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Andersons Inlet Evolution and Surf Beach Erosion

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Synopsis: This report provides a brief analysis of the Andersons Inlet variability and resultant shoreline changes as well as summary of management options to the erosion of Surf Beach.	
Keywords: Coastal erosion, Inlet evolution, remote-sensing	

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1. REPORT CONTEXT

Inverloch is a well-loved tourist destination and regional centre on the coast of Victoria. The town is located on the northern shore of Andersons Inlet (Figure 1) with both the inlet and the open coast beaches being major attractions. Moreover, besides the tourism and economic aspect, the region has great geomorphological, ecological and cultural heritage value associated to its coastal barrier.

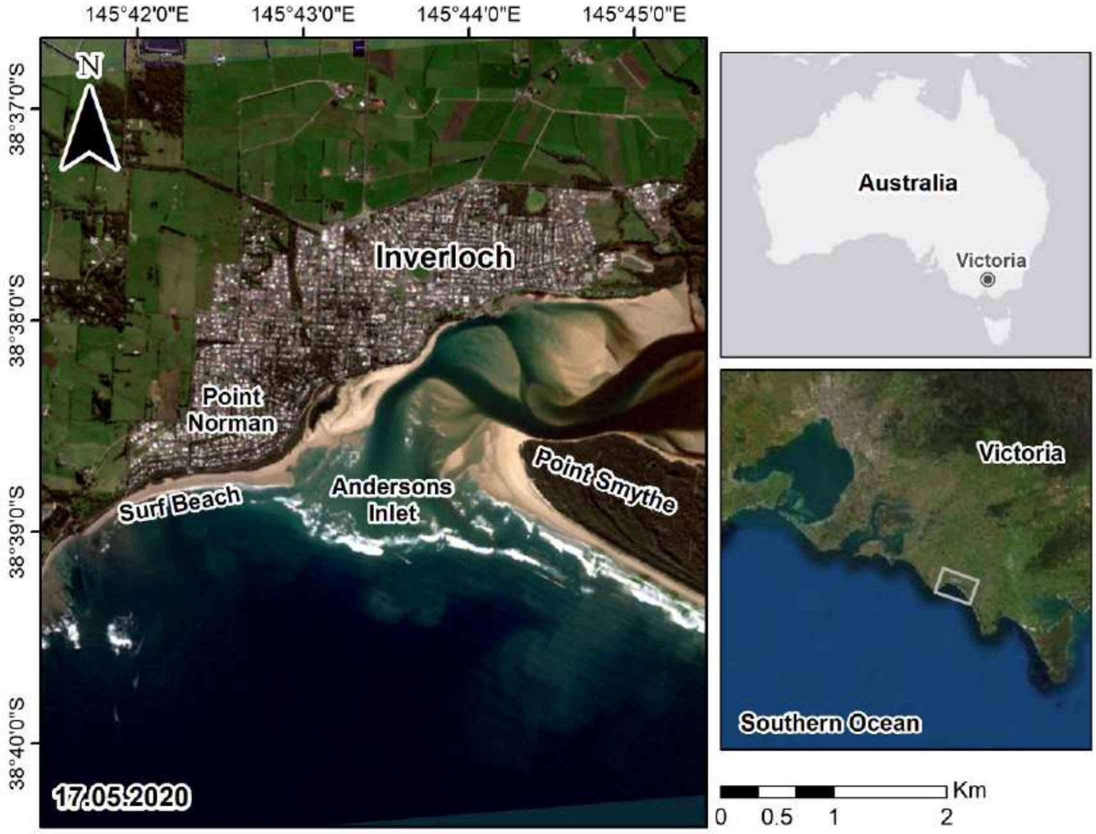


Figure 1: Study area location (Source: Image from 17 May 2020 - Sentinel-2; Google Earth base maps – EsriArcG's: Digital Globe, GeoEye, USGS).

On the other hand, Inverloch coast comprises a highly complex coastal zone. Large headlands create an enclosed bay with several features on it: an inlet system, rocky platforms, sand spits, sandy beaches and vegetated foredunes. The equilibrium between the dynamic of the different ecosystems has a fundamental role on the coastal resilience of Inverloch.

Over the last decade, persistent erosion at Surf Beach has been observed and triggered community concern. According to residents and previous coastal assessments, the current erosive state has never been reported before. Changes within Andersons Inlet have been also stated and discussed to be altering the Inverloch coastline morphodynamics.

Under these circumstances, this report was proposed in order to investigate the long-term variability of Inverloch coast and review possible alternatives of coastal interventions.

Therefore, this report covers:

- The variability of Andersons Inlet channels and ebb and flood-tidal deltas over the last 70 years (1950 to 2020) based on remote-sensing analysis in order to investigate their influence on the erosive state of Surf Beach.
- Shoreline and dune vegetation base variability from 1950 to 2020 based on remote sensing analysis in order to investigate the timescale and magnitude of the erosion process on the region.
- An overview of management options proposed as a basis for discussion with the community.

Hydrodynamic and sediment transport modelling are beyond the scope of this report. However, the report will identify where such modelling will be required in order to better clarify coastal processes, and management option effectiveness.

2. METHODS

In order to investigate the variability of Andersons Inlet and the erosional condition of Surf Beach, the remote-sensing technique was applied.

Remote-sensing

A dataset of 69 historical aerial photographs and satellite images (Google Earth Pro, Sentinel-2 L1C/L2A) comprising 69 individual days from 1950 to 17 May 2020 were analysed using the ArcGIS® ArcMap10.3. Historical photographs and Google Earth images were rectified and projected in the geographic coordinate system referenced to the WGS 1984 Datum, UTM Zone 56S. The 95% confidence interval error was calculated for each image based on the root mean-square (RMS) errors, following FGDC-STD (1998) and Araujo et al. (2009). The maximum RMS value observed for the aerial photograph was for 1950 (4.7 m with 95% confidence interval). In this sense, the errors resulting from the rectification process are in the order of less than 5 m, and therefore they can be considered negligible for this analysis. The tide correction, however, was not possible to be included and should cause some interference in the mapped shoreline positions. For that, shoreline results are recommended to be interpreted as a function of the trends observed in the time series, instead of comparing individual days.

Using all rectified images, shoreline indicators such as waterline shoreline and vegetation base (Figure 2) were mapped according to Boak and Turner (2005). The shoreline changes were analysed using the Digital Shoreline Analysis System (DSAS) version 4.3 (Himmelstoss, 2009) that is a freely available software application that works within the ESRI®-ArcGIS software. DSAS computes the distance of the shoreline vector data from a defined baseline in a determined number of regularly spaced profiles. In total, 214 profiles with 50 m spacing were created for Inverloch coast (120 transects) and Point Smythe (94 transects) (Figure 2). In addition, features such as flood-tidal delta deposits, subaerial beach and main river channel were mapped to develop the schematic maps and analyse the variability of Andersons Inlet.

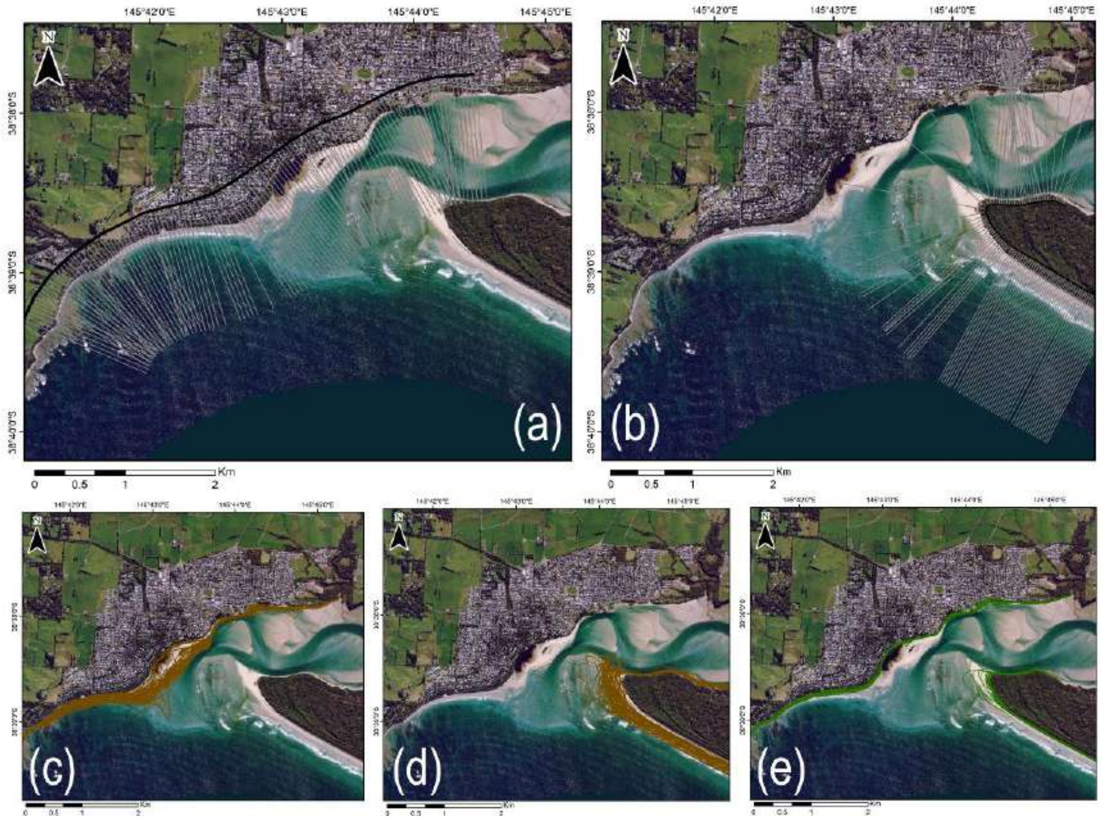


Figure 2: Remote-sensing analysis. (a) and (b) present the DSAS transects spaced at every 50m along the shore-parallel baselines of Inverloch coast and Point Smythe. (c) and (d) show the shoreline mapped using the waterline indicator, while (e) indicate the vegetation-based line from 1950 to 2020.

3. RESULTS

The following results present the Andersons Inlet variability as well as shoreline/vegetation and flood-tidal delta deposits changes throughout the years (1950 to 2020).

3.1. Andersons Inlet Channel and Sand Deposits Migration

A previous analysis of a series of historical aerial photographs of Andersons Inlet in Inverloch Foreshore Coastal Processes Assessment (Byrne - March 2000) proposed that the Andersons Inlet entrance has remained considerably unchanged over the last 140 years, positioned adjacent to Point Norman, and with wide sand deposits between Point Smythe and the inlet. This assessment is no doubt based on the *Venus Bay and Anderson Inlet Survey* dated 1868-9 (Courtesy of the SGCS Members). Although the study presented here does not have equal timespan, current results show that at least for 60 years (1950 to 2009) (Figure 3) the Andersons Inlet position was observed similar to the description made on this early report.

This does not indicate, however, that changes were not happening in the inlet-sand deposits system. In fact, it is possible to note that an area of 1.4 km^2 from the Point Smythe attached-sand deposit was previously (in 1950) above water level and dry, and then appeared flooded in 1979 (Figure 3). Although the remote-sensing analysis between two individual days with almost 30 years difference needs to be interpreted with thoughtfulness, it is relevant that the area that seemed to be once a dry sandy upper beach in 1950 appeared as an attached flood-delta deposit for the next years until 2009 (Figure 3). Between 2002 and 2008, tidal flow-driven erosion and deposition features are detected forming over the flood-tidal delta deposit until it separates from Point Smythe in 2009 (Figure 3).

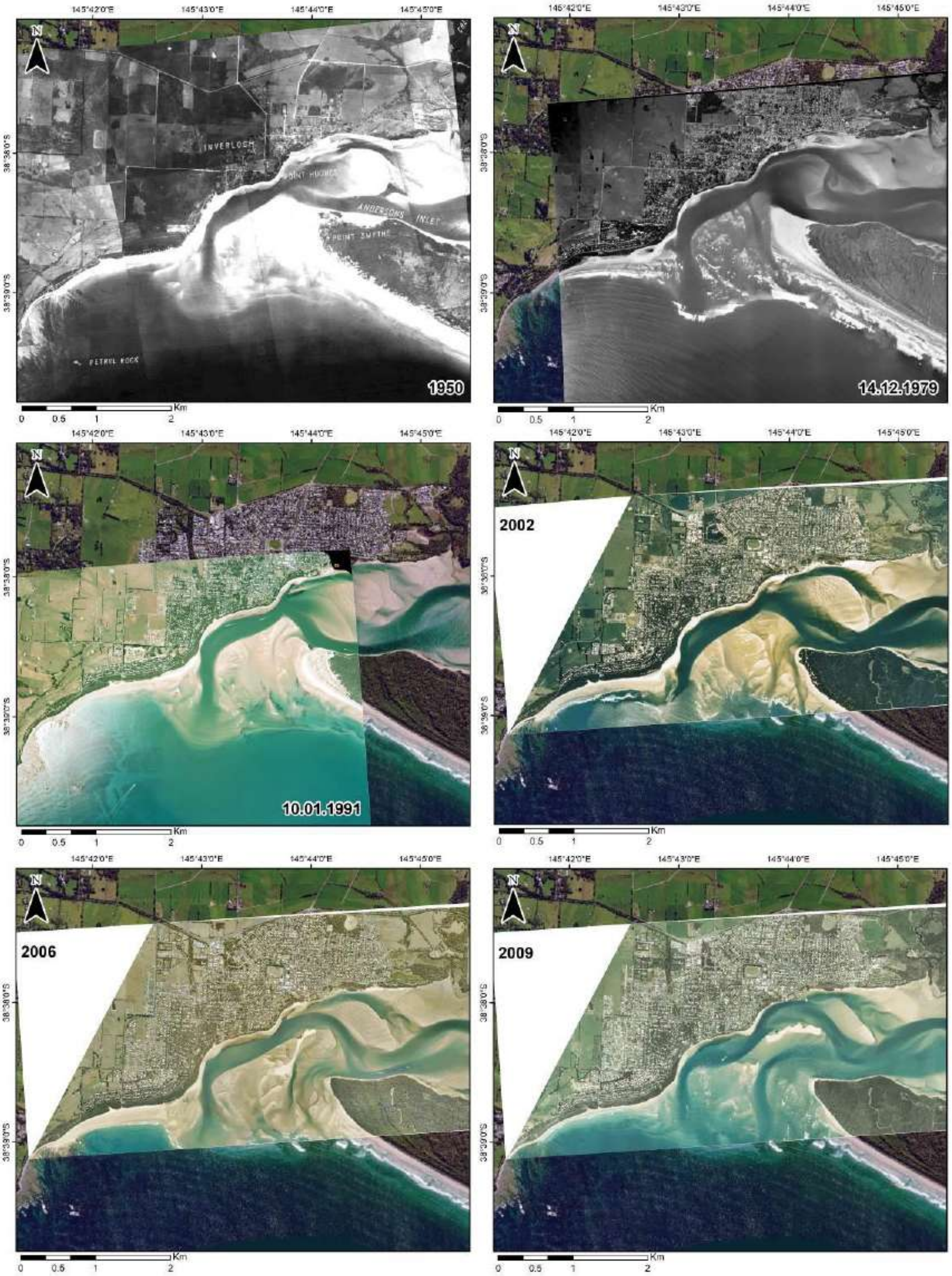


Figure 3: Aerial images from 1950 to 2009 showing that Andersons Inlet persisted in a similar configuration for 60 years, until the channel broke through Point Smythe. It is also observed that the sand deposit attached to Point Smythe has evidence of tidal flow-driven erosion and depositional features developing over time.

Examining the river meandering upstream (Figure 4), it is observed that a stronger meander has formed since 1950, eroding the internal shore of Point Smythe and placing the flood-tidal delta deposits towards the northern channel margin (Figure 4). Even though the cause of this change in channel dynamics is unknown, it is likely that this variability of the meander also contributed to the breakthrough of a new channel at Point Smythe. In addition, the process of sand bypassing the inlet entrance between Point Smythe and Point Norman might have been also modified as a result of the formation of the second inlet channel by 2009 (Figure 3).

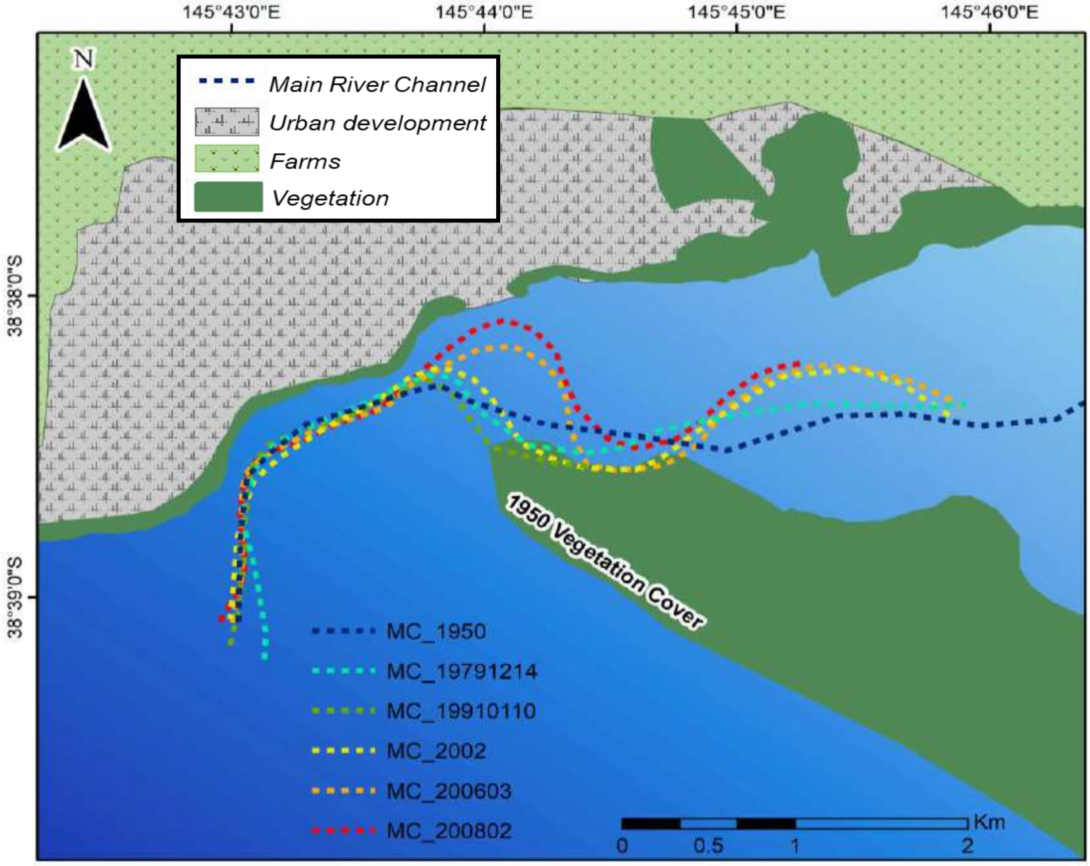


Figure 4: Representation of the channel and inlet position from 1950 (dark blue) to 2008 (red).

A consequence of the formation of a second channel is a weakening of flow from the previously dominant western channel thereby reducing the “hydraulic groyne” effect of the tidal flow. This feature results from the interaction between sediment moving towards the channel under wave-induced currents and the tidal inlet currents at the inlet, which act to block sediment movement resulting in deposition along the margin of the inlet channel which in this case is evident as the spit of sand at Point Norman. The reduction in the hydraulic groyne effect resulted in a reduction in the apparent size of the Point Norman spit.

After this event in 2009, Andersons Inlet dynamics entered a period of readjustment. The sand deposits once attached to Point Smythe started to migrate towards the northern channel margin (Figure 5). In the meanwhile, two main channels are observed (Figure 6). Between 2013 and 2014, the sand banks weld to the Inverloch shoreline (Figure 5) and one main channel prevails with the inlet positioned about

900 m eastward of its previous quasi-permanent (over 60 years) location (Figure 6). The hydrodynamic mechanism leading the migration of this sand bank is not investigated here, however, it is relevant to note that the sand deposits attached to Point Smythe show an accretionary condition towards the northwest, which supports the sand bank migrating and splitting onshore-offshore (Figure 5).

Point Norman spit formation also responded to the inlet variability by gradually shifting from southeast to east, with 50° of change between 2002 and 2013 (Figure 5). Considering that the previous inlet discharge would force Point Norman spit offshore in a southeast direction, as the inlet location was altered and with some contribution to the predominant wave direction the current spit moved its position more onshore (~ 500m) (Figure 5). One possible consequence of this variation is the sand movement from Surf Beach towards Point Norman and into Andersons inlet, however, a more detailed investigation including wave and sediment transport statistics and numerical modelling would provide a more certain answer to this hypothesis.

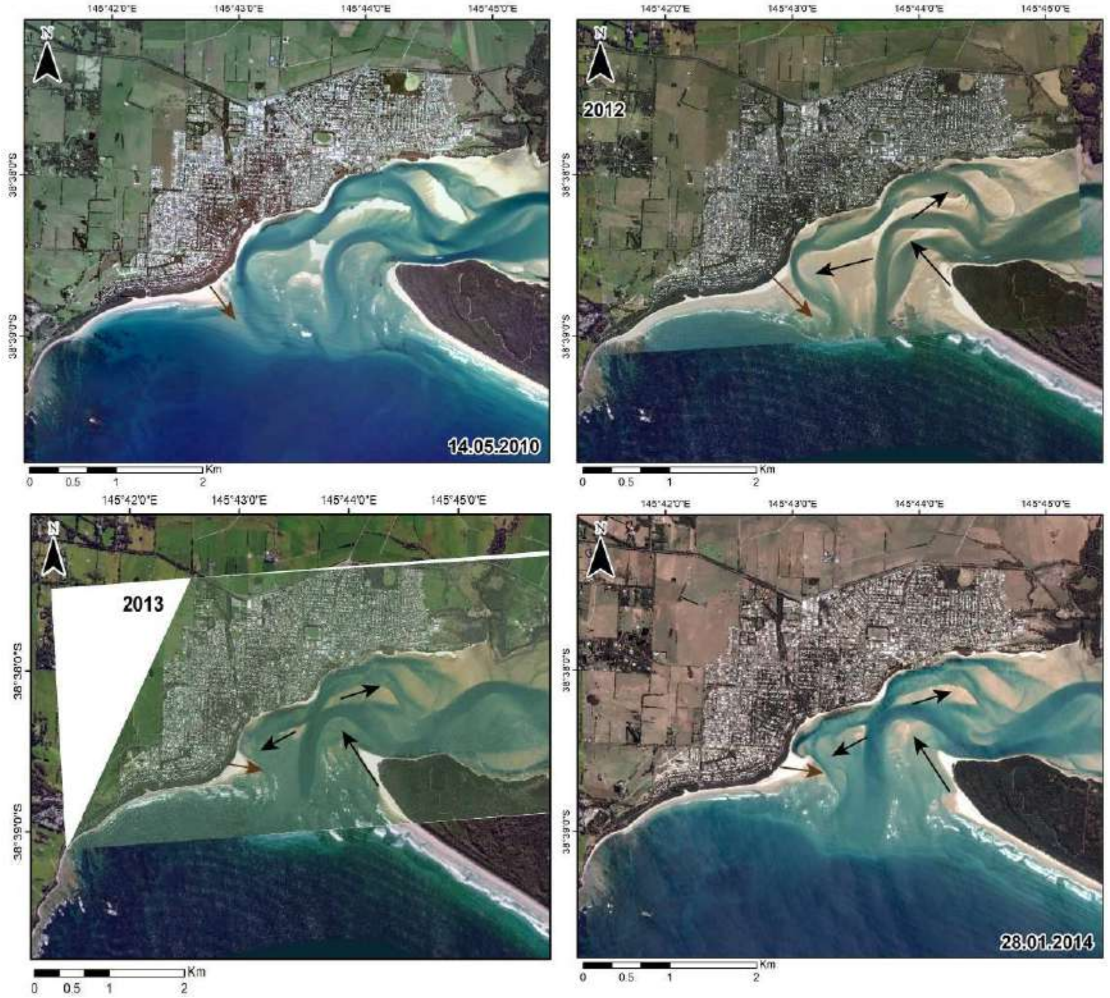


Figure 5: Aerial Photograph (2013) and satellite images showing the sand deposits migration between 2010 and 2013. Black arrows indicate the migration of the sand deposits previously attached to Point Smythe. Brown arrows indicate the formation of the sand spit at Point Norman.

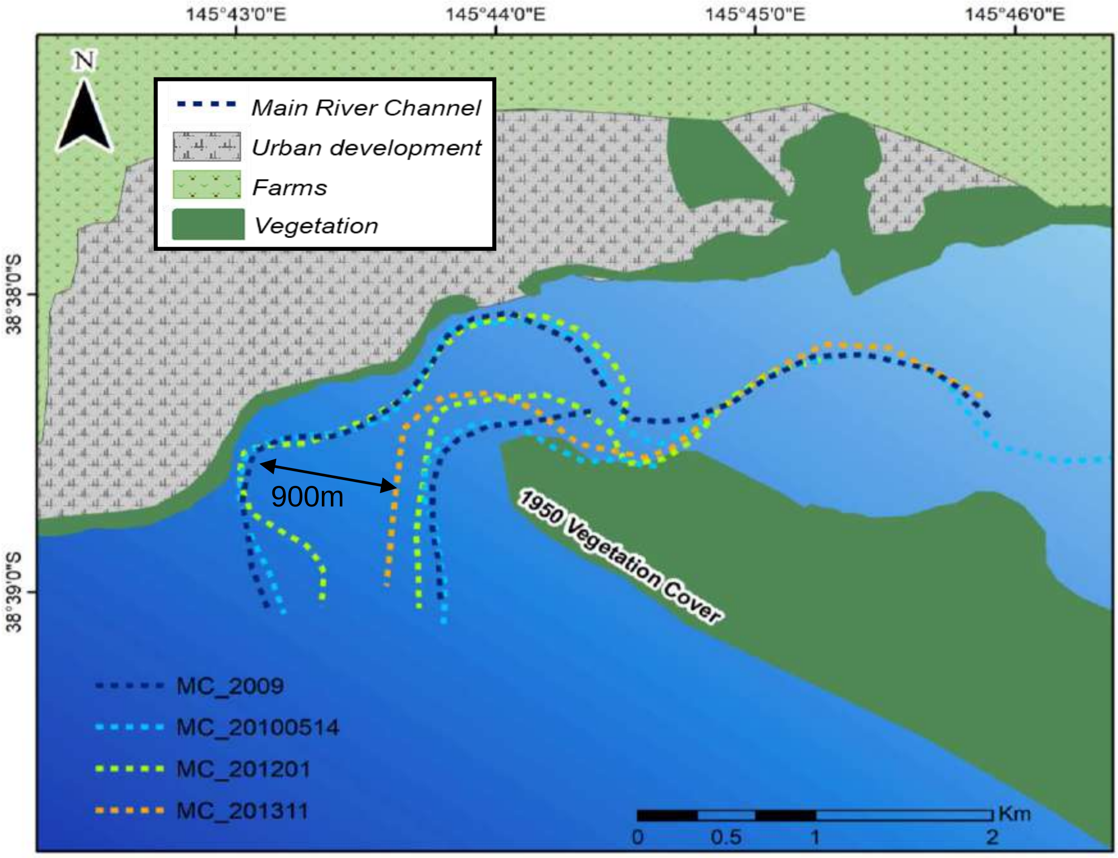


Figure 6: Representation of the river channel and inlet position from 2009 (dark blue) to November 2013 (orange).

Between 2014 and 2016, this sediment building around Point Norman increased and forced the inlet eastward (Figure 7). In the meanwhile, Point Smythe sand deposits kept growing onshore, creating a more complex meandering system close to the entrance (Figure 7). Moreover, the sand bank that now is welded to the Inverloch shoreline created an estuary sandy beach with an enclosed lagoon (Figure 8). By the end of 2016, a freshwater flood (identified by the dark brown colour of the estuary water) washed out the sand spit forming at Point Norman (Figure 8).

Throughout 2017 until mid-2018, a strongly curved meander ending in an elongated inlet channel (Figure 9) was the dominant configuration. With this, Andersons inlet starts to return to a closer location to where it was before 2009. The flood-tidal delta deposits attached to Point Smythe need to increase and stabilize in order to force and maintain the inlet further west (Figure 9), however Point Smythe spit still had its growth sustained towards the north.

In August 2018, a freshwater flood event caused the channel to break through the Point Smythe sand deposit, modifying the inlet meandering system once again (Figure 10). Since then, Point Smythe has started to build up towards the west and the meandering system was smoothened. On the other side of the channel, erosion has been observed around Point Norman and towards the estuary sandy beach (Figure 10). It is not possible to confirm if Andersons Inlet will find its equilibrium configuration in a similar manner as it was until early 2000's, however, it seems that the inlet system is adjusting towards it.

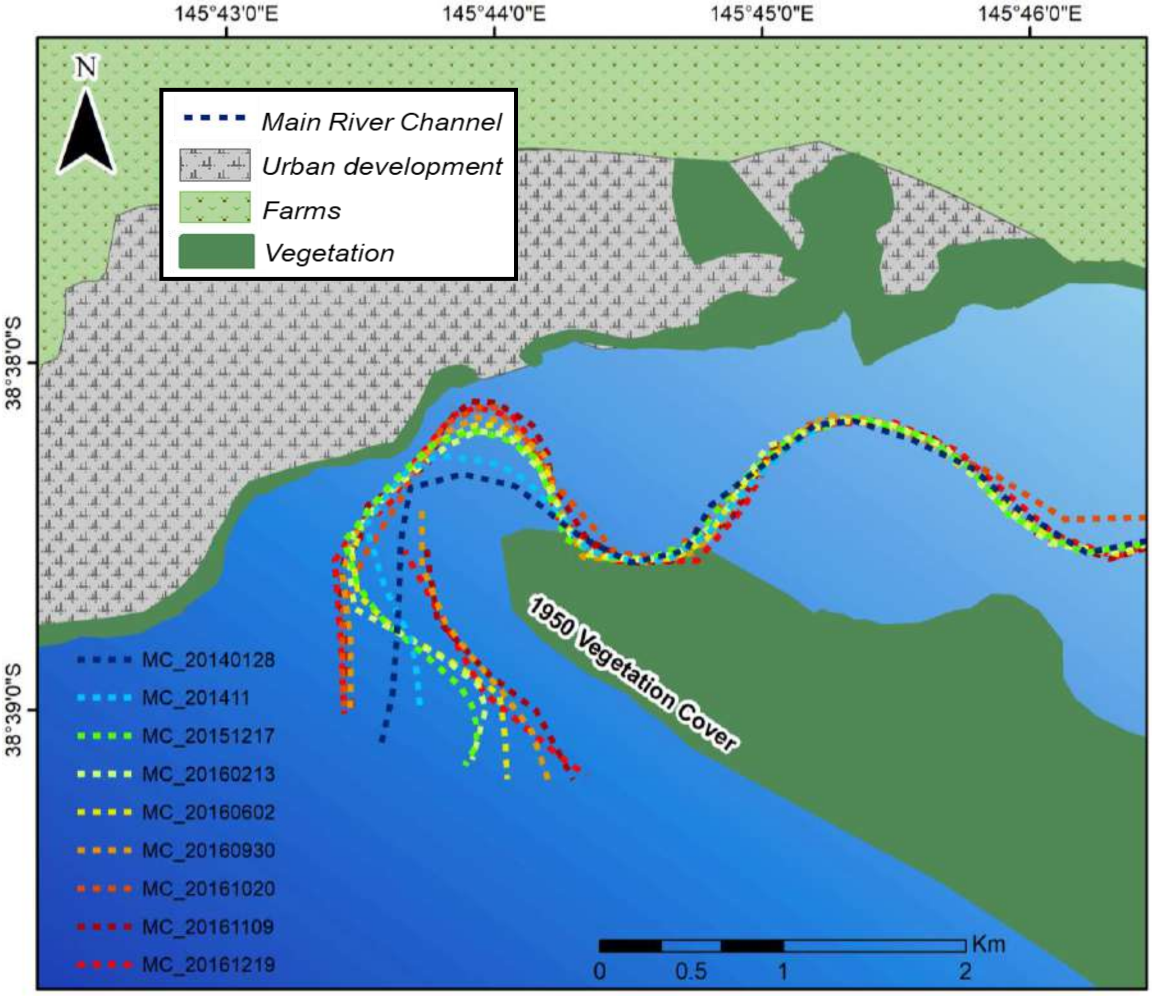


Figure 7: Representation of the river channel and inlet position from 2014 (dark blue) to December 2016 (red).

Figure 8: Aerial image (2014) and satellite images showing Andersons inlet variability between 2014 and 2016. Point Smythe sand deposit builds up towards north while Point Norman sand spit is formed towards east, creating a complex meandering system and moving the inlet eastward. In 2016, however, a flood breaks through Point Norman sand spit.

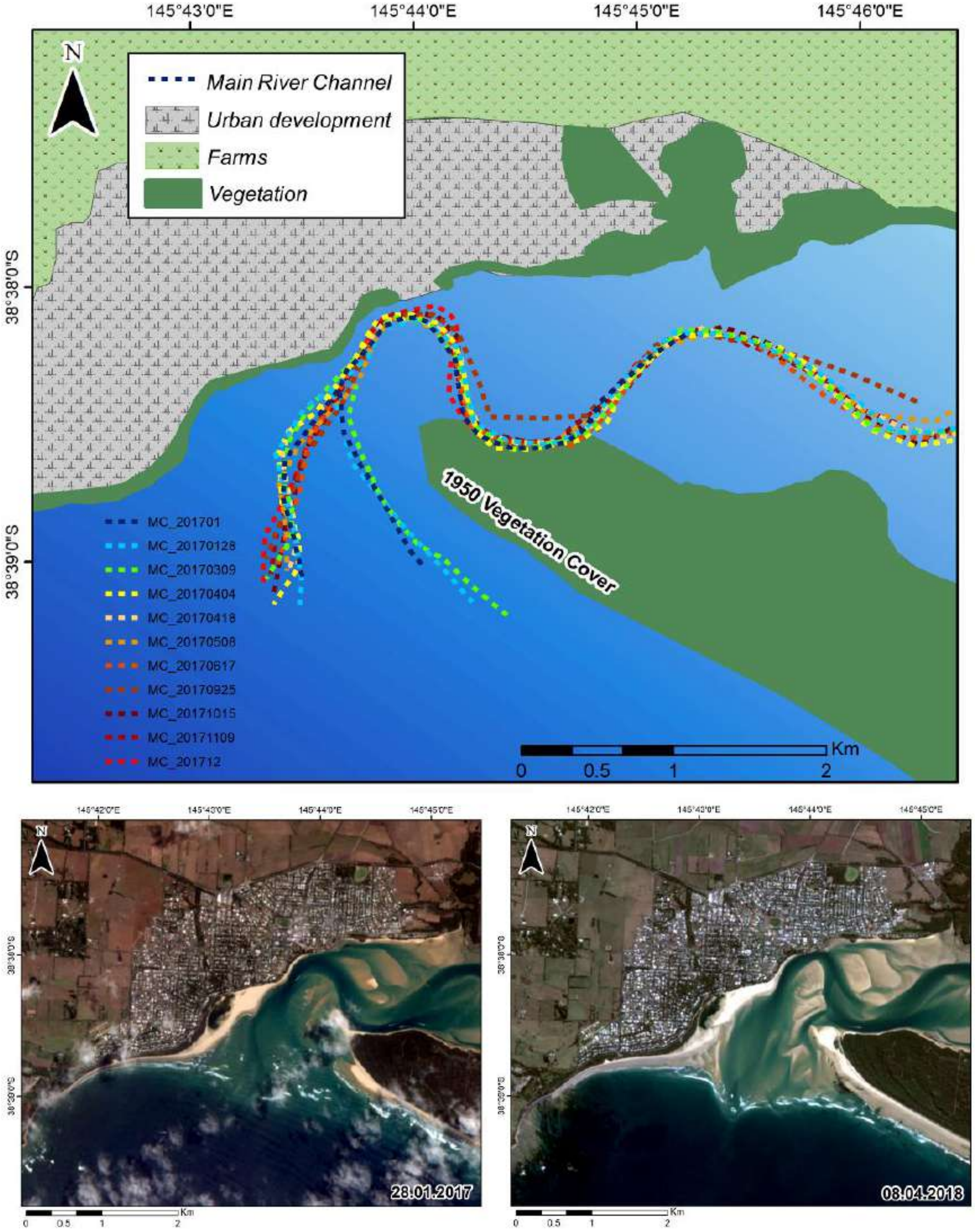


Figure 9: Above, representation of the river channel and inlet position between January 2017 (dark blue) to December 2017 (red). Below, satellite images exemplify the river configuration that prevailed during 2017 until mid-2018.

Figure 10: Satellite images showing the river system variability between 2018 and 2020. In 2018, a flood broke through Point Smythe sand deposits and change the main channel position. Point Smythe started to grow towards west.

3.2. Shoreline Variability

3.2.1 Point Smythe

The spit formation observed in Point Smythe has undergone substantial recession since 1950. About 1.3 km of shoreline retreat occurred from 1950 to 2009 (Figure 11a). From 2010 onwards, shoreline position started to oscillate with no significant trend (Figure 11b). As presented before in section 4.1 and Figure 3, Point Smythe has been gradually flooded which has caused shoreline recession, and transformed the sandy upper beach of 1950 into a flood-delta deposit that was detached from Point Smythe in 2009.

The seaside shoreline at Point Smythe does not present any significant trend, and most of the variability could be related to tidal excursions. It is noteworthy, however, that towards the western limit of the beach (Transects 45 to 55) a 330 m shoreline retraction (Figure 11c) occurred between 2006 and 2008, and persists until 2009-2010. By 2012, the beach accretes back and oscillates around the same position along the following years. On the inland side of Point Smythe, shoreline recession has occurred since 1950, retreating about 230 m until 2015 (Figure 11d). More than half of this shoreline recession (136 m) happened between 1950 and 1979 in response to changes on the river meander (Figure 4).

3.2.2. Inverloch Estuarine Coastline to Point Norman

Along Inverloch coastline – where nowadays a large sandy beach that encloses a small lagoon is located – the shoreline was usually in a more onshore position prior to the migration of the inlet channel (Figure 12a). The Andersons Inlet channel would flow nearshore and impede a major accretion of the estuary sandy beach (Figure 3).

Around 2014, the sand deposits that were detached from Point Smythe started to merge with the coastline on the western side of the estuary channel (Figure 8). The development of the estuary sandy beach is firstly observed near Point Norman and gradually develops at the upstream transects (Figure 12b). By the end of 2016, the sand deposit was completely emerged, and the new shoreline position stabilized (Figure 12b).

An erosion spot was detected around transect 40 from mid-2018 to early 2019 (Figure 12c) as a result of a freshwater flood (Figure 10). The area was infilled back by March 2019 (Figure 12c), which seemed to happen due to upstream migration of sand along the shoreline. Sand deposits around transects 50 to 55 (downstream), for instance, started to gradually erode since early 2019 (Figure 12d).

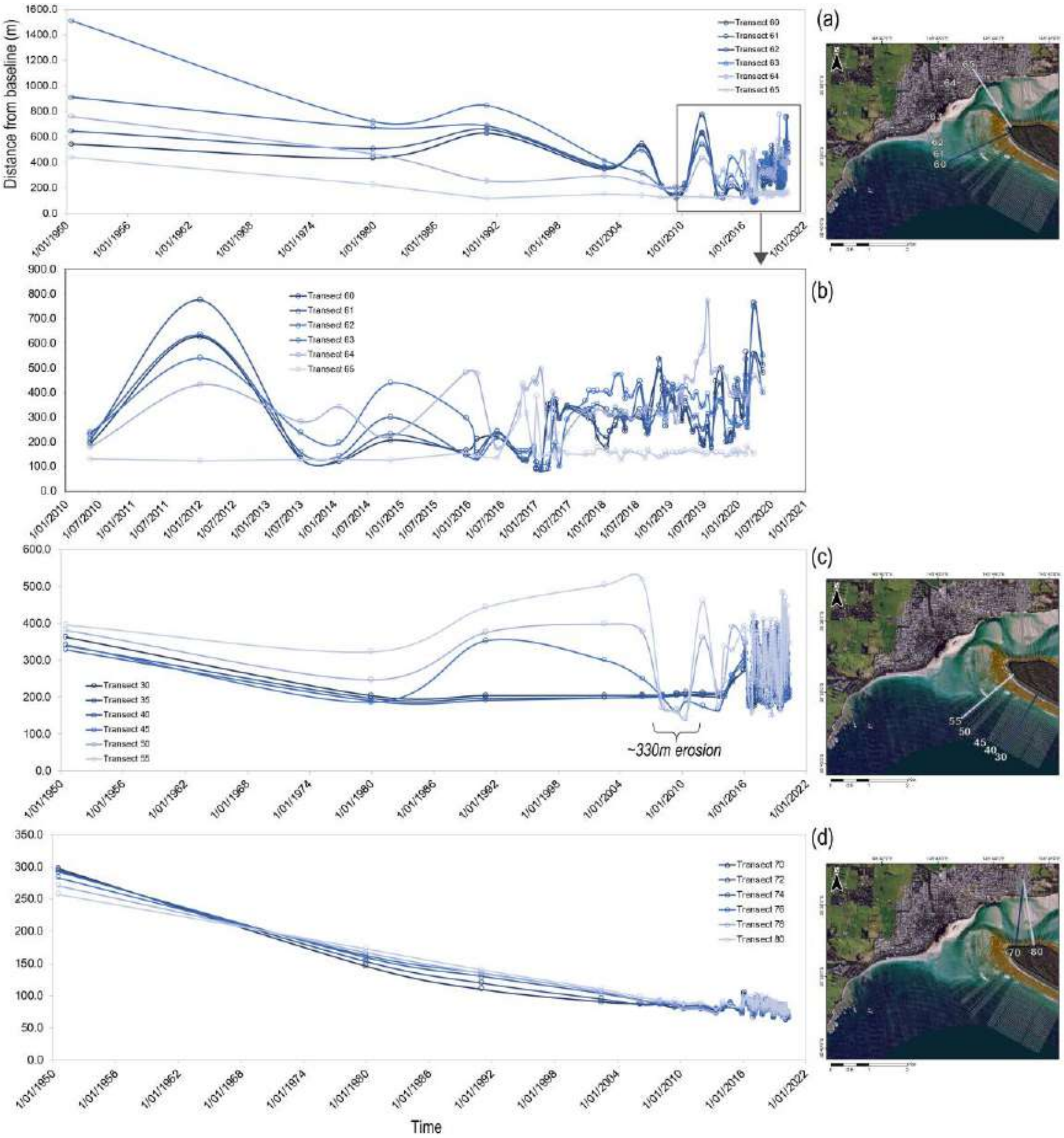


Figure 11: Shoreline position variability at Point Smythe. (a) time-series for transects 60 to 65 covering the period from 1950 onwards; (b) variability of the same transects for the period from 2010 onwards; (c) time-series for transects 30, 35, 40, 45, 50 and 55 covering the period from 1950 onwards; and (d) time-series for transects 70, 72, 74, 76, 78 and 80 covering the period from 1950 onwards.

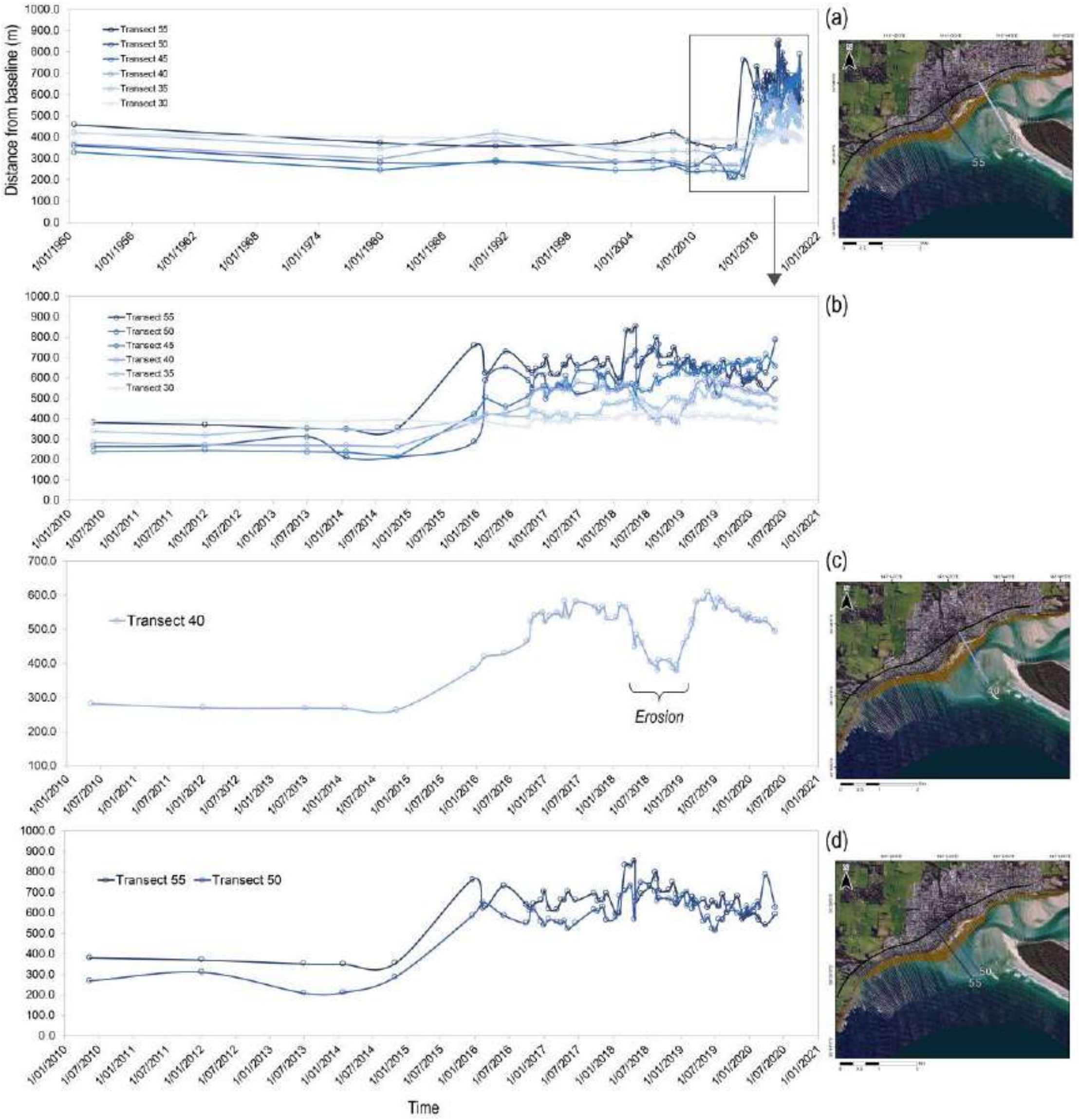


Figure 12: Shoreline position variability along Inverloch coastline. (a) time-series for transects 30, 35, 40, 45, 50 and 55 covering the period from 1950 onwards; (b) variability of the same transects for the period from 2010 onwards; (c) time-series for transects 40 covering the period from 2010 onwards; and (d) time-series for transects 50 and 55 covering the period from 2010 onwards.

At Point Norman, specifically analysing transects 60 and 66 (Figure 13), a change in the orientation of the spit formation occurred after 2010. In 2006, a sand spit was developing towards south at transect 66 (Figure 13), however which was completely eroded by 2009-2010. In 2012, the sandspit was developing towards the east at transect 60 (Figure 13). This indicates an upstream movement of sand which could have been related to the changes in inlet position and the migration of the flood-delta deposits. Over the last 2 years, the sand deposits around Point Norman have been observed to be gradually eroding.

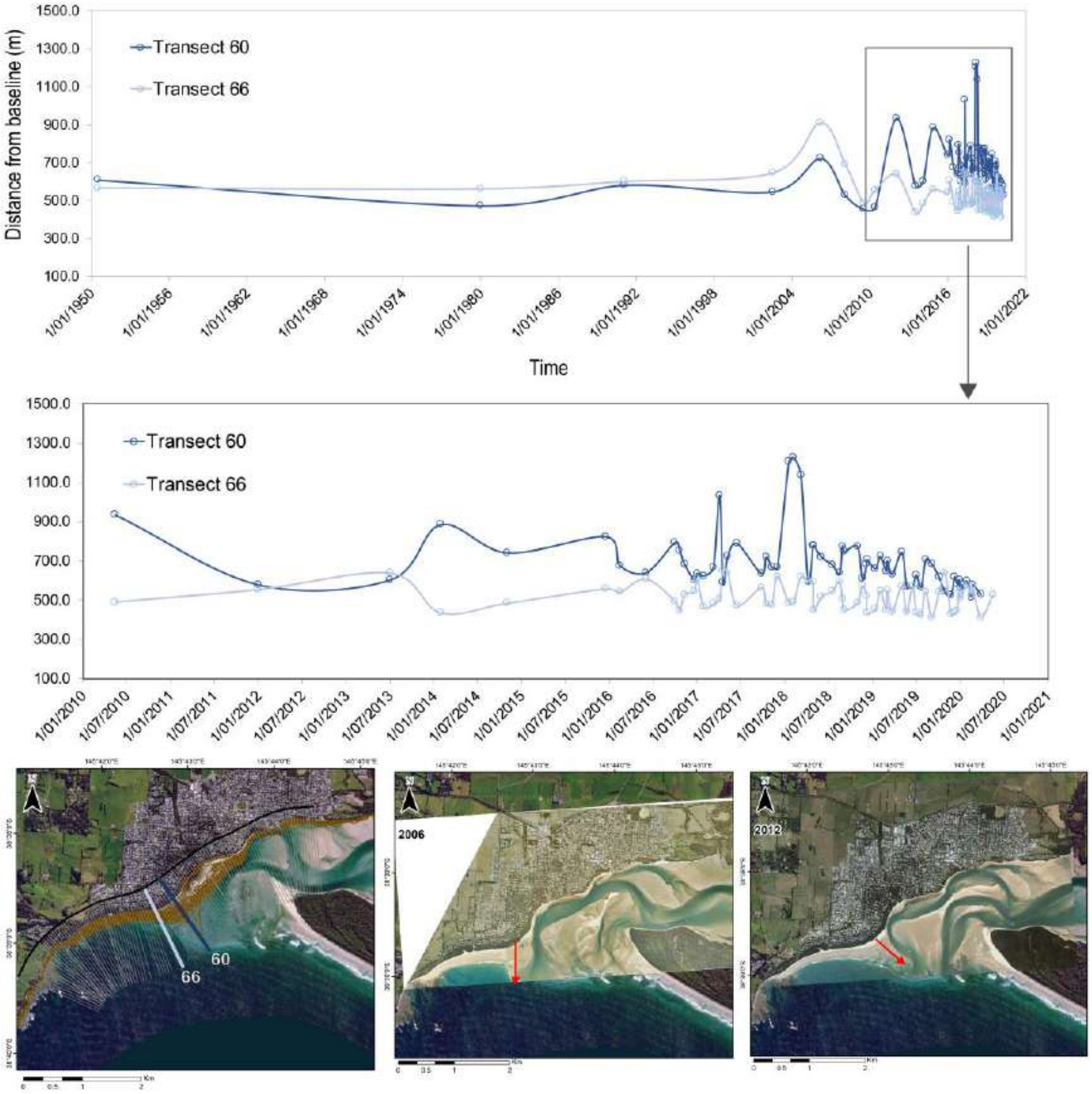


Figure 13: Shoreline position variability at Point Norman. Above, time-series for transects 60 and 66 covering the period from 1950 onwards. Below, variability of the same transects for the period from 2010 onwards.

3.2.3. Surf Beach

West of Point Norman, the Surf Beach has also presented changes in shoreline position over the last decade. Although through this assessment it is not possible to provide measurement of the sand movement between the Surf Beach and Andersons inlet, it is evident that the morphodynamic equilibrium of the beach system was disturbed by the changes within the inlet, and possibly by the hydrodynamic forcing (e.g. sea-level changes, wave energy and direction variability and/or sediment transport) that led to these changes.

The analysis of different transects along the coast showed that Surf Beach has a uniform pattern of variability of the shoreline position, however, it appears more accentuated near Point Norman and gradually less towards the west (Figure 14). From 1950 to early 2000’s, shoreline presented a stabilized position (Figure 14). Between 2006 and 2008, a peak of beach accretion occurred, more significantly near

Point Norman. After this period, shoreline recession along the Surf Beach started (Figure 14).

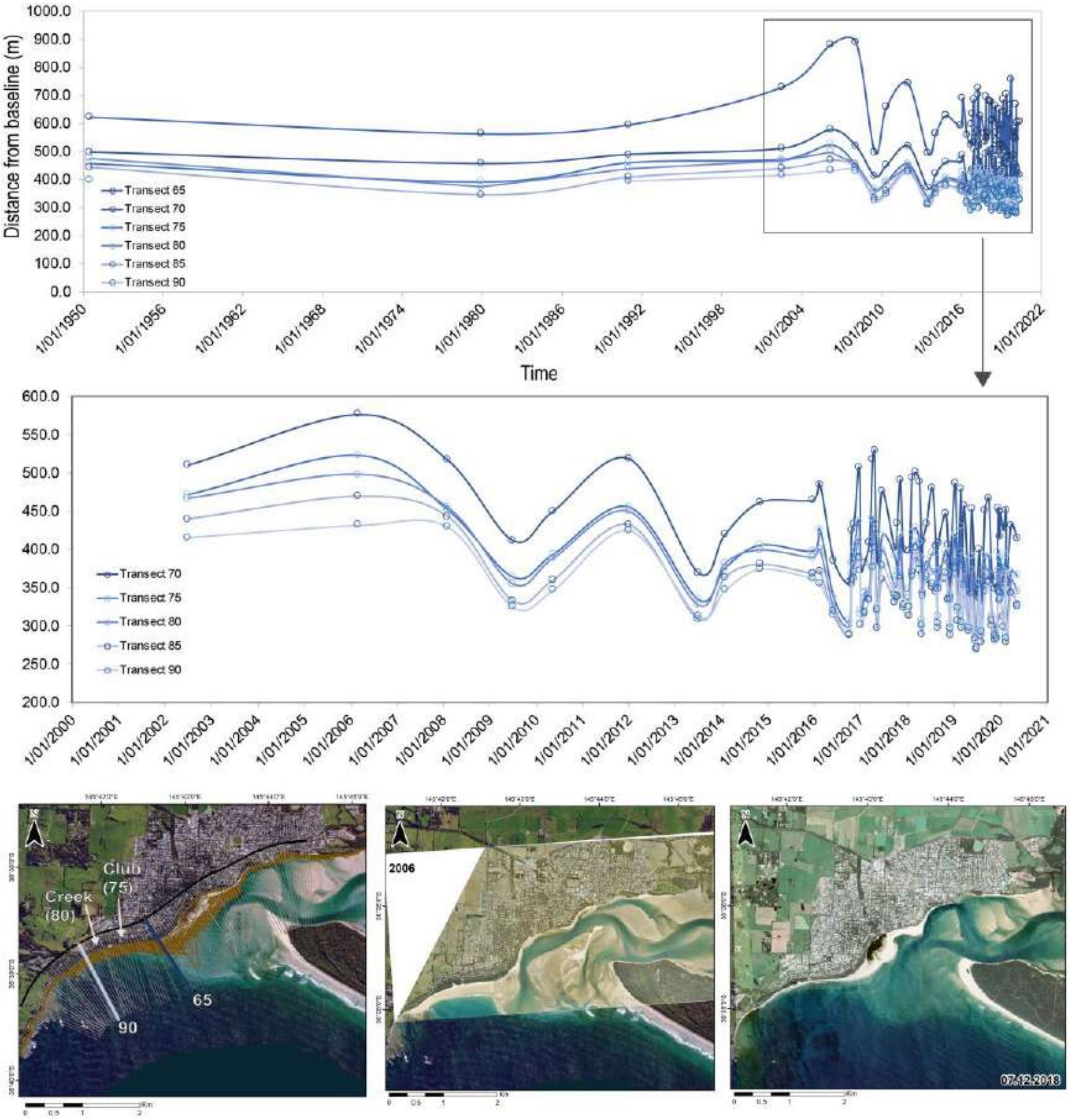


Figure 14: Shoreline position variability along Surf Beach. Above, time-series for transects 65, 70, 75, 80, 85 and 90 covering the period from 1950 onwards. Below, variability of the same transects (excluding Transect 65) for the period from 2001 onwards.

It is not possible to observe a significant trend of erosion, but instead a gradual and oscillatory shoreline retreat. Comparing the maximum shoreline accretion (2006-2008) with the maximum erosion (2018-2019), about 200 m of recession occurred along the last decade (Figure 14) near Point Norman and gradually less further to the west. However, it is not possible to project from the shoreline position time-series that intense erosive trends are going to persist for the future years.

3.3. Vegetation Variability

The vegetation line on Point Smythe, Point Norman and Surf Beach has responded to the trends of the shoreline position. The vegetation along Inverloch coastline, however, does not show a clear pattern of variability.

3.3.1. Point Smythe

At the western limit of Point Smythe, shoreline retreat was observed already in the 1970’s. The vegetation line, on the other hand, had a sustained growth from 1980’s until early 1990’s (Figure 15a). At this point, the beach width was drastically reduced, and shoreline recession reached the vegetation base. Between 1991 and 2009, the vegetation line in Point Smythe retreated by around 250 to 400m (Figure 15a). Over the following decade, the vegetation base persisted in a similar position (Figure 15a).

The inland side of Point Smythe has endured recession of the vegetation line since the 1970’s (Figure 15b), as a result of the migration of the meander eroding the region. On the ocean side of Point Smythe, however, vegetation has grown between 1950 and 1970’s, and maintained at a similar position since then (Figure 15c).

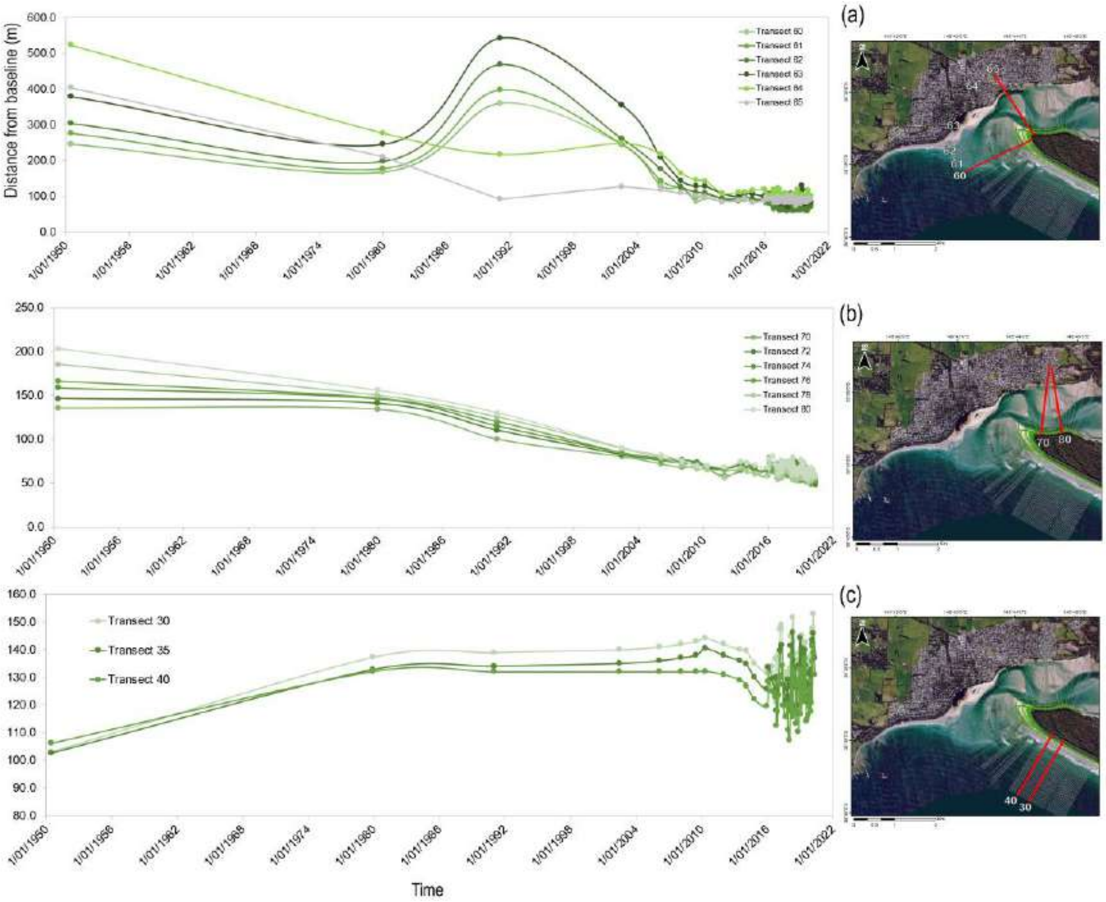


Figure 15: Vegetation line variability at Point Smythe. (a) time-series for transects 60 to 65 covering the period from 1950 onwards; (b) time-series for transects 70, 72, 74, 76, 78 and 80 covering the period from 1950 onwards; and (c) time-series for transects 30, 35 and 40 covering the period from 1950 onwards.

3.3.2. Point Norman

At Point Norman, similarly to the shoreline position, vegetation growth occurred at transect 66 with a maximum accretion around 2006 (Figure 16a). After this, vegetation line has retreated in this section, and slightly accreted at transect 60 (Figure 16a), located towards the entrance of Andersons inlet. Over the last decade, no significant trend is detectable towards erosion or accretion of the vegetation area (Figure 16b), which impedes the projections for the following years.

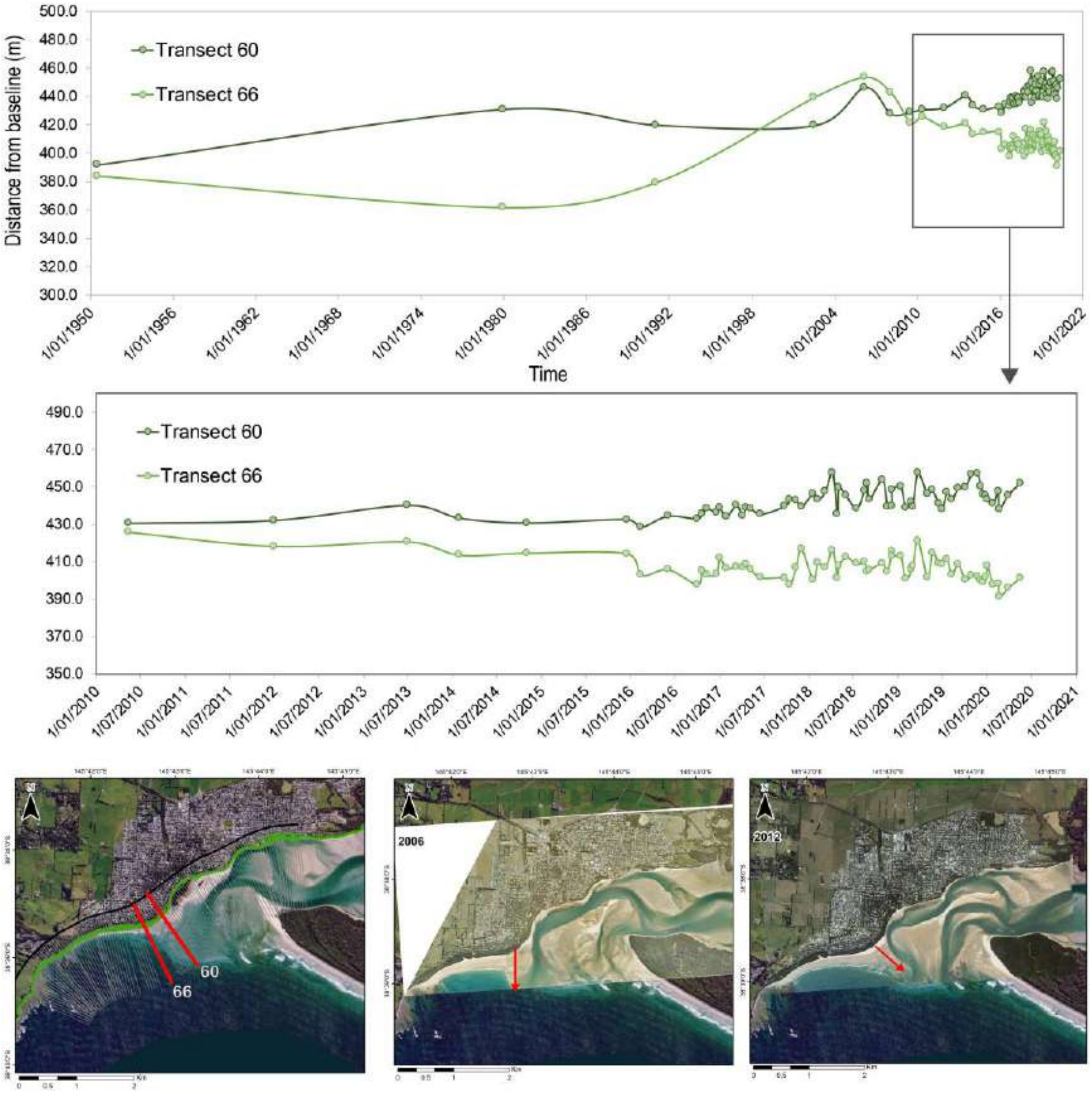


Figure 16: Vegetation line variability at Point Norman. Above, time-series for transects 60 and 66 from 1950 onwards. Below, variability of the same transects for the period from 2010 onwards.

3.3.3. Surf Beach

Surf Beach vegetation has changed remarkably, especially over the last decade. Between 1950 and 1970’s, the vegetation line accreted around 40 m (Figure 17). A slight retreat of 10 to 20 m occurred between 1970’s and 2010 (Figure 17). After that, a major erosive period started and persists until now (Figure 17). About 70 m of vegetated dunes have been eroded along the coastline of Surf Beach, receding the vegetation line to 30 m onshore from 1950’s position. The significant erosion trend observed over last decade (average $r^2 = 0.75$) (Figure 17) indicates that Surf Beach vegetation area might still endure erosion over the near future.

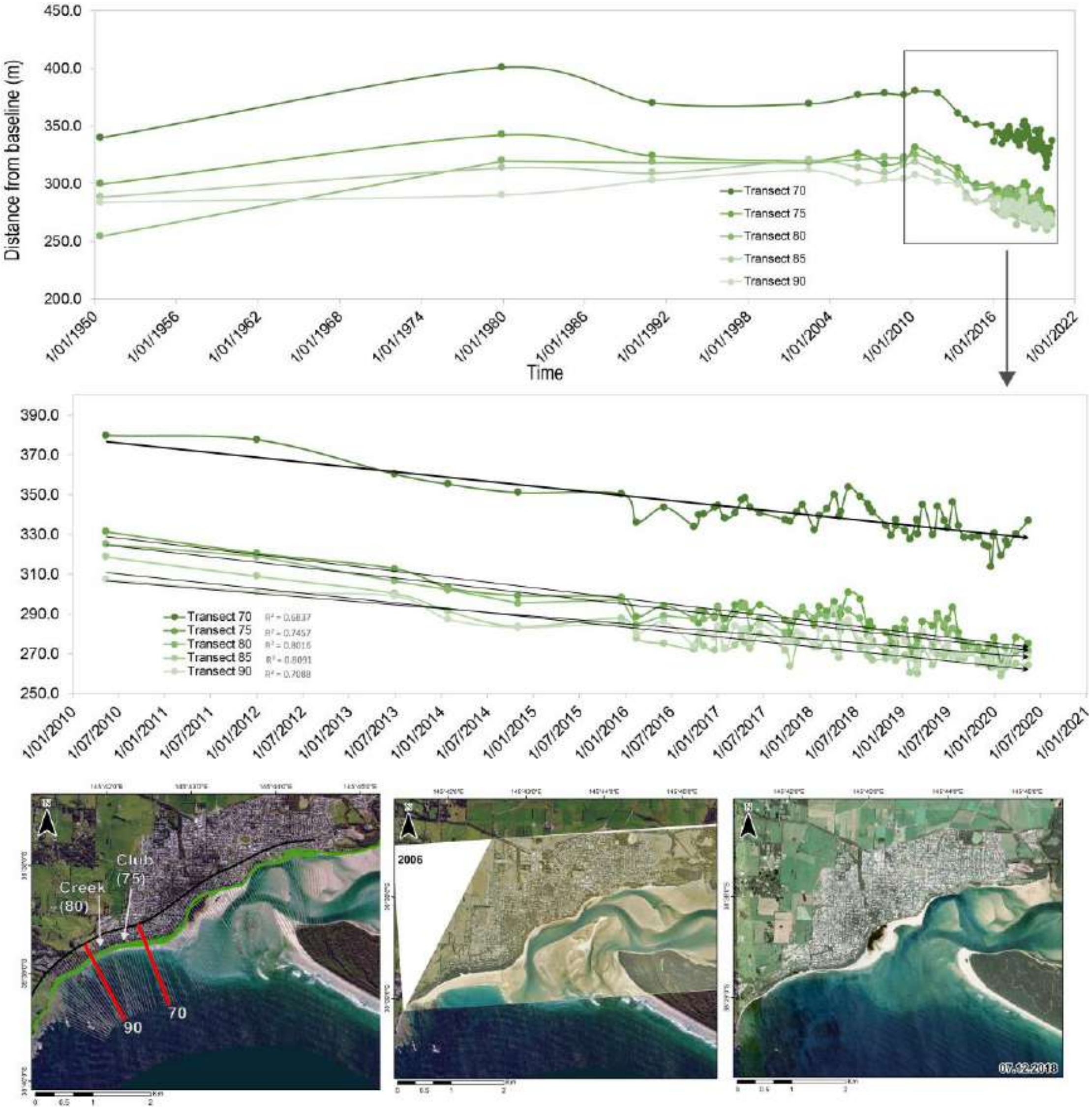


Figure 17: Vegetation line variability at Surf Beach. Above, time-series for transects 70, 75, 80, 85 and 90 from 1950 onwards. Below, variability of the same transects for the period from 2010 onwards. Black arrows indicate the linear trend for each transect time-series.

4. FINDINGS AND RECOMMENDATIONS FROM COASTAL PROCESS ASSESSMENT

1. The stability of the inlet is key for the equilibrium of Surf beach in both profile and planform. Whilst a detailed assessment of the hydrodynamic forcing which results in changes in channel and shoal formations is beyond the scope of this study, the breaching of a second channel at Point Smythe which become evident in 2009 has resulted in a significant change in sediment volume at Point Norman through the apparent reduction in the hydraulic groyne effect.
2. The stability of the inlet is also largely affected by changes on Point Smythe beach and attached flood-delta deposits. Sand accumulation on the western side of Andersons inlet – near Inverloch urban development – might have been supported by sand migration from Surf Beach, however it was primarily formed by the sand deposit that detached from Point Smythe following the second channel breaching in 2009.
3. The process of erosion of Point Smythe beach and flood-delta deposits has occurred in over a long-term – from ~1950 to 2000's. These longer-term changes combined with short-term triggers (to be discussed in the next section) led to a breach of the inlet eastward of the long-term position in 2009. From this point, the whole inlet system started to readjust.
4. The analysis has shown that the erosion of Surf Beach shoreline has been progressing since 2006-2008 and foredune vegetation since 2010-2012. The shoreline erosion rate has increased since 2010.
5. The analysis has indicated that key periods when significant changes occurred include between 2005-2009 and 2012-2013. Further detailed analysis or modelling to verify wave, tide and rainfall conditions should be undertaken.
6. Longshore sediment transport is critical to understand the variations on the system, including sand bypassing the inlet. Detailed sediment transport modelling is required to quantify the rates of longshore transport and the storm-cut volumes.
7. Although there is a clear connection with the breaching of the second channel in the late 2000s, Point Smythe has been eroding since the 1950s and this erosion created the conditions for the second channel breaching. Identifying the underlying processes that led to erosion of Point Smythe is very important to future coastal planning, since it may be a long-term phenomenon.
8. Note: Recent evidence from drone surveys by the South Gippsland Conservation Society (Heath pers comm, 2021) and on-site inspection shows that surf beach is currently still eroding and the western inlet channel is becoming more dominant and realigning to its pre-2009 configuration.

Moreover, it is also recommended that in order to manage the erosion of Surf Beach and the inlet dynamics more effectively in the longer-term, a decision-support system in order to predict the inlet migration and flood-tidal delta evolution should be developed. This should be based on detailed analysis of all historical data; hydrodynamic and sediment transport numerical modelling of conceptual scenarios considering distinct bathymetric conditions, and identification of hydrodynamic drivers and climate drivers.

5. MANAGEMENT OPTIONS

5.1. Coastal process drivers

It is clear from the analysis of the morphological changes occurring in the inlet that the system has been relatively stable for decades prior to the mid-2000s. This is confirmed by the report by Byrne (2000) which was referenced in the management options for Abbott Street erosion report by Oldfield (2011).

In terms of on-going management options, the key findings of previous studies and particularly those presented in this report are as follows:

- Surf beach needs to be considered as part of the ebb-tidal delta of Andersons Inlet. Consequently, changes in the channel configurations and subsequent ebb-channel discharge orientation will have an impact on the state of the beach.
- Following a period of "dynamic" stability (potentially since historical records are available) there has clearly been a change in shoreline response since the mid-2000s. This is shown in Figures 3 and 5.
- Regardless of the cause – or trigger - for these changes, the response the system appears to be as follows:
    - Accelerated erosion of Surf beach;
    - The concern for erosion of Abbott Street (Oldfield, 2011) has reduced due to the migration of shoals to that site;
    - In the absence of any detailed coastal process studies it would appear there is longshore transport along Surf Beach towards the inlet at all times;
    - The recent change in the orientation of the ebb discharge channel back to its more usual location adjacent to Point Norman will reinforce the longshore entrainment toward the entrance resulting in a buildup at Point Norman.

The development of effective management options requires detailed hydrodynamic and sediment transport studies of current and predicted processes. However, it is important to identify a natural process (such as rapid sea-level rise, major storm events, shifts in average wave conditions, major fresh-water flooding) or artificial intervention (such as channel dredging or shoreline reclamation) which may have "triggered" apparently rapid changes in the inlet/beach condition such as the breaching of the second channel.

Preliminary investigation for this report suggests two possible triggers leading the second channel breaching and subsequent changes throughout the inlet/beach system.

- One likely trigger (but unconfirmed) for the changes in the inlet may be the rapid increase in relative sea level (RSLR) over the last 20 years or so (See Figure 18). [It should be noted that sea level rise varied globally and around the Australia coastline, and Figure 18 is presented as indicative of recent change]. Detailed analysis of RSLR (Watson, 2020) shows this and suggests that RSLR is accelerating due to land subsidence in the region. The implications of accelerated RSLR on inlet dynamics is not well-understood and would require detailed morphological modelling, however, a first pass assessment suggests that accelerated beach erosion both at Surf Beach and Point Smythe would occur as the rate of rise would have been higher than the readjustment of the beach profile. This in turn would impact on the inlet channel hydraulics and possibly trigger the breaching.

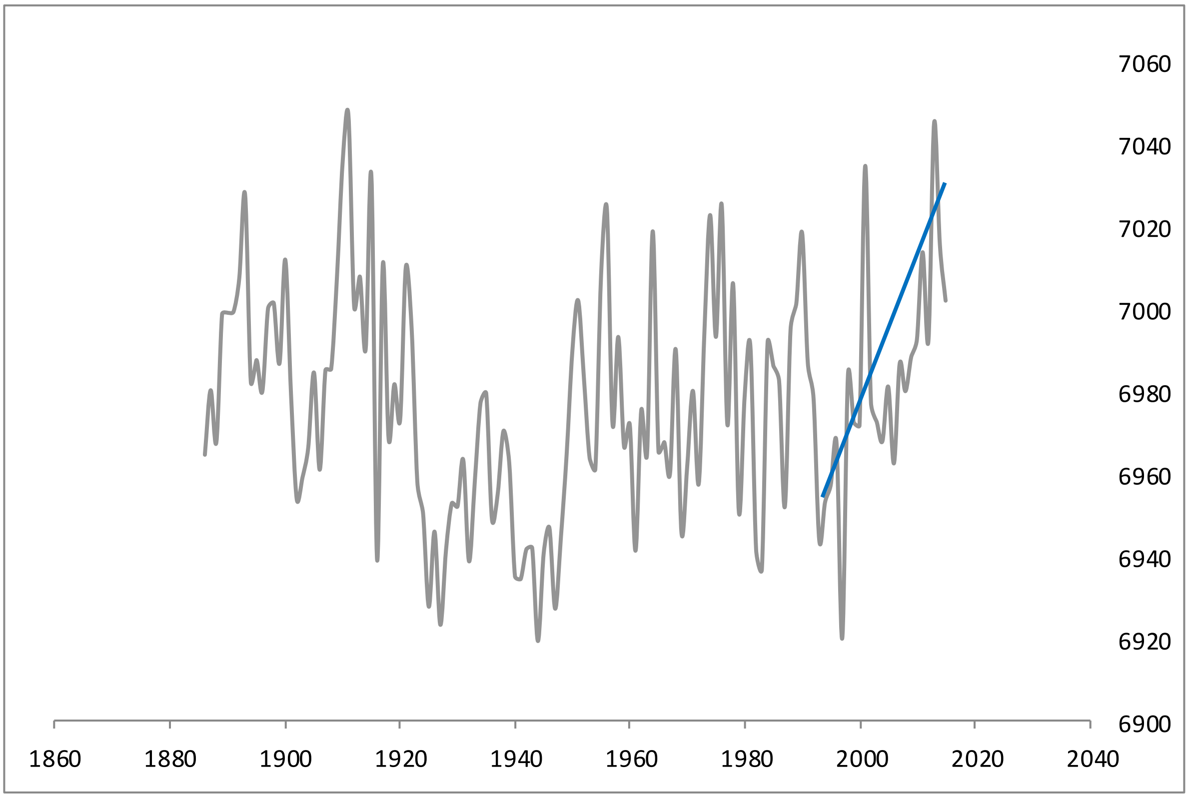


Figure 18: Normalised Mean Sea Level at Sydney (Helman and Tomlinson, 2018) showing the rapid increase since the early 2000s.

- A second trigger could have been the exceptional storm surge that occurred on the 19th June 2004. Whilst full details of the storm (Wave height and direction, storm surge duration) have not been quantified, photographic evidence has been provided by SGCS members as shown in Figure 19. Interpretation of these photographs suggests a storm surge of around 1.5m.

  Although this event occurred a number of years before the second channel breaching in 2009, our analysis indicates that changes were occurring on the shoals and shoreline from around 2005. Given the lack of details bathymetry and imagery around this time, it is reasonable to postulate that this extreme storm surge event may have caused changes in channel configurations and/or scour of shoals throughout the inlet. Consequently, a new dominant flow path could have developed resulting in the second channel breaching.

Figure 19: Photographs of the Screw Creek pedestrian bridge and from Sur Parade of the storm surge on 19 June 2004 (Courtesy of SGCS members).

5.2. Management Options

There are numerous guides, compendiums, reports and papers dealing with beach erosion management on open coastlines. The Compendium used by Queensland Coastal Councils is provided as an Annex to this report. In summary, commonly discussed management/adaptation options that could be considered include:

- Do nothing
- Beach nourishment including sand bypassing and backpassing
- Seawalls
- Dune rehabilitation, fencing
- Groynes, entrance training walls
- Offshore structures – emerged and submerged breakwaters, artificial reefs
- Managed retreat – including land swap, relocation

An option which would be very effective, but is often not included in compendia is:

- Inlet channel management – dredging of artificial channels, realignment of existing channels, entrance training walls

As will be discussed later, this option usually is rejected because of concerns over disruption to habitat.

In terms of erosion within a tidal inlet or estuary, bank stability due to channel meandering or boat wash can be managed with revetments, short groyne fields or flow deflectors.

5.2.1. Do nothing

Given that there has already been management action taken at Surf Beach, this option is more of a “leave it as is” option. Actions taken are the 2 trial sections of wet sand fencing (100metres each), installation of a sand filled geotextile container wall at the Surf Club, and formation of 140 m rock wall west of the Surf Club, to protect a section of Cape Paterson Road. The fencing appears to be functional and our process assessment and SGCS surveys suggests that the inlet is realigning following the significant shift of the mid-late 2000s with the inlet channel discharging closer to Point Norman and in a more southerly direction as was the case in earlier years of stability. Over time, the blocking “hydraulic groyne” effect of the ebb channel may result in less loss of sand on Surf Beach. However, this is just of the processes impacting on Surf Beach with major storms likely to continue to be the dominant erosion mechanism. Construction of seawalls whether geotextile or rock is a standard response to imminent threats to infrastructure and should continue to deliver that function.

5.2.2. Beach Nourishment

Direct nourishment can be sourced from offshore as on Gold Coast which adds “new” sand into the compartment from non-active sources, e.g. from deep water offshore. It can also be sourced from non-active deposits within estuaries such as Andersons Inlet (Figures 20 and 21). Caution is needed in the latter case to ensure that the sand is truly “inactive” and not part of the dynamic equilibrium flood tide deposits. This method was used at Noosa until the deposits ran out and the backpassing system implemented. It was also used when navigation channels need to be maintained in the Gold Coast Broadwater. In this case, even though the sand is “active” there are other requirements for its removal.

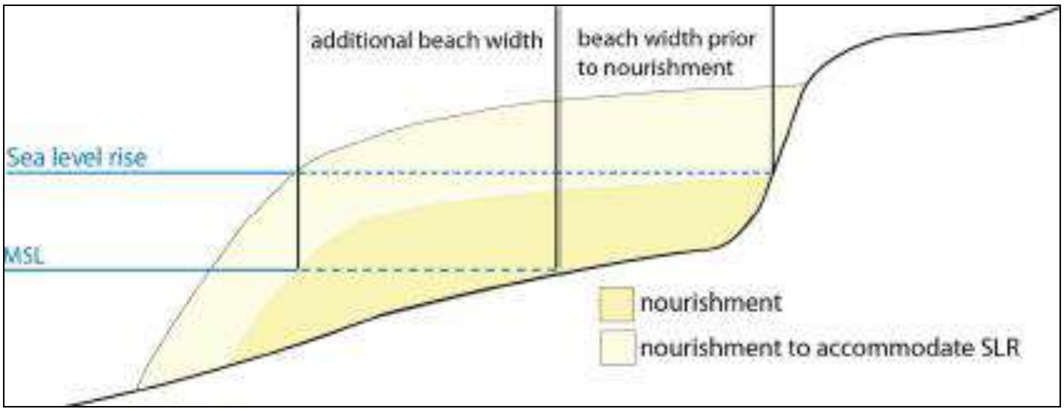


Figure 20: The principle of beach nourishment for adapting to sea level rise.

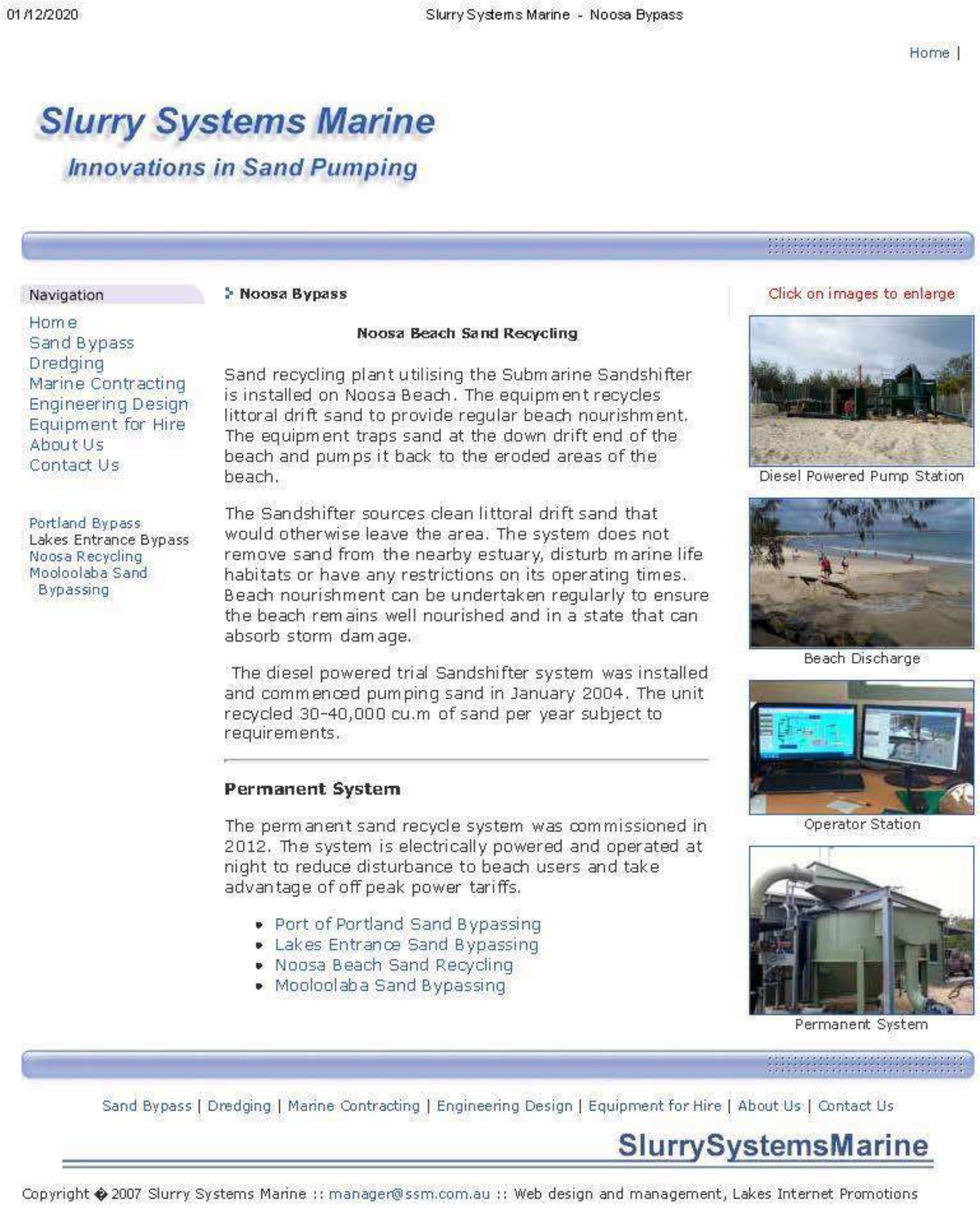
Figure 21: Nearshore nourishment on the Gold Coast.

Bypassing which ensures that blockages to natural sand supply to a coastal compartment such as Surf Beach are overcome. This has been employed at the Tweed River Entrance, the Gold Coast Seaway and Lakes Entrance for example. It can also be achieved by “short circuiting” the natural processes as occurs at a tidal inlet where natural infilling is countered by regular dredging of the entrance with placement on the downdrift side such as at Currumbin (Figure 22) and Tallebudgera Creeks and the Gold Coast.

Figure 22: Currumbin Creek dredging to improve water quality and flooding. Natural longshore sand transport is “bypassed” or short-circuited onto Palm Beach.

Backpassing entails capturing sand on the downdrift end of a coastal compartment and returning it to the updrift end. This is being done for Noosa Main beach where approximately 25,000 m^3 per year of sand is pumped from near the entrance to the Noosa River back to the eastern end of Main beach (Figure 23). A large-scale operation is planned for Surfers Paradise with approximately 120,000 m^3 per year will be pumped from the Seaway Sand pumping jetty back to various location along Main and Surfers Paradise Beaches. A similar small-scale back-passing has been investigated for the Tweed River entrance (Figure 24) where piping and dredging were considered.

For Inverloch, backpassing would involve capturing sand from Point Norman, the inlet deposits or Point Smythe and depositing the sand at the western end of Surf Beach from where natural longshore process would appear to redistribute the sand along Surf beach. This could be via fixed pipe networks or specific dredging activity (as for Figure 24).



01/12/2020 Slurry Systems Marine - Noosa Bypass

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Noosa Bypass

Noosa Beach Sand Recycling

Sand recycling plant utilising the Submarine Sandshifter is installed on Noosa Beach. The equipment recycles littoral drift sand to provide regular beach nourishment. The equipment traps sand at the down drift end of the beach and pumps it back to the eroded areas of the beach.

The Sandshifter sources clean littoral drift sand that would otherwise leave the area. The system does not remove sand from the nearby estuary, disturb marine life habitats or have any restrictions on its operating times. Beach nourishment can be undertaken regularly to ensure the beach remains well nourished and in a state that can absorb storm damage.

The diesel powered trial Sandshifter system was installed and commenced pumping sand in January 2004. The unit recycled 30-40,000 cu.m of sand per year subject to requirements.

Permanent System

The permanent sand recycle system was commissioned in 2012. The system is electrically powered and operated at night to reduce disturbance to beach users and take advantage of off peak power tariffs.

- Port of Portland Sand Bypassing
- Lakes Entrance Sand Bypassing
- Noosa Beach Sand Recycling
- Mooloolaba Sand Bypassing

Click on images to enlarge

Diesel Powered Pump Station

Beach Discharge

Operator Station

Permanent System

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Figure 23: Noosa Main Beach Backpassing System.

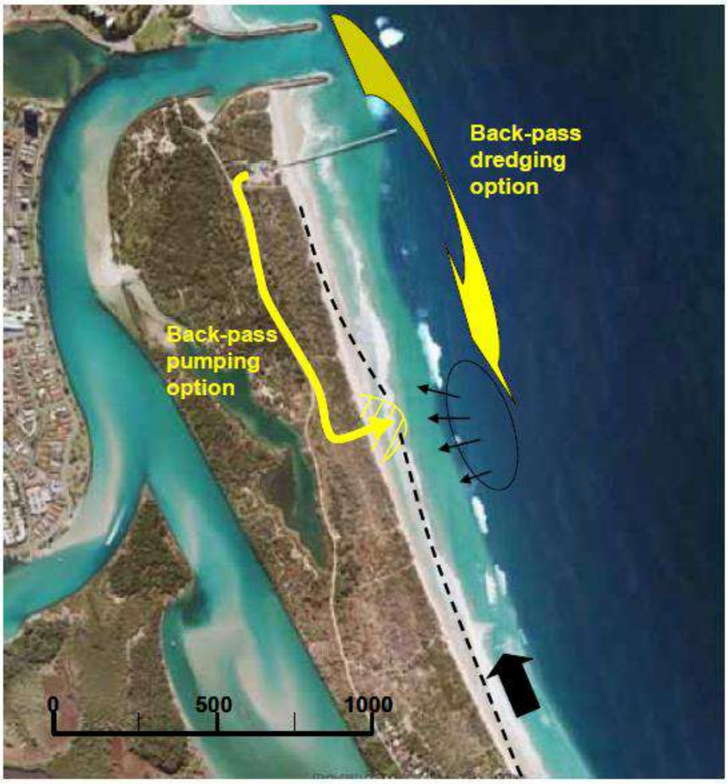

Figure 24: Backpassing proposal for the Tweed River entrance (Source: BMT (2010) for the Tweed River entrance Sand Bypassing Project)

5.2.3. Seawalls

Seawalls are constructed in response to infrastructure being threatened by erosion – a classic example being the rock wall protecting the road at Wreck Creek. Seawall construction can be using rocks, concrete block or geotextile bags. Seawalls can be an emergency response as is the case in Byron Bay at the moment where geofabric bags are deployed at Clark's beach while the system responds to large scale erosion/accretion processes. In an ongoing eroding situation caused by a longer - term deficit in sand supply, a seawall will inevitably result in the loss of beach amenity unless of course the beach is replenished by nourishment on a regular basis. In this case it is possible to bury the seawall as on the Gold Coast.

5.2.4. Dune Rehabilitation

Regardless of any other option being adopted it is critical to implement on-going dune rehabilitation. In itself, a healthy vegetated dune will still erode during a large storm event. It will, however, provide a larger buffer for the storm demand, and will enhance recovery during calmer periods.

5.2.5. Groynes and entrance training walls

Structures which are perpendicular to the shoreline such as groynes are effective at blocking longshore sand movement and are very common world-wide. Invariably however they result in erosion on the downdrift side which is either compensated for by constructing another groyne (and eventually a groyne field), or in some case the downdrift side is able to cope with exaggerated recession.

An example of a groyne near a tidal inlet is at Tuggerah Lakes in NSW (Figure 25). The groyne was built a couple of years ago to maintain the beach, however, there are strong suggestions that it is also acting as a training wall influencing the entrance channel configuration and may be leading to increased flooding inside the Lake.

A groyne at Point Norman may be an option and would need to be considered as part of an entrance management strategy to be discussed later. Without a detailed hydrodynamic and sediment transport study it is difficult to assess the impact of a Point Norman groyne in terms of inlet dynamics, localized coastal flooding, or long-term changes in sediment distribution along the coastline. However, provided it can be established that the dominant longshore transport direction is toward Point Norman, then a groyne can be expected to maintain a more usable beach width for some distance back towards the Surf Club. Conceptually, an effective way to do this may be to construct a low-level groyne (mid-high tide level), perhaps made of geotextile containers and along the alignment of Point Norman – attached to the existing dune face and ending at the low-water mark. It is anticipated that a low-level groyne would have less impact on natural sediment movement into the inlet and yet provide a widening of Surf Beach.

Figure 25: Groyne constructed at Tuggerah Lakes entrance to maintain the beach to the south

5.2.6. Offshore Structures

There are a range of hard engineering structures such as offshore breakwaters that are used worldwide to protect infrastructure. These tend to be emergent and overall are not aesthetically pleasing and significantly change the alignment of the coastline. An example of this type of structure from Western Australia is shown in Figure 26. This type of structure would not be suitable at Inverloch, mainly as they are emergent and not aesthetically pleasing from the shore. In a longshore transport environment such as Surf Beach they also act to trap sand and while this would have a positive impact on Surf Beach width, there may be impacts on the overall dynamics of the beach/inlet system by limiting the movement of sand towards the inlet.

Figure 26: Offshore emergent structures creating tombolos - Western Australia

A less invasive solution is a submerged artificial reef such as at Narrowneck on the Gold Coast (Figure 27). These can be designed to provide a localized coastal protection outcome as well as an improvement in overall surfing amenity. The overall beach widening effect is less that for emerged structure (eg. Figure 26), however Narrowneck has been shown to maintain a wider beach some few kilometres south of the reef and yet has not demonstrated typical downdrift erosion effects as would normally be expected from a rock groyne. Again, the concern with this option would be the unknown response of the overall sand movement patterns at the inlet. However, if geotextile fabric containers are used to construct the reef (as at Narrowneck), it is relatively easy to remove the structure if negative impact are observed.

At a much smaller scale, geotextile containers can be used as shore-parallel berms, emerged or submerged as shown in Figure 28 where the structure protects a 5-star hotel.

Figure 27: Large Geotextile container reef at Narrowneck (Gold Coast – QLD).

Figure 28: Shore parallel geotextile container structure - Sir Baniyas Island UAE (International Coastal Management P/L).

5.2.7. Managed Retreat

Should the erosion issues at Surf beach be found to be long-term (mainly in response to climate change), then the community may need to consider transforming the urban footprint to remove assets from the erosion zone and create sufficient buffer to enable the natural dune ecosystem function. There are number of options available to achieve this (Figure 29), such as:

- Buyout of foreshore properties and converting land to public sacrificial space. This was tried at Collaroy-Narrabeen, but in the end only a few properties were bought out interspersed with remaining properties. Unless all properties in the area of concern are acquired then this approach is ineffectual.

- Change of land-use or swapping high value and low value assets (eg. Schools moved to high ground – caravan parks or community parkland moved to where the school was), or relocating assets out of harms way.

- Development setbacks: Through a transition process, future development or re-development can be controlled through town planning or state government controls (Figure 30).

Managed retreat via any of these mechanisms will of course require the community accepting the concept of "retreat" from the coastal hazard. This is a complex social, political and economic issue and while it has been discussed and suggested for many location, is yet to be implemented anywhere for a community the size of Inverloch. The Managed Retreat option at Inverloch would involve relocation of a significant amount of housing and also the loss of the environmental, social and economic values of the vegetated dunes that were highlighted in the Inverloch Coastal Resilience Project report.

A classic example of an attempt to implement this adaptation is Byron Bay where in 1988 the NSW government (during a period when the council was under administration) introduced a set back requirement for new and existing development based on a trigger when the erosion scarp reached a certain distance to property. This has only resulted in endless legal challenges from beach front property owners, and has not provided an effective process for future adaptation.

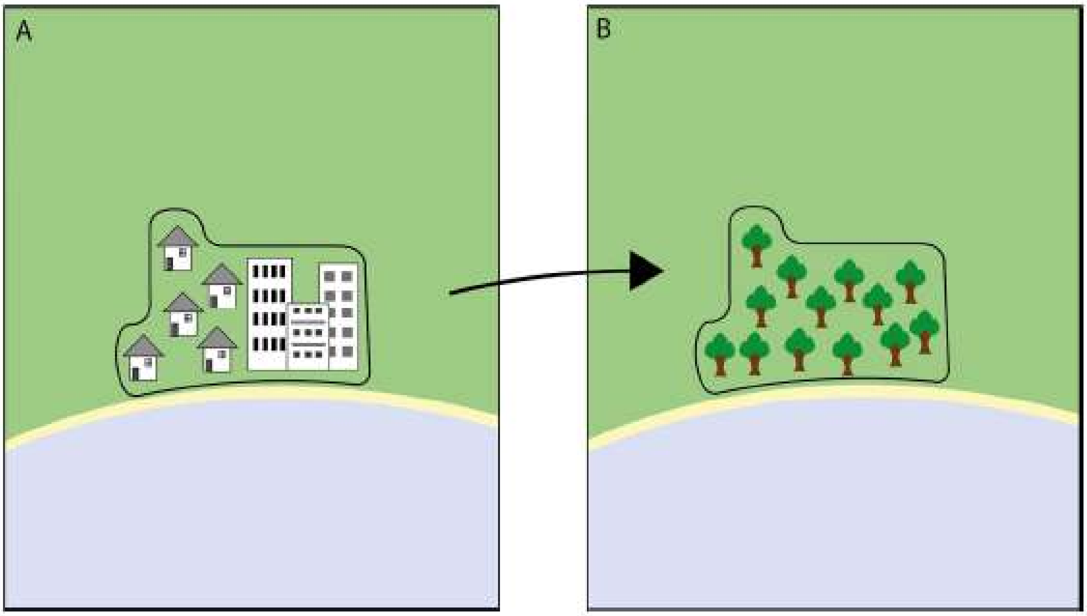

Figure 29: Land-use change through land purchase or swap.

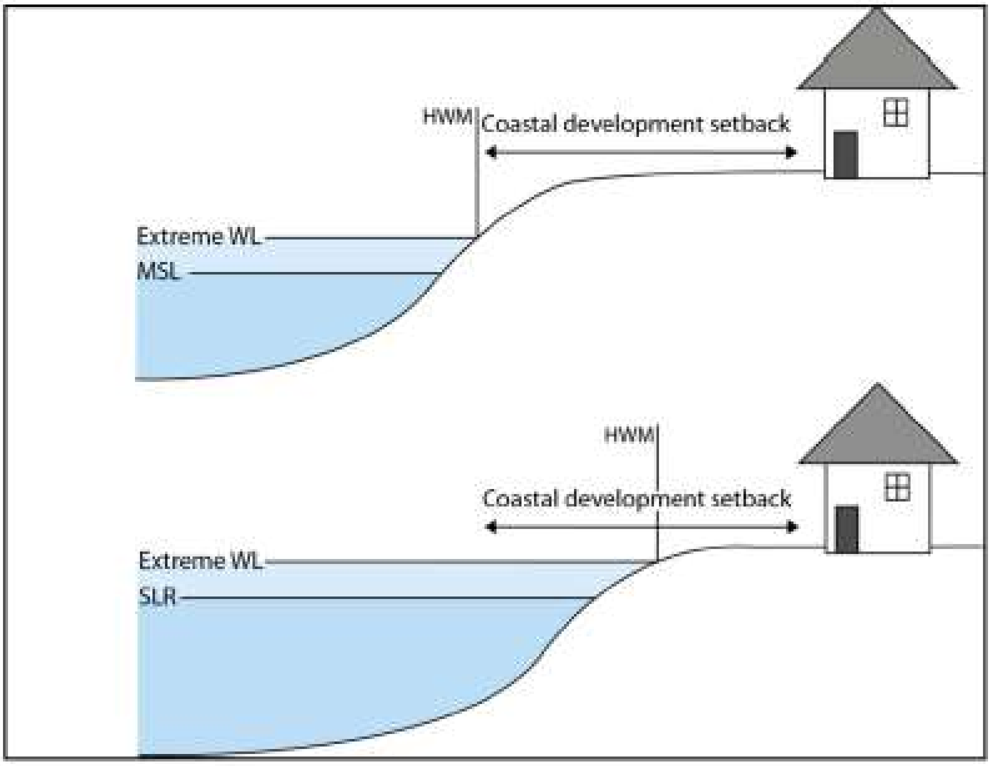

Figure 30: Development setback as part of a managed retreat option.

5.2.8. Entrance Channel Management

Should a detailed hydrodynamic and sediment transport assessment of channel characteristics demonstrate that Surf Beach erosion is directly related to the orientation and location of the ebb-tidal channel, then there is the opportunity for a management strategy which will mitigate the erosion by artificially manipulating the channel based on an understanding of the overall inlet dynamics. This has been proposed and/or implemented at a number of locations such as the Noosa and Maroochy river entrances on the Sunshine Coast, and at the Tuggerah Lakes entrance. For example, at Tuggerah, following a major flooding event within the lake system early this year, a channel was somewhat belatedly dredged through the sand spit to the north of the entrance (evident in Figure 25).

In the case of Noosa and Maroochy, the state government will not accept artificial channel management as a solution to erosion issues at the entrance due to the potential impact of the channel dredging on marine habitat inside the entrance. Whether similar constraints apply in Victoria has not been explored.

In the case of Intermittently Open and Closed Coastal Lakes and Lagoons (ICOLLS) – common in New South Wales – it is generally accepted that artificial breakthrough of the berm is the appropriate management strategy to avoid flooding and water quality issues.

Overall, the impact of artificially forcing a channel relocation at a permanently open natural inlet such as Andersons Inlet will depend on whether the inlet system is actually in the process of returning to a state of longer-term equilibrium. If that is the case (as appears at Inverloch at the moment) then the channel dredging would be expected to speed up the process reducing erosion on Surf Beach. However, if the system is not approaching a long-term equilibrium then there may only be a short-term relief from localised erosion. It is futile to fight nature in many cases.

If demonstrated by detailed studies to be effective in the management of the beach/inlet system, entrance channel management could be implanted a number of ways at Inverloch.

- A channel could be dredged across the entrance shoals to facilitate a more direct pathways for tidal flow. This could be effective in the event of a second channel breaching again near Point Smythe, by accelerating a return to the long-term dominant channel near Point Norman. This would require an ocean-going dredger to be deployed, with the dredge spoil being deposited at Point Smythe to infill the second channel.
- Once re-established as the dominant channel, the apparently stable long-term western alignment and the ebb-channel discharge alignment could be maintained by regularly dredging the channel across the ebb-delta, particularly if monitoring suggest a re-alignment might be being triggered. An ocean-going dredger would most likely be required, however other could include a fixed pipe network to which a smaller dredge could be connected during calm weather. Deposition location for the spoil would require more detailed assessment.
- As discussed earlier, another option may be to construct a groyne at Point Norman along the alignment of the spit and the dominant channel direction. This would effectively become an entrance training walls which from other examples given above would tend to control the channel alignment and ebb discharge. To be effective it is anticipated that the wall would need to be above the high-tide level, and to be more robust in construction as it is likely that the channel will scour out a dominant position along the edge of the wall.

Entrance management options will require very detailed engineering studies to asses both their feasibility and effectiveness. A more detailed analysis of inlet behaviour over time would provide more certainty to the timing and location of a channel management option.

6. SUMMARY

- The key finding of our first-pass coastal process assessment is that the erosion of Surf Beach cannot be considered in isolation from the ebb and flood tidal delta characteristics of Andersons Inlet.
- The overall system was very stable until the mid-2000s and the cause of the significant changes since then are not clear.
- There are a number of options that could be considered to manage the erosion – all have pros and cons, and all require detailed coastal engineering assessment. In brief:
    - *Do Nothing* – effective provided the erosion processes are localised and short-term;
    - *Beach Nourishment* – constrained by sand supplies which are considered to be inactive;
    - *Backpassing* – effective for short-term readjustment of sand budget between Point Norman and Surf beach;
    - *Seawalls* – appropriate response to risk to infrastructure, longer-term benefits would come if combined with nourishment;
    - *Groynes and entrance works* – effective at widening Surf Beach, but overall would create significant disruption to inlet dynamics;

  - *Offshore structures* – submerged geotextile reef may minimise wave-induced erosion and create additional surfing amenity, but overall may create significant disruption to beach/inlet sediment dynamics;
  - *Planned retreat* – effective, but at what social and political cost;
  - *Inlet channel management* – based on this preliminary analysis, this appears to have the potential to be effective, but it would need to be implemented in an adaptive management framework.

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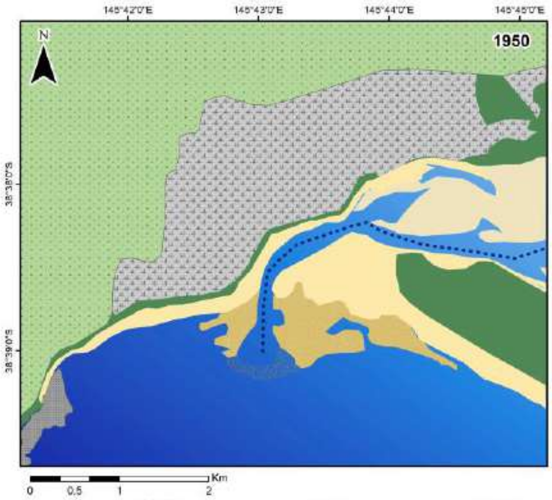
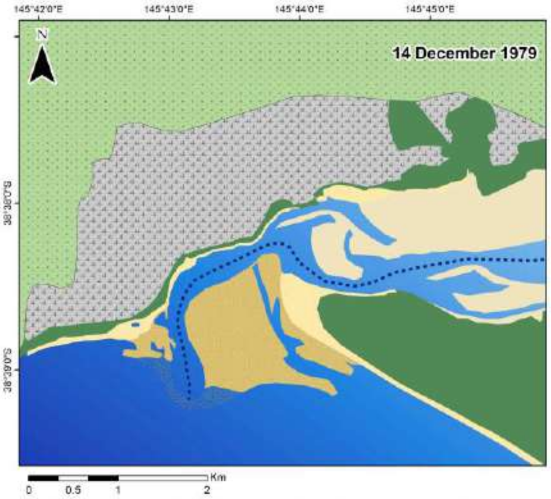
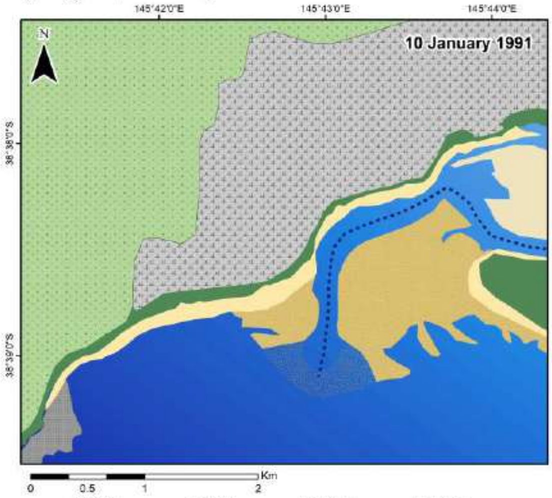
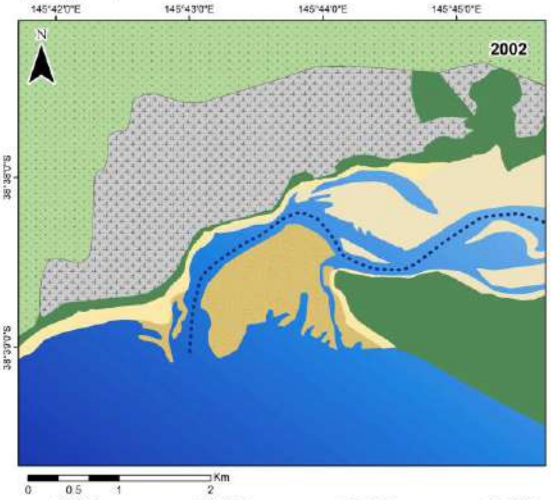
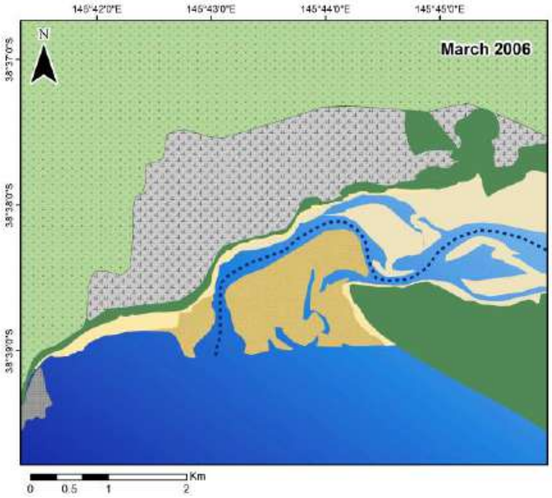
APPENDIX A – ANDERSONS INLET EVOLUTION

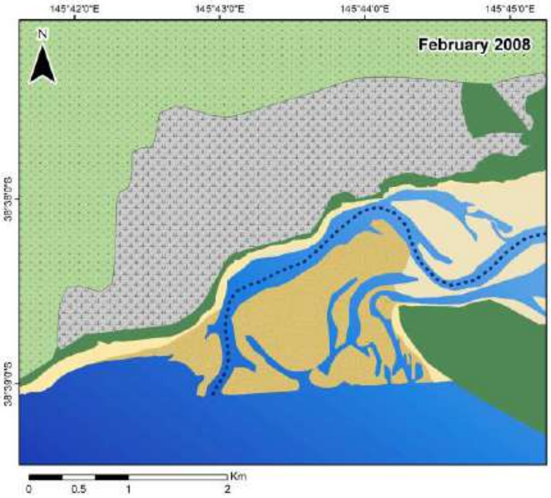


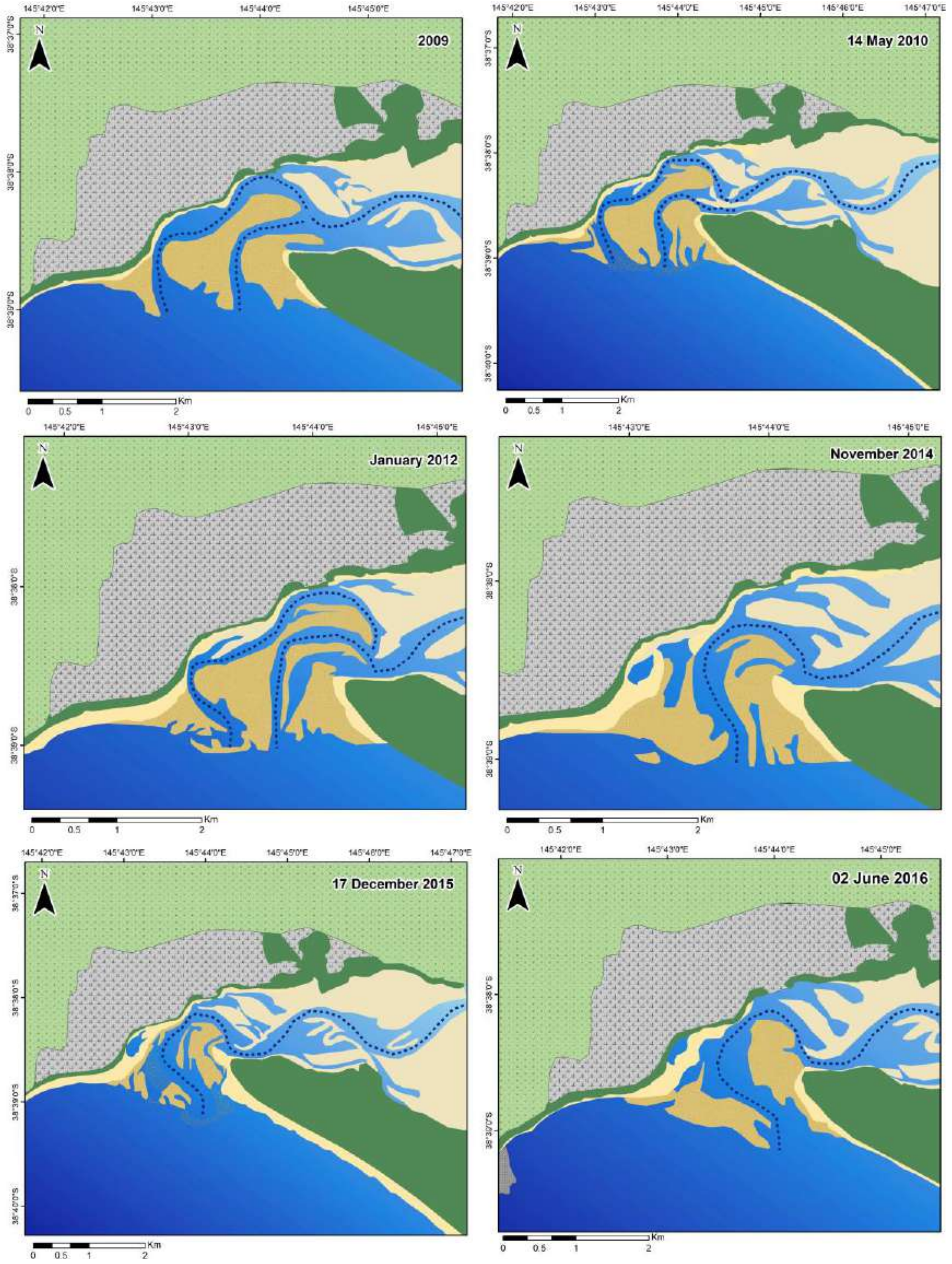








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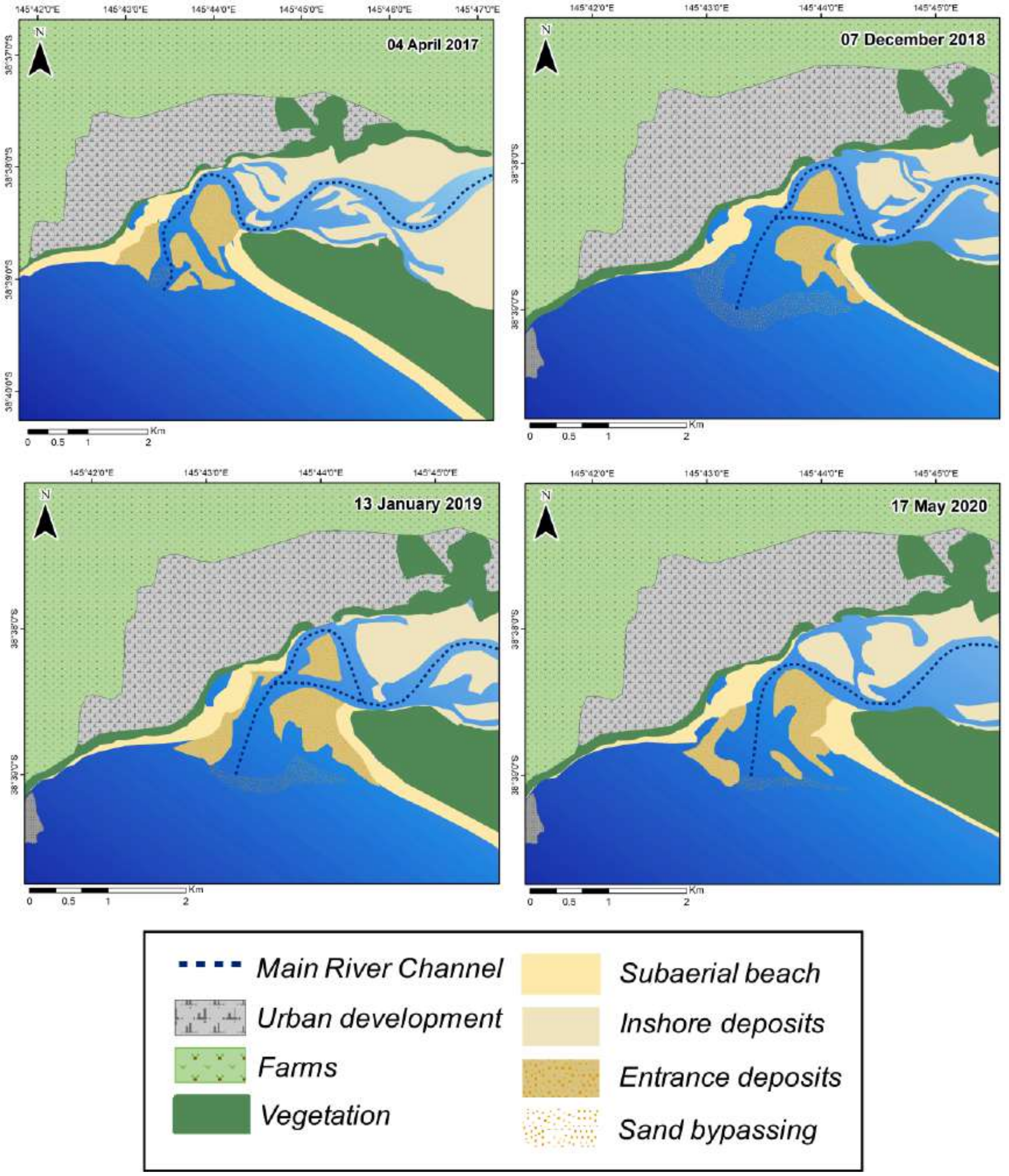
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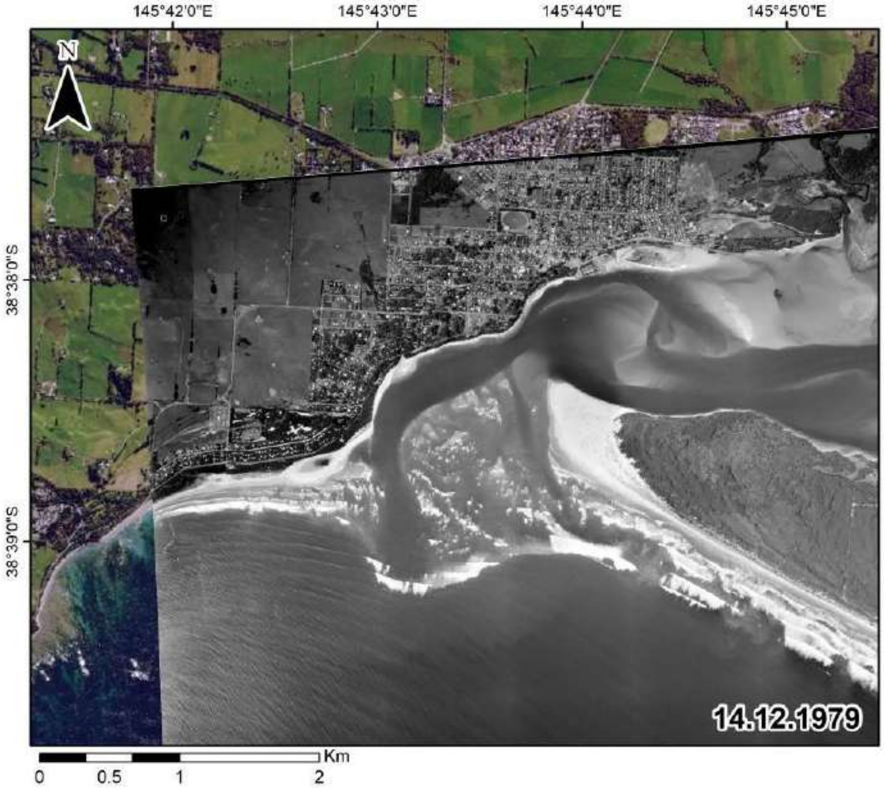
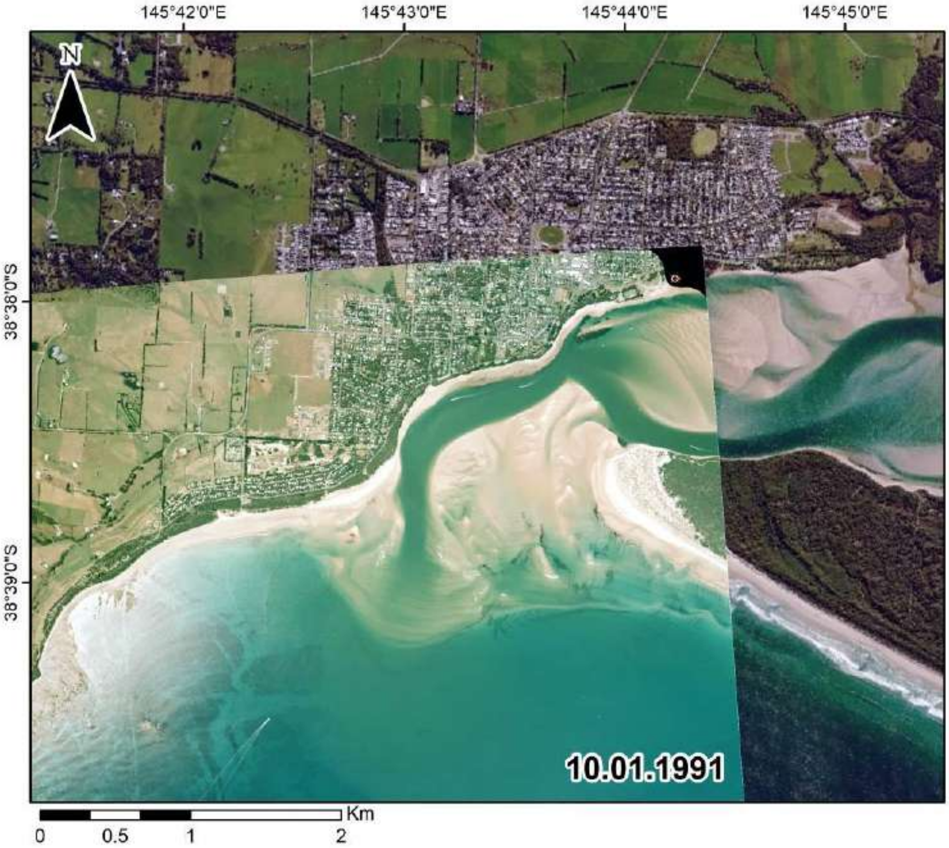
Inshore deposits
Entrance deposits
Sand bypassing

APPENDIX B – IMAGES FROM 1950 TO 2020

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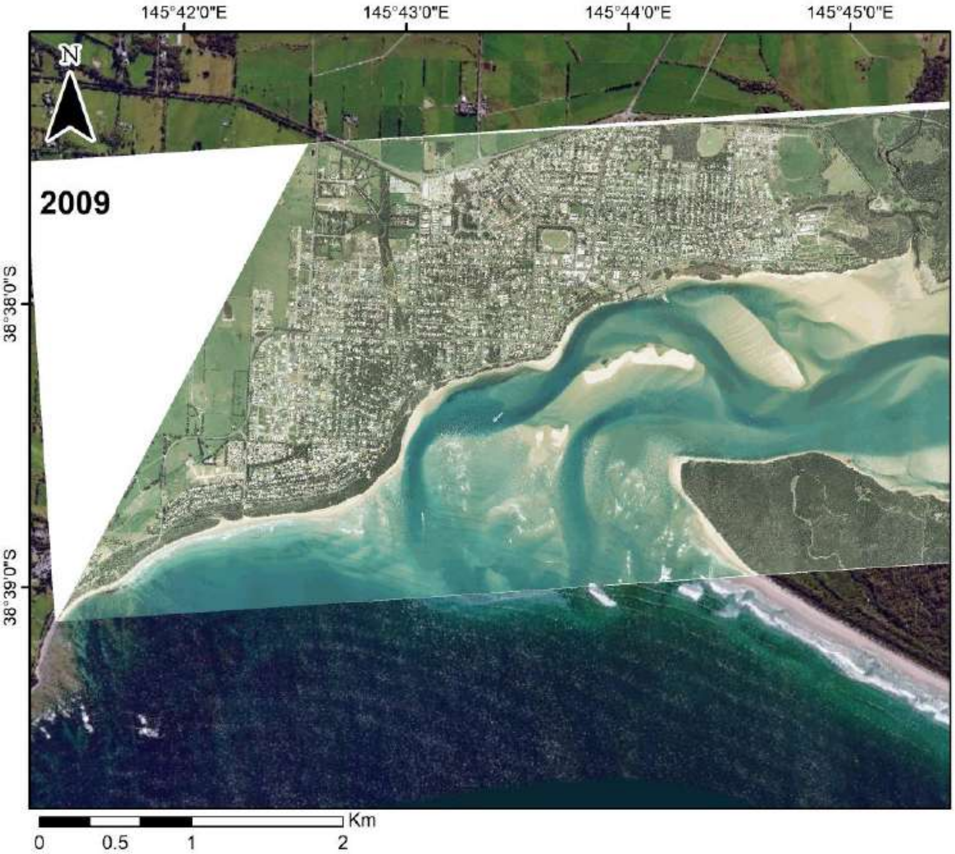
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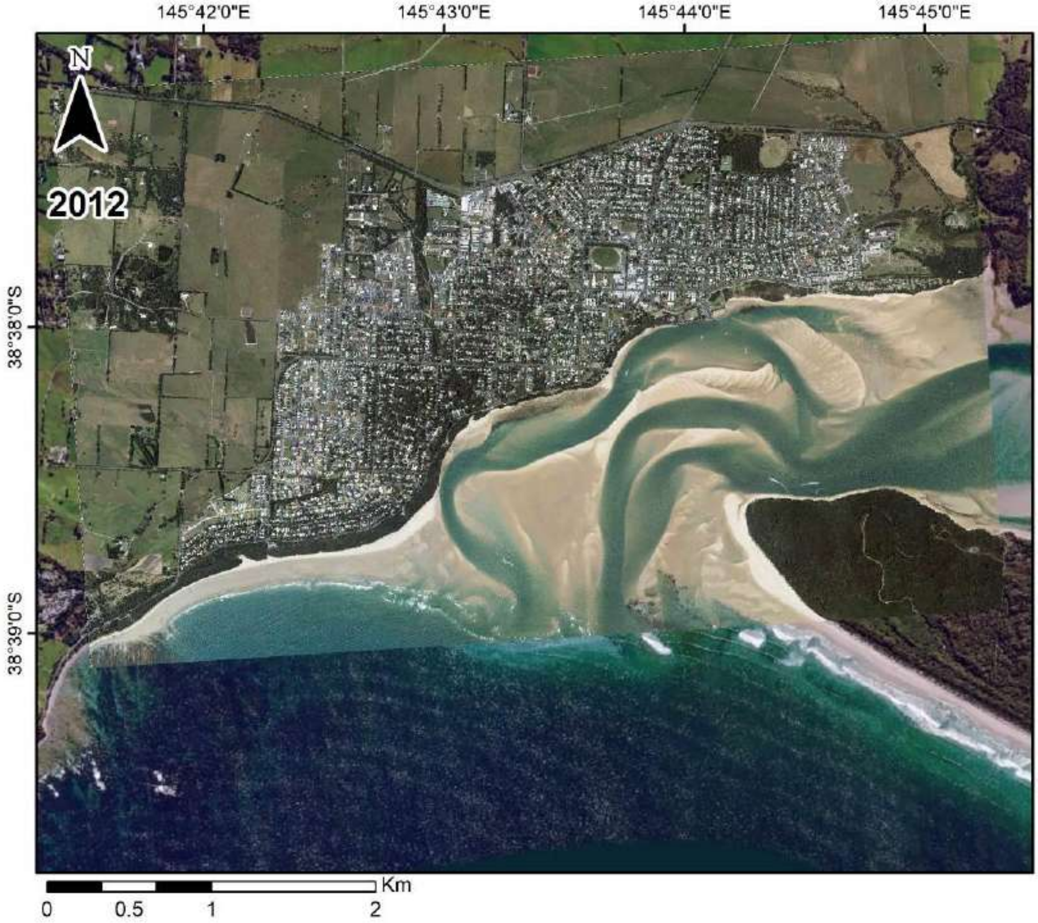
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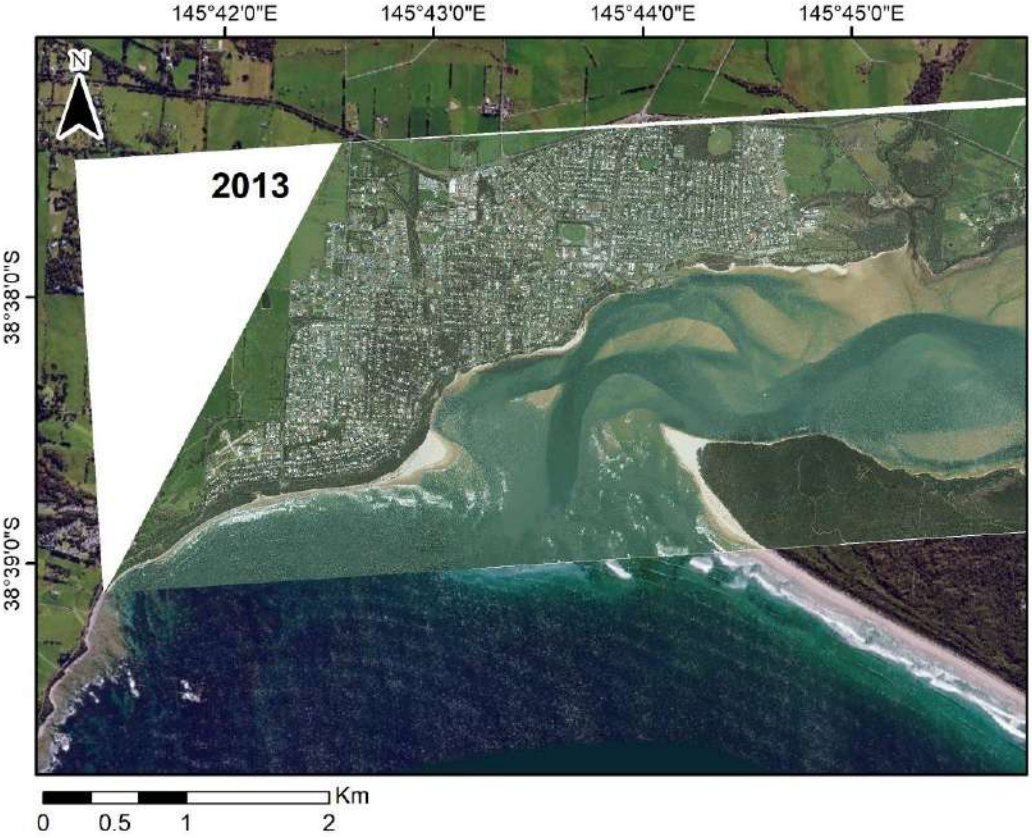
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1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
28.01.2014
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
Nov 2014
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
17.12.2015
0
0.5
1
2
Km


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
13.02.2016
0
0.5
1
2
Km


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
30.09.2016
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
20.10.2016
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
09.11.2016
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
19.12.2016
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
28.01.2017
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
09.03.2017
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
04.04.2017
0
0.5
1
2
Km


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
18.04.2017
0
0.5
1
2
Km


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
08.05.2017
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
17.06.2017
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
25.09.2017
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
15.10.2017
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
09.11.2017
0
0.5
1
2
Km


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
18.01.2018
0
0.5
1
2
Km

09.03.2018

08.04.2018


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
28.04.2018
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
03.05.2018
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
02.06.2018
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
17.07.2018
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
16.08.2018
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
26.08.2018
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
05.09.2018
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
30.10.2018
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
N
38°38'0"S
38°39'0"S
19.11.2018
0
0.5
1
2
Km


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
N
38°38'0"S
38°39'0"S
07.12.2018
0
0.5
1
2
Km


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
09.12.2018
0
0.5
1
2
Km


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
13.01.2019
0
0.5
1
2
Km


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
02.02.2019
0
0.5
1
2
Km


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
27.02.2019
0
0.5
1
2
Km


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
04.03.2019
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
24.03.2019
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
03.05.2019
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
23.05.2019
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
17.06.2019
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
02.07.2019
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
N
38°38'0"S
38°39'0"S
22.07.2019
0
0.5
1
2
Km


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
N
38°38'0"S
38°39'0"S
11.08.2019
0
0.5
1
2
Km


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
05.09.2019
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
05.10.2019
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
30.10.2019
0
0.5
1
2
Km


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
24.11.2019
0
0.5
1
2
Km


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
09.12.2019
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
19.12.2019
Km
0
0.5
1
2

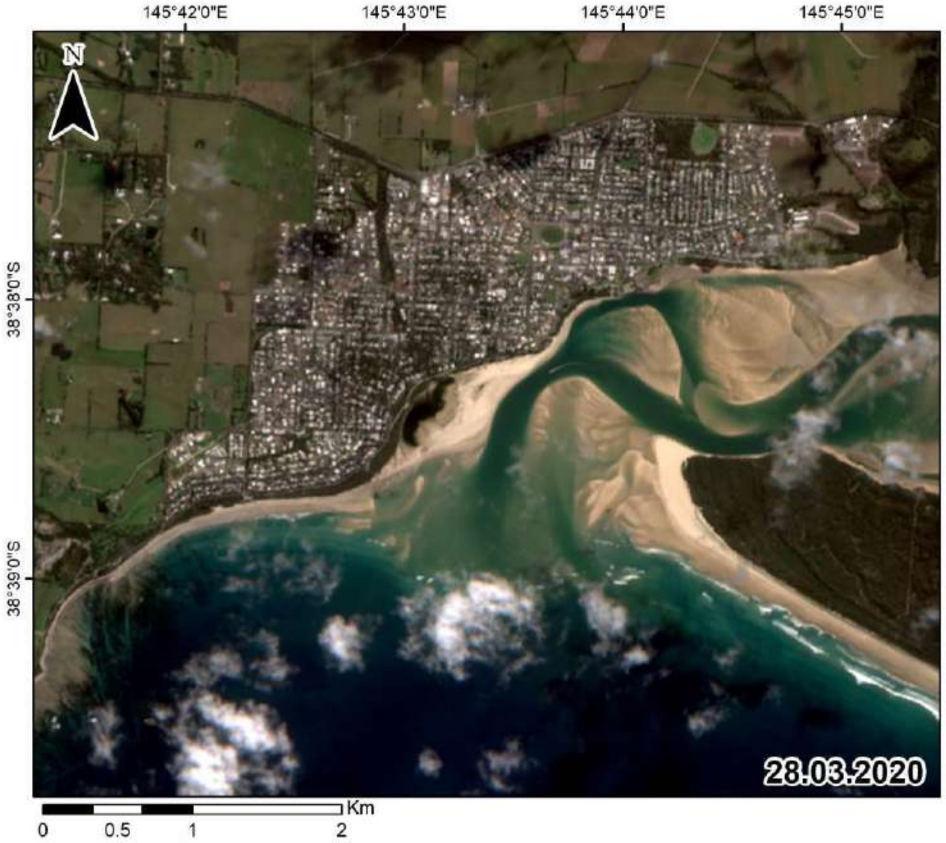

145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
N
38°38'0"S
38°39'0"S
29.12.2019
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
N
38°38'0"S
38°39'0"S
03.01.2020
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
28.01.2020
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
17.02.2020
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
22.02.2020
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
28.03.2020
Km
0
0.5
1
2


145°42'0"E
145°43'0"E
145°44'0"E
145°45'0"E
38°38'0"S
38°39'0"S
N
17.05.2020
0
0.5
1
2
Km