Appendix B

Conceptual Sediment Transport Model – Batemans Bay

Inner Batemans Bay
Conceptual Sediment Transport Model

Eurobodalla Open Coast Coastal Management Program - Stage 2: Vulnerability Assessments

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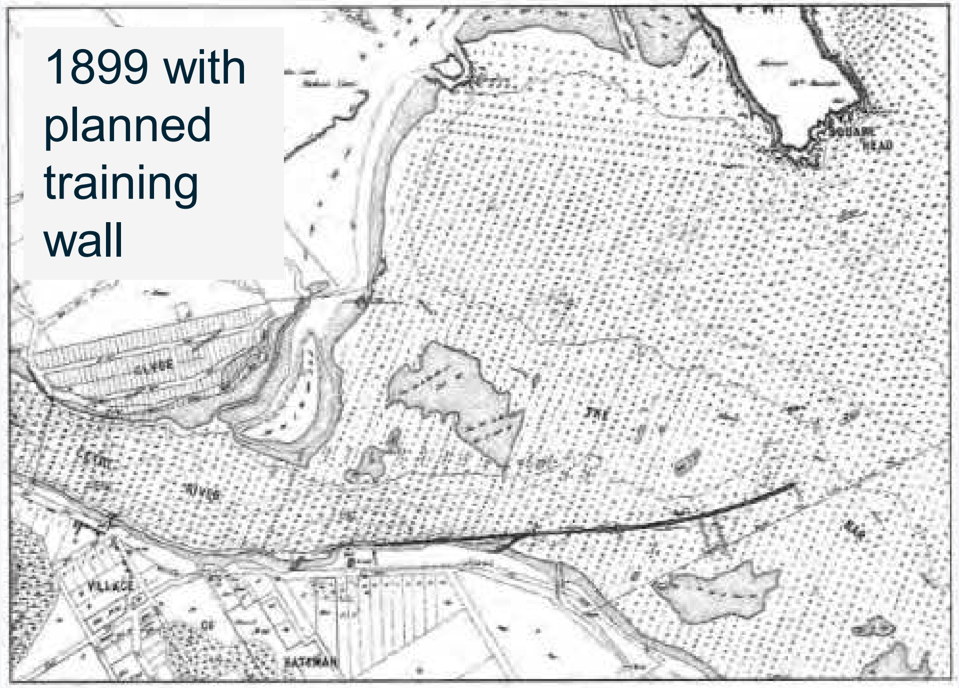
Historical Timeline

- Development
  - 1899 to 1905 – Training wall constructed (low crested structure)
  - 1950s – Princes Highway Bridge constructed
  - circa 1950s/60s – Training wall upgraded (higher crest)
  - circa 1960s/70s – Construction of Seawalls (various) including at Wharf Road
  - 1989 – Extension of training wall
- Dredging
  - Regular dredging of the entrance shoal up until early 1950s (then 1957-8, 1961-2, 1964)
  - Recent dredging of entrance shoal included 2013, 2016 and 2020
- Nourishment
  - Dredged spoil typically placed on Corrigans (up until 60s)
  - Dune Nourishment at Northern Surfside East, circa 1996
  - Nourishment at Surfside West, 2016
  - Nourishment of shoal offshore of Surfside, 2020

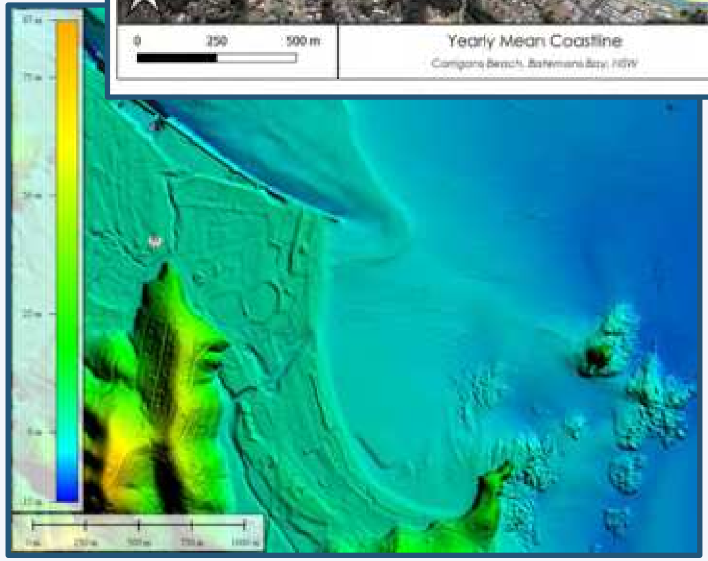


Sediments in the Inner Bay

- WBM (2000) completed field sampling of surface sediments
- The sediments of inner Batemans Bay are:
  - Predominantly lithic sands
  - Higher proportion of angular (fluvial) quartz compared to well rounded (marine) quartz
  - Carbonate content increased further out into the Bay
- The predominance of fluvially derived sediments indicates flood events are the significant contributor of sediment to the Bay
- Annual average fluvial sand supply is estimated to be in excess of 22,000m^3 per year (WBM, 2000).

Corrigans Beach

- History
  - 1899 to 1905 – Training wall constructed (low crested)
  - circa 1950s/60s – Training wall upgraded (~+2mAHD crest)
  - 1991 – Extension of training wall
  - Significant accretion has occurred (~8,000m^3 /year since 1942)
- Sediment Transport
  - Accretion due to construction of training wall and subsequent upgrade and extension
  - Training wall (both pre- and post- upgrade) was an effective trap of bed load sediment transport (the principal mechanism of sediment transport/morphological change since 1900)
  - Longshore sediment movement of fluvially supplied sediments to the north, minor bypassing of training wall back into the shoal

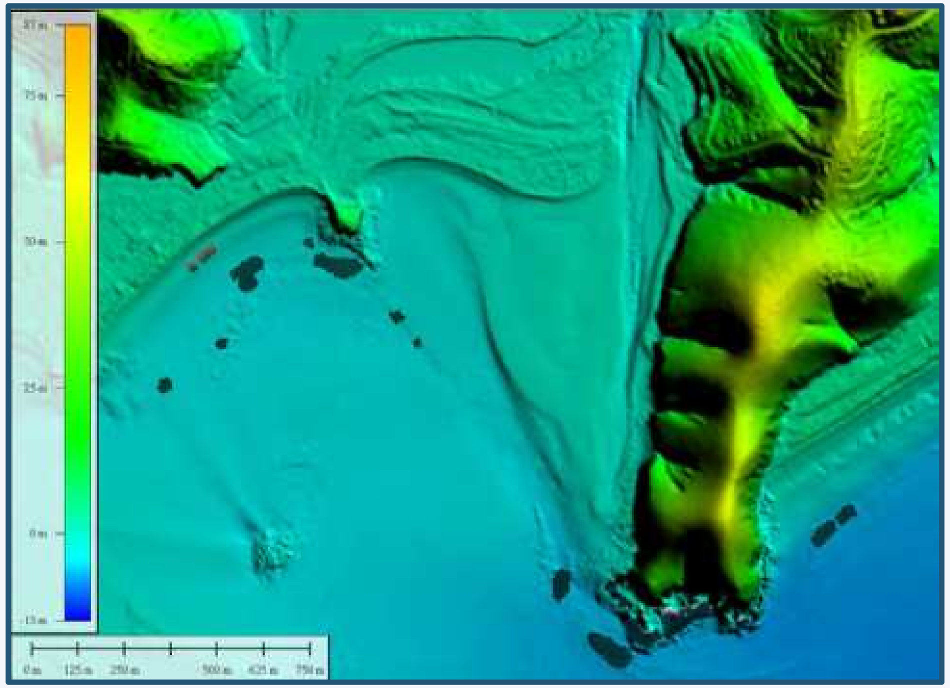


Original training wall

Upgraded training wall

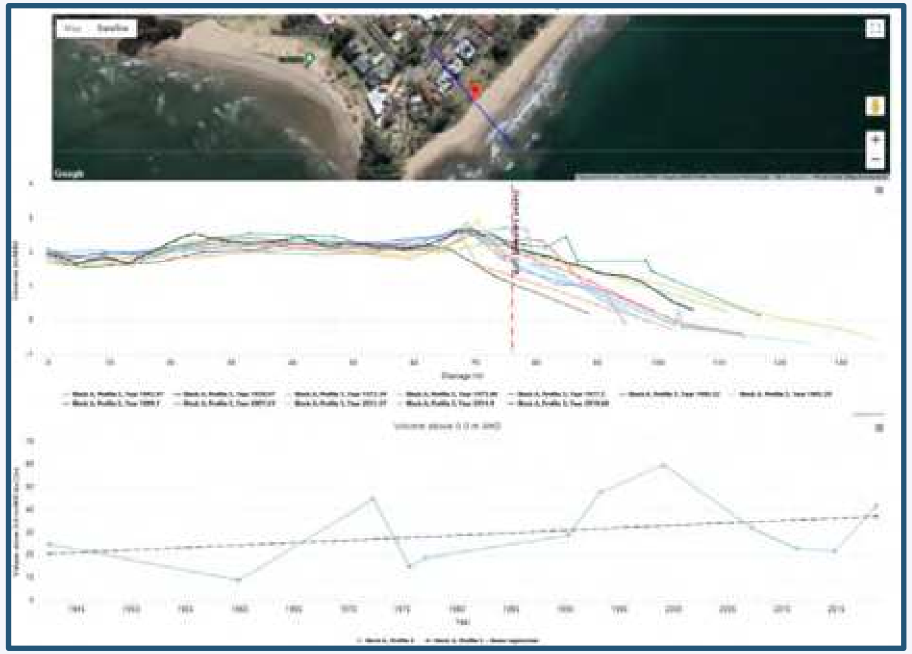
Cullendulla Beach

- History
  - Embayed by Square Head and Hawk's Nest Head.
  - Chenier Plains to the rear (variably spaced - a function of the variable rate of falling sea level over ~6000 yrs).
  - Significant flood delta (Square Head Shoal) from Cullendulla Creek fed by flood flows/runoff. Protected from incident waves.
  - Limited human interference.
- Sediment Transport
  - Eastern longshore transport.
  - Ongoing recession at the western end (90 m between 1942 to 2018) following end to seaward progression of the beach ridge system after stable/rising sea levels over the last ~1000 years.
  - No direct mechanism of fluvial sediment from Cullendulla Creek to reach the adjacent shoreline to the west.



Surfside East

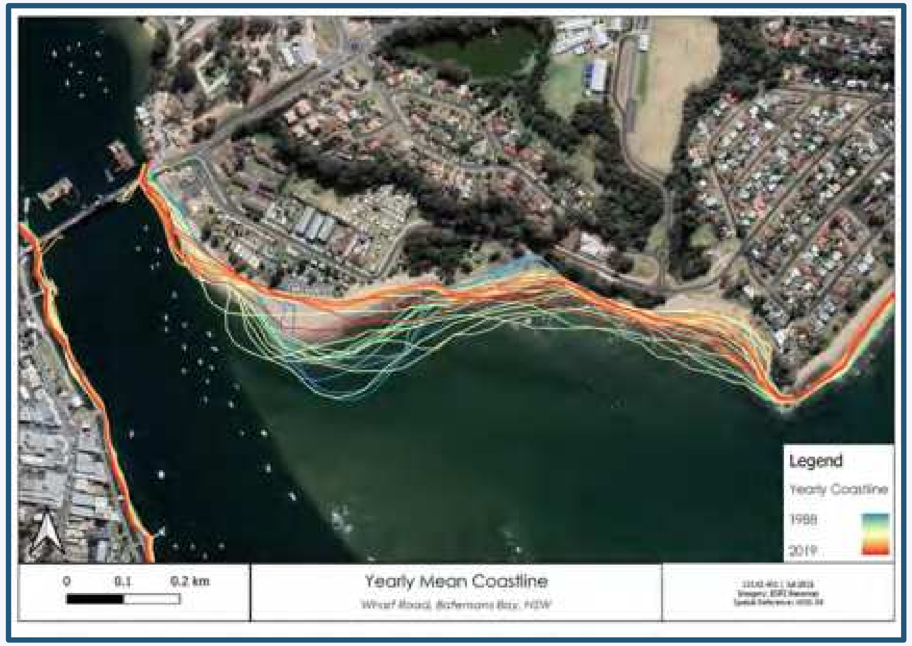
- History
  - Surfside development, circa 1940s
  - Sand nourishment at Northern End (1996) – ~12,000m^3
- Low to negligible net longshore transport (shoreline in alignment with incident waves)
- Limited transfer of sand to/from Cullendulla Beach
- Onshore transport likely from nearshore bars (when configuration allows)
- Otherwise marginal SW transport (Nth to Sth)
- Generally dynamically stable
  - Marginal recession trend at northern end
  - Marginal accretion trend at southern end

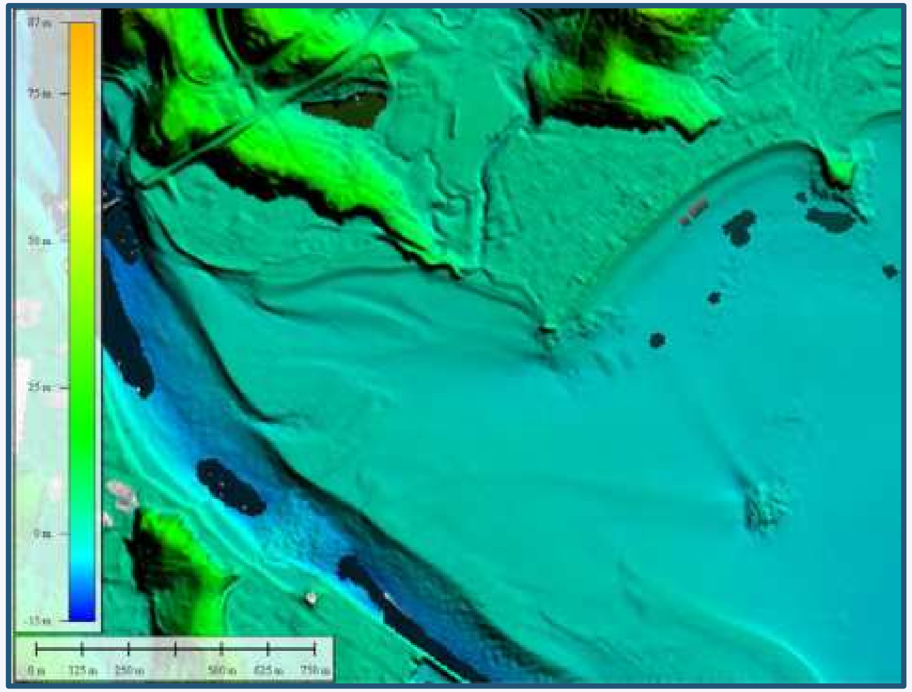


Surfside West / Wharf Road

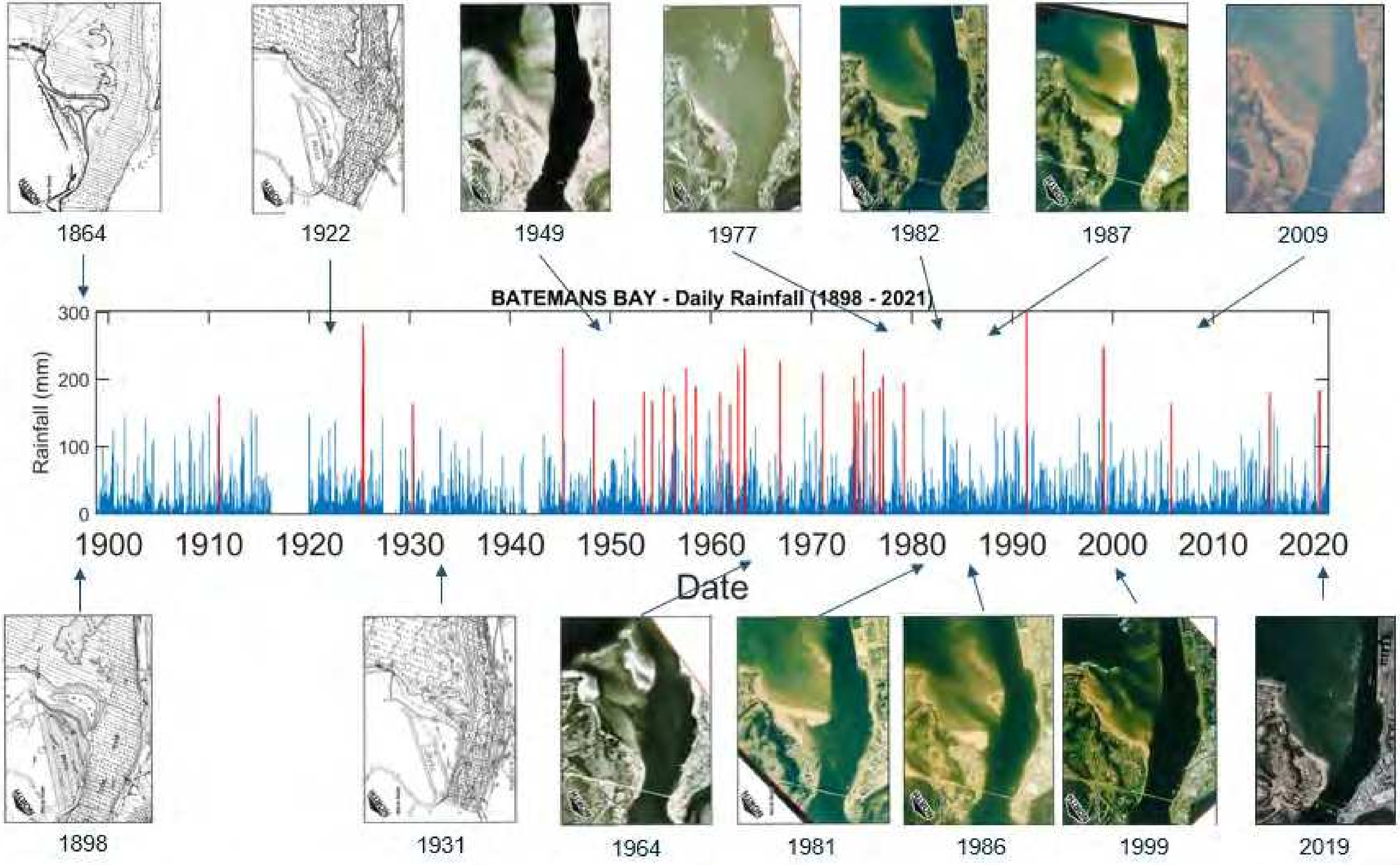
- Surfside West History
  - Natural creek line channelized with culvert at western end (circa 1950s)
  - Dynamic fluctuating shoreline

- Wharf Road History
  - Located along a 400 m stretch of active coastline with considerable instability.
  - Residential allotments created in the 1800s during an accreted phase has meant that many allotments are now below the high water mark.
  - A seawall was constructed in the 1960s/1970s at the North West end.

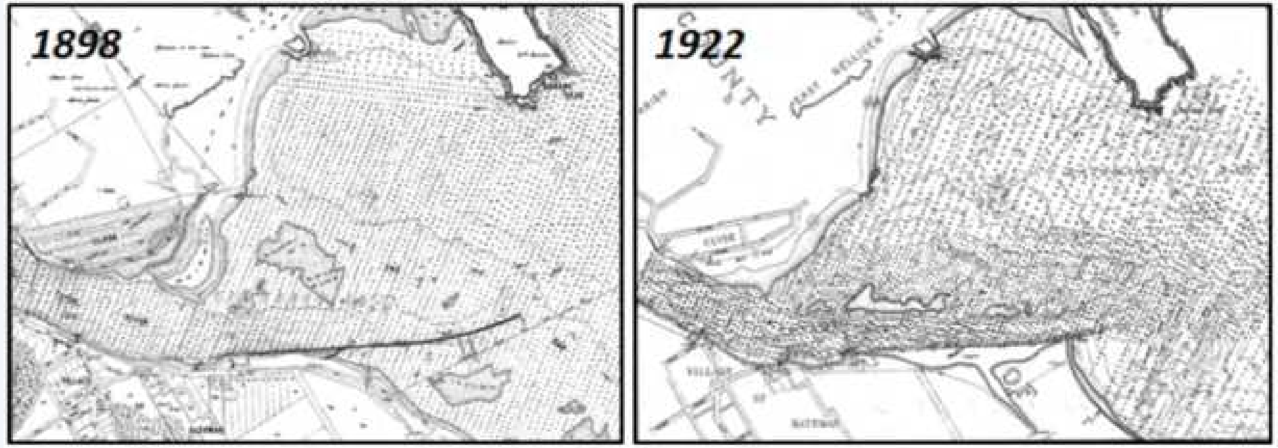


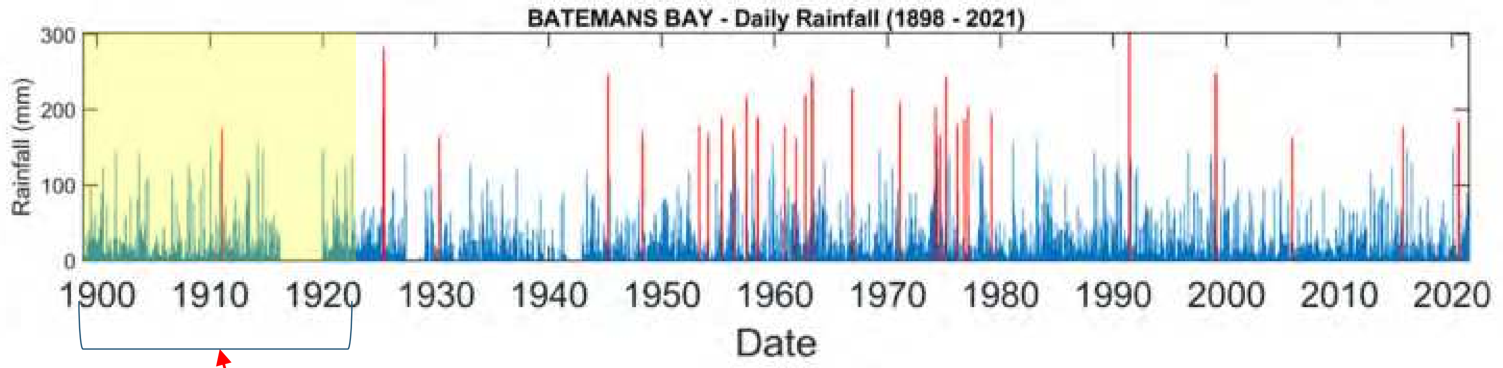


Rainfall and Flooding

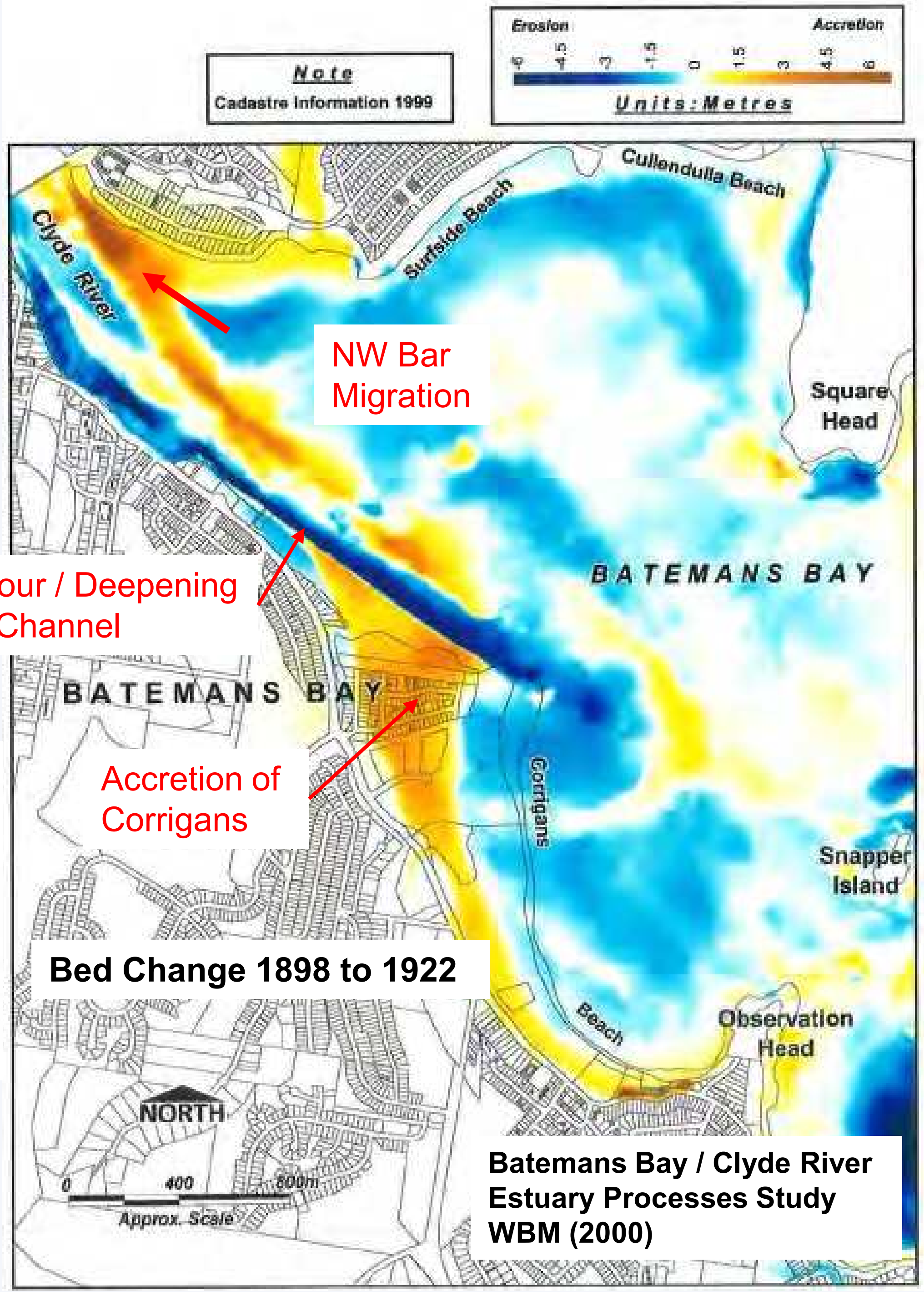


Low Rainfall Period



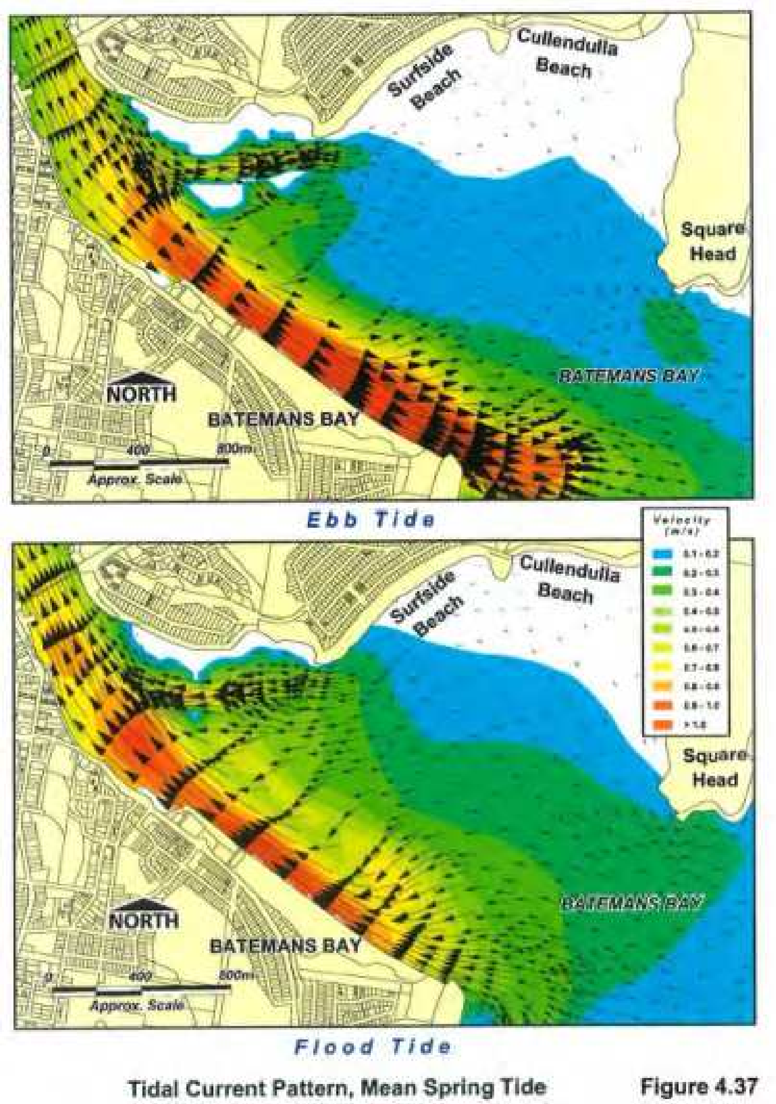


Low Rainfall period

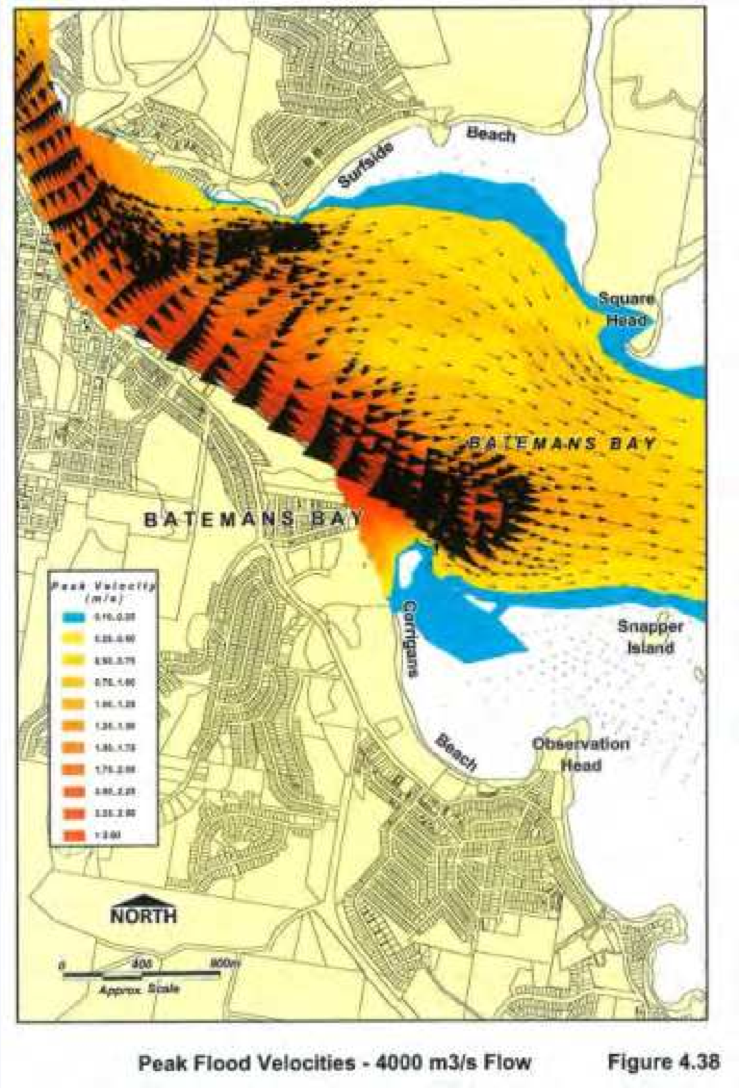


Surfside West / Wharf Road

- Tide
  - Tidal flows generate currents across Wharf Road/Surfside in excess of 0.5m/s (dependent on shoal configuration)
  - Would hinder onshore transport of sediment from nearshore shoals when present
- Flood
  - Flood flows generate currents across Wharf Road/Surfside in excess of 2m/s
  - Will drive significant sediment transport through area
  - Flow structure dependent on shoal configuration prior to flood and flood magnitude



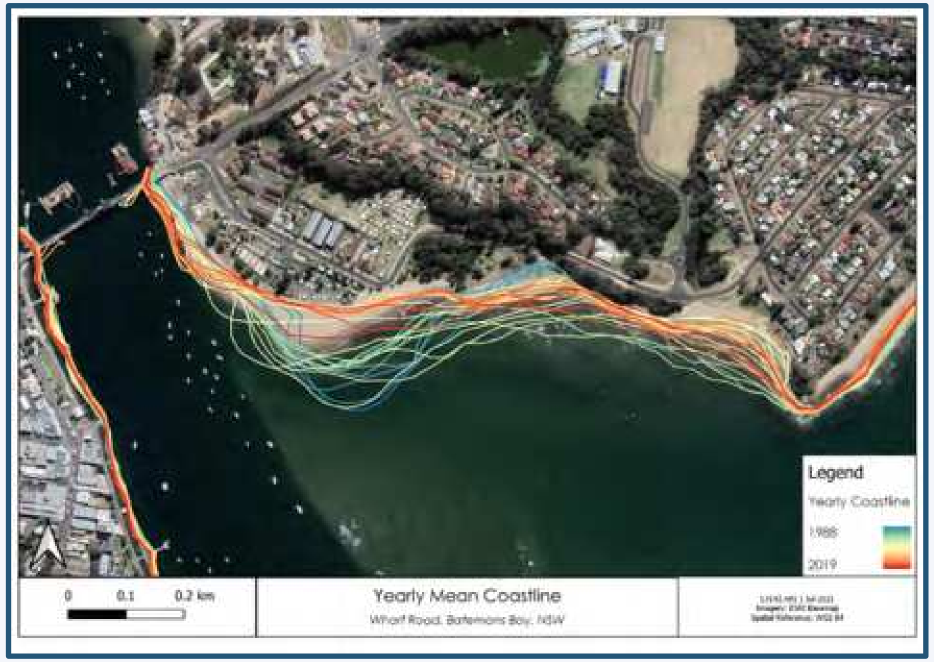
WBM (2000)

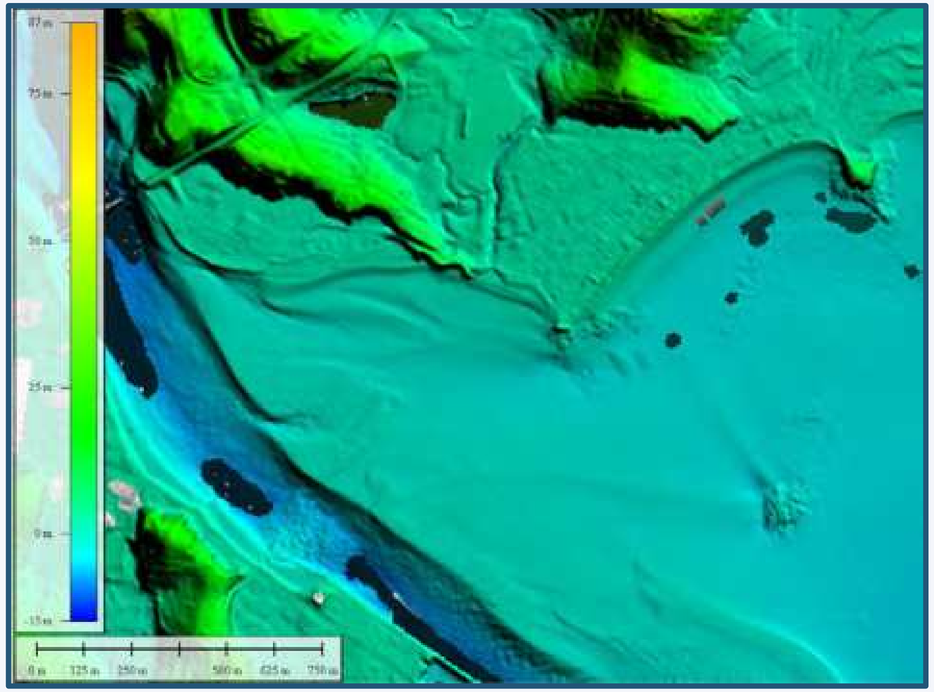


WBM (2000)

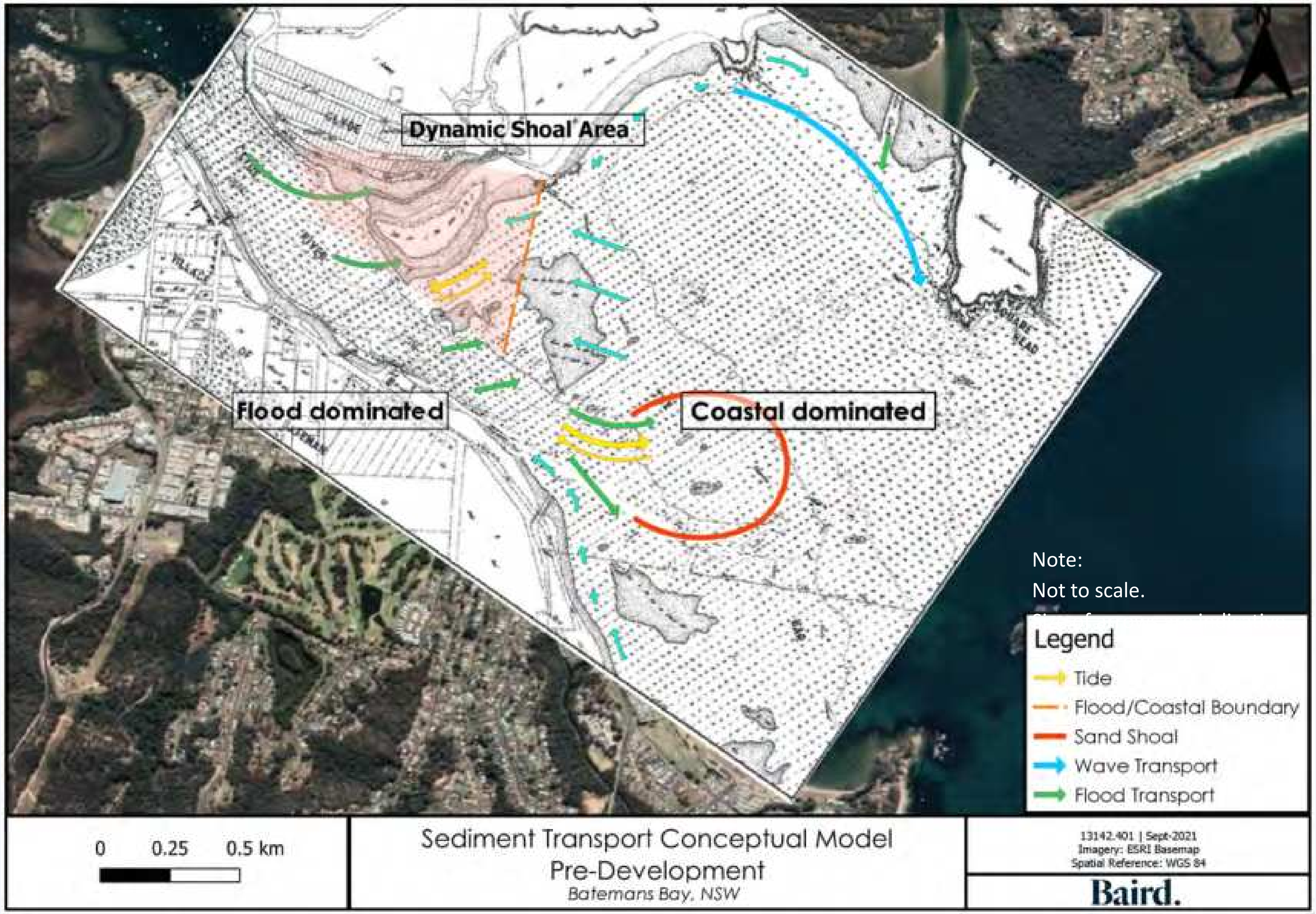
Wharf Road

- Sediment Transport
  - Clyde River flood events are the major influence on re-working the Wharf Road beach and shoal, with large flows close to the beach and across the shoals leading to scour
  - Wave induced transport during ambient and elevated offshore swell, which replenish Wharf Rd shoreline from the shoal (over time)
  - Longshore transport is to the west along the beach, predominantly from wave driven currents and a flood tide inequality (flood > ebb currents).

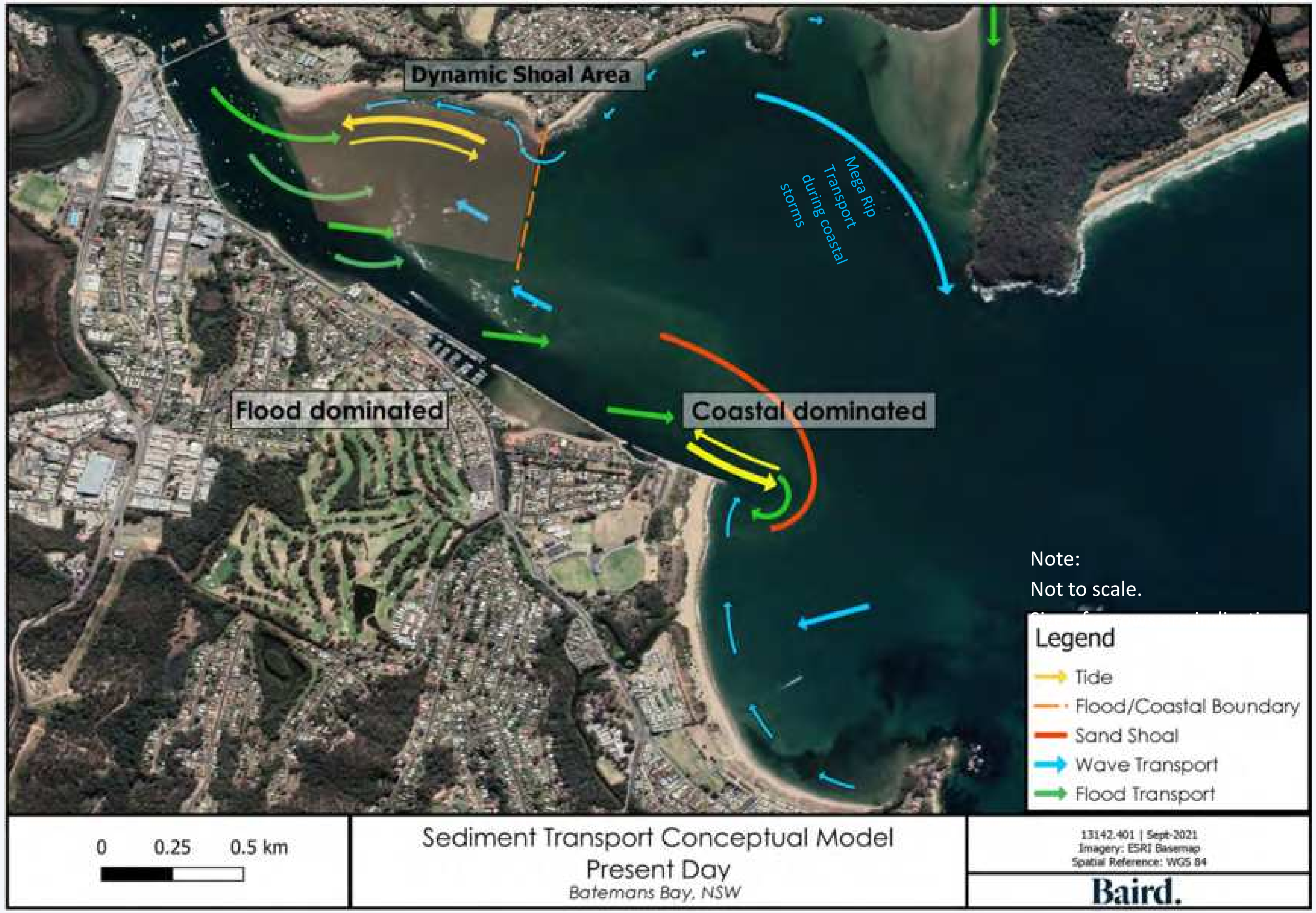




Sediment Transport Concept Models – Pre-Training Wall



Sediment Transport Concept Models – Present Day



Appendix C

WRL (2017) Coastal Hazard Maps

Note 1: Landward movement of the shoreline could be limited by the presence of bedrock.
Note 2: The shoreline could potentially move landward of the hazard lines in the watercourse entrance instability region due to lowering of the beach profile from entrance scouring.

Maloneys Beach
Deterministic erosion/recession hazard lines

2017
2050
2065
2100

Watercourse instability region

Figure I.1

Note 1: Landward movement of the shoreline could be limited by the presence of bedrock.
Note 2: Areas landward of the bedrock (non-erodible) line could be subject to coastal cliff or slope instability hazards which are beyond the scope of this study.

Sunshine Bay
Deterministic erosion/recession hazard lines

2017
2050
2065
2100
Bedrock (non-erodible)

Figure I.12

Note 1: Landward movement of the shoreline could be limited by the presence of bedrock.
Note 2: The shoreline could potentially move landward of the hazard lines in the watercourse entrance instability region due to lowering of the beach profile from entrance scouring.

Guerilla Bay (south)
Deterministic erosion/recession hazard lines

2017
2050
2065
2100

Watercourse instability region

Figure I.17

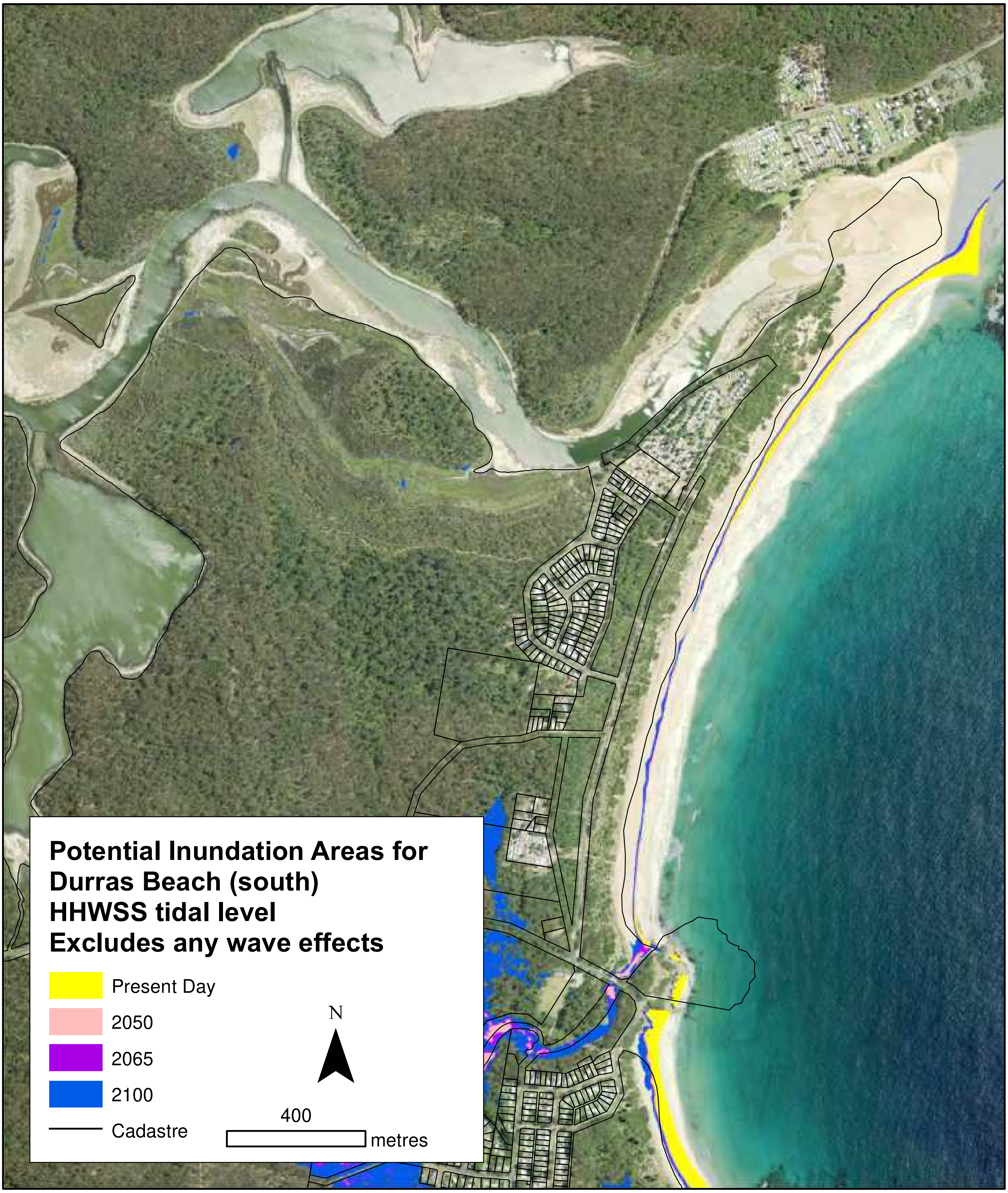
Note 1: Landward movement of the shoreline could be limited by the presence of bedrock.
Note 2: The shoreline could potentially move landward of the hazard lines in the watercourse entrance instability region due to lowering of the beach profile from entrance scouring.
Note 3: Hazard lines do not extend to the western end of the beach as this is the limit of available photgrammetry.

Barlings Beach
Deterministic erosion/recession hazard lines

2017
2050
2065
2100

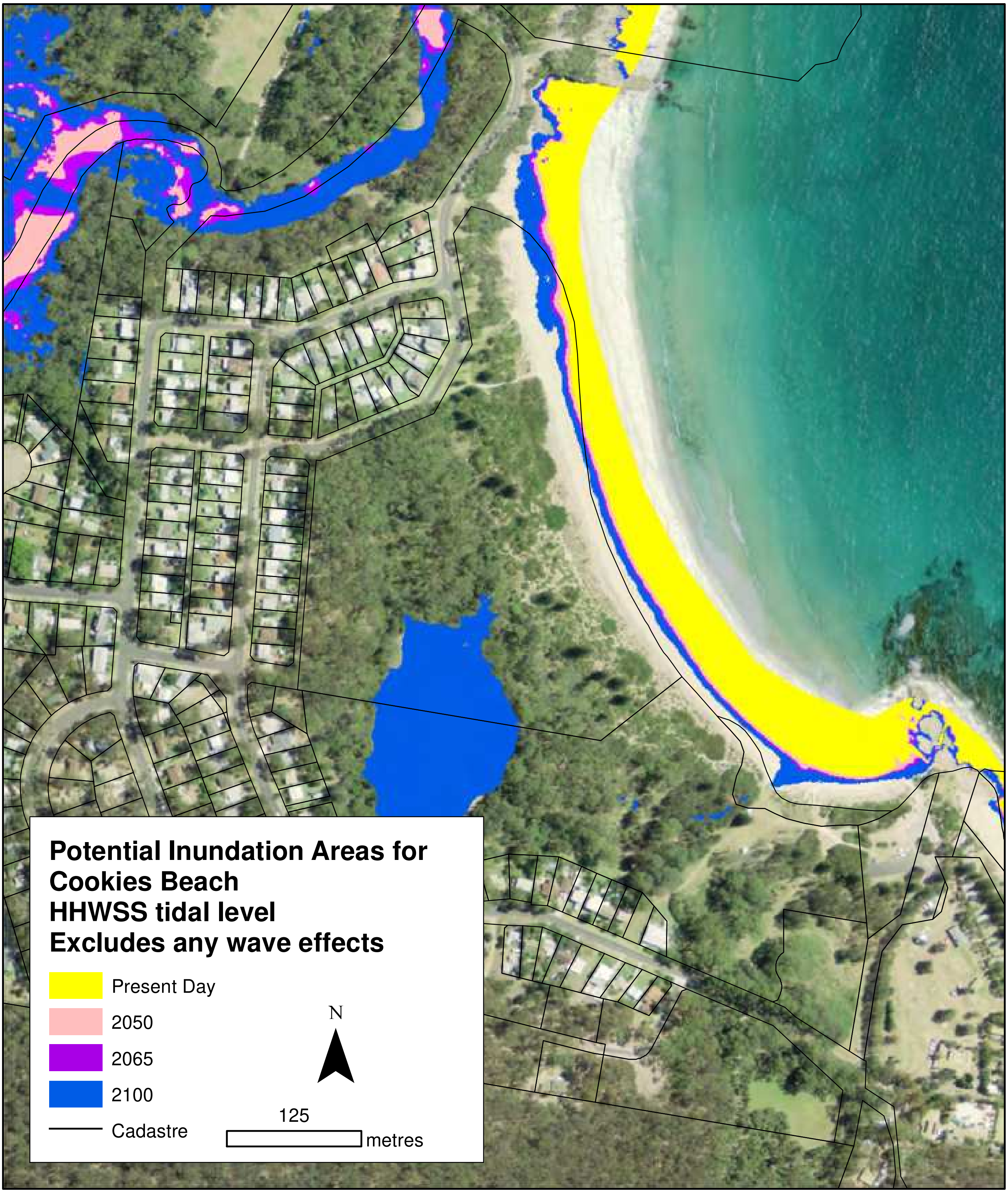
Watercourse instability region

Figure I.18



Inundation areas are mapped based on the most recent year of LIDAR data available (2011). The mapping has been based on the ground elevation (the "all ground" LIDAR layer) and does not consider flow paths, flow velocities or loss of flow momentum. It does not include allowance for future landward recession of the beach face and assumes that the crest level of the seawall (if present) and the topography remain as they were from the 2011 LIDAR data. By 2050, 2065 or 2100 both of these assumptions may not be valid. Should the seawall/dune be allowed to fail then the landward extent of inundation may increase. WRL is not responsible for the accuracy of the LIDAR data. Local surveys by a registered surveyor are recommended to determine local inundation extents.

Figure K.1



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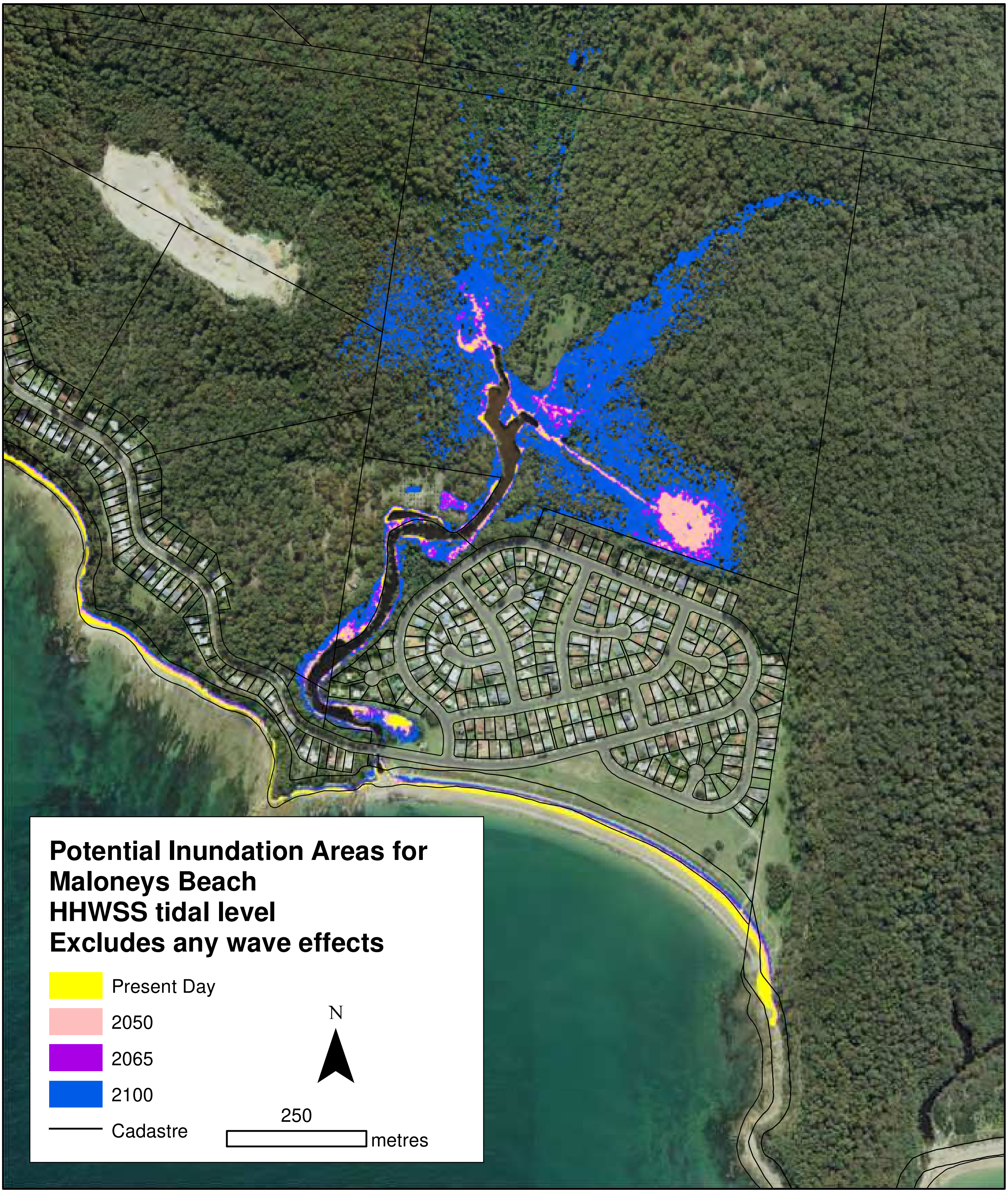

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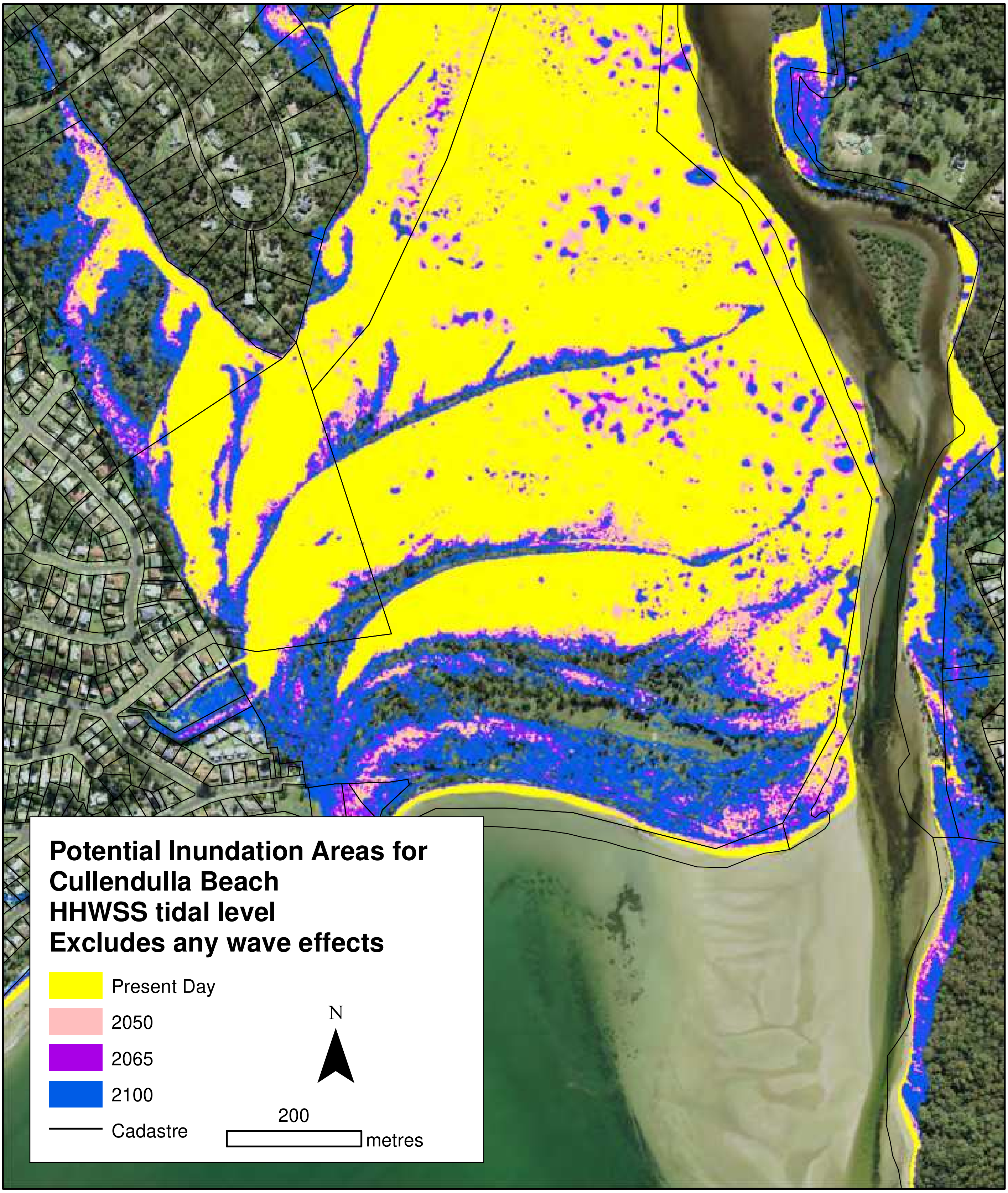

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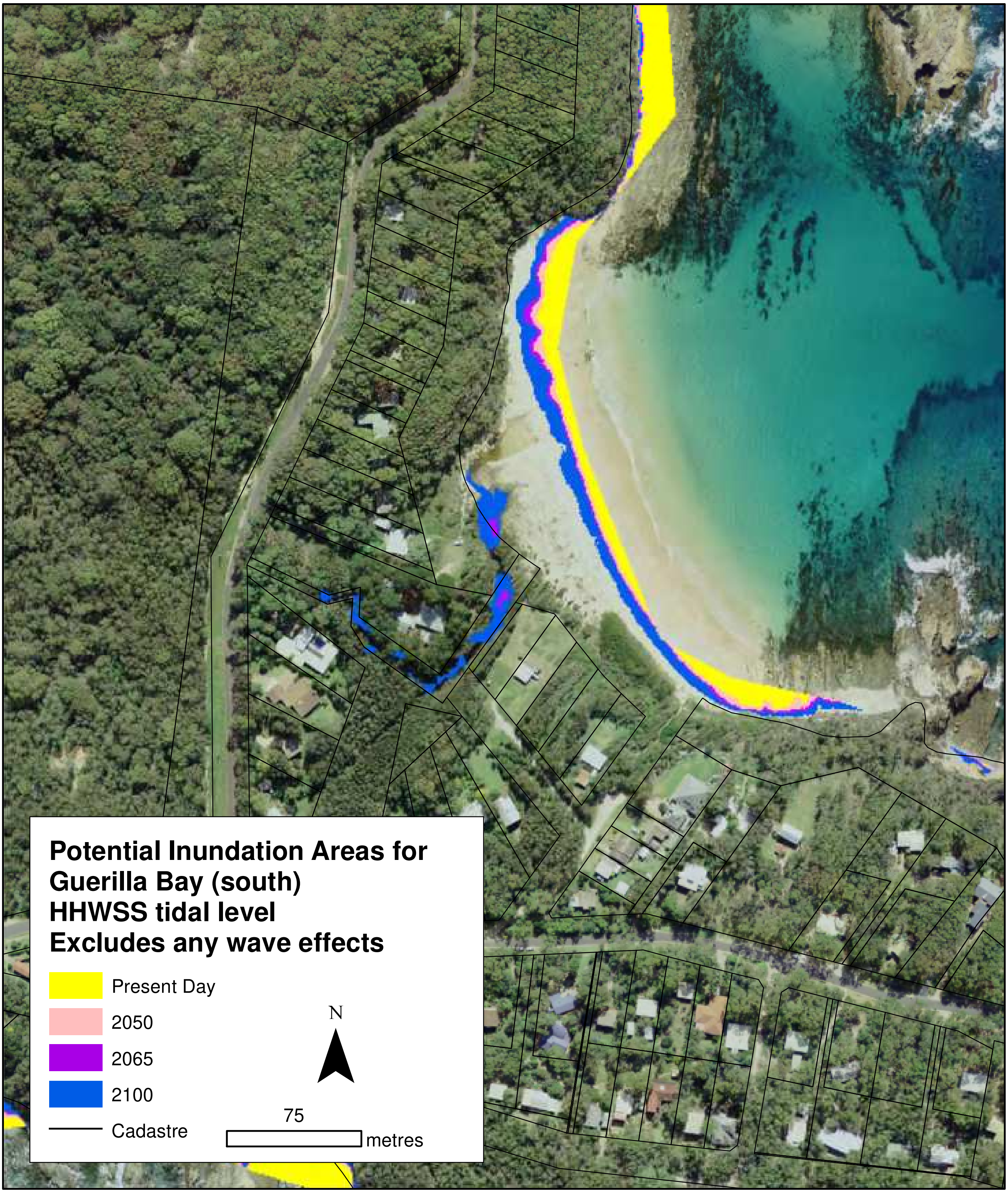

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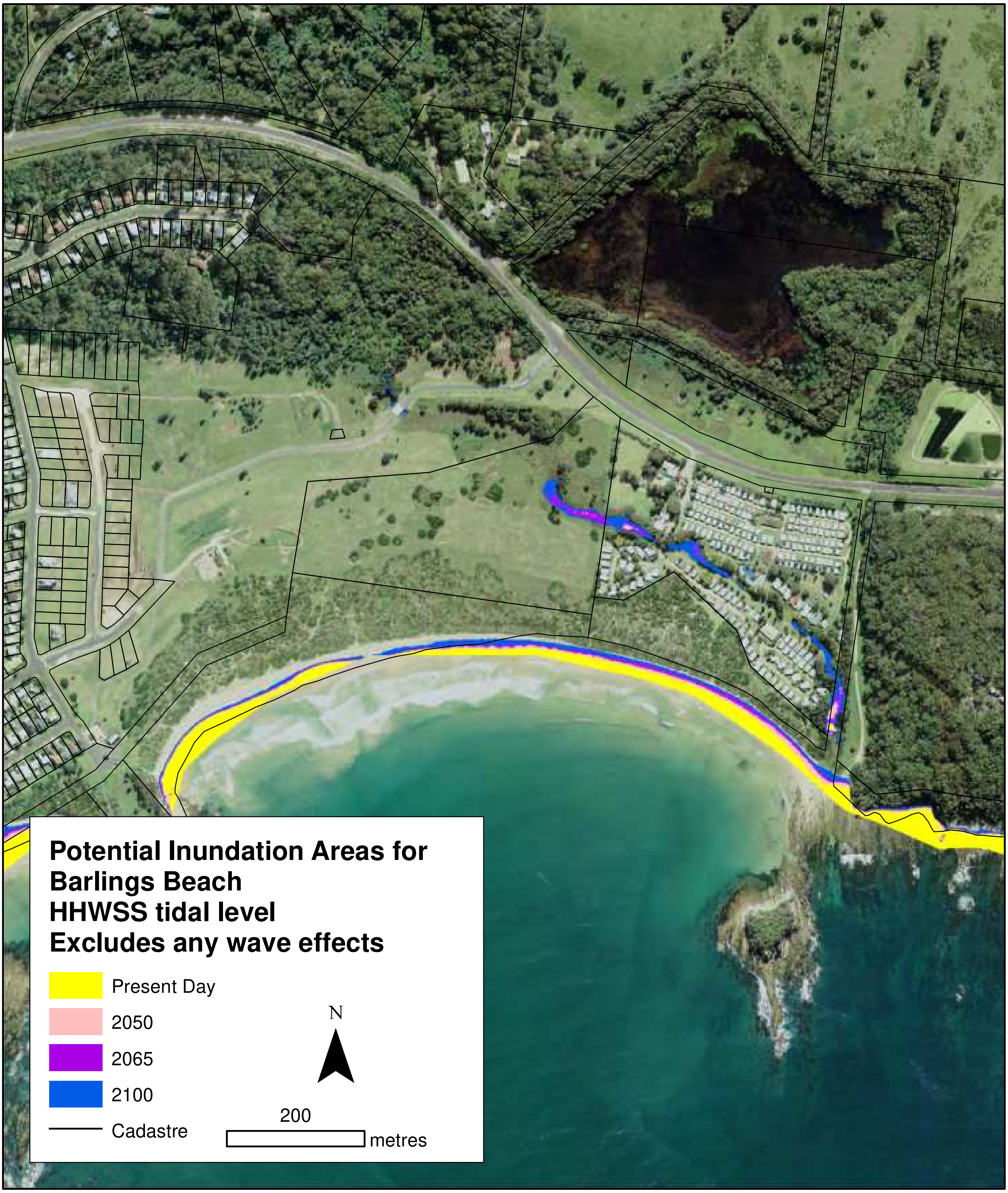
Figure K.16



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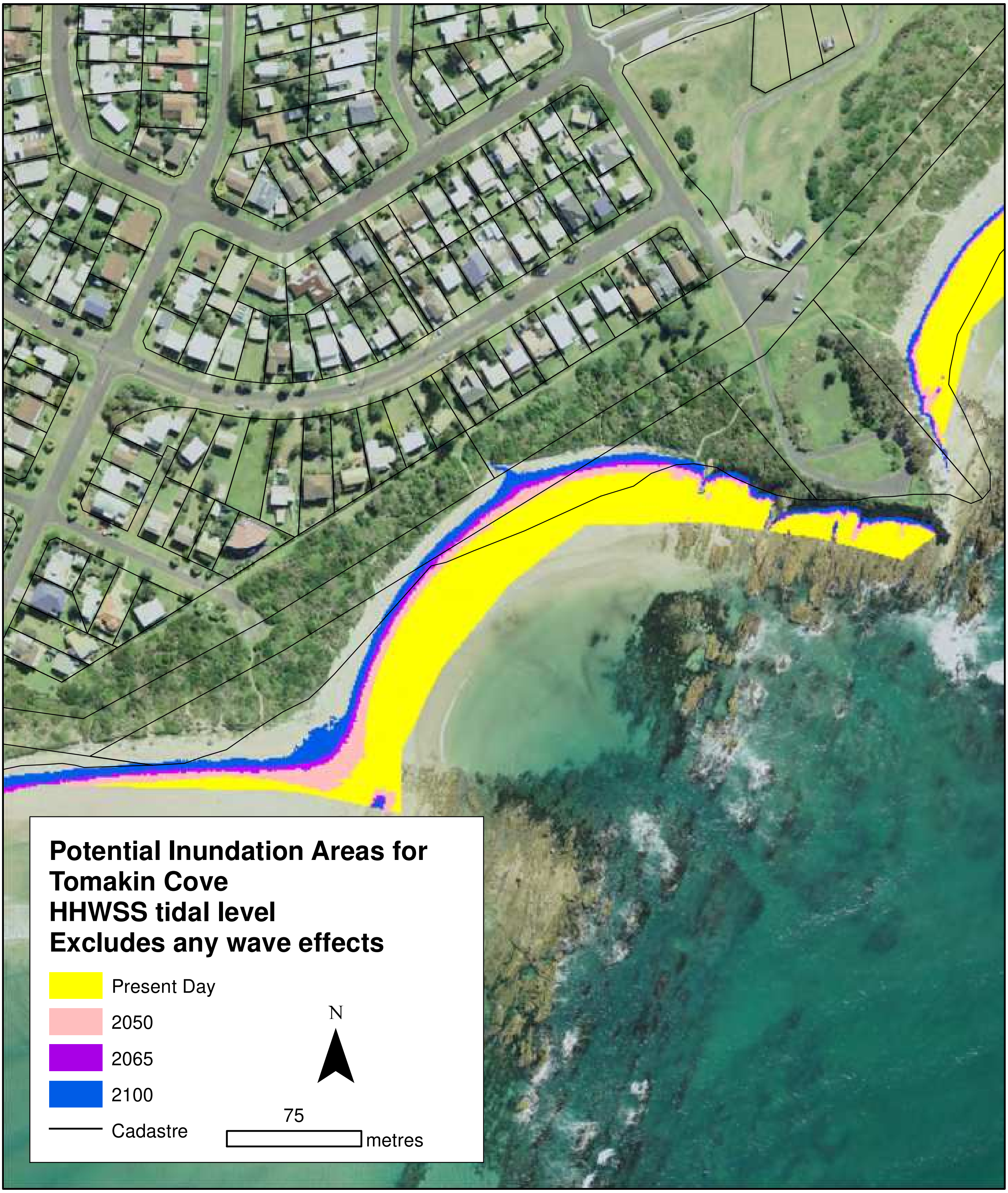

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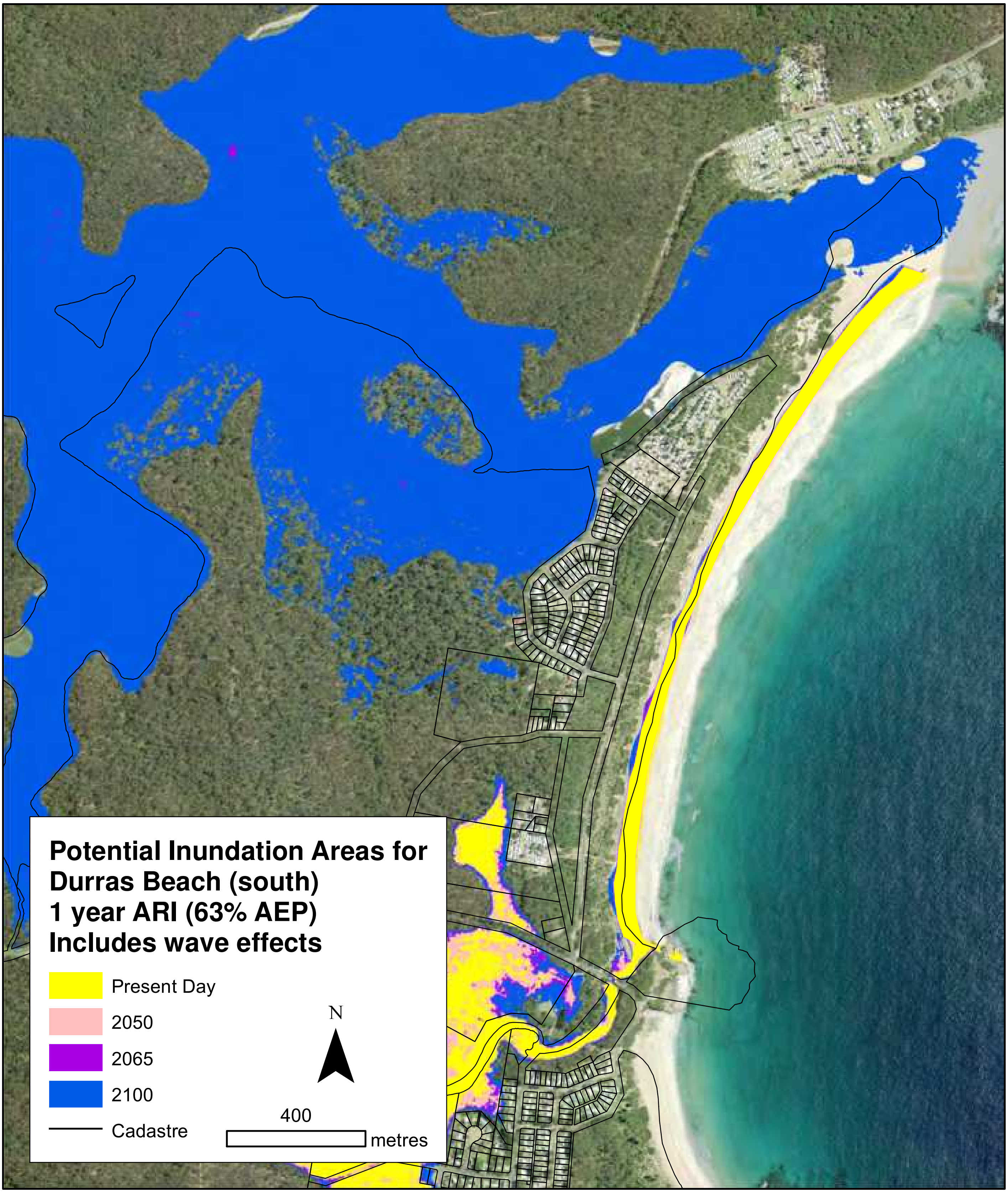

Inundation of the beachface and the area immediately landward of the dune crest is based on the most recent year of LIDAR data available (2011) and is in accordance with ESC's sea level rise policy and planning framework. It does not include allowance for future landward recession of the beach face and assumes that the crest level of the seawall (if present) and the topography remain as they were from the 2011 LIDAR data. By 2050, 2065 or 2100 both of these assumptions may not be valid. Should the seawall/dune be allowed to fail then the landward extent of inundation may increase. Inundation of low lying areas behind the beach is based on the most recent year of LIDAR data available (2011). The low lying inundation areas behind the beach are mapped based on the ground elevation (the "all ground" LIDAR layer) and do not consider flow paths, flow velocities, loss of flow momentum or wave propagation into creek areas. WRL is not responsible for the accuracy of the photogrammetry or LIDAR data. Local surveys by a registered surveyor are recommended to determine local inundation extents.

Figure L.1

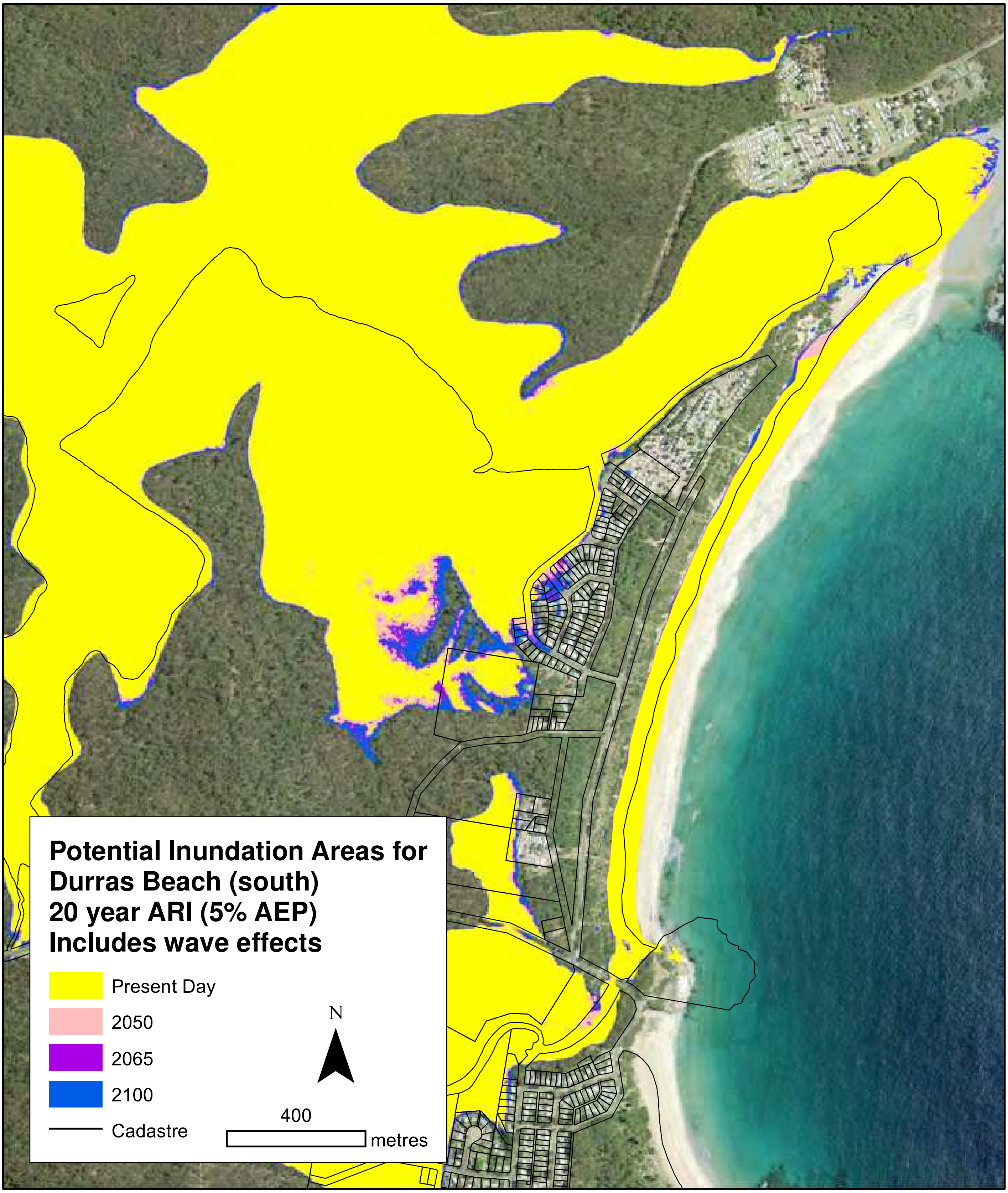

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Figure L.2

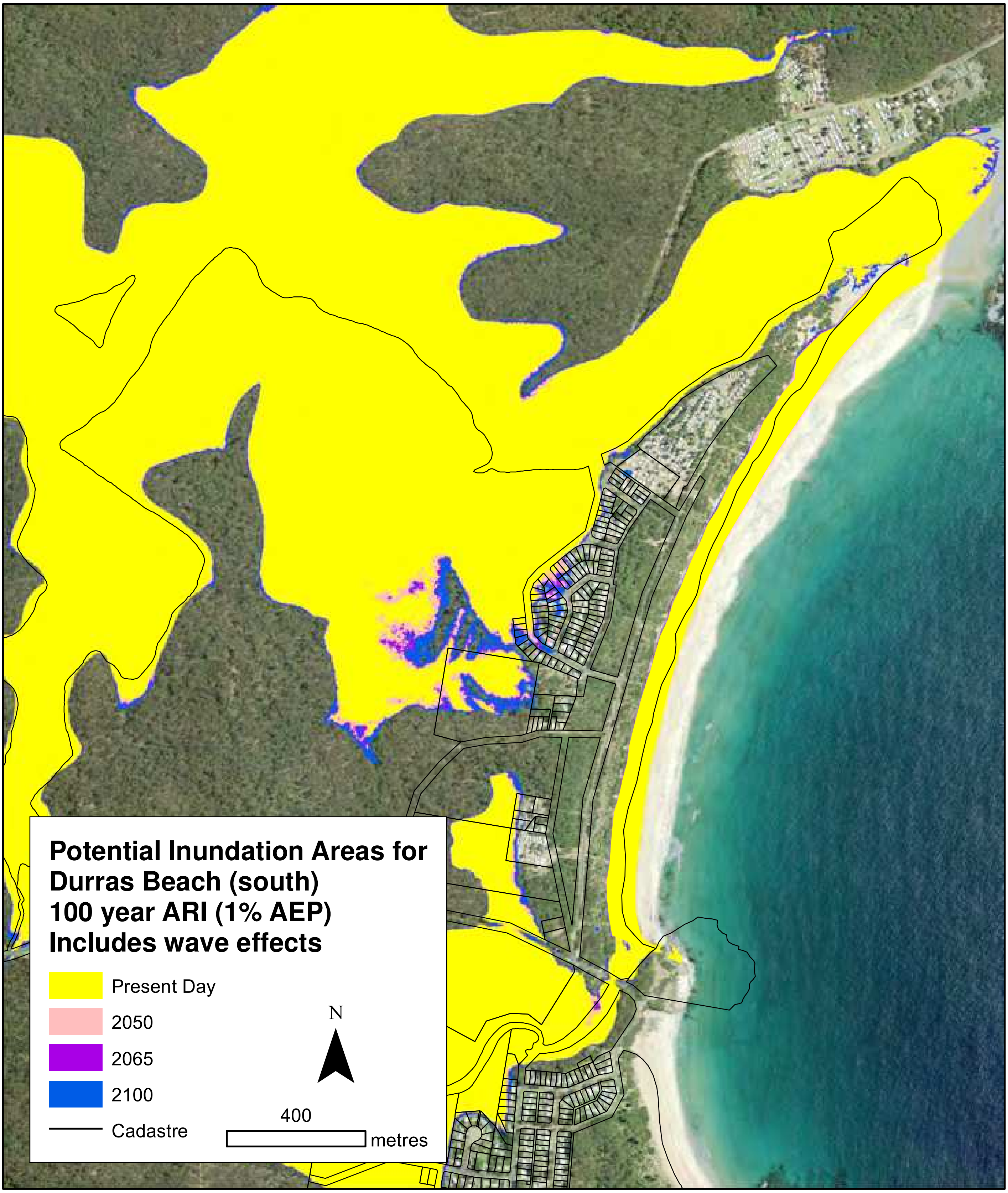

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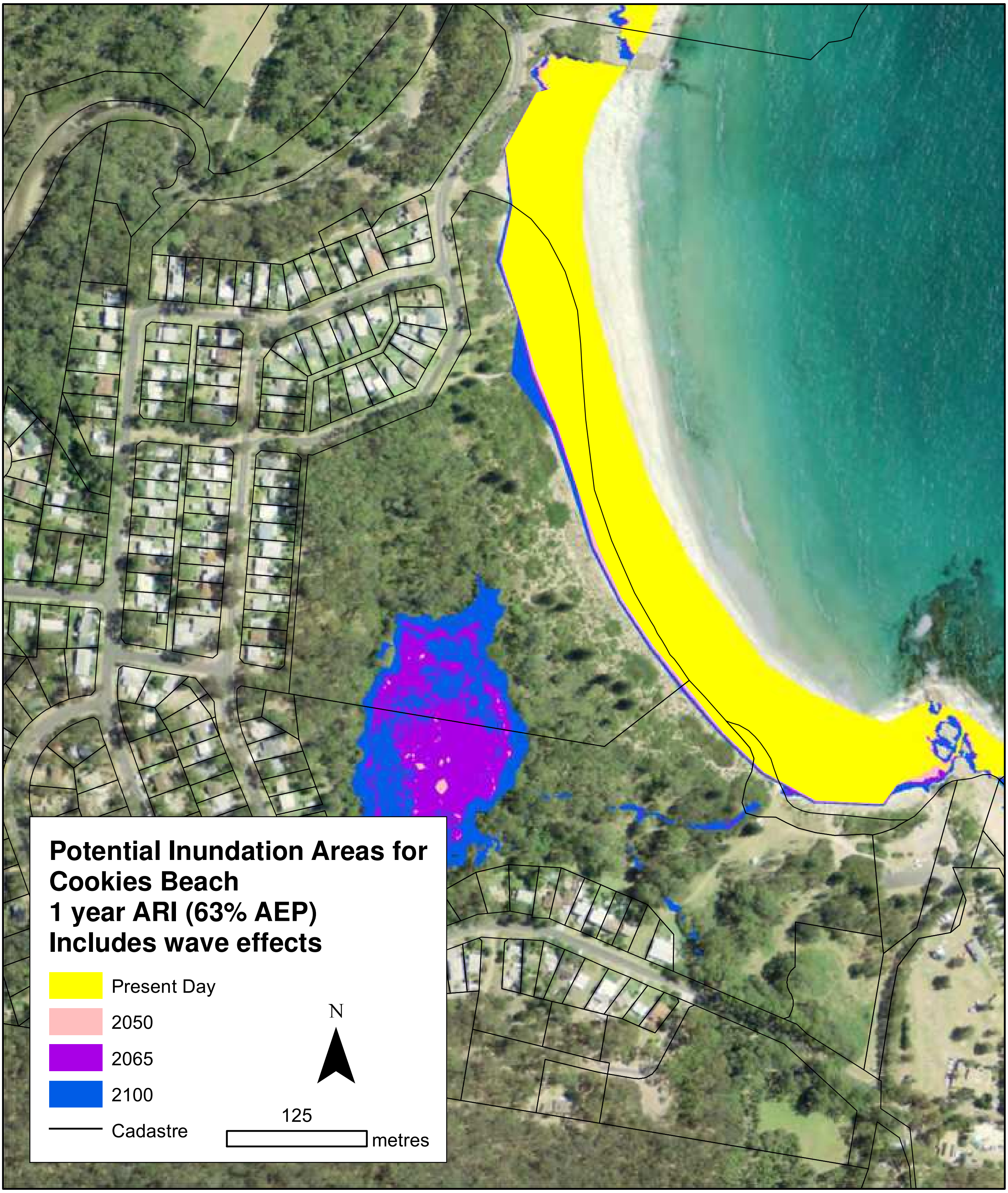
Figure L.3



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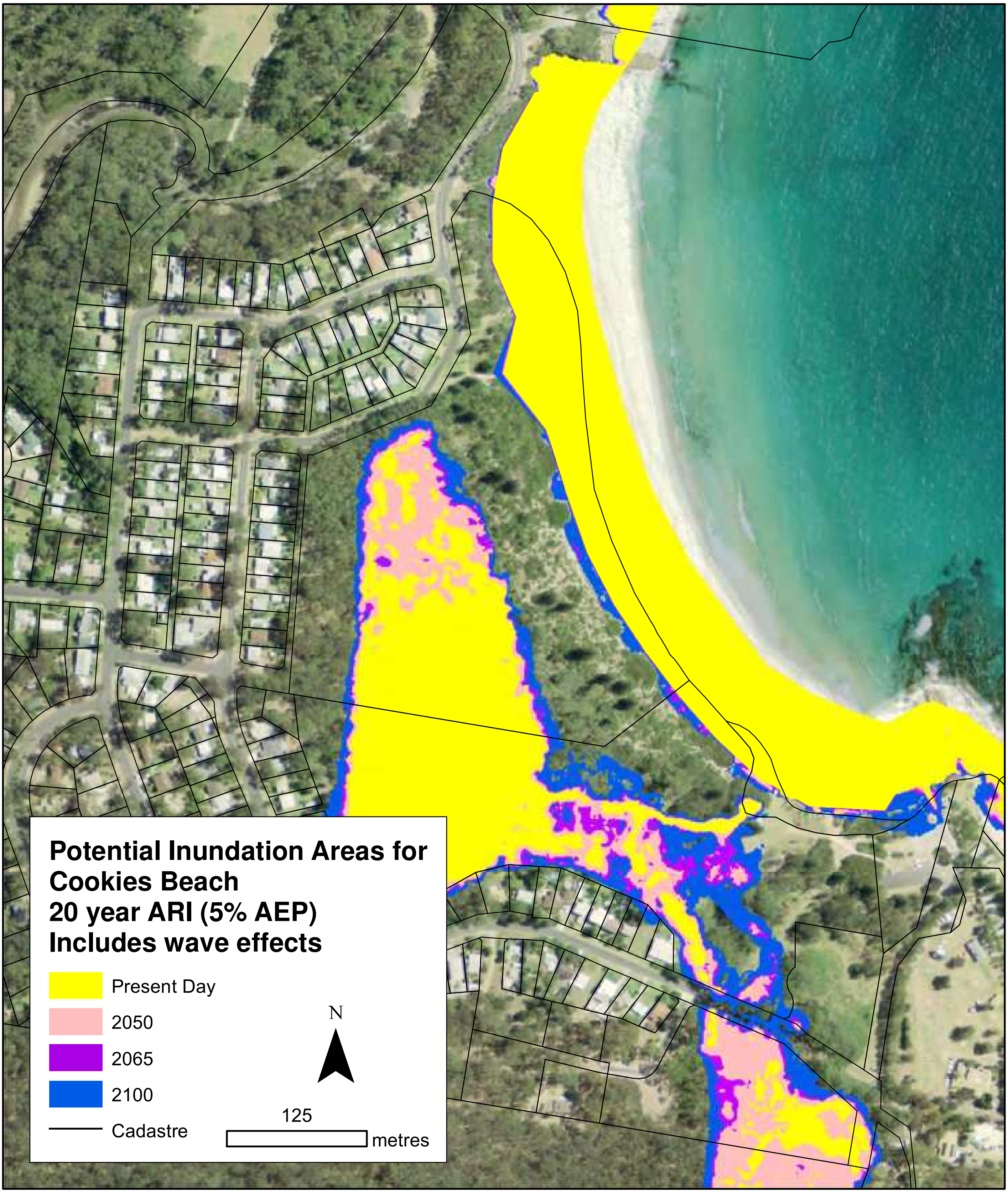

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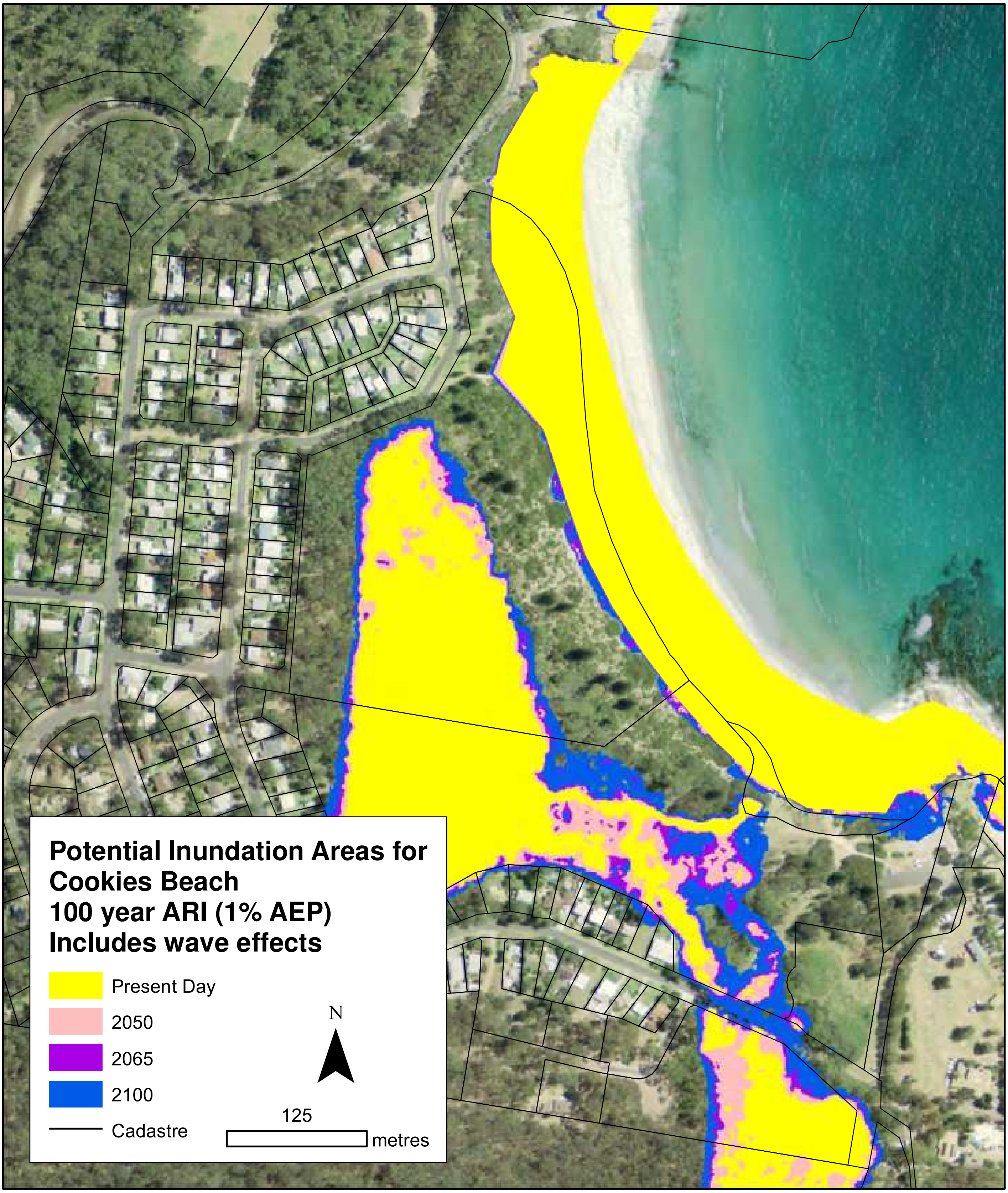
Figure L.5



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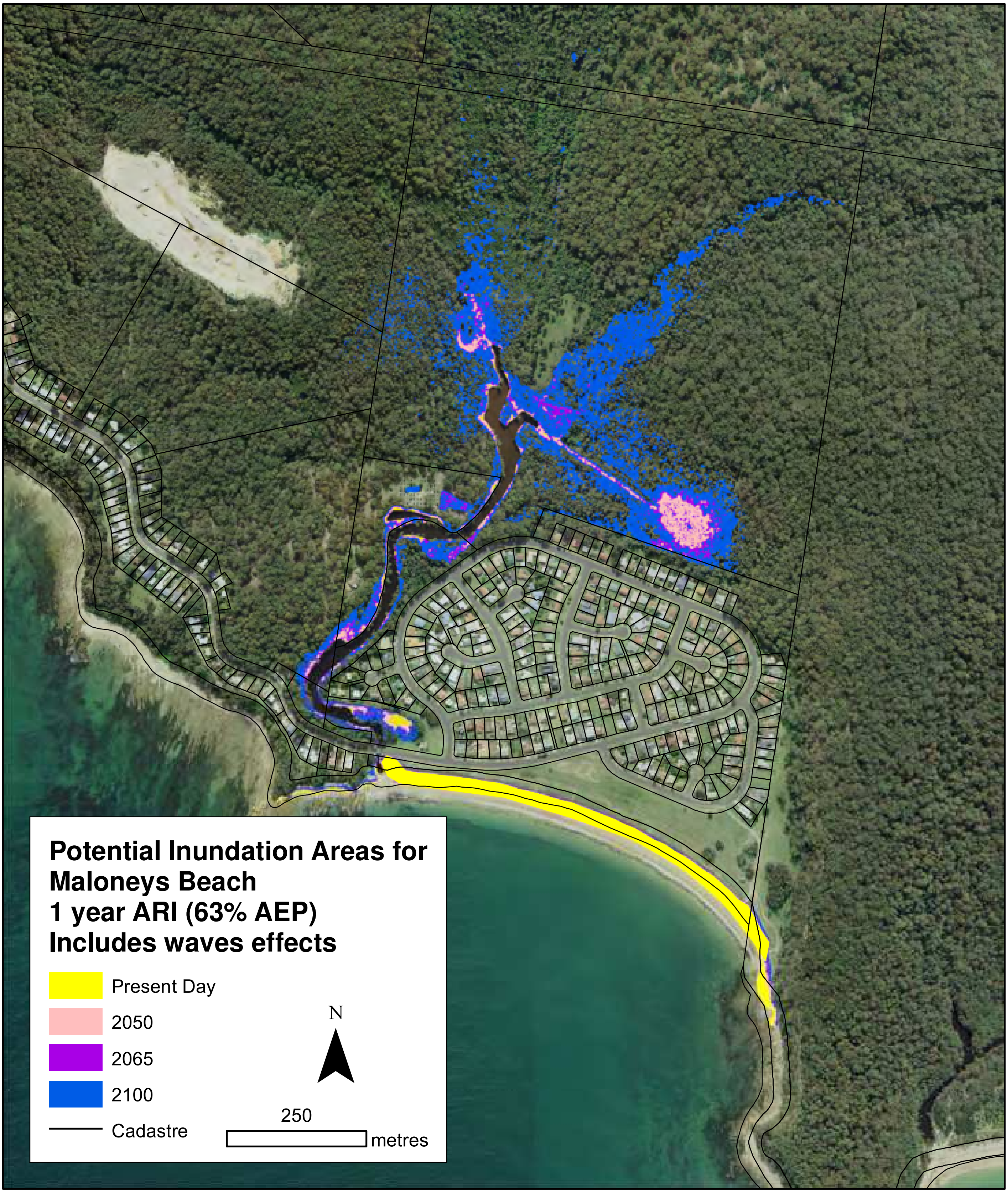

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Figure L.7

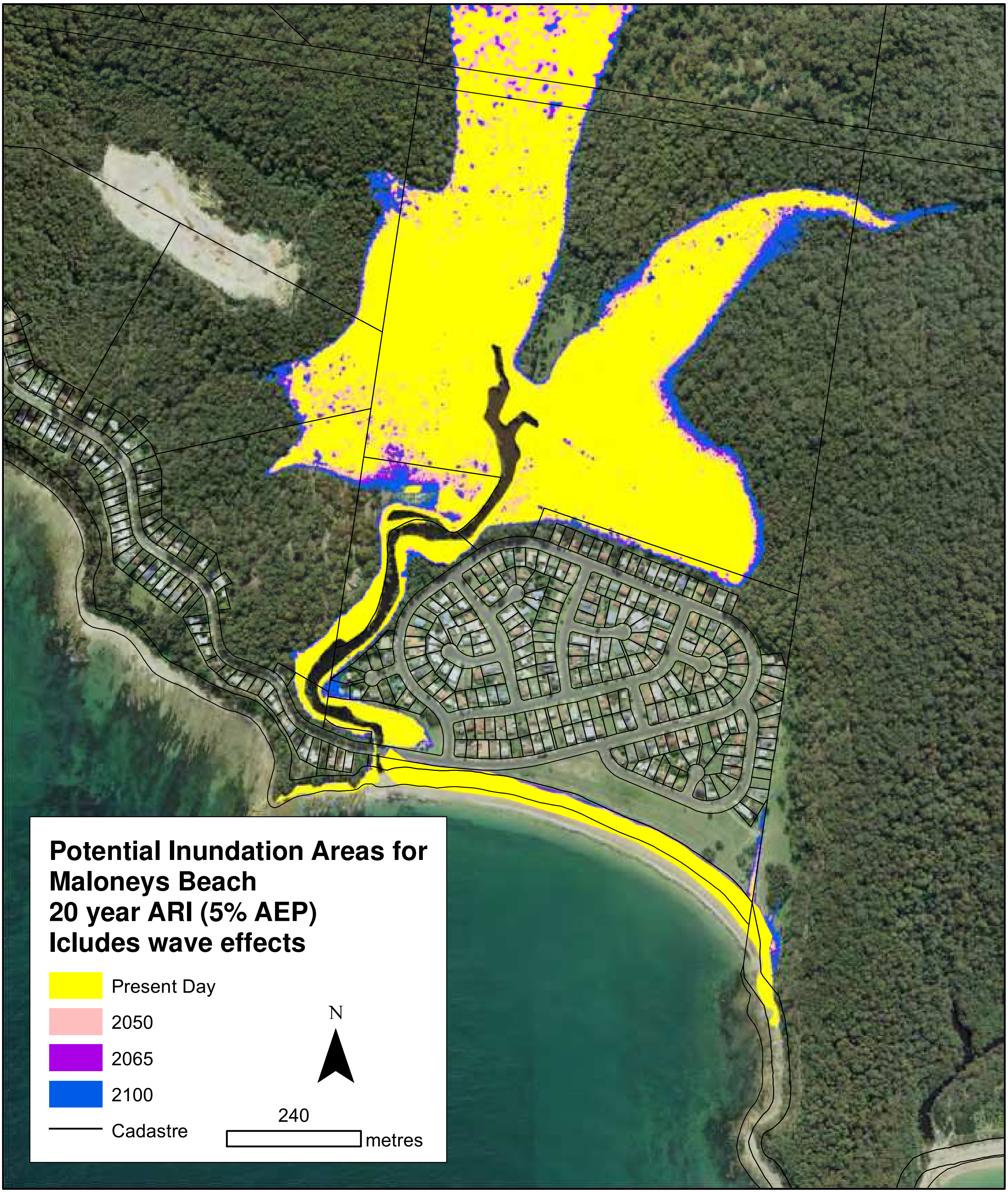

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Figure L.8

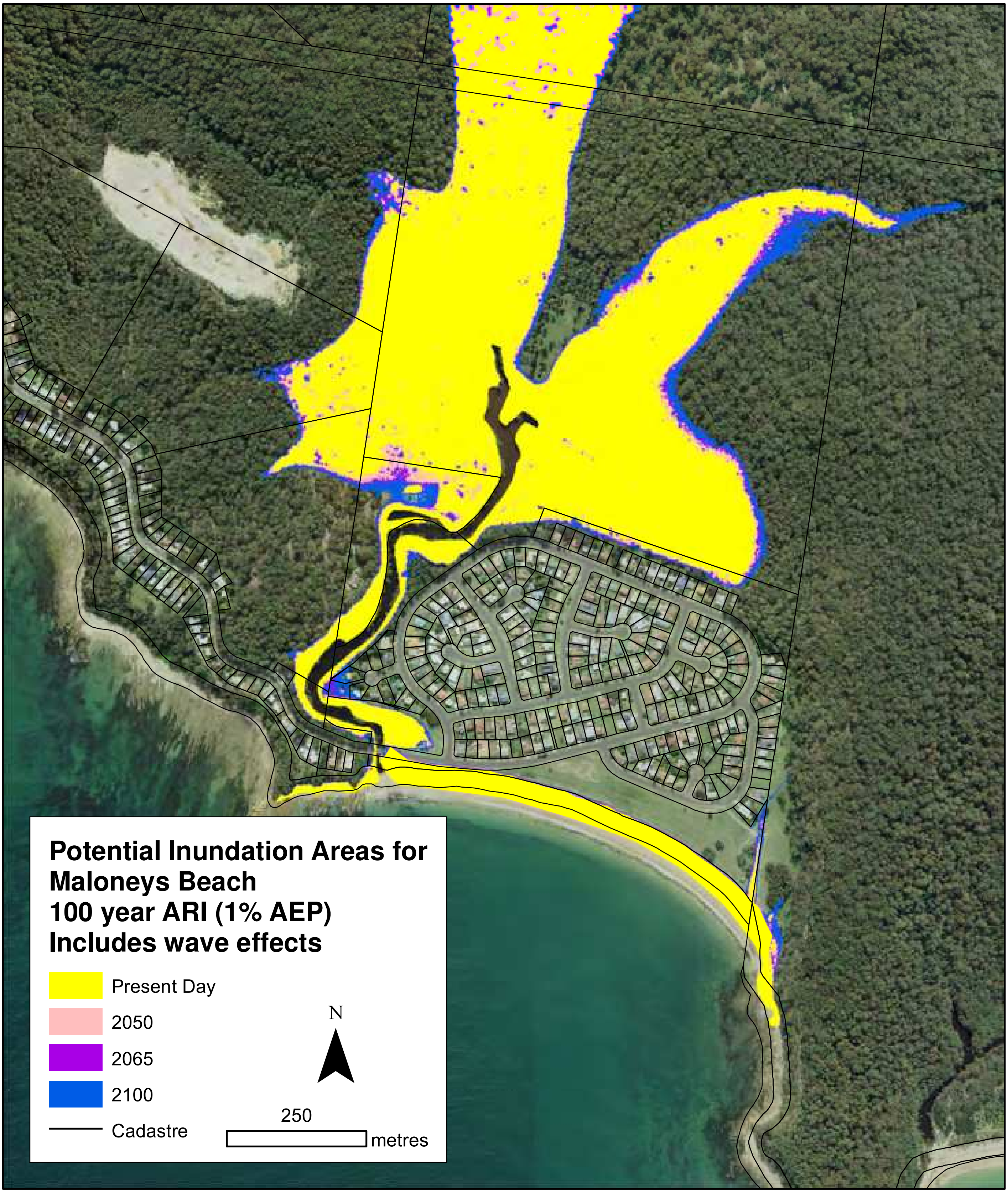

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Figure L.9

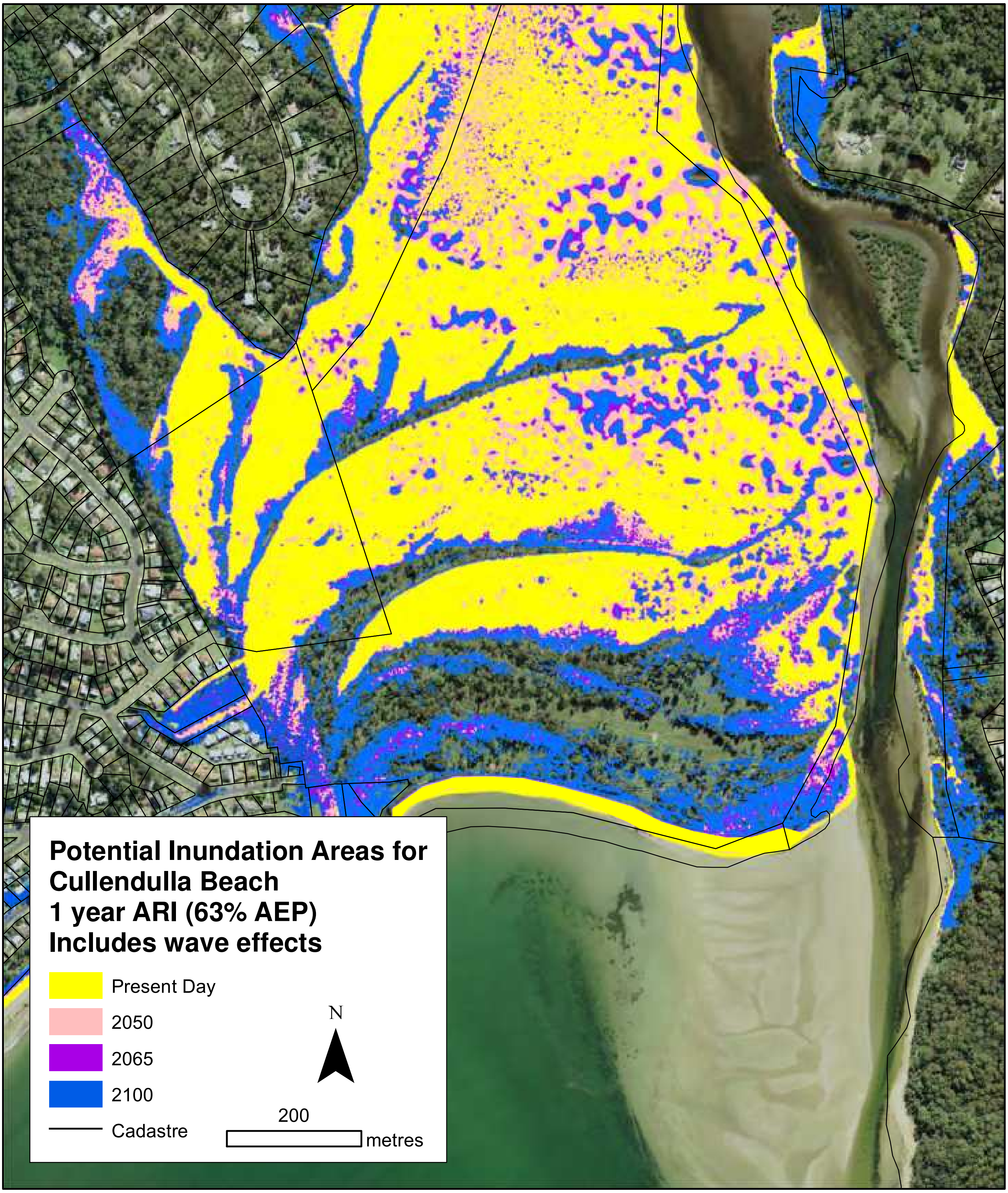

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Figure L.19

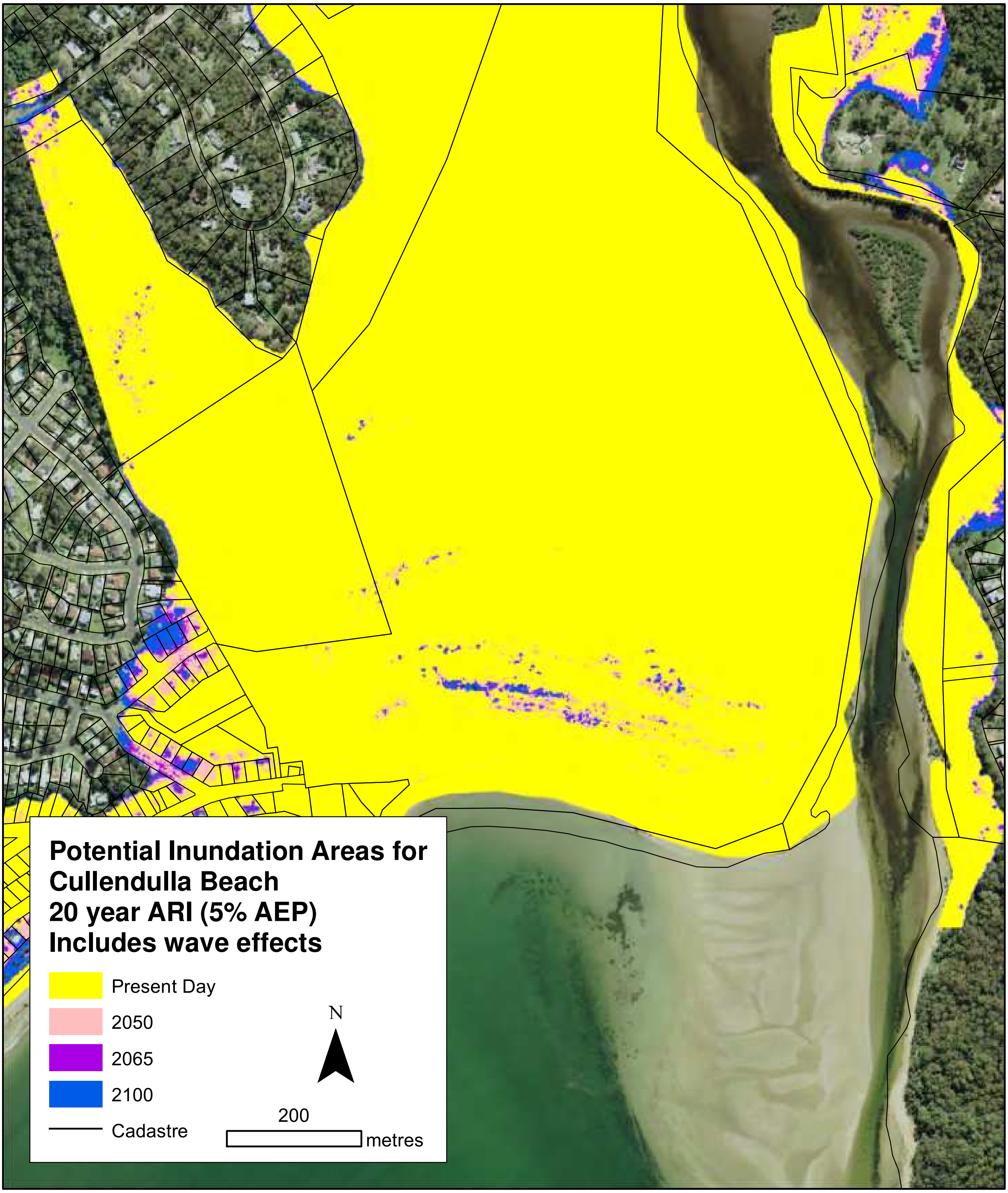

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Figure L.20

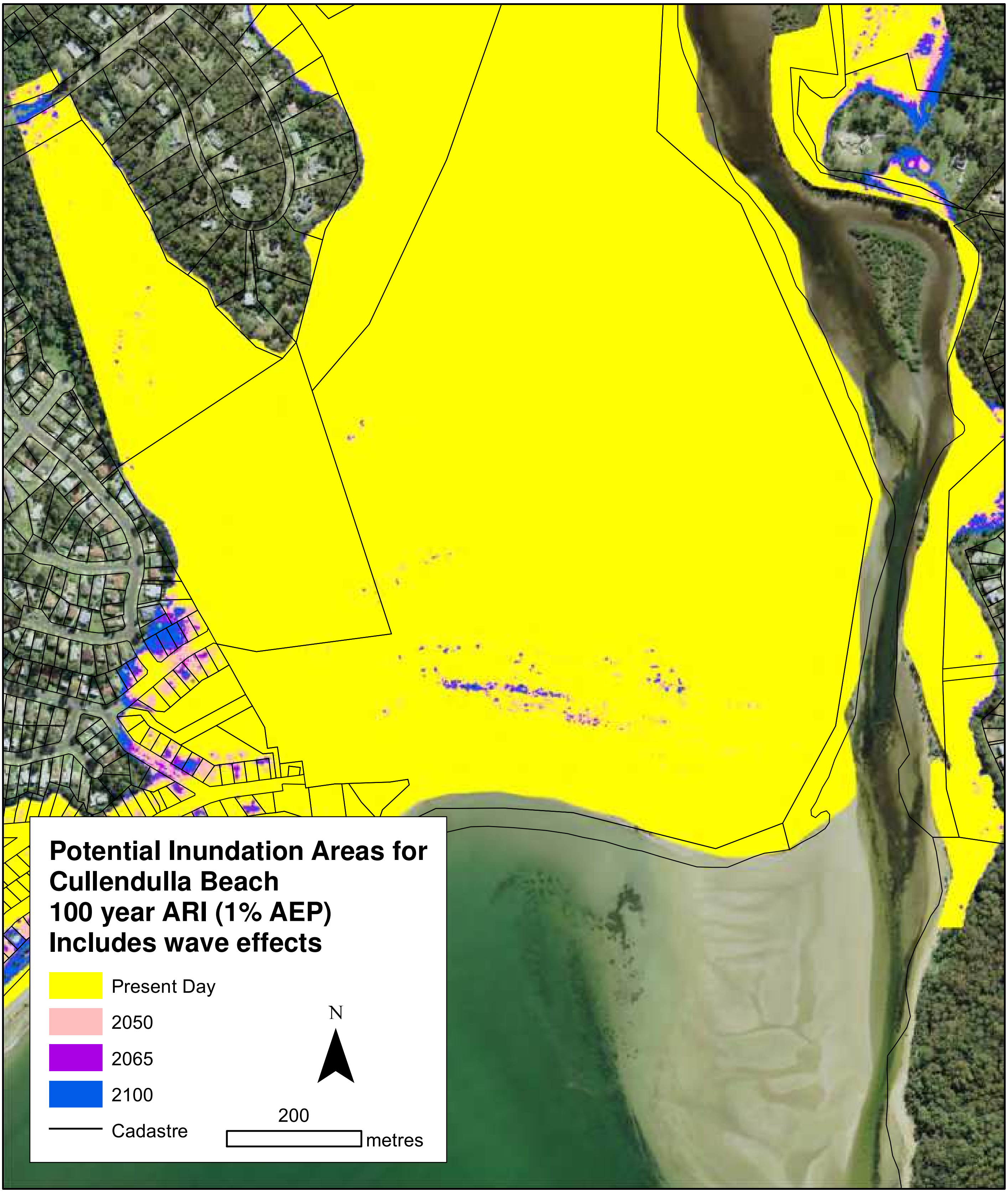

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Figure L.21

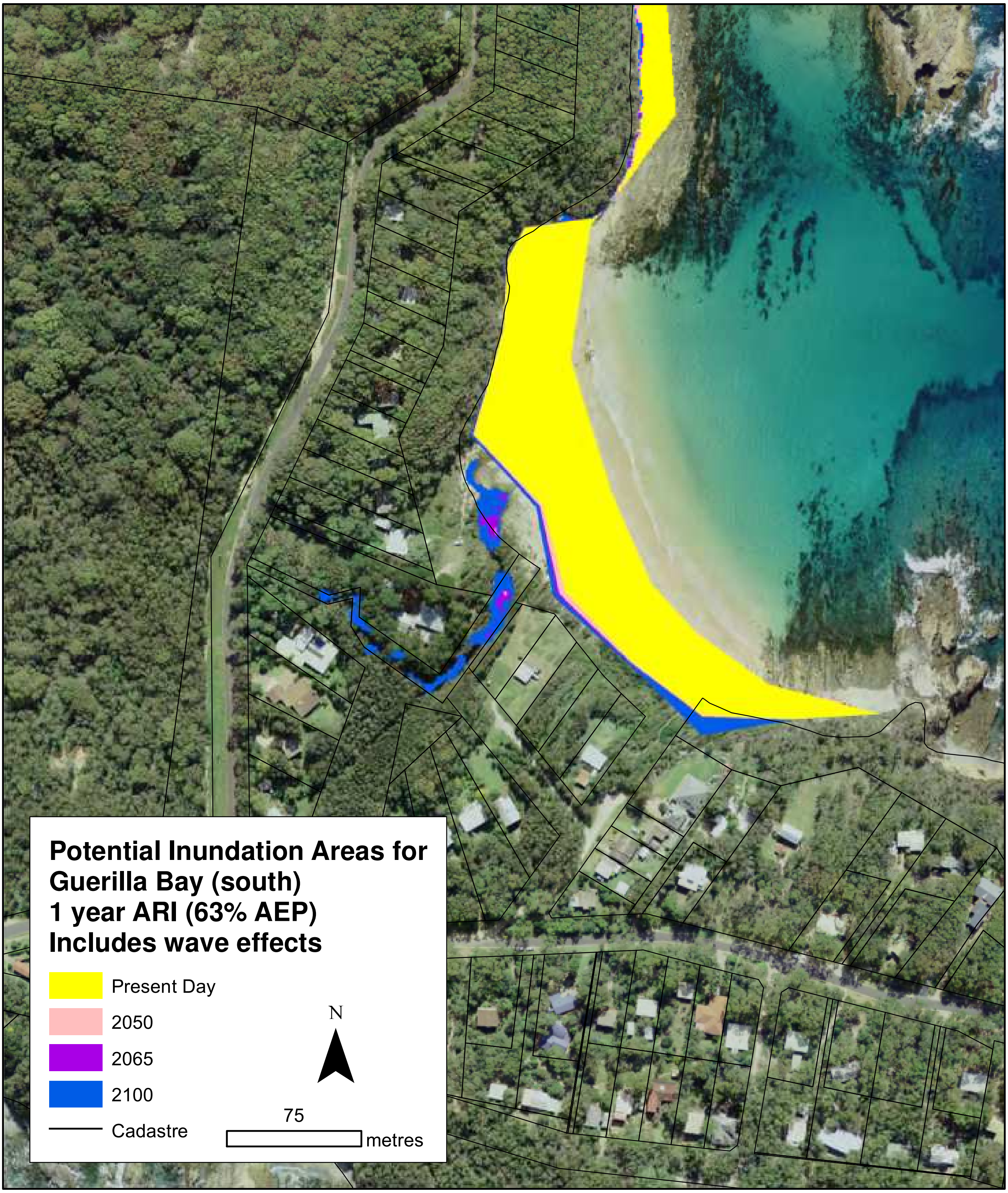

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Figure L.46

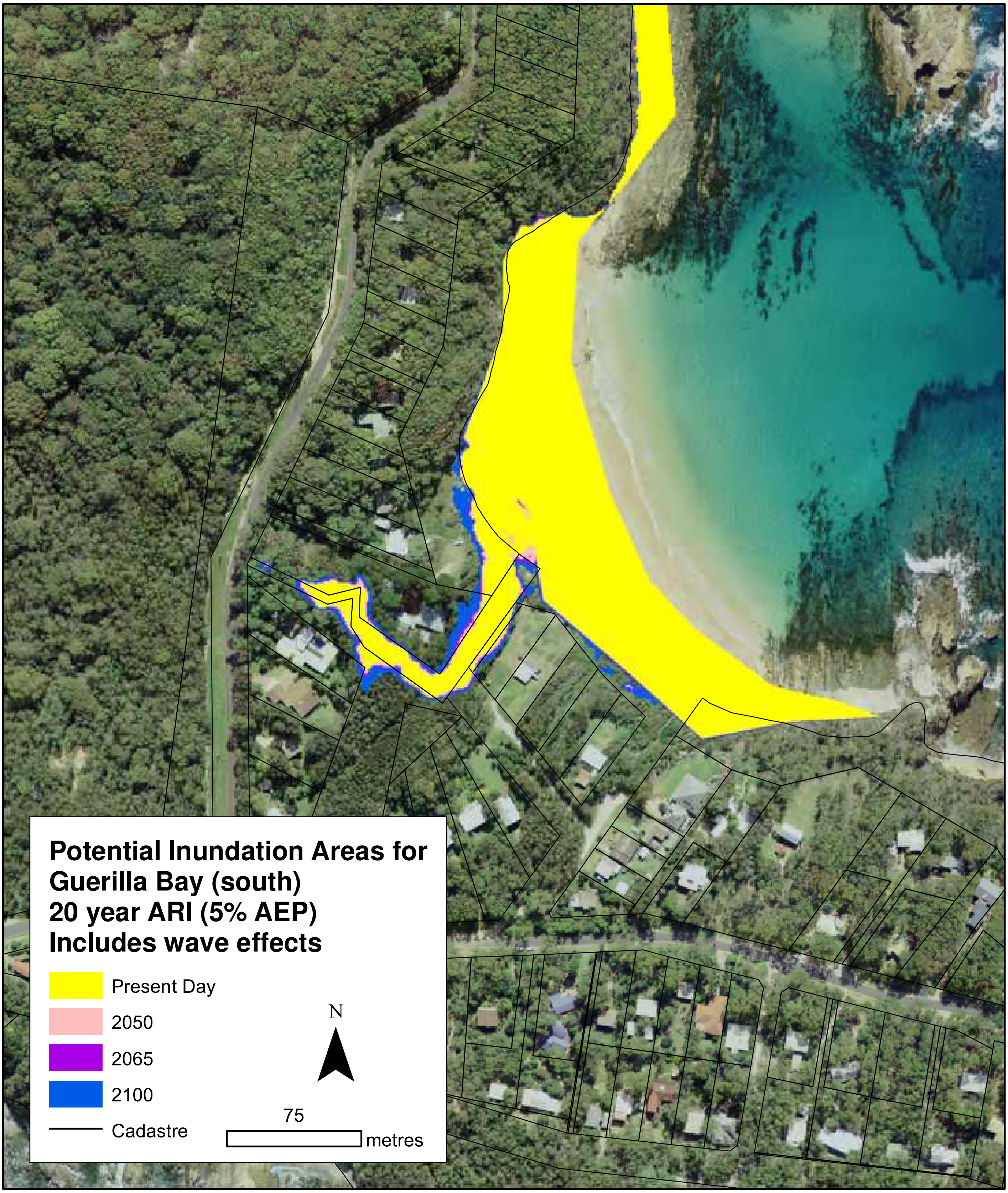

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Figure L.47

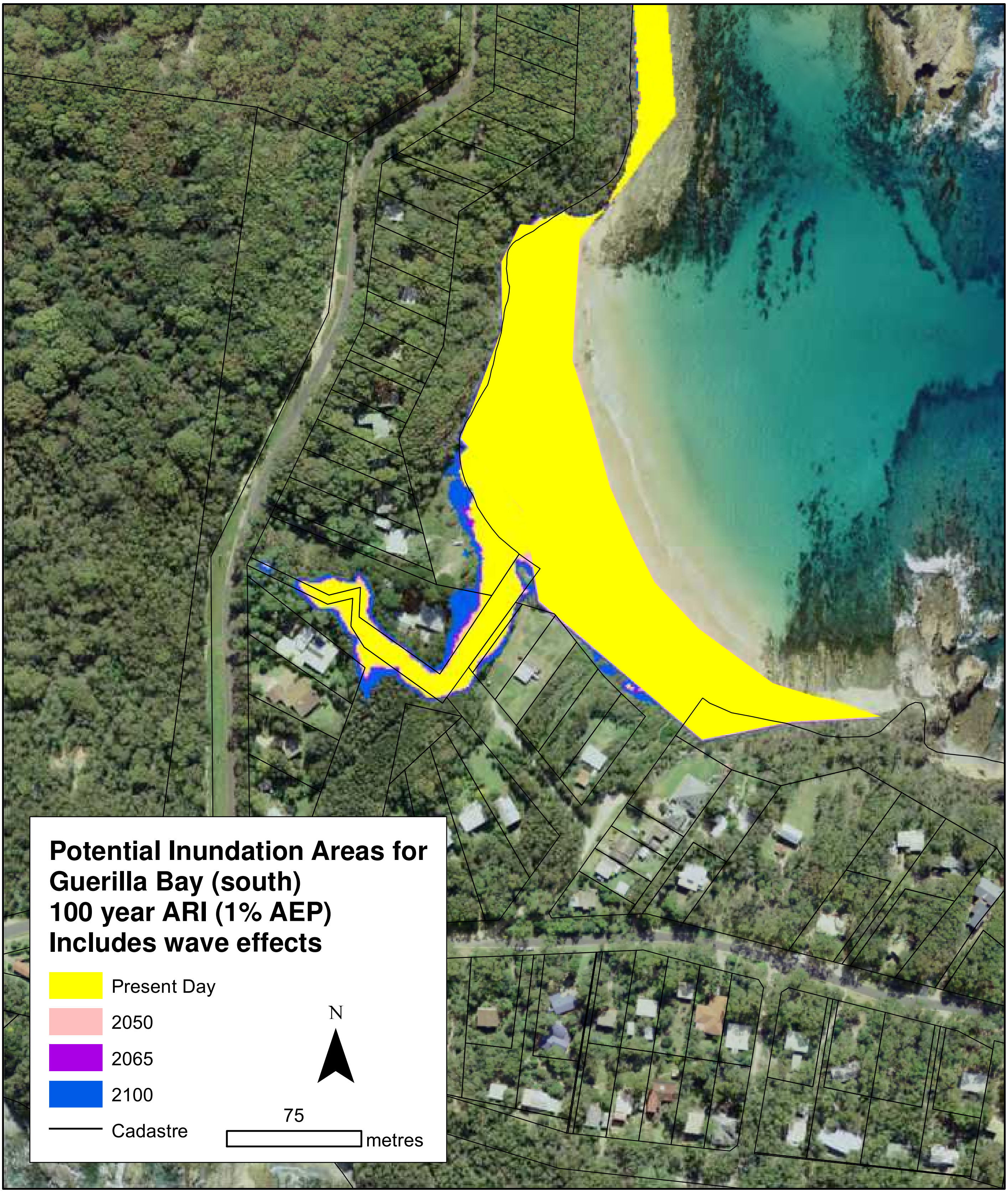

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Figure L.48

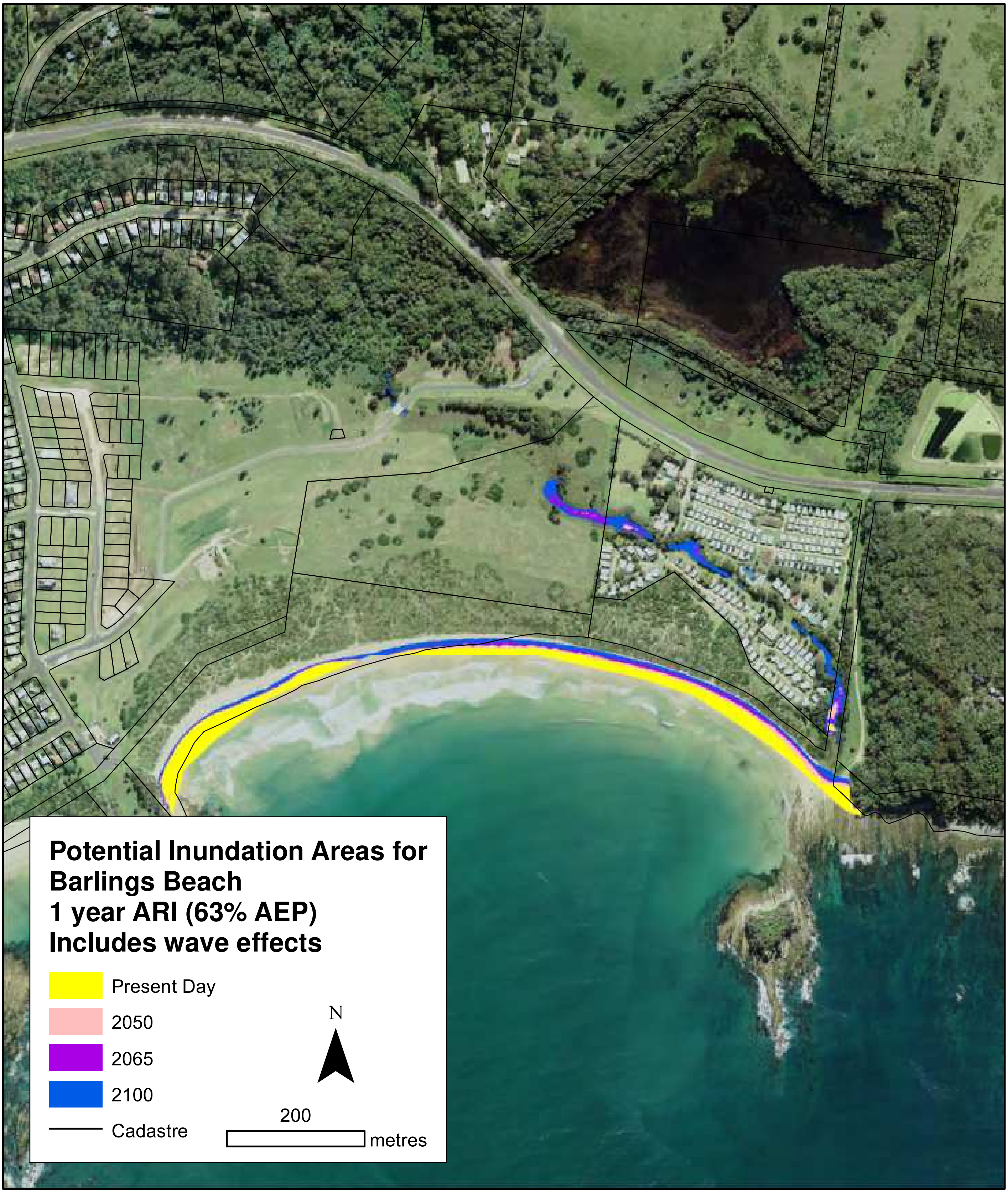

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Figure L.49

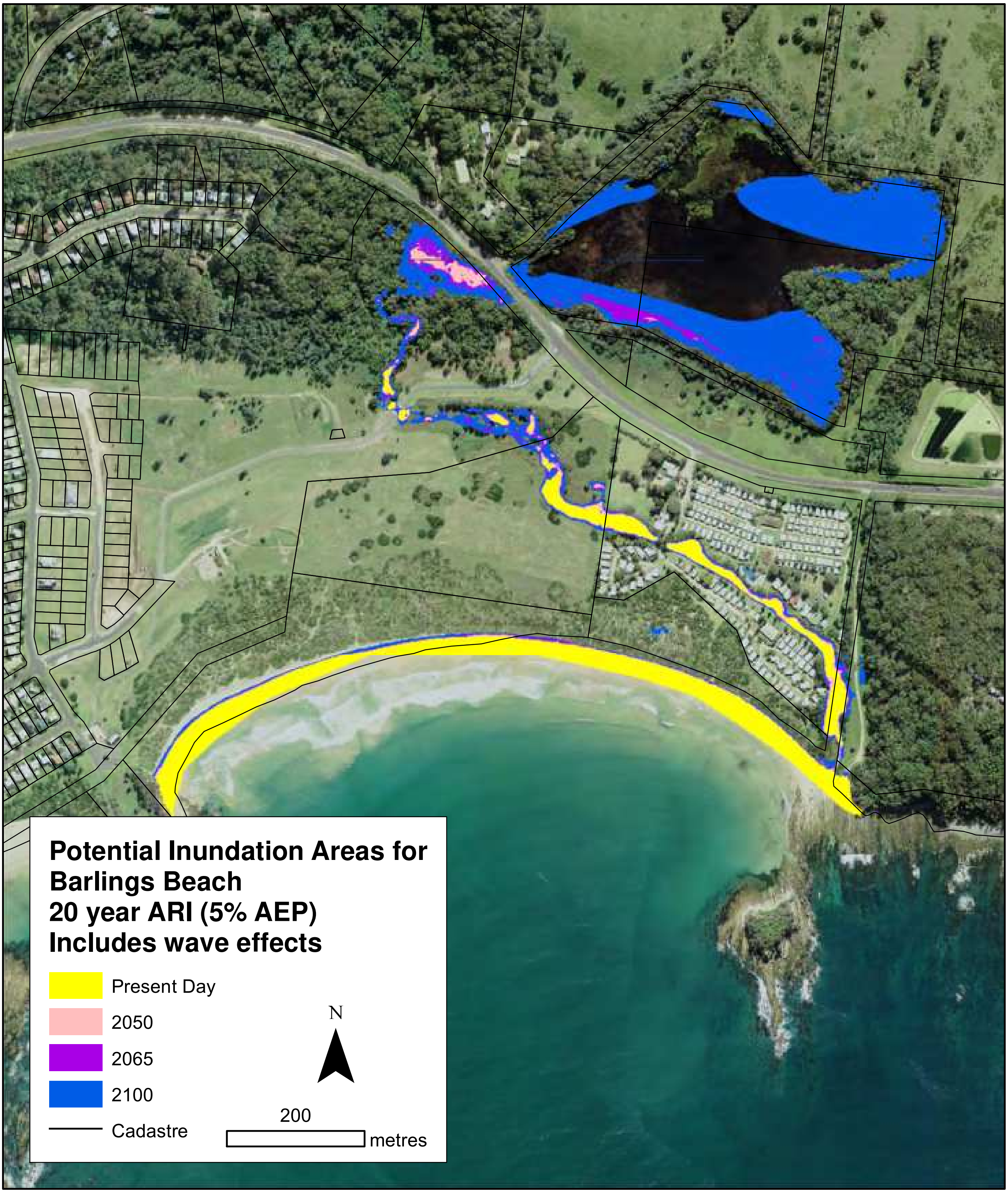

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Figure L.50

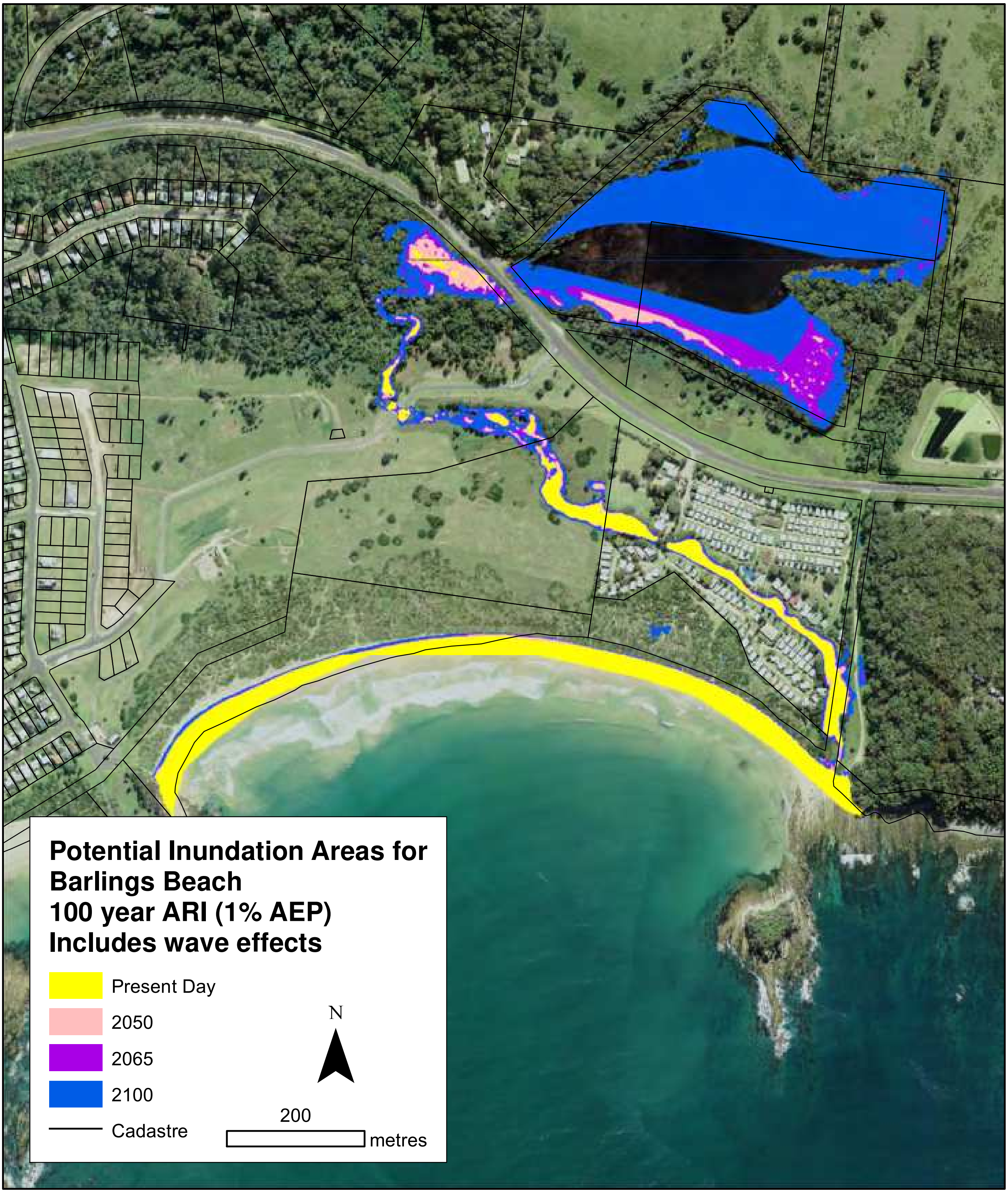

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Figure L.51

Appendix D

Assumption and Limitations:
Section 10 from WRL (2017)

10. Assumptions and Limitations

10.1 Introduction

The methodology applied in this report for the Eurobodalla Coastal Hazard Assessment was developed in consultation with Eurobodalla Shire Council and the NSW Office of Environment and Heritage (NSW OEH), and considers the following documents:

- NSW Coastal Management Act (2016) ;
- *Draft* NSW Coastal Management Manual (OEH, 2016);
- Coastal Risk Management Guide (DECCW, 2010);
- ESC sea level rise policy and planning framework (ESC, 2014;Whitehead & Associates, 2014);
- NSW Coastline Management Manual (NSW Government, 1990).

The assumptions and limitations applicable to the analysis and the data used in this study are described below.

10.2 Site Inspections

A visual assessment of the dunes and seawalls allowed general and qualitative observations of the present seawall conditions. A detailed stability assessment was not part of the scope of works and a geotechnical investigation was not undertaken for this study. Representative crest levels and foreshore geometry were estimated by experienced coastal engineers, however, in some locations these levels vary along the dune or seawall.

10.3 Sea Level Rise

The sea level rise projections adopted in this investigation were based ESC's sea level rise policy and planning framework (ESC, 2014). No further reassessment of these benchmarks was undertaken by WRL. These locally adjusted sea level rise benchmarks are based on projections from the IPCC and actual sea level rise may be higher or lower than these benchmarks over the planning period. The IPCC reviews and revises sea level projections at generally 5-7 year intervals, with the most recent revision (Assessment Report 5) being in 2013/14, and Assessment Report 6 due in 2021/2022.

10.4 Water Levels and Wave Climate

For erosion modelling purposes, a Mean High Water Spring (MHWS) tide time series was assumed, to which a tidal anomaly was added, such that the peak water level corresponded to the 100 year ARI storm surge water level. For modelling purposes the peak in predicted tide and tidal anomaly was assumed to coincide with the peak wave height of the storm.

The nearshore wave climate around the beaches of Eurobodalla Shire was determined using a numerical wave propagation model (SWAN version 41.10). The model inputs were offshore boundary conditions and bathymetric data. Offshore boundary conditions relied on extreme wave and wind statistics analysis undertaken by WRL (Shand et al., 2011) for the Australian Climate Change Adaptation Research Network for Settlements and Infrastructure (ACCARNSI). Bathymetric data was obtained from NSW OEH, NSW RMS and AHS. Data collection and analysis was undertaken by reputable organisations, however, minor survey errors are possible. Some temporal change in the seabed after surveys is almost certain which adds further uncertainty to the impacts of coastal hazards.

10.5 Beach Erosion and Recession

The volumes of storm erosion adopted in this study were informed by two methods undertaken by WRL: analysis of photogrammetry and numerical SBEACH erosion modelling.

For beaches where photogrammetry was available in 1972 and 1975 (Surfside Beach (East), Barlings Beach and Tomakin Cove) the maximum storm demand estimated from photogrammetry is considered a reasonable representation of the erosion that occurred due to the May-June 1974 storm sequence. However, the maximum storm demands estimated at the other beaches are considered to be an underestimate because the available photogrammetry dates do not capture the pre- and post-storm-sequence (i.e. beach recovery has occurred following the erosion event).

The SBEACH model has previously been calibrated and validated at numerous places around Australia. For this study, SBEACH was calibrated nearby to the study area against measured erosion at Bengello Beach. The sand grain size modelled at each beach was equivalent to the sediment samples acquired during the site inspections. Based on the experience of this report's authors, their engineering judgement, and consultation with OEH for this project, it was elected to model "design" erosion volumes using 2 x 100 year ARI storm events to account for storm clusters. Note that the Western Australian *Statement Of Planning Policy No. 2.6 (*Western Australian Planning Commission, 2003), specifies 3 x design storms to simulate clusters. Note also that changes to coastal geomorphology since 2014/2015 (when the majority of topographic and nearshore bathymetric survey data was recorded) will not be fully captured. The SBEACH model was calibrated under two separate conditions – aiming to achieve the maximum storm erosion observed at a single profile at Bengello Beach in 1974 (170 m^3/m above 0 m AHD) and, over the four (4) modelled profiles, to achieve the average erosion observed across the whole beach over the same period (95 m^3/m above 0 m AHD). These two target values were established because it is not known whether the singe profile maximum volume coincided with a rip-head embayment (three-dimensional dynamic formations like rip-heads are not included in SBEACH). Since SBEACH calibration was based on a high energy calibration location with a low beach slope, modelled erosion volumes at beaches with steep slopes may be over-predicted. WRL considers that this is likely to be the case at Maloneys Beach and Guerilla Bay (south).

The rates of recession adopted in this study ultimately relied on the analysis of temporal data sets of beach profile fluctuations. These were obtained using photogrammetric data made available by the OEH and ESC. The accuracy of this information rests with OEH and Jacobs (for photogrammetry data commissioned directly by ESC), however, photogrammetric analysis is undertaken to best current practice by skilled and experienced staff. The temporal resolution of the dataset limits the accuracy and reliability of the estimates.

Future shoreline recession as a result of sea level rise was estimated using the Bruun rule and the NSW Government's *Coastal Risk Management Guide* (DECCW, 2010). The limitations of this methodology are well recognised (Ranasinghe et al., 2007) and were taken into consideration. However, no robust and scientifically recognised alternative currently exists. Where known or obvious, the presence of underlying bedrock shelves was taken into account in the initial Bruun factor estimates in this study. However, there may be bedrock present in other areas where it is not visible.

10.6 Wave Runup and Overtopping

Best practice empirical prediction methods based on the most current published literature (Cox and Machemehl, 1986; Mase, 1989; FEMA, 2005 and EurOtop, 2016) were applied to estimate wave overtopping extents and runup levels at the dunes and seawalls. Statistical and data uncertainties related to these methodologies are discussed in the referenced literature (Shand et al., 2011 and EurOtop, 2016). The effect of wind on overtopping rates was not considered. Site specific physical modelling is the only available method offering greater certainty than the methods used.

10.7 Mapping of Coastal Hazard Lines

Mapping of coastal hazard lines was produced to provide general guidance for coastal planning and to identify areas prone to coastal hazards. Mapping was undertaken using state-of-the-art methodologies. Mapping was based on the most recent photogrammetry profiles for each beach (generally 2014, except 2011 for Barlings Beach and Broulee Beach). The limitations of the temporal and spatial resolution of the available photogrammetry data applies to the mapping. Site specific investigations and surveys are encouraged to overcome such limitations. WRL is not responsible for the accuracy of the photogrammetry data.

10.8 Modelling and Mapping of Coastal Inundation Zones

Mapping of coastal inundation zones was produced to provide general guidance for coastal planning and to identify areas prone to coastal inundation. Mapping was undertaken using state-of-the-art methodologies. Assessment of coastal inundation was performed using a combination of three methods at each beach section:

- A "bathtub" method was employed to map the extent of "quasi-static" inland inundation;
- If the dune or seawall crest level exceeds the "quasi-static" water level, the extent of the wave runup was estimated based on elevation using the Mase (1989) method for dunes and EurOtop (2016) for seawalls; and
- If the runup elevation exceeds the crest level, the Cox and Machemehl (1986) method, as adjusted by FEMA (2005), was used to estimate the landward propagation distance of wave bores.

Mapping of inland inundation assumed that topography remains as it was from the 2005 and 2011 LiDAR data provided by NSW LPI and did not consider flow paths, flow velocities, loss of flow momentum or wave propagation into creek areas. No changes were made to isolated "quasi-static" inundated areas that appear to be hydraulically disconnected; further detailed hydraulic modelling considering localised effects would be required to eliminate or confirm their validity. A qualitative check indicated that the LiDAR data was consistent with the observed land forms, however, WRL is not responsible for the accuracy of the LiDAR data.

Mapping of runup and overtopping wave bores was based on the 2011 or 2014 photogrammetry data or 2005 LiDAR data and did not include any allowance for future landward recession. Mapping of runup and overtopping was only undertaken along the crest of the dune or seawall along each beach section; it was not mapped inside watercourse entrances, inside the Batemans Bay Boat Harbour, at rock platforms or cliffed regions.