the additional assessment.

Table 3 – Modelled Flood levels at Belfast Lough and Bank Street

SLR (+m relative 1990)	River Event (AEP)	Ocean Event (AEP)	Water Level Belfast Lough (mAHD)	Water Level Bank Street (mAHD)
0.4	1%	10%	2.37	2.03
0.4	10%	1%	1.92	1.89
0.4	1%	5%	2.40	2.19
0.4	5%	1%	2.06	2.02
0.8	1%	10%	2.66	2.53
0.8	10%	1%	2.37	2.35
0.8	1%	5%	2.78	2.67
0.8	5%	1%	2.61	2.59
1.2	1%	10%	3.21	3.15
1.2	10%	1%	3.23	3.22
1.2	1%	5%	3.34	3.27
1.2	5%	1%	3.32	3.31

Table 3 indicates that the SLR rise component is the major factor in the variation in flood levels through Port Fairy and at Belfast Lough. With a 0.8m sea level rise, the difference between the maximum expected level and minimum level across the complete set of scenarios modelled in Belfast Lough is 22cm. In the same sea level rise case, the difference between the 1% riverine flood events for each tidal boundary condition is only 5cm.

It appears that as the sea level rise increases to 1.2m, the combination events start to converge, indicating that there is some sort of equilibrium point for inflow and outflows to Belfast Lough at the combination of 1% and 5% events, based on the design events modelled. We also note that at the 1.2m SLR 10% AEP combination, the level in Belfast Lough is slightly higher in the 1% AEP ocean event (storm tide) case when compared to the 1% river case however the difference is only a few centimetres.

4. Flood Planning Event

The choice of events to provide the flood planning level in coastal areas is complex and is made increasingly difficult by the uncertainties associated with climate change. The specific selection of a combination of events that underpin the adoption of flood risk related planning controls is ultimately a policy decision.

At its simplest, a flood planning overlay indicates an area where flood risk should be a consideration in local government planning decisions. The response to these risks can be different depending on the proposed development, the expected land use and other factors and is ultimately a balance between competing outcomes. In Victoria, flood planning overlays, such as the Land Subject to Inundation Overlay (LSIO) are required to reflect the extent of the 1% AEP flood event. The risk posed by flooding has been traditionally considered as static. That is the, level of risk posed by a 1%AEP flood does not change over time. However, the effects of climate change, and particularly sea level rise mean that flood levels around the coast are expected to increase over time.

The Victorian Marine and Coastal Policy, Section 6, deals with the management of coastal hazard risk. Coastal hazard risk includes flooding and/or coastline recession. The intended outcomes of the policy are:

> *Coastal hazard risks and climate change impacts are understood and planned for.*
>
> *Communities, land managers and decision makers have the capability and capacity to respond to coastal hazards.*
>
> *The impacts of climate change on values of the marine and coastal environment are minimised.*
>
> *Adaptation is embedded as a core component of planning in the marine and coastal environment and is used to manage uncertainty and build resilience.*

The policy includes consideration of future planning for sea level rise at policy items 6.1, 6.2, 6.3, 6.4 and 6.7:

> *6.1 - Plan for sea level rise of not less than 0.8 metres by 2100, and allow for the combined effects of tides, storm surges, flooding, coastal processes and local conditions such as topography and geology, when assessing risks and coastal impacts associated with climate change.*
>
> *6.2 - Consider available local coastal hazard assessments and localised projections when planning for coastal hazard risks*
>
> *6.3 - Avoid development in identified areas that are vulnerable to coastal hazard risk from impacts such as erosion and flooding (both estuarine and coastal), inundation, landslips and landslides, and geotechnical risk*

> *6.4 - Consider and plan for how coastal hazard risks will change over time including from gradual increases in the sea level*
>
> *6.7 - Take a pathway approach to planning that:*
>
> > *a. assesses the full range of available adaptation actions in order of: non-intervention, avoid, nature-based methods, accommodate, retreat, and protect.*
> >
> > *b. assesses costs, effectiveness, benefits, impacts (direct, cumulative and synergistic) and path-dependency of adaptation actions.*

The amount of sea level rise to be planned for will be revised through the development of the Marine and Coastal Strategy. This document is not yet available for review.

The 2016 Victorian Floodplain Management Strategy (VFMS), provides guidance on the development of flood planning levels in the riverine space. Section 9 of this strategy provides guidance on climate change assessment. Section 13 provides guidance on flood planning policy and section 15 provides guidance on consideration of climate change risks including coastal flooding. For riverine flooding, it is recommended that the impact of climate change be assessed through a sensitivity-based approach that could be used to inform the adoption of freeboard levels. The requirements for coastal flooding are superseded by those in the Marine and Coastal Policy described above, noting that the policy objectives are virtually identical between the documents.

As far as we are aware, no planning scheme overlay in Victoria includes consideration of climate change for the derivation of flood planning zones or layers (UFZ, FO, LSIO and SBO) where the source of flooding is from riverine or pluvial sources only. Consideration of climate change risk factors have generally only been considered in the adoption of flood related planning controls in the coastal floodplain setting.

4.1 Technical guidance on the combination of riverine and ocean flood events

There are a number of technical approaches to determine the assessment of flooding at the coast. These include Australian Rainfall and Runoff 2019, Melbourne Water's Flood Mapping specification and the NSW Floodplain Risk Management Guide - Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways (OEH, 2015). These documents provide technical guidance on the implementation of a reasoned approach to the selection of scenarios in a flood study investigating the risks associated with coastal floodplains (including estuaries) both now and into the future.

4.1.1 ARR2019

Australian Rainfall and Runoff 2019, Book 5, chapter 5 provides a joint probability approach for the assessment of flood levels in areas where the design flood level can be caused by a number of combinations of storm tide and riverine flood events. The approach assumes that the ocean boundary levels are static and that the inland catchment rainfall is weakly associated with a coastal storm surge (low atmospheric pressure) event.

The method requires, for each scenario, that 49 model runs be undertaken using a range of tidal and riverine inputs from no flow up to the 0.05% AEP flow and the water level recorded for each event at locations of interest.

This approach would require significant additional effort to be adopted at Port Fairy. Given that water levels in Belfast Lough are derived from both flood volume and tidal level, due to storage considerations, it is also unclear if the method can be applied appropriately at Port Fairy. Other uncertainties such as event timing and the temporal distribution of rainfall may also need to be considered.

4.1.2 Melbourne Water Flood Mapping Specification

The Melbourne Water flood mapping specification (Melbourne Water, 2020) provides the guidance for the setting of tailwater levels for models that discharge directly to Port Philip or Westernport Bay, or to the open coast. These are detailed in Appendix 3 of the document. Melbourne Water adopts a fully dependent approach in that the tailwater level is considered to be at the same AEP as the riverine flood event.

This approach is consistent for climate change events and the impact of increased rainfall intensity is also included. Melbourne Water adopts an RCP 8.5 pathway for assessing the expected increase in rainfall intensity, which results in an increase in rainfall intensity of 19.5% for every AEP event at a 2100 planning horizon. If this fully dependent approach was adopted at Port Fairy, the flood levels would be based on a current day 0.5% AEP riverine flood and the 1.2m sea level rise case.

This approach is considered too conservative to be adopted for floodplain planning at Port Fairy. Although the events may not be fully independent, analysis of the historical events at Port Fairy, undertaken as part of the regional flood study (Water Technology 2008, 2010), indicated that the most likely storm residual was in the order of the 1 exceedance per year when a flood event was occurring. This is two orders of magnitude lower than that adopted by Melbourne Water. In previous versions of the flood mapping specification, Melbourne Water have adopted a 1% river and 10% ocean boundary for the joint probability assessment.

4.1.3 NSW Floodplain Risk Management Guide - Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways

This guideline developed by the NSW Office of Environment and Heritage (OEH) provides advice on the selection of appropriate joint probability events for coastal floodplain modelling to determine flood related planning control extents. The approach at any given site is based on the landform (open coast, coastal lagoon, estuary, etc) and the local wave and tide climate. For the derivation of flood planning controls, the guidance adopts an envelope approach:

Deriving design or planning flood levels in coastal waterways uses an approach involving the use of a series of catchment flood and oceanic inundation scenarios to produce an envelope of peak flood levels and velocities as these vary with location. Deriving the peak flood levels and velocities for a one per cent AEP event, may involve the testing of the following scenarios:

- *Design one per cent AEP oceanic inundation with five per cent AEP catchment flooding with coincident peaks, to test peak levels.*
- *Design five per cent AEP oceanic inundation with one per cent AEP catchment flooding with coincident peaks; to test peak levels.*
- *Coincidence of ISLW in indicative spring and neap tide cycle (Appendix C) with one per cent AEP catchment flooding to test peak velocities.*

The approach also recommends the use of dynamic ocean boundaries to properly determine the impact of changing tide levels on floodplain behaviour. For climate change scenarios it recommends that sea level rise be assessed by replacing the current day ocean levels with the sea level rise projections.

4.1.4 Other Victorian Projects

Victorian estuary floodplain studies have typically adopted the static 10% AEP tidal level as the downstream boundary condition for a 1% AEP riverine flood in the estuary. This approach was consistent with the advice in *Floodplain Management in Australia: Best Practice Principles and Guidelines* (SCARM, 2000).

The Bellarine Peninsula – Corio Bay Local Coastal Hazard Vulnerability Assessment adopted a 1% ocean event with 7 sea level rises cases (between 0 and 1.4 metres) with a 10% existing riverine flow hydrograph in the Barwon River. It was noted that the coincident timing of the peak flows in the Barwon River and the tidal level could impact the reported flood levels in Lake Connewarre by significant amounts (>100mm) with relatively small changes in event timing.

4.2 Approach adopted at Port Fairy

WRL was contacted to ascertain the reasoning behind the events modelled in the PFCHVA. They advised that these events were required by the project brief, as shown in Figure 7.

Table 1 - Required modelling scenarios

Current	2040	2070	2100	SLR (m)		Tide[1]		Wave and storm surge (AEP %)		Catchment flows (AEP%)[2]
Likely	Virtually certain			0	+	MHWS-10	+	2%	+	10%
About as likely as not	Likely	Virtually certain		0.2	+	MHWS-10	+	2%	+	10%
Unlikely	About as likely as not	Likely	Virtually certain	0.4	+	MHWS-10	+	1%	+	10%
	Exceptionally Unlikely.	About as likely as not	Likely	0.5	+	MHWS-10	+	1%	+	10%
		Exceptionally Unlikely	About as likely as not	0.8	+	MHWS-10	+	1%	+	5%
			Unlikely	1.2	+	MHWS-10	+	1%	+	5%
			Exceptionally unlikely	1.5	+	MHWS-10	+	0.50%	+	2%

– Note 1. MHWS-10 indicates a level that is exceeded by 10% of the high tides.

– Note 2. Where applicable. In some cased catchment flows need not be considered.

Figure 7 – Required modelling scenarios PFCHVA

Additional advice from WRL was that the adoption of the 5% flood level for the sea level rise cases of 0.8 and 1.2 metres was to allow for some increase in the intensity of rainfall falling in the inland catchment as a result of climate change.

Based on ARR2019, under an RCP 8.5 scenario, the expected rainfall intensity increase at 2100 would be approximately 19% above current conditions. For the 48-hour rainfall event, the Bureau of Meteorology shows that the average rainfall depth in the Moyne River catchment at Spencers Road is 83.5mm for the 10% AEP rainfall event (10-year ARI). At the same location, the 5% AEP (20-year ARI) rainfall depth is 101 mm. This is an increase of approximately 20%. As such, the adoption of the existing 5% AEP at the 2080 and 2100 timeframes is indicative of increased rainfall intensity associated with a future 10% AEP storm as a result of climate change.

It is noted that adopting the 5% AEP storm event at the 2100 planning horizon would be consistent with the approach recommended for enveloping in the NSW Flood Risk Management Guide (OEH 2015).

4.3 Impact on Planning Layers

To assess the number of properties that would be impacted by the overlays, indicative planning layers were developed for the for the Floodway Overlay (FO) and the Land Subject to Inundation Overlay (LSIO) have been based on the scenarios described in Section 3.5. The floodway overlay has been determined from the same envelope of cases as the LSIO. The definition of the floodway overlay is based on the GHCMA guidelines (GHCMA, 2013) and requires that the area have a depth of greater than 0.5m or a velocity by depth product of greater than 0.4. The LSIO overlay is the flood extent, with the area of FO removed.

The number of properties impacted in each scenario modelled for each overlay and the total number of properties impacted by the overlay has been calculated is shown in Table 4. This has also been assessed against the previously exhibited overlays, which used a 1.2m SLR case with a 5% riverine and 1% ocean boundary. Note that the new overlay extents have been shifted in accordance with Section 5 of this report.

Table 4 – Properties included in potential overlays

Scenario	Properties in FO	Properties in LSIO	Total Properties
Exhibited Overlay (1.2m SLR, 1% Ocean-5% River)	819	820	1,041
A (0.4m SLR, 1%-10%)	442	587	739
B (0.4m SLR, 1%-5%)	482	568	748
C (0.8m SLR, 1%-10%)	579	529	819
D (0.8m SLR, 1%-5%)	622	447	833
E (1.2m SLR, 1%-10%)	860	550	1,065
F (1.2m SLR, 1%-5%)	893	544	1,089

There are a large number of properties that appear in both overlays. It should also be noted that the previously exhibited overlay adopted an alternate method for the determination of the Floodway Overlay. The previous method would result in less area being considered FO.

4.4 Recommended Approach

Based on the assessment above, it is recommended to adopt the 1.2m sea level rise case adopting an envelope of the maximum flood extent from the 1% River and 5% Ocean AEP events and the 5% River and 1% Ocean AEP events as the planning flood extent defined by the LSIO.

This is consistent with the approach recommended by the NSW OEH guideline. It is the recommended approach for the following reasons:

- The approach provides a reasonable upper limit for inundation as a result of sea level rise, in combination with a riverine flood event.
- For areas that are not currently developed, the approach will provide an indication of areas that will be subject to inundation under future climatic conditions.
- The resultant mapping provides an appropriate extent for triggering the consideration of present day and future flood risk in floodplain development decisions. It does not necessarily restrict the setting of floor levels to account for the estimated maximum 1%AEP flood level for the adopted future sea level scenario across the entire extent of the floodplain.
- Moyne Shire and GHCMA should consider a Local Floodplain Development Plan to define an adaptive approach to planning requirements for existing and new land parcels in the

LSIO and FO areas. Such a progressive approach will be consistent with the new Marine and Coastal Strategy.

- The level of the maximum 0.8m SLR cases plus a 300mm freeboard level is unlikely to provide protection against flood levels likely to occur in the area when sea level rise exceeds the 0.8m threshold, noting that the latest IPCC report (Sept. 2019) for the Oceans and Cryosphere has revised upward the projected global average increase in sea level to 1.1 metres by 2100.

The floodway overlay has been determined from the same envelope of flood scenarios as the LSIO. The revised floodway overlay map has been delineated according to the GHCMA guidelines (GHCMA, 2013) and requires that the area have a depth of 0.5m or more and/or a velocity by depth product of 0.4 metres squared per second or more.

5. Datasets and Mapping

5.1 Mapping Shift

The GHCMA identified an error in the georeferencing of the mapped flood extents. Flood results are extracted directly from the model results. The following checks were performed to assess if there was a systemic issue in the mapping provided from previous studies:

- The model grids were checked against the previous models and confirmed to be in the same spatial location
- The results from the modelling were compared to GIS results from WRL and were found to have effectively identical extents
- The model outputs were compared to high resolution land surface data to identify if the flood levels were nominally lower than the surrounding topography
- Terrain features were checked against orthorectified aerial photos to identify if features were properly captured.

It was identified that there appeared to be a systemic shift in the model results. This is believed to have been an artefact in the modelling adopted from the previous studies. This can occur when topographic data is sampled to develop model grids and small shifts are introduced based on how that sampling occurs. This is because of the way the data is sampled and read, where the value of the cell could represent the physical location at the centre, bottom left or top right of an individual grid cell.

To assess the potential shift, tests were undertaken on results from the 0.8mSLR, 1% River 5% Ocean case at a number of locations, chosen to identify if a shift had occurred. These locations are shown in Figure 7 to Figure 10, with the sections in Figures 11 to 14. At each location, the raw model outputs are shown, along with those outputs shifted west and south by 5m and 10m in both directions. The 5m shift was chosen as it is half the grid cell size used in the model and the 10m value is a whole grid cell.

In each of the section figures, the dark blue line represents the land surface, and the other colour represents the expected water surface elevation.

Figure 7 – Korongah Road Section

Figure 8 – Gipps Street Section

Figure 9 – Battery Lane Section

Figure 10 – Murray Brook Section

Figure 11 – Korongah Road Mapping Shift Assessment

Figure 12 – Gipps Street Mapping Shift Assessment

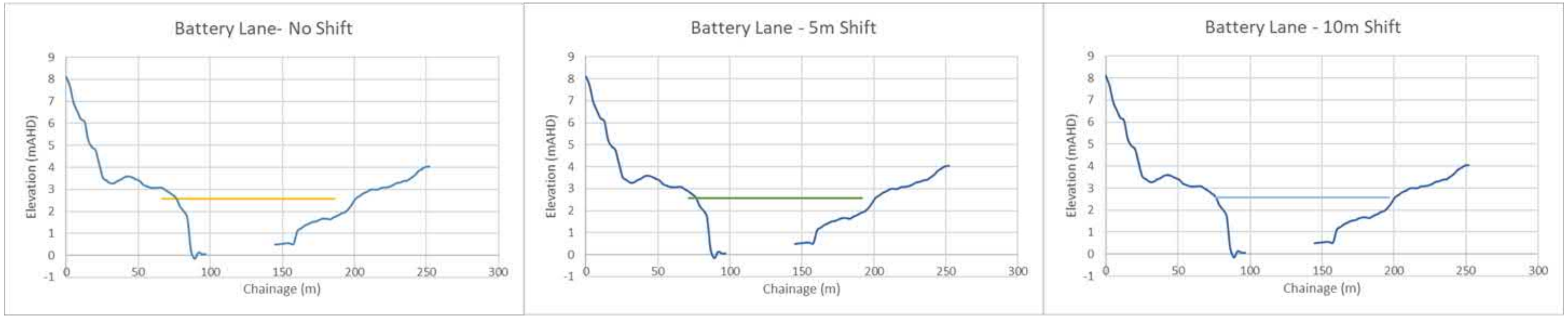


Figure 13 – Battery Lane Mapping Shift Assessment

Figure 14 – Murray Brook Mapping Shift Assessment

From the figures presented above, it is clear that shifting the data by 10m to the south and west provides for a better match to the high-resolution topographic data. The shift does not represent any error in the modelling and is a mapping display issue only.

5.2 Datasets Provided

As a result of the shift identified in the mapping in section 5.1, all previous data outputs for the Translation of the Port Fairy Coastal Hazard Assessment project have been shifted and provided with this report. The additional scenarios run as part of the extension undertaken for this report have also been provided with this data shift.

For this modelling in this assessment, both the individual model runs and the envelope approaches have been provided in digital GIS format. An LSIO and FO map for each envelope condition has also been provided in digital format.

5.3 Overlay changes

For the preferred overlay, we have assessed the properties where the previously exhibited FO or LSIO has changed. Three changes are possible for a property:

- A property previously indicated as flooded in an overlay is no longer flooded
- A property previously indicated as not flooded is now included in the overlay (designated as flooded)
- A property has shifted from FO to LSIO or vice-versa.

There are a number of properties which are covered by both the FO and LSIO. These properties are only included in the change count if they shift to be covered by a single overlay only. The changes are shown in Table 5

Table 5 – Changes in number of properties under Planning Controls

Change	Number of Properties
Not flooded to FO	38
FO to not flooded	10
FO to LSIO only	26
Not flooded to LSIO	71
LSIO to not flooded	50
LSIO to FO only	307

6. Conclusions and Recommendations

The assessment undertaken as part of this project has included review of the historical flood and coastal studies at Port Fairy and included additional analysis of potential flooding for the purpose of developing planning control maps that account for the likely change in risk as sea level rises. It is concluded that:

- The 2008 Port Fairy Regional Flood Study provides the best estimation of catchment inflows at Port Fairy. However, the adoption of static tide levels may increase flood levels in Belfast Lough.
- Both regional flood study reports do not take into account the elevated sea state along the south facing coastline, particularly the South Beach/Ocean Drive/Southwest Passage areas.
- The Port Fairy Coastal Hazard Vulnerability Assessment remains the definitive assessment of coastal process at Port Fairy. The project adopts the riverine inputs from the regional flood study and appropriately accounts for additional coastal processes such as wave overtopping and setup.
- The Translation of the Port Fairy Coastal Hazard Assessment project is effectively an extension to the PFCHVA. It includes some improvements to the model to account for mitigation works in Reedy Creek and extension of the model westward along the coastline, but did not generate additional ocean information. The modelling ensured that all scenarios envisaged in the PFCHVA were modelled using dynamic ocean boundaries and wave overtopping, which are important to flood levels in Belfast Lough and at Ocean Drive.
- Additional assessment was undertaken in this project to provide an envelope of flooding from both river and ocean dominated events to ensure the drivers of flood risk are fully understood.
- The adoption of the 1.2m SLR 1%/5% envelope flooding is recommended for the planning scheme LSIO layer. This approach is consistent with that recommended by the NSW OEH guideline for coastal flood risk modelling for the purpose of delineating flood controls in planning schemes
- A mapping shift of the model results of 10m south and west from those presented in previous studies is required to better match the topography of the land. This shift has been applied to all datasets provided as part of this project, including the proposed overlays.

It is recommended that the GHCMA and Council consider the following items for the development of planning controls in Port Fairy.

- The development of a local floodplain development plan to define the floor level and other planning controls for both existing and developing areas of Port Fairy, noting that these controls may be different.
- Future township expansion is not recommended in areas that are inside the 2100 flood envelope.

7. References

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia (Geoscience Australia), 2019

Cardno (2019), Translation of the Port Fairy Coastal Hazard Assessment, prepared for Moyne Shire Council, Melbourne, VIC

CSIRO (2000), *Floodplain management in Australia : best practice principles and guidelines,* Standing Committee on Agriculture and Resource Management (SCARM), Collingwood, VIC

Glenelg Hopkins Catchment Management Authority (GHCMA) (2013), *Flood delineation for planning scheme maps, Standard Approach*, GHCMA, Hamilton, VIC.

Melbourne Water (2020), *Interim AM STA 6200 Flood Mapping Projects Specification*, Melbourne Water Corporation, Melbourne, VIC

McInnes, K.L., Macadam, I. and O'Grady, J., (2009), *The Effect of Climate Change on Extreme Sea Levels along Victoria's Coast,* CSIRO, Aspendale, VIC

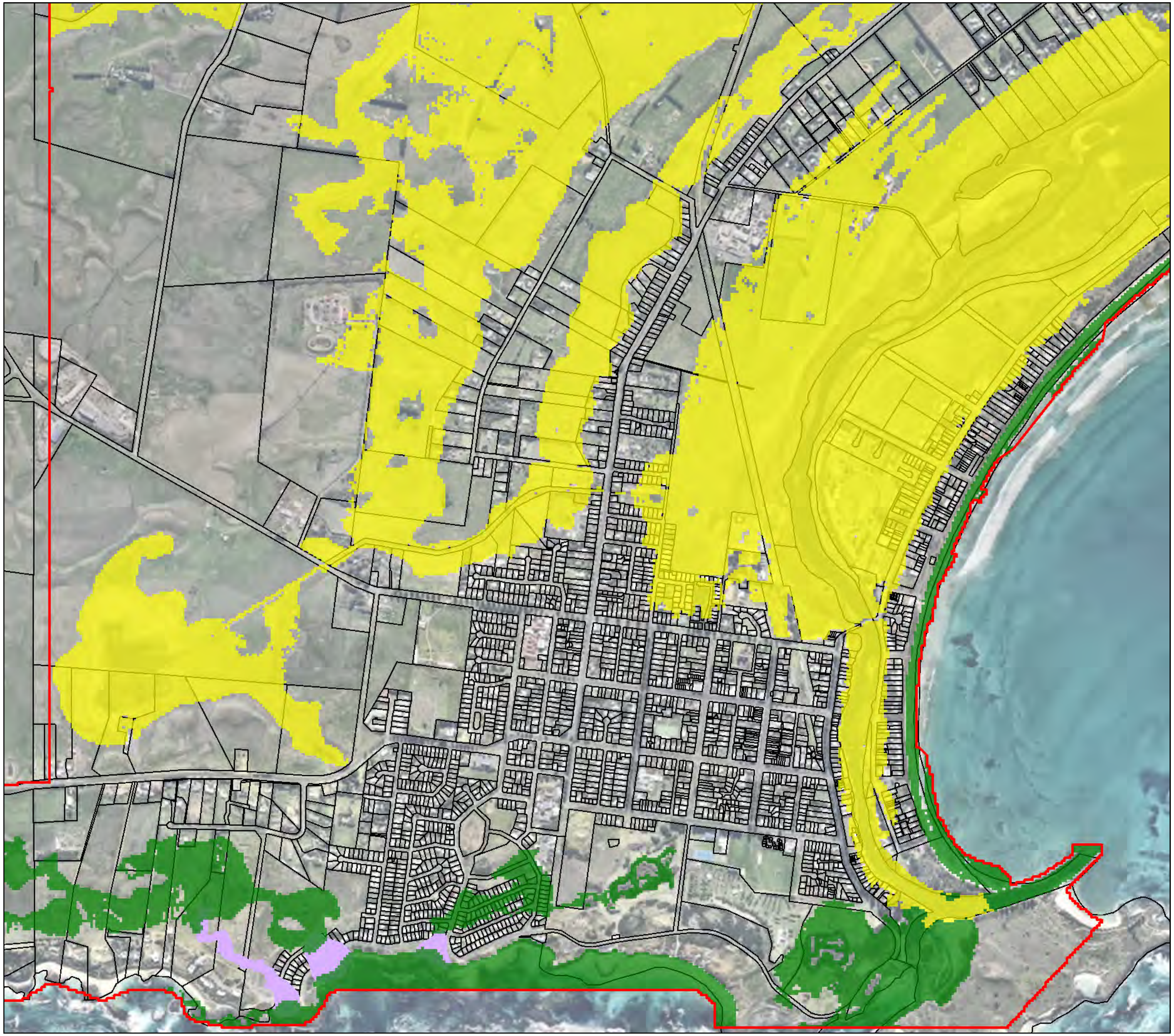
NSW Office of Environment and Heritage (OEH) (2015), *Floodplain Risk Management Guide - Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways*, State of New South Wales and Office of Environment and Heritage, Sydney, NSW

Water Technology (2008), *Port Fairy Regional Flood Study*, prepared for the Glenelg Hopkins Catchment Management Authority, Melbourne, VIC

Water Technology (2010), *Port Fairy Regional Flood Study Addendum – Sea Level Rise Modelling,* prepared for the Glenelg Hopkins Catchment Management Authority, Melbourne, VIC

University of NSW Water Resource Laboratory (WRL) (2012), *Port Fairy Coastal Hazard Vulnerability Assessment*, prepared for Moyne Shire Council, Sydney, NSW

Appendix A Flood Maps



Port Fairy Township Coastal Hazard Assessment

Critical Flooding Mechanism

0.4m SLR Scenario
100yr River + 10yr Ocean
10yr River + 100yr Ocean

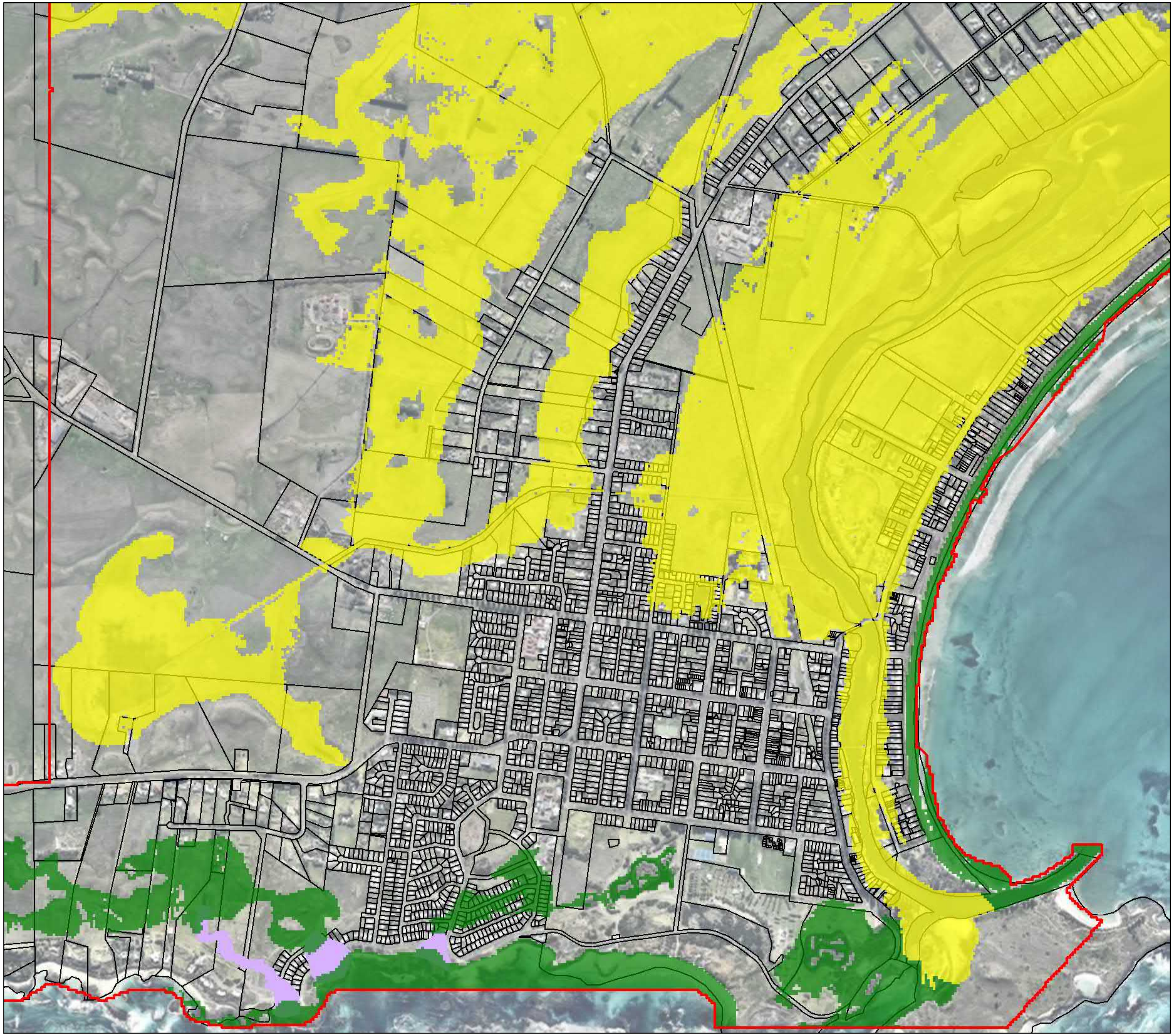
Critical Mechanism
- River
- Ocean
- Hydraulic Model Extent
- Swash Zone

N

0 500
metres

Cardno

Map Produced by Cardno Water & Environment
Date: 27/07/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:Moyne_2021_Updates.wor



Port Fairy Township Coastal Hazard Assessment

Critical Flooding Mechanism

0.4m SLR Scenario
100yr River + 20yr Ocean
20yr River + 100yr Ocean

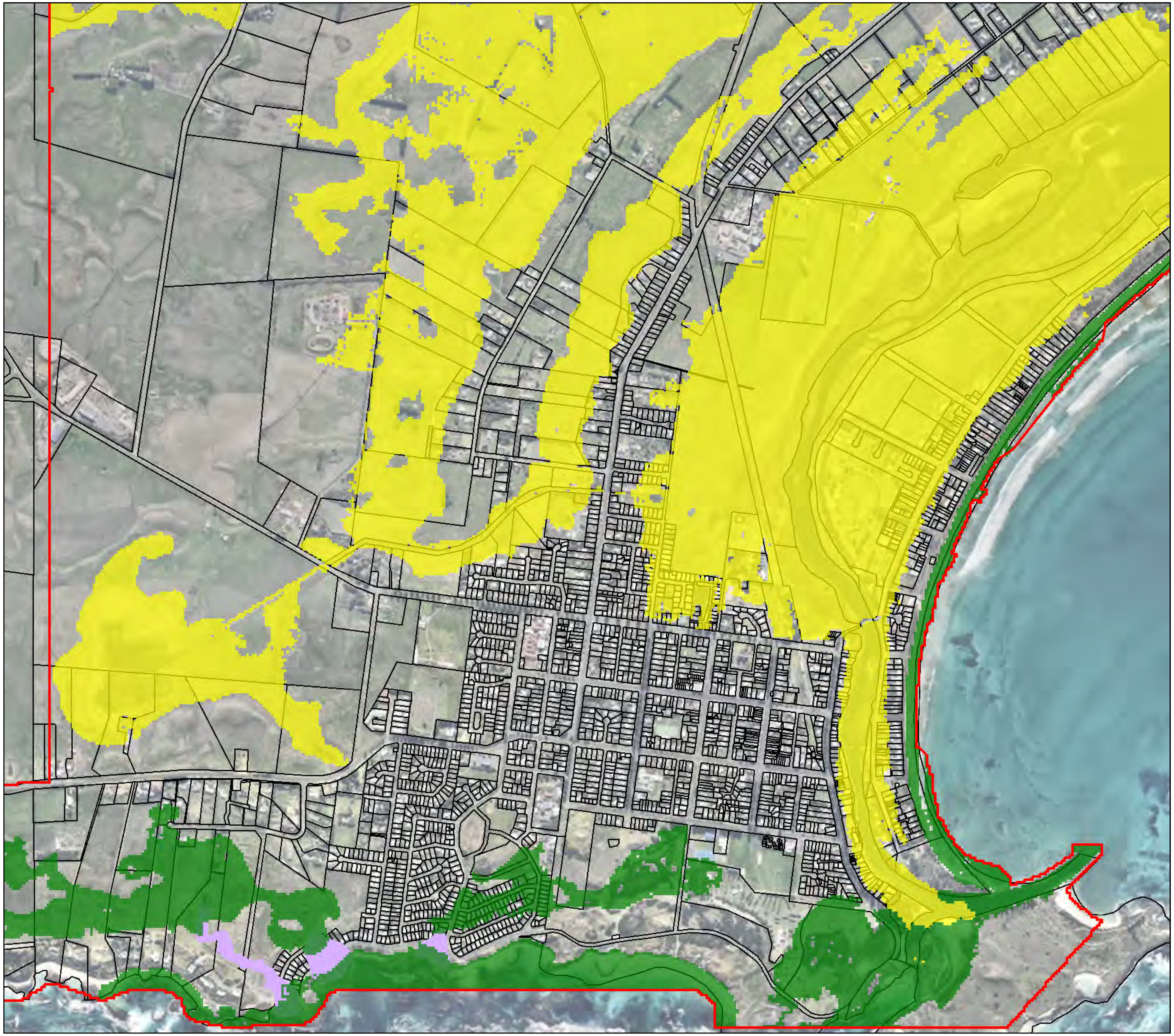
Critical Mechanism
- River
- Ocean
- Hydraulic Model Extent
- Swash Zone

N

0 500
metres

Cardno

Map Produced by Cardno Water & Environment
Date: 12/08/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:Moyne_2021_Updates.wor



Port Fairy Township Coastal Hazard Assessment

Critical Flooding Mechanism

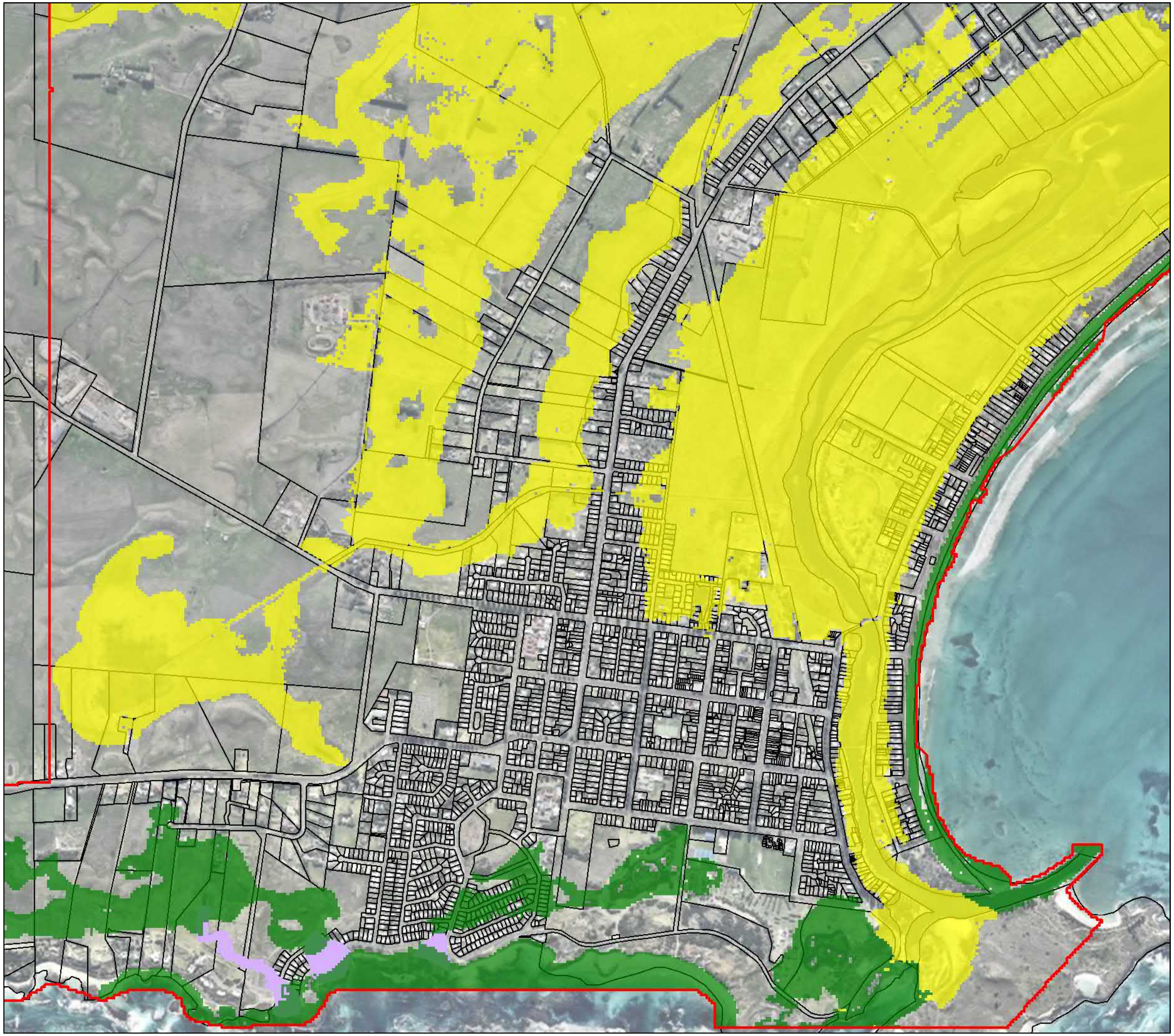
0.8m SLR Scenario
100yr River + 10yr Ocean
10yr River + 100yr Ocean

Critical Mechanism

- River
- Ocean
- Hydraulic Model Extent
- Swash Zone

Cardno

Map Produced by Cardno Water & Environment
Date: 27/07/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:Moyne_2021_Updates.wor



Port Fairy Township Coastal Hazard Assessment

Critical Flooding Mechanism

0.8m SLR Scenario
100yr River + 20yr Ocean
20yr River + 100yr Ocean

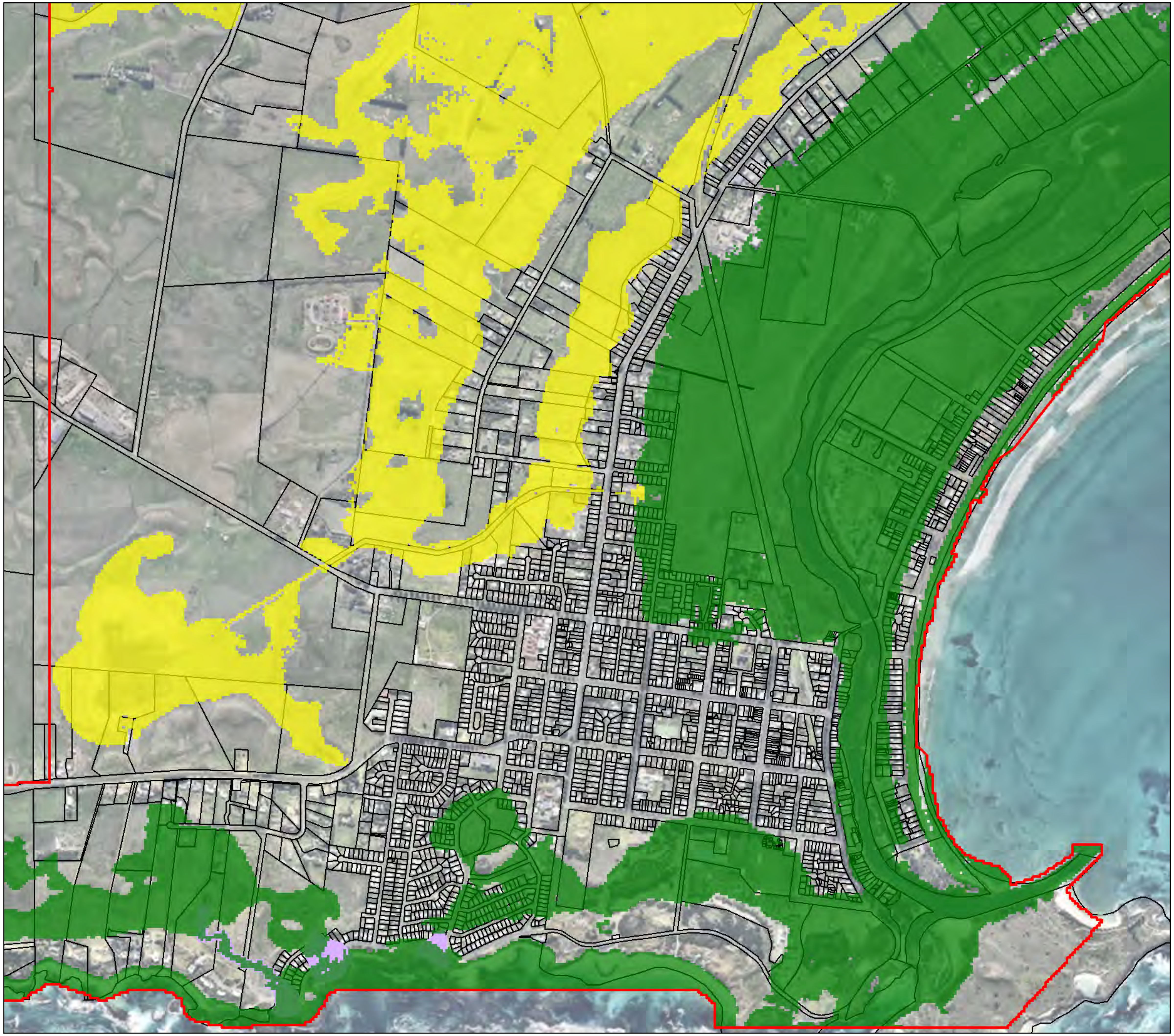
Critical Mechanism
- River
- Ocean
- Hydraulic Model Extent
- Swash Zone

N

0 500
metres

Cardno

Map Produced by Cardno Water & Environment
Date: 18/08/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:Moyne_2021_Updates.wor



Port Fairy Township Coastal Hazard Assessment

Critical Flooding Mechanism

1.2m SLR Scenario
100yr River + 10yr Ocean
10yr River + 100yr Ocean

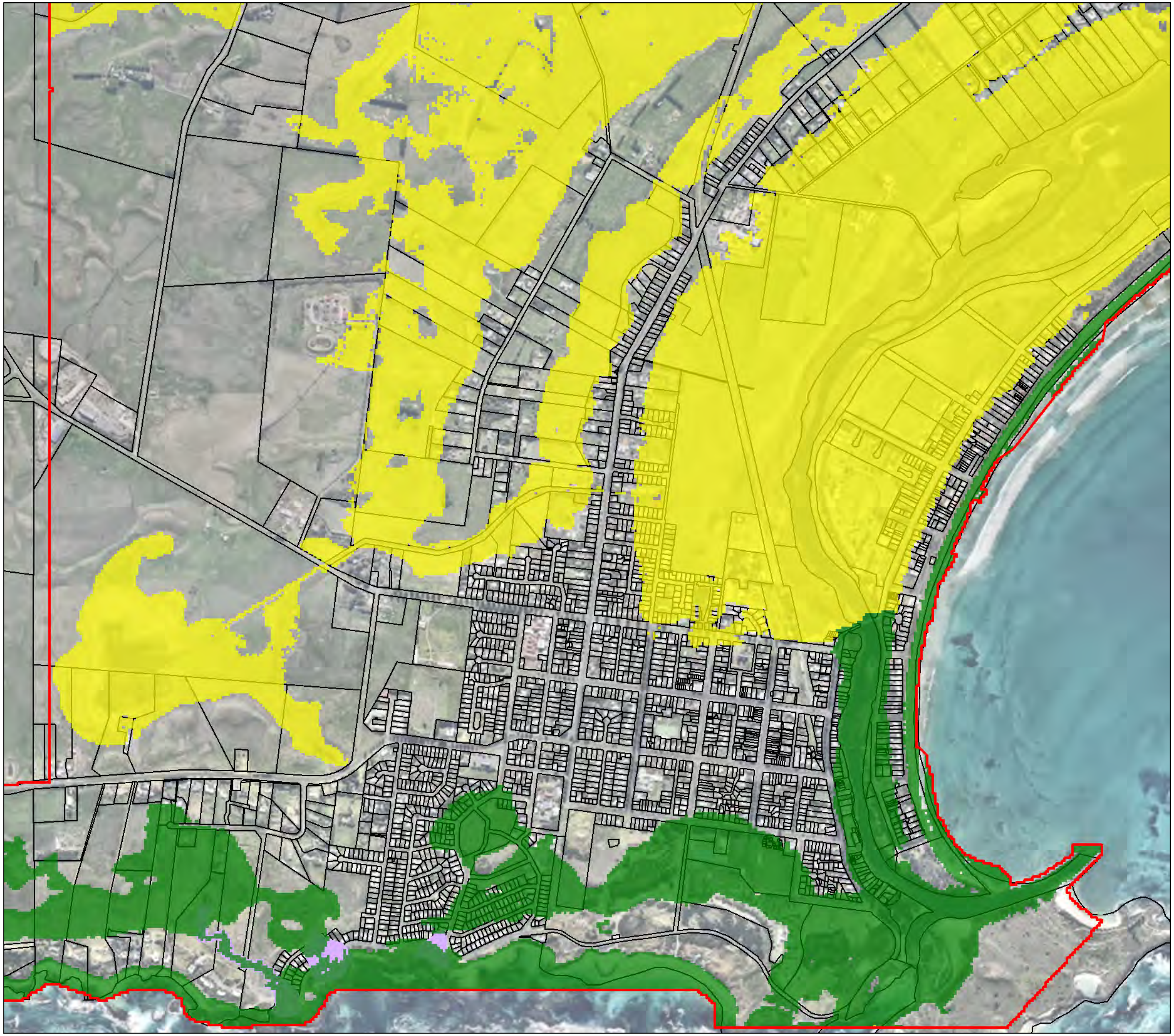
Critical Mechanism
- River
- Ocean
- Hydraulic Model Extent
- Swash Zone

N

0 500
metres

Cardno

Map Produced by Cardno Water & Environment
Date: 27/07/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:Moyne_2021_Updates.wor



Port Fairy Township Coastal Hazard Assessment

Critical Flooding Mechanism

1.2m SLR Scenario
100yr River + 20yr Ocean
20yr River + 100yr Ocean

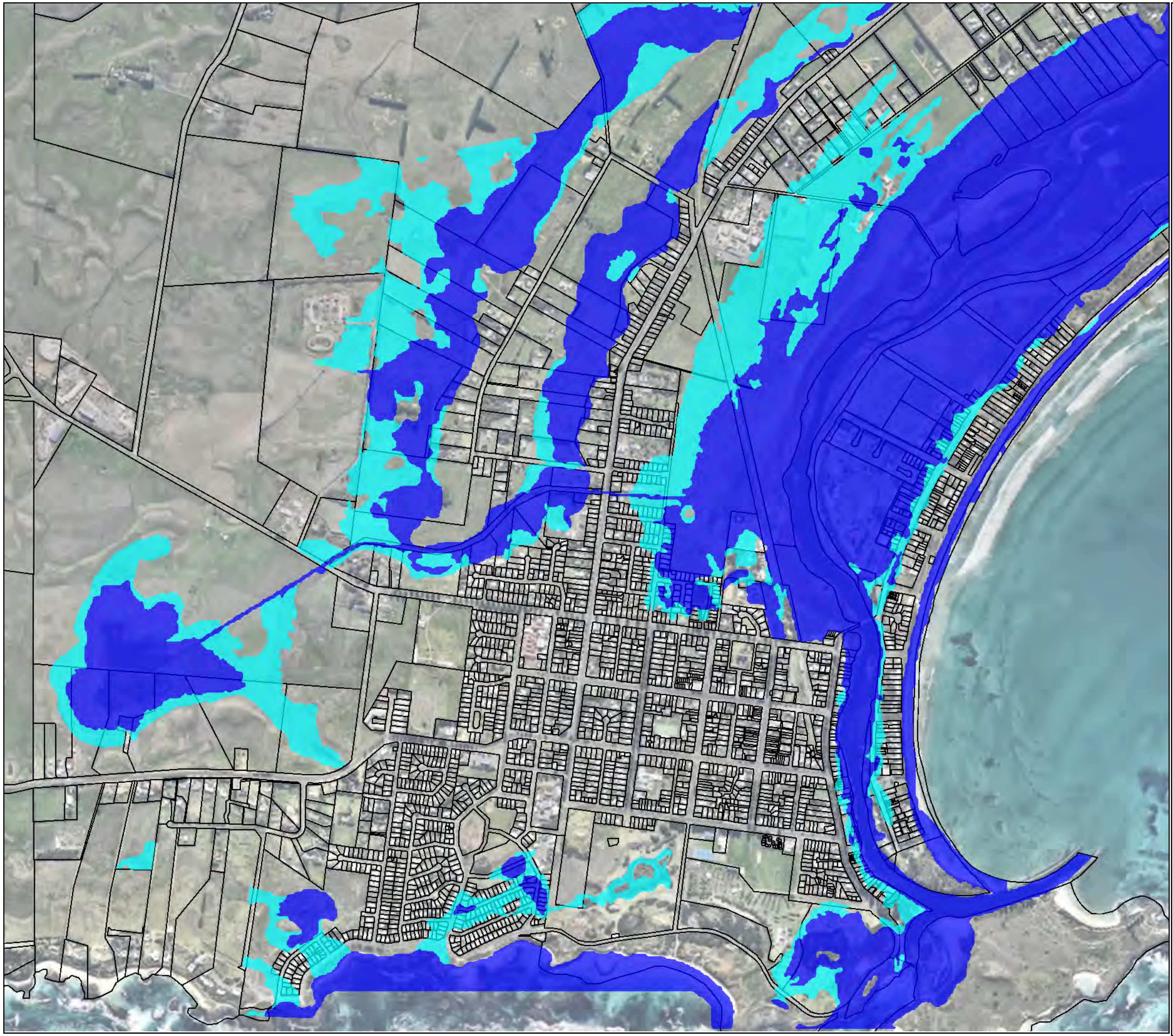
Critical Mechanism
River
Ocean
Hydraulic Model Extent
Swash Zone

N

0 500
metres

Cardno

Map Produced by Cardno Water & Environment
Date: 27/07/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:Moyne_2021_Updates.wor



Port Fairy Township Coastal Hazard Assessment

Flood Overlays

0.4m SLR Scenario
100yr River + 10yr Ocean
10yr River + 100yr Ocean

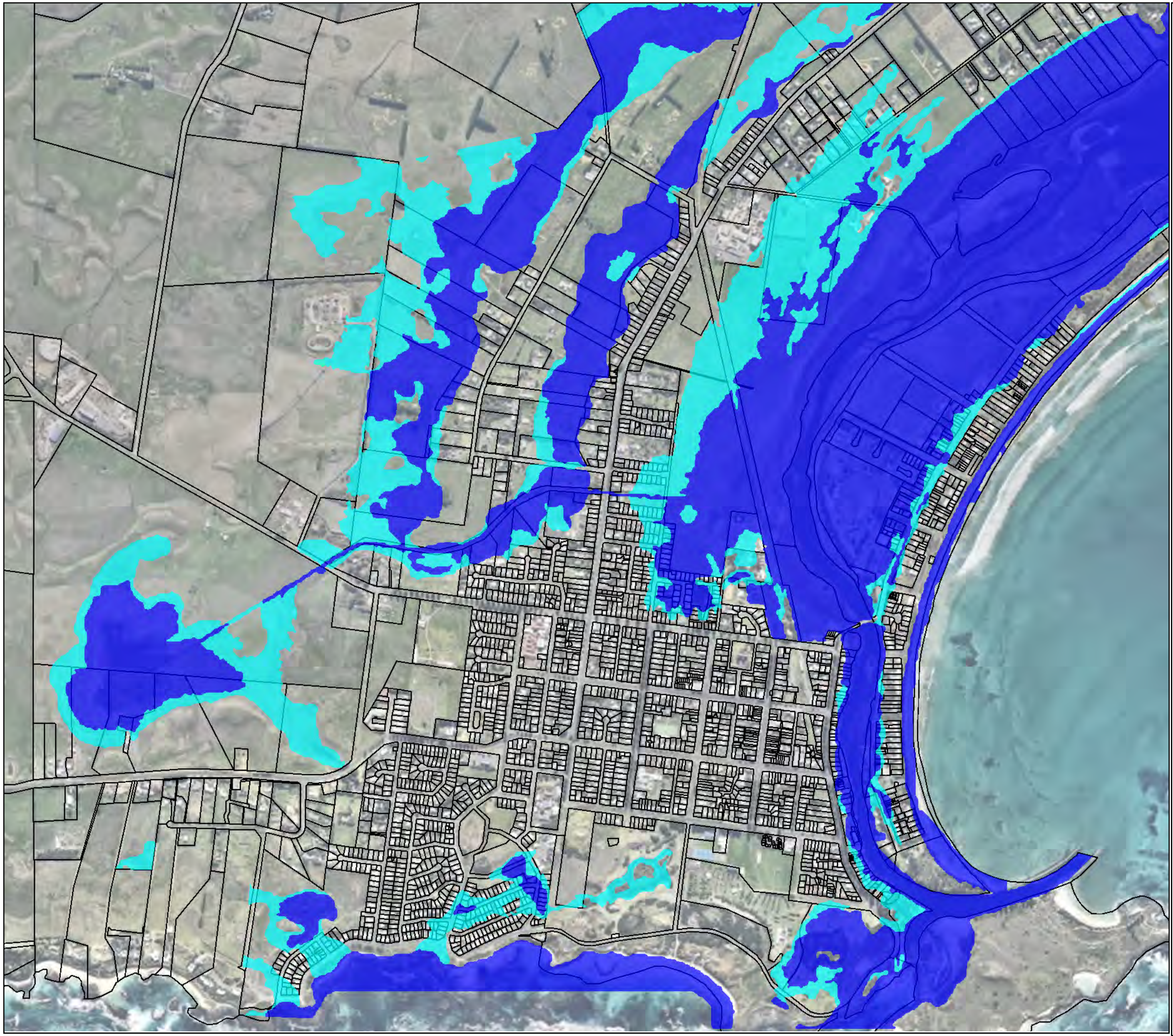
Flood Overlay (FO)
Land Subject To Inundation (LSIO)

N

0 500
metres

Cardno

Map Produced by Cardno Water & Environment
Date: 20/07/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:Moyne_2021_Updates.wor



Port Fairy Township Coastal Hazard Assessment

Flood Overlays

0.4m SLR Scenario
100yr River + 20yr Ocean
20yr River + 100yr Ocean

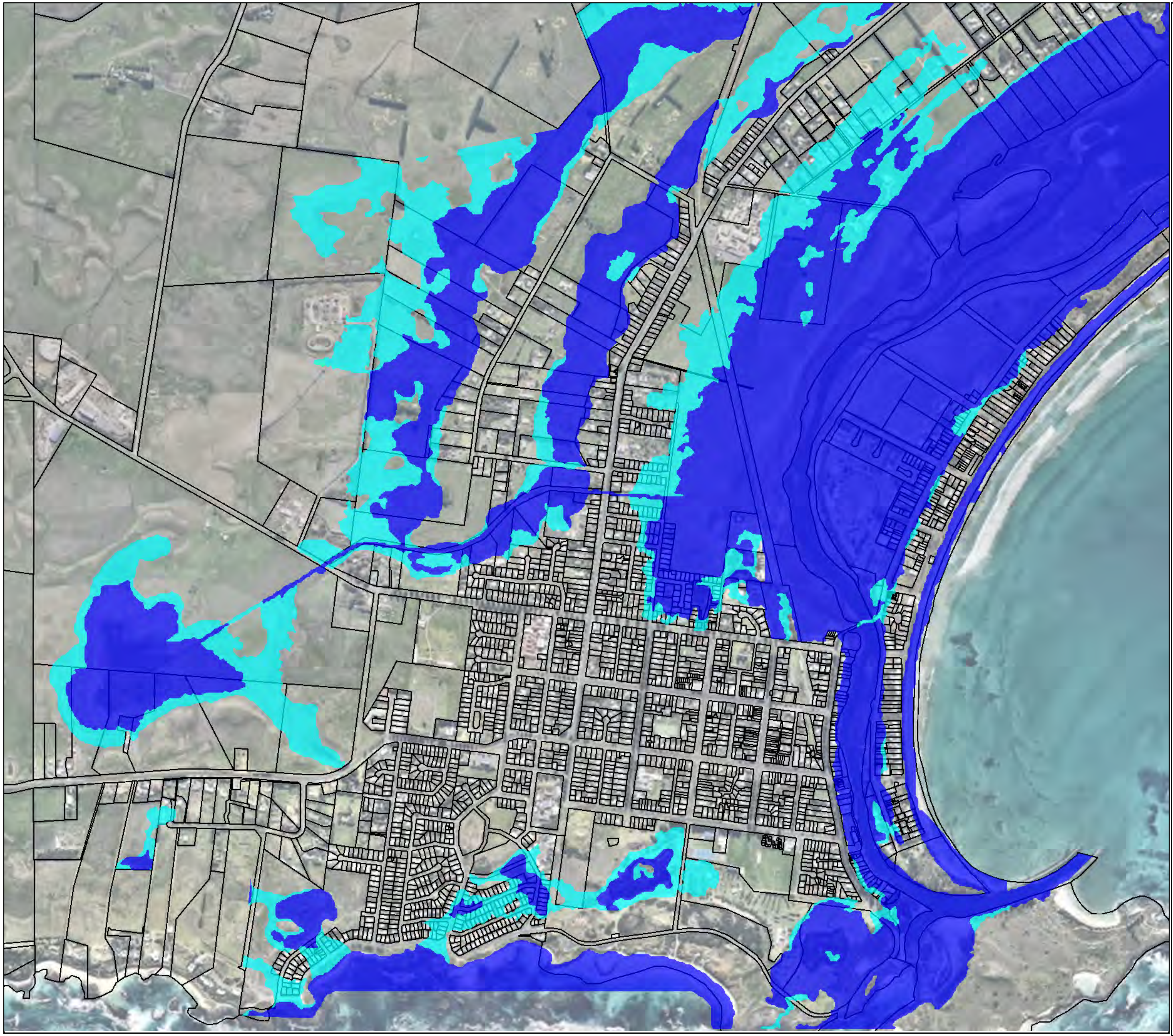
Flood Overlay (FO)
Land Subject To Inundation (LSIO)

N

0 500
metres

Cardno

Map Produced by Cardno Water & Environment
Date: 20/07/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:Moyne_2021_Updates.wor



Port Fairy Township Coastal Hazard Assessment

Flood Overlays

0.8m SLR Scenario
100yr River + 10yr Ocean
10yr River + 100yr Ocean

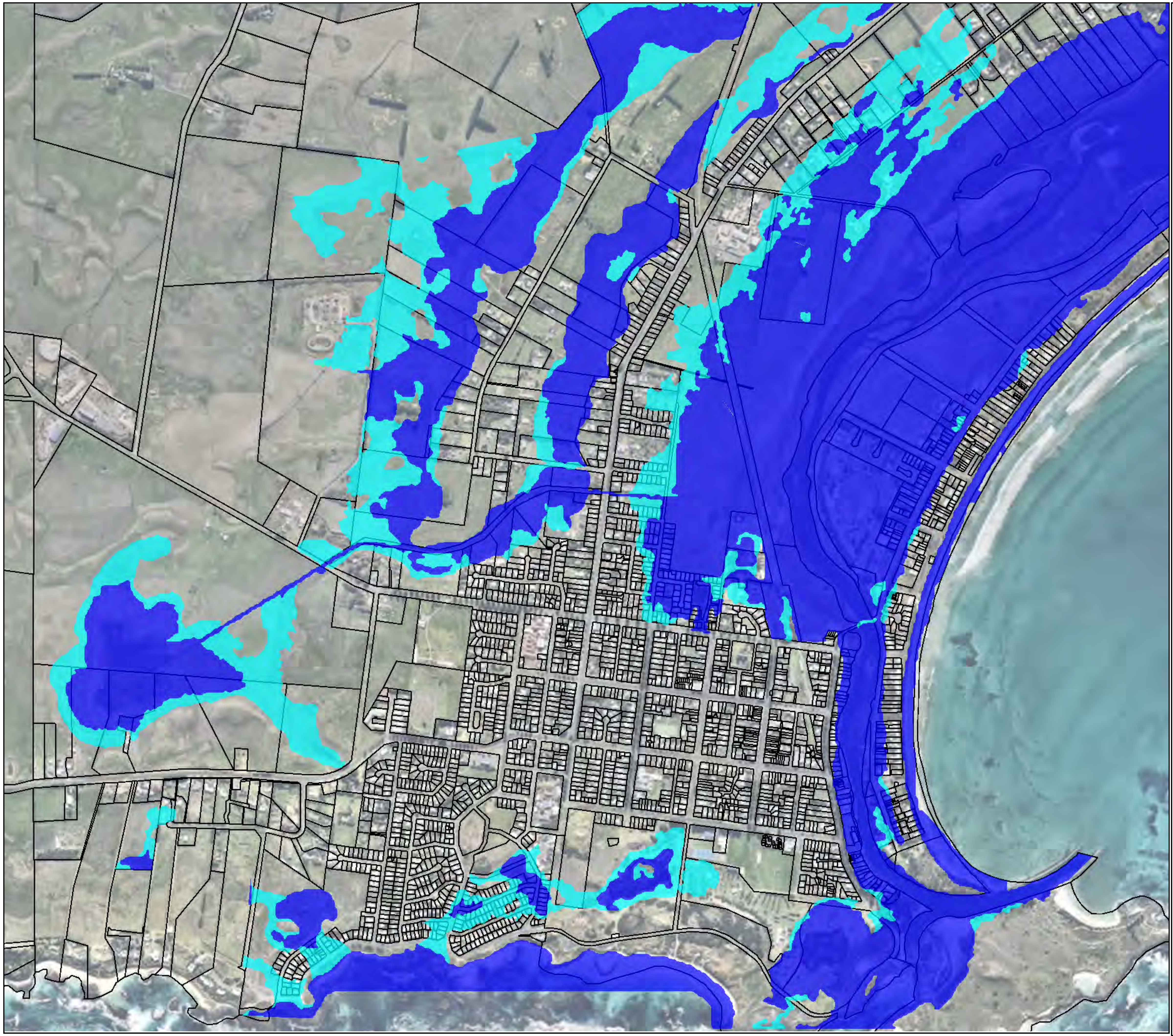
Flood Overlay (FO)
Land Subject To Inundation (LSIO)

N

0 500
metres

Cardno

Map Produced by Cardno Water & Environment
Date: 20/07/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:Moyne_2021_Updates.wor



Port Fairy Township Coastal Hazard Assessment

Flood Overlays

0.8m SLR Scenario
100yr River + 20yr Ocean
20yr River + 100yr Ocean

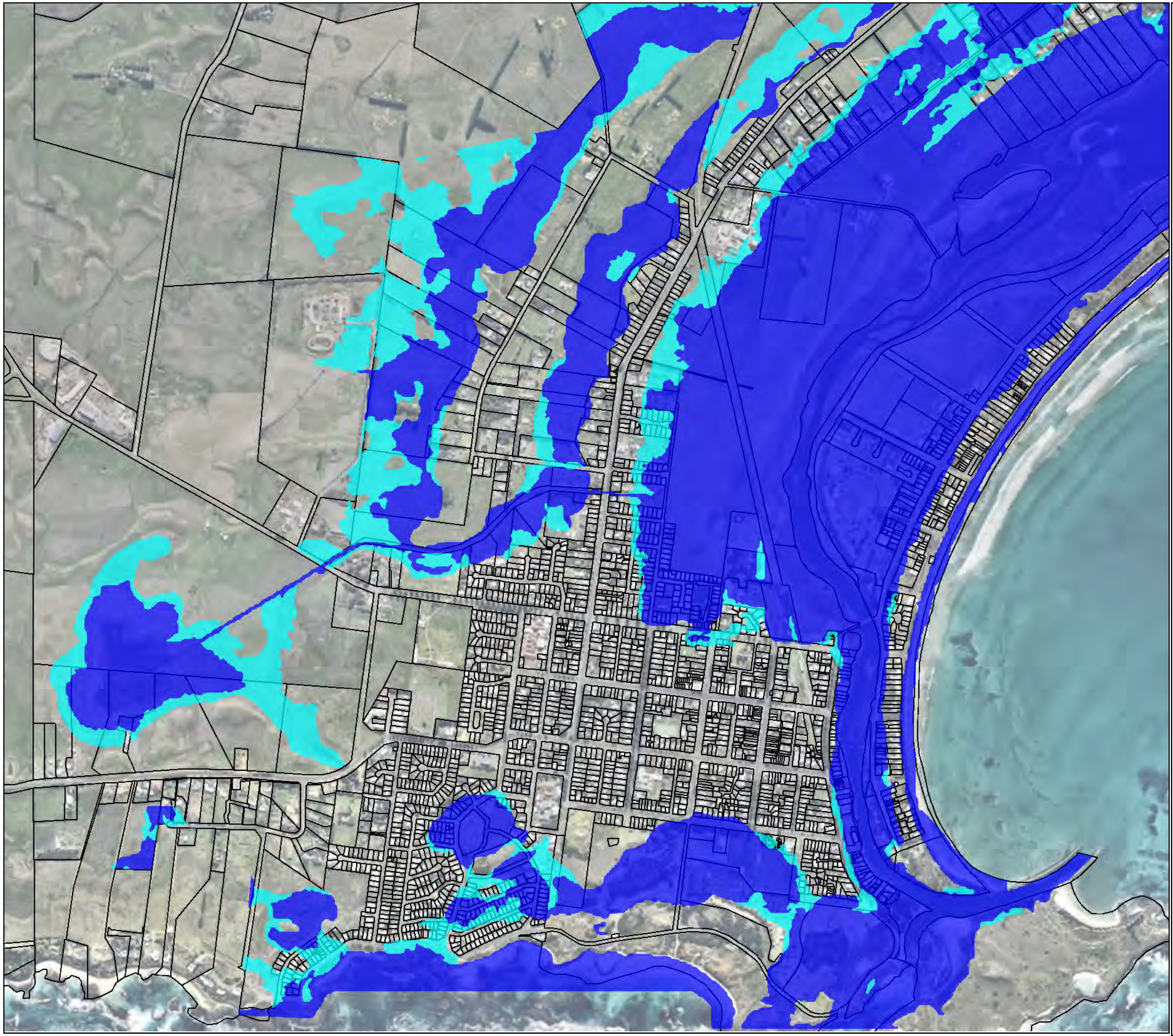
Flood Overlay (FO)
Land Subject To Inundation (LSIO)

N

0 500
metres

Cardno

Map Produced by Cardno Water & Environment
Date: 20/07/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:Moyne_2021_Updates.wor



Port Fairy Township Coastal Hazard Assessment

Flood Overlays

1.2m SLR Scenario
100yr River + 10yr Ocean
10yr River + 100yr Ocean

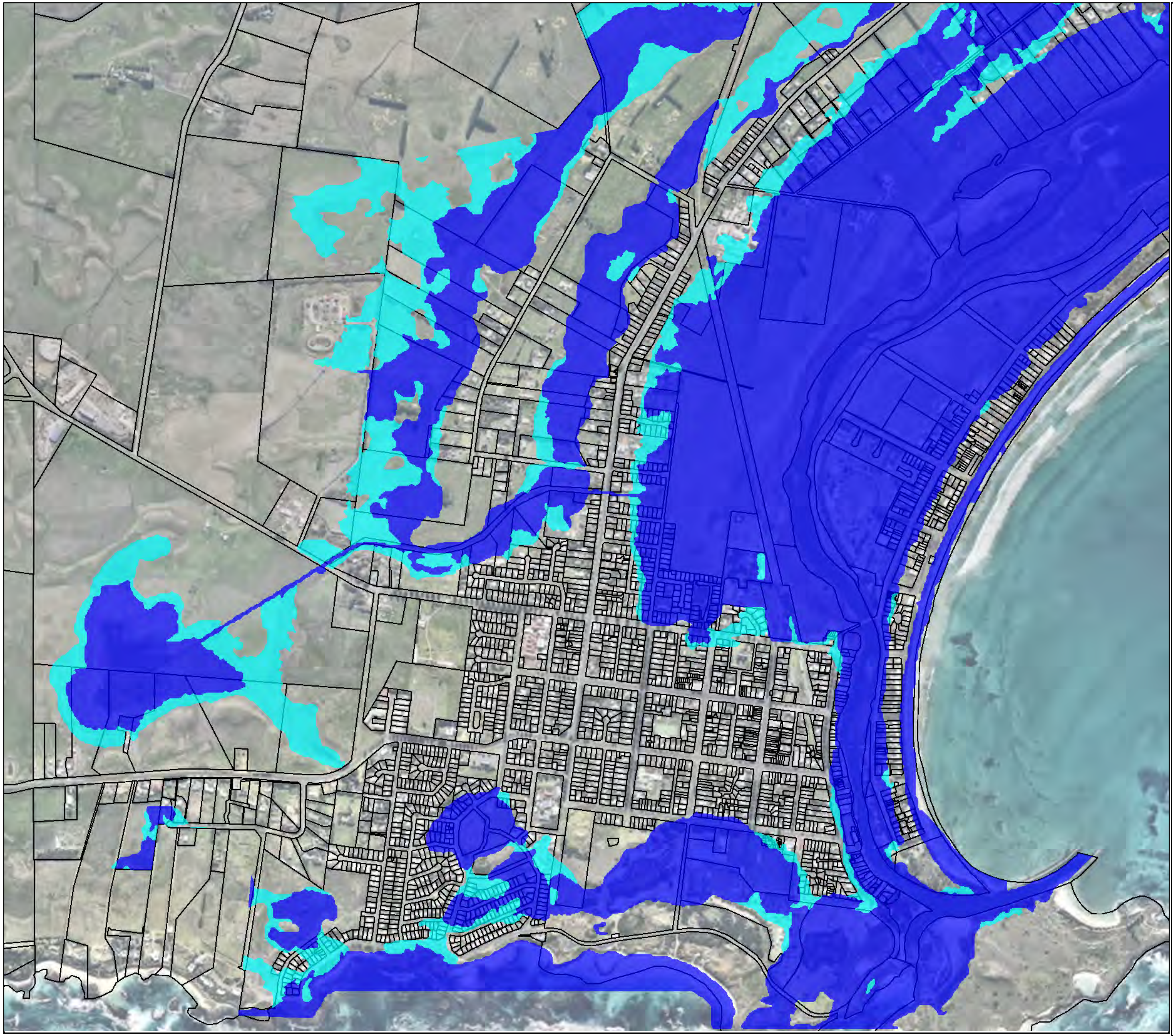
Flood Overlay (FO)
Land Subject To Inundation (LSIO)

N

0 500
metres

Cardno

Map Produced by Cardno Water & Environment
Date: 20/07/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:Moyne_2021_Updates.wor



Port Fairy Township Coastal Hazard Assessment

Flood Overlays

1.2m SLR Scenario
100yr River + 20yr Ocean
20yr River + 100yr Ocean

Flood Overlay (FO)

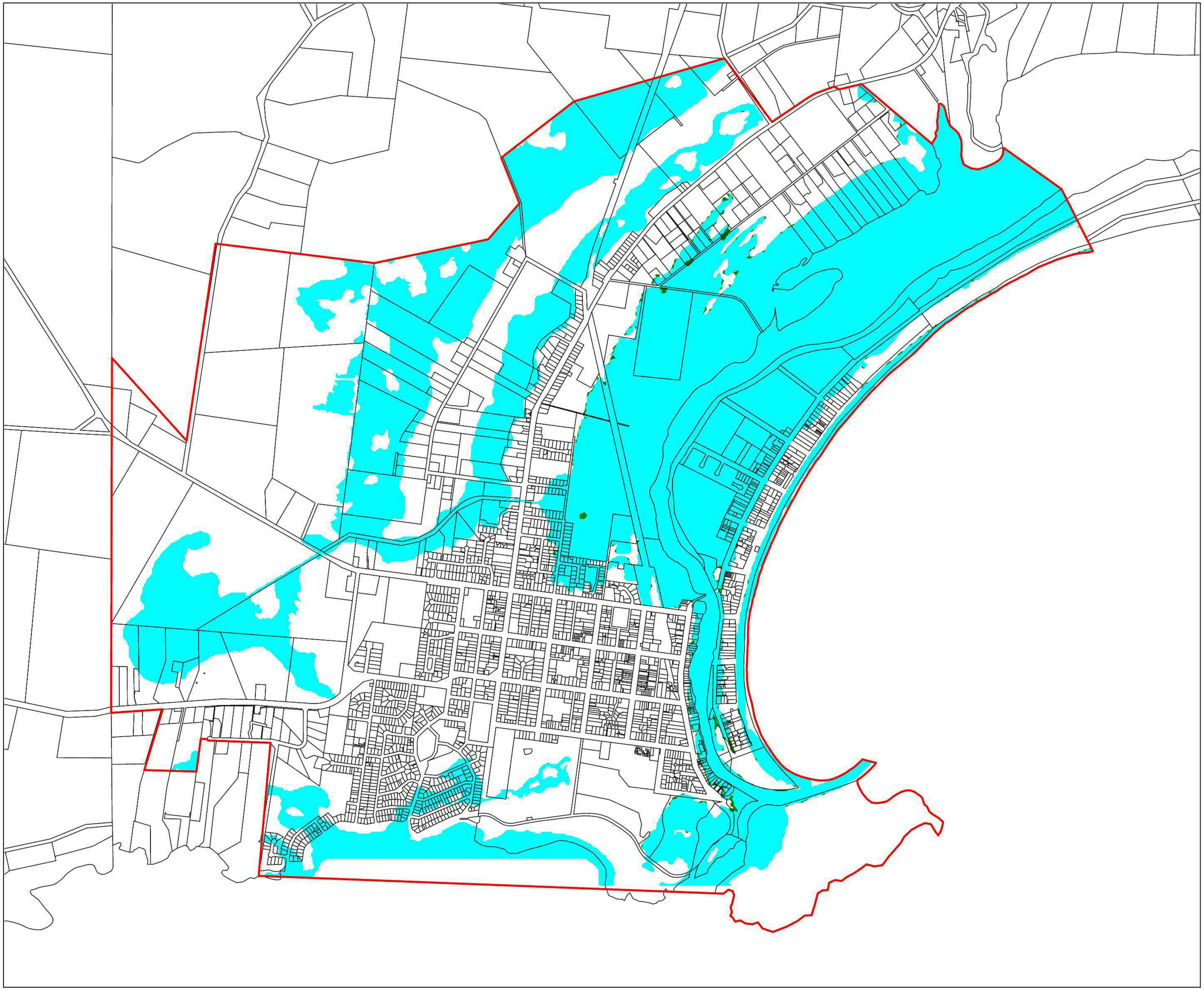
Land Subject To Inundation (LSIO)

N

0 500
metres

Cardno

Map Produced by Cardno Water & Environment
Date: 20/07/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:Moyne_2021_Updates.wor



Port Fairy Township Coastal Hazard Assessment

Sea Level Comparison

0.4m SLR Scenario

Extent of Proposed Overlays

1% AEP - 10% AEP Combination Flood Extent

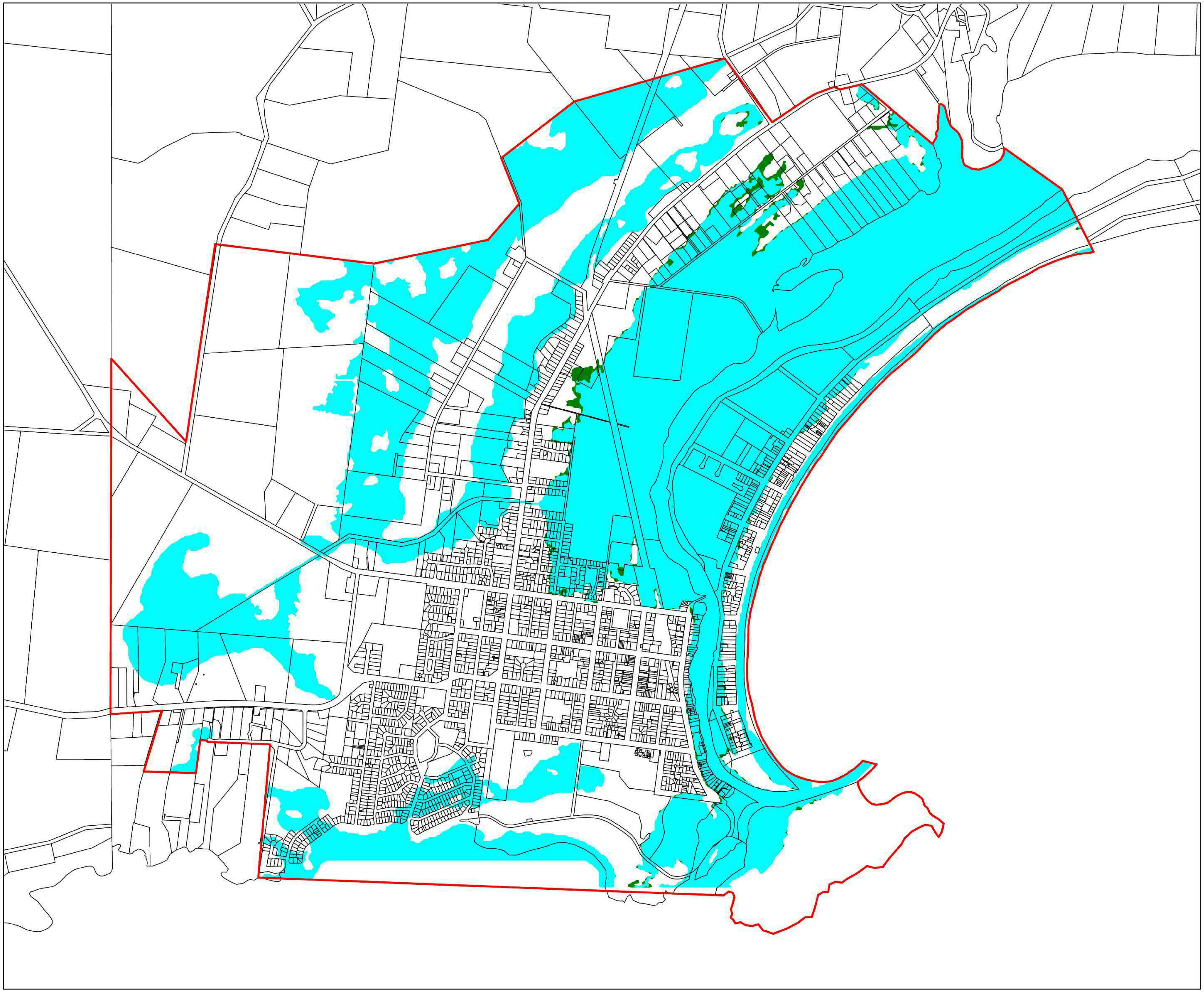
1% AEP - 5% AEP Combination Flood Extent

N

0 500
metres

Cardno

Map Produced by Cardno Water & Environment
Date: 20/07/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:ComparisonMaps.wor



Port Fairy Township Coastal Hazard Assessment

Sea Level Comparison

0.8m SLR Scenario

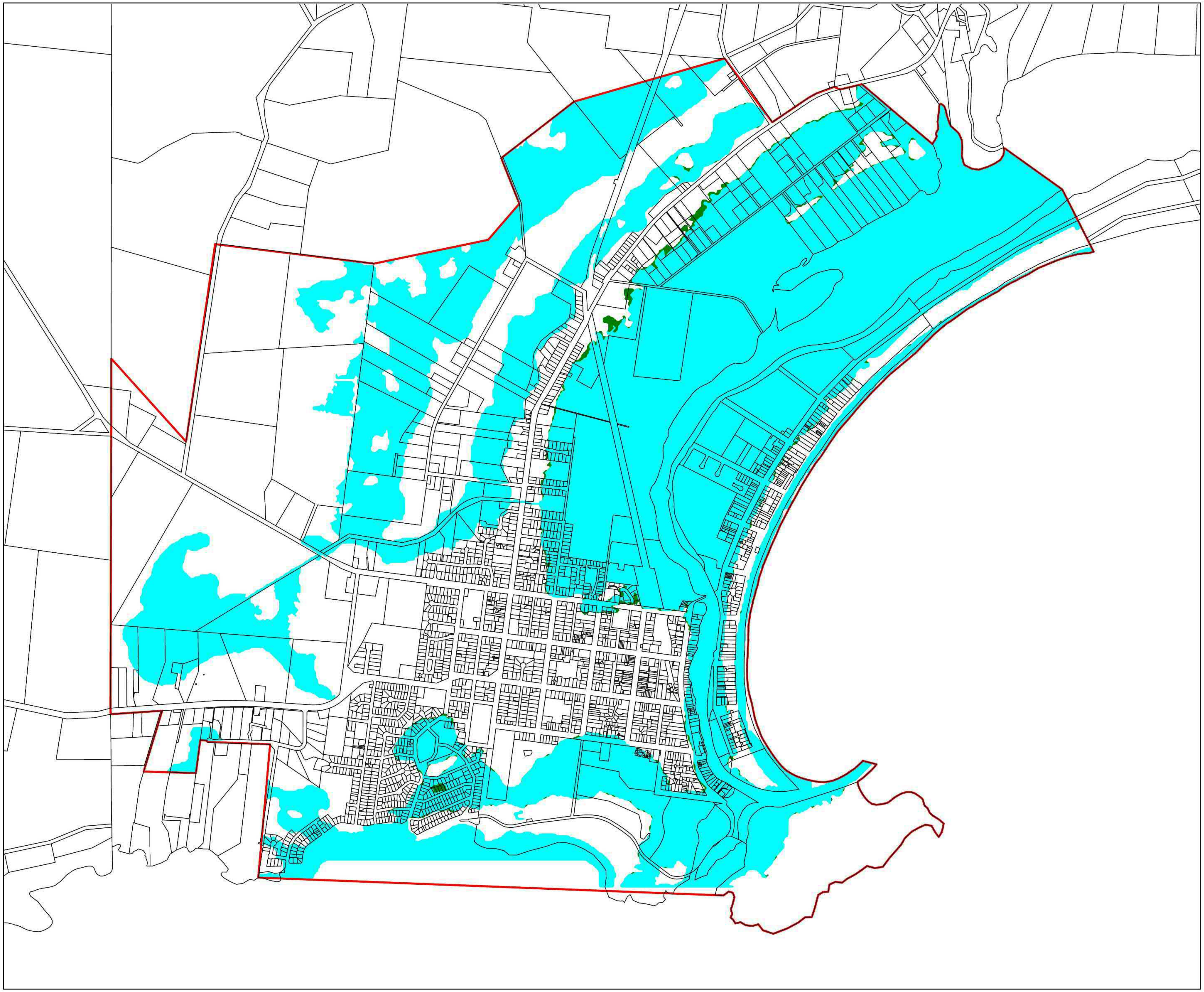
- Extent of Proposed Overlays
- 1% AEP - 10% AEP Combination Flood Extent
- 1% AEP - 5% AEP Combination Flood Extent

N

0 500
metres

Cardno

Map Produced by Cardno Water & Environment
Date: 20/07/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:ComparisonMaps.wor



Port Fairy Township Coastal Hazard Assessment

Sea Level Comparison

1.2m SLR Scenario

Extent of Proposed Overlays

1% AEP - 10% AEP Combination Flood Extent

1% AEP - 5% AEP Combination Flood Extent

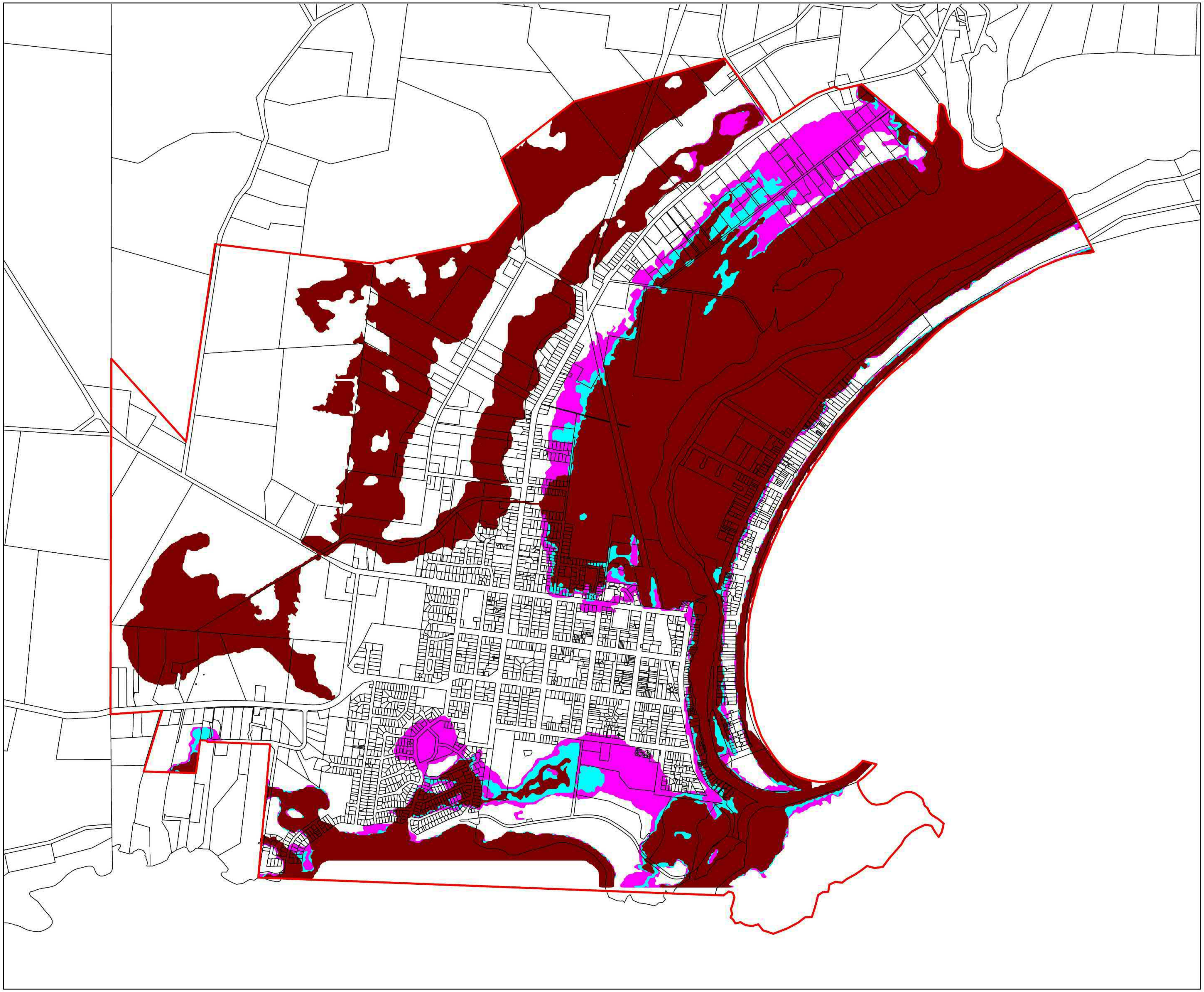
N

0 500

metres

Cardno

Map Produced by Cardno Water & Environment
Date: 20/07/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:ComparisonMaps.wor



Port Fairy Township Coastal Hazard Assessment

Sea Level Comparison

1% AEP - 10% AEP Combination
Flood Scenario

- Extent of Proposed Overlays
- 0.4m SLR Flood Extent
- 0.8m SLR Flood Extent
- 1.2m SLR Flood Extent

N

0 500
metres

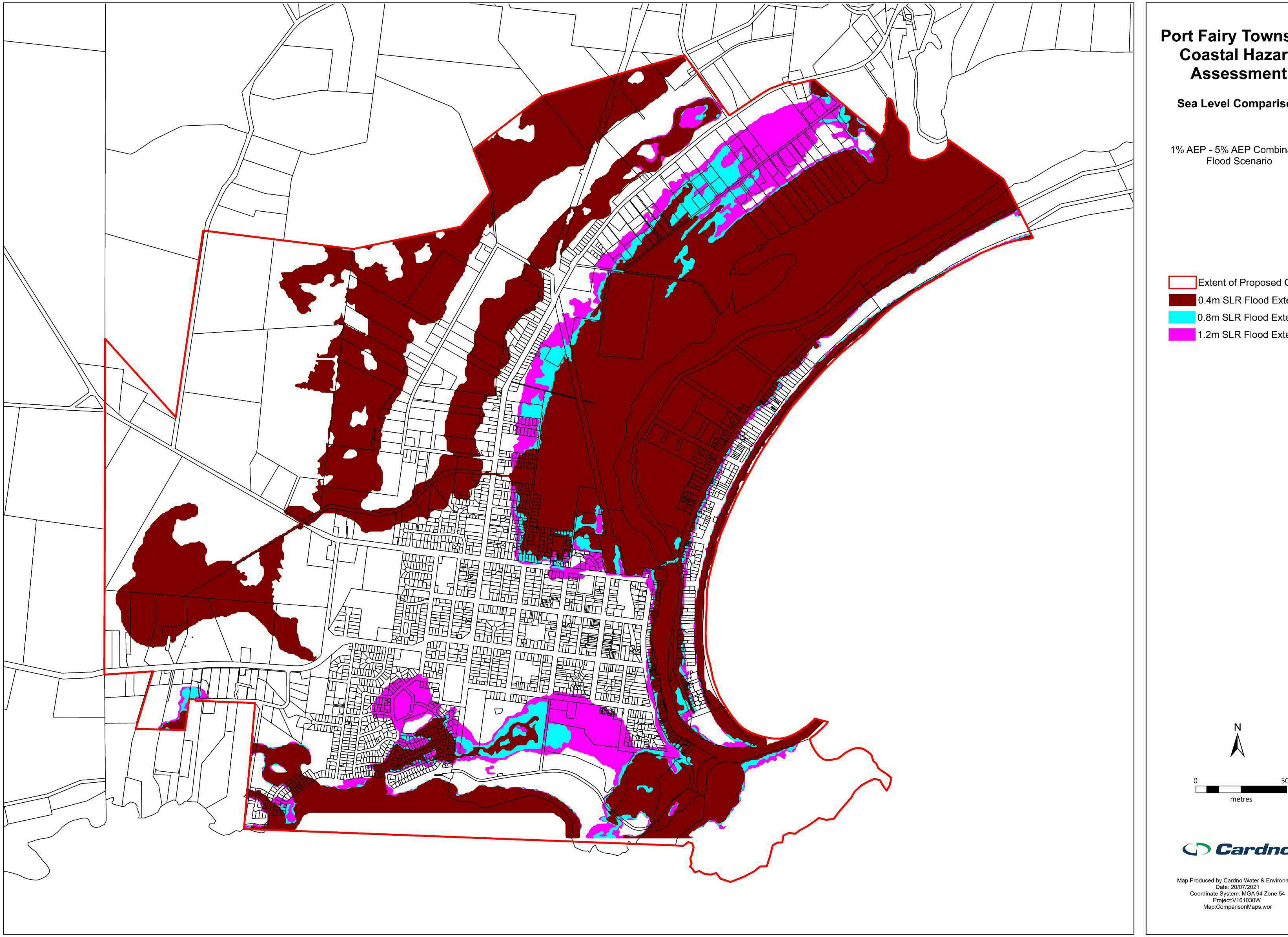
Cardno

Map Produced by Cardno Water & Environment
Date: 20/07/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:ComparisonMaps.wor

Port Fairy Township Coastal Hazard Assessment

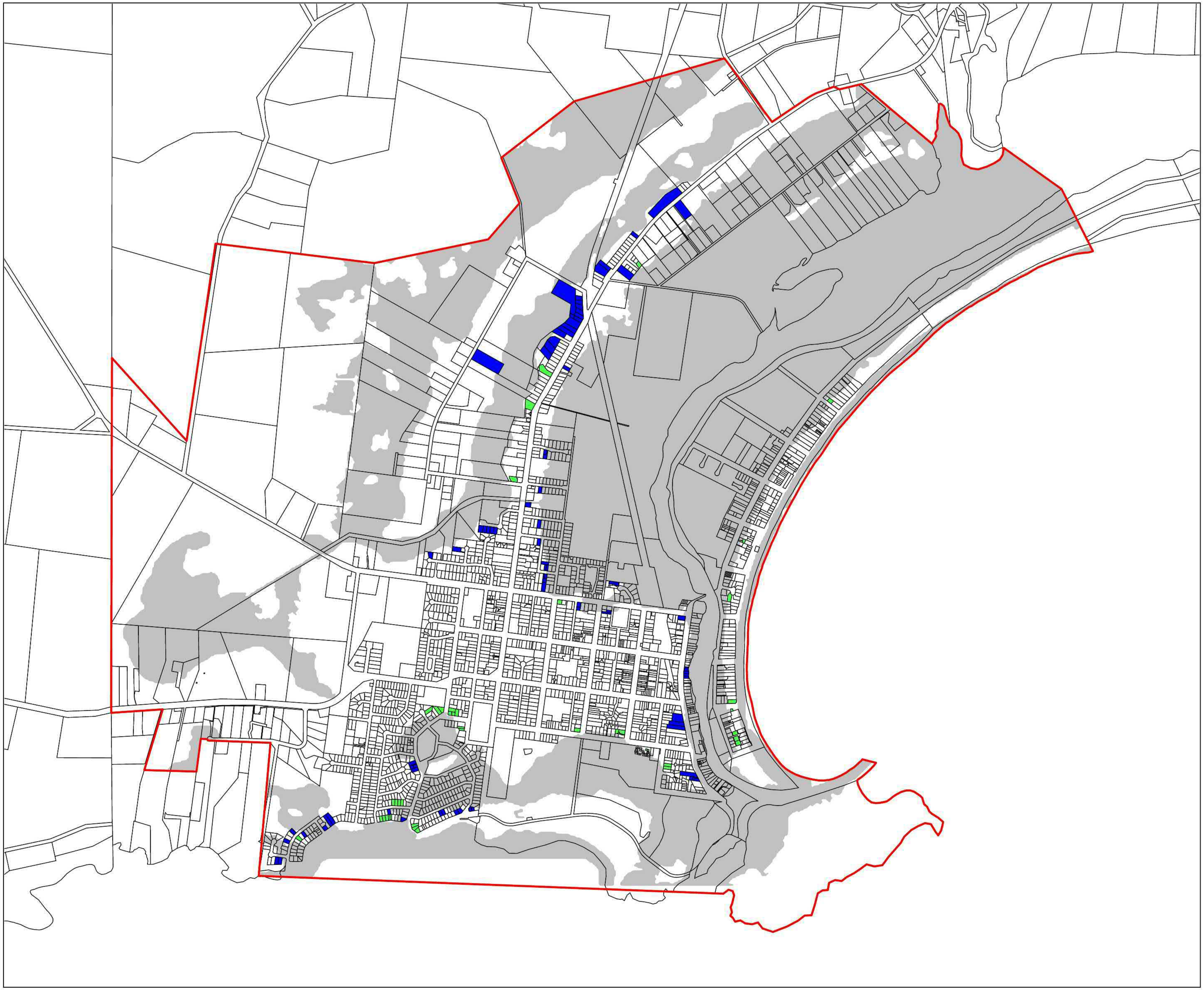
Sea Level Comparison

1% AEP - 5% AEP Combination
Flood Scenario



Cardno

Map Produced by Cardno Water & Environment
Date: 20/07/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:ComparisonMaps.wor



Port Fairy Township Coastal Hazard Assessment

Change In Overlay

Exhibited Overlay Compared to the Updated Preferred Scenario

Extent of Proposed Overlays
Extent of Proposed Overlays
Properties Now Included Within an Overlay
Properties No Longer Included Within an Overlay

N

0 500
metres

Cardno

Map Produced by Cardno Water & Environment
Date: 20/07/2021
Coordinate System: MGA 94 Zone 54
Project:V161030W
Map:ComparisonMaps.wor