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Geomorphological considerations in landscaping options for Tinderbox Beach and adjacent backshore

Report to Kingborough Council

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Front cover photo: View westwards along Tinderbox Beach and its backing fill and soil margin. Much of the soil margin visible immediately behind the beach is being actively eroded by wave action (see more detailed photos in text) Photo by Chris Sharples 23rd November 2021.

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SUMMARY

Recently active coastal erosion has been in progress for at least a decade in soil margins and sediment deposits immediately behind and adjacent Tinderbox Beach (southern Tasmania) but has probably only commenced in the last couple of decades or less. Similar erosion in coastal soil margins has been noted at other beaches in Kingborough, including at the ends of Blackmans Bay and Nebraska Beach as well as numerous other locations. The most plausible explanation available for such widespread soil margin erosion is that it is a consequence of the incipient impacts of ongoing global sea-level rise starting to become apparent.

Kingborough Council has recently upgraded public recreational facilities on council land immediately backing the eroding soil margin at Tinderbox Beach, and the capacity to stabilise the eroding soil margin itself is now available. There are several advantages to hardening and protecting the soil margin, and little reason not to do so given that the opportunity exists. In particular, the eroding soil margin is itself an artificial feature (representing an historic episode of land reclamation by infilling), hence there would appear to be little reason not to further stabilise it artificially in order to eliminate its current erosion problems.

The most important disadvantage of stabilising the eroding soil margin is that this will eventually cause the beach to be squeezed out (drowned) against the hardened slope as global sea-level continues to rise. However complete loss of the beach would be decades in the future, hence is not an issue needing a near-term solution.

It is recommended that the current opportunity to stabilise and landscape the eroding soil margin behind Tinderbox Beach be taken in order to replace a messy, eroding and potentially hazardous scarp with a stable landscaped feature incorporating safe steps or ramps directly to the beach. This will preserve council land (and existing trees) for recreational purposes. It is recommended that the local community be consulted with on the design and materials to be used for such hardening and landscaping (see section 3.1).

In the case that hardening of the eroding soil margin does not occur soon, it is also recommended that repeated quantitative survey profiles be measured across the eroding scarp at several locations, in order to allow some quantitative measurement of the rates of change across the eroding scarp to be made.

1.0 INTRODUCTION

Kingborough Council has recently expanded and reconstructed a carpark and associated facilities situated on council land immediately behind Tinderbox Beach (southern Tasmania). However, a short, partly eroding slope about 1.0 to 1.5m high of artificial fill comprising soil, boulders, cobbles, and concrete fragments immediately backs the beach itself. Together with a back-beach fringe of trees this separates the beach from the new car park behind. This area not been recently landscaped and is in part actively eroding (see below).

This report was commissioned by Jon Doole (Environmental Manager, Kingborough Council) as part of a process to determine the most appropriate ongoing management and landscaping of the partly eroding strip of Council ground between the beach and the new carpark. The principal question addressed by the report is whether or not there are good reasons to artificially landscape the eroding scarp behind the beach, and to what degree such landscape is justified or worthwhile.

Acknowledgements

Local Tinderbox resident Rolan Eberhard (also a professional geomorphologist) has discussed Tinderbox Beach erosion and other issues with the author, both in recent weeks and also at intervals over the last decade or more. Rolan has been a resident at Tinderbox for well over a decade and has witnessed a number of storm and wave erosion events at Tinderbox Beach in that time. His assistance with providing information for this report is gratefully acknowledged.

2.0 SITE DESCRIPTION

Tinderbox Beach is a small (100m long) sandy pocket beach embayed into a long hard rocky coastline on the northern side of the north entrance of D'Entrecasteaux Channel from Storm Bay and the lower Derwent River estuary. Tinderbox Beach is located about 19 kilometres south of Hobart and eight kilometres south of Kingston. The short (100 metres) sandy beach is immediately

Figure 1: Recent air photo (circa 2021) with key features annotated. Photo © Land Information System Tasmania (LIST), 2021.

Figure 2: Detail of an air photo dated 9th Jan. 1948, showing Tinderbox Beach at that time. This is the oldest air photo available for Tinderbox Beach. The jetty seen in this photo extended 76 metres offshore from the back of the sandy beach but had been removed by 1965 (air photo evidence). The position of the soil (fill) margin at the back of the beach in this 1948 air photo is clearly evident and is indistinguishable from the position of the soil margin in a 2012 air photo (see discussion in section 2.3 below). Air photo © Land Information Services Tasmania (LIST). Metric map co-ordinates are based on Map Grid of Australia Zone 55 (MGA55), GDA94 datum.

backed by a low-lying northwards-oriented valley between moderately sloping hilly cleared rural land.

The low-lying area immediately backing the beach is at least partly underlain by artificial fill comprising soil, boulders, and concrete debris, which is exposed in a short eroding slope immediately behind the beach. This area has good public road access, is owned by Kingborough Council, and is a popular location for undertaking recreation aquatic activities including sailing, power boating, kayaking, swimming, and scuba diving. A public jetty with road access is located at the eastern end of the beach, with an adjacent public carpark (see Figure 1).

Further eastwards around the foreshore, an artificial terrace and seawall has previously been constructed on private land about 100 metres east of the present jetty (see Figure 1 & Figure 9). The history of these features has not been investigated by the writer, but it has been suggested that these may have been recreational facilities associated with a time (possibly early-mid Twentieth Century?) when Tinderbox had a much larger jetty (see Figure 2) and was a stopping point for more passenger boat traffic than it receives today (Rolan Eberhard *pers. comm.*). The artificial fill backing the beach may also date from around the same time, and may have been placed there for related reasons, however this has not been confirmed.

2.1 *Geology, geomorphology, and processes*

Previous information on the geology and geomorphology of Tinderbox Beach includes the following:

Kingborough 1:50,000 geological mapping (Farmer 1981);
Blackmans Bay 1:25,000 geological mapping (Calver 2007);
Tinderbox Beach geomorphic description (Sharples & Donaldson 2014);

Tinderbox Bay is a small south-facing embayment on a mainly rocky coast of Triassic-age sandstone (Figure 4). Natural cliffs, overhangs, and shore platforms of sandstone feature prominently westwards from the west end of the beach, however the rocky shoreline for over 100 metres east of the beach has been strongly modified by construction of a jetty, car park and an older terrace and seawall (see Figure 1 and Figure 9).

The beach itself is a reflective fine-grained sandy beach about 100 metres long (Short 2006, p.136). Sand also dominates the adjacent subtidal bottom for several hundred metres offshore from both the beach and adjacent rocky shores (see Figure 5). Although the sandy beach is assumed to be of natural origin, a berm of rounded cobbles and boulders in the upper part of the beach-face is likely to be at least partly winnowed out of artificial backshore fill by waves (see further below). The beach face typically exposes more cobbles and small boulders with only a thin sand veneer following stormy weather (Jon Doole, *pers. comm.*), when storm-wave backwash draws beach sand down into the offshore zone. However, the beach is more sand dominated after periods of relatively calm weather when attenuated fair weather swells slowly return sand to the beach from the shallow subtidal zone.

There is no sandy foredune backing the present-day beach, although under natural conditions a small foredune might be expected to have backed the beach. The fact that the relatively low-lying

Figure 3: View westwards along Tinderbox Beach. This view shows the upper beach cobble berm backed in turn by the rising bouldery soil margin which is the seawards edge of artificial fill placed over backshore areas at an unknown time in the past (at least decades ago). Much of the soil margin visible immediately behind the beach is being actively eroded by wave action (see more detailed photos in text). Photo by Chris Sharples 23rd November 2021.

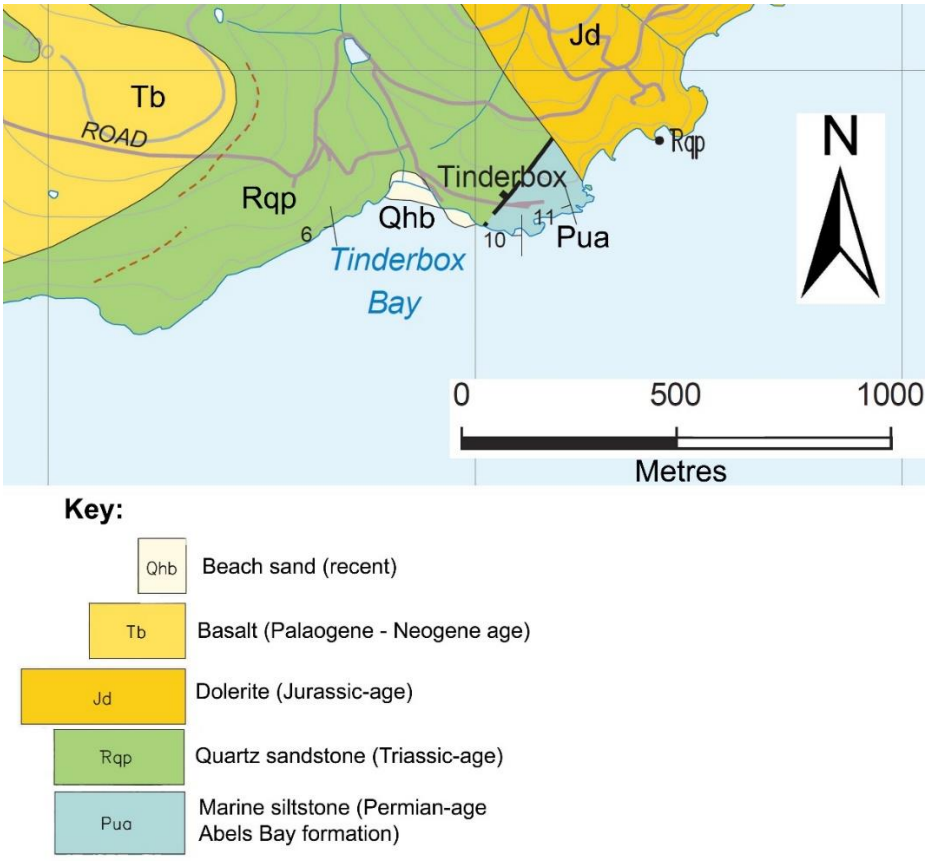

Figure 4: Map of terrestrial geology for Tinderbox Beach area. Map and key selectively copied from Calver (2007), with modifications to key by C. Sharples. Subject to Crown Copyright.

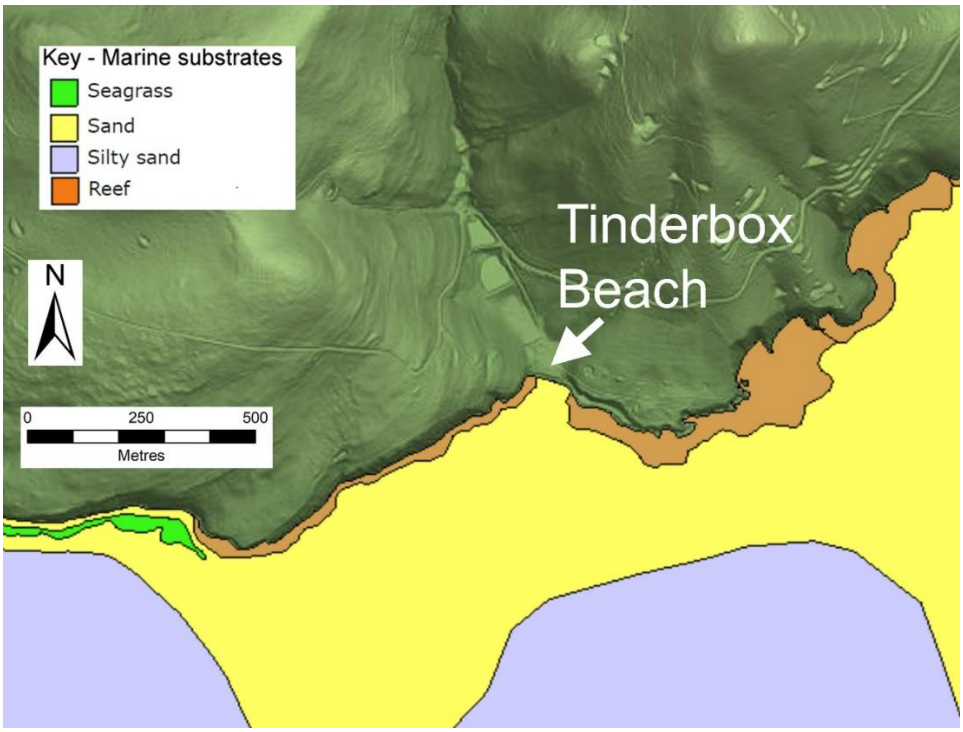

Figure 5: Marine substrates (habitats) in northern D'Entrecasteaux Channel adjacent Tinderbox Beach. This 1:25,000 scale mapping is based on field sampling data collected by the SeaMap marine habitat mapping project (Tasmanian Aquaculture and Fisheries Institute, University of Tasmania), and is copied from the Land Information Tasmania (LIST) website. Compare aerial photography depicted on Figure 1 above. Terrestrial topography shown is based on LIDAR survey. Subject to Crown Copyright.

backshore area has been artificially infilled (see below) suggests that in its natural state it may have included wet poorly drained marshy areas and/or lagoons, perhaps impounded behind a small foredune[1]. If originally present, these features would have been destroyed by the infilling.

Instead of a foredune, the beach and cobble berm are immediately backed by a short steep soil slope 1.0 to 1.5 metres high, which is actively eroding in parts, especially towards its west end (see Figure 10). This slope is referred to here as the seawards soil margin. Visual inspection indicates that the soil margin includes soil, rounded sandstone boulders and fragments of concrete up to boulder size. Although no historical research on this matter has been undertaken by the writer, this material is interpreted as artificial fill that has at some past time been used to infill the backshore area up to the back of the beach. The dating of this infilling and the source of the fill materials are unknown to the writer.

Wave climate

The main cause of shoreline erosion at Tinderbox Beach is inferred to be swell wave storms and locally generated wind waves. Boat wakes could be a possible additional cause of shoreline erosion at Tinderbox, however there is little information on which to assess this possibility.

Tinderbox Bay faces south to southwest and receives mainly low energy swell waves approaching from south-easterly to southerly directions after they have refracted into the north end of D'Entrecasteaux Channel from Storm Bay. However, these do sometimes arrive with sufficient energy to cause erosion at Tinderbox (as happened on 9th – 10th July 2011 – see Figure 11), but such occasions are likely to be infrequent.

The dominant (most frequent) wind directions at the nearest Bureau of Meteorology weather station to Tinderbox - at Dennes Point, 2.0 km south-eastwards directly across D'Entrecasteaux Channel - are westerly and south-westerly winds (see Figure 6). These are likely to also be the dominant winds at Tinderbox Beach, which directly faces the southwest across a fetch of four to 10 kilometres over northern D'Entrecasteaux Channel. Under strong south-westerly wind conditions, high steep locally generated wind waves wind waves would probably cause significant erosion at Tinderbox Beach, particularly at high tide.

Sand budget

Sand budget refers to the balance between sand being lost and gained by a beach. A beach prone to losing more sand in the long term than it gains may be more susceptible to persistent erosion than one with a stable or gaining budget.

Tinderbox Beach is well-embayed between long rocky headlands and is aligned roughly perpendicular to the dominant wave arrival directions (southerly to south-westerly, with dominantly onshore swell and wind-wave approaches). Consequently, there is unlikely to be significant alongshore sand transport into or out of the beach embayment via wave-generated littoral (drift) currents. Instead, most sand transport is likely to be onshore-offshore. That is, eroded beach sand will move directly offshore during storm events, with reflected storm wave backwash pulling sand down the beach and dumping it offshore. This will normally be followed by a slower return of sand to the beach by fair-weather swells and gentle wind waves pushing the eroded sand back onto the beach. Together with the presence of ample and extensive offshore sands available to replace any sand loss that does occurs (see Figure 5), this means the beach probably has a stable sand budget with short term gains and losses from the beach face but little long term net loss.

[1] This inference is suggested by a well-documented history in south-east Tasmania over the last century or so, of numerous coastal lagoons and swamps being "reclaimed" by infilling with soil, rocks, and other waste materials.

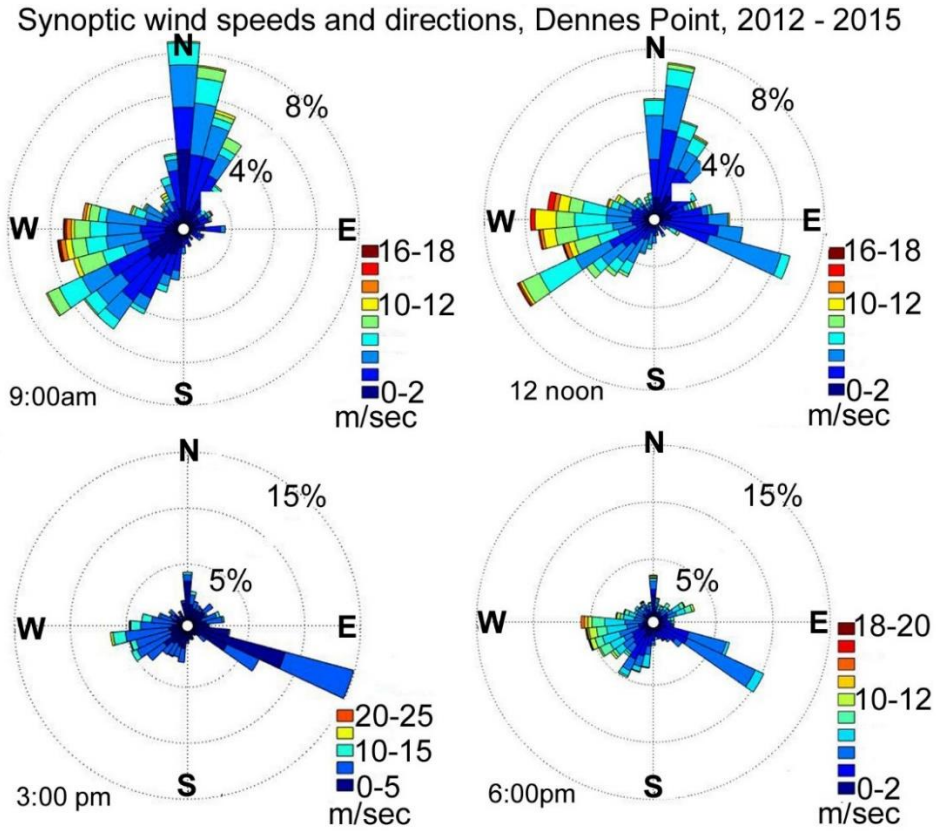

Figure 6: Wind data from the Dennes Point Bureau of Meteorology (BoM) Station number 94255, for Sept 2012 to Oct 2015. Synoptic wind data is measured at 3-hourly intervals; this figure provides wind roses for four selected times representative of the most frequent wind directions in this record. Note that whereas the westerly to south-westerly winds are significant at all times and are likely to as important at Tinderbox as at Dennes Point, the strong but less persistent northerly and south-easterly winds in this record probably reflect (respectively) topographically steered winds blowing down the Derwent Valley, and onshore seasonal sea breezes. These may not be as significant at Tinderbox as they are at Dennes Point. Plots prepared from original BoM data by Chris Sharples.

2.2 *Cultural landscape modifications*

Several substantial artificial landscape modifications at and adjacent Tinderbox Beach have been referred to above. Several of these exhibit evidence of recent erosion, hence, are summarised here (below).

A notable midden deposit (containing shell fragments and charcoal) is exposed beneath about 0.3m depth of fine silty-sand non-midden sediment in a small sandstone sea-cave at the head of a small sandstone cove west of Tinderbox Beach. This deposit has been exposed by recent erosion and currently has a fresh erosion scarp (see Figure 7). The midden deposit has not been dated or otherwise studied; however, the presence of an overlying sediment layer suggests a considerable age. The freshness of the erosion suggests its cause may be related to the causes of other instances of fresh erosion directly behind Tinderbox Beach and further along the shore east of the beach (below).

As mentioned above, the low-lying ground behind the beach has been infilled with artificially placed soil, cobbles, boulders (mainly of sandstone) and concrete pieces which are exposed in a partly scarped rise 1.0 to 1.5 m high immediately behind the beach. The landwards extent of the artificial fill is undetermined, nor are the date or dates of filling known to this writer. The source of the fill is also unknown although some of it could have come from excavations associated with a terrace east of the beach (see below). The purpose of the infill may (speculatively) be related to high usage of the site by boating traffic in the mid- and early-Twentieth Century (see long jetty in

Figure 7: Tinderbox resident Rolan Eberhard with actively wave-eroding midden layer in the floor of a small sea cave at the head of a small cove a short distance west of Tinderbox Beach. The cultural horizon has not been dated although radiometric dates could be obtained from carbonaceous fragments (including charcoal) in the midden. The apparent lack of midden components in the overlying approximately 30 cm of light brown sediment suggests the cultural layer could be of the order of millennia old. Photo by C. Sharples 23rd November 2021.

Figure 8: Relatively intact section of the seawards margin of the soil and artificial fill behind Tinderbox Beach (see also Figure 10 for a view of a freshly eroding scarp in the same soil margin just a few metres leftwards from the above location). Note the large concrete slab which is either part of the original artificial fill or has later been deliberately placed to prevent erosion, but in either case contributes to an ugly and messy beach front aesthetic. This view also shows an informal access route used by many visitors (including the writer) to carry kayaks and other recreational equipment from the carpark to the beach by a more direct route across the soil margin scarp than is provided by the recently constructed ramp at the east end of the beach. Photo by C. Sharples 23rd November 2021.

Figure 9: Artificial terrace on private land approximately 100 m east of Tinderbox Beach and jetty. Cement-and-stone seawall is intact on the right but has been destroyed by wave attack in the foreground – left. Recent wave erosion of the artificial terrace infill (soil) is apparent, with exposure of the roots of large living trees. Photo by C. Sharples 23rd November 2021.

1948 air photo: Figure 2). The filling may have been undertaken to reclaim marshy backshore ground for recreational or utility purposes related to boating activity.

Approximately 100 metres east of the beach is a notable flat terrace of soil and rock which has evidently been obtained by excavating the backing soil and sandstone outcrops (see Figure 9). The purpose and age of the terrace is unknown, and it is unclear what relationship it may have to the artificial infilling behind the beach. This terrace was protected from wave erosion by a cemented stone wall which has failed in parts, presumably under wave attack. Some sections of the terrace are now eroding on fresh soil scarps which are exposing the roots of large mature trees nearby (Figure 9). The artificial terrace is mainly or wholly located on private land (Rolan Eberhard *pers. comm.*).

Adjacent the eastern terrace but closer to the beach is an area of artificially emplaced, rounded dolerite cobbles which now form a wave-built berm on what is probably a remnant of a natural rocky shore platform. The cobble berm has impounded a swale on its landwards side which now forms a poorly drained wet area. The cobbles are evidently artificially emplaced since dolerite cobbles are not locally occurring on this rocky sandstone shore (although they probably occur some hundreds of metres further eastwards along the rocky shore – see Figure 4). The date and purpose of emplacement is unknown but assumed to be associated with the adjacent terrace described above. However, photo monitoring by Rolan Eberhard (*pers. comm.*) has demonstrated that the cobble berm has migrated somewhat landwards over the last decade. This is potentially significant since it probably implies more frequently higher wave action on the shore during the last decade than in the past, which is an expected consequence of progressive sea-level rise.

More-recent artificial modifications at the eastern end of Tinderbox Beach include the current jetty with its access road protected on the seawards side by large imported angular dolerite bounders (see Figure 13) and an adjacent boulder-delimited gravel carpark between the west end of the beach and the older terrace and cobble berm described above (see Figure 1).

2.3 Current shoreline erosion and its causes

Fresh erosion scarping occurs at several locations at and adjacent Tinderbox Beach (where "fresh" erosion scarping means clean vertical faces exposing the eroded material without significant slumping, rounding or new vegetation growth, and is indicative of recently active erosion). The following locations (described in sections 2.1 & 2.2 above) exhibit fresh erosion:

- Aboriginal midden deposit (plus overlying silty-sandy sediment).
- Low-lying backshore area of artificial fill behind Tinderbox Beach, actively eroding at the (artificially emplaced) soil margin immediately backing the beach.
- Artificial terrace of soil infill 100 metres east of Tinderbox Beach, with erosion of both stone seawall and exposed soil fill occurring (with exposure of large tree roots).

In addition, an artificially emplaced cobble berm (date unknown) between the eastern terrace and the beach is showing evidence of landwards migration within the last decade (see section 2.2 above), which is indicative of wave action to higher levels than previously.

In each of these cases, the erosion observed is a progressive "one-way" phenomenon, with no recovery evident or expected. Sandy foredunes and sandy beaches typically recover after erosion because fair-weather waves return eroded sand to the beach, and onshore winds blow it back into a dune. However, this is not true of the material now being eroded at Tinderbox Beach, which although it does include some sand fraction, is mostly a mixture of coarser (boulders, concrete lumps) and finer (silt, clay, organic humic) materials. None of these is capable of being naturally returned to the eroded landform.

The direct cause of most coastal erosion is higher-than-normal wave events, however the ability of waves to erode soft shores is determined by underlying causes such as changes to the shape of the shore, changes in the level of the sea or changes in the size and frequency of storms. Soft substrates such as soil will generally adjust comparatively rapidly into a profile excavated out by the prevailing storm wave climate (and will thus reach a stable equilibrium with it). If the eroding artificial substrates at Tinderbox had been just recently emplaced, then an ongoing adjustment of the shore profile to the local wave climate would be a likely explanation of the observed erosion. However, since these soil (and associated material) profiles are actively eroding many decades (or perhaps even a century or more in some cases) after they were artificially emplaced, this suggests that some other, and perhaps new process is causing a renewal of erosional recession of the shoreline.

Comparison of historic air photos (see 1948 air photo in Figure 2) provides evidence that the freshly active erosion of the soil margin shown in Figure 10 is a relatively recent phenomenon. Direct comparison of the earliest and the most recent air photos of Tinderbox Beach available to the writer (1948 and 2012) demonstrate that the soil margin at the back of the beach did not detectably recede over that period. That is, any movement of the margin was less than the 0.7 m pixel size of the scanned air photos (and also less than the ±2.3 m mean ortho-rectification error margin for these photos)[2]. Comparison of ground photos between 2007 and 2013 (Figure 12) show an active mostly fresh erosion scarp behind the beach over that period, but not a major shoreline retreat as yet.

The implication of this evidence is that the currently active erosion seen in the soil margin must have mainly developed within the last decade or two following at least 60 years of stability and has

[2] Photos obtained from Land Information Services Tasmania (LIST) as scanned images (0.7m pixel size) and ortho-rectified by Chris Sharples (i.e., distortion removed and geo-referenced to the map co-ordinate system) with a mean positional error margin of ±2.3 m. The air photo details are 9th January 1948 (film 167 frame 971, scale 1:15,840) and 30th March 2012 (film 1471 frame 206, scale 1:24,000). © LIST.

Figure 10: Fresh erosion scarp in the soil and artificial fill margin immediately behind the sandy beach at Tinderbox Beach. Photo by C. Sharples 23rd November 2021.

Figure 11: Storm surge wave conditions at the west end of Tinderbox Beach (9th July 2011). A large swell wave event on 9th-10th July 2011 caused shoreline erosion at numerous locations around Tasmania's coast. This view shows a wave impacting the soil margin at the back of Tinderbox Beach during this event and is indicative of the sort of storm surge wave that has caused erosion at Tinderbox Beach. Photo by Rolan Eberhard (Tinderbox resident).

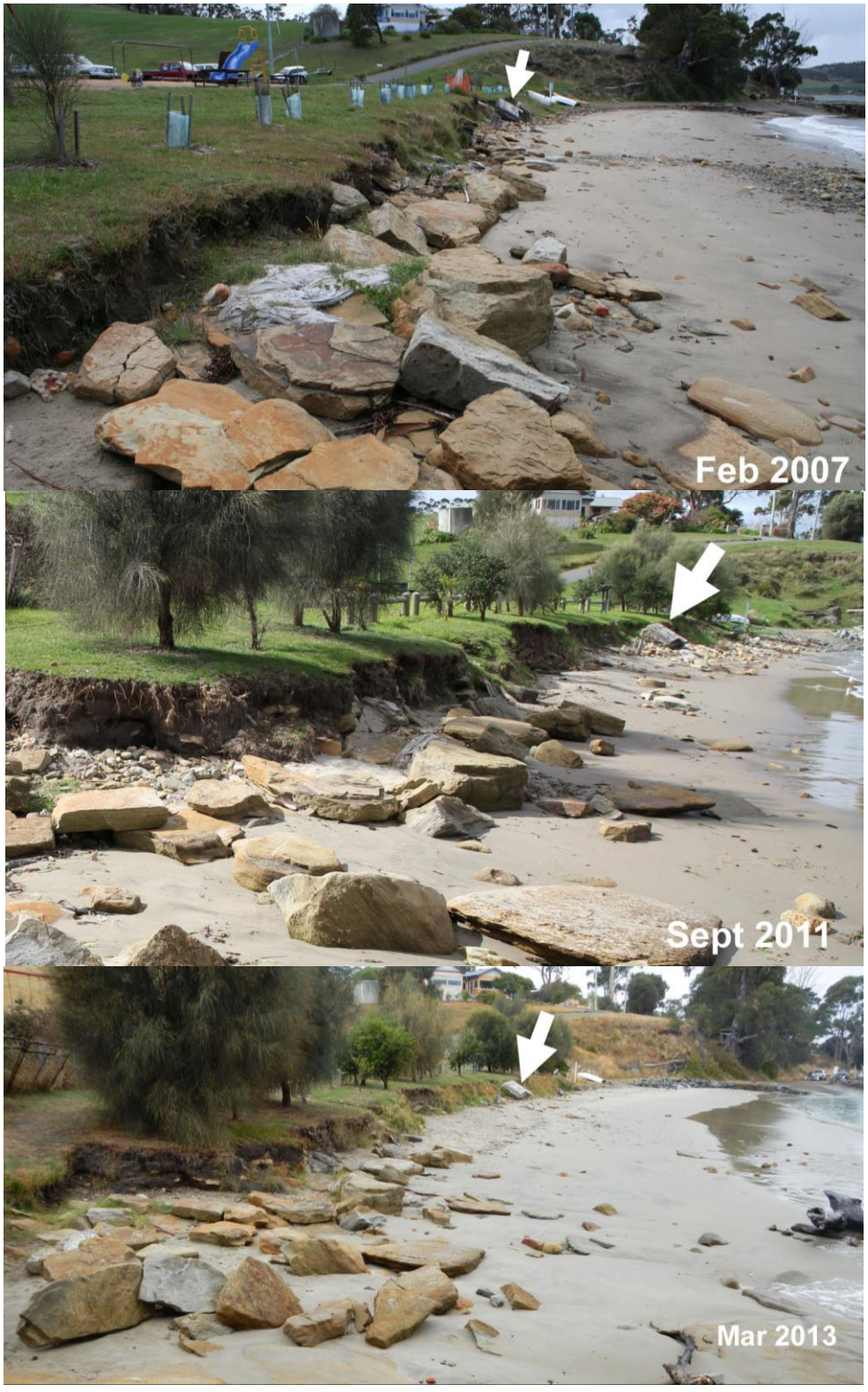

Figure 12: Three views along the same section of Tinderbox Beach in 2007, 2011 and 2013. View east from west end of beach; white arrow indicates the same concrete slab in each photo. The photos show a relatively fresh and active erosion scarp throughout the period, although the 2013 photo shows some vegetation growth since a major erosion event in 2011. Comparison with Figure 10 above shows a fresh scarp in 2021 equivalent to part of the scarp section close to the viewpoint in the 2013 photo above. However, no quantitative monitoring of change in this scarp has yet been undertaken. Photos by Rolan Eberhard.

not yet progressed very far inland. On the other hand, the freshness of parts of the erosion (see Figure 10) suggest that the rate may be recently increasing along some parts of the soil margin behind the beach. There is as yet unfortunately no quantitative monitoring data to test this inference against, however it is noteworthy that detectable landwards movement of an artificially placed dolerite cobble berm east of the beach (section 2.2) is a different type of evidence that is also suggestive of more rapid geomorphic change (due to higher wave action) at Tinderbox than in earlier decades.

Global averaged sea-level has risen over 21 cm since the 1880s (Church & White 2011), and sea-levels around Tasmania have risen by a similar average height over that period (White et al. 2014). In the absence of other more likely underlying causes for the recent fresh erosion seen at Tinderbox Beach and adjacent areas, the most likely available explanation is that global sea-level rise is now causing sufficiently frequent higher storm waves as to be starting to impact on coastal soil margins which until recent decades have been higher than all but the most extreme storm events (e.g., greater than 1 in 100-year events). Similar recent erosion of formerly stable coastal soil margins has been observed recently in a variety of other coastal locations in Kingborough and elsewhere (e.g., Sharples 2021a; Sharples 2021b)

3.0 OPTIONS FOR THE BEACH FRONT

An opportunity exists for Kingborough Council to undertake some degree of landscaping and hardening works on the eroding soil margin backing Tinderbox Beach. The alternative option is to do little or nothing to the eroding soil margin. The sub-sections below identify the pros and cons of these two options.

3.1 Option 1: Artificial protection and landscaping of soil margin behind beach

Consequences of hardening soil margin and preventing erosion

The eroding soil margin behind the beach is evidently an artificial fill (as discussed in section 2 above), as indicated by evidence such as included concrete fragments. Hence the issue of interfering with natural features and changing natural processes does not arise in this case since the eroding soil margin has itself been artificially constructed decades ago.

Obvious benefits if artificial hardening and landscaping is undertaken include:

- Prevention of loss of further backshore land for utility and recreation purposes.
- Prevention of further erosional retreat of the soil margin will also protect several trees a couple of metres behind the current erosion scarp from being eventually undermined and toppled by continuing erosional retreat of the eroding soil margin.
- Hardening the eroding soil margin provides an opportunity to incorporated permanent and safely constructed steps or ramps at one or more convenient locations along the soil margin, to facilitate users carrying equipment directly to the beach from the carpark without detouring to use the ramp at the far east end of the beach. (Currently many people use an *ad hoc* route over the scarp as shown in Figure 8, which could be unsafe for some users.)

On the other hand, hardening and "fixing in place" the eroding soil margin scarp means that as sea-level continues to rise over coming decades, the sandy beach itself will get narrower and eventually be squeezed out (submerged) against the hard wall. This can be temporarily mitigated by replenishing the beach with sand trucked in or scraped from adjacent subtidal areas, but these are expensive options which must be periodically repeated to maintain a beach under a sea-level rise

scenario. However complete loss of the beach would be several decades in the future, hence is not an issue needing immediate resolution.

Considerations for protecting soil margin

The writer is not an engineer and does not provide engineering designs for coastal protection or landscaping works. However, a number of comments relating to possible protection works are worth noting here.

- Given their flexibility and ease of placement and removal, sandbags can be considered as a rapid but limited-term form of shoreline protection to be used while longer-term solutions are developed. However, sandbags are inherently a short-term solution with a lack of permanence about both their appearance and their long-term integrity.
- Local resident Rolan Eberhard (recent comment to C. Sharples) notes that local residents generally do not like the existing revetment (or 'wall') of angular dolerite boulders which protects the jetty road at the eastern end of the beach (see Figure 1 and Figure 13). This is reported to be because the blue-grey angular dolerite boulders imported to make the wall are quite unlike the locally occurring brownish – yellowish and sometimes rounded sandstone and siltstone boulders found naturally along the foreshore. Ideally any further use of boulders and boulder walls for beach protection should use sandstone or siltstone boulders, ideally rounded if possible, so as to be more sympathetic with the nature Tinderbox environment.
- Assuming hard beach protection is constructed, the question arises of whether to install it at the present soil margin location, or to locate it further seawards or further landwards. If it is constructed further to seawards, the protected area of backshore is increased, however wave reflection off the wall will increasingly scour a narrower and stonier beach. On the other hand, construction further to landwards will result in some loss of backshore area but will preserve a wider beach for longer. However, the loss of the beach as a result of sea-level rise will only be postponed, not prevented. Given the pros and cons, construction of any beach protection in approximately the present soil margin position is probably the best compromise, not least because it represents the natural erosion margin resulting from adjustment of the artificial fill to the local wave climate over a period of many decades.
- It should be noted that structures built to prevent wave erosion of the soil margin will not necessarily prevent flooding of backshore areas by over-topping waves. Coastal inundation hazard assessment and protection is a separate issue not dealt with here.

Figure 13: View west along Tinderbox Beach from the east end adjacent the Jetty. The dolerite boulder wall ('revetment') in the foreground protects the jetty access road, beyond which the eroding soil margin directly backs the sandy beach. Photo by C. Sharples 23rd Nov 2021.

3.1 Option 2: Do nothing

Consequences of not artificially protecting soil margin behind beach

Predictable consequences in the case that artificial hardening and landscaping of the eroding soil margin is not undertaken include:

- Erosion of the soil margin will continue to progress landwards (partly or wholly in response to ongoing sea-level rise). The rate of soil margin recession is problematical to predict at present due to lack of comparable monitoring data but is likely to be of the order of a metre or two within a decade or two. Ultimately continuing erosion will encroach into backshore assets.
- In particular, several trees a couple of metres behind the current erosion scarp will eventually be undermined and toppled by continuing retreat of the eroding soil margin.
- On the other hand, without a hard surface to block it, the sandy beach itself will be able to maintain itself by migrating landwards (pushed by fair-weather wave action) as the soil margin retreats through erosion. The beach will thereby remain an asset of the site.
- However, the eroding soil margin will continue to be an untidy changing feature with boulders and concrete fragments emerging and falling from it. The changing nature of the eroding soil margin will interfere with any *ad hoc* or purpose-designed walking routes over the scarp. creating potential hazards to people.
- Boulders and cobbles eroded from the scarp (part of the artificial fill) will pile up with the current cobble/boulder berm at the back of the beach, which may itself slowly be pushed landwards by higher waves as sea-level rises and the soil margin continues to retreat.

4.0 CONCLUSIONS AND RECOMMENDATIONS

There are several advantages to hardening and protecting the eroding soil margin scarp immediately behind Tinderbox Beach, and little reason not to do so given that the opportunity exists. In particular, the eroding soil margin is itself an artificial feature (representing an historic episode of land reclamation by infilling), hence there would appear to be little reason not to stabilise it further artificially in order to eliminate its current erosion problems.

The most important disadvantage of stabilising the eroding soil margin is that this will eventually cause the beach to be squeezed out (drowned) against the hardened slope as global sea-level continues to rise. However complete loss of the beach would be decades in the future, hence is not an issue needing a near-term solution.

It is recommended that the current opportunity to stabilise and landscape the eroding soil margin behind Tinderbox Beach be taken in order to replace a messy, eroding and potentially hazardous scarp with a stable landscaped feature incorporating safe steps or ramps directly to the beach. This will preserve council land (and existing trees) for recreational purposes. It is recommended that the local community be consulted with on the design and materials to be used for such hardening and landscaping (see section 3.1).

In the case that hardening of the eroding soil margin does not occur soon, it is also recommended that repeated quantitative survey profiles be measured across the eroding scarp at several locations, in order to allow some quantitative measurement of the rates of change across the eroding scarp to be made.

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