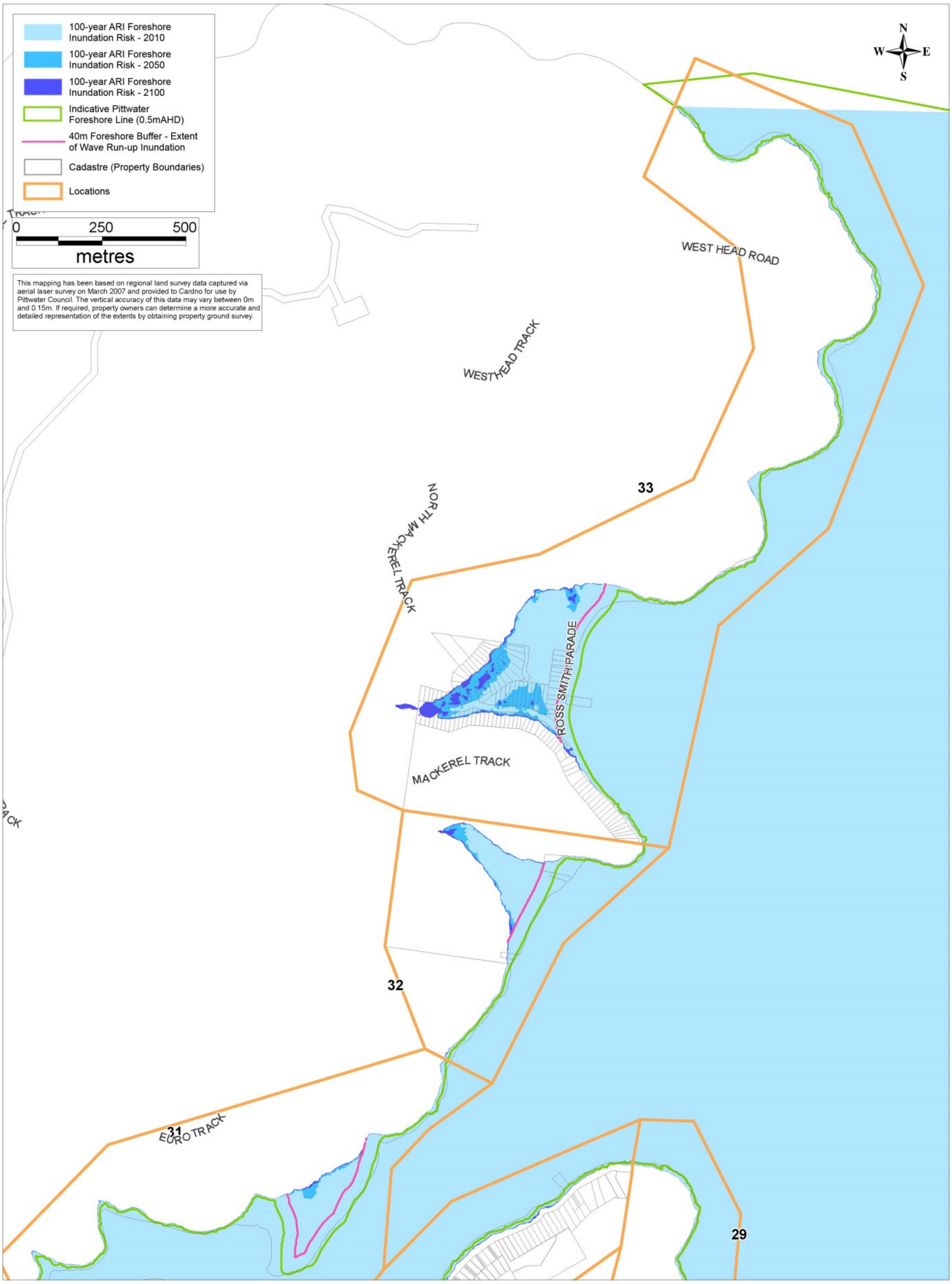

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.2A
100-YEAR ARI FORESHORE INUNDATION RISK
(2010, 2050 AND 2100) - INUNDATION MAPPING
MAPPING AREA 1

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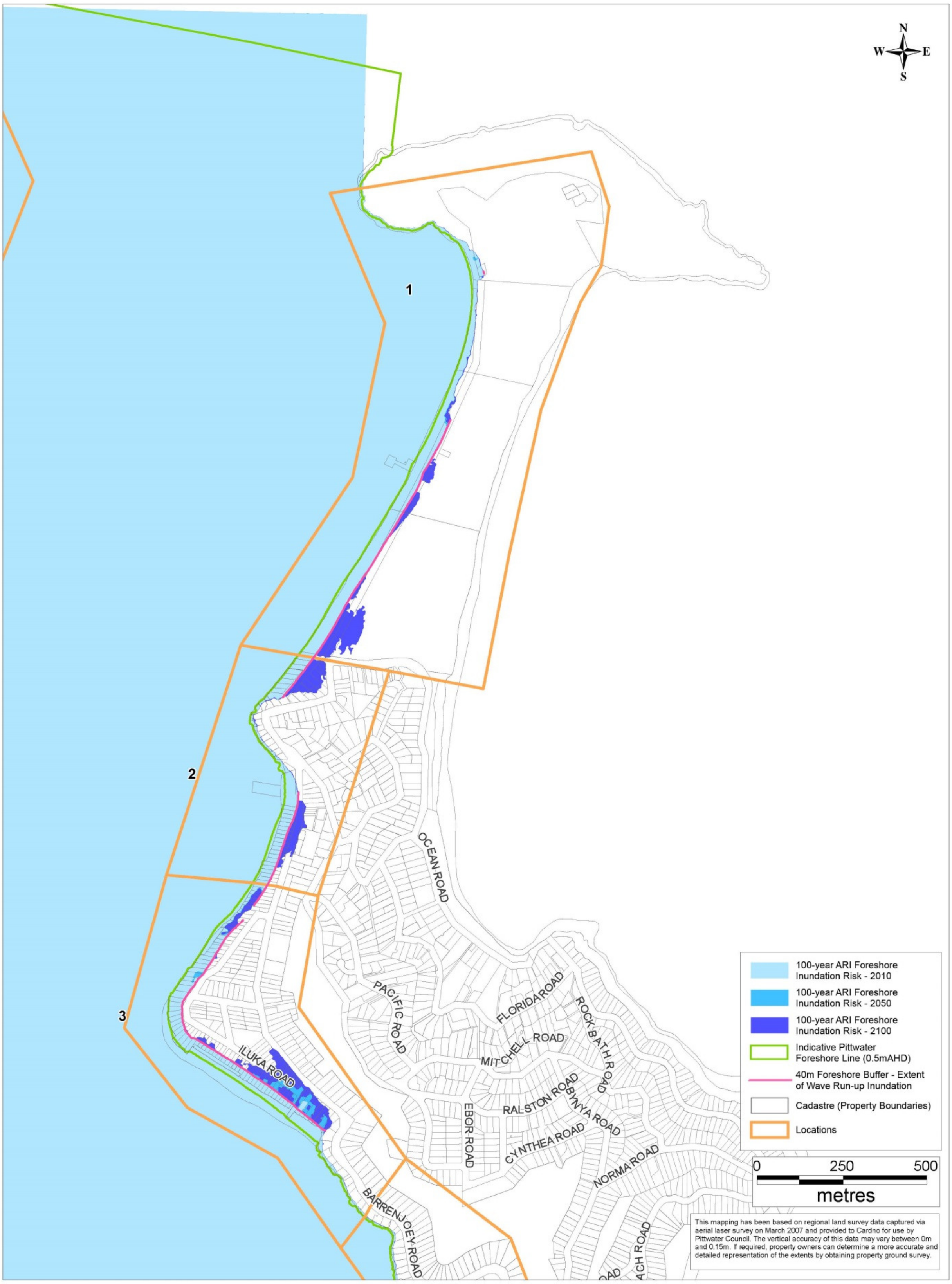

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.2B
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MAPPING AREA 2

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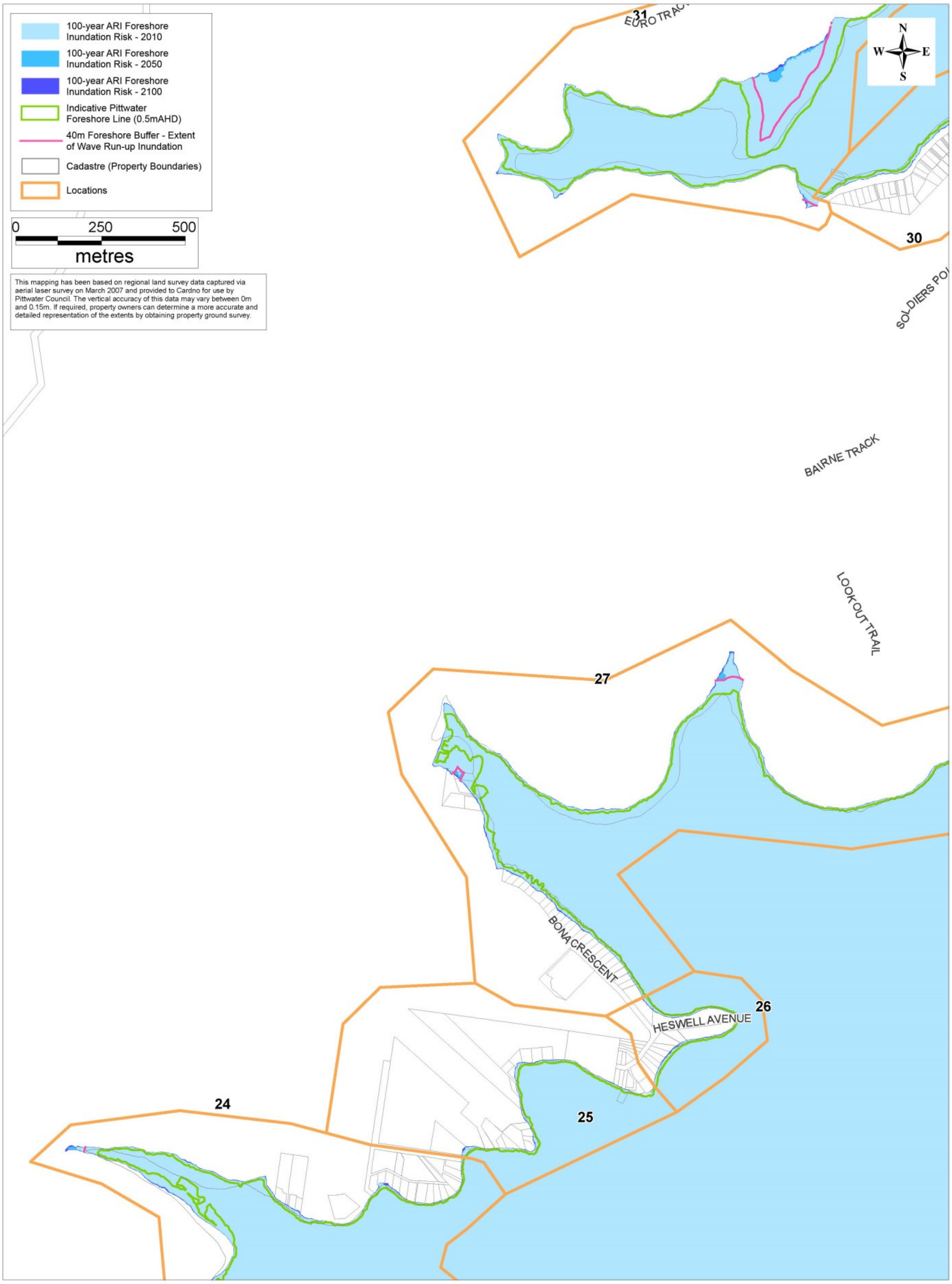

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.2C
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MAPPING AREA 3

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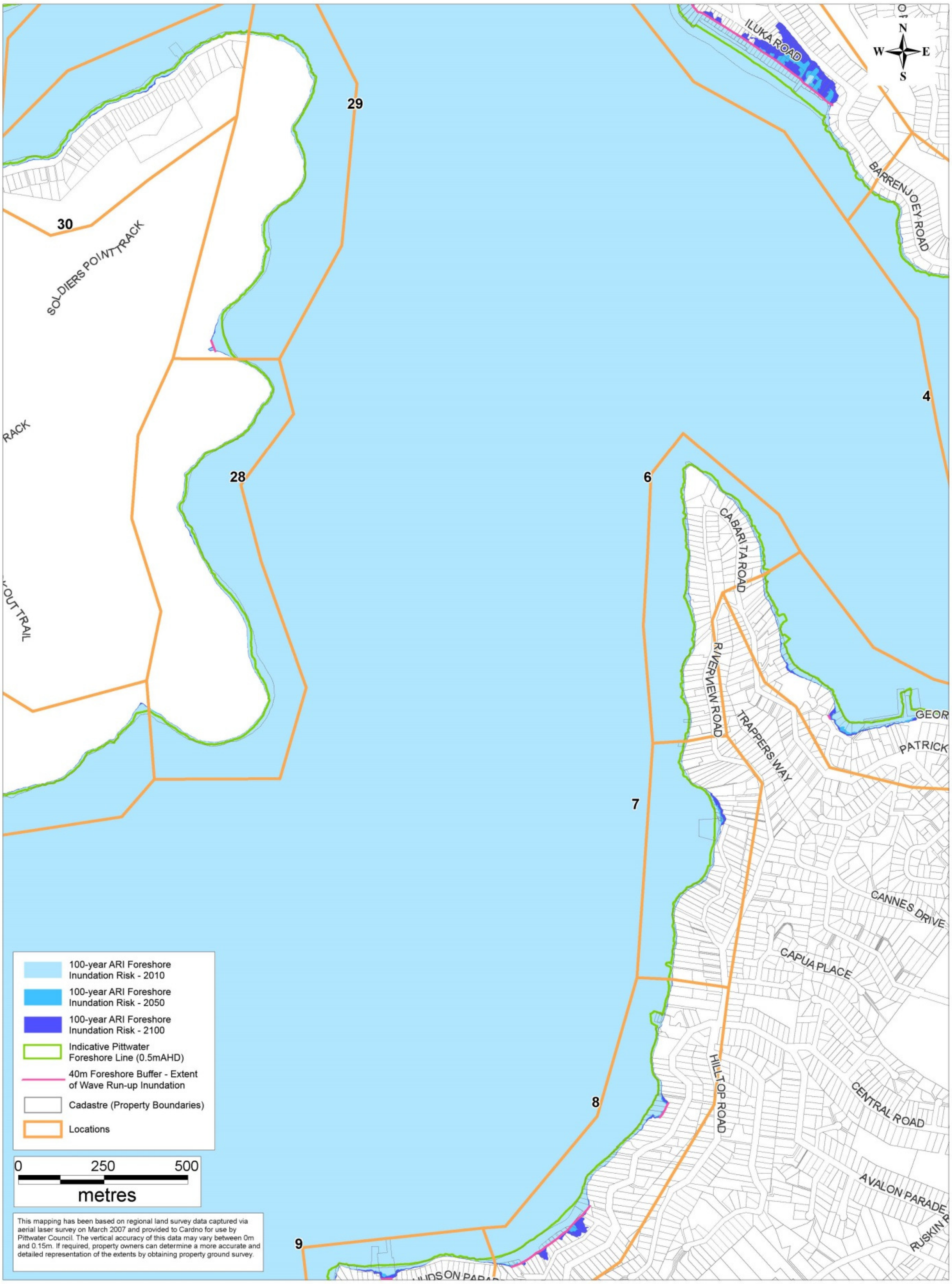

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.2D
100-YEAR ARI FORESHORE INUNDATION RISK
(2010, 2050 AND 2100) - INUNDATION MAPPING
MAPPING AREA 4

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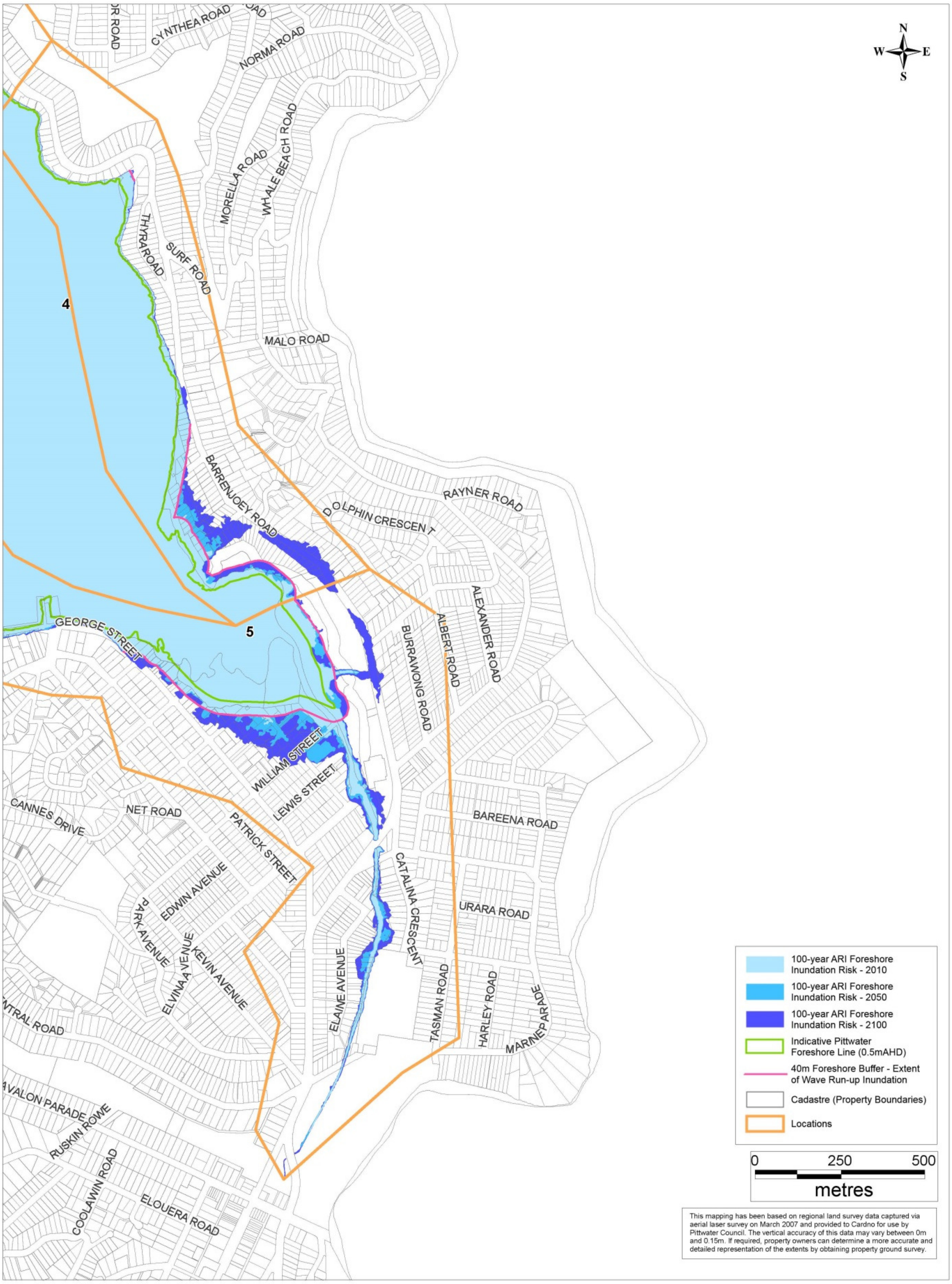

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.2E
100-YEAR ARI FORESHORE INUNDATION RISK (2010, 2050 AND 2100) - INUNDATION MAPPING
MAPPING AREA 5

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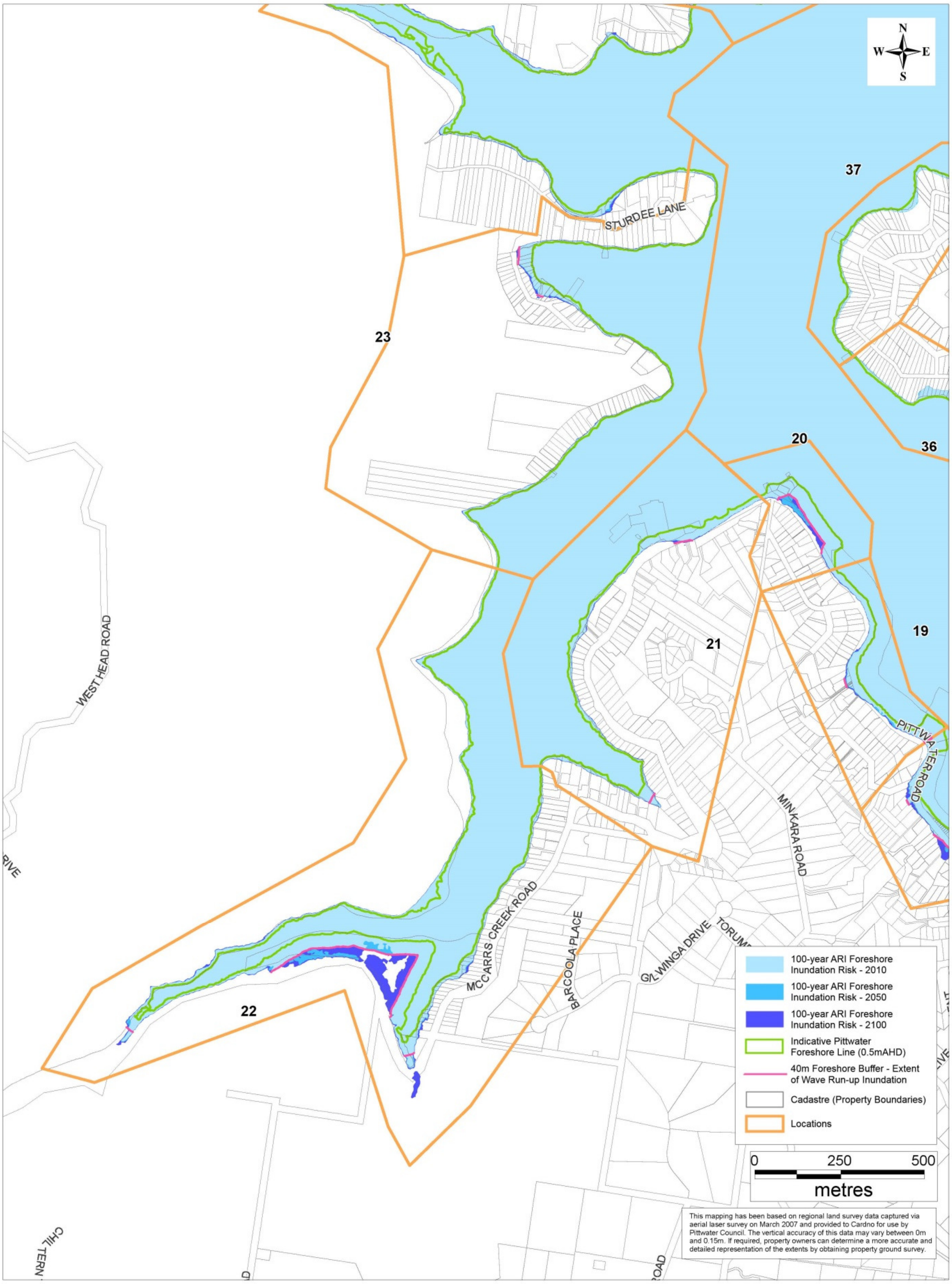

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.2F
100-YEAR ARI FORESHORE INUNDATION RISK
(2010, 2050 AND 2100) - INUNDATION MAPPING
MAPPING AREA 6

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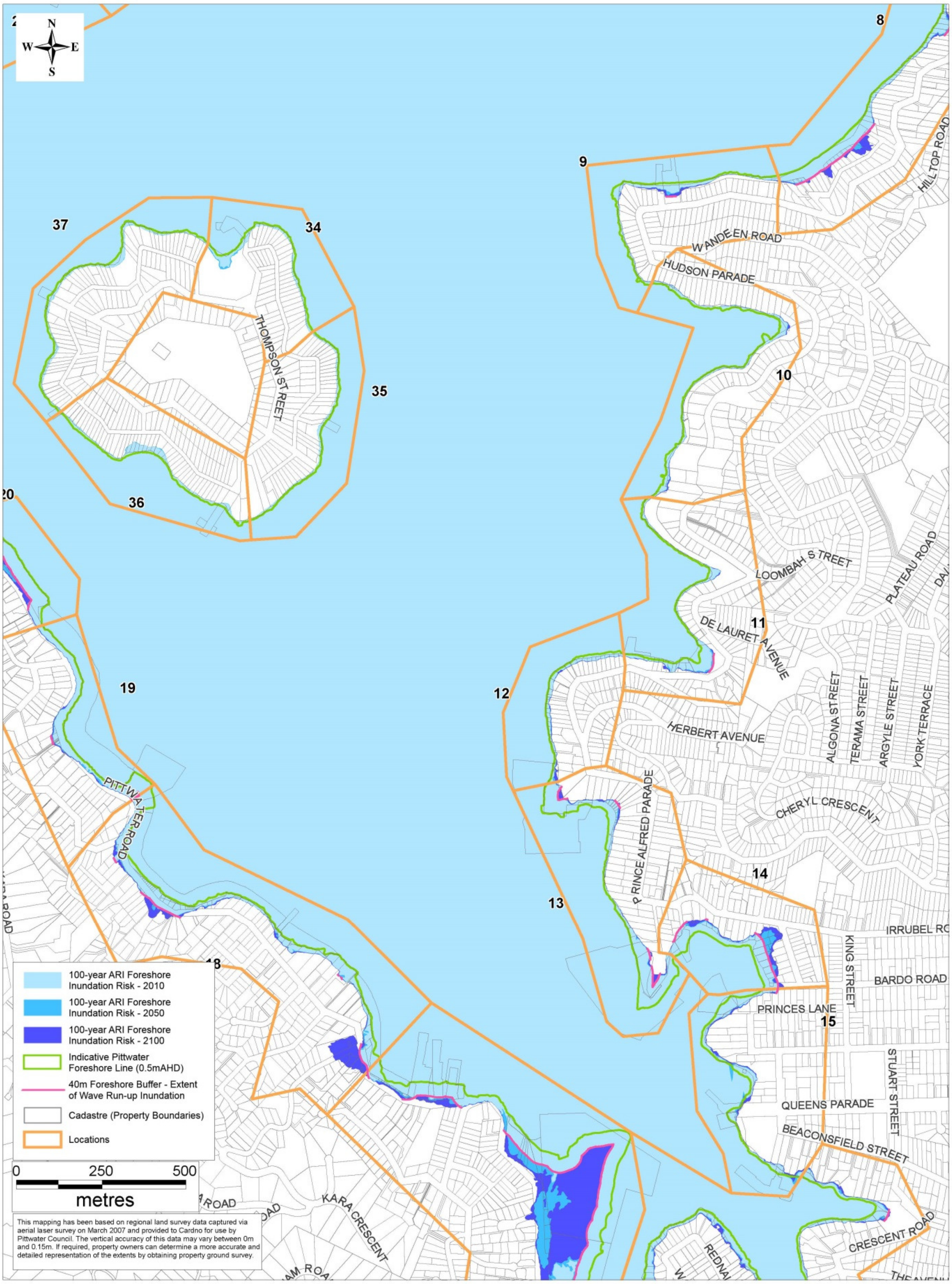

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.2H
100-YEAR ARI FORESHORE INUNDATION RISK
(2010, 2050 AND 2100) - INUNDATION MAPPING
MAPPING AREA 8

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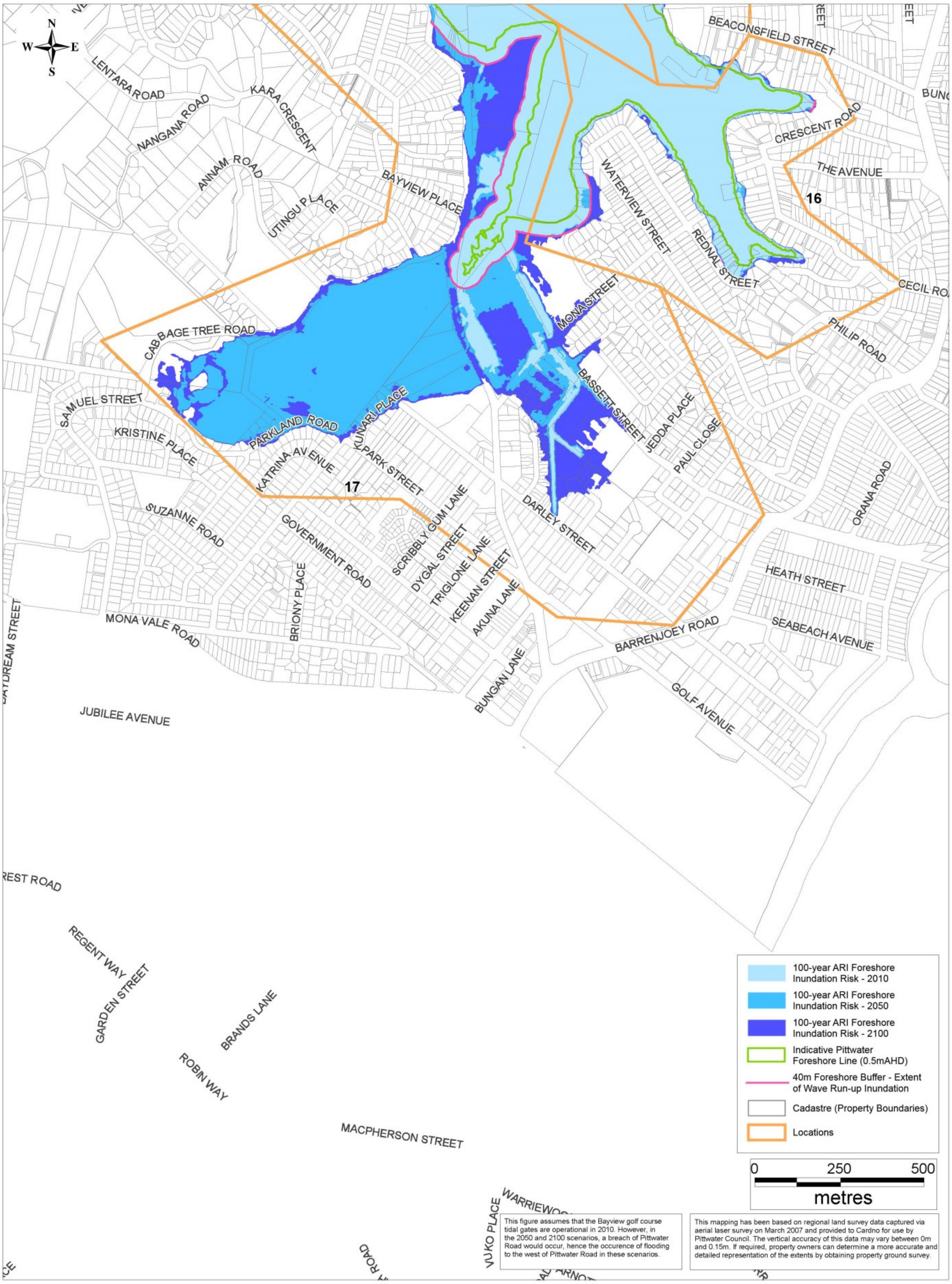

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.2H
100-YEAR ARI FORESHORE INUNDATION RISK
(2010, 2050 AND 2100) - INUNDATION MAPPING
MAPPING AREA 8

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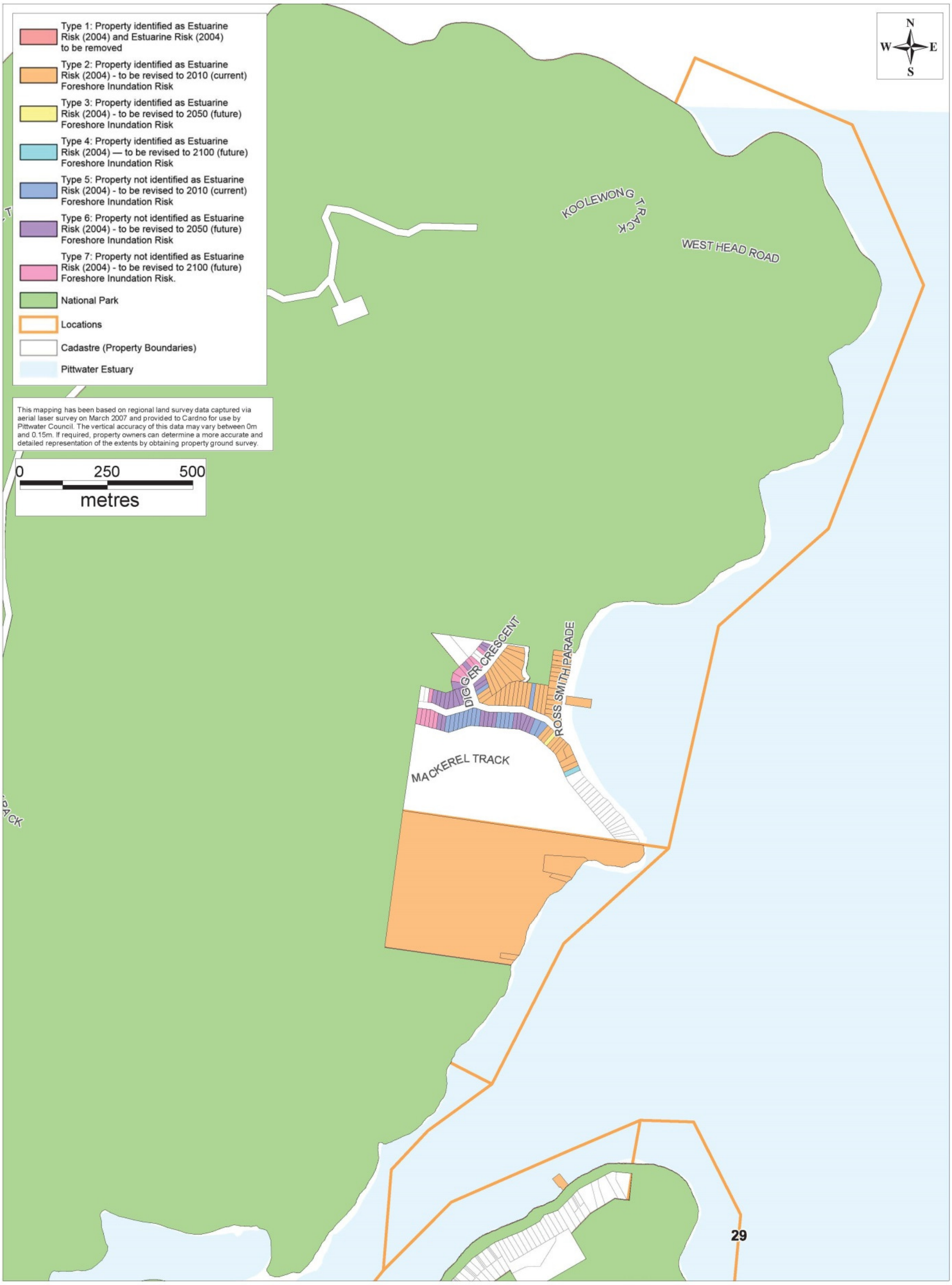

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.3A
100-YEAR ARI FORESHORE INUNDATION RISK (2010 AND 2100) - AFFECTED PROPERTIES
MAPPING AREA 1

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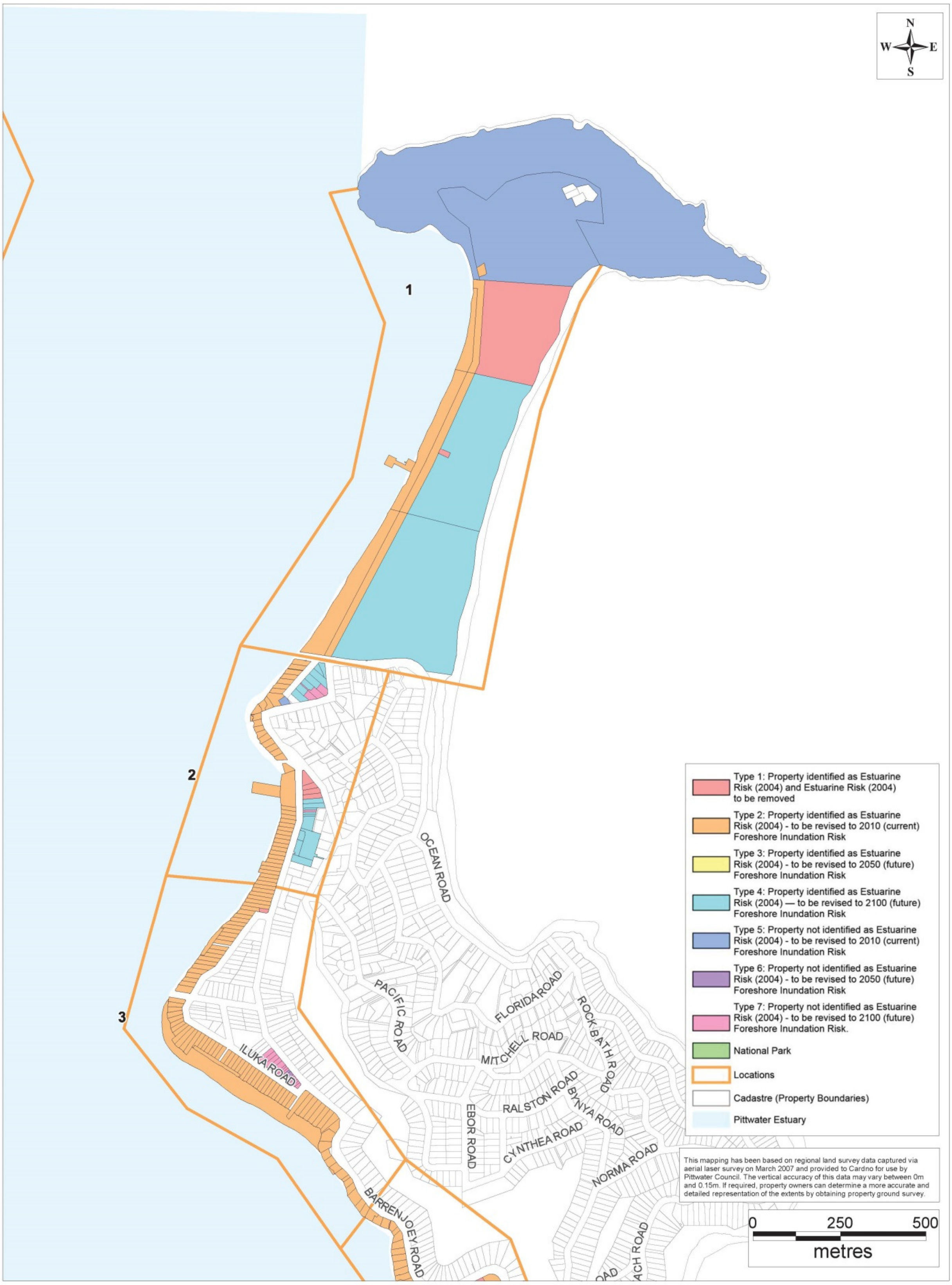

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.3B
100-YEAR ARI FORESHORE INUNDATION RISK (2010 AND 2100) - AFFECTED PROPERTIES
MAPPING AREA 2

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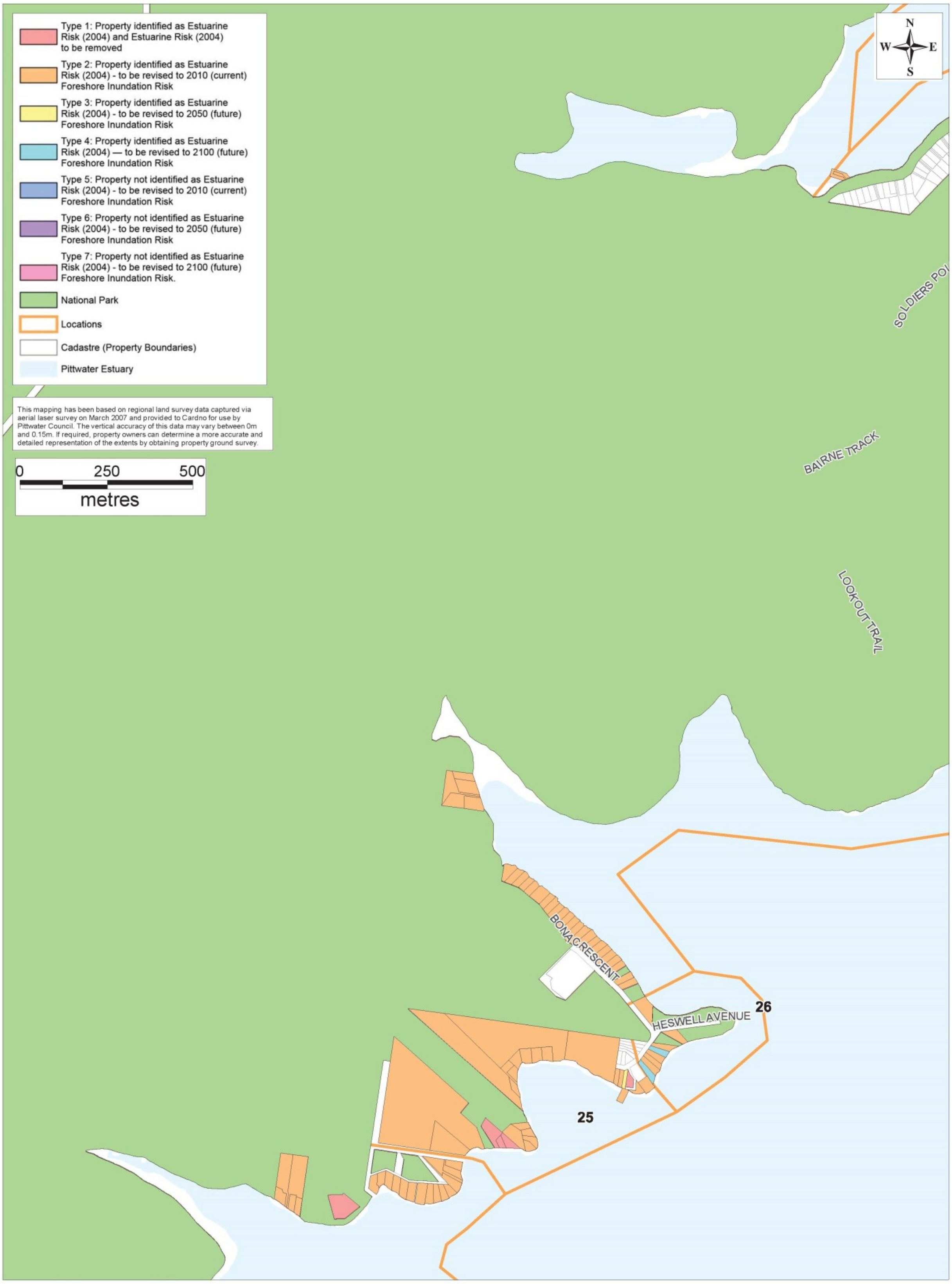

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.3C
100-YEAR ARI FORESHORE INUNDATION RISK
(2010 AND 2100) - AFFECTED PROPERTIES
MAPPING AREA 3

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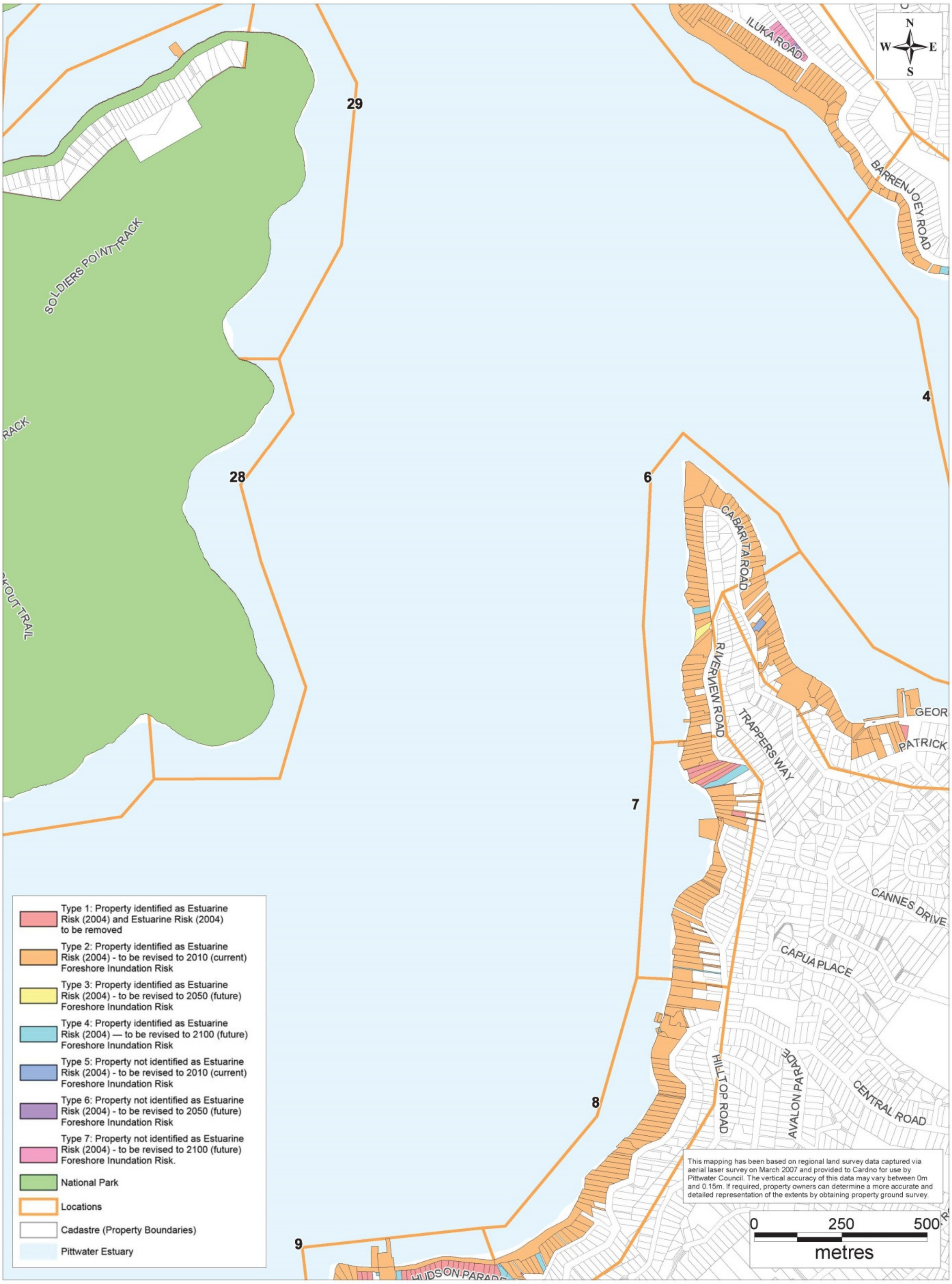

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.3D
100-YEAR ARI FORESHORE INUNDATION RISK (2010 AND 2100) - AFFECTED PROPERTIES
MAPPING AREA 4

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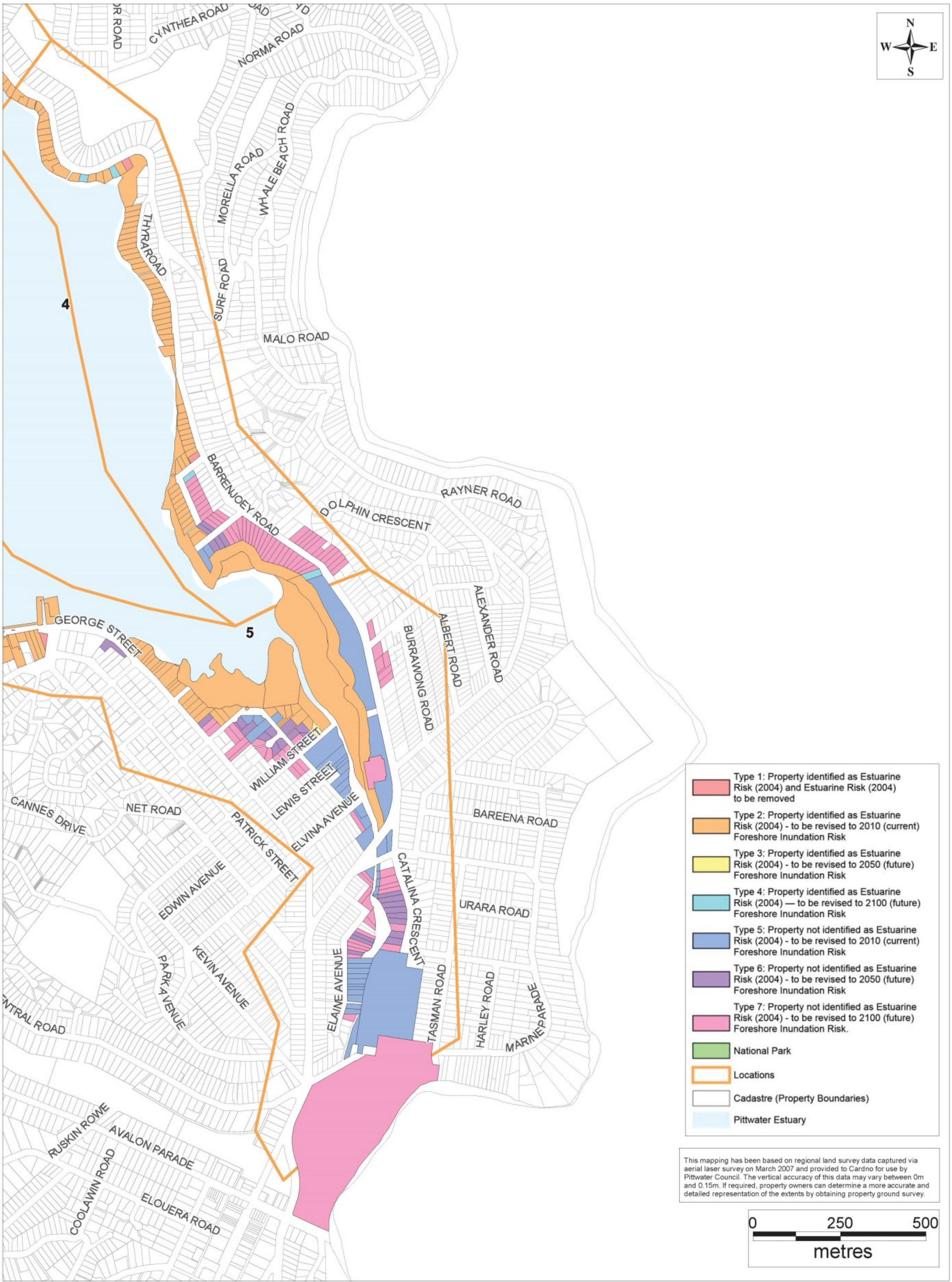

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.3E
100-YEAR ARI FORESHORE INUNDATION RISK (2010 AND 2100) - AFFECTED PROPERTIES
MAPPING AREA 5

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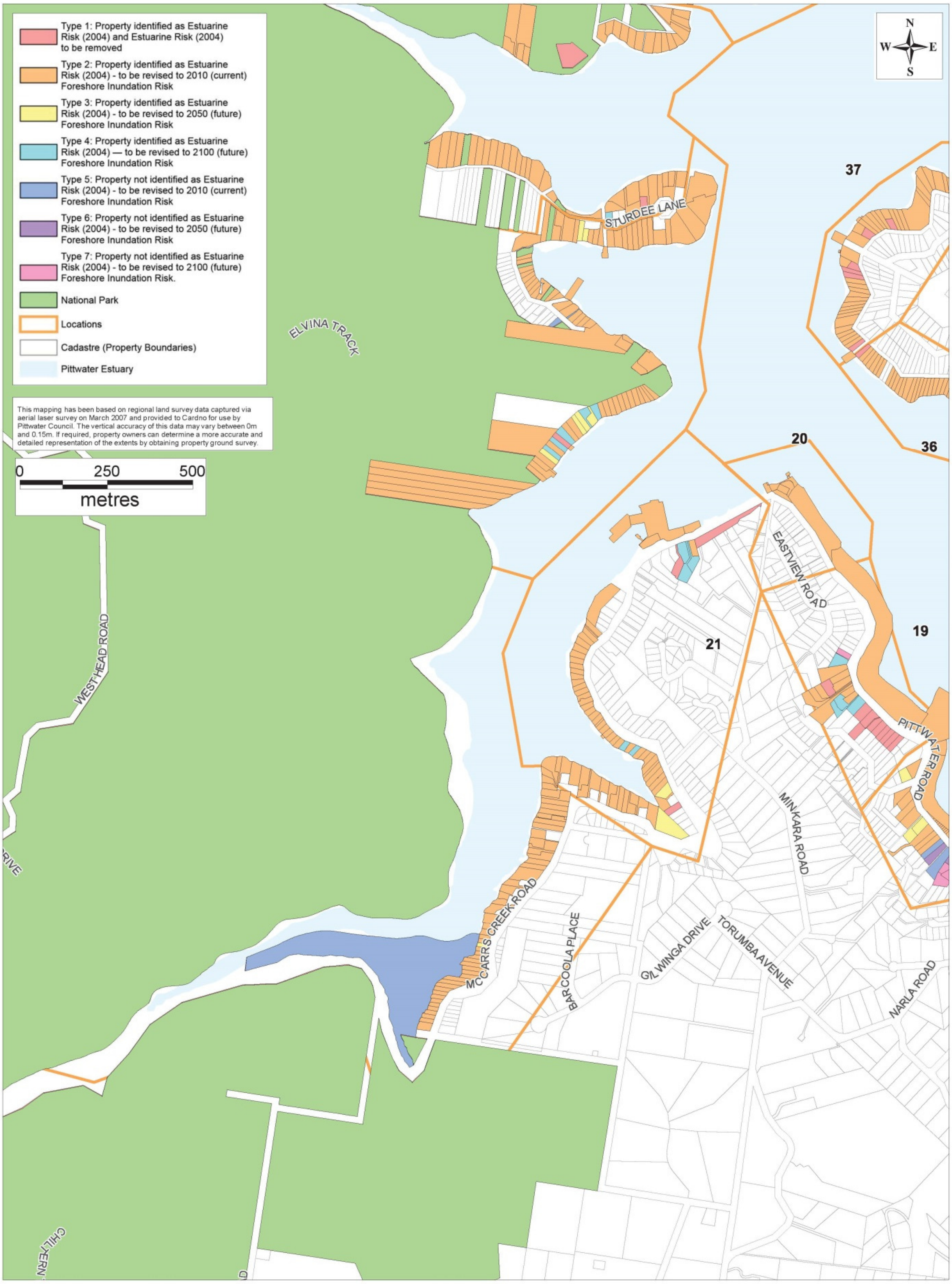

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.3F
100-YEAR ARI FORESHORE INUNDATION RISK (2010 AND 2100) - AFFECTED PROPERTIES
MAPPING AREA 6

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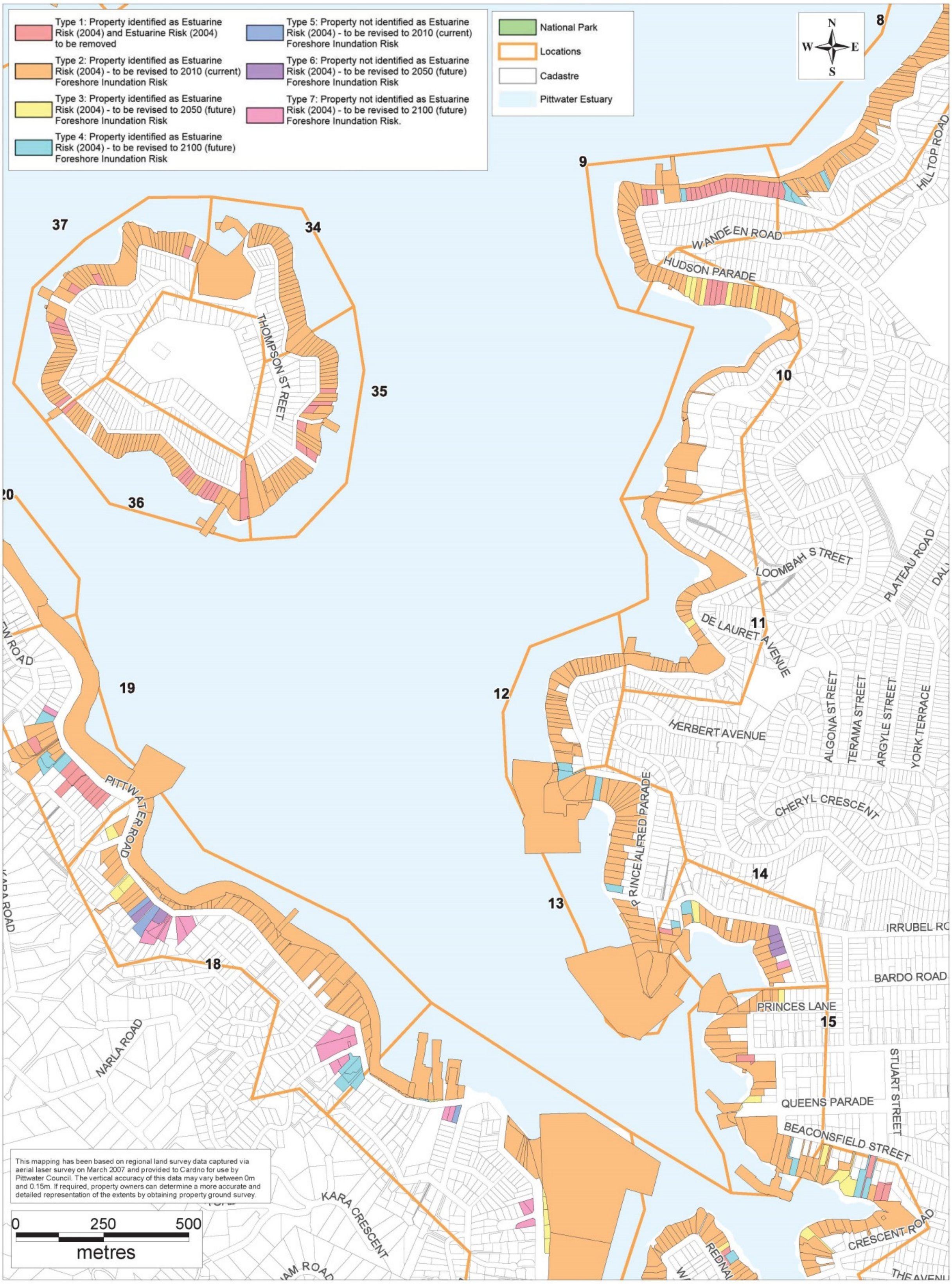

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.3G
100-YEAR ARI FORESHORE INUNDATION RISK (2010 AND 2100) - AFFECTED PROPERTIES
MAPPING AREA 7

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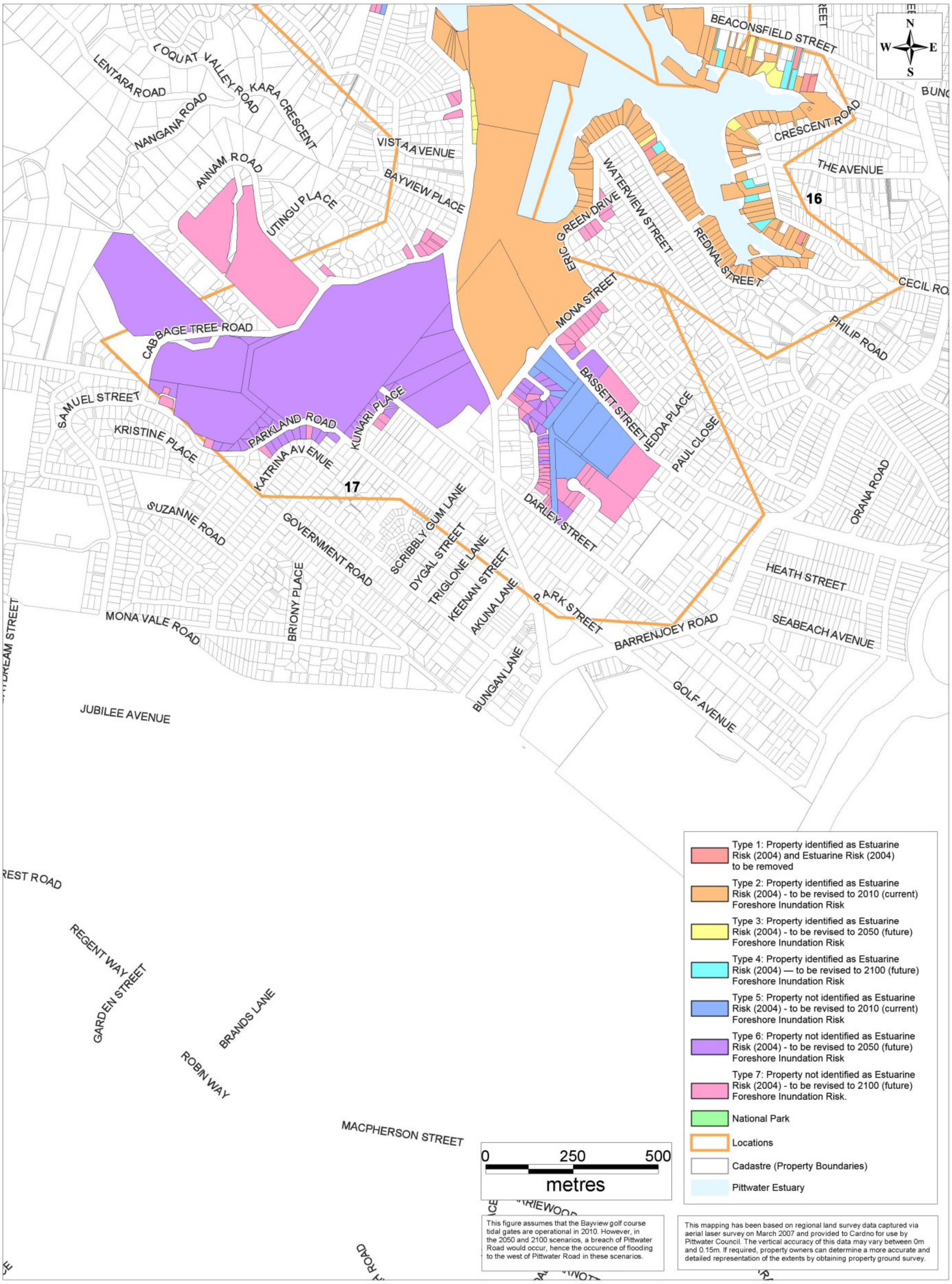

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.3H
100-YEAR ARI FORESHORE INUNDATION RISK
(2010 AND 2100) - AFFECTED PROPERTIES
MAPPING AREA 8

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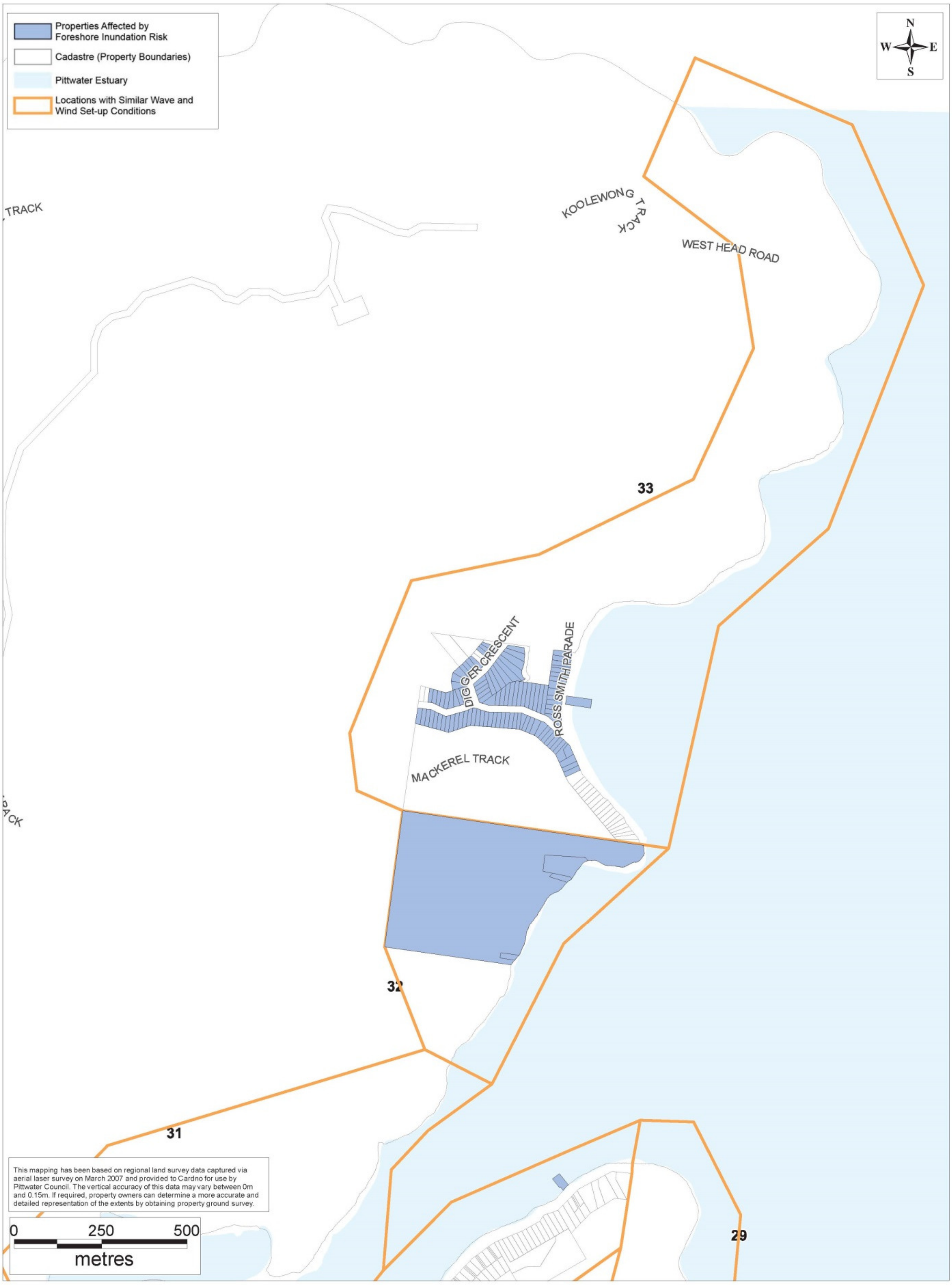

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.4A
FLOOD RISK MAP FOR PITTWATER ESTUARY FORESHORE
MAPPING AREA 1

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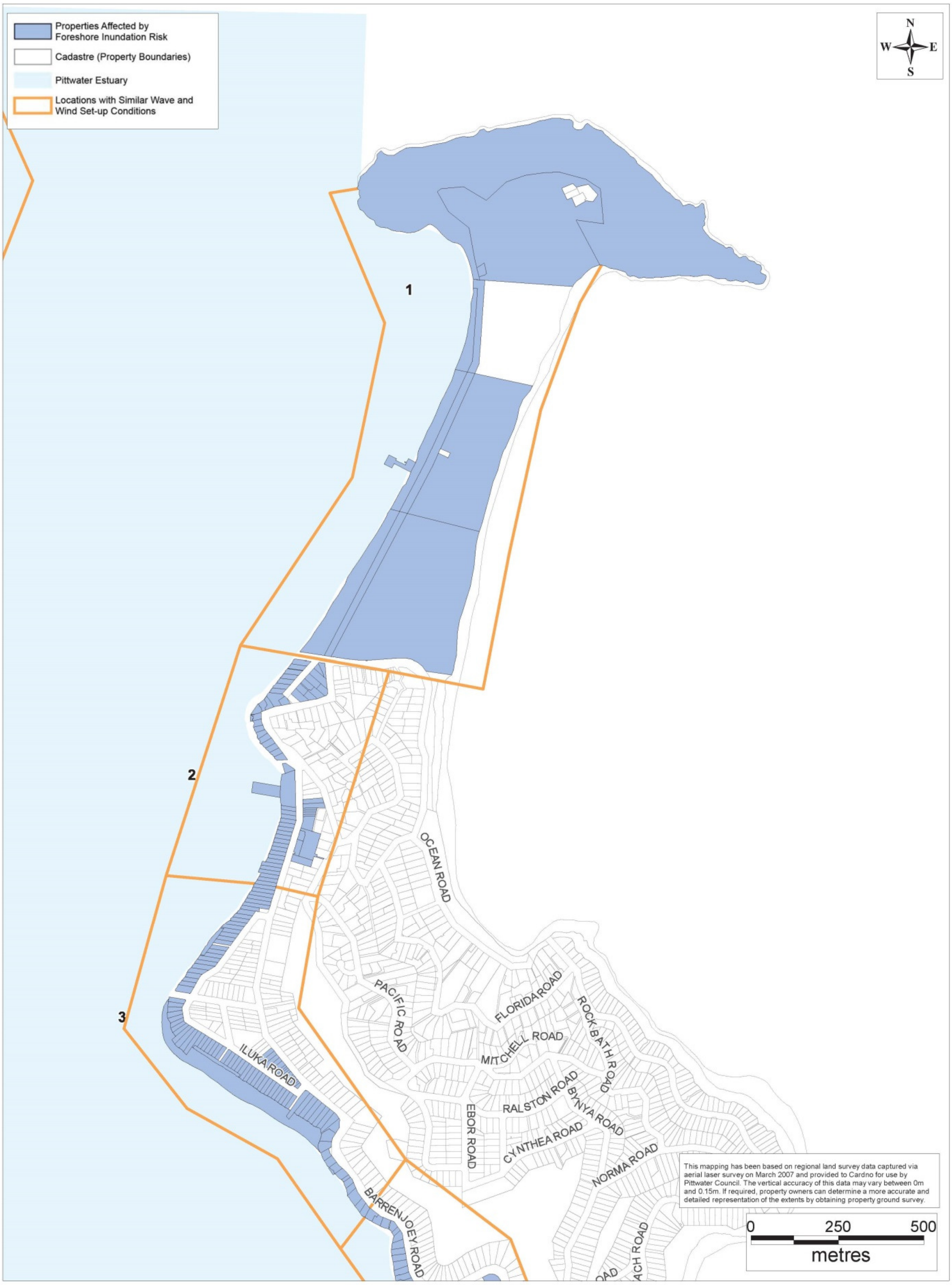

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.4B
FLOOD RISK MAP FOR PITTWATER ESTUARY FORESHORE
MAPPING AREA 2

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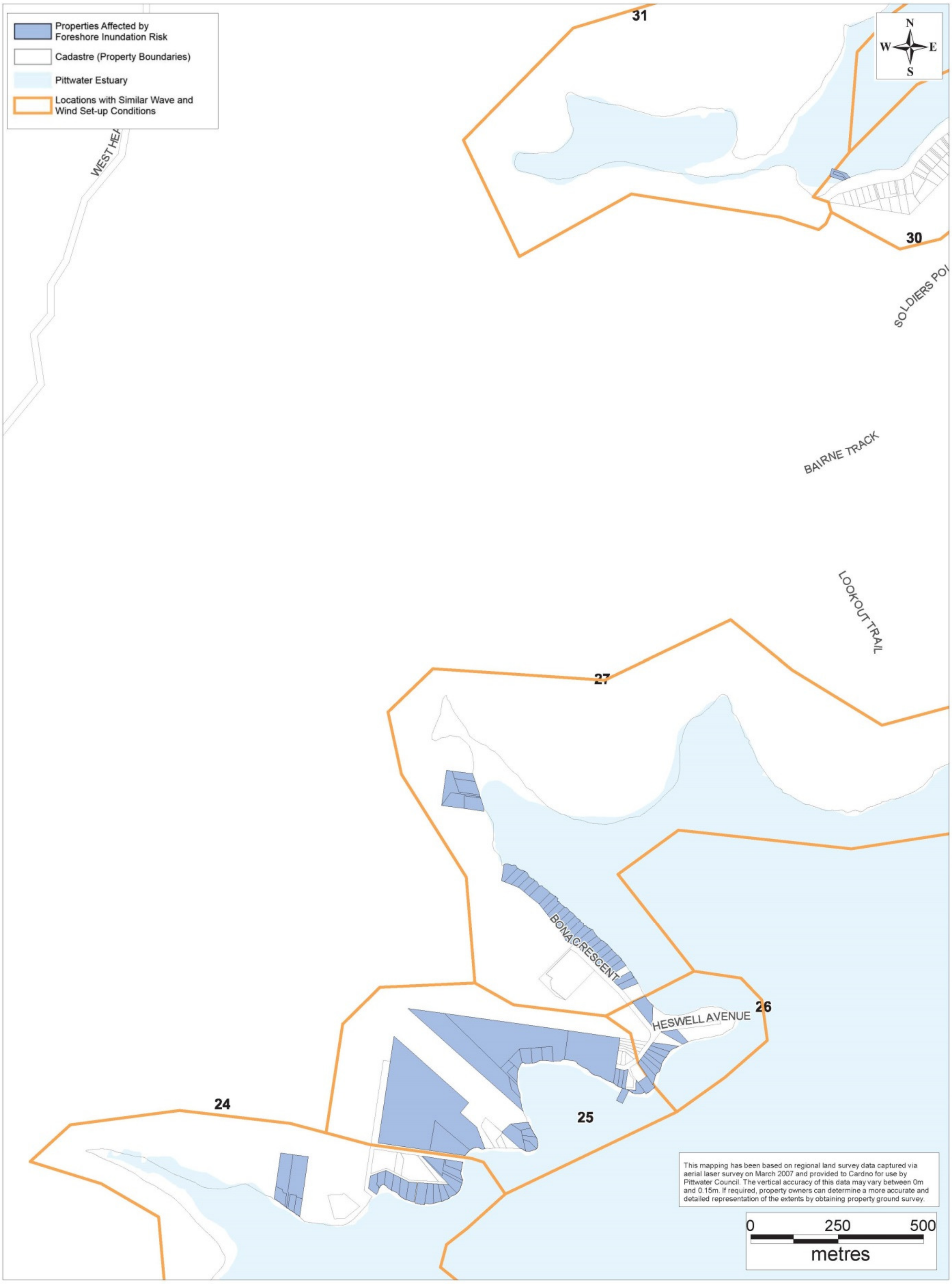

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.4C
FLOOD RISK MAP FOR PITTWATER
ESTUARY FORESHORE
MAPPING AREA 3

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FIGURE 4.4D
FLOOD RISK MAP FOR PITTWATER
ESTUARY FORESHORE
MAPPING AREA 4

PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

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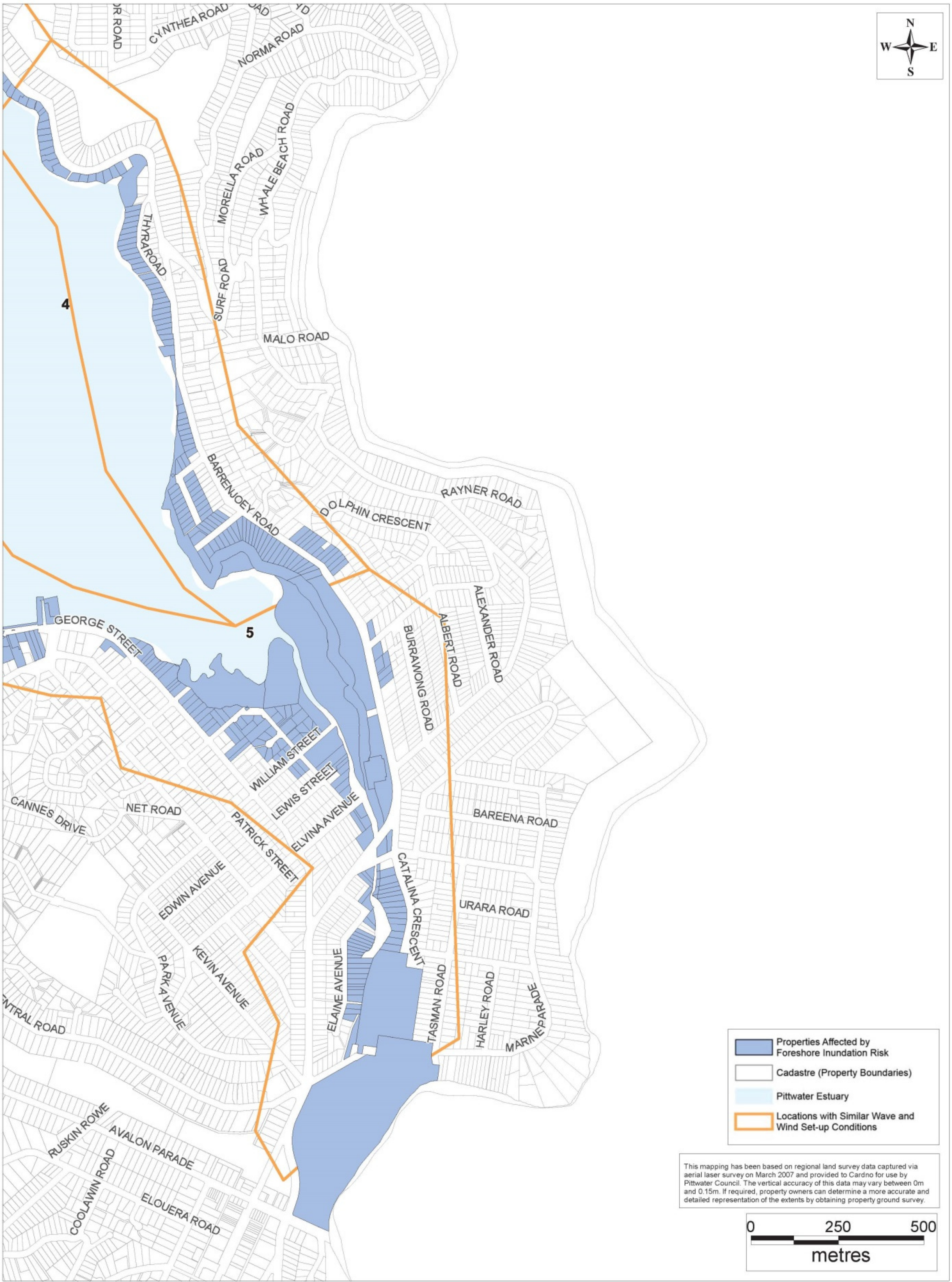

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.4E
FLOOD RISK MAP FOR PITTWATER ESTUARY FORESHORE
MAPPING AREA 5

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MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.4F
FLOOD RISK MAP FOR PITTWATER ESTUARY FORESHORE
MAPPING AREA 6

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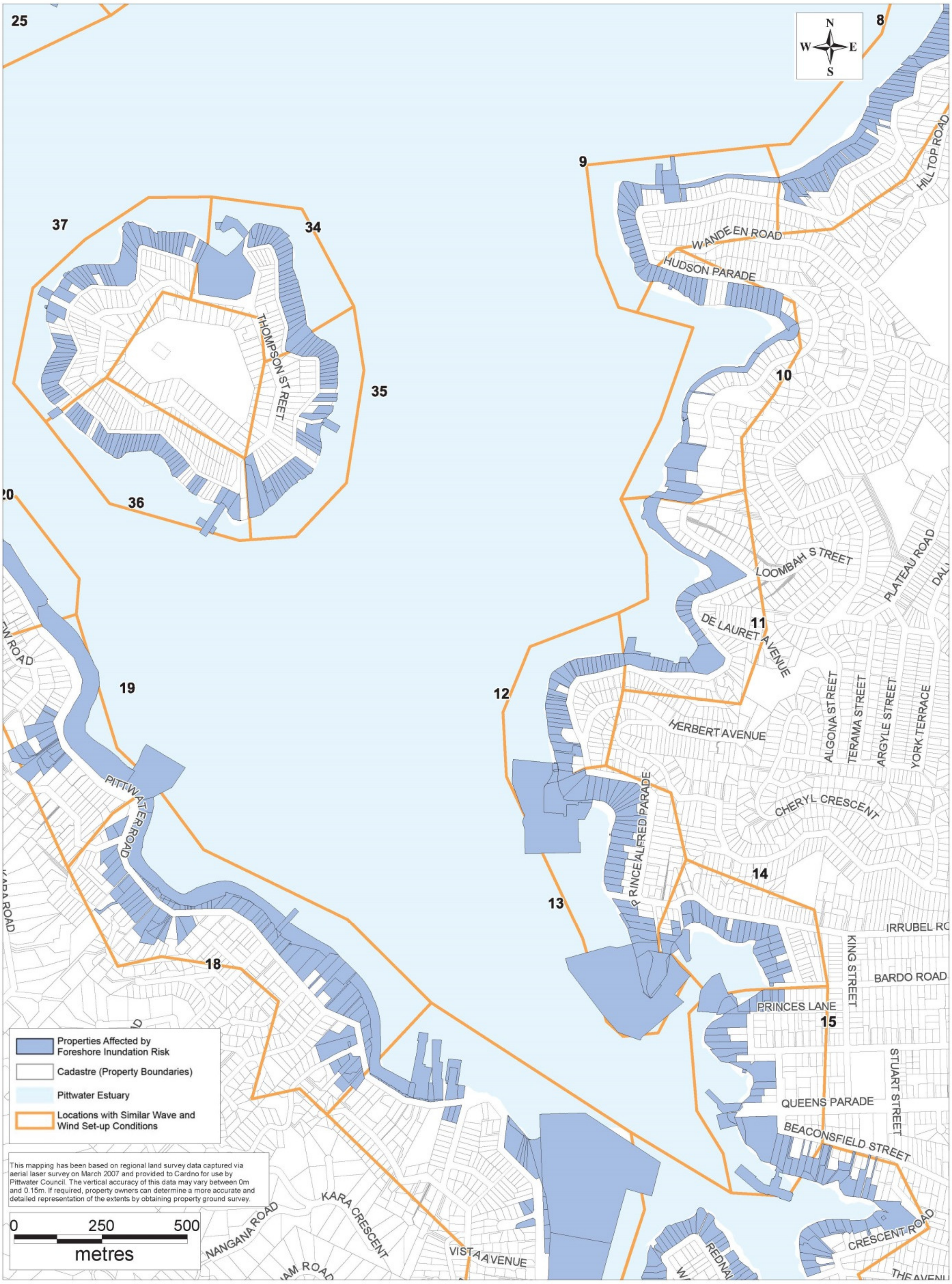

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FIGURE 4.4G
FLOOD RISK MAP FOR PITTWATER
ESTUARY FORESHORE
MAPPING AREA 7

PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

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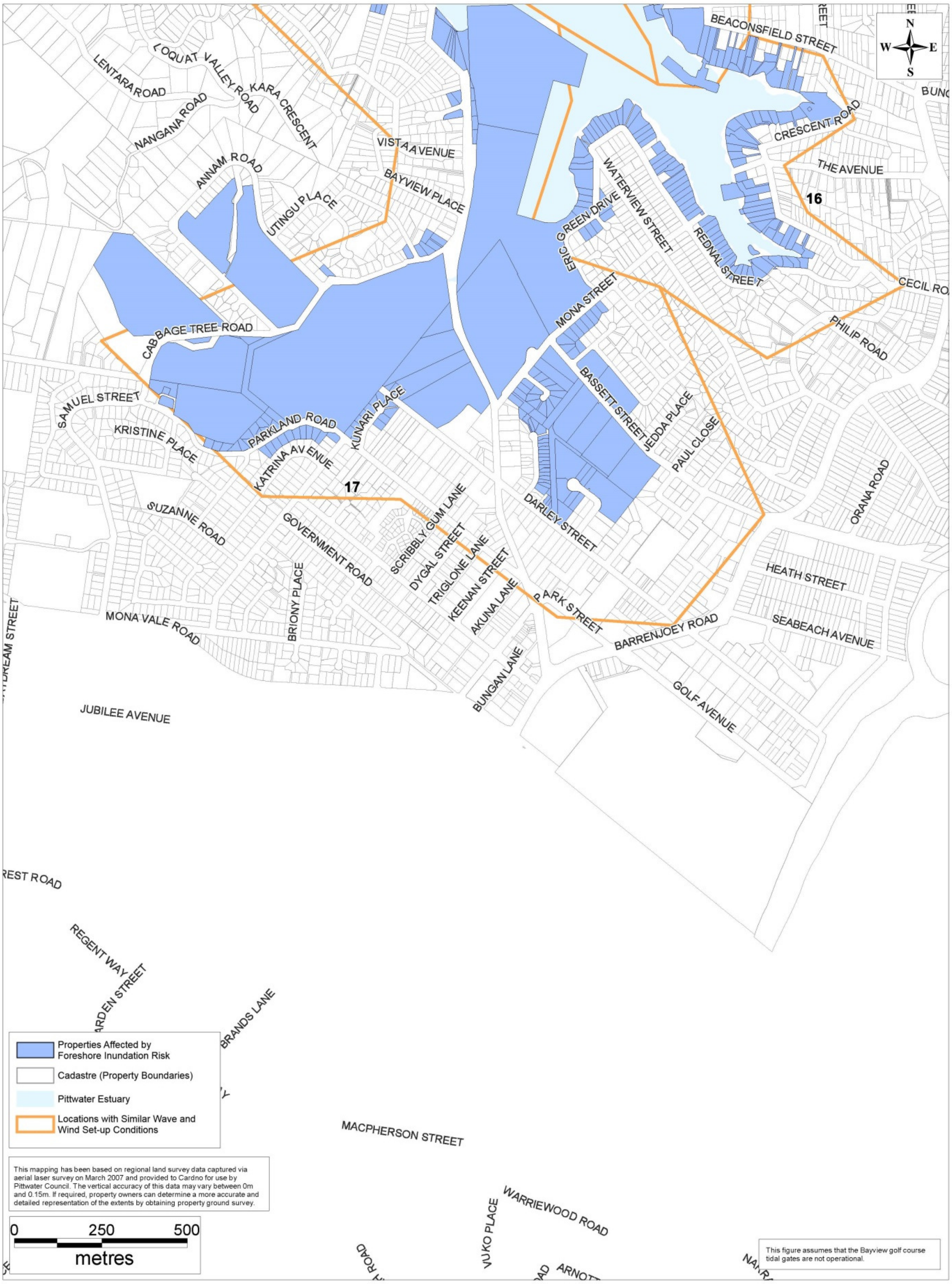

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PITTWATER ESTUARY
MAPPING OF SEA LEVEL RISE IMPACTS

FIGURE 4.4H
FLOOD RISK MAP FOR PITTWATER
ESTUARY FORESHORE
MAPPING AREA 8

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Appendix A

Coastal Processes

A1 Introduction

Coastal water levels are influenced by a variety of astronomical, meteorological/oceanographical and tectonic factors, the most readily apparent being the astronomical tides. At times, these factors interact in a complex way to elevate water levels significantly above normal tide level. Storms, which produce low atmospheric pressure (also known as barometric pressure), strong onshore winds and large waves, are the most common cause of elevated water levels on a short-term basis. Long term changes in water levels are the result of sea level rise. Combined, short and long term changes in water levels are those levels that require consideration in planning for new and re-development.

Elevated water levels are of concern because they can cause damage to the coastline and to coastal developments. Elevated water levels allow larger waves to cross offshore bars and break closer to the beach, which in turn increases beach erosion and the threat to coastal developments. Elevated water levels can inundate low lying areas of the coastline and around estuaries.

The information contained in this appendix is primarily sourced from the NSW Coastline Management Manual (NSW Government, 1990).

A2 Astronomical Tides

The astronomical tide is caused by the gravitational effect of the moon, and to a lesser extent, the sun and other planets on the water mass of the oceans. Along the NSW coast, tides are semi-diurnal, i.e. two high tides and two low tides per day.

Tidal ranges (the difference between low and high tide) vary significantly throughout each lunar month and from month to month. Very high and very low tides (King Tides) occur around the summer and winter solstice (i.e. around Christmas and in the mid-winter months). The tidal range is relatively constant along the open coast of New South Wales. The spring tide range is about 1.8 to 2.2m.

Detailed tidal predictions for the NSW coast are published annually by the Hydrographer of the Royal Australian Navy in the form of Tide Tables. The Maritime Service Board publishes summary tidal information.

A3 Meteorological / Oceanographical Processes

Three different meteorological processes can affect coastal water levels:

- Storms;
- Meteorological oscillations; and
- Climate change.

Storms are local meteorological disturbances. The other two processes are semi-global or global in nature.

Storms

The increase in coastal water level associated with a storm depends primarily on the following factors:

- the intensity, scale and direction and speed of movement of the storm;
- the bathymetry of the coastal area, including the presence or otherwise of offshore reefs and islands;
- the shape of the coastline, including the topography of the nearshore areas which may be inundated; and
- the prevailing astronomical tide.

A storm can increase coastal water levels in four distinct ways: by "setup" due to barometric, wind and wave effects and by wave "run-up". **Figure A1** illustrates these components of elevated water levels.

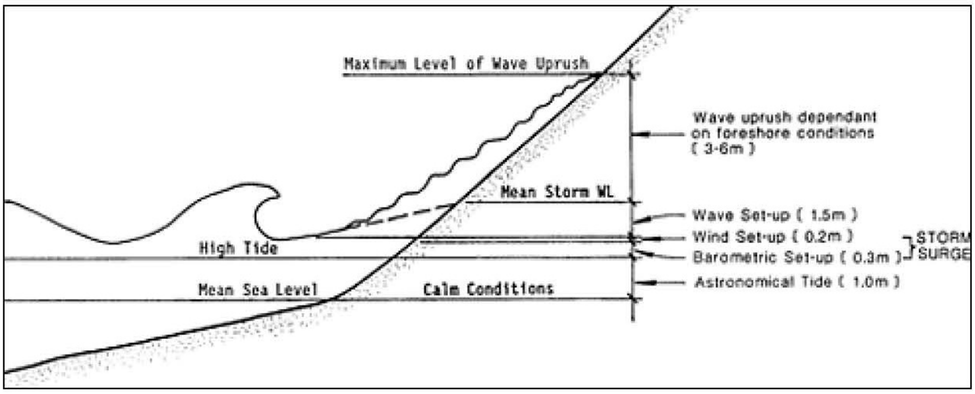

Figure A1 Elevated Water Levels During a Storm (NSW Government, 1990)

Barometric setup

The reduced barometric pressures that generate storm winds also cause a local rise in ocean level (the inverse barometer effect). Providing low pressures persist for a sufficient length of time, the increase in water level amounts to about 0.10m for each 10hPa drop below normal barometric pressure (1013hPa). In a severe storm with a central pressure of 980hPa, this amounts to approximately 0.3m.

Wind setup

Wind blowing onshore over the ocean's surface drives the surface waters before it and against the coastline. This results in elevated water levels in coastal areas, the degree of elevation being higher for extensive shallow areas and semi-enclosed bays.

Storm Surge

The sum of barometric and wind setup is often referred to as storm surge. Along the New South Wales coast storm surge amounts to approximately 0.3 to 0.6m.

Wave Setup

The action of waves breaking results in an increase in water levels in the surf zone known as "wave setup". Wave setup is associated with the conversion of the wave's kinetic energy into potential energy. The degree of setup depends upon the type, size and period of the waves at breaking and the slope of the beach.

On the New South Wales coast wave setup during severe storms can be in the order of 1.5m and often makes the largest contribution to the elevated water level.

Wave Run-up

Wave run-up is an oscillatory phenomenon and refers to the vertical distance the uprush of water from a breaking wave reaches above the combined level of the tide, storm surge and wave setup. A wave run-up of more than 6m can occur. The magnitude of run-up depends upon a variety of factors, particularly the slope and roughness of the run-up surface. Run-up on flat beaches is generally less than on steeper beaches; run-up on smooth vertical sea walls is generally greater than on protective works with rough sloping faces.

Wave run-up can result in the intermittent discharge of seawater into backbeach areas that may appear to be protected by beach barriers, such as sand dunes or seawalls.

The wave run-up and overtopping calculations adopted in this study are provided in more detail in **Appendix B**.

Rainfall Runoff

Surface runoff from any rainfall accompanying a storm may cause an increase in water levels within estuaries and tidal inlets. However, catchment rainfall and runoff tends to have no significant effect on coastal water levels for the open coast.

Oceanographic Effects

Distant meteorological disturbances (say in Bass Strait) that are characterised by a sharp pressure gradient can generate a long low wave with a period of up to 10 days and a height of up to 0.2m. As this wave travels along the continental shelf, it becomes a "shelf wave" that is "trapped" by the shelf which acts as a wave guide. Shelf waves (also known as coastally trapped waves) can also modify coastal water levels.

Other effects which can result in changes to ocean water levels (also known as tidal anomalies) include variations in sea temperature and salinity and the influence of strong currents such as the Eastern Australian Current.

Meteorological Oscillations

Major meteorological phenomena, such as the El Nino Southern Oscillation (ENSO) can affect water levels along the NSW coastline. ENSO results from interactions between the atmosphere and major ocean currents over the Pacific Ocean and appears to occur about every three to eight years. ENSO is thought to have a major impact on climate over the eastern half of Australia, particularly with regard to the sequence of "dry" and "wet" years. The associated water level change along the New South Wales coast attributed to ENSO is approximately ±0.1m.

Climate Change

A "eustatic" sea level change refers to a change in the mean water level of the oceans around the globe. A eustatic rise can occur through two mechanisms: the expansion of the surface waters of the ocean caused by a global warming and by the melting of land-based glacier ice that accompanies any such warming. In the initial period of any global warming, i.e. the first 50 to 100 years, the first effect will be the more significant.

The period 17,000 to 6,500 years before present (B.P.) saw the demise of the last ice age and the release of vast volumes of frozen water. The eustatic sea level rise associated with this event was approximately 140m. In response to this sea level rise, the shoreline of Australia retreated landwards from around the edge of the continental shelf to its present position.

DECCW (2009) outlines the predicted sea level rise associated with the effects of global warming for two planning horizons – 2050 and 2011, being 0.4 and 0.9 m respectively.

Appendix B

Wave Run-Up and Overtopping Calculations

B1 Wave Run-up and Overtopping Calculations

In defining the wave run-up level, three mechanisms of wave run-up were identified:

- Wave run-up without overtopping of the foreshore crest,
- Wave run-up rising above the foreshore crest, thereby resulting in wave overtopping, and
- Wave overtopping when the design still water level is above the foreshore crest.

Wave set-up influences wave runup. The process of wave set-up refers to the deviation of the mean water level as a result of wave shoaling, breaking and momentum flux conservation as waves progress shoreward across the surf zone. Goda (2000) provides an approximation of this set-up based on the significant wave height (H_s) or the breaking wave height (H_b) near the shoreline, whichever is smaller. The calculation of wave set-up was implicitly included in the calculation of the wave run-up heights.

Wave Run-up with No Overtopping

Run-up algorithms on smooth slopes can be found in many published articles and manuals. For the purposes of this study, the de Waal and van der Meer (1992) wave run-up algorithm for smooth slopes, as specified in the Coastal Engineering Manual (CEM, 2002) was adopted. The equation for this calculation is presented in **Section B3**. It is described as a robust approximation developed using extensive measurements of model run-up data (CEM, 2002). Should the run-up level not exceed the defined crest level, then the EPL is considered to simply be the still water level plus the run-up height (including sea level rise and plus the freeboard).

The definition of run-up on a vertical wall is quite different to a smooth slope. For a smooth impermeable, continuous wall the run-up level can be approximated as the wave height above the still water level (SWL), or approximately two times the crest level above the SWL. This is derived from linear wave theory which is suitable for short period waves.

The mechanism of wave run-up with no overtopping is shown graphically in **Plate B1**.

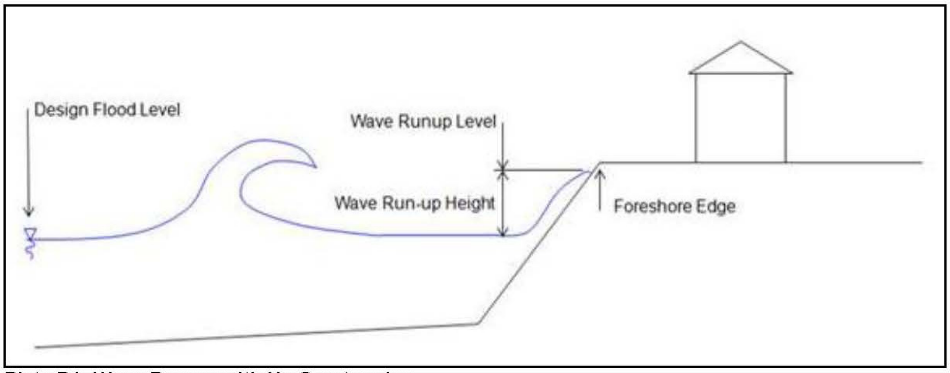

Plate B1: Wave Run-up with No Overtopping.

Wave Run-up with Overtopping

Once the crest level is reached by the wave, the mechanism of run-up is no longer applicable because there is no foreshore (edge treatment) slope to allow the run-up process to continue. In this case, overtopping of the crest occurs and a wave is transmitted onto the foreshore area. This transmitted wave can be defined using an algorithm developed by Seelig (1980) as defined in the Shoreline Protection Manual (CERC, 1984). The equation is presented in **Section B3**. The run-up level can then simply be defined as the height of the transmitted wave (i.e. overtopping wave height) added to the crest level (plus the freeboard). Note though, that local wind wave propagation over land is much less than it is for swell and this is accounted for by applying a reduction factor as the wave propagates inland, this is discussed in **Section B2**.

The mechanism of wave run-up with overtopping is shown graphically in **Plate B2**.

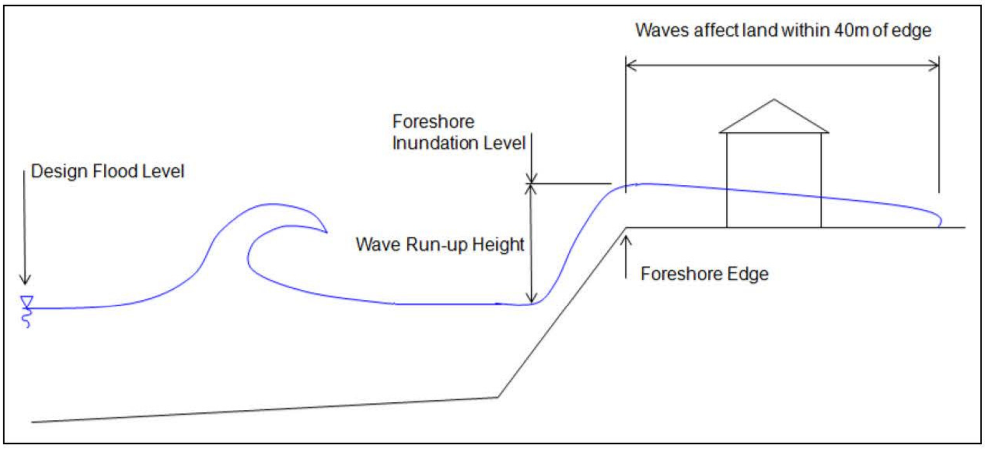

Plate B2: Wave Run-up with Overtopping.

Overtopping when Still Water Level is above the Crest

Should the design still water level be above the foreshore crest level, then waves are able to directly surge over the foreshore crest and onto the foreshore areas, albeit with some attenuation due to the reduction in depth below the wave. Studies undertaken by the Public Works Department (2001) define the height of this surge as half the approaching wave height above the design still water level. This is thought to be a realistic approximation of the wave dynamics and from this; the EPL can be defined as the height of the penetrated wave over the crest plus the storm tide level (including sea level rise, plus the freeboard). Again, this approximation is defined in **Section B3**.

The mechanism of overtopping when SWL is above the crest is shown graphically in **Plate B3**.

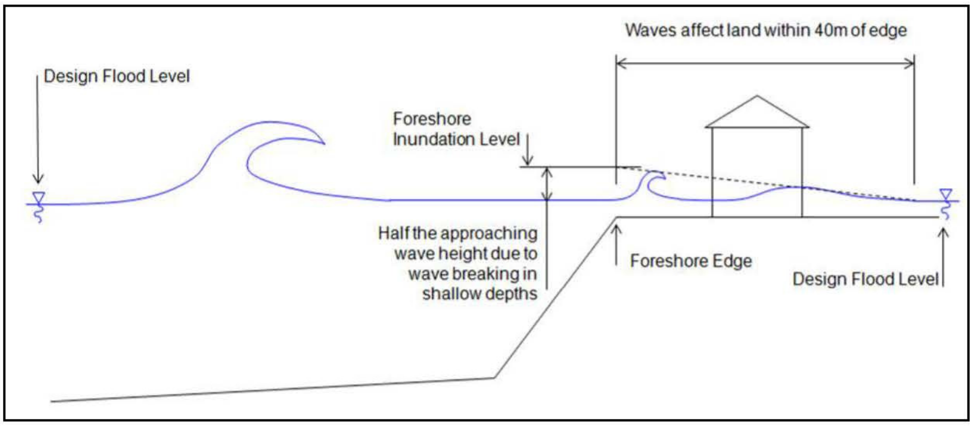

Plate B3: Overtopping when SWL is above the Crest.

Foreshore Surface Types

The magnitude of wave run-up is also dependant on the type of foreshore surface. Generally, the higher the porosity or roughness of the foreshore surface, the lower the run-up height is. The algorithms adopted for run-up calculations incorporated reduction coefficients in line with published literature (CEM, 2002) and based on the possible foreshore surface types around Pittwater. They are presented in **Table B1**.

Table B1 Surface Roughness Reduction Factors

Type of Edge Treatment Surface (Foreshore Type)	Reduction Factor for $R_{u2\%}$
Smooth, concrete, asphalt, sand and block/brick revetment	1.0
Grass/vegetated bank	0.90
Rocky Shoreline	0.60

B2 Inland Attenuation

The inland extent of the wave inundation is assumed to be 40m from the edge treatment (foreshore) crest. The EPL should therefore include wave run-up and overtopping values over this 40m wide area of the foreshore. Landward of this area, the EPL should be based on the calculated local water level for the appropriate foreshore location (including sea level rise, plus the freeboard).

Where a property slopes steeply back from the foreshore, the EPL may affect only a small part of the property. However, where a property is relatively flat, wave run-up may penetrate some distance inland, but is attenuated by percolation and friction. This landward reduction of wave inundation cannot be estimated with great confidence, and has been based on observational experience. It is assumed that wave run-up diminishes to zero at a point 40m inland from the edge structure as local waves have less overland penetration capacity than swell. Nevertheless, the wave set-up component remains.

B3 Wave Run-up Equations

Parameters

H_s - significant wave height

T - wave period

H_o - deepwater wave height

L_o - deepwater wave length $\left(= gT^2/2\pi\right)$

s_{op} - deepwater wave steepness $\left(= H_o/L_o\right)$

α - slope angle

ξ_{op} - surf similarity parameter $\left(= \tan\alpha/\sqrt{s_{op}}\right)$

$R_{u2\%}$ - Run-up height exceeded by 2% of waves

R_c - freeboard

K_{TO} - Transmitted overtopping wave coefficient

H_{TO} - Transmitted overtopping wave height

SWL - Still water level

Wave run-up without overtopping

De Waal and van der Meer (1992)

$$\frac{R_{u2\%}}{H_s} = \begin{cases} 1.6\xi_{op} \; for & 0.5 < \xi_{op} \le 2 \\ 3.2 \; for & 2 < \xi_{op} \le 3-4 \end{cases}$$

$$Level = SWL + R_{u2\%}$$

Wave run-up with overtopping

Van der Meer and Janssen (1995)

$$K_{TO} = C\left(1.0 - R_c/R_{u2\%}\right)$$

where C = 0.51 for transmitted wave at the crest

$$H_{TO} = K_{TO} \times H_s$$

$$Level = Crest + H_{TO}$$

Wave overtopping when still water is above the crest

Public Works Department (1990)

$$Level = SWL + \frac{H_s}{2}$$

Wave run-up/overtopping of a vertical wall

$$Level = SWL + H_s$$

Appendix C

Components Used in Calculation of Estuarine Planning Levels

100yr ARI Planning Levels - 2010 Planning Period - Existing Sea Levels

Foreshore Types:

1. Rocky Shoreline (1 in 5 slope)
2. Sea Wall
3. Grassed or Sandy Slope (1 in 10 slope)
4. Mangroves

100-year ARI Storm Tide at Fort Denison i: **1.44** mAHD (excluding Sea Level Rise)

EPLs for all sea wall heights less than 1m will be the equivalent.

Mean Sea Level Rise Allowances taken from State Policy **0.00** m to the year 2010

Freeboard of **0.3** m included in EPLs

Foreshore Location		100yrARI					Estuarine Planning Level (m)									
		Hs (m)	Tz (sec)	Local Wind Setup* (m)	Local (Still) Water Level (mAHD)	Local (Still) Water Level with 0.3m Freeboard (mAHD)	Foreshore Type ##									
							1			2			3			4
							Crest Level (mAHD)									
					2010	2010	1	1.5	2	1	1.5	2	1	1.5	2	N/A
1	Station Beach	1.55	10.7	0.03	1.47	1.77	2.55	2.58	2.95	2.55	2.58	2.82	2.55	2.58	2.97	1.77
2	Snapperman Beach	1.10	10.7	0.05	1.49	1.79	2.34	2.36	2.73	2.34	2.36	2.60	2.34	2.36	2.76	1.79
3	Sand Point	1.17	2.6	0.06	1.50	1.80	2.39	2.40	2.58	2.39	2.40	2.64	2.39	2.40	2.57	1.80
4	Careel Bay North	0.78	2.1	0.06	1.50	1.80	2.19	2.20	2.38	2.19	2.20	2.44	2.19	2.20	2.28	1.80
5	Careel Bay South	0.69	2.1	0.08	1.52	1.82	2.17	2.17	2.37	2.17	2.17	2.41	2.17	2.17	2.27	1.82
6	Stokes Point	0.92	2.4	0.06	1.50	1.80	2.26	2.27	2.47	2.26	2.27	2.51	2.26	2.27	2.52	1.80
7	Paradise Beach	0.90	2.4	0.07	1.51	1.81	2.26	2.26	2.46	2.26	2.26	2.51	2.26	2.26	2.37	1.81
8	Clareville Beach	0.98	2.4	0.08	1.52	1.82	2.31	2.31	2.49	2.31	2.31	2.56	2.31	2.31	2.39	1.82
9	Taylors Point	1.12	2.6	0.08	1.52	1.82	2.38	2.38	2.57	2.38	2.38	2.63	2.38	2.38	2.47	1.82
10	Refuge Cove	0.82	2.4	0.08	1.52	1.82	2.23	2.23	2.44	2.23	2.23	2.47	2.23	2.23	2.34	1.82
11	Salt Pan Cove	0.80	2.4	0.09	1.53	1.83	2.23	2.23	2.44	2.23	2.23	2.47	2.23	2.23	2.35	1.83
12	Salt Pan Point	0.82	2.4	0.09	1.53	1.83	2.24	2.24	2.44	2.24	2.24	2.48	2.24	2.24	2.35	1.83
13	Horseshoe Cove	0.80	2.4	0.09	1.53	1.83	2.23	2.23	2.44	2.23	2.23	2.47	2.23	2.23	2.35	1.83
14	Crystal Bay	0.43	1.8	0.09	1.53	1.83	2.05	2.05	2.22	2.05	2.05	2.26	2.05	2.05	2.12	1.83
15	Haystack Point	0.54	1.8	0.10	1.54	1.84	2.11	2.11	2.28	2.11	2.11	2.34	2.11	2.11	2.17	1.84
16	Winji Jimmi Bay	0.46	1.8	0.13	1.57	1.87	2.10	2.10	2.28	2.10	2.10	2.32	2.10	2.10	2.17	1.87
17	Winnererremy Bay-Maybanke Cove	0.80	2.4	0.10	1.54	1.84	2.24	2.24	2.44	2.24	2.24	2.47	2.24	2.24	2.35	1.84
18	Bayview Foreshore	0.98	2.4	0.09	1.53	1.83	2.32	2.32	2.50	2.32	2.32	2.56	2.32	2.32	2.40	1.83
19	Church Point Foreshore	0.90	2.4	0.09	1.53	1.83	2.28	2.28	2.47	2.28	2.28	2.52	2.28	2.28	2.38	1.83
20	Church Point	0.88	2.4	0.10	1.54	1.84	2.28	2.28	2.47	2.28	2.28	2.51	2.28	2.28	2.38	1.84
21	Browns Bay	0.60	2.1	0.11	1.55	1.85	2.15	2.15	2.36	2.15	2.15	2.38	2.15	2.15	2.27	1.85
22	McCarrs Creek	0.56	1.8	0.11	1.55	1.85	2.13	2.13	2.30	2.13	2.13	2.36	2.13	2.13	2.19	1.85
23	Elvina Bay	0.86	2.4	0.10	1.54	1.84	2.27	2.27	2.46	2.27	2.27	2.50	2.27	2.27	2.37	1.84
24	Lovett Bay	0.74	2.1	0.09	1.53	1.83	2.20	2.20	2.39	2.20	2.20	2.44	2.20	2.20	2.29	1.83
25	Little Lovett Bay	1.10	2.6	0.08	1.52	1.82	2.37	2.37	2.56	2.37	2.37	2.62	2.37	2.37	2.46	1.82
26	Woody Point	0.72	2.1	0.08	1.52	1.82	2.18	2.18	2.38	2.18	2.18	2.42	2.18	2.18	2.28	1.82
27	Morning Bay	0.88	2.4	0.08	1.52	1.82	2.26	2.26	2.46	2.26	2.26	2.50	2.26	2.26	2.36	1.82
28	Longnose Point	1.20	2.6	0.07	1.51	1.81	2.41	2.41	2.59	2.41	2.41	2.66	2.41	2.41	2.49	1.81
29	Soldiers Point	1.15	10.7	0.06	1.50	1.80	2.38	2.39	2.75	2.38	2.39	2.63	2.38	2.39	2.79	1.80
30	Coasters Retreat	0.90	2.4	0.07	1.51	1.81	2.26	2.26	2.46	2.26	2.26	2.51	2.26	2.26	2.42	1.81
31	The Basin	0.86	2.4	0.07	1.51	1.81	2.24	2.24	2.45	2.24	2.24	2.49	2.24	2.24	2.35	1.81
32	Currawong Beach	1.15	2.6	0.06	1.50	1.80	2.38	2.39	2.63	2.38	2.39	2.63	2.38	2.39	2.67	1.80
33	Mackerel Beach	0.96	2.4	0.05	1.49	1.79	2.27	2.28	2.52	2.27	2.28	2.53	2.27	2.28	2.57	1.79
34	Pitt Point	0.82	2.4	0.08	1.52	1.82	2.23	2.23	2.44	2.23	2.23	2.47	2.23	2.23	2.34	1.82
35	East Scotland Island	0.94	2.4	0.08	1.52	1.82	2.29	2.29	2.48	2.29	2.29	2.53	2.29	2.29	2.38	1.82
36	South Scotland Island	1.15	2.6	0.08	1.52	1.82	2.40	2.40	2.58	2.40	2.40	2.64	2.40	2.40	2.48	1.82
37	North West Scotland Island	1.00	2.6	0.09	1.53	1.83	2.33	2.33	2.53	2.33	2.33	2.57	2.33	2.33	2.44	1.83

100yr ARI Planning Levels - 2050 Planning Period - 0.4m Sea Level Rise

Foreshore Types:

1. Rocky Shoreline (1 in 5 slope)
2. Sea Wall
3. Grassed or Sandy Slope (1 in 10 slope)
4. Mangroves

100-year ARI Storm Tide at Fort Denison i **1.84** mAHD (including projected Sea Level Rise of 0.4m)
EPLs for all sea wall heights less than 1m will be the equivalent.

Mean Sea Level Rise Allowances taken from State Policy **0.40** m to the year 2050
Freeboard of **0.3** m included in EPLs

Foreshore Location		100yrARI					Estuarine Planning Level (m)									
							Foreshore Type ##									
		Hs (m)	Tz (sec)	Local Wind Setup* (m)	Local (Still) Water Level (mAHD)	Local (Still) Water Level with 0.3m Freeboard (mAHD)	1			2			3			4
							Crest Level (mAHD)									
					2050	2050	1	1.5	2	1	1.5	2	1	1.5	2	N/A
1	Station Beach	1.55	10.7	0.03	1.87	2.17	2.95	2.95	3.06	2.95	2.95	3.02	2.95	2.95	3.06	2.17
2	Snapperman Beach	1.10	10.7	0.05	1.89	2.19	2.74	2.74	2.83	2.74	2.74	2.80	2.74	2.74	2.84	2.19
3	Sand Point	1.17	2.6	0.06	1.90	2.20	2.79	2.79	2.83	2.79	2.79	2.85	2.79	2.79	2.81	2.20
4	Careel Bay North	0.78	2.1	0.06	1.90	2.20	2.59	2.59	2.64	2.59	2.59	2.65	2.59	2.59	2.61	2.20
5	Careel Bay South	0.69	2.1	0.08	1.92	2.22	2.57	2.57	2.60	2.57	2.57	2.61	2.57	2.57	2.59	2.22
6	Stokes Point	0.92	2.4	0.06	1.90	2.20	2.66	2.66	2.71	2.66	2.66	2.72	2.66	2.66	2.69	2.20
7	Paradise Beach	0.90	2.4	0.07	1.91	2.21	2.66	2.66	2.70	2.66	2.66	2.71	2.66	2.66	2.69	2.21
8	Clareville Beach	0.98	2.4	0.08	1.92	2.22	2.71	2.71	2.75	2.71	2.71	2.76	2.71	2.71	2.73	2.22
9	Taylors Point	1.12	2.6	0.08	1.92	2.22	2.78	2.78	2.82	2.78	2.78	2.83	2.78	2.78	2.80	2.22
10	Refuge Cove	0.82	2.4	0.08	1.92	2.22	2.63	2.63	2.67	2.63	2.63	2.68	2.63	2.63	2.66	2.22
11	Salt Pan Cove	0.80	2.4	0.09	1.93	2.23	2.63	2.63	2.67	2.63	2.63	2.67	2.63	2.63	2.65	2.23
12	Salt Pan Point	0.82	2.4	0.09	1.93	2.23	2.64	2.64	2.68	2.64	2.64	2.68	2.64	2.64	2.66	2.23
13	Horseshoe Cove	0.80	2.4	0.09	1.93	2.23	2.63	2.63	2.67	2.63	2.63	2.67	2.63	2.63	2.65	2.23
14	Crystal Bay	0.43	1.8	0.09	1.93	2.23	2.45	2.45	2.48	2.45	2.45	2.48	2.45	2.45	2.47	2.23
15	Haystack Point	0.54	1.8	0.10	1.94	2.24	2.51	2.51	2.54	2.51	2.51	2.54	2.51	2.51	2.53	2.24
16	Winji Jimmi Bay	0.46	1.8	0.13	1.97	2.27	2.50	2.50	2.52	2.50	2.50	2.52	2.50	2.50	2.51	2.27
17	Winnererremy Bay-Maybanke Cove	0.80	2.4	0.10	1.94	2.24	2.64	2.64	2.67	2.64	2.64	2.68	2.64	2.64	2.66	2.24
18	Bayview Foreshore	0.98	2.4	0.09	1.93	2.23	2.72	2.72	2.76	2.72	2.72	2.76	2.72	2.72	2.74	2.23
19	Church Point Foreshore	0.90	2.4	0.09	1.93	2.23	2.68	2.68	2.72	2.68	2.68	2.72	2.68	2.68	2.70	2.23
20	Church Point	0.88	2.4	0.10	1.94	2.24	2.68	2.68	2.71	2.68	2.68	2.72	2.68	2.68	2.70	2.24
21	Browns Bay	0.60	2.1	0.11	1.95	2.25	2.55	2.55	2.58	2.55	2.55	2.58	2.55	2.55	2.57	2.25
22	McCarrs Creek	0.56	1.8	0.11	1.95	2.25	2.53	2.53	2.55	2.53	2.53	2.56	2.53	2.53	2.54	2.25
23	Elvina Bay	0.86	2.4	0.10	1.94	2.24	2.67	2.67	2.70	2.67	2.67	2.71	2.67	2.67	2.69	2.24
24	Lovett Bay	0.74	2.1	0.09	1.93	2.23	2.60	2.60	2.63	2.60	2.60	2.64	2.60	2.60	2.62	2.23
25	Little Lovett Bay	1.10	2.6	0.08	1.92	2.22	2.77	2.77	2.81	2.77	2.77	2.82	2.77	2.77	2.79	2.22
26	Woody Point	0.72	2.1	0.08	1.92	2.22	2.58	2.58	2.62	2.58	2.58	2.63	2.58	2.58	2.60	2.22
27	Morning Bay	0.88	2.4	0.08	1.92	2.22	2.66	2.66	2.70	2.66	2.66	2.71	2.66	2.66	2.68	2.22
28	Longnose Point	1.20	2.6	0.07	1.91	2.21	2.81	2.81	2.85	2.81	2.81	2.87	2.81	2.81	2.83	2.21
29	Soldiers Point	1.15	10.7	0.06	1.90	2.20	2.78	2.78	2.86	2.78	2.78	2.84	2.78	2.78	2.87	2.20
30	Coasters Retreat	0.90	2.4	0.07	1.91	2.21	2.66	2.66	2.70	2.66	2.66	2.71	2.66	2.66	2.69	2.21
31	The Basin	0.86	2.4	0.07	1.91	2.21	2.64	2.64	2.68	2.64	2.64	2.69	2.64	2.64	2.67	2.21
32	Currawong Beach	1.15	2.6	0.06	1.90	2.20	2.78	2.78	2.82	2.78	2.78	2.84	2.78	2.78	2.80	2.20
33	Mackerel Beach	0.96	2.4	0.05	1.89	2.19	2.67	2.67	2.72	2.67	2.67	2.73	2.67	2.67	2.70	2.19
34	Pitt Point	0.82	2.4	0.08	1.92	2.22	2.63	2.63	2.67	2.63	2.63	2.68	2.63	2.63	2.66	2.22
35	East Scotland Island	0.94	2.4	0.08	1.92	2.22	2.69	2.69	2.73	2.69	2.69	2.74	2.69	2.69	2.71	2.22
36	South Scotland Island	1.15	2.6	0.08	1.92	2.22	2.80	2.80	2.84	2.80	2.80	2.85	2.80	2.80	2.82	2.22
37	North West Scotland Island	1.00	2.6	0.09	1.93	2.23	2.73	2.73	2.77	2.73	2.73	2.77	2.73	2.73	2.75	2.23

100yr ARI Planning Levels - 2100 Planning Period - 0.9m Sea Level Rise

Foreshore Types:

1. Rocky Shoreline (1 in 5 slope)
2. Sea Wall
3. Grassed or Sandy Slope (1 in 10 slope)
4. Mangroves

100-year ARI Storm Tide at Fort Denison i **2.34** mAHD (including projected Sea Level Rise of 0.9m)
EPLs for all sea wall heights less than 1m will be the equivalent.

Mean Sea Level Rise Allowances taken from State Policy **0.90** m to the year 2100
Freeboard of **0.3** m included in EPLs

	Foreshore Location	100yrARI					Estuarine Planning Level (m)									
		Hs (m)	Tz (sec)	Local Wind Setup* (m)	Local (Still) Water Level (mAHD)	Local (Still) Water Level with 0.3m Freeboard (mAHD)	Foreshore Type ##									
							1			2			3			4
							Crest Level (mAHD)									
					2100	2100	1	1.5	2	1	1.5	2	1	1.5	2	N/A
1	Station Beach	1.55	10.7	0.03	2.37	2.67	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	3.45	2.67
2	Snapperman Beach	1.10	10.7	0.05	2.39	2.69	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	3.24	2.69
3	Sand Point	1.17	2.6	0.06	2.40	2.70	3.29	3.29	3.29	3.29	3.29	3.29	3.29	3.29	3.29	2.70
4	Careel Bay North	0.78	2.1	0.06	2.40	2.70	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09	2.70
5	Careel Bay South	0.69	2.1	0.08	2.42	2.72	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	3.07	2.72
6	Stokes Point	0.92	2.4	0.06	2.40	2.70	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	2.70
7	Paradise Beach	0.90	2.4	0.07	2.41	2.71	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	2.71
8	Clareville Beach	0.98	2.4	0.08	2.42	2.72	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	3.21	2.72
9	Taylors Point	1.12	2.6	0.08	2.42	2.72	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28	2.72
10	Refuge Cove	0.82	2.4	0.08	2.42	2.72	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	2.72
11	Salt Pan Cove	0.80	2.4	0.09	2.43	2.73	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	2.73
12	Salt Pan Point	0.82	2.4	0.09	2.43	2.73	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	2.73
13	Horseshoe Cove	0.80	2.4	0.09	2.43	2.73	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	2.73
14	Crystal Bay	0.43	1.8	0.09	2.43	2.73	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.95	2.73
15	Haystack Point	0.54	1.8	0.10	2.44	2.74	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	2.74
16	Winji Jimmi Bay	0.46	1.8	0.13	2.47	2.77	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	2.77
17	Winnererremy Bay-Maybanke Cove	0.80	2.4	0.10	2.44	2.74	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	2.74
18	Bayview Foreshore	0.98	2.4	0.09	2.43	2.73	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22	3.22	2.73
19	Church Point Foreshore	0.90	2.4	0.09	2.43	2.73	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	2.73
20	Church Point	0.88	2.4	0.10	2.44	2.74	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	2.74
21	Browns Bay	0.60	2.1	0.11	2.45	2.75	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	2.75
22	McCarrs Creek	0.56	1.8	0.11	2.45	2.75	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	3.03	2.75
23	Elvina Bay	0.86	2.4	0.10	2.44	2.74	3.17	3.17	3.17	3.17	3.17	3.17	3.17	3.17	3.17	2.74
24	Lovett Bay	0.74	2.1	0.09	2.43	2.73	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	2.73
25	Little Lovett Bay	1.10	2.6	0.08	2.42	2.72	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	2.72
26	Woody Point	0.72	2.1	0.08	2.42	2.72	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	2.72
27	Morning Bay	0.88	2.4	0.08	2.42	2.72	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	2.72
28	Longnose Point	1.20	2.6	0.07	2.41	2.71	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	3.31	2.71
29	Soldiers Point	1.15	10.7	0.06	2.40	2.70	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28	2.70
30	Coasters Retreat	0.90	2.4	0.07	2.41	2.71	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	3.16	2.71
31	The Basin	0.86	2.4	0.07	2.41	2.71	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	2.71
32	Currawong Beach	1.15	2.6	0.06	2.40	2.70	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28	3.28	2.70
33	Mackerel Beach	0.96	2.4	0.05	2.39	2.69	3.17	3.17	3.17	3.17	3.17	3.17	3.17	3.17	3.17	2.69
34	Pitt Point	0.82	2.4	0.08	2.42	2.72	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	3.13	2.72
35	East Scotland Island	0.94	2.4	0.08	2.42	2.72	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19	2.72
36	South Scotland Island	1.15	2.6	0.08	2.42	2.72	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	2.72
37	North West Scotland Island	1.00	2.6	0.09	2.43	2.73	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	3.23	2.73

Appendix D

Photo Log of the Foreshore

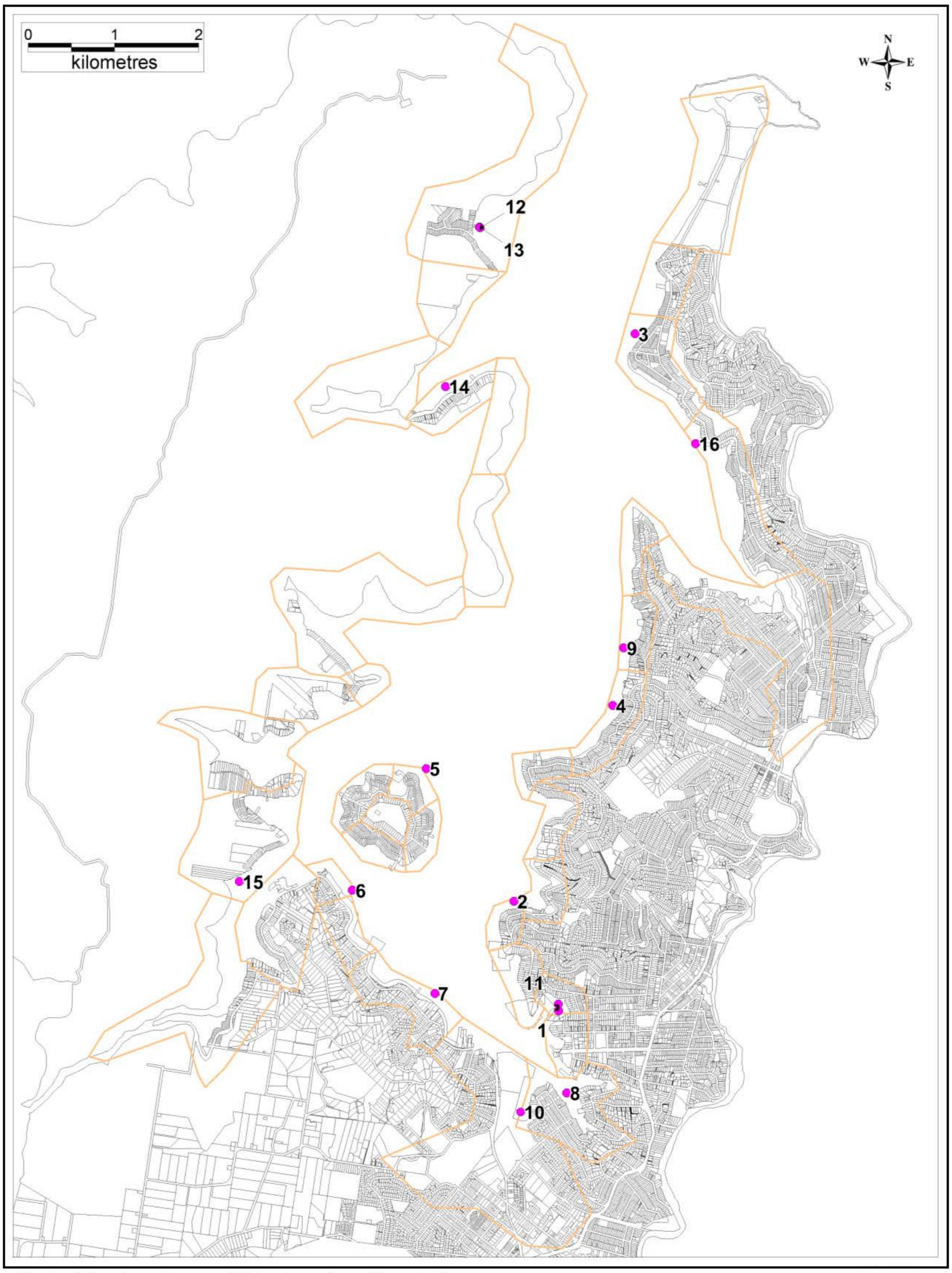

Photo Sites (see Figure 3.1 for Location Mapping)

Photo 1: Location 14 sea wall (0.5m).

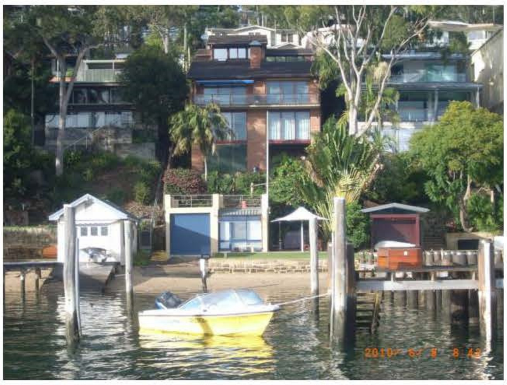

Photo 2: Location 12 sea wall (0.5m).

Photo 3: Location 3 sea wall (0.5m).

Photo 4: Location 8 sea wall (1.0m).

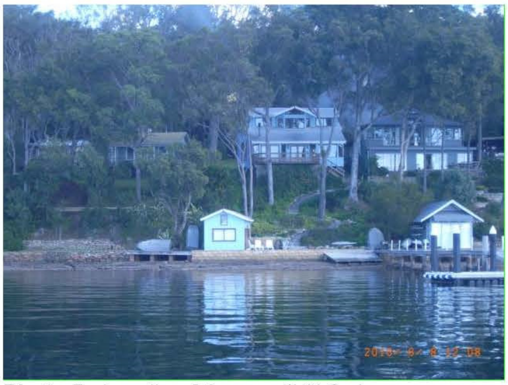

Photo 5: Location 34 sea wall (1.0m).

Photo 6: Location 20 sea wall (1.0m).

Photo 7: Location 18 sea wall (1.0m).

Photo 8: Location 16 sea wall (1.5m).

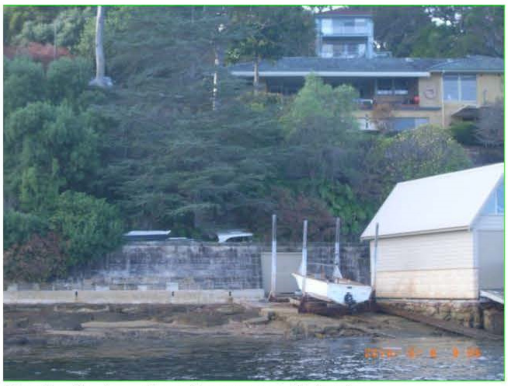

Photo 9: Location 7 sea wall (1.5m).

Photo 10: Location 16 natural slope (grassy).

Photo 11: Location 15 natural slope (grassy).

Photo 12: Location 33 natural slope (sandy).

Photo 13: Location 33 natural slope (sandy).

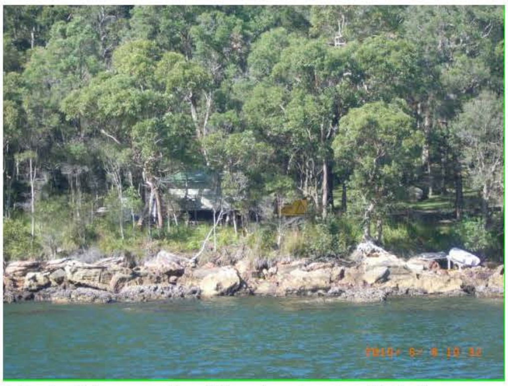

Photo 14: Location 30 natural rocky (0.5m).

Photo 15: Location 23 natural rocky (1.0m).

Photo 16: Location 4 natural rocky (2.0m).

Appendix E

Community Engagement Information and Results Summary

Community Engagement Information and Results Summary

The table below provides a summary of the results of the community engagement strategy carried out after completion of the draft report and associated mapping.

The "ID" column refers to a unique identifier to distinguish each appointment that was made and undertaken. Both call-back sessions (via telephone) and community information sessions (in person) are included in the table.

Columns A-D represent four comments/issues/questions that were commonly raised by community members during the consultation:

- A – Wanting to get a general overview of the study and what it entailed;
- B – Wanting to know the proposed EPL at their property;
- C – Wanting to know how their property would be affected by sea level rise; and
- D – Wanting to understand how the proposed EPLs would affect their property (especially in relation to dwelling extensions, redevelopment, foreshore structures and property sale).

For each appointment, a tick has been placed against each relevant questions/comments that were raised. If other or more specific comments were received, these have been described in the "Other" column, with the response in italics.

The "Suburb" column gives an indication of the address of the resident.

ID	Key Issues/Comments/Questions					Suburb
	A	B	C	D	Other (*Response in Italics*)	
1			✓			Bayview
2				✓	1. Process that you have to go through to do a Risk Report? *No different to current process, however name will change from Estuarine Risk Report to Foreshore Flood* Risk Report.*	Great Mackerel Beach
3				✓	1. Will maximum building heights be amended in accordance with new EPLs? *Council has not finalised this as yet. Currently maximum building height sits at 8m above the planning level.* 2. Will new EPLs apply to extend an existing dwelling (i.e. not a new dwelling). *Council has not finalised this as yet. Currently, planning levels apply to any extensions/additions carried out on an existing dwelling/structure.* 3. Is foreshore flood* risk the same catchment flood risk in terms of getting finance? *Advised to speak with an external financial services provider.*	Avalon
4		✓		✓		Great Mackerel Beach
5		✓				Bayview
6		✓				Great Mackerel Beach
7				✓		Avalon

ID	Key Issues/Comments/Questions					Suburb
	A	B	C	D	Other (*Response in Italics*)	
8		✓		✓	1. Objects to state government policy on climate change. *Noted.*	Bayview
9				✓		Bayview
10				✓		Newport
11			✓	✓	1. How long until the proposed EPLs are adopted? *All going to plan, approximately three months.*	Avalon
12	✓				1. What will be the wording of the s149 Certificate? *Has not been finalised however wording would be similar to existing s149 Certificates.*	McCarrs Creek
13				✓		Palm Beach
14				✓	1. How are non-habitable structures impacted by EPLs? *Non-habitable structures generally still come under development controls and are affected by planning levels.*	Newport
15			✓			Church Point
16					1. Readability of maps and Council's online planning levels tool needs improvement. The tool needs to explicitly say "This property has an EPL". *Noted.*	Avalon
17				✓		Newport
18	✓			✓		Mona Vale
19			✓		1. Flood gates at Bayview do not seem to let enough water through. *Beyond the scope of this study, concerns to be forwarded to Council.*	Bayview
20					1. Has not observed any sea level rises over the last 55 years since he has lived in the area. *Noted.*	Palm Beach
21	✓					Bayview
22		✓	✓	✓		Palm Beach
23	✓	✓	✓	✓		Newport
24	✓				1. What can be done? *This study and the maps are the first stage in what will be a fairly lengthy process of assessing and planning for sea level rise in Pittwater. Mitigation/adaptation measures are to be determined in future studies.*	Palm Beach
25			✓	✓		Palm Beach
26	✓				1. Flood gates at Bayview do not seem to let enough water through, and there is polluted water and sewer overflow issues. *Beyond the scope of this study, concerns to be forwarded to Council.*	Mona Vale
27	✓			✓		Avalon
28	✓		✓	✓	1. What can be done? *This study and the maps are the first stage in what will be a fairly lengthy process of assessing and planning for sea level rise in Pittwater. Mitigation/adaptation measures are to be determined in future studies.*	Palm Beach
29	✓		✓			Palm Beach
30			✓			Avalon

ID	Key Issues/Comments/Questions					Suburb
	A	B	C	D	Other (*Response in Italics*)	
31		✓				Palm Beach
32			✓			Newport
33				✓		Newport
34	✓				1. How are swimming pools affected by EPLs? A decision has not yet been reached however currently, FPLs have provisions for swimming pools whereas EPLs do not.	Mona Vale
35	✓		✓	✓		Avalon
36					1. The mapping is unclear in that the 40m wave inundation extent should only be shown where it is relevant. *To be updated.*	Church Point
37	✓		✓	✓		Avalon
38	✓	✓	✓	✓		Avalon
39				✓		Newport
40	✓			✓	Has groundwater been considered in the study? *No. Potential groundwater impacts are likely to vary considerably depending on various site-specific factors (location, slope of land, soil/rock type etc.). Independent geotechnical advice should be sought for site-specific details.*	Palm Beach
41	✓		✓			Bayview
42	✓					Mona Vale
43	✓	✓	✓			Palm Beach
44	✓		✓	✓		Newport
45			✓	✓		Great Mackerel Beach
46	✓		✓	✓		Mona Vale
47	✓		✓		1. What can be done? *This study and the maps are the first stage in what will be a fairly lengthy process of assessing and planning for sea level rise in Pittwater. Mitigation/adaptation measures are to be determined in future studies.*	Palm Beach
48			✓	✓	1. McCarrs Creek has been silting up over the years. *Noted and issue to be forwarded to Council.*	Church Point
49			✓	✓	1. How long until the proposed EPLs are adopted? *All going to plan, approximately three months.*	Avalon
50	✓			✓		Palm Beach

* Since that time, the naming of the planning levels and risk has been modified to reflect the same naming as per the Cardno (2004) report, i.e. *Estuarine Flood Risk* and *Estuarine Planning Level.*

C10.2 Flood Emergency Response Planning for Development in Pittwater

Meeting: Natural Environment Committee **Date:** 2 March 2015

COMMUNITY STRATEGIC PLAN STRATEGY: **Disaster, Emergency & Risk Management**

COMMUNITY STRATEGIC PLAN OBJECTIVE:

- To promote a well-informed community and that the Council knows how to effectively respond to disaster and emergency situations before during and after
- To effectively respond to disasters, emergency situations and provide effective relief measures
- To work effectively with all emergency and utility agencies to improve emergency response
- To adhere to best practice risk management principles to facilitate more effective decision-making
- To manage public liability and risks associated with public infrastructure
- To increase community awareness on effective risk management
- To incorporate risk management in all business activities
- To plan for risks due to natural and manmade hazards
- To provide for business continuity in the event of a major disruption to the Council

DELIVERY PROGRAM ACTION:

- Develop and implement programs to increase resilience to flood and coastal storms
- Develop, review and implement flood and coastal storm risk studies and plans in accordance with NSW Government guidelines

1.0 EXECUTIVE SUMMARY

1.1 SUMMARY

To help minimise the flood risk to occupants within flood prone land, it is important that developments have provisions to facilitate emergency response (either evacuation or shelter-in-place).

By establishing a Flood Emergency Response Planning for Development in Pittwater Policy and associated DCP control, the flood risk associated with the development can be identified and the flood risk to life appropriately managed.

The NSW Government Flood Prone Land Policy highlights that the primary responsibility for floodplain risk management rests with Local Councils. The NSW State Government has prepared the *Floodplain Development Manual* (2005) in accordance with its Flood Prone Land Policy to guide Local Councils in the management of their flood risks.

Provided Councils utilise the framework provided by the Floodplain Development Manual, and they have acted in good faith, Councils can provide themselves with indemnity under Section 733 of the Local Government Act, 1993.