Land-sea sediment dynamics of the Mackay coastal zone: the role of landscape setting in the integration of waterway, estuary and coastline management

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Key Points

- Like many parts of the Australian coastline, the Mackay coastal zone has a diversity of geomorphic features and processes, combined with urban development
- Understanding landscape context facilitates an integrated approach to coastal management, as demonstrated through a review of Mackay case study sites
- Planning for climate change adaptation is crucial for Australian coastlines in the coming years, and improved outcomes will be achieved through considering the role of fluvial, aeolian and shoreline processes in forming and shaping the coastal zone.

Abstract

The Mackay coastal zone is a picturesque and dynamic section of the Queensland coast with a diverse range of features including; waterways, estuary zones, coastal wetlands, extensive tidal flats, sandy beaches, parabolic dune systems, rocky headlands, and the Great Barrier Reef. Extensive development has occurred within the coastal zone since European settlement (1860s), including the Mackay township, residential zones, and the Mackay Harbour (1935). The Pioneer River is a major source of sand to the coastline, and has a history of commercial sediment extraction which is still ongoing at several locations.

In this study we examine landscape setting and geomorphic processes at a set of case study sites. We highlight how an integrated approach to reviewing coastal zone processes, including the estuary, coastline and dune systems, can better inform our understanding of the long-term trajectory of change. This understanding facilitates innovation in the strategic management of coastal zones, including climate change adaptation planning, erosion mitigation approaches, guiding future urban development and retreat, monitoring programs, and community engagement.

Keywords

Coastal processes, rivers, sediment transport, sea level rise, erosion, climate change adaptation

Introduction

Study region

From Dudgeon Point to Dolphin Heads (Figure 1, Figure 2) the Mackay coastal zone is characterised by a diverse range of features including; the Pioneer River, coastal wetlands, extensive tidal flats (up to 4 km wide) with a large tidal range (up to 8 m), a network of sandy beaches including a limited zone of high parabolic dune systems, rocky headlands, and the adjacent Great Barrier Reef. The Pioneer River carries a large sandy bedload and, combined with the remnant dune systems, is the major source of sediment for over 30 km of the adjacent coastal beaches (EPA 2004, Gourlay and

Hacker 1986). Detailed descriptions of the geology, soils, climate, vegetation, fauna, land use, and historical geomorphic changes for the Mackay region are provided in the Mackay Coast Study (EPA 2004).

Anthropogenic impacts

Extensive development has occurred within the coastal zone since European settlement (1860s), including the Mackay township around the Pioneer River mouth, residential zones along the coastline, and the harbour construction (1935) on Harbour Beach. Human impacts along the coastline are well documented by the EPA (2004) study, with key elements of the history including:

- Reclamation of extensive areas of low-lying land along the coastline for development
- Alignment training of the Pioneer River mouth, and ongoing sand and gravel extraction from the Pioneer River
- Residential and commercial development on past dune systems
- Erosion control works at several locations, primarily formal and informal rock wall structures.

Human activity has had a major impact on landscape form, sediment supply and distribution, which has contributed to shoreline recession and accretion at several locations, including some with long term recession (EPA 2004) (Figure 1, Figure 2). Future development has also been planned along Harbour Beach South. Notable changes in sediment dynamics along the coastline include:

- Reduction in sediment supply and distribution from the Pioneer River due to past catchment modifications including river regulation (establishment of weirs) and ongoing commercial sand extraction. Sediment supply from the Pioneer River to the coast is estimated to be less than a 25% of pre-regulation loads (Gourlay and Hacker 1986, Alluvium 2015a).
- Alternation / interruption to sediment transport pathways due to alignment training of the Pioneer River mouth and construction of the harbour and harbour breakwaters (EPA 2004).
- Loss of large sections of dune systems and associated sediment stores due to residential and commercial development.

Approach to assessment and management

To date, waterways, estuaries and coastlines are typically assessed and managed as relatively separate landscape components. Several factors may contribute to this, including the high level of complexity associated with geomorphic and ecological dynamics for each, and the fine spatial scales relevant for most management works (including modelling and engineering design). However, for longer term strategic management, there is need to ensure the broader landscape context is well understood, including sediment sources and transport pathways across all landscape components.

The purpose of the recent Mackay coastline study (Alluvium 2015b) was to update the understanding of coastal geomorphic processes in the region, and implications for future management. For this paper, three example sites – Lamberts Beach, Harbour Beach north, and Far Beach - are discussed, to demonstrate how an integrated understanding of sediment sources and transport processes – fluvial, aeolian, and littoral – can inform a strategic approach to managing coastal zones.

	Predicted short term erosion potential (m/a) (EPA 2004)	Predicted coastline recession in 50 years (m) (EPA 2004)
Blacks Beach North	16	40
Blacks Beach South	-	20
Lamberts Beach	26	35
Harbour Beach North	9	80
Harbour Beach South	15	10

Figure 1. Mackay coastline aerial (DEHP 2015) - Harbour Beach South to Dolphin Heads – Indicative sediment supply and distribution and erosion potential - after EPA (2004) and 2016 site observations.

	Predicted short term erosion potential (m/a) (EPA 2004)	Predicted coastline recession in 50 years (m) (EPA 2004)
Town Beach	5	10
Far Beach	5	50
Bakers Creek – Shellgrit Creek	5	20

Figure 2. Mackay coastline aerial (DEHP 2015) - Dudgeon Point to Harbour Beach South – Indicative sediment supply and distribution and erosion potential - after EPA (2004) and 2016 site observations

Site observations

Slade Point and Lamberts Beach

Slade Point headland is at the northern extent of the study reach (Figure 1). The eastern side of the headland consists of rocky outcrops and pocket beaches, including Slade Point Beach and Lamberts Beach (Figure 1). As can be observed from the LiDAR data (Figure 3), a substantial field of parabolic dunes extends from Slade Point to Harbour Beach South, which has not been well documented previously. Along tropical sections of the Australian coastline parabolic dune systems are relatively rare, and are therefore an unusual and significant geomorphic feature of the Mackay region. These dune systems are an important backshore sand source to the adjacent beaches, and historically would have provided a major aeolian sand supply from south of Slade Point across the headland to Slade Bay.

Levelling of dunes, or development on dunes across the Slade Point headland, at Lamberts Beach, and the harbour, has resulted in a loss of sand supply to the associated beach systems. The development of the harbour has also interrupted northward longshore sediment transport from the Pioneer River towards Slade Point, further reducing available supply. Subsequently, Slade Point Beach and Lamberts Beach have been reportedly experiencing coastline recession, and will continue to do so into the future (EPA 2004). Comparison of 2009 and 2015 aerial imagery as part of this current study indicated recent shoreline recession in the order of 10 – 15 m has occurred at both Slade Point Beach and Lamberts Beach. Field observations confirmed the presence of an eroding scarp at these beaches that has impacted on coastal infrastructure.

With a loss of both aeolian and longshore sediment supply, continued shoreline retrogradation at Lamberts Beach and Slade Point Beach is likely. EPA (2004) predicted 35 m of potential recession at Lamberts Beach over 50 years, primarily based on reduced longshore sediment transport predictions – retrogradation may be greater if the loss of dune sand storages is also considered. Observations from this current study have shown retrogradation in the order of 10 – 15 m has occurred within the last six years.

Lamberts beach and Slade Point beach are relatively enclosed systems, and therefore it is likely that only a limited quantity of sand supplied to these pocket beaches would be transported around the headland into Slade Bay and beyond. Cross-shore sediment transport is likely to dominate at these beaches, and therefore sand renourishment would be a reasonably effective management strategy to assist with maintaining the beach. Establishment of hard engineering structures such as rock walls along the shoreline at this location could ultimately result in the complete loss of the highly valued sandy beach over time (and potentially relatively quickly in storm events). Beach renourishment, and a potentially a groyne at the northward extent of the beach to interrupt littoral drift and keep sand circulating within the pocket beach, may be a feasible strategy for future management. In a landscape context, sand renourishment could be viewed as restoring a supply of sediment to pocket beaches that was lost when development occurred on the dune systems.

Harbour Beach north

Harbour Beach north extends from the northern harbour wall to the rocky outcrop forming the southern end of Lamberts Beach (Figure 1). As noted previously, this extent of the Mackay coastline has a substantial field of relatively intact and rare parabolic dunes (Figure 3). Along Harbour Beach north the dunes are enclosed within a conservation zone. The establishment and progressive enlargement of the harbour in the last decade to incorporate the marina and improve defence against storm and cyclone activity, has interrupted the northward longshore sand supply (Figure 1). EPA (2004) predicted up to 80 m of shoreline recession over 50 years along Harbour Beach north, and recommended sand bypassing systems be established to move sand from Harbour Beach south to Harbour Beach north. Sand bypassing has not been implemented to date, and should be reviewed given the regional value of the parabolic dune system. Major sand by-passing systems elsewhere on the Queensland Coast, including the Gold Coast Seaway (Coughlan and Robinson 1990), and Tweed River entrance (Dyson et al. 2001), have been successful in restoring sand supply to target beaches.

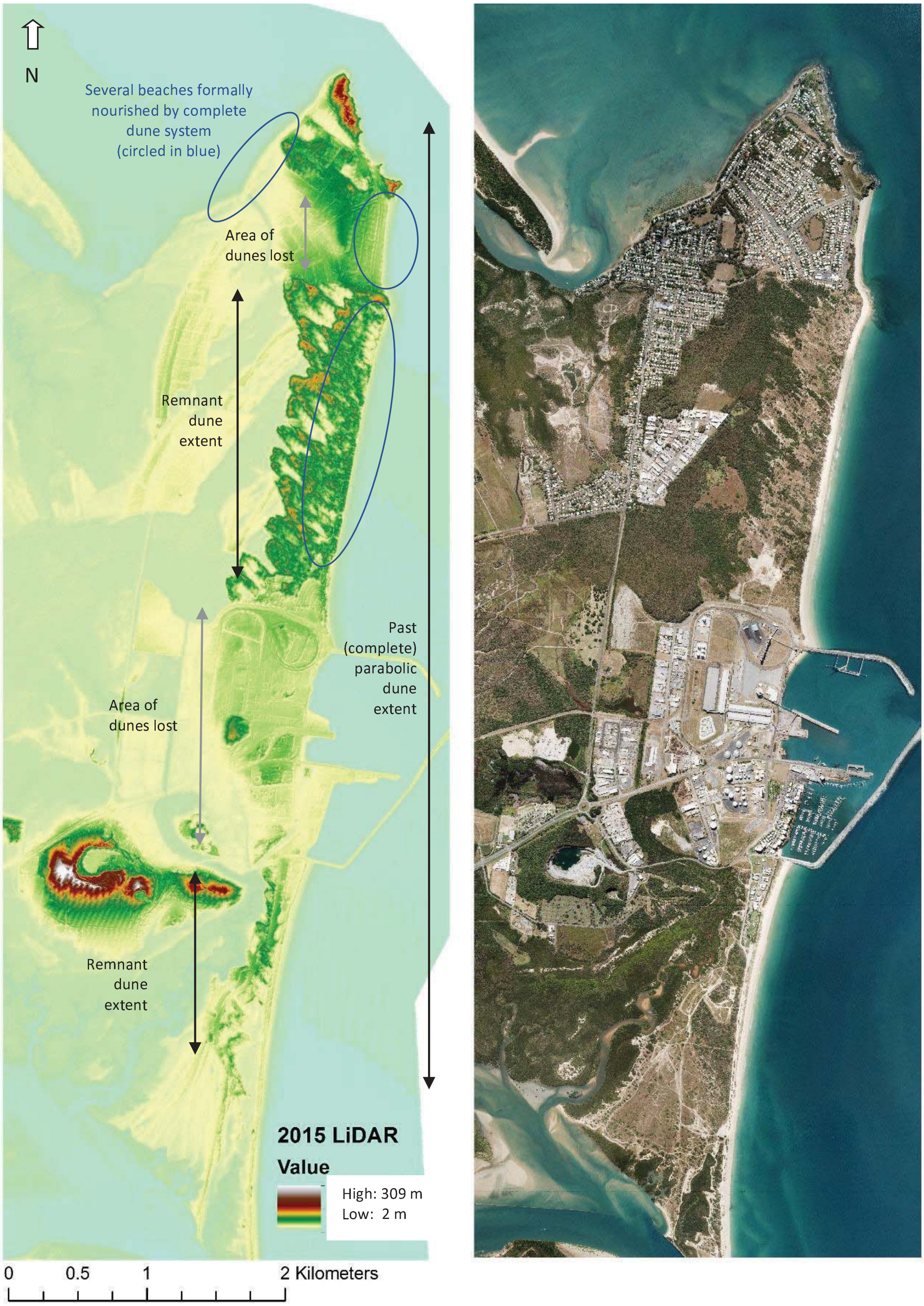

Figure 3. Slade Bay to Harbour Beach South – 2015 aerial and LiDAR imagery (DEHP 2015), presence of parabolic dune system evident from the LiDAR, with a loss of dunes at Lambert's beach and at the harbour. Beaches formally nourished by the past (complete) dune system, via aeolian, cross-shore and long-shore transport processes, circled in blue.

Comparison of 2009 and 2015 aerial imagery for this study indicated recent shoreline recession in the order of 8 – 15 m, and up to 20 m in some locations, along Harbour Beach north. Field observations confirmed the presence of an eroding scarp extending north from the harbour at the base of the dunes.

With a loss of longshore sediment supply, the shoreline at Harbour Beach north is likely to continue to retrograde resulting in further recession into the parabolic dunes. In the absence of intervention, there will likely be a continued recession of Harbour Beach north until a dynamic equilibrium is reached with the current cross-shore and longshore transport conditions. The volume of sand intercepted compared with that bypassing the harbour wall is not currently known. Of particular interest at this site is the opportunity to monitor the response of the established parabolic dune field to reduced sand supply and climate change impact on sea-level and shoreline processes. The results of monitoring at Harbour Beach north, over the next 5 – 10 years and beyond, would assist with determining if management intervention, including sand by-passing of the Harbour, is desirable. Monitoring would also provide data on parabolic dune changes in response to sediment and climate drivers that will have significance for coastal science in Australia and abroad.

Far Beach

Far Beach extends from the southern end of Town Beach south to the Illawong Resort at the Shellgrit Creek mouth (Figure 2, Figure 4). Far Beach has a different morphology to the northern beaches, as it is strongly influenced by a large tidal range over extensive tidal flats. EPA (2004) predict up to 50 m of retrogradation at Far Beach over 50 years, inclusive of the dynamic processes evident at Illawong Resort. For this study, comparison of the 2009 and 2015 aerial imagery of Far Beach north of the resort indicated shoreline regtrogradation in the order of 10 – 15 m at some locations (Figure 4). At fine scales observed during site inspections, areas of prograding dunes were also evident.

At Illawong Resort there has been considerable recession, up to 80 m, evidenced by past rock walls now stranded 80 m and 60 m offshore, and documented by EPA (2004) and Reef Catchments (2013). Ongoing and rapid retrogradation has also occurred between 2009 and 2015. Aerial imagery indicates that in that period there has been (Figure 4):

- Shoreline retrogradation at the resort in the order of 50 m, resulting in loss of the lagoon area
- Migration of the meander at Shellgrit Creek mouth, adjacent to the resort up to 40 m north towards the resort buildings
- Increased development of a sand bar across this creek mouth.

The ongoing recession at Illawong Resort is evidently driven by a mix of coastal and fluvial processes, and fine scale sediment dynamics in this zone. This includes flood and ebb tides, fluvial energy at the Shellgrit Creek mouth (not well documented previously), and the presence of rock walls in this zone (past and present). It is likely that in the absence of intervention, meander migration will continue to progress north and threaten resort infrastructure. In addition, further recession from the coastline side may also be expected.

Considerable investment would be required to develop and construct suitable defense infrastructure that will be successful in accommodating both coastal and fluvial erosion and maintaining the integrity and viability of the infrastructure. The resort is adjacent to other areas of undeveloped land. Given the likely cost and potential risk to adjacent shorelines associated with erosion defense, the resort site is an excellent candidate for buy-back or resort relocation (land swap or other scheme) and conversion to a reserve / conservation area.

Figure 4. Illawong Resort at Far Beach – aerial imagery (DEHP 2015) - 2009 (left) and 2015 (right) indicating shoreline recession at the resort in the order of 50 m, resulting in loss of the lagoon swimming enclosure, and meander migration of Shellgrit Creek in the order of 40 m north towards the resort, resulting in further loss of land. Red line indicates 2009 approximate shoreline position, and purple lines represent approximate 2009 creek bank position.

Strategic planning

Coastal hazard adaptation

Planning for climate change will be a major focus for Australian coastlines in the coming years (DERM 2011, Climate Commission 2012, CSIRO 2015). Queensland's State Planning Policy (SPP) 3/11: Coastal Protection, which took effect on 3 February 2012, requires each affected Council to prepare a Coastal Hazard Adaptation Strategy (CHAS) for urban localities that are projected to be within a high coastal hazard area between the commencement of the SPP and the year 2100. The adaptation strategy is based on an assessment of options that will mitigate the hazard, including retreat, avoidance, and defend, and a cost-benefit analysis to determine the most cost effective works or actions, taking into account long-term social, financial and environmental factors (DIICCSRTE 2015).

Townsville City Council were the first council to complete a CHAS (GHD 2012a), with Mackay and other regions to follow in the near future. A series of learnings were identified from the pilot study process, including the need to improve predictions of erosion prone areas (DIICCSRTE 2015). Incorporation of landscape setting including fluvial, aeolian and shoreline dynamics, in both the planning and implementation phases of the CHAS, will assist with prediction of erosion prone areas, and appropriate management response.

Trial programs for management works

There is a range of management strategies employed for coastline erosion / recession, often with varying degrees of success. Strategies to dissipate and absorb energy and create a depositional environment include beach nourishment, establishing and revegetating dunes, and installing permeable and flexible structures such as permeable groynes and submerged reefs (e.g. Mariani et al. 2012). Hard engineering options such as rock walls and rock groynes may provide some direct protection of assets such as houses, however these structures disconnect sediment sources, reflect energy and will create an environment that may scour over time, resulting in the complete loss of sandy beaches unless extensive artificial re-nourishment is ongoing. Recent reviews of erosion mitigation options include those reviewed for the Townsville CHAS (GHD 2012b) and also an international study (Mariani et al. 2012).

Only limited trials and testing have been undertaken to date on innovative options such as artificial reefs and permeable groynes. There is strategic opportunity in the next decade to improve testing of innovation in coastline management, particularly where *defend* and *accommodate* are the objectives for climate change management. It is important that trial programs of works are guided by the landscape geomorphic setting of individual beaches, to inform the most appropriate options.

Retreat zones

With sea level rise predictions in the order of 0.13 m for the Mackay region in 2030, and in the order of 0.4 m by 2090 (CSIRO 2015, moderate scenario), retreat is an unavoidable option for some coastal regions. The CHAS processes specifies 'retreat' as a management option for the planning and management of urban infrastructure (housing, roads etc.). Long term strategic planning will also be required to accommodate retreat for ecological communities and their coastal habitats. In many cases along the coastline, existing coastal habitat (e.g. beaches, dunes and vegetation) has development situated directly behind, limiting the potential for retreat. The challenge for future planning will be to identify suitable ecological retreat zones for our developed sections of coastlines, informed by geomorphic setting and processes, to accommodate for climate change processes and preserve unique habitat in specific geographic regions. For example, it may be important to limit development around estuary zones and coastal wetlands and waterways, in order to preserve a zone to accommodate ecological retreat.

Engagement and monitoring

Finally, an appreciation of landscape setting, can assist with informing the development of community engagement programs. Communicating the unique nature of the networks of waterways, wetlands, dune systems and other shoreline features in different geographic regions can facilitate a strong sense of connection to the landscape, to inspire community understanding of trajectories of change, and involvement in coastal management works. Tailored monitoring and evaluation programs for specific sections of coastlines can also be developed, informed by geomorphic setting and processes.

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