When did you last NABE a beach – beach scraping demystified for fun and profit

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Introduction

Beach "scraping" is a surprisingly poorly understood concept and management technique. The original and more descriptive term for the technique was "Nature Assisted Beach Enhancement" (NABE), thereby indicating that the process was an augmentation of the natural system rather than some ill-defined anthropogenic intervention. Interestingly, over time a variety of other terms have been used to describe the same process. These include: beach skimming; beach planning; assisted beach recovery and; beach re-cycling and re-profiling (Carley et al 2010).

NABE is a methodology for accelerating the natural processes of returning sand to the subaerial beach and foredunes. It is particularly useful, and cost effective, for rebuilding dunes that are a buffer to the impact of multiple storm events and for expeditiously restoring beaches of high recreational value. Dunes are "nature's seawalls" and where used as a buffer to protect assets, need to be managed like any other seawall. It is therefore incumbent on all coastal managers to have a meaningful understanding of management concepts such as NABE, where and when such techniques can be usefully applied, or not, and the impacts of the process.

NABE is not a measure that will overcome long-term recession of a beach compartment suffering from a sediment budget deficiency but it can reduce the rate of recession in some locations due to its mitigating effect on the impacts of multiple storm events in a single season. That is, appropriately used NABE can extend the life of coastal assets under threat. However the particular circumstances at each site will determine the feasibility and viability of a NABE management policy.

Carley et al (2010) provide an excellent compendium and review of available documents on NABE. They also summarise and present examples of the volumes of sand involved and the operational costs of the process. This paper aims to expand on Carley et al by examining the various elements that are involved, and coalescing the information from the references and from the authors own experience.

Coastal Datums

Beaches are at the interface between the ocean and the land. As such they are also at the interface between two datum systems. This often leads to confusion when dealing with beach and dune levels. The normal datum used for land-based levels is Australian Height Datum (AHD). On the NSW coast this is approximately mean sea level; historically making it relatively easy for surveyors in remote locations to set a datum by tidal observations in a nearby estuary or river. However seabed levels are related to low water datums, traditionally using the term Indian Springs Low Water (ISLW), which is approximately chart datum (zero) on the Fort Denison tide gauge. The reason for the use of a low water datum is that the main purpose of hydrographic charts is to provide mariners with "clearance depths" so that they won't run aground. ISLW is also convenient for tidal information, because it means that most tidal information can be expressed as a positive number. The problem is that in NSW there is approximately a

0.9 metre difference between AHD and ISLW. For the purpose of discussion it is convenient to round this up to 1 metre. Thus, on a particular day high tide might be say 1.6m (ISLW), which means it is 0.6m (AHD) and low tide could be 0.5m (ISLW) which means it is -0.5m (AHD); historically a ready source for confusion.

The importance in understanding these two datum regimes is that discussions regarding beaches levels and quantities of sand removed by erosion, or needed for restoration, often produce confusion through apparently different and conflicting information. For example, a beach berm can be described as being at +2m AHD, or alternately, as +3m ISLW, Similarly dune profiles and crest levels suffer the same element of confusion with +6m AHD being +7m ISLW. Often beach scour levels are incorrectly reported as 0 AHD when they are in fact 0 ISLW, almost 1m lower. It is therefore vital that the datum system selected and used at any site is consistent.

Coastal elements of the "beach" profile involved in NABE

In order to understand and differentiate between the interaction of the NABE process with the zone of fluctuation of beach systems It is convenient to divide the overall profile into six elements: the back beach dunes or escarpment at the most landward extent of the zone of overall fluctuations; the foredunes; the beach berm between the swash zone and the dunes, sometimes referred to as the subaerial beach; the swash zone which includes not only the intertidal zone but also the zone of wave runup; the nearshore zone, incorporating the surf zone out to the inner closure depth which is generally between -8m and -15m (ISLW) on the open NSW coast, with the lesser value being in the more sheltered ends of beaches and the greater being at the more exposed and; the outer nearshore zone which extends from the inner zone typically out to a closure depth of between -28m to -35m (ISLW).

Beach process terminology

Beach "erosion" is an oft-abused terminology. It can variously be used to describe the loss of sand off a beach because of wave attack during a storm. It can also be used to refer to: the long-term recession of a coastline due to a sediment budget deficiency; or the artificial removal of sand from a beach system; or the landward loss of sand into the dunes by wind action or wave overtopping. In addition the commonly used reference to beach cycles of "erosion and accretion" only refer to the offshore/on-shore movement of sand between the beach and the nearshore region and hence represent only one aspect of the overall behaviour of beach systems. Its impact on shoreline movements has recently been well demonstrated by Harley et al (2015) in their graph of 10 years of beach behaviour at Narrabeen/Collaroy.

The term "beach erosion" should be confined to the process of the loss of beach volume during an event; it is an erosion of the subaerial beach profile, including potentially the foredune due to a particular coastal event, or series of clustered events. Such events can include: storm wave attack, with or without high water levels; modest wave action but with elevated water levels; post storm wave action exacerbated by rip cells; dune over wash by wave action and wind driven inshore losses into dunes during strong onshore wind events. Long term aeolian losses into hind dunes or the inland migration of hind dune systems, or losses longshore around headlands or offshore into "sinks", tend to produce long-term shoreline recession rather than event driven "beach erosion".

When considering the application and potential benefits, or dis-benefits, of sophisticated management options, coastal managers need a more comprehensive understanding of the processes and the terminology required to differentiate between the various coastal mechanisms. Gordon (1987) suggested that when considering beach behaviour it was helpful to separate the envelope of shoreline fluctuations from any net movement of a beach location over time, whether it is accretional or recessional, and characterising that net movement under the terminology of "shoreline change". Hence there is: shoreline "erosion" caused by an event; "shoreline fluctuations" referring to the envelope of the profile changes due to the erosion that occurs during an event, or series of events, along with the beach recovery after the event(s); and "shoreline change" due to longer term variations in the sediment budget of a coastal compartment. On the NSW coast shoreline change, where it occurs, generally takes the form of coastal recession.

These more specific concepts are important in understanding the impacts of various types of management options and in particular the more subtle features of options such as NABE and hence they are detailed in the following.

Beach erosion processes

Coastal profiles, from the foredunes to the offshore limits of movement, trend towards an equilibrium between the shape required to absorb the incident wave energy and the net quantum of energy flux prevailing at the time. Storm induced erosion normally takes place in a matter of hours, at most a day or two, although there may be multiple events in a stormy period, whereas recovery during the accretion phase takes weeks, months or, following extreme erosion event(s), years if not more than a decade; as with the post 1974 period (Gordon, 1987). Both Atkinson et al (2015) and Harley et al (2015) provide contemporary comment information and references on the processes. In summary, excess wave energy produces a rapid profile response, but tends to be short lived, whereas low wave energy, is the predominant regime, but produces far slower profile response.

Waves from nearby or even distant storm systems can remove sand from the subaerial beach profile and deposit it offshore. Wave attack from distant storms, regardless of the wave height, often may only remove sand from the subaerial beach leaving a scarp in the berm; particularly on an accreted beach. However nearby storms produce waves that are also accompanied by elevated water levels due to storm surge and/or wave set-up, which allow waves to directly attack the back of beach and dunes and thereby dramatically increase the quantum of erosion; a situation that can be further exacerbated at times of spring tides. The magnitude of the wave set-up can be very dependent on wave approach direction, while the storm surge component is dependent on the proximity, direction and speed of movement of the storm cell, the magnitude and distribution of its atmospheric pressure and the strength, and direction of the winds in the vicinity of the coastline. The duration of the storm is also an important variable as high wave conditions that last for more than one tidal cycle can be expected to exacerbate the removal of sand from the beach and foredunes.

Under typical annual storm conditions the sand removed from the subaerial beach and dunes is deposited as offshore bars that in turn help to dissipate wave energy by effectively "flattening" the underwater slope and modifying the waves to reduce their ability to remove sand from the subaerial beach. However, during rare major storm events the formation of surf zone bars, with an associated build up of water "trapped" inside these bars, can exacerbate the formation of very large rip cells. These "mega rips" transferred sand well outside the "normal" surf zone, onshore/offshore system.

Sand transported into deeper water by such rip activity may take many years to return. For example, Gordon (1987) estimated that following the May 1974 Sygna storm (Foster et al, 1975), and the subsequent storm in June 1974, the sand transferred offshore to deeper water took in the order of a decade to return to the “normal” surf zone/beach system. In the case of the 1974 storms the “deep water” deposition at the rip heads extended out to depths of approximately 35m (ISLW), typically over a kilometre offshore.

Beach accretion processes

The NABE management option focuses on the accretion (recovery) phase and in particular the processes by which beach berm and dune recovery occurs after erosion events. It is therefore vital to understand how this naturally occurs so as to appreciate the benefits, and limitations, of the NABE process.

The accretion phase results from the dis-equilibrium between the post-storm reduced wave energy environment and the net, relatively flat, seabed slope that then exists throughout the surf zone. During the lower wave energy environment, which prevails for most of the year, waves produce mass sediment transport onshore as they seek to restore the balance between the seabed profile and the prevailing lower wave energy. The recovery phase can often be observed as the storm formed surf zone bars migrating shoreward, infilling the nearshore “gutter” and “welding” themselves onto the base of the swash zone; for a while producing a shallow flat underwater plateau extending offshore from the beach. Even small waves can entrain and mass transport sand shoreward across this shallow “plateau” and deposit it in the lower region of the beach swash zone. This action in turn produces a seaward “growth” of the swash zone followed by a recovery of beach berm width as the wave runup redistributes the sand onto the berm.

The accretion phase commences immediately after the erosion event and sometimes even during the dying phases of the event. If the erosion has resulted in an escarpment at the back of the beach, then typically the toe of the escarpment is somewhere between low and mid tide level (approximately 0m to 1m ISLW) immediately following the storm but often, within a very few days the “beach” level, the incipient beach berm, at the toe of the escarpment has recovered to +2m ISLW (approximately high tide with a small component of wave runup superimposed) and continues to build over the following weeks to +3m ISLW.

The rate of recovery and the berm height, at this stage, is directly related to the prevailing wave conditions and the tidal phase. The volume of sand available for berm building is dependent on the available wave energy flux as determined by wave height and period (steepness) and direction, as this wave energy flux drives the rate of shoreward translation of the offshore bar(s) and hence the source of material for berm building. The level of the top of the berm is dependent on both the wave conditions and the tidal phase as the height of the berm crest is determined by the ability of the wave runup to move sand up to, and over, the incipient berm crest. Spring tides, even with very modest waves, will produce relatively rapid recovery of crest levels to +3m ISLW (that is approximately 1m above high tide) whereas the same waves may only establish a crest at +2m to +2.5m (ISLW) during neap tides.

While spring tides tend to elevate the berm level, neap tides tend to increase its width as the sand moving onshore is added to the swash zone causing it to be translated seaward.

As the berm width and elevation increases, the opportunity for on-shore winds to entrain the dry sand on top of the berm also increases. Offshore winds do not usually enjoy the same opportunity because the dunes and/or vegetation, and/or buildings at the rear of the beach tend to shelter the berm to some degree. The on-shore winds, entraining and transporting the dry sand landward continue to elevate the surface of the beach berm, progressively lifting the more landward region of the berm, typically to elevations of at least +3m to +4m ISLW on open coast NSW beaches. Further, as the wind borne sand reaches the back of the "beach" the wind field is deflected upwards due to the erosion escarpment, and/or dunes, and/or vegetation, and/or buildings. The upward deflection of the wind field allows gravity to play a more dominant role in the fate of the transported sand and hence a greater portion tends to be deposited at the back of the beach, thereby forming the incipient foredunes. Over time, and without the disruption of a further erosion event, these can grow to the same height as their backing dunes or the hinterland level behind the beach. Some sand is transported landward over the existing dunes or hinterland level unless trapped by vegetation. By trapping the windborne sand, vegetation plays a vital role in the rate of rebuilding of the incipient foredunes.

The key point of understanding the berm and dune-rebuilding phase, and hence the relevance of NABE, is the reliance of the natural process on fickle and episodic circumstances. If a nearshore bar "welds" onto the base of the swash zone, and the waves and tides favour berm building, then the berm can rapidly develop a wide flat surface of dry sand. If this is followed by a period of strong on-shore winds then the berm will increase in height and foredune re-formation will commence and proceed, albeit this process may still take months rather than weeks. If however these favourable conditions do not occur, or are intermittent, then rebuilding of "nature's seawall" will be delayed leaving built assets and infrastructure, located behind the beach, at risk for months if not years.

NABE

Nature Assisted Beach Enhancement is a mechanical intervention to speed up the berm and foredune recovery process. It more rapidly forms both the natural seawall offered by the dunes, while at the same time it more speedily re-establishes the width of the recreational beach. By reforming a foredune sand buffer prior to secondary storms, it provides potential to limit the erosion impacts of subsequent storms, and hence can reduce, but not overcome, the long-term rate of shoreline recession.

So how does NABE work? To understand the process it is necessary to consider the interrelationship between the process and four of the six elements of the "beach profile" mentioned previously. The outer nearshore zone, because of the timeframes and the scale of the processes, plays only a very minor role and hence can be dispensed with when considering NABE.

Initial focus is on the swash zone. Material is bulldozed from the swash zone, starting at low tide, and pushed up onto the berm working up the swash zone as the tide rises. This effectively flattens the active surf zone slope by increasing the distance between the shoreline and the offshore limit of the active profile. As a result the restorative on-shore seabed transport of sand is accelerated as the profile seeks to naturally adjust to restore the balance between profile shape and the prevailing wave energy regime. The sand harvested from the swash zone onto the berm can then be moved to the back of the beach during the higher phases of the tide to form incipient foredunes. This supplants the far slower natural process of the berm having to first grow in width, then develop a dry surface, then have strong enough onshore winds to entrain and move the sand back to form the foredunes.

Focus on dune re-formation is vital as the sooner a sediment buffer is re-established at the back of the beach, the better to provide protection against following storm events. Also, the formation of an incipient foredune assists with the deflection of the onshore winds at the rear of the beach thereby allowing gravity to play its part in releasing sand to be deposited on the new, emerging dune form. In addition, the sooner the incipient dunes are formed the sooner re-planting and re-colonisation by remnant vegetation can take place, thereby "kick-starting" the natural process which will eventually lead to the re-establishment of an effective, vegetated, dune system. Rapid foredune formation and re-vegetation can also be important in preventing long-term inland loss of sand from the active sediment budget of the beach/surfzone region and therefore accelerated shoreline recession. Gordon (1992) provided dramatic evidence of the long-term reversal in shoreline recession in Bate Bay that resulted from the reconstruction, revegetation and maintenance of the foredune system.

Experience dictates that there is no need to fully re-build eroded dunes using NABE. Rather, NABE should be used to commence the process and provide early opportunities for re-planting so that the natural sand trapping can take over the dune building process. However the crest level of a mechanically created incipient foredune needs to be sufficient to prevent wave overtopping and wash through. The desirable incipient foredune crest level and other dimensions will vary from location to location, and even within a coastal compartment. However, given data on the prevailing wave climate and the topography of the beach, hind beach area and surfzone, Carley et al (2009) have demonstrated that it is a relatively simple matter to design the required dune formation for a NABE project.

Historically, through programs such as Coastcare, many volunteers have been involved in both accelerating foredune re-building using sand catching fences and in planting the dunes, thereby not only stimulating the re-creation of dunes but also their ecosystems. Such efforts in restoring dunes and their natural flora and fauna are similar in philosophy to NABE as both are an anthropogenic intervention to speed up the natural processes of dune building and hence ensuring that, for a far greater period of time, there is a healthy foredune environment; both physical and ecological. NABE is simply a methodology of initially accelerating the process and providing an early start to any Coastcare operations.

As previously indicated, the rate of rebuilding of the foredunes and the berm is naturally limited by the rate of onshore movement of sand into the swash zone. In relatively quiescent periods, following storm erosion, it is often found that the rate of natural resupply from the offshore region to the swash zone is initially rapid so that typically, a 0.2m skimming of the swash zone on one tide can result in complete reinstatement of the previous swash zone by the next tide. Over time this rate of re-supply decreases, and there can be interruptions during periods of increased wave energy, so careful monitoring is essential to ensure the rate of harvesting of the sand in the swash zone is matched by the re-supply. Such monitoring will also provide a guide as to when the NABE operation is experiencing diminishing returns and therefore should be scaled back or terminated for the current restoration activity. Rayner et al (2012) concluded that before their 3 month initial post construction survey, the beach profile in their study area the beach berm and swash zone had been naturally fully restored following an extensive NABE program that yielded a net $20m^3/m$ of mechanically harvested sand for foredune formation.

NABE Impacts

Natural beach erosion during a storm can result in up to 4m loss of elevation of the beach berm and in the case of foredune attack typically 5 to 7m, or more for fully developed dunes resulting in up to $250m^3/m$ of sand being removed from the beach into the nearshore and/or offshore zone, all in a mater of hours (Gordon, 1987). Such erosion can move shorelines landward up to 30m (Harley et al, 2015) in a single tide. That is, natural erosion processes can devastate the ecological environment and the recreational beach amenity of a beach in a matter of hours, without warning and may take weeks, if not months, to recover.

The on-going dynamic nature of fluctuations of the surf zone, the beach berm and the foredunes means that any benthic organisms, bird life or other beach/dune flora and/or fauna need a high tolerance to several forms of environmental stress. Experience has shown that the environmental impacts of NABE are likely to be short term and have a lesser impact than the dynamics of the natural system (Parsons Brinckerhoff, 2009 and Smith et al, 2011). Experience has also demonstrated that with the right equipment and a sensitive design, a sufficient quantity of sand can be harvested in a relatively short period of time. For example Shand and Carley (2009) documented that a kilometre of foredune could be re-established in a fortnight. Re-colonisation of the benthic organisms tends to be rapid (Smith et al, 2011), this is particularly the situation if the NABE process is limited to 0.2m to 0.3m deep scrapes per day

In order to minimise any adverse impacts it is highly desirable that the nesting times of bird species and turtles be avoided. Hence, any NABE project should first identify the resident species and the vulnerable times in their breeding cycles.

An often overlooked impact is that the faster the sand is encouraged to migrate onshore, the sooner the offshore sand bars dissipate, an outcome which may reduce surfing opportunities. This is a factor that should be considered in determining the extent of any NABE program.

It is therefore desirable to undertake beach NABE at times of post storm low wave energy, during the spring tidal phase, outside the breeding/nesting seasons, at times of low beach/surfzone access requirements and during the planting season so as to provide the best opportunity for post NABE foredune stabilisation. From a practical viewpoint it may not be possible to satisfy all these criteria however they should all be taken into consideration when designing a project. Clearly the impacts on wildlife breeding and nesting should be given priority as these are the least flexible considerations.

Equipment

Project design should ensure that there is sufficient appropriate equipment available to undertake the work in a timely manner. Working on a beach, and particularly in the swash zone, is a harsh environment for any mechanical equipment and it is often impractical to use anything other than track tread vehicles such as bulldozers and track tread front-end loaders for swash zone work. If the swash zone region is particularly "soft", often the result of rapid onshore sand movement, dozers fitted with wider tracks, colloquially known as "swampies", can prove useful. Rubber tired vehicles can provide more rapid transport on the beach berm, particularly where sand has to be moved longshore. They are generally favoured in such circumstances as track tread equipment become inefficient as distances of movement increase. Where the borrow zone is somewhat remote, scrapers generally assisted by dozer pushers, become practical. There is a compromise vehicle known as a scraper dozer that can not only bulldoze with a blade, but also has a "bowl" which can typically carry 4 to $6m^3$; a full scrape of the swash zone. The scraper dozer is generally most efficient over distances of 50 to 100m and where the sand is to be harvested in the swash zone immediately seaward of the proposed dune formation, the overall distance is usually less than 50m making the scraper dozer a practical choice however, unfortunately they are often not readily available.

Typical considerations for NABE project design

Carley et al (2009) and Shand and Carley (2009) provide data on the realistic yield of bulldozers indicating that a D6 can move $94m^3$/hr, a D7, $175m^3$/hr and a D9, $188m^3$/hr. Given that it is often desirable to establish a foredune with a crest level of at least 6m ISLW, to prevent overtopping, and initial slopes of 1V to 3H then, given the beach berm has likely recovered to at least +2m ISLW the volumes required vary between $25m^3$/m and $50m^3$/m depending whether there is or is not a backing escarpment formation already in existence. Assuming a cut depth of 0.3m and a swash zone width of 12m (based on a 1 in 10 swash zone slope extending from 1.8m ISLW down to 0.6m ISLW as the practical operating limits for mechanical equipment in the harvest area), each dozer pass yields $3.6m^3$/m and with say 4 passes per tidal opportunity the harvest can be approximately $14m^3$/m. Carley et al (2009) suggest 12 to $16m^3$/m. Hence it could be expected to take, approximately 2 to 4 days to achieve the required dune shape. Given a D9 has a productive rate of $188m^3$/hr, and taking a 7 hour day operating partly in the swash zone and, at higher phases of the tide moving sand back across the berm, then approximately 100m of dune can be constructed in 2 days, for a dune fronting an escarpment. Both Carley et al (2009) and Shand and Carley (2009) suggest costs of scraping between $5/m³ and $10/m³. So indicative beach NABE costs are between $130 and $260 per m run of beach for the scraping component, or double this if there is no back beach escarpment and a full foredune shape is required.

From a practical viewpoint it is often prudent to ensure projects are undertaken using at least two machines. Not only does this speed up production thereby reducing disruption to beach usage but also, given the adverse operating environment, it ensures there is back up for retrieval if one of the machines becomes bogged. Experience dictates the potential for this situation to be quite likely, from time to time, especially when working in the swash zone.

In order to both stabilise the NABE foredune and to provide the basis for it to grow further under natural processes and re-establish an ecosystem, it is desirable that the dune be planted with appropriate pioneer species as soon as possible after the dune has been shaped. Carley et al (2009) suggest costs of the initial planting of the new dunes of between $11 and $22 per m run of dune; the range reflecting the difference between volunteer labour and labour at full cost.

Summary

NABE is basically a mechanical intervention to speed up the natural processes of beach and foredune recovery after a storm event. It is a useful tool to achieve rapid re-establishment of a foredune and beach berm. It can not only be used to create a buffer against further back beach erosion during following storms, but can also re-establish a dune crest level that will prevent a wash through from wave overtopping. While it is not a panacea for overcoming long-term coastal recession it can reduce the rate of recession by mitigating the compounding impacts of multiple storm erosion events.

The costs of NABE are modest, at between $140,000 and $260,000 per km, excluding design and set-up costs and depending on the required dune, and as to whether volunteer labour is available to establish the vegetation. These figures could be doubled in areas where there is no remaining back of beach escarpment and so the NABE needs to re-establish a complete dune formation to prevent inundation of low country inland of the beach. Depending on the back beach development that might be at threat, the cost/benefit ratio can therefore be very favourable even if the process needs to be repeated after rare but severe storm events. Not only can NABE rapidly re-establish a viable dune system but experience dictates that it also improves the rate of berm recovery and hence re-establishment of the public beach amenity.

The costs and minimisation of impacts, and hence success of a project, is however dependent on a competent design, appropriate equipment, favourable weather and tide conditions, timing to avoid nesting and breeding seasons of resident wildlife, including, in some situations, turtle nesting seasons and the ability to take advantage of favourable planting conditions.

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